Appendix 5A
# Essential Fish Habitat Assessment

## 5A.1 Essential Fish Habitat Assessment

Section 305(b) of the Magnuson-Stevens Fishery Conservation and Management Act of 1976 for Essential Fish Habitat (MSA), as amended by the Sustainable Fisheries Act of 1996 (Public Law 104-267), requires federal agencies to consult with the National Marine Fisheries Service (NMFS) on activities that may adversely affect essential fish habitat (EFH) for species that are managed under federal fishery management plans for U.S. waters. Section 3 of the MSA defines EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity" (16 United States Code § 1802). These waters include aquatic areas and their associated physical, chemical, and biological habitat features necessary to support the entire life cycle of the species in question and may include areas historically used by these species. *Adverse effect* means any impact that reduces the quality or quantity of EFH and may include direct or indirect physical, chemical, or biological alteration of the waters or substrate and loss of (or injury to) benthic organisms, prey species and their habitat, and other ecosystem components.

The MSA also requires that NMFS designate habitat areas of particular concern (HAPCs) for each federally managed fish species. HAPCs are subsets of EFH, which are rare, particularly susceptible to human-induced degradation, ecologically important, or located in an environmentally stressed area. HAPCs are not afforded additional protection beyond that of the EFH; however, federal projects with potential adverse effects on HAPCs will be given more scrutiny during the consultation process.

## 5A.2 Regulatory Setting

The proposed action constitutes a federal action requiring EFH consultation under Section 305(b) of the MSA. The proposed action will also require federal permitting under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act. These federal actions will also require EFH consultation.

The objective of this EFH assessment is to describe potential adverse effects of the proposed action on EFH, federally managed fish species, and the habitats upon which these species rely. This assessment also describes conservation measures proposed to avoid, minimize, or otherwise offset potential adverse effects resulting from the proposed action on EFH.

### 5A.2.1 Proposed Action

For a full description of the proposed action, refer to Chapter 3, *Description of the Proposed Action*.

### 5A.2.2 EFH Species and Habitats in the Action Area

The action area occurs in habitats designated EFH for Pacific salmon, which includes Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley fall-

run/late fall–run Chinook salmon. The action area is also designated as EFH for northern anchovy (Coastal Pelagic Species) and starry flounder, brown rockfish, and English sole (Pacific Coast groundfish species).

As defined above, EFH is those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity. For the purpose of interpreting the definition of EFH, "waters" include aquatic areas and their associated physical, chemical, and biological properties that are used by fish, and may include areas historically used by fish where appropriate; "substrate" includes sediment, hard bottom, structures underlying the waters, and associated biological communities; "necessary" means habitat required to support a sustainable fishery and a healthy ecosystem; and "spawning, breeding, feeding, or growth to maturity" covers a species full life cycle. The following components of EFH must be adequate for spawning, rearing, and migration.

- Substrate composition
- Water quality
- Water quantity
- Depth and velocity
- Channel gradient and stability
- Food
- Cover and habitat complexity
- Space
- Access and passage
- Habitat connectivity

The proposed action's effects on spring and winter-run Chinook salmon, which are listed under the federal Endangered Species Act (ESA), and their designated critical habitat is described in Chapter 5, *Effects Analysis for Chinook Salmon, California Central Valley Steelhead, Green Sturgeon, and Killer Whale*. Similar to the NMFS (2019) State Water Project (SWP)/Central Valley Project (CVP) Biological Opinion (BiOp), these effects generally define the effects of the action on EFH relative to these (listed above) Evolutionarily Significant Units (ESUs). The following assessment with respect to Pacific salmon EFH focuses on Central Valley fall-run/late fall–run Chinook salmon, which are not listed but covered under the MSA. The final conclusions for effects on Pacific Salmon EFH consider the effects on all ESUs as necessary.

Brown rockfish and English sole are found as far landward as Suisun Bay, and English sole are rarely caught in the west Delta (only in the drought years of 1989 and 1991 [Baxter et al. 1999]). Brown rockfish have been captured only once in Suisun Bay in 1984 and in very low catch-per-unit effort (CPUE) (Baxter et al. 1999). In plots of CPUE for English sole, Baxter et al. (1999) showed only trace CPUE in both the west Delta and Suisun Bay as compared to other embayments within the San Francisco Estuary from 1980–1995. Because these areas are on the extreme margins of these species range and because the proposed action would only negligibly affect, if at all, conditions in their main ranges, it was concluded that there would be no effect on the EFH for these species. No further analysis was conducted for brown rockfish and English sole.

Because northern anchovy and starry flounder are not listed under ESA, but are covered under the MSA, their status, distribution, life history, and habitat requirements are reviewed below. For information related to Central Valley fall-run/late fall–run Chinook salmon, refer to Chapter 4,

*Action Area and Environmental Baseline*, Section 4.4.3, *Chinook Salmon, Central Valley Fall-Run and Late Fall–Run ESU.*

# 5A.3 Description of Potentially Affected Species

## 5A.3.1 Coastal Pelagic Species

### 5A.3.1.1 Coastal Pelagic Species EFH in the Action Area

Northern anchovy is a species for which EFH exists in the San Francisco Estuary and Delta, as one of the managed Coastal Pelagic Species. The overall extent of coastal pelagic EFH is based on a thermal range bordered by the geographic area where Coastal Pelagic Species occur at any life stage, where Coastal Pelagic Species have occurred historically during periods of similar environmental conditions, or where environmental conditions do not preclude colonization by Coastal Pelagic Species. Species diversity and abundance declines on an upstream gradient as determined by the tolerance of individual species for low and variable salinity conditions.

### 5A.3.1.2 Northern Anchovy Status and Distribution

Northern anchovy is distributed along the West Coast from British Columbia to Baja California (Miller and Lea 1972). The Central subpopulation, which is present in the action area, ranges from approximately San Francisco, California, to Punta Baja, Baja California. Members of the central population move north during the summer and south during the winter (Haugen et al. 1969). Northern anchovy is an important forage fish for other resident and migratory species in the San Francisco Estuary and Delta, including salmon, jacksmelt, and striped bass (Baxter et al. 1999:167). It supports a moderate commercial fishery for live bait (Smith and Kato 1979). The annual abundance of northern anchovy is highly variable between years (Baxter et al. 1999; Figure 5A.3-1). Surveys have shown that the greatest densities occur in San Pablo Bay and central and south San Francisco Bay, and only in late summer were they collected in appreciable numbers in Suisun Bay (Baxter et al. 1999; Figure 5A.3-2).

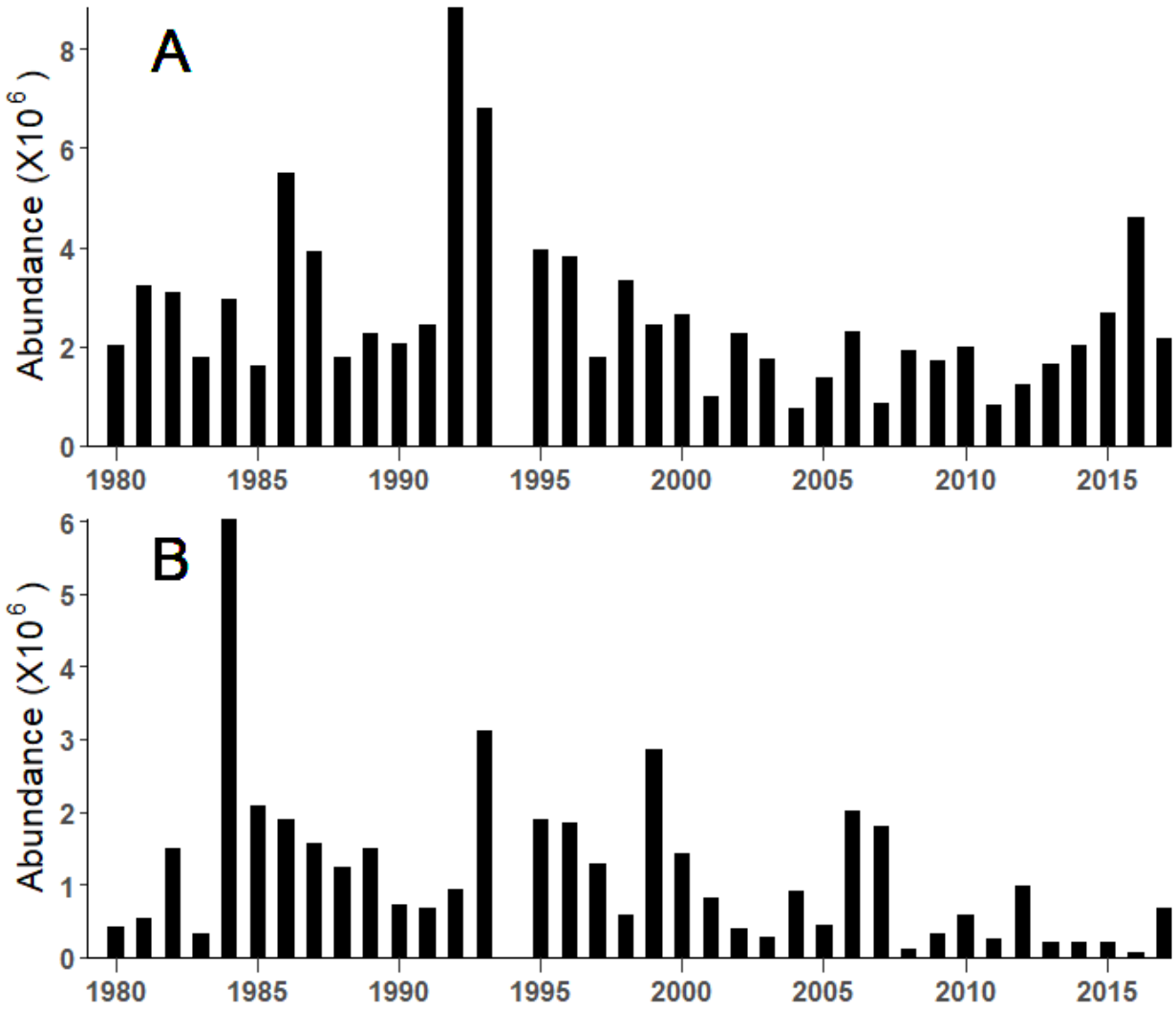


**Figure 5A.3-1. Annual Abundance of Northern Anchovy: (A) Age 0 and (B) Age 1+, No Abundance Index Was Calculated for 1994 (following analyses of Baxter et al. 1999)**

Similarly, age-1+ northern anchovy had a similar annual distribution but unlike age-0 fish, the south San Francisco Bay catch-per-unit effort of age-l+ fish tended to be greater than the CPUE in San Pablo Bay, especially after 1984.

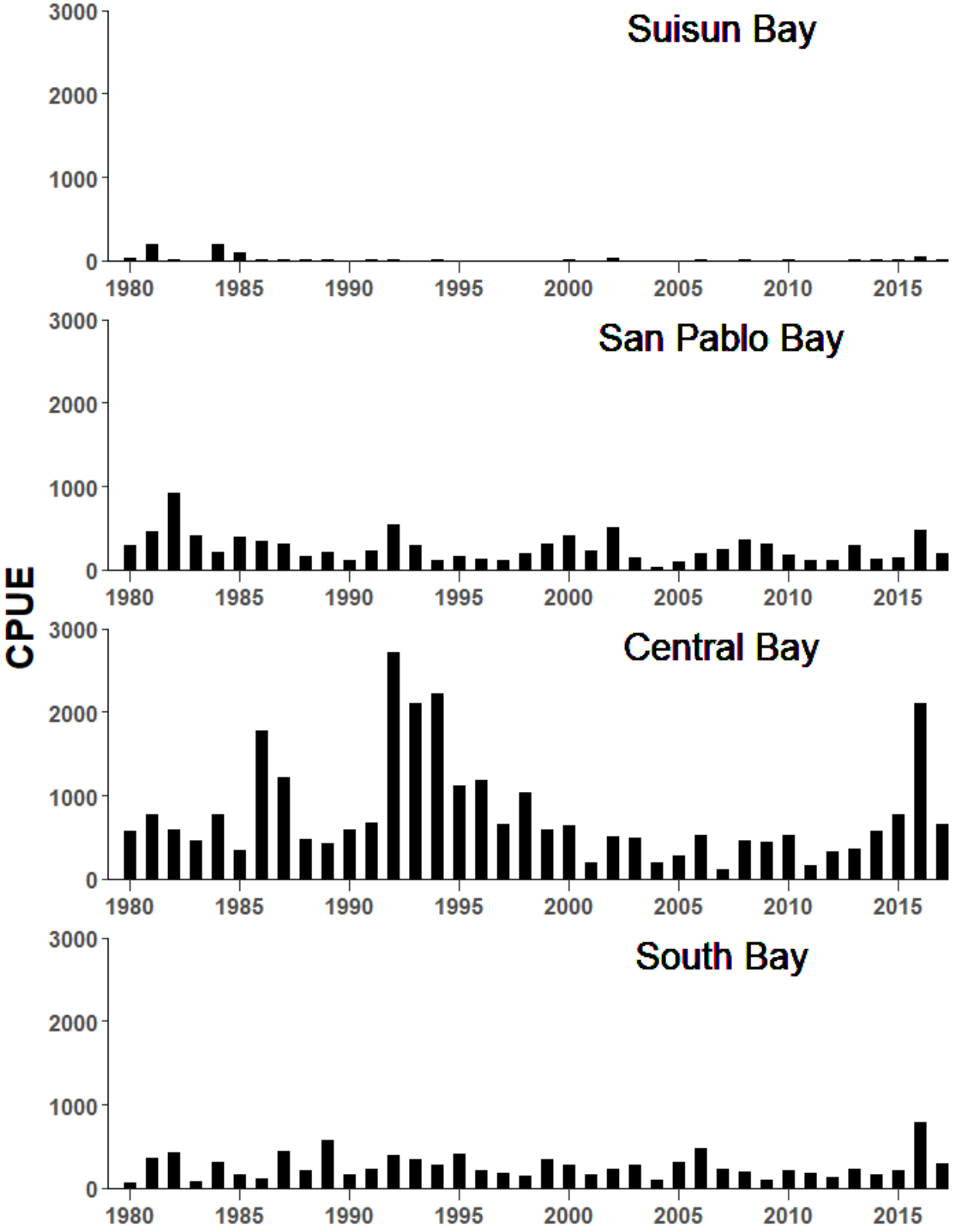


**Figure 5A.3-2. Catch-per-Unit Effort of Age-0 Northern Anchovy by San Francisco Embayment 1980–2017 (following analyses of Baxter et al. 1999)**

### Northern Anchovy Life History

Northern anchovy is a small fish typically found in schools near the surface of the water. They rarely live past 4 years of age. A portion of the population reaches maturity at the end of their first year, about 50% by the end of their second year, and all are mature by their third or fourth year (Clark and Phillips 1952). Female anchovy are batch spawners, spawning 20 to 30 thousand eggs a year in two or three events (Baxter 1967). Spawning can occur during every month of the year and is temperature dependent, increasing in late winter and early spring and peaking from February to April. They spawn in nearshore areas across their entire range, in the upper 50 meters of the water column. Spawning in the San Francisco Bay-Delta occurs at higher temperatures and lower salinities than spawning in coastal areas (McCrae 1994; Bergen and Jacobson 2001). Northern anchovy eggs and larvae are found near the surface, and eggs need 2 to 4 days to hatch, depending on water temperatures. The bay is a very productive nursery area because of high abundance of food for both larvae and adults, advective losses are lower than in adjacent coastal waters, and the bay is warmer, with varying salinity allowing for eggs and larvae throughout the year (Bureau of Reclamation 2008). Anchovies feed diurnally either by filter feeding or biting, depending on the size of the food. Juvenile and adult anchovy feed at a higher trophic level than larvae, selectively feeding on larger zooplankton (mysids), fish eggs, and fish larvae and have been observed to eat small fish at times, even their own species (Baxter 1967).

Larvae eat phytoplankton and dinoflagellates, while larger larvae pick up copepods and other zooplankton. Larger female anchovies can consume up to 4%–5% of their total body weight per day. Competitors with the anchovy for food include sardines and other schooling planktivores, such as jacksmelt and topsmelt. These species are also potential predators of young anchovy life stages (Goals Project 2000). All life stages of the northern anchovy are important prey for virtually every predatory fish, bird, and mammal in San Francisco Bay, including California halibut, Chinook salmon, rockfishes, sharks, harbor seal, sea lions, brown pelican, sooty shearwater, and cormorants.

### Factors Affecting Northern Anchovy Abundance

Factors affecting anchovy production are mostly natural influences, such as ocean temperature. Offshore within the California Current, temperature, upwelling, and stable stratification of the water column are believed to work together to produce conditions that are favorable to anchovy larvae (Lasker 1975). Investigation of the correlations between Delta outflow (X2) and indices of abundance and habitat did not find statistically significant relationships (Kimmerer et al. 2009). The distribution of northern anchovy shifted toward higher salinity when *Potamocorbula* invaded in the mid- to late 1980s, reducing summer abundance by more than 90% in the low-salinity region of the San Francisco Estuary and Delta (Kimmerer 2006).

## 5A.3.2 Pacific Coast Groundfish

### 5A.3.2.1 Pacific Coast Groundfish EFH in the Action Area

Starry flounder is a species for which EFH exists in the San Francisco Estuary and Delta. The overall extent of Pacific Groundfish EFH includes all water and substrate in depths that are less than or equal to 11,483 feet (3,500 meters or 1,914 fathoms) to the mean high-water level or the upriver extent of saltwater intrusion (upstream area and landward where waters have salinities less than 0.5 parts per thousand [ppt]), known spawning habitat and thermal refugia, complex channels and floodplains, and areas containing estuarine and marine submerged aquatic vegetation.

#### 5A.3.2.2 Starry Flounder Status and Distribution

Starry flounder is a flatfish that belongs to the family Pleuronectidae (Moyle 2002). Starry flounder range from north of the Bering Strait south to Los Angeles Harbor. Older juveniles and adults are found from 120 kilometers (km) upstream to the outer continental shelf at 375-meter depth, but most adults are found at less than 150-meter depth. Most juvenile fish are found in shallow, fresh to brackish water, and shift to salinities of 10–15 ppt as they mature, but appear to remain within estuaries through at least their second year (Baxter et al. 1999; Moyle 2002). During the late fall and winter, mature starry flounder probably migrate to shallow coastal waters to spawn (Orcutt 1950). Adults primarily inhabit coastal marine waters (Orcutt 1950; Haertel and Osterberg 1967; Bottom et al. 1984; Hieb and Baxter 1993). Distribution of age-0 juveniles within the San Francisco Estuary and Delta is primarily in Suisun Bay and San Pablo Bay, with lower abundance in the west Delta (Baxter et al. 1999:410; Figure 5A.3-3). Starry flounder older than age 1 (age-1+ fish) occur principally in San Pablo Bay, Suisun Bay, and central San Francisco Bay (Baxter et al. 1999:411–412; Figure 5A.3-4).

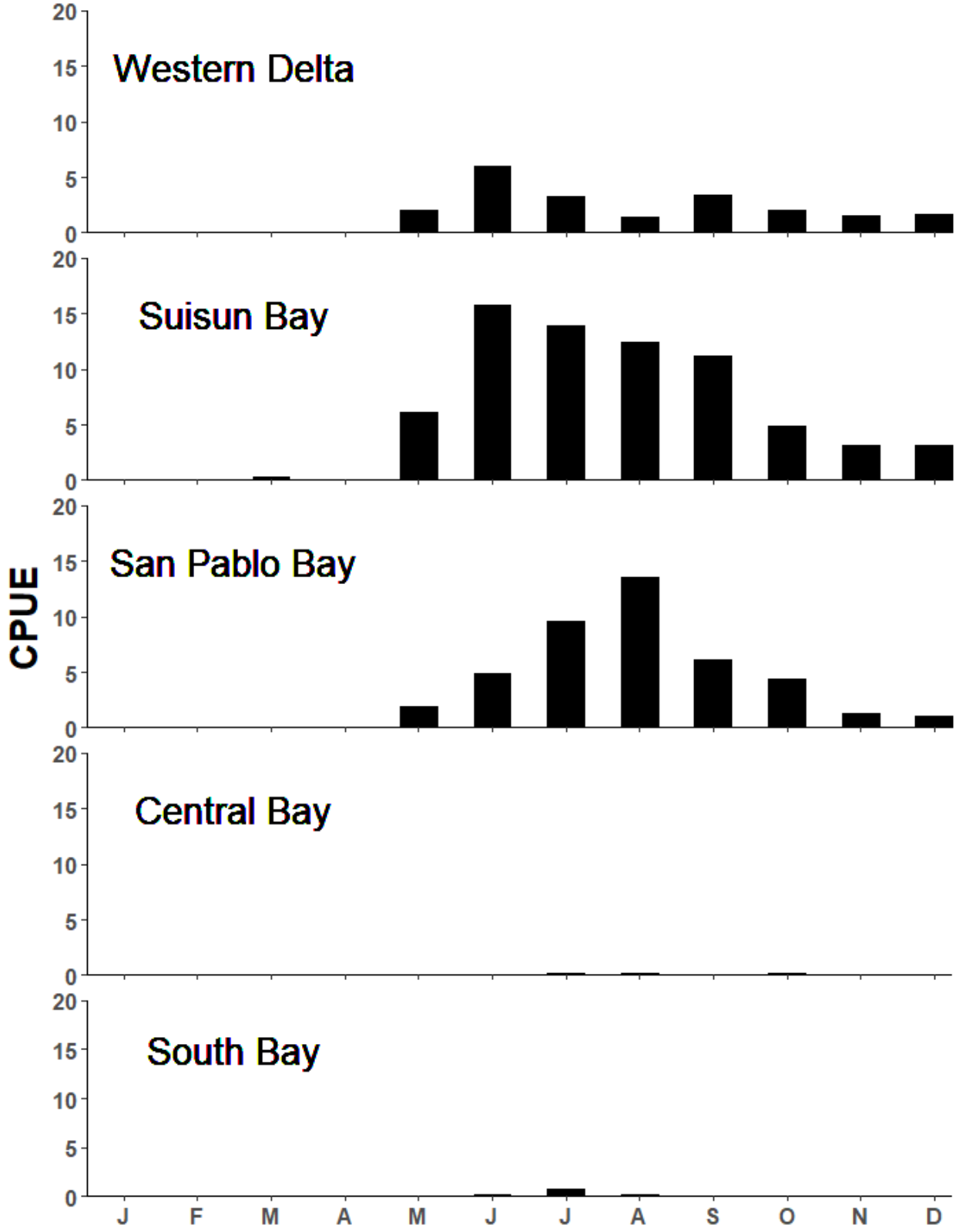


**Figure 5A.3-3. Catch-per-Unit Effort of Age-0 Starry Flounder by San Francisco Embayment 1981–2017 (following analyses of Baxter et al. 1999)**

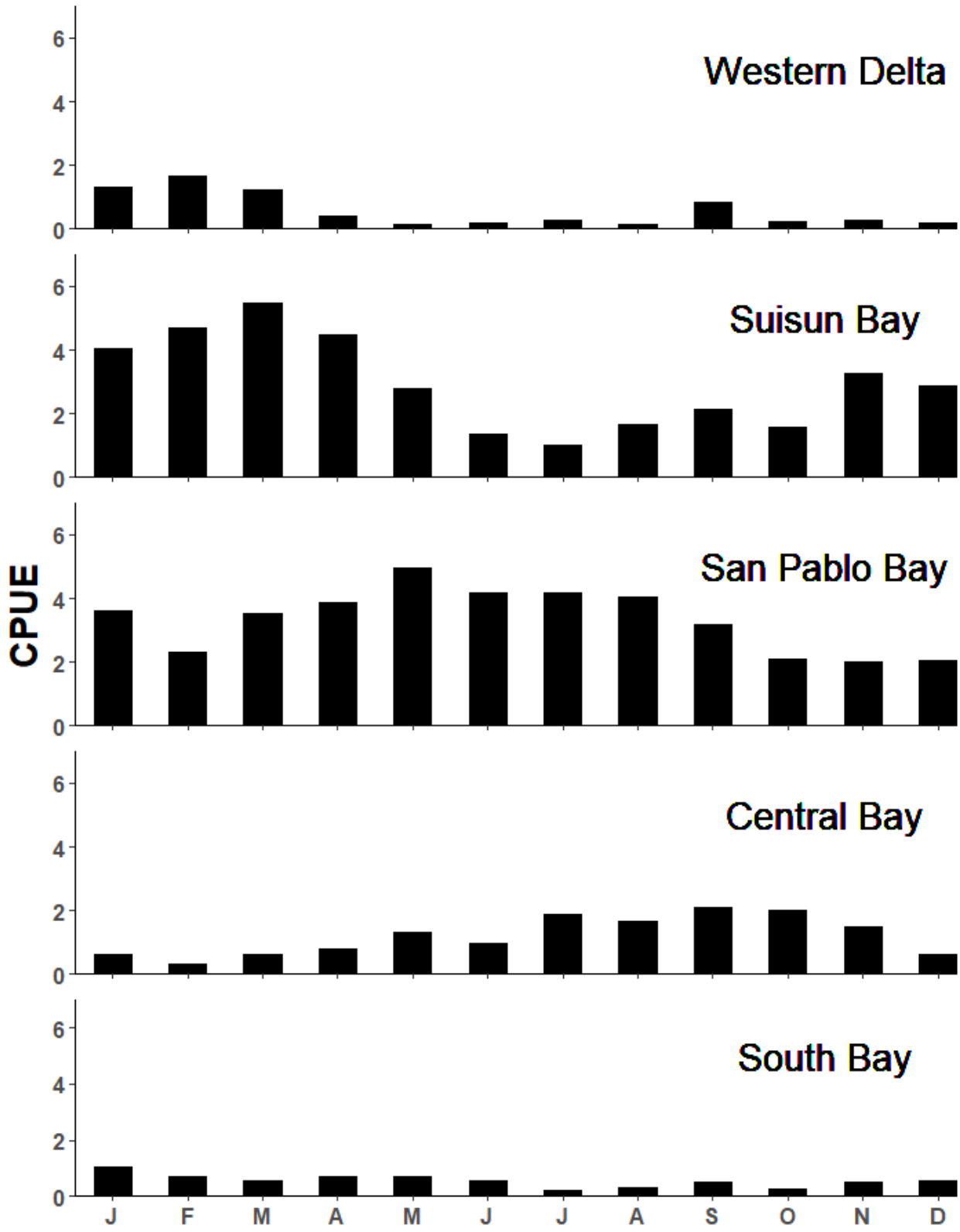


**Figure 5A.3-4. Catch-per-Unit Effort of Age-1+ Starry Flounder by San Francisco Embayment 1981–2017 (following analyses of Baxter et al. 1999)**

Though seldom targeted, the starry flounder is common in both commercial and recreational fisheries of Northern and central California (Orcutt 1950, Haugen 1992, Karpov et al. 1995). The best indicator of starry flounder abundance within the Delta and Suisun Bay is the number of starry flounder salvaged and the UC Davis Suisun Marsh monitoring study. Combined salvage at the pumping facilities shows a decline over time although the correlation between year and the number of starry flounder salvaged is not significant statistically (Figure 5A.3-5; Spearman rank correlation, rho = -0.48, p = 0.0103).

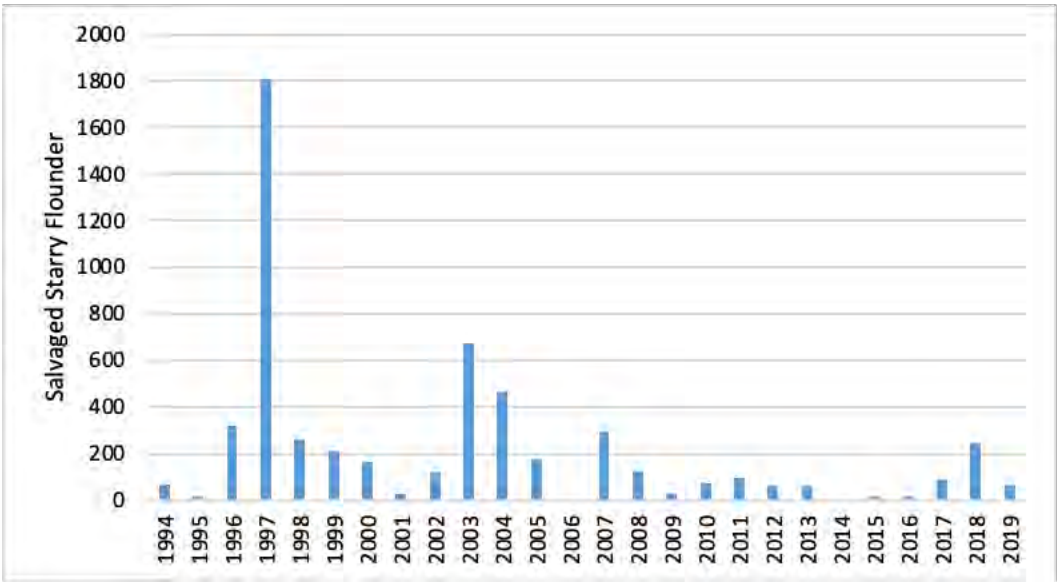


**Figure 5A.3-5. Salvage by Year of Starry Flounder at Pumping Facilities 1981–2019**

Similar to the pumping facilities, the UC Davis Suisun Marsh monitoring study shows a negative trend by year, but the Spearman rank correlation was not statistically significant (Figure 5A-6; Spearman rank correlation, rho = -0.17, p = 0.29).

The population status of starry flounder has not been studied, but commercial catches and recreational catches have trended downward since the 1980s. The California population is now at all-time lows. This could be the product of the relocation of adult fish associated with the 1976–1977 oceanic regime shift or the result of overfishing of spawning adults in commercial catches. The large population declines suggested by commercial and recreational catches are substantiated by the Bay Study trawl survey that showed age-0 and age-1+ starry founder abundance and CPUE dropping dramatically during the late 1980s and remaining at low levels through the 1990s (Baxter et al. 1999).

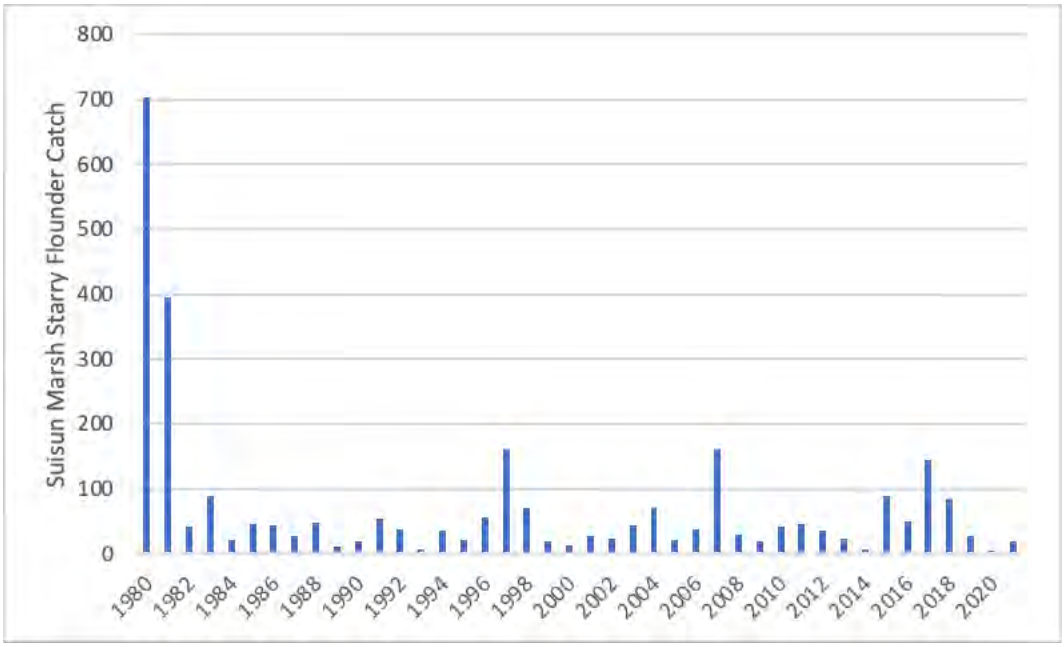


**Figure 5A.3-6. Total Catch by Year UC Davis Monitoring Study 1980–2020**

## Starry Flounder Life History

In general, abundance indices from the past decade suggest a decline relative to several decades ago, consistent with declines in commercial and recreational catch (ICF International 2016:5.E-12 and 5.E-13). Starry flounder are found on different substrates including gravel, clean shifting sand, hard stable sand, and mud substrata, but fishermen report the largest catches over soft sand. Prey from mud (sternapsid worms) and sand (*Siliqua patula* clams) habitats have been observed in the stomach of a single individual, suggesting fish move freely from one habitat type to another (Orcutt 1950). Starry flounder also consume crabs, shrimps, worms, clams and clam siphons, other small mollusks, small fishes, nemertean worms, and brittle stars (Hart 1973). Starry flounder can tolerate a wide range of salinities. In the Sacramento and San Joaquin Rivers, starry flounder have been observed in salinities of 0.02–0.06 ppt (i.e., essentially fresh water) (Orcutt 1950) and have been collected 75 miles upstream in the Columbia River. Age-0 and age-1+ starry flounder are a common species in estuarine habitats along the West Coast (see Orcutt 1950; Sopher 1974; Pearson 1989; Emmett et al. 1991; Baxter et al. 1999; Kimmerer 2002). Spawning occurs primarily during the winter months of December and January (Orcutt 1950). Starry flounder reach approximately 110 millimeters (mm) in length by the end of their first year. By the time they reach age 2 many fish have migrated to ocean habitats adjacent to their natal estuaries. Starry flounder become reproductively mature at age 2 for males and age 3 for females, which equates to approximately 28 centimeters (cm) in males and approximately 35 cm in females. Adults may move seasonally into shallow coastal waters to spawn, perhaps in proximity to estuaries to take advantage of estuarine circulation, which would advect fertilized eggs near the bottom into nursery areas.

## Factors Affecting Starry Flounder Abundance

The significance of estuarine rearing for age-0 and age-1 starry flounder is implied from high habitat association with fresh to mesohaline waters and from the small numbers of age-0, age-l and age-2 fish found in coastal marine areas (Rogers et al. 1988; Yoklavich et al. 1991).

Hieb and Baxter (1993) established specific habitat criteria for starry flounder young-of-year (<70 mm) in the San Francisco Estuary: 90% were collected from intertidal and subtidal habitats less than 7 meters in depth and with accompanying salinities of less than 22%. The exclusivity of fresh and brackish water rearing habitat in age-0 and age-1 starry flounder coupled with the relationship between freshwater outflow and abundance makes a strong case for estuarine dependence (Emmett et al. 1991; Hieb and Baxter 1993). However, spawning in coastal areas and variation in abundance during high outflow years suggest that coastal ocean conditions as well as high outflow work in conjunction to determine year class abundance (Hieb and Baxter 1993). There is a significant correlation between Delta outflow (X2) and indices of starry flounder abundance in the San Francisco Estuary and Delta, although the mechanism underlying the correlation does not appear to be related to extent of habitat and may be related to enhanced transport to estuarine rearing grounds by increased residual circulation with increased outflow (Kimmerer et al. 2009). It is unknown the extent to which this potential enhanced transport and apparent greater abundance in the San Francisco Estuary and Delta with greater outflow may contribute to overall coastwide starry flounder abundance (Grimaldo 2018:13-14).

## 5A.3.3 Pacific Salmon

### 5A.3.3.1 Pacific Salmon EFH in the Action Area

The four races of Chinook salmon occurring in the action area are covered under the MSA (collectively as "Pacific salmon").[1] Each uses the action area extensively as juvenile rearing habitat and juvenile and adult migration corridors. Coho salmon are restricted to the mixed marine/estuarine habitats of San Pablo Bay and San Francisco Bay, which they historically used as juvenile and adult migratory corridors and foraging habitats between the ocean and natal tributaries area. However, any occurrence in the action area is expected to be rare at best because this species is believed to have been extirpated from tributaries to San Francisco Bay and San Pablo Bay (National Marine Fisheries Service 2012). Pacific Salmon HAPCs include all Pacific Salmon EFH within the proposed action area that can serve as spawning habitat or thermal refugia for Pacific salmon, contain complex channels, floodplains, and estuarine and marine submerged aquatic vegetation, and occur within estuarine waters with an inland extent of ocean-derived salts measuring less than 0.5 ppt during the period of average annual low freshwater flow.

The status, distribution, life history, and habitat requirements of winter-run and spring-run Chinook salmon, which are listed under the ESA, are provided in Chapter 4. Chapter 4 also contains a review of fall-run/late fall–run Chinook salmon that is referenced in this EFH analysis.

# 5A.4 Potential Effects of Proposed Action

## 5A.4.1 Coastal Pelagic Species

Coastal pelagic EFH in the action area is known to support one species, the northern anchovy. The proposed action is at the edge of this species occurrence within the San Francisco Estuary, and it is likely that its occurrence will be infrequent and generally affect fish during their early life history stages.

[1] Sacramento River winter-run, Central Valley spring-run, Central Valley fall-run, and Central Valley late fall–run.

To the extent that there is exposure, the proposed action has the potential to affect EFH for this Coastal Pelagic Species through the following main mechanisms during construction.

- Water quality effects from *turbidity and suspended sediment* during construction.
- Water quality effects from *contaminant exposure*.
- *Acoustic effects* associated with construction.
- *Fish stranding* from the placement of the cofferdam during construction.
- *Direct physical injury* during active periods of construction.
- *Loss/alteration of habitat* associated with construction or permanent placement of engineered structures in habitat.

### 5A.4.1.1 Northern Anchovy

Potential action effects may include minimal short- to long-term water quality degradation (e.g., from sediment disturbance during construction) and changes in depth, food, cover and habitat complexity, and habitat connectivity. However, there is expected to be very low overlap of northern anchovy with these near-field effects because, as discussed in Section 5A.3.1.2, *Northern Anchovy Status and Distribution*, the species primarily occurs well downstream of the Delta (Figures 5A.3-1 and 5A.3-2), with very low abundance even in Suisun Bay (as a result of reduced food availability caused by *Corbula amurensis* invasion; Kimmerer 2006). Therefore, based upon the minimal short-term impacts, the very low likelihood of species presence, and the small fraction of the habitat impacted, any potential adverse effects on EFH would be undetectable.

#### Effects of Water Facility Construction

##### North Delta Intakes

Construction of the north Delta intakes (Chapter 5, Figure 5.1-1) could result in turbidity and suspended sediment, potential contaminant exposure from spills or mobilization of contaminated sediment, underwater noise, fish stranding, direct physical injury, and temporary to long-term losses or alteration of migration and rearing habitat. However, as previously noted, such effects would be expected to be minimal, and the species principally occurs well downstream of the Delta (Figures 5A.3-1 and 5A.3-2); therefore, any adverse effects on coastal pelagic EFH would be undetectable (represented by northern anchovy).

***Turbidity and Suspended Sediment***

The construction of the proposed action would result in the generation and release of suspended sediments to the water column, temporarily increasing water column turbidity above ambient levels and altering habitat conditions for fish and aquatic resource species. Turbidity-producing construction activities include bed and bank disturbance during cofferdam and log boom installation, dredging for riprap placement adjacent to the new intake locations, and the placement of bed and bank armoring. Propeller wash associated with boat traffic at construction sites during placement of riprap at the end of construction may also produce localized turbidity pulses, depending on location.

These activities would occur during the expected in-water construction window (typically June 1 through October 31). Behavioral effects may include alarm reaction, altered schooling behavior,

cover abandonment, and avoidance or attraction depending on the type of sediments and sediment concentration.

Such behavioral effects may be caused by changes in light penetration/scattering. Physiological effects may include changes in respiration rate, choking, coughing, abrasion and puncturing of structures (gills, epidermis), reduced feeding, reduced water filtration rates, smothering, delayed or reduced hatching of eggs, reduced larval growth/development, abnormal larval development, and reduced responses to physical stimuli. Northern anchovy, similar to bay anchovy, would be considered a sensitive species, with 24-hour LC10 > 1,000 milligrams per liter (mg/L) and < 10,000 mg/L. A 24-hour exposure to 1,000 mg/L of suspended sediment caused mechanical damage to the epidermis of Pacific herring larvae (similar to northern anchovy), while 4,000 mg/L caused epidermal punctures and abrasion of micro-ridges on scales (Newcombe and Jensen 1996).

With the implementation of the proposed avoidance and minimization measures (AMMs) to minimize potential water quality impacts (Appendix 3A, *General Avoidance and Minimization Measures*), the potential effects of increased turbidity and suspended sediment on EFH would be limited to temporary, localized degradation of water quality and substrate in the vicinity of the intake construction sites. No substantial, long-term effects on EFH would occur, and the effect would be undetectable.

***Contaminant Exposure***

Construction of the north Delta intakes could affect EFH through accidental spills of contaminants, including cement, oil, fuel, hydraulic fluids, and paint, and through disturbance and mobilization of contaminated soil or sediments within the temporary and permanent footprints of the intake facilities. The potential for contaminant exposure is highest during in-water construction activities (June 1–October 31), but some risk would exist during the entire construction period. The risk of exposure of northern anchovy to contaminants would be effectively minimized by the implementation of proposed pollution prevention and control AMMs, specifically AMM-27: *Develop and Implement a Barge Operations Plan* (Appendix 3A), AMM-2: *Develop and Implement Hazardous Materials Management Plans*, and AMM-3: *Develop and Implement Spill Prevention, Containment, and Countermeasure Plans.* These AMMs will minimize contaminants entering waterbodies and, if they are accidentally released, cleanup plans will minimize effects on special-status species. These measures are explained in detail in Appendix 3A. No substantial, long-term effects would occur on EFH and any effects would be immeasurable.

***Acoustic Effects***

Underwater noise would be generated by a variety of construction activities including pile driving, boat operations, geotechnical investigations, riprap placement, and tunnel boring machine (TBM) activities. Impact pile driving in or near aquatic habitat generates sound levels that can injure or kill fish and other aquatic organisms. The proposed action includes physical or structural components that would require vibratory and/or impact driving of temporary and permanent piles during construction. Several of these components involve pile driving activities within or adjacent to waterbodies supporting special-status fish species, resulting in potential exposure of species to pile driving noise.

These activities would cause EFH near pile driving operations to become unsuitable because of the potential for injury or mortality of northern anchovy. The acoustic effects of pile driving noise on listed salmonids (described in Chapter 5) are generally applicable to northern anchovy. Northern

anchovy would likely occur in low abundance, as compared to overall abundance within the San Francisco Estuary during in-water construction periods in the north Delta. Cumulative noise levels sufficient in intensity and duration to cause injury and mortality would occur for several weeks at each facility. Impact pile driving could also result in behavioral responses that may alter normal behavior.

California Department of Water Resources (DWR) proposes to minimize the extent and duration of potentially harmful pile driving noise by implementing AMM-26: *Develop and Implement an Underwater Sound Control and Abatement Plan*), in Appendix 3A). This underwater sound control and abatement plan will contain measures such as changing the time of activities, best practices, and equipment that will be used to avoid and minimize the effects of underwater construction noise on fish, particularly the underwater noise effects associated with impact pile driving activities.

The underwater sound control and abatement plan (AMM-26: *Develop and Implement an Underwater Sound Control and Abatement Plan*) will be provided to the appropriate fish and wildlife agencies for their review and approval prior to implementation of any in-water impact pile driving activities. The plan will evaluate the potential effects of underwater noise on fish using applicable and interim underwater noise thresholds established for disturbance and injury of fish (California Department of Transportation 2015:4-21–4-23). It is assumed these measures will also be protective to northern anchovy.

The underwater noise generated by impact pile driving will be abated using the best available and practicable technologies. Examples of such technologies include the use of vibratory rather than impact pile driving equipment; use of an impact pile driver to proof piles initially placed with a vibratory pile driver; noise attenuation with pile caps (e.g., wood or micarta), bubble curtains, air-filled fabric barriers, or isolation piles; or installation of piling-specific cofferdams. Specific techniques to be used will be selected based on site-specific conditions.

#### *Fish Stranding*

Although unlikely due to their preference for higher salinity water, northern anchovy could be present in the vicinity of intake construction on the Sacramento River during the period when cofferdams are installed to isolate work areas. This presents the potential for entrapment and also temporary loss of EFH habitat in isolated work areas. DWR proposes to implement a fish rescue and salvage plan that will identify appropriate procedures for monitoring and implementing appropriate collection and relocation methods if special-status species are detected (Appendix 3A, AMM-25: *Develop and Implement a Fish Rescue and Salvage Plan*).

#### *Reduced Prey Availability*

Construction of the proposed action has the potential to reduce prey availability (e.g., zooplankton, benthic invertebrates, small fish) for fish and aquatic species through disturbance of aquatic habitat. Prey species may be affected by pile driving (e.g., from noise effects or direct physical contact), barge and tugboat operations (e.g., noise, contaminants, and sediment disturbance), dredging (e.g., direct entrainment and sediment disturbance), removal of riparian aquatic habitat (i.e., reducing habitat structures for prey in or above water), and riprap placement (e.g., direct physical contact and sediment disturbance). Isolation of construction areas with cofferdams would prevent fish and aquatic species access to prey in these areas. The potential effects would be limited in extent relative to the overall area of habitat available to fish and aquatic species in the Delta.

***Direct Physical Injury***

In-water construction for the proposed action may result in direct physical injury or mortality to northern anchovy from activities including pile driving, barge and tugboat operations, enclosing construction areas, riprap placement, and construction water diversion from surface waters. Due to the timing of construction and salinity preferences of San Pablo and central San Francisco Bay, the majority of northern anchovy will not be present during the construction period. Thus, the potential for injury to northern anchovy is minimal due to the timing of in-water construction activities and likely avoidance of active construction areas.

***Loss/Alteration of Habitat***

Construction of the north Delta intakes would result in temporary to permanent losses or alteration of a small fraction of EFH for early life stages of northern anchovy. The species inhabits the whole of the San Francisco Estuary, and the loss of this EFH habitat within the proposed action would be a fraction of a percent of the total EFH habitat that is available to the species. In addition to the temporary effects on water quality and other construction-related hazards described above, the overall footprint of construction activities is approximately 7.112 acres of combined temporary and permanent impact, including approximately 5.574 acres of permanent impact on tidal perennial habitat (Chapter 5, Table 5.4-7).[2] The footprint impact on channel margin habitat in the Sacramento River is approximately 494 linear feet of temporary impact and approximately 3,124 linear feet of permanent impact (Chapter 5, Table 5.4-8).

The effects of habitat loss or alteration on listed salmonids and their designated critical habitat (described in Chapter 5, Section 5.5, *Effects of Water Facility Construction on Designated Critical Habitat*) are generally applicable to coastal pelagic EFH (represented by northern anchovy). DWR will implement AMM-14: *Construction Best Management Practices for Biological Resources* to limit the extent of loss and alteration of aquatic and riparian habitat during construction, and following construction, to restore temporarily disturbed areas to preconstruction conditions. All construction and site restoration BMPs will be subject to an approved construction and postconstruction monitoring plan to ensure their effectiveness. Any unavoidable losses of designated EFH will be offset through restoration of habitat at an approved restoration site and/or the purchase of conservation credits at an approved conservation bank. Consequently, any effects are immeasurable.

## 5A.4.2 Pacific Coast Groundfish

Pacific Coast groundfish EFH in the action area is known to support three species; however, as noted in Section 5A.2.2, *EFH Species and Habitats in the Action Area*, it was concluded that there would be no effect on the EFH for brown rockfish and English sole. No further analysis was conducted for these two species. Starry flounder inhabit the whole of the San Francisco Estuary, and the proposed action area involves the extreme edge of its EFH habitat. Starry flounder would likely be found only in the early juvenile life stage and infrequently within the proposed action area EFH habitat; therefore, any potential adverse effects on Pacific Coast groundfish EFH would be undetectable (represented by starry flounder).

[2] Temporary effects are the habitat acres that can be returned to original basic use following completion of construction; permanent effects are the habitat acres that cannot be returned to original basic use following completion of construction.

To the extent there is exposure, the proposed action has the potential to affect EFH for Pacific Coast groundfish through the following main mechanisms.

### 5A.4.2.1 Effects of Water Facility Construction

- Water quality effects from *turbidity and suspended sediment* during construction.
- Water quality effects from *contaminant exposure*.
- *Acoustic effects* associated with construction.
- *Fish stranding* from the placement of the cofferdam during construction.
- *Direct physical injury* during active periods of construction.
- *Loss/Alteration of habitat* associated with construction or permanent placement of engineered structures in habitat.

### 5A.4.2.2 Starry Flounder

The proposed action is expected to have short- and long-term effects on EFH for starry flounder, although the species inhabits the whole of the San Francisco Estuary and the loss of EFH habitat within the action area would be a fraction of a percent of the total EFH habitat that is available to the species. Potential action effects include short- to long-term water quality degradation and changes in depth, food, cover and habitat complexity, and habitat connectivity. Overlap of starry flounder with near-field effects (e.g., from construction) would be expected to be limited, however, because the species' main range is downstream of the Delta, as discussed in Section 5A.2.2 (Figures 5A.3-3 and 5A.3-4).

#### Effects of Water Facility Construction

##### North Delta Intakes

Construction of the north Delta intakes (see Chapter 5, Figure 5.1-1) could result in turbidity and suspended sediment, potential contaminant exposure from spills or mobilization of contaminated sediment, underwater noise, fish stranding, direct physical injury, and temporary to long-term losses or alteration of migration and rearing habitat. However, the effect would be negligible because of the small fraction of habitat affected and the minor potential overlap with starry flounder.

***Turbidity and Suspended Sediment***

Because starry flounder are benthic fish and they inhabit naturally turbid waters, they are unlikely to be affected by a temporary increase in turbidity within their EFH habitat, although the suspension of contaminants within bottom substrates could affect starry flounder if the exposure is prolonged. With the implementation of the proposed AMMs to minimize potential water quality impacts (Appendix 3A), the potential effects of increased turbidity and suspended sediment on EFH would be limited to temporary, localized degradation of water quality and substrate in the vicinity of the intake construction sites.

***Contaminant Exposure***

Construction of the north Delta intakes could affect EFH through accidental spills of contaminants, including cement, oil, fuel, hydraulic fluids, and paint, and through disturbance and mobilization of contaminated soil or sediments within the temporary and permanent footprints of the intake facilities. The potential for contaminant exposure is highest during in-water construction activities (June 1–October 31), but some risk would exist during the entire construction period. The risk of exposure of starry flounder to contaminants would be effectively minimized by the implementation of proposed pollution prevention and control AMMs, specifically AMM-27: *Develop and Implement a Barge Operations Plan* (Appendix 3A), AMM-2: *Develop and Implement Hazardous Materials Management Plans*, and AMM-3: *Develop and Implement Spill Prevention, Containment, and Countermeasure Plans.* These AMMs will minimize contaminants entering waterbodies and, if they are accidentally released, cleanup plans will minimize effects on special-status species. These measures are explained in detail in Appendix 3A. No substantial, long-term effects would occur on EFH, and any effects would be immeasurable.

***Acoustic Effects***

Underwater noise would be generated by a variety of construction activities including pile driving, boat operations, geotechnical investigations, riprap placement, and TBM activities. Impact pile driving in or near aquatic habitat generates sound levels that can injure or kill fish and other aquatic organisms. The proposed action includes physical or structural components that would require vibratory and/or impact driving of temporary and permanent piles during construction. Several of these components involve pile driving activities within or adjacent to waterbodies supporting special-status fish species, resulting in potential exposure of species to pile driving noise.

These activities would cause EFH near pile driving operations to become unsuitable because of the potential for injury or mortality of groundfish, including starry flounder. Young-of-year and juvenile starry flounder could be present near the intakes during June through September, with abundance then tapering off through December; however, as previously noted, the main range of the species is well downstream of the intakes (Figures 5A.3-3 and 5A.3-4). It is assumed the acoustic effects of pile driving noise on listed salmonids (described in Chapter 5) are generally applicable to starry flounder. Starry flounder would likely occur in low abundance, as compared to overall abundance within the San Francisco Estuary during in-water construction periods in the north Delta. Cumulative noise levels sufficient in intensity and duration to cause injury and mortality would occur for several weeks at each facility. Impact pile driving could also result in behavioral responses that may alter normal behavior.

DWR proposes to minimize the extent and duration of potentially harmful pile driving noise by implementing AMM-26: *Develop and Implement an Underwater Sound Control and Abatement Plan* (Appendix 3A). This underwater sound control and abatement plan will contain measures such as changing the time of activities, best practices, and equipment that will be used to avoid and minimize the effects of underwater construction noise on fish, particularly the underwater noise effects associated with impact pile driving activities.

The underwater sound control and abatement plan (AMM-26: *Develop and Implement an Underwater Sound Control and Abatement Plan*) will be provided to the appropriate fish and wildlife agencies for their review and approval prior to implementation of any in-water impact pile driving activities. The plan will evaluate the potential effects of underwater noise on fish using applicable and interim underwater noise thresholds established for disturbance and injury of fish (California

Department of Transportation 2015:4-21–4-23). It is assumed these measures will also be protective to starry flounder.

The underwater noise generated by impact pile driving will be abated using the best available and practicable technologies. Examples of such technologies include the use of vibratory rather than impact pile driving equipment; use of an impact pile driver to proof piles initially placed with a vibratory pile driver; noise attenuation with pile caps (e.g., wood or micarta), bubble curtains, air-filled fabric barriers, or isolation piles; or installation of piling-specific cofferdams. Specific techniques to be used will be selected based on site-specific conditions.

***Fish Stranding***

Starry flounder could be present in the vicinity of intake construction on the Sacramento River during the period when cofferdams are installed to isolate work areas, although this is considered unlikely due to the preference for higher salinity water (Figures 5A.3-3 and 5A.3-4). This presents the potential for entrapment and temporary loss of EFH habitat in isolated work areas. DWR proposes to implement a fish rescue and salvage plan that will identify appropriate procedures for monitoring and implementing appropriate collection and relocation methods if special-status species are detected (Appendix 3A, AMM-25: *Develop and Implement a Fish Rescue and Salvage Plan*).

***Reduced Prey Availability***

Construction of the proposed action has the potential to reduce prey availability (e.g., zooplankton, benthic invertebrates, small fish) for fish and aquatic species through disturbance of aquatic habitat. Prey species may be affected by pile driving (e.g., from noise effects or direct physical contact), barge and tugboat operations (e.g., noise, contaminants, and sediment disturbance), dredging (e.g., direct entrainment and sediment disturbance), removal of riparian aquatic habitat (i.e., reducing habitat structures for prey in or above water), and riprap placement (e.g., direct physical contact and sediment disturbance). Isolation of construction areas with cofferdams would prevent fish and aquatic species access to prey in these areas. The potential effects would be limited in extent relative to the overall area of habitat available to fish and aquatic species in the Delta.

***Direct Physical Injury***

In-water construction for the proposed action may result in direct physical injury or mortality to northern anchovy from activities including pile driving, barge and tugboat operations, enclosing construction areas, riprap placement, and construction water diversion from surface waters. Due to the timing of construction and salinity preferences of San Pablo and central San Francisco Bay, the majority of starry flounder will not be present during the construction period. Thus, the potential for injury to northern anchovy is minimal due to the timing of in-water construction activities and likely avoidance of active construction areas.

***Loss/Alteration of Habitat***

Construction of the north Delta intakes would result in temporary to permanent losses or alteration of a small fraction of EFH for starry flounder. The species' main range is downstream of the Delta and includes the whole of the San Francisco Estuary. The loss of this EFH habitat within the proposed action would be a fraction of a percent of the total EFH habitat that is available to the species. In addition to the temporary effects on water quality and other construction-related hazards described above, the overall footprint of construction activities is approximately 7.112

acres of temporary impact and approximately 5.574 acres of permanent impact on tidal perennial habitat (Chapter 5, Table 5.4-7).[3] The footprint impact on channel margin habitat in the Sacramento River is approximately 494 linear feet of temporary impact and approximately 3,124 linear feet of permanent impact (Chapter 5, Table 5.4-8).

## 5A.4.3 Pacific Salmon

Pacific salmon EFH in the action area is known to support four ESUs of one species, Chinook salmon. As previously noted, this assessment of Pacific salmon EFH follows the NMFS (2019) BiOp in concluding that the effects analysis for winter-run and spring-run Chinook salmon presented in Chapter 5 of this Biological Assessment (BA) generally is expected to apply to Pacific salmon EFH. The analysis presented below focuses on fall-run/late fall–run Chinook salmon, with conclusions for Pacific salmon EFH considering all races together, including hatchery-origin fish.

To the extent there is exposure, the proposed action has the potential to affect EFH for Pacific Salmon through the following main mechanisms.

- Water quality effects from *turbidity and suspended sediment* during construction.
- Water quality effects from *contaminant exposure*.
- *Acoustic effects* associated with construction.
- *Fish stranding* from the placement of the cofferdam during construction.
- *Direct physical injury* during active periods of construction.
- *Loss/alteration of habitat* associated with construction or permanent placement of engineered structures in habitat.

### 5A.4.3.1 Fall-Run and Late Fall–Run Chinook Salmon

#### Effects of Water Facility Construction

Refer to Chapter 5 for details of construction-related effects on fall-run/late fall–run Chinook salmon. This includes acoustic effects, sediment disturbance, construction contaminants, direct physical injury, reduced prey availability, increased predation, increased water temperature, and reduced habitat extent and access.

## 5A.4.4 Effects of Mitigation Measures

### 5A.4.4.1 Compensatory Mitigation

#### Northern Anchovy

The Compensatory Mitigation Plan (CMP) (Appendix 3B, *Compensatory Mitigation Plan for Special-Status Species and Aquatic Resources*) could result in impacts on northern anchovy. Compensatory mitigation (tidal perennial and channel margin habitat restoration) would be upstream of areas

[3] Temporary effects are the habitat acres that can be returned to original basic use following completion of construction; permanent effects is the habitat acres that cannot be returned to original basic use following completion of construction.

where northern anchovy typically occur (Baxter et al. 1999), although there could be some spatial overlap, thereby providing the benefit of some additional habitat for the species.

#### Starry Flounder

The CMP could result in impacts on starry flounder. Compensatory mitigation (tidal perennial and channel margin habitat restoration) would be upstream of areas where starry flounder typically occur (Baxter et al. 1999), although there could be some spatial overlap, thereby providing the benefit of some additional habitat for the species.

#### Pacific Salmon

The CMP could result in impacts on Pacific salmon. Additional details of this analysis can be found in Chapter 5.

### 5A.4.4.2 Avoidance and Minimization Measures Effects

The AMMs are actions that are incorporated into the engineering or design of the proposed action and are intended to avoid, reduce, or minimize adverse effects that apply to one or more species. AMMs vary depending on the protected resource, with different approaches used for wildlife and fish. Biological differences between listed species of wildlife and fish species result in very different AMMs. Fish are generally not known to occur in a given site; rather, if the site is known to provide suitable habitat, fish are assumed to be potentially present, at least at certain times of the year. Therefore, AMMs for fish are heavily focused on protecting their habitat from stresses such as water quality impairment, dewatering, and/or underwater noise. Wildlife species, on the other hand, often have very specific habitat requirements, and the individual animals can often be detected through application of established survey protocols, making field surveys a key component of wildlife AMMs. Refer to Appendix 3A for additional information.

#### Pacific Salmon

The AMMs proposed could result in impacts on Pacific salmon. Additional details of this analysis can be found in Chapter 5.

## 5A.5 Conclusions

### 5A.5.1 Effects of Water Facility Construction and Maintenance

Construction and maintenance of water facilities under the proposed action has the potential to affect EFH for Coastal Pelagic Species, Pacific Coast groundfish, and Pacific salmon. The effects of construction activities will be minimized through AMMs, and temporary and permanent habitat losses will be offset by habitat creation and enhancement through channel margin enhancement and tidal wetland restoration (Appendix 3B).

Underwater noise generated by impact pile driving in or near surface waters will result in temporary reductions in habitat suitability in the vicinity of the pile driving. This will be minimized by implementation of, AMM-26: *Develop and Implement an Underwater Sound Control and Abatement Plan* (Appendix 3A).

Structural changes associated with temporary (construction) or permanent placement of engineered structures in habitat include placement of in-water pilings and over-water structures. Such structures may offer cover for predators and may locally reduce foraging habitat quality. These effects will be minimized by implementation of the AMMs described in Appendix 3A. Additionally, these effects will be offset by habitat creation at ratio of 1:1 acre created for each acre affected, to be provided at an approved NMFS mitigation bank (Appendix 3B).

Water quality effects from in-water construction may occur as a result of turbidity, disturbance of existing contaminated sediments, or due to accidental spills of contaminants such as cement, oil, fuel, hydraulic fluid, paint, or other construction-related materials. These potential effects will be minimized by implementing the AMMS described in Appendix 3A, including AMM14: *Construction Best Management Practices for Biological Resources,* AMM-4b: *Develop and Implement Stormwater Pollution Prevention Plans,* AMM-4a: *Develop and Implement Erosion and Sediment Control Plans,* and AMM-3: *Develop and Implement Spill Prevention, Containment, and Countermeasure Plans*.

Northern anchovy, starry flounder, or Pacific salmon could be present in the vicinity of intake construction on the Sacramento River during the period when cofferdams are installed to isolate work areas. This presents the potential for entrapment within the isolated work areas and the subsequent blockage of their use of their total EFH habitat. Effects would also be minimized through the implementation of avoidance and minimization measures in Appendix 3A.

In summary, the expected construction and maintenance effects on EFH for Coastal Pelagic Species, Pacific Coast groundfish, and Pacific salmon primarily would be temporary, localized, and for Pacific Coast groundfish and Coastal Pelagic Species, well outside the species' main range. Permanent habitat changes associated with new in-water structures would be offset by creation of equal or higher quality habitat at a NMFS-approved location or mitigation bank. Therefore, the effects of construction and maintenance of the proposed action on EFH would be negligible.

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Appendix 5B

# Delta Conveyance Project North Delta Diversion Fisheries Field Studies Workplan

# Delta Conveyance Project North Delta Diversion Fisheries Field Studies Workplan

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# Acronyms and Other Abbreviations

| Acronym | Definition |
|---|---|
| 2D | two-dimensional |
| 3D | three-dimensional |
| ARIS | Adaptive Resolution Imaging Sonar |
| BDCP | Bay Delta Conservation Plan |
| CDFW | California Department of Fish and Wildlife |
| cm | centimeters |
| CVP | Central Valley Project |
| | |
| Delta | Sacramento–San Joaquin Delta |
| DELVE | Data Explorer for Learning, Visualization, and Export |
| DFW | California Department of Fish and Wildlife |
| DIDSON | Dual-Frequency Identification Sonar |
| DJFMP | Delta Juvenile Fish Monitoring Program |
| DWR | California Department of Water Resources |
| eDNA | environmental DNA |
| GPS | global positioning system |
| IEP | Interagency Ecological Program |
| ITAG | Interagency Telemetry Advisory Group |
| mm | millimeters |
| NDD | north Delta diversion |
| PIT | passive integrated transponder |
| project | Delta Conveyance Project |
| SAIL | Salmon and Sturgeon Assessment of Indicators by Life Stage |
| SWP | State Water Project |
| USFWS | U.S. Fish and Wildlife Service |

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# Appendix 5B
# North Delta Diversion Fisheries Field Studies Workplan

## 5B.1 Introduction and Background

The State Water Project (SWP) water conveyance facilities in the Sacramento–San Joaquin Delta (Delta), including Clifton Court Forebay and the Harvey O. Banks Pumping Plant in the south Delta, enable the California Department of Water Resources (DWR) to divert water from the Delta into the California Aqueduct. The proposed Delta Conveyance Project ( proposed action) would construct and operate new conveyance facilities in the Delta that would add to the existing SWP infrastructure. New intake facilities would be constructed in the north Delta along the Sacramento River between Freeport and the divergence with Sutter Slough. The new facilities would also include a tunnel and associated infrastructure that would convey water from the new intakes to existing SWP conveyance facilities in the south Delta. The new facilities would provide alternative locations for diverting water from the Delta and would be operated in coordination with the existing SWP south Delta pumping facilities, in compliance with state and federal regulatory requirements. New facilities proposed for the proposed action may include, but are not limited to, the following:

- Intake facilities on the Sacramento River (referred to in this report as the north Delta diversion [NDD] facilities).
- A tunnel and tunnel shafts.
- South Delta Pumping Plant.
- Southern Forebay on Byron Tract.
- Bethany Complex (a potential alternative to the South Delta Pumping Plant and Southern Forebay under consideration).

## 5B.2 Purpose

This workplan for fisheries field studies has been developed as part of the proposed action to address uncertainties concerning the proposed action's potential effects on fishery resources and inform the operation and adaptive management of the proposed future NDD facilities to protect those resources. This workplan focuses on study elements related to species loss and habitat modification to provide adequate detail to support their consideration in the consultation process and expedite their implementation. This document describes fisheries-related studies that would primarily assess and influence operations and adaptive management and require characterization of the baseline condition as a basis for comparison. Additional topics, such as hydrologic and hydraulic modeling, species life-cycle modeling, and potential specific operational monitoring components (e.g., fish entrainment and impingement monitoring) are covered in other project documents, including technical analyses, engineering analyses, and the Delta Conveyance Project Biological Assessment.

This document defines a plan for field studies and monitoring that would be conducted in the north Delta to characterize baseline conditions and monitor effects of and inform proposed action implementation, including future real-time operations, as part of an adaptive management process. The workplan is organized as follows:

- **Section 5B.3, Study Identification,** identifies specific potential effect mechanisms of the proposed action on listed fish species and describes links to research questions and/or uncertainties, ultimately identifying fisheries field studies intended to inform study questions and/or uncertainties.
- **Section 5B.4, Study Organization and Phasing,** provides the sequence for all studies based on the proposed action timeline and phases.
- **Section 5B.5, Study Plan Requirements and Considerations,** describes study plan organization, requirements, and considerations for implementation.
- **Section 5B.6, Draft Study Plans,** details draft plans for each proposed study.
- **Section 5B.7, Future Real-Time Decision Making,** describes the decision-making processes for real-time changes to current SWP and Central Valley Project (CVP) operations.
- **Section 5B.8, Implementation Schedule,** presents a draft schedule of study implementation.
- **Section 5B.9**, **Preliminary Cost Estimates**, will be developed in future drafts.
- **Section 5B.10, References and Links,** provides details for websites presented in the text, as well as full reference information for the citations in this document.

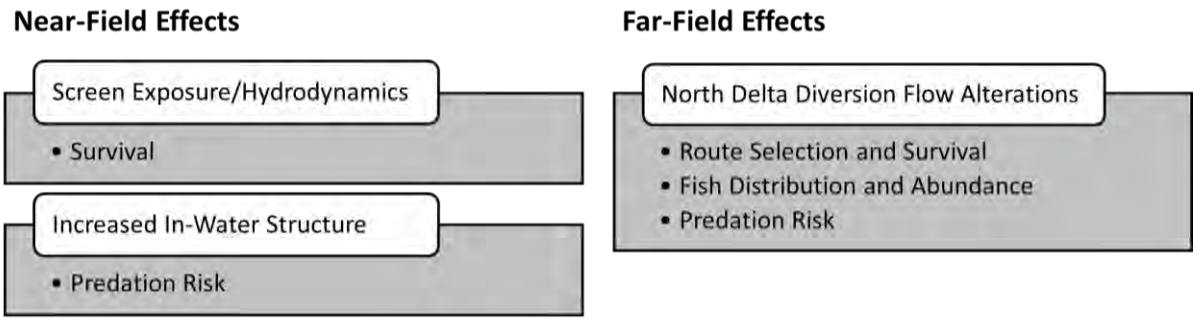
# 5B.3 Study Identification

## 5B.3.1 Link to Delta Conveyance Project Effect Mechanisms

Several potential operational effects and their consequential linkages to listed fish species and/or habitats have been identified to support investigations characterizing baseline conditions and informing operation and adaptive management of the proposed action. This workplan focuses on the proposed NDD facilities because they do not currently exist. There are several existing study and monitoring programs throughout the Delta, many of which focus on the south Delta facilities (e.g., pre-screen loss management and monitoring [predatory fish removal and relocation], fish facility evaluations, Old and Middle River flow regulation and monitoring). It is assumed that these existing programs provide an adequate characterization of baseline conditions in this region, against which proposed action operations and adaptive management could be measured.

Because of the size and scope of the proposed action, the analysis of potential proposed action effects associated with the NDD facilities has been organized by spatial scale as near-field and far-field effects.[1] At each scale, primary effect mechanisms were identified that require additional field studies to characterize baseline conditions, thus providing a basis of comparison for monitoring the effects of proposed proposed action operations, and to inform adaptive management (**Figure 5B-1**).

[1] While potential project effects are organized at near- and far-field spatial scales, future analyses/studies would also consider potential effects at an intermediate scale, focusing on cross-sectional fish distribution in the river and the proportion of fish potentially at increased risk of exposure to the intakes from implementation of the Delta Conveyance Project. For example, these efforts would help capture effects during the transition from far-field to near-field spatial scales and associated effects near the intakes. Additionally, the study areas identified in this workplan focus on the north Delta, where potential effects from the project would be more directly detectable.




Note: The primary effect mechanisms of the proposed north Delta diversion facilities are shown in the white boxes; the bulleted items list their biological responses.

**Figure 5B-1. Delta Conveyance Project, North Delta Diversion Facilities—Primary Effect Mechanisms and Their Biological Responses**

## 5B.3.2 Identified Studies

Five fisheries field studies, organized into three study elements (Migration and Survival, Predation, and Abundance and Distribution), have been identified to evaluate the proposed action's effect mechanisms and biological responses. **Table 5B-1** identifies the fisheries field studies that would characterize baseline conditions, monitor DCP operations, and inform adaptive management. Table 1 describes the listed fish species affected by each biological response, the primary objectives of each study, and the relationship to previous and current environmental compliance and permitting efforts (see the operations adaptive management and monitoring plan in Appendix 3C, *North Delta Diversion Operations Adaptive Management and Monitoring*). The details of each study are provided in Section 5B.6.

## 5B.3.3 Relationship to Previous Planning Efforts

Most of the fisheries field studies identified in Table 5B-1 have their origins in previous planning efforts (i.e., Bay Delta Conservation Plan [BDCP] and California WaterFix). The technical studies identified as part of the previously proposed BDCP, or terms and conditions required in the National Marine Fisheries Service biological opinion or California Department of Fish and Wildlife (CDFW) incidental take permit for California WaterFix, are cross-referenced to the field studies being proposed as part of the proposed action in Table 5B-1. The draft study plans detailed in Section 5B.6 consider previous planning efforts (e.g., the 2013 workplan for the Intake Design Criteria and Performance Monitoring of the BDCP) and incorporate study components that were aligned with the proposed action.

**Table 5B-1. Summary of Fisheries Field Study Needs, Primary Effect Mechanisms, Study Objectives, and Relationship to Previous Permitting Efforts for the Delta Conveyance Project**

| Scale | Effect | Response | Focal Species[1] | Study Element | Study Objectives | Relationship to Previous Planning Efforts[2] |
|---|---|---|---|---|---|---|
| Near-Field | Exposure to Fish Screen and Altered Hydrodynamics | Survival | CHK, STH, GS, (DS, LFS by inference) | Migration and Survival | Three-Dimensional Distribution, Movement Patterns | BDCP: Technical Study #10<br>WaterFix NMFS BO: N/A<br>WaterFix ITP: Pre-Con and Post-Con #11 |
| | New In-Water Structures | Predation Risk | Predatory fish that prey on CHK, STH, DS, LFS, GS | Predation | Predator Distribution and Abundance | BDCP: Technical Study #9<br>WaterFix NMFS BO: T&C 3aii<br>WaterFix ITP: Pre-Con and Post-Con #9 and Pre-Con and Post-Con #5 |
| | | | | | Predation Rate | BDCP: N/A<br>WaterFix NMFS BO: N/A<br>WaterFix ITP: Post-Con #5 |
| Far-Field | North Delta Diversion Flow Alterations | Survival and Routing | CHK, STH | Migration and Survival | Route Entrainment/Selection and Survival | BDCP: Technical Study #10<br>WaterFix NMFS BO: N/A<br>WaterFix ITP: Pre-Con and Post-Con #10 and #12 |
| | | Predation Risk | Fish that prey on CHK, STH, DS, LFS, GS | Predation | Predator Distribution and Abundance | BDCP: Technical Study #9<br>WaterFix NMFS BO: T&O 3aii<br>WaterFix ITP: Pre-Con and Post-Con #9 |
| | | Abundance and Distribution | CHK, STH, GS, DS, LFS | Abundance and Distribution | Demographics, Regional-Scale Abundance and Distribution, Reach-Scale Abundance and Distribution | BDCP: Technical Study #11<br>WaterFix NMFS BO: N/A<br>WaterFix ITP: Pre-Con and Post-Con #11 |

Notes:
[1] CHK = Chinook Salmon, DS = delta smelt, GS = green sturgeon, LFS = longfin smelt, STH = steelhead.
[2] BDCP = Bay Delta Conservation Plan; BiOp = biological opinion; ITP = incidental take permit; NMFS = National Marine Fisheries Service; Post-Con = postconstruction survey; Pre-Con = preconstruction survey; T&C = term and condition; WaterFix = California WaterFix.

# 5B.4 Study Organization and Phasing

The studies identified in Section 5B.3 need to be sequenced relative to the proposed action's implementation timeline to ensure that outcomes and results are available to inform the development of intake operations and adaptive management (**Figure 5B-2**). Therefore, the identified studies were mapped to the following study phases that relate to the proposed action implementation timeline:

1. **Project Development and Refinement:** If the proposed action is approved after the completion of appropriate environmental review, the Project Development and Refinement study phase would occur during the first 1 to 2 years of proposed action implementation (after applicable permits have been obtained), before final design and construction activities. During this study phase, the project may incorporate relevant design elements such as predator refugia features or other structural elements that can be introduced during adaptive management to improve the performance of the NDD facilities, if warranted.
2. **Baseline:** During the Baseline proposed action study phase, field monitoring studies of predatory fish, the survival and abundance of listed fish, and other ecological responses would be conducted, building on baseline information from existing programs and the prior environmental analyses. The field monitoring studies would be conducted before and during in-water construction (i.e., during the preconstruction and construction phases) to characterize baseline conditions and inform adaptive management during the Initial Operations phase. Field studies would be initiated prior to in-water construction (i.e., prior to intake construction) to characterize preconstruction conditions. During in-water construction, field studies would continue to monitor intake study sites under a transitional condition (i.e., during in-water construction, before intake operations). The baseline conditions (preconstruction and construction) would inform trends in study site characteristics and aid analyses in refining potential effects, including those that were initially identified through prior environmental review.
3. **Initial Operations:** proposed action operations would have two sub-phases: Initial Operations and Long-Term Operations. Field monitoring studies initiated during the Baseline DCP study phase would continue into the Initial Operations sub-phase, to evaluate the performance of initial design and operations of the proposed action intakes and inform the adaptive management of proposed action operations. In addition to informing operations, monitoring studies would inform the adaptive management of relevant design elements previously identified during the proposed action's Project Development and Refinement study phase. The Initial Operations phase is anticipated to last approximately 5 years.
4. **Long-Term Operations:** During the Long-Term Operations sub-phase, field monitoring studies would be merged with existing interagency monitoring programs for coordinated long-term operations of the SWP and CVP, as part of broader system-wide long-term operations and associated fisheries-based real-time operation decision support processes.

In addition to the chronological sequencing of study elements, it is important to understand the connection of each study element to the relevant design components and operations of the NDD facilities, and connections to other studies. The link between the study elements and relevant design components or operations are performance metrics by which each study would be evaluated to inform the NDD. Section 5B.6 describes the preliminary, generalized performance metrics evaluated by each study element.

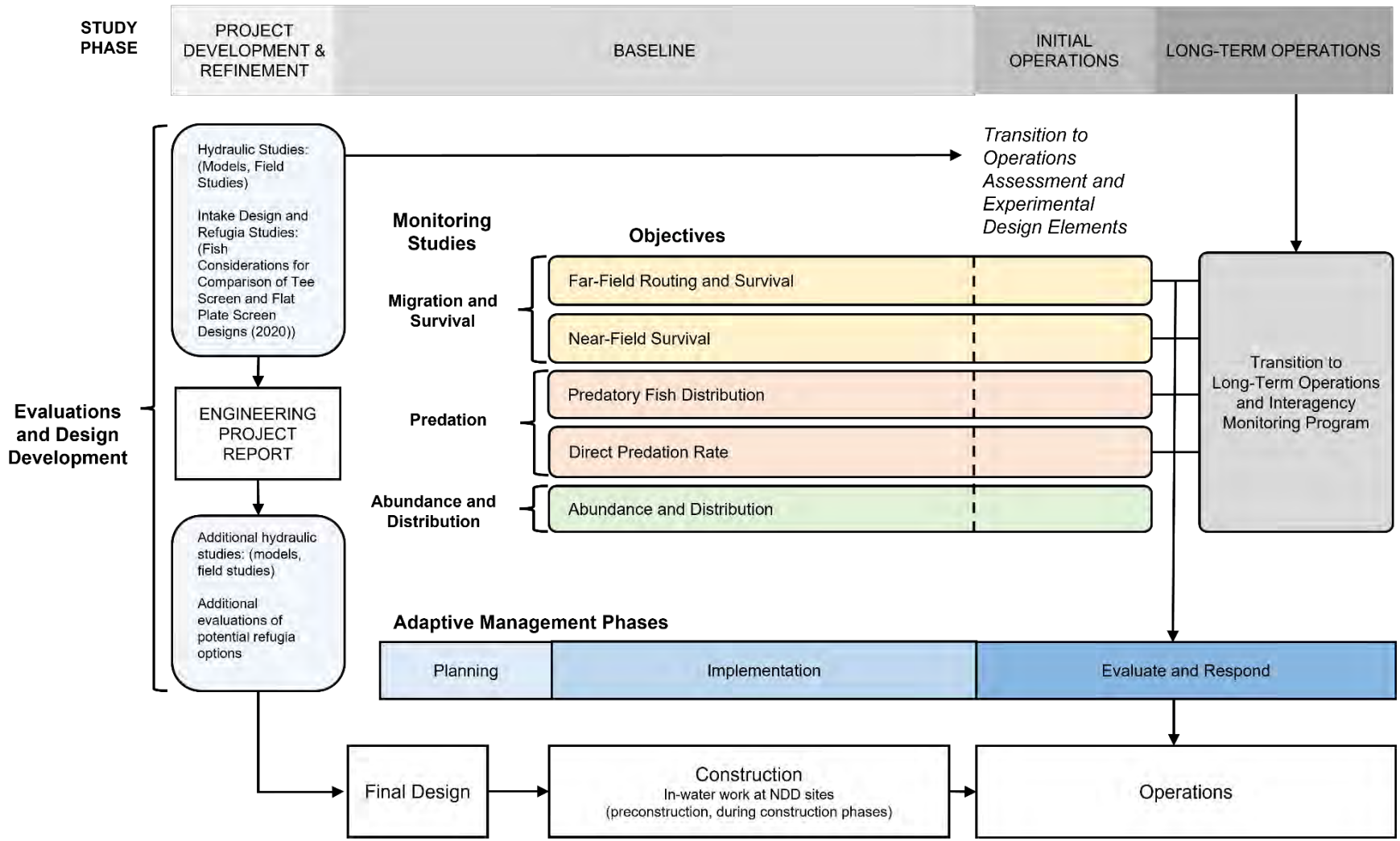



**Figure 5B-2. Fisheries Field Studies and Delta Conveyance Project Implementation Chart**

# 5B.5 Study Plan Requirements and Considerations

Each study plan has been organized to accommodate information necessary to successfully implement the study. Each study plan would include interagency coordination with regulatory agencies for collaboration or input and comments on the study plans. The plan would provide the study objective, key questions to be addressed by the study, and preliminary performance metrics that would be used to inform the adaptive management of NDD operations and relevant design elements (e.g., experimental refugia integrated within intake design). **Table 5B-2** details the general requirements and key considerations for each study plan. These requirements would be treated as individual sections of each study plan.

**Table 5B-2. Requirements and Key Considerations for Delta Conveyance Project Study Plans**

| Study Plan Element | Requirement or Consideration |
|---|---|
| Focal Species | List the affected species and life stages that are the focus of the study or to which the results of the study pertain. |
| Proposed Action Effect Links | Diagram the conceptual links to the effect mechanisms as detailed in Table 5B-1 of this workplan. |
| Objective(s) | Describe the high-level objective(s) of the study. |
| Key Questions | Describe the key questions to be addressed by the study that inform either the design or the operations of the NDD facilities. |
| Background | Detail previous/ongoing efforts in the Central Valley and Delta to inform the study plan's objective. This includes a review of previous studies and literature addressing this objective. This review should provide information regarding ongoing study efforts and explain how they may be used to supplement or work in concert with the new study. |
| Methods | *Study Area*: Provide details of the study area, including maps depicting the extent of the fieldwork.<br>*Methods*: Provide detailed methods for all aspects of the study. The methods should be described at a level of detail that allows for environmental review and permit acquisition. Additional details (e.g., power analysis, analytical methods, technology, study fish quantity and origin) should be developed by the study implementation team. |
| Performance Metrics | Include performance metrics to provide the direct connection to the operation (adaptive management) of the NDD facilities and attempt to answer the key questions of the study (listed above). |
| Links to Other Delta Conveyance Project Studies and Analytical Tools | Describe any direct or indirect links to other proposed action studies or analytical tools. |

Notes: NDD = north Delta diversion.

# 5B.6 Draft Study Plans

## 5B.6.1 Migration and Survival Study

The migration and survival study elements identified in this section have been developed to assess the survival of listed species in reaches that could be affected by implementation of the proposed

action, as well as changes to baseline (preconstruction and construction) as the proposed action is implemented. The baseline telemetry study elements detailed in this section are designed to collect and synthesize data on a range of factors (e.g., hydrodynamics, fish health, other abiotic factors) that contribute to survival and passage at both the near-field and far-field scales. Each study element addresses a specific subset of factors and has been developed in close coordination with related studies. The findings of these study elements would be used to determine how the proposed action would influence survival and behavior. Data generated during the study would also be used to inform other studies (e.g., see Section 5B.6.2.1, *Predatory Fish Distribution*, and Section 5B.6.2.2, *Direct Predation Rate*), model development, and performance metrics.

The goal of the migration and survival study is to determine whether and to what extent the proposed DCP would alter the survival of listed species relative to baseline conditions, and to inform management actions targeted toward improving survival. To meet this goal, two study elements are proposed to address specific areas of interest for informing management actions related to survival:

- **Far-Field Routing and Survival:** This study element is proposed to determine overall survival.
- **Near-Field Survival:** This study element is proposed to determine the direct influence of the NDD facilities on the downstream survival of juvenile salmonids.

Together, these study elements would provide the information necessary to evaluate survival before, during, and after proposed action construction at the reach-specific, near-field (in the vicinity of the intakes), and through-Delta (far-field) scales. The results of the migration and survival study would be documented in annual technical reports. The following subsections detail each individual element of the migration and survival study.

### 5B.6.1.1 Far-Field Routing and Survival

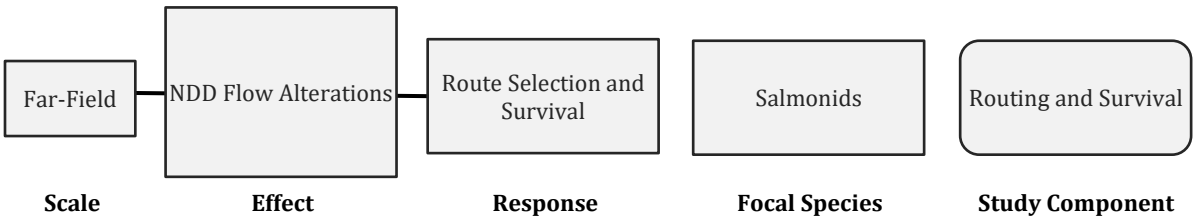
The far-field routing and survival element of the study would be used to analyze baseline (preconstruction and construction) migration survival and route entrainment conditions for juvenile Chinook salmon and steelhead by reach within the lower Sacramento River and through the Delta. These baseline conditions would be compared to levels of survival and route entrainment in the same reaches during proposed action operations, thus enabling the detection of changes in survival and route entrainment that may result from the construction and operation of the NDD facilities. This study would be coordinated with ongoing outmigration studies in the lower Sacramento River and Delta, including the lower San Joaquin River (and south Delta channels), to leverage resources and improve overall efficiency, improve statistical power, and maximize the value of the collected data.

Although green sturgeon could be affected by NDD construction and operation, the ability of this proposed action to detect changes would be hindered by the potential for difficulties related to the rearing, tagging, tracking, and behavioral attributes of green sturgeon within the Delta (e.g., the species does not exhibit unidirectional migration). Moreover, capturing green sturgeon in the numbers needed to meet statistical power objectives may not be possible. However, future improvements to green sturgeon monitoring, production, and/or tracking efforts would be considered for incorporation into survival and route entrainment studies for this species.

#### Focal Species

The study element would evaluate migration survival and route entrainment for juvenile Chinook salmon and steelhead (salmonids).

## Proposed Action Effect Links




## Objectives

The objectives and associated research questions of the far-field routing and survival study element are as follows:

1. **Route Entrainment:** Evaluate the impacts of NDD operations on route entrainment.
    a. How does route entrainment of juvenile salmonids vary at key Delta junctions (e.g., Sutter, Steamboat, and Georgiana sloughs) within and among years under baseline (preconstruction and during construction) and operating (postconstruction) conditions?
    b. Which factors—if any—that explain differences in route entrainment variation between baseline (preconstruction and during construction) and operating (postconstruction) conditions are attributable to the NDD facilities?
2. **Survival:** Evaluate the impacts of NDD operations on reach-scale and regional-scale outmigration survival.
    a. How does the survival of juvenile salmonids vary during their outmigration within and among years under baseline (preconstruction and during construction) and operating (postconstruction) conditions?
    b. Which factors—if any—that explain differences in outmigration survival between baseline (preconstruction and during construction) and operating (postconstruction) conditions are attributable to the NDD facilities?

## Methods

The far-field routing and survival study element would adapt methods described in other acoustic telemetry studies of routing and survival in the Delta (e.g., Peven et al. 2005; Burau et al. 2007; Perry et al. 2010; California Department of Water Resources 2012, 2014; Holbrook et al. 2013; Romine et al. 2013; Perry et al. 2018). The methods seek to answer key questions and achieve study objectives through monitoring of juvenile salmonids' migration from their release site(s) to Chipps Island, which has been identified as the monitoring endpoint for through-Delta survival. The results of prior power analyses are provided below (see the "Fish Tagging and Release" subsection); however, additional power analyses would be used before study implementation to verify the number of tagged salmonids needed to detect a relative change in the probability of survival or route entrainment as a function of the NDD facilities.

### Study Area

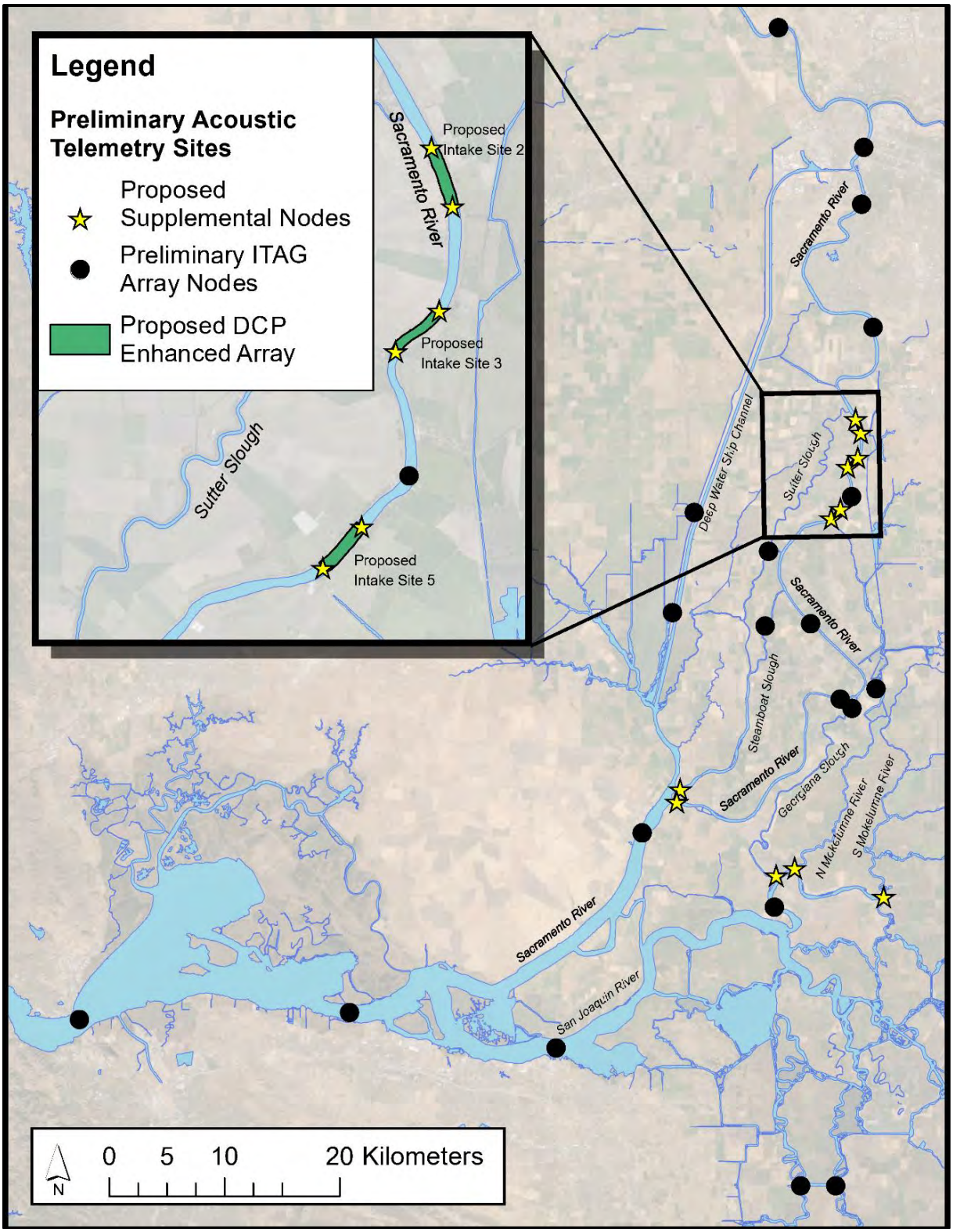
The study area for the far-field routing and survival study element would include waters throughout the lower Sacramento River in the Delta. Designated junctions and study reaches of the lower Sacramento River, defined by nodes (hydrophone locations) in survival and route selection models, would be identified and would include reaches where the NDD intake structures are proposed to be sited (**Figure 5B-3**).

### Telemetry System

Currently, the Interagency Ecological Program (IEP) Interagency Telemetry Advisory Group (ITAG)[2] is working to establish a coordinated acoustic telemetry array within the Central Valley and Delta that consists of numerous acoustic nodes (hydrophone locations; see Figure 3). To estimate routing and survival, the study element proposes to use and supplement the ITAG array (or other coordinated acoustic telemetry efforts) with additional receiver nodes and associated beacon transmitters. These additional receivers would include up to four acoustic hydrophones/receivers at upstream and downstream boundaries of the study reaches for the proposed NDD intake locations, and at the upstream and downstream junctions of major migration routes through the Delta (e.g., mainstem Sacramento River, Sutter and Steamboat sloughs, the Delta Cross Channel, and Georgiana Slough as in Perry et al. [2010]; see Figure 5B-3). At route junctions, nodes would consist of one or more receivers, as needed, to maximize the probability of detection at each station. These receiver stations would continuously monitor the passage of tagged salmonids released as part of the study, as well as salmonids and sturgeon tagged as part of other studies. The selection of acoustic telemetry technology (e.g., Vemco, Juvenile Salmon Acoustic Telemetry System) for tags (transmitters), hydrophones, and receivers would likely be consistent with other concurrent studies and the regional acoustic telemetry array unless one technology is more optimal for a given experimental design. To minimize direct take, receivers and hydrophones should be able to detect and decode transmissions from acoustic-tagged fish that are released by other studies and should be installed in a manner that would augment and leverage acoustic detections by other monitoring programs using the array. Investigations of tag life and detection efficiency within the array would be incorporated to accurately parameterize models.

[2] ITAG was founded to meet the following management objectives, designed to achieve a reliable coordinated acoustic telemetry program to fulfill implementation of the Salmon and Sturgeon Assessment of Indicators by Life Stage (SAIL) monitoring improvements:

- Annual estimates of reach-specific survival, including to the Golden Gate: winter-run, late fall–run, spring-run, fall-run.
- Route-specific survival estimates.
- Run-specific abundance estimates entering the Delta (Sacramento River) and exiting the Delta (Chipps Island).
- Real-time survival detections, with potential application for the biological opinion and Water Infrastructure Improvements for the Nation Act.
- Acoustic telemetry support for SAIL objectives for green sturgeon.




Note: Although three proposed intake sites are shown, only two sites would likely be selected, requiring only two enhanced arrays.

**Figure 5B-3. Example of How the Preliminary Interagency Telemetry Advisory Group Acoustic Array in the North Delta Would Be Supplemented with Proposed Nodes to Enhance Arrays**

### Fish Tagging and Release

In addition to salmonids tagged for use in concurrent studies and programs, supplemental hatchery-raised fish (late fall–run, fall-run, winter-run, and spring-run Chinook salmon, and steelhead) ranging in fork length from 80 to 220 millimeters (mm) would be tagged and released upstream of the receiver array annually to estimate regional and reach-level survival as scaled by travel time, and routing at junctions. Based on the reach-scale and through-Delta survival estimates of Perry et al. (2010, 2016), recommendations from Burau et al. (2007), and power analyses, approximately 4,000 to 6,000 study fish would need to be tagged and released upstream of the new diversions at regular intervals from December through May.

Release intervals would be defined using one of three methods—semi-continuous, blocked, or adaptive—summarized as follows:

- **Semi-continuous method:** This method was used in DWR's Georgiana Slough non-physical barrier studies (California Department of Water Resources 2012, 2014, 2015) and the 6-year steelhead outmigration study (e.g., U.S. Bureau of Reclamation 2018a, 2018b, 2018c). In this approach, groups of study fish are released semi-continuously at 3-hour intervals across 24-hour days for the duration of the study. This method ensures an even distribution of fish moving through the study area over a wide range of conditions; however, it is labor intensive and would require significant investment.
- **Blocked method:** This approach involves semi-continuously releasing groups of study fish every 3 hours for a defined period (e.g., 16 days) as a "release block" and then halting releases for a defined period, which constitutes a "no release block." This results in reduced labor while still accommodating statistical power requirements and the ability to analyze covariates, albeit at a coarser resolution that may not fully characterize some covariates, such as flow and associated conditions (e.g., turbidity) for a given period or season.
- **Adaptive method:** This method uses a power analysis based on survival rates from previous studies (California Department of Water Resources 2012, 2014, 2015) and adapts release strategies in semi–real time based on statistical power. The power analysis estimates the minimum number of acoustic tags that must be detected through the entire route to meet the power requirements to detect a change under a given condition or set of conditions (e.g., predefined range of flows, turbidities, water temperatures). Releases begin as in the semi-continuous or blocked methods, but they are halted once a real-time count of tags that have passed through the array exceeds the minimum for a given condition. This is followed by a no release block, which lasts for the remaining period where the predefined condition occurs. This strategy may result in reduced costs; however, it may also sacrifice understanding of certain covariates, such as dynamic weather events, flow, and pumping rates, which may not be fully captured within the predefined condition sets.

The release strategy and total number of tagged salmonids may need to be reassessed based on the results of the initial study year(s) to ensure that study objectives are met in subsequent years. If juvenile green sturgeon from a hatchery are not available for study purposes to inform survival estimates, alternative analytical approaches (e.g., modeling) may be needed to help estimate the probability of survival and route entrainment for this species.

After tagging, fish would be transported to their release site (if not tagged at the release site) and allowed to acclimate for 24 hours before release for recovery from transportation and tagging. After acclimation, the fish would be released following the release schedule. The release schedule would be selected to ensure an even distribution of study fish across tidal and diel cycles. Final decisions regarding study fish and release strategy would be developed and described in a detailed study plan before study implementation. (See California Department of Water Resources 2012, 2014,2015 for a more detailed description of fish tagging, and release procedures.)

#### Array Maintenance and Data Management

Equipment would be checked at regular intervals with field crews and via remote monitoring, which would allow for regular assessment of the functionality of systems. Field crews would be available as needed to perform routine maintenance or equipment checks (e.g., battery replacement, hydrophone cleaning, maintenance or replacement of hydrophones and receivers, and tag detection checks). Field crews would maintain detailed standardized logs of receiver checks and ensure that system functionality is always maintained. Data collected during the study would require storage on a secure, remote cloud server, given the volume of data to be produced. Data would be stored and organized in a repository that is readily accessible for analysis, consistent with industry standard practices for database sharing (e.g., California fish tracking consortium, DWR Data Explorer for Learning, Visualization, and Export [DELVE] platform data standards).

#### Data Processing

In general, data processing for routing and survival analysis would require processing transmissions from acoustic transmitters into time-ordered detection histories. In some cases, data processing procedures would be somewhat determined by the requirements of the chosen acoustic tagging technology.

#### Survival Estimation

Survival and routing estimation would follow statistical models described in Burau et al. (2007), Perry et al. (2010, 2016), Holbrook et al. (2013), and others, and would be scaled by travel time to account for differing survival rates as a function of spending more time in certain areas (Hassrick et al. 2022). A Cormack-Jolly-Seber mark-recapture model (e.g., Perry et al. 2010; Holbrook et al. 2013) would form the basis of the statistical analysis for survival estimation and routing probabilities. Results would be evaluated in the context of findings from other studies. Additionally, estimates would incorporate new and advancing methods to reduce bias of estimates, including estimation of premature tag failure (Holbrook et al. 2013), removal of eaten individuals from the movement analysis (e.g., Romine et al. 2014), and body size and migration timing of study fish used as surrogates for wild, listed fish (see Section 5B.6.3, *Abundance and Distribution Study*). Results from baseline data on routing and survival would be compared to results during operations to inform operational effects and adaptive management, as necessary.

### Reporting

The results of the far-field routing and survival study element would be documented in annual technical reports. The reports would be reviewed annually and revised as needed.

### Links to Other Delta Conveyance Project Studies and Analytical Tools

The far-field routing and survival study element should be coordinated, when possible, with ongoing routing and survival studies in the study area to improve efficiency and maximize the collection of spatial and temporal data. In addition, the acoustic array would also be used in the predation study (see Section 5B.6.2, *Predation Study*). The results of the predation study may be used to inform predation parameters within the survival model, while information from the migration and survival study would also help to scope when the predation study experiments should take place.

## 5B.6.1.2 Near-Field Survival

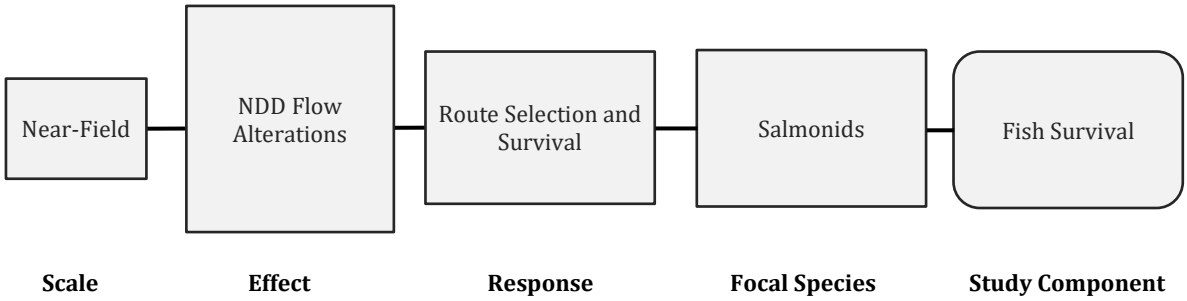
This near-field element of the study would be used to analyze baseline passage and near-field survival characteristics for juvenile salmonids in reaches surrounding the proposed NDD intakes. These baseline characteristics would be compared to passage and near-field survival characteristics

during proposed action operations in the same reaches, so that a difference, as determined a priori by a power analysis, could be detected. The movement patterns of tagged juvenile salmonids would be tracked during their passage along reaches covering the proposed NDD intake sites. The results of the study would be used to compare movement at the NDD intake locations before construction, during construction, and after construction of the intakes to determine whether movement and survival have changed in response to installation of the diversion structures or proposed action operations. This study would be coordinated with ongoing outmigration studies in the area to leverage efficiency and maximize the collection of spatial and temporal data.

## Focal Species

Near-field behavior and survival of juvenile Chinook salmon and steelhead would be evaluated. (Note that effects on habitat and survival associated with the NDD facilities would also be assessed in the abundance and distribution study [see Section 5B.6.3].)

## Conceptual Links




## Objectives

The objectives and associated research questions of the near-field survival study element are as follows:

1. **Three-Dimensional (3D) Distribution:** Evaluate the impact of NDD structure and operations on horizontal and vertical density distributions of juvenile salmonids in the vicinity of the NDD intakes.
    a. How are juvenile salmonid densities distributed in 3D space at the locations of the intakes during baseline (preconstruction and during construction) and operating (postconstruction) conditions?
    b. Which factors—if any—that explain differences in 3D density distribution between baseline (preconstruction and during construction) and operating (postconstruction) conditions are attributable to the NDD facilities?
2. **Movement Patterns:** Evaluate the impacts of NDD structure and operations on fine-scale movement patterns of juvenile fish in the vicinity of the NDD intakes.
    a. How much do the movement patterns of juvenile salmonids vary during their outmigration within and among years during baseline (preconstruction and during construction) and operating (postconstruction) conditions?
    b. Which factors—if any—that explain differences in fine-scale movement patterns between baseline (preconstruction and during construction) and operating (postconstruction) conditions are attributable to the NDD facilities?

## Methods

The near-field survival study element would adapt methods found in studies using 3D acoustic telemetry positioning and tracking to evaluate movement at the intake structures (e.g., Perry et al. 2003) and movements associated with near- and intermediate-field hydrodynamics, including those related to critical streakline concepts (e.g., Hance et al. 2020) and predation (e.g., Romine et al. 2014). Power analyses based on past studies (e.g., Perry et al. 2016) and initial study years would be used to evaluate the number of tagged individuals needed to detect significant differences (e.g., $\alpha$ = 0.1 [type 1 error rate of 10% or a 90%confidence interval]) in behavior patterns, considering scheduled releases of juvenile salmonids from concurrent nearby studies.

### Study Area

The study area for the near-field survival study element would include study reaches, defined by nodes (see Figure 5B.3), at NDD intake structures as well as control reaches near the NDD intake facilities, within the lower Sacramento River.

### Telemetry System

For 3D tracking and positioning, enhanced arrays would be installed along reaches encompassing the proposed intake screen faces, and along control reaches. Each enhanced array would consist of approximately 9 to 12 acoustic receivers, depending on the shoreline length of the reach (approximately 0.9 to 1 kilometer) and channel width (approximately 165 to 225 meters) designed and operated to provide 3D positioning capability. This array would contain four receivers (two upstream and two downstream of the proposed screen location) that would function as nodes in the routing and survival estimation, but it would also contain additional receivers positioned to provide the ability to estimate the 3D position of an acoustically tagged individual. The array would be able to characterize movements by tagged smolt and predatory fish (see Section 5B.6.2), and provide for determination of predation events on smolts using a mixture model approach (e.g., Romine et al. 2014). The number and position of each hydrophone would need to be determined based on hydrodynamics and channel morphology; however, there should be enough vertical and horizontal difference between hydrophone positions to accurately position the tagged study fish. Receivers and hydrophones would be located on permanent or semi-permanent structures to improve positioning error estimates and provide the highest confidence reasonably possible in tracking data.

### Fish Tagging

It is anticipated that no additional fish would be required for this element of the migration and survival study. Fish tagged for other studies or tagged as part of the far-field routing and survival element of this study could also be used for this element of the study. As described in Section 5B.6.1.1, *Far-Field Routing and Survival*, based on power analyses and the results of the initial study year(s), the total number of tagged salmonids may need to be reassessed (and increased) to ensure that study objectives (and statistical power requirements) are met.

### Array Maintenance and Data Management

Equipment would be checked at regular intervals with field crews or via remote monitoring that would allow for the regular assessment of the functionality of systems. Field crews would perform routine maintenance or equipment checks (e.g., battery replacement, hydrophone cleaning, maintenance or replacement of receivers, and tag detection checks). Field crews (data management and field) would maintain detailed standardized logs of receiver checks and ensure that system functionality is always maintained. Data collected during the study would require storage on a secure, remote cloud server. The data would be stored and organized in a manner that would allow

for safe repository and access for analysis, consistent with industry standard practices for data (e.g., California fish tracking consortium, DWR DELVE platform data standards).

### Near-Field and Intermediate-Field Hydrodynamics

For hydrodynamic evaluations, side-looking horizontal acoustic Doppler current profilers would be installed along reaches encompassing the proposed intake screen faces to measure surface water velocity fields. With this information, it would be possible to estimate the location of entrainment zones by delineating critical streaklines associated with varying discharge and diversion rates. The critical streakline concept is a way of collapsing a complex flow field into understanding how fish are likely to route, considering the side of the critical streakline on which they are located. This provides a simple metric for comparing the potential for entrainment (or other measures of intake influence) under a variety of conditions at the proposed intake screen faces.

The location of the critical streakline can be estimated using flow station discharge records and diversion rates to compute intake entrainment ratios, which can then be scaled by the cross-sectional width of the river to produce estimates of critical streakline locations (Hance et al. 2020). A detailed analysis of critical streakline estimates produced using this approach, in combination with two-dimensional (2D) and/or 3D fish tracks and potentially other techniques (e.g., fish behavior models [Eulerian-Lagrangian Agent Models]), would be used to inform an evaluation of near- and intermediate-field effects of the intakes on fish passage and near-field survival. The critical streakline estimate developed as part of this study element would also be compared to 2D modeling–based critical streakline estimates developed as part of planning-level analyses.

### Data Processing

Data processing procedures would be influenced by the chosen technology. In general, data processing for movement and tracking analyses requires processing transmissions from acoustic transmitters into time-ordered position estimates for each fish. These are then converted into vector tracks that can be analyzed for density and movement patterns.

### Movement Analysis

Tagged fish tracks and position estimates would be statistically analyzed to characterize 3D density distributions and movement patterns (e.g., Perry et al. 2003; Gurarie et al. 2009; Romine et al. 2014; Signer et al. 2019) from baseline data, and compared to movements under with- proposed operations to inform adaptive management. Horizontal and vertical distribution density within the water column would inform the extent to which fish interact with or avoid the intake structures or hydrodynamics created by operations, which would be compared with densities before and during structure construction. Additionally, this array would be used to inform passage performance (e.g., Castro-Santos and Perry 2012). Finally, this array would be used to track predatory fish and inform predator distributions, predation losses (e.g., Romine et al. 2014), and impacts on migration from changes in predation risk.

Given the nature of this study element (e.g., movement patterns in the vicinity of the proposed intake sites), this study would need to consider the approximate 5-year in-water intake construction period as a transitional condition between preconstruction, construction, and operations (Initial Operations and Long-Term Operations sub-phases). Further, construction activities may require a reduced array that limits 3D positioning capabilities.

## Reporting

The results of the near-field survival study element would be documented in annual technical reports. The reports would be reviewed annually and revised as needed.

### Links to Other Delta Conveyance Project Studies and Analytical Tools

The near-field survival study element should be coordinated, when possible, with ongoing routing and survival studies in the area to minimize directed take, improve efficiency, and maximize the collection of spatial and temporal data. The data from this study element could be used to inform survival estimates within the study and control reaches for the far-field routing and survival study element, as well as informing the predation study through additional evidence of predation events and predator distribution; the acoustic array would also be utilized in the predation study (see Section 5B.6.2). The predation study would concurrently use the enhanced arrays to examine movements by predatory fish associated with the intake structures, informing predatory fish abundance, distribution, and predation risk.

### 5B.6.1.3 Performance Metrics

Each study element is designed to meet its objectives by answering the associated research questions, which would inform adaptive management of proposed action operations by providing data to assess performance metrics and associated criteria. Performance metrics and associated criteria for each element would be developed by the study implementation team and would provide the direct connection to operation and adaptive management of the NDD intakes. Preliminary, generalized performance metrics for each element are as follows:

#### Far-Field Routing and Survival

a. Trends in route entrainment conditions attributable to NDD operations relative to trends under baseline (preconstruction and during construction) conditions.

b. Trends in north Delta salmonid survival attributable to NDD operations relative to trends under baseline (preconstruction and during construction) conditions.

c. Trends in through-Delta (Sacramento River corridor to Chipps Island, also considering pathways to the central and south Delta) salmonid survival attributable to NDD operations relative to trends under baseline (preconstruction and during construction) conditions.

#### Near-Field Survival

a. Trends in horizontal and vertical distribution of juvenile salmonids within the locations of the NDD intakes during operation of the facilities relative to trends under baseline (preconstruction and construction) conditions and/or compared to control reaches.

b. Trends in movement patterns within the locations of the NDD intakes during operation relative to trends under baseline (preconstruction and construction) conditions and/or compared to control reaches.

c. Trends in salmonid survival past the NDD intake structures during operations relative to trends under baseline (preconstruction and construction) conditions and/or compared to control reaches within the locations of the NDD structures.

## 5B.6.2 Predation Study

The predation study elements identified below have been developed to assess a baseline risk of predation to which listed fish species are exposed in the reaches likely to be affected by proposed action implementation and changes to that baseline (preconstruction and construction) as the proposed action is implemented. The study elements detailed in this section are designed to collect and synthesize data on a range of factors that contribute to predation risk at both the near-field and far-field scales. Each study element is tailored to address a specific subset of these factors and has

been developed in close coordination with other related studies. Baseline data would be collected over multiple years to capture and characterize a wide range of water year types and environmental conditions.

The findings of the predation study would be used to determine changes in predation risk associated with the project. Data derived from the study elements would also be used to inform other related studies, model development, and performance metrics. The study elements would also provide the foundation on which to develop adaptive management strategies.

The goal of the predation study is to determine whether the proposed action would increase predation risks for listed species relative to baseline conditions and to inform adaptive management actions aimed at reducing predation risks. To meet this goal, two study elements are proposed to address specific areas of interest for informing management actions related to predation risk:

- **Predatory Fish Distribution:** This study element is proposed to characterize relative abundance and distribution of the predatory fish community and to determine habitat use.
- **Predation Rate:** This study element is proposed to quantify changes in predation rate relative to baseline (preconstruction and construction) conditions.

Together, these study elements would provide the information necessary to evaluate predation risks during baseline (preconstruction and during construction) and operations (Initial Operations and Long-Term Operations sub-phases). The results of the predation study would be documented in annual technical reports. The following subsections detail each individual element.

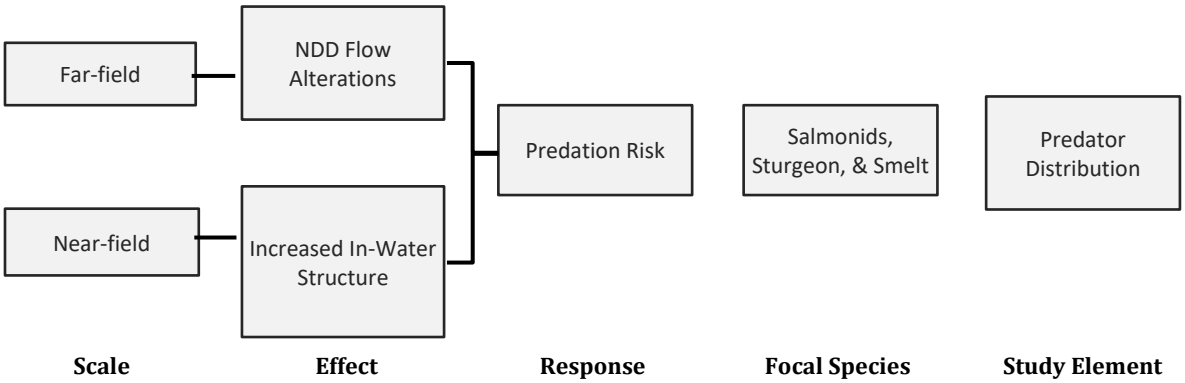
### 5B.6.2.1 Predatory Fish Distribution

The predatory fish distribution study element would be used to establish the baseline species composition, demographics, and distribution of predatory fish in the study area. The results of the field studies would be used to identify the geographic and seasonal distribution of predatory fish within each designated treatment and control reach of the river, species composition, diet, and size composition.

#### Focal Species

The study element would evaluate predatory fishes that are known to prey on juvenile Chinook salmon and steelhead, adult delta smelt and longfin smelt, and juvenile green sturgeon (e.g., black bass, catfish, Sacramento pikeminnow, striped bass).

#### Action Effect Links



## Objectives

The objectives and associated research questions of the predatory fish distribution study element are as follows:

1. **Predator Demographics:** Establish the baseline species composition, size class distribution, and diet of predatory fish in reaches where the NDD facilities are proposed. Compare operations (postconstruction) conditions to both baseline (preconstruction and during construction) and control reach conditions.
    a. What are the predatory fish species that inhabit the study sites? What is the species composition, relative and absolute abundance, and length and weight? How do these characteristics vary within and among years, and among locations, and with other abiotic factors within the lower river?
    b. What is the diet of the predatory fish inhabiting the study sites? How does the diet of these predatory fish vary on a species-specific basis, by predatory fish and prey size, and by season or other abiotic factors?
2. **Habitat Use, Distribution, and Density:** Establish a baseline of predatory fish habitat use, distribution, and density in reaches where the NDD intakes are proposed.
    a. How do predatory fish use habitat features in the study area? How does habitat use in the area where the NDD intakes are proposed compare during baseline (preconstruction and during construction) and operating (postconstruction) conditions?
    b. What are the densities of predatory fish at each study site? How do predator densities compare between baseline (preconstruction and during construction) and operating (postconstruction) conditions?
    c. How do predatory fish densities vary by season and in response to changes in Sacramento River flow, water temperatures, turbidity, time of day, and other factors such as water velocity, areas of turbulence, and proximity to shorelines and physical structures between baseline (preconstruction and during construction) and operating (postconstruction) conditions?
3. **Predation Risk:** Identify which factors contribute to predation risk in the study area.
    a. Which habitat features and associated hydraulic conditions influence predatory fish behavior in the study area?
    b. How does predatory fish density and movement behavior relate to direct predation observed during the direct predation rate study element (see Section 5B.6.2.2)? How does this relationship inform predation risk?
    c. Where in the study area is the probability of encountering predatory fish highest? When and where do listed species share habitat with predatory fish?

To meet these objectives, several discrete data collection efforts are proposed to address specific areas of interest under the umbrella of predator distribution.

## Methods

Several methods would be employed to capture, enumerate, and track predatory fish. The application of each method would be tailored to achieve thorough sampling of fish species that are representative of the predatory fish community (e.g., black bass, striped bass, catfish, Sacramento pikeminnow), temporally and spatially throughout the course of the study. Once captured, all predatory fish would be identified to species, weighed, and measured to fork length. A subset of captured fish would be euthanized and preserved for diet analysis. Others would be implanted with

either a passive integrated transponder (PIT) tag or a PIT plus an acoustic tag (dependent on tag burden) and released. PIT tags are important for identifying previously captured fish during capture efforts.

### Study Area

The study area for the predatory fish distribution study element would include the lower Sacramento River in the vicinity of the NDD facilities. Four control sites (two upstream of NDD and two downstream of NDD) would be selected based on data collected during the baseline phase, in addition to the treatment site(s) at the NDD facilities to control for temporal changes in the river not associated with the NDD facilities. The boundary of the sampling and monitoring efforts would be 2 miles downstream of the downstream-most control site and 2 miles upstream of the upstream-most control site.

### Predatory Fish Collection and Tagging

Predatory fish would be captured using the following methods:

- Hook-and-line
- Electrofishing
- Fyke and hoop traps
- Trawling
- Seining

All predatory fish of sufficient size to be implanted with acoustic tags (not exceeding a tag burden weight of 5% [weight of tag/weight of fish]) would be eligible for tagging. A determination of species composition and whether a fish is large enough to prey n listed species/relevant life stage would be made before study implementation, based on the available literature.

#### *Hook-and-Line*

Hook-and-line sampling using bait and artificial lures would be conducted from shore or on boats. Two boats suitable for fishing the lower Sacramento River would be used on each sampling day. Each boat would be equipped with a recirculating live well. Each boat would be staffed by two crew members. Hooks would be removed carefully immediately after capture and fish would be placed in well-aerated live wells filled with cool water.

#### *Electrofishing*

Boat-based electrofishing would be implemented, when feasible, to capture predatory fish along the channel margins. Two electrofishing boats, each specifically designed and outfitted with equipment necessary to temporarily stun fish and hold them in recirculating live wells, would be used on each day of sampling. Each electrofishing boat would be staffed by four crew members, consisting of two netters, a data collector, and a boat operator.

#### *Fyke and Hoop Trapping*

Stationary fyke and hoop traps would be used at the downstream and upstream ends of the study area to capture migratory/roaming predatory fish species such as striped bass, Sacramento pikeminnow, catfish, and black bass. Sampling would follow plans like those used in annual striped bass monitoring conducted by CDFW (Dubois and Danos 2018), where fyke traps would be anchored to shore and rolled in and out of the water by electric winches, and like those at Clifton Court Forebay, where hoop traps are deployed in paired sets and anchored on the bottom.

Depending on the characteristics of the site and/or the conditions of the river, fish would be removed from the trap either via boat or from shore. A crew of four would be required for each day of sampling.

#### *Trawling*

Surface trawls, otter trawls, or lampara purse seines may be used to capture predatory fishes throughout the water column. Surface and otter trawls would sample at fixed depths, towed from the stern of a single boat. Trawls would follow transects parallel to shore across the river, towing nets downstream, or down-current on reversing tides. A second boat may be used to set the lampara net, depending on river conditions.

#### *Seining*

Beach seines may be used to capture predatory fishes from shore, where the bank is shallow enough for this technique to be feasible. Beach seines would follow protocols used by the Delta Juvenile Fish Monitoring Program and by predatory fish removal studies carried out in Clifton Court Forebay.

### Tagging

Tagging stations would be assembled at pre-identified locations (e.g., stable, shaded, providing safe access from boat or land, and located no more than 1 mile from sampling sites) throughout the study reach. Each station would be equipped with all materials necessary to safely tag and recover predatory fish. On each day of sampling, the tagging stations would be staffed by three trained crew members, consisting of one tagger, one tagging assistant, and one data recorder. Fish would be tagged with PIT tags for identification of recaptured individuals or with acoustic transmitters for detection within the acoustic array (see Section 5B.6.1, *Migration and Survival Study*).

### Acoustic Tracking of Predatory Fish

Predatory fish would be tagged with acoustic transmitters compatible with the dominant concurrently installed acoustic array within the Delta (e.g., Vemco, Juvenile Salmon Acoustic Telemetry System, or other technology) and match those from the migration and survival study. Final decisions regarding the technology used would be coordinated with concurrent studies and/or programs to leverage existing instrumentation and ensure maximum usefulness of generated data.

Tagged predatory fish would be monitored using the acoustic detection and monitoring network used by the migration and survival study (described in Section 5B.6.1). All array maintenance, data management, and data processing efforts would be combined with the migration and survival study as well.

### Fixed and Mobile Split-Beam Echo Sounder

Fixed and mobile echo sounder surveys would be conducted to estimate near-field and far-field relative abundance, biomass, and size distribution of predatory fish throughout the study reach. Fixed split-beam echo sounders would be deployed in the immediate vicinity of the NDD facilities to assess temporal changes in fish use of the NDD structural components. Boats equipped with portable autonomous split-beam echo sounders would survey along transect lines from the upstream-most control site through the treatment site and extending to the downstream-most control site. Two boats, each staffed with three crew members, would be used on each day of sampling.

#### Predatory Fish Demographics

Collected predatory fish would be identified to species and measured to fork length and weight. Analyses of relative abundance and size class distribution would be conducted. The findings would be incorporated into predatory fish populations and bioenergetics models.

### Reporting

The results of the predatory fish distribution study element would be documented in annual technical reports. The reports would be reviewed annually and revised as needed.

### Links to Other Delta Conveyance Project Studies and Analytical Tools

When feasible, the predatory fish distribution study element should be coordinated with ongoing predator distribution studies in the area to improve efficiency and maximize the value of the collected data. In addition, the acoustic array used for the migration and survival study (see Section 5B.6.1) would be used in this study. Acoustic data from the migration and survival study would be used in combination with predator tracking data and active hydroacoustic sampling data to assess the probability of predator encounters. Findings from the direct predation rate study element (see Section 5B.6.2.2) would be used in conjunction to inform predation risk estimates for the study reach.

## 5B.6.2.2 Direct Predation Rate

The direct predation rate element of the study would be used to establish the rate at which listed species would be lost to predation in the study area during baseline (preconstruction and construction) and operating (postconstruction) conditions. This effort is also designed to identify which environmental factors are most associated with increased rates of predation. Selected study sites (four control, NDD treatment) would provide temporal controls to allow for the inference of relationships between predation risk and numerous environmental covariates (e.g., flow, temperature, turbidity, habitat variables).

Findings would be used in combination with the species composition, geographic and seasonal distribution, diet, and size composition of predatory fish data collected in the predatory fish distribution study element to estimate predation risk for the study area.

### Focal Species

This study would evaluate where, when, and how frequently predation on juvenile Chinook salmon, and by extension, steelhead, adult delta smelt and longfin smelt, and juvenile green sturgeon, occurs.

### Conceptual Links

## Objectives

The objectives and associated research questions of the direct predation rate study element are as follows:

1. **Predation Rate:** Establish the loss to predation in reaches where the NDD facilities are proposed and in control reaches. Monitor changes in predation rate at NDD locations during operating (postconstruction) conditions relative to baseline (preconstruction and during construction) conditions and at control reaches.
    a. What is the rate of loss to predation at the study sites? How does direct loss to predation vary within and among years and among locations? What is the net rate of loss across all study reaches/locations?
2. **Identify Factors:** Assess the range of environmental conditions that may contribute to different rates of direct predation during periods when listed species are most likely to be present. Monitor changes to these conditions relative to the control.
    a. How do predation rates vary by season (winter and spring) and in response to changes in Sacramento River flow, water temperatures, turbidity, time of day, and other factors such as water velocity, areas of turbulence, and proximity to shorelines and physical structures within the river between baseline (preconstruction and during construction) and operating (postconstruction) conditions?

## Methods

The predation rate of salmonids would be determined with tethered devices for recording fish predation events (Michel et al. 2020) and with acoustic tag data (Romine et al. 2014). Methods would be adapted from the most recent available local literature and would be comparable to similar ongoing efforts.

## Study Area

The study area for the direct predation rate study element would include the lower Sacramento River in the vicinity of the NDD facilities. Four control sites (two upstream of the NDD facilities and two downstream of the facilities) would be selected in addition to the treatment site at the NDD facilities. The boundary of the sampling and monitoring efforts would be 2 miles downstream of the downstream-most control site and 2 miles upstream of the upstream-most control site.

### Tethering

Predation rates would be quantified throughout the lower Sacramento River using floating predation event recorders that would record the exact times and locations of predation events, like the recorders used by Demetras et al. (2016) and Michel et al. (2020). Sampling would occur weekly to capture seasonal variability in conditions and cover the entire range of predator and prey life history. These recorders are drifting buoys with a live hatchery-origin juvenile Chinook salmon attached as bait. (Alternatively, surrogate prey species such as a golden shiner, *Notemigonus crysoleucas*, may be used. Golden shiners may be chosen instead of juvenile Chinook salmon because they are more resilient to the warmer ambient water temperatures that are expected to occur during the warmer months [May through July] and may be more readily available). The drifting recorders are outfitted with a global positioning system (GPS) tracker and triggering timer to determine the exact time and back-calculate the location of predation events. Daily sampling sessions would occur during crepuscular periods, to amplify any potential predation risk and develop more robust relationships between predation risk and variables associated with the NDD

facilities. Previous studies have shown that predation risk is highest at sunset (Demetras et al. 2016) and artificial light tends to influence predation rates after dark (Nelson et al. 2021).

Recorders would be deployed in the water for preestablished durations per day. A boat-based crew would begin deploying floating recorders at the upstream end of the study reach (as determined by the direction of the current during that tide cycle). That boat would tend to the floating recorders as needed, dislodging them from submerged aquatic vegetation and redeploying at the upstream end of the reach once they reach the end of the reach. If necessary, a floating line, suspended from anchored buoys, may be used to guide recorders and corral them at the terminal end. When there is little to no flow, recorders would be allowed to soak for fixed durations within 100 meters of the NDD facilities. The goal would be to have the same "soak" time per day and let the number of deployments vary. Every time a recorder is removed from the water, the status of the predation-triggered timer and bait would be recorded, the timer reset, and the bait replaced before redeployment, if necessary.

Either a Cox proportional hazard model used by Michel et al. (2020), a temporally explicit model that allows spatial and temporal conditions to be associated for each unique recorder drift, or a boosted regression tree approach would be used to evaluate predation rates as a function of distance to the NDD facilities. Because distance to the NDD facilities would be used as a covariate, the model would be able to identify the effects of seasonal trends (e.g., increasing water temperature) or daily trends (e.g., time to sunset).

#### Acoustic Tag Analysis

Acoustic data from the migration and survival study would be analyzed for evidence of predation events. The analysis of fish movement behavior would be informed by the most recent available scientific literature, and predation events of acoustically tagged juvenile salmon and/or steelhead would be assigned accordingly. Environmental data and fish release and tracking data would be used to assess each predation event and identify contributing factors.

#### Stationary Sonar Imaging Camera

In addition to studies to evaluate increased predation rate at the NDD facilities, dual-frequency identification sonar (DIDSON) or similar (e.g., adaptive resolution imaging sonar [ARIS]) camera surveys would be used to assess predator management strategies at in-water structures and habitat features of interest. Upon assessment of the habitat features likely to aggregate predatory fish in the study reach, sonar cameras would be used to assess fine-scale abundance and behavior at control sites, at the locations of proposed action -related in-water structures, or in the vicinity of experimental refugia.

### Reporting

The results of the direct predation rate study element would be documented in annual technical reports. The reports would be reviewed annually and revised as needed.

### Links to Other Delta Conveyance Project Studies and Analytical Tools

To the extent feasible, the direct predation rate study element should be coordinated with ongoing predator distribution studies in the area to improve efficiency and maximize the value of the collected data. In addition, the acoustic array used for the migration and survival study (see Section 5B.6.1) would also be used in this study. Acoustic data from the migration and survival study would be used in combination with predator tracking data and active hydroacoustic sampling data to assess the probability of predator encounters. Findings from the predatory fish distribution study

element (see Section 5B.6.2.1) would be used in conjunction to inform predation risk estimates for the study reach.

### 5B.6.2.3 Performance Metrics

Each study element would inform adaptive management of proposed action operations by providing data to assess performance metrics and associated criteria. Performance metrics and associated criteria for each element would be developed by the study implementation team and would provide a direct connection to operation and adaptive management of the NDD intakes. Preliminary, generalized performance metrics for each element are as follows:

a. Trends in net losses to predation attributable to the proposed action relative to trends under baseline (preconstruction and during construction) conditions and compared to control sites.

b. Trends in predation risk (i.e., changes in predatory fish abundance) in areas affected by the proposed action relative to trends under baseline (preconstruction and during construction) conditions and compared to control sites.

## 5B.6.3 Abundance and Distribution Study

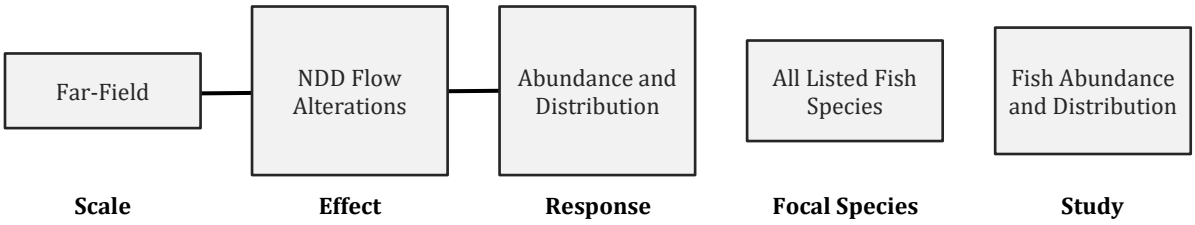
### 5B.6.3.1 Summary of Study

The abundance and distribution study identified below has been developed to determine baseline densities and seasonal and geographic distribution of all life stages of listed fish species inhabiting the reaches of the lower Sacramento River likely to be affected by the proposed action and changes to baseline conditions as the proposed action is implemented. Findings would be used to determine the distribution and abundance of all listed fish species associated with the proposed action. Data derived from the study would also be used to inform related studies, model development, and performance metrics used in adaptive management. The results would be documented in annual technical reports. This study would be critically reviewed annually and revised as needed.

#### Focal Species

The study would primarily monitor the abundance and distribution of all life stages of all listed fish species (i.e., salmonids, green sturgeon, delta smelt, longfin smelt).

#### Proposed Action Effect Links




#### Objectives

The objectives of the abundance and distribution study are as follows:

1. **Fish Demographics:** Evaluate the impacts of the NDD facilities on the demographics of listed fish species observed at the NDD facilities and at sites upstream and downstream.

a. What are the demographics (i.e., length, weight, maturity, species composition, relative abundance) of all life stages of listed fish species observed at the NDD facilities and at nearby sites?

b. Are there any factors attributable to the NDD facilities that explain differences in demographics between baseline (preconstruction and during construction) and operating (postconstruction) conditions?

2. 2. **Regional-Scale Abundance and Distribution:** Evaluate the impacts of the NDD facilities on the seasonal and geographic distribution of listed fish species in the lower Sacramento River within the Delta.

   a. What is the seasonal and geographic abundance and distribution of each life stage of listed fish species in the vicinity of the NDD facilities and in adjacent reaches in the lower Sacramento River?

   b. Are there any factors attributable to the NDD facilities that explain differences in regional-scale abundance and distribution between baseline (preconstruction and during construction) and operating (postconstruction) conditions?

3. **Fine-Scale Abundance and Distribution:** Evaluate the impacts of the NDD facilities on the abundance and distribution of listed species within the water column and laterally across the channel during baseline (preconstruction and during construction) and operating (postconstruction) conditions.

   a. Is the distribution of each life stage of listed fish species inhabiting the lower Sacramento River uniform vertically within the river water column and laterally across the channel width, or does the distribution vary spatially? Does the spatial distribution vary between day and night?

   b. Are there any factors attributable to the NDD facilities that explain differences in local abundance and distribution between baseline (preconstruction and during construction) and operating (postconstruction) conditions?

## Methods

This study would adapt methods the U.S. Fish and Wildlife Service (USFWS) and CDFW have used to conduct a number of fishery surveys on the lower Sacramento River, including beach seine, Kodiak trawl sampling, and 20-mm and larval fish sampling. Additionally, the U.S. Bureau of Reclamation's Directed Outflow Project uses these methods to sample at fixed depths. Night sampling may be required to characterize changes in fish distribution in response to the vertical migration of the prey field. Additional field fishery surveys would be designed in collaboration with CDFW and USFWS to collect similar information on the occurrence, density, and seasonal, spatial, and geographic distribution of each life stage of listed fish species in the study area. The sample design would be consistent with the Enhanced Delta Smelt Monitoring Program, initiated as part of the Delta Juvenile Fish Monitoring Program (DJFMP). Non-invasive sampling methods like environmental DNA (eDNA) and echo sounder abundance estimates may be employed to minimize handling and incidental take of critically endangered species like delta smelt. Existing long-term data sets would be used to calibrate expanded data collection efforts under the baseline condition to characterize the abundance and distribution of listed fish communities in the study area.

### Study Area

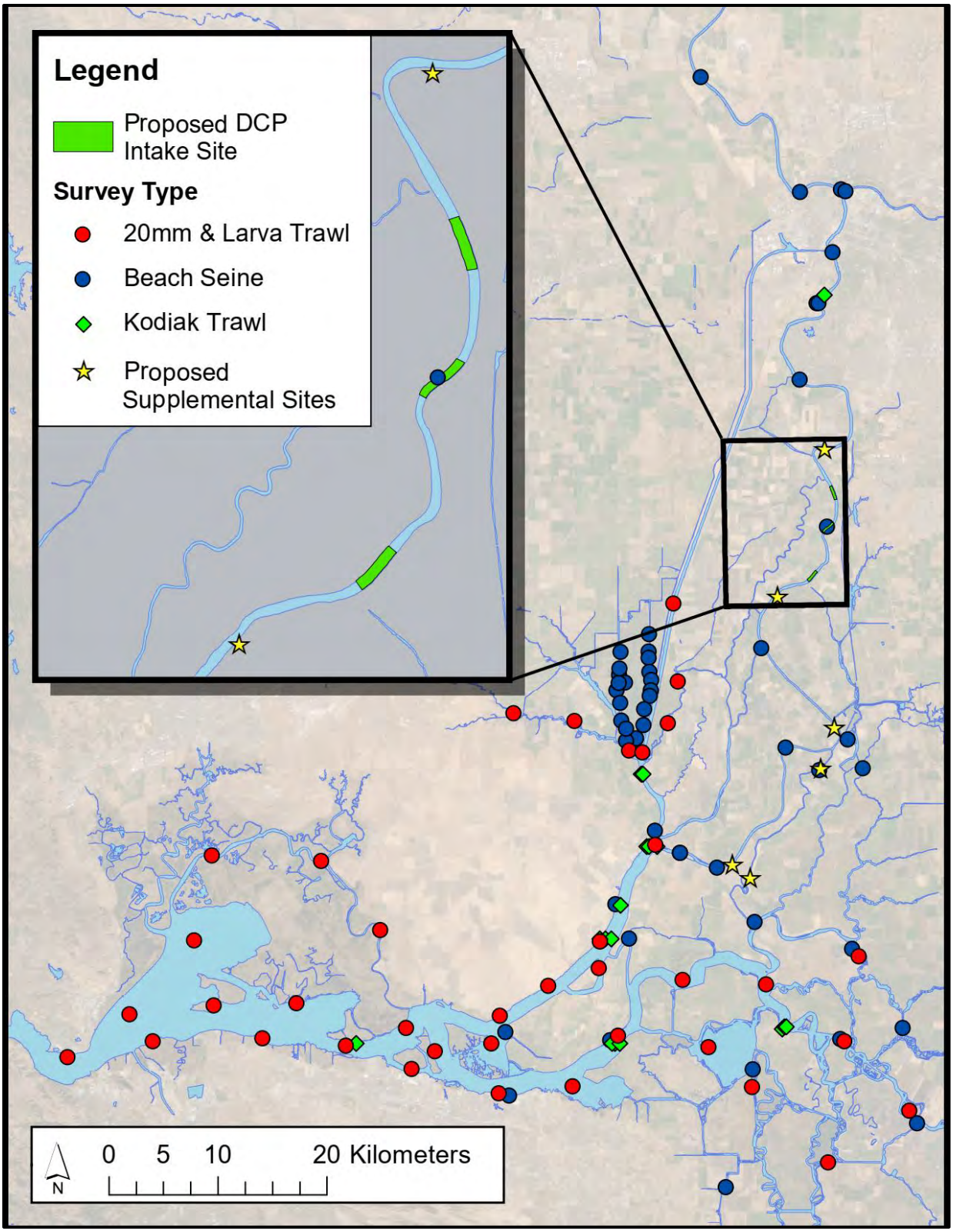
The study area would include waters throughout the lower Sacramento River and in the San Francisco Estuary (Figure 5B-4).

## Regional-Scale Methods

Regional-scale collection methods would rely primarily on existing surveys conducted by the IEP, specifically the CDFW Summer Townet Survey and Fall Midwater Trawl Survey, and the USFWS Enhanced Delta Smelt Monitoring Program and DJFMP, as well as supplemental sampling performed with specific gear types. Surveys and gear types are described briefly below. For some supplemental sampling methods, eDNA transects and/or echo sounder transects would be run simultaneously to verify and calibrate catch detection data for newer, less-invasive sampling techniques.

### *Summer Townet Survey*

CDFW operates the Summer Townet Survey, which collects zooplankton and juvenile fish samples at multiple stations in the Delta on a biweekly basis in June, July, and August. The townet consists of a fixed D-frame sled on runners with an 18-foot net. The main net body is 11 feet long with 0.5-inch stretch, knotted, nylon mesh tapering down to a 7-foot cod-end with a section of woven mesh with approximately eight holes per inch. A zooplankton net (modified Clarke-Bumpas net, 160-micron mesh) is attached to the top of the net frame to sample mesozooplankton prey availability during one of the fish tows at each station. Two 10-minute stepped oblique tows are performed at each station. A third tow is conducted if any fish are captured during the first two tows. All fishes and several invertebrate species are counted and measured.




Note: Although three proposed intake sites are shown, only two sites would ultimately be selected.

**Figure 5B-4. Example of How the Current DJFMP Surveys in the North Delta Would Be Supplemented with Proposed Additional Survey Sites**

***Fall Midwater Trawl***

In September, the Summer Townet Survey is replaced by the Fall Midwater Trawl, which operates monthly and collects zooplankton samples in addition to fish sampling at a subset of its fish sampling stations. The midwater trawl net has mouth dimensions of 12 feet by 12 feet. Net mesh sizes graduate in nine sections from 8-inch stretch-mesh at the mouth to 0.5-inch stretch-mesh at the cod-end. All four corners of the net mouth are connected to doors that hold the net mouth open when being towed through the water. At each station, a 12-minute stepped oblique tow is conducted. All fishes and several invertebrate species are counted and measured. At stations where zooplankton is collected, a mesozooplankton net (modified Clarke-Bumpas net, 160-micron mesh) and a net attached to a steel frame is sampled by a stepwise-oblique tow immediately before or after fish sampling.

***Delta Juvenile Fish Monitoring Program***

The USFWS DJFMP has monitored juvenile Chinook salmon and other fish species within the San Francisco Estuary since 1976 using a combination of surface trawls and beach seines. Since 2000, three trawl sites and 58 beach seine sites have been sampled weekly or biweekly within the estuary and the lower Sacramento and San Joaquin Rivers. Surface trawls at Sacramento, Mossdale, and Chipps Island (Kodiak or midwater trawls) are used to assess the timing of Delta entry and exit, and survival of juvenile salmonids through the Delta. Each trawl site is sampled 3 days per week, 10 tows per day, and throughout the year, ten 20-minute tows are collected between approximately 7 a.m. and 1 p.m. at all trawl sites. Beach seines are used to evaluate the spatial distribution of fishes occurring in shallow near-shore habitats throughout the lower Sacramento and San Joaquin Rivers, the Delta, and the lower San Francisco Estuary. The beach seine net used by the DJFMP is a 15.2-meter by 1.3-meter seine net with 0.3-square-centimeter mesh and a 1.3-meter by 1.3-meter bag. Each net has a float line and lead line attached to 1.8-meter-long wooden poles at each end. Seines are conducted weekly or once every 2 weeks (depending on region) year-round. Full details on methods and data are available in the Environmental Data Initiative data package.

***Enhanced Delta Smelt Monitoring Program***

The Enhanced Delta Smelt Monitoring Program was initiated by USFWS in 2016 to provide estimates of delta smelt distribution and abundance. It also provides data on other fishes, including salmon. The program conducts stratified random sampling via Kodiak trawls (July through March) and larval gear (May through June). Over the course of a week, field crews sample between 18 and 37 random sites, with at least two samples in the Suisun Marsh (sites are randomly selected, so they are not shown on the sampling figure). A minimum of two tows are conducted at each site. All fish collected are identified (in the field when possible, and in the lab for early life stages), measured, enumerated, and recorded. In addition to fish information, environmental data are collected for each sampling event. Full details on methods and data are available in the Environmental Data Initiative data package. Because this data set began in 2016, it could not be used to make many historical comparisons, but it provides the best information on delta smelt distribution and abundance from recent years.

***Kodiak Trawl***

Currently, CDFW, USFWS, and the DJFMP operate Kodiak trawl survey protocols within the Delta annually from January to May, extending from the estuary up the Sacramento River to Ryde. This effort would be supplemented with four additional study sites extending up the Sacramento River to Clarksburg and two sites in Georgiana Slough (Figure 5B-4). Methods for the supplemental Kodiak trawl would match methods from the current monitoring program, and efforts would be closely coordinated with the monitoring to ensure that data from both surveys are comparable. The Kodiak

trawl net would comprise five panels of decreasing mesh size (5.1 centimeters [cm], 3.8 cm, 2.5 cm, 1.3 cm, 0.6 cm) and end in a live box cod-end, and a mouth opening of 7.62 meters by 1.96 meters.

***20 mm Trawl***

Currently, CDFW and USFWS operate a 20 mm survey protocol within the Delta annually, extending from the estuary up the Sacramento River to Ryde. This effort begins in early spring (March/April) and conducted every 2 weeks through July/August. This effort would be supplemented with four additional study sites extending up the Sacramento River to Clarksburg (Figure 5B-4). Methods for the supplemental 20 mm surveys would match methods from the 20 mm survey protocol, and efforts would be closely coordinated with the ongoing monitoring to ensure that data from both surveys are comparable. The net would be a conical plankton net 5.5 meters in length with a mouth opening of 1.51 square meters, mounted on a weighted tow frame with skids. The net would be made of 1,600-micrometer nylon delta mesh. At the cod-end, a 2.2-liter collection jar would be screened with 474-micrometer stainless steel wire bolting cloth. At each site, three 10-minute stepped oblique tows (1.2 meters per step) would be completed.

***Smelt Larval Surveys***

The Smelt Larval Surveys, initiated in January 2009 by CDFW, provide near real-time distribution data for longfin smelt larvae in the Delta, Suisun Bay, and the Suisun Marsh. These data are used by agency managers to assess the vulnerability of longfin smelt larvae to entrainment in the south Delta export pumps. This effort would be supplemented to include delta smelt in addition to longfin smelt and would occur from December through May. Consistent with CDFW surveys, sampling would repeat every other week through the second week in March. Paired 10-minute fixed-depth tows conducted deep and shallow at each survey location would be performed during the day and at night, using an egg and larva net. The 505-micron mesh net is hung on a rigid frame shaped like an inverted U, which in turn is attached to skis to prevent it from digging into the bottom when deployed. The net mouth area measures 0.37 square meters. The conical net tapers back from the frame 3.35 meters to a 1-liter cod-end jar, which collects and concentrates the sample. Immediately after each tow, larval and juvenile-stage fishes would be removed, identified, measured, and returned to the water, and the remaining larvae would be preserved in 10% formalin for later identification in a laboratory.

***Beach Seining***

Beach seining conducted by the DJFMP in the Sacramento River is currently conducted at eight regions. Regions 2 and 3 would be especially important for documenting proposed action impacts on native fish abundance and distributions within the lower Sacramento River and Georgiana Slough. Beach seining would be conducted following the methods from the DJFMP, supplementing current efforts with additional sites to better resolve changes in distribution and abundance.

***Environmental DNA***

Simultaneous samples for eDNA can be collected while trawling using any of the methods identified above, using a continuous sampling pump fitted to a pole with glass fiber filters. This technique would be used to generally provide presence/absence data. Presence/absence data can be used to verify the presence of species, although abundance estimates cannot be obtained at this time. Detection range may be verified using caged fish placed at a known location and sampled over a tidal cycle from measured distances from the point source. Cage experiments could also be used to inform distribution and abundance estimates (see Carraro et al. 2018; Pont et al. 2018). Any detections upstream of the NDD facilities could be assumed to be produced from an upstream source, given the unidirectional nature of flow that far upstream in the river.

#### *Split Beam Echo Sounder*

Split beam echo sounders can be deployed in two ways, depending on the research objective. The first is a stationary deployment at the NDD facilities to detect temporal dynamics of fishes moving around the facilities. It is possible to estimate the temporal abundance and velocity trajectories of target fish species and investigate how these dynamics relate to environmental covariates like temperature, turbidity, and flow. The second approach is a mobile survey to capture relative changes in spatial variation in abundance around the NDD facilities. Echo sounders produce a continuous count of relative abundance called the nautical area scattering coefficient; these values can be used to identify predator hotspots along a transect.

#### *Image-Recognition Survey*

Photogrammetry is being developed as a less-invasive alternative to traditional net capture and handling surveys with the development of machine learning algorithms for identifying species and individuals by capturing unique identifying features on camera. SmeltCam (Feyrer et al. 2013) is one example of this technique, in which a camera is deployed in an open cod-end of a trawl net to count and identify each fish species encountered by the net without having to handle them. Another example in development uses a push net in front of a pontoon barge to funnel fish into a live well outfitted with cameras that can capture and identify every individual passing through the system.

### Fine-Scale Methods

A combination of acoustic telemetry (as detailed in Section 5B.6.1), side-scan sonar, and sonar imaging (as detailed in Section 5B.6.2) would be used to evaluate fish density and distribution within the proposed locations of the NDD facilities and nearby reaches. Given the inability to accurately identify species using side-scan sonar and sonar imaging, results would focus on the density and distribution of all fish within specified size categories. The density and distribution of each size category would be analyzed separately to evaluate the impacts of NDD intake construction, structure, and operation.

## Reporting

The results of the fish abundance and distribution study would be documented in annual technical reports. The reports would be reviewed annually and revised as needed.

## Links to Other Delta Conveyance Project Studies and Analytical Tools

This study should be coordinated with ongoing fish abundance and distribution studies in the area to improve efficiency and maximize the value of collected data. In addition, the acoustic array from the migration and survival study would be used to inform the fine-scale density and distribution of salmonids within control and study reaches. Predator abundance and distribution sampling methods from the predation study would be used to provide data for this study as well.

# 5B.6.3.2 Performance Metrics

The study element is designed to answer research questions that would inform adaptive management of proposed action operations by providing data to assess performance metrics and associated criteria. Performance metrics and associated criteria for the study would be developed by the study implementation team and would provide the direct connection to operation and adaptive management of the NDD intakes. Preliminary, generalized performance metrics for each element are as follows:

a. Trends in the geographic distribution of listed fish species relative to trends under baseline (preconstruction and during construction) conditions and historical data.

b. Trends in abundance (i.e., catch data indices and catch per unit of effort) from regional sampling efforts relative to trends under baseline (preconstruction and during construction) conditions and historical data.

c. Trends in fine-scale density and distribution relative to trends under baseline (preconstruction and during construction) conditions.

# 5B.7 Future Real-Time Decision Making

Real-time changes to current SWP/CVP operations, supported by established decision-making processes and work groups (e.g., the IEP, Water Operations Management Team, Collaborative Adaptive Management Team) are critical to avoid and minimize adverse effects on listed species while also considering public health, safety, and water supply reliability. Like current SWP/CVP operations, operations under the proposed action have the potential to be influenced by several real-time factors. To facilitate future real-time operational decisions and coordination with the fish and wildlife agencies (USFWS, National Marine Fisheries Service, and CDFW), a set of processes to collect data, disseminate information, develop recommendations, make decisions, and provide transparency consistent with the processes (and work groups and/or teams) already in place for current SWP/CVP operations would be developed for the proposed action. These processes are anticipated to be informed by information generated through the implementation of this workplan across the Baseline phase and Initial and Long-Term Operations sub-phases and may also include data associated with existing monitoring programs (e.g., trawls, beach seines, screw traps) that are separate or proposed to be supplemented by the proposed action.

# 5B.8 Implementation Schedule

Each study would be conducted annually, corresponding to when listed species are expected to be in the study area.

Each study would begin before in-water construction begins, to form a baseline set of data against which data from subsequent years could be assessed. The first 1 to 2 years of the baseline period would constitute a pilot study period. This pilot study period would be necessary to ensure that sample sizes and study designs have sufficient power to answer key questions, meet study objectives, and inform adaptive resource management.

Baseline monitoring would continue during the construction period to inform construction impacts and ensure compliance. Because the in-water work window, which generally extends from May to October, would occur outside of the time of juvenile outmigration, it is unlikely that monitoring would occur during physical construction work efforts (i.e., during the period of the in-water work window); however, the potential presence of green sturgeon during this period may make it necessary to conduct monitoring for this species.

Monitoring would continue during the proposed action Initial and Long-Term Operations sub-phases which is anticipated to last for 5 years. Afterward, continued monitoring of survival, route entrainment, fish distribution, and abundance is anticipated to continue as part of established interagency monitoring programs.

# 5B.9 Preliminary Cost Estimates

To be developed in subsequent drafts.

# 5B.10 References and Links

## 5B.10.1 Useful Links

The items listed here appear in blue font within this plan, where they are linked to their respective documents or web pages.

California Department of Fish and Wildlife Summer Townet Survey: https://wildlife.ca.gov/Conservation/Delta/Townet-Survey

California Department of Fish and Wildlife Fall Midwater Trawl: https://www.wildlife.ca.gov/Conservation/Delta/Fall-Midwater-Trawl

Environmental Data Initiative EDI Data Portal: https://portal.edirepository.org/nis/mapbrowse?packageid=edi.244.8

U.S. Fish and Wildlife Service Enhanced Delta Smelt Monitoring Program: https://www.fws.gov/project/enhanced-delta-smelt-monitoring-program

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Attachment 5B1

# Study Considerations

| Study | Study Element | Activity | ESA/CESA Take Considerations | Permitting Considerations |
|---|---|---|---|---|
| Migration and Survival | Far-Field Routing and Survival | Pile driving required for anchoring telemetry hydrophones for 1D array. | Impact to benthic habitat (food production) & natural river habitat. Increased boat traffic, construction-related disturbance to aquatic habitat. Sound impacts requiring acoustic monitoring for mitigation, WQ (turbidity) monitoring during in-water installations of scientific equipment and supporting infrastructure. | ITP, LSAA |
| | | Shore-based install of cables, solar panels, on-site support infrastructure, or other scientific equipment. | Develop WQ Control Plan, Spill Prevention and Control Plan. Conduct preconstruction surveys and biological monitoring for sensitive plant and animal species. | N/A |
| | | Tagging, holding, & releasing hatchery-reared salmonids | N/A | CDFW SCP, CDFW MOU, & 10(a)(1)(A) or 4(d) (for Steelhead) |
| | Near-Field Survival | Pile driving required for anchoring telemetry hydrophones for 3D array. | Impact to benthic habitat (food production) & natural river habitat. Increased boat traffic, construction-related disturbance to aquatic habitat. Sound impacts requiring acoustic monitoring for mitigation, WQ (turbidity) monitoring during in-water installations of scientific equipment and supporting infrastructure. | ITP, LSAA |
| | | Shore-based install of cables, solar panels, on-site support infrastructure, or other scientific equipment. | Develop WQ Control Plan, Spill Prevention and Control Plan. Conduct preconstruction surveys and biological monitoring for sensitive plant and animal species. | N/A |
| | | Tagging, holding, & releasing hatchery-reared salmonids | N/A | CDFW SCP, CDFW MOU, & 10(a)(1)(A) or 4(d) (for Steelhead) |
| Predation Study | Predatory fish Capture, | Hook-and-Line | Minimal bycatch with careful gear selection. | CDFW SCP |

| Study | Study Element | Activity | ESA/CESA Take Considerations | Permitting Considerations |
|---|---|---|---|---|
| | Tagging, Holding, Release, & Tracking | Electrofishing, Trawling, Seining, Fyke & Hoop Trapping | Bycatch of non-target (including listed) fish, bird, mammal, reptile, & amphibian species. | CDFW SCP, CDFW MOU, & 10(a)(1)(A), 4(d) |
| | | Tagging, holding, & releasing predatory fish | N/A | CDFW SCP |
| | | Pile driving required for anchoring telemetry hydrophones for 3D array. | Impact to benthic habitat (food production) & natural river habitat. Increased boat traffic, construction-related disturbance to aquatic habitat. Sound impacts requiring acoustic monitoring for mitigation, WQ (turbidity) Monitoring during in-water installations of scientific equipment and supporting infrastructure. | ITP, LSAA |
| | | Shore-based install of cables, solar panels, on-site support infrastructure, or other scientific equipment. | Develop WQ Control Plan, Spill Prevention and Control Plan. Conduct preconstruction surveys and biological monitoring for sensitive plant and animal species. | N/A |
| | Fixed and Mobile Split-Beam Echo Sounder Surveys | Install of fixed equipment | Minimal impact during install. Minimal equipment in water & on land, minor alteration of habitat. Take via sonar/photography. | |
| | | Mobile surveys | Increased boat traffic. Take via sonar/photography. | CDFW SCP, CDFW MOU, & 10(a)(1)(A), 4(d) |
| | Direct Predation Rate (PERs) | Tethering prey, Conducting Study | Increased boat traffic. | CDFW SCP, CDFW MOU (for Chinook) |
| | DIDSON | Install of fixed equipment, operating DIDSON | Minimal impact during install. Minimal equipment in water & on land, minor alteration of habitat. Take via sonar/photography. | CDFW SCP, CDFW MOU, & 10(a)(1)(A), 4(d) |
| Abundance & Distribution | Supplemental Data Collection | Kodiak Trawl, Beach Seine | Bycatch of non-target (including listed) fish, bird, mammal, reptile, & amphibian species. | CDFW SCP, CDFW MOU, & 10(a)(1)(A), 4(d) |

| Study | Study Element | Activity | ESA/CESA Take Considerations | Permitting Considerations |
|---|---|---|---|---|
| | | 20-mm & larval fish sampling | Bycatch of non-target (including listed) fish, bird, mammal, reptile, & amphibian species. | CDFW SCP, CDFW MOU, & 10(a)(1)(A), 4(d) |
| | | eDNA | N/A | N/A |
| | | Split-Beam Echo Sounder | Minimal impact during install. Minimal equipment in water & on land, minor alteration of habitat. Take via sonar/photography. | CDFW SCP, CDFW MOU, & 10(a)(1)(A), 4(d) |
| | | Mobile split-beam, side scan & sonar imaging surveys | Increased boat traffic. Take via sonar/photography. | CDFW SCP, CDFW MOU, & 10(a)(1)(A), 4(d) |

Appendix 5C

# Operations and Maintenance Effects Analysis for Chinook Salmon, California Central Valley Steelhead, Green Sturgeon, and Killer Whale

## 5C.1 Introduction

This appendix includes analyses to describe effects of the proposed action on species under the jurisdiction of the National Marine Fisheries Service (NMFS). Those species include the following.

- Chinook salmon (*Oncorhynchus tshawytscha*), Sacramento River winter-run evolutionarily significant unit (ESU)
- Chinook salmon, Central Valley spring-run ESU[1]
- Chinook salmon, Central Valley fall-/late fall–run ESU
- Steelhead (*Oncorhynchus mykiss*), California Central Valley distinct population segment (DPS)
- Green sturgeon (*Acipenser medirostris*), Southern DPS
- Killer whale (*Orcinus orca*), Southern Resident DPS

Specifically, this appendix includes operations and maintenance effect analyses to inform programmatic consultation under Section 7(a)(1) of the Endangered Species Act. More information on the consultation strategy can be found in Section 1.7, *Consultation Approach*.

## 5C.2 Temporal Occurrence

Refer to Chapter 5, *Effects Analysis for Chinook Salmon, California Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5.2, *Temporal Occurrence*.

## 5C.3 Spatial Occurrence

Refer to Chapter 5, Section 5.3, *Spatial Occurrence.*

[1] As described in Section 4.4.2, *Chinook Salmon*, *Central Valley Spring-Run ESU*, of Chapter 4, *Action Area and Environmental Baseline*, this effects analysis includes consideration of effects in the Delta on both San Joaquin River spring-run Chinook salmon, which are considered to represent both the experimental, non-essential population reintroduced as part of the San Joaquin River Restoration Program and spring-running Chinook salmon observed in San Joaquin River tributaries in recent years.

# 5C.4 Effects of Water Facility Construction on Chinook Salmon, Central Valley Steelhead, and Green Sturgeon

Refer to Chapter 5, Section 5.4, *Effect of Water Facility Construction on Chinook Salmon, Central Valley Steelhead, and Green Sturgeon,* for project specific construction analyses.

# 5C.5 Effects of Water Facility Construction on Designated Critical Habitat

Refer to Chapter 5, Section 5.5, *Effect of Water Facility Construction on Designated Critical Habitat,* for project specific construction analyses.

# 5C.6 Effects of Conservation Measures

Refer to Chapter 5, Section 5.6, *Effects of Conservation Measures*.

# 5C.7 Effects of Operations and Maintenance of Water Conveyance Facilities on Sacramento River Winter-Run Chinook Salmon

Potential effects of the proposed action on winter-run Chinook salmon are discussed in terms of near-field effects (i.e., in the immediate proximity) of north Delta exports and south Delta exports (e.g., entrainment), in addition to far-field effects (e.g., changes to through-Delta survival and habitat suitability). Analyses were focused primarily on the San Francisco Estuary and Sacramento–San Joaquin Delta (Delta). Life cycle modeling integrates potential effects within the Delta and upstream habitat and was undertaken using three available life cycle models for winter-run Chinook salmon (i.e., Interactive Object-Oriented Simulation [IOS], Oncorhynchus Bayesian Analysis (OBAN), and the Sacramento River Winter-Run Chinook Salmon Life Cycle Model). Analyses were developed in consideration of habitat attributes believed to be of importance to the species based on existing conceptual models (e.g., Windell et al. 2017) and best available methods (e.g., ICF International 2016; California Department of Water Resources 2020).

## 5C.7.1 Near-Field Effects

### 5C.7.1.1 North Delta Exports

The potential for negative near-field effects of the north Delta intakes on juvenile winter-run Chinook salmon (i.e., entrainment, impingement, and predation) is dependent on the occurrence of the species close to the intakes, both vertically (i.e., at similar water depth) and horizontally (i.e., on the same side of the river and near the edge of the river), as well as exposure time. At the scale of the

whole downstream-migrating juvenile winter-run Chinook salmon population, only those individuals remaining in the Sacramento River (as opposed to entering Yolo Bypass) would pass the north Delta intakes. Under existing conditions, flows enter the Yolo Bypass in approximately 60%–70% of years, with the estimated percentage of the juvenile winter-run Chinook salmon population remaining in the Sacramento River averaging around 94% of the population in wet and above-normal years and more than 99% of the population in dry and critically dry years (Acierto et al. 2014).[2]

With respect to vertical distribution, migrating juvenile salmonids generally are in the upper portion of the water column (Smith et al. 2009). This was illustrated in a hydroacoustic study near the Delta Cross Channel, for which fish were particularly abundant between around 4 and 7 meters (13 and 23 feet) below the surface of the 13-meter-deep (43-foot) water column (Blake and Horn 2006:Figure 41); that is, fish were found at approximately 30%–50% of water-column depth. Based on available design information (Table 5C.7-2), the top of the cylindrical tee screens for the intakes would be located in the upper half of the water column much of the time during the main months of winter-run occurrence (i.e., November–April): generally 75%–95% or more of the time at Intake B (Table 5C.7-3), and 25%–50% of the time at Intake C (Table 5C.7-4), reflecting the relative position of each intake in the water column (i.e., Intake C is closer to the bottom, see Table 5C.7-1). This suggests that exposure of juvenile migrating winter-run Chinook salmon to the screens could be frequent, based on their typical vertical migration distribution, if they occurred near the left riverbank, where the proposed intakes would be located.

**Table 5C.7-2. Elevation of North Delta Diversion Intakes**

| Intake | Mean River Bottom Elevation (ft, NAVD) | Bottom of Cylindrical Tee Screen (ft, NAVD) | Top of Cylindrical Tee Screen (ft, NAVD) |
|---|---|---|---|
| B | -25 | -13 | -5 |
| C | -17 | -13 | -5 |

Source: Delta Conveyance Design and Construction Authority (2022a:11, 2022b:53).
ft, NAVD = feet elevation, North American Vertical Datum.

**Table 5C.7-3. Water Column Position (U = Upper 50%; L = Lower 50%) of Top of Cylindrical Tee Screens at Intake B during Various Monthly Water Surface Elevation Exceedance Percentiles**

| Month | 1% | 5% | 25% | 50% | 75% | 95% | 99% |
|---|---|---|---|---|---|---|---|
| Jan | L | L | U | U | U | U | U |
| Feb | L | L | U | U | U | U | U |
| Mar | L | L | U | U | U | U | U |
| Apr | L | L | U | U | U | U | U |
| May | L | U | U | U | U | U | U |
| Jun | U | U | U | U | U | U | U |

[2] The *Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project Final Environmental Impact Statement/Environmental Impact Report* estimated that, on average, 1.2% of juvenile winter-run <80-millimeter fork length enter Yolo Bypass under existing conditions (Bureau of Reclamation and California Department of Water Resources 2019:8-291). Note that with notching of the Fremont Weir, as would occur prior to implementation of the proposed action, the percentage of the juvenile winter-run Chinook salmon population remaining in the mainstem Sacramento River would be less than existing conditions (e.g., an overall mean of ~93% for juveniles <80-millimeter fork length; Bureau of Reclamation and California Department of Water Resources 2019:8-291).

| Month | 1% | 5% | 25% | 50% | 75% | 95% | 99% |
|---|---|---|---|---|---|---|---|
| Jul | U | U | U | U | U | U | U |
| Aug | U | U | U | U | U | U | U |
| Sep | U | U | U | U | U | U | U |
| Oct | U | U | U | U | U | U | U |
| Nov | U | U | U | U | U | U | U |
| Dec | L | U | U | U | U | U | U |

Source: Based on elevation data in Table 5C.7-18 and data sources in Delta Conveyance Design and Construction Authority (2022a).
Note: Percentiles indicate water surface elevation that would be exceeded 1%, 5%, etc., of the time, so, for example, an "L" in the 5% column indicates that the top of the cylindrical tee screens would be in the lower 50% of the water column 5% of the time. As a further example, in January, "U" in the 25%–99% columns but not in the 1% and 5% columns indicates that the top of cylindrical tee screens would be in the upper 50% of the water column at least 75% of the time.

**Table 5C.7-4. Water Column Position (U = Upper 50%; L = Lower 50%) of Top of Cylindrical Tee Screens at Intake C during Various Monthly Water Surface Elevation Exceedance Percentiles.**

| Month | 1% | 5% | 25% | 50% | 75% | 95% | 99% |
|---|---|---|---|---|---|---|---|
| Jan | L | L | L | U | U | U | U |
| Feb | L | L | L | U | U | U | U |
| Mar | L | L | L | U | U | U | U |
| Apr | L | L | L | U | U | U | U |
| May | L | L | L | U | U | U | U |
| Jun | L | L | U | U | U | U | U |
| Jul | L | L | U | U | U | U | U |
| Aug | L | L | U | U | U | U | U |
| Sep | L | U | U | U | U | U | U |
| Oct | U | U | U | U | U | U | U |
| Nov | L | U | U | U | U | U | U |
| Dec | L | L | L | U | U | U | U |

Source: Based on elevation data in Table 5C.7-18 and data sources in Delta Conveyance Design and Construction Authority (2022a).
Note: Percentiles indicate water surface elevation that would be exceeded 1%, 5%, etc., of the time, so, for example, an "L" in the 25% column indicates that the top of the cylindrical tee screens would be in the lower 50% of the water column 25% of the time. As a further example, in January, "U" in the 25%–99% columns but not in the 1% and 5% columns indicates that the top of cylindrical tee screens would be in the upper 50% of the water column at least 75% of the time.

With respect to horizontal distribution of juvenile winter-run Chinook salmon across the river cross-section and potential exposure to the near-bank cylindrical tee screens proposed under the proposed action, several studies in the Sacramento River provide evidence for the distribution of fish being toward the outer sides of river bends, including at Clarksburg Bend (Burau et al. 2007:Figure C.17), the Delta Cross Channel (Burau et al. 2007:Figure 2.5), and near Fremont Weir (Blake et al. 2017:Figures 2 and 20). The distribution of fish toward the outside of bends is the result of centrifugal and pressure forces in bends that induce a secondary flow that lies in a plane perpendicular to the primary flow direction (Dinehart and Burau 2005) and is reflected in the bathymetry of such areas. The deeper areas, including the thalweg (i.e., the line of lowest elevation within the river channel), coincide with the areas subject to the secondary flow (Burau et al. 2007:Figure C.1). These observations are consistent with the general pattern of downstream-

migrating juvenile salmonids in the Pacific northwest often being distributed near the thalweg or shoreline (Smith et al. 2009), and the coincidence of fish occurring near the thalweg with the secondary flow results in fish being moved to the outside of bends. The two proposed sites for the north Delta intakes reflected the Fish Facilities Technical Team's[3] (2011:42) earlier recommendation to locate the north Delta intakes within straight reaches of the river or mild outside bends to avoid complex flow patterns, sedimentation, and excessive scour. Locating the intakes at the outside of the river bends may lead to a greater proportion of juvenile salmonids passing close to the intakes than if the fish were evenly distributed across the channel cross section. However, when holding (e.g., during the day; Plumb et al. 2016), juvenile salmonids could also occur on the inside of river bends, as illustrated at Clarksburg Bend (Burau et al. 2007:Figure C.15).

Two-dimensional modeling of the hydrodynamic effects of the north Delta intakes illustrates that the proportion of the river channel width from which water is drawn toward the intakes[4] varies depending on diversion rate and river flow (Table 5C.7-5). Beyond this, streamlines proceed past the intakes, which indicates that any potential increase in exposure to near-field effects of the screens as a result of fish being drawn toward the intakes would be limited to this portion of the channel cross-section. Note, however, that fish being on the intake side of the critical streakline does not necessarily mean that the fish would be drawn to the intakes;[5] as described in Chapter 3, *Description of the Proposed Action*, sweeping velocity would be at least double the approach velocity (see additional discussion below), thereby limiting the potential for fish to be drawn to the intakes and minimizing the potential for negative near-field effects, such as injury from contacting the screens. The CalSim modeling of the north Delta diversions provides context for the frequency of occurrence of diversions at different river flows and, therefore, the potential portion of the river channel flow drawn toward the north Delta intakes, by showing the percentage of months that would be within various combinations of river flows and diversions (Table 5C.7-6).[6] For example, under the proposed action, in December during Freeport flows of 18,000 cfs or less, the streakline at intakes B and C would be around 13%–17% of the river width or less, based on the results of modeling run 4F (Table 5C.7-5), coupled with consideration of the frequency of diversion in relation to Freeport flow (Table 5C.7-6). Based on the operating criteria, high levels of diversion at low river flows would be very rare (see, for example, percentages for Table 5C.7-6 corresponding to Freeport flow <=18,000 cfs and diversions >5,000–6,000 cfs). The two-dimensional modeling does not account for fish behavior or the distribution of fish in the channel (see above discussion). In addition, as described in the next section, *Entrainment and Impingement*, north Delta intake operations would meet fishery agency standards for approach and sweeping velocity in order to limit the potential for negative effects on juvenile winter-run Chinook salmon and other species.

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[3] The Fish Facilities Technical Team included as participating agencies the Bay Delta Conservation Plan, Reclamation, CDFW (then the California Department of Fish and Game), DWR, NMFS, and USFWS (Fish Facilities Technical Team 2011:10).

[4] This location is the critical *streakline*, defined as the location dividing the parcel of water that is diverted into the intake and the parcel that remains in the river channel (adapting the definition of Hance et al. [2020] for open channels), as determined by examining animated streamlines from hydrodynamic modeling.

[5] For example, at the Sacramento River and Georgiana Slough junction, Hance et al. (2020) found that the probability of Chinook salmon smolts entering Georgiana Slough when on the Georgiana Slough side of the critical streakline varied between ~0.2 and ~0.9 depending on Sacramento River flow. Note that the Sacramento River and Georgiana Slough junction is an open river channel junction, and therefore velocity entering the junction would be greater than the limited approach velocity at the north Delta intake screens, likely resulting in greater probability of fish being drawn toward the junction than would be the case at the north Delta intake screens.

[6] See Appendix 5D, Section 5D.1, *Juvenile Chinook Salmon Screen Passage Duration*.

**Table 5C.7-5. Distance and Percentage of River Width of Critical Streakline at North Delta Intakes B and C from Two-Dimensional Hydrodynamic Modeling**

| Model Run | Freeport Flow (cfs) | Diversion Flow by Intake (cfs) | Intake B River Width (ft) | Intake B Streakline (ft; % of River Width) | Intake B % of Flow Diverted | Intake C River Width (ft) | Intake C Streakline (ft; % of River Width) | Intake C % of Flow Diverted | Notes |
|---|---|---|---|---|---|---|---|---|---|
| **2D** | 50,000 [a] | 3,000 B&C [c] | 560 | 80 (14%) | 6.0% [d] | 660 | 100 (15%) | 6.4% [d] | High river velocity during operation |
| **3D** | 30,000 [a] | 3,000 B&C [c] | 550 | 80 (15%) | 10.0% [d] | 650 | 120 (18%) | 11.1% [d] | Moderate river velocity during operation, high diversion |
| **3E** | 30,000 [a] | 2,000 B&C [c] | 550 | 70 (13%) | 6.7% [d] | 650 | 100 (15%) | 7.1% [d] | Moderate river velocity during operation, moderate diversion |
| **3F** | 30,000 [a] | 1,000 B&C [c] | 550 | 50 (9%) | 3.3% [d] | 650 | 70 (11%) | 3.4% [d] | Moderate river velocity during operation, low diversion |
| **4D** | 18,000 [a] | 3,000 B&C [c] | 540 | 110 (20%) | 16.7% [d] | 630 | 180 (29%) | 20.0% [d] | Low river velocity during operation, high diversion |
| **4E** | 18,000 [a] | 2,000 B&C [c] | 540 | 90 (17%) | 11.1% [d] | 640 | 140 (22%) | 12.5% [d] | Low river velocity during operation, moderate diversion |
| **4F** | 18,000 [a] | 1,000 B&C | 540 | 70 (13%) | 5.6% [d] | 640 | 110 (17%) | 5.9% [d] | Low river velocity during operation, low diversion |
| **5B** | Hydrograph [b] | 3,000 B&C [c] | 540 | 130 (24%) | 14.2% [d] | 640 | 160 (25%) | 15.3% [d] | Low tide, 12/01/2016 02:00 |
| **5C** | Hydrograph [b] | 3,000 B&C [c] | 540 | 150 (28%) | 16.7% [d] | 640 | 180 (28%) | 19.1% [d] | Dropping tide, 12/01/2016 11:00 |
| **5D** | Hydrograph [b] | 3,000 B&C [c] | 540 | 180 (33%) | 23.4% [d] | 640 | 280 (44%) | 37.1% [d] | High tide, 12/01/2016 18:00 |

Source: Delta Conveyance Design and Construction Authority (2022b).
Note: The *critical streakline* is the location in the river channel dividing the parcel of water that is diverted into the intake and the parcel that remains in the river channel, as determined by examining animated streamlines from hydrodynamic modeling. The location of the critical streakline is measured as the distance from the left

bank of the river to the flow streamline that enters the intake screens at the most downstream location; this streakline extends to a point a short distance upstream of the intake structure, where the streamline is consistent with the upstream streamlines that are unaffected by the diversions. River width is at the upstream end of the intake.
cfs = cubic feet per second; ft = feet.
[a] Steady-state runs (river flow constant, no tidal changes).
[b] Tidally varying flows at mean daily Freeport flow of around 18,000 cfs. Note that this run was done to understand potentially worst-case hydraulic conditions at the facilities; CalSim modeling of the proposed action shows that the likelihood of this operational scenario occurring is zero.
[c] Amount of diversion shown is at each intake.
[d] Percent of flow diverted is calculated by dividing the intake diversion level by flow upstream of the specific intake site. For example, under model run 2D, Intake B is diverting 3,000 cfs during Freeport flows of 50,000 cfs, which would equate to 6% of flow diverted at Intake B. Under this scenario, Intake C would be diverting 6.4% of flow (3,000 cfs diversions/ 47,000 cfs flow upstream of Intake C).

**Table 5C.7-6. Percentage of Months with North Delta Diversions Within 1,000-cfs Ranges, Categorized by Sacramento River at Freeport Flow, Proposed Action, Based on CalSim Modeling**

| Freeport Flow | Total North Delta Diversion | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|---|---|---|---|---|
| <=18,000 cfs | 0 cfs | 48% | 78% | 53% | 19% | 4% | 10% | 13% | 48% | 53% | 67% |
| <=18,000 cfs | <=1,000 cfs | 9% | 5% | 16% | 38% | 28% | 12% | 9% | 1% | 7% | 5% |
| <=18,000 cfs | >1,000–2,000 cfs | 7% | 5% | 4% | 5% | 5% | 2% | 0% | 4% | 1% | 3% |
| <=18,000 cfs | >2,000–3,000 cfs | 2% | 3% | 3% | 0% | 0% | 1% | 2% | 0% | 3% | 0% |
| <=18,000 cfs | >3,000–4,000 cfs | 2% | 1% | 5% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| <=18,000 cfs | >4,000–5,000 cfs | 2% | 0% | 2% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| <=18,000 cfs | >5,000–6,000 cfs | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| <=18,000 cfs | All | 70% | 93% | 85% | 63% | 37% | 24% | 23% | 53% | 65% | 76% |
| >18,000–30,000 cfs | 0 cfs | 23% | 1% | 0% | 0% | 0% | 2% | 2% | 15% | 5% | 0% |
| >18,000–30,000 cfs | <=1,000 cfs | 2% | 1% | 1% | 2% | 3% | 5% | 2% | 2% | 4% | 1% |
| >18,000–30,000 cfs | >1,000–2,000 cfs | 2% | 3% | 1% | 4% | 7% | 5% | 1% | 1% | 2% | 2% |
| >18,000–30,000 cfs | >2,000–3,000 cfs | 0% | 1% | 1% | 2% | 10% | 6% | 6% | 1% | 0% | 6% |
| >18,000–30,000 cfs | >3,000–4,000 cfs | 1% | 0% | 6% | 3% | 3% | 6% | 15% | 2% | 0% | 0% |
| >18,000–30,000 cfs | >4,000–5,000 cfs | 0% | 0% | 0% | 0% | 3% | 2% | 5% | 0% | 1% | 3% |
| >18,000–30,000 cfs | >5,000–6,000 cfs | 1% | 0% | 0% | 0% | 0% | 0% | 2% | 0% | 1% | 2% |
| >18,000-30,000 cfs | All | 30% | 6% | 10% | 12% | 27% | 28% | 34% | 21% | 14% | 15% |
| >30,000–50,000 cfs | 0 cfs | 0% | 0% | 1% | 1% | 1% | 0% | 3% | 13% | 6% | 0% |
| >30,000–50,000 cfs | <=1,000 cfs | 0% | 0% | 0% | 0% | 0% | 1% | 1% | 0% | 3% | 1% |
| >30,000–50,000 cfs | >1,000–2,000 cfs | 0% | 0% | 1% | 1% | 0% | 1% | 1% | 0% | 1% | 2% |

| Freeport Flow | Total North Delta Diversion | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|---|---|---|---|---|
| >30,000–50,000 cfs | >2,000–3,000 cfs | 0% | 0% | 1% | 2% | 2% | 1% | 2% | 1% | 3% | 3% |
| >30,000–50,000 cfs | >3,000–4,000 cfs | 0% | 1% | 2% | 3% | 0% | 1% | 4% | 1% | 1% | 0% |
| >30,000–50,000 cfs | >4,000–5,000 cfs | 0% | 0% | 0% | 4% | 3% | 4% | 7% | 0% | 0% | 0% |
| >30,000–50,000 cfs | >5,000–6,000 cfs | 0% | 0% | 0% | 3% | 6% | 7% | 2% | 0% | 1% | 1% |
| >30,000-50,000 cfs | All | 0% | 1% | 5% | 15% | 13% | 16% | 21% | 15% | 16% | 7% |
| >50,000–70,000 cfs | 0 cfs | 0% | 0% | 0% | 2% | 2% | 5% | 7% | 6% | 4% | 1% |
| >50,000–70,000 cfs | <=1,000 cfs | 0% | 0% | 0% | 0% | 0% | 2% | 1% | 0% | 1% | 0% |
| >50,000–70,000 cfs | >1,000–2,000 cfs | 0% | 0% | 0% | 0% | 0% | 2% | 1% | 0% | 0% | 1% |
| >50,000–70,000 cfs | >2,000–3,000 cfs | 0% | 0% | 0% | 0% | 3% | 1% | 2% | 0% | 0% | 0% |
| >50,000–70,000 cfs | >3,000–4,000 cfs | 0% | 0% | 0% | 0% | 2% | 3% | 1% | 1% | 0% | 0% |
| >50,000–70,000 cfs | >4,000–5,000 cfs | 0% | 0% | 0% | 2% | 2% | 4% | 2% | 1% | 0% | 0% |
| >50,000–70,000 cfs | >5,000–6,000 cfs | 0% | 0% | 0% | 4% | 7% | 4% | 2% | 0% | 0% | 0% |
| >50,000-70,000 cfs | All | 0% | 0% | 0% | 9% | 17% | 22% | 17% | 9% | 5% | 2% |
| >70,000 cfs | 0 cfs | 0% | 0% | 0% | 2% | 2% | 5% | 4% | 0% | 0% | 0% |
| >70,000 cfs | <=1,000 cfs | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 2% | 0% | 0% |
| >70,000 cfs | >1,000–2,000 cfs | 0% | 0% | 0% | 0% | 1% | 1% | 0% | 0% | 0% | 0% |
| >70,000 cfs | >2,000–3,000 cfs | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| >70,000 cfs | >3,000–4,000 cfs | 0% | 0% | 0% | 0% | 0% | 2% | 0% | 0% | 0% | 0% |
| >70,000 cfs | >4,000–5,000 cfs | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% |
| >70,000 cfs | >5,000–6,000 cfs | 0% | 0% | 0% | 0% | 1% | 1% | 0% | 0% | 0% | 0% |
| >70,000 cfs | All | 0% | 0% | 0% | 2% | 6% | 10% | 4% | 2% | 0% | 0% |

Note: The values in each month column (excluding the "All" row) sum to 100%, reflecting that each cell in the table represents the percentage of the total number of months (i.e., from a total of 94 months for the CalSim modeling of water years 1922–2015) with the given Freeport flow and total north Delta diversion range shown in the two left-hand columns. The "All" row indicates the percentage of the total months within the given Freeport flow category (i.e., the sum of all the diversion categories for each Freeport flow category).
cfs = cubic feet per second.

Screen-passage time is a useful measure of the duration that potential negative effects on Chinook salmon could occur, with shorter passage times limiting the potential for negative near-field effects (e.g., predation or screen contact or impingement). A fish moving downstream at the same velocity as river flow with 0.4-foot sweeping velocity would pass a single, approximately 30-foot[7] cylindrical tee screen unit in 75 seconds (i.e., 30 feet ÷ 0.4 foot per second = 75 seconds); a combined screen unit length of 900 feet—the approximate screen unit length of each of Intakes B and C with 3,000-cfs capacity—in 37.5 minutes (i.e., 900 feet ÷ 0.4 foot per second = 2,250 seconds = 37.5 minutes). However, laboratory studies of juvenile Chinook salmon in close proximity to a test fish screen showed that fish may swim against the current, resulting in longer passage time than sweeping velocity alone may produce (Swanson et al. 2004).

Application of the relationships from the laboratory studies of Swanson et al. (2004) for a representative water temperature of 12°C[8] illustrated how screen-passage time may differ in relation to sweeping velocity at an approach velocity of 0.2 feet per second[9] (Table 5C.7-7). It should be noted that the equations of Swanson et al. (2004) give very long screen-passage times at certain sweeping velocity and approach velocity combinations—for example, almost 3,000 minutes for 7.9-centimeter fish along a 900-foot combined screen unit length at sweeping velocity of 0.4 feet per second[10] during the day—and that fish had to remain within the vicinity of the screens and were not able to swim away as they would in the wild. Such estimates are far in excess of the duration of the experimental trials (i.e., 120 minutes) used to derive the swimming data and, therefore, should be treated with caution. Very high estimated screen-passage time reflects fish that would be holding station in front of a screen for a long time. Larger fish have greater swimming ability and, therefore, are able to hold station for longer periods than smaller fish, so their peak screen-passage time is somewhat greater than that of smaller fish, based on the results of Swanson et al. (2004). Swanson et al. (2004) found that older (i.e., smolt-size) fish acclimated to warmer temperature exhibited higher rates of negative rheotaxis (i.e., swimming with flow rather than against it), a behavior consistent with downstream migration, which would decrease passage time.

The laboratory studies of Swanson et al. (2004) showed that swimming velocity is lower at night than during the day for a given set of flow conditions; this generally results in screen-passage time decreasing as sweeping velocity increases over the full range of sweeping flows examined here, because screen-passage velocity becomes more negative (i.e., fish move downstream more quickly). As noted above, most migration occurs at night (Plumb et al. 2016) and so the estimates for night may be more representative of conditions that migrating juvenile fish could experience at the north Delta intake screens.[11] Longer screen lengths increase screen-passage time: For example, at a

[7] The cylindrical fish screen units actually would be 29.33 feet long and separated by a gap of 1 foot; each screen unit would include 7.66 feet of manifold between the two screens comprising each unit, so that there actually would be a 21.67-foot length of fish screen per screen unit.

[8] Swanson et al. (2004) tested fish at 12°C (February–June) and 19°C (June–August), with the latter testing period including only larger fish by day. Based on the available relationships, greater temperatures increased negative rheotaxis, that is, the tendency to orient more with flow (rather than against it) and swim downstream more quickly.

[9] Note that approach velocity may be less than 0.2-foot per second at lower rates of diversion.

[10] Note that north Delta diversion operators would be likely to employ a safety margin for sweeping velocity, so diversions would be likely to occur at sweeping velocity greater than 0.4-foot per second.

[11] Note, however, that as described in Final EIR Appendix 5A, Section C.6.5.1, to avoid nocturnal pumping during the main juvenile salmonid outmigration season, Delta Simulation Model II modeling assumed the north Delta intakes generally operated during daytime hours (6 a.m.–6 p.m.) to the extent possible (except during the months

sweeping velocity of 0.4 feet per second during the night, a 4.4-centimeter juvenile encountering a single 30-foot cylindrical tee screen may pass in 3.1 minutes, compared to nearly 94 minutes for the combined length of thirty 30-foot screens. For the proposed action, juvenile winter-run Chinook salmon migrating downstream close to shore could encounter more than one of the north Delta intakes within a few hours and be susceptible to potential near-field effects, depending on travel time. For example, based on mean migration rates of acoustic tagged winter-run Chinook salmon discussed further below (Table 5C.7-9), a winter-run juvenile could move from Intake B to Intake C (2.5 river miles) in 2.0–4.3 hours. There is uncertainty in the applicability of the laboratory results to cylindrical tee screens given that the laboratory studies were more suited to vertical flat plate screens that fish would be passing horizontally next to, as opposed to potentially immediately above or under as well as horizontally next to as in the case of cylindrical tee screens, and the fish in the laboratory had to remain within relatively close proximity (< 5 feet) to the fish screen as opposed to the proposed cylindrical screen locations within the several-hundred-foot-wide Sacramento River channel. This is illustrated by conducting the same analysis at 19°C (Table 5C.7-6a).

**Table 5C.7-7. Estimated Screen Passage Time (minutes) of Juvenile Chinook Salmon for Screen Lengths of 30 Feet, 450 Feet, and 900 Feet at 0.2-Foot-per-Second Approach Velocity Based on Laboratory Studies of Swanson et al. (2004) at Temperature of 12 Degrees Celsius**

| Fish Size (centimeters) | Day/Night | Sweeping Velocity (feet per second) | Time to pass 30 Feet (minutes) | Time to pass 450 Feet (minutes) | Time to pass 900 Feet (minutes) |
|---|---|---|---|---|---|
| 4.4 | Day | 0.4 | 3.1 | 46.9 | 93.8 |
| 4.4 | Day | 0.5 | 2.1 | 32.2 | 64.5 |
| 4.4 | Day | 0.75 | 1.3 | 19.2 | 38.5 |
| 4.4 | Day | 1 | 0.9 | 14.1 | 28.2 |
| 4.4 | Day | 1.25 | 0.8 | 11.3 | 22.5 |
| 4.4 | Day | 1.5 | 0.6 | 9.4 | 18.8 |
| 4.4 | Day | 1.75 | 0.5 | 8.1 | 16.2 |
| 4.4 | Day | 2 | 0.5 | 7.1 | 14.2 |
| 4.4 | Night | 0.4 | 1.3 | 18.9 | 37.8 |
| 4.4 | Night | 0.5 | 1.1 | 17.0 | 34.0 |
| 4.4 | Night | 0.75 | 0.9 | 14.2 | 28.3 |
| 4.4 | Night | 1 | 0.8 | 12.5 | 24.9 |
| 4.4 | Night | 1.25 | 0.7 | 11.2 | 22.5 |
| 4.4 | Night | 1.5 | 0.7 | 10.3 | 20.6 |
| 4.4 | Night | 1.75 | 0.6 | 9.5 | 19.0 |
| 4.4 | Night | 2 | 0.6 | 8.8 | 17.7 |
| 7.9 | Day | 0.4 | 99.4 | >120 [a] | >120 [a] |
| 7.9 | Day | 0.5 | 7.4 | 110.7 | >120 [a] |
| 7.9 | Day | 0.75 | 2.2 | 33.3 | 66.6 |

of July–September). As described in Chapter 3, operators would operate the facility within the constraints at each intake, including minimum sweeping requirements and allowable approach velocities. To the extent possible, the SWP will prioritize north Delta diversion sub-daily diversions during daylight hours. As noted in Chapter 3, the diel behavior in the intake reaches would be further studied.

| Fish Size (centimeters) | Day/Night | Sweeping Velocity (feet per second) | Time to pass 30 Feet (minutes) | Time to pass 450 Feet (minutes) | Time to pass 900 Feet (minutes) |
|---|---|---|---|---|---|
| 7.9 | Day | 1 | 1.4 | 20.5 | 40.9 |
| 7.9 | Day | 1.25 | 1.0 | 15.0 | 29.9 |
| 7.9 | Day | 1.5 | 0.8 | 11.8 | 23.7 |
| 7.9 | Day | 1.75 | 0.7 | 9.8 | 19.7 |
| 7.9 | Day | 2 | 0.6 | 8.4 | 16.8 |
| 7.9 | Night | 0.4 | 2.2 | 32.4 | 64.7 |
| 7.9 | Night | 0.5 | 1.8 | 27.1 | 54.2 |
| 7.9 | Night | 0.75 | 1.4 | 20.6 | 41.1 |
| 7.9 | Night | 1 | 1.1 | 17.2 | 34.3 |
| 7.9 | Night | 1.25 | 1.0 | 14.9 | 29.8 |
| 7.9 | Night | 1.5 | 0.9 | 13.3 | 26.6 |
| 7.9 | Night | 1.75 | 0.8 | 12.0 | 24.0 |
| 7.9 | Night | 2 | 0.7 | 11.0 | 21.9 |

Note: Estimates for 7.9-centimeter fish at night involve extrapolation beyond range of experimental data.
[a] Values greater than 120 minutes are beyond the length of time of experimental trials from which the statistical relationships were developed.

**Table 5C.7-8a. Estimated Screen Passage Time (minutes) of Juvenile Chinook Salmon for Screen Lengths of 30 Feet, 450 Feet, and 900 Feet at 0.2-Feet-per-Second Approach Velocity Based on Laboratory Studies of Swanson et al. (2004), at Temperature of 19 Degrees Celsius**

| Fish Size (centimeters) | Day/Night | Sweeping Velocity (feet per second) | Time to pass 30 Feet (minutes) | Time to pass 450 Feet (minutes) | Time to pass 900 Feet (minutes) |
|---|---|---|---|---|---|
| 4.4 | Day | 0.4 | 1.0 | 15.5 | 31.1 |
| 4.4 | Day | 0.5 | 0.9 | 13.5 | 27.0 |
| 4.4 | Day | 0.75 | 0.7 | 10.5 | 21.1 |
| 4.4 | Day | 1 | 0.6 | 8.8 | 17.6 |
| 4.4 | Day | 1.25 | 0.5 | 7.6 | 15.2 |
| 4.4 | Day | 1.5 | 0.4 | 6.7 | 13.4 |
| 4.4 | Day | 1.75 | 0.4 | 6.0 | 12.0 |
| 4.4 | Day | 2 | 0.4 | 5.4 | 10.9 |
| 4.4 | Night | 0.4 | 0.7 | 10.4 | 20.9 |
| 4.4 | Night | 0.5 | 0.7 | 9.8 | 19.6 |
| 4.4 | Night | 0.75 | 0.6 | 8.8 | 17.6 |
| 4.4 | Night | 1 | 0.5 | 8.1 | 16.2 |
| 4.4 | Night | 1.25 | 0.5 | 7.6 | 15.1 |
| 4.4 | Night | 1.5 | 0.5 | 7.1 | 14.3 |
| 4.4 | Night | 1.75 | 0.4 | 6.7 | 13.5 |
| 4.4 | Night | 2 | 0.4 | 6.4 | 12.8 |
| 7.9 | Day | 0.4 | 1.6 | 23.6 | 47.3 |
| 7.9 | Day | 0.5 | 1.3 | 19.2 | 38.4 |

| Fish Size (centimeters) | Day/Night | Sweeping Velocity (feet per second) | Time to pass 30 Feet (minutes) | Time to pass 450 Feet (minutes) | Time to pass 900 Feet (minutes) |
|---|---|---|---|---|---|
| 7.9 | Day | 0.75 | 0.9 | 13.7 | 27.4 |
| 7.9 | Day | 1 | 0.7 | 10.9 | 21.8 |
| 7.9 | Day | 1.25 | 0.6 | 9.1 | 18.2 |
| 7.9 | Day | 1.5 | 0.5 | 7.9 | 15.7 |
| 7.9 | Day | 1.75 | 0.5 | 6.9 | 13.8 |
| 7.9 | Day | 2 | 0.4 | 6.2 | 12.4 |
| 7.9 | Night | 0.4 | 0.9 | 13.5 | 27.1 |
| 7.9 | Night | 0.5 | 0.8 | 12.5 | 25.0 |
| 7.9 | Night | 0.75 | 0.7 | 10.9 | 21.8 |
| 7.9 | Night | 1 | 0.7 | 9.9 | 19.7 |
| 7.9 | Night | 1.25 | 0.6 | 9.1 | 18.2 |
| 7.9 | Night | 1.5 | 0.6 | 8.5 | 16.9 |
| 7.9 | Night | 1.75 | 0.5 | 7.9 | 15.8 |
| 7.9 | Night | 2 | 0.5 | 7.5 | 14.9 |

Note: Estimates for 7.9-cm fish at night involve extrapolation beyond range of experimental data.

The estimates of screen-passage time based on laboratory swimming trials can be compared to migration-speed estimates from acoustically tagged juvenile winter-run Chinook salmon in the Sacramento River between Freeport and Hood. Based on data from 2013–2019, the time to travel 30 feet (i.e., equivalent to one cylindrical tee screen) ranged from 0.09 minute to 3.3 minutes; the time to travel 450 feet (i.e., the equivalent of 15 cylindrical tee screens) ranged from 1.4 minutes to just under 50 minutes; and the time to travel 900 feet (i.e., the equivalent of 30 cylindrical tee screens) ranged from 2.8 minutes to nearly 100 minutes (Table 5C.7-9). In general, these estimates are comparable to or lower than the screen passage estimates based on swimming behavior in the laboratory at 12°C (Table 5C.7-7).

**Table 5C.7-9. Mean, Minimum, and Maximum Time (Minutes) for Juvenile Salmon Acoustic Telemetry System (JSATS)-Tagged Winter-Run Chinook Salmon to Travel Distances of 30, 450, and 900 Feet in 2013–2019**

| Year | Number of Fish | 30 Feet Mean | 30 Feet Minimum | 30 Feet Maximum | 450 Feet Mean | 450 Feet Minimum | 450 Feet Maximum | 900 Feet Mean | 900 Feet Minimum | 900 Feet Maximum |
|---|---|---|---|---|---|---|---|---|---|---|
| 2013 | 7 | 0.58 | 0.37 | 0.76 | 8.74 | 5.52 | 11.34 | 17.48 | 11.05 | 22.68 |
| 2014 | 116 | 0.27 | 0.15 | 2.33 | 4.00 | 2.25 | 34.95 | 8.01 | 4.51 | 69.89 |
| 2015 | 184 | 0.31 | 0.14 | 2.68 | 4.67 | 2.07 | 40.15 | 9.33 | 4.13 | 80.30 |
| 2016 | 257 | 0.26 | 0.09 | [a] | 3.89 | 1.38 | [a] | 7.78 | 2.77 | [a] |
| 2017 | 223 | 0.30 | 0.11 | 2.94 | 4.45 | 1.58 | 44.09 | 8.90 | 3.15 | 88.18 |
| 2018 | 145 | 0.28 | 0.11 | 1.20 | 4.14 | 1.61 | 18.03 | 8.28 | 3.21 | 36.07 |
| 2019 | 199 | 0.30 | 0.11 | 3.28 | 4.45 | 1.71 | 49.17 | 8.90 | 3.42 | 98.35 |
| Mean | – | 0.33 | 0.15 | 2.20 | 4.91 | 2.30 | 32.96 | 9.81 | 4.61 | 65.91 |

Source: Ammann pers. comm.
[a] Maximum could not be calculated because slowest migration was upstream movement. Mean fish size was generally 90–100-millimeter fork length. Migration speed was based on detections between Freeport and Hood.

Fisheries studies would be undertaken to provide information on the near-field effects of the north Delta intakes on juvenile salmonids once they are operational, to inform the refinement of future operations and adaptive management (Appendix 5B, *Delta Conveyance Project North Delta Diversion Fisheries Field Studies Workplan*).

## Entrainment and Impingement

North Delta intake operations would meet fishery agency standards for approach velocity (0.2 foot per second per USFWS criteria for delta smelt) and a minimum sweeping velocity of 0.4 feet per second to limit the potential for negative effects on juvenile winter-run Chinook salmon and other species. As noted in Chapter 3, refinements to these criteria will be considered through ongoing fish agency coordination as well as through real time operations and adaptive management.

Calculations suggest that a 1.75-millimeter screen-opening size, as proposed for the north Delta intakes to meet fishery agency criteria (National Marine Fisheries Service 1997; California Department of Fish and Game 2000), would be effective at excluding juvenile salmonids of 22-millimeter standard length and greater (ICF International 2016:5-103), which is the equivalent of approximately 25-millimeter fork length. This would be expected to exclude all juvenile winter-run Chinook salmon occurring in the vicinity of the north Delta intakes (see summary of fish sizes in the north Delta by National Marine Fisheries Service 2017:579). Cylindrical tee screens installed in the Columbia River have a hydraulic bypass effect created by moving water encountering the nose cone at the upstream end of the screens and forming a *bow wave*, which physically keeps organisms away from the screens and also allows organisms to detect and avoid it (Coutant 2021). The upstream end of the most-upstream screen of each of the north Delta intakes also would have a nose cone, so a bow-wave effect could, in addition to screen characteristics meeting protective velocity criteria, limit the potential for entrainment, as well as impingement, over the extent of the intakes experiencing the bow-wave effect. The extent to which the bow-wave effect would extend over the length of the multiple-screen array (i.e., 15 or 30 screens) and other hydrodynamics along the screen face is not known, and it is uncertain how observations made in the Columbia River (Coutant 2021) with a different screen configuration and generally greater flow may translate to the Delta. During design of the intakes, computational modeling would be undertaken, and field measurements or baffle adjustments would be performed during commissioning and operation, both to demonstrate compliance with velocity criteria (Delta Conveyance Design and Construction Authority 2022c).

The potential for juvenile salmonids to contact and become impinged on the screens of the north Delta intakes would be very limited. Experimental studies at the University of California, Davis, Fish Treadmill facility found that Chinook salmon experienced frequent contact with the simulated fish screen, but rarely became impinged (i.e., prolonged screen contacts of >2.5 minutes), and impingement was not related to any of the experimental variables examined (Swanson et al. 2004). Of the experiments they conducted, Swanson et al. (2004:274) noted:

> The injury rates of both pre-experiment and experimental fish were generally high but most injuries consisted of minor damage to fins and scales. Among the four treatments, significant differences in injury indices were apparently related to the duration of laboratory holding, with larger, older fish exhibiting more damage. Within treatments, the injury index was not significantly affected by either flow regime or screen contact rate (regression and correlation, $P > 0.3$, all tests) and, in general, pre-experimental indices were similar to those measured for fish after exposure in the Fish Treadmill.
>
> Survival in all experiments was high. Of the more than 3,200 fish tested, only five fish from four experiments died during the experiment and one fish, from a fifth experiment, during the 48-hour

post-experiment period. Two of the mortalities were from daytime experiments and four were from nighttime experiments. All mortalities were from flow treatments with a sweeping flow component, but the small number precluded the detection of significant flow effects on survival. The death of these fish did not appear to be related to observed impingements.

The laboratory environment described above does not fully represent Sacramento River conditions for factors such as water quality conditions and only provides information on the subset of all fish that would be in relatively close proximity to the screens. The proposed north Delta intake cylindrical tee screens would have a smooth screen surface and would be frequently (i.e., several times a day, with capability of once every 5 minutes, if necessary) cleaned by internal and external brushes, which would provide additional protection to minimize screen-surface impingement of juvenile winter-run Chinook salmon. The smooth surface also would serve to reduce the risk of abrasion and scale loss for any fish that do come into contact with the screens (Swanson et al. 2004). As noted above, the hydraulic bypass effect of cylindrical tee screens may also limit potential negative effects from screen contact. Overall, the observed experimental results and the design of the fish screens indicate that minimal risk would be expected from entrainment or impingement for juvenile winter-run Chinook salmon.

Diversions by the north Delta intakes are likely to entrain foodweb organisms for juvenile winter-run Chinook salmon. As described further for delta smelt in Chapter 6, *Effects Analysis for Delta Smelt, Longfin Smelt, and Terrestrial Species*, Section 6.1, *Effects on Delta Smelt*, the potential for entrainment of phytoplankton carbon at the north Delta intakes to affect the Delta foodweb is limited, particularly considering the *in situ* production within the Delta. Juvenile Chinook salmons' diet in the north Delta and lower Sacramento River mostly includes zooplankton and insects (Kjelson et al. 1982; Sommer et al. 2001). Although some entrainment of zooplankton is likely to occur, effects on juvenile Chinook salmon prey availability are likely to be limited, given relatively high *in situ* production within the Delta compared to inputs from freshwater flow (Jassby et al. 2002; Sobczak et al. 2002). For additional information, refer to the analysis of *Food Availability* in Section 6.1.3.4, *Habitat Effects*.

## Predation

Increased predation of juvenile winter-run Chinook salmon at the north Delta intakes could occur if predatory fish aggregate along the north Delta intake cylindrical tee screens or associated in-water structures (i.e., the floating log boom and its support pilings, including accumulated debris) at greater density than existing conditions. Studies in the Delta have shown greater abundance of predatory fish at manmade structures (Sabal et al. 2016), but, as discussed in Section 5.4, *Effects of Water Facility Construction on Special-Status Species*, the relatively limited extent of in-water human-made structures in the Delta suggests that these are unlikely to have a population-level effect on species such as migrating juvenile salmonids (Lehman et al. 2019). Two Central Valley studies provide an assessment of predation in the vicinity of cylindrical screens (Demetras et al. 2013) or intakes projecting into the river (Michel et al. 2014). Demetras et al. (2013) found very few potential juvenile salmonid predators and no predator aggregations near cylindrical fish screens in the Sacramento River at Redding (Bella Vista Water District's Wintu Pumping Plant). There was no evidence of predation upon juvenile salmonids that might be attributed to or influenced by the design of the diversion facility (Demetras et al. 2013), although the studied intakes were

considerably smaller and in water of lower temperature than the proposed north Delta intakes.[12] In the Delta, Michel et al. (2014) found predation rate at the City of Sacramento Water Treatment Plant diversion—which includes an intake with flat plate fish screens on both sides of an in-river intake structure located approximately 240 feet from the left bank of the approximately 720-foot-wide river channel—was similar to other non-diversion bank locations in the vicinity.

Aggregation of predatory fish has been previously observed at the Hamilton City intake (Vogel 2008), which is the only completed study of predation at long fish screens in the Central Valley, and which involved calculation of survival along the fish screen based on recapture of marked juvenile Chinook salmon released from several locations. Vogel's (2008) study found that mean survival of tagged juvenile Chinook salmon at the Hamilton City intake in 2007—the only year of the study in which flow-control blocks at the weir at the downstream end of the fish screen were removed to reduce predatory fish concentration—was approximately 95% along the fish screen. However, the percentage of tagged juvenile Chinook salmon released at the upstream end of the fish screen that were recaptured at a downstream sampling location was similar to or slightly greater than for fish released at the downstream end of the fish screen, when standardized for the distance that the fish had to travel to the recapture site. These data suggest that survival along the screen was at least similar to survival in the portion of the channel without the screen (i.e., screen survival was similar to baseline survival, if the latter is assumed to be represented by the channel downstream of the screen). Note that sweeping velocity at the Hamilton City intake is higher than at the proposed north Delta intakes, which could give a lower predation risk based on available flow-survival studies (e.g., Perry et al. 2018). However, test fish providing the estimate of survival in the channel downstream of the screen were released prior to the fish that were released at the upstream end of the fish screen, which could have confounded comparisons of relative survival between these groups if predatory fishes became partly satiated prior to the arrival of the fish released at the upstream end of the screen (thus potentially making their survival relatively higher than otherwise would have occurred) (Vogel 2008:12). In addition, batch releases of relatively high numbers of test fish could have given greater survival than if smaller numbers of fish had passed along the fish screen (Vogel 2008:20).

A recent study of acoustically tagged juvenile late fall–run Chinook salmon survival by Henderson et al. (2019) primarily provides information regarding far-field effects of flow, but also has value in allowing inference regarding near-field effects of diversions. Henderson et al. (2019:Table 1) hypothesized that the density of diversions (i.e., number per kilometer) would be negatively related to survival because of higher predator densities near the diversions. In fact, they found the opposite and speculated that greater survival with higher diversion density may be more a function of habitat conditions where diversions are more abundant, for example, armored banks resulting in reduced predator density and predation mortality (Henderson et al. 2019:1558). Reach-specific survival estimates by Henderson et al. (2019) give context for the near-field effects provided by the physical structure of the existing long Red Bluff Diversion Dam and Glenn Colusa Irrigation District Hamilton City intakes. During the 2007–2011 study years, survival in the reach, including the Red Bluff intake, ranged in rank from highest survival (2007, 2011) to second-lowest survival of 19 reaches in 2008. Survival in the Hamilton City reach ranged from highest survival (2010, 2011) to 12$^{th}$ highest survival of 19 reaches in 2008. The studies by Henderson et al. (2019) and Vogel (2008) are not

[12] Note that the study by Demetras et al. (2013) was based on two 70–100-cfs diversion facilities in the upper Sacramento River at 6–10-foot depth where the main predatory species were rainbow trout. Water temperature at these sites is lower than at the proposed north Delta intakes.

inconsistent in suggesting that near-field survival at large fish screens does not appear to be greatly different from reaches without intakes. (These studies do not quantify predation directly. It is assumed that predation is the main reason for survival differences, although it is possible that factors such as injury from screen contact and subsequent mortality could occur, although this appears less likely based on the laboratory studies of Swanson et al. [2004], discussed above.)

Overall, the weight of available information suggests that near-field predation effects of the north Delta intakes on juvenile winter-run Chinook salmon would be limited, albeit with some uncertainty, given that the studies were not of long cylindrical tee screen structures in the north Delta. Fisheries studies would be undertaken to provide information on predatory fish and predation rate at the north Delta intakes once they are operational, to inform the refinement of future operations and adaptive management (Appendix 5B).

### 5C.7.1.2 South Delta Exports

#### Juvenile Entrainment

As described in Chapter 3, the existing facilities in the south Delta would be governed by the applicable regulatory requirements, such as the SWRCB's *Bay-Delta Water Quality Control Plan*, federal BiOps (National Marine Fisheries Service 2019; U.S. Fish and Wildlife Service 2019), California Endangered Species Act Incidental Take Permit for SWP (California Department of Fish and Wildlife 2020), and USACE Clifton Court diversion limits.

The CalSim modeling for existing conditions and the proposed action includes representation of regulatory requirements, although not all real-time requirements, such as those based on monitoring of fish presence, are able to be fully represented by the modeling (Appendix 5D, *Bay-Delta Methods and Results*). The risk of winter-run Chinook salmon entrainment under existing conditions and the proposed action would be minimized by the inclusion of the various regulatory requirements from the existing permits noted above (e.g., take limits for number of winter-run Chinook salmon lost to entrainment at the south Delta export facilities).

Two analyses assess the potential for changes to south Delta entrainment risk for juvenile winter-run Chinook salmon. As described in Appendix 5D (Section 5D.2, *Salvage-Density Method*), the salvage-density method weights CalSim-modeled south Delta exports by historical patterns of juvenile winter-run Chinook salmon entrainment loss density (i.e., fish per acre-foot of water exported). Note that although this method provides an index of entrainment loss, it primarily functions to illustrate south Delta export rate differences between modeling scenarios. The method does not account for differences in salvage and entrainment loss that could occur because of other operational effects (e.g., changes in juvenile salmonid routing because of the north Delta intakes[13]). The results from application of the salvage-density method illustrated that south Delta exports generally would be similar or slightly lower under the proposed action relative to existing conditions at the SWP Banks and CVP Jones south Delta export facilities during the December–April time period when winter-run Chinook salmon are generally salvaged (

Table 5C.7-10 and Table 5C.7-11).[14] Generally somewhat lower south Delta exports at the SWP Banks Pumping Plant occur for several reasons, which vary by month. For example, in spring the

[13] Such changes are analyzed below in the *Hydrodynamic Effects* section and are considered as part of the Delta Passage Model in the *Through-Delta Survival* section below, which also includes south Delta export effects.

[14] Results averaged by water year type and month are provided in Appendix 5D (Tables 5D.2 1 and 5D.2 2).

most common factors are (1) SWP San Luis Reservoir share is fuller under the proposed action than existing conditions because of prior north Delta exports, so Banks Pumping Plant cannot or does not need to export as much, and (2) regulatory control has shifted to E:I ratio under the proposed action due to north Delta exports, leading to a shift in exports in the south Delta from Banks Pumping Plant to Jones Pumping Plant to satisfy COA sharing requirements. Also, more rarely, (3) Banks Pumping Plant exports less due to an ITP export cut that only occurs under the proposed action because of north Delta exports diverting outflow below the 44,500 cfs threshold for triggering that cut.

As noted above, various regulatory requirements would be implemented under existing conditions and therefore are part of the Existing Conditions and are incorporated into the proposed action to minimize entrainment effects on winter-run Chinook salmon. The proposed action includes mitigation[15] for the north Delta hydrodynamics effects of the north Delta diversions, particularly with respect to reversing flows at the Sacramento River–Georgiana Slough junction, has the potential to increase juvenile fish entry into the interior Delta. Although such hydrodynamic effects could affect the potential for south Delta entrainment at the SWP and CVP facilities, take of winter-run Chinook salmon would not exceed existing authorized take because of the same operational criteria being in place as existing conditions and because the mitigation would offset the hydrodynamic effects of the north Delta diversions. The mitigation, which is proposed to offset the north Delta hydrodynamics effects of the north Delta diversions, would, in association with the existing restrictive criteria for south Delta operations, ensure that take at the south Delta export facilities does not exceed that authorized by the existing permits.

**Table 5C.7-10. Entrainment Loss of Juvenile Winter-Run Chinook Salmon at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 2,217 | 1,987 (-10%) |
| Above normal | N/A | (-6%) |
| Below normal | 1,519 | 1,380 (-9%) |
| Dry | 1,011 | 939 (-7%) |
| Critically dry | 890 | 824 (-7%) |

Notes: Percentage values in parentheses indicate differences of proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
The analysis was based on historical salvage data during 2009–2019, which did not include any above-normal water years; results for above-normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare proposed action.
EC = existing conditions; N/A = not applicable.

[15] See description of Mitigation Measure CMP in Appendix 3B, *Compensatory Mitigation Plan for Special-Status Species and Aquatic Resources*, specifically CMP-25: *Tidal Habitat Restoration to Mitigate North Delta Hydrodynamic Effects on Chinook Salmon Juveniles* in Table 3B.1-3 in Attachment 3B.1, *Compensatory Mitigation Design Parameters*.

**Table 5C.7-11. Entrainment Loss of Juvenile Winter-Run Chinook Salmon at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 228 | 233 (2%) |
| Above normal | N/A | (3%) |
| Below normal | 526 | 552 (5%) |
| Dry | 304 | 317 (4%) |
| Critically dry | 82 | 83 (1%) |

Notes: Percentage values in parentheses indicate differences of proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
The analysis was based on historical salvage data during 2009–2019, which did not include any above-normal water years; results for above-normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare proposed action.
EC = existing conditions; N/A = not applicable.

As described above, the salvage-density method is essentially a means of examining changes in south Delta exports weighted by historical salvage density to account for species timing between months; the method does not account for potential nonlinear relationships between salvage (i.e., entrainment) and south Delta exports, nor does it account for other factors that may influence salvage, such as Delta channel flows that could influence the survival or migration routes that juvenile salmonids may take. Zeug and Cavallo (2014) demonstrated that these other factors could be linked statistically to salvage of marked hatchery-reared juvenile Chinook salmon. The methods employed by Zeug and Cavallo (2014) were used to assess potential differences in juvenile winter-run Chinook salmon entrainment risk between existing conditions and the proposed action (see detailed methods description in Appendix 5D, Section 5D.3, *Juvenile Winter-Run Chinook Salmon Salvage Based on Zeug and Cavallo [2014]*). The results of this method were consistent with the salvage-density method in suggesting that salvage of juvenile winter-run Chinook salmon would be similar or somewhat lower under the proposed action relative to existing conditions (Table 5C.7-12; summary plots of the results are also provided in Appendix 5D, Section 5D.3.2, *Results*), reflecting differences in south Delta exports between the scenarios. As noted above in the analysis based on the salvage-density method, the proposed action includes mitigation for the north Delta hydrodynamics effects of the north Delta diversions, particularly with respect to reversing flows at the Sacramento River–Georgiana Slough junction, which as discussed further below in Section 5C.7.2, *Far-Field Effects,* has the potential to increase juvenile fish entry into the interior Delta. Although such hydrodynamic effects could affect the potential for south Delta entrainment at the SWP and CVP facilities, take of winter-run Chinook salmon would be expected to be consistent with existing take limits because of the same operational criteria being in place as existing conditions and because the mitigation would offset the hydrodynamic effects of the north Delta diversions. The mitigation, which is proposed to offset the north Delta hydrodynamics effects of the north Delta diversions, would, in association with the existing restrictive criteria for south Delta operations, ensure that take is consistent with the existing permits.

**Table 5C.7-12. Proportion of Juvenile Winter-Run Chinook Salmon Entering the Delta Salvaged at the South Delta Export Facilities, Averaged by Water Year Type, Based on Zeug and Cavallo (2014)**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 0.0037 | 0.0031 (-18%) |
| Above normal | 0.0022 | 0.0022 (-2%) |

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Below normal | 0.0022 | 0.0022 (-1%) |
| Dry | 0.0018 | 0.0018 (-2%) |
| Critically dry | 0.0017 | 0.0016 (-2%) |

Notes: Percentage values in parentheses indicate differences of proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
This table only includes mean responses and does not consider model uncertainty. Results are not future predictions and are intended only to compare proposed action.
EC = existing conditions.

### Adult Entrainment

In addition to juvenile winter-run Chinook salmon, adult winter-run Chinook salmon are also subject to entrainment at the south Delta export facilities (California Department of Fish and Wildlife 2020, Attachment 8:60–63). It is estimated that 466 adult Chinook salmon were salvaged during 1993–2018 (i.e., an annual mean of ~18 fish), all during the months of September through May, with highest salvage in November, December, and March, which overlaps with adult winter-run Chinook salmon occurrence in the Delta (California Department of Fish and Wildlife 2020, Attachment 8:60–63; Table 2-4 shows February–April as the main period of occurrence). South Delta exports under the proposed action generally would be similar or slightly less than under existing conditions, indicating entrainment risk for adult winter-run Chinook salmon generally would be similar or slightly less than existing conditions (California Department of Water Resources 2023).

## 5C.7.2 Far-Field Effects

### 5C.7.2.1 Indirect Mortality within the Delta

In addition to potential near-field effects, direct effects on winter-run Chinook salmon resulting from the proposed action have the potential to result indirectly in changes to mortality of juvenile winter-run Chinook salmon in the Delta because of changes in flow patterns and resulting survival or routing of fish into migration pathways with differing survival probabilities. This section includes a summary of hydrodynamic effects based on potential indicators of indirect mortality risk (e.g., channel velocity and flow routing into junctions), as well as an assessment of through-Delta survival, using available models.

As described in more detail in Chapter 3, the proposed action includes operational criteria for the proposed north Delta intakes to minimize potential negative effects on fish—in particular, juvenile winter-run Chinook salmon. In addition to the previously discussed velocity criteria for minimizing potential for near-field effects (see *Entrainment and Impingement* in Section 5C.7.1.1, *North Delta Exports*), the new operational criteria would include bypass-flow criteria and pulse protection and low-level pumping.

As described in Chapter 3, the proposed operations criteria and tidal restoration[16] are intended to minimize and fully mitigate the potential impacts of the north Delta diversion operations. The real-time decision-making specific to the north Delta diversion operations would be mainly associated with reviewing real-time abiotic and fish monitoring data and ensuring proposed weekly, daily, and

[16] See description of Mitigation Measure CMP in Appendix 3B, specifically CMP-25: *Tidal Habitat Restoration to Mitigate North Delta Hydrodynamic Effects on Chinook Salmon Juveniles* in Table 3B.1-3 in Attachment 3B.1.

sub-daily operations are consistent with the permitted criteria and within the effects analyzed in the permits. Tables 3.1-3 and 3.1-4 in Chapter 3 provide preliminary proposed operations criteria and proposed north Delta intake bypass flow and pulse protection requirements.

## Hydrodynamic Effects

Diversion of flow by the north Delta diversion would result in less Sacramento River flow moving downstream, which would increase the effect of tides, juvenile Chinook salmon travel time (and, therefore, potential exposure to predatory fish), and the potential for flow to be diverted into the interior Delta at Georgiana Slough and Delta Cross Channel,[17] where juvenile Chinook salmon survival is lower than on the mainstem Sacramento River (Perry et al. 2018; Hance et al. 2022). An assessment of potential hydrodynamic changes was undertaken, using Delta Simulation Model II-HYDRO outputs. This illustrated the reduced overlap in north Delta velocity of the proposed action compared to existing conditions, including during key portions of the juvenile winter-run Chinook salmon downstream-migration period, with little difference in interior and south Delta hydrodynamics reflecting little difference in south Delta exports as suggested by the salvage-density discussed previously with respect to *Juvenile Entrainment*. The reduced overlap in velocity between the proposed action and existing conditions generally reflected the somewhat-lower velocity associated with the proposed action, as illustrated for the Sacramento River, just downstream of Intake C (Table 5C.7-13). The Delta Simulation Model II modeling also indicated that a somewhat greater proportion of flow would enter the interior Delta at Georgiana Slough in some months, with relatively high occurrence of juvenile winter-run Chinook salmon—in particular January–March (Figure 5D.4-29 in Appendix 5D)—which generally indicates that a greater proportion of juvenile Chinook salmon would enter Georgiana Slough based on available studies (e.g., Cavallo et al. 2015) and that there generally would be greater incidence of reversing flow in the Sacramento River just downstream of Georgiana Slough (Table 5C.7-14). Months with smaller differences in these hydrodynamic indicators (e.g., April) reflect other operational constraints on overall Delta water operations, such as meeting the longfin smelt spring-outflow requirements from the California Department of Fish and Wildlife (CDFW) (2020) ITP. Reduced velocity, increased reversing flow just downstream of Georgiana Slough, and increased flow into the interior Delta at Georgiana Slough would tend to reduce juvenile winter-run Chinook salmon through-Delta survival, as analyzed further below, in *Through-Delta Survival*. As discussed previously, the proposed action includes mitigation[18] for the north Delta hydrodynamics effects of the north Delta diversions, particularly with respect to reversing flows at the Sacramento River–Georgiana Slough junction. This would offset north Delta hydrodynamic effects, would also offset the potential for increased movement of juvenile winter-run Chinook salmon toward the south Delta export facilities; as noted above, even without this mitigation being shown in modeling, interior and south Delta hydrodynamics are little different between existing conditions and the proposed action.

[17] Perry et al. (2016:16–17) illustrated the concept of the "critical streakline" (i.e., the spatial divide between parcels of water that enter a side channel or remain in the main channel) and how this is affected by the riverine and tidal hydrodynamics at channel junctions.

[18] See description of Mitigation Measure CMP in Appendix 3B, Compensatory Mitigation Plan for Special-Status Species and Aquatic Resources, specifically CMP-25: *Tidal Habitat Restoration to Mitigate North Delta Hydrodynamic Effects on Chinook Salmon Juveniles* in Table 3B.1-3 in Attachment 3B.1.

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**Table 5C.7-13. Mean Channel Velocity (feet per second) in the Sacramento River Downstream of Intake C**

| Water Year Type | September | | October | | November | | December | | January | | February | | March | | April | | May | | June | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action |
| Wet | 1.51 | 1.49 (-2%) | 1.10 | 1.07 (-3%) | 1.40 | 1.33 (-5%) | 2.51 | 2.43 (-3%) | 3.18 | 3.11 (-2%) | 3.59 | 3.60 (0%) | 3.24 | 3.24 (0%) | 2.65 | 2.66 (0%) | 2.31 | 2.28 (-1%) | 1.75 | 1.68 (-4%) |
| Above normal | 1.46 | 1.44 (-1%) | 0.94 | 0.93 (-1%) | 1.05 | 0.98 (-7%) | 1.59 | 1.49 (-6%) | 2.70 | 2.54 (-6%) | 2.93 | 2.80 (-4%) | 2.76 | 2.62 (-5%) | 1.76 | 1.72 (-3%) | 1.78 | 1.71 (-4%) | 1.42 | 1.32 (-8%) |
| Below normal | 1.14 | 0.98 (-14%) | 0.93 | 0.90 (-2%) | 1.07 | 0.98 (-8%) | 1.36 | 1.29 (-5%) | 1.59 | 1.48 (-7%) | 1.94 | 1.81 (-7%) | 1.82 | 1.63 (-11%) | 1.27 | 1.28 (1%) | 1.24 | 1.23 (-1%) | 1.13 | 1.11 (-1%) |
| Dry | 0.80 | 0.76 (-5%) | 0.88 | 0.90 (1%) | 0.93 | 0.89 (-5%) | 1.02 | 0.97 (-5%) | 1.17 | 1.10 (-6%) | 1.77 | 1.65 (-7%) | 1.55 | 1.44 (-7%) | 1.04 | 1.04 (0%) | 0.98 | 0.98 (0%) | 1.12 | 1.12 (0%) |
| Critically dry | 0.69 | 0.69 (0%) | 0.72 | 0.70 (-3%) | 0.71 | 0.68 (-4%) | 1.03 | 1.00 (-3%) | 1.09 | 1.01 (-7%) | 1.22 | 1.17 (-4%) | 1.11 | 1.06 (-4%) | 0.81 | 0.81 (1%) | 0.76 | 0.75 (-1%) | 0.86 | 0.86 (0%) |

Note: Percentage values in parentheses indicate differences of proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
EC = existing conditions.

**Table 5C.7-14. Number of Hours Within Each Month with Reversing Flow in the Sacramento River Downstream of Georgiana Slough (Delta Simulation Model II Channel 423)**

| Water Year Type | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | September | | October | | November | | December | | January | | February | | March | | April | | May | | June | |
| Wet (720) | 7.3 | 10.1 (2.8/38%) | - | - | 144.9 | 155.2 (10.3/7%) | - | - | - | - | - | - | - | - | 197.5 | 202.0 (4.5/2%) | - | - | 98.2 | 121.1 (22.9/23%) |
| Above normal (720) | 12.8 | 18.3 (5.5/43%) | - | - | 172.3 | 182.2 (9.9/6%) | - | - | - | - | - | - | - | - | 190.4 | 198.6 (8.2/4%) | - | - | 191.1 | 205.6 (14.5/8%) |
| Below normal (720) | 44.3 | 53.7 (9.3/21%) | - | - | 202.5 | 208.2 (5.7/3%) | - | - | - | - | - | - | - | - | 206.2 | 210.4 (4.2/2%) | - | - | 210.6 | 212.8 (2.2/1%) |
| Dry (720) | 93.2 | 113.2 (20.0/21%) | - | - | 210.3 | 214.9 (4.6/2%) | - | - | - | - | - | - | - | - | 244.4 | 242.3 (-2.1/-1%) | - | - | 220.9 | 221.2 (0.3/0%) |
| Critically dry (720) | 129.0 | 141.4 (12.3/10%) | - | - | 252.2 | 251.4 (-0.8/0%) | - | - | - | - | - | - | - | - | 291.0 | 290.6 (-0.4/0%) | - | - | 256.7 | 255.7 (-1.0/0%) |
| Wet (744) | - | - | 180.4 | 180.0 (-0.4/0%) | - | - | 16.8 | 20.4 (3.6/22%) | 0.0 | 0.1 (0.1) | - | - | 173.3 | 176.1 (2.8/2%) | - | - | 11.4 | 14.7 (3.3/29%) | - | - |
| Above normal (744) | - | - | 236.3 | 235.7 (-0.6/0%) | - | - | 25.9 | 29.6 (3.7/14%) | 0.4 | 5.2 (4.8/1076%) | - | - | 198.1 | 204.9 (6.7/3%) | - | - | 22.5 | 27.9 (5.4/24%) | - | - |
| Below normal (744) | - | - | 227.3 | 220.8 (-6.4/-3%) | - | - | 79.7 | 85.3 (5.5/7%) | 19.6 | 23.7 (4.1/21%) | - | - | 232.5 | 252.4 (19.9/9%) | - | - | 71.5 | 71.5 (0.1/0%) | - | - |
| Dry (744) | - | - | 241.9 | 242.0 (0.1/0%) | - | - | 142.7 | 143.4 (0.8/1%) | 35.7 | 48.6 (13.0/36%) | - | - | 279.8 | 286.1 (6.3/2%) | - | - | 144.9 | 140.9 (-4.0/-3%) | - | - |
| Critically dry (744) | - | - | 252.1 | 254.7 (2.7/1%) | - | - | 221.3 | 221.5 (0.3/0%) | 91.5 | 104.0 (12.4/14%) | - | - | 294.8 | 297.7 (3.0/1%) | - | - | 209.6 | 206.5 (-3.1/-1%) | - | - |
| Wet (675) | - | - | - | - | - | - | - | - | - | - | 0.0 | 2.2 (2.2/6700%) | - | - | - | - | - | - | - | - |
| Above normal (680) | - | - | - | - | - | - | - | - | - | - | 0.0 | 1.2 (1.2) | - | - | - | - | - | - | - | - |
| Below normal (680) | - | - | - | - | - | - | - | - | - | - | 9.1 | 24.1 (15.0/164%) | - | - | - | - | - | - | - | - |
| Dry (677) | - | - | - | - | - | - | - | - | - | - | 39.3 | 53.0 (13.7/35%) | - | - | - | - | - | - | - | - |
| Critically dry (680) | - | - | - | - | - | - | - | - | - | - | 115.1 | 117.7 (2.6/2%) | - | - | - | - | - | - | - | - |

Note: Numbers in parentheses after water year type indicate total number of hours by month. Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Absolute differences are shown in parentheses when existing conditions percentage is zero.
EC = existing conditions

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## Through-Delta Survival

Operation of the proposed action could affect juvenile winter-run Chinook salmon migrating through the Delta by reducing Sacramento River flow downstream of the north Delta intakes, which could influence through-Delta survival based on flow-survival relationships. The potential for such effects was assessed using a spreadsheet version of the through-Delta survival function formulated by Perry et al. (2018),[19] which estimates through-Delta survival as a function of daily Sacramento River flow at Freeport, as well as the Delta Cross Channel gate position. The results of this analysis showed that, during the main period of juvenile winter-run Chinook salmon, occurrence in the Delta (i.e., December–April; see Table 4.4.1-1 in Chapter 4, *Action Area and Environmental Baseline*) meant that through-Delta survival under the proposed action was 0%–3% less than existing conditions (Table 5C.7-15). The results reflect the various operational criteria described further in Chapter 3, for example, meeting the longfin smelt spring outflow requirements from the CDFW (2020) ITP during April and May. Larger differences in through-Delta survival occurred in September (up to 5%–6% less than existing conditions in below normal years), a period that generally is prior to the first juvenile winter-run occurrence in trawls or beach seines at Sacramento, except in some years (see *Delta Conveyance Project Final Environmental Impact Report* (Final EIR) Appendix 12A, Attachment 12A.1, *Juvenile Salmonid Monitoring, Sampling, and Salvage Timing Summary from SacPAS* [California Department of Water Resources 2023]). Relatively large differences in survival (8%–10% less under the proposed action) also occurred in June of above-normal years, although this is after the period of nearly all juvenile winter-run occurrence and has more relevance to juvenile spring-run and fall-run Chinook salmon (discussed further in Section 5C.8, *Effects of Operations and Maintenance of Water Conveyance Facilities on Central Valley Spring-Run Chinook Salmon*).

Note that the spreadsheet version of the Perry et al. (2018) model does not account for the variability in coefficient estimates (Perry et al. 2018:Figure 6), which likely would give appreciable overlap of estimates in through-Delta survival between existing conditions and the proposed action, particularly in relation to the relatively small differences. Note also that the CDFW (2020) SWP ITP requires a Georgiana Slough Migratory Barrier to be installed to reduce juvenile winter- and spring-run Chinook salmon entry into Georgiana Slough by means of acoustic and light stimuli deterring the juveniles from entering Georgiana Slough (California Department of Water Resources 2015). To illustrate the potential effects of such a barrier being implemented on relative survival differences between existing conditions and the proposed action, a sensitivity analysis was undertaken with the assumption that the barrier was installed and reduced proportional entry into Georgiana Slough by

[19] The spreadsheet model was provided by Perry (pers. comm.) and reproduces the mean response of the STARS (Survival, Travel time, And Routing Simulation) model (Perry et al. 2019). There is some uncertainty in the extent to which the relationships in the model are representative of wild-origin, winter-run Chinook salmon juveniles, given that the model was based on results from larger hatchery-origin, late fall–run Chinook salmon juveniles; however, the results of the Delta Passage Model, described below, are based on hatchery-origin, winter-run Chinook salmon juveniles. Note that for both models, the analyses are based on studies of smolt-sized fish because there is no information on through-Delta survival for smaller-sized migrants, with the assumption that the relative differences between scenarios are reasonably representative of smaller migrants as well.

50%,[20] compared to no barrier, during January through May.[21] Although the sensitivity analysis gave higher absolute estimates of through-Delta survival in January–May, as expected, there was no change in the relative pattern of percentage differences between existing conditions and the proposed action (compare corresponding cells in Table 5C.7-16 with Table 5C.7-15).

[20] A 50% reduction in entry to Georgiana Slough was observed during the 2012 pilot testing of the barrier (California Department of Water Resources 2015).

[21] Implementation of the Georgiana Slough Migratory Barrier, consisting of a BioAcoustic Fish Fence (BAFF) would be as follows during 2023–2030 (National Marine Fisheries Service 2022:9-10): "BAFF operations would occur from January 1 until May 31 during Project Year 1. During Project Years 2 through 8, BAFF operations would occur from January 1 until April 30; however, BAFF operations in November, December, and May would be adaptively managed each Project year by DWR in coordination with CDFW, NMFS, and USFWS. PG&E would provide electricity to the BAFF from January until April in all Project years. If the BAFF will be operated in May, diesel generators would be located at the Point Ranch Property to provide power to the BAFF for the month of May. The full operations plan is being developed by DWR in coordination with NMFS, USFWS, and CDFW, which may result in changes to the optimal BAFF operation period (i.e., January to May) to better cover a greater portion of the juvenile SR winter-run and CV spring-run Chinook salmon migration period." For the purposes of the illustrative analysis in this BA, it was assumed that a BAFF would be installed from January to May.

**Table 5C.7-15. Probability of Juvenile Chinook Salmon Through-Delta Survival, Averaged by Month and Water Year Type, Based on Perry et al. (2018)**

| | September | | October | | November | | December | | January | | February | | March | | April | | May | | June | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Water Year Type** | **EC** | **Proposed Action** | **EC** | **Proposed Action** | **EC** | **Proposed Action** | **EC** | **Proposed Action** | **EC** | **Proposed Action** | **EC** | **Proposed Action** | **EC** | **Proposed Action** | **EC** | **Proposed Action** | **EC** | **Proposed Action** | **EC** | **Proposed Action** |
| Wet | 0.37 | 0.37 (-1%) | 0.37 | 0.37 (0%) | 0.40 | 0.39 (-2%) | 0.47 | 0.46 (-2%) | 0.61 | 0.60 (-2%) | 0.64 | 0.63 (-1%) | 0.62 | 0.61 (-1%) | 0.57 | 0.57 (-1%) | 0.55 | 0.54 (-1%) | 0.43 | 0.41 (-4%) |
| Above normal | 0.36 | 0.36 (-1%) | 0.34 | 0.34 (1%) | 0.38 | 0.37 (0%) | 0.46 | 0.45 (-2%) | 0.58 | 0.56 (-3%) | 0.60 | 0.58 (-2%) | 0.59 | 0.57 (-3%) | 0.50 | 0.49 (-1%) | 0.50 | 0.49 (-2%) | 0.39 | 0.35 (-10%) |
| Below normal | 0.31 | 0.29 (-6%) | 0.31 | 0.32 (2%) | 0.37 | 0.37 (1%) | 0.48 | 0.47 (-2%) | 0.48 | 0.47 (-3%) | 0.51 | 0.50 (-3%) | 0.50 | 0.48 (-4%) | 0.44 | 0.44 (0%) | 0.44 | 0.44 (0%) | 0.33 | 0.33 (0%) |
| Dry | 0.27 | 0.26 (-2%) | 0.34 | 0.34 (0%) | 0.33 | 0.33 (0%) | 0.42 | 0.41 (-3%) | 0.43 | 0.42 (-2%) | 0.50 | 0.49 (-3%) | 0.48 | 0.46 (-3%) | 0.41 | 0.41 (0%) | 0.41 | 0.41 (0%) | 0.33 | 0.33 (0%) |
| Critically dry | 0.26 | 0.25 (-3%) | 0.32 | 0.31 (-2%) | 0.31 | 0.31 (0%) | 0.38 | 0.38 (-1%) | 0.42 | 0.41 (-2%) | 0.44 | 0.43 (-1%) | 0.42 | 0.42 (-1%) | 0.38 | 0.38 (0%) | 0.37 | 0.37 (0%) | 0.29 | 0.29 (0%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The main period of juvenile winter-run Chinook salmon occurrence in the Delta is December–April. The table only includes mean responses and does not consider model uncertainty. Results are not future predictions and are intended only to compare EC to the proposed action.
EC = existing conditions.

**Table 5C.7-16. Probability of Juvenile Chinook Salmon Through-Delta Survival, Averaged by Month and Water Year Type, Based on Perry et al. (2018), Including Assumption that Georgiana Slough Migratory Barrier Reduces Entry in Georgiana Slough by 50% During January–May**

| | September | | October | | November | | December | | January | | February | | March | | April | | May | | June | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Water Year Type** | **EC** | **Proposed Action** | **EC** | **Proposed Action** | **EC** | **Proposed Action** | **EC** | **Proposed Action** | **EC** | **Proposed Action** | **EC** | **Proposed Action** | **EC** | **Proposed Action** | **EC** | **Proposed Action** | **EC** | **Proposed Action** | **EC** | **Proposed Action** |
| Wet | 0.37 | 0.37 (-1%) | 0.37 | 0.37 (0%) | 0.40 | 0.39 (-2%) | 0.47 | 0.46 (-2%) | 0.37 | 0.63 (-2%) | 0.67 | 0.66 (-1%) | 0.65 | 0.64 (-1%) | 0.61 | 0.60 (-1%) | 0.58 | 0.58 (-1%) | 0.43 | 0.41 (-4%) |
| Above Normal | 0.36 | 0.36 (-1%) | 0.34 | 0.34 (1%) | 0.38 | 0.37 (0%) | 0.46 | 0.45 (-2%) | 0.36 | 0.60 (-2%) | 0.63 | 0.62 (-2%) | 0.62 | 0.61 (-2%) | 0.54 | 0.53 (-1%) | 0.54 | 0.53 (-1%) | 0.39 | 0.35 (-10%) |
| Below Normal | 0.31 | 0.29 (-6%) | 0.31 | 0.32 (2%) | 0.37 | 0.37 (1%) | 0.48 | 0.47 (-2%) | 0.31 | 0.51 (-2%) | 0.55 | 0.54 (-2%) | 0.54 | 0.52 (-4%) | 0.48 | 0.48 (0%) | 0.48 | 0.48 (0%) | 0.33 | 0.33 (0%) |
| Dry | 0.27 | 0.26 (-2%) | 0.34 | 0.34 (0%) | 0.33 | 0.33 (0%) | 0.42 | 0.41 (-3%) | 0.27 | 0.46 (-2%) | 0.54 | 0.53 (-2%) | 0.52 | 0.50 (-2%) | 0.45 | 0.46 (0%) | 0.45 | 0.45 (0%) | 0.33 | 0.33 (0%) |
| Critically Dry | 0.26 | 0.25 (-3%) | 0.32 | 0.31 (-2%) | 0.31 | 0.31 (0%) | 0.38 | 0.38 (-1%) | 0.26 | 0.45 (-2%) | 0.48 | 0.47 (-1%) | 0.46 | 0.46 (-1%) | 0.43 | 0.43 (0%) | 0.42 | 0.42 (0%) | 0.29 | 0.29 (0%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The main period of juvenile winter-run Chinook salmon occurrence in the Delta is December–April. Table only includes mean responses and does not consider model uncertainty. Results are not future predictions and are intended only to compare the proposed action to EC.
EC = existing conditions.

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The results of the Delta Passage Model (see description of method in Appendix 5D, Section 5D.5, *Delta Passage Model*) were similar to those of the analysis based on the Perry et al. (2018) through-Delta survival function, with mean estimated through-Delta survival of juvenile winter-run Chinook salmon under the proposed action ranging from 1% to 3% less than existing conditions (Table 5C.7-17; compare in particular to the December–April results in Table 5C.7-15, which as previously described represents the main period of juvenile winter-run occurrence in the Delta and is reflected in the Delta Passage Model entry distribution; see Figure 5D.5-2_entry in Appendix 5D).[22]

**Table 5C.7-17. Through-Delta Survival of Juvenile Winter-Run Chinook Salmon, Averaged by Water Year Type, Based on the Delta Passage Model**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 0.31 | 0.31 (-2%) |
| Above normal | 0.25 | 0.24 (-2%) |
| Below normal | 0.19 | 0.18 (-3%) |
| Dry | 0.16 | 0.16 (-3%) |
| Critically dry | 0.14 | 0.14 (-1%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
This table only includes mean responses and does not consider model uncertainty. Results are not future predictions and are intended only to compare the proposed action to EC.
EC = existing conditions.

The two through-Delta survival analyses (spreadsheet implementation of the Perry et al. [2018] survival function and the Delta Passage Model) suggested that the potential for through-Delta survival under the proposed action would be somewhat less than existing conditions. As previously described, these modeling results reflect flow-based criteria and requirements, but do not account for adjustments to operations. These adjustments may be in response to real-time monitoring of fish to further limit potential negative effects. Fisheries studies would be undertaken to provide information on the far-field effects of the north Delta intakes on juvenile salmonids once they are operational, to inform the refinement of future operations and adaptive management, as needed (Appendix 5B).

## 5C.7.2.2 Habitat Suitability

Several aspects of habitat suitability for winter-run Chinook salmon and the potential far-field effects of the proposed action were examined: riparian and wetland bench inundation (i.e., juvenile rearing habitat); water temperature; *Microcystis* harmful algae blooms; and metals (i.e., selenium and mercury).

### Riparian and Wetland Bench Inundation

Channel-margin habitat in the Delta—and in much of the Sacramento and San Joaquin Rivers, in general—has been considerably reduced in relation to historical extent due to the construction of levees and armoring of their banks with riprap (Williams 2006). These practices have reduced the extent of high-value rearing or holding habitat for Chinook salmon juveniles. Whereas previous

[22] Note that the Delta Passage Model is based on results from juvenile Chinook salmon ≥80 millimeter in length.

riverbank protection of levees focused on solely riprap installation, more recent protection incorporates riparian and wetland benches, as well as other habitat features, to restore habitat function (H.T. Harvey & Associates and PRBO Conservation Science 2010; Hellmair et al. 2018). The riparian and wetland benches are shallow, restored areas along the channel margins that have relatively gentle slopes (e.g., 10:1 instead of the customary 3:1; Casas et al. 2012) and are designed to be wetted or flooded during certain parts of the year to provide habitat for listed species of fish, including juvenile Chinook salmon and other species. Wetland benches are at lower elevations, where more frequent wetting and inundation may be expected, and riparian benches occupy higher portions of the slope, where inundation is restricted to high-flow events. These benches are planted and often secured with riprap or other materials.

Several levee improvement projects in the north Delta have been implemented and included the restoration of benches intended to be inundated under specific flows during certain months to provide suitable habitat for listed species of fish; the total length is approximately 47,000 linear feet (~8.9 miles).[23] Restored benches in the north Delta potentially could be affected by the water operations of the proposed action because of changes in water level; for example, less water in the Sacramento River below the north Delta intakes could result in riparian benches being inundated less frequently. This possibility was examined by calculating bench-inundation indices for juvenile Chinook salmon (see detailed method description in Appendix 5D, Section 5D.6, *Riparian and Wetland Bench Inundation*). These indices range from 0 (i.e., no availability of bench habitat) to 1 (i.e., water depth on the bench is optimal for juvenile Chinook salmon all the time).[24] The analysis was undertaken for riparian and wetland benches in five geographic locations within the north Delta by linking bench elevation data to Delta Simulation Model II-HYDRO-simulated water surface elevation for three seasonal periods (i.e., fall: October–November; winter: December–February; spring: March–June).

The analysis of bench inundation suggested the potential for changes in inundation under the proposed action relative to existing conditions, ranging from little difference to just over 20% (relative difference) less bench inundation under the proposed action (Table 5C.7-18). The largest differences were for riparian benches in the Sacramento River downstream of the north Delta diversion in winter and spring, with little difference in areas well downstream (e.g., Cache Slough). There was also little difference for wetland benches, which are intended to be inundated at lower water-surface elevations that would be available at much-lower flows. The proposed action would result in less availability of inundated bench habitat for juvenile winter-run Chinook salmon compared to existing conditions. Multiplying the proportional difference in inundation indices between the proposed action and existing conditions by the length of bench in each area allows the differences as a result of the proposed action to be expressed in linear feet, which subsequently is used for mitigation calculations; the overall differences relative to existing conditions can be found in Table 5C.7-19.

[23] By way of comparison, the total length of riverbank (including both banks) along the main migratory pathways in the north Delta upstream of Rio Vista is ~90 miles (mainstem Sacramento River), ~12 miles (Sutter Slough), ~18 miles (Steamboat Slough), and ~14 miles (Miner Slough).

[24] For example, a bench inundation index of 0.20 equates to optimal depth (suitability = 1) 20% of the time within a season (with no other inundation occurring), or equates to relatively poor depth (suitability = 0.20) 100% of the time within a season. Note that, depending on water depth under existing conditions, bench inundation indices could be greater, the same, or less under the proposed action, as a result of differences in suitability with differences in water depth (Figure 5A-2), although the modeling indicated mostly lower inundation indices under the proposed action because of the north Delta diversions.

**Table 5C.7-18. Mean Riparian and Wetland Bench Inundation Index by Geographic Group, Season, and Water Year Type**

| Geographic Group | Bench Type | WYT | Season | EC | Proposed Action |
|---|---|---|---|---|---|
| Cache Slough | Riparian | W | Winter | 0.23 | 0.23 (-2%) |
| Cache Slough | Riparian | AN | Winter | 0.16 | 0.15 (-3%) |
| Cache Slough | Riparian | BN | Winter | 0.10 | 0.09 (-3%) |
| Cache Slough | Riparian | D | Winter | 0.08 | 0.08 (-2%) |
| Cache Slough | Riparian | C | Winter | 0.08 | 0.08 (-2%) |
| Cache Slough | Wetland | W | Winter | 0.64 | 0.63 (0%) |
| Cache Slough | Wetland | AN | Winter | 0.61 | 0.60 (-1%) |
| Cache Slough | Wetland | BN | Winter | 0.55 | 0.54 (0%) |
| Cache Slough | Wetland | D | Winter | 0.53 | 0.53 (0%) |
| Cache Slough | Wetland | C | Winter | 0.53 | 0.53 (0%) |
| Sacramento River above north Delta intakes | Riparian | W | Winter | 0.22 | 0.23 (4%) |
| Sacramento River above north Delta intakes | Riparian | AN | Winter | 0.26 | 0.26 (1%) |
| Sacramento River above north Delta intakes | Riparian | BN | Winter | 0.24 | 0.23 (-2%) |
| Sacramento River above north Delta intakes | Riparian | D | Winter | 0.16 | 0.15 (-6%) |
| Sacramento River above north Delta intakes | Riparian | C | Winter | 0.12 | 0.12 (-5%) |
| Sacramento River above north Delta intakes | Wetland | W | Winter | 0.14 | 0.15 (4%) |
| Sacramento River above north Delta intakes | Wetland | AN | Winter | 0.27 | 0.28 (6%) |
| Sacramento River above north Delta intakes | Wetland | BN | Winter | 0.49 | 0.50 (3%) |
| Sacramento River above north Delta intakes | Wetland | D | Winter | 0.61 | 0.63 (2%) |
| Sacramento River above north Delta intakes | Wetland | C | Winter | 0.69 | 0.70 (2%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | W | Winter | 0.42 | 0.42 (0%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | AN | Winter | 0.35 | 0.34 (-3%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | BN | Winter | 0.18 | 0.15 (-16%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | D | Winter | 0.07 | 0.06 (-22%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | C | Winter | 0.05 | 0.04 (-19%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | W | Winter | 0.32 | 0.35 (9%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | AN | Winter | 0.46 | 0.49 (7%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | BN | Winter | 0.57 | 0.58 (1%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | D | Winter | 0.58 | 0.57 (-1%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | C | Winter | 0.56 | 0.55 (-1%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | W | Winter | 0.56 | 0.55 (-2%) |

| Geographic Group | Bench Type | WYT | Season | EC | Proposed Action |
|---|---|---|---|---|---|
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | AN | Winter | 0.44 | 0.41 (-7%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | BN | Winter | 0.21 | 0.18 (-14%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | D | Winter | 0.11 | 0.10 (-13%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | C | Winter | 0.09 | 0.08 (-9%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | W | Winter | 0.43 | 0.45 (6%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | AN | Winter | 0.55 | 0.58 (5%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | BN | Winter | 0.64 | 0.64 (1%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | D | Winter | 0.63 | 0.63 (-1%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | C | Winter | 0.63 | 0.62 (-1%) |
| Sutter/Steamboat Sloughs | Riparian | W | Winter | 0.54 | 0.54 (-1%) |
| Sutter/Steamboat Sloughs | Riparian | AN | Winter | 0.48 | 0.46 (-4%) |
| Sutter/Steamboat Sloughs | Riparian | BN | Winter | 0.31 | 0.29 (-7%) |
| Sutter/Steamboat Sloughs | Riparian | D | Winter | 0.24 | 0.22 (-5%) |
| Sutter/Steamboat Sloughs | Riparian | C | Winter | 0.21 | 0.21 (-3%) |
| Sutter/Steamboat Sloughs | Wetland | W | Winter | 0.44 | 0.47 (6%) |
| Sutter/Steamboat Sloughs | Wetland | AN | Winter | 0.59 | 0.62 (5%) |
| Sutter/Steamboat Sloughs | Wetland | BN | Winter | 0.74 | 0.76 (2%) |
| Sutter/Steamboat Sloughs | Wetland | D | Winter | 0.78 | 0.78 (1%) |
| Sutter/Steamboat Sloughs | Wetland | C | Winter | 0.79 | 0.79 (0%) |
| Cache Slough | Riparian | W | Spring | 0.14 | 0.14 (-1%) |
| Cache Slough | Riparian | AN | Spring | 0.09 | 0.09 (-3%) |
| Cache Slough | Riparian | BN | Spring | 0.07 | 0.07 (-2%) |
| Cache Slough | Riparian | D | Spring | 0.07 | 0.07 (-1%) |
| Cache Slough | Riparian | C | Spring | 0.07 | 0.07 (0%) |
| Cache Slough | Wetland | W | Spring | 0.60 | 0.60 (0%) |
| Cache Slough | Wetland | AN | Spring | 0.56 | 0.56 (-1%) |
| Cache Slough | Wetland | BN | Spring | 0.53 | 0.53 (0%) |
| Cache Slough | Wetland | D | Spring | 0.52 | 0.52 (0%) |
| Cache Slough | Wetland | C | Spring | 0.52 | 0.52 (0%) |
| Sacramento River above north Delta intakes | Riparian | W | Spring | 0.27 | 0.27 (0%) |
| Sacramento River above north Delta intakes | Riparian | AN | Spring | 0.31 | 0.29 (-5%) |
| Sacramento River above north Delta intakes | Riparian | BN | Spring | 0.17 | 0.17 (-4%) |
| Sacramento River above north Delta intakes | Riparian | D | Spring | 0.12 | 0.11 (-5%) |
| Sacramento River above north Delta intakes | Riparian | C | Spring | 0.07 | 0.07 (-3%) |
| Sacramento River above north Delta intakes | Wetland | W | Spring | 0.25 | 0.26 (5%) |
| Sacramento River above north Delta intakes | Wetland | AN | Spring | 0.37 | 0.39 (6%) |

| Geographic Group | Bench Type | WYT | Season | EC | Proposed Action |
|---|---|---|---|---|---|
| Sacramento River above north Delta intakes | Wetland | BN | Spring | 0.61 | 0.62 (2%) |
| Sacramento River above north Delta intakes | Wetland | D | Spring | 0.69 | 0.70 (1%) |
| Sacramento River above north Delta intakes | Wetland | C | Spring | 0.77 | 0.77 (0%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | W | Spring | 0.38 | 0.36 (-5%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | AN | Spring | 0.24 | 0.21 (-10%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | BN | Spring | 0.07 | 0.06 (-17%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | D | Spring | 0.04 | 0.03 (-19%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | C | Spring | 0.02 | 0.02 (-16%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | W | Spring | 0.46 | 0.46 (1%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | AN | Spring | 0.59 | 0.58 (0%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | BN | Spring | 0.58 | 0.58 (-1%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | D | Spring | 0.55 | 0.55 (0%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | C | Spring | 0.50 | 0.50 (0%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | W | Spring | 0.44 | 0.42 (-4%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | AN | Spring | 0.27 | 0.24 (-10%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | BN | Spring | 0.11 | 0.09 (-12%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | D | Spring | 0.07 | 0.07 (-9%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | C | Spring | 0.05 | 0.05 (-5%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | W | Spring | 0.55 | 0.56 (0%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | AN | Spring | 0.65 | 0.64 (0%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | BN | Spring | 0.64 | 0.64 (0%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | D | Spring | 0.62 | 0.62 (0%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | C | Spring | 0.60 | 0.60 (0%) |
| Sutter/Steamboat Sloughs | Riparian | W | Spring | 0.47 | 0.46 (-3%) |
| Sutter/Steamboat Sloughs | Riparian | AN | Spring | 0.36 | 0.34 (-6%) |
| Sutter/Steamboat Sloughs | Riparian | BN | Spring | 0.23 | 0.22 (-4%) |
| Sutter/Steamboat Sloughs | Riparian | D | Spring | 0.20 | 0.19 (-3%) |

| Geographic Group | Bench Type | WYT | Season | EC | Proposed Action |
|---|---|---|---|---|---|
| Sutter/Steamboat Sloughs | Riparian | C | Spring | 0.18 | 0.17 (-1%) |
| Sutter/Steamboat Sloughs | Wetland | W | Spring | 0.60 | 0.61 (1%) |
| Sutter/Steamboat Sloughs | Wetland | AN | Spring | 0.72 | 0.74 (2%) |
| Sutter/Steamboat Sloughs | Wetland | BN | Spring | 0.79 | 0.79 (0%) |
| Sutter/Steamboat Sloughs | Wetland | D | Spring | 0.79 | 0.79 (0%) |
| Sutter/Steamboat Sloughs | Wetland | C | Spring | 0.79 | 0.79 (0%) |
| Cache Slough | Riparian | W | Fall | 0.07 | 0.07 (-1%) |
| Cache Slough | Riparian | AN | Fall | 0.07 | 0.07 (-1%) |
| Cache Slough | Riparian | BN | Fall | 0.06 | 0.06 (-1%) |
| Cache Slough | Riparian | D | Fall | 0.05 | 0.05 (-1%) |
| Cache Slough | Riparian | C | Fall | 0.06 | 0.06 (0%) |
| Cache Slough | Wetland | W | Fall | 0.54 | 0.54 (0%) |
| Cache Slough | Wetland | AN | Fall | 0.54 | 0.54 (0%) |
| Cache Slough | Wetland | BN | Fall | 0.53 | 0.52 (0%) |
| Cache Slough | Wetland | D | Fall | 0.52 | 0.52 (0%) |
| Cache Slough | Wetland | C | Fall | 0.52 | 0.52 (0%) |
| Sacramento River above north Delta intakes | Riparian | W | Fall | 0.15 | 0.15 (0%) |
| Sacramento River above north Delta intakes | Riparian | AN | Fall | 0.07 | 0.07 (1%) |
| Sacramento River above north Delta intakes | Riparian | BN | Fall | 0.08 | 0.08 (-4%) |
| Sacramento River above north Delta intakes | Riparian | D | Fall | 0.07 | 0.06 (-3%) |
| Sacramento River above north Delta intakes | Riparian | C | Fall | 0.04 | 0.04 (-2%) |
| Sacramento River above north Delta intakes | Wetland | W | Fall | 0.64 | 0.64 (1%) |
| Sacramento River above north Delta intakes | Wetland | AN | Fall | 0.76 | 0.76 (0%) |
| Sacramento River above north Delta intakes | Wetland | BN | Fall | 0.75 | 0.75 (0%) |
| Sacramento River above north Delta intakes | Wetland | D | Fall | 0.77 | 0.77 (0%) |
| Sacramento River above north Delta intakes | Wetland | C | Fall | 0.78 | 0.78 (0%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | W | Fall | 0.09 | 0.08 (-8%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | AN | Fall | 0.02 | 0.02 (-4%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | BN | Fall | 0.02 | 0.02 (-15%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | D | Fall | 0.01 | 0.01 (-13%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | C | Fall | 0.01 | 0.01 (-3%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | W | Fall | 0.54 | 0.54 (0%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | AN | Fall | 0.53 | 0.53 (-1%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | BN | Fall | 0.51 | 0.51 (-1%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | D | Fall | 0.49 | 0.49 (0%) |

| Geographic Group | Bench Type | WYT | Season | EC | Proposed Action |
|---|---|---|---|---|---|
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | C | Fall | 0.47 | 0.47 (-1%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | W | Fall | 0.12 | 0.11 (-6%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | AN | Fall | 0.05 | 0.05 (-2%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | BN | Fall | 0.05 | 0.04 (-6%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | D | Fall | 0.04 | 0.04 (-4%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | C | Fall | 0.03 | 0.03 (-1%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | W | Fall | 0.62 | 0.62 (0%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | AN | Fall | 0.61 | 0.61 (0%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | BN | Fall | 0.60 | 0.60 (0%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | D | Fall | 0.59 | 0.59 (0%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | C | Fall | 0.58 | 0.58 (0%) |
| Sutter/Steamboat Sloughs | Riparian | W | Fall | 0.24 | 0.23 (-2%) |
| Sutter/Steamboat Sloughs | Riparian | AN | Fall | 0.19 | 0.19 (-1%) |
| Sutter/Steamboat Sloughs | Riparian | BN | Fall | 0.18 | 0.17 (-2%) |
| Sutter/Steamboat Sloughs | Riparian | D | Fall | 0.17 | 0.16 (-1%) |
| Sutter/Steamboat Sloughs | Riparian | C | Fall | 0.16 | 0.16 (-1%) |
| Sutter/Steamboat Sloughs | Wetland | W | Fall | 0.78 | 0.78 (0%) |
| Sutter/Steamboat Sloughs | Wetland | AN | Fall | 0.80 | 0.80 (0%) |
| Sutter/Steamboat Sloughs | Wetland | BN | Fall | 0.80 | 0.80 (0%) |
| Sutter/Steamboat Sloughs | Wetland | D | Fall | 0.80 | 0.80 (0%) |
| Sutter/Steamboat Sloughs | Wetland | C | Fall | 0.80 | 0.80 (0%) |

Notes: Percentage values in parentheses indicate differences of the proposed action to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
Results are not future predictions and are intended only to compare the proposed action to EC.
EC = existing conditions; WYT = water year type (W = wet, AN = above normal, BN = below normal, D = dry, C = critically dry).

### Table 5C.7-19. Riparian Bench Length and Total Deficit Compared to Existing Conditions (linear feet)

| Geographic Location | Bench Type | Length | Proposed Action |
|---|---|---|---|
| Cache Slough | Riparian | 2,950 | -91 |
| Cache Slough | Wetland | 3,992 | -27 |
| Sacramento River above north Delta intakes | Riparian | 18,251 | -1,089 |
| Sacramento River above north Delta intakes | Wetland | 3,766 | -14 |

| Geographic Location | Bench Type | Length | Proposed Action |
|---|---|---|---|
| Sacramento River below north Delta intakes to Sutter/Steamboat Sloughs | Riparian | 3,037 | -669 |
| Sacramento River below north Delta intakes to Sutter/Steamboat Sloughs | Wetland | 3,115 | -41 |
| Sacramento River from Sutter/Steamboat Sloughs To Rio Vista | Riparian | 1,685 | -236 |
| Sacramento River from Sutter/Steamboat Sloughs To Rio Vista | Wetland | 2,430 | -14 |
| Sutter/Steamboat Sloughs | Riparian | 5,235 | -358 |
| Sutter/Steamboat Sloughs | Wetland | 2,670 | 0 |
| Total | Both | 47,131 | -2,540 (-5%) |

Note: Results are not future predictions and are intended only to compare the proposed action to existing conditions.

## Water Temperature

The proposed action would have minimal effects on water temperature relative to existing conditions. Kimmerer (2004:19–20) noted that the water temperature in the San Francisco Estuary depends mainly on air temperature and that even in the Delta the relationship between air and water temperature is only affected slightly by freshwater inflow. Kimmerer (2004) further noted that at Freeport high inflow reduces water temperature on cool days, presumably because water reaches the Delta before its temperature equilibrates with air temperature; at Antioch, low inflow increases water temperature on cool days, likely because of the moderating effect of warmer estuarine water moving farther upstream. USFWS (2008:194) suggested, based on Kimmerer (2004), that water temperatures at Freeport can be cooled up to about 3°C by high Sacramento River flows, but only by very high river flows that cannot be sustained by SWP and CVP (reservoir) operations. Operations-based flow-related effects on Delta water temperatures are expected to be minor (Wagner et al. 2011). This was illustrated by Delta Simulation Model II-QUAL modeling for representative locations on the Sacramento River (downstream of Intake C and at Rio Vista; Table 5C.7-20 and Table 5C.7-21) and San Joaquin River (at Jersey Point; Table 5C.7-22).

**Table 5C.7-20. Mean Water Temperature (degrees Celsius) by Water Year Type and Month from Delta Simulation Model II-QUAL Modeling, Sacramento River Immediately Downstream of Intake C**

| Water Year Type | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action |
|---|---|---|---|---|---|---|---|---|---|---|
| | Wet | | Above Normal | | Below Normal | | Dry | | Critically Dry | |
| Jan | 9.4 | 9.4 (0.0) | 9.4 | 9.4 (0.0) | 8.7 | 8.7 (0.0) | 8.4 | 8.4 (0.0) | 8.7 | 8.7 (0.0) |
| Feb | 10.8 | 10.8 (0.0) | 10.6 | 10.6 (0.0) | 10.3 | 10.3 (0.0) | 10.4 | 10.4 (0.0) | 10.8 | 10.8 (0.0) |
| Mar | 12.6 | 12.6 (0.0) | 12.8 | 12.9 (0.0) | 12.5 | 12.5 (0.0) | 12.7 | 12.7 (0.0) | 13.1 | 13.1 (0.0) |
| Apr | 14.7 | 14.7 (0.0) | 15.0 | 15.0 (0.0) | 15.1 | 15.1 (0.0) | 15.0 | 15.0 (0.0) | 14.9 | 14.9 (0.0) |
| May | 17.7 | 17.7 (0.0) | 17.8 | 17.8 (0.0) | 17.3 | 17.3 (0.0) | 17.3 | 17.3 (0.0) | 17.1 | 17.1 (0.0) |
| Jun | 19.5 | 19.5 (0.0) | 19.6 | 19.6 (0.0) | 19.7 | 19.7 (0.0) | 19.7 | 19.7 (0.0) | 19.3 | 19.3 (0.0) |
| Jul | 20.9 | 20.9 (0.0) | 21.2 | 21.2 (0.0) | 21.0 | 21.0 (0.0) | 20.7 | 20.7 (0.0) | 21.0 | 21.0 (0.0) |
| Aug | 20.7 | 20.7 (0.0) | 20.7 | 20.7 (0.0) | 20.5 | 20.5 (0.0) | 20.3 | 20.3 (0.0) | 20.3 | 20.3 (0.0) |
| Sep | 19.6 | 19.6 (0.0) | 19.6 | 19.6 (0.0) | 19.3 | 19.3 (0.0) | 19.1 | 19.1 (0.0) | 19.2 | 19.2 (0.0) |

| Water Year Type | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action |
|---|---|---|---|---|---|---|---|---|---|---|
| | Wet | | Above Normal | | Below Normal | | Dry | | Critically Dry | |
| Oct | 16.5 | 16.5 (0.0) | 16.8 | 16.8 (0.0) | 16.6 | 16.6 (0.0) | 16.2 | 16.2 (0.0) | 16.7 | 16.7 (0.0) |
| Nov | 12.7 | 12.7 (0.0) | 12.1 | 12.1 (0.0) | 12.4 | 12.4 (0.0) | 12.2 | 12.2 (0.0) | 12.6 | 12.6 (0.0) |
| Dec | 10.0 | 10.0 (0.0) | 9.4 | 9.4 (0.0) | 9.2 | 9.2 (0.0) | 9.2 | 9.1 (0.0) | 9.0 | 9.0 (0.0) |

Note: Values in parentheses indicate absolute differences of the proposed action compared to existing conditions.
EC = existing conditions.

### Table 5C.7-21. Mean Water Temperature (degrees Celsius) by Water Year Type and Month from Delta Simulation Model II-QUAL Modeling, Sacramento River at Rio Vista

| Water Year Type | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action |
|---|---|---|---|---|---|---|---|---|---|---|
| | Wet | | Above Normal | | Below Normal | | Dry | | Critically Dry | |
| Jan | 9.3 | 9.2 (0.0) | 9.1 | 9.1 (0.0) | 8.1 | 8.1 (0.0) | 7.6 | 7.6 (0.0) | 8.1 | 8.0 (0.0) |
| Feb | 10.9 | 10.9 (0.0) | 10.6 | 10.6 (0.0) | 10.2 | 10.2 (0.0) | 10.2 | 10.2 (0.0) | 10.7 | 10.7 (0.0) |
| Mar | 12.8 | 12.8 (0.0) | 13.1 | 13.1 (0.0) | 12.7 | 12.7 (0.0) | 12.9 | 12.9 (0.0) | 13.5 | 13.5 (0.0) |
| Apr | 14.7 | 14.7 (0.0) | 14.9 | 14.9 (0.0) | 14.8 | 14.8 (0.0) | 14.8 | 14.8 (0.0) | 14.5 | 14.5 (0.0) |
| May | 17.4 | 17.4 (0.0) | 17.4 | 17.4 (0.0) | 16.6 | 16.6 (0.0) | 16.6 | 16.6 (0.0) | 16.5 | 16.5 (0.0) |
| Jun | 19.1 | 19.1 (0.0) | 19.1 | 19.1 (0.0) | 19.2 | 19.2 (0.0) | 19.1 | 19.1 (0.0) | 18.8 | 18.8 (0.0) |
| Jul | 20.8 | 20.8 (0.0) | 21.2 | 21.2 (0.0) | 20.9 | 20.9 (0.0) | 20.4 | 20.4 (0.0) | 21.2 | 21.2 (0.0) |
| Aug | 20.5 | 20.5 (0.0) | 20.5 | 20.5 (0.0) | 20.3 | 20.2 (0.0) | 19.9 | 19.9 (0.0) | 20.5 | 20.5 (0.0) |
| Sep | 19.2 | 19.2 (0.0) | 19.2 | 19.2 (0.0) | 19.0 | 18.9 (0.0) | 18.7 | 18.6 (0.0) | 19.2 | 19.2 (0.0) |
| Oct | 16.1 | 16.1 (0.0) | 16.6 | 16.7 (0.0) | 16.3 | 16.3 (0.0) | 15.8 | 15.8 (0.0) | 16.6 | 16.6 (0.0) |
| Nov | 12.8 | 12.8 (0.0) | 12.3 | 12.3 (0.0) | 12.6 | 12.6 (0.0) | 12.4 | 12.4 (0.0) | 12.9 | 12.9 (0.0) |
| Dec | 9.8 | 9.8 (0.0) | 9.0 | 9.0 (0.0) | 8.9 | 8.8 (0.0) | 8.8 | 8.8 (0.0) | 8.6 | 8.6 (0.0) |

Note: Values in parentheses indicate absolute differences of the proposed action compared to existing conditions.
EC = existing conditions.

### Table 5C.7-22. Mean Water Temperature (degrees Celsius) by Water Year Type and Month from Delta Simulation Model II-QUAL Modeling, San Joaquin River at Jersey Point

| Water Year Type | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action |
|---|---|---|---|---|---|---|---|---|---|---|
| | Wet | | Above Normal | | Below Normal | | Dry | | Critically Dry | |
| Jan | 8.9 | 8.9 (0.0) | 8.7 | 8.7 (0.0) | 12.8 | 12.8 (0.0) | 7.0 | 7.0 (0.0) | 7.5 | 7.4 (0.0) |
| Feb | 10.9 | 10.9 (0.0) | 10.5 | 10.4 (0.0) | 14.6 | 14.6 (0.0) | 9.8 | 9.8 (0.0) | 10.2 | 10.2 (0.0) |
| Mar | 13.1 | 13.1 (0.0) | 13.4 | 13.5 (0.0) | 16.3 | 16.3 (0.0) | 13.0 | 13.0 (0.0) | 13.6 | 13.6 (0.0) |
| Apr | 14.8 | 14.8 (0.0) | 14.8 | 14.8 (0.0) | 18.9 | 18.9 (0.0) | 14.8 | 14.8 (0.0) | 14.5 | 14.5 (0.0) |
| May | 17.2 | 17.1 (0.0) | 17.0 | 17.0 (0.0) | 20.8 | 20.8 (0.0) | 16.3 | 16.3 (0.0) | 16.3 | 16.3 (0.0) |
| Jun | 18.9 | 18.9 (0.0) | 18.8 | 18.8 (0.0) | 20.1 | 20.1 (0.0) | 18.9 | 18.9 (0.0) | 18.6 | 18.6 (0.0) |
| Jul | 20.6 | 20.6 (0.0) | 21.0 | 21.0 (0.0) | 18.9 | 18.9 (0.0) | 20.3 | 20.3 (0.0) | 21.2 | 21.2 (0.0) |
| Aug | 20.5 | 20.5 (0.0) | 20.5 | 20.5 (0.0) | 16.3 | 16.3 (0.0) | 19.9 | 19.9 (0.0) | 20.6 | 20.6 (0.0) |
| Sep | 19.0 | 19.0 (0.0) | 18.9 | 18.9 (0.0) | 12.9 | 12.9 (0.0) | 18.6 | 18.6 (0.0) | 19.2 | 19.2 (0.0) |
| Oct | 16.0 | 16.0 (0.0) | 16.7 | 16.7 (0.0) | 8.9 | 8.9 (0.0) | 15.8 | 15.8 (0.0) | 16.6 | 16.6 (0.0) |

| Water Year Type | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action | EC | Proposed Action |
|---|---|---|---|---|---|---|---|---|---|---|
| | Wet | | Above Normal | | Below Normal | | Dry | | Critically Dry | |
| Nov | 13.1 | 13.1 (0.0) | 12.7 | 12.7 (0.0) | 12.8 | 12.8 (0.0) | 12.8 | 12.8 (0.0) | 13.2 | 13.2 (0.0) |
| Dec | 9.8 | 9.8 (0.0) | 8.9 | 8.9 (0.0) | 14.6 | 14.6 (0.0) | 8.9 | 8.9 (0.0) | 8.7 | 8.7 (0.0) |

Note: Values in parentheses indicate absolute differences of the proposed action compared to existing conditions.
EC = existing conditions.

### Cyanobacteria Harmful Algal Blooms

Early migrating juvenile winter-run Chinook salmon entering the Delta could have the potential to encounter cyanobacteria harmful algal blooms (CHABs), including *Microcystis*, which occur during the warmer part of the year with temperature above 19°C (66.2°F; see discussion in Impact WQ-14: *Effects on Cyanobacteria Harmful Algal Blooms Resulting from Facility Operations and Maintenance* in Chapter 9, *Water Quality*, of the Final EIR [California Department of Water Resources 2023]). However, as discussed in the Final EIR, changes in CHABs are concluded to be less than significant and, therefore, would not affect early migrating winter-run in the Delta (California Department of Water Resources 2023).

### Metals

Methylmercury and selenium have the potential to negatively affect habitat suitability for winter-run Chinook salmon in the Delta. As discussed in detail in Chapter 9 of the Final EIR changes in water operations related to the proposed action would have very little effect on Delta fish tissue concentrations of methylmercury and selenium relative to existing conditions (California Department of Water Resources 2023).

### Adult Straying

There is little information from which to infer the potential for adult winter-run Chinook salmon migratory delay because of reductions in Delta inflow as a result of north Delta exports, although the available information for hatchery fall-run Chinook salmon indicates straying rates of fish returning to the Sacramento River are always low across a wide range of hydrological conditions (Marston et al. 2012). This suggests relatively little influence of flows within the range of likely hydrological conditions and therefore no likely difference between the project alternatives and existing conditions for potential straying of adult winter-run Chinook salmon.

## 5C.7.3 Life Cycle Modeling

Three life cycle models were run to provide population-level assessment of operations impacts of the proposed action: IOS, OBAN, and the Sacramento River Winter-Run Chinook Salmon Life Cycle Model (Hendrix et al. 2014, 2019). The methods for IOS and OBAN are described in Appendix 5D, Section 5D.7, *Interactive Object-Oriented Simulation (IOS)*, and in Appendix 5D, Attachment 5D.2, *Results of OBAN Analysis of Delta Conveyance Project Alternatives 2020*. The methods for the Winter-Run Chinook Salmon Life Cycle Model are described in Appendix 5D.

Under the proposed action, the results of the IOS modeling gave overall (all-year) mean adult female winter-run Chinook salmon escapement under the proposed action of 8%–11% less than existing conditions (Table 5C.7-23). This reflected lower juvenile through-Delta survival under proposed operations as compared to existing conditions (Table 5C.7-22) because survival was similar

between proposed operations and existing conditions for egg, fry, and riverine life stages (Table 5C.7-22, Table 5C.7-25, Table 5C.7-26, and Table 5C.7-27). (Graphical summaries are also provided in Appendix 5D, Section 5D.7.3, *Results*).

### Table 5C.7-23. Mean Adult Female Winter-Run Chinook Salmon Escapement (Number of Fish) Based on the IOS Model

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 3,769 | 3,448 (-9%) |
| Above normal | 3,498 | 3,210 (-8%) |
| Below normal | 3,319 | 2,945 (-11%) |
| Dry | 3,468 | 3,157 (-9%) |
| Critically dry | 2,128 | 1,931 (-9%) |
| All | 3,301 | 2,993 (-9%) |

Notes: Percentage values in parentheses indicate differences of the proposed action to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
This table only includes mean responses and does not consider model uncertainty. Results are not future predictions and are intended only to compare the proposed action to the EC.
EC = existing conditions; IOS = Interactive Object-Oriented Simulation.

### Table 5C.7-24. Mean Juvenile Winter-Run Chinook Salmon Through-Delta Proportional Survival Based on the IOS Model

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 0.35 | 0.34 (-1%) |
| Above normal | 0.31 | 0.30 (-3%) |
| Below normal | 0.26 | 0.25 (-4%) |
| Dry | 0.20 | 0.19 (-5%) |
| Critically dry | 0.17 | 0.16 (-4%) |

Notes: Percentage values in parentheses indicate differences of the proposed action to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
This table only includes mean responses and does not consider model uncertainty. Results are not future predictions and are intended only to compare the proposed action to the EC.
EC = existing conditions; IOS = Interactive Object-Oriented Simulation.

### Table 5C.7-25. Mean Winter-Run Chinook Salmon Egg Proportional Survival Based on the IOS Model

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 1.00 | 1.00 (0%) |
| Above normal | 1.00 | 1.00 (0%) |
| Below normal | 1.00 | 1.00 (0%) |
| Dry | 1.00 | 1.00 (0%) |
| Critically dry | 0.86 | 0.89 (3%) |

Notes: Percentage values in parentheses indicate differences of the proposed action to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
This table only includes mean responses and does not consider model uncertainty. Results are not future predictions and are intended only to compare the proposed action to the EC.
EC = existing conditions; IOS = Interactive Object-Oriented Simulation.

**Table 5C.7-26. Mean Winter-Run Chinook Salmon Fry Proportional Survival Based on the IOS Model**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 0.95 | 0.95 (0%) |
| Above normal | 0.96 | 0.96 (0%) |
| Below normal | 0.96 | 0.96 (0%) |
| Dry | 0.95 | 0.95 (0%) |
| Critically dry | 0.81 | 0.83 (2%) |

Notes: Percentage values in parentheses indicate differences of the proposed action to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
This table only includes mean responses and does not consider model uncertainty. Results are not future predictions and are intended only to compare the proposed action to the EC.
EC = existing conditions; IOS = Interactive Object-Oriented Simulation.

**Table 5C.7-27. Mean Juvenile Winter-Run Chinook Salmon Riverine Proportional Survival Based on the IOS Model**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 0.29 | 0.29 (0%) |
| Above normal | 0.26 | 0.26 (0%) |
| Below normal | 0.25 | 0.25 (0%) |
| Dry | 0.25 | 0.25 (0%) |
| Critically dry | 0.25 | 0.25 (0%) |

Notes: Percentage values in parentheses indicate differences of the proposed action to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
This table only includes mean responses and does not consider model uncertainty. Results are not future predictions and are intended only to compare the proposed action to the EC.
EC = existing conditions; IOS = Interactive Object-Oriented Simulation.

The methods and results of the OBAN model are discussed in detail in Appendix 5D, Attachment 5D.2. The proposed action had median abundance less than existing conditions when averaged across the timeseries. Differences in the performance of the proposed action compared to existing conditions was due in large part to the egg-through-fry survival stage of the OBAN model, which uses temperature at Bend Bridge and minimum flow at Bend Bridge as physical drivers. The OBAN model's Delta survival component only includes south Delta exports as the predictor of Delta survival, as described further in Appendix 5D, Attachment 5D.2. To address the potential for the proposed action to increase mortality because of the north Delta intakes, the OBAN model was run with two mortality assumptions (5% and 10% relative increase in mortality in the Delta survival stage).[25] These sensitivity results showed that the proposed action had lower median abundance than existing conditions with the 5% and 10% mortality assumption (see "Mean Escapement % Difference" in Table 5C.7-18).

[25] The discussion in Appendix 5D, Attachment 5D.2, focuses on the additional mortality as being related to near-field mortality, although the results are relevant to mortality generally and need not pertain only to near-field mortality; as previously discussed above in the *Predation* section of Section 5C.7.1.1, *North Delta Exports*, analysis of near-field effects, there is little evidence supporting a substantial near-field mortality effect. Values of +5% and +10% mortality were generally informed by the mid- and upper range of differences suggested by through-Delta survival modeling.

**Table 5C.7-28. OBAN Winter-Run Chinook Salmon Escapement Results: Mean Difference (Proposed Action Minus Existing Conditions, Based on Annual Median) and Mean Probability of Greater Escapement under Proposed Action Compared to Existing Conditions**

| Alternative | Mean Escapement Absolute Difference | Mean Escapement % Difference | Mean Probability > EC |
|---|---|---|---|
| Proposed Action | -1.5 | -12 | 0.41 |
| Proposed Action 5% | -3.4 | -25 | 0.31 |
| Proposed Action 10% | -5.2 | -36 | 0.24 |

Note: This table only includes mean responses and does not consider model uncertainty; *5%* and *10%* after the proposed action indicates sensitivity analyses for additional through-Delta mortality of 5% and 10% representing additional near- or far-field mortality not captured by the OBAN model—that was added to the through-Delta survival calculated by the OBAN model. The 5% and 10% values were chosen on the basis of other analyses, such as through-Delta survival analyses suggesting potential decreases of this general magnitude.
EC = existing conditions; OBAN = Oncorhynchus Bayesian Analysis.

In contrast to the IOS and OBAN models, the Winter-Run Chinook Salmon Life Cycle Model results suggested spawner abundance, freshwater productivity, and cohort replacement rate may be slightly greater under the proposed action than existing conditions (Table 5C.7-27). The mechanisms and explanation for these results will be fully investigated and reported during the project permitting process.

**Table 5C.7-27. Summary of Winter-Run Chinook Salmon Life Cycle Model Results.**

| Output | Result |
|---|---|
| Spawner abundance (mean % difference relative to EC) | 5.16% |
| Probability of spawner abundance > EC | 1.00 |
| Freshwater productivity (mean % difference in gulf smolts per spawner relative to EC) | 0.52% |
| Cohort replacement rate (mean % difference relative to EC) | 0.62% |
| Probability of cohort replacement rate > EC | 0.98 |

EC = existing conditions.

## 5C.7.4 Maintenance Effects

Maintenance of the north Delta intake facilities associated with the proposed action would have very limited effects on the adjacent aquatic environment and, hence, very little potential for effects on winter-run Chinook salmon. The cylindrical tee screens at each intake would be lifted out of the water with the intake's gantry crane for cleaning purposes and may be fixed at the top of the guide rail before being washed with a high-pressure, mobile-power washer approximately every 6 months (Delta Conveyance Design and Construction Authority 2022d:11), with approximately half a day of associated work (including 1 hour of actual washing) for each screen at each intake (i.e., a total of 15 days of washing for each 3,000-cfs intake). This washing process may cause removed sediment and aquatic growth or vegetation to reenter the river, resulting in its redistribution by river currents and minimal effects on the river and species, such as winter-run Chinook salmon, because of the very small amount of material compared to the size of the receiving waterbody. The velocity of diverted water through the cylindrical tee screen system and piping generally is expected to be sufficient to keep sediment moving until it reaches the settling basins (Delta Conveyance Design and Construction Authority 2022d:13). Sediment jetting would only be required at the base of the screen structure to help keep sediment from accumulating beneath the screens; this jetting would be

performed frequently (i.e., hourly to daily, depending on needs), thereby resulting in minimal changes to suspended sediment and turbidity, with sediment jetted from the screen rapidly dispersing within the river channel and, therefore, having very limited or no effects on any winter-run Chinook salmon occurring in the vicinity. When the screen units are lifted up to the deck for cleaning, solid panels would be installed behind the screen in the back guide rail for the unit being cleaned. These panels would seal off that unit's intake area from diversions, so there would be no potential to divert water through an unscreened area while the screen is being cleaned and, therefore, no risk of fish entrainment. Periodic removal of debris from the log booms at each intake (e.g., accumulations following storms) would involve hand and power tools (Delta Conveyance Design and Construction Authority 2022e), but would not be likely to affect juvenile winter-run Chinook salmon negatively, which, if in the vicinity, would be startled and swim away. Removal of accumulated debris would limit increases in potential predatory-fish holding habitat.

# 5C.8 Effects of Operations and Maintenance of Water Conveyance Facilities on Central Valley Spring-Run Chinook Salmon

Effects of the proposed action on spring-run Chinook salmon generally would be similar to those previously discussed in Section 5C.7, *Effects of Operations and Maintenance of Water Conveyance Facilities on Sacramento River Winter-Run Chinook Salmon*, for winter-run Chinook salmon, with some differences caused by spring-run biology and ecology.

## 5C.8.1 Near Field Effects

### 5C.8.1.1 North Delta Exports

#### Entrainment and Impingement

Similar to winter-run Chinook salmon, there would be no risk of juvenile entrainment at the north Delta intakes based on spring-run size distribution (National Marine Fisheries Service 2017:579). As discussed in more detail for winter-run Chinook salmon (Section 5C.7.1.1, *North Delta Exports*, under *Entrainment and Impingement*), experimental results and the design of the fish screens indicate that minimal risk would be expected from entrainment or impingement for juvenile spring-run Chinook salmon.

The timing of juvenile spring-run occurrence in the Delta generally is December through May (Chapter 4, Table 4.4.2-2, with a quantitative summary for juveniles in Tables 4.4.2-2a and 4.4.2-2b[26]), with very few individuals occurring following May; however, yearlings may begin to occur in the fall months (see Final EIR Appendix 12A, Attachment 12A.1), beginning in October (California Department of Water Resources 2023). Within the period of occurrence, the potential for near-field

[26] As shown in the Final EIR Appendix 12A, Attachment 12A.1, the earliest occurrence of juvenile spring-run-sized Chinook salmon can be in October; Table 4.4.2-2 reflects the prevailing patterns noted by NMFS (2019:84); see also Tables 4.4.2-2a and 4.4.2-2b.

effects from entrainment and impingement, as well as entrainment for foodweb organisms, generally would be as discussed in detail for winter-run Chinook salmon.

### Predation

As discussed under winter-run Chinook salmon, Section 5C.7.1.1, under *Predation*, the weight of available information regarding predation suggests that near-field predation effects of the north Delta intakes on juvenile spring-run Chinook salmon would be limited, albeit with some uncertainty given that the studies were not of long cylindrical tee screen structures in the north Delta. Fisheries studies would be undertaken to provide information on predatory fish and predation rate at the north Delta intakes once they are operational, to inform the potential refinement of future operations and adaptive management (Appendix 5B).

## 5C.8.1.2 South Delta Exports

### Juvenile Entrainment

The results from application of the salvage-density method illustrated that south Delta exports generally would be similar or slightly lower under the proposed action, relative to existing conditions at the SWP Banks and CVP Jones south Delta export facilities during the time period that spring-run Chinook salmon generally are salvaged (Table 5C8-1 and Table 5C 8-2).[27] As noted in more detail for winter-run Chinook salmon, north Delta diversion hydrodynamics effects have the potential to increase juvenile fish entry into the interior Delta via Georgiana Slough but would be mitigated, thereby ensuring that take at the south Delta export facilities does not exceed that authorized by the existing permits.

As noted for winter-run Chinook salmon, various regulatory requirements that are required under existing conditions would also apply to the proposed action; therefore, they are part of the existing conditions and are incorporated into the proposed action to minimize south Delta entrainment effects on spring-run Chinook salmon. As noted in more detail for winter-run Chinook salmon, north Delta diversion hydrodynamics effects have the potential to increase juvenile fish entry into the interior Delta via Georgiana Slough but would be mitigated, thereby ensuring that take at the south Delta export facilities does not exceed that authorized by the existing permits.

**Table 5C.8-1. Entrainment Loss of Juvenile Spring-Run Chinook Salmon at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 43,712 | 39,676 (-9%) |
| Above normal | N/A | (-12%) |
| Below normal | 3,256 | 3,079 (-5%) |
| Dry | 3,120 | 3,121 (0%) |
| Critically dry | 3,043 | 3,038 (0%) |

Notes: Percentage values in parentheses indicate differences of proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

[27] Results averaged by water year type and month are provided in Appendix 5D (Tables 5D.2-3 and 5D.2-4).

The analysis was based on historical salvage data during 2009–2019, which did not include any above-normal water years; results for above-normal years focus only on relative difference in exports based on salvage-density patterns from wet years.
EC = existing conditions; SWP = State Water Project.

**Table 5C.8-2. Entrainment Loss of Juvenile Spring-Run Chinook Salmon at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 8,259 | 8,776 (6%) |
| Above normal | N/A | (8%) |
| Below normal | 3,401 | 3,419 (1%) |
| Dry | 3,152 | 3,156 (0%) |
| Critically dry | 156 | 157 (1%) |

Notes: Percentage values in parentheses indicate differences of proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
The analysis was based on historical salvage data during 2009–2019, which did not include any above-normal water years; results for above-normal years focus only on relative difference in exports based on salvage-density patterns from wet years.
CVP = Central Valley Project; EC = existing conditions; N/A = not applicable.

Maintenance of the north Delta intake facilities for the proposed action would have very limited effects on the adjacent aquatic environment and, hence, very little potential for effects on spring-run Chinook salmon. Screen pressure washing and sediment jetting would have very minor effects at the riverscape scale based on redistribution of sediment or accumulated vegetation and other materials.

### Adult Entrainment

In addition to juvenile spring-run Chinook salmon, adult spring-run Chinook salmon are also subject to entrainment at the south Delta export facilities (California Department of Fish and Wildlife 2020, Attachment 8:60–63). It is estimated that 466 adult Chinook salmon were salvaged during 1993–2018 (i.e., an annual mean of ~18 fish), all during the months of September through May, with highest salvage in November, December, and March, which overlaps with adult spring-run Chinook salmon occurrence in the Delta (California Department of Fish and Wildlife 2020, Attachment 8:60–63; Table 4.4.2-2 in Chapter 4 shows January through June as the period of occurrence). South Delta exports under the proposed action generally would be similar or slightly less than under existing conditions (Appendix 5D, Figure 5C.8-1and Tables 5D.2-3, 5D.2-4, 5D.2-5, 5D.2-6, 5D.2-7, and 5D.2-8), indicating entrainment risk for adult spring-run Chinook salmon generally would be similar or slightly less than existing conditions (California Department of Water Resources 2023).

## 5C.8.2 Far Field Effects

### 5C.8.2.1 Indirect Mortality within the Delta

In addition to potential near-field effects, direct effects on spring-run Chinook salmon resulting from the proposed action has the potential to indirectly result in changes to mortality of juvenile spring-run Chinook salmon in the Delta as a result of changes in flow patterns and resulting survival or routing of fish into migration pathways with differing survival probabilities. This section includes a summary of hydrodynamic effects based on potential indicators of indirect mortality risk (e.g.,

channel velocity and flow routing into junctions) as well as an assessment of through-Delta survival using available models

## Hydrodynamic Effects

Diversion of flow by the north Delta diversions would result in less Sacramento River flow moving downstream. Less Sacramento River flow would increase the effect of tides, would increase juvenile Chinook salmon travel time and therefore potential exposure to predatory fish, and would increase the potential for flow to be diverted into the interior Delta at Georgiana Slough and the DCC, where juvenile Chinook salmon survival is lower than on the mainstem Sacramento River (Perry et al. 2018). As described in Appendix 5D, Section 5D.4, *Hydrodynamic Effects Based on DSM2-HYDRO Data*, an assessment of potential hydrodynamic changes was undertaken using DSM2-HYDRO outputs. This illustrated the reduced overlap in north Delta velocity of the proposed action compared to existing conditions, including during key portions of the juvenile spring-run Chinook salmon downstream migration period (see, for example, Figures 5D.4-1 through 5D.4-3 in Appendix 5D), with very little difference in interior and south Delta hydrodynamics (e.g., Figures 5D.4-4 through 5D.4-6 in Appendix 5D). The reduced overlap in velocity between the proposed action and existing conditions generally reflected the somewhat lower velocity associated with the proposed action, as illustrated for the Sacramento River just downstream of Intake C (Table 5C.8-3 in Appendix 5D). The DSM2 modeling also indicated that a somewhat greater proportion of flow would enter the interior Delta at Georgiana Slough in some months with relatively high occurrence of juvenile spring-run Chinook salmon, in particular January–March (Figure 5D.4 29 in Appendix 5D), which generally indicates a greater proportion of juvenile Chinook salmon would enter Georgiana Slough based on available studies (e.g., Cavallo et al. 2015), and that there generally would be greater incidence of reversing flow in the Sacramento River just downstream of Georgiana Slough (Table 5C.8-4 in Appendix 5D). Months with smaller differences in these hydrodynamic indicators (e.g., April) reflect other operational constraints on overall Delta water operations, such as meeting the longfin smelt spring outflow requirements from the CDFW (2020) ITP. Reduced velocity, increased reversing flow just downstream of Georgiana Slough, and increased flow into the interior Delta at Georgiana Slough would tend to reduce juvenile spring-run Chinook salmon through-Delta survival, as analyzed further below in Through-Delta Survival.

## Through-Delta Survival

Operations of the proposed action could affect juvenile spring-run Chinook salmon migrating through the Delta by reducing Sacramento River flow downstream of the north Delta intakes, which could influence through-Delta survival based on flow-survival relationships. The potential for such effects was assessed using a spreadsheet version of the through-Delta survival function formulated by Perry et al. (2018),[28] which estimates through-Delta survival as a function of daily Sacramento River flow at Freeport as well as Delta Cross Channel gate position. The results of this analysis showed that during the main period of juvenile spring-run Chinook salmon occurrence in the Delta (i.e., November–May; Table 4.4.2-2 in Chapter 4), mean through-Delta survival under the proposed action was 0%–4% less than existing conditions (Table 5D.2-3 in Appendix 5D). The largest

[28] The spreadsheet model was provided by Perry (pers. comm.) and reproduces the mean response of the STARS (Survival, Travel time, And Routing Simulation) model (Perry et al. 2019). There is some uncertainty in the extent to which the relationships in the model are representative of wild-origin winter-run Chinook salmon juveniles, given that the model was based on results from larger hatchery-origin late fall–run Chinook salmon juveniles; however, the results of the Delta Passage Model are based on hatchery-origin winter-run Chinook salmon juveniles.

differences in through-Delta survival occurred in September (up to 5%–6% less than existing conditions in below normal years), which is a period that is generally prior to the first juvenile spring-run occurrence in trawls or beach seines at Sacramento except in some years (see Final EIR Appendix 12A, Attachment 12A.1). Relatively large differences in survival (10% less under the proposed action) also occurred in June of above normal years. However, spring-run juveniles generally are not expected to be present in June (Table 4.4.2-1 in Chapter 4), but presence of spring-run-sized juveniles has been noted in small numbers (see Final EIR Appendix 12A, Attachment 12A.1; for example, Sacramento trawls at Sherwood Harbor). Differences during the fall (i.e., September, October, and November) yearling migration period range from 6% less than existing conditions to 2% more than existing conditions (i.e., October in below-normal years under the proposed action; Table 5D.2-3 in Appendix 5D).

As discussed above under winter-run Chinook salmon, the CDFW (2020) SWP ITP requires a Georgiana Slough Migratory Barrier to be installed to reduce juvenile winter- and spring-run Chinook salmon entry into Georgiana Slough by means of acoustic and light stimuli deterring the juveniles from entering Georgiana Slough (California Department of Water Resources 2015). To illustrate the potential effects of the barrier on relative survival differences between existing conditions and the proposed action, a sensitivity analysis was undertaken assuming the barrier was installed and reduced proportional entry into Georgiana Slough by 50%[29] compared to no barrier, during September through June. Although the sensitivity analysis gave higher absolute estimates of through-Delta survival, as expected, there was no change in the relative pattern of percentage differences between existing conditions and the proposed action (compare corresponding cells in Table 5D.2-2with Table 5D.2-3 in Appendix 5D).

The results of the Delta Passage Model (see description of method in Appendix 5D, Section 5D.5) were similar to those of the analysis based on the Perry et al. (2018) through-Delta survival function, with mean estimated through-Delta survival of juvenile spring-run Chinook salmon under the proposed action ranging from 1% to 3% less than existing conditions (Table 5C.8-3; compare in particular to the November through May results in Table 5D.2 3, which as previously described represents the main period of juvenile spring-run occurrence in the Delta and is reflected in the Delta Passage Model entry distribution; see Figure 5C.8-2 in Appendix 5D).[30]

**Table 5C.8-5. Through-Delta Survival of Juvenile Spring-Run Chinook Salmon, Averaged by Water Year Type, Based on the Delta Passage Model**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 0.33 | 0.32 (-2%) |
| Above normal | 0.26 | 0.26 (-2%) |
| Below normal | 0.19 | 0.19 (-3%) |
| Dry | 0.17 | 0.17 (-2%) |
| Critically dry | 0.14 | 0.14 (-1%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
This table only includes mean responses and does not consider model uncertainty.

[29] A 50% reduction in entry to Georgiana Slough was observed during the 2012 pilot testing of the barrier (California Department of Water Resources 2015).
[30] Note that the Delta Passage Model is based on results from juvenile Chinook salmon ≥80 mm in length.

Spring-run Chinook salmon have been reintroduced to the San Joaquin River Basin, and there is evidence for through-Delta flow-survival effects on juvenile Chinook salmon following entry from the San Joaquin River Basin (e.g., Buchanan and Skalski 2020), through-Delta survival effects on juveniles were analyzed with the Structured Decision Model San Joaquin River routing application. The results of this analysis indicated that changes in south Delta operations as a result of the proposed action generally would not result in lower through-Delta survival relative to existing conditions, although there may be somewhat lower survival in dry years (Table 5C.8-6). The results reflect the relatively small differences in south Delta export operations between the proposed action and existing conditions, because the other model components related to San Joaquin River flows are essentially the same for the proposed action and existing conditions.

**Table 5C.8-6. Through-Delta Survival of Juvenile Spring-Run Chinook Salmon from the San Joaquin River Basin, Averaged by Water Year Type, Based on the Structured Decision Model Routing Application**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 0.033 | 0.032 (0%) |
| Above normal | 0.033 | 0.033 (0%) |
| Below normal | 0.028 | 0.028 (2%) |
| Dry | 0.026 | 0.024 (-5%) |
| Critically dry | 0.017 | 0.017 (0%) |

Notes: Percentage values in parentheses indicate differences of proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
Table only includes mean responses and does not consider model uncertainty.
EC = existing conditions.

## 5C.8.2.2 Habitat Suitability

Several aspects of habitat suitability for spring-run Chinook salmon and the potential far-field effects of the proposed action were examined: riparian and wetland bench inundation (juvenile rearing habitat); water temperature; *Microcystis* harmful algae blooms; and metals (selenium and mercury).

### Riparian bench and wetland inundation

As discussed under winter-run Chinook salmon, restored benches in the north Delta could potentially be affected by the water operations of the proposed action because of changes in water level; for example, less water in the Sacramento River below the north Delta intakes could result in riparian benches being inundated less frequently. This possibility was examined by calculating bench inundation indices for juvenile Chinook salmon (see detailed method description in Appendix 5D, Section 5D.6). These indices range from 0 (no availability of bench habitat) to 1 (water depth on the bench is optimal for juvenile Chinook salmon all the time).[31] The analysis was undertaken for

[31] For example, a bench inundation index of 0.20 equates to optimal depth (suitability = 1) 20% of the time within a season (with no other inundation occurring); or equates to relatively poor depth (suitability = 0.20) 100% of the time within a season. Note that depending on water depth under existing conditions, bench inundation indices could be greater, the same, or less under the proposed action, as a result of differences in suitability with differences in water depth (see Figure 5D.3 2 in Appendix 5D), although the modeling indicated mostly lower inundation indices under the proposed action because of the north Delta diversions.

riparian and wetland benches in five geographic locations within the north Delta, by linking bench elevation data to DSM2-HYDRO-simulated water surface elevation for three seasonal periods (fall: October–November; winter: December–February; spring: March–June).

The analysis of bench inundation suggested the potential for changes in inundation under the proposed action relative to existing conditions, ranging from little difference to 19% (relative difference) less bench inundation under the proposed action (Table 5D.6-1 in Appendix 5D). The largest differences were for riparian benches in the Sacramento River downstream of the north Delta diversions in winter and spring, with little difference in areas well downstream (e.g., Cache Slough). There was also little difference for wetland benches, which are intended to be inundated at lower water surface elevations that would be available at much lower flows. Riparian bench-rearing and holding habitat in the Sacramento River downstream of the north Delta diversions under the proposed action would be around 5%–19% less than existing conditions during March–May in wetter water year types (Table 5D.6-1 in Appendix 5D). The proposed action would result in less availability of inundated bench habitat for juvenile spring-run Chinook salmon compared to existing conditions. Multiplying the proportional difference in inundation indices between the proposed action and existing conditions by the length of bench in each area allows the differences as a result of the proposed action to be expressed in linear feet, which is subsequently used for mitigation calculations; the overall differences relative to existing conditions can be found in Table 5D.6-1 in Appendix 5D.

### Water Temperature

As discussed above under winter-run Chinook salmon, the proposed action would have minimal effects on water temperature relative to existing conditions. Operations-based flow-related effects on Delta water temperature are expected to be minor (Wagner et al. 2011). This was illustrated by DSM2-QUAL modeling for representative locations on the Sacramento River (downstream of Intake C and at Rio Vista; Table 5C.7-18 and Table 5C.7-19) and San Joaquin River (at Jersey Point; Table 5C.7-20).

### Cyanobacteria Harmful Algal Blooms

Juvenile spring-run Chinook salmon typically enter the Delta in November and are present until May. They are unlikely to encounter CHABs including *Microcystis*, which occur during the warmer part of the year when the water temperature is above 19°C (66.2°F; see discussion in Impact WQ-14 in Chapter 9 of the Final EIR [California Department of Water Resources 2023]).

### Metals

Methylmercury and selenium have the potential to negatively affect habitat suitability for spring-run Chinook salmon in the Delta. As discussed in detail in Chapter 9 of the Final EIR, changes in water operations related to the proposed action would have very little effect on Delta fish tissue concentrations of methylmercury and selenium, relative to existing conditions (California Department of Water Resources 2023).

### Adult Straying

There is little information from which to infer the potential for adult spring-run Chinook salmon migratory delay because of reductions in Delta inflow as a result of north Delta exports, although the available information for hatchery fall-run Chinook salmon indicates straying rates of fish returning

to the Sacramento River are always low (Marston et al. 2012). This suggests relatively little influence of flows and therefore no likely difference between the proposed action and existing conditions for potential straying of adult spring-run Chinook salmon.

### 5C.8.3 Maintenance Effects

Maintenance of the north Delta intake facilities for the proposed action would have very limited effects on the adjacent aquatic environment and hence very little potential for effects on spring-run Chinook salmon. Screen pressure washing and sediment jetting would have very small impacts at the riverscape scale based on redistribution of sediment or accumulated vegetation and other materials.

## 5C.9 Effects of Operations and Maintenance of Water Conveyance Facilities on Central Valley Fall-Run/Late Fall–Run Chinook Salmon

Impacts of the proposed action on fall-run and late fall–run Chinook salmon generally would be similar to those previously discussed for winter-run Chinook salmon and spring-run Chinook salmon, with some differences caused by fall-run and late fall–run biology and ecology. The fall run/late fall–run Chinook salmon analysis is utilized as part of Appendix 5A, *Essential Fish Habitat Assessment*.

There may be a small risk of juvenile entrainment at the north Delta intake cylindrical fish screens based on fall-run and late fall–run size distribution (National Marine Fisheries Service 2017:579), although cylindrical tee screens in the Columbia River have been shown to virtually eliminate entrainment risk (Coutant 2021), albeit under different configuration and generally greater flow than in the Delta (see also discussion for winter-run Chinook salmon, Chapter 5, Section 5.6.1).

The timing of juvenile fall-run and late fall–run occurrence in the Delta is primarily November/December–June (Figures 4.4.3-1 and 4.4.3-2 in Chapter 4). As previously discussed for winter- and spring-run Chinook salmon, operations of the north Delta diversion would result in periods of lower channel velocity (Table 5C.7-13), increased flow reversals in the Sacramento River below Georgiana Slough (Table 5C.7-14), and increased proportion of flow entering the interior Delta (Figures 5D.4-26 through 5D.4-37 in Appendix 5D), compared to existing conditions. These hydrodynamic indicators of through-Delta survival effects are reflected in the results of the Delta Passage Model (Table 5C.9-1 and Table 5C.9-2) and the modeling based on Perry et al. (2018; Table 5C.7-15), which generally showed mean survival up to 1%–2% lower under the proposed action, compared to existing conditions, with the Perry et al. (2018) model also showing 10% less through-Delta survival in June of above-normal years (Table 5C.7-15).

**Table 5C.9-1. Through-Delta Survival of Juvenile Fall-Run Chinook Salmon, Averaged by Water Year Type, Based on the Delta Passage Model**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 0.28 | 0.27 (-2%) |
| Above normal | 0.21 | 0.20 (-2%) |
| Below normal | 0.17 | 0.17 (-1%) |
| Dry | 0.15 | 0.15 (0%) |
| Critically dry | 0.13 | 0.13 (0%) |

Notes: Percentage values in parentheses indicate differences of proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
This table only includes mean responses and does not consider model uncertainty.
EC = existing conditions.

**Table 5C.9-2. Through-Delta Survival of Juvenile Late Fall-Run Chinook Salmon, Averaged by Water Year Type, Based on the Delta Passage Model**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 0.25 | 0.25 (-1%) |
| Above normal | 0.20 | 0.20 (-3%) |
| Below normal | 0.16 | 0.16 (-3%) |
| Dry | 0.14 | 0.14 (-2%) |
| Critically dry | 0.13 | 0.13 (-1%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
This table only includes mean responses and does not consider model uncertainty.
EC = existing conditions.

The results from application of the salvage-density method illustrated that south Delta exports generally would be similar or slightly lower under the proposed action relative to existing conditions at the SWP Banks and CVP Jones south Delta export facilities during the time period that fall- and late fall–run Chinook salmon generally are salvaged (Table 5C.9-3, Table 5C.9-4, Table 5C.9-5, and Table 5C.9-6),[32] indicating that entrainment risk would not be greater under the proposed action compared to existing conditions. As noted for winter-run and spring-run Chinook salmon, various regulatory requirements would be implemented under existing conditions and, therefore, are part of the baseline and incorporated into the proposed action to minimize south Delta entrainment effects on listed Chinook salmon. Although focused on listed Chinook salmon, the temporal overlap with fall-run and late fall–run Chinook would result in ancillary protection for the unlisted Chinook salmon.

[32] Results averaged by water year type and month are provided in Appendix 5D (Tables Table 5C.9-3 through 5C.9-4.)

**Table 5C.9-3. Entrainment Loss of Juvenile Fall-Run Chinook Salmon at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 21,628 | 20,462 (-5%) |
| Above normal | N/A | (-8%) |
| Below normal | 2,933 | 2,757 (-6%) |
| Dry | 3,952 | 3,910 (-1%) |
| Critically dry | 3,747 | 3,671 (-2%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
The analysis was based on historical salvage data during 2009–2019, which did not include any above-normal water years; results for above-normal years focus only on relative difference in exports based on salvage-density patterns from wet years.
EC = existing conditions; N/A = not applicable; SWP = State Water Project.

**Table 5C.9-4. Entrainment Loss of Juvenile Fall-Run Chinook Salmon at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 9,143 | 9,614 (5%) |
| Above normal | N/A | (7%) |
| Below normal | 2,884 | 2,878 (0%) |
| Dry | 4,160 | 4,147 (0%) |
| Critically dry | 178 | 179 (0%) |

Notes: Percentage values in parentheses indicate differences of proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
The analysis was based on historical salvage data during 2009–2019, which did not include any above-normal water years; results for above-normal years focus only on relative difference in exports based on salvage-density patterns from wet years.
CVP = Central Valley Project; EC = existing conditions; N/A = not applicable.

**Table 5C.9-5. Entrainment Loss of Juvenile Late Fall–Run Chinook Salmon at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 1,361 | 1,316 (-3%) |
| Above normal | N/A | (-6%) |
| Below normal | 387 | 376 (-3%) |
| Dry | 1,053 | 953 (-10%) |
| Critically dry | 708 | 667 (-6%) |

Notes: Percentage values in parentheses indicate differences of proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
The analysis was based on historical salvage data during 2009–2019, which did not include any above-normal water years; results for above-normal years focus only on relative difference in exports based on salvage-density patterns from wet years.
EC = existing conditions; N/A = not applicable; SWP = State Water Project.

**Table 5C.9-6. Entrainment Loss of Juvenile Late Fall–Run Chinook Salmon at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 262 | 261 (0%) |
| Above normal | N/A | (0%) |
| Below normal | 67 | 69 (3%) |
| Dry | 93 | 86 (-7%) |
| Critically dry | 30 | 30 (1%) |

Notes: Percentage values in parentheses indicate differences of proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
The analysis was based on historical salvage data during 2009–2019, which did not include any above-normal water years; results for above-normal years focus only on relative difference in exports based on salvage-density patterns from wet years.
CVP = Central Valley Project; EC = existing conditions; N/A = not applicable.

Adult fall-run Chinook salmon also are subject to entrainment at the south Delta export facilities. In 2019, 10 adult Chinook salmon were captured during a study in the Clifton Court Forebay and identified as fall-run Chinook salmon based on size and time of year. These fish were captured from October to November which overlaps with adult fall-run Chinook salmon occurrence in the Delta (California Department of Fish and Wildlife 2020, Attachment 8:59; Figure 4.4.3-1 in Chapter 4 shows July to November as the main period of occurrence). South Delta exports under the proposed action generally would be similar or slightly less than under existing conditions indicating entrainment risk for adult fall-run Chinook salmon generally would be similar or slightly less than existing conditions.

Fall-run Chinook salmon occur in the San Joaquin River Basin, with evidence for flow-survival effects when passing through the Delta (e.g., Buchanan and Skalski 2020), and so through-Delta survival effects on juveniles were analyzed with the Structured Decision Model San Joaquin River routing application. The results of this analysis indicated that south Delta operations under the proposed action generally would give similar through-Delta survival as existing conditions (Table 5C.9-7).

**Table 5C.9-7. Through-Delta Survival of Juvenile Fall-Run Chinook Salmon from the San Joaquin River Basin, Averaged by Water Year Type, Based on the Structured Decision Model Routing Application**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 0.033 | 0.033 (0%) |
| Above normal | 0.033 | 0.033 (0%) |
| Below normal | 0.029 | 0.030 (1%) |
| Dry | 0.027 | 0.026 (-4%) |
| Critically dry | 0.017 | 0.017 (0%) |

Notes: Percentage values in parentheses indicate differences of proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
This table only includes mean responses and does not consider model uncertainty.
EC = existing conditions.

The straying rate of adult fall-run Chinook salmon to the San Joaquin River Basin could be affected by changes in south Delta water operations under the proposed action relative to existing conditions. Statistical equations developed by Marston et al. (2012) were used to estimate straying rate as a function of October and November San Joaquin River flows and south Delta exports. This analysis suggested that there is the potential for mean straying rate to be around 1% to approximately 11% less under the proposed action, compared to existing conditions (Table 5C.9-8), albeit with appreciable uncertainty because it is unclear whether San Joaquin River pulse flows, south Delta exports, or both, are the main driver of straying (Marston et al. 2012).

**Table 5C.9-8. Straying Rate (percent) of San Joaquin River Basin Fall-Run Chinook Salmon to the Sacramento River Basin, Averaged by Water Year Type, Based on Marston et al. (2012)**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 22% | 20% (-11%) |
| Above normal | 23% | 22% (-5%) |
| Below normal | 17% | 16% (-9%) |
| Dry | 19% | 19% (-1%) |
| Critically dry | 11% | 11% (-6%) |

Notes: Percentage values in parentheses indicate relative differences of proposed action compared to existing conditions (relative differences are larger than absolute differences). Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
This table only includes mean responses and does not consider model uncertainty.
EC = existing conditions.

In addition to fall-run Chinook salmon from the Sacramento River and San Joaquin River Basins, the proposed action would have the potential to affect fall-run from the Mokelumne river basin. For juvenile outmigration, the main effect of concern is related to entrainment risk caused by March–June south Delta exports (Workman 2018:14), although historical population-level losses were estimated to be small by DWR (2020:4-229–4-230). During March–June, the proposed action generally would have similar or somewhat fewer south Delta exports relative to existing conditions (Table 5C.9-9, Table 5C.9-10, Table 5C.9-11, and Table 5C.9-12), and, therefore, south Delta entrainment risk would not be greatly different under the proposed action than existing conditions. Indicators of broader hydrodynamic effects of water operations relevant to Mokelumne River fall-run juveniles also indicated limited differences between the proposed action, including the proportion of flow entering the south Delta from the mainstem San Joaquin River at the mouth of Old River, Fisherman's Cut, False River, and Jersey Point (Appendix 5D, Figures 5D.4 34, 5D.4 35, 5D.4 36, and 5D.4 37, respectively).

**Table 5C.9-9. Mean South Delta Exports (cubic feet per second) by Water Year Type, March**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 7,664 | 7,187 (-6%) |
| Above normal | 6,203 | 6,192 (0%) |
| Below normal | 5,433 | 5,427 (0%) |
| Dry | 4,713 | 4,715 (0%) |
| Critically dry | 4,294 | 4,183 (-3%) |

Note: Percentage values in parentheses indicate differences of proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
EC = existing conditions.

**Table 5C.9-10. Mean South Delta Exports (cubic feet per second) by Water Year Type, April**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 7,004 | 6,544 (-7%) |
| Above normal | 4,675 | 4,528 (-3%) |
| Below normal | 3,608 | 3,615 (0%) |
| Dry | 3,053 | 3,070 (1%) |
| Critically dry | 2,125 | 2,162 (2%) |

Note: Percentage values in parentheses indicate differences of proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
EC = existing conditions.

**Table 5C.9-11. Mean South Delta Exports (cubic feet per second) by Water Year Type, May**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 6,643 | 6,762 (2%) |
| Above normal | 5,049 | 5,110 (1%) |
| Below normal | 3,646 | 3,781 (4%) |
| Dry | 3,254 | 3,240 (0%) |
| Critically dry | 2,653 | 2,614 (-1%) |

Note: Percentage values in parentheses indicate differences of proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
EC = existing conditions.

**Table 5C.9-12. Mean South Delta Exports (cubic feet per second) by Water Year Type, June**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 8,095 | 8,095 (0%) |
| Above normal | 6,783 | 6,779 (0%) |
| Below normal | 5,683 | 5,711 (0%) |
| Dry | 5,257 | 5,238 (0%) |
| Critically dry | 2,091 | 2,114 (1%) |

Note: Percentage values in parentheses indicate differences of proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
EC = existing conditions.

Potential effects related to straying of adult Mokelumne River fall-run Chinook salmon to the Sacramento River when the Delta Cross Channel is open during October and November (Setka 2018) were also evaluated. As described in Chapter 3, the Delta Cross Channel, as with all CVP facilities, would continue to be operated consistently with applicable laws and contractual obligations. The CalSim modeling results for the number of days that the Delta Cross Channel is open showed that the proposed action had similar or fewer mean number of days of when the Delta Cross Channel would be open, compared to existing conditions for wet, above-normal, and below-normal years, with 2 to 4 more days of the Delta Cross Channel being open under the proposed action in October (Table 5C.9-13 and Table 5C.9-14). These results reflect modeling assumptions and do not account for Delta Cross Channel closure in association with Mokelumne River pulse flows, as required under the Reinitiation of Consultation on the Coordinated Long-Term Operation of the proposed action

(Bureau of Reclamation 2019:3-37), and which is part of existing conditions and the proposed action, with implementation as illustrated in October 2021 (Salmon Monitoring Team 2021).

**Table 5C.9-13. Mean Number of Days with Delta Cross Channel Open by Water Year Type, October**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 16 | 13 (-20%) |
| Above normal | 25 | 23 (-10%) |
| Below normal | 17 | 15 (-9%) |
| Dry | 18 | 22 (18%) |
| Critically dry | 9 | 11 (25%) |

Note: Percentage values in parentheses indicate differences of proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
EC = existing conditions.

**Table 5C.9-14. Mean Number of Days with Delta Cross Channel Open by Water Year Type, November**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 13 | 11 (-12%) |
| Above normal | 15 | 12 (-20%) |
| Below normal | 17 | 16 (-5%) |
| Dry | 16 | 12 (-24%) |
| Critically dry | 14 | 13 (-12%) |

Note: Percentage values in parentheses indicate differences of proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
EC = existing conditions.

Maintenance of the north Delta intake facilities for the proposed action would have very limited effects on the adjacent aquatic environment and, hence, very little potential for effects on fall- and late fall–run Chinook salmon. Screen pressure washing and sediment jetting would have very small effects at the riverscape scale based on redistribution of sediment or accumulated vegetation and other materials.

# 5C.10 Effects of Operations and Maintenance of Water Conveyance Facilities on California Central Valley Steelhead

Impacts of the proposed action on California Central Valley steelhead generally would be similar in nature to those previously discussed for winter-, spring-, fall-, and late fall–run Chinook salmon.

As described in Chapter 4, the main juvenile steelhead migration period in the Delta is February to May. Through-Delta flow-survival relationships analogous to those for juvenile Chinook salmon (e.g., Perry et al. 2018; see also discussion for winter-run Chinook salmon in Section 5C.7) have not been established for migrating juvenile steelhead from the Sacramento River Basin, although the species

does show analogous route-specific survival differences (Singer et al. 2013), and there are flow-survival relationships for steelhead from the San Joaquin River Basin emigrating through the Delta (Buchanan et al. 2021). Assuming that flow may affect survival in a somewhat similar manner to juvenile Chinook salmon, which is uncertain, the modeling based on the through-Delta survival function formulated by Perry et al. (2018) suggests that mean through-Delta survival of juvenile steelhead under the proposed action may be similar or somewhat less (up to 4%) (Table 5C.7-15). This reflects hydrodynamic changes, such as channel velocity (Table 5C.7-13), and the proportion of time with reversing flow in the Sacramento River below Georgiana Slough (Table 5C.7-14).

Studies of acoustically tagged juvenile steelhead found San Joaquin River flow at Vernalis, presence of a rock barrier at Head of Old River, fish size, and year to be significant predictors of through-Delta survival, whereas south Delta exports were not supported as significant predictors of survival (Buchanan et al. 2021). Given the absence of a Head of Old River rock barrier under existing conditions and the proposed action, as well as essentially identical Vernalis flows (Table 5C.10-1, Table 5C.10-2, Table 5C.10-3, and Table 5C.10-4), there would be no difference in juvenile steelhead through-Delta survival from the San Joaquin River Basin between the proposed action and existing conditions.

**Table 5C.10-1. Mean San Joaquin River Flow at Vernalis (cubic feet per second) by Water Year Type, February**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 9,589 | 9,598 (0%) |
| Above normal | 4,972 | 4,980 (0%) |
| Below normal | 3,218 | 3,224 (0%) |
| Dry | 1,962 | 1,969 (0%) |
| Critically dry | 1,912 | 1,917 (0%) |

Note: Percentage values in parentheses indicate differences of proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
EC = existing conditions.

**Table 5C.10-2. Mean San Joaquin River Flow at Vernalis (cubic feet per second) by Water Year Type, March**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 11,043 | 11,054 (0%) |
| Above normal | 5,487 | 5,496 (0%) |
| Below normal | 3,065 | 3,072 (0%) |
| Dry | 1,963 | 1,968 (0%) |
| Critically dry | 1,799 | 1,804 (0%) |

Note: Percentage values in parentheses indicate differences of proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
EC = existing conditions.

**Table 5C.10-3. Mean San Joaquin River Flow at Vernalis (cubic feet per second) by Water Year Type, April**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 11,459 | 11,471 (0%) |
| Above normal | 6,128 | 6,138 (0%) |
| Below normal | 3,804 | 3,813 (0%) |
| Dry | 2,434 | 2,439 (0%) |
| Critically dry | 1,987 | 1,991 (0%) |

Note: Percentage values in parentheses indicate differences of proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
EC = existing conditions.

**Table 5C.10-4. Mean San Joaquin River Flow at Vernalis (cubic feet per second) by Water Year Type, May**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 9,893 | 9,909 (0%) |
| Above normal | 5,531 | 5,548 (0%) |
| Below normal | 3,858 | 3,868 (0%) |
| Dry | 2,712 | 2,717 (0%) |
| Critically dry | 2,059 | 2,065 (0%) |

Note: Percentage values in parentheses indicate differences of proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
EC = existing conditions.

The results from application of the salvage-density method illustrated that south Delta exports generally would be similar or slightly lower under the proposed action relative to existing conditions at the SWP Banks and CVP Jones south Delta export facilities during the time period that steelhead generally are salvaged (Table 5C.10-5 and Table 5C.10-6).[33] As noted for winter-run and spring-run steelhead, various regulatory requirements under existing conditions would also apply to the proposed action and, therefore, are part of the baseline and incorporated into the proposed action to minimize south Delta entrainment effects on steelhead.

**Table 5C.10-5. Entrainment Loss of Juvenile Steelhead at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 5,216 | 4,664 (-11%) |
| Above normal | N/A | (-6%) |
| Below normal | 3,251 | 2,986 (-8%) |
| Dry | 2,327 | 2,221 (-5%) |
| Critically dry | 2,130 | 2,018 (-5%) |

Notes: Percentage values in parentheses indicate differences of proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

[33] Results averaged by water year type and month are provided in Appendix 5D (Tables 5D.2 1 through 5D.2 12).

The analysis was based on historical salvage data during 2009–2019, which did not include any above-normal water years; results for above-normal years focus only on relative difference in exports based on salvage-density patterns from wet years.
EC = existing conditions; N/A = not applicable; SWP = State Water Project.

**Table 5C.10-6. Entrainment Loss of Juvenile Steelhead at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 295 | 304 (3%) |
| Above normal | N/A | (4%) |
| Below normal | 945 | 997 (6%) |
| Dry | 677 | 702 (4%) |
| Critically dry | 200 | 202 (1%) |

Notes: Percentage values in parentheses indicate differences of proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
The analysis was based on historical salvage data during 2009–2019, which did not include any above-normal water years; results for above-normal years focus only on relative difference in exports based on salvage-density patterns from wet years.
CVP = Central Valley Project; EC = existing conditions; N/A = not applicable.

As discussed for fall- and late-fall-run Chinook salmon, there would not be an increase in south Delta entrainment risk for juvenile steelhead emigrating from the Mokelumne River based on south Delta exports (Table 5C.9-9, Table 5C.9-10, Table 5C.9-11, and Table 5C.9-12) and hydrodynamic indicators (Appendix 5D, Figures 5D.4-34 through 5D.4-37).

In addition to juvenile steelhead, adult steelhead are also subject to entrainment at the south Delta export facilities (Table 4.4.3-1 in Chapter 4 shows September–February as the main period of occurrence in the San Joaquin River). As discussed for fall- and late fall–run Chinook salmon, South Delta exports under the proposed action generally would be similar or slightly less than under existing conditions indicating entrainment risk for adult steelhead generally would be similar or slightly less than existing conditions.

Maintenance of the north Delta intake facilities for the proposed action would have very limited effects on the adjacent aquatic environment and, hence, very little potential for effects on steelhead. Screen pressure washing and sediment jetting would have very small effects at the riverscape scale, based on redistribution of sediment or accumulated vegetation and other materials.

# 5C.11 Effects of Operations and Maintenance of Water Conveyance Facilities on Southern DPS Green Sturgeon

Analyses of potential effects of the proposed action on green sturgeon were developed in consideration of habitat attributes believed to be of importance to the species, based on existing conceptual models (Heublein et al. 2017a, 2017b) and best available methods (e.g., ICF International 2016; California Department of Water Resources 2020).

Relative to juvenile salmonids, there are no field-based investigations informing the risk from near-field effects of the proposed action at the north Delta intakes for green sturgeon.

Laboratory investigations are available from which risk of entrainment and impingement can be inferred. Larval green sturgeon occur well upstream of the Delta (Heublein et al. 2017a), so there would be no risk of entrainment at the north Delta intakes. Although screen velocity criteria for green sturgeon have not been developed by NMFS or CDFW, the laboratory studies of Verhille et al. (2014) provided recommendations for intake approach velocity based on flow-tolerance criteria (Table 5C.11-1). The proposed north Delta intake approach velocity of 0.2 foot per second would be well below the criteria described by Verhille et al. (2014; i.e., 29 centimeters per second [~1 foot per second] or greater, depending on the month), suggesting that green sturgeon juveniles would be protected, particularly given that they would be larger in size than the larvae tested by Verhille et al. (2014). Juvenile green sturgeon were found to contact frequently or become impinged on laboratory fish screens with approach velocity several times greater than proposed for the north Delta intakes (~0.66 and ~1.2 feet per second; Poletto et al. 2014), but those screens were in a V-shape across the test channel. The very low approach velocity of the proposed north Delta intake screens indicates that the potential for negative effects would be very small; in addition, as discussed for winter-run Chinook salmon, the cylindrical tee screen design has been noted to reduce the potential for near-field effects because of the bow-wave hydraulic effect (Coutant 2021, albeit with the caveats previously described for winter-run Chinook salmon).

**Table 5C.11-1. Overview of Flow-Tolerance Limitations of Green and White Sturgeon throughout the Sacramento–San Joaquin Watershed According to Location and Time of Year, Based on Critical Swimming Speed**

| Month | Upper River | Middle River | Lower River/Delta/Bays |
|---|---|---|---|
| January | >50 cm/s | >50 cm/s | >50 cm/s |
| February | >50 cm/s | WS early larvae | >50 cm/s |
| March | >50 cm/s | WS early larvae | >50 cm/s |
| April | GS early larvae | WS early larvae | >50 cm/s |
| May | GS early larvae | WS early larvae | >50 cm/s |
| June | GS and WS ≤ 29 cm/s | GS and WS ≤ 29 cm/s | GS and WS ≤ 29 cm/s |
| July | >50 cm/s | WS ≤ 45 cm/s | WS ≤ 45 cm/s |
| August | >50 cm/s | GS ≤ 50 cm/s | GS ≤ 50 cm/s |
| September | >50 cm/s | >50 cm/s | >50 cm/s |
| October | >50 cm/s | GS ≤ 40 cm/s | GS ≤ 40 cm/s |
| November | >50 cm/s | GS ≤ 40 cm/s | GS ≤ 40 cm/s |
| December | >50 cm/s | >50 cm/s | >50 cm/s |

Source: Verhille et al. (2014).
Note: GS = green sturgeon; WS = white sturgeon. "GS early larvae" and "WS early larvae" demarcate presence of life stages which are predicted to be intolerant of even very low water velocities. Behavioral (e.g., avoidance) considerations were not part of this analysis, and they remain an important topic for future research. The north Delta intakes are in the "lower river/delta/bays" area.

Green sturgeon entrainment at the south Delta export facilities can occur in most months of the year, reflecting the year-round presence of juveniles in the Delta. However, salvage of green sturgeon has been very low in recent years, and entrainment is regarded as a threat of low importance to the population in the NMFS green sturgeon recovery plan (National Marine Fisheries

Service 2018:26). The salvage-density analysis (see description in Appendix 5D, Section 5D.2) was used to assess the potential for differences in south Delta entrainment between the proposed action and existing conditions. The method weights south Delta exports at the south Delta export facilities by historical salvage per unit volume (i.e., salvage density) of juvenile green sturgeon. The results of the analysis suggest that there would be very little difference in south Delta entrainment risk between the proposed action and existing conditions at either export facility (Table 5C.11-2 and Table 5C.11-).[34]

**Table 5C.11-2. Salvage of Green Sturgeon at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 1 | 1 (-13%) |
| Above normal | N/A | (-7%) |
| Below normal | 1 | 1 (0%) |
| Dry | 0 | 0 (0%) |
| Critically dry | 0 | 0 (0%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
The analysis was based on historical salvage data during 2009–2019, which did not include any above-normal water years; results for above-normal years focus only on relative difference in exports based on salvage-density patterns from wet years.
EC = existing conditions; N/A = not applicable; SWP = State Water Project.

**Table 5C.11-3. Salvage of Green Sturgeon at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 7 | 7 (5%) |
| Above normal | N/A | (6%) |
| Below normal | 0 | 0 (0%) |
| Dry | 0 | 0 (0%) |
| Critically dry | 0 | 0 (0%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
The analysis was based on historical salvage data during 2009–2019, which did not include any above-normal water years; results for above-normal years focus only on relative difference in exports based on salvage-density patterns from wet years.
CVP = Central Valley Project; EC = existing conditions; N/A = not applicable.

Based on observations in the Delta on white sturgeon (Stewart et al. 2004), selenium bioaccumulation is a concern for sturgeon. As discussed in detail in Chapter 9 of the Final EIR, changes in water operations under the proposed action would have little effect on sturgeon tissue concentrations of selenium, relative to existing conditions (California Department of Water Resources 2023). Methylmercury is also a concern for green sturgeon (Lee et al. 2011), but analyses described in Chapter 9 of the Final EIR found there would be little difference in fish tissue

[34] Results averaged by water year type and month are provided in Appendix 5A (Tables 5A-11 and 5A-12).

methylmercury between the proposed action and existing conditions (California Department of Water Resources 2023).

The NMFS green sturgeon recovery plan suggested that larval abundance and distribution may be influenced by spring and summer outflow, and recruitment may be highest in wet years, making water flow an important habitat parameter (National Marine Fisheries Service 2018:12). As noted by NMFS (2018:12), there are correlations between white sturgeon and Delta outflow, which have previously been used to infer potential effects on green sturgeon (ICF International 2016:5-197–5-205). It is uncertain the extent to which the correlations observed for white sturgeon would also apply to green sturgeon, given differences in life history. The mechanism behind the importance of higher flows for white sturgeon is not known and may involve both upstream and downstream (Delta) factors. Hypotheses for the mechanism underlying flow effects include higher flows facilitating young white sturgeon dispersal downstream, providing increased freshwater rearing habitat, increasing spawning activity cued by higher upstream flows, increasing nutrient loading into nursery areas, or increasing downstream migration rate and survival through reduced exposure time to predators (U.S. Fish and Wildlife Service 1995; Israel pers. comm.). Regression analyses conducted for white sturgeon relate year–class strength to March–July and April–May Delta outflow (see Impact AQUA-9 in California Department of Water Resources 2023). The results of the analyses differ, depending on Delta outflow averaging period used: the water-year-type means for March–July under the proposed action were 0%–39% (Table 5C.11-) lower than existing conditions, but 3% greater to 7% lower for April–May (Table 5C.11-5), when requirements of the CDFW (2020) for April–May Delta outflow apply for the proposed action, as well as for existing conditions. The March–July differences in estimated year–class strength reflect lower Delta outflow being required under the proposed action for meeting Delta salinity requirements. It is highly uncertain that less summer Delta outflow under the proposed action—which would occur because of less Delta outflow being necessary to meet Delta salinity requirements—would result in an adverse effect on green sturgeon for the following reasons: the statistical relationships are based on a surrogate species and may be related to upstream flow or Delta inflow as opposed to Delta outflow; changes are limited to differences within water year type, as opposed to hydrological condition–scale differences; the prediction intervals of the statistical relationship range over several orders of magnitude; and there is little difference in estimates based on one (April–May) of the averaging periods examined. For additional information, refer to Impact AQUA-9: *Effects of Operations and Maintenance of Water Conveyance Facilities on White Sturgeon* in Chapter 9 of the Final EIR (California Department of Water Resources 2023).

**Table 5C.11-4. White Sturgeon Year-Class Strength Averaged by Water Year Type, Based on March–July Delta Outflow-Year Class Strength Regression**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 117 | 113 (-3%) |
| Above normal | 46 | 38 (-16%) |
| Below normal | 7 | 5 (-23%) |
| Dry | 1 | 0 (-39%) |
| Critically dry | 0 | 0 (0%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.
EC = existing conditions.

**Table 5C.11-5. White Sturgeon Year-Class Strength Averaged by Water Year Type, Based on April–May Delta Outflow-Year Class Strength Regression**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 144 | 140 (-2%) |
| Above normal | 62 | 58 (-7%) |
| Below normal | 20 | 19 (-3%) |
| Dry | 4 | 4 (3%) |
| Critically dry | 0 | 0 (15%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.
EC = existing conditions.

Maintenance of the north Delta intake facilities for the proposed action would have very limited effects on the adjacent aquatic environment and, hence, very little potential for effects on green sturgeon. Screen pressure washing and sediment jetting would have very small effects at the riverscape scale, based on redistribution of sediment or accumulated vegetation and other materials.

# 5C.12 Effects of Water Facility Operations and Maintenance on Designated Critical Habitat

This effects analysis also provides an analysis of effects on critical habitat for winter-run Chinook salmon, spring-run Chinook salmon, steelhead, and green sturgeon. For all four species, designated critical habitat is present in the Delta and adjacent areas,. The analysis includes potential effects on the following PBFs of critical habitat for each species.

## 5C.12.1 Sacramento River Winter-Run Chinook Salmon

Sacramento winter-run Chinook salmon has designated critical habitat in the Sacramento River.

***PBF 1: Access from Pacific Ocean to spawning areas in the upper Sacramento River***

The available information for hatchery fall-run Chinook salmon indicates that straying rates of fish returning to the Sacramento River are always low (Marston et al. 2012). This suggests relatively little influence of flows and, therefore, no likely difference for potential straying of adult winter-run Chinook salmon.

***PBF 3: Riparian habitat that provides for successful juvenile development and survival***

The changes in riparian and wetland bench inundation from the proposed action would affect this PBF. Restored benches in the north Delta potentially could be affected by the water operations of the proposed action because of changes in water level; less water in the Sacramento River below the north Delta intakes could result in riparian benches being inundated less frequently. The largest differences were for riparian benches in the Sacramento River, downstream of the north Delta diversion, in winter and spring, with little difference in areas well downstream (e.g., Cache Slough).

There was also little difference for wetland benches, which are intended to be inundated at lower water surface elevations that would be available at much lower flows. (See *Riparian and Wetland Bench Inundation* in Section 5C.7.2.2, *Habitat Suitability)*. The proposed action would result in less availability of inundated bench habitat for juvenile winter-run Chinook salmon, compared to existing conditions, with bench inundation being ~5% less under proposed action. DWR proposes to offset effects on the designated critical habitat of winter-run Chinook salmon through restoration of tidal perennial habitat and channel-margin habitat at an approved restoration site and/or the purchase of conservation credits at an approved conservation bank.

***PBF 4: Access downstream so that juveniles can migrate from spawning grounds to San Francisco Bay and the Pacific Ocean***

Operations of the proposed intakes have the potential to negatively affect access downstream from spawning grounds to San Francisco Bay. Negative effects on critical habitat could occur near the intakes during operations; however, the intakes would be screened to meet fishery agency standards for approach velocity, sweeping velocity, and opening size to limit the potential for negative effects on juvenile winter-run Chinook salmon and their critical habitat. Refinements to these criteria would be considered through adaptive management. Overall, the observed experimental results discussed above in Section 5C.7.1.1, and the design of the fish screens indicate that minimal risk would be expected from entrainment or impingement for PBF4 for juvenile winter-run Chinook salmon.

Predation during operation of the new intakes could also affect this PBF. Overall, as discussed above in Section 5C.7.1.1, available information suggests that near-field predation effects of the north Delta intakes on juvenile winter-run Chinook salmon would be limited, albeit with some uncertainty, given that the studies were not of long cylindrical tee screen structures in the north Delta. Fisheries studies would be undertaken to provide information on predatory fish and predation rate at the north Delta intakes, once they are operational, to inform the refinement of future operations and adaptive management, if needed (Appendix 5B).

In addition to near-field effects on access downstream, north Delta intake operations have the potential to have negative far-field effects on access downstream, for example, from flow-survival effects (see *Through-Delta Survival* in Section 5C.7.2.1, *Indirect Mortality within the Delta*). The new operational criteria would include bypass-flow criteria and pulse protection and low-level pumping. As previously discussed, the proposed operations criteria and mitigation[35] are intended to minimize and fully mitigate the potential impacts of the north Delta diversion operations. The adaptive management specific to the north Delta diversion operations would be mainly associated with reviewing abiotic and fish monitoring data and ensuring that operations are consistent with the permitted criteria and within the effects analyzed in the permits. See Chapter 3, Section 3.4, *Real-Time Operational Decision-Making Process,* for additional details. Tables 3.3-1 and 3.3-2 in Chapter 3 provide proposed operations criteria and north Delta intake bypass flow and pulse protection requirements. These criteria will limit the potential for negative effects on winter-run Chinook salmon downstream access critical habitat.

[35] CMP-25: *Tidal Habitat Restoration to Mitigate North Delta Hydrodynamic Effects on Chinook Salmon Juveniles* would reduce negative hydrodynamic effects such as flow reversals in the Sacramento River at Georgiana Slough, thereby reducing the potential for negative effects on winter-run Chinook salmon through-Delta survival as a result of factors such as flow-related changes in migration speed and probability of entering the low-survival interior Delta migration pathway.

## 5C.12.2 Central Valley Spring-Run Chinook Salmon

Central Valley spring-run Chinook salmon has designated critical habitat in the Sacramento River and north Delta.

***PBF 1: Freshwater rearing habitat with water quantity and quality, floodplain connectivity, forage, and natural cover supporting juvenile development, growth, mobility, and survival***

Riparian and wetland bench inundation would be affected by decreasing flows and decreased inundation of riparian benches (bench inundation ~5% less under proposed action; Table 5C.7-17). The proposed action would result in less availability of inundated-bench rearing habitat for juvenile spring-run Chinook salmon. As discussed above, under winter-run Chinook salmon (see PBF 3 in Section 5C.12.1, *Sacramento River Winter-Run Chinook Salmon*), DWR proposes to offset impacts to the designated critical habitat through restoration of tidal perennial habitat and channel-margin habitat at an approved restoration site and/or the purchase of conservation credits at an approved conservation bank (Table 3B-4 in Appendix 3B).

***PBF 2: Freshwater migration corridors free of obstruction and excessive predation with water quantity and quality conditions and natural cover supporting juvenile and adult mobility and survival***

As noted above for winter-run Chinook salmon, there is the potential for negative near-field and far-field effects on freshwater migration corridors and downstream access. Fish screen design and the relatively small extent of the intake structures would limit the potential for negative near-field effects. Operational criteria and mitigation would limit the negative far-field effects such as the potential for lower survival caused by diversions at the north Delta intakes reducing river flow. Proposed action–related changes to flow would not be expected to affect adult mobility and survival, as discussed above for winter-run Chinook salmon.

***PBF 3: Estuarine areas free of obstruction and excessive predation supporting mobility and survival, with water quantity, water quality, and salinity conditions supporting juvenile and adult physiological transitions between fresh and saltwater, and natural cover and forage supporting growth, maturation, and survival***

Hydrodynamic effects in the north Delta from the proposed action would cause reduced velocities, increased reversing flow just downstream of Georgiana Slough, and increased flow into the interior Delta at Georgiana Slough. These changes in flows would tend to reduce spring-run Chinook salmon through-Delta survival, although effects on critical habitat would be limited by operational criteria and tidal habitat restoration.

## 5C.12.3 Central Valley Steelhead

Central Valley steelhead has designated critical habitat in the Sacramento River and throughout the Delta.

***PBF 1: Freshwater rearing habitat with water quantity and quality, floodplain connectivity, forage, and natural cover supporting juvenile development, growth, mobility, and survival***

As discussed above for spring-run Chinook salmon (*PBF 1* in Section 5C.12.2, *Central Valley Spring-Run Chinook Salmon*), there would be less inundation of riparian benches (bench inundation ~5%

less under proposed action; Table 5C.7-17). DWR proposes to offset impacts to the designated critical habitat through restoration of tidal perennial habitat and channel-margin habitat at an approved restoration site and/or the purchase of conservation credits at an approved conservation bank (see Table 3B-4 in Appendix 3B).

***PBF 2: Freshwater migration corridors free of obstruction and excessive predation with water quantity and quality conditions and natural cover supporting juvenile and adult mobility and survival***

As noted above for winter-run and spring-run Chinook salmon, there is the potential for negative near-field and far-field effects on freshwater migration corridors and downstream access. Fish screen design and the relatively small extent of the intake structures would limit the potential for negative near-field effects. Operational criteria and mitigation would limit the negative far-field effects such as the potential for lower survival caused by diversions at the north Delta intakes reducing river flow. Proposed action–related changes to flow would not be expected to affect adult mobility and survival, as discussed above for winter-run Chinook salmon.

***PBF 3: Estuarine areas free of obstruction and excessive predation supporting mobility and survival, with water quantity, water quality, and salinity conditions supporting juvenile and adult physiological transitions between fresh and saltwater, and natural cover and forage supporting growth, maturation, and survival***

Entrainment at the south Delta export facilities would occur, but the results from application of the salvage-density method illustrated that south Delta exports generally would be similar or slightly lower under the proposed action relative to existing conditions at the SWP Banks and CVP Jones south Delta export facilities during the time period when steelhead generally are salvaged. This generally indicates that the effects of the proposed action on critical habitat for steelhead should not be greatly different than existing conditions in the south Delta. The existing facilities in the south Delta would be governed by the applicable regulatory requirements, such as the SWRCB's B*ay-Delta Water Quality Control Plan*, federal BiOps (National Marine Fisheries Service 2019; U.S. Fish and Wildlife Service 2019), California Endangered Species Act Incidental Take Permit for SWP (California Department of Fish and Wildlife 2020), and USACE Clifton Court diversion limits.

Adult entrainment from operational activities in the south Delta could be affected under the proposed action, but generally would be similar or slightly less than under existing conditions, indicating that entrainment risk for adult steelhead generally would be similar or slightly less than existing conditions (see Section 5C.10, *Effects of Operation and Maintenance of Water Conveyance Facilities on California Central Valley Steelhead*).

Hydrodynamic effects in the north Delta from the proposed action would cause reduced velocities, increased reversing flow just downstream of Georgiana Slough, and increased flow into the interior Delta at Georgiana Slough. These changes in flows would tend to reduce steelhead through-Delta survival, although effects on critical habitat would be limited by operational criteria and tidal habitat restoration. In the San Joaquin River, studies of acoustically tagged juvenile steelhead found San Joaquin River flow at Vernalis, presence of a rock barrier at Head of Old River, fish size, and year to be significant predictors of through-Delta survival, whereas south Delta exports were not supported as significant predictors of survival (Buchanan et al. 2021). Given the absence of a Head of Old River rock barrier under the proposed action and existing conditions, as well as essentially identical Vernalis flows (Table 5C.10-1, Table 5C.10-2, Table 5C.10-3, and Table 5C.10-4), there would be no

difference in juvenile steelhead through-Delta survival from the San Joaquin River Basin as a result of the proposed action.

## 5C.12.4 Green Sturgeon

***PBF 1: Water flow regime with flow magnitude, duration, seasonality, and rate-of-change supporting growth, survival, and migration of all life stages***

As described in Section 5C.11, *Effects of Operations and Maintenance of Water Conveyance Facilities on Southern DPS Green Sturgeon*, the NMFS green sturgeon recovery plan suggested that green sturgeon may be may be influenced by spring and summer outflow (National Marine Fisheries Service 2018:12), with correlations between white sturgeon year-class strength and Delta outflow applied to infer potential effects on green sturgeon. This could, therefore, be an effect on PBF 1 for green sturgeon. As discussed in Section 5C.11, the results of the regression analyses suggested the potential for negative effects as a result of the proposed action. It is highly uncertain that less summer Delta outflow under the proposed action—which would occur because less Delta outflow would be necessary to meet Delta salinity requirements—would result in an adverse effect on green sturgeon critical habitat for the following reasons: the statistical relationships are based on a surrogate species and may be related to upstream flow or Delta inflow as opposed to Delta outflow; changes are limited to differences within water-year type, as opposed to hydrological condition–scale differences; the prediction intervals of the statistical relationship range over several orders of magnitude; and there is little difference in estimates based on one (April–May) of the averaging periods examined.

***PBF 2: Migratory corridor free of obstruction and excessive predation with water quantity and quality conditions supporting safe and timely passage of juveniles and adults within and between riverine, estuarine, and marine habitats***

Entrainment and impingement in the north Delta and south Delta intakes could affect the migratory corridor. Larval green sturgeon are at the same risk of entrainment as the other species discussed above, so there is little risk of entrainment at the north Delta intakes. The cylindrical tee-screen design has been noted to reduce the potential for near-field effects because of the bow wave hydraulic effect (Coutant 2021, albeit with the caveats previously described for winter-run Chinook salmon). In the south Delta, salvage of green sturgeon has been very low in recent years, and entrainment is regarded as a threat of low importance to the population in the NMFS green sturgeon recovery plan (National Marine Fisheries Service 2018:26). The results of the analysis suggest that there would be very little difference in south Delta entrainment risk between the proposed action and existing conditions.

Selenium bioaccumulation is a concern for sturgeon. Changes in water operations under the proposed action would have little effect on sturgeon tissue concentrations of selenium, relative to existing conditions. Methylmercury is also a concern for green sturgeon (Lee et al. 2011), but analyses found there would be little difference in fish tissue methylmercury between the proposed action and existing conditions. Therefore, there would be no effect on critical habitat.

# 5C.13 Effects on Southern Resident Killer Whale and Southern Resident DPS Killer Whale Critical Habitat

The proposed actions' construction, operation, or maintenance would not directly affect ocean conditions; however, operations have the potential to affect killer whales indirectly by influencing the number of Chinook salmon that enter the Pacific Ocean and become available as a food supply (Figure 5C.13-1). This potential impact was evaluated qualitatively, based on the potential effects on Chinook salmon, particularly any changes in production. The proposed action has the potential to affect Southern Resident DPS killer whale by altering the amount of Chinook salmon from the Central Valley that enter the Pacific Ocean.

Significant changes in food availability for killer whales have occurred over the past 150 years, largely because of human effects on prey species. Salmon abundance has been reduced over the entire range of the Southern Resident DPS killer whale, from British Columbia to California. The *Recovery Plan for Southern Resident DPS Killer Whales* (National Marine Fisheries Service 2008) indicates that wild salmon have declined, primarily because of degraded aquatic ecosystems, overharvesting, and production of fish in hatcheries. The recovery plan supports restoration efforts to rebuild depleted salmon populations and other prey to ensure an adequate food base for Southern Resident DPS killer whales. Central Valley streams produce Chinook salmon that contribute to the diet of Southern Resident DPS whales. The number of Central Valley salmon that annually enter the ocean and survive to a size susceptible to predation by killer whales is not known. However, estimates of total Chinook salmon production produced by the Comprehensive Assessment and Monitoring Program, administered by USFWS and Reclamation, provide an approximation of the size of the ocean population of Central Valley Chinook salmon potentially available to killer whales.

Data on the abundance and composition of Central Valley Chinook salmon indicates that approximately 75% of all Central Valley-origin Chinook salmon available for consumption by Southern Resident DPS killer whales are produced by Central Valley fall-run Chinook salmon hatcheries (Palmer-Zwhalen and Kormos 2013). Many Central Valley hatchery fall-run Chinook salmon are released directly into San Francisco Bay and, thus, bypass potential effects from project operations, even where there might be a nexus with SWP and CVP operations. The purpose of Central Valley fall-run Chinook salmon hatchery programs is to produce large numbers of fish independent of freshwater conditions.

Since fall-run Chinook salmon hatcheries began operating more than 40 years ago, the only period of exceptionally low returns was attributed principally to unusual ocean conditions (Lindley et al. 2007). Ocean commercial and recreational fisheries annually harvest hundreds of thousands of Chinook salmon. The Northwest Region of NMFS (2009) used a model that estimates prey reduction associated with the salmon fishery and which considers the metabolic requirements of killer whales and the remaining levels of prey availability. Their analysis concluded that the salmon fishery was not likely to result in jeopardy for Southern Resident DPS killer whale.

Chinook salmon is an important component of the killer whale diet, and the Independent Science Panel reported that Southern Resident DPS killer whales depend on Chinook salmon as a critical food resource (Hilborn et al. 2012). Hanson et al. (2010) analyzed tissues from predation events and feces to confirm that Chinook salmon were the most frequent prey item for killer whales in two

regions of the whale's summer range off the coast of British Columbia and Washington state, representing more than 90% of the diet in July and August. Samples indicated that when Southern Resident DPS killer whales are in inland waters from May to September, they consume Chinook salmon stocks that originate from regions that include the Fraser River, Puget Sound, the Central British Columbia Coast, West and East Vancouver Island, and California's Central Valley (Hanson et al. 2010). Available fish harvest data and killer whale diet and contaminants analyses suggest that Central Valley Chinook salmon comprise a significant portion of the total abundance of Chinook salmon available to killer whale throughout their range in most, if not all, years (National Marine Fisheries Service 2019).

Ford et al. (2016) helped confirm the importance of Chinook salmon to Southern Resident DPS killer whales in the summer months using DNA sequencing from whale feces. The researchers found that more than 90 percent of the whale's inferred diet consisted of salmonids; almost 80 percent was Chinook Salmon. Bellinger et al. (2015) estimated that Central Valley Chinook salmon comprised about 22 percent of the Chinook salmon sampled off the Oregon coast and about 50 percent of those sampled off the California coast (south to Big Sur). Although killer whale, an apex predator, eats a variety of other species, Central Valley Chinook Salmon (all runs) can be estimated to make up approximately 40% of the killer whale diet when killer whales are off the California coast and 18% of the killer whale diet when the killer whales are off the Oregon coast.

As discussed by NMFS (2017:831), individual-level effects on killer whale from changes in Chinook salmon prey could include changes in areas searched for prey and consequent changes in energy expended for such searches, resulting in changes in energy intake and the risk of nutritional stress. Changes in energy consumption and nutritional stress could lead to changes in body size, condition, and growth and changes in reproductive and survival rates for adults (National Marine Fisheries Service 2017:831).

The southern DPS of killer whales is thought to move with the seasonal abundance of salmonids returning to natal rivers to spawn from early summer through fall. There are correlations between the occurrence of southern residents and commercial and sport salmon fishery catches in US waters off southeastern Vancouver Island and in Puget Sound (Heimlich-Boran 1986). This population of killer whales is commonly found off southeastern Vancouver Island and in Puget Sound, Washington, from late spring to late fall (Ford 2006, Osborne 1999). The winter distribution of Southern Resident DPS killer whales is poorly known. K and L pods have been observed off the mouth of the Columbia River and in Monterey Bay, California, associated with local production of Chinook Salmon (Wiles 2004; Balcomb 2006).

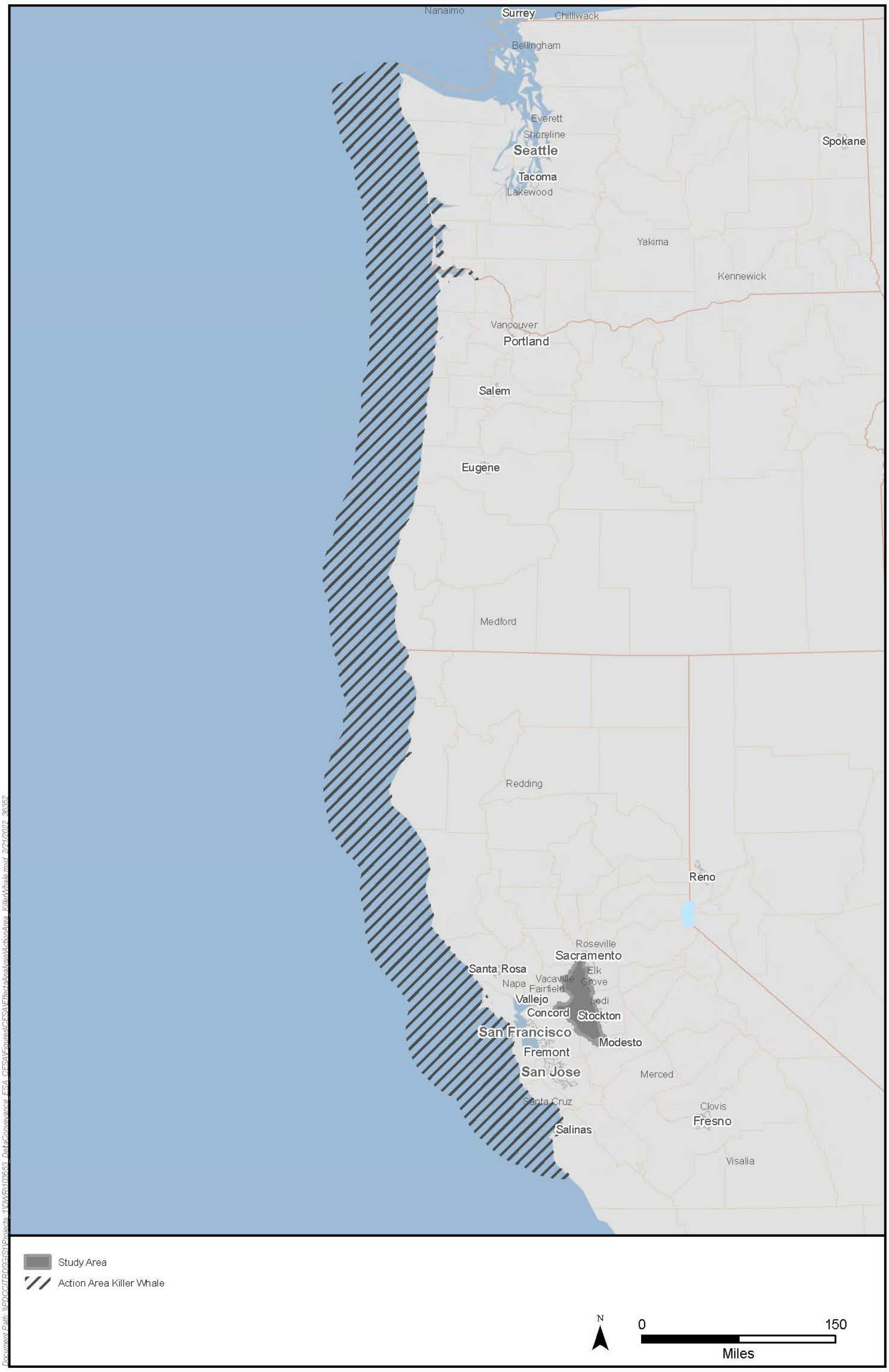


**Figure 5C.13-1. Delta Water Conveyance Action Area for the Southern Resident DPS Killer Whale**

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## 5C.13.1 Effects of Operations

The operations of the north Delta intakes would have negative effects on Chinook salmon. The analyses discussed above for winter-run (Section 5C.7) and spring-run (Section 5C.8) Chinook salmon demonstrate that the near-field effects of the north Delta intakes would be limited, but acknowledge some uncertainty and noted that fishery studies of juvenile Chinook salmon distribution and survival, as well as predatory fish and predation, would be undertaken to inform the adaptive-management process. Near-field effects of south Delta exports (i.e., entrainment) under the proposed action would be similar to or potentially somewhat less than existing conditions because some diversions would occur at the north Delta intakes, instead of the south Delta facilities. Analyses of habitat suitability suggested limited potential for negative effects of the proposed action relative to existing conditions on water quality.

Approach and sweeping velocity criteria at the north Delta intake screens would minimize potential for near-field effects (see *Entrainment and Impingement* in Section 5C.7.1.1). In addition, new operational criteria would include bypass-flow criteria and pulse protection and low-level pumping. The proposed operations criteria and mitigation is intended to minimize and fully mitigate the potential impacts of the north Delta diversion operations. The adaptive management specific to the north Delta diversion operations would be mainly associated with reviewing real-time abiotic and fish monitoring data and ensuring proposed weekly, daily and sub-daily operations are consistent with the permitted criteria and within the effects analyzed in the permits. See Chapter 3, Section 3.4, *Real-Time Operational Decision-Making Process* for additional details. Tables 3.3-1 and 3.3-2 in Chapter 3 provide proposed operations criteria and north Delta intake bypass flow and pulse protection requirements.

In addition to listed (winter-run and spring-run) Chinook salmon, the proposed action would have the potential for similar types of negative effects on fall-run and late fall–run Chinook salmon. For example, lower through-Delta survival (Tables 5C.9-1 and 5C.9-2) and similar or lower potential for south Delta entrainment (Tables 5C.13-1, 5C.13-4, 5C.13-5, and 5C.13-6).

The available information indicates that diversion at the north Delta diversion would negatively affect juvenile Chinook salmon through flow-survival and habitat impacts. To address these effects, identified conservation measures would be implemented. These specifically would include tidal habitat restoration to mitigate hydrodynamic effects on Chinook salmon juveniles and channel-margin habitat restoration for operations effects on Chinook salmon juveniles. These efforts would reduce negative hydrodynamic effects, such as flow reversals in the Sacramento River at Georgiana Slough and reduced effects from reduced inundation of riparian and wetland benches as a result of north Delta diversion operations.

Effects on San Joaquin and Mokelumne fall-run Chinook salmon generally would be similar to existing conditions. South Delta operations under the proposed action generally would give similar through-Delta survival as existing conditions for fall-run Chinook salmon from the San Joaquin River (Table 5C.13-2). South Delta exports, an indicator of Mokelumne River fall-run Chinook salmon entrainment risk (Workman 2018:14), would be similar or less during the March–June juvenile migration period (Tables 5C.13-3, 5C.13-10, 5C.13-11, and 5C.13-12).

Although the proposed action is likely to affect individual Central Valley Chinook salmon negatively from operation of the export facilities, this reduction is not expected to result in decreased overall ocean abundance or availability of prey for killer whale, when weighed against hatchery production.

Studies have suggested that most Chinook salmon in the coastal ocean off California appear to be of hatchery origin (Barnett-Johnson et al. 2007; Johnson et al. 2015). The potential effects of the proposed action on Central Valley Chinook salmon stocks would be expected to be zero to minimal on hatchery-origin juvenile Chinook salmon released downstream of the Delta. The percentage of hatchery-origin fish released downstream of the Delta has been variable over time (Sturrock et al. 2019). For example, from the mid-1980s to 2012, the proportion of hatchery fall-run Chinook salmon juveniles released downstream of the Delta by state and federal hatcheries varied from around 20%–60% (Huber and Carlson 2015). Similarly, from 2013 to 2017, the percentage of juvenile fall-run and spring-run Chinook salmon released by state Central Valley hatcheries downstream of the Delta varied between 24% (2016) and 60% (2013) (California Department of Fish and Wildlife 2018).

Due to the generally medium priority (18%–41% of the diet, only when off the coast of California and Oregon) of the Central Valley stocks that could be affected by proposed action among many stocks contributing to the Southern Resident DPS killer whale diet, and the contribution of hatchery-origin Chinook salmon released downstream of the potential influence of proposed action, population-level effects of the proposed action to Southern Resident DPS killer whale prey species are not expected.

### 5C.13.2 Effects of Maintenance

Maintenance of the north Delta intake facilities for the proposed action would have very limited effects on the adjacent aquatic environment and, hence, very little potential for effects on Chinook salmon. Screen pressure washing and sediment jetting would have very small effects at the riverscape scale, based on redistribution of sediment or accumulated vegetation and other materials. Thus, maintenance is not anticipated to affect the Southern Resident DPS killer whale.

### 5C.13.3 Effects of Conservation Measures

Refer to Chapter 5, Section 5.7.1, *Effects of Conservation Measures on Southern Resident DPS Killer Whale*.

### 5C.13.4 Effects on Southern Resident Killer Whale Critical Habitat

Refer to Chapter 5, Section 5.7.2, *Effects on Southern Resident Killer Whale Critical Habitat*.

## 5C.14 Cumulative Effects on Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale

Refer to Chapter 5, Section 5.8, *Cumulative Effects on Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*.

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Israel, Josh. Fisheries Biologist, U.S. Bureau of Reclamation. February 20, 2012—Telephone communication with Rick Wilder (ICF International) discussing flow correlates of white sturgeon year class strength, possible mechanisms for relationships, and previous analyses to determine correlations and reporting of them.

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# Appendix 5D
# Bay-Delta Methods and Results

This appendix includes quantitative methods and selected results for analyses used in support of Chapter 5, *Effects Analysis for Chinook Salmon, California Central Valley Steelhead, Green Sturgeon, and Killer Whale*. The proposed action is included in the analysis of the *Delta Conveyance Project Final Environmental Impact Report* (Final EIR) (California Department of Water Resources 2023).as Alternative 5 ), often abbreviated as Alt 5.

## 5D.1 Juvenile Chinook Salmon Screen Passage Duration

Swanson et al. (2004) found that juvenile Chinook salmon mortality and injury rates in fish treadmill experiments were not statistically related to flow regime or screen contact rates. Although Swanson et al. (2004) provide equations to estimate screen contact rates for juvenile Chinook salmon, preliminary calculations for this effects analysis suggested that these equations did not perform well for the lengths of screen contemplated for the north Delta diversions (NDD). Screen passage time is another useful measure of potential effects on Chinook salmon, with shorter passage times being desirable. To illustrate the potential passage time at the proposed north Delta intake screens, screen passage time for juvenile Chinook salmon of the smallest (4.4 centimeters [cm] standard length) and largest (7.9 cm standard length) sizes examined by Swanson et al. (2004) was calculated by dividing screen length by screen passage velocity, based on Swanson et al.'s (2004) equation for the latter.

> Screen passage velocity (centimeters per second [cm/s]) = 30.94 – 11.87(day/night; day =1, night = 2) - 1.32(sweeping velocity, cm/s) + 0.72(swimming velocity, cm/s) – 0.39(orientation, degrees) + 0.27(sweeping velocity × day/night); n = 124, $r^2$ = 0.9064, SEE = 6.56

Swimming velocity and orientation for the above equation were calculated using other equations from Swanson et al. (2004).

> Swimming velocity (cm/s) = 27.35 – 12.85(day/night; day =1, night = 2) - 1.25(standard length, cm) + 0.21(resultant water velocity [cm/s] × day/night); n = 142, $r^2$ = 0.7517, SEE = 4.09

> Orientation (degrees) = 112.7 – 41.1(day/night, day = 1, night = 2) + 3.6(temperature, °C) – 1.4(resultant water velocity, cm/s) -1.1(swimming velocity, cm/s) – 0.3(flow angle, degrees) + 0.6(resultant water velocity × day/night); n = 124, $r^2$ = 0.4877, SEE = 18.8

In the above equations, resultant water velocity was calculated as the square root of (approach velocity$^2$ + sweeping velocity$^2$), and flow angle was calculated as the arctangent of (approach velocity)/(sweeping velocity), as described by Swanson et al. (2004). Water temperature was assumed to be 12 degrees Celsius, consistent with "winter and spring" conditions noted by Swanson et al. (2004). Note that experimental fish 5.6–7.9 cm were not tested at night, so there is extrapolation beyond the tested data in estimates of 7.9-cm fish in nighttime conditions.

# 5D.2 Salvage-Density Method

## 5D.2.1 Methods

- All data were downloaded from https://apps.wildlife.ca.gov/Salvage.[1]
- Water years 2009–2020 were included, as these water years were complete and representative of recent salvage patterns, and the water year type was known (California Department of Water Resources 2021a).
- Juvenile salmonids with clipped and unclipped adipose fins were included, as together they represent hatchery-origin and wild fish that are all part of the Evolutionarily Significant Unit.
- Daily salvage (or loss for juvenile salmonids) density (fish per thousand acre-feet of water exported) was calculated for the State Water Project and Central Valley Project south Delta export facilities.
- The daily loss or salvage density values for each month, facility, and water year type were multiplied by the CalSim-modeled exports (1922–2015) for the modeled scenarios. Note that there were no above normal years in 2009–2020, so the monthly pattern for wet years was used, and only percentage difference was reported in the results.

The salvage-density method gives outputs in terms of numbers of fish salvaged (or lost), but these outputs are not predictions of future entrainment but rather differences in south Delta exports between the proposed action and existing conditions weighted by historical salvage or loss density of fish.

## 5D.2.2 Results

Overall annual mean results by water year type are discussed in Appendix 5C, *Operations and Maintenance Effects Analysis for Chinook Salmon, California Central Valley Steelhead, Green Sturgeon, and Killer Whale*. Table 5D.2-1 through Table 5D.2-12 below show mean results by water year type and month.

**Table 5D.2-1. Entrainment Loss of Juvenile Winter-Run Chinook Salmon at SWP Banks Pumping Plant, Averaged by Water Year Type and Month, Based on the Salvage-Density Method**

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Wet | Jan | 170 | 168 (-1%) |
| Wet | Feb | 538 | 491 (-9%) |
| Wet | Mar | 1,219 | 1,064 (-13%) |
| Wet | Apr | 107 | 88 (-18%) |
| Wet | May | 3 | 3 (-5%) |
| Wet | Jun | 0 | 0 (0%) |
| Wet | Jul | 0 | 0 (0%) |
| Wet | Aug | 0 | 0 (0%) |

[1] This website includes salvage density for all species and loss density for salmonids; the latter was used in this analysis.

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Wet | Sep | 0 | 0 (0%) |
| Wet | Oct | 0 | 0 (0%) |
| Wet | Nov | 0 | 0 (0%) |
| Wet | Dec | 180 | 172 (-4%) |
| Above normal | Jan | N/A | (1%) |
| Above normal | Feb | N/A | (-2%) |
| Above normal | Mar | N/A | (-7%) |
| Above normal | Apr | N/A | (-22%) |
| Above normal | May | N/A | (-11%) |
| Above normal | Jun | N/A | (0%) |
| Above normal | Jul | N/A | (0%) |
| Above normal | Aug | N/A | (0%) |
| Above normal | Sep | N/A | (0%) |
| Above normal | Oct | N/A | (0%) |
| Above normal | Nov | N/A | (0%) |
| Above normal | Dec | N/A | (-10%) |
| Below normal | Jan | 204 | 205 (0%) |
| Below normal | Feb | 590 | 569 (-3%) |
| Below normal | Mar | 685 | 567 (-17%) |
| Below normal | Apr | 26 | 26 (0%) |
| Below normal | May | 9 | 8 (-8%) |
| Below normal | Jun | 0 | 0 (0%) |
| Below normal | Jul | 0 | 0 (0%) |
| Below normal | Aug | 0 | 0 (0%) |
| Below normal | Sep | 0 | 0 (0%) |
| Below normal | Oct | 0 | 0 (0%) |
| Below normal | Nov | 0 | 0 (0%) |
| Below normal | Dec | 5 | 4 (-4%) |
| Dry | Jan | 110 | 101 (-9%) |
| Dry | Feb | 123 | 116 (-6%) |
| Dry | Mar | 619 | 579 (-7%) |
| Dry | Apr | 16 | 17 (0%) |
| Dry | May | 0 | 0 (0%) |
| Dry | Jun | 0 | 0 (0%) |
| Dry | Jul | 0 | 0 (0%) |
| Dry | Aug | 0 | 0 (0%) |
| Dry | Sep | 0 | 0 (0%) |
| Dry | Oct | 0 | 0 (0%) |

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Dry | Nov | 0 | 0 (0%) |
| Dry | Dec | 141 | 128 (-10%) |
| Critically dry | Jan | 97 | 91 (-6%) |
| Critically dry | Feb | 119 | 111 (-6%) |
| Critically dry | Mar | 564 | 517 (-8%) |
| Critically dry | Apr | 16 | 16 (1%) |
| Critically dry | May | 0 | 0 (0%) |
| Critically dry | Jun | 0 | 0 (0%) |
| Critically dry | Jul | 0 | 0 (0%) |
| Critically dry | Aug | 0 | 0 (0%) |
| Critically dry | Sep | 0 | 0 (0%) |
| Critically dry | Oct | 0 | 0 (0%) |
| Critically dry | Nov | 0 | 0 (0%) |
| Critically dry | Dec | 94 | 89 (-6%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare the proposed action to existing conditions.
N/A = not applicable; SWP = State Water Project.

### Table 5D.2-2. Entrainment Loss of Juvenile Winter-Run Chinook Salmon at CVP Jones Pumping Plant, Averaged by Water Year Type and Month, Based on the Salvage-Density Method

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Wet | Jan | 33 | 33 (-1%) |
| Wet | Feb | 50 | 51 (2%) |
| Wet | Mar | 93 | 98 (5%) |
| Wet | Apr | 3 | 3 (6%) |
| Wet | May | 0 | 0 (0%) |
| Wet | Jun | 0 | 0 (0%) |
| Wet | Jul | 0 | 0 (0%) |
| Wet | Aug | 0 | 0 (0%) |
| Wet | Sep | 0 | 0 (0%) |
| Wet | Oct | 0 | 0 (0%) |
| Wet | Nov | 0 | 0 (0%) |
| Wet | Dec | 49 | 49 (0%) |
| Above normal | Jan | N/A | (-1%) |
| Above normal | Feb | N/A | (2%) |
| Above normal | Mar | N/A | (7%) |
| Above normal | Apr | N/A | (8%) |

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Above normal | May | N/A | (0%) |
| Above normal | Jun | N/A | (0%) |
| Above normal | Jul | N/A | (0%) |
| Above normal | Aug | N/A | (0%) |
| Above normal | Sep | N/A | (0%) |
| Above normal | Oct | N/A | (0%) |
| Above normal | Nov | N/A | (0%) |
| Above normal | Dec | N/A | (0%) |
| Below normal | Jan | 107 | 110 (3%) |
| Below normal | Feb | 159 | 173 (9%) |
| Below normal | Mar | 224 | 232 (4%) |
| Below normal | Apr | 35 | 35 (0%) |
| Below normal | May | 0 | 0 (0%) |
| Below normal | Jun | 0 | 0 (0%) |
| Below normal | Jul | 0 | 0 (0%) |
| Below normal | Aug | 0 | 0 (0%) |
| Below normal | Sep | 0 | 0 (0%) |
| Below normal | Oct | 0 | 0 (0%) |
| Below normal | Nov | 0 | 0 (0%) |
| Below normal | Dec | 1 | 1 (-8%) |
| Dry | Jan | 74 | 76 (3%) |
| Dry | Feb | 72 | 78 (9%) |
| Dry | Mar | 135 | 140 (4%) |
| Dry | Apr | 7 | 7 (0%) |
| Dry | May | 0 | 0 (0%) |
| Dry | Jun | 0 | 0 (0%) |
| Dry | Jul | 0 | 0 (0%) |
| Dry | Aug | 0 | 0 (0%) |
| Dry | Sep | 0 | 0 (0%) |
| Dry | Oct | 0 | 0 (0%) |
| Dry | Nov | 0 | 0 (0%) |
| Dry | Dec | 17 | 15 (-8%) |
| Critically dry | Jan | 28 | 29 (1%) |
| Critically dry | Feb | 0 | 0 (0%) |
| Critically dry | Mar | 40 | 40 (1%) |
| Critically dry | Apr | 4 | 4 (1%) |
| Critically dry | May | 0 | 0 (0%) |
| Critically dry | Jun | 0 | 0 (0%) |

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Critically dry | Jul | 0 | 0 (0%) |
| Critically dry | Aug | 0 | 0 (0%) |
| Critically dry | Sep | 0 | 0 (0%) |
| Critically dry | Oct | 0 | 0 (0%) |
| Critically dry | Nov | 0 | 0 (0%) |
| Critically dry | Dec | 10 | 10 (1%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare the proposed action to existing conditions.
CVP = Central Valley Project; N/A = not applicable.

### Table 5D.2-3. Entrainment Loss of Juvenile Spring-Run Chinook Salmon at SWP Banks Pumping Plant, Averaged by Water Year Type and Month, Based on the Salvage-Density Method

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Wet | Jan | 5 | 5 (-1%) |
| Wet | Feb | 62 | 56 (-9%) |
| Wet | Mar | 1,558 | 1,361 (-13%) |
| Wet | Apr | 14,063 | 11,527 (-18%) |
| Wet | May | 25,987 | 24,786 (-5%) |
| Wet | Jun | 2,037 | 1,941 (-5%) |
| Wet | Jul | 0 | 0 (0%) |
| Wet | Aug | 0 | 0 (0%) |
| Wet | Sep | 0 | 0 (0%) |
| Wet | Oct | 0 | 0 (0%) |
| Wet | Nov | 0 | 0 (0%) |
| Wet | Dec | 0 | 0 (0%) |
| Above normal | Jan | N/A | (1%) |
| Above normal | Feb | N/A | (-2%) |
| Above normal | Mar | N/A | (-7%) |
| Above normal | Apr | N/A | (-22%) |
| Above normal | May | N/A | (-11%) |
| Above normal | Jun | N/A | (-9%) |
| Above normal | Jul | N/A | (0%) |
| Above normal | Aug | N/A | (0%) |
| Above normal | Sep | N/A | (0%) |
| Above normal | Oct | N/A | (0%) |
| Above normal | Nov | N/A | (0%) |
| Above normal | Dec | N/A | (0%) |

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Below normal | Jan | 0 | 0 (0%) |
| Below normal | Feb | 0 | 0 (0%) |
| Below normal | Mar | 571 | 473 (-17%) |
| Below normal | Apr | 1,624 | 1,627 (0%) |
| Below normal | May | 1,038 | 958 (-8%) |
| Below normal | Jun | 23 | 22 (-5%) |
| Below normal | Jul | 0 | 0 (0%) |
| Below normal | Aug | 0 | 0 (0%) |
| Below normal | Sep | 0 | 0 (0%) |
| Below normal | Oct | 0 | 0 (0%) |
| Below normal | Nov | 0 | 0 (0%) |
| Below normal | Dec | 0 | 0 (0%) |
| Dry | Jan | 0 | 0 (0%) |
| Dry | Feb | 0 | 0 (0%) |
| Dry | Mar | 118 | 110 (-7%) |
| Dry | Apr | 2,182 | 2,189 (0%) |
| Dry | May | 820 | 821 (0%) |
| Dry | Jun | 0 | 0 (0%) |
| Dry | Jul | 0 | 0 (0%) |
| Dry | Aug | 0 | 0 (0%) |
| Dry | Sep | 0 | 0 (0%) |
| Dry | Oct | 0 | 0 (0%) |
| Dry | Nov | 0 | 0 (0%) |
| Dry | Dec | 0 | 0 (0%) |
| Critically dry | Jan | 0 | 0 (0%) |
| Critically dry | Feb | 0 | 0 (0%) |
| Critically dry | Mar | 108 | 99 (-8%) |
| Critically dry | Apr | 2,111 | 2,138 (1%) |
| Critically dry | May | 824 | 801 (-3%) |
| Critically dry | Jun | 0 | 0 (0%) |
| Critically dry | Jul | 0 | 0 (0%) |
| Critically dry | Aug | 0 | 0 (0%) |
| Critically dry | Sep | 0 | 0 (0%) |
| Critically dry | Oct | 0 | 0 (0%) |
| Critically dry | Nov | 0 | 0 (0%) |
| Critically dry | Dec | 0 | 0 (0%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019,

which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare the proposed action to existing conditions.
N/A = not applicable; SWP = State Water Project.

**Table 5D.2-4. Entrainment Loss of Juvenile Spring-Run Chinook Salmon at CVP Jones Pumping Plant, Averaged by Water Year Type and Month, Based on the Salvage-Density Method**

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Wet | Jan | 3 | 3 (-1%) |
| Wet | Feb | 12 | 12 (2%) |
| Wet | Mar | 145 | 152 (5%) |
| Wet | Apr | 1,768 | 1,867 (6%) |
| Wet | May | 5,914 | 6,305 (7%) |
| Wet | Jun | 409 | 429 (5%) |
| Wet | Jul | 0 | 0 (0%) |
| Wet | Aug | 0 | 0 (0%) |
| Wet | Sep | 0 | 0 (0%) |
| Wet | Oct | 0 | 0 (0%) |
| Wet | Nov | 0 | 0 (0%) |
| Wet | Dec | 8 | 8 (0%) |
| Above normal | Jan | N/A | (-1%) |
| Above normal | Feb | N/A | (2%) |
| Above normal | Mar | N/A | (7%) |
| Above normal | Apr | N/A | (8%) |
| Above normal | May | N/A | (9%) |
| Above normal | Jun | N/A | (6%) |
| Above normal | Jul | N/A | (0%) |
| Above normal | Aug | N/A | (0%) |
| Above normal | Sep | N/A | (0%) |
| Above normal | Oct | N/A | (0%) |
| Above normal | Nov | N/A | (0%) |
| Above normal | Dec | N/A | (0%) |
| Below normal | Jan | 1 | 1 (3%) |
| Below normal | Feb | 6 | 6 (9%) |
| Below normal | Mar | 576 | 598 (4%) |
| Below normal | Apr | 1,687 | 1,689 (0%) |
| Below normal | May | 1,121 | 1,115 (-1%) |
| Below normal | Jun | 10 | 10 (-1%) |
| Below normal | Jul | 0 | 0 (0%) |
| Below normal | Aug | 0 | 0 (0%) |
| Below normal | Sep | 0 | 0 (0%) |

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Below normal | Oct | 0 | 0 (0%) |
| Below normal | Nov | 0 | 0 (0%) |
| Below normal | Dec | 0 | 0 (0%) |
| Dry | Jan | 0 | 0 (0%) |
| Dry | Feb | 0 | 0 (0%) |
| Dry | Mar | 194 | 202 (4%) |
| Dry | Apr | 2,063 | 2,064 (0%) |
| Dry | May | 889 | 884 (-1%) |
| Dry | Jun | 6 | 6 (-1%) |
| Dry | Jul | 0 | 0 (0%) |
| Dry | Aug | 0 | 0 (0%) |
| Dry | Sep | 0 | 0 (0%) |
| Dry | Oct | 0 | 0 (0%) |
| Dry | Nov | 0 | 0 (0%) |
| Dry | Dec | 0 | 0 (0%) |
| Critically dry | Jan | 0 | 0 (0%) |
| Critically dry | Feb | 0 | 0 (0%) |
| Critically dry | Mar | 51 | 52 (1%) |
| Critically dry | Apr | 87 | 88 (1%) |
| Critically dry | May | 18 | 18 (-1%) |
| Critically dry | Jun | 0 | 0 (0%) |
| Critically dry | Jul | 0 | 0 (0%) |
| Critically dry | Aug | 0 | 0 (0%) |
| Critically dry | Sep | 0 | 0 (0%) |
| Critically dry | Oct | 0 | 0 (0%) |
| Critically dry | Nov | 0 | 0 (0%) |
| Critically dry | Dec | 0 | 0 (0%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare the proposed action to existing conditions.
CVP = Central Valley Project; N/A = not applicable.

### Table 5D.2-5. Entrainment Loss of Juvenile Fall-Run Chinook Salmon at SWP Banks Pumping Plant, Averaged by Water Year Type and Month, Based on the Salvage-Density Method

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Wet | Jan | 1,054 | 1,043 (-1%) |
| Wet | Feb | 2,765 | 2,525 (-9%) |
| Wet | Mar | 330 | 288 (-13%) |

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Wet | Apr | 437 | 358 (-18%) |
| Wet | May | 9,011 | 8,595 (-5%) |
| Wet | Jun | 7,958 | 7,583 (-5%) |
| Wet | Jul | 12 | 11 (-9%) |
| Wet | Aug | 0 | 0 (0%) |
| Wet | Sep | 0 | 0 (0%) |
| Wet | Oct | 0 | 0 (0%) |
| Wet | Nov | 0 | 0 (0%) |
| Wet | Dec | 63 | 60 (-4%) |
| Above normal | Jan | N/A | (1%) |
| Above normal | Feb | N/A | (-2%) |
| Above normal | Mar | N/A | (-7%) |
| Above normal | Apr | N/A | (-22%) |
| Above normal | May | N/A | (-11%) |
| Above normal | Jun | N/A | (-9%) |
| Above normal | Jul | N/A | (-22%) |
| Above normal | Aug | N/A | (0%) |
| Above normal | Sep | N/A | (0%) |
| Above normal | Oct | N/A | (0%) |
| Above normal | Nov | N/A | (0%) |
| Above normal | Dec | N/A | (-10%) |
| Below normal | Jan | 0 | 0 (0%) |
| Below normal | Feb | 7 | 7 (-3%) |
| Below normal | Mar | 72 | 60 (-17%) |
| Below normal | Apr | 597 | 598 (0%) |
| Below normal | May | 1,912 | 1,766 (-8%) |
| Below normal | Jun | 333 | 317 (-5%) |
| Below normal | Jul | 4 | 3 (-22%) |
| Below normal | Aug | 0 | 0 (0%) |
| Below normal | Sep | 0 | 0 (0%) |
| Below normal | Oct | 0 | 0 (0%) |
| Below normal | Nov | 0 | 0 (0%) |
| Below normal | Dec | 6 | 6 (-4%) |
| Dry | Jan | 0 | 0 (0%) |
| Dry | Feb | 11 | 10 (-6%) |
| Dry | Mar | 36 | 34 (-7%) |
| Dry | Apr | 1,049 | 1,052 (0%) |
| Dry | May | 2,336 | 2,339 (0%) |

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Dry | Jun | 35 | 36 (1%) |
| Dry | Jul | 0 | 0 (0%) |
| Dry | Aug | 0 | 0 (0%) |
| Dry | Sep | 0 | 0 (0%) |
| Dry | Oct | 0 | 0 (0%) |
| Dry | Nov | 0 | 0 (0%) |
| Dry | Dec | 485 | 439 (-10%) |
| Critically dry | Jan | 0 | 0 (0%) |
| Critically dry | Feb | 11 | 10 (-6%) |
| Critically dry | Mar | 33 | 30 (-8%) |
| Critically dry | Apr | 1,014 | 1,027 (1%) |
| Critically dry | May | 2,349 | 2,283 (-3%) |
| Critically dry | Jun | 16 | 15 (-7%) |
| Critically dry | Jul | 0 | 0 (0%) |
| Critically dry | Aug | 0 | 0 (0%) |
| Critically dry | Sep | 0 | 0 (0%) |
| Critically dry | Oct | 0 | 0 (0%) |
| Critically dry | Nov | 0 | 0 (0%) |
| Critically dry | Dec | 324 | 305 (-6%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare.
N/A = not applicable; SWP = State Water Project.

### Table 5D.2-6. Entrainment Loss of Juvenile Fall-Run Chinook Salmon at CVP Jones Pumping Plant, Averaged by Water Year Type and Month, Based on the Salvage-Density Method

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Wet | Jan | 662 | 658 (-1%) |
| Wet | Feb | 648 | 664 (2%) |
| Wet | Mar | 150 | 157 (5%) |
| Wet | Apr | 79 | 84 (6%) |
| Wet | May | 4,750 | 5,063 (7%) |
| Wet | Jun | 2,805 | 2,938 (5%) |
| Wet | Jul | 34 | 34 (1%) |
| Wet | Aug | 2 | 2 (0%) |
| Wet | Sep | 0 | 0 (0%) |
| Wet | Oct | 0 | 0 (0%) |
| Wet | Nov | 1 | 1 (0%) |

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Wet | Dec | 15 | 14 (0%) |
| Above normal | Jan | N/A | (-1%) |
| Above normal | Feb | N/A | (2%) |
| Above normal | Mar | N/A | (7%) |
| Above normal | Apr | N/A | (8%) |
| Above normal | May | N/A | (9%) |
| Above normal | Jun | N/A | (6%) |
| Above normal | Jul | N/A | (9%) |
| Above normal | Aug | N/A | (-5%) |
| Above normal | Sep | N/A | (0%) |
| Above normal | Oct | N/A | (0%) |
| Above normal | Nov | N/A | (3%) |
| Above normal | Dec | N/A | (0%) |
| Below normal | Jan | 7 | 7 (3%) |
| Below normal | Feb | 16 | 18 (9%) |
| Below normal | Mar | 119 | 124 (4%) |
| Below normal | Apr | 737 | 738 (0%) |
| Below normal | May | 1,831 | 1,820 (-1%) |
| Below normal | Jun | 173 | 170 (-1%) |
| Below normal | Jul | 2 | 2 (-1%) |
| Below normal | Aug | 0 | 0 (0%) |
| Below normal | Sep | 0 | 0 (0%) |
| Below normal | Oct | 0 | 0 (0%) |
| Below normal | Nov | 0 | 0 (0%) |
| Below normal | Dec | 0 | 0 (0%) |
| Dry | Jan | 4 | 4 (3%) |
| Dry | Feb | 5 | 6 (9%) |
| Dry | Mar | 22 | 23 (4%) |
| Dry | Apr | 1,784 | 1,786 (0%) |
| Dry | May | 2,273 | 2,260 (-1%) |
| Dry | Jun | 40 | 40 (-1%) |
| Dry | Jul | 0 | 0 (0%) |
| Dry | Aug | 0 | 0 (0%) |
| Dry | Sep | 0 | 0 (0%) |
| Dry | Oct | 0 | 0 (0%) |
| Dry | Nov | 0 | 0 (0%) |
| Dry | Dec | 30 | 28 (-8%) |
| Critically dry | Jan | 0 | 0 (0%) |

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Critically dry | Feb | 10 | 11 (2%) |
| Critically dry | Mar | 11 | 11 (1%) |
| Critically dry | Apr | 86 | 87 (1%) |
| Critically dry | May | 70 | 69 (-1%) |
| Critically dry | Jun | 0 | 0 (0%) |
| Critically dry | Jul | 0 | 0 (0%) |
| Critically dry | Aug | 0 | 0 (0%) |
| Critically dry | Sep | 0 | 0 (0%) |
| Critically dry | Oct | 0 | 0 (0%) |
| Critically dry | Nov | 0 | 0 (0%) |
| Critically dry | Dec | 0 | 0 (0%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare.
CVP = Central Valley Project; N/A = not applicable.

### Table 5D.2-7. Entrainment Loss of Juvenile Late Fall–Run Chinook Salmon at SWP Banks Pumping Plant, Averaged by Water Year Type and Month, Based on the Salvage-Density Method

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Wet | Jan | 571 | 565 (-1%) |
| Wet | Feb | 89 | 82 (-9%) |
| Wet | Mar | 9 | 7 (-13%) |
| Wet | Apr | 0 | 0 (0%) |
| Wet | May | 0 | 0 (0%) |
| Wet | Jun | 0 | 0 (0%) |
| Wet | Jul | 0 | 0 (0%) |
| Wet | Aug | 0 | 0 (0%) |
| Wet | Sep | 0 | 0 (0%) |
| Wet | Oct | 0 | 0 (0%) |
| Wet | Nov | 0 | 0 (0%) |
| Wet | Dec | 692 | 662 (-4%) |
| Above normal | Jan | N/A | (1%) |
| Above normal | Feb | N/A | (-2%) |
| Above normal | Mar | N/A | (-7%) |
| Above normal | Apr | N/A | (0%) |
| Above normal | May | N/A | (0%) |
| Above normal | Jun | N/A | (0%) |
| Above normal | Jul | N/A | (0%) |

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Above normal | Aug | N/A | (0%) |
| Above normal | Sep | N/A | (0%) |
| Above normal | Oct | N/A | (0%) |
| Above normal | Nov | N/A | (0%) |
| Above normal | Dec | N/A | (-10%) |
| Below normal | Jan | 159 | 159 (0%) |
| Below normal | Feb | 102 | 98 (-3%) |
| Below normal | Mar | 16 | 13 (-17%) |
| Below normal | Apr | 0 | 0 (0%) |
| Below normal | May | 0 | 0 (0%) |
| Below normal | Jun | 0 | 0 (0%) |
| Below normal | Jul | 0 | 0 (0%) |
| Below normal | Aug | 0 | 0 (0%) |
| Below normal | Sep | 0 | 0 (0%) |
| Below normal | Oct | 0 | 0 (0%) |
| Below normal | Nov | 0 | 0 (0%) |
| Below normal | Dec | 110 | 105 (-4%) |
| Dry | Jan | 21 | 19 (-9%) |
| Dry | Feb | 0 | 0 (0%) |
| Dry | Mar | 0 | 0 (0%) |
| Dry | Apr | 0 | 0 (0%) |
| Dry | May | 0 | 0 (0%) |
| Dry | Jun | 0 | 0 (0%) |
| Dry | Jul | 0 | 0 (0%) |
| Dry | Aug | 0 | 0 (0%) |
| Dry | Sep | 0 | 0 (0%) |
| Dry | Oct | 0 | 0 (0%) |
| Dry | Nov | 0 | 0 (0%) |
| Dry | Dec | 1,033 | 934 (-10%) |
| Critically dry | Jan | 18 | 17 (-6%) |
| Critically dry | Feb | 0 | 0 (0%) |
| Critically dry | Mar | 0 | 0 (0%) |
| Critically dry | Apr | 0 | 0 (0%) |
| Critically dry | May | 0 | 0 (0%) |
| Critically dry | Jun | 0 | 0 (0%) |
| Critically dry | Jul | 0 | 0 (0%) |
| Critically dry | Aug | 0 | 0 (0%) |
| Critically dry | Sep | 0 | 0 (0%) |

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Critically dry | Oct | 0 | 0 (0%) |
| Critically dry | Nov | 0 | 0 (0%) |
| Critically dry | Dec | 690 | 650 (-6%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare.
N/A = not applicable; SWP = State Water Project.

### Table 5D.2-8. Entrainment Loss of Juvenile Late Fall–Run Chinook Salmon at CVP Jones Pumping Plant, Averaged by Water Year Type and Month, Based on the Salvage-Density Method

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Wet | Jan | 65 | 64 (-1%) |
| Wet | Feb | 2 | 2 (2%) |
| Wet | Mar | 0 | 0 (0%) |
| Wet | Apr | 0 | 0 (0%) |
| Wet | May | 0 | 0 (0%) |
| Wet | Jun | 0 | 0 (0%) |
| Wet | Jul | 0 | 0 (0%) |
| Wet | Aug | 0 | 0 (0%) |
| Wet | Sep | 0 | 0 (0%) |
| Wet | Oct | 1 | 1 (-3%) |
| Wet | Nov | 1 | 1 (0%) |
| Wet | Dec | 194 | 194 (0%) |
| Above normal | Jan | N/A | (-1%) |
| Above normal | Feb | N/A | (2%) |
| Above normal | Mar | N/A | (0%) |
| Above normal | Apr | N/A | (0%) |
| Above normal | May | N/A | (0%) |
| Above normal | Jun | N/A | (0%) |
| Above normal | Jul | N/A | (0%) |
| Above normal | Aug | N/A | (0%) |
| Above normal | Sep | N/A | (0%) |
| Above normal | Oct | N/A | (-2%) |
| Above normal | Nov | N/A | (3%) |
| Above normal | Dec | N/A | (0%) |
| Below normal | Jan | 50 | 52 (3%) |
| Below normal | Feb | 8 | 9 (9%) |
| Below normal | Mar | 2 | 2 (4%) |

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Below normal | Apr | 1 | 1 (0%) |
| Below normal | May | 0 | 0 (0%) |
| Below normal | Jun | 0 | 0 (0%) |
| Below normal | Jul | 0 | 0 (0%) |
| Below normal | Aug | 0 | 0 (0%) |
| Below normal | Sep | 0 | 0 (0%) |
| Below normal | Oct | 0 | 0 (0%) |
| Below normal | Nov | 0 | 0 (0%) |
| Below normal | Dec | 7 | 6 (-8%) |
| Dry | Jan | 7 | 7 (3%) |
| Dry | Feb | 0 | 0 (0%) |
| Dry | Mar | 0 | 0 (0%) |
| Dry | Apr | 0 | 0 (0%) |
| Dry | May | 0 | 0 (0%) |
| Dry | Jun | 0 | 0 (0%) |
| Dry | Jul | 0 | 0 (0%) |
| Dry | Aug | 0 | 0 (0%) |
| Dry | Sep | 0 | 0 (0%) |
| Dry | Oct | 0 | 0 (0%) |
| Dry | Nov | 0 | 0 (0%) |
| Dry | Dec | 87 | 79 (-8%) |
| Critically dry | Jan | 6 | 6 (1%) |
| Critically dry | Feb | 0 | 0 (0%) |
| Critically dry | Mar | 0 | 0 (0%) |
| Critically dry | Apr | 0 | 0 (0%) |
| Critically dry | May | 0 | 0 (0%) |
| Critically dry | Jun | 0 | 0 (0%) |
| Critically dry | Jul | 0 | 0 (0%) |
| Critically dry | Aug | 0 | 0 (0%) |
| Critically dry | Sep | 0 | 0 (0%) |
| Critically dry | Oct | 0 | 0 (0%) |
| Critically dry | Nov | 0 | 0 (0%) |
| Critically dry | Dec | 24 | 24 (1%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare.
CVP = Central Valley Project; N/A = not applicable.

**Table 5D.2-9. Entrainment Loss of Juvenile Steelhead at SWP Banks Pumping Plant, Averaged by Water Year Type and Month, Based on the Salvage-Density Method**

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Wet | Jan | 270 | 267 (-1%) |
| Wet | Feb | 2,093 | 1,911 (-9%) |
| Wet | Mar | 963 | 841 (-13%) |
| Wet | Apr | 1,177 | 965 (-18%) |
| Wet | May | 441 | 421 (-5%) |
| Wet | Jun | 251 | 239 (-5%) |
| Wet | Jul | 0 | 0 (0%) |
| Wet | Aug | 0 | 0 (0%) |
| Wet | Sep | 6 | 6 (-4%) |
| Wet | Oct | 4 | 4 (-8%) |
| Wet | Nov | 5 | 4 (-9%) |
| Wet | Dec | 7 | 7 (-4%) |
| Above normal | Jan | N/A | (1%) |
| Above normal | Feb | N/A | (-2%) |
| Above normal | Mar | N/A | (-7%) |
| Above normal | Apr | N/A | (-22%) |
| Above normal | May | N/A | (-11%) |
| Above normal | Jun | N/A | (-9%) |
| Above normal | Jul | N/A | (0%) |
| Above normal | Aug | N/A | (0%) |
| Above normal | Sep | N/A | (-3%) |
| Above normal | Oct | N/A | (-2%) |
| Above normal | Nov | N/A | (-9%) |
| Above normal | Dec | N/A | (-10%) |
| Below normal | Jan | 269 | 271 (0%) |
| Below normal | Feb | 1,261 | 1,217 (-3%) |
| Below normal | Mar | 1,203 | 995 (-17%) |
| Below normal | Apr | 312 | 312 (0%) |
| Below normal | May | 124 | 115 (-8%) |
| Below normal | Jun | 68 | 64 (-5%) |
| Below normal | Jul | 6 | 5 (-22%) |
| Below normal | Aug | 0 | 0 (0%) |
| Below normal | Sep | 0 | 0 (0%) |
| Below normal | Oct | 0 | 0 (0%) |
| Below normal | Nov | 0 | 0 (0%) |
| Below normal | Dec | 7 | 7 (-4%) |

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Dry | Jan | 149 | 136 (-9%) |
| Dry | Feb | 519 | 486 (-6%) |
| Dry | Mar | 898 | 839 (-7%) |
| Dry | Apr | 445 | 447 (0%) |
| Dry | May | 192 | 192 (0%) |
| Dry | Jun | 67 | 67 (1%) |
| Dry | Jul | 20 | 20 (-2%) |
| Dry | Aug | 0 | 0 (0%) |
| Dry | Sep | 0 | 0 (0%) |
| Dry | Oct | 0 | 0 (0%) |
| Dry | Nov | 7 | 6 (-8%) |
| Dry | Dec | 31 | 28 (-10%) |
| Critically dry | Jan | 131 | 123 (-6%) |
| Critically dry | Feb | 499 | 468 (-6%) |
| Critically dry | Mar | 818 | 749 (-8%) |
| Critically dry | Apr | 431 | 436 (1%) |
| Critically dry | May | 193 | 187 (-3%) |
| Critically dry | Jun | 30 | 28 (-7%) |
| Critically dry | Jul | 5 | 5 (-5%) |
| Critically dry | Aug | 0 | 0 (0%) |
| Critically dry | Sep | 0 | 0 (0%) |
| Critically dry | Oct | 0 | 0 (0%) |
| Critically dry | Nov | 3 | 3 (-12%) |
| Critically dry | Dec | 21 | 20 (-6%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare.
N/A = not applicable; SWP = State Water Project.

### Table 5D.2-10. Entrainment Loss of Juvenile Steelhead at CVP Jones Pumping Plant, Averaged by Water Year Type and Month, Based on the Salvage-Density Method

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Wet | Jan | 44 | 44 (-1%) |
| Wet | Feb | 137 | 140 (2%) |
| Wet | Mar | 34 | 36 (5%) |
| Wet | Apr | 12 | 13 (6%) |
| Wet | May | 35 | 37 (7%) |
| Wet | Jun | 31 | 32 (5%) |

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Wet | Jul | 0 | 0 (0%) |
| Wet | Aug | 0 | 0 (0%) |
| Wet | Sep | 1 | 1 (1%) |
| Wet | Oct | 0 | 0 (0%) |
| Wet | Nov | 0 | 0 (0%) |
| Wet | Dec | 2 | 2 (0%) |
| Above normal | Jan | N/A | (-1%) |
| Above normal | Feb | N/A | (2%) |
| Above normal | Mar | N/A | (7%) |
| Above normal | Apr | N/A | (8%) |
| Above normal | May | N/A | (9%) |
| Above normal | Jun | N/A | (6%) |
| Above normal | Jul | N/A | (0%) |
| Above normal | Aug | N/A | (0%) |
| Above normal | Sep | N/A | (-3%) |
| Above normal | Oct | N/A | (0%) |
| Above normal | Nov | N/A | (0%) |
| Above normal | Dec | N/A | (0%) |
| Below normal | Jan | 47 | 48 (3%) |
| Below normal | Feb | 465 | 506 (9%) |
| Below normal | Mar | 251 | 261 (4%) |
| Below normal | Apr | 109 | 110 (0%) |
| Below normal | May | 62 | 62 (-1%) |
| Below normal | Jun | 10 | 10 (-1%) |
| Below normal | Jul | 0 | 0 (0%) |
| Below normal | Aug | 0 | 0 (0%) |
| Below normal | Sep | 0 | 0 (0%) |
| Below normal | Oct | 0 | 0 (0%) |
| Below normal | Nov | 0 | 0 (0%) |
| Below normal | Dec | 0 | 0 (0%) |
| Dry | Jan | 30 | 31 (3%) |
| Dry | Feb | 151 | 164 (9%) |
| Dry | Mar | 295 | 306 (4%) |
| Dry | Apr | 111 | 111 (0%) |
| Dry | May | 71 | 71 (-1%) |
| Dry | Jun | 12 | 12 (-1%) |
| Dry | Jul | 0 | 0 (0%) |
| Dry | Aug | 0 | 0 (0%) |

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Dry | Sep | 0 | 0 (0%) |
| Dry | Oct | 0 | 0 (0%) |
| Dry | Nov | 0 | 0 (0%) |
| Dry | Dec | 7 | 6 (-8%) |
| Critically dry | Jan | 0 | 0 (0%) |
| Critically dry | Feb | 80 | 81 (2%) |
| Critically dry | Mar | 80 | 81 (1%) |
| Critically dry | Apr | 31 | 31 (1%) |
| Critically dry | May | 9 | 9 (-1%) |
| Critically dry | Jun | 0 | 0 (0%) |
| Critically dry | Jul | 0 | 0 (0%) |
| Critically dry | Aug | 0 | 0 (0%) |
| Critically dry | Sep | 0 | 0 (0%) |
| Critically dry | Oct | 0 | 0 (0%) |
| Critically dry | Nov | 0 | 0 (0%) |
| Critically dry | Dec | 0 | 0 (0%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare.
Central Valley Project; N/A = not applicable.

### Table 5D.2-11. Salvage of Green Sturgeon at SWP Banks Pumping Plant, Averaged by Water Year Type and Month, Based on the Salvage-Density Method

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Wet | Jan | 0 | 0 (0%) |
| Wet | Feb | 0 | 0 (0%) |
| Wet | Mar | 1 | 1 (-13%) |
| Wet | Apr | 0 | 0 (0%) |
| Wet | May | 0 | 0 (0%) |
| Wet | Jun | 0 | 0 (0%) |
| Wet | Jul | 0 | 0 (0%) |
| Wet | Aug | 0 | 0 (0%) |
| Wet | Sep | 0 | 0 (0%) |
| Wet | Oct | 0 | 0 (0%) |
| Wet | Nov | 0 | 0 (0%) |
| Wet | Dec | 0 | 0 (0%) |
| Above normal | Jan | N/A | (0%) |
| Above normal | Feb | N/A | (0%) |

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Above normal | Mar | N/A | (-7%) |
| Above normal | Apr | N/A | (0%) |
| Above normal | May | N/A | (0%) |
| Above normal | Jun | N/A | (0%) |
| Above normal | Jul | N/A | (0%) |
| Above normal | Aug | N/A | (0%) |
| Above normal | Sep | N/A | (0%) |
| Above normal | Oct | N/A | (0%) |
| Above normal | Nov | N/A | (0%) |
| Above normal | Dec | N/A | (0%) |
| Below normal | Jan | 1 | 1 (0%) |
| Below normal | Feb | 0 | 0 (0%) |
| Below normal | Mar | 0 | 0 (0%) |
| Below normal | Apr | 0 | 0 (0%) |
| Below normal | May | 0 | 0 (0%) |
| Below normal | Jun | 0 | 0 (0%) |
| Below normal | Jul | 0 | 0 (0%) |
| Below normal | Aug | 0 | 0 (0%) |
| Below normal | Sep | 0 | 0 (0%) |
| Below normal | Oct | 0 | 0 (0%) |
| Below normal | Nov | 0 | 0 (0%) |
| Below normal | Dec | 0 | 0 (0%) |
| Dry | Jan | 0 | 0 (0%) |
| Dry | Feb | 0 | 0 (0%) |
| Dry | Mar | 0 | 0 (0%) |
| Dry | Apr | 0 | 0 (0%) |
| Dry | May | 0 | 0 (0%) |
| Dry | Jun | 0 | 0 (0%) |
| Dry | Jul | 0 | 0 (0%) |
| Dry | Aug | 0 | 0 (0%) |
| Dry | Sep | 0 | 0 (0%) |
| Dry | Oct | 0 | 0 (0%) |
| Dry | Nov | 0 | 0 (0%) |
| Dry | Dec | 0 | 0 (0%) |
| Critically dry | Jan | 0 | 0 (0%) |
| Critically dry | Feb | 0 | 0 (0%) |
| Critically dry | Mar | 0 | 0 (0%) |
| Critically dry | Apr | 0 | 0 (0%) |

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Critically dry | May | 0 | 0 (0%) |
| Critically dry | Jun | 0 | 0 (0%) |
| Critically dry | Jul | 0 | 0 (0%) |
| Critically dry | Aug | 0 | 0 (0%) |
| Critically dry | Sep | 0 | 0 (0%) |
| Critically dry | Oct | 0 | 0 (0%) |
| Critically dry | Nov | 0 | 0 (0%) |
| Critically dry | Dec | 0 | 0 (0%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare.
N/A = not applicable; SWP = State Water Project.

### Table 5D.2-12. Salvage of Green Sturgeon at CVP Jones Pumping Plant, Averaged by Water Year Type and Month, Based on the Salvage-Density Method

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Wet | Jan | 0 | 0 (0%) |
| Wet | Feb | 0 | 0 (0%) |
| Wet | Mar | 0 | 0 (0%) |
| Wet | Apr | 0 | 0 (0%) |
| Wet | May | 0 | 0 (0%) |
| Wet | Jun | 7 | 7 (5%) |
| Wet | Jul | 0 | 0 (0%) |
| Wet | Aug | 0 | 0 (0%) |
| Wet | Sep | 0 | 0 (0%) |
| Wet | Oct | 0 | 0 (0%) |
| Wet | Nov | 0 | 0 (0%) |
| Wet | Dec | 0 | 0 (0%) |
| Above normal | Jan | N/A | (0%) |
| Above normal | Feb | N/A | (0%) |
| Above normal | Mar | N/A | (0%) |
| Above normal | Apr | N/A | (0%) |
| Above normal | May | N/A | (0%) |
| Above normal | Jun | N/A | (6%) |
| Above normal | Jul | N/A | (0%) |
| Above normal | Aug | N/A | (0%) |
| Above normal | Sep | N/A | (0%) |
| Above normal | Oct | N/A | (0%) |

| Water Year Type | Month | Existing Conditions | Proposed Action |
|---|---|---|---|
| Above normal | Nov | N/A | (0%) |
| Above normal | Dec | N/A | (0%) |
| Below normal | Jan | 0 | 0 (0%) |
| Below normal | Feb | 0 | 0 (0%) |
| Below normal | Mar | 0 | 0 (0%) |
| Below normal | Apr | 0 | 0 (0%) |
| Below normal | May | 0 | 0 (0%) |
| Below normal | Jun | 0 | 0 (0%) |
| Below normal | Jul | 0 | 0 (0%) |
| Below normal | Aug | 0 | 0 (0%) |
| Below normal | Sep | 0 | 0 (0%) |
| Below normal | Oct | 0 | 0 (0%) |
| Below normal | Nov | 0 | 0 (0%) |
| Below normal | Dec | 0 | 0 (0%) |
| Dry | Jan | 0 | 0 (0%) |
| Dry | Feb | 0 | 0 (0%) |
| Dry | Mar | 0 | 0 (0%) |
| Dry | Apr | 0 | 0 (0%) |
| Dry | May | 0 | 0 (0%) |
| Dry | Jun | 0 | 0 (0%) |
| Dry | Jul | 0 | 0 (0%) |
| Dry | Aug | 0 | 0 (0%) |
| Dry | Sep | 0 | 0 (0%) |
| Dry | Oct | 0 | 0 (0%) |
| Dry | Nov | 0 | 0 (0%) |
| Dry | Dec | 0 | 0 (0%) |
| Critically dry | Jan | 0 | 0 (0%) |
| Critically dry | Feb | 0 | 0 (0%) |
| Critically dry | Mar | 0 | 0 (0%) |
| Critically dry | Apr | 0 | 0 (0%) |
| Critically dry | May | 0 | 0 (0%) |
| Critically dry | Jun | 0 | 0 (0%) |
| Critically dry | Jul | 0 | 0 (0%) |
| Critically dry | Aug | 0 | 0 (0%) |
| Critically dry | Sep | 0 | 0 (0%) |
| Critically dry | Oct | 0 | 0 (0%) |
| Critically dry | Nov | 0 | 0 (0%) |
| Critically dry | Dec | 0 | 0 (0%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare.
CVP = Central Valley Project; N/A = not applicable.

# 5D.3 Juvenile Winter-Run Chinook Salmon Salvage Based on Zeug and Cavallo (2014)

## 5D.3.1 Methods

An analysis to evaluate differences in salvage at the south Delta export facilities between the modeled scenarios was done following the statistical models of salvage of marked (coded wire tags) hatchery-reared Chinook salmon published by Zeug and Cavallo (2014). This analysis focused on winter-run Chinook salmon; spring-run Chinook salmon were not included because very few marked individuals were salvaged, and the statistical models could not be fit successfully (Zeug and Cavallo 2014). The model was based on marked fish released in 1994–2007 during Freeport flows of 14,600–68,700 cubic feet per second (cfs). Several modifications to the methods of Zeug and Cavallo (2014) were employed to focus on relevant model predictors. First, statistical models of the empirical data were constructed using only releases of winter-run Chinook salmon raised at the Livingston Stone Hatchery. Second, salvage at the south Delta export facilities from both the State Water Project (SWP) and Central Valley Project (CVP) facilities was modeled. Some variables were excluded from the statistical models because they were not significant in the original analysis, or they were not relevant in this context. For example, the original analysis used the variable "distance of release from the facilities." However, winter-run Chinook salmon were only released from a single location, making this predictor irrelevant. Finally, to determine which hydrologic variables were the best predictors of salvage, a model selection exercise was performed using the original data from Zeug and Cavallo (2014). The model selection exercise included five potential hydrologic predictor variables including: Old and Middle River flows, inflow-export ratio (I-E), total south Delta exports, San Joaquin River flow, Sacramento River flow, and one biological variable (mean fork length at release). Most of these variables were strongly correlated so models were constructed only with variables that had correlation coefficients <|0.70|. One million individuals were used as the total release size (offset variable) for each candidate model with standardized predictors for both the count and zero-inflation portion of the models. To select the best approximating model, Akaike's Information Criterion (AIC) was calculated for each model. The model with the lowest AIC value was identified as the best approximating model. The AIC value of all other models was subtracted from the value of the best approximating model to calculate the ΔAIC. Any model that had a ΔAIC value ≤2.0 was considered a competing model with the best approximating model.

A single best model of salvage was selected with no other model having a ΔAIC <2.8. This model had three predictor variables for the count model and zero inflation models including mean fork length of fish at release, Sacramento River flow, and total exports. The final count model indicated that non-zero salvage was greater when fish were released at a larger size (coefficient = 0.709, $P$ <0.001), flow in the Sacramento River was higher (coefficient = 0.155, $P$ = 0.707), and exports were higher (coefficient = 0.350, $P$ = 0.006). For the zero-inflation model, coefficients indicated zero salvage was more likely when fish were released at a smaller size (coefficient = -0.776, $P$ <0.001), Sacramento

River flow was higher (coefficient = 0.610, $P$ = 0.140), and exports were lower (coefficient = -0.957, $P$ <0.001).

To predict salvage under the modeled scenarios, daily flow and export data from the 1922–2015 Delta Simulation Model II (DSM2) output was aggregated into 7-day running means and standardized to the same scale as the empirical data. This was done to mimic the way data were aggregated in the original publication (7-day means) and the winter-run specific models described above. A 7-day mean was used because an acoustic tagging study revealed that was the approximate mean time Chinook salmon smolts spent transiting through the Delta (Zeug and Cavallo 2014). The total number of fish entering the Delta in a season was then multiplied by the daily entry proportion defined by the same distribution used in the Delta Passage Model. The log-transformed product of this calculation was used as the offset on each day. The distribution did not weight the result but simply distributed the fish over time.

The values described above (DSM2 data, offset, fish fork length) are used as inputs in the Zero-Inflated Negative Binomial model to predict the mean salvage for each day. The size of fish entering the Delta was set as the midpoint size on the 15th of each month using the Delta length-at-date model. After January, the midpoint value was higher than the observed sizes at release and the model was set to the maximum observed fork length from February–June (95 millimeters [mm]). However, it should be noted that the statistical model uses size at release in the Sacramento River near Redding, CA, and fish are assumed to grow between release and the salvage facilities. The mean daily salvage values were then summarized by month and reported as the proportion of total annual salvage observed in each month. Additionally, the annual predicted value of salvage in each of the water years was plotted for the modeled scenarios.

## 5D.3.2 Results

Tabulated results are presented here and are discussed in Appendix 5C, with graphical summaries in Figure 5D.3-1 through Figure 5D.3-7 below.

Note: Alt_5 in the figures is equivalent to the proposed action.

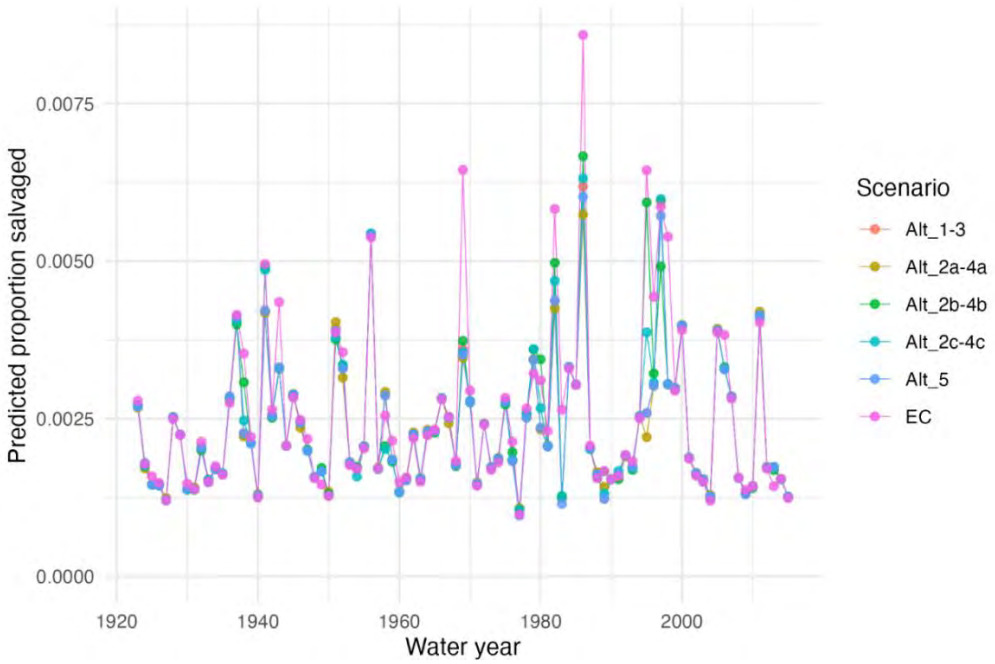



**Figure 5D.3-1. Time Series of Proportional Juvenile Winter-Run Chinook Salmon Salvage for the Analysis Based on Zeug and Cavallo (2014)**

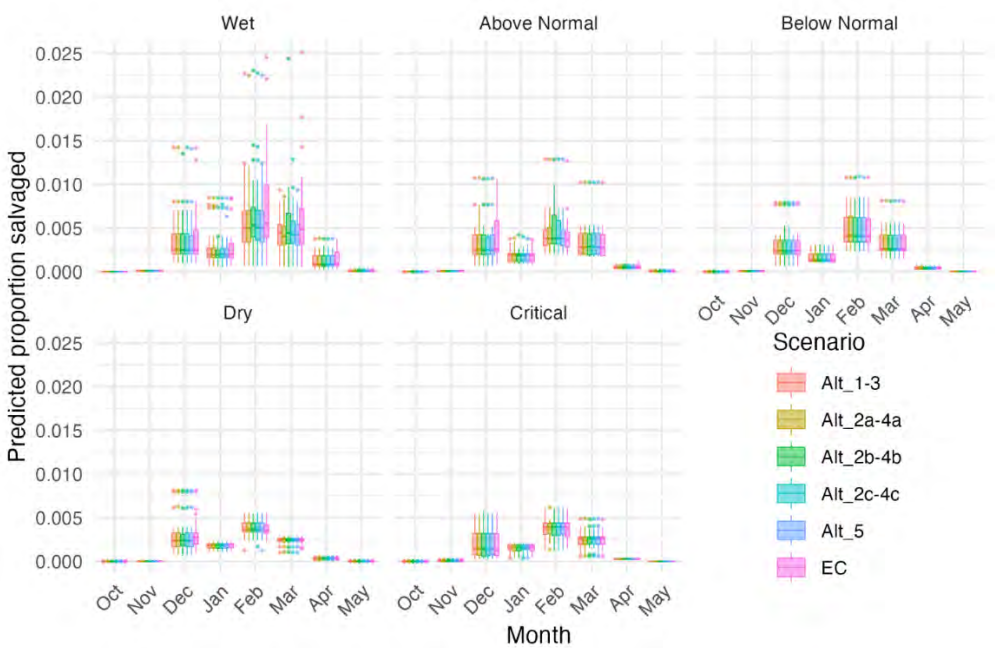



**Figure 5D.3-2. Box Plot of Proportional Juvenile Winter-Run Chinook Salmon Salvage by Water Year Type and Month for the Analysis Based on Zeug and Cavallo (2014)**

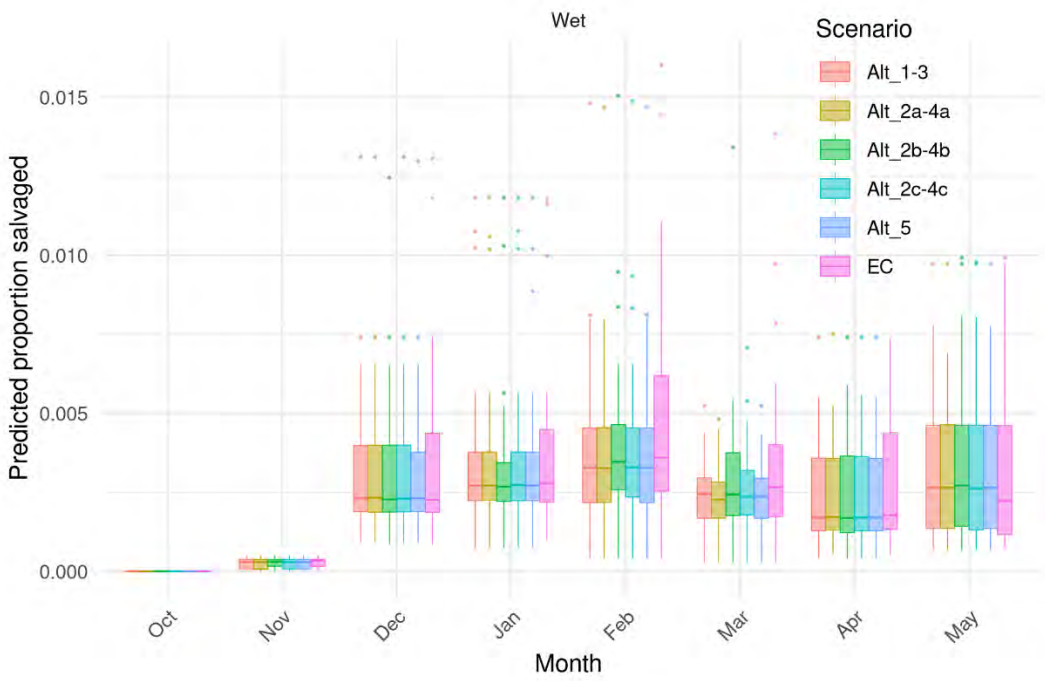



**Figure 5D.3-3. Box Plot of Proportional Juvenile Winter-Run Chinook Salmon Salvage by Month in Wet Water Years for the Analysis Based on Zeug and Cavallo (2014)**

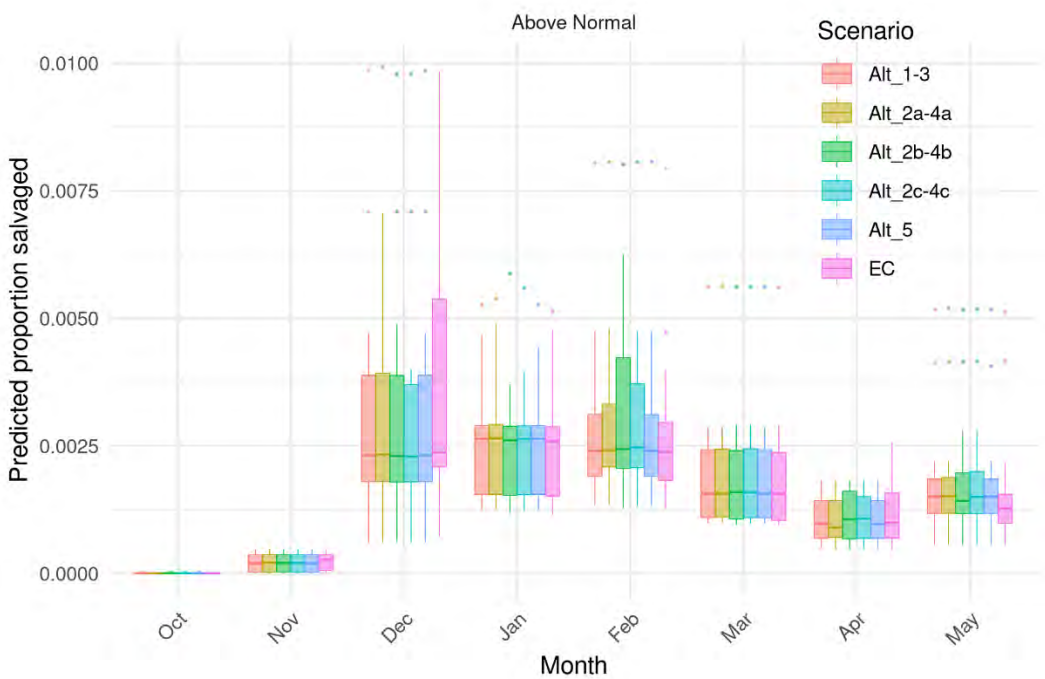



**Figure 5D.3-4. Box Plot of Proportional Juvenile Winter-Run Chinook Salmon Salvage by Month in Above Normal Water Years for the Analysis Based on Zeug and Cavallo (2014)**

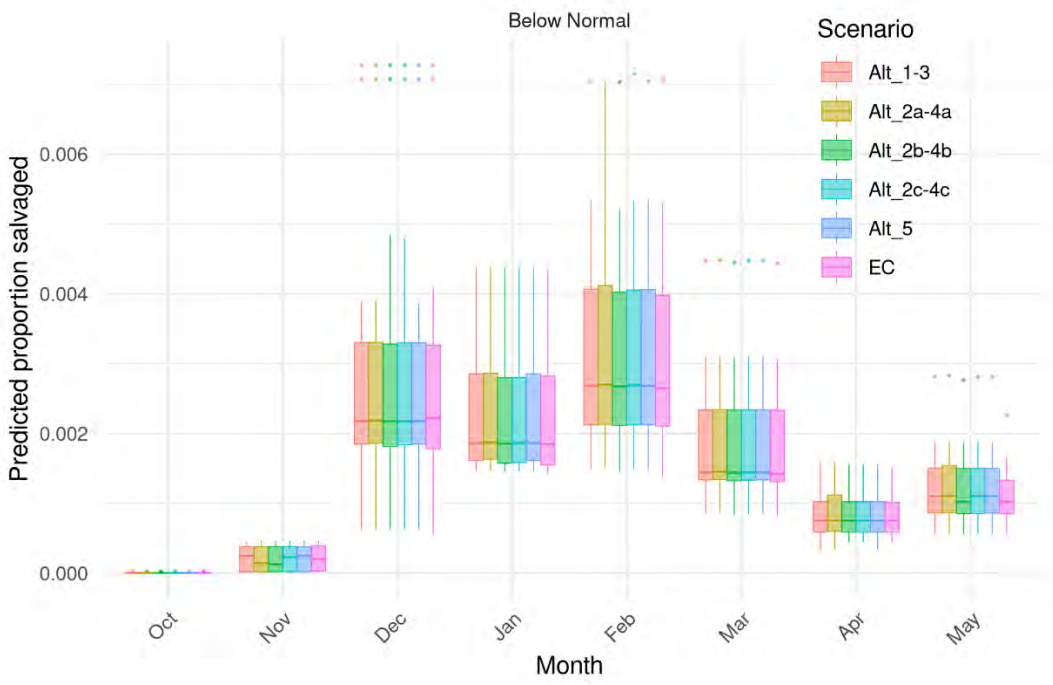



**Figure 5D.3-5. Box Plot of Proportional Juvenile Winter-Run Chinook Salmon Salvage by Month in Below Normal Water Years for the Analysis Based on Zeug and Cavallo (2014)**

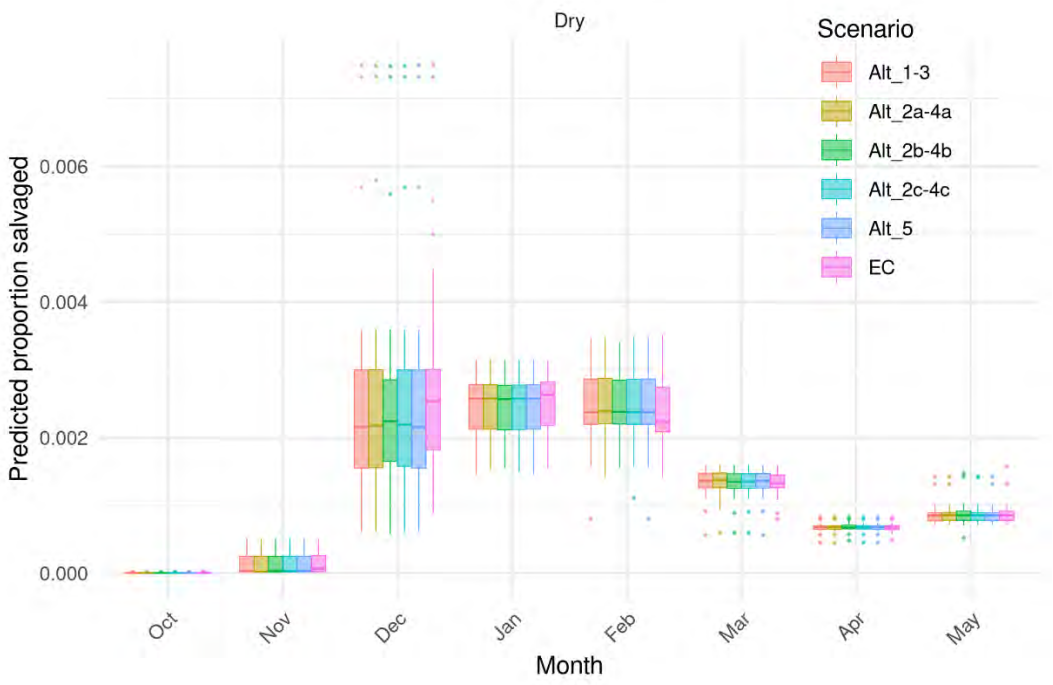



**Figure 5D.3-6. Box Plot of Proportional Juvenile Winter-Run Chinook Salmon Salvage by Month in Dry Water Years for the Analysis Based on Zeug and Cavallo (2014)**

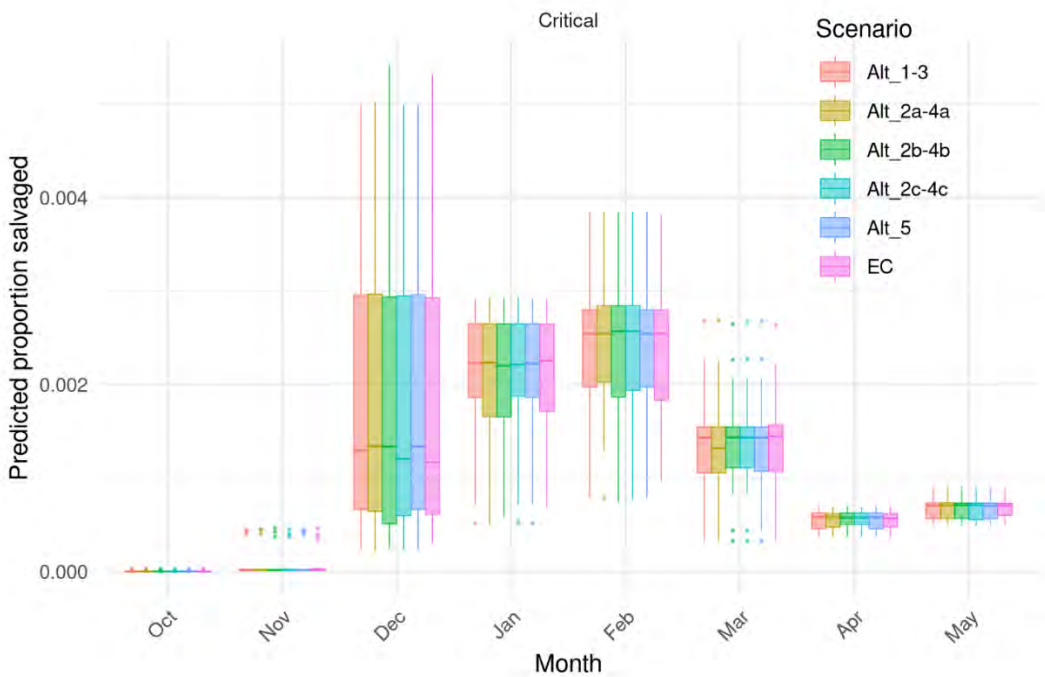



**Figure 5D.3-7. Box Plot of Proportional Juvenile Winter-Run Chinook Salmon Salvage by Month in Critically Dry Water Years for the Analysis Based on Zeug and Cavallo (2014)**

# 5D.4 Hydrodynamic Effects Based on DSM2-HYDRO Data

## 5D.4.1 Velocity

### 5D.4.1.1 Methods

In order to assess the potential for water project operations to influence survival and routing, Delta hydrodynamic conditions were analyzed by creating maps from DSM2-HYDRO modeling. The maps are based on a comparative metric, proportion overlap (more below), to capture channel-level hydrodynamic details as a single number for color-scale mapping of Delta channels.

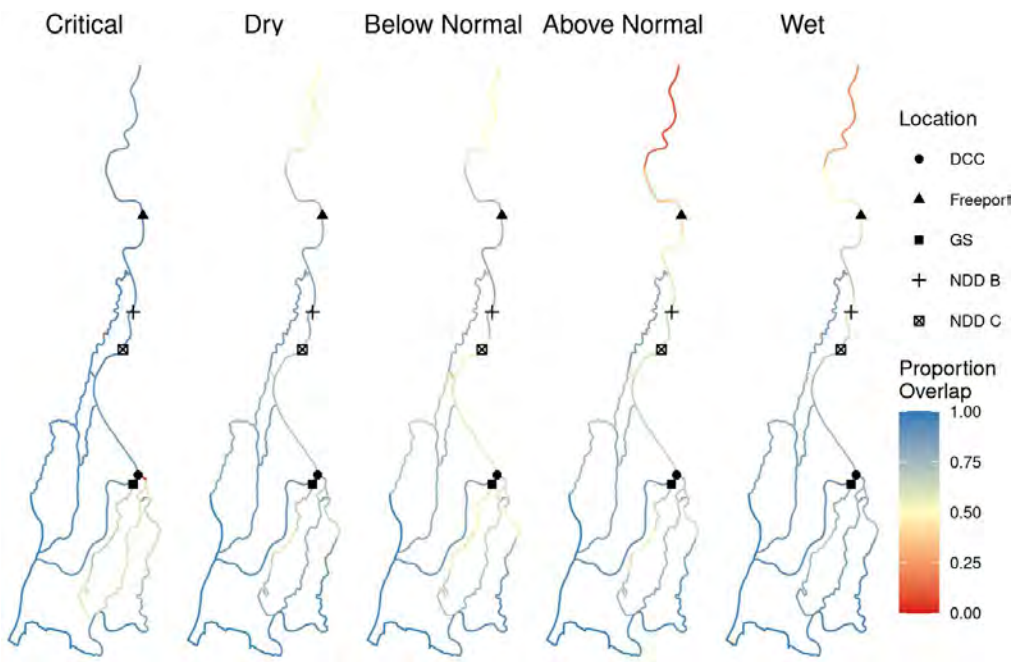
The objective of the comparative metric is to summarize the water velocity time series for each channel and scenario such the channel-level comparison is captured in a single number. For the proportion overlap metric, kernel density estimates are calculated on each time series. The kernel density estimates represent a non-parametric smoothing of the empirical distribution of time series values. The proportion overlap of two kernel density estimates is calculated with the following steps: (1) calculate the total area under the curve ($AUC_t$) as the sum of the AUC for each density estimate, (2) calculate the AUC of the overlapping portions ($AUC_o$) of the two density distributions being compared, and (3) calculate the overlapping proportion of the density distributions as $AUC_o/AUC_t$. Proportion overlap is naturally bound by zero and one; a value of zero indicates no overlap and a value of one indicates complete overlap. Lower values of proportion overlap identify channels demonstrating larger differences in a scenario comparison.

The proportion overlap metric is best applied over relatively short time periods because seasonal and annual variation in water velocity can overwhelm differences between scenarios. Thus, the proportion overlap for every DSM2 channel for each month in each water year (1922–2015) was calculated. The proportion overlap was calculated based on hourly DSM2 output. Because each month was roughly 30 days, each comparison involved roughly 1,440 DSM2 values (2 scenarios × 24 hours × 30 days) for each channel.

Because the proportion overlap was calculated for each channel in each water year, the proportion overlap values were summarized prior to mapping (i.e., it was not feasible to map proportion overlap for every comparison in every water year). To summarize, the minimum proportion overlap for each channel for each water year type for each comparison was found. The minimum values represent the maximum expected effect of the alternatives. Note that the year with the minimum proportion overlap for one channel might not be the same year as for another channel.

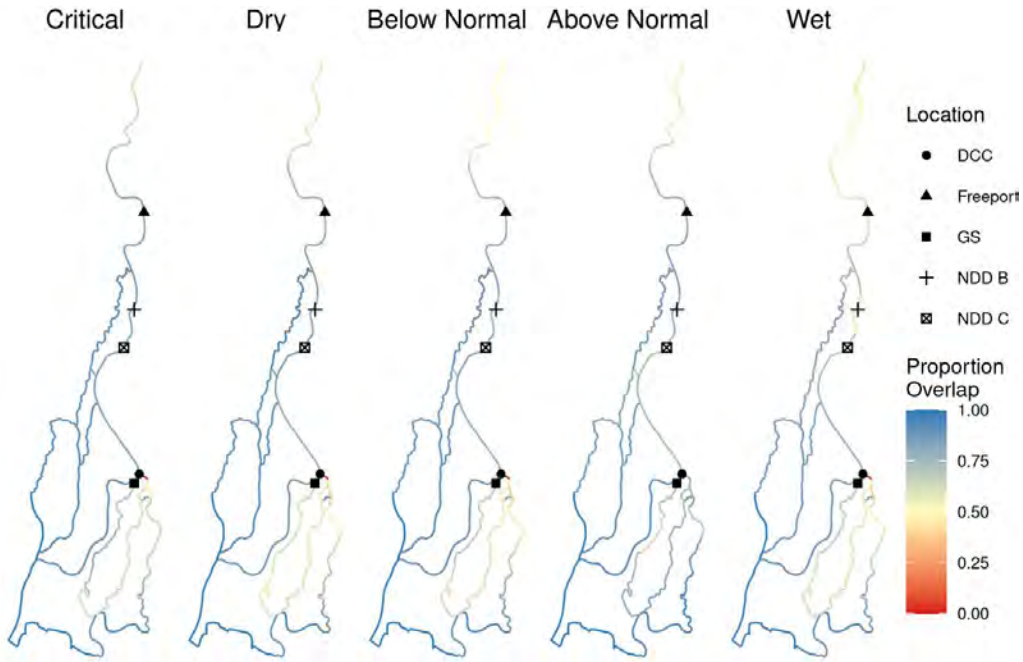
### 5D.4.1.2 Results

Results of the analysis are presented in Figure 5D.4-1 through Figure 5D.4-24 and are discussed in Appendix 5C.



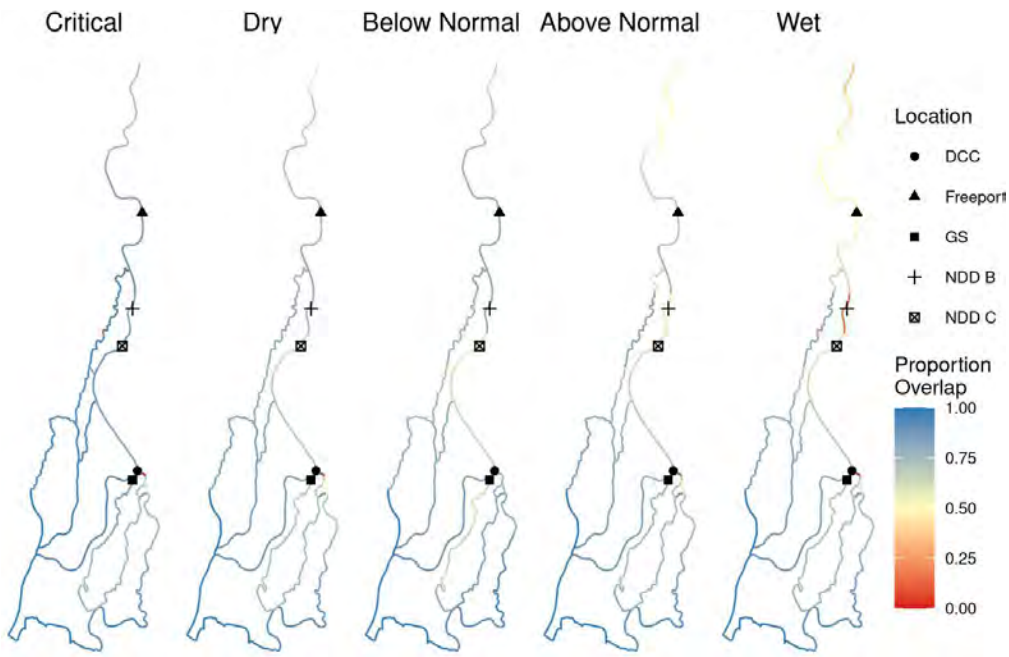

Note: DCC = Delta Cross Channel; GS = Georgiana Slough; NDD B = North Delta Diversion Intake B; NDD C = North Delta Diversion Intake C.

**Figure 5D.4-1. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the North Delta between Existing Conditions and the Proposed Action, September**



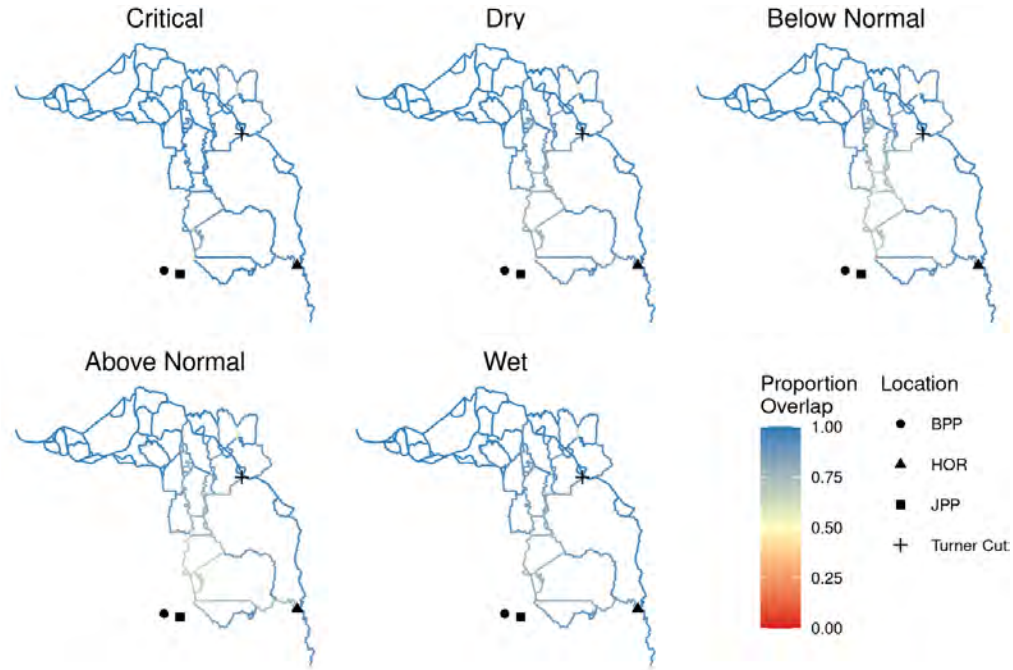

Note: DCC = Delta Cross Channel; GS = Georgiana Slough; NDD B = North Delta Diversion Intake B; NDD C = North Delta Diversion Intake C.

**Figure 5D.4-2. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the North Delta between Existing Conditions and Proposed Action, October**



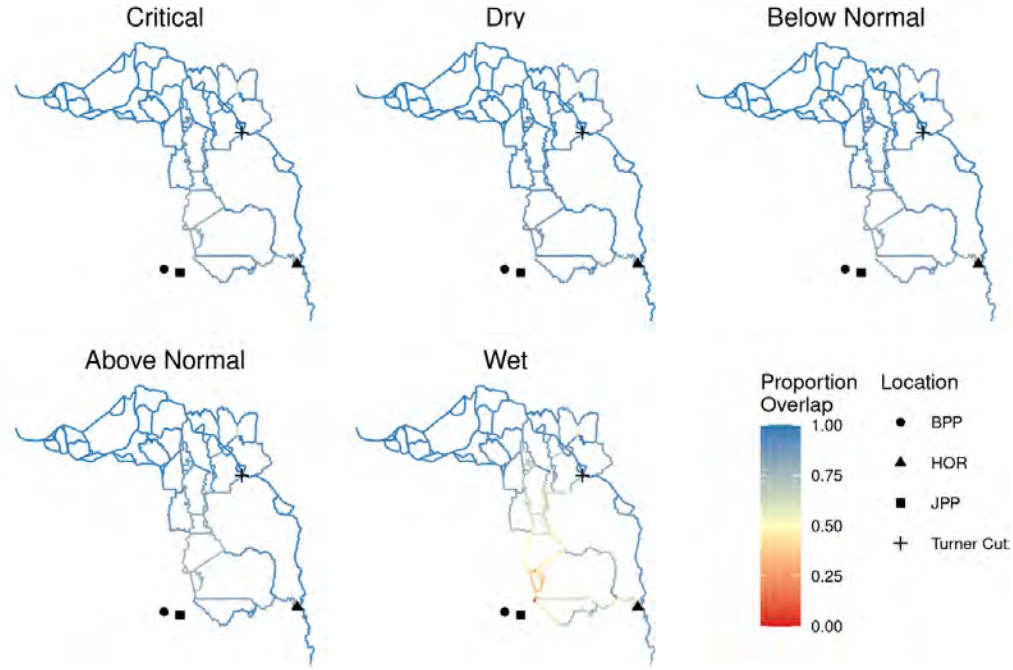

Note: DCC = Delta Cross Channel; GS = Georgiana Slough; NDD B = North Delta Diversion Intake B; NDD C = North Delta Diversion Intake C.

**Figure 5D.4-3. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the North Delta between Existing Conditions and the Proposed Action, November**



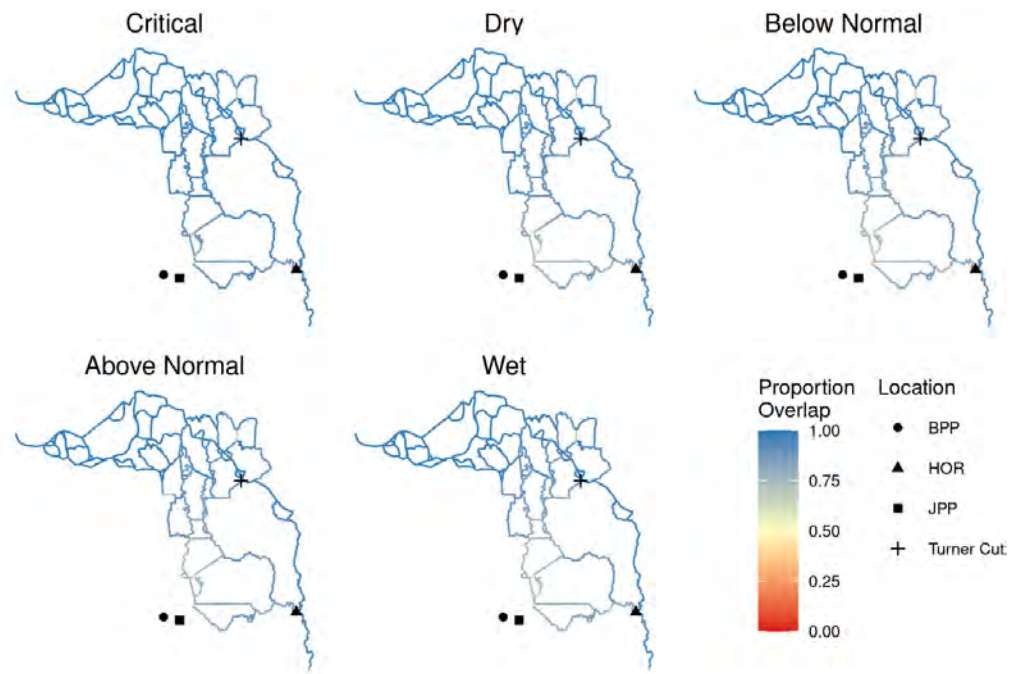

Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant.

**Figure 5D.4-4. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the South Delta between Existing Conditions and the Proposed Action, September**



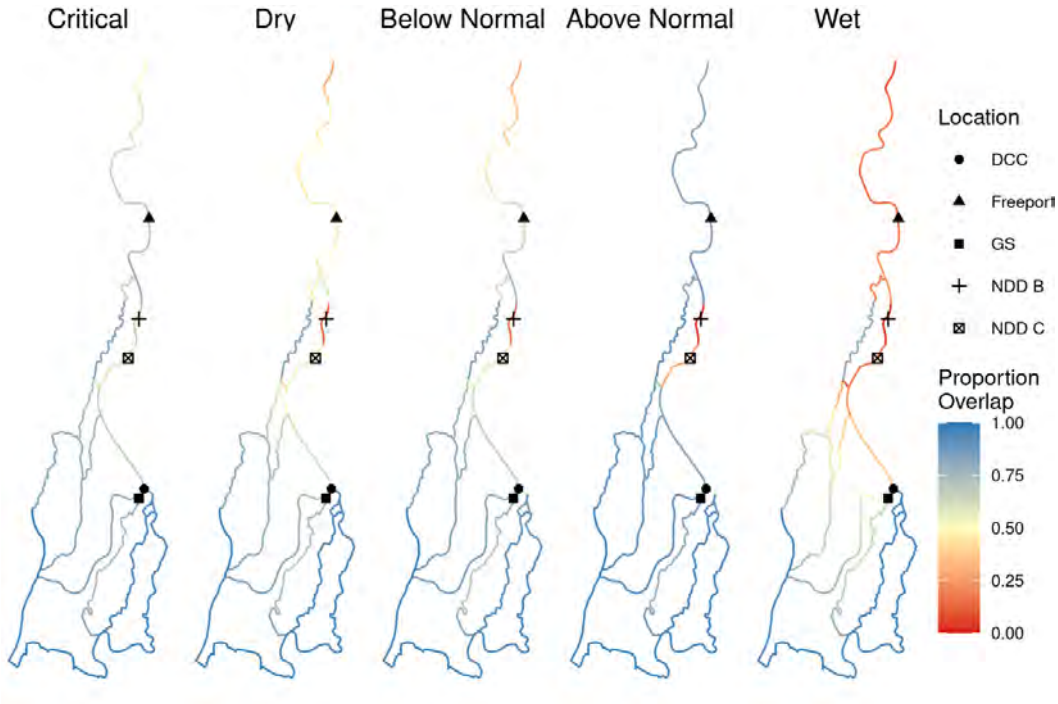

Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant.

**Figure 5D.4-5. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the South Delta between Existing Conditions and the Proposed Action, October**



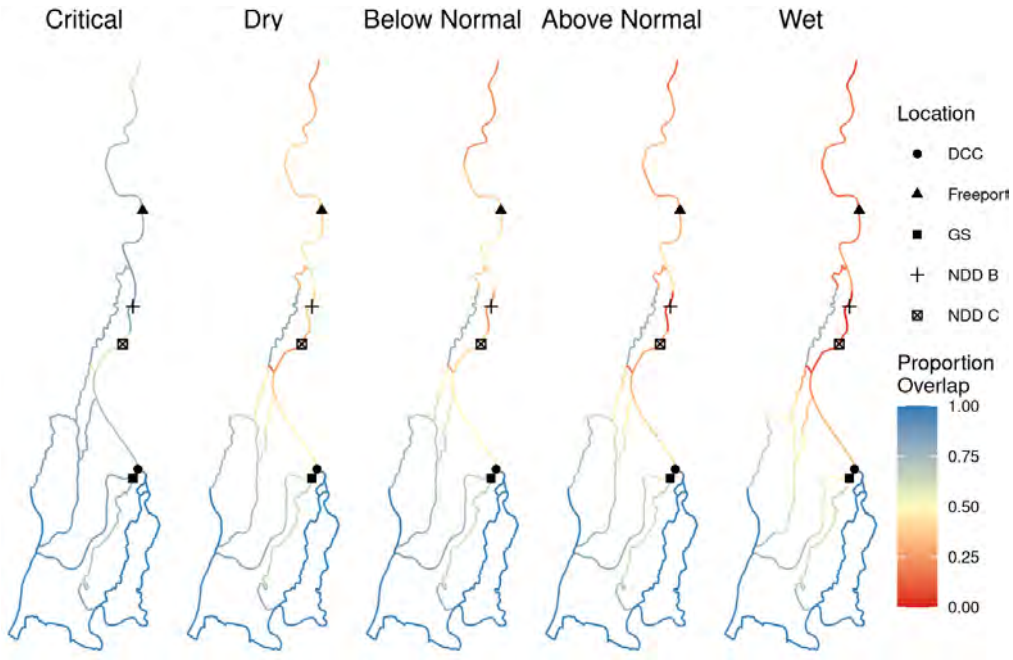

Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant.

**Figure 5D.4-6. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the South Delta between Existing Conditions and the Proposed Action, November**



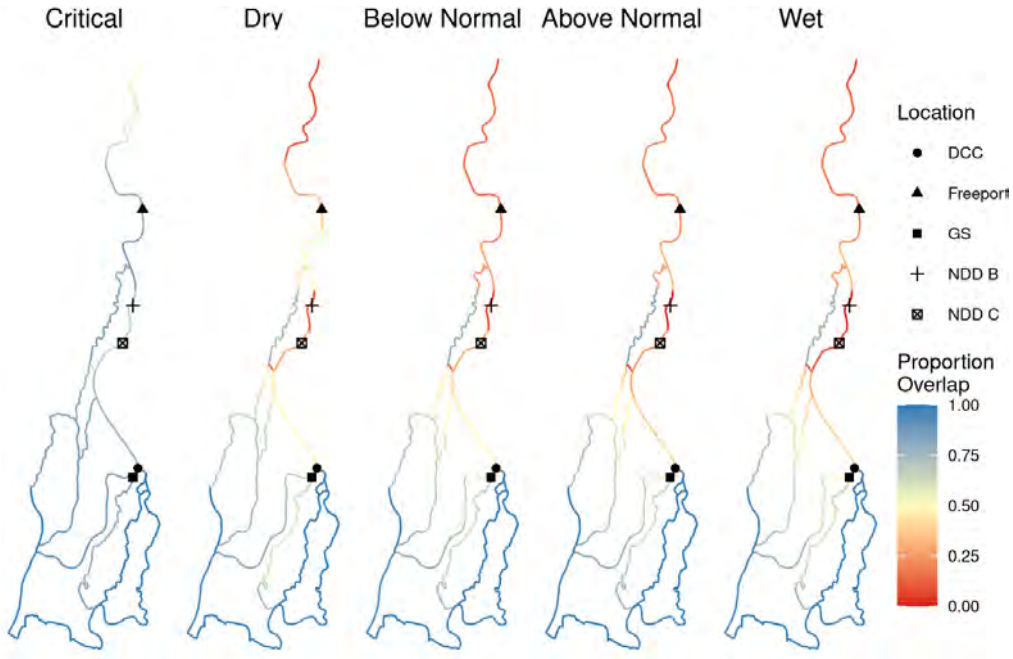

Note: DCC = Delta Cross Channel; GS = Georgiana Slough; NDD B = North Delta Diversion Intake B; NDD C = North Delta Diversion Intake C.

**Figure 5D.4-7. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the North Delta between Existing Conditions and the Proposed Action, December**



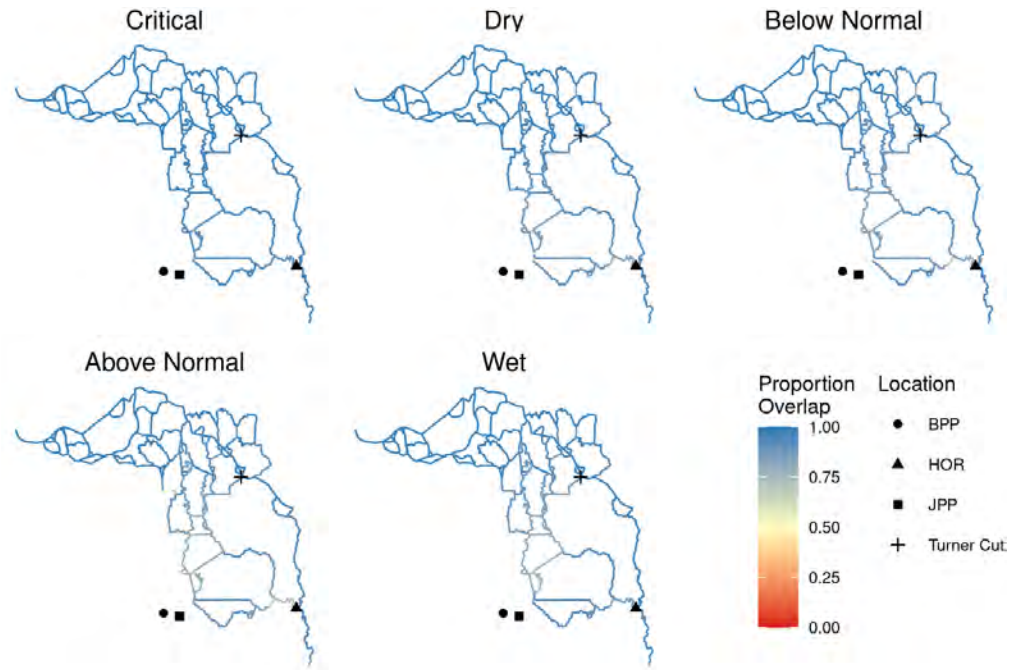

Note: DCC = Delta Cross Channel; GS = Georgiana Slough; NDD B = North Delta Diversion Intake B; NDD C = North Delta Diversion Intake C.

**Figure 5D.4-8. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the North Delta between Existing Conditions and the Proposed Action, January**



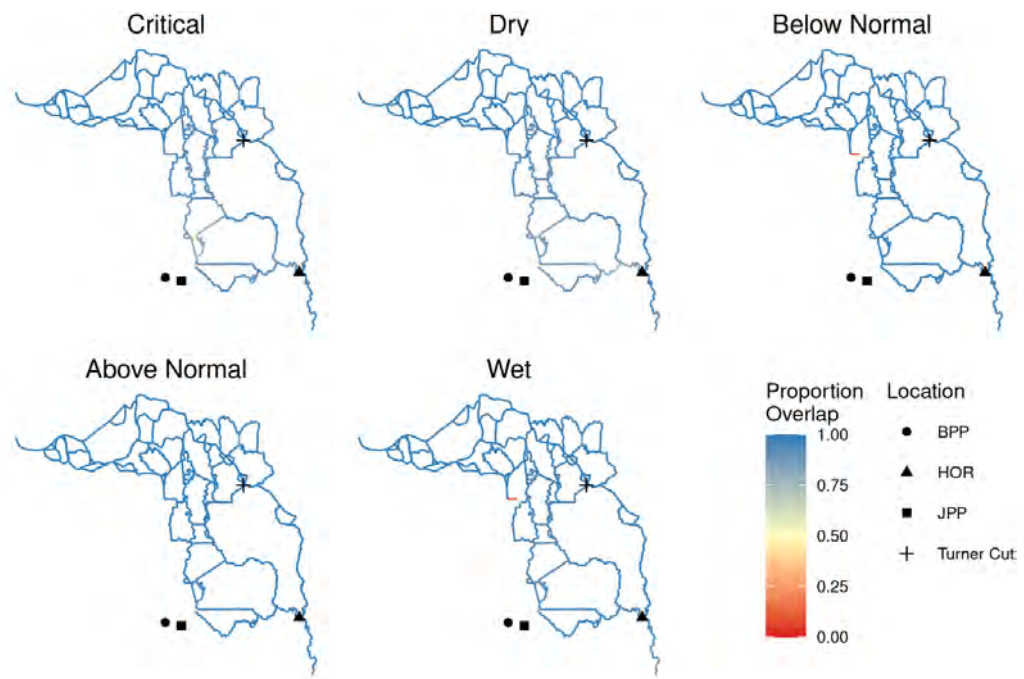

Note: DCC = Delta Cross Channel; GS = Georgiana Slough; NDD B = North Delta Diversion Intake B; NDD C = North Delta Diversion Intake C.

**Figure 5D.4-9. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the North Delta between Existing Conditions and the Proposed Action, February**



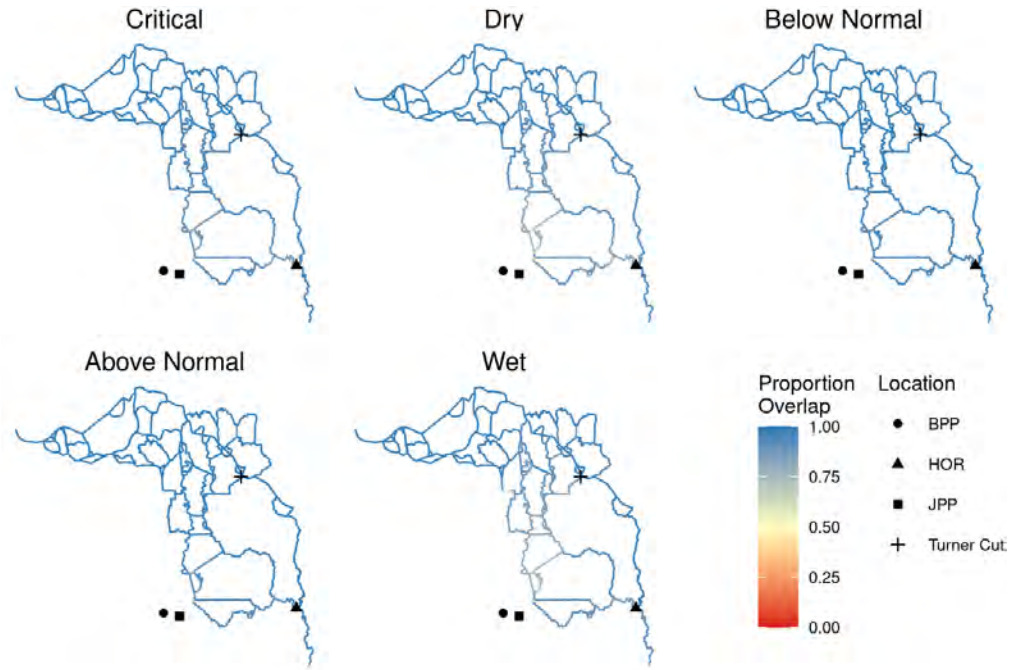

Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant.

**Figure 5D.4-10. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the South Delta between Existing Conditions and the Proposed Action, December**



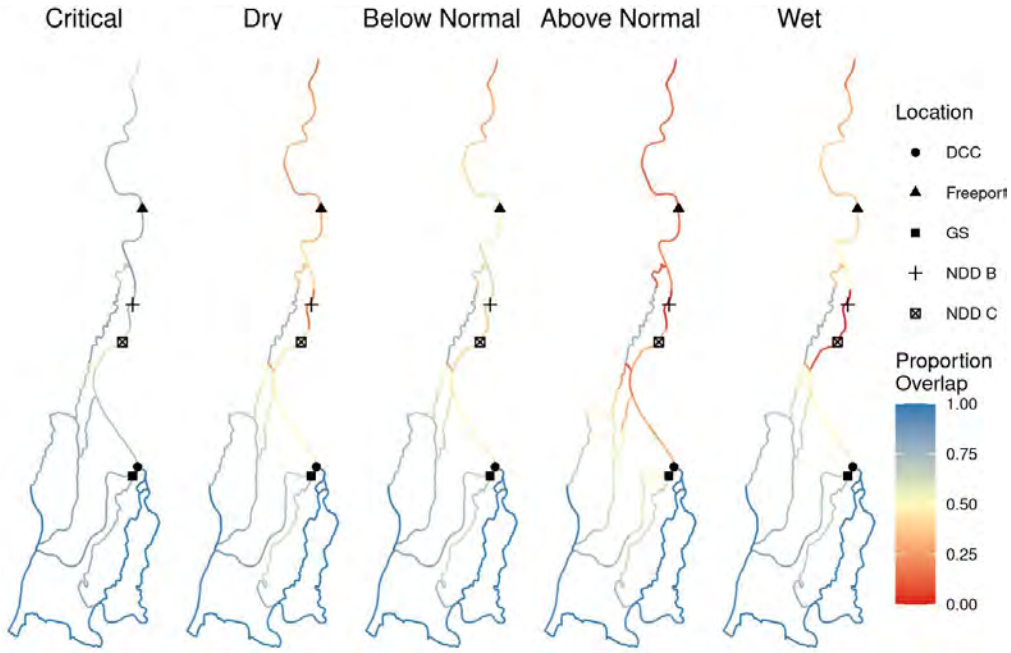

Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant.

**Figure 5D.4-11. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the South Delta between Existing Conditions and the Proposed Action, January**



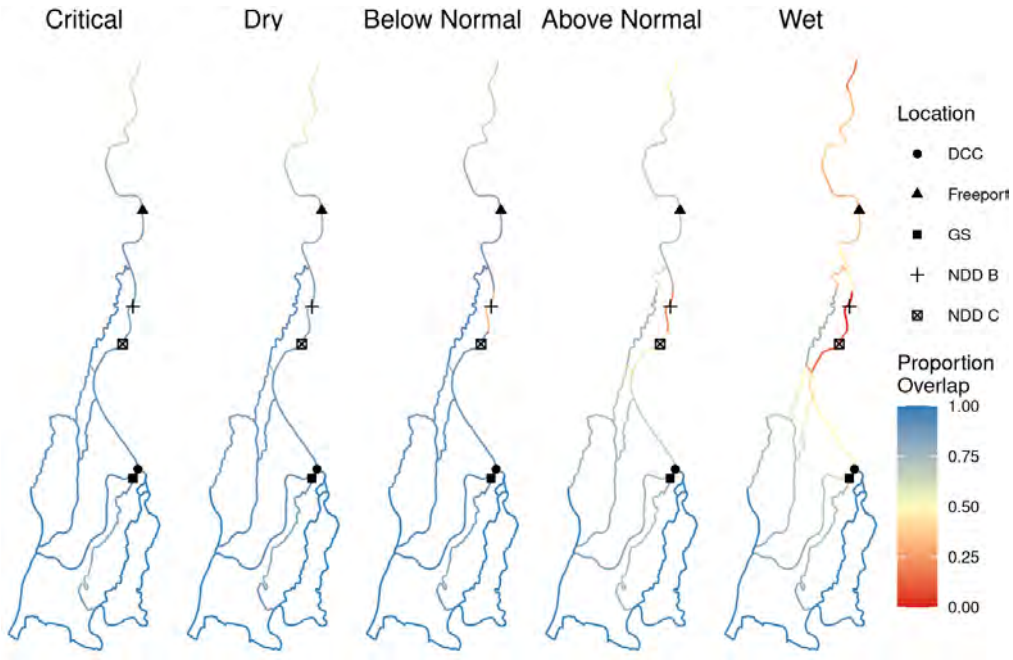

Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant.

**Figure 5D.4-12. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the South Delta between Existing Conditions and the Proposed Action, February**



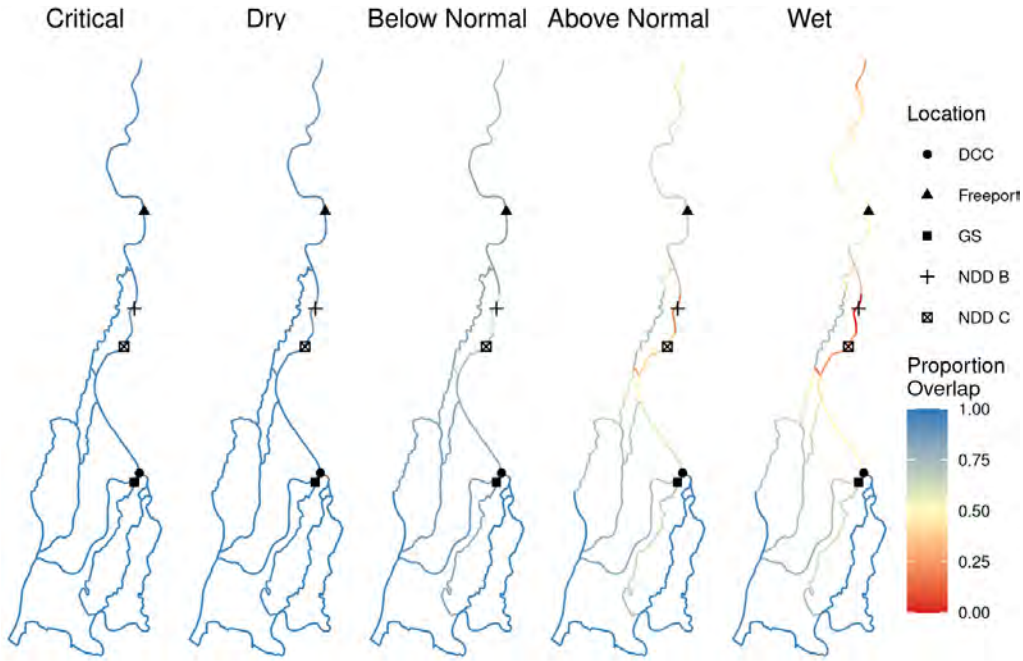

Note: DCC = Delta Cross Channel; GS = Georgiana Slough; NDD B = North Delta Diversion Intake B; NDD C = North Delta Diversion Intake C.

**Figure 5D.4-13. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the North Delta between Existing Conditions and the Proposed Action, March**



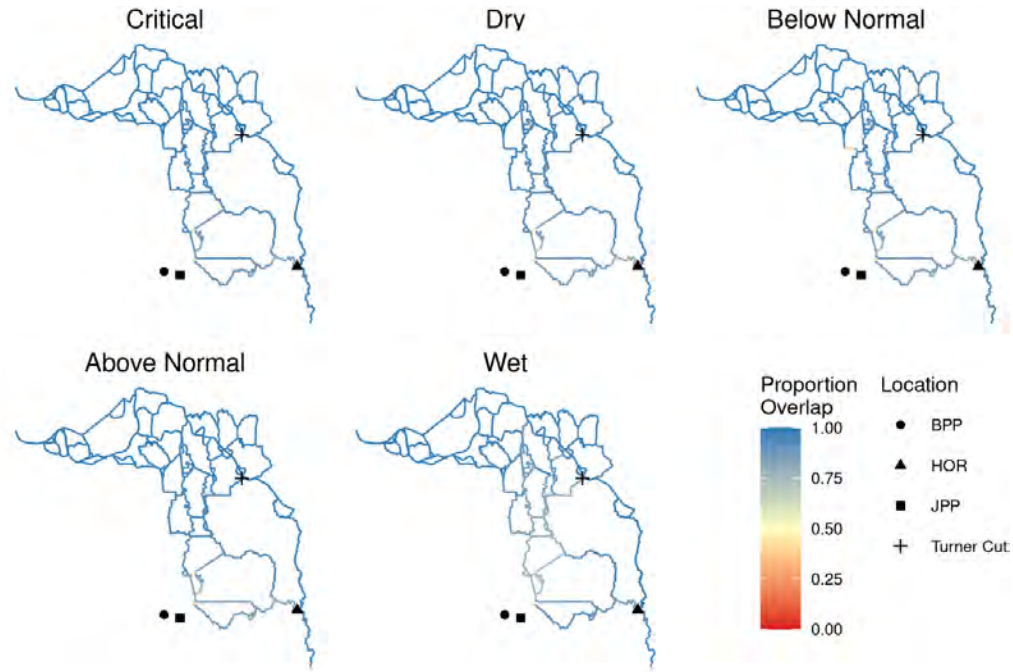

Note: DCC = Delta Cross Channel; GS = Georgiana Slough; NDD B = North Delta Diversion Intake B; NDD C = North Delta Diversion Intake C.

**Figure 5D.4-14. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the North Delta between Existing Conditions and the Proposed Action, April**



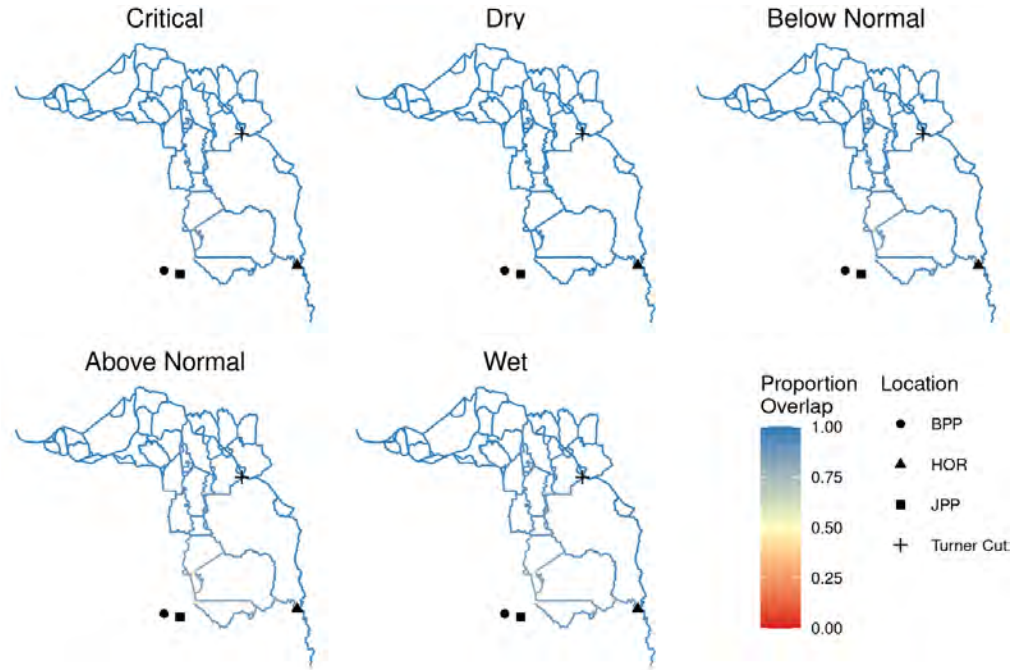

Note: DCC = Delta Cross Channel; GS = Georgiana Slough; NDD B = North Delta Diversion Intake B; NDD C = North Delta Diversion Intake C.

**Figure 5D.4-15. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the North Delta between Existing Conditions and the Proposed Action, May**



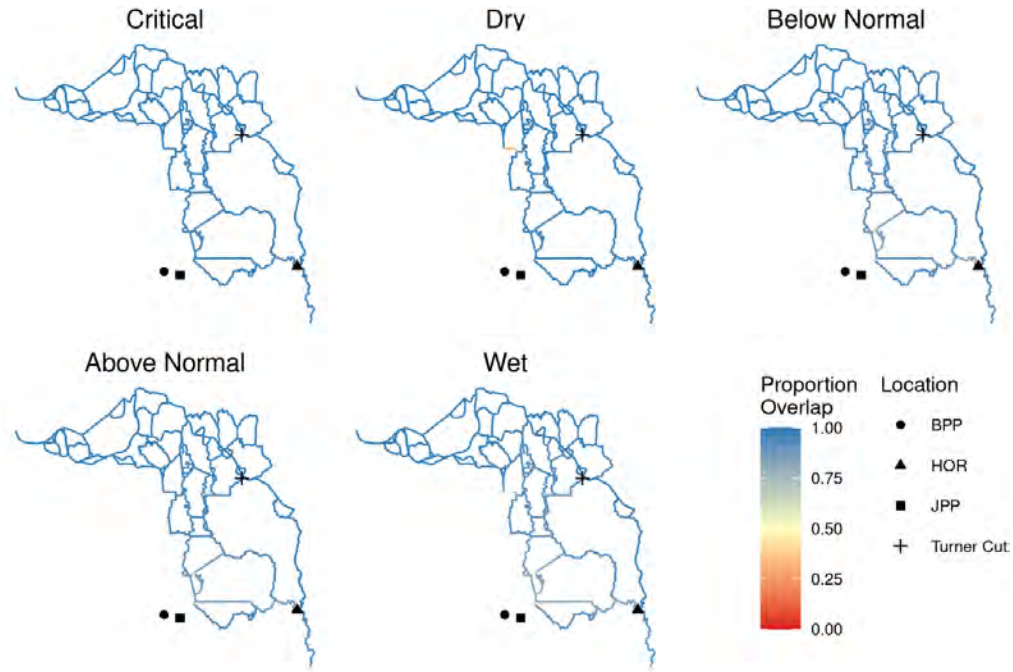

Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant.

**Figure 5D.4-16. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the South Delta between Existing Conditions and the Proposed Action, March**



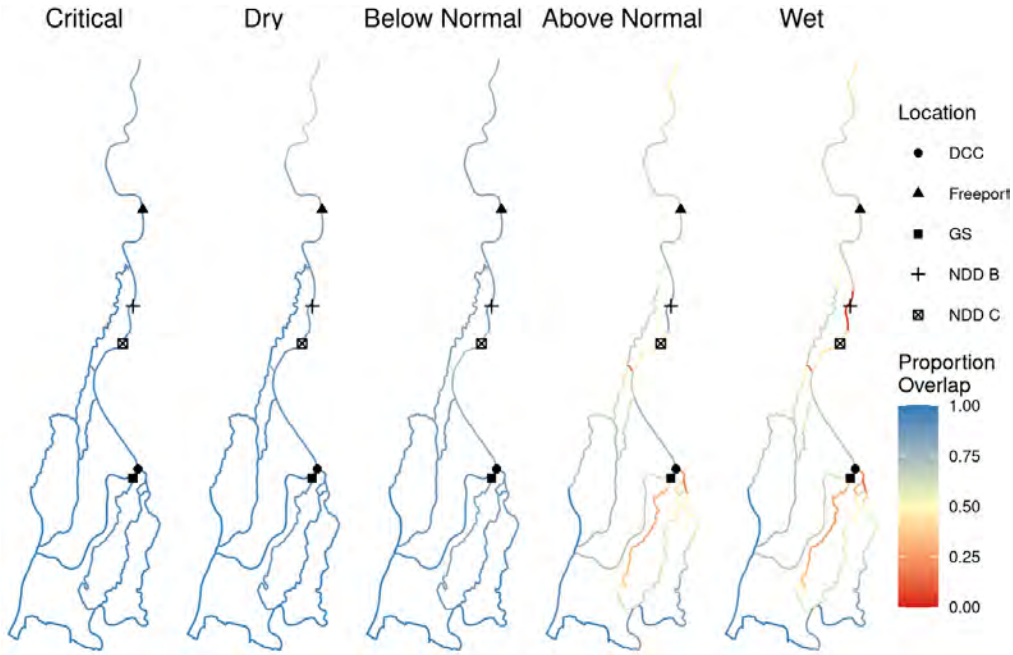

Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant.

**Figure 5D.4-17. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the South Delta between Existing Conditions and the Proposed Action, April**



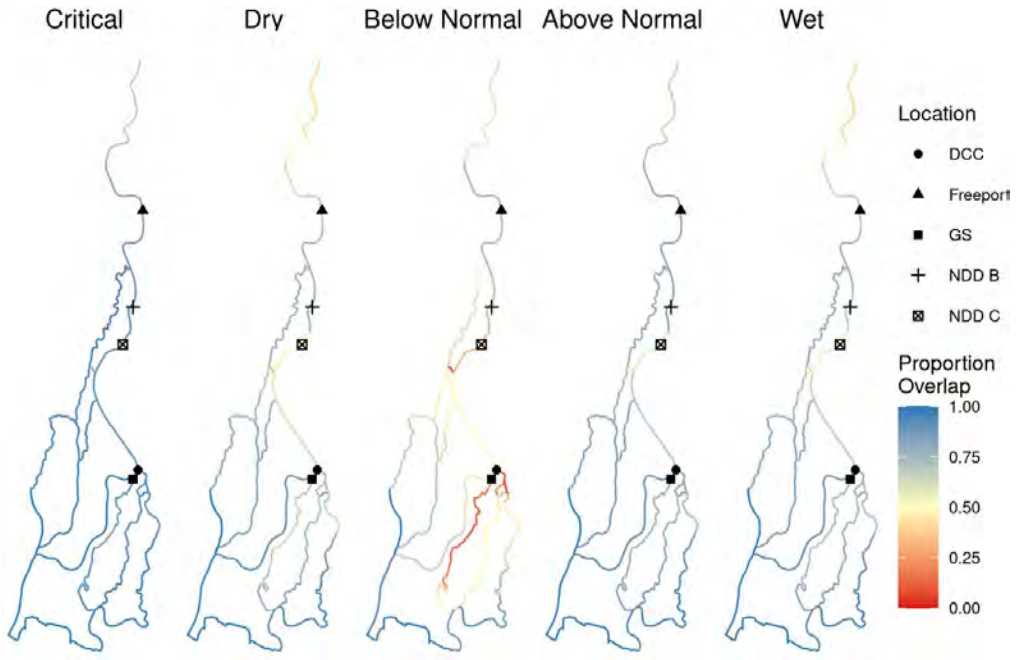

Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant.

**Figure 5D.4-18. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the South Delta between Existing Conditions and the Proposed Action, May**



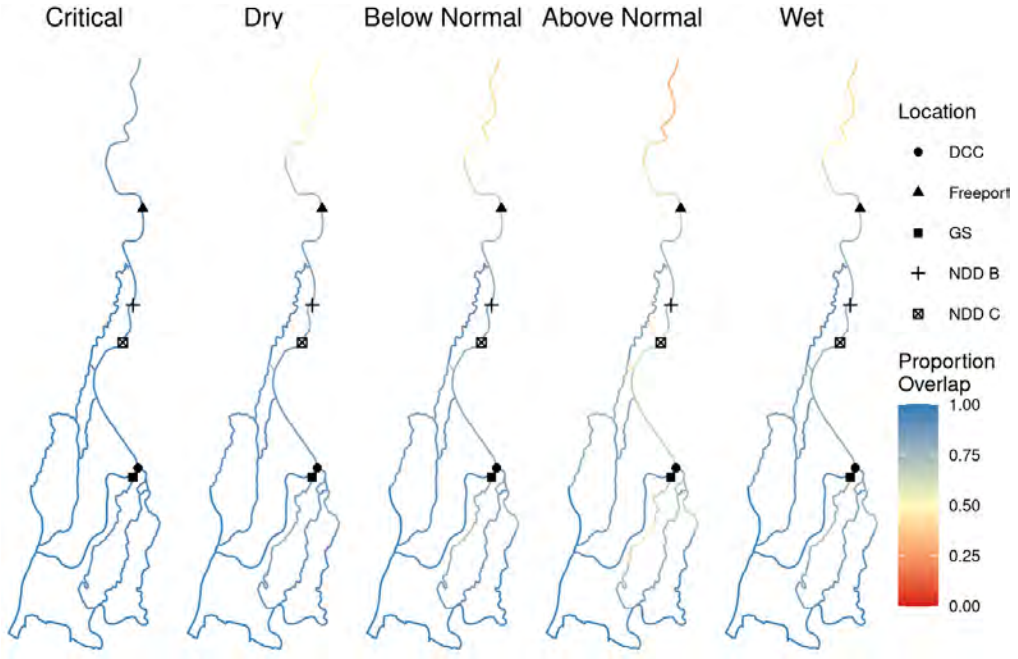

Note: DCC = Delta Cross Channel; GS = Georgiana Slough; NDD B = North Delta Diversion Intake B; NDD C = North Delta Diversion Intake C.

**Figure 5D.4-19. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the North Delta between Existing Conditions and the Proposed Action, June**



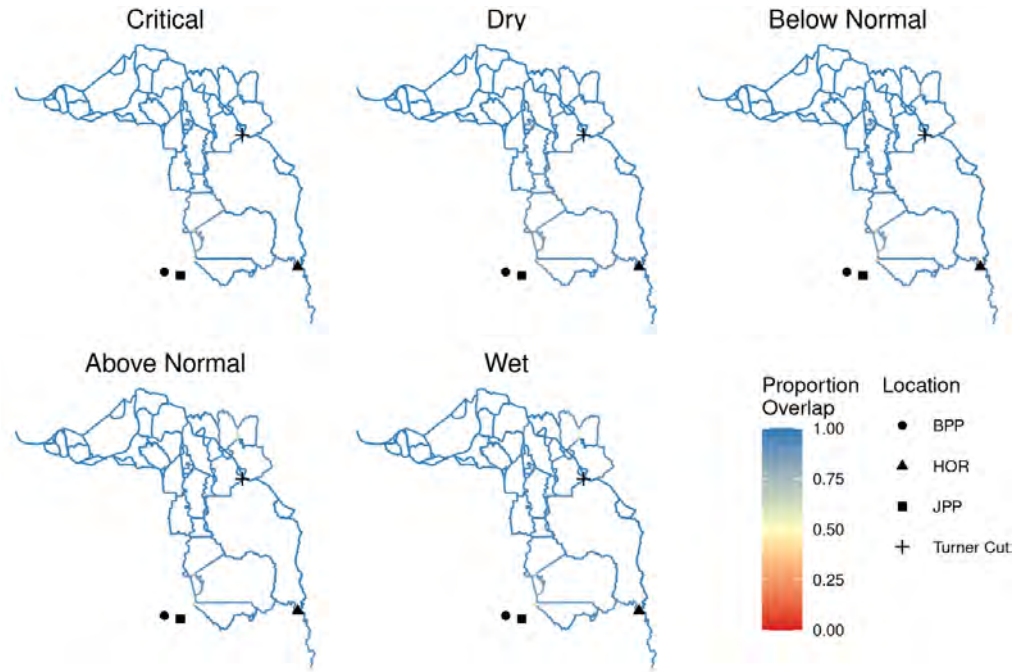

Note: = Delta Cross Channel; GS = Georgiana Slough; NDD B = North Delta Diversion Intake B; NDD C = North Delta Diversion Intake C.

**Figure 5D.4-20. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the North Delta between Existing Conditions and the Proposed Action, July**



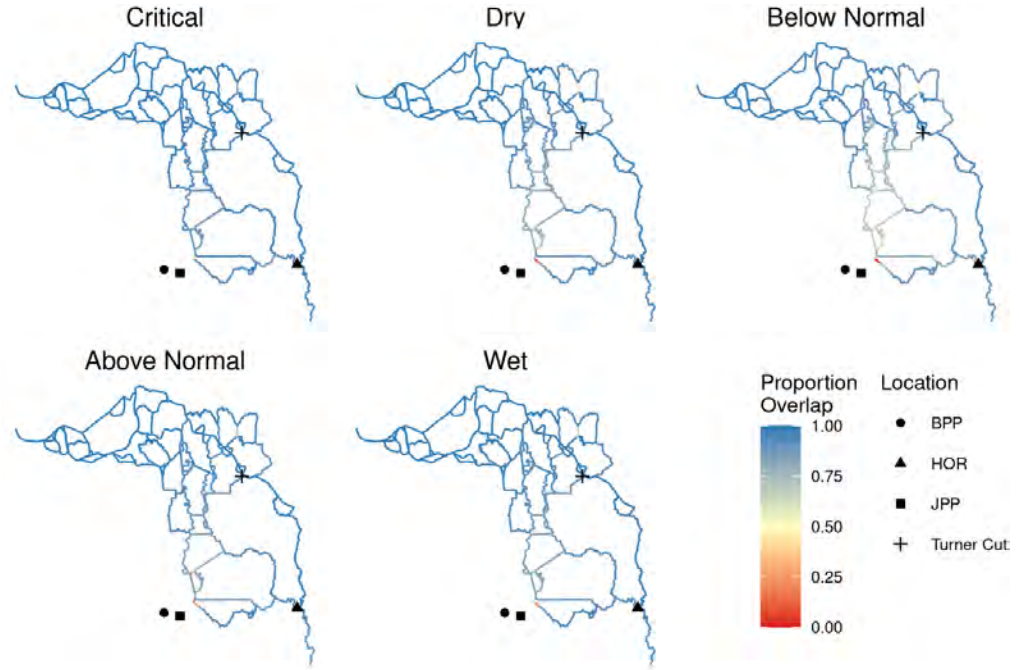

Note: DCC = Delta Cross Channel; GS = Georgiana Slough; NDD B = North Delta Diversion Intake B; NDD C = North Delta Diversion Intake C.

**Figure 5D.4-21. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the North Delta between Existing Conditions and the Proposed Action, August**



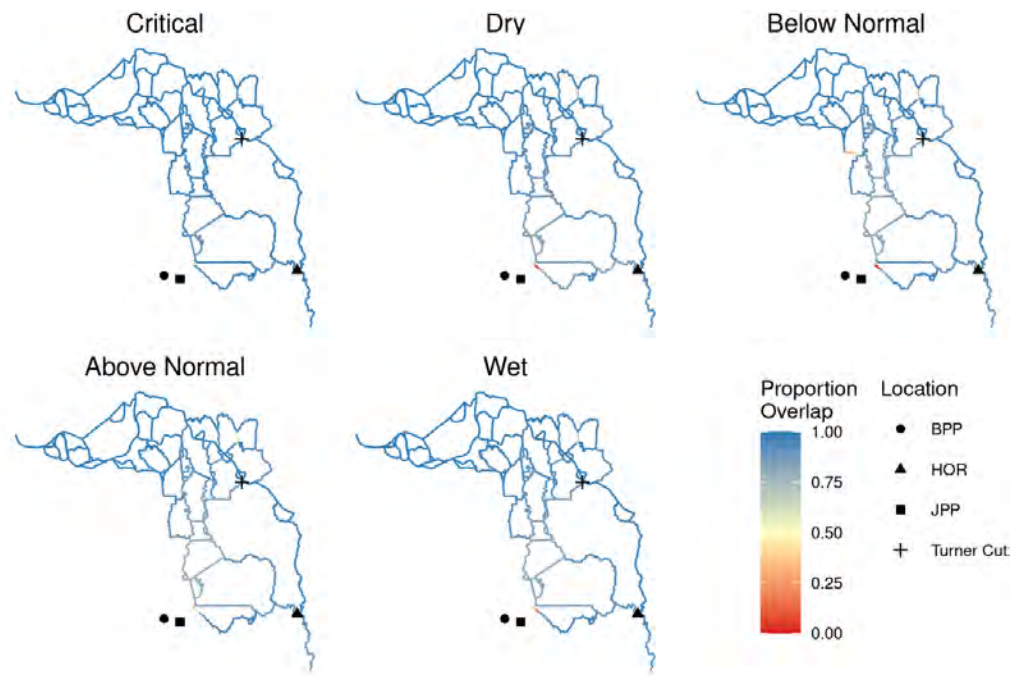

Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant.

**Figure 5D.4-22. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the South Delta between Existing Conditions and the Proposed Action, June**




Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant.

**Figure 5D.4-23. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the South Delta between Existing Conditions and the Proposed Action, July**




Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant.

**Figure 5D.4-24. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the South Delta between Existing Conditions and the Proposed Action, August**

# 5D.4.2 Flow into Junctions

## 5D.4.2.1 Methods

Many routes can potentially be used by fish migrating through the Delta and survival through these routes can be significantly different (Newman 2008; Perry et al. 2010). Thus, routing of fish at junctions and how routing could be affected by project operations has the potential to influence through-Delta survival. In general, routes that keep fish in the mainstem Sacramento and San Joaquin Rivers are superior to routes leading into the interior Delta (Hankin et al. 2010; Perry et al. 2010), although some recent findings for the San Joaquin River have not supported this generality (Buchanan et al. 2013). Perry (2010) found that the routing of fish into the interior delta through the combined junction of Georgiana Slough and the Delta Cross Channel was a function of the total flow entering the interior delta through both of those junctions. This is the function represented in Figure 6.7 within Perry (2010). This function indicated that the slope of the relationship was less than 1.

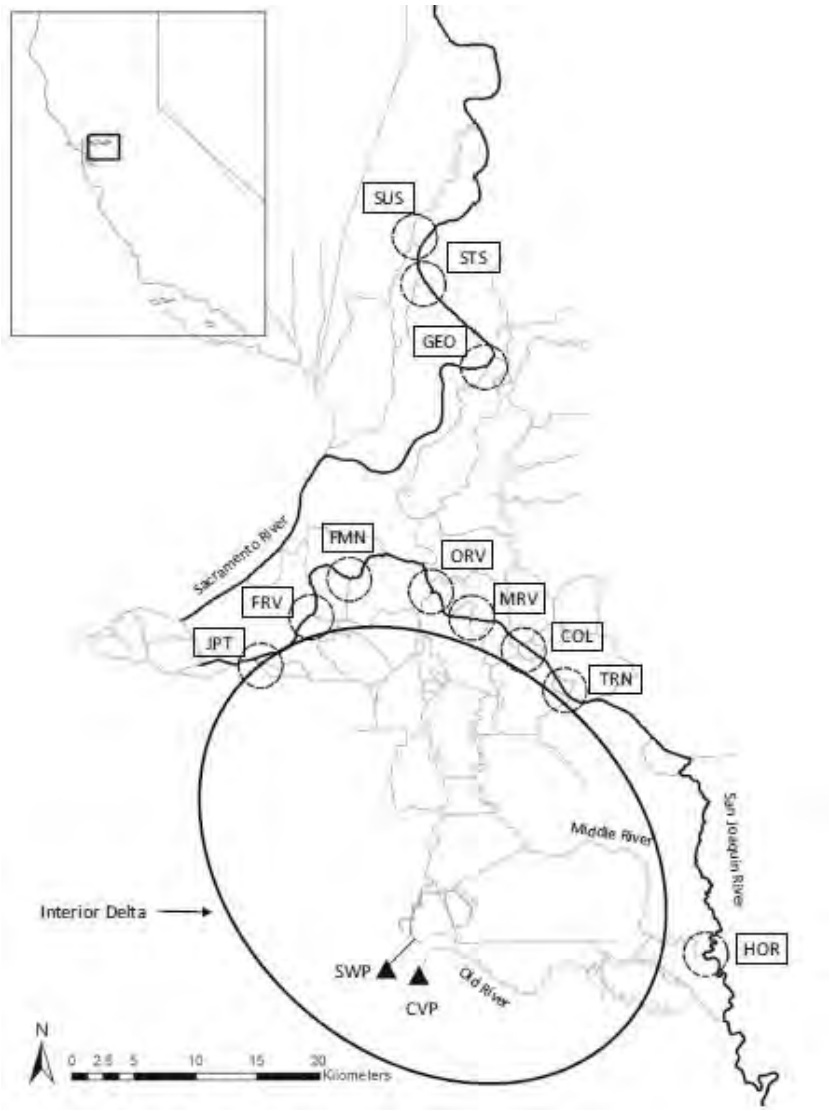
Cavallo et al. (2015) performed a meta-analysis of routing at six Delta junctions and found that the proportion of flow entering a junction explained 70% of the variation in routing. Similar to the Perry (2010) study, the slope of this relationship was less than 1, suggesting fish move into junctions at a rate less than the proportion of flow. Both of these studies present strong evidence that routing at junctions is a function of the proportion of flow into that junction.

For the present analysis, flow routing into junctions was based on the proportion of flow entering a junction away from the mainstem, from DSM2-HYDRO outputs. Fifteen-minute data were used to calculate the daily proportion of flow that enters the junction, following the methods of Cavallo et al.

(2015). The daily value calculated from the 15-minute data was used to calculate summary statistics (box plots) for each month (December–June) and water year-type by modeled scenario.

Flow into a number of junctions of interest with respect to movement in the north Delta and toward the south Delta was analyzed: Sutter Slough, Steamboat Slough, the Delta Cross Channel, Georgiana Slough, the head of Old River, Turner Cut, Columbia Cut, the mouth of Middle River, the mouth of Old River, Fisherman's Cut, False River, and Jersey Point (Figure 5D.4-25).

The combined evidence from the literature strongly indicates routing is a function of flow. Thus, it can be assumed routing of fish into a junction will increase as the proportion of flow entering the junction increases. However, the slope of the relationship will be less than 1 based on the available studies (Perry 2010; Cavallo et al. 2015).



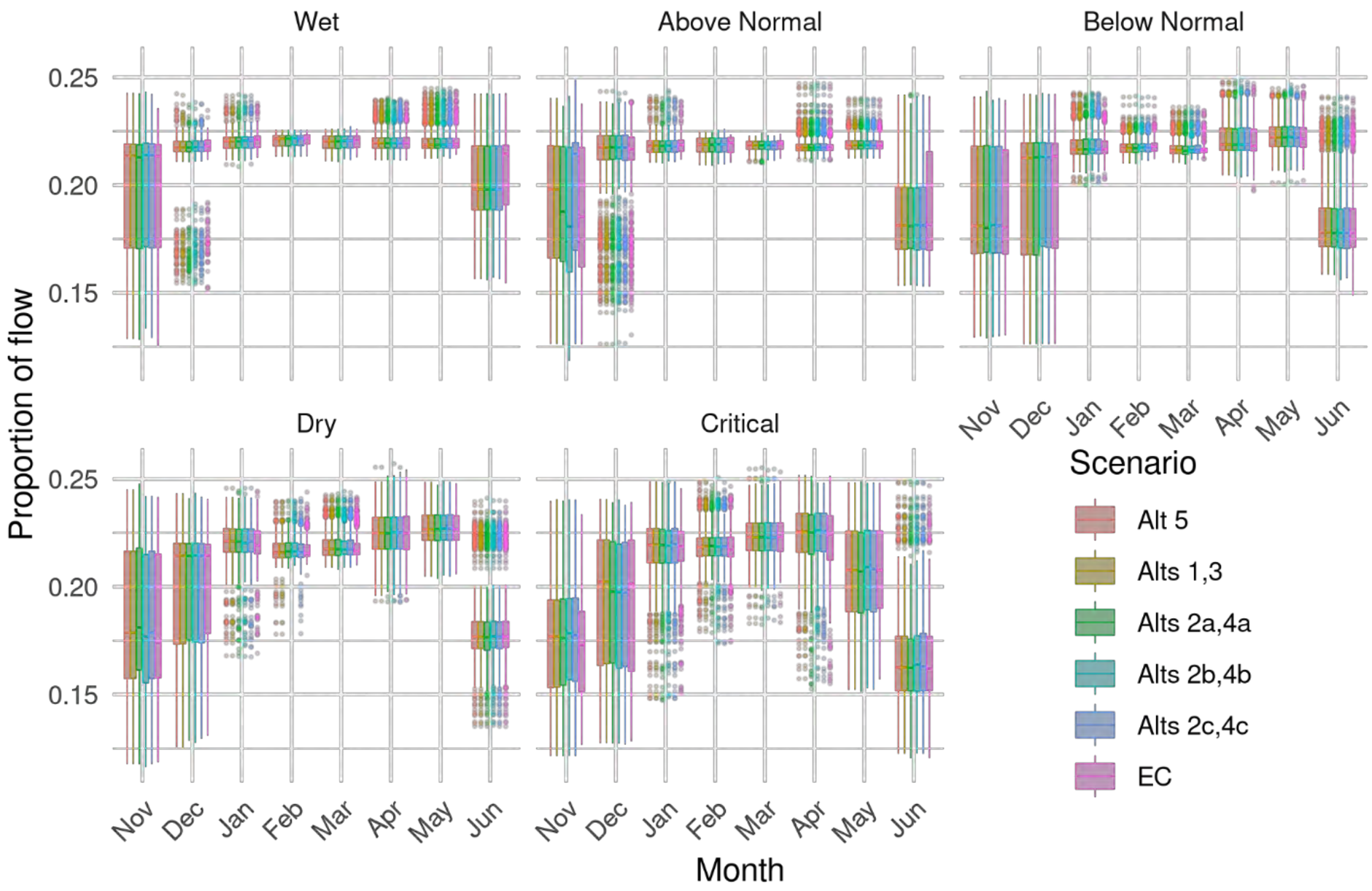

Source: Cavallo et al. 2015.
Note: Junction abbreviations include Sutter Slough (SUS), Steamboat Slough (STS), Georgiana Slough (GEO), the head of Old River (HOR), Turner Cut (TRN), Columbia Cut (COL), the mouth of Middle River (MRV), the mouth of Old River (ORV), Fisherman's Cut (FMN), False River (FRV), and Jersey Point (JPT). Also analyzed but not shown on the map was the Delta Cross Channel, immediately adjacent to GEO.

**Figure 5D.4-25. Map of Junctions Analyzed for Flow Entry Based on DSM2-HYDRO Outputs**

### 5D.4.2.2 Results

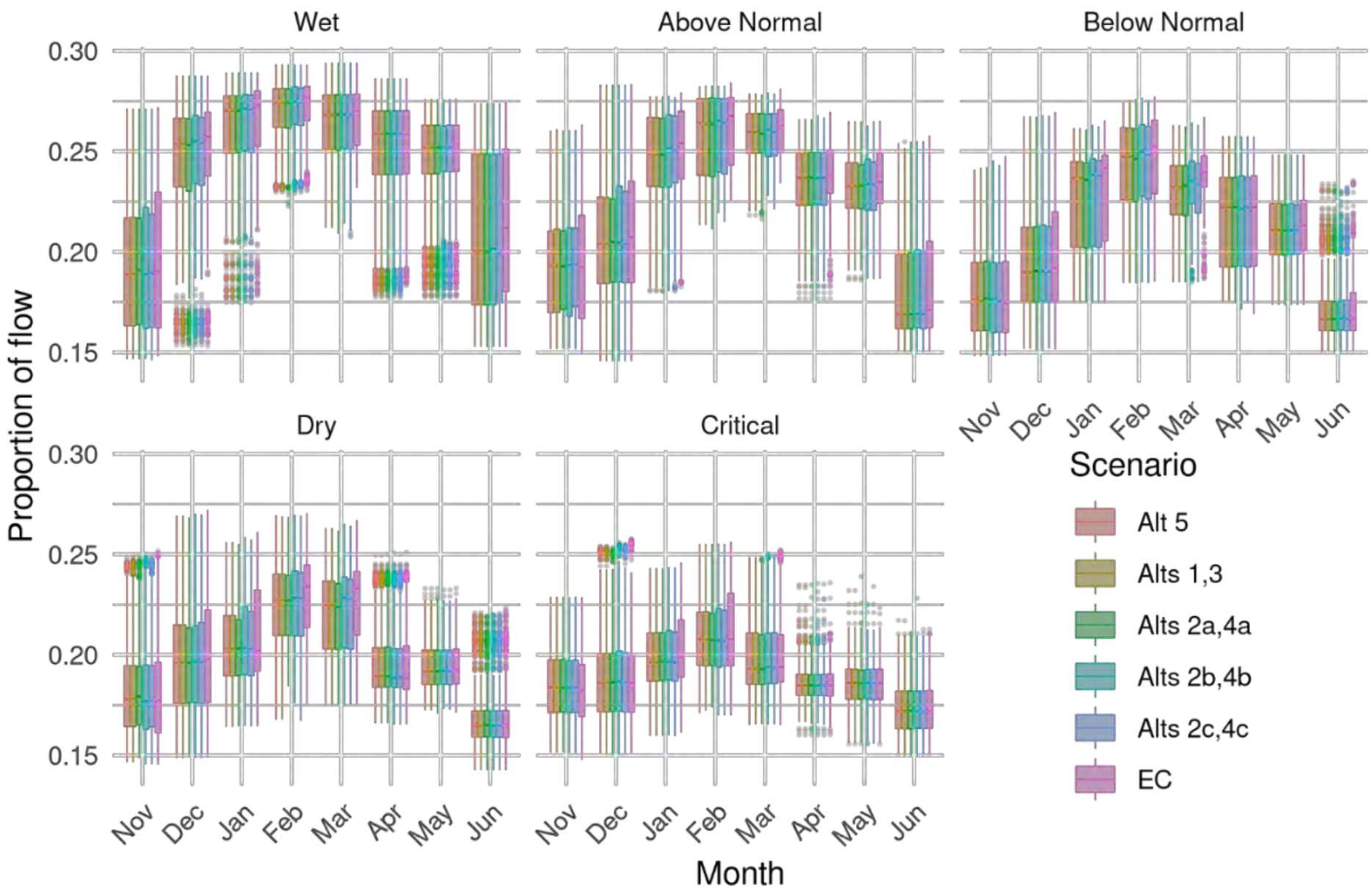
Results of the analysis are presented in Figure 5D.4-26 through Figure 5D.4-37 and in Table 5D.4-1, and are discussed in Appendix 5C and Appendix 6C, *Operations and Maintenance Effects Analysis for Delta Smelt, Longfin Smelt, and Terrestrial Species*.

Note: Alt 5 is in the figures is equivalent to the proposed action.



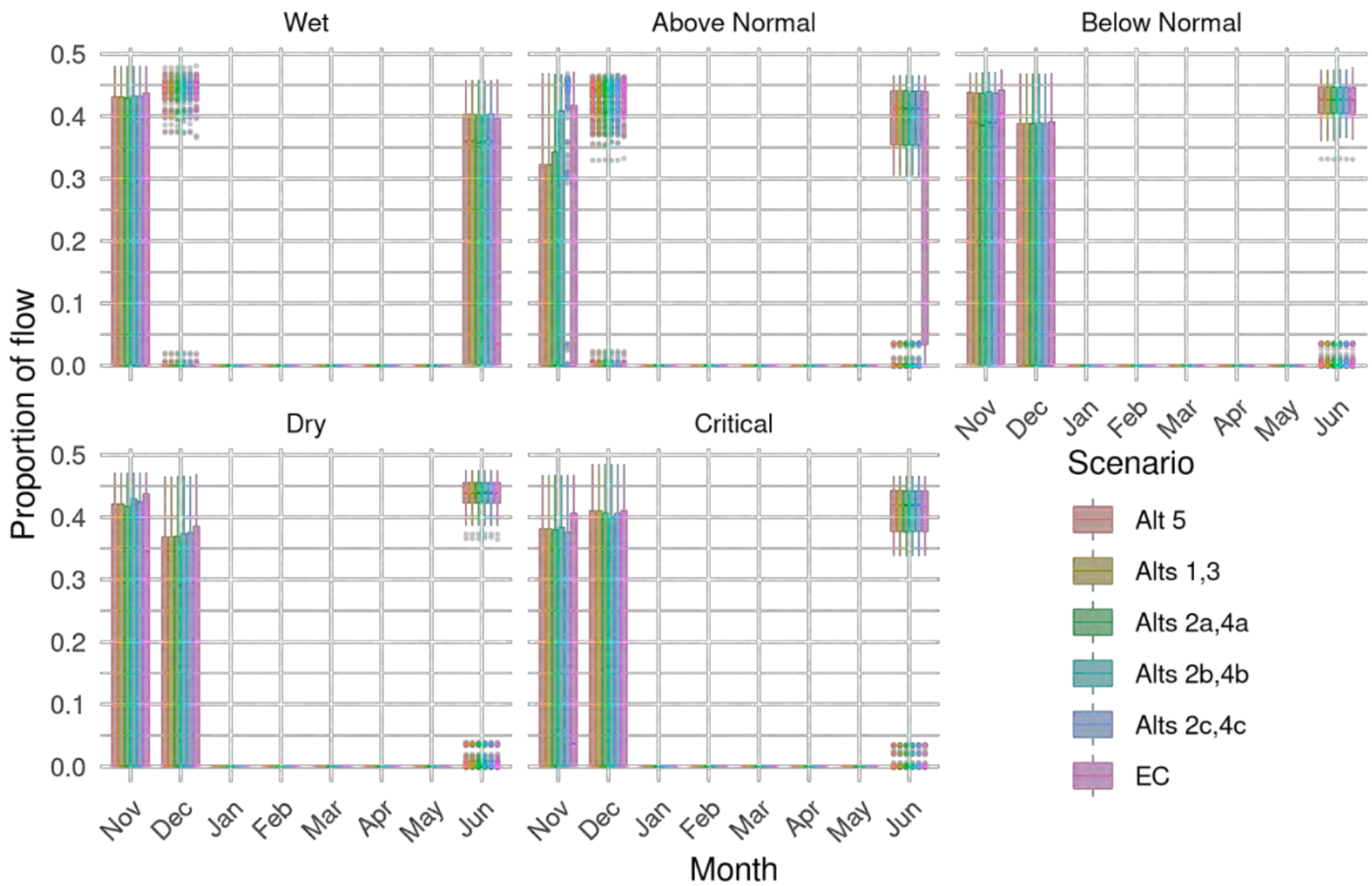

Note: Boxes represent median (horizontal line) and 25th/75th percentiles; whiskers represent 5th/95th percentiles; points represent additional observations outside this range.

**Figure 5D.4-26. Proportion of Flow Entering Sutter Slough from DSM2-HYDRO Modeling Data**



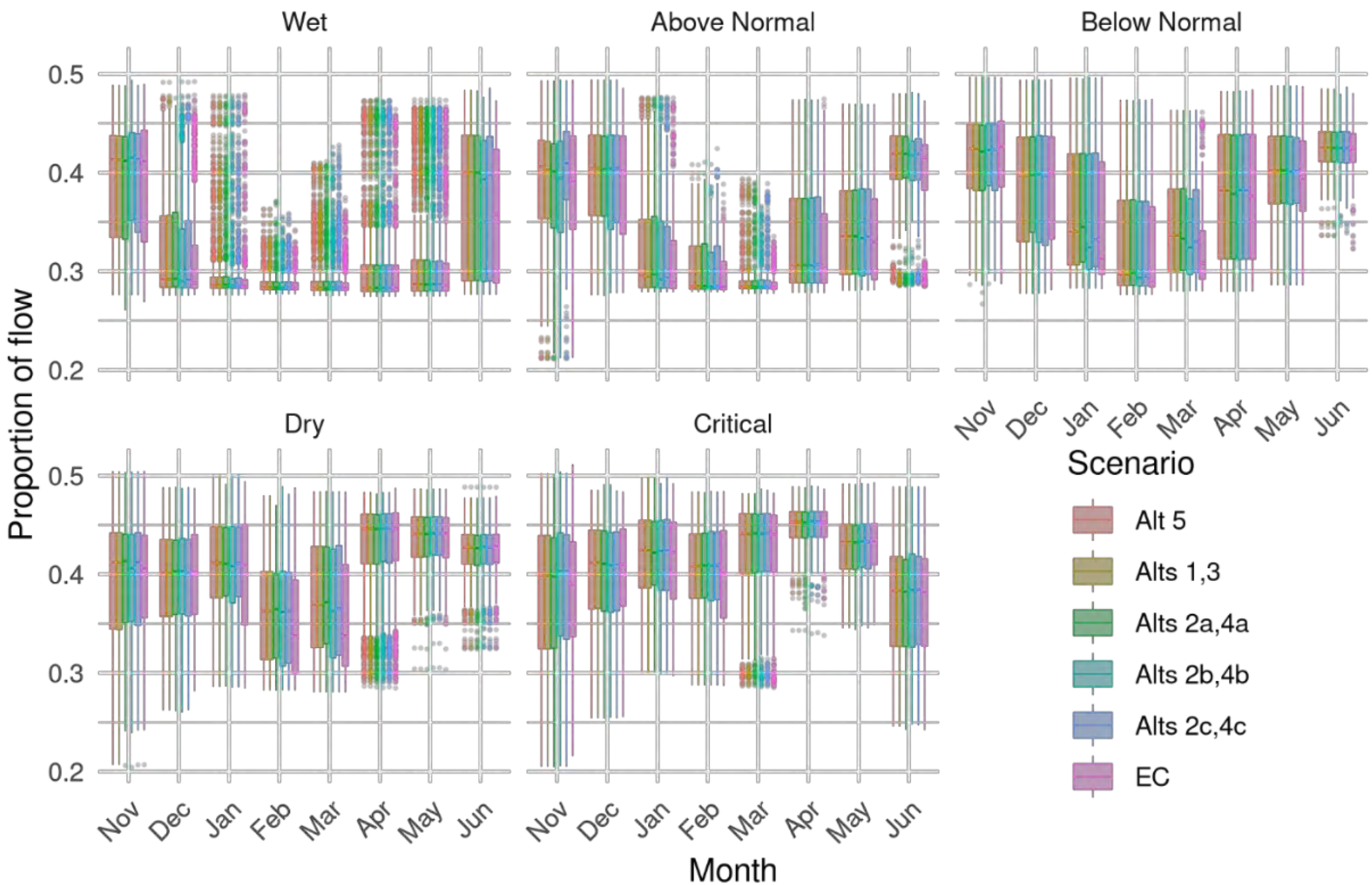

Note: Boxes represent median (horizontal line) and 25th/75th percentiles; whiskers represent 5th/95th percentiles; points represent additional observations outside this range.

**Figure 5D.4-27. Proportion of Flow Entering Steamboat Slough from DSM2-HYDRO Modeling Data**



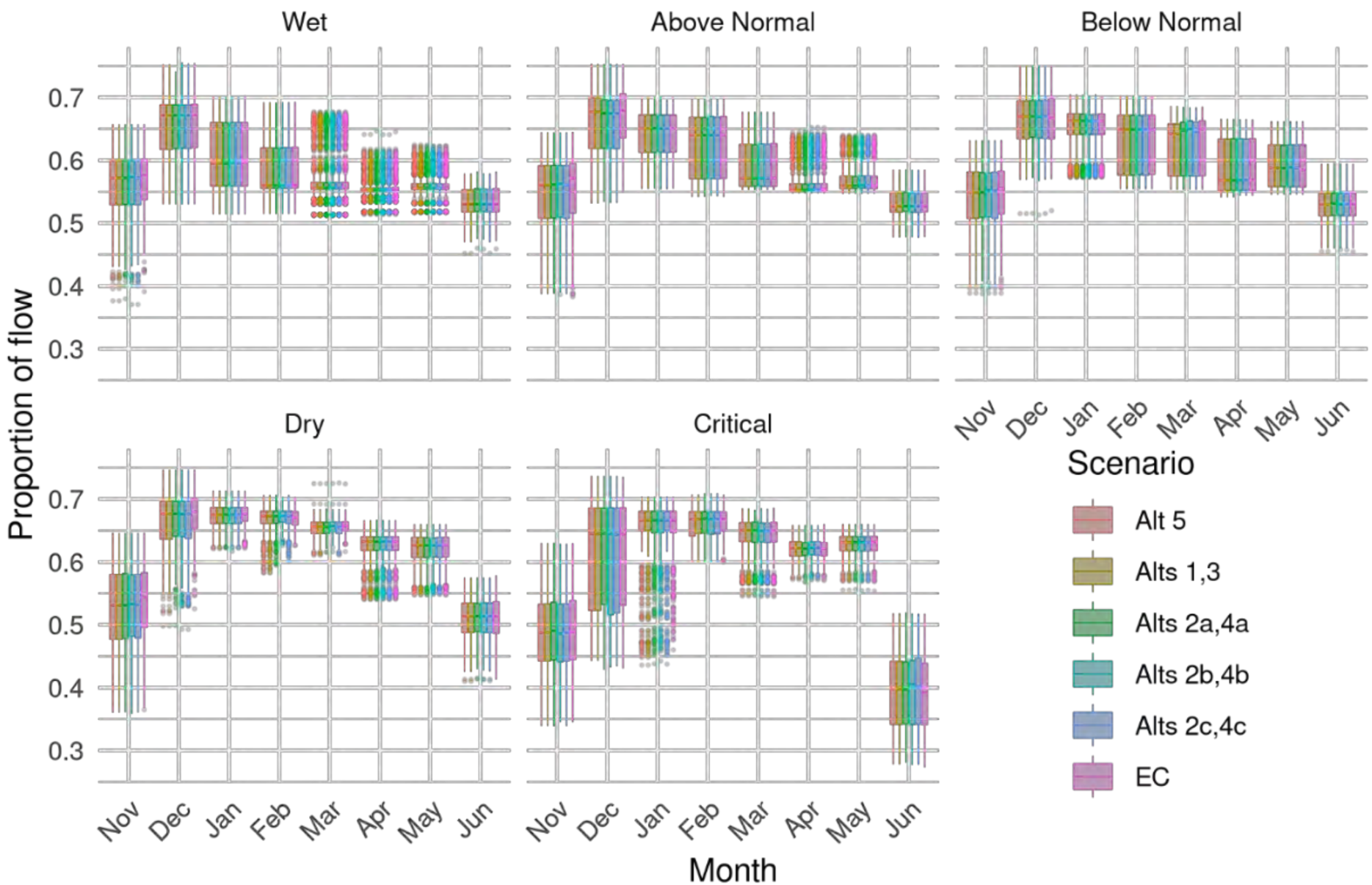

Note: Boxes represent median (horizontal line) and 25th/75th percentiles; whiskers represent 5th/95th percentiles; points represent additional observations outside this range.

**Figure 5D.4-28. Proportion of Flow Entering the Delta Cross Channel from DSM2-HYDRO Modeling Data**



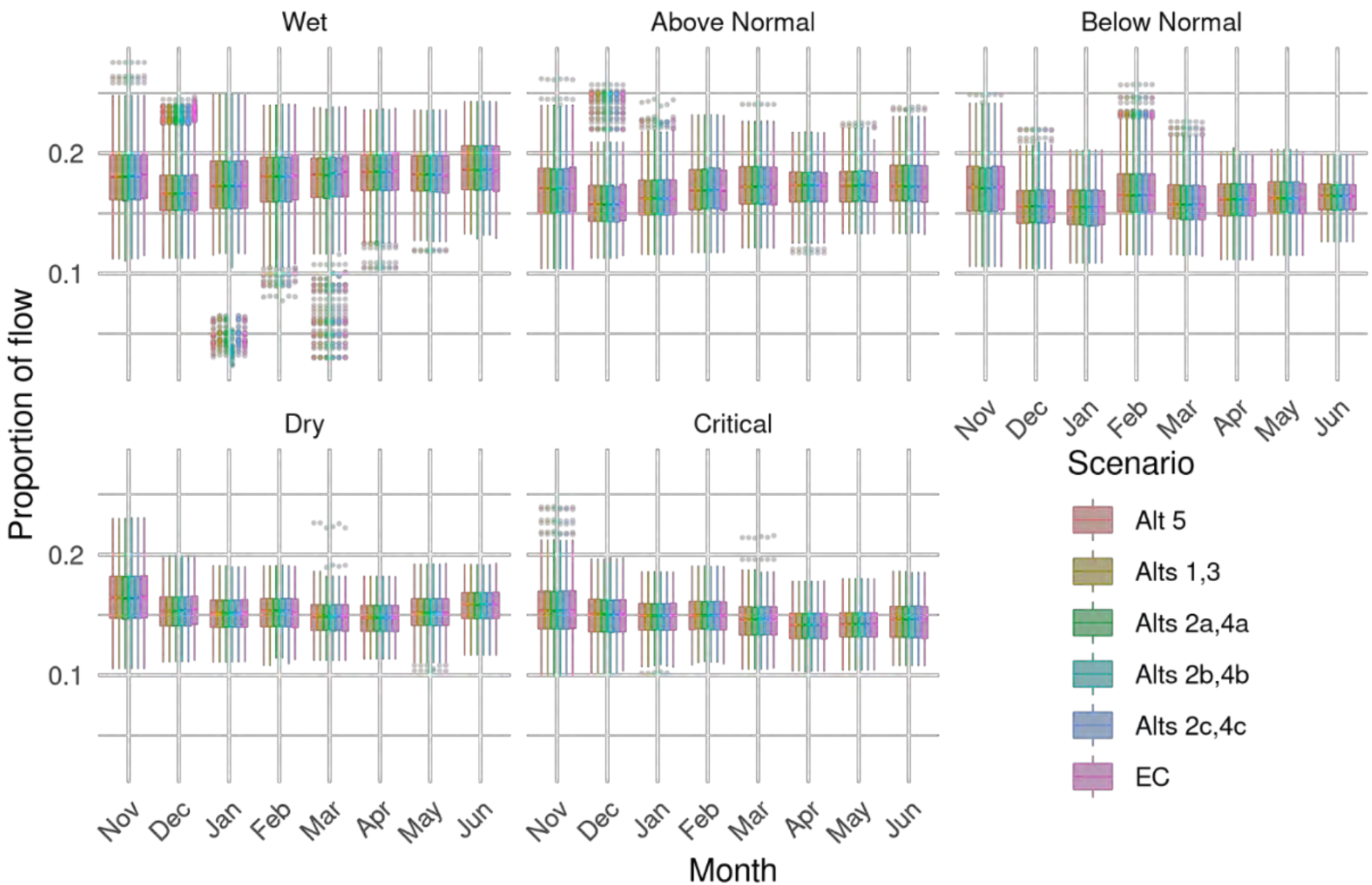

Note: Boxes represent median (horizontal line) and 25th/75th percentiles; whiskers represent 5th/95th percentiles; points represent additional observations outside this range.

**Figure 5D.4-29. Proportion of Flow Entering Georgiana Slough from DSM2-HYDRO Modeling Data**



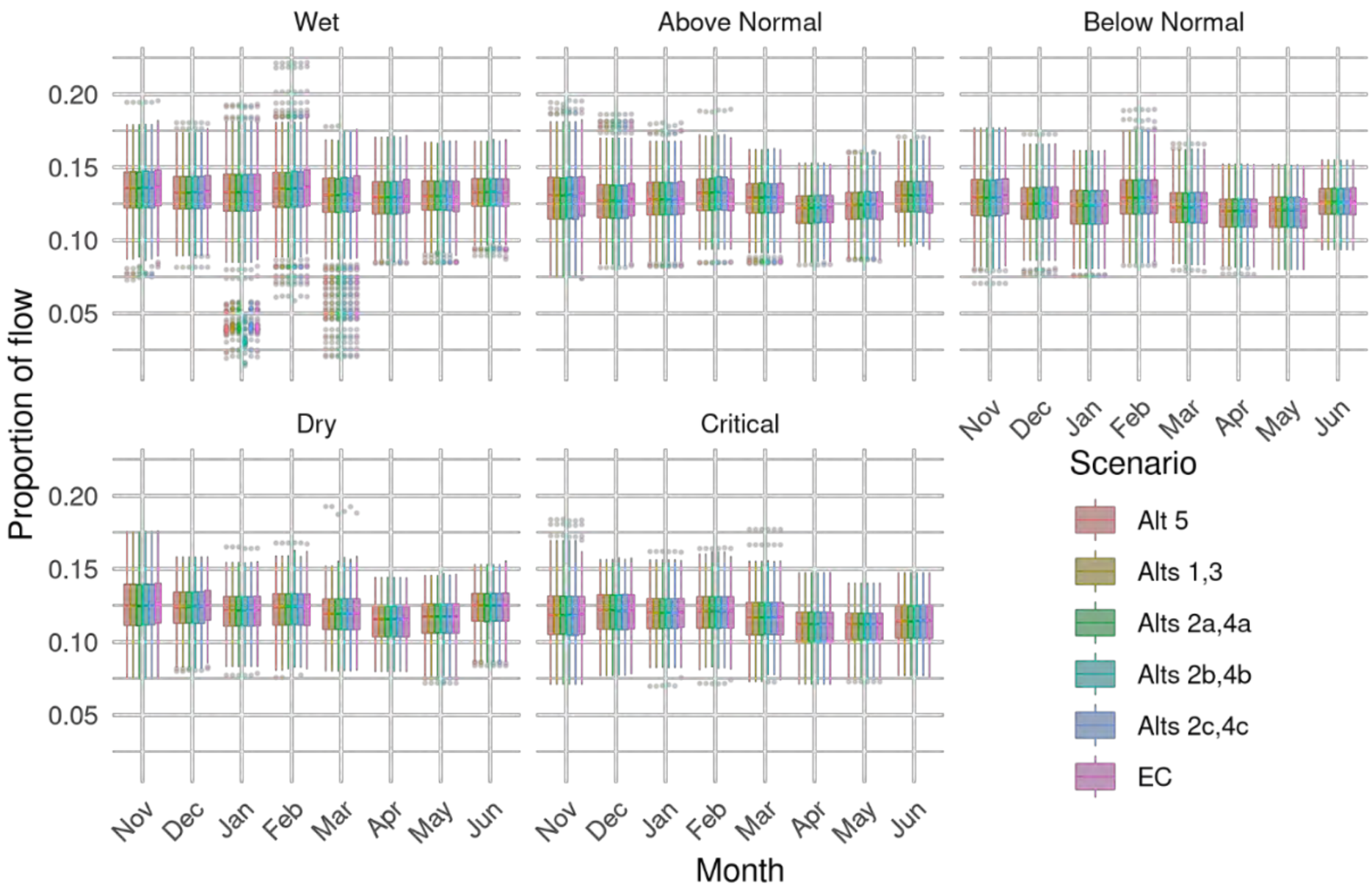

Note: Boxes represent median (horizontal line) and 25th/75th percentiles; whiskers represent 5th/95th percentiles; points represent additional observations outside this range.

**Figure 5D.4-30. Proportion of Flow Entering Head of Old River from DSM2-HYDRO Modeling Data**



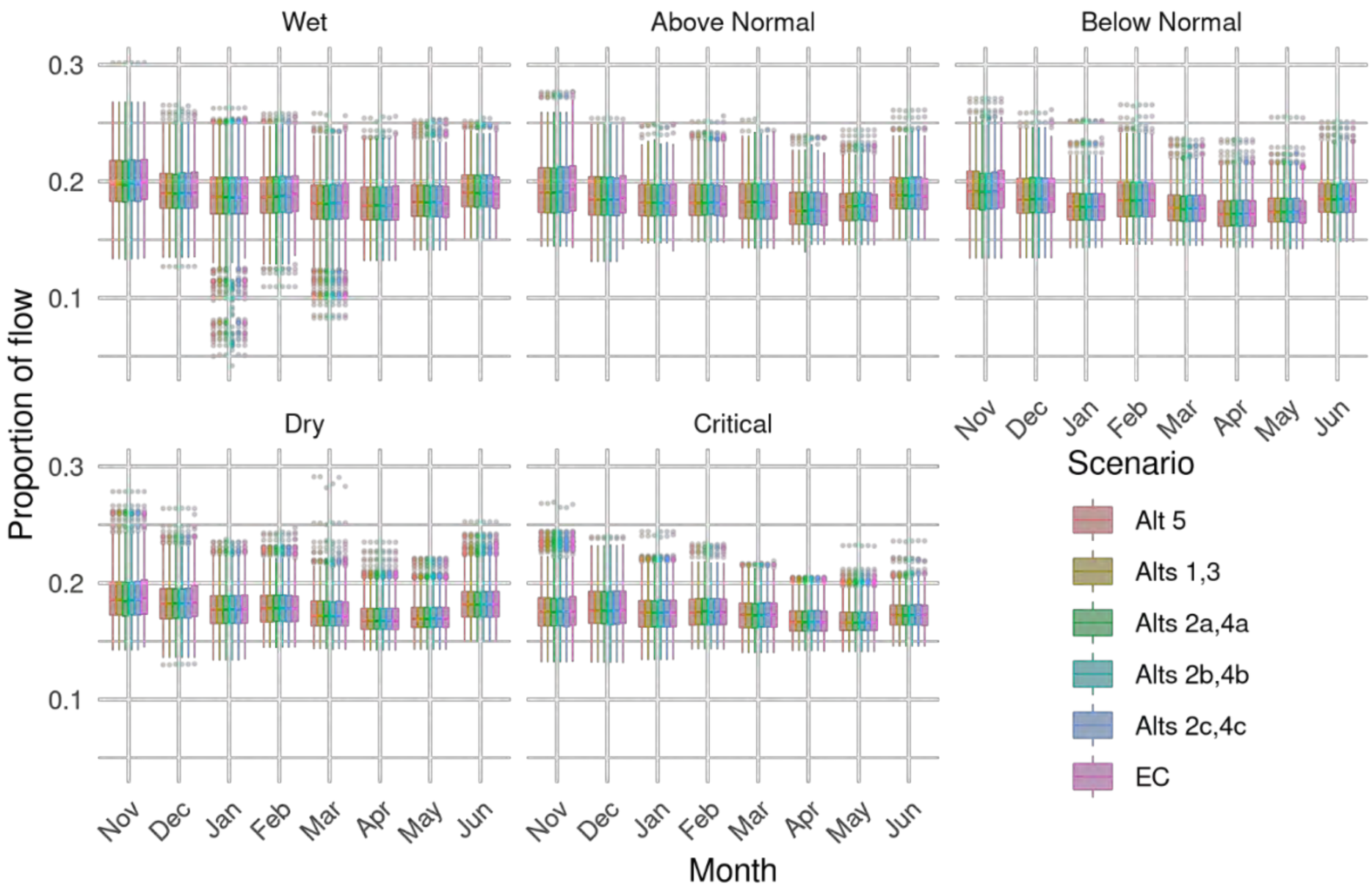

Note: Boxes represent median (horizontal line) and 25th/75th percentiles; whiskers represent 5th/95th percentiles; points represent additional observations outside this range.

**Figure 5D.4-31. Proportion of Flow Entering Turner Cut from DSM2-HYDRO Modeling Data**



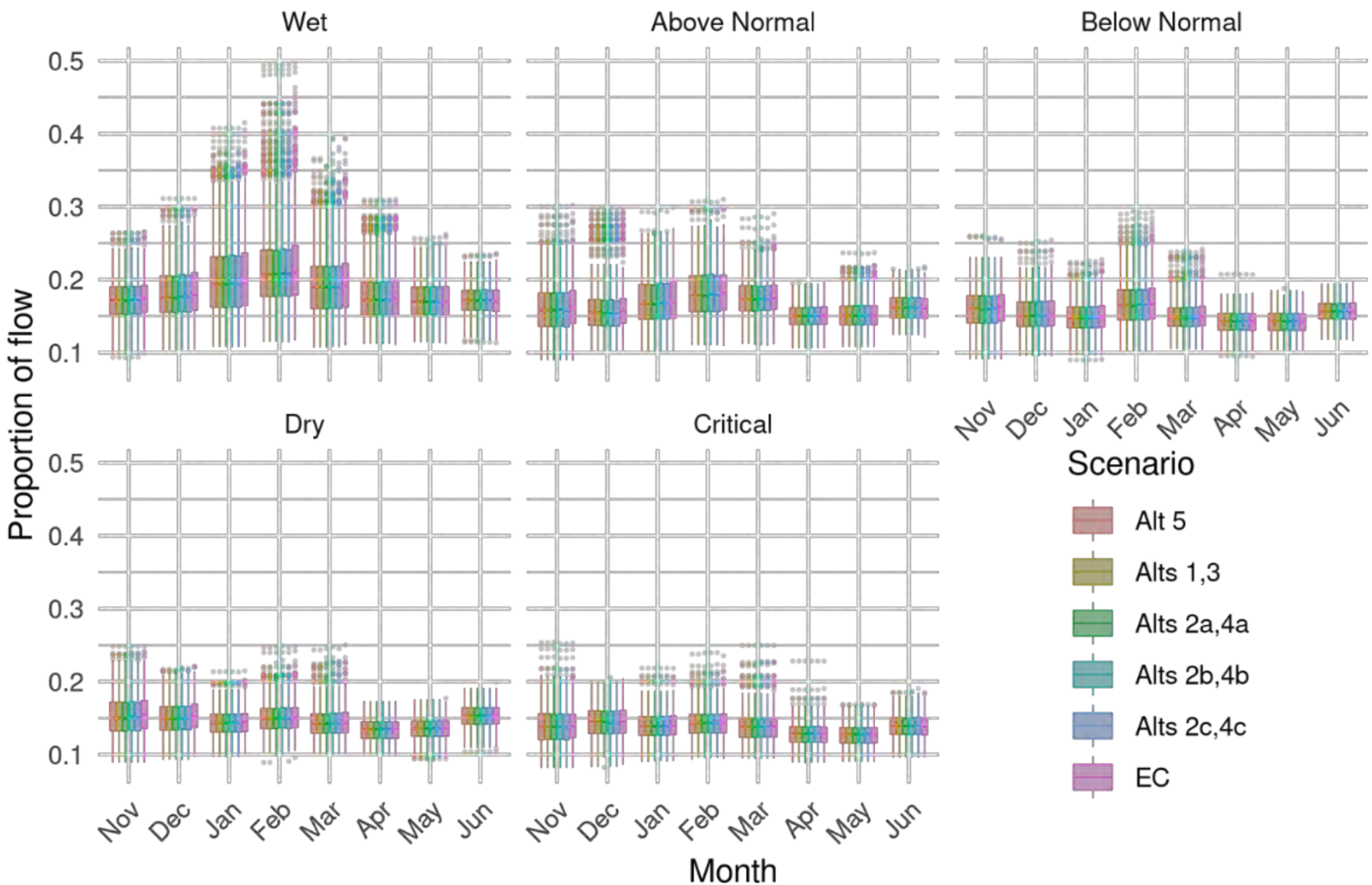

Note: Boxes represent median (horizontal line) and 25th/75th percentiles; whiskers represent 5th/95th percentiles; points represent additional observations outside this range.

**Figure 5D.4-32. Proportion of Flow Entering Columbia Cut from DSM2-HYDRO Modeling Data**



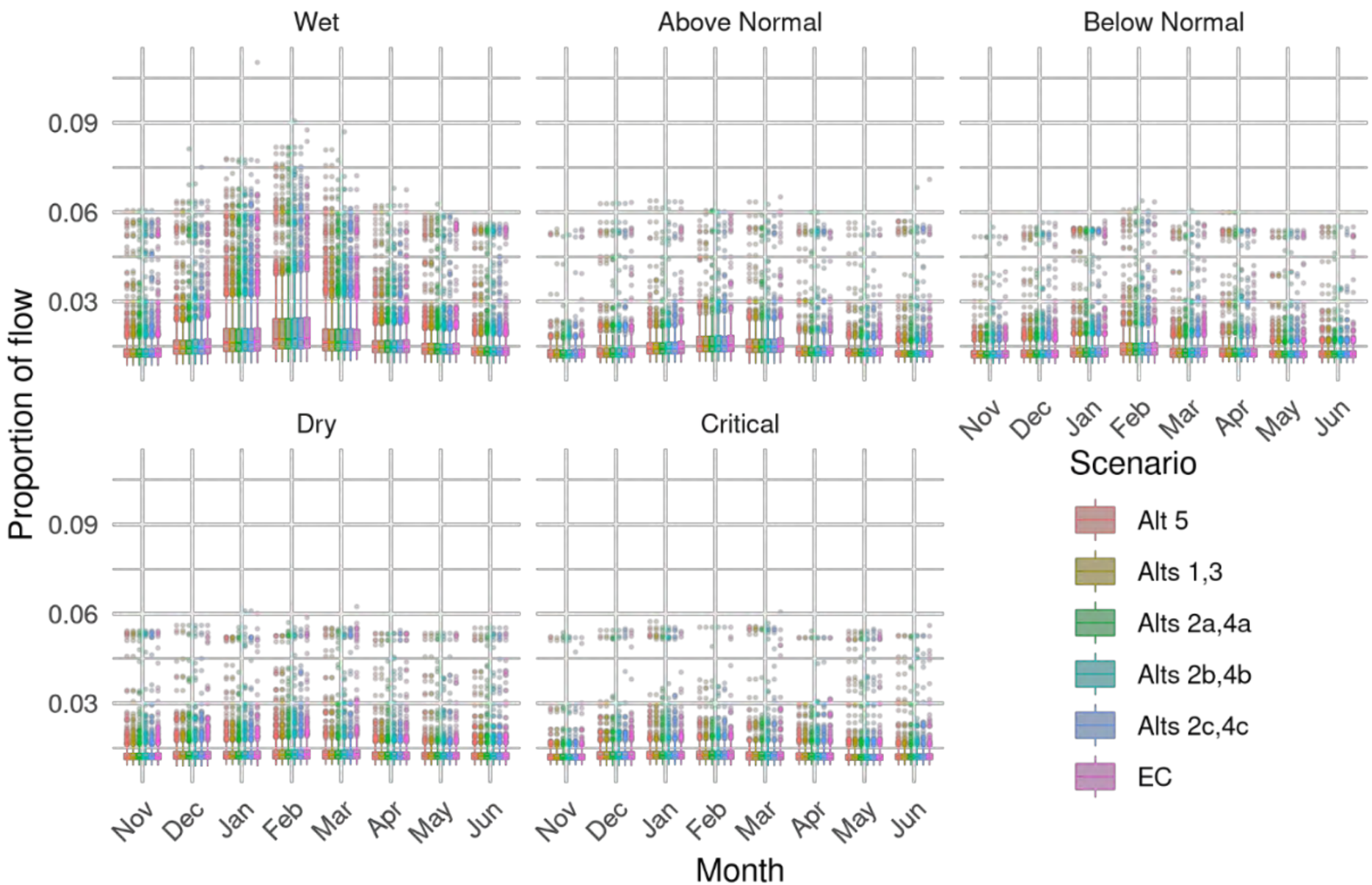

Note: Boxes represent median (horizontal line) and 25th/75th percentiles; whiskers represent 5th/95th percentiles; points represent additional observations outside this range.

**Figure 5D.4-33. Proportion of Flow Entering the Mouth of Middle River from DSM2-HYDRO Modeling Data**



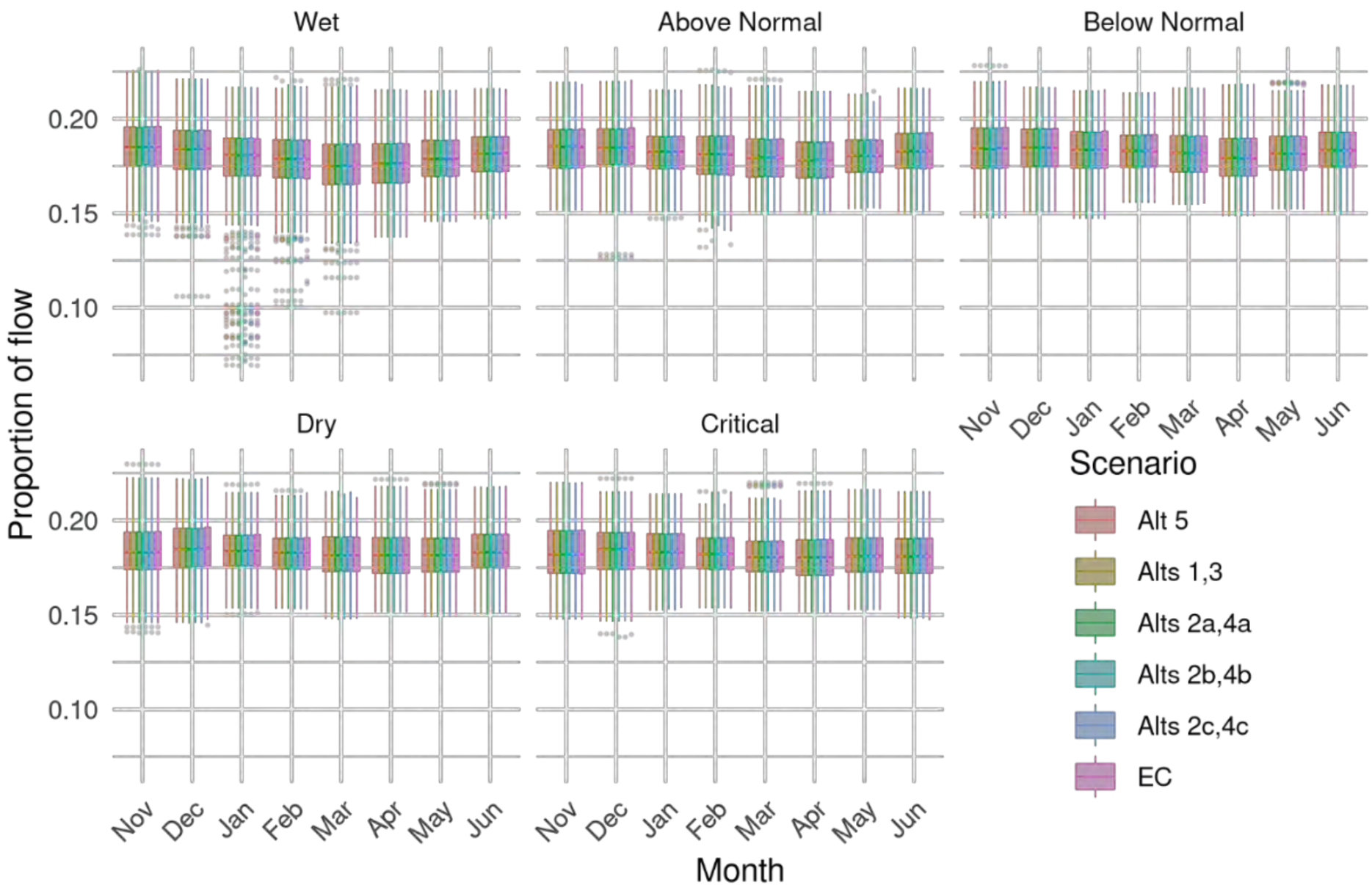

Note: Boxes represent median (horizontal line) and 25th/75th percentiles; whiskers represent 5th/95th percentiles; points represent additional observations outside this range.

**Figure 5D.4-34. Proportion of Flow Entering the Mouth of Old River from DSM2-HYDRO Modeling Data**



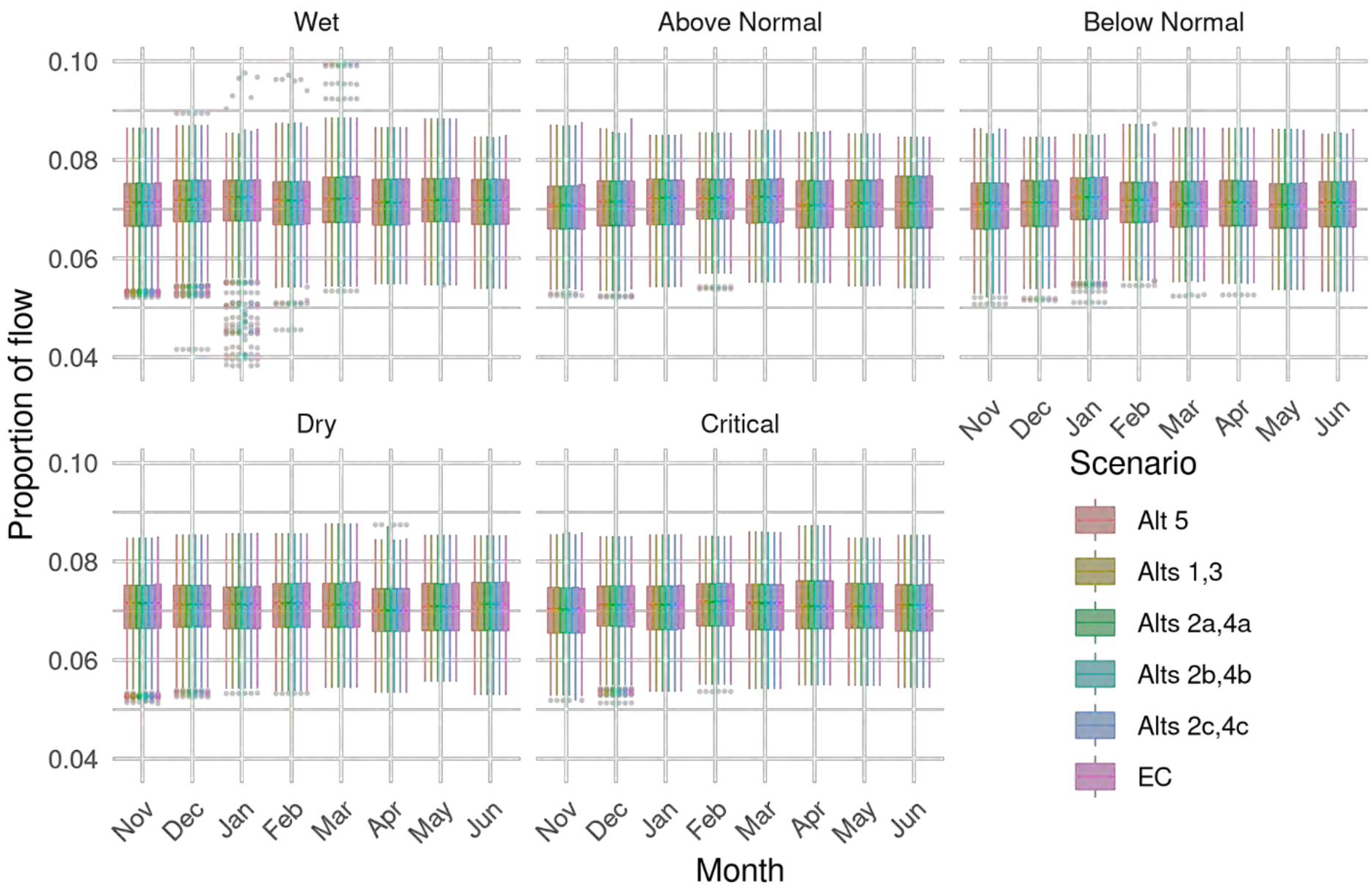

Note: Boxes represent median (horizontal line) and 25th/75th percentiles; whiskers represent 5th/95th percentiles; points represent additional observations outside this range.

**Figure 5D.4-35. Proportion of Flow Entering Fisherman's Cut from DSM2-HYDRO Modeling Data**




Note: Boxes represent median (horizontal line) and 25th/75th percentiles; whiskers represent 5th/95th percentiles; points represent additional observations outside this range.

**Figure 5D.4-36. Proportion of Flow Entering False River from DSM2-HYDRO Modeling Data**




Note: Boxes represent median (horizontal line) and 25th/75th percentiles; whiskers represent 5th/95th percentiles; points represent additional observations outside this range.

**Figure 5D.4-37. Proportion of Flow Entering Jersey Point from DSM2-HYDRO Modeling Data**

**Table 5D.4-1. Mean Daily Proportion of Flow Entering Delta Junctions by Month and Water Year Type.**

| Junction | Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|---|
| Columbia Cut | Nov | Wet | 0.135 | 0.134 (-1%) |
| Columbia Cut | Nov | Above normal | 0.130 | 0.128 (-1%) |
| Columbia Cut | Nov | Below normal | 0.130 | 0.129 (-1%) |
| Columbia Cut | Nov | Dry | 0.127 | 0.126 (-1%) |
| Columbia Cut | Nov | Critical | 0.120 | 0.120 (-1%) |
| Columbia Cut | Dec | Wet | 0.132 | 0.132 (0%) |
| Columbia Cut | Dec | Above normal | 0.128 | 0.127 (-1%) |
| Columbia Cut | Dec | Below normal | 0.126 | 0.126 (0%) |
| Columbia Cut | Dec | Dry | 0.125 | 0.123 (-1%) |
| Columbia Cut | Dec | Critical | 0.121 | 0.121 (0%) |
| Columbia Cut | Jan | Wet | 0.130 | 0.130 (0%) |
| Columbia Cut | Jan | Above normal | 0.128 | 0.128 (0%) |
| Columbia Cut | Jan | Below normal | 0.123 | 0.123 (0%) |
| Columbia Cut | Jan | Dry | 0.122 | 0.121 (0%) |
| Columbia Cut | Jan | Critical | 0.121 | 0.120 (0%) |
| Columbia Cut | Feb | Wet | 0.136 | 0.135 (-1%) |
| Columbia Cut | Feb | Above normal | 0.131 | 0.131 (0%) |
| Columbia Cut | Feb | Below normal | 0.131 | 0.131 (0%) |
| Columbia Cut | Feb | Dry | 0.123 | 0.122 (0%) |
| Columbia Cut | Feb | Critical | 0.120 | 0.120 (0%) |
| Columbia Cut | Mar | Wet | 0.129 | 0.128 (-1%) |
| Columbia Cut | Mar | Above normal | 0.128 | 0.128 (0%) |
| Columbia Cut | Mar | Below normal | 0.123 | 0.123 (0%) |
| Columbia Cut | Mar | Dry | 0.119 | 0.119 (0%) |
| Columbia Cut | Mar | Critical | 0.117 | 0.117 (0%) |
| Columbia Cut | Apr | Wet | 0.129 | 0.128 (-1%) |
| Columbia Cut | Apr | Above normal | 0.121 | 0.121 (0%) |
| Columbia Cut | Apr | Below normal | 0.119 | 0.119 (0%) |
| Columbia Cut | Apr | Dry | 0.115 | 0.115 (0%) |
| Columbia Cut | Apr | Critical | 0.111 | 0.111 (0%) |
| Columbia Cut | May | Wet | 0.129 | 0.130 (0%) |
| Columbia Cut | May | Above normal | 0.123 | 0.123 (0%) |
| Columbia Cut | May | Below normal | 0.119 | 0.120 (1%) |
| Columbia Cut | May | Dry | 0.117 | 0.117 (0%) |
| Columbia Cut | May | Critical | 0.111 | 0.111 (0%) |
| Columbia Cut | Jun | Wet | 0.132 | 0.132 (0%) |

| Junction | Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|---|
| Columbia Cut | Jun | Above normal | 0.128 | 0.129 (0%) |
| Columbia Cut | Jun | Below normal | 0.127 | 0.127 (0%) |
| Columbia Cut | Jun | Dry | 0.124 | 0.124 (0%) |
| Columbia Cut | Jun | Critical | 0.113 | 0.114 (1%) |
| Delta Cross Channel | Nov | Wet | 0.195 | 0.170 (-13%) |
| Delta Cross Channel | Nov | Above normal | 0.140 | 0.100 (-28%) |
| Delta Cross Channel | Nov | Below normal | 0.262 | 0.238 (-9%) |
| Delta Cross Channel | Nov | Dry | 0.229 | 0.183 (-20%) |
| Delta Cross Channel | Nov | Critical | 0.200 | 0.162 (-19%) |
| Delta Cross Channel | Dec | Wet | 0.024 | 0.024 (0%) |
| Delta Cross Channel | Dec | Above normal | 0.100 | 0.101 (2%) |
| Delta Cross Channel | Dec | Below normal | 0.133 | 0.135 (1%) |
| Delta Cross Channel | Dec | Dry | 0.129 | 0.127 (-2%) |
| Delta Cross Channel | Dec | Critical | 0.171 | 0.168 (-2%) |
| Delta Cross Channel | Jan | Wet | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Jan | Above normal | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Jan | Below normal | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Jan | Dry | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Jan | Critical | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Feb | Wet | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Feb | Above normal | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Feb | Below normal | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Feb | Dry | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Feb | Critical | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Mar | Wet | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Mar | Above normal | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Mar | Below normal | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Mar | Dry | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Mar | Critical | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Apr | Wet | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Apr | Above normal | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Apr | Below normal | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Apr | Dry | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Apr | Critical | 0.000 | 0.000 (0%) |
| Delta Cross Channel | May | Wet | 0.000 | 0.000 (0%) |
| Delta Cross Channel | May | Above normal | 0.000 | 0.000 (0%) |
| Delta Cross Channel | May | Below normal | 0.000 | 0.000 (0%) |
| Delta Cross Channel | May | Dry | 0.000 | 0.000 (0%) |

| Junction | Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|---|
| Delta Cross Channel | May | Critical | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Jun | Wet | 0.198 | 0.249 (26%) |
| Delta Cross Channel | Jun | Above normal | 0.309 | 0.337 (9%) |
| Delta Cross Channel | Jun | Below normal | 0.373 | 0.374 (0%) |
| Delta Cross Channel | Jun | Dry | 0.384 | 0.384 (0%) |
| Delta Cross Channel | Jun | Critical | 0.358 | 0.359 (0%) |
| Fisherman's Cut | Nov | Wet | 0.014 | 0.014 (-3%) |
| Fisherman's Cut | Nov | Above normal | 0.013 | 0.013 (-1%) |
| Fisherman's Cut | Nov | Below normal | 0.013 | 0.013 (0%) |
| Fisherman's Cut | Nov | Dry | 0.013 | 0.013 (0%) |
| Fisherman's Cut | Nov | Critical | 0.012 | 0.012 (0%) |
| Fisherman's Cut | Dec | Wet | 0.016 | 0.016 (-3%) |
| Fisherman's Cut | Dec | Above normal | 0.014 | 0.014 (-1%) |
| Fisherman's Cut | Dec | Below normal | 0.013 | 0.013 (2%) |
| Fisherman's Cut | Dec | Dry | 0.013 | 0.013 (-1%) |
| Fisherman's Cut | Dec | Critical | 0.013 | 0.013 (-1%) |
| Fisherman's Cut | Jan | Wet | 0.020 | 0.020 (-1%) |
| Fisherman's Cut | Jan | Above normal | 0.016 | 0.016 (-5%) |
| Fisherman's Cut | Jan | Below normal | 0.015 | 0.014 (-2%) |
| Fisherman's Cut | Jan | Dry | 0.014 | 0.014 (0%) |
| Fisherman's Cut | Jan | Critical | 0.013 | 0.014 (2%) |
| Fisherman's Cut | Feb | Wet | 0.022 | 0.022 (-2%) |
| Fisherman's Cut | Feb | Above normal | 0.018 | 0.017 (-3%) |
| Fisherman's Cut | Feb | Below normal | 0.015 | 0.016 (2%) |
| Fisherman's Cut | Feb | Dry | 0.014 | 0.014 (-1%) |
| Fisherman's Cut | Feb | Critical | 0.013 | 0.013 (-1%) |
| Fisherman's Cut | Mar | Wet | 0.019 | 0.019 (1%) |
| Fisherman's Cut | Mar | Above normal | 0.017 | 0.017 (-2%) |
| Fisherman's Cut | Mar | Below normal | 0.014 | 0.014 (-4%) |
| Fisherman's Cut | Mar | Dry | 0.014 | 0.014 (-3%) |
| Fisherman's Cut | Mar | Critical | 0.013 | 0.013 (0%) |
| Fisherman's Cut | Apr | Wet | 0.016 | 0.016 (-1%) |
| Fisherman's Cut | Apr | Above normal | 0.014 | 0.014 (1%) |
| Fisherman's Cut | Apr | Below normal | 0.014 | 0.014 (2%) |
| Fisherman's Cut | Apr | Dry | 0.013 | 0.013 (-1%) |
| Fisherman's Cut | Apr | Critical | 0.013 | 0.013 (0%) |
| Fisherman's Cut | May | Wet | 0.015 | 0.015 (1%) |
| Fisherman's Cut | May | Above normal | 0.014 | 0.014 (1%) |

| Junction | Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|---|
| Fisherman's Cut | May | Below normal | 0.013 | 0.013 (-1%) |
| Fisherman's Cut | May | Dry | 0.013 | 0.013 (-1%) |
| Fisherman's Cut | May | Critical | 0.013 | 0.013 (0%) |
| Fisherman's Cut | Jun | Wet | 0.014 | 0.014 (0%) |
| Fisherman's Cut | Jun | Above normal | 0.014 | 0.014 (1%) |
| Fisherman's Cut | Jun | Below normal | 0.013 | 0.013 (0%) |
| Fisherman's Cut | Jun | Dry | 0.013 | 0.013 (-1%) |
| Fisherman's Cut | Jun | Critical | 0.013 | 0.013 (0%) |
| False River | Nov | Wet | 0.185 | 0.185 (0%) |
| False River | Nov | Above normal | 0.184 | 0.184 (0%) |
| False River | Nov | Below normal | 0.185 | 0.185 (0%) |
| False River | Nov | Dry | 0.184 | 0.184 (0%) |
| False River | Nov | Critical | 0.183 | 0.183 (0%) |
| False River | Dec | Wet | 0.183 | 0.183 (0%) |
| False River | Dec | Above normal | 0.185 | 0.184 (0%) |
| False River | Dec | Below normal | 0.185 | 0.185 (0%) |
| False River | Dec | Dry | 0.185 | 0.185 (0%) |
| False River | Dec | Critical | 0.184 | 0.184 (0%) |
| False River | Jan | Wet | 0.178 | 0.179 (0%) |
| False River | Jan | Above normal | 0.182 | 0.182 (0%) |
| False River | Jan | Below normal | 0.184 | 0.184 (0%) |
| False River | Jan | Dry | 0.184 | 0.184 (0%) |
| False River | Jan | Critical | 0.184 | 0.184 (0%) |
| False River | Feb | Wet | 0.178 | 0.178 (0%) |
| False River | Feb | Above normal | 0.181 | 0.181 (0%) |
| False River | Feb | Below normal | 0.183 | 0.183 (0%) |
| False River | Feb | Dry | 0.183 | 0.183 (0%) |
| False River | Feb | Critical | 0.182 | 0.182 (0%) |
| False River | Mar | Wet | 0.177 | 0.176 (0%) |
| False River | Mar | Above normal | 0.180 | 0.180 (0%) |
| False River | Mar | Below normal | 0.182 | 0.182 (0%) |
| False River | Mar | Dry | 0.182 | 0.182 (0%) |
| False River | Mar | Critical | 0.181 | 0.181 (0%) |
| False River | Apr | Wet | 0.177 | 0.177 (0%) |
| False River | Apr | Above normal | 0.179 | 0.179 (0%) |
| False River | Apr | Below normal | 0.180 | 0.180 (0%) |
| False River | Apr | Dry | 0.181 | 0.181 (0%) |
| False River | Apr | Critical | 0.181 | 0.181 (0%) |

| Junction | Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|---|
| False River | May | Wet | 0.179 | 0.179 (0%) |
| False River | May | Above normal | 0.180 | 0.181 (0%) |
| False River | May | Below normal | 0.182 | 0.182 (0%) |
| False River | May | Dry | 0.182 | 0.182 (0%) |
| False River | May | Critical | 0.182 | 0.182 (0%) |
| False River | Jun | Wet | 0.182 | 0.181 (0%) |
| False River | Jun | Above normal | 0.183 | 0.183 (0%) |
| False River | Jun | Below normal | 0.184 | 0.184 (0%) |
| False River | Jun | Dry | 0.184 | 0.184 (0%) |
| False River | Jun | Critical | 0.182 | 0.182 (0%) |
| Georgiana Slough | Nov | Wet | 0.389 | 0.390 (0%) |
| Georgiana Slough | Nov | Above normal | 0.381 | 0.386 (1%) |
| Georgiana Slough | Nov | Below normal | 0.410 | 0.409 (0%) |
| Georgiana Slough | Nov | Dry | 0.392 | 0.395 (1%) |
| Georgiana Slough | Nov | Critical | 0.389 | 0.390 (0%) |
| Georgiana Slough | Dec | Wet | 0.319 | 0.326 (2%) |
| Georgiana Slough | Dec | Above normal | 0.389 | 0.391 (1%) |
| Georgiana Slough | Dec | Below normal | 0.390 | 0.390 (0%) |
| Georgiana Slough | Dec | Dry | 0.402 | 0.401 (0%) |
| Georgiana Slough | Dec | Critical | 0.410 | 0.410 (0%) |
| Georgiana Slough | Jan | Wet | 0.297 | 0.301 (1%) |
| Georgiana Slough | Jan | Above normal | 0.318 | 0.325 (2%) |
| Georgiana Slough | Jan | Below normal | 0.353 | 0.364 (3%) |
| Georgiana Slough | Jan | Dry | 0.399 | 0.408 (2%) |
| Georgiana Slough | Jan | Critical | 0.417 | 0.425 (2%) |
| Georgiana Slough | Feb | Wet | 0.286 | 0.288 (1%) |
| Georgiana Slough | Feb | Above normal | 0.295 | 0.303 (3%) |
| Georgiana Slough | Feb | Below normal | 0.320 | 0.325 (2%) |
| Georgiana Slough | Feb | Dry | 0.356 | 0.366 (3%) |
| Georgiana Slough | Feb | Critical | 0.402 | 0.406 (1%) |
| Georgiana Slough | Mar | Wet | 0.290 | 0.295 (2%) |
| Georgiana Slough | Mar | Above normal | 0.288 | 0.295 (2%) |
| Georgiana Slough | Mar | Below normal | 0.326 | 0.350 (7%) |
| Georgiana Slough | Mar | Dry | 0.357 | 0.373 (4%) |
| Georgiana Slough | Mar | Critical | 0.425 | 0.428 (1%) |
| Georgiana Slough | Apr | Wet | 0.305 | 0.307 (1%) |
| Georgiana Slough | Apr | Above normal | 0.326 | 0.329 (1%) |
| Georgiana Slough | Apr | Below normal | 0.380 | 0.382 (0%) |

| Junction | Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|---|
| Georgiana Slough | Apr | Dry | 0.427 | 0.427 (0%) |
| Georgiana Slough | Apr | Critical | 0.452 | 0.452 (0%) |
| Georgiana Slough | May | Wet | 0.311 | 0.315 (2%) |
| Georgiana Slough | May | Above normal | 0.342 | 0.348 (2%) |
| Georgiana Slough | May | Below normal | 0.389 | 0.394 (2%) |
| Georgiana Slough | May | Dry | 0.434 | 0.434 (0%) |
| Georgiana Slough | May | Critical | 0.425 | 0.423 (0%) |
| Georgiana Slough | Jun | Wet | 0.360 | 0.381 (6%) |
| Georgiana Slough | Jun | Above normal | 0.398 | 0.409 (3%) |
| Georgiana Slough | Jun | Below normal | 0.422 | 0.425 (0%) |
| Georgiana Slough | Jun | Dry | 0.423 | 0.422 (0%) |
| Georgiana Slough | Jun | Critical | 0.365 | 0.367 (1%) |
| Head of Old River | Nov | Wet | 0.568 | 0.561 (-1%) |
| Head of Old River | Nov | Above normal | 0.548 | 0.542 (-1%) |
| Head of Old River | Nov | Below normal | 0.551 | 0.545 (-1%) |
| Head of Old River | Nov | Dry | 0.537 | 0.529 (-1%) |
| Head of Old River | Nov | Critical | 0.497 | 0.495 (0%) |
| Head of Old River | Dec | Wet | 0.657 | 0.656 (0%) |
| Head of Old River | Dec | Above normal | 0.665 | 0.658 (-1%) |
| Head of Old River | Dec | Below normal | 0.668 | 0.667 (0%) |
| Head of Old River | Dec | Dry | 0.677 | 0.667 (-2%) |
| Head of Old River | Dec | Critical | 0.612 | 0.611 (0%) |
| Head of Old River | Jan | Wet | 0.610 | 0.610 (0%) |
| Head of Old River | Jan | Above normal | 0.638 | 0.638 (0%) |
| Head of Old River | Jan | Below normal | 0.651 | 0.651 (0%) |
| Head of Old River | Jan | Dry | 0.675 | 0.672 (0%) |
| Head of Old River | Jan | Critical | 0.657 | 0.654 (0%) |
| Head of Old River | Feb | Wet | 0.587 | 0.586 (0%) |
| Head of Old River | Feb | Above normal | 0.627 | 0.627 (0%) |
| Head of Old River | Feb | Below normal | 0.622 | 0.621 (0%) |
| Head of Old River | Feb | Dry | 0.671 | 0.669 (0%) |
| Head of Old River | Feb | Critical | 0.662 | 0.659 (0%) |
| Head of Old River | Mar | Wet | 0.570 | 0.570 (0%) |
| Head of Old River | Mar | Above normal | 0.595 | 0.593 (0%) |
| Head of Old River | Mar | Below normal | 0.620 | 0.616 (-1%) |
| Head of Old River | Mar | Dry | 0.657 | 0.654 (0%) |
| Head of Old River | Mar | Critical | 0.647 | 0.647 (0%) |
| Head of Old River | Apr | Wet | 0.556 | 0.555 (0%) |

| Junction | Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|---|
| Head of Old River | Apr | Above normal | 0.567 | 0.566 (0%) |
| Head of Old River | Apr | Below normal | 0.586 | 0.586 (0%) |
| Head of Old River | Apr | Dry | 0.625 | 0.625 (0%) |
| Head of Old River | Apr | Critical | 0.622 | 0.623 (0%) |
| Head of Old River | May | Wet | 0.560 | 0.561 (0%) |
| Head of Old River | May | Above normal | 0.571 | 0.571 (0%) |
| Head of Old River | May | Below normal | 0.587 | 0.588 (0%) |
| Head of Old River | May | Dry | 0.620 | 0.619 (0%) |
| Head of Old River | May | Critical | 0.632 | 0.631 (0%) |
| Head of Old River | Jun | Wet | 0.532 | 0.531 (0%) |
| Head of Old River | Jun | Above normal | 0.532 | 0.532 (0%) |
| Head of Old River | Jun | Below normal | 0.530 | 0.530 (0%) |
| Head of Old River | Jun | Dry | 0.512 | 0.511 (0%) |
| Head of Old River | Jun | Critical | 0.398 | 0.403 (1%) |
| Jersey Point | Nov | Wet | 0.071 | 0.071 (0%) |
| Jersey Point | Nov | Above normal | 0.071 | 0.071 (0%) |
| Jersey Point | Nov | Below normal | 0.071 | 0.071 (0%) |
| Jersey Point | Nov | Dry | 0.071 | 0.071 (0%) |
| Jersey Point | Nov | Critical | 0.070 | 0.070 (0%) |
| Jersey Point | Dec | Wet | 0.072 | 0.072 (0%) |
| Jersey Point | Dec | Above normal | 0.071 | 0.071 (0%) |
| Jersey Point | Dec | Below normal | 0.071 | 0.071 (0%) |
| Jersey Point | Dec | Dry | 0.071 | 0.071 (0%) |
| Jersey Point | Dec | Critical | 0.071 | 0.071 (0%) |
| Jersey Point | Jan | Wet | 0.072 | 0.072 (0%) |
| Jersey Point | Jan | Above normal | 0.072 | 0.072 (0%) |
| Jersey Point | Jan | Below normal | 0.072 | 0.072 (0%) |
| Jersey Point | Jan | Dry | 0.071 | 0.071 (0%) |
| Jersey Point | Jan | Critical | 0.071 | 0.071 (0%) |
| Jersey Point | Feb | Wet | 0.071 | 0.071 (0%) |
| Jersey Point | Feb | Above normal | 0.072 | 0.072 (0%) |
| Jersey Point | Feb | Below normal | 0.072 | 0.072 (0%) |
| Jersey Point | Feb | Dry | 0.071 | 0.071 (0%) |
| Jersey Point | Feb | Critical | 0.071 | 0.071 (0%) |
| Jersey Point | Mar | Wet | 0.072 | 0.072 (0%) |
| Jersey Point | Mar | Above normal | 0.072 | 0.072 (0%) |
| Jersey Point | Mar | Below normal | 0.071 | 0.071 (0%) |
| Jersey Point | Mar | Dry | 0.071 | 0.071 (0%) |

| Junction | Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|---|
| Jersey Point | Mar | Critical | 0.071 | 0.071 (0%) |
| Jersey Point | Apr | Wet | 0.071 | 0.071 (0%) |
| Jersey Point | Apr | Above normal | 0.071 | 0.071 (0%) |
| Jersey Point | Apr | Below normal | 0.071 | 0.071 (0%) |
| Jersey Point | Apr | Dry | 0.070 | 0.070 (0%) |
| Jersey Point | Apr | Critical | 0.071 | 0.071 (0%) |
| Jersey Point | May | Wet | 0.072 | 0.072 (0%) |
| Jersey Point | May | Above normal | 0.071 | 0.071 (0%) |
| Jersey Point | May | Below normal | 0.071 | 0.071 (0%) |
| Jersey Point | May | Dry | 0.071 | 0.071 (0%) |
| Jersey Point | May | Critical | 0.071 | 0.071 (0%) |
| Jersey Point | Jun | Wet | 0.072 | 0.072 (0%) |
| Jersey Point | Jun | Above normal | 0.071 | 0.071 (0%) |
| Jersey Point | Jun | Below normal | 0.071 | 0.071 (0%) |
| Jersey Point | Jun | Dry | 0.071 | 0.071 (0%) |
| Jersey Point | Jun | Critical | 0.071 | 0.071 (0%) |
| Mouth of Middle River | Nov | Wet | 0.201 | 0.199 (-1%) |
| Mouth of Middle River | Nov | Above normal | 0.195 | 0.193 (-1%) |
| Mouth of Middle River | Nov | Below normal | 0.195 | 0.193 (-1%) |
| Mouth of Middle River | Nov | Dry | 0.190 | 0.189 (-1%) |
| Mouth of Middle River | Nov | Critical | 0.180 | 0.180 (0%) |
| Mouth of Middle River | Dec | Wet | 0.192 | 0.191 (0%) |
| Mouth of Middle River | Dec | Above normal | 0.190 | 0.189 (-1%) |
| Mouth of Middle River | Dec | Below normal | 0.190 | 0.189 (0%) |
| Mouth of Middle River | Dec | Dry | 0.186 | 0.184 (-1%) |
| Mouth of Middle River | Dec | Critical | 0.181 | 0.181 (0%) |
| Mouth of Middle River | Jan | Wet | 0.186 | 0.185 (0%) |
| Mouth of Middle River | Jan | Above normal | 0.185 | 0.185 (0%) |
| Mouth of Middle River | Jan | Below normal | 0.180 | 0.180 (0%) |
| Mouth of Middle River | Jan | Dry | 0.180 | 0.179 (0%) |
| Mouth of Middle River | Jan | Critical | 0.177 | 0.177 (0%) |
| Mouth of Middle River | Feb | Wet | 0.190 | 0.188 (-1%) |
| Mouth of Middle River | Feb | Above normal | 0.185 | 0.185 (0%) |
| Mouth of Middle River | Feb | Below normal | 0.188 | 0.188 (0%) |
| Mouth of Middle River | Feb | Dry | 0.180 | 0.180 (0%) |
| Mouth of Middle River | Feb | Critical | 0.176 | 0.176 (0%) |
| Mouth of Middle River | Mar | Wet | 0.182 | 0.181 (-1%) |
| Mouth of Middle River | Mar | Above normal | 0.184 | 0.184 (0%) |

| Junction | Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|---|
| Mouth of Middle River | Mar | Below normal | 0.179 | 0.179 (0%) |
| Mouth of Middle River | Mar | Dry | 0.174 | 0.175 (0%) |
| Mouth of Middle River | Mar | Critical | 0.174 | 0.174 (0%) |
| Mouth of Middle River | Apr | Wet | 0.182 | 0.181 (0%) |
| Mouth of Middle River | Apr | Above normal | 0.176 | 0.177 (1%) |
| Mouth of Middle River | Apr | Below normal | 0.174 | 0.173 (0%) |
| Mouth of Middle River | Apr | Dry | 0.169 | 0.170 (0%) |
| Mouth of Middle River | Apr | Critical | 0.168 | 0.168 (0%) |
| Mouth of Middle River | May | Wet | 0.184 | 0.185 (0%) |
| Mouth of Middle River | May | Above normal | 0.178 | 0.178 (0%) |
| Mouth of Middle River | May | Below normal | 0.175 | 0.176 (1%) |
| Mouth of Middle River | May | Dry | 0.172 | 0.172 (0%) |
| Mouth of Middle River | May | Critical | 0.169 | 0.169 (0%) |
| Mouth of Middle River | Jun | Wet | 0.191 | 0.192 (1%) |
| Mouth of Middle River | Jun | Above normal | 0.189 | 0.190 (0%) |
| Mouth of Middle River | Jun | Below normal | 0.187 | 0.187 (0%) |
| Mouth of Middle River | Jun | Dry | 0.185 | 0.184 (0%) |
| Mouth of Middle River | Jun | Critical | 0.172 | 0.173 (1%) |
| Mouth of Old River | Nov | Wet | 0.174 | 0.171 (-2%) |
| Mouth of Old River | Nov | Above normal | 0.164 | 0.160 (-2%) |
| Mouth of Old River | Nov | Below normal | 0.163 | 0.160 (-2%) |
| Mouth of Old River | Nov | Dry | 0.156 | 0.154 (-2%) |
| Mouth of Old River | Nov | Critical | 0.144 | 0.142 (-1%) |
| Mouth of Old River | Dec | Wet | 0.183 | 0.179 (-2%) |
| Mouth of Old River | Dec | Above normal | 0.164 | 0.161 (-2%) |
| Mouth of Old River | Dec | Below normal | 0.156 | 0.155 (-1%) |
| Mouth of Old River | Dec | Dry | 0.152 | 0.149 (-2%) |
| Mouth of Old River | Dec | Critical | 0.146 | 0.146 (0%) |
| Mouth of Old River | Jan | Wet | 0.205 | 0.202 (-2%) |
| Mouth of Old River | Jan | Above normal | 0.175 | 0.172 (-1%) |
| Mouth of Old River | Jan | Below normal | 0.151 | 0.149 (-1%) |
| Mouth of Old River | Jan | Dry | 0.145 | 0.144 (-1%) |
| Mouth of Old River | Jan | Critical | 0.142 | 0.141 (-1%) |
| Mouth of Old River | Feb | Wet | 0.224 | 0.220 (-2%) |
| Mouth of Old River | Feb | Above normal | 0.186 | 0.184 (-1%) |
| Mouth of Old River | Feb | Below normal | 0.173 | 0.171 (-1%) |
| Mouth of Old River | Feb | Dry | 0.151 | 0.150 (-1%) |
| Mouth of Old River | Feb | Critical | 0.143 | 0.142 (0%) |

| Junction | Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|---|
| Mouth of Old River | Mar | Wet | 0.194 | 0.191 (-2%) |
| Mouth of Old River | Mar | Above normal | 0.177 | 0.175 (-1%) |
| Mouth of Old River | Mar | Below normal | 0.151 | 0.150 (-1%) |
| Mouth of Old River | Mar | Dry | 0.145 | 0.144 (-1%) |
| Mouth of Old River | Mar | Critical | 0.139 | 0.139 (0%) |
| Mouth of Old River | Apr | Wet | 0.175 | 0.173 (-1%) |
| Mouth of Old River | Apr | Above normal | 0.150 | 0.149 (0%) |
| Mouth of Old River | Apr | Below normal | 0.143 | 0.143 (0%) |
| Mouth of Old River | Apr | Dry | 0.134 | 0.135 (0%) |
| Mouth of Old River | Apr | Critical | 0.128 | 0.129 (0%) |
| Mouth of Old River | May | Wet | 0.171 | 0.171 (0%) |
| Mouth of Old River | May | Above normal | 0.149 | 0.149 (0%) |
| Mouth of Old River | May | Below normal | 0.142 | 0.143 (1%) |
| Mouth of Old River | May | Dry | 0.136 | 0.136 (0%) |
| Mouth of Old River | May | Critical | 0.128 | 0.128 (0%) |
| Mouth of Old River | Jun | Wet | 0.170 | 0.170 (1%) |
| Mouth of Old River | Jun | Above normal | 0.159 | 0.160 (0%) |
| Mouth of Old River | Jun | Below normal | 0.157 | 0.157 (0%) |
| Mouth of Old River | Jun | Dry | 0.153 | 0.153 (0%) |
| Mouth of Old River | Jun | Critical | 0.138 | 0.139 (1%) |
| Sutter Slough | Nov | Wet | 0.196 | 0.196 (0%) |
| Sutter Slough | Nov | Above normal | 0.188 | 0.192 (2%) |
| Sutter Slough | Nov | Below normal | 0.186 | 0.187 (1%) |
| Sutter Slough | Nov | Dry | 0.182 | 0.186 (2%) |
| Sutter Slough | Nov | Critical | 0.175 | 0.180 (3%) |
| Sutter Slough | Dec | Wet | 0.216 | 0.216 (0%) |
| Sutter Slough | Dec | Above normal | 0.208 | 0.207 (0%) |
| Sutter Slough | Dec | Below normal | 0.197 | 0.196 (-1%) |
| Sutter Slough | Dec | Dry | 0.201 | 0.200 (0%) |
| Sutter Slough | Dec | Critical | 0.193 | 0.194 (0%) |
| Sutter Slough | Jan | Wet | 0.220 | 0.220 (0%) |
| Sutter Slough | Jan | Above normal | 0.219 | 0.219 (0%) |
| Sutter Slough | Jan | Below normal | 0.219 | 0.219 (0%) |
| Sutter Slough | Jan | Dry | 0.221 | 0.222 (1%) |
| Sutter Slough | Jan | Critical | 0.219 | 0.220 (0%) |
| Sutter Slough | Feb | Wet | 0.221 | 0.221 (0%) |
| Sutter Slough | Feb | Above normal | 0.219 | 0.219 (0%) |
| Sutter Slough | Feb | Below normal | 0.218 | 0.217 (0%) |

| Junction | Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|---|
| Sutter Slough | Feb | Dry | 0.218 | 0.217 (0%) |
| Sutter Slough | Feb | Critical | 0.218 | 0.219 (0%) |
| Sutter Slough | Mar | Wet | 0.220 | 0.220 (0%) |
| Sutter Slough | Mar | Above normal | 0.219 | 0.218 (0%) |
| Sutter Slough | Mar | Below normal | 0.217 | 0.217 (0%) |
| Sutter Slough | Mar | Dry | 0.219 | 0.219 (0%) |
| Sutter Slough | Mar | Critical | 0.223 | 0.223 (0%) |
| Sutter Slough | Apr | Wet | 0.220 | 0.220 (0%) |
| Sutter Slough | Apr | Above normal | 0.219 | 0.219 (0%) |
| Sutter Slough | Apr | Below normal | 0.221 | 0.222 (0%) |
| Sutter Slough | Apr | Dry | 0.225 | 0.225 (0%) |
| Sutter Slough | Apr | Critical | 0.222 | 0.224 (0%) |
| Sutter Slough | May | Wet | 0.220 | 0.220 (0%) |
| Sutter Slough | May | Above normal | 0.219 | 0.219 (0%) |
| Sutter Slough | May | Below normal | 0.222 | 0.223 (0%) |
| Sutter Slough | May | Dry | 0.227 | 0.227 (0%) |
| Sutter Slough | May | Critical | 0.203 | 0.203 (0%) |
| Sutter Slough | Jun | Wet | 0.202 | 0.199 (-1%) |
| Sutter Slough | Jun | Above normal | 0.187 | 0.186 (-1%) |
| Sutter Slough | Jun | Below normal | 0.182 | 0.182 (0%) |
| Sutter Slough | Jun | Dry | 0.180 | 0.180 (0%) |
| Sutter Slough | Jun | Critical | 0.164 | 0.164 (0%) |
| Steamboat Slough | Nov | Wet | 0.199 | 0.197 (-1%) |
| Steamboat Slough | Nov | Above normal | 0.197 | 0.195 (-1%) |
| Steamboat Slough | Nov | Below normal | 0.182 | 0.180 (-1%) |
| Steamboat Slough | Nov | Dry | 0.184 | 0.184 (0%) |
| Steamboat Slough | Nov | Critical | 0.181 | 0.184 (2%) |
| Steamboat Slough | Dec | Wet | 0.247 | 0.243 (-2%) |
| Steamboat Slough | Dec | Above normal | 0.209 | 0.207 (-1%) |
| Steamboat Slough | Dec | Below normal | 0.199 | 0.196 (-1%) |
| Steamboat Slough | Dec | Dry | 0.196 | 0.195 (-1%) |
| Steamboat Slough | Dec | Critical | 0.185 | 0.185 (0%) |
| Steamboat Slough | Jan | Wet | 0.264 | 0.261 (-1%) |
| Steamboat Slough | Jan | Above normal | 0.249 | 0.245 (-2%) |
| Steamboat Slough | Jan | Below normal | 0.229 | 0.224 (-2%) |
| Steamboat Slough | Jan | Dry | 0.212 | 0.206 (-2%) |
| Steamboat Slough | Jan | Critical | 0.203 | 0.199 (-2%) |
| Steamboat Slough | Feb | Wet | 0.272 | 0.271 (-1%) |

| Junction | Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|---|
| Steamboat Slough | Feb | Above normal | 0.263 | 0.259 (-2%) |
| Steamboat Slough | Feb | Below normal | 0.246 | 0.243 (-1%) |
| Steamboat Slough | Feb | Dry | 0.228 | 0.224 (-2%) |
| Steamboat Slough | Feb | Critical | 0.210 | 0.207 (-1%) |
| Steamboat Slough | Mar | Wet | 0.264 | 0.262 (-1%) |
| Steamboat Slough | Mar | Above normal | 0.261 | 0.258 (-1%) |
| Steamboat Slough | Mar | Below normal | 0.236 | 0.228 (-3%) |
| Steamboat Slough | Mar | Dry | 0.227 | 0.222 (-2%) |
| Steamboat Slough | Mar | Critical | 0.200 | 0.199 (-1%) |
| Steamboat Slough | Apr | Wet | 0.252 | 0.251 (0%) |
| Steamboat Slough | Apr | Above normal | 0.237 | 0.235 (-1%) |
| Steamboat Slough | Apr | Below normal | 0.216 | 0.215 (0%) |
| Steamboat Slough | Apr | Dry | 0.197 | 0.197 (0%) |
| Steamboat Slough | Apr | Critical | 0.184 | 0.185 (0%) |
| Steamboat Slough | May | Wet | 0.247 | 0.245 (-1%) |
| Steamboat Slough | May | Above normal | 0.233 | 0.231 (-1%) |
| Steamboat Slough | May | Below normal | 0.215 | 0.213 (-1%) |
| Steamboat Slough | May | Dry | 0.196 | 0.195 (0%) |
| Steamboat Slough | May | Critical | 0.185 | 0.186 (0%) |
| Steamboat Slough | Jun | Wet | 0.214 | 0.206 (-4%) |
| Steamboat Slough | Jun | Above normal | 0.184 | 0.180 (-2%) |
| Steamboat Slough | Jun | Below normal | 0.172 | 0.171 (-1%) |
| Steamboat Slough | Jun | Dry | 0.169 | 0.169 (0%) |
| Steamboat Slough | Jun | Critical | 0.175 | 0.175 (0%) |
| Turner Cut | Nov | Wet | 0.181 | 0.180 (-1%) |
| Turner Cut | Nov | Above normal | 0.171 | 0.169 (-1%) |
| Turner Cut | Nov | Below normal | 0.172 | 0.172 (0%) |
| Turner Cut | Nov | Dry | 0.166 | 0.166 (0%) |
| Turner Cut | Nov | Critical | 0.158 | 0.157 (0%) |
| Turner Cut | Dec | Wet | 0.169 | 0.168 (0%) |
| Turner Cut | Dec | Above normal | 0.162 | 0.161 (-1%) |
| Turner Cut | Dec | Below normal | 0.158 | 0.158 (0%) |
| Turner Cut | Dec | Dry | 0.154 | 0.153 (-1%) |
| Turner Cut | Dec | Critical | 0.151 | 0.151 (0%) |
| Turner Cut | Jan | Wet | 0.170 | 0.169 (0%) |
| Turner Cut | Jan | Above normal | 0.165 | 0.164 (0%) |
| Turner Cut | Jan | Below normal | 0.156 | 0.156 (0%) |
| Turner Cut | Jan | Dry | 0.152 | 0.151 (0%) |

| Junction | Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|---|
| Turner Cut | Jan | Critical | 0.151 | 0.150 (0%) |
| Turner Cut | Feb | Wet | 0.178 | 0.177 (-1%) |
| Turner Cut | Feb | Above normal | 0.169 | 0.170 (0%) |
| Turner Cut | Feb | Below normal | 0.172 | 0.172 (0%) |
| Turner Cut | Feb | Dry | 0.152 | 0.152 (0%) |
| Turner Cut | Feb | Critical | 0.149 | 0.149 (0%) |
| Turner Cut | Mar | Wet | 0.177 | 0.175 (-1%) |
| Turner Cut | Mar | Above normal | 0.169 | 0.170 (0%) |
| Turner Cut | Mar | Below normal | 0.162 | 0.163 (1%) |
| Turner Cut | Mar | Dry | 0.148 | 0.149 (0%) |
| Turner Cut | Mar | Critical | 0.147 | 0.147 (0%) |
| Turner Cut | Apr | Wet | 0.184 | 0.183 (0%) |
| Turner Cut | Apr | Above normal | 0.170 | 0.170 (0%) |
| Turner Cut | Apr | Below normal | 0.162 | 0.162 (0%) |
| Turner Cut | Apr | Dry | 0.148 | 0.148 (0%) |
| Turner Cut | Apr | Critical | 0.141 | 0.141 (0%) |
| Turner Cut | May | Wet | 0.181 | 0.182 (1%) |
| Turner Cut | May | Above normal | 0.169 | 0.170 (0%) |
| Turner Cut | May | Below normal | 0.163 | 0.164 (1%) |
| Turner Cut | May | Dry | 0.153 | 0.153 (0%) |
| Turner Cut | May | Critical | 0.142 | 0.142 (0%) |
| Turner Cut | Jun | Wet | 0.185 | 0.186 (0%) |
| Turner Cut | Jun | Above normal | 0.172 | 0.172 (0%) |
| Turner Cut | Jun | Below normal | 0.164 | 0.165 (0%) |
| Turner Cut | Jun | Dry | 0.158 | 0.158 (0%) |
| Turner Cut | Jun | Critical | 0.145 | 0.146 (0%) |

# 5D.5 Delta Passage Model

The Delta Passage Model (DPM) simulates migration of Chinook Salmon smolts entering the Delta from the Sacramento River at Fremont Weir and estimates survival to Chipps Island. The DPM uses available time-series data and values taken from empirical studies or other sources to parameterize model relationships and inform uncertainty, thereby using the greatest amount of data available to dynamically simulate responses of smolt survival to changes in water management. The DPM contains relationships derived from studies of all four runs of Chinook salmon. Relationships for individual runs were not developed due to sample size limitations for some runs and the model assumes all migrating Chinook salmon smolts will respond similarly to Delta conditions. Delta entry timing for each run is unique for each run based on collections in the Sacramento trawl. The DPM results presented here reflect the most current version of the model, which continues to be

reviewed and refined, and for which a sensitivity analysis has been completed to examine various aspects of uncertainty related to the model's inputs and parameters.

Although studies have shown considerable variation in emigrant size, with Central Valley Chinook Salmon migrating as fry, parr, and smolts (Brandes and McLain 2001; Williams 2001), the DPM relies predominantly on data from acoustic-tagging studies of smolt-sized (≥ 80 millimeter [mm]) fish, and therefore should be applied cautiously to pre-smolt migrants. Salmon juveniles less than 70 mm are more likely to exhibit rearing behavior in the Delta (Kjelson et al. 1982) and thus likely will be represented poorly by the DPM. It has been assumed that the downstream emigration of fry, when spawning grounds are well upstream, is probably a dispersal mechanism that helps distribute fry among suitable rearing habitats. However, even when rearing habitat does not appear to be a limiting factor, downstream movement of fry still may be observed, suggesting that fry emigration is a viable alternative life-history strategy (Healy 1980; Healey and Jordan 1982; Miller et al. 2010). Unfortunately, survival data are lacking for small (fry-sized) juvenile emigrants because of the difficulty of tagging such small individuals. Therefore, the DPM should be viewed as a smolt survival model only, with its survival relationships generally having been derived from larger juveniles (≥ 80 mm), with the fate of pre-smolt emigrants not incorporated into model results.

The version of the DPM described here has undergone substantial revisions based on a large amount of telemetry data that has become available since the original version of the model was constructed. Initial model structure was modified based on comments received through the Bay-Delta Conservation Plan preliminary proposal anadromous team meetings and in particular through feedback received during a workshop held on August 24, 2010, a 2-day workshop held June 23–24, 2011, and since then from various meetings of a workgroup consisting of agency biologists and consultants. The current version builds on this breadth of input and resolves many of the uncertainties identified in previous reviews. This documentation reflects the most recent version of the DPM as of December 2020.

Survival and routing estimates generated by the DPM are not intended to predict future outcomes. Instead, the DPM is a decision support tool that compares the effects of different water management options on smolt migration survival, with accompanying estimates of uncertainty. The DPM is a tool to compare different scenarios and is not intended to predict actual through-Delta survival under current or future conditions. It is possible that underlying relationships (e.g., flow-survival, export-survival) that are used to inform the DPM will change in the future. Just as this latest update was completed to incorporate newly available data, it may be necessary to re-examine the relationships as new information becomes available.

# 5D.5.1 Methods

## 5D.5.1.1 Model Overview

The DPM is based on migratory pathways and reach-specific mortality as Chinook Salmon smolts travel through a simplified network of reaches and junctions (Figure 5D.5-1). The biological functionality of the DPM is based on releases of acoustically tagged Chinook salmon performed between 2007 and 2019. The previous version of the DPM primarily relied on releases of large (> 140 mm) acoustically tagged late-fall run Chinook salmon performed by Perry (2010) and coded wire tag releases of late-fall run reported by Newman and Brandes (2010). There was considerable uncertainty about the transferability of those relationships to other runs that migrate at different times of year and at smaller sizes. The revised model is based on acoustically tagged winter run,

spring run, fall run and late fall run individuals (≥ 80 mm) released in the upper reaches of the Sacramento River and within the Delta. These releases are primarily comprised of hatchery fish. However, wild spring- and fall-run salmon are included in the data set. These releases cover a wide range of environmental conditions including extreme drought in 2014 and 2015 and high flow years. Uncertainty is explicitly modeled in the DPM by incorporating environmental stochasticity and estimation error whenever available. Some model functions (e.g., flow-survival estimates) are randomly sampled from a distribution of values based on model coefficients; 500 iterations of the model were run for each scenario to generate 500 sets of outputs, each reflecting different random sampling from distributions of the different functions in the model.

The major model functions in the DPM are as follows.

1. Delta Entry Timing, which models the temporal distribution of smolts entering the Delta for each race of Chinook salmon.
2. Fish Behavior at Junctions, which models fish movement as they approach river junctions.
3. Migration Speed, which models reach-specific smolt migration speed and travel time.
4. Route-Specific Survival, which models route-specific survival response to non-flow factors.
5. Flow-Dependent Survival, which models reach-specific survival response to flow.
6. Export-Dependent Survival, which models survival response to water export levels in the Interior Delta reach (see Table 5D.5-1 for reach description).

Functional relationships are described in detail in Section 5D.5.1.5, *Model Functions*.

### 5D.5.1.2 Model Timestep

The DPM operates on a daily timestep using simulated daily average flows and south Delta exports as model inputs. The DPM does not attempt to represent sub-daily flows or diel salmon smolt behavior in response to the interaction of tides, flows, and specific channel features. The DPM is intended to represent the net outcome of migration and mortality occurring over one day, not three-dimensional movements occurring over minutes or hours (e.g., Blake and Horn 2003). It is acknowledged that finer scale modeling with a shorter timestep may match the biological processes governing fish movement better than a daily timestep (e.g., because of diel activity patterns; Plumb et al. 2015) and that sub-daily differences in flow proportions into junctions make daily estimates somewhat coarse (Cavallo et al. 2015).

### 5D.5.1.3 Spatial Framework

The DPM is composed of ten reaches and three junctions (Figure 5D.5-1; Table 5D.5-1) selected to represent primary salmonid migration corridors for fish originating from the Sacramento River basin where high-quality data were available for fish and hydrodynamics. For simplification, Sutter Slough and Steamboat Slough are combined as the reach SS; and Georgiana Slough and the Delta Cross Channel (DCC) are a combined junction. Sacramento Chinook Salmon that enter the DCC migrate through the forks of the Mokelumne River and fish entering Georgiana Slough migrate only through that route. The Interior Delta reach can be entered from the Mokelumne River or Georgiana Slough route. The entire Interior Delta region is treated as a single model reach. The three distributary junctions (channel splits) depicted in the DPM are (A) Sacramento River at Fremont Weir (head of Yolo Bypass), (B) Sacramento River at head of Sutter and Steamboat Sloughs, and (C)

Sacramento River at the combined junction with Georgiana Slough and DCC (Figure 5D.5-1, Table 5D.5-1).

**Table 5D.5-1. Description of Modeled Reaches and Junctions in the Delta Passage Model**

| Reach/Junction [a] | Description | Approximate Reach Length (km) | Final Receiver Name/Location |
|---|---|---|---|
| Verona | Sacramento River Between Fremont Weir and Freeport | 57 | Freeport |
| Sac_1 | Sacramento River Between Freeport and the combined junction of Steamboat and Sutter Slough | 19 | Sacramento River Below Steamboat Slough |
| Sac_2 | Sacramento River from Sutter/Steamboat Sloughs junction to junction with Delta Cross Channel/Georgiana Slough | 11 | Sacramento River Below Georgiana Slough |
| Sac_3 | Sacramento River from Below Georgiana Slough to Chipps Island | 46 | Chipps Island |
| SS | Steamboat and Sutter Sloughs from their junction with the Sacramento River to Chipps Island | 51 | Chipps Island |
| Yolo Bypass | Fremont weir to Highway 84 Ferry | NA | Highway 84 Ferry |
| Sac_4 (Yolo fish only) | Highway 84 to Chipps Island | 30 | Chipps Island |
| Georgiana Slough | Georgiana Slough from the junction with the Sacramento River to the base of the Mokelumne River | 25 | Mokelumne Base |
| Mokelumne | Confluence of the DCC to Mokelumne Base/SF Mokelumne | 25 | Mokelumne Base/South Fork Mokelumne |
| Interior Delta | Confluence of Mokelumne and San Joaquin Rivers to Chipps Island | NA | Chipps Island |
| A | Junction of Yolo Bypass and Sacramento River | NA | NA |
| B | Combined junction of Sutter Slough and Steamboat Slough with the Sacramento River | NA | NA |
| C | Combined junction of the Delta Cross Channel and Georgiana Slough with the Sacramento River | NA | NA |

km = kilometers.
[a] Yolo and interior Delta reach lengths are not defined because multiple migration pathways are possible.

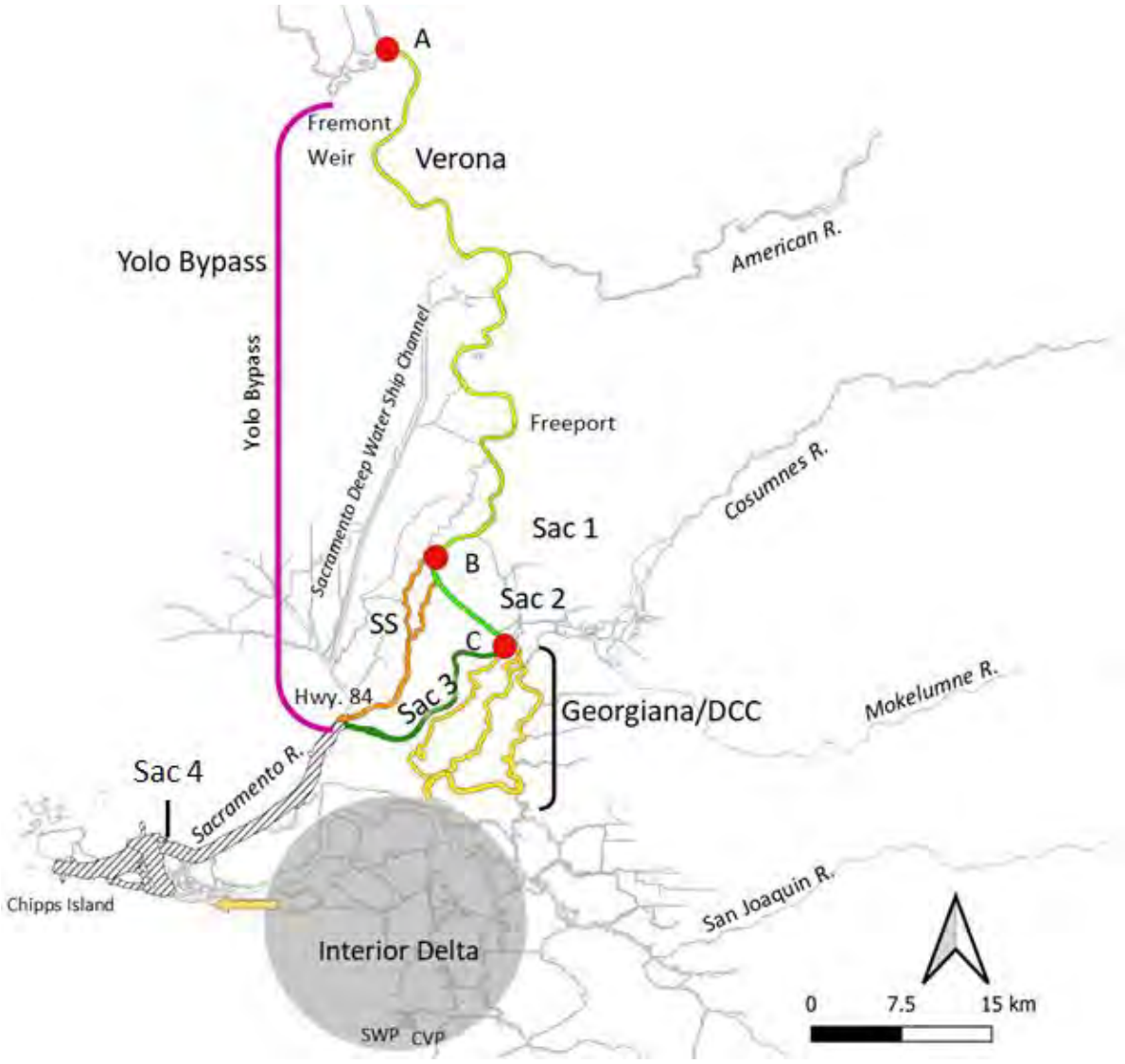



**Figure 5D.5-1. Map of the Sacramento–San Joaquin River Delta Showing the Modeled Reaches and Junctions of the Delta Applied in the Delta Passage Model**

## 5D.5.1.4 Flow Input Data

Water movement through the Delta as input to the DPM is derived from daily (tidally averaged) flow output produced by the hydrology module of the DSM2-HYDRO (California Department of Water Resources 2021b) or from CalSim 3.

The nodes in the DSM2-HYDRO and CalSim models that were used to provide flow for specific reaches in the DPM are shown in Table 5D.5-2.

**Table 5D.5-2. Delta Passage Model Reaches and Associated Output Locations from DSM2-HYDRO and CalSim Models**

| DPM Reach or Model Component | DSM2 Output Locations | CalSim Node |
|---|---|---|
| Sac1 | rsac155 | - |
| Sac2 | rsac128 | - |
| Sac3 | rsac123 | - |
| Sac4 | rsac101, Channel 398 (Yolo only) | - |
| Yolo | - | d160a+d166aa |
| Verona | - | C160a |
| SS | slsbt011 | - |
| Geo/DCC | dcc+georg_sl | - |
| South Delta Export Flow | Clifton Court Forebay + Delta Mendota Canal | - |
| Sacramento River flow at Fremont Weir | - | C129a |

DPM = Delta Passage Model; DSM2 = Delta Simulation Model II.

## 5D.5.1.5 Model Functions

### Delta Entry Timing

Catch data for emigrating juvenile smolts for five Central Valley Chinook salmon runs were used to inform the daily proportion of juveniles entering the Delta for each run (Table 5D.5-3). Because the DPM models the survival of smolt-sized juvenile salmon, pre-smolts were removed from catch data before creating entry timing distributions. The lower 95th percentile of the range of salmon fork lengths visually identified as smolts by the U.S. Fish and Wildlife Service (USFWS) in Sacramento trawls was used to determine the lower length cutoff for smolts. A lower fork length cutoff of 70 mm for smolts was applied, and all catch data of fish smaller than 70 mm were eliminated. To isolate wild production, all fish identified as having an adipose-fin clip (hatchery production) were eliminated, recognizing that most (75%) of the fall-run hatchery fish released upstream of Sacramento are not marked. Daily catch data for each brood year were divided by total annual catch to determine the daily proportion of smolts entering the DPM for each run (Figure 5D.5-2). Sampling was not conducted daily at most stations and catch was not expanded for fish caught but not measured. Finally, a generic probability density function was fit to the data using the package “sm” in R software (R Core Team 2021). The R fitting procedure estimated the best-fit probability distribution of the daily proportion of fish entering the DPM.

For the current analysis, the most recent data from the Sacramento trawl survey were added to the data used in previous versions of the DPM to determine if entry distributions had shifted since the original fitting. Only late fall Chinook Salmon exhibited substantial change from the original fit and the entry distribution for that race was updated (Figure 5D.5-2).

**Table 5D.5-3. Sampling Gear Used to Create Juvenile Delta Entry Timing Distributions for Each Central Valley Run of Chinook Salmon**

| Chinook Salmon Run | Gear | Agency | Brood Years |
|---|---|---|---|
| Sacramento River Winter Run | Trawls at Sacramento | USFWS | 1995–2009 |
| Sacramento River Spring Run | Trawls at Sacramento | USFWS | 1995–2005 |
| Sacramento River Fall Run | Trawls at Sacramento | USFWS | 1995–2005 |
| Sacramento River Late Fall Run | Trawls at Sacramento | USFWS | 1995–2018 |

USFWS = U.S. Fish and Wildlife Service.

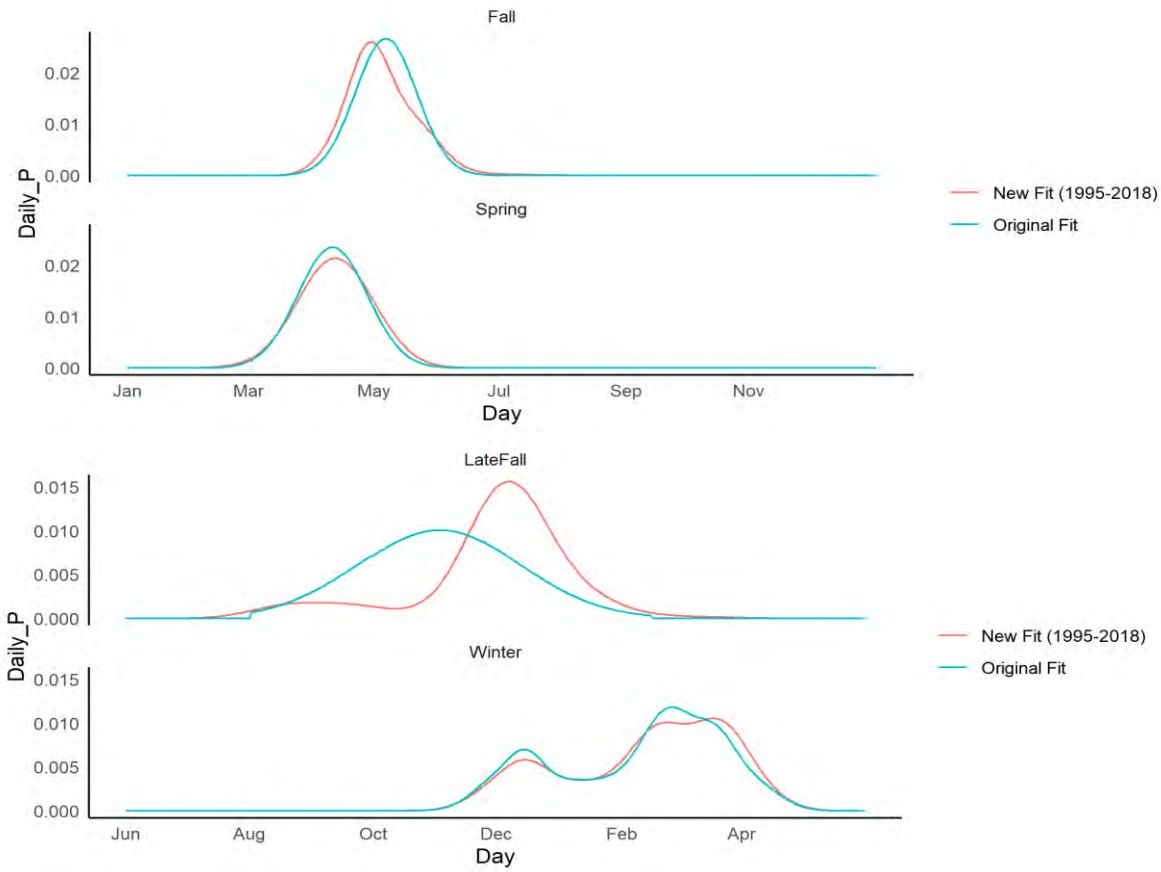



**Figure 5D.5-2. Delta Entry Distributions (Daily_P = Daily Proportion) for Chinook Salmon Smolts Applied in the Delta Passage Model for Sacramento River Winter-Run, Central Valley Spring-Run (Sacramento River), Central Valley Fall-Run (Sacramento River), and Central Valley Late Fall–Run**

## Migration Speed

The DPM assumes a net daily movement of smolts in the downstream direction. The rate of smolt movement in the DPM affects the timing of arrival at Delta junctions and reaches, which can affect route selection and survival as flow conditions or water project operations change.

Smolt movement in all reaches except Yolo Bypass and the Interior Delta is a function of reach-specific length and migration speed as observed from acoustic-tagging results. Reach-specific length (kilometers [km]) is divided by reach migration speed (km/day) the day smolts enter the reach to calculate the number of days smolts will take to travel through the reach.

For north Delta reaches Verona, Sac1, Sac2, SS, Georgiana Slough, and Mokelumne, mean migration speed through the reach is predicted as a function of flow. Many studies have found a positive relationship between juvenile Chinook salmon migration rate and flow in the Columbia River Basin (Raymond 1968; Berggren and Filardo 1993; Schreck et al. 1994), with Berggren and Filardo (1993) finding a logarithmic relationship for Snake River yearling Chinook salmon. Ordinary least squares regression was used to test for a logarithmic relationship between reach-specific migration speed (km/day) and average daily reach-specific flow (cubic meters per second) for the first day smolts entered a particular reach for reaches where acoustic-tagging data was available (Sac1, Sac2, Sac3, Sac4, Georgiana Slough, Mokelumne, and SS):

$$Speed = \beta_0 \ln(flow) + \beta_1;$$

where $\beta_0$ is the slope parameter and $\beta_1$ is the intercept.

Individual smolt reach-specific travel times were calculated from detection histories of releases of acoustically tagged smolts conducted in December and January for three consecutive winters (2006/2007, 2007/2008, and 2008/2009) (Perry 2010). Reach-specific migration speed (km/day) for each smolt was calculated by dividing reach length by travel days. Flow data was queried from the California Department of Water Resources (DWR) California Data Exchange website (2021a).

Migration speed was significantly related to flow for reaches Sac1 (df = 450, F = 164.36, $P$ <0.001), Sac2 (df = 292, F = 4.17, $P$ = 0.042), and Geo/DCC (df = 84, F = 13.74, $P$ <0.001). Migration speed increased as flow increased for all three reaches (Table 5D.5-4, Figure 5D.5-3). Therefore, for reaches Sac1, Sac2, and Geo/DCC, the regression coefficients shown in Table 5D.5-8 are used to calculate the expected average migration rate given the input flow for the reach and the associated standard error of the regressions is used to inform a normal probability distribution that is sampled from the day smolts enter the reach to determine their migration speed throughout the reach. The minimum migration speed for each reach is set at the minimum reach-specific migration speed observed from the acoustic-tagging data. The flow-migration rate relationship that was used for Sac1 also was applied for the Verona reach.

**Table 5D.5-4. Sample Size and Slope ($\beta_0$) and Intercept ($\beta_1$) Parameter Estimates with Associated Standard Error (in Parenthesis) for the Relationship between Migration Speed and Flow for Reaches Sac1, Sac2, and Geo/DCC**

| Reach | N | $\beta_0$ | $\beta_1$ |
|---|---|---|---|
| Sac1 | 452 | 21.34 (1.66) | -105.98 (9.31) |
| Sac2 | 294 | 3.25 (1.59) | -8.00 (8.46) |
| Geo/DCC | 86 | 11.08 (2.99) | -33.52 (12.90) |

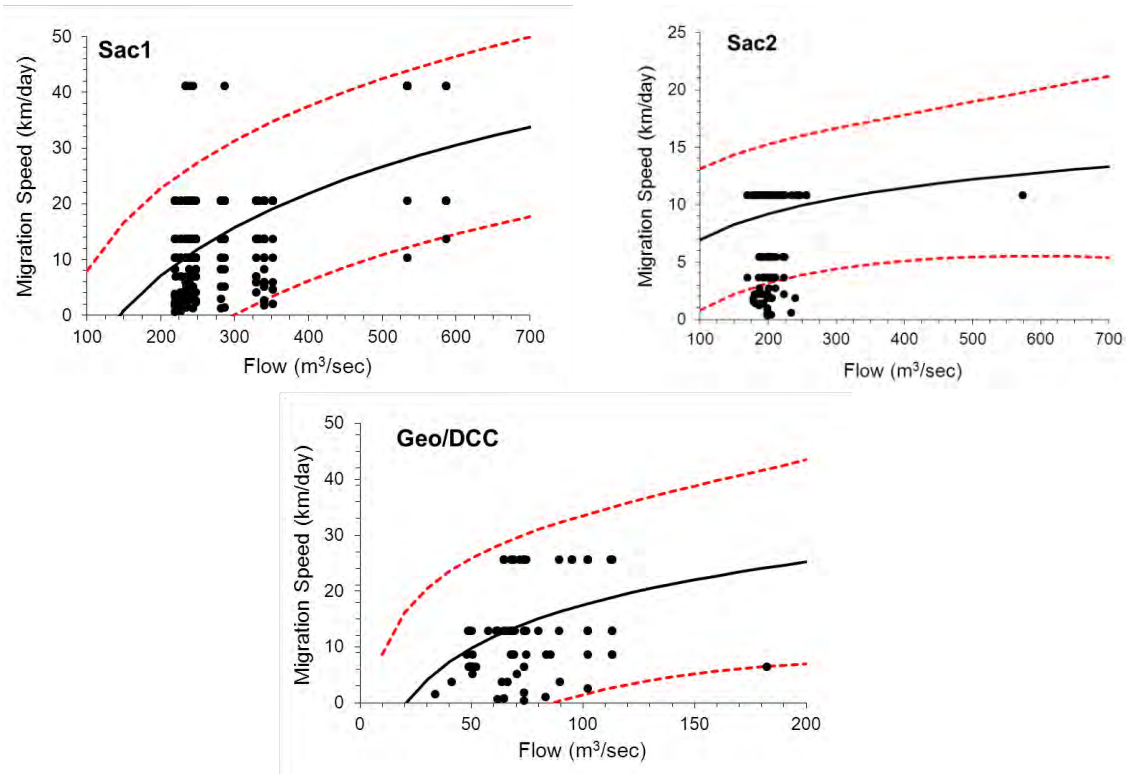



**Figure 5D.5-3. Reach-Specific Migration Speed (km/day) as a Function of Flow ($m^3/s$) Applied in Reaches Sac1, Sac2, and Geo/DCC**

No significant relationship between migration speed and flow was found for reaches Sac3 (df = 100, F = 1.13, $P$ = 0.29), Sac4 (df = 60, F = 0.33, $P$ = 0.57), and SS (df = 28, F = 0.86, $P$ = 0.36). Therefore, for these reaches the observed mean migration speed and associated standard deviation is used to inform a normal probability distribution that is sampled from the day smolts enter the reach to determine their migration speed throughout the reach. As applied for reaches Sac1, Sac2, and Geo/DCC, the minimum migration speed for reaches Sac3, Sac4, and SS is set at the minimum reach-specific migration speed observed from the acoustic-tagging data.

Yolo Bypass travel time data from Sommer et al. (2005) for coded wire-tagged, fry-sized (mean size = 57-mm fork length) Chinook Salmon were used to inform travel time through the Yolo Bypass in the DPM. Because the DPM models the migration and survival of smolt-sized juveniles, the range of the shortest travel times observed across all 3 years (1998–2000) by Sommer et al. (2005) was used to inform the bounds of a uniform distribution of travel times (range = 4–28 days), on the assumption that smolts would spend less time rearing and would travel faster than fry. On the day smolts enter the Yolo Bypass, their travel time through the reach is calculated by sampling from this uniform distribution of travel times.

The travel time of smolts migrating through the Interior Delta in the DPM is informed by observed mean travel time (7.95 days) and associated standard deviation (6.74) from North Delta acoustic-tagging studies (Perry 2010). However, the timing of smolt passage through the Interior Delta does not affect Delta survival because there are no Delta reaches located downstream of the Interior Delta.

## Fish Behavior at Junctions (Channel Splits)

Perry et al. (2010) and Cavallo et al. (2015) found that acoustically tagged smolts arriving at Delta junctions exhibited inconsistent movement patterns in relation to the flow being diverted. For Junction A (entry into the Yolo Bypass at Fremont Weir), the following relationships were used.

- Proportion of smolts entering Yolo Bypass = Fremont Weir spill/(Fremont Weir spill + Sacramento River at Verona flows).

As noted above in Section 5D.5.1.4, *Flow Input Data*, the flow data informing Yolo Bypass entry were obtained by disaggregating CalSim estimates using historical daily patterns of variability because DSM2 does not provide daily flow data for these locations.

For Junction B (Sacramento River-Sutter/Steamboat Sloughs), Both Perry et al. (2010) and Cavallo et al. (2015) found that smolts consistently entered downstream distributaries in proportion to the flow being diverted. Therefore, smolts arriving at Junction B in the model move proportionally with flow according to the linear relationship found in Cavallo et al. (2015):

$$P_{SS} = -0.00203 + P_{flowSS} * 0.775344;$$

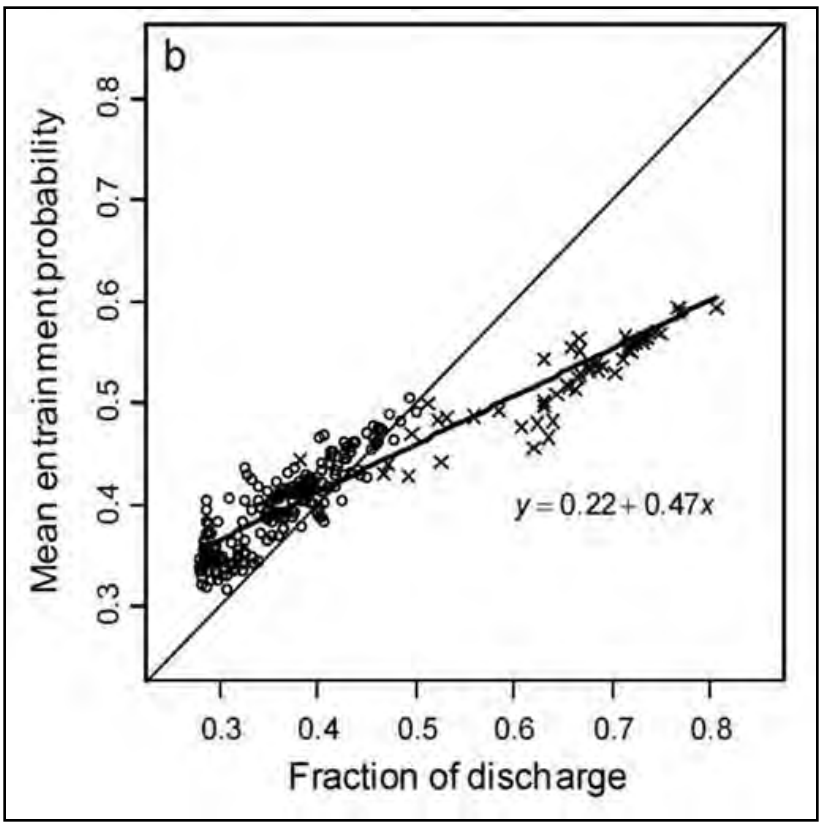
where $P_{SS}$ is the proportion of fish entering the SS reach, and $P_{flowSS}$ is the proportion of flow entering Sutter/Steamboat Slough distributaries from the total flow in the mainstem Sacramento River.

For Junction C (Sacramento River–Georgiana Slough/DCC), Perry (2010) found a linear, nonproportional relationship between flow and fish movement. His relationship for Junction C was applied in the DPM:

$$y = 0.22 + 0.47x;$$

where $y$ is the proportion of fish diverted into Geo/DCC and $x$ is the proportion of flow diverted into Geo/DCC (Figure 5D.5-4).

In the DPM, this linear function is applied to predict the daily proportion of fish movement into Geo/DCC as a function of the proportion of flow into Geo/DCC.




Note: Circles depict DCC gates closed. Crosses depict DCC gates open.

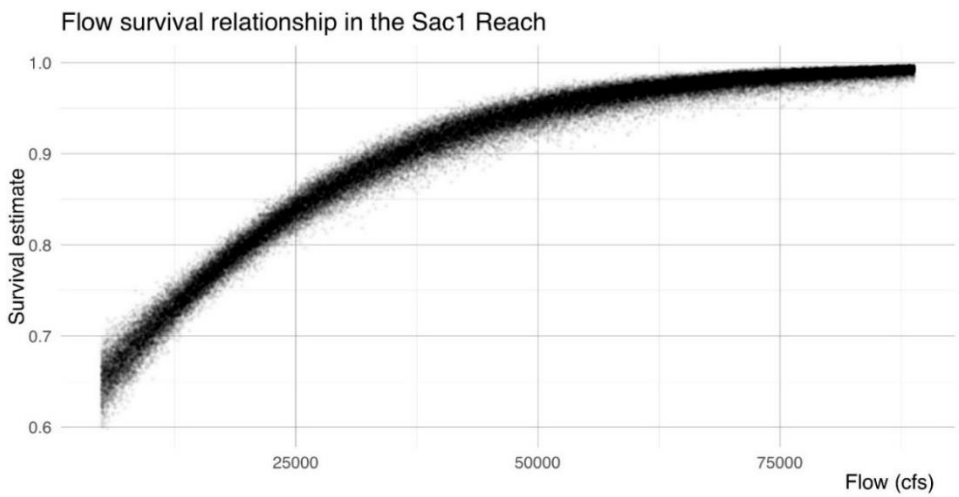
**Figure 5D.5-4. Figure from Perry (2010) Depicting the Mean Entrainment Probability (Proportion of Fish Being Diverted into Reach Geo/DCC) as a Function of Fraction of Discharge (Proportion of Flow Entering Reach Geo/DCC)**

## Reach-Specific Survival

To update survival estimates in the DPM, a dataset of detections from >2,000 acoustically tagged (Juvenile Salmon Acoustic Telemetry System [JSATS]) fish recorded in the DPM region of the Sacramento–San Joaquin Delta from 2013 through 2019 was analyzed. To estimate survival from such a large and heterogeneous dataset (receiver combinations, monitored reaches, and release locations differed from year to year), only detections from receivers at the endpoint of reaches in the DPM were used, and binary detection histories along DPM routes were constructed. Moving downstream from receiver to receiver along a route, it was assumed that if a fish was not seen again in the route after a given receiver, the fish did not survive. The probability of being detected again downstream (assumed to be a direct proxy for survival) was then modeled as a function of an individual's detection history and time-specific covariates associated with reach entry. From this analysis, four reaches were associated with a consistent relationship between flow and survival: Sac1, Sac2, Sac3, and Sac4 (see Figure 5D.5-5 through Figure 5D.5-8); all other reaches had no consistent flow-survival relationship, and survival in those reaches of the DPM is drawn from a normal distribution derived from a reach-specific, intercept-only model of survival and standard deviation from the JSATS data.

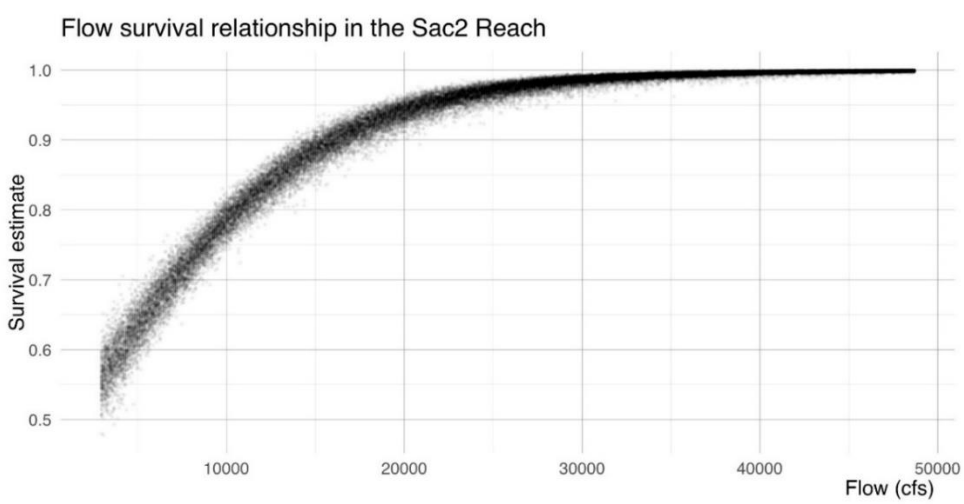
## Flow-Dependent Survival

Survival through a given reach is estimated and applied the first day smolts enter that reach. For reaches where analysis of the JSATS detections supported a consistent flow-survival relationship, flow on the day fish enter the reach is used to predict survival through the entire reach even if migration through the reach takes place over more than one day. As previously described, only reaches Sac1, Sac2, Sac3, and Sac4 were associated with consistent flow-survival relationships (Figure 5D.5-5 through Figure 5D.5-8).



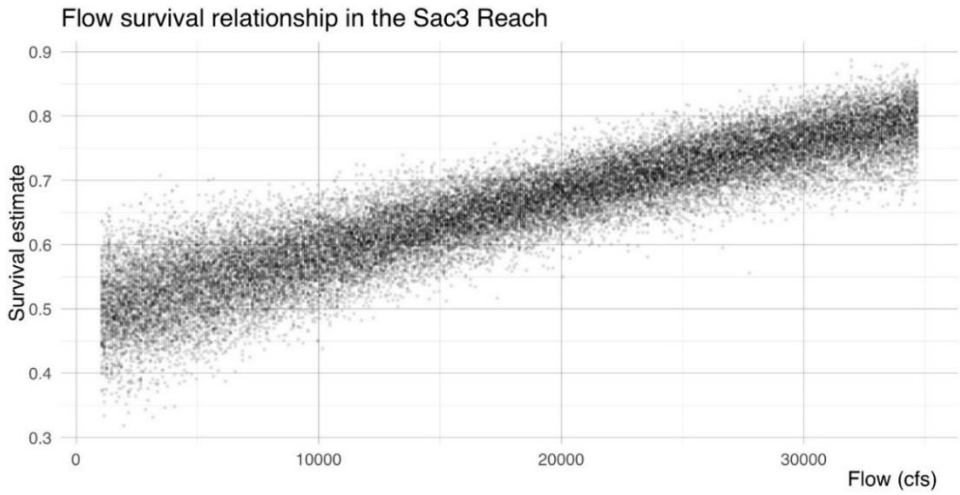

Note: Plot shows model predictions of simulated data across the observed flow range.

**Figure 5D.5-5. Relationship between Sacramento River Discharge and Survival Through the Delta Passage Model Sac1 Reach Modeled with JSATS Releases of Multiple Runs of Juvenile Chinook Salmon**



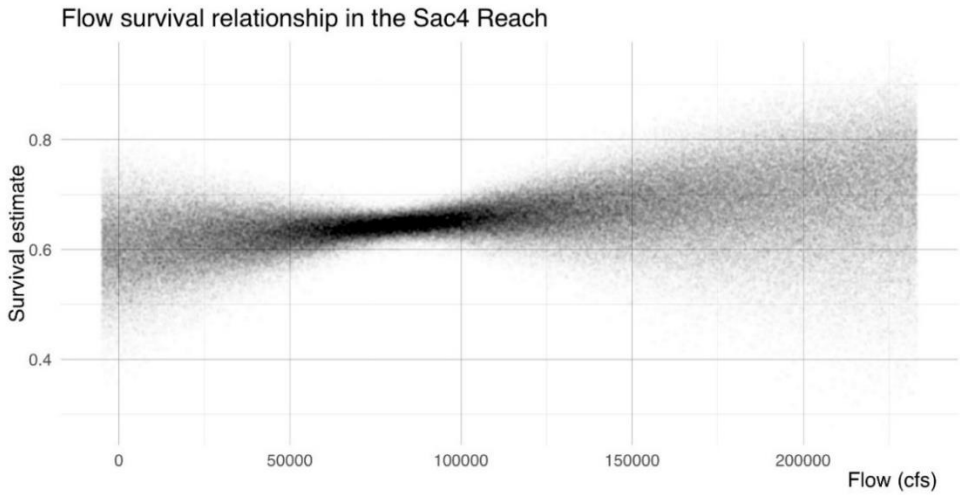

Note: Plot shows model predictions of simulated data across the observed flow range.

**Figure 5D.5-6. Relationship between Sacramento River Discharge and Survival Through the Delta Passage Model Sac2 Reach Modeled with JSATS Releases of Multiple Runs of Juvenile Chinook Salmon**




Note: Plot shows model predictions of simulated data across the observed flow range.

**Figure 5D.5-7. Relationship between Sacramento River Discharge and Survival Through the Delta Passage Model Sac3 Reach Modeled with JSATS Releases of Multiple Runs of Juvenile Chinook Salmon**




Note: Plot shows model predictions of simulated data across the observed flow range.

**Figure 5D.5-8. Relationship between Sacramento River Discharge and Survival through the Delta Passage Model Sac4 Reach Modeled with JSATS Releases of Multiple Runs of Juvenile Chinook Salmon**

In order to capture the effect of changed flows within the Sac1 reach being altered by the proposed NDD before the start of the Sac2 reach and the junction with reach SS, a modification was applied to the flows in reach Sac1. The modification reflected the location of the proposed NDD (Intake A[2] = RM 41, Intake B = RM 39.5, and Intake C = RM 37). Flows in reach Sac1 were represented by the length-

[2] Note that the proposed action does not include Intake A, but other Final EIR alternatives do. The formula remains the same, with no diversions at Intake A for the proposed action (i.e., Final EIR Alternative 5).

weighted average of flows in each of the following subreaches (lengths used for weighting are given in parentheses).

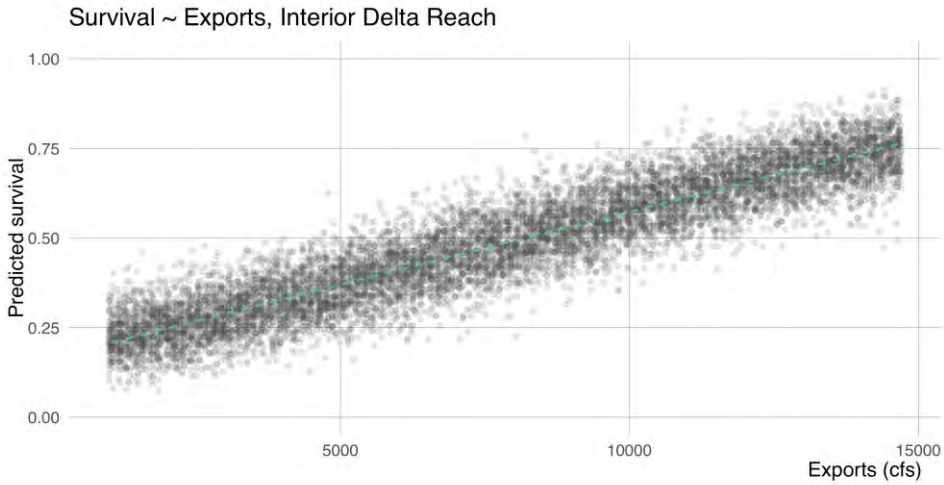
- Upstream end of Sac1 to Intake A (4 miles).
- Intake A to Intake B (1.5 miles).
- Intake B to Intake C (2.5 miles).
- Intake C to downstream end of Sac1 (4 miles).

## Export-Dependent Survival

An export-survival relationship was only tested for fish entering the interior Delta from the Mokelumne River and Georgiana Slough. Hydrodynamic data for exports covering the period of JSATS detection data (2013–2019) was queried from Dayflow (California Natural Resources Agency 2021). A model that included exports and Sacramento River at Freeport flow was also tested. Exports observed over the data period ranged from 1,038 cfs to 14,650 cfs.

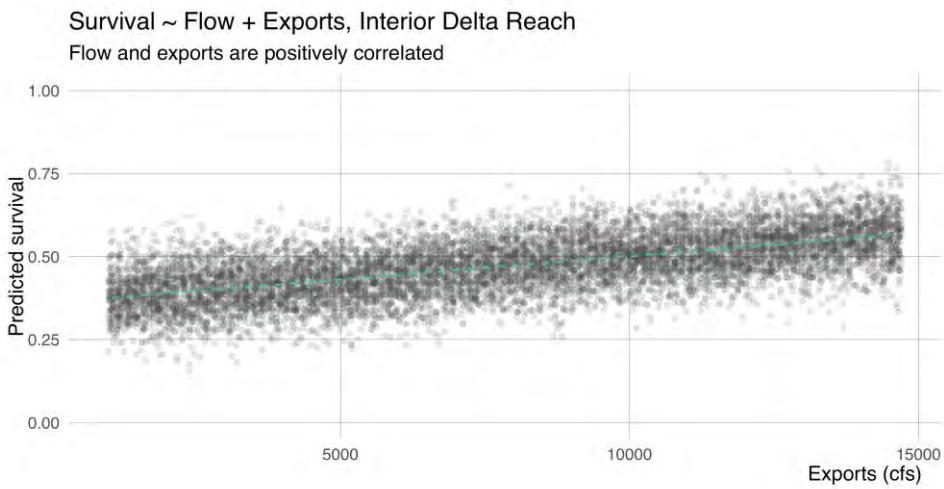
For the model that included exports only, the coefficient for the export effect was positive and well supported, indicating higher survival probabilities with greater exports (Figure 5D.5-9). In the model including both exports and flow, the export coefficient remained positive but was not well supported with a mean effect that included zero in the distribution (Figure 5D.5-10). This positive effect of exports may seem contradictory based on coded wire tag studies used in the previous model version that includes a weak, yet negative effect (Newman and Brandes 2010). The effect of exports on Sacramento River-origin Chinook Salmon was a source of uncertainty identified in the previous version. Hydrodynamic analysis indicates that there is little effect of exports on hydrodynamics in the Sacramento River (Cavallo et al. 2015) and only fish entering the interior Delta, and the Old-Middle River corridor specifically, are likely to be exposed to the hydrodynamic effects of exports (see, for example, Bureau of Reclamation 2019, Appendix H, p. 4). Previous studies of export effects relied on the relative survival of coded wire tagged salmon released into Georgiana Slough relative to the Sacramento River (Newman and Brandes 2010). Thus, export effects in the coded wire tag studies are not directly estimated for fish in the area of interest. In previous workshops and comments, it was suggested that modeling potential effects of exports on individually tagged fish would be a superior approach. The JSATS data analyzed here represents the best data set available and covers a wide range of export conditions. Thus, the data strongly suggest the absence of a negative effect of exports on survival of Sacramento River-origin Chinook Salmon that enter the interior Delta.

Based on the above analysis, for juvenile Chinook salmon entering the Interior Delta route, the DPM uses the export value (in cfs) on the day the fish enters the reach to apply the effect of exports from the JSATS model accounting for Sacramento River flow (Figure 5D.5-10) to predict survival through the entire Interior Delta reach (even if migration through the reach takes place over more than one day); the Sacramento River flow at Freeport for the same day is also included in the estimate, per the relationship shown in Figure 5D.5-10. Note that the model does not explicitly include salvage (including collection, handling, trucking, and release) at the south Delta exports facilities; to the extent that salvage of JSATS-tagged fish entering the interior Delta occurred and these fish reached Chipps Island, this would be reflected in survival estimates for the interior Delta reach.




Note: Plot shows model predictions of simulated data across the observed flow range. The coefficient for the effect of exports was well supported with a credible interval that did not include zero.

**Figure 5D.5-9. Relationship between South Delta Exports and Survival through the Delta Passage Model Interior Delta Reach Modeled with JSATS Releases of Multiple Runs of Juvenile Chinook Salmon**




Note: Plot shows model predictions of simulated data across the observed flow range. When flow is included in the model, the effect of exports on survival remains positive but is no longer well supported (compared to Figure 5D.16-1).

**Figure 5D.5-10. Relationship between South Delta Exports and Survival through the Delta Passage Model Interior Delta Reach When Sacramento River at Freeport Discharge Was Held at Its Mean Value, Modeled with JSATS Releases of Multiple Runs of Juvenile Chinook Salmon**

## 5D.5.2 Results

Tabulated results are presented and results discussed in Appendix 5C, with graphical summaries in Figure 5D.5-11 through Figure 5D.5-16.

Note: Alt 5 corresponds to the proposed action.

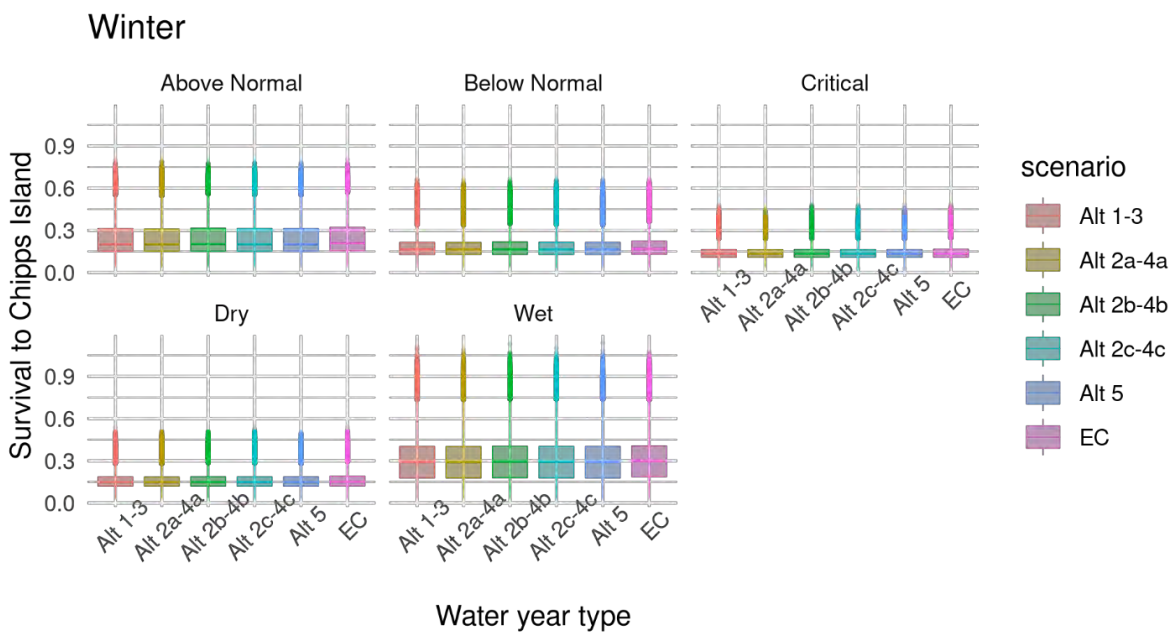



**Figure 5D.5-11. Box Plot of Delta Passage Model Results, Winter-Run Chinook Salmon**

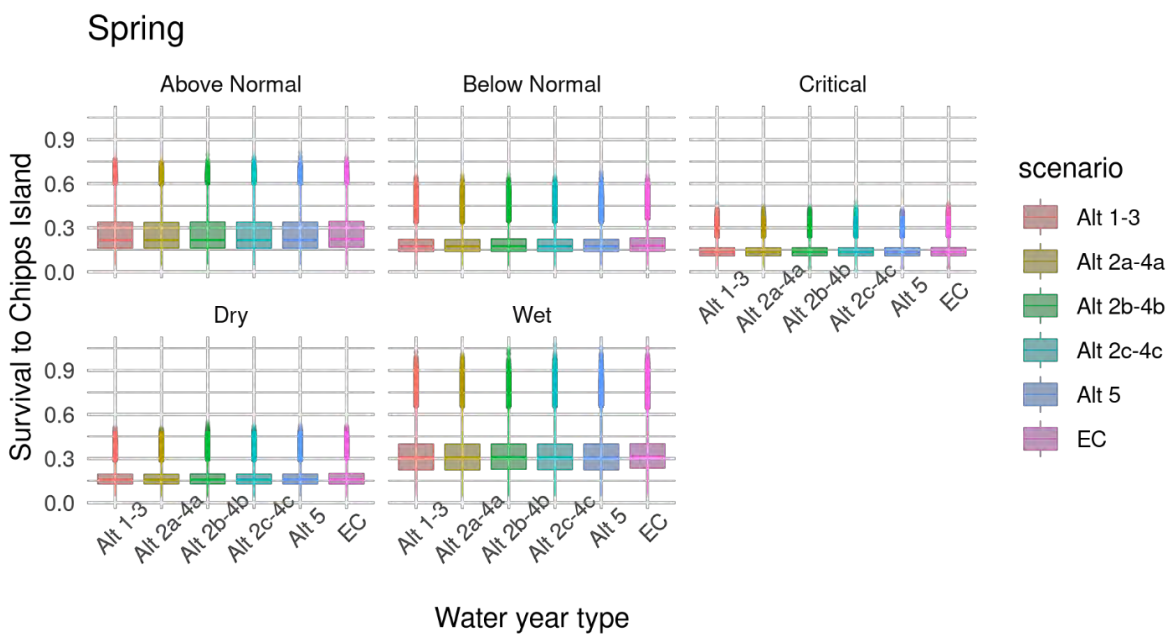



**Figure 5D.5-12. Box Plot of Delta Passage Model Results, Spring-Run Chinook Salmon**

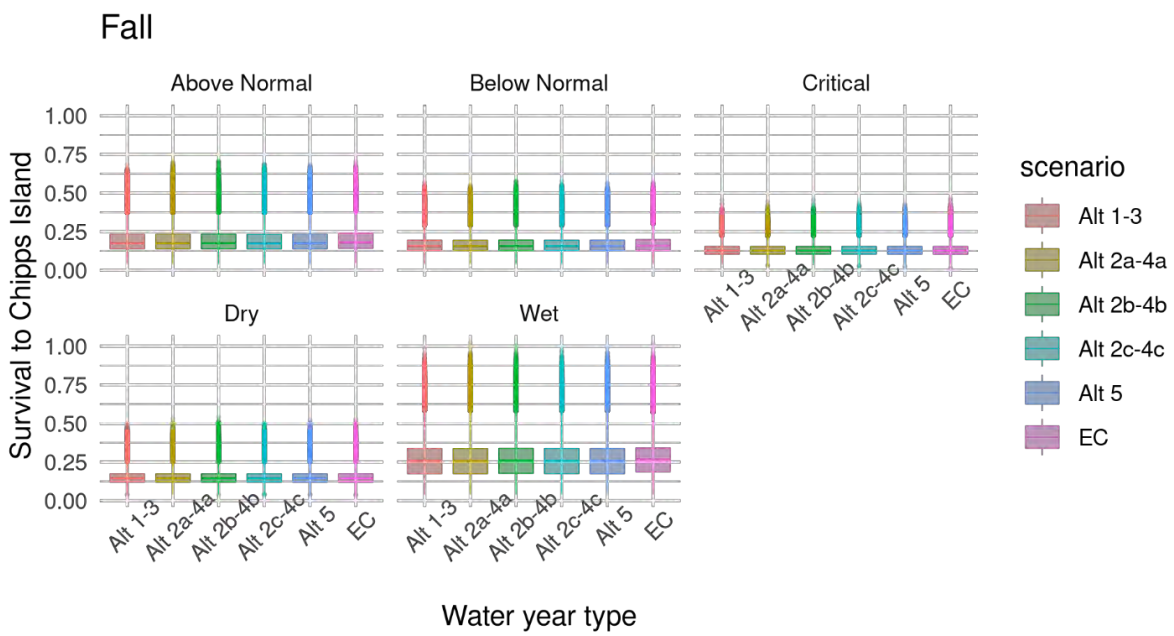



**Figure 5D.5-13. Box Plot of Delta Passage Model Results, Fall-Run Chinook Salmon**

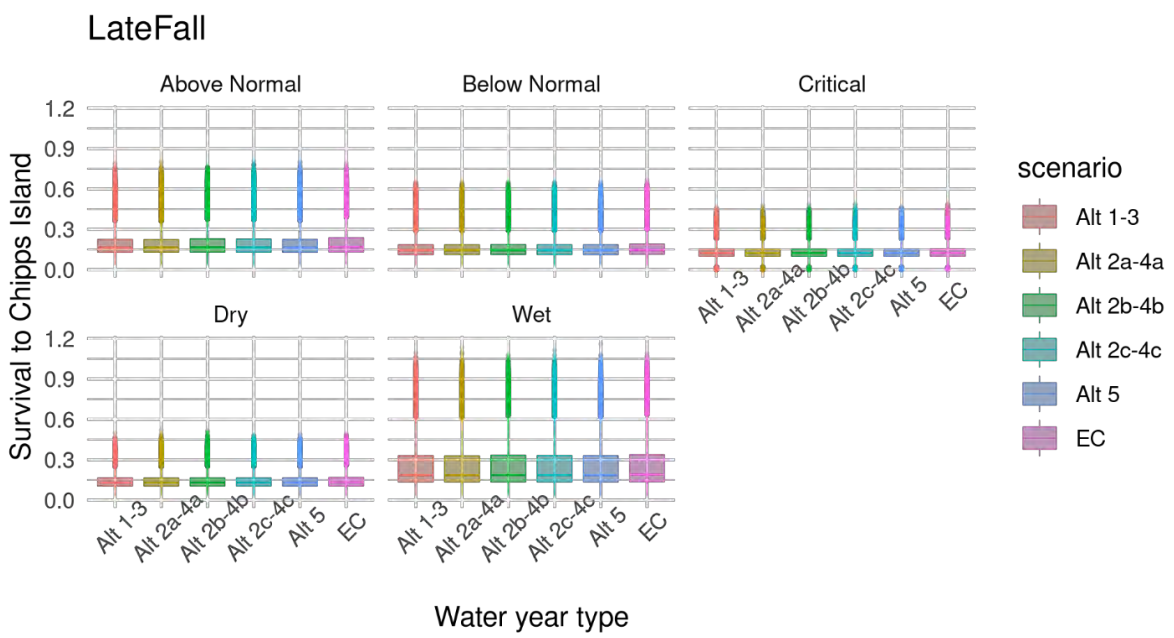
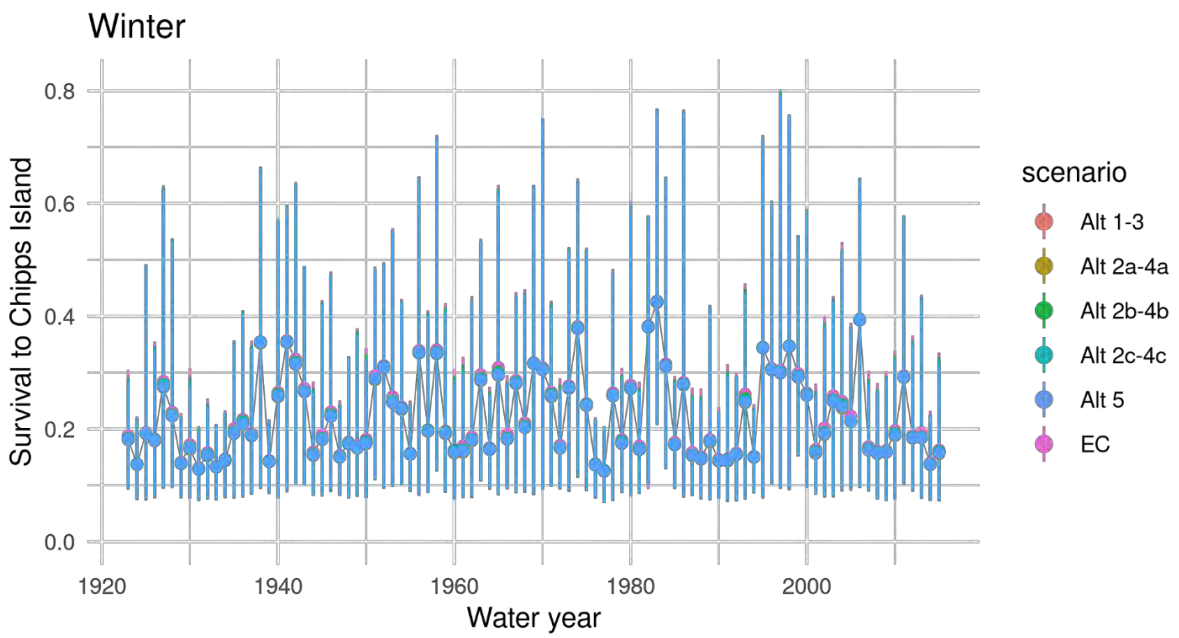
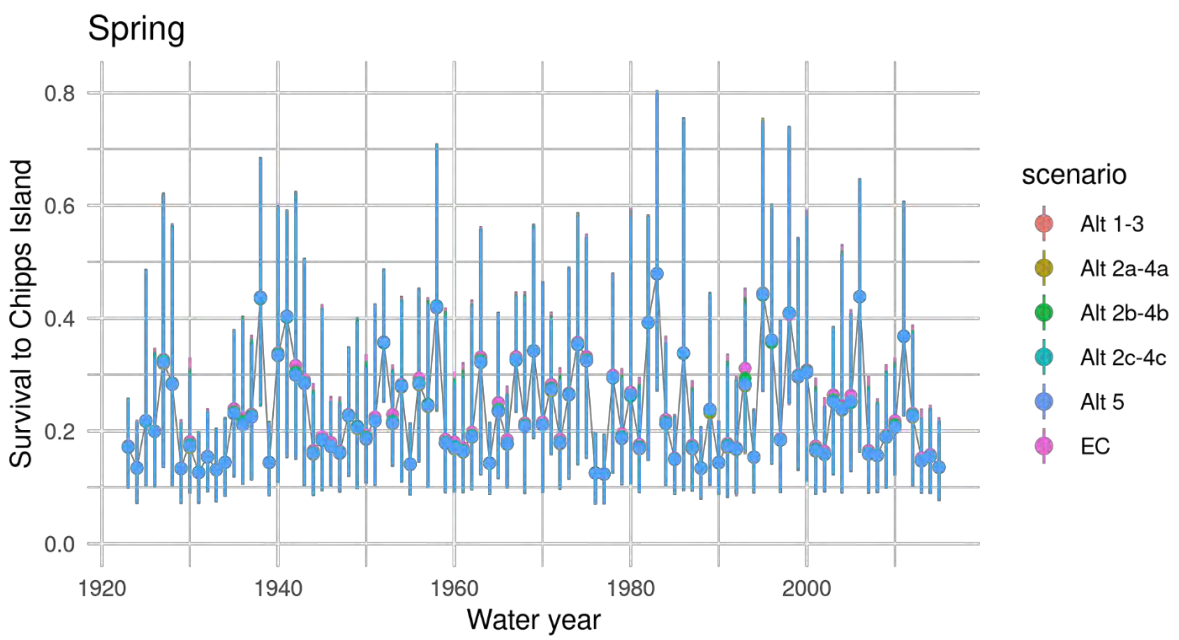



**Figure 5D.5-14. Box Plot of Delta Passage Model Results, Late Fall–Run Chinook Salmon**



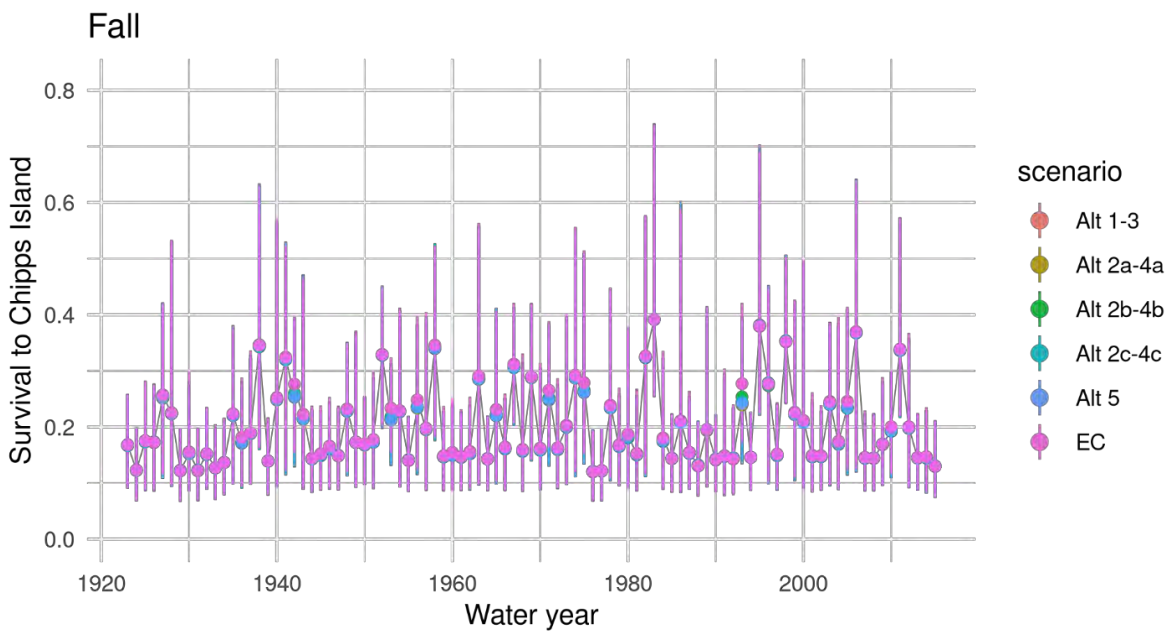

Note: Whiskers represent 95% confidence intervals.

**Figure 5D.5-15. Time Series Plot of Delta Passage Model Results, Winter-Run Chinook Salmon**



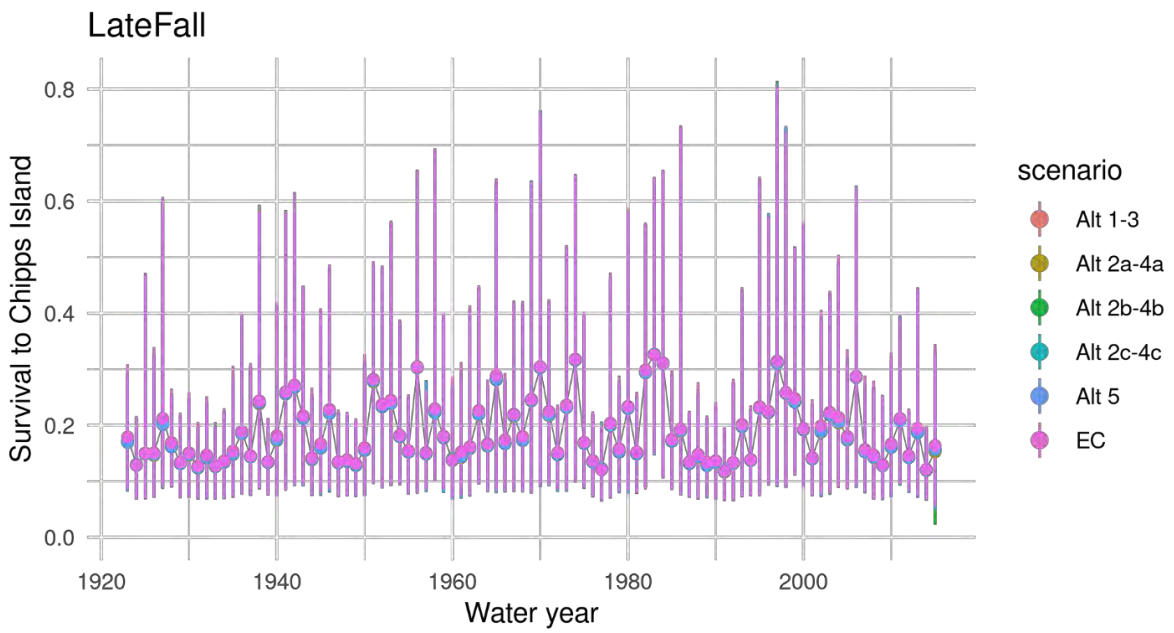

Note: Whiskers represent 95% confidence intervals.

**Figure 5D.5-16. Time Series Plot of Delta Passage Model Results, Spring-Run Chinook Salmon**




Note: Whiskers represent 95% confidence intervals.

**Figure 5D.5-17. Time Series Plot of Delta Passage Model Results, Fall-Run Chinook Salmon**




Note: Whiskers represent 95% confidence intervals.

**Figure 5D.5-18. Series Plot of Delta Passage Model Results, Late Fall–Run Chinook Salmon**

# 5D.6 Riparian and Wetland Bench Inundation

Operations of the proposed action has the potential to affect the extent of riparian and wetland bench inundation (e.g., by lowering water surface elevation downstream of the NDD), thereby affecting the suitability of channel margin habitat for juvenile Chinook salmon. This potential effect was assessed by calculating bench inundation indices for a number of habitat benches in the north Delta.

Data for 37 riparian benches (total length = 31,428 feet; 6.0 miles) and 17 wetland benches (total length = 15,973 feet; 3.0 miles) in the north Delta were obtained (Table 5D.6-1). Some riparian and wetland benches were located at the same site (Figure 5D.6-1), indicated in Table 5D.6-1 by having the same number in their codes. Each bench belonged to one of five grouped geographic locations, and each bench was matched with the nearest DSM2-HYDRO output location for which stage data were available. A focus on length data is consistent with previous application of the method (e.g., ICF International 2016); bench widths were not available for a number of benches.

In order to represent inundation of differing levels of the benches over their entire elevations, four equally spaced increments were calculated between the minimum and maximum elevations. For example, riparian bench R1 in Cache Slough (minimum elevation = 4.3 feet, maximum elevation = 6.3 feet) was divided into the increments 4.3 feet, 4.8 feet, 5.3 feet, and 5.8 feet. In essence, this process divided each bench into four sub-benches, each of slightly different elevation. This process was adopted because division into regular increments (e.g., every 0.5 feet or every 1 foot) would have been computationally intensive because the difference between maximum and minimum elevations was 5 feet or more in some cases (e.g., riparian bench R5), whereas for others the difference was small (less than 2 feet).

Water depth on each sub-bench was calculated for every 15-minute timestep available from the 1923–2015 DSM2-HYDRO simulation. The depth was calculated as the difference between the water surface elevation at the nearest DSM2-HYDRO output location and the sub-bench elevation; if this calculation was negative, it indicated that the water was below the level of the sub-bench, and water depth was zero. Water depth was converted to a habitat suitability score by applying the suitability curve from USFWS (2005) for juvenile winter-run Chinook salmon (Figure 5D.6-2). USFWS (2005:218–221) provides several different curves, but the curve for juvenile winter-run Chinook salmon was selected because it represents juveniles >60 mm in length, which is representative of most winter-run-sized juvenile Chinook salmon entering the Delta, for example (del Rosario et al. 2013:8). Water velocity was not considered because fine-scale velocity data were not available from DSM2-HYDRO.

The habitat suitability score for each sub-bench in each 15-minute period was then multiplied by the length of the site at which each sub-bench occurred. An overall bench inundation index was calculated for each bench type in each of the five geographic locations in three seasons (fall: October–November; winter: December–February; spring: March–June) in each water year, by summing all of the applicable 15-minute length-weighted habitat suitability scores, then dividing by the sum of the corresponding site lengths for all of these observations. This final bench inundation index represents the overall suitability of bench habitat for juvenile Chinook salmon, based on water depth. The index ranges from 0 (no water of suitable depth available at any time) to 1 (optimal water depth available at all times on all sub-benches).

**Table 5D.6-1. Characteristics of the Benches Analyzed for Inundation Effects of the Proposed Action**

| Bench Type | Code | Location | Water body | Length (feet) | Min. Elevation (feet NAVD) | Max. Elevation (feet NAVD) | DSM2-HYDRO Node |
|---|---|---|---|---|---|---|---|
| Riparian | R1 | Cache Slough | Cache Slough | 495 | 4.3 | 6.3 | CACHE_RYER |
| Riparian | R2 | Sacramento River above NDD | Sacramento River | 268 | 5.0 | 10.0 | NDD_US |
| Riparian | R3 | Sacramento River above NDD | Sacramento River | 894 | 5.0 | 10.0 | NDD_US |
| Riparian | R4 | Sacramento River above NDD | Sacramento River | 166 | 5.0 | 10.0 | NDD_US |
| Riparian | R5 | Sacramento River above NDD | Sacramento River | 322 | 5.1 | 10.4 | NDD_US |
| Riparian | R6 | Sacramento River above NDD | Sacramento River | 285 | 5.8 | 10.4 | NDD_US |
| Riparian | R7 | Sacramento River above NDD | Sacramento River | 1,254 | 6.0 | 8.6 | NDD_US |
| Riparian | R8 | Sacramento River above NDD | Sacramento River | 1,320 | 6.0 | 10.6 | NDD_US |
| Riparian | R9 | Sacramento River above NDD | Sacramento River | 730 | 6.5 | 7.5 | NDD_US |
| Riparian | R10 | Sacramento River above NDD | Sacramento River | 1,061 | 7.1 | 8.3 | NDD_US |
| Riparian | R11 | Sacramento River above NDD | Sacramento River | 1,473 | 8.0 | 10.0 | NDD_US |
| Riparian | R12 | Sacramento River above NDD | Sacramento River | 329 | 8.0 | 10.0 | NDD_US |
| Riparian | R13 | Sacramento River above NDD | Sacramento River | 888 | 8.0 | 10.0 | NDD_US |
| Riparian | R14 | Sacramento River above NDD | Sacramento River | 720 | 8.0 | 10.0 | NDD_US |
| Riparian | R15 | Sacramento River above NDD | Sacramento River | 1,566 | 8.0 | 10.0 | NDD_US |
| Riparian | R16 | Sacramento River above NDD | Sacramento River | 298 | 8.0 | 10.0 | NDD_US |
| Riparian | R17 | Sacramento River above NDD | Sacramento River | 970 | 8.0 | 12.0 | NDD_US |
| Riparian | R18 | Sacramento River above NDD | Sacramento River | 770 | 3.9 | 3.9 | NDD_US |
| Riparian | R19 | Sacramento River from Sutter/Steamboat Sloughs to Rio Vista | Sacramento River | 210 | 5.0 | 5.8 | RSAC123 |
| Riparian | R21 | Sacramento River from Sutter/Steamboat Sloughs to Rio Vista | Sacramento River | 660 | 4.6 | 6.6 | RSAC123 |

| Bench Type | Code | Location | Water body | Length (feet) | Min. Elevation (feet NAVD) | Max. Elevation (feet NAVD) | DSM2-HYDRO Node |
|---|---|---|---|---|---|---|---|
| Riparian | R22 | Sacramento River from Sutter/Steamboat Sloughs to Rio Vista | Sacramento River | 815 | 5.0 | 7.0 | RSAC123 |
| Riparian | R24 | Sacramento River above NDD | Sacramento River | 1,322 | 4.6 | 13.9 | RSAC155 |
| Riparian | R25 | Sacramento River above NDD | Sacramento River | 198 | 5.5 | 8.2 | RSAC155 |
| Riparian | R26 | Sacramento River above NDD | Sacramento River | 1,124 | 6.1 | 9.1 | RSAC155 |
| Riparian | R27 | Sacramento River above NDD | Sacramento River | 1,668 | 6.3 | 8.5 | RSAC155 |
| Riparian | R28 | Sacramento River above NDD | Sacramento River | 895 | 8.0 | 12.0 | RSAC155 |
| Riparian | R29 | Sacramento River below NDD to Sutter/Steamboat Sloughs | Sacramento River | 292 | 4.9 | 5.5 | SAC_DS_SUTSL |
| Riparian | R30 | Sacramento River below NDD to Sutter/Steamboat Sloughs | Sacramento River | 420 | 5.5 | 6.1 | SAC_DS_SUTSL |
| Riparian | R31 | Sacramento River below NDD to Sutter/Steamboat Sloughs | Sacramento River | 2,325 | 6.2 | 8.2 | SAC_DS_SUTSL |
| Riparian | R33 | Cache Slough | Cache Slough | 2,455 | 4.6 | 6.6 | SLCCH016 |
| Riparian | R34 | Sutter/Steamboat Sloughs | Steamboat Slough | 708 | 2.1 | 5.0 | SLSBT011 |
| Riparian | R35 | Sutter/Steamboat Sloughs | Steamboat Slough | 740 | 2.1 | 8.0 | SLSBT011 |
| Riparian | R36 | Sutter/Steamboat Sloughs | Steamboat Slough | 439 | 5.1 | 7.0 | SLSBT011 |
| Riparian | R37 | Sutter/Steamboat Sloughs | Steamboat Slough | 430 | 4.3 | 6.3 | SLSBT011 |
| Riparian | R38 | Sutter/Steamboat Sloughs | Steamboat Slough | 353 | 5.1 | 5.8 | STMBT_SL |
| Riparian | R39 | Sutter/Steamboat Sloughs | Sutter Slough | 1,415 | 4.2 | 7.2 | SUT_US_MIN |
| Riparian | R40 | Sutter/Steamboat Sloughs | Sutter Slough | 1,150 | 4.2 | 7.2 | SUT_US_MIN |
| Wetland | W1 | Cache Slough | Cache Slough | 495 | 2.3 | 4.3 | CACHE_RYER |
| Wetland | W8 | Sacramento River above NDD | Sacramento River | 1,320 | 2.9 | 4.1 | NDD_US |
| Wetland | W19 | Sacramento River from Sutter/Steamboat Sloughs to Rio Vista | Sacramento River | 210 | 0.9 | 2.1 | RSAC123 |

| Bench Type | Code | Location | Water body | Length (feet) | Min. Elevation (feet NAVD) | Max. Elevation (feet NAVD) | DSM2-HYDRO Node |
|---|---|---|---|---|---|---|---|
| Wetland | W20 | Sacramento River from Sutter/Steamboat Sloughs to Rio Vista | Sacramento River | 745 | -0.5 | 3.4 | RSAC123 |
| Wetland | W21 | Sacramento River from Sutter/Steamboat Sloughs to Rio Vista | Sacramento River | 660 | 2.6 | 4.6 | RSAC123 |
| Wetland | W22 | Sacramento River from Sutter/Steamboat Sloughs to Rio Vista | Sacramento River | 815 | 2.9 | 4.9 | RSAC123 |
| Wetland | W23 | Sacramento River below NDD to Sutter/Steamboat Sloughs | Sacramento River | 790 | -0.5 | 3.4 | RSAC142 |
| Wetland | W24 | Sacramento River above NDD | Sacramento River | 1,322 | -0.8 | 4.2 | RSAC155 |
| Wetland | W26 | Sacramento River above NDD | Sacramento River | 1,124 | 1.8 | 2.8 | RSAC155 |
| Wetland | W31 | Sacramento River below NDD to Sutter/Steamboat Sloughs | Sacramento River | 2,325 | 3.2 | 5.2 | SAC_DS_SUTSL |
| Wetland | W32 | Cache Slough | Cache Slough | 1,042 | 0.9 | 2.1 | SLCCH016 |
| Wetland | W33 | Cache Slough | Cache Slough | 2,455 | 2.6 | 4.6 | SLCCH016 |
| Wetland | W34 | Sutter/Steamboat Sloughs | Steamboat Slough | 708 | 0.9 | 2.1 | SLSBT011 |
| Wetland | W35 | Sutter/Steamboat Sloughs | Steamboat Slough | 740 | 0.9 | 2.1 | SLSBT011 |
| Wetland | W36 | Sutter/Steamboat Sloughs | Steamboat Slough | 439 | 0.9 | 2.1 | SLSBT011 |
| Wetland | W37 | Sutter/Steamboat Sloughs | Steamboat Slough | 430 | 2.3 | 4.3 | SLSBT011 |
| Wetland | W38 | Sutter/Steamboat Sloughs | Steamboat Slough | 353 | 0.9 | 2.1 | STMBT_SL |

Source: ICF International 2016:5.D-272.
NAVD = North American Vertical Datum of 1988; NDD = north Delta diversion.

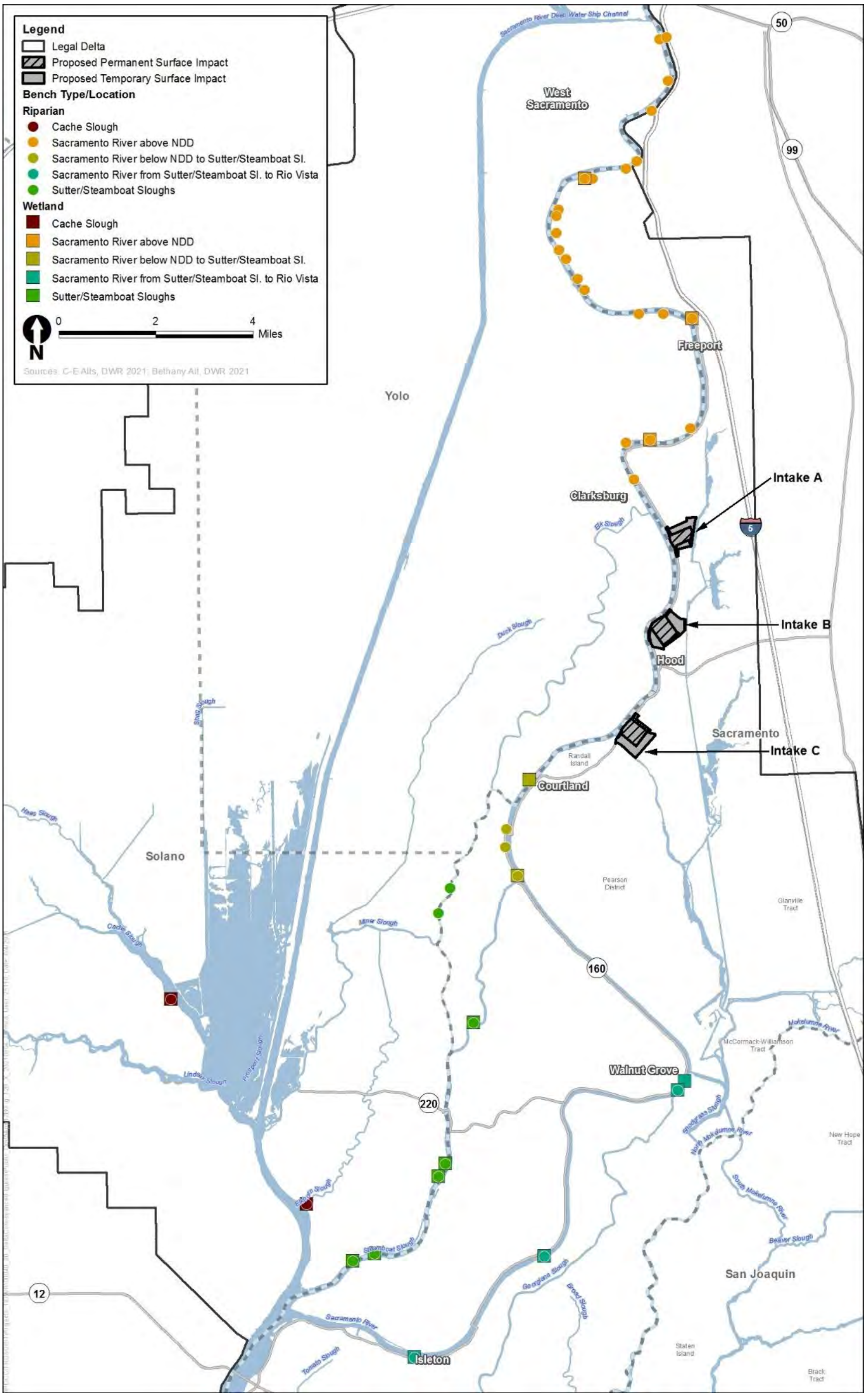



**Figure 5D.6-1. Benches Analyzed for Inundation Effects of the Proposed Action**

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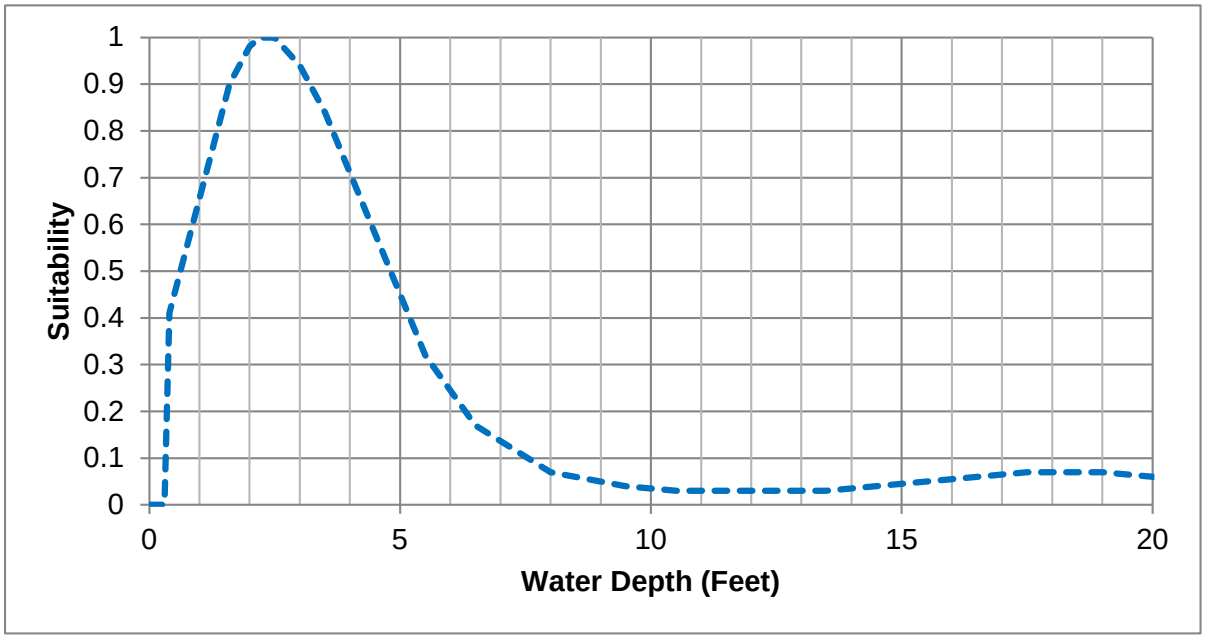



Source: U.S. Fish and Wildlife Service 2005:221.

**Figure 5D.6-2. Habitat Suitability Curve for Juvenile Winter-Run Chinook Salmon**

# 5D.7 Interactive Object-Oriented Simulation

## 5D.7.1 Model Structure

The Interactive Object-Oriented Simulation (IOS) model is composed of six model stages defined by a specific spatiotemporal context and are arranged sequentially to account for the entire life cycle of winter-run Chinook salmon, from eggs to returning spawners (Figure 5D.7-1). In sequential order, the IOS Model stages are listed below.

1. Spawning, which models the number and temporal distribution of eggs deposited in the gravel at the spawning grounds in the upper Sacramento River between Red Bluff Diversion Dam and Keswick Dam as a function of water Temperatures in April and May.
2. Early Development, which models the effect of temperature on maturation timing and mortality of eggs incubating in the gravel.
3. Fry Rearing, which models the relationship between temperature and mortality of fry during the river rearing period in the upper Sacramento River between Red Bluff Diversion Dam and Keswick Dam.
4. River Migration, which estimates mortality of migrating smolts in the Sacramento River between Red Bluff and the Delta as a function of river flow.
5. Delta Passage, which models the effect of flow, routing, and exports on the survival of smolts migrating through the Delta to San Francisco Bay.
6. Ocean Survival, which estimates the effect of natural mortality, ocean harvest, and ocean conditions to predict survival and spawning returns by age.

A detailed description of each model stage follows.

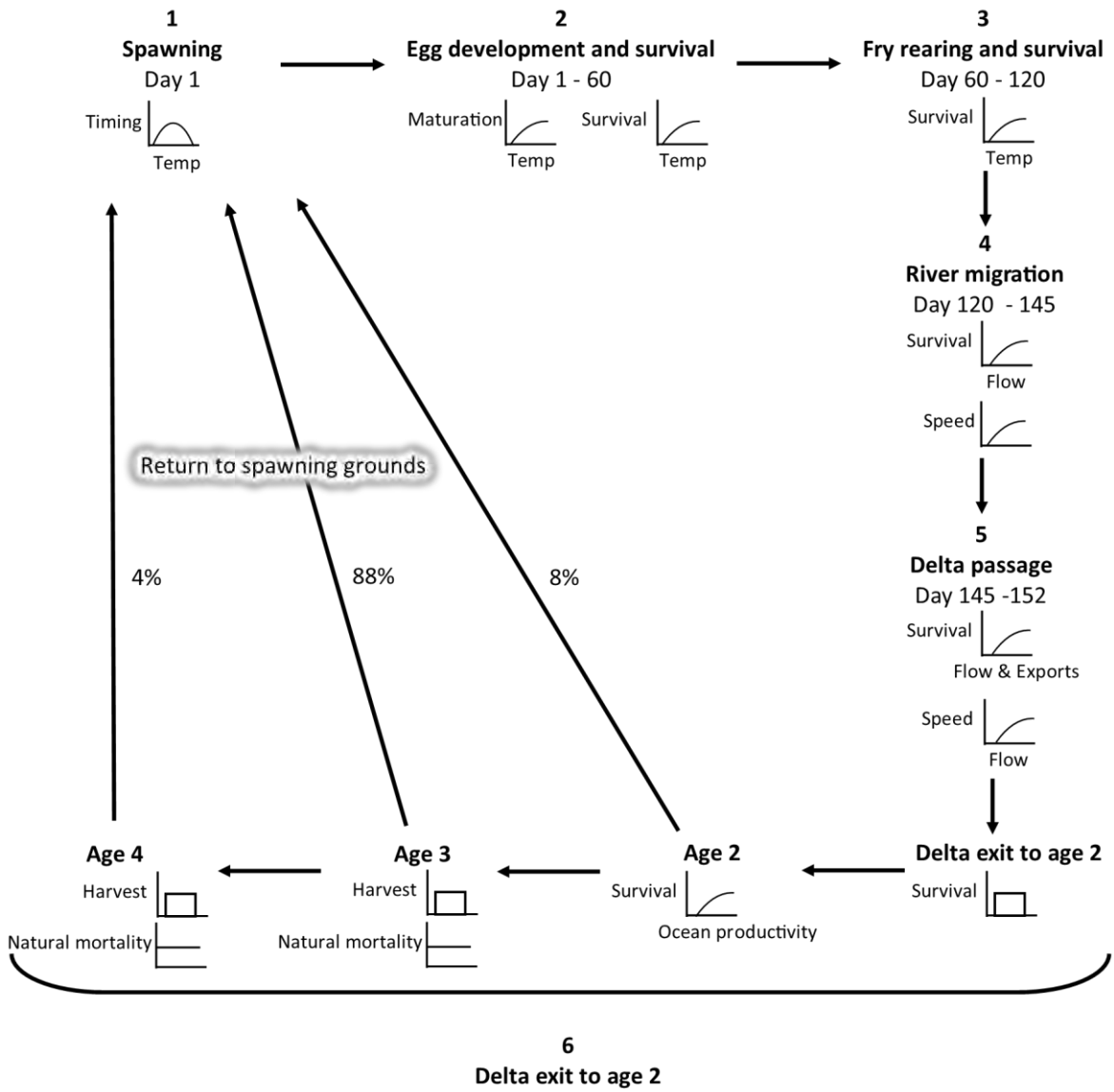



**Figure 5D.7-1. Conceptual Diagram of the IOS Model Stages and Environmental Influences on Survival and Development of Winter-Run Chinook Salmon at Each Stage**

### 5D.7.1.1 Spawning

For the first four simulation years of the 82-year CALSIM simulation period, the model is seeded with 5,000 spawners, of which 3,087.5 are female based on the wild male to female ratio of spawners. In each subsequent simulation year, the number of female spawners is determined by the model's probabilistic simulation of survival to this life stage. To ensure that developing fish experience the correct environmental conditions during each year, spawn timing is a function of water temperatures in April and May as described by the function of Dusek Jennings and Hendrix (2020: 8). Eggs deposited on a particular date are treated as cohorts that experience temperature on a daily timestep during the early development stage. The daily number of female spawners is

calculated by multiplying the predicted daily proportion of spawners by the total Jolly-Seber estimate of female spawners (Poytress and Carillo 2010:22):

(Equation 1) $$S_d = P_d S_{JS}$$

where, $S_d$ is the daily number of female spawners, $P_d$ is the daily proportion of total spawners and $S_{JS}$ is the total Jolly-Seber estimate of female spawners.

To account for the time difference between egg deposition and carcass observations, the date of egg deposition is assumed to be 14 days prior to carcass observations (based on input from USFWS Red Bluff Fish and Wildlife Office Hatchery Evaluation staff).

To obtain estimates of juvenile production, a Ricker stock-recruitment curve (Ricker 1975) was fit between the winter run Juvenile Production Index each year (estimated by rotary screw–trap sampling at Red Bluff Diversion Dam) and the number of female spawners (from USFWS carcass surveys) for years 1996–1999 and 2002–2017:

(Equation 2) $$R = \alpha S e^{-\beta S} + \varepsilon$$

where $\alpha$ is a parameter that describes recruitment rate, and $\beta$ is a parameter that measures the level of density dependence.

The density-dependent parameter ($\beta$) did not differ significantly from 0 (t = 1.662, $P$ = 0.114), indicating that the relationships between emergent fry and female spawners was linear (density-independent). Therefore, $\beta$ was removed from the equation and a linear version of the stock-recruitment relationship was estimated. The number of female spawners explained 90% of the variation in fry production ($F_{1,19}$ = 173, $P$ <0.001) in the data, so the value of $\alpha$ was taken from the regression:

(Equation 3) $$R = 1027*S$$

In the IOS model, this linear relationship is used to predict values for mean fry production along with the confidence intervals for the predicted values. These values are then used to define a normal probability distribution, which is randomly sampled to determine the annual fry production. Although the Ricker model accounts for mortality during egg incubation, additional mortality was imposed at temperatures higher than those experienced during the years used to construct the Ricker model.

### 5D.7.1.2 Early Development

Data from three laboratory studies were used to estimate the relationship between temperature, egg mortality, and development time (Murray and McPhail 1988; Beacham and Murray 1989; U.S. Fish and Wildlife Service 1999). Using data from these experiments, a relationship was constructed between maturation time and water temperature. First *maturation time* (days) was converted to a *daily maturation rate* (1/day):

(Equation 4) $$\textit{daily maturation rate} = \textit{maturation time}^{-1}$$

A significant linear relationship between maturation rate and water temperature was detected using linear regression. Daily water temperature explained 99% of the variation in *daily maturation rate* ($F$ =2188; df =1,15; $p$<0.001):

(Equation 5) $$\textit{daily maturation rate} = 0.00058*\textit{Temp}-0.018$$

In the IOS model, the daily mean maturation rate of the incubating eggs is predicted from daily water temperatures using a linear function; the predicted mean maturation rate, along with the confidence intervals of the predicted values, is used to define a normal probability distribution, which then is randomly sampled to determine the daily maturation rate. A cohort of eggs accumulates a percentage of total maturation each day from the above equation until 100% maturation is reached.

Data from experimental work (U.S. Fish and Wildlife Service 1999) was used to parameterize the relationship between temperature and mortality of developing winter-run Chinook salmon eggs. Predicted proportional mortality over the entire incubation period was converted to a daily mortality rate to apply these temperature effects in the IOS Model. This conversion was used to calculate daily mortality using the methods described by Bartholow and Heasley (2006:32):

(Equation 6) $$mortality = 1-(1-total\ mortality)^{(1/development\ time)}$$

where *total mortality* is the predicted mortality over the entire incubation period observed for a particular water temperature and *development time* was the time to develop from fertilization to emergence.

Limited sample size in the USFWS study (1999) did not allow a statistically valid test for effects of temperature on mortality (e.g., a general additive model) to be performed. However, the following exponential relationship was fitted between observed *daily mortality* and observed water temperatures (U.S. Fish and Wildlife Service 1999) to provide the required values for the IOS Model:

(Equation 7) $$daily\ mortality = 1.38*10^{-15}e^{(0.503*Temp)}$$

Equation 7 yields the following graphic (Figure 5D.7-2), which indicates that proportional daily egg mortality increases rapidly with only small changes in water temperature. For example, within the predominant water temperature range found in model scenarios (55°F to 60°F), proportional daily mortality increases over ten-fold (~0.001 at 55°F to ~0.018 at 60°F).

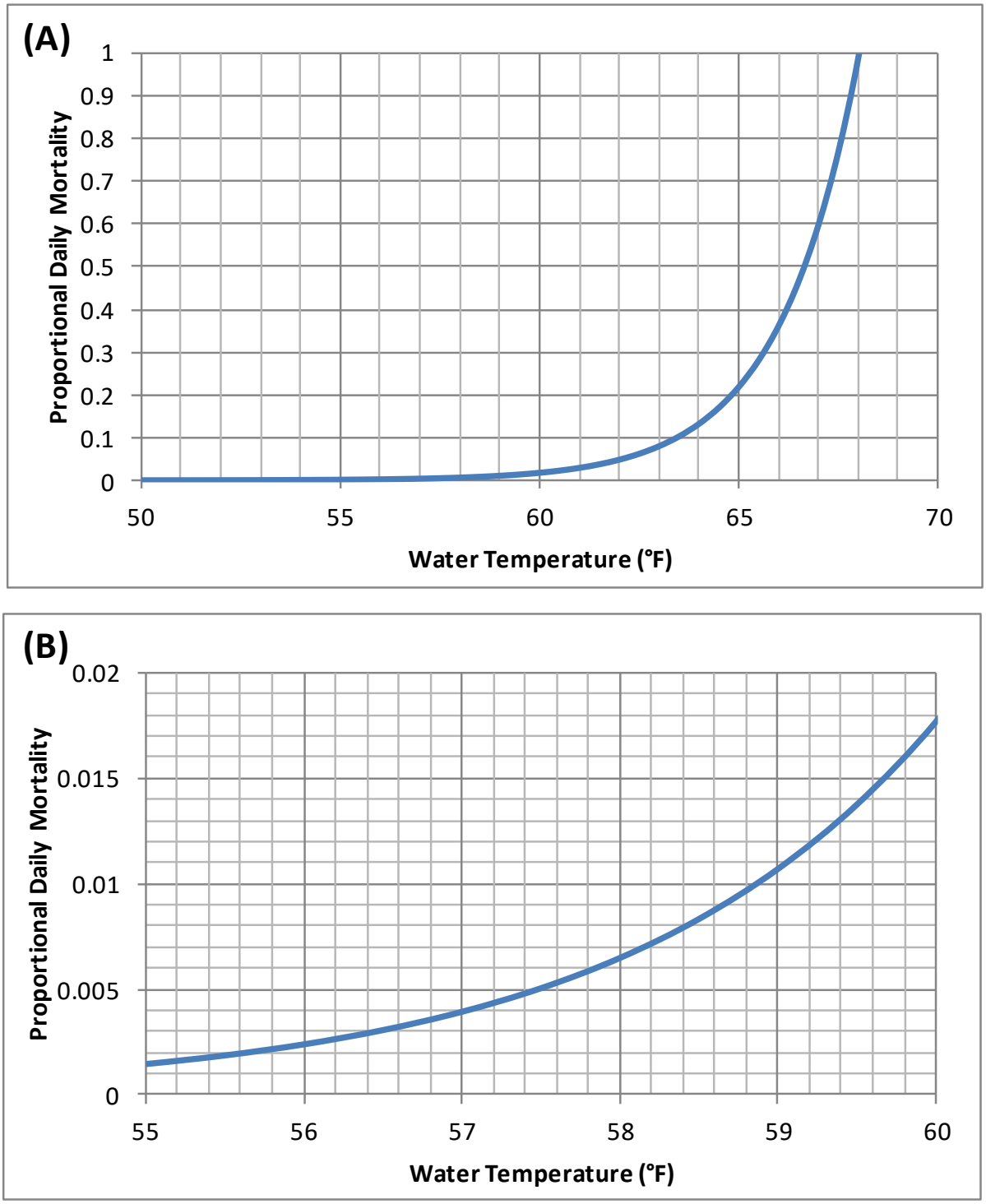



**Figure 5D.7-2. Relationship between Proportional Daily Mortality of Winter-Run Chinook Salmon Eggs and Water Temperature (Equation 7) for (A) the Entire Temperature Range and (B) the Predominant Range Found in Model Scenarios**

In the IOS model, mean daily mortality rates of the incubating eggs are predicted from weighted mean daily water temperature at Keswick Dam and Balls Ferry where temperatures are weighted by a 10-year average distribution of winter run redds between these two locations. The predicted mean mortality rate, along with the confidence intervals of the predicted values, is used to define a normal probability distribution, which then is randomly sampled to determine the daily egg mortality rate.

### 5D.7.1.3 Fry Rearing

Data from USFWS (1999) was used to model fry mortality during rearing as a function of water temperature. Again, because of a limited sample size from the study by USFWS, statistical analyses to test for the effects of water temperature on rearing mortality could not be run. However, to acquire predicted values for the model, the following exponential relationship was fitted between observed daily mortality and observed water temperatures (U.S. Fish and Wildlife Service 1999):

(Equation 8) *daily mortality = 3.92*10-12e (0.349*Temp)*

Equation 8 yields the following graphic (Figure 5D.7-3), which indicates that proportional daily fry mortality increases rapidly with only small changes in water temperature. For example, within the predominant water temperature range found in model scenarios (55°F to 60°F), proportional daily mortality increases over five-fold (~0.001 at 55°F to ~0.005 at 60°F). This indicates that, although fry mortality is highly sensitive to changes in water temperature, this sensitivity is not as great as that of egg mortality within the predominant range observed in the model scenarios in focus.

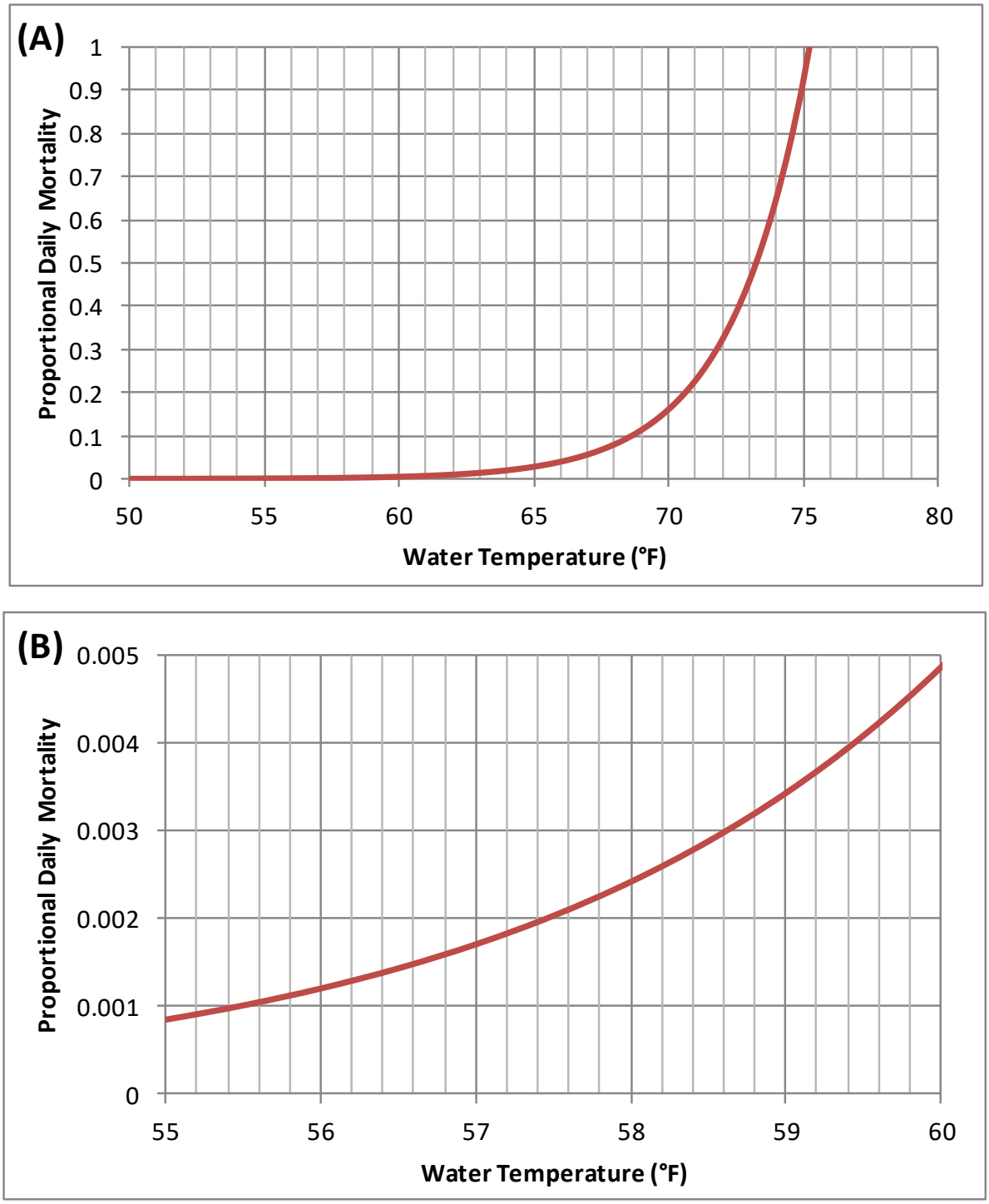



**Figure 5D.7-3. Relationship between Proportional Daily Mortality of Winter-Run Chinook Salmon Fry and Water Temperature (Equation 8) for (A) the Entire Temperature Range and (B) the Predominant Range Found in Model Scenarios**

Each day the mean proportional mortality of the rearing fish is predicted from the daily water temperature using the above exponential relationship; the predicted mean mortality, along with the confidence intervals of the predicted values, is used to define a normal probability distribution, which then is randomly sampled to determine the daily mortality of the rearing fish. Temperature mortality is applied to rearing fry for 60 days, which is the approximate time required for fry to transition into smolts (U.S. Fish and Wildlife Service 1999) and enter the *River Migration* stage. All fish migrating through the Delta are assumed to be smolts.

#### 5D.7.1.4 River Migration

Survival of smolts between Red Bluff Diversion Dam and Fremont Weir is estimated as a function of flow at Bend Bridge (Figure 5D.7-4). The flow-survival relationship in this reach was modeled using 7 years of releases of winter-run smolts from Livingston Stone hatchery that were implanted with JSATS transmitters (total of 2,912 tagged fish detected at Red Bluff). Mortality in this stage is applied on the day fish pass Red Bluff with the specific value estimated based on flow at Bend Bridge. Smolts are delayed from entering the next model stage to account for travel time. Mean travel time (20 days) is used along with the standard error (3.6 days) to define a normal probability distribution, which is randomly sampled to provide estimates of the total travel time of migrating smolts.

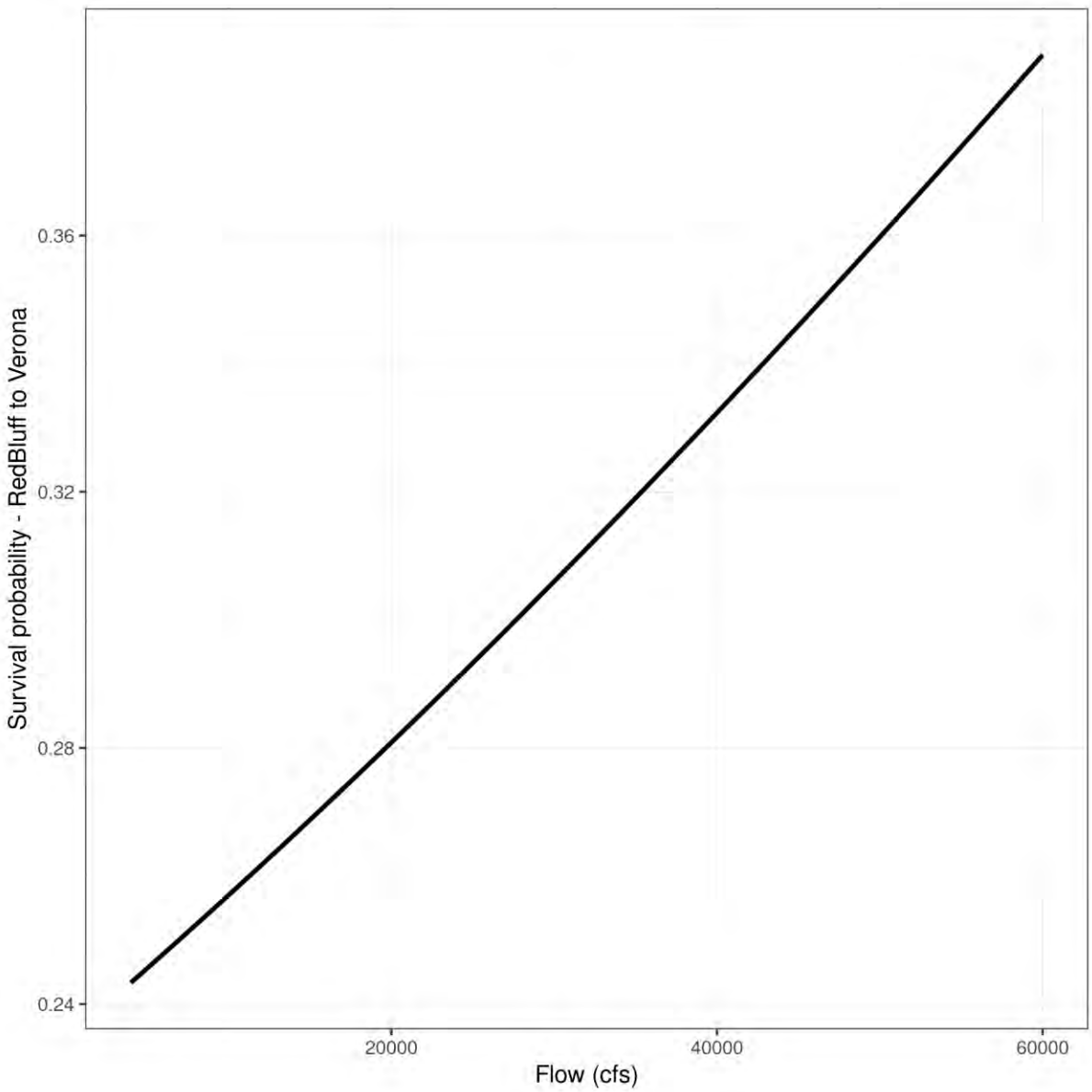
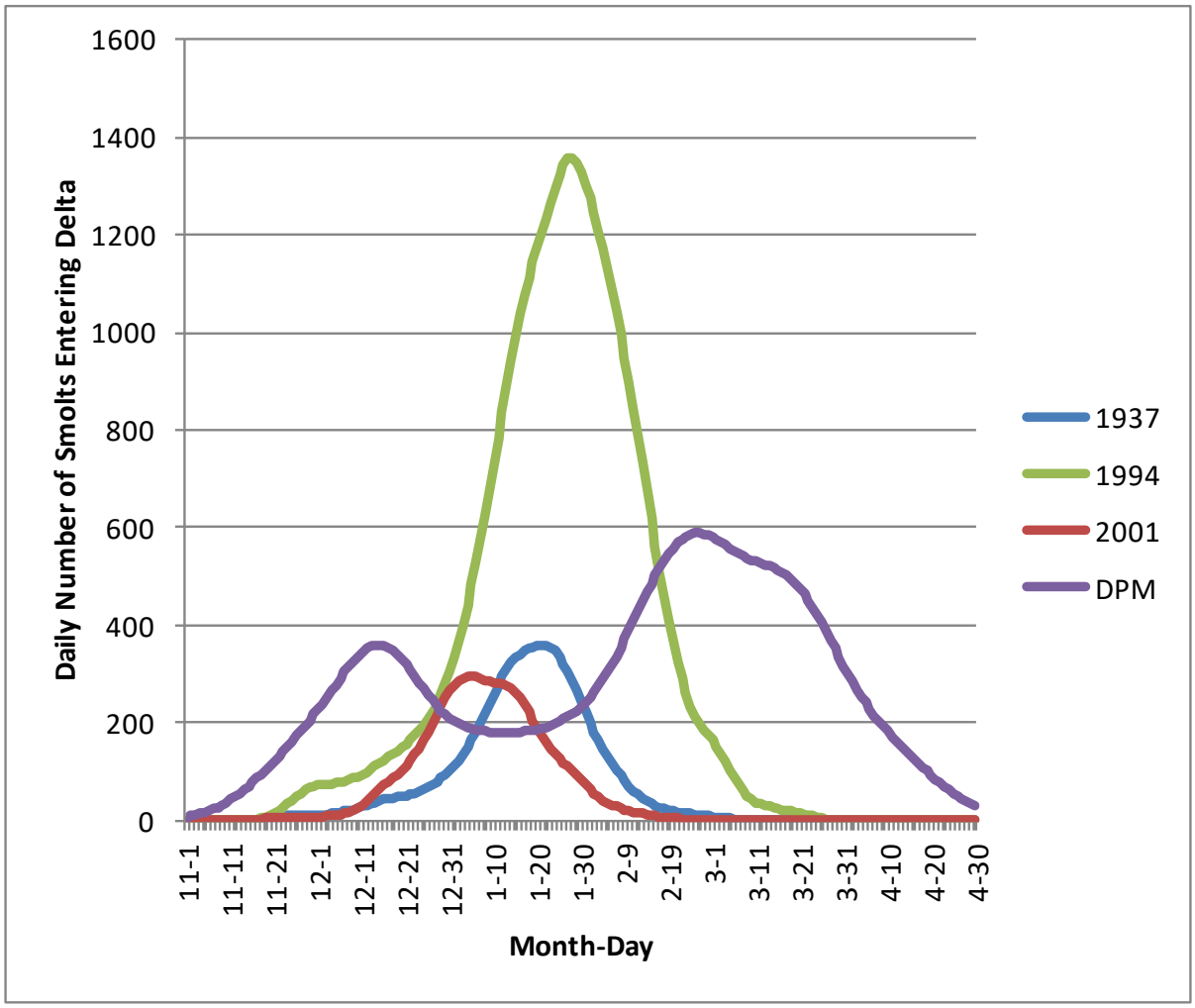



**Figure 5D.7-4. Relationship between Flow at Bend Bridge and the Probability of Winter-Run Smolt Survival between Red Bluff and the First Delta Passage Reach at Verona; This Relationship Includes Smolts that Entered the Yolo Bypass and Those that Remained in the Sacramento River**

### 5D.7.1.5 Delta Passage

Winter-run Chinook salmon passage through the Delta within IOS is modeled with the DPM, which is described fully in Section 5D.5, *Delta Passage Model*. Note that there is one difference between the implementation of the DPM in IOS and the standalone DPM. The timing of winter-run entry into the Delta is a function of upstream fry/egg rearing and river migration so timing changes annually, in contrast to the fixed nature of Delta entry for the standalone DPM. Also, the IOS entry distribution is a unimodal term that tends to peak between the bimodal peaks of the standalone DPM entry distribution (Figure 5D.7-5). As each cohort of smolts exits the final reaches of the Delta (Sac4 and the interior Delta), the cohorts accumulate until all cohorts from that year have exited the Delta.

After all cohorts have arrived, they all enter the *Ocean Survival* model as a single cohort and the model begins applying mortality on an annual timestep.




DPM: purple line, fixed bimodal distribution.
IOS in 1937: blue line, an average peak of January 21.
IOS in 1994: green line, a late peak of January 28.IOS in 2001: red line, an early peak of January 4.
IOS data are from scenario ALT9_LLT of the Bay Delta Conservation Plan EIR/EIS.

**Figure 5D.7-5. Winter-Run Chinook Salmon Smolt Delta Entry Distributions Assumed under the Delta Passage Model Compared with Entry Distributions for IOS in 1937, 1994, and 2001**

### 5D.7.1.6 Ocean Survival

As described by Zeug et al. (2012:461), this model stage uses a set of equations for smolt-to-age-2 mortality, winter mortality, ocean harvest, and spawning returns to predict yearly survival and escapement numbers (i.e., individuals exiting the ocean to spawn). Certain values during the ocean survival life stage were fixed constant among model scenarios. Ocean survival model-stage elements are listed in Table 5D.7-1 and discussed below.

**Table 5D.7-1. Functions and Environmental Variables Used in the Ocean Survival Stage of the IOS Model**

| Model Element | Environmental Variable | Value |
|---|---|---|
| Smolt-age 2 mortality | None | Uniform random variable between 94% and 98% |
| Age 2 ocean survival | Wells' Index of Ocean productivity | Equation 13 |
| Age 3 ocean survival | None | Equation 14 |
| Age 4 ocean survival | None | Equation 15 |
| Age 3 harvest | None | Fixed at 17.5% |
| Age 4 harvest | None | Fixed at 45% |

Relying on ocean harvest, mortality, and returning spawner data from Grover et al. (2004:19–29), a uniformly distributed random variable between 94% and 98% mortality was applied for winter-run Chinook salmon from ocean entry to age 2 and functional relationships were developed to predict ocean survival and returning spawners for age 2 (8%), age 3 (88%), and age 4 (4%), assuming that 100% of individuals that survive to age 4 return for spawning. In the IOS model, ocean survival to age 2 is given by:

(Equation 13) $$A_2 = A_i(1-M_2)(1-M_w)(1-H_2)(1-S_{r2})*W$$

Survival to age 3 is given by:

(Equation 14) $$A_3 = A_2(1-M_w)(1-H3)(1-S_{r3})$$

And survival to age 4 is given by:

(Equation 15) $$A_4 = A_3(1-M_w)(1-H_4)$$

where $A_i$ is initial abundance at ocean entry (from the DPM stage), $A_{2,3,4}$ are abundances at ages 2–4, $H_{2,3,4}$ are harvest percentages at ages 3–4 represented by uniform distributions bounded by historical harvest levels, $M_2$ is smolt-to-age-2 mortality, $M_w$ is winter mortality for ages 2–4, and $S_{r2,r3}$ are returning spawner percentages at age 2 and age 3.

Harvest mortality is represented by a uniform distribution that is bounded by historical levels of harvest. Age 2 survival is multiplied by a scalar $W$ that corresponds to the value of Wells Index of ocean productivity. This metric was shown to significantly influence over-winter survival of age 2 fish (Wells et al. 2007). The value of Wells Index is a normally distributed random variable that is resampled each year of the simulation. In the analysis, the following values from Grover et al. (2004) were used: $H_2$ = 0%, $H_3$ = 0-39%, $H_4$ = 0-74%, $M_2$ = 94-98%, $M_w$ = 20%, $S_{r2}$ = 8%, and $S_{r3}$ = 96%.

Adult fish designated for return to the spawning grounds are assumed to be 65% female and are assigned a pre-spawn mortality of 5% to determine the final number of female returning spawners (Snider et al. 2001:Appendix Table 6).

# 5D.7.2 Methods

## 5D.7.2.1 Timestep

The IOS Model operates on a daily timestep, advancing the age of each cohort/life stage and thus tracking their numerical fate throughout the different stages of the life cycle. Some variables (e.g., annual mortality estimates) are randomly sampled from a distribution of values and are applied once per year; 500 iterations of the model were run for each scenario to generate 500 sets of outputs, each reflecting different random sampling from distributions of the different variables and model functions in the model (see also the description of Delta Passage Model above). Although a daily timestep is implemented for the Delta Passage component of IOS, flow inputs that rely on CalSim outputs are based on monthly modeling and are assumed to be constant within a particular month. In addition, for the ocean phase of the life cycle, the model operates on an annual timestep by applying annual survival estimates to each ocean cohort.

## 5D.7.2.2 Model Inputs

Delta flows and export flow into SWP and CVP pumping plants were modeled using monthly flow output from CalSim 3 or daily flows from DSM2 (see Table 5D.5-2 in Section 5D.5.1.4), with the monthly average flow in a particular month being applied to all days within that month, as described above. A separate set of flow inputs was developed for the proposed action, based on the CalSim 3 flow predictions for the entire modeled period. Flows into the Yolo Bypass over Fremont Weir were based on disaggregated monthly CalSim 3 data based on historical patterns of variability. Temperature data for the Sacramento River was obtained from the Sacramento River Water Quality Model (SRWQM) developed by the Bureau of Reclamation. The nodes in the CalSim and SRWQM models that were used to provide flow and temperature data for specific reaches in the Sacramento River and Delta are shown in Table 5D.7-2.

**Table 5D.7-2. IOS Reaches and Associated Channels from CalSim and SRWQM Models**

| IOS Reach | CalSim Channel | SRWQM |
|---|---|---|
| Spawning-Rearing Reach | – | Weighted average of Keswick and Balls Ferry temperatures based on spawning distribution |
| River Migration | Bend Bridge | |
| Delta | See Table 5D.5-2 | – |

## 5D.7.2.3 Model Outputs

Four model outputs are used to determine differences among model scenarios.

1. Egg survival: The Sacramento River between Keswick Dam and the Red Bluff Diversion Dam provides egg incubation habitat for winter-run Chinook salmon. Water temperature has a large effect on the survival of Chinook salmon during the egg incubation period by controlling mortality as well as development rate. Temperatures in this reach are partially controlled by releases of cold water from Shasta Reservoir and ambient weather conditions.
2. Fry survival: The Sacramento River between Keswick Dam and Red Bluff Diversion Dam provides rearing habitat for juvenile winter-run Chinook salmon. Water temperature can have a large effect on the survival of Chinook salmon during the fry rearing stage by controlling

mortality and development rate. Temperatures in this reach are partially controlled by releases of cold water from Shasta Reservoir and ambient weather conditions.

3. River migration survival: The Sacramento River between Red Bluff Diversion Dam and Fremont Weir is a migration route for juvenile winter-run Chinook salmon. Flow magnitude at the Bend Bridge station influences survival and travel time in this reach. Flows at Bend Bridge are partially controlled by releases from Shasta and Keswick Reservoirs.
4. Through-Delta survival: The Delta between the Fremont Weir on the Sacramento River and Chipps Island is a migration route for juvenile winter-run Chinook salmon. Flow magnitude in different reaches of the Delta influences survival and travel time and entrainment into alternative migration routes with different survival probabilities.
5. Escapement: Each year of the IOS Model simulation, escapement is calculated as the combined number of 2-, 3-, and 4-year-old fish that leave the ocean and migrate back into the Sacramento River to spawn between Keswick Dam and the Red Bluff Diversion Dam. These numbers are influenced by the combination of all previous life stages and the functional relationships between environmental variables and survival rates.

#### 5D.7.2.4 Model Limitations and Assumptions

The following model limitations and assumptions should be recognized when interpreting results.

1. Other important ecological relationships likely exist but quantitative relationships are not available for integration into IOS (e.g., the interaction among flow, turbidity, and predation). To the extent that these unrepresented relationships are important and alter IOS outcomes, each alternative (including the proposed action) considered is assumed to be affected in the same way.
2. For relationships that are represented in IOS, operational alternatives considered are not assumed to alter those underlying functional relationships.
3. There is a specific range of environmental conditions (temperature, flow, exports, and ocean productivity) under which functional relationships were derived. These functional relationships are assumed to hold true for the environmental conditions in the scenarios considered.
4. Differential growth because of different environmental conditions (e.g., river temperature) and subsequent potential differences in survival and other factors are not directly included in the model. Differences in survival related to growth are indirectly included to an unknown extent in flow-survival, temperature-survival, and ocean productivity-survival relationships.
5. Juvenile winter-run Chinook salmon migrating through the Delta all are assumed to be smolts that are not rearing in the Delta.

#### 5D.7.2.5 Model Sensitivity and Influence of Environmental Variables

Zeug et al. (2012) examined the sensitivity of the previous IOS model estimates of escapement to its input parameter values, input parameters being the functional relationships between environmental inputs and biological outputs. Although revisions have been undertaken to IOS since that time, particularly the river survival function, the main points from their analysis are still likely to be valid.

Zeug et al. (2012) found that escapement of different age classes was sensitive to different input parameters (Table 5D.7-3). Escapement of age-2 fish (which compose 8% of the total returning fish in a given cohort) was most sensitive to smolt-to-age-2-survival and water year when considering either independent or interactive effects of these parameters, and there was also sensitivity to river migration survival when considering interactive effects of this parameter with other parameters. Escapement of age-3 fish (which compose 88% of the total returning fish in a given cohort) was sensitive to several input parameters when considering the independent effects of these parameters but was sensitive to through-Delta survival alone when considering first-order interactions between parameters. Escapement of age-4 fish (which compose 4% of the total returning fish in a given cohort) was sensitive to nearly all input parameters when considering the independent effects of these parameters but was not sensitive to any of the parameters when considering first-order interactions between parameters (Zeug et al. 2012).

Zeug et al. (2012) also explored how uncertainty in model parameter estimates influences model output by increasing by 10% to 50% the variation around the mean of selected parameters that could be addressed by management actions (egg survival, fry-to-smolt survival, river migration survival, Delta survival, age-3 harvest, and age-4 harvest). They found that model output was robust to parameter uncertainty and that age-3 and age-4 harvest had the greatest coefficients of variation as a result of the uniform distribution of these parameters. Zeug et al. (2012) noted that there are limitations in the data used to inform certain parameters in the model that may be ecologically relevant but that are not sensitive in the current IOS configuration: river survival is a good example because it is based on a three-year field study of relatively low-flow conditions that does not cover the range of potential conditions that may be experienced by downstream-migrating juvenile Chinook salmon.

To understand the influence of environmental parameter inputs on escapement estimates from IOS, Zeug et al. (2012) performed three sets of simulations of a baseline condition and either a 10% increase or a 10% decrease in river flow, exports, water temperature (on the Sacramento River at Bend Bridge; see above), and ocean productivity (i.e., Wells Index; see Section 5D.7.1.6, *Ocean Survival*). They found that only 10% changes in temperature produced a statistically significant change in escapement; a 10% increase in temperature produced a far greater reduction in escapement (>95%) than a 10% decrease in temperature gave an increase in escapement (>10%). Zeug et al. (2012) suggested that the lack of significant changes in escapement with 10% changes of flow, exports, and ocean productivity may reflect the fact that these variables' relationships within the model were based on observational studies with large error estimates associated with the responses. In contrast, temperature functions were parameterized with data from controlled experiments with small error estimates. Also, Zeug et al. (2012) noted that water temperatures within the winter-run Chinook salmon spawning and rearing area are close to the upper tolerance limit for the species; therefore, even small changes have the potential to significantly affect the population.

**Table 5D.7-3. Sobol's Sensitivity Indices (Standard Deviation in Parentheses) for Each Age Class of Returning Spawners Based on 1,000 Monte Carlo Iterations, Conducted to Test Sensitivity of IOS Input Parameters by Zeug et al. (2012)**

| Input Parameter | Age 2 | | Age 3 | | Age 4 | |
|---|---|---|---|---|---|---|
| | Main Index (Effect Independent of Other Input Parameters) | Total Index (Effect Accounting for First-Order Interactions with Other Input Parameters) | Main Index (Effect Independent of Other Input Parameters) | Total Index (Effect Accounting for First-Order Interactions with Other Input Parameters) | Main Index (Effect Independent of Other Input Parameters) | Total Index (Effect Accounting for First-Order Interactions with Other Input Parameters) |
| Water year | 0.300 [a] (0.083) | 0.306 [a] (0.079) | 0.181 [a] (0.091) | 0.150 (0.091) | 0.073 (0.067) | 0.012 (0.065) |
| Egg survival | 0.030 (0.016) | -0.006 (0.016) | 0.222 [a] (0.081) | -0.021 (0.081) | 0.102 [a] (0.044) | -0.072 (0.044) |
| Fry-to-smolt survival | 0.039 (0.020) | -0.009 (0.020) | 0.166 (0.090) | 0.091 (0.092) | 0.079 [a] (0.017) | -0.071 (0.017) |
| River migration survival | 0.007 (0.034) | 0.135 [a] (0.034) | 0.164 (0.084) | 0.062 (0.085) | 0.079 (0.018) | -0.07 (0.018) |
| Delta survival | 0.010 [a] (0.002) | -0.009 (0.002) | 0.404 [a] (0.180) | 0.643 [a] (0.177) | 0.313 [a] (0.134) | -0.009 (0.132) |
| Smolt to age 2 survival | 0.734 [a] (0.118) | 0.454 [a] (0.113) | 0.015 (0.016) | -0.006 (0.016) | 0.057 [a] (0.017) | -0.052 (0.017) |
| Ocean productivity | 0.003 (0.009) | 0.009 (0.009) | 0.034 [a] (0.015) | -0.034 (0.015) | 0.061[a] (0.030) | -0.048 (0.029) |
| Age 3 harvest | N/A | N/A | 0.029 [a] (0.001) | -0.028 (0.001) | 1.48 [a] (0.306) | 0.188 (0.293) |
| Age 4 harvest | N/A | N/A | N/A | N/A | 0.055 [a] (0.003) | -0.054 (0.003) |

Source: Zeug et al. 2012.
[a] Index value was statistically significant at α=0.05.

## 5D.7.3 Results

Tabular summaries of IOS results are presented and discussed in Appendix 5C and Appendix 6C; graphical summaries are provided below in box plots and time series plots (Figure 5D.7-6 through Figure 5D.7-15).

Note: Alt_5 corresponds to the proposed action.

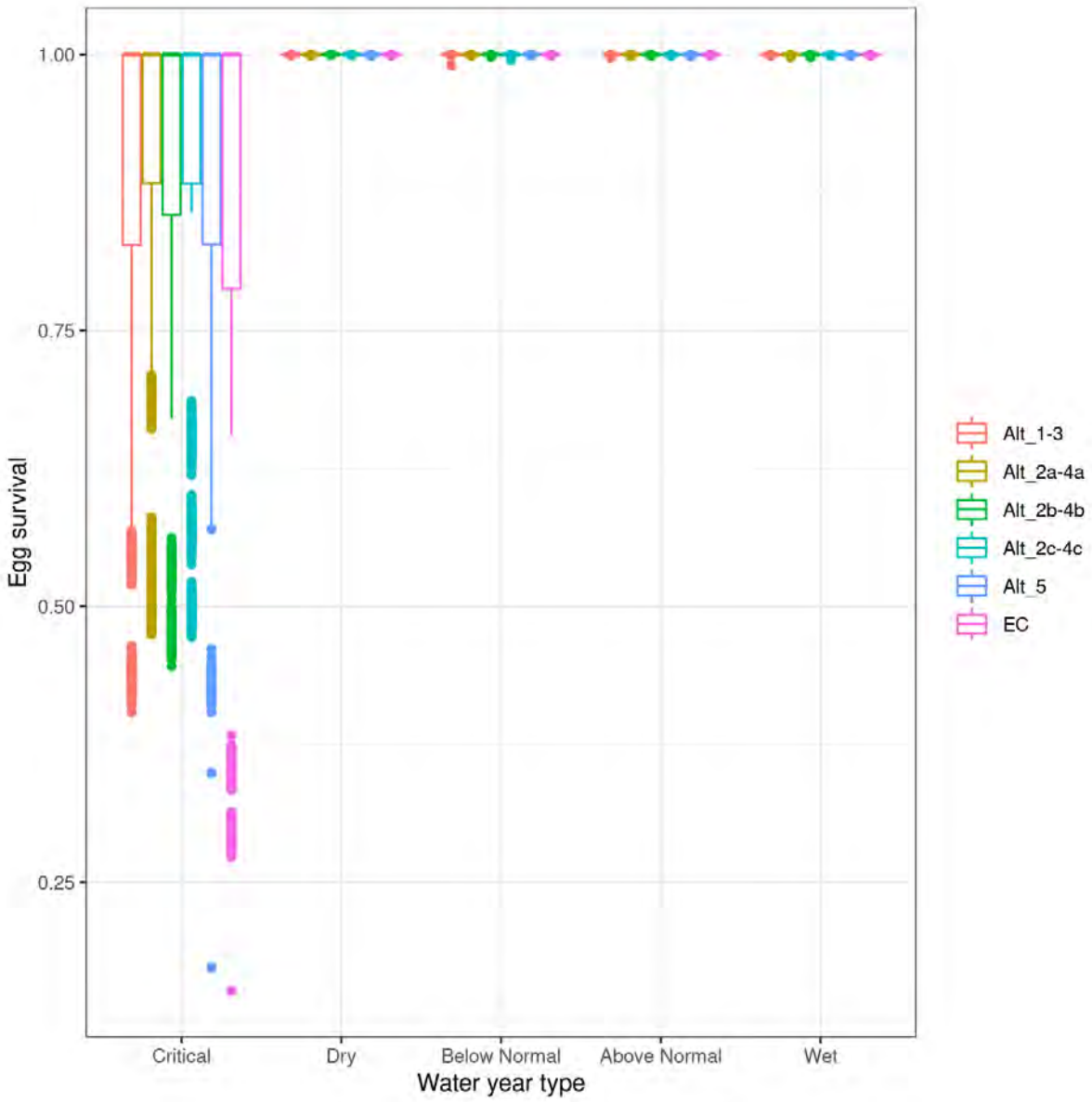



**Figure 5D.7-6. Box Plot of IOS Egg Survival Results**

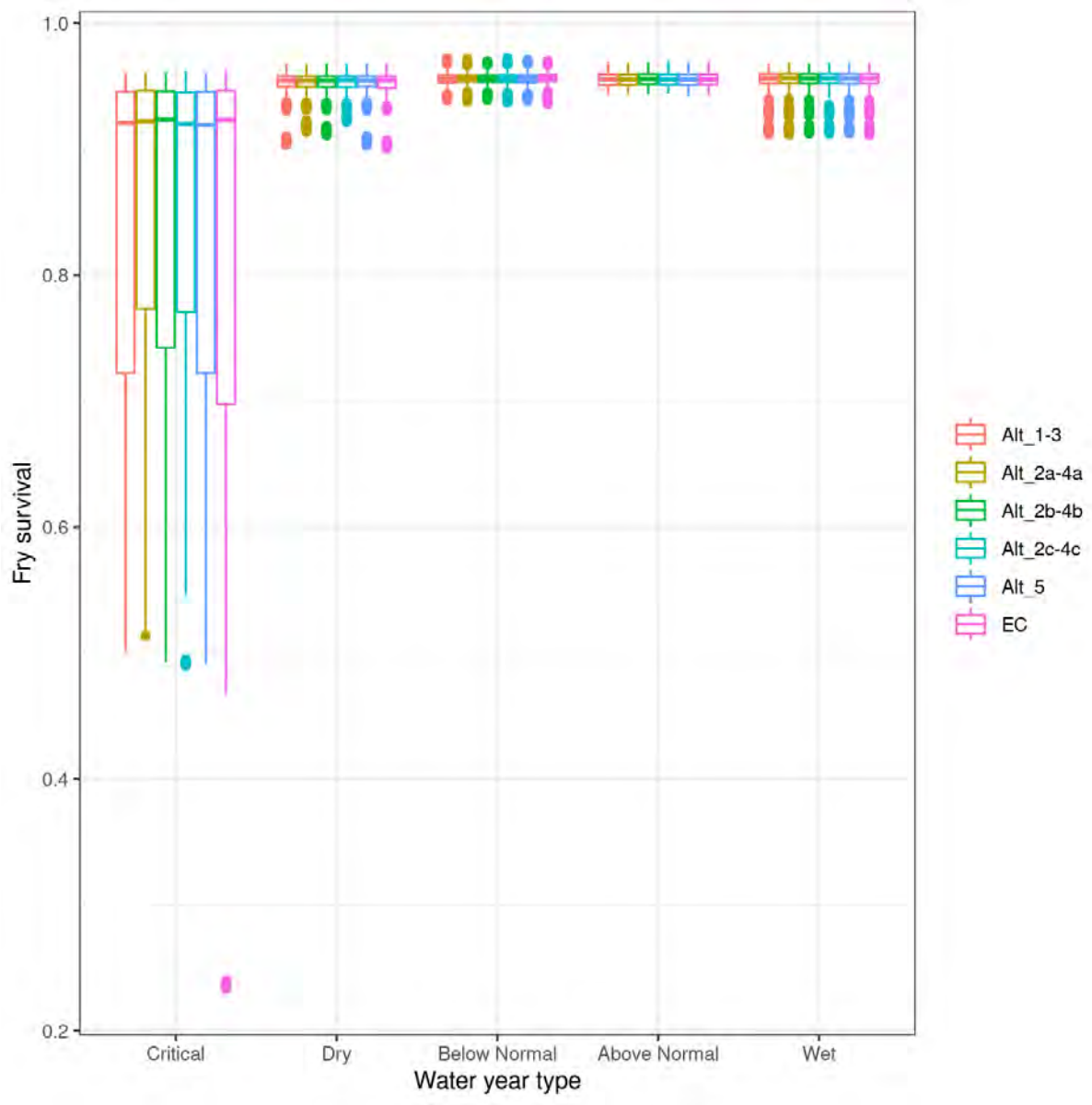



**Figure 5D.7-7. Box Plot of IOS Fry Survival Results**

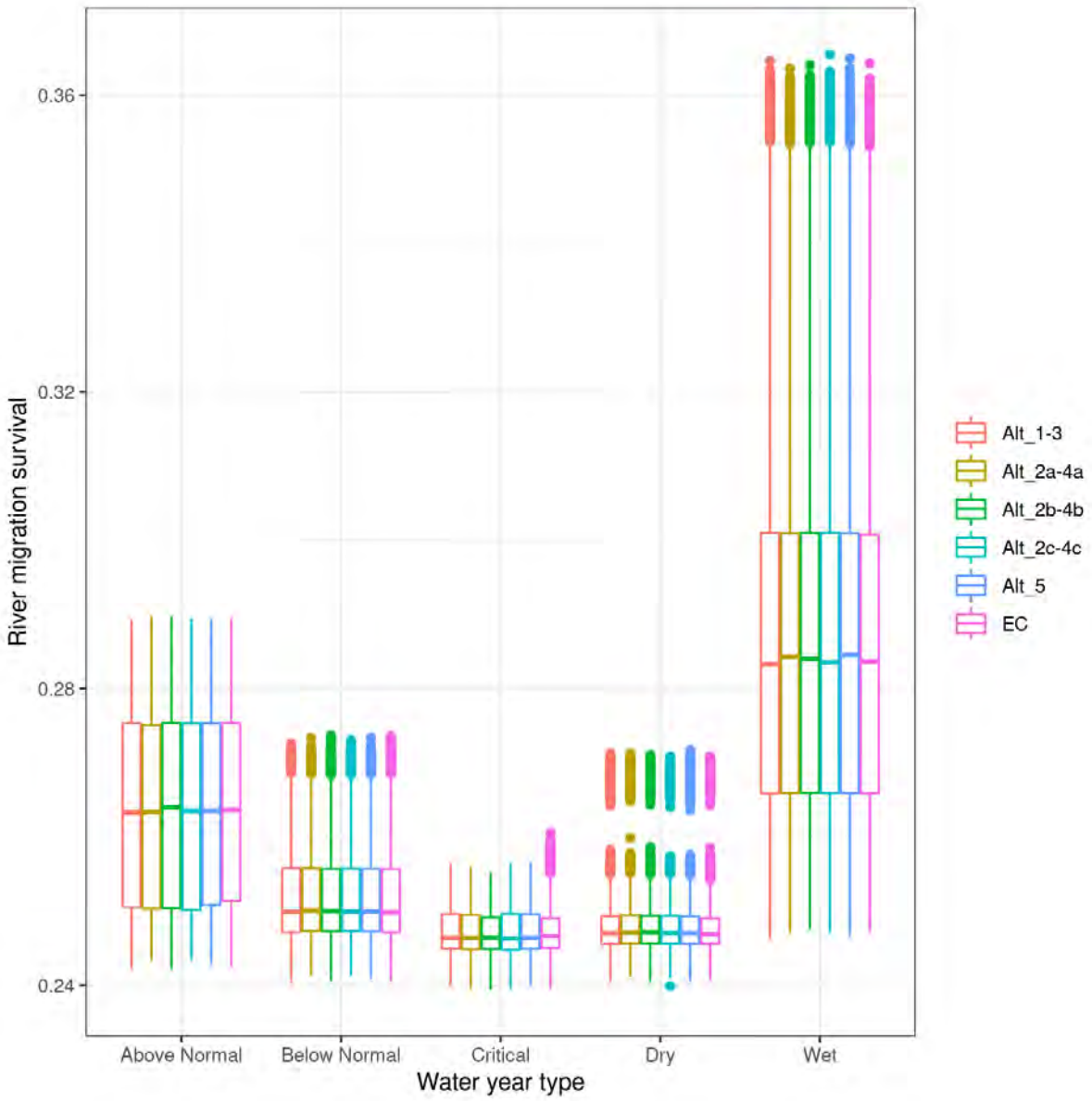



**Figure 5D.7-8. Box Plot of IOS Riverine Juvenile Migration Survival Results**

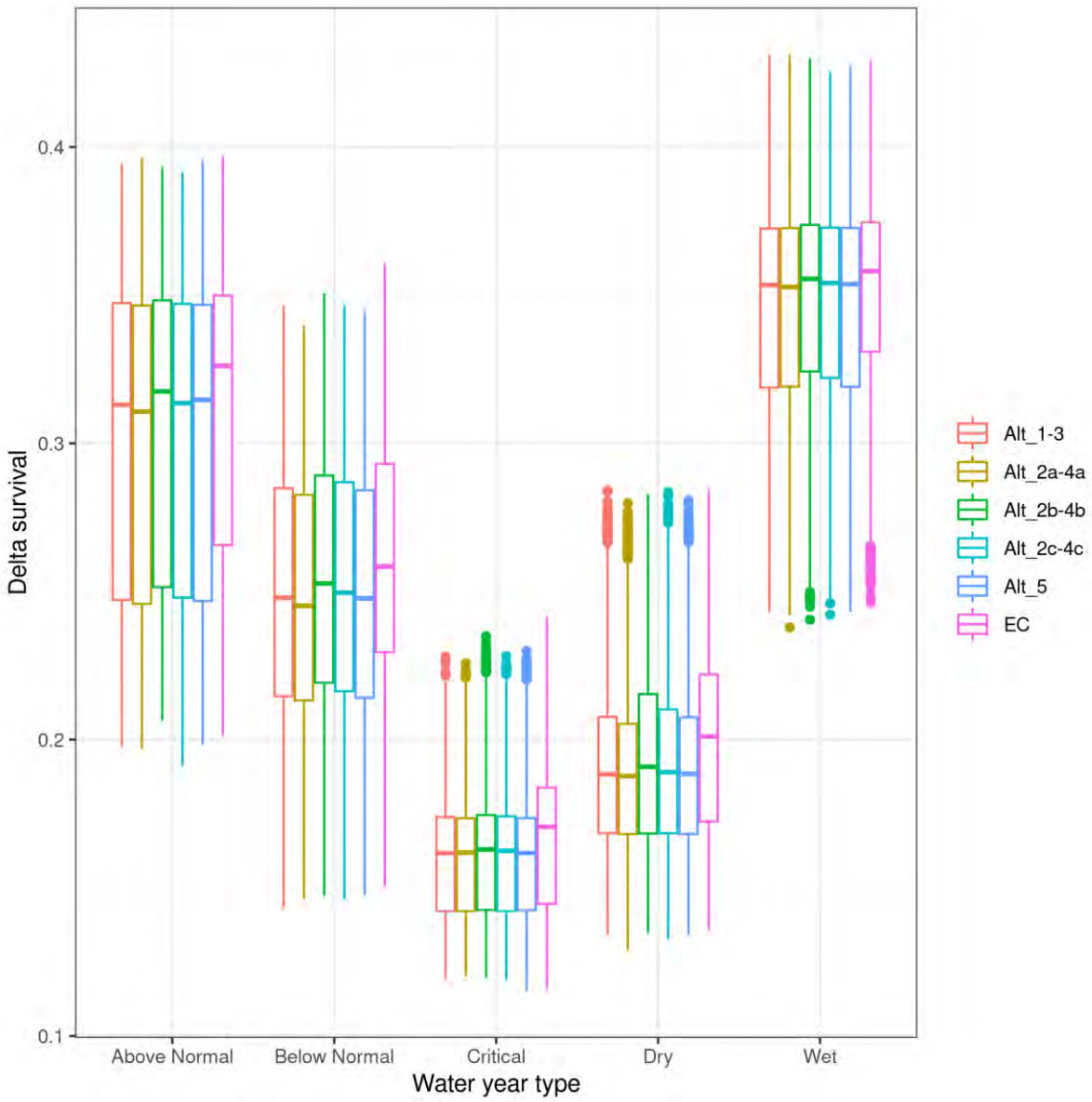



**Figure 5D.7-9. Box Plot of IOS Through-Delta Juvenile Migration Survival Results**

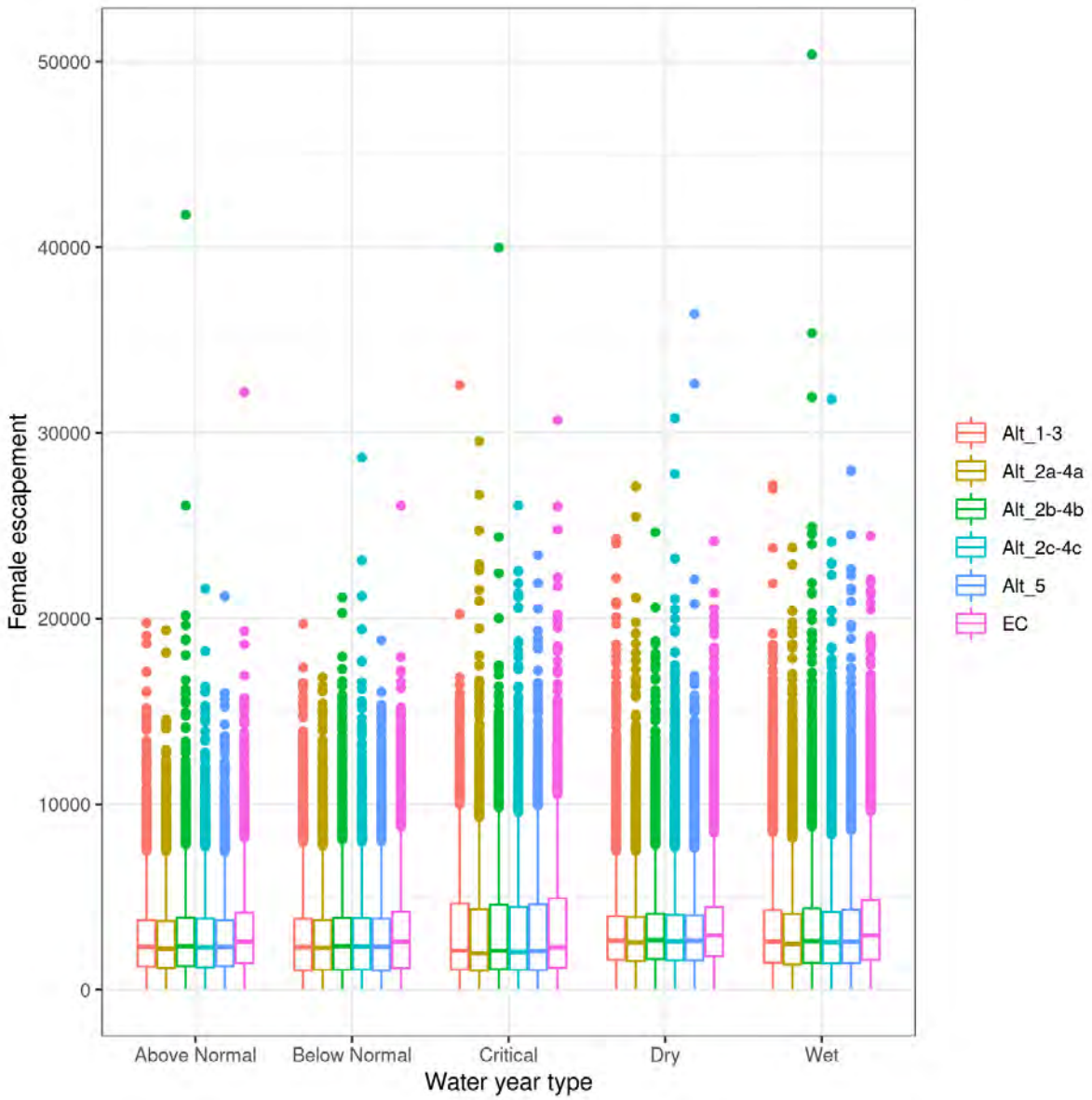



**Figure 5D.7-10. Box Plot of IOS Female Escapement Results**

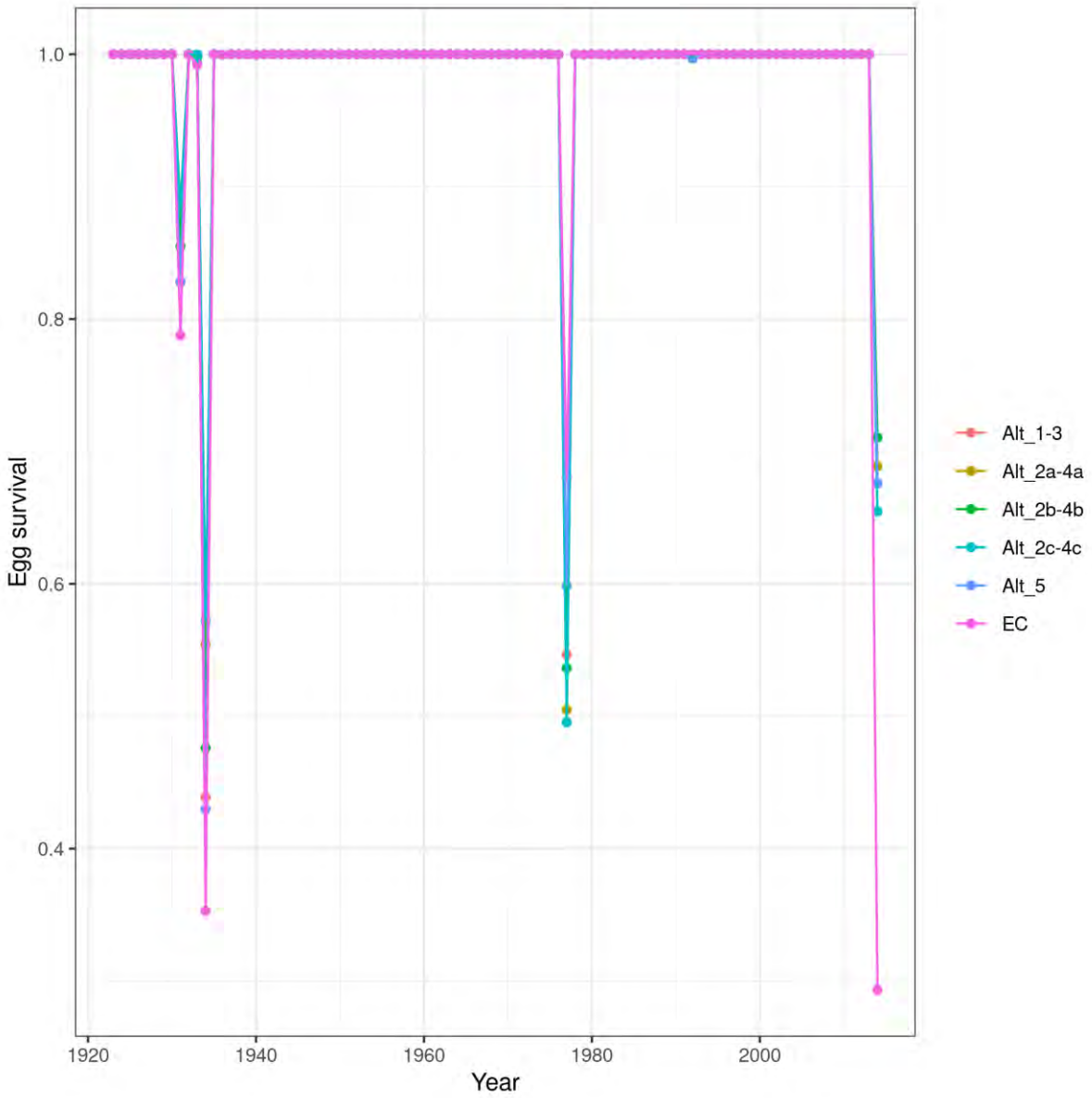



**Figure 5D.7-11. Time Series of IOS Egg Survival Results**

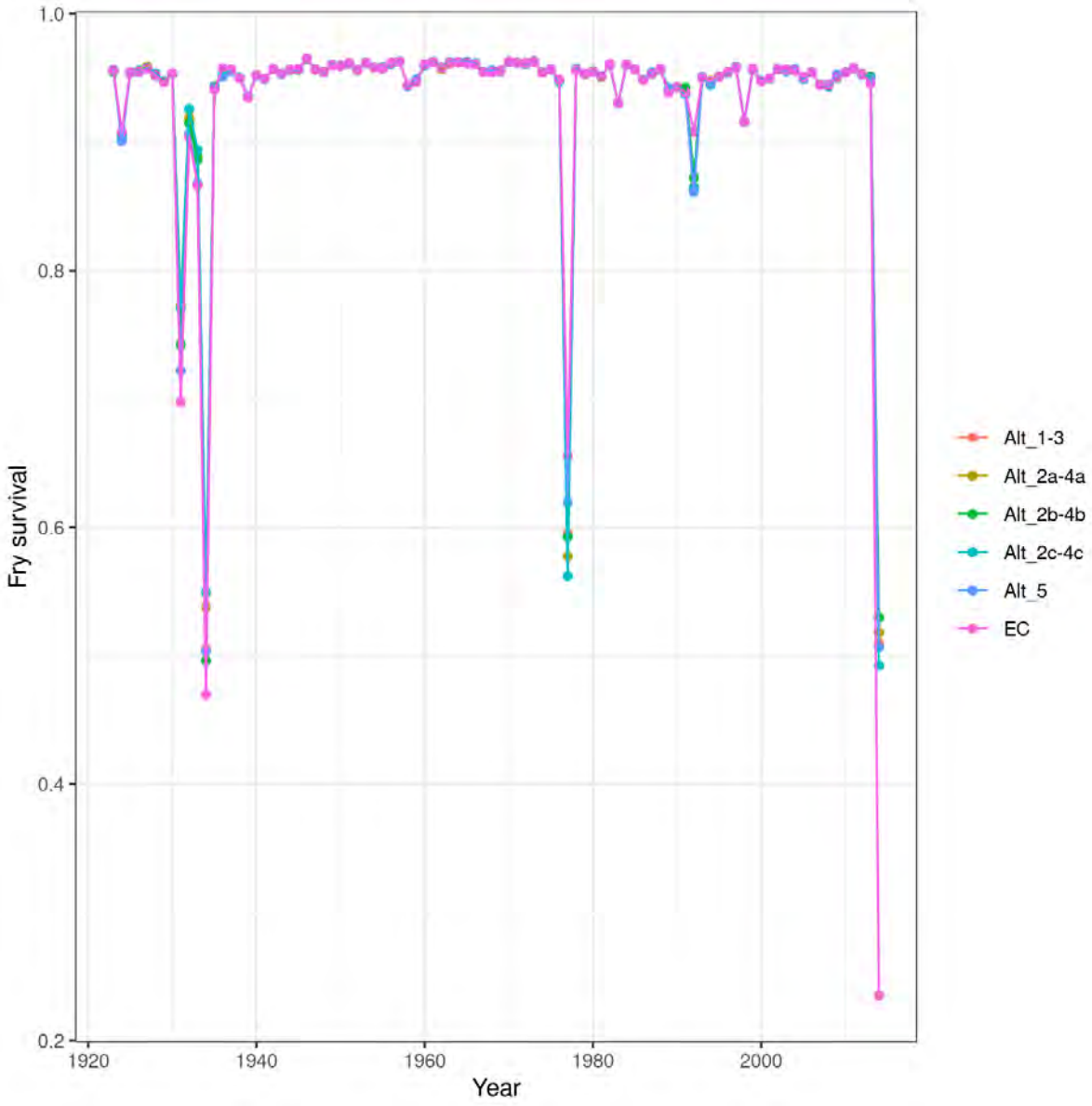



**Figure 5D.7-12. Time Series of IOS Fry Survival Results**

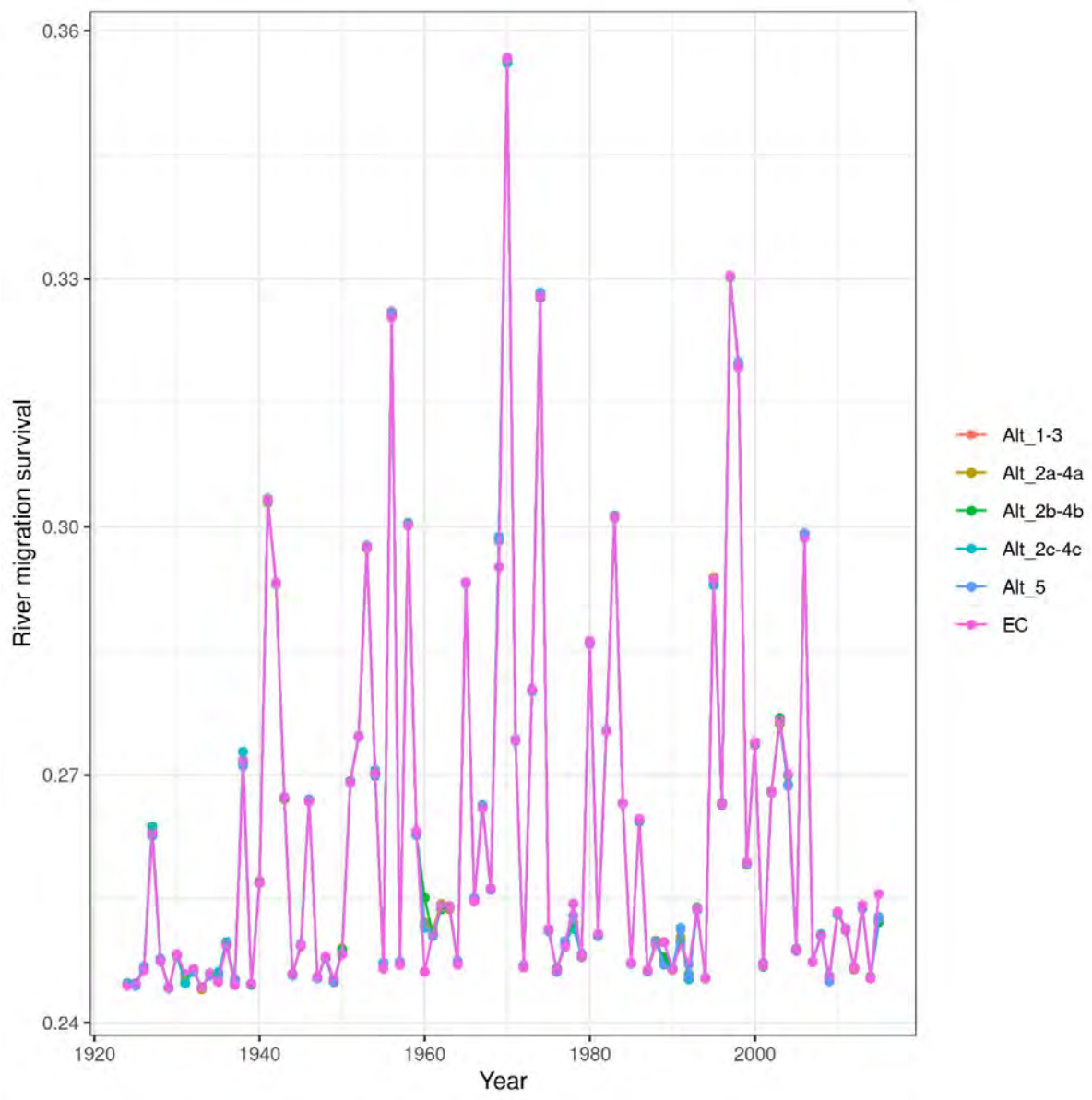



**Figure 5D.7-13. Time Series of IOS Riverine Juvenile Migration Survival Results**

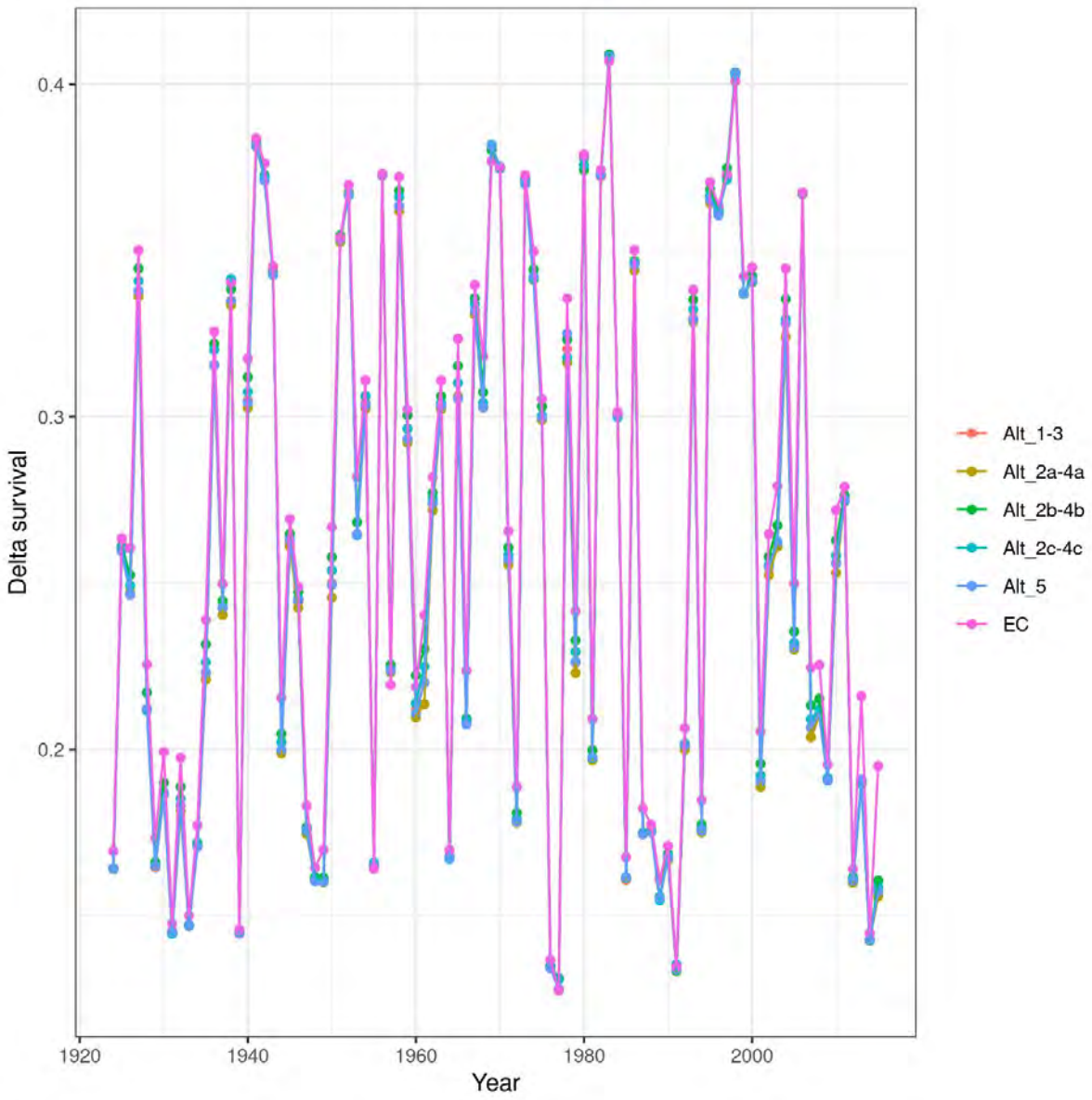



**Figure 5D.7-14. Time Series of IOS Through-Delta Juvenile Migration Survival Results**

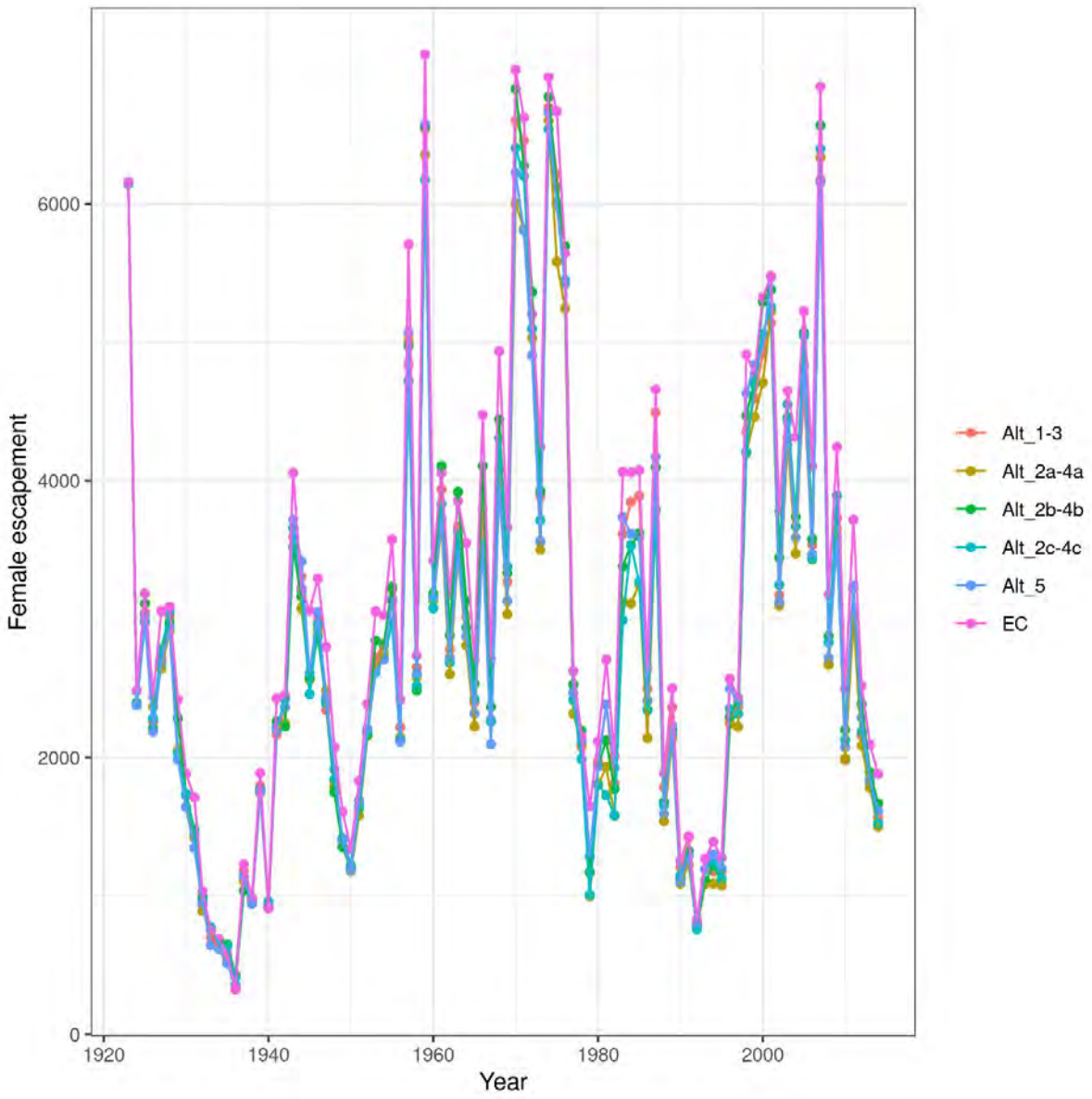



**Figure 5D.7-15. Time Series of IOS Female Escapement Results**

# 5D.8 Oncorhynchus Bayesian Analysis

Attachment 5D.2, *esults of OBAN Analysis of Delta Conveyance Project Alternatives 2020*, describes the methods and results from the Oncorhynchus Bayesian Analysis winter-run Chinook salmon life cycle model. Additional discussion of the results is provided in Chapter 5.

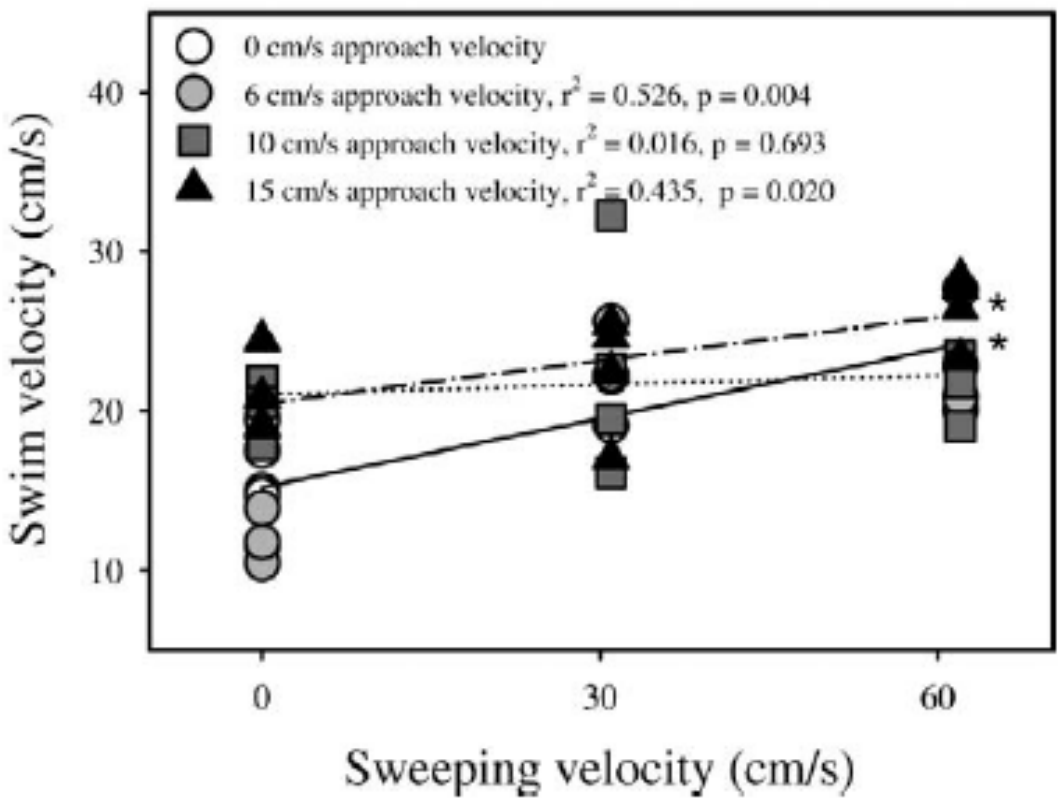
# 5D.9 Delta Smelt Upstream Migration Past North Delta Diversions

When it rains during the winter, the delta smelt population expands its distribution in response to the increase in turbid fresh water (Sommer et al. 2011; Murphy and Hamilton 2013). This expansion is probably facilitated by numerous behaviors, but tidal surfing (changes in how the fish use channels when tides change) is one set of behavioral mechanisms that delta smelt can use to either stay in a desired location or to move rapidly (Feyrer et al. 2013; Bennett and Burau 2015). An analysis employing particle tracking modeling (PTM) using a simple tide surfing behavior originally described by Culberson et al. (2004) to evaluate the likelihood that adult delta smelt could tide surf to the proposed locations of the NDDs indicated that there was no measurable probability that tide surfing fish could ascend the Sacramento River to Isleton, much less even farther upstream to the reach of river where the NDDs would be constructed (ICF International 2016:6-75). This makes intuitive sense for two reasons. First, the tidal energy extending up into Cache Slough is much greater than the tidal energy extending into the comparatively narrow mainstem Sacramento River channel. Second, both flood and ebb tide flows are usually moving downstream in the Sacramento River where the proposed NDDs would be built. Once the tides stop flowing in two directions, the standard tide surfing mechanisms would no longer work to move fish upstream. However, a few adult delta smelt do ascend the Sacramento River (Merz et al. 2011), in one robustly documented instance, even reaching Knight's Landing, which is well beyond the reach of tidal influence (Vincik and Julienne 2012). The most parsimonious explanation for how delta smelt can accomplish this against strong water velocities is to do something they do less frequently further downstream—move toward the shoreline where water velocities are slower.

Once constructed, each of the NDDs will consist of a row cylindrical tee-screens backed by a vertical concrete wall. If adult delta smelt attempt to move upstream along the east bank of the river, these areas will have less shoreline with relatively low velocity (other than regions such as the intake manifolds or spaces between the cylindrical tee-screens), requiring swimming against in-channel velocities if attempting to pass the screens. By virtue of small body size delta smelt are relatively "poor" swimmers (Swanson et al. 1998). In addition, they are non-continuous swimmers. This makes sense because they evolved in a high velocity tidal environment (as did their immediate ancestor, the surf smelt *Hypomesus pretiosus*) where it would be energetically wasteful for a small fish to swim against currents all the time.

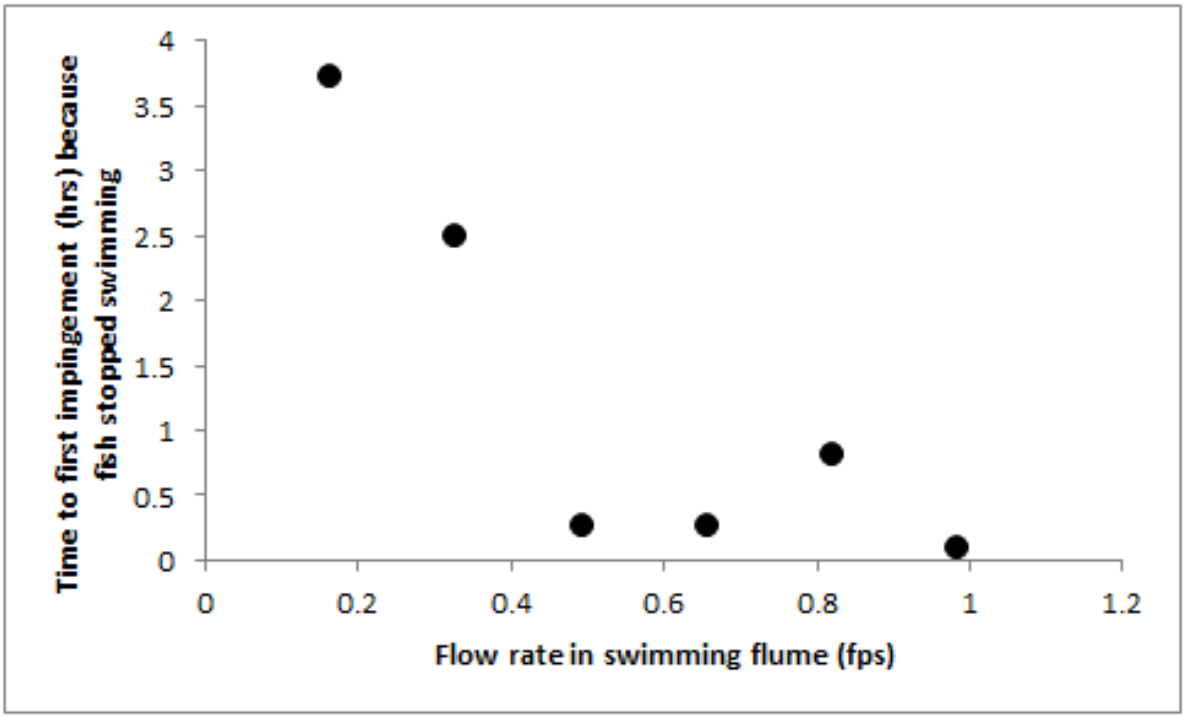
Swanson et al. (1998) estimated that on average, the maximum sustainable swimming speed for delta smelt is 27.6 ±5.1 cm/s (0.91 ±0.17 feet per second [feet/s]), for about 10 minutes. This estimate was not sensitive to fish length over the size range 30 to 70 mm (see Figure 1 of Swanson et al. 1998). Thus, for a delta smelt to swim upstream at all, the river velocity has to be less than their sustainable swimming speed. If the river velocity is higher than the sustainable swimming speed and delta smelt cannot escape the current, then they will be pushed back downstream. Young et al. (2010) found that sweeping velocities in the Fish Treadmill affected the swimming speed of adult delta smelt; when sweeping velocity was experimentally increased (analogous to river velocity), delta smelt increased their swimming speed (Young et al. 2010; Figure 5D.9-1). However, the observed increases were very slight, and the mean swimming speed predictions from the equation produce even slower swimming speeds than the Swanson et al. (1998) results. Note the 1998 swimming speed estimate is very close to the maximum observed at the maximum sweeping velocity tested and therefore it provides an optimistic estimate of delta smelt's swimming ability. If

the average 2010 swimming speeds are substituted for the 1998 results, then no adult delta smelt could ever pass the NDD except when flows are too low to enable pumping. Thus, it is acknowledged that calculations based on the 1998 swimming speed estimate will be inherently optimistic for three reasons. First, newer estimates suggest slower mean swimming speeds based on longer duration calculations (Young et al. 2010). Second, lacking information on how straight of a line delta smelt would swim in when trying to pass a long fish screen, it is necessary to make the assumption that they will swim in a perfectly straight line. Third, delta smelt are unlikely to swim continuously for lengthy periods of time when there is a current (Swanson et al. 1998; Figure 5D.9-2), but for this analysis it was considered too speculative to try to adjust calculations based on such a nonlinear response developed under confined conditions to which the fish are not adapted. Thus, for the following analysis, the simplifying assumptions are made that the fish will swim past the fish screen in a straight line and that if they can swim the necessary distance in one hour or less that they will swim continuously except during the moments they are predicted to be impinged. The 1-hour timestep is reasonable because at the minimum channel velocity at which diversions were assumed to be allowable in the operations modeling (0.4 feet/s) delta smelt could theoretically swim upstream 900 feet (i.e., the approximate length of thirty, ~30-foot screens) in just under 30 minutes. On the basis of the 0.91-feet/s maximum sustainable swimming speed, this would happen whenever Sacramento River velocity in front of the fish screens was less than 0.535 feet/s (or when Sacramento River flow was low enough that flood tide currents "reversed" the river flow and moved net currents in an upstream direction).




Source: Young et al. 2010:Figure 7.

**Figure 5D.9-1. Sweeping Velocity in the UC Davis Fish Treadmill versus Swimming Velocity of Adult Delta Smelt during Two-Hour Experiments**



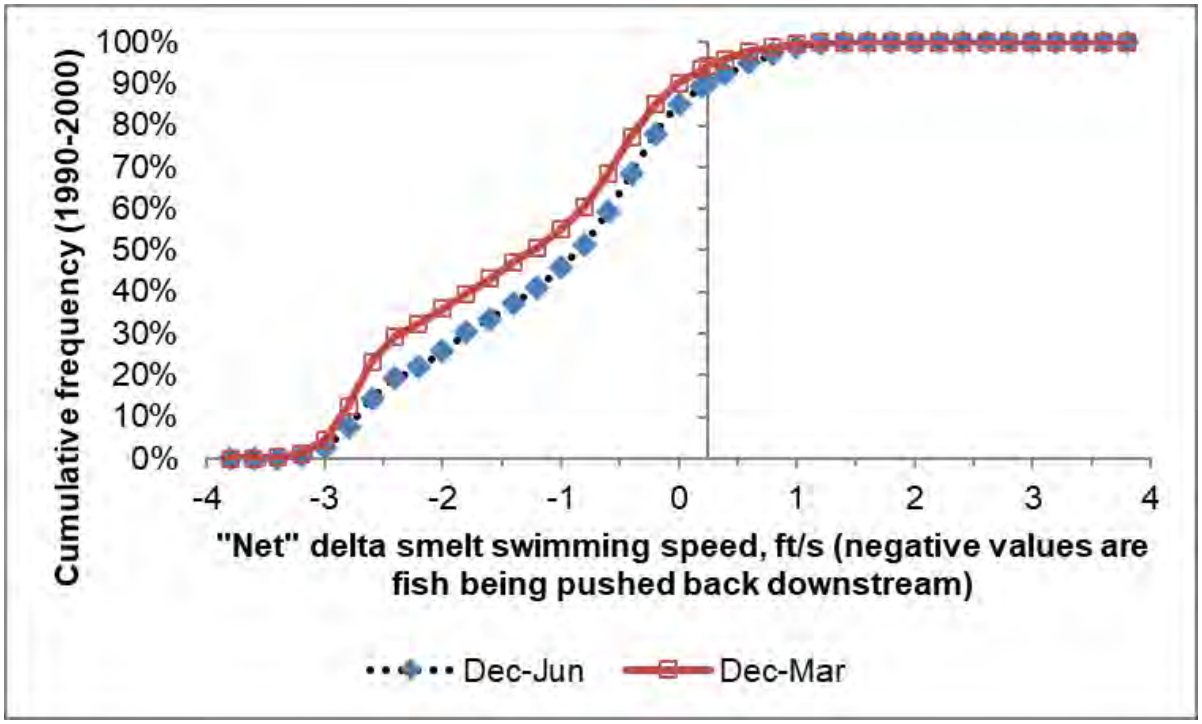

Source: Swanson et al. 1998: Table 1.

**Figure 5D.9-2. Flow Rates Experienced by Delta Smelt in a Swimming Flume versus Time until the Fish Were First Impinged against the Back of the Flume Because They Had Stopped Swimming**

The best available information on what Sacramento River velocities might be in front of the NDDs is from the velocity gauge in the river at Freeport (CDEC gauge FPT, sensor 21).[3] These data were downloaded at an hourly timestep for the months of December through June. The Freeport velocity data used were for 1990 through 2000. The hourly river velocities were converted into net upstream swimming velocities for adult delta smelt: 0.91 feet/s minus measured velocity, and the results were summarized using a histogram. This analysis was also repeated using only December through March data, which based on the fish salvage facilities in the south Delta, represents a time of year that most adult delta smelt "migration" occurs (Grimaldo et al. 2009).

Hourly river velocities slow enough that delta smelt could swim upstream more than 900 feet in an hour occurred with a frequency of 0.0975 from December through June 1990–2000, and 0.0572 from December through March 1990–2000 (Figure 5D.9-3). This analysis was repeated using a swimming speed of 19 cm/s (0.62 feet/s), which was loosely derived from Young et al. (2010). The use of this slower swimming speed had the obvious effect of making estimates of successful fish passage even rarer; 0.0578 and 0.0268 for December through June and December through March, respectively (results not shown).

[3] As discussed further in Chapter 12, *Fish and Aquatic Resources,* of the Final EIR (California Department of Water Resources 2023), velocity near the river banks or river bottom could be much lower than the mean channel velocity, which is a limitation of this analysis based on the available data.




Note: The *y* axis crosses the *x* axis at 0.25 feet/s, the velocity at which delta smelt could swim far enough in 1 hour to theoretically pass a 900-foot-long fish screen.

**Figure 5D.9-3. Cumulative Frequency Distributions of Estimated Swimming Velocities of Adult Delta Smelt in the Sacramento River (0.91 feet/s minus measured velocity at Freeport) for December–June 1990–2000 (blue symbols with black line) and December–March 1990–2000 (red line and symbols)**

February 1–27, 1991, was a low-flow period in a drought year in which data were fairly complete and in-channel river velocities were frequently slow enough (based on the assumptions described above) to enable delta smelt to move upstream at rates exceeding 900 feet per hour. Therefore, this time period was used to develop estimates of survival rates of delta smelt passing the proposed fish screens using the daytime mortality equation provided by Swanson et al. (2005). To the extent that Freeport velocity represents a bypass flow velocity in front of the NDD fish screens, during February 1991, hourly river velocities were high enough to allow NDD pumping 72% of the time (based solely on the 0.4 feet/s velocity criterion assumed for modeling purposes, and not accounting for any other NDD operations considerations), but the percentage of time that pumping could occur *and* delta smelt could theoretically pass the screen was only 12%—comparable to the longer term fraction shown in Figure 5D.10-1. The analysis of mortality was restricted to these 12 percent of observations because it was assumed that river velocities exceeding the maximum sustained swimming speed of delta smelt will prevent the fish from even trying to pass the screen, and that river velocities that delta smelt can only very slowly swim upstream against will likewise dissuade fish from attempting to pass the screen. Note that these fates are accounted for by the large fractions of impassable velocities shown in Figure 5D.9-3.

The linear regression equation describing the estimated mortality from the fish treadmill experiments (Swanson et al. 2005) was:

48-hour % mortality (day) = -26.59 + 171.90 (contact rate, contacts/fish/min) + 1.31 (temperature, °C) + 1.04(approach velocity, cm/s); n= 56, $r^2$ = 0.4815, SEE = 13.31

As previously noted, Swanson et al. (2005) also developed an equation for nighttime exposures that predicts a lower mortality rate. This equation was not used because several assumptions about swimming speed had already been made in the calculations and because data were lacking to indicate that delta smelt actively migrate at night. Freeport water temperature data (CDEC gauge FPT, sensor 25) for February 1–27, 2010, through 2015, were downloaded to generate a range of likely water temperatures during which delta smelt would be expected to ascend the Sacramento River.

The screen contact rate is a linear regression function of the approach and sweeping velocities:

Contact rate (contacts/fish/min) = 0.042 + 0.009 (approach velocity, cm/s) – 0.001 (sweeping velocity, cm/s); $r^2 = 0.421$

The Freeport velocity data were used to represent the sweeping velocity required for the calculation of mortality, and the approach velocity in both equations was assumed to be 0.2 feet/s (6.1 cm/s) if Freeport velocity equaled or exceeded 0.4 feet/s (12.2 cm/s) and zero otherwise, consistent with the modeling assumption that no pumping would be allowed when a 0.4-ft/s sweeping velocity criterion was not met.

The probability that an individual delta smelt would successfully pass the downstream-most NDD screen was estimated as:

$$P = U*S$$

where $P$ is the probability of successful passage, $U$ is the probability water velocity was slow enough that an average delta smelt could swim at least 900 feet upstream in one hour or less, and $S$ is the survival of delta smelt passing the screen in the event they could.

Survival was derived from the predictions of the 48-hour mortality equation (Swanson et al. 2005) presented above as 1-(mortality/100); variation in $S$ was generated using variation in upstream swimming distances of delta smelt derived from variation in Freeport velocity (1990–2000) and using the six years of hourly water temperature data described above (2010–2015).

# 5D.10 Delta Smelt Larval Entrainment (DSM2 Particle Tracking Model)

The most recent version of the Particle Tracking Model (DSM2-PTM was used in the effects analysis to estimate the relative change in entrainment of delta smelt larvae by various water diversions (i.e., the south Delta export facilities and the North Bay Aqueduct [NBA] Barker Slough Pumping Plant). This approach assumed that the susceptibility of delta smelt larvae can be represented by entrainment of passive particles, based on existing literature (Kimmerer 2008, 2011). Results of the PTM simulations do not represent the actual entrainment of larval delta smelt that may have occurred in the past or would occur in the future, but rather should be viewed as a comparative indicator of the relative risk of larval entrainment under different operational scenarios. For purposes of this effects analysis, those particles that were estimated to have entered the various water diversion locations included in the PTM outputs (e.g., south Delta export facilities and NBA) are characterized as having been entrained. The latest version of DSM2-PTM allows agricultural diversions to be excluded as sources of entrainment (while still being included as water diversion sources): For this effects analysis, these agricultural diversions were excluded, given the relative

coarseness of the assumptions related to specific locations of the agricultural diversions, the timing of water withdrawals by individual irrigators, and field observations that the density of young delta smelt entrained by these diversions is relatively low (Nobriga et al. 2004; Kimmerer 2008).S

Delta smelt starting distributions used in the PTM larval entrainment analysis were based on the California Department of Fish and Wildlife 20-mm Survey and were developed in association with M. Nobriga (USFWS Bay-Delta Office). This method paired observed delta smelt larval distributions from survey data with modeled hydraulic conditions from DSM2-PTM. Each pair was made by matching the observed Delta outflows of the first 20-mm Survey that captured larval smelt (16 years of 20-mm Surveys, 1995–2011) with the closest modeled mean monthly Delta outflow for the months of March to June in the 90+ years of PTM simulations.

The 20-mm Survey samples multiple stations throughout the Delta fortnightly. The average length of delta smelt caught during each survey was averaged across all stations (8–10 surveys per year) (Table 5D.10-1 through Table 5D.10-8). The survey with mean fish length closest to 13 mm was chosen to represent the starting distribution of larval smelt in the Delta for that particular year (Table 5D.10-1 through Table 5D.10-8). A length of 13 mm was chosen in order to represent a consistent period each year with respect to size/age of delta smelt larvae, while accounting for the mean size by survey across all years and the general pattern of more efficient capture with greater size. Catch efficiency changes rapidly for delta smelt larvae as they grow (see Figure 8 of Kimmerer 2008); the choice of 13 mm represents a compromise between larger larvae/early juveniles (e.g., ≥ 20 mm) that are captured more efficiently but which may have moved too far to accurately represent starting distribution and likely would be behaving less like passive particles, and smaller larvae (e.g., <10 mm) that are not sampled efficiently enough to provide a reliable depiction of starting distribution. During the period included in the analysis (1995–2011), the fourth survey was selected most frequently (range between the first and fifth surveys).

Once a survey date was chosen for a given year, the actual delta smelt catch during this survey was examined by station number. Stations downstream of the confluence of the Sacramento and San Joaquin River confluence (in Suisun Bay and Suisun Marsh) were eliminated, as particles originating in these areas would not be subject to entrainment in the Delta, and the PTM is better suited for the channels of the Delta than for the open-estuary environment of Suisun Bay. Several stations in the Cache Slough area also were not included as they were introduced in 2008 and did not have data for the entire period from which starting distributions are calculated. A list of stations and counts of delta smelt are provided in, along with the fish count not used to calculate the starting distribution, as a percentage of total fish caught during a given survey. Note that the percentage of larvae collected downstream of the Sacramento–San Joaquin confluence varies from zero to almost 100%, depending on water year. For example, in 2002 (survey 4), with relatively low outflow of approximately 13,500 cfs, only 2.5% of larvae were downstream of the confluence. In contrast, over 70% of larvae were downstream in 1998 (survey 4), with outflow of nearly 70,000 cfs (Figure 5D.10-1). These percentages were used to adjust the percentage of particles (particles representing larvae) that would be considered susceptible to entrainment.

Delta smelt counts per station were then divided by the contributing area of a given station in acres (Table 5D.10-9), to remove spatial disparities, and percentages of the total number of Delta Smelt caught were calculated for each of the main areas included in the analysis. The final annual starting distributions then were established by evenly distributing assigned percentages to each DSM2-PTM node (i.e., model particle insertion points) in a given area.

In order to facilitate review, for example, for CDFW staff to conduct other forms of analyses based on the modeling outputs, the raw PTM outputs are provided in Attachment 5D.3, *Raw DSM2 Particle Tracking Modeling Output*.

**Table 5D.10-1. Distribution of Larval Delta Smelt (Number of Smelt) in Selected Survey Period (Survey Number) at West Delta/Lower Sacramento River Sampling Stations**

| Year | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Survey Number | 1 | 3 | 4 | 4 | 2 | 4 | 5 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 |
| Average Monthly Outflow (cfs) | 90,837 | 46,021 | 12,257 | 67,612 | 35,509 | 22,057 | 9,612 | 13,483 | 41,877 | 12,354 | 29,876 | 82,004 | 11,235 | 9,482 | 11,944 | 25,102 | 84,981 |
| 508 | – | 51 | – | 1 | 3 | 1 | – | – | 1 | – | 2 | – | – | – | – | – | – |
| 513 | – | 110 | 3 | – | 1 | 18 | 1 | – | 1 | 7 | 7 | – | – | – | – | 2 | – |
| 520 | 4 | 65 | 26 | 1 | – | 9 | – | – | 1 | – | 2 | – | – | – | – | 1 | 1 |
| 801 | – | 41 | 2 | – | 8 | 18 | – | – | 2 | 13 | 1 | – | – | 1 | – | 1 | – |

Note: "–" indicates the cell is blank.
cfs = cubic feet per second.

**Table 5D.10-2. Distribution of Larval Delta Smelt (Number of Smelt) in Selected Survey Period (Survey Number) at West Delta/ Sacramento–San Joaquin Confluence Sampling Stations**

| Year | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Survey Number | 1 | 3 | 4 | 4 | 2 | 4 | 5 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 |
| Average Monthly Outflow (cfs) | 90,837 | 46,021 | 12,257 | 67,612 | 35,509 | 22,057 | 9,612 | 13,483 | 41,877 | 12,354 | 29,876 | 82,004 | 11,235 | 9,482 | 11,944 | 25,102 | 84,981 |
| 704 | – | 11 | 8 | – | 4 | – | 3 | – | – | 1 | – | – | – | 1 | – | – | – |
| 705 | – | 4 | 12 | – | – | 1 | 14 | 5 | 1 | 8 | – | 1 | – | – | 1 | – | – |
| 706 | – | 4 | 14 | 2 | – | 1 | 5 | 1 | – | 3 | 1 | – | 1 | – | – | 1 | – |
| 707 | – | – | – | – | – | – | 11 | – | – | 2 | – | – | – | – | – | – | – |

Note: "–" indicates the cell is blank.
cfs = cubic feet per second.

**Table 5D.10-3. Distribution of Larval Delta Smelt (Number of Smelt) in Selected Survey Period (Survey Number) at Cache Slough and North Delta Sampling Stations**

| Year | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Survey Number | 1 | 3 | 4 | 4 | 2 | 4 | 5 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 |
| Average Monthly Outflow (cfs) | 90,837 | 46,021 | 12,257 | 67,612 | 35,509 | 22,057 | 9,612 | 13,483 | 41,877 | 12,354 | 29,876 | 82,004 | 11,235 | 9,482 | 11,944 | 25,102 | 84,981 |
| 711 | – | – | 7 | – | – | 1 | 1 | 1 | – | – | – | 1 | 1 | – | – | – | – |
| 716 | – | – | 6 | – | – | 3 | 5 | 1 | 2 | 2 | 1 | 3 | – | – | 1 | 2 | 1 |
| 719 | – | – | – | – | – | – | – | – | – | – | – | – | – | 2 | 12 | 38 | 39 |

Note: "–" indicates the cell is blank.
cfs = cubic feet per second.

**Table 5D.10-4. Distribution of Larval Delta Smelt (Number of Smelt) in Selected Survey Period (Survey Number) at West Delta/Lower San Joaquin River Sampling Stations**

| Year | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Survey Number | 1 | 3 | 4 | 4 | 2 | 4 | 5 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 |
| Average Monthly Outflow (cfs) | 90,837 | 46,021 | 12,257 | 67,612 | 35,509 | 22,057 | 9,612 | 13,483 | 41,877 | 12,354 | 29,876 | 82,004 | 11,235 | 9,482 | 11,944 | 25,102 | 84,981 |
| 804 | – | 8 | 32 | 12 | 15 | 8 | – | 4 | 4 | 5 | – | 1 | – | 1 | – | 1 | – |
| 809 | – | 20 | 13 | – | – | – | 28 | 1 | 1 | 87 | – | – | – | – | – | – | – |
| 812 | – | 8 | 6 | – | – | 1 | 49 | 3 | – | 6 | – | – | – | 1 | – | – | – |
| 815 | – | 3 | 5 | – | 18 | 1 | 13 | 5 | – | 26 | 1 | 1 | – | 2 | 1 | 1 | – |
| 901 | – | 5 | 5 | – | 7 | – | 13 | 2 | 1 | 4 | – | – | – | – | – | – | – |

Note: "–" indicates the cell is blank.
cfs = cubic feet per second.

**Table 5D.10-5. Distribution of Larval Delta Smelt (Number of Smelt) in Selected Survey Period (Survey Number) at South Delta Sampling Stations**

| Year | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Survey Number | 1 | 3 | 4 | 4 | 2 | 4 | 5 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 |
| Average Monthly Outflow (cfs) | 90,837 | 46,021 | 12,257 | 67,612 | 35,509 | 22,057 | 9,612 | 13,483 | 41,877 | 12,354 | 29,876 | 82,004 | 11,235 | 9,482 | 11,944 | 25,102 | 84,981 |
| 902–915 | – | 0 | 4 | – | 45 | 18 | 11 | 14 | 8 | 3 | 2 | – | – | 3 | 2 | 1 | – |
| 918 | – | 1 | – | – | – | 21 | 1 | 1 | – | 2 | 1 | – | – | – | – | – | – |

Note: "–" indicates the cell is blank.
cfs = cubic feet per second.

**Table 5D.10-6. Distribution of Larval Delta Smelt (Number of Smelt) in Selected Survey Period (Survey Number) at East Delta Sampling Stations**

| Year | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Survey Number | 1 | 3 | 4 | 4 | 2 | 4 | 5 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 |
| Average Monthly Outflow (cfs) | 90,837 | 46,021 | 12,257 | 67,612 | 35,509 | 22,057 | 9,612 | 13,483 | 41,877 | 12,354 | 29,876 | 82,004 | 11,235 | 9,482 | 11,944 | 25,102 | 84,981 |
| 919 | – | 1 | 5 | – | – | 1 | 10 | 1 | – | – | – | – | – | – | – | – | – |

Note: "–" indicates the cell is blank.
cfs = cubic feet per second.

**Table 5D.10-7. Distribution of Larval Delta Smelt (Number of Smelt) in Selected Survey Period (Survey Number) at Other Sampling Stations**

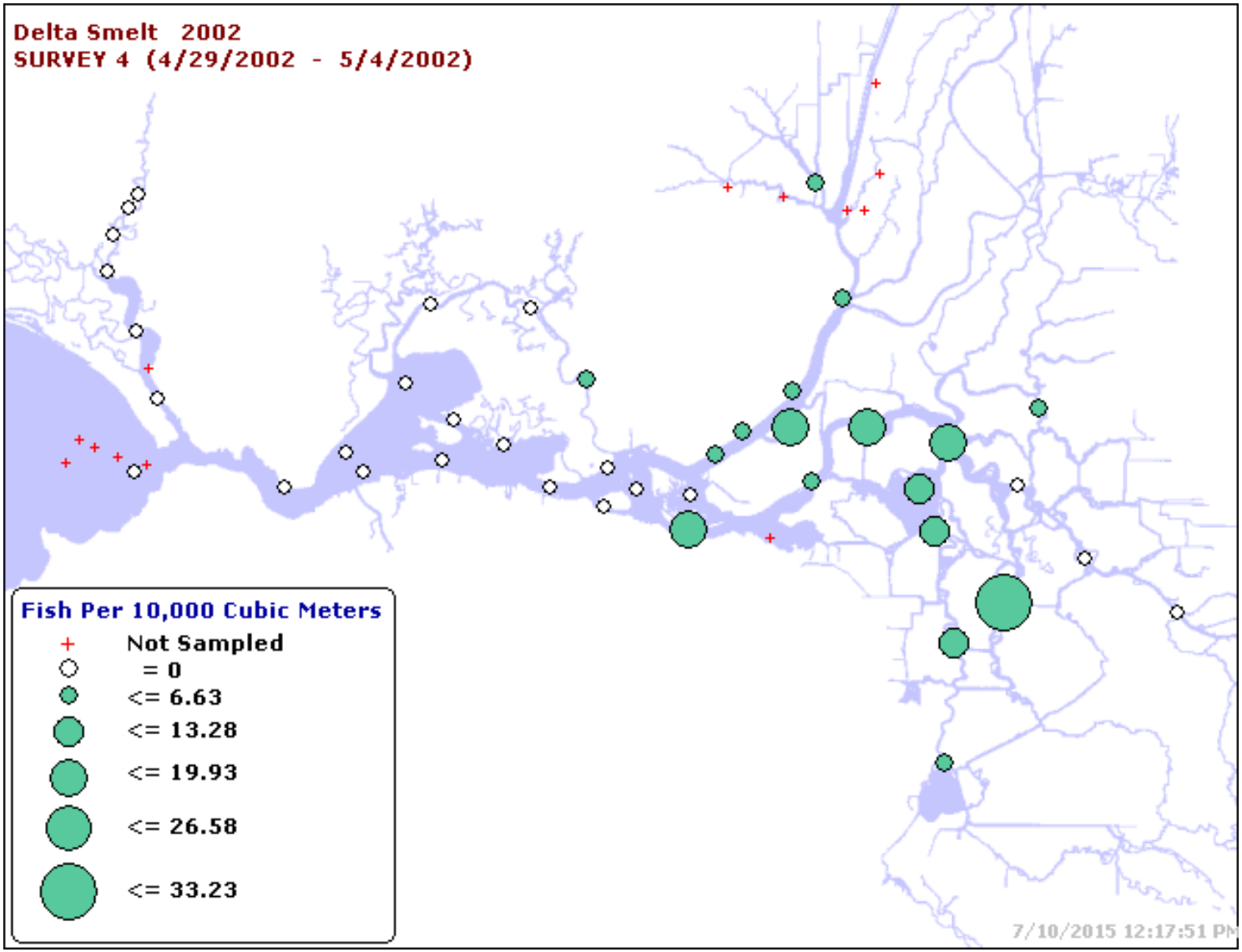
| Year | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Survey Number | 1 | 3 | 4 | 4 | 2 | 4 | 5 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 |
| Average Monthly Outflow (cfs) | 90,837 | 46,021 | 12,257 | 67,612 | 35,509 | 22,057 | 9,612 | 13,483 | 41,877 | 12,354 | 29,876 | 82,004 | 11,235 | 9,482 | 11,944 | 25,102 | 84,981 |
| Cache Slough Stations | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 4 | 16 | 4 |
| Downstream of Confluence | 7 | 567 | 66 | 43 | 127 | 46 | 8 | 1 | 7 | 20 | 50 | 242 | 1 | 0 | 1 | 4 | 120 |

cfs = cubic feet per second.

**Table 5D.10-8. Percentage of Total Larval Delta Smelt Count in Selected Survey Period (Survey Number) Not Considered for Starting Distribution**

| Year | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Survey Number | 1 | 3 | 4 | 4 | 2 | 4 | 5 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 |
| Average Monthly Outflow (cfs) | 90,837 | 46,021 | 12,257 | 67,612 | 35,509 | 22,057 | 9,612 | 13,483 | 41,877 | 12,354 | 29,876 | 82,004 | 11,235 | 9,482 | 11,944 | 25,102 | 84,981 |
| Cache Slough Stations | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 47.6 | 18.2 | 23.5 | 2.4 |
| Downstream of Confluence | 63.6 | 63.1 | 30.8 | 72.9 | 55.7 | 31.1 | 4.6 | 2.5 | 24.1 | 10.6 | 73.5 | 97.2 | 33.3 | 0 | 4.5 | 5.9 | 72.7 |

cfs = cubic feet per second.




Source: California Department of Fish and Wildlife 2015.

**Figure 5D.10-1. Density of Delta Smelt from 20-mm Survey 4, 2002**

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**Table 5D.10-9. Area of Water Represented by Each 20-mm Survey Station**

| Station | Area (acres) |
|---|---|
| 508 | 2,296 |
| 513 | 1,703 |
| 520 | 438 |
| 801 | 2,226 |
| 704 | 605 |
| 705 | 277 |
| 706 | 931 |
| 707 | 1,859 |
| 711 | 1,994 |
| 716 | 3,110 [a] |
| 719 | 3,110 [a] |
| 804 | 1,195 |
| 809 | 1,392 |
| 812 | 1,767 |
| 815 | 4,023 |
| 901 | 3,822 |
| 902 | 1,744 |
| 906 | 1,780 |
| 910 | 1,925 |
| 912 | 1,225 |
| 914 | 1,554 |
| 915 | 1,146 |
| 918 | 1,601 |
| 919 | 2,043 |

Source: Saha 2008.
[a] Acreage for Station 716 was split between Stations 716 and 719.

Each of the months included in the PTM (i.e., March–June in the 1923–2015 simulation period) was matched to the closest starting distribution based on the average monthly Delta outflow. Average monthly Delta outflow for the months modeled by PTM hydroperiods were based on CalSim (existing conditions scenario). Average monthly Delta outflow during the selected 20-mm Survey period was calculated from Dayflow. If the selected survey period spanned 2 months (usually April–May), the applied outflow was for the month when most of the sampling occurred. The correspondence between the modeled Delta outflow and the applied starting distribution outflow from the 20-mm Survey was reasonable: the mean difference was 7% (median = 3%), with a range from -195% (modeled Delta outflow of nearly 270,000 cfs in March 1983 matched with historical outflow of 90,837 cfs during survey 1 of 1995) to +70% (modeled Delta outflow of 2,863 cfs in June 1976 matched with historical outflow of 9,482 cfs during survey 4 of 2008). Analysis of the PTM outputs was then done by multiplying the percentage of particles entrained from each release location by the applicable starting distribution percentage summarized in Table 5D.10-10 through Table 5D.10-15.

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**Table 5D.10-10. Percentage of Particles at PTM Insertion Locations in Sacramento–San Joaquin Confluence Area Used as Starting Distributions in the Delta Smelt Particle Tracking Analysis**

| Average Monthly Outflow in cfs | 9,482 | 9,612 | 11,235 | 11,944 | 12,257 | 12,354 | 13,483 | 22,057 | 25,102 | 29,876 | 35,509 | 46,021 | 67,612 | 82,004 | 84,891 | 90,837 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sacramento River at Sherman Lake | 16.52 | 7.72 | 1.65 | 0 | 8.21 | 0 | 0.11 | 2.65 | 0 | 6.55 | 2.65 | 19.9 | 3.65 | 0 | 2.92 | 25.00 |
| Sacramento River at Port Chicago | 16.52 | 7.72 | 1.65 | 0 | 8.21 | 0 | 0.11 | 2.65 | 0 | 6.55 | 2.65 | 19.9 | 3.65 | 0 | 2.92 | 25.00 |
| San Joaquin River downstream of Dutch Slough | 16.52 | 7.72 | 1.65 | 0 | 8.21 | 0 | 0.11 | 2.65 | 0 | 6.55 | 2.65 | 19.9 | 3.65 | 0 | 2.92 | 25.00 |
| Sacramento River at Pittsburg | 16.52 | 7.72 | 1.65 | 0 | 8.21 | 0 | 0.11 | 2.65 | 0 | 6.55 | 2.65 | 19.9 | 3.65 | 0 | 2.92 | 25.00 |

cfs = cubic feet per second; PTM = Particle Tracking Model.

**Table 5D.10-11. Percentage of Particles at PTM Insertion Locations in Lower Sacramento River Area Used as Starting Distributions in the Delta Smelt Particle Tracking Analysis**

| Average Monthly Outflow in cfs | 9,482 | 9,612 | 11,235 | 11,944 | 12,257 | 12,354 | 13,483 | 22,057 | 25,102 | 29,876 | 35,509 | 46,021 | 67,612 | 82,004 | 84,891 | 90,837 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Threemile Slough | 1.30 | 0.67 | 4.24 | 8.76 | 6.96 | 10.64 | 9.10 | 2.35 | 6.00 | 4.13 | 2.35 | 2.13 | 2.12 | 8.76 | 0 | 0 |
| Sacramento River at Rio Vista | 1.30 | 0.67 | 4.24 | 8.76 | 6.96 | 10.64 | 9.10 | 2.35 | 6.00 | 4.13 | 2.35 | 2.13 | 2.12 | 8.76 | 0 | 0 |
| Sacramento River downstream of Decker Island | 1.30 | 0.67 | 4.24 | 8.76 | 6.96 | 10.64 | 9.10 | 2.35 | 6.00 | 4.13 | 2.35 | 2.13 | 2.12 | 8.76 | 0 | 0 |

cfs = cubic feet per second; PTM = Particle Tracking Model.

**Table 5D.10-12. Percentage of Particles at PTM Insertion Locations in Cache Slough and North Delta Area Used as Starting Distributions in the Delta Smelt Particle Tracking Analysis**

| Average Monthly Outflow in cfs | 9,482 | 9,612 | 11,235 | 11,944 | 12,257 | 12,354 | 13,483 | 22,057 | 25,102 | 29,876 | 35,509 | 46,021 | 67,612 | 82,004 | 84,891 | 90,837 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Miner Slough | 0.32 | 0.35 | 0.06 | 5.86 | 1.26 | 1.05 | 0.40 | 0 | 9.11 | 0.60 | 0 | 0 | 0 | 5.86 | 9.82 | 0 |
| Sacramento Deep Water Ship Channel | 0.32 | 0.35 | 0.06 | 5.86 | 1.26 | 1.05 | 0.40 | 0 | 9.11 | 0.60 | 0 | 0 | 0 | 5.86 | 9.82 | 0 |
| Cache Slough at Shag Slough | 0.32 | 0.35 | 0.06 | 5.86 | 1.26 | 1.05 | 0.40 | 0 | 9.11 | 0.60 | 0 | 0 | 0 | 5.86 | 9.82 | 0 |
| Cache Slough at Liberty Island | 0.32 | 0.35 | 0.06 | 5.86 | 1.26 | 1.05 | 0.40 | 0 | 9.11 | 0.60 | 0 | 0 | 0 | 5.86 | 9.82 | 0 |
| Lindsey Slough at Barker Slough | 0.32 | 0.35 | 0.06 | 5.86 | 1.26 | 1.05 | 0.40 | 0 | 9.11 | 0.60 | 0 | 0 | 0 | 5.86 | 9.82 | 0 |
| Sacramento River at Sacramento | 0.32 | 0.35 | 0.06 | 5.86 | 1.26 | 1.05 | 0.40 | 0 | 9.11 | 0.60 | 0 | 0 | 0 | 5.86 | 9.82 | 0 |
| Sacramento River at Sutter Slough | 0.32 | 0.35 | 0.06 | 5.86 | 1.26 | 1.05 | 0.40 | 0 | 9.11 | 0.60 | 0 | 0 | 0 | 5.86 | 9.82 | 0 |
| Sacramento River at Ryde | 0.32 | 0.35 | 0.06 | 5.86 | 1.26 | 1.05 | 0.40 | 0 | 9.11 | 0.60 | 0 | 0 | 0 | 5.86 | 9.82 | 0 |
| Sacramento River near Cache Slough confluence | 0.32 | 0.35 | 0.06 | 5.86 | 1.26 | 1.05 | 0.40 | 0 | 9.11 | 0.60 | 0 | 0 | 0 | 5.86 | 9.82 | 0 |

cfs = cubic feet per second; PTM = Particle Tracking Model.

**Table 5D.10-13. Percentage of Particles at PTM Insertion Locations in West Delta/San Joaquin River Area Used as Starting Distributions in the Delta Smelt Particle Tracking Analysis**

| Average Monthly Outflow in cfs | 9,482 | 9,612 | 11,235 | 11,944 | 12,257 | 12,354 | 13,483 | 22,057 | 25,102 | 29,876 | 35,509 | 46,021 | 67,612 | 82,004 | 84,891 | 90,837 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| San Joaquin River at Potato Slough | 0.80 | 2.86 | 25.12 | 7.00 | 10.87 | 11.13 | 19.73 | 17.80 | 0 | 13.16 | 17.80 | 4.24 | 26.34 | 7.00 | 0 | 0 |
| San Joaquin River at Twitchell Island | 0.80 | 2.86 | 25.12 | 7.00 | 10.87 | 11.13 | 19.73 | 17.80 | 0 | 13.16 | 17.80 | 4.24 | 26.34 | 7.00 | 0 | 0 |
| San Joaquin River near Jersey Point | 0.80 | 2.86 | 25.12 | 7.00 | 10.87 | 11.13 | 19.73 | 17.80 | 0 | 13.16 | 17.80 | 4.24 | 26.34 | 7.00 | 0 | 0 |

cfs = cubic feet per second; PTM = Particle Tracking Model.

**Table 5D.10-14. Percentage of Particles at PTM Insertion Locations in Central/South Delta Area Used as Starting Distributions in the Delta Smelt Particle Tracking Analysis**

| Average Monthly Outflow in cfs | 9,482 | 9,612 | 11,235 | 11,944 | 12,257 | 12,354 | 13,483 | 22,057 | 25,102 | 29,876 | 35,509 | 46,021 | 67,612 | 82,004 | 84,891 | 90,837 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| San Joaquin River downstream of Rough and Ready Island | 2.47 | 5.50 | 0.47 | 0 | 0.07 | 2.34 | 0.50 | 2.89 | 0 | 1.66 | 2.89 | 0.10 | 0 | 0 | 0 | 0 |
| San Joaquin River at Buckley Cove | 2.47 | 5.50 | 0.47 | 0 | 0.07 | 2.34 | 0.50 | 2.89 | 0 | 1.66 | 2.89 | 0.10 | 0 | 0 | 0 | 0 |
| San Joaquin River near Medford Island | 2.47 | 5.50 | 0.47 | 0 | 0.07 | 2.34 | 0.50 | 2.89 | 0 | 1.66 | 2.89 | 0.10 | 0 | 0 | 0 | 0 |
| Old River near Victoria Canal | 2.47 | 5.50 | 0.47 | 0 | 0.07 | 2.34 | 0.50 | 2.89 | 0 | 1.66 | 2.89 | 0.10 | 0 | 0 | 0 | 0 |
| Old River at Railroad Cut | 2.47 | 5.50 | 0.47 | 0 | 0.07 | 2.34 | 0.50 | 2.89 | 0 | 1.66 | 2.89 | 0.10 | 0 | 0 | 0 | 0 |
| Old River near Quimby Island | 2.47 | 5.50 | 0.47 | 0 | 0.07 | 2.34 | 0.50 | 2.89 | 0 | 1.66 | 2.89 | 0.10 | 0 | 0 | 0 | 0 |
| Middle River at Victoria Canal | 2.47 | 5.50 | 0.47 | 0 | 0.07 | 2.34 | 0.50 | 2.89 | 0 | 1.66 | 2.89 | 0.10 | 0 | 0 | 0 | 0 |
| Middle River u/s of Mildred Island | 2.47 | 5.50 | 0.47 | 0 | 0.07 | 2.34 | 0.50 | 2.89 | 0 | 1.66 | 2.89 | 0.10 | 0 | 0 | 0 | 0 |
| Grant Line Canal | 2.47 | 5.50 | 0.47 | 0 | 0.07 | 2.34 | 0.50 | 2.89 | 0 | 1.66 | 2.89 | 0.10 | 0 | 0 | 0 | 0 |
| Frank's Tract East | 2.47 | 5.50 | 0.47 | 0 | 0.07 | 2.34 | 0.50 | 2.89 | 0 | 1.66 | 2.89 | 0.10 | 0 | 0 | 0 | 0 |

cfs = cubic feet per second; PTM = Particle Tracking Model.

**Table 5D.10-15. Percentage of Particles at PTM Insertion Locations in East Delta Area Used as Starting Distributions in the Delta Smelt Particle Tracking Analysis**

| Average Monthly Outflow in cfs | 9,482 | 9,612 | 11,235 | 11,944 | 12,257 | 12,354 | 13,483 | 22,057 | 25,102 | 29,876 | 35,509 | 46,021 | 67,612 | 82,004 | 84,891 | 90,837 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Little Potato Slough | 0 | 0.08 | 0 | 0 | 0.26 | 0.30 | 0.74 | 0.00 | 0 | 0 | 0 | 0.03 | 0 | 0 | 0 | 0 |
| Mokelumne River downstream of Cosumnes confluence | 0 | 0.08 | 0 | 0 | 0.26 | 0.30 | 0.74 | 0.00 | 0 | 0 | 0 | 0.03 | 0 | 0 | 0 | 0 |
| South Fork Mokelumne | 0 | 0.08 | 0 | 0 | 0.26 | 0.30 | 0.74 | 0.00 | 0 | 0 | 0 | 0.03 | 0 | 0 | 0 | 0 |
| Mokelumne River downstream of Georgiana confluence | 0 | 0.08 | 0 | 0 | 0.26 | 0.30 | 0.74 | 0.00 | 0 | 0 | 0 | 0.03 | 0 | 0 | 0 | 0 |
| North Fork Mokelumne | 0 | 0.08 | 0 | 0 | 0.26 | 0.30 | 0.74 | 0 | 0 | 0 | 0 | 0.03 | 0 | 0 | 0 | 0 |
| Georgiana Slough | 0 | 0.08 | 0 | 0 | 0.26 | 0.30 | 0.74 | 0 | 0 | 0 | 0 | 0.03 | 0 | 0 | 0 | 0 |

cfs = cubic feet per second; PTM = Particle Tracking Model.

Results were summarized for 30-day particle tracking periods as the percentage of particles being entrained at the south Delta exports or NBA. The total number of particles released at each location was 4,000. Note that a 30-day particle tracking period may result in relatively low fate resolution at low flows (Kimmerer and Nobriga 2008), but the relative differences between scenarios would be expected to be consistent, based on previous model comparisons of 30-day and 60-day fates.

# 5D.11 *Eurytemora affinis*–X2 Analysis

## 5D.11.1 Methods

This analysis followed Kimmerer's (2002) methods to conduct an analysis of the relationship between the smelt zooplankton prey *Eurytemora affinis* and spring (March–May) X2 for the period from 1980 to 2017, as described by Greenwood (2018). The main steps in preparing the data for analysis were as follows.

1. Historical zooplankton data were obtained from California Department of Fish and Wildlife (2018).
    a. Data were subset to only include surveys 3, 4, and 5 (March–May).
    b. Specific conductance was converted to salinity by applying Schemel's (2001) method, then only samples within the low salinity zone (salinity = 0.5–6) were selected.
    c. A constant of 10 was added to *E. affinis* adult catch per unit effort (number per cubic meter) in each sample, then the resulting value was log10-transformed.
    d. The $\log_{10}$-transformed values were averaged first by month, and then by year.
2. Historical X2 data were obtained from Dayflow (https://www.water.ca.gov/Programs/Environmental-Services/Compliance-Monitoring-And-Assessment/Dayflow-Data).
    a. For years prior to water year 1997 (which is the year Dayflow X2 values began to be provided), the Dayflow daily predictive equation for X2 was used, based on a starting value from Anke Mueller-Solger (see Greenwood 2018 for details).
    b. The mean March–May X2 was calculated for each year.

Similar to Kimmerer (2002), a general linear model was used to regress mean annual $\log_{10}$-transformed *E. affinis* catch per unit effort against mean March–May X2, including a step change between 1987 and 1988 to reflect the *Potamocorbula amurensis* clam invasion and a step change between 2002 and 2003 to reflect the onset of the Pelagic Organism Decline (POD) (Thomson et al. 2010). The interaction of X2 and the step change was included in a full model, but the interaction was not statistically significant, so the model was rerun with only X2 and the step changes included. These analyses were conducted in SAS 9.4 software.4 The statistical outputs indicate that there is little difference in the coefficients for the post-*Potamocorbula* and POD step changes, whereas both coefficients were significantly less than the coefficient for the pre-*Potamocorbula* period. Regression

[4] Copyright 2002–2012, SAS Institute Inc. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA.

coefficients from the model were stored for prediction of *E. affinis* relative abundance for the existing conditions and proposed action.

The stored regression coefficients from the regression of historical *E. affinis* catch per unit effort vs. X2 and step changes were then applied to the No Action Alternative and Alternatives 1–3 using PROC PLM in SAS 9.4 software. The basic regression model being applied was:

$$\log_{10}(\textit{E. affinis}\text{ catch per unit effort}) = 3.9404 - 0.0152\text{ (mean March–May X2)} - 0.7863$$

where 3.9404 is the intercept and -0.7863 is the coefficient for the POD step change. Predictions were back-transformed to the original measurement scale (catch per unit effort, number per cubic meter) for summary of results. X2 inputs for the analysis came from the CalSim modeling of water years 1922 through 2015.

## 5D.11.2 Results

The results of the analysis based on water year type means are discussed in Appendix 5C. Table 5D.11-1 presents the mean and prediction intervals of the results by individual year.

**Table 5D.11-1. Mean and Upper and Lower 95% Prediction Limits of *Eurytemora affinis* Density (adults per cubic meter) in the Low Salinity Zone**

| Year | EC, Mean | EC, Lower 95% | EC, Upper 95% | Proposed Action, Mean | Proposed Action, Lower 95% | Proposed Action, Upper 95% |
|---|---|---|---|---|---|---|
| 1922 | 161 | 23 | 884 | 156 | 22 | 857 |
| 1923 | 117 | 14 | 651 | 115 | 14 | 643 |
| 1924 | 70 | 5 | 418 | 69 | 5 | 416 |
| 1925 | 136 | 18 | 754 | 136 | 18 | 753 |
| 1926 | 125 | 16 | 693 | 125 | 16 | 693 |
| 1927 | 180 | 26 | 991 | 176 | 25 | 971 |
| 1928 | 162 | 23 | 890 | 160 | 22 | 883 |
| 1929 | 74 | 6 | 436 | 72 | 5 | 430 |
| 1930 | 107 | 12 | 599 | 102 | 11 | 576 |
| 1931 | 65 | 4 | 395 | 61 | 3 | 375 |
| 1932 | 96 | 10 | 545 | 97 | 10 | 549 |
| 1933 | 71 | 5 | 424 | 69 | 5 | 416 |
| 1934 | 82 | 7 | 478 | 83 | 8 | 480 |
| 1935 | 152 | 21 | 837 | 144 | 20 | 795 |
| 1936 | 146 | 20 | 806 | 139 | 19 | 767 |
| 1937 | 159 | 22 | 877 | 157 | 22 | 866 |
| 1938 | 217 | 32 | 1,205 | 217 | 32 | 1,206 |
| 1939 | 79 | 7 | 464 | 79 | 7 | 461 |
| 1940 | 178 | 26 | 982 | 176 | 25 | 969 |

| Year | EC, Mean | EC, Lower 95% | EC, Upper 95% | Proposed Action, Mean | Proposed Action, Lower 95% | Proposed Action, Upper 95% |
|---|---|---|---|---|---|---|
| 1941 | 207 | 31 | 1,148 | 207 | 31 | 1,145 |
| 1942 | 181 | 26 | 998 | 175 | 25 | 962 |
| 1943 | 174 | 25 | 960 | 169 | 24 | 928 |
| 1944 | 99 | 11 | 560 | 95 | 10 | 541 |
| 1945 | 121 | 15 | 674 | 117 | 14 | 651 |
| 1946 | 124 | 16 | 690 | 118 | 15 | 656 |
| 1947 | 98 | 11 | 553 | 94 | 10 | 537 |
| 1948 | 135 | 18 | 748 | 134 | 18 | 741 |
| 1949 | 124 | 16 | 690 | 121 | 15 | 671 |
| 1950 | 120 | 15 | 669 | 115 | 14 | 644 |
| 1951 | 142 | 19 | 781 | 138 | 18 | 761 |
| 1952 | 210 | 31 | 1,164 | 210 | 31 | 1,166 |
| 1953 | 141 | 19 | 777 | 133 | 17 | 736 |
| 1954 | 166 | 24 | 914 | 164 | 23 | 900 |
| 1955 | 83 | 8 | 482 | 84 | 8 | 485 |
| 1956 | 173 | 25 | 954 | 169 | 24 | 930 |
| 1957 | 147 | 20 | 812 | 145 | 20 | 800 |
| 1958 | 213 | 32 | 1,181 | 211 | 31 | 1,173 |
| 1959 | 100 | 11 | 563 | 97 | 10 | 549 |
| 1960 | 104 | 12 | 587 | 96 | 10 | 547 |
| 1961 | 96 | 10 | 545 | 92 | 9 | 525 |
| 1962 | 117 | 14 | 651 | 112 | 13 | 625 |
| 1963 | 182 | 26 | 1,003 | 177 | 25 | 975 |
| 1964 | 79 | 7 | 464 | 78 | 7 | 458 |
| 1965 | 158 | 22 | 870 | 148 | 20 | 817 |
| 1966 | 119 | 15 | 662 | 114 | 14 | 634 |
| 1967 | 198 | 29 | 1,095 | 195 | 29 | 1,077 |
| 1968 | 114 | 14 | 637 | 112 | 13 | 626 |
| 1969 | 208 | 31 | 1,153 | 208 | 31 | 1,153 |
| 1970 | 126 | 16 | 699 | 123 | 16 | 685 |
| 1971 | 163 | 23 | 895 | 160 | 22 | 881 |
| 1972 | 110 | 13 | 615 | 105 | 12 | 592 |
| 1973 | 159 | 22 | 874 | 158 | 22 | 868 |
| 1974 | 195 | 29 | 1,077 | 194 | 28 | 1,072 |
| 1975 | 179 | 26 | 987 | 179 | 26 | 985 |
| 1976 | 67 | 4 | 406 | 68 | 5 | 409 |
| 1977 | 60 | 3 | 373 | 60 | 3 | 373 |

| Year | EC, Mean | EC, Lower 95% | EC, Upper 95% | Proposed Action, Mean | Proposed Action, Lower 95% | Proposed Action, Upper 95% |
|---|---|---|---|---|---|---|
| 1978 | 180 | 26 | 990 | 178 | 26 | 982 |
| 1979 | 133 | 17 | 735 | 129 | 17 | 714 |
| 1980 | 160 | 23 | 883 | 157 | 22 | 867 |
| 1981 | 110 | 13 | 616 | 106 | 12 | 598 |
| 1982 | 212 | 32 | 1,177 | 212 | 32 | 1,176 |
| 1983 | 226 | 34 | 1,258 | 226 | 34 | 1,258 |
| 1984 | 143 | 19 | 786 | 139 | 19 | 767 |
| 1985 | 92 | 9 | 524 | 90 | 9 | 514 |
| 1986 | 168 | 24 | 924 | 166 | 23 | 911 |
| 1987 | 105 | 12 | 590 | 102 | 11 | 575 |
| 1988 | 73 | 6 | 434 | 73 | 6 | 434 |
| 1989 | 137 | 18 | 757 | 136 | 18 | 752 |
| 1990 | 80 | 7 | 466 | 79 | 7 | 460 |
| 1991 | 104 | 12 | 584 | 102 | 11 | 575 |
| 1992 | 96 | 10 | 548 | 95 | 10 | 541 |
| 1993 | 176 | 25 | 971 | 166 | 23 | 912 |
| 1994 | 83 | 8 | 483 | 83 | 8 | 483 |
| 1995 | 219 | 33 | 1,217 | 219 | 33 | 1,220 |
| 1996 | 195 | 29 | 1,079 | 196 | 29 | 1,085 |
| 1997 | 122 | 15 | 679 | 121 | 15 | 671 |
| 1998 | 212 | 31 | 1,174 | 212 | 32 | 1,177 |
| 1999 | 170 | 24 | 934 | 168 | 24 | 926 |
| 2000 | 164 | 23 | 901 | 162 | 23 | 893 |
| 2001 | 106 | 12 | 593 | 101 | 11 | 569 |
| 2002 | 102 | 11 | 576 | 97 | 10 | 552 |
| 2003 | 163 | 23 | 896 | 155 | 22 | 855 |
| 2004 | 124 | 16 | 686 | 121 | 15 | 671 |
| 2005 | 174 | 25 | 960 | 170 | 24 | 934 |
| 2006 | 220 | 33 | 1,226 | 220 | 33 | 1,226 |
| 2007 | 97 | 10 | 551 | 93 | 10 | 530 |
| 2008 | 88 | 9 | 506 | 89 | 9 | 509 |
| 2009 | 116 | 14 | 649 | 115 | 14 | 643 |
| 2010 | 141 | 19 | 777 | 134 | 18 | 742 |
| 2011 | 204 | 30 | 1,130 | 204 | 30 | 1,128 |
| 2012 | 140 | 19 | 770 | 136 | 18 | 752 |
| 2013 | 85 | 8 | 491 | 81 | 7 | 470 |
| 2014 | 84 | 8 | 485 | 81 | 7 | 470 |

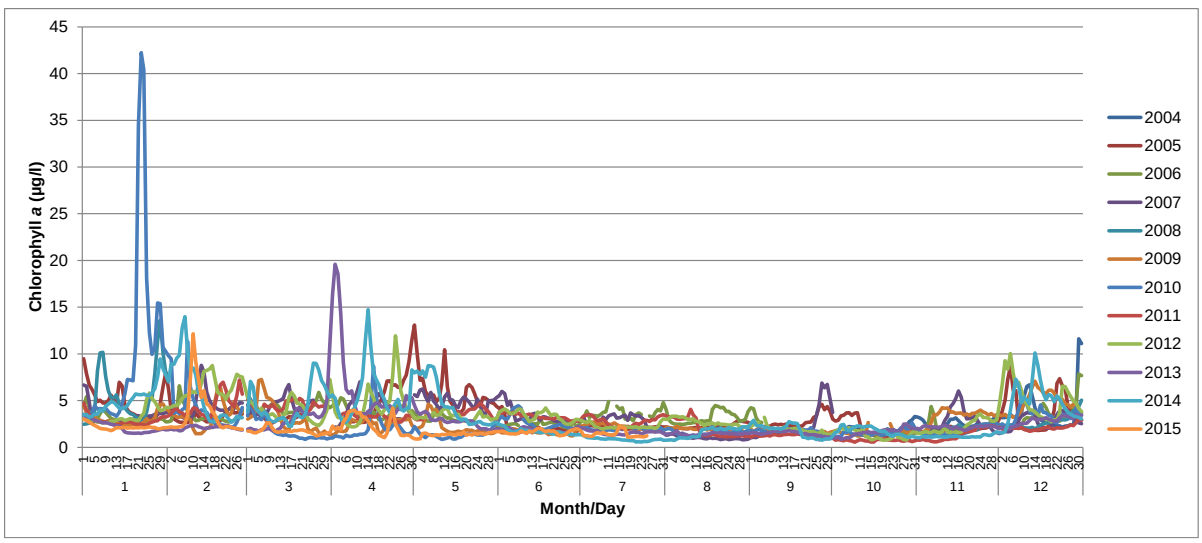
| Year | EC, Mean | EC, Lower 95% | EC, Upper 95% | Proposed Action, Mean | Proposed Action, Lower 95% | Proposed Action, Upper 95% |
|---|---|---|---|---|---|---|
| 2015 | 77 | 6 | 455 | 76 | 6 | 448 |

EC = existing conditions.

# 5D.12 Phytoplankton Carbon Entrainment by North Delta Diversions

By removing water from the Sacramento River, the NDD will also remove small planktonic organisms that otherwise would enter the Delta where they could contribute to the foodweb that supports delta smelt. This section describes the methods used to estimate this loss in relation to the overall quantity of these organisms in the Delta.

The indicator of foodweb material entrainment used in this analysis was phytoplankton carbon. This choice was based on data availability and the likelihood that phytoplankton cells would be relatively uniformly distributed in the water column so that their removal from the river could be reasonably represented using DSM2-HYDRO outputs. Fluorescence data from a continuous recorder operated by DWR were assembled for various stations in the Delta. These data are calibrated to represent the concentration (micrograms per liter [µg/L]) of chlorophyll *a* in the water column. Data from the Sacramento River at the town of Hood were used to estimate the rate of removal of phytoplankton carbon that otherwise would continue to be transported farther into the Delta. The 15-minute data used were from October 4, 2004, to July 27, 2015; daily means were calculated to simplify subsequent calculations (Figure 5D.12-1).




Source: Jones pers. comm.). Note: Chlorophyll *a* values are estimated by calibration from raw fluorescence data.

**Figure 5D.12-1. Daily Mean Chlorophyll *a* in the Sacramento River at Hood**

The estimated chlorophyll *a* concentrations (µg/L) were converted to phytoplankton carbon using a standard ratio of 35 (Jassby et al. 2002). Thus, there were 11 to 12 estimates of daily mean phytoplankton carbon concentrations for each calendar day of the year. The 11 to 12 estimates of mean phytoplankton carbon data were matched by day of the year to daily mean DSM2-HYDRO flow

data for water years 1923–2015 to illustrate potential variability in NDD phytoplankton carbon entrainment across years. Sacramento River flow upstream of the NDD was represented by DSM2-HYDRO outputs for ND336U and flow downstream of the NDD was represented as outputs from ND338D; ND336U minus ND338D represented NDD export rate. Daily load (metric tons/day) of phytoplankton carbon entrained by the NDD was estimated for each day of the 1923–2015 DSM2-HYDRO simulation by multiplying NDD export flow by the corresponding daily mean concentration of phytoplankton carbon for 2004–2015. The resulting matrix of entrained phytoplankton carbon load (metric tons/day) was summarized into percentiles by month.

The estimates of phytoplankton carbon load entrained by the NDD were placed into the context of first-order estimates of the total biomass of phytoplankton carbon simultaneously present in the Delta by multiplying an estimated mean concentration of phytoplankton carbon in the Delta by a static average volume of the Delta (i.e., it was considered too speculative to try to adjust the volume of the Delta based on tidal cycles and flow variation). Fluorescence data—for Antioch from September 25, 2004, to July 27, 2015, were again converted to density of chlorophyll using the method described above for Hood. The Antioch data were assumed to provide a conservatively low chlorophyll *a* density compared to other available locations because of its proximity to areas that are intensively grazed by the overbite clam, so that the actual proportional entrainment is likely less than predicted using this method. The volume of the Delta upstream of Chipps Island—minus the Sacramento River upstream of Sutter Slough, in order to exclude the area approximately including and upstream of the NDD—is approximately 690,000 acre-feet, based on the Delta channel volumes that are used in the DSM2 model (see Table 5.2-1 in Section 5.2 of Jones & Stokes 2005). The total Delta-wide phytoplankton carbon biomass was estimated for each month of each year (2004 to 2015). From these data, the 5th, 50th (median), and 95th percentiles of the NDD entrained phytoplankton carbon estimates were calculated to characterize the variability in the data. Note that this method does not account for in-situ production that would replace some portion of the entrained phytoplankton, as well as less entrainment by the south Delta export facilities under the proposed action; these factors are discussed qualitatively in the impact analysis.

# 5D.13 Delta Smelt Selenium Bioaccumulation

Waterborne selenium concentrations and delta smelt tissue selenium concentrations were estimated for the modeled scenarios. DSM2 volumetric fingerprint estimates plus additional modeling and analyses were used to predict changes to waterborne and delta smelt tissue selenium concentrations resulting from water operations under the modeled scenarios.

## 5D.13.1 Selenium Concentrations in Water

Monthly-averaged DSM2 volumetric fingerprinting output for 1922 through 2015 was compiled for five locations, representative of fractional contributions of water of differing selenium concentrations: San Joaquin River at Prisoners Point, Cache Slough at Ryer Island, Sacramento River at Emmaton, San Joaquin River at Antioch, and Suisun Bay at Mallard Island. Each of the six source-water inputs below was assigned a selenium load based on historical data (Table 5D.13-1).

**Table 5D.13-1. Delta Water Source Inputs and Associated Selenium Concentrations**

| Source | Representation | Geometric Mean Se Concentration (µg/L) | Data Source |
|---|---|---|---|
| Delta agriculture | Agricultural drainage inflow | 0.11 | Lucas and Stewart 2007 |
| Sacramento River at Freeport | Inflow from the Sacramento River | 0.09 | U.S. Geological Survey 2014) |
| San Joaquin River at Mallard Island | Inflow from Calaveras, Cosumnes, Mokelumne | 0.10 | None (estimate) |
| Martinez/Suisun Bay | Inflow from Suisun Bay | 0.10 | San Francisco Estuary Institute 2014 |
| San Joaquin River at Vernalis | Inflow from the San Joaquin River | 0.22 | U.S. Geological Survey 2021 |
| Sacramento River at Knights Landing | Inflow from Yolo Bypass | 0.23 | California Department of Water Resources 2009 |

µg/L = micrograms per liter.

The geometric mean selenium concentrations for each of the six source water inputs were then multiplied by the fraction of that source water at each of the five DSM2 output locations to estimate monthly-averaged water selenium concentration for the modeled scenarios (Equation 1).

Equation 1: $C_{watermonthly} = [(I_1*C_1) + (I_2*C_2) + (I_3*C_3) + (I_4*C_4) + (I_5*C_5) + (I_6*C_6)]/100$

where:

$C_{watermonthly}$ = monthly mean selenium concentration in water (µg/L);

$I_{1\text{-}6}$ = modeled monthly inflow from each of the six sources of water to the Delta for each DSM2 output location (percentage);

$C_{1\text{-}6}$ = selenium concentration in water (µg/L) from each of the six inflow sources to the Delta.

Delta smelt whole-body selenium tissue concentrations were estimated using a bioaccumulation model developed for the Bay-Delta (Presser and Luoma 2013).

Equation 2: $C_{particulate} = C_{watermonthly}*K_d$

where:

$C_{particulate}$ = selenium concentration in particulate material in (µg/kilogram [kg], dry weight);

$C_{watermonthly}$ = selenium concentration in the water column (µg/L);

$K_d$ = selenium particulate to water ratio.

Total selenium water concentrations obtained from Equation 1 were converted to bioavailable particulate selenium using Equation 2. Particulate selenium includes selenium in detritus and phytoplankton. $K_d$ values for the estuary vary by flow, location and season, and can range from approximately 500 to 30,000. Two $K_d$ values, 3000 and 6000, were selected based on the observed means in Suisun Bay and the Delta to represent the range of particulate selenium conditions in delta smelt habitat (Presser and Luoma 2013:14).

## 5D.13.2 Selenium Concentrations in Biota

The concentrations of selenium accumulated into Delta Smelt tissue were estimated using $C_{particulate}$ calculated from Equation 2 and two trophic transfer factors (TTF) that represent a simplified food web linkage for delta smelt (Equation 3). Selenium accumulation from particulate matter ($C_{particulate}$) into prey items was represented by a TTF value for copepods (1.35; Presser and Luoma 2013:18). A second TTF value (1.1) represented the bioaccumulation of selenium from copepods into delta smelt tissue, consistent with the value assumed for fish by Presser and Luoma 2013:25). Delta smelt selenium tissue concentrations were estimated using the following equation:

Equation 3: $C_{smelt} = C_{particulate} * TTF_{copepod} * TTF_{fish}$

where:

$C_{smelt}$ = selenium concentration in particulate material in (µg/kg, dry weight);

$C_{particulate}$ = particulate selenium concentration in the water column (µg/L);

$TTF_{copepod}$= trophic transfer factor in copepods;

$TTF_{smelt}$ = trophic transfer factor in fish.

## 5D.13.3 Evaluation of Tissue Concentrations

Whole-body tissue concentrations were then compared to known effects thresholds available in scientific literature. Selenium effects thresholds for whole-body tissue concentrations are not available for delta smelt, or any closely related or trophically similar fish species. Whole-body tissue effect thresholds were available for Sacramento splittail (*Pogonichthys macrolepidotus*) deformities and rainbow trout (*Oncorhynchus mykiss*) growth. Delta smelt and splittail co-evolved, and co-occur, in the Delta ecosystem. Although trophically different, splittail $EC_{10}$ was selected to be nearer in relevance to delta smelt than rainbow trout for purposes of comparison. The $EC_{10}$ for splittail, 7.2 µg/gram (g), was the whole-body concentration that resulted in deformities in 10% of a juvenile test population fed a selenium-spiked diet, based on a conversion from 7.90 µg/g (95% confidence interval: 4.99–9.45 µg/g) muscle concentration (Rigby et al. 2010). Note that the analysis does not consider quantitatively incorporate uncertainty in the estimate of the $EC_{10}$ (e.g., by consideration of confidence intervals around the 7.2-µg/g threshold, or in the values of $K_d$), although there is qualitative discussion. Scatter and box plots were produced to summarize delta smelt tissue concentration data.

## 5D.13.4 Modeling Assumptions

The analysis of potential selenium effects to delta smelt makes the following assumptions.

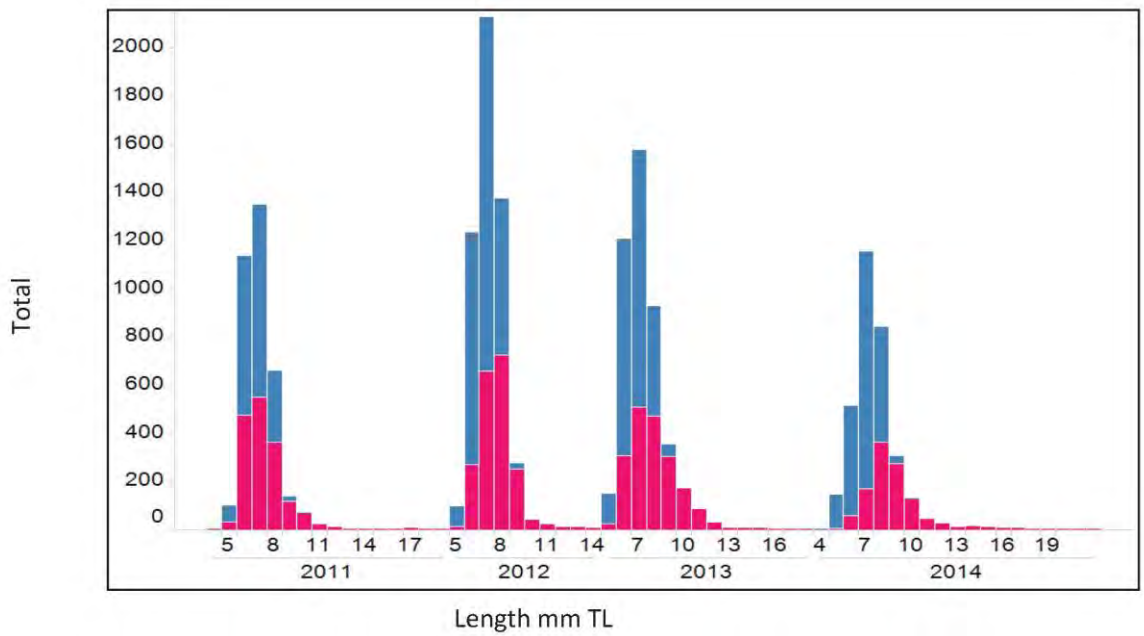
- DSM2 accurately represents future hydrodynamic conditions in the Delta.
- Selenium loading is linearly proportional to source water volume.
- Historical geometric mean selenium concentrations do not vary greatly with flow or season and are similar to inputs that will occur in the near-term future.
- Concentrations of selenium in phytoplankton can be estimated by $K_d$.
- Transfer of selenium from one trophic level to the next can be sufficiently represented by a constant (TTF).

- The $EC_{10}$ derived for Sacramento splittail (Rigby et al. 2010) is approximately the same for delta smelt.
- Whole-body tissue concentrations modeling at the five sites investigated presume that delta smelt and its prey occupy that site long enough to accumulate the environmental selenium present.

# 5D.14 Longfin Smelt Larval Entrainment (DSM2 Particle Tracking Model)

## 5D.14.1 Derivation of Larval Longfin Smelt Hatching Locations

The potential effect of the proposed action on entrainment in the Delta and Suisun Marsh was evaluated through a PTM of neutrally buoyant particles representing newly hatched larvae inserted at various locations in the Delta. The first step in the analysis involved determining appropriate weights for particle insertion points to reflect the hatching locations of larval longfin smelt. Injection points for comparisons of the scenarios were determined through examination of the spatial distributions of larvae observed in the Smelt Larva Survey (SLS) from 2009 to 2014. Data were obtained from the California Department of Fish and Wildlife website (California Department of Fish and Wildlife 2021). For most of this time period, the SLS generally included 5 to 6 surveys at 35 stations in the Delta and Suisun Marsh and Bay from January through March; stations 323 to 343 in the Napa River were added in 2014 but are not considered in the present analysis because the first few years had missing data for these locations. Data were filtered to include longfin smelt larvae ≤6-mm total length, which represents mostly newly hatched larvae, but includes some larvae up to 8 days old, assuming conservative hatch lengths as low of 4-mm standard length and growth rate up to ~0.25 mm/day (California Department of Fish and Game 2009b:9). Inspection of size distribution and presence of yolk-sacs of the larval longfin smelt catch from the SLS data suggest that most newly hatched larvae are around 6-mm total length (Figure 5D.14-1), which is consistent with the presumed range of 4- to 8-mm standard length (Wang 2007:34; California Department of Fish and Game 2009b).




Note: Larvae with yolk-sacs are represented by blue bars. The California Department of Fish and Game did not distinguish yolk sac larvae in 2009 and 2010.

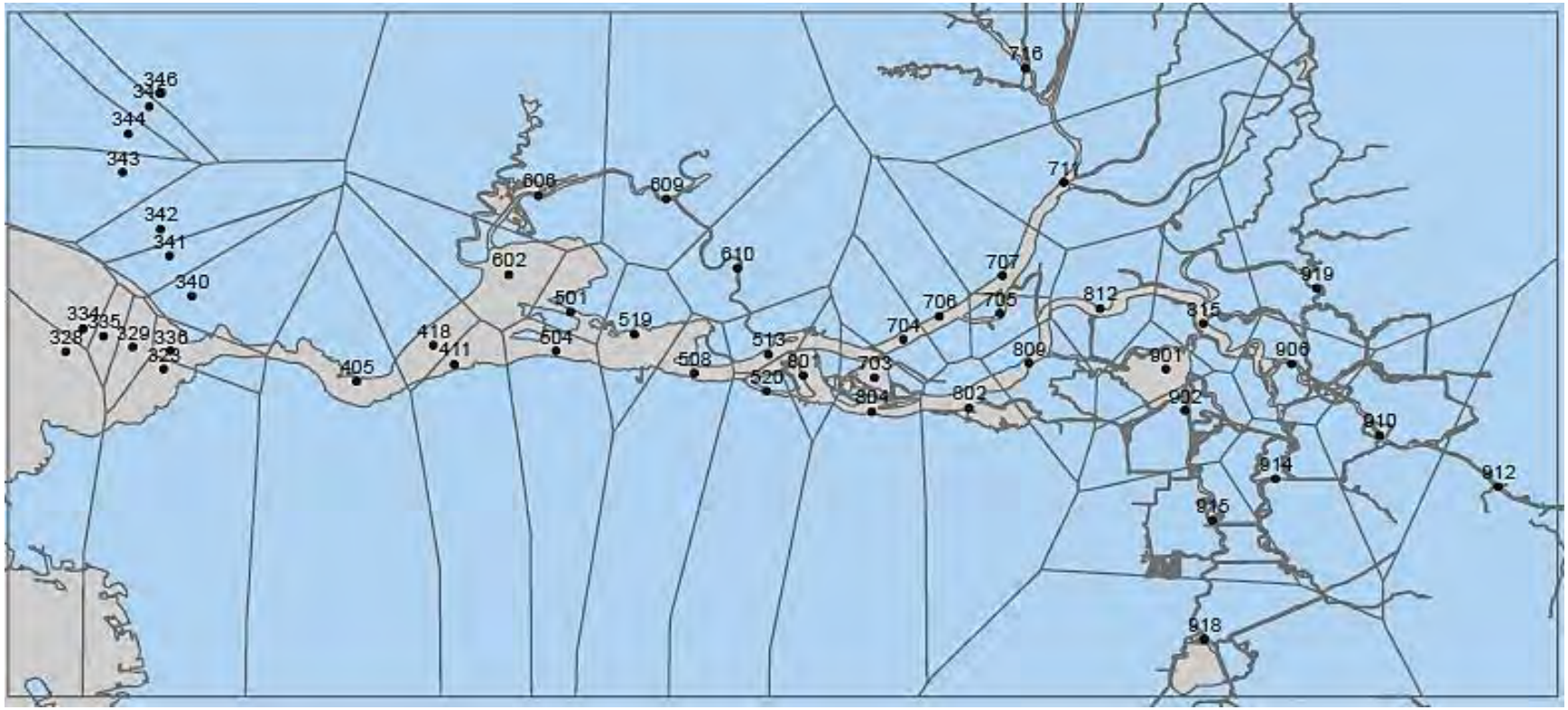
**Figure 5D.14-1. Length-Frequency Histogram of Longfin Smelt Larvae Collected in the Smelt Larvae Survey**

The density of larvae (≤ 6-mm total length) per cubic meter sampled at each station was calculated as:

$$\text{Density} = \text{Number of larvae}/(0.37*(26873+99999)*\text{Net meter reading}),$$

where the conversion factor derives from calibration of the net flow meter used during SLS sampling.

The SLS includes a subset of the stations that are used for the March through June 20-mm Survey for larval/juvenile delta smelt. Saha (2008) estimated the areas and volumes that each of the 20-mm Survey stations represents within the Delta and Suisun Marsh and Bay using a Voronoi diagram (Figure 5D.14-2). There is a station (723) that was not part of the 20-mm Survey when Saha (2008) made the area and volume calculations; this station is close to station 716, so the area and volume represented by station 716 were halved for the present analysis, with the other half being considered to be the area and volume represented by station 723 (Table 5D.14-1).




Source: Saha 2008.

**Figure 5D.14-2. Division of the Delta and Suisun Marsh and Bay Around 20-mm Survey Stations with a Voronoi Diagram**

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**Table 5D.14-1. Area and Volume Represented by Smelt Larvae Survey Stations**

| Station | Area (acre) | Volume (acre-feet) | Area (square meters) | Volume (cubic meters) |
|---|---|---|---|---|
| 405 | 3,547 | 139,804 | 14,354,198 | 172,445,718 |
| 411 | 2,119 | 37,344 | 8,575,288 | 46,063,152 |
| 418 | 2,756 | 63,186 | 11,153,135 | 77,938,794 |
| 501 | 3,692 | 36,856 | 14,940,992 | 45,461,213 |
| 504 | 2,403 | 44,046 | 9,724,595 | 54,329,948 |
| 508 | 2,296 | 53,344 | 9,291,581 | 65,798,864 |
| 513 | 1,703 | 41,921 | 6,891,796 | 51,708,799 |
| 519 | 4,101 | 67,942 | 16,596,156 | 83,805,234 |
| 520 | 438 | 12,130 | 1,772,523 | 14,962,137 |
| 602 | 7,361 | 72,852 | 29,788,907 | 89,861,631 |
| 606 | 1,332 | 17,685 | 5,390,412 | 21,814,129 |
| 609 | 727 | 8,114 | 2,942,064 | 10,008,473 |
| 610 | 259 | 3,156 | 1,048,136 | 3,892,869 |
| 703 | 2,091 | 25,853 | 8,461,976 | 31,889,210 |
| 704 | 605 | 15,952 | 2,448,348 | 19,676,505 |
| 705 | 277 | 3,741 | 1,120,979 | 4,614,456 |
| 706 | 931 | 24,539 | 3,767,623 | 30,268,415 |
| 707 | 1,859 | 37,076 | 7,523,105 | 45,732,579 |
| 711 | 1,994 | 39,391 | 8,069,431 | 48,588,089 |
| 716* | 3,110 | 51,796 | 12,583,699 | 63,889,434 |
| 723* | 3,110 | 51,796 | 12,583,699 | 63,889,434 |
| 801 | 2,226 | 45,662 | 9,008,301 | 56,323,255 |
| 802 | 3,546 | 45,094 | 14,350,151 | 55,622,637 |
| 804 | 1,195 | 32,119 | 4,835,993 | 39,618,208 |
| 809 | 1,392 | 33,562 | 5,633,224 | 41,398,123 |
| 812 | 1,767 | 43,810 | 7,150,795 | 54,038,846 |
| 815 | 4023 | 72053 | 16,280,502 | 88,876,079 |
| 901 | 3,822 | 33,855 | 15,467,084 | 41,759,533 |
| 902 | 1,744 | 22,095 | 7,057,717 | 27,253,785 |
| 906 | 1,780 | 32,694 | 7,203,404 | 40,327,461 |
| 910 | 1,925 | 25,760 | 7,790,198 | 31,774,496 |
| 912 | 1,225 | 13,747 | 4,957,399 | 16,956,677 |
| 914 | 1,554 | 23,552 | 6,288,814 | 29,050,968 |
| 915 | 1,146 | 13,302 | 4,637,697 | 16,407,778 |
| 918 | 1601 | 14,685 | 6,479,016 | 18,113,683 |
| 919 | 2,043 | 20,702 | 8,267,727 | 25,535,544 |

The total number of longfin smelt larvae ≤6 mm in the volume of water represented by each station (Table 5D.14-1) was calculated by multiplying the density of larvae by the volume of each station.[5] The proportion of larvae in the volume of water represented by each SLS station was calculated for each survey as the number of larvae per station divided by the total sum of larvae across all stations (Table 5D.14-2).

There was little evidence that the general distribution of longfin smelt larvae from the SLS varied by year in relation to hydrological conditions, at least for the groups of stations examined herein (Table 5D.14-3).[6] Therefore, an overall mean distribution was used to weigh the results of the DSM2-PTM analysis, based on the mean proportion by station from all surveys from 2009 through 2014.

## 5D.14.2 DSM2-Particle Tracking Modeling Runs

Ninety-day-long DSM2-PTM runs were undertaken for the modeled scenarios at 39 particle injection locations in the Delta and Suisun Marsh and Bay (Table 5D.14-4) during January, February, and March in 1923–2015. The particle injection locations were chosen to provide a representative variety of locations generally associated with SLS stations, with particular emphasis on the Delta. For each run, 4,000 neutrally buoyant passive particles were injected evenly every hour (i.e., about 160 particles per hour) over a 24.75-hour period at the beginning of the month. The fate of the particles was output at ninety days. For consistency with the analysis conducted by CDFG (2009a), runs were also undertaken with surface (top 10% of water column) orientation of particles.

Particle tracking runs were done for 39 particle injection locations in the Delta and Suisun Marsh and Bay (Table 5D.14-4) during January, February, and March. The particle injection locations were chosen to provide a representative variety of locations generally associated with SLS stations, with particular emphasis on the Delta. For each run, 4,000 neutrally buoyant passive particles were injected evenly every hour (i.e., about 160 particles per hour) over a 24.75-hour period at the beginning of the month. For consistency with the analysis conducted by CDFG (2009a), runs were also undertaken with surface (top 10% of water column) orientation of particles.

[5] For reference, the overall estimated number of larvae across all stations ranged from around 600,000 (survey 6 in 2014) to around 160,000,000 (survey 4 in 2009). Dividing these estimates by fecundity of 7,500 (California Department of Fish and Game 2009b: Figure 3) for a 2-year-old female and multiplying by 2 (under the assumption of a 1:1 sex ratio) gives an estimate of adult Longfin Smelt abundance, assuming 100% survival from eggs to larvae. Applying 10%, 50%, and 90% survival from eggs to larvae gives estimates of adult population size of around 500–2,300 (survey 6 in 2014) to 130,000–650,000 (survey 4 in 2009). These estimates bracket the "tens of thousands" of adults suggested by Newman (pers. comm. to California Department of Fish and Game 2009b), perhaps providing some indication that the numbers are of a reasonable order of magnitude for the purposes of the present analysis. Note, however, that the analysis is not dependent on absolute numbers of larvae to be accurately represented, as gear efficiency for smaller stages would need to be refined.

[6] This does not preclude the possibility of a considerable proportion of the population occurring downstream of the SLS sampling area during wet years, for example.

**Table 5D.14-2. Volume-Weighted Proportion of Longfin Smelt Larvae ≤6 mm By Station, 2009–2014**

| Year | Survey | 405 | 411 | 418 | 501 | 504 | 508 | 513 | 519 | 520 | 602 | 606 | 609 | 610 | 703 | 704 | 705 | 706 | 707 | 711 | 716 | 723 | 801 | 804 | 809 | 812 | 815 | 901 | 902 | 906 | 910 | 912 | 914 | 915 | 918 | 919 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2009 | 1 | 0.0466 | 0.0000 | 0.0000 | 0.0118 | 0.0000 | 0.0151 | 0.2600 | 0.0217 | 0.0079 | 0.0000 | 0.0164 | 0.0000 | 0.0000 | 0.0164 | 0.0173 | 0.0104 | 0.2071 | 0.0365 | 0.0504 | 0.0161 | 0.0470 | 0.1693 | 0.0089 | 0.0193 | 0.0000 | 0.0000 | 0.0110 | 0.0000 | 0.0106 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2009 | 2 | 0.0000 | 0.0000 | 0.0000 | 0.0034 | 0.0000 | 0.1338 | 0.0993 | 0.0057 | 0.0227 | 0.0142 | 0.0015 | 0.0014 | 0.0033 | 0.0144 | 0.0771 | 0.0221 | 0.0779 | 0.2020 | 0.0296 | 0.0254 | 0.0045 | 0.0437 | 0.0848 | 0.0651 | 0.0150 | 0.0179 | 0.0324 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0027 | 0.0000 | 0.0000 |
| 2009 | 3 | 0.0000 | 0.0000 | 0.0000 | 0.0035 | 0.0021 | 0.0479 | 0.0019 | 0.0099 | 0.0099 | 0.0029 | 0.0083 | 0.0037 | 0.0009 | 0.0774 | 0.0369 | 0.0125 | 0.1055 | 0.1392 | 0.0355 | 0.1416 | 0.1250 | 0.0784 | 0.0316 | 0.0437 | 0.0632 | 0.0124 | 0.0056 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0006 | 0.0000 | 0.0000 |
| 2009 | 4 | 0.1055 | 0.0222 | 0.0320 | 0.0052 | 0.0016 | 0.0773 | 0.2536 | 0.0267 | 0.0164 | 0.0827 | 0.0007 | 0.0013 | 0.0005 | 0.0126 | 0.0231 | 0.0027 | 0.0101 | 0.0309 | 0.0000 | 0.0305 | 0.0302 | 0.1554 | 0.0467 | 0.0209 | 0.0016 | 0.0028 | 0.0050 | 0.0008 | 0.0000 | 0.0000 | 0.0000 | 0.0008 | 0.0005 | 0.0000 | 0.0000 |
| 2009 | 5 | 0.0152 | 0.0190 | 0.0447 | 0.1238 | 0.0582 | 0.2174 | 0.1067 | 0.0734 | 0.0199 | 0.0931 | 0.0095 | 0.0012 | 0.0002 | 0.0129 | 0.0052 | 0.0015 | 0.0062 | 0.0139 | 0.0000 | 0.0178 | 0.0185 | 0.0587 | 0.0543 | 0.0047 | 0.0084 | 0.0064 | 0.0090 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2010 | 1 | 0.0130 | 0.0118 | 0.0218 | 0.0429 | 0.0161 | 0.1210 | 0.0807 | 0.0456 | 0.0451 | 0.0300 | 0.0000 | 0.0014 | 0.0006 | 0.0048 | 0.0105 | 0.0078 | 0.0526 | 0.1396 | 0.0035 | 0.0639 | 0.0745 | 0.0257 | 0.0383 | 0.0734 | 0.0421 | 0.0000 | 0.0272 | 0.0038 | 0.0000 | 0.0000 | 0.0000 | 0.0021 | 0.0000 | 0.0000 | 0.0000 |
| 2010 | 4 | 0.0506 | 0.0167 | 0.0480 | 0.0663 | 0.1274 | 0.0574 | 0.0304 | 0.0226 | 0.0283 | 0.0371 | 0.0000 | 0.0019 | 0.0033 | 0.0086 | 0.0753 | 0.0031 | 0.0841 | 0.1396 | 0.0038 | 0.0225 | 0.0094 | 0.0457 | 0.0631 | 0.0208 | 0.0095 | 0.0133 | 0.0097 | 0.0019 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2010 | 5 | 0.0670 | 0.1457 | 0.0848 | 0.1239 | 0.0744 | 0.0428 | 0.0147 | 0.0515 | 0.0162 | 0.0436 | 0.0000 | 0.0011 | 0.0000 | 0.0280 | 0.0164 | 0.0038 | 0.0361 | 0.0436 | 0.0106 | 0.0197 | 0.0534 | 0.0400 | 0.0274 | 0.0283 | 0.0175 | 0.0000 | 0.0071 | 0.0016 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0011 | 0.0000 |
| 2010 | 6 | 0.0171 | 0.0000 | 0.0000 | 0.0000 | 0.0106 | 0.1488 | 0.3585 | 0.0163 | 0.0095 | 0.0103 | 0.0095 | 0.0000 | 0.0005 | 0.0143 | 0.0479 | 0.0000 | 0.1063 | 0.0431 | 0.0167 | 0.0220 | 0.1016 | 0.0112 | 0.0161 | 0.0120 | 0.0138 | 0.0000 | 0.0088 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0022 | 0.0000 | 0.0029 |
| 2011 | 1 | 0.0130 | 0.0110 | 0.0187 | 0.0146 | 0.0212 | 0.1665 | 0.0837 | 0.2172 | 0.0349 | 0.0542 | 0.0204 | 0.0008 | 0.0006 | 0.0159 | 0.0576 | 0.0030 | 0.0682 | 0.1289 | 0.0000 | 0.0096 | 0.0102 | 0.0034 | 0.0278 | 0.0186 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2011 | 2 | 0.0336 | 0.0024 | 0.0307 | 0.0287 | 0.0181 | 0.0758 | 0.0363 | 0.0819 | 0.0251 | 0.0191 | 0.0053 | 0.0005 | 0.0044 | 0.0029 | 0.0314 | 0.0042 | 0.0487 | 0.0846 | 0.0193 | 0.0785 | 0.1454 | 0.0624 | 0.0531 | 0.0296 | 0.0137 | 0.0134 | 0.0490 | 0.0013 | 0.0000 | 0.0000 | 0.0008 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2011 | 3 | 0.0000 | 0.0079 | 0.0062 | 0.0150 | 0.0301 | 0.0522 | 0.0043 | 0.0143 | 0.0067 | 0.0000 | 0.0000 | 0.0009 | 0.0010 | 0.0725 | 0.0207 | 0.0069 | 0.0611 | 0.1476 | 0.0775 | 0.2083 | 0.1842 | 0.0000 | 0.0228 | 0.0259 | 0.0190 | 0.0075 | 0.0075 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2011 | 4 | 0.0000 | 0.0038 | 0.0000 | 0.0916 | 0.1170 | 0.2984 | 0.0612 | 0.0802 | 0.0198 | 0.0184 | 0.0000 | 0.0000 | 0.0005 | 0.0113 | 0.0252 | 0.0030 | 0.0097 | 0.1250 | 0.0144 | 0.0057 | 0.0846 | 0.0128 | 0.0044 | 0.0000 | 0.0050 | 0.0000 | 0.0049 | 0.0031 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2011 | 5 | 0.2285 | 0.0972 | 0.0192 | 0.0641 | 0.1032 | 0.0171 | 0.0000 | 0.0814 | 0.0078 | 0.2402 | 0.0000 | 0.0000 | 0.0009 | 0.0236 | 0.0183 | 0.0012 | 0.0000 | 0.0000 | 0.0124 | 0.0000 | 0.0289 | 0.0000 | 0.0100 | 0.0096 | 0.0259 | 0.0000 | 0.0106 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2012 | 1 | 0.0000 | 0.0000 | 0.0127 | 0.0206 | 0.0000 | 0.1460 | 0.1212 | 0.0000 | 0.0075 | 0.0282 | 0.0017 | 0.0022 | 0.0000 | 0.0224 | 0.0130 | 0.0028 | 0.0766 | 0.1361 | 0.0000 | 0.1099 | 0.1076 | 0.0275 | 0.0437 | 0.0819 | 0.0196 | 0.0189 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2012 | 2 | 0.2521 | 0.0066 | 0.0415 | 0.0310 | 0.0193 | 0.0884 | 0.0153 | 0.0077 | 0.0072 | 0.0519 | 0.0029 | 0.0010 | 0.0009 | 0.0301 | 0.0301 | 0.0011 | 0.0460 | 0.0765 | 0.0000 | 0.0543 | 0.0935 | 0.0384 | 0.0047 | 0.0355 | 0.0373 | 0.0000 | 0.0203 | 0.0035 | 0.0019 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0012 |
| 2012 | 3 | 0.0000 | 0.0000 | 0.0143 | 0.0081 | 0.0000 | 0.1628 | 0.0815 | 0.0082 | 0.0225 | 0.0258 | 0.0000 | 0.0009 | 0.0024 | 0.0026 | 0.0182 | 0.0024 | 0.0551 | 0.1591 | 0.0164 | 0.1159 | 0.1445 | 0.0047 | 0.0522 | 0.0050 | 0.0373 | 0.0508 | 0.0095 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2012 | 4 | 0.0593 | 0.0053 | 0.0236 | 0.0390 | 0.0248 | 0.0813 | 0.0322 | 0.1418 | 0.0230 | 0.0000 | 0.0000 | 0.0011 | 0.0000 | 0.0099 | 0.0250 | 0.0015 | 0.0829 | 0.1637 | 0.0168 | 0.0388 | 0.1124 | 0.0754 | 0.0192 | 0.0043 | 0.0000 | 0.0000 | 0.0102 | 0.0063 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0019 | 0.0000 |
| 2012 | 6 | 0.0894 | 0.0469 | 0.0522 | 0.0211 | 0.2308 | 0.1499 | 0.0583 | 0.0204 | 0.0683 | 0.1683 | 0.0000 | 0.0000 | 0.0048 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0151 | 0.0000 | 0.0392 | 0.0082 | 0.0000 | 0.0274 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2013 | 1 | 0.1422 | 0.0980 | 0.0000 | 0.0635 | 0.1968 | 0.0000 | 0.2731 | 0.0000 | 0.0000 | 0.1031 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0078 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0208 | 0.0000 | 0.0141 | 0.0192 | 0.0000 | 0.0614 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2013 | 2 | 0.0124 | 0.0147 | 0.1148 | 0.0597 | 0.0858 | 0.0918 | 0.0308 | 0.1344 | 0.0087 | 0.1266 | 0.0000 | 0.0000 | 0.0000 | 0.0330 | 0.0013 | 0.0009 | 0.0704 | 0.0787 | 0.0034 | 0.0423 | 0.0280 | 0.0224 | 0.0202 | 0.0117 | 0.0000 | 0.0000 | 0.0079 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2013 | 3 | 0.0440 | 0.0000 | 0.0713 | 0.0527 | 0.0554 | 0.0301 | 0.0232 | 0.0568 | 0.0187 | 0.0499 | 0.0000 | 0.0000 | 0.0000 | 0.0514 | 0.0289 | 0.0037 | 0.0223 | 0.0807 | 0.0462 | 0.0927 | 0.1084 | 0.0435 | 0.0099 | 0.0472 | 0.0098 | 0.0164 | 0.0348 | 0.0000 | 0.0018 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2013 | 4 | 0.0000 | 0.0548 | 0.0103 | 0.0188 | 0.0253 | 0.0369 | 0.0194 | 0.0912 | 0.0116 | 0.0510 | 0.0000 | 0.0000 | 0.0000 | 0.0045 | 0.0296 | 0.0035 | 0.0585 | 0.1107 | 0.0934 | 0.1044 | 0.1985 | 0.0276 | 0.0201 | 0.0110 | 0.0036 | 0.0000 | 0.0134 | 0.0017 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2013 | 5 | 0.0689 | 0.0000 | 0.0506 | 0.0253 | 0.0280 | 0.1278 | 0.0172 | 0.0957 | 0.0245 | 0.0084 | 0.0000 | 0.0000 | 0.0000 | 0.0083 | 0.0134 | 0.0029 | 0.0422 | 0.1206 | 0.0498 | 0.0531 | 0.1243 | 0.0666 | 0.0384 | 0.0192 | 0.0115 | 0.0000 | 0.0034 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2013 | 6 | 0.0000 | 0.0680 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.1270 | 0.0000 | 0.0550 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0411 | 0.0000 | 0.0000 | 0.3130 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.3286 | 0.0000 | 0.0000 | 0.0000 | 0.0673 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2014 | 1 | 0.0000 | 0.0000 | 0.0190 | 0.0094 | 0.0000 | 0.2113 | 0.2272 | 0.0000 | 0.0332 | 0.0382 | 0.0053 | 0.0022 | 0.0100 | 0.0320 | 0.0287 | 0.0008 | 0.0131 | 0.0197 | 0.0276 | 0.0126 | 0.0259 | 0.0814 | 0.0425 | 0.0773 | 0.0467 | 0.0175 | 0.0183 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2014 | 2 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0494 | 0.0598 | 0.0291 | 0.0171 | 0.0373 | 0.0020 | 0.0009 | 0.0007 | 0.0137 | 0.0079 | 0.0021 | 0.0095 | 0.0501 | 0.0446 | 0.2024 | 0.2176 | 0.0570 | 0.0096 | 0.0156 | 0.1374 | 0.0143 | 0.0162 | 0.0057 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2014 | 3 | 0.0000 | 0.0168 | 0.0415 | 0.0223 | 0.0137 | 0.0434 | 0.0381 | 0.0462 | 0.0159 | 0.0413 | 0.0000 | 0.0042 | 0.0000 | 0.0148 | 0.0024 | 0.0046 | 0.0042 | 0.0230 | 0.0367 | 0.2676 | 0.1165 | 0.1119 | 0.0160 | 0.0664 | 0.0324 | 0.0000 | 0.0201 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2014 | 4 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0098 | 0.0124 | 0.0606 | 0.1058 | 0.0194 | 0.0000 | 0.0000 | 0.0018 | 0.0014 | 0.0208 | 0.0358 | 0.0000 | 0.0762 | 0.1184 | 0.0000 | 0.0980 | 0.2803 | 0.1038 | 0.0000 | 0.0280 | 0.0207 | 0.0000 | 0.0070 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2014 | 5 | 0.0000 | 0.0000 | 0.2679 | 0.0000 | 0.1638 | 0.0460 | 0.0423 | 0.0652 | 0.0338 | 0.0000 | 0.0000 | 0.0000 | 0.0105 | 0.0000 | 0.0000 | 0.0000 | 0.0221 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0900 | 0.1203 | 0.0316 | 0.0391 | 0.0000 | 0.0673 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2014 | 6 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.3797 | 0.0000 | 0.0000 | 0.0000 | 0.1078 | 0.0000 | 0.0000 | 0.0000 | 0.0338 | 0.0000 | 0.0000 | 0.0000 | 0.4788 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

Note: Surveys 2 and 3 in 2010 and 5 in 2012 had missing data and were excluded from the analysis.

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**Table 5D.14-3. Mean Proportion of Longfin Smelt Larvae in Each Group of Smelt Larvae Survey Stations**

| Year | Mean December–March Delta Outflow (cfs) | 400s | 500s | 600s | 700s | 800s | 900s |
|---|---|---|---|---|---|---|---|
| 2009 | 13,808 | 0.06 | 0.33 | 0.05 | 0.35 | 0.20 | 0.02 |
| 2010 | 19,863 | 0.12 | 0.39 | 0.03 | 0.32 | 0.12 | 0.02 |
| 2011 | 55,663 | 0.09 | 0.37 | 0.07 | 0.37 | 0.07 | 0.02 |
| 2012 | 11,946 | 0.12 | 0.33 | 0.06 | 0.36 | 0.13 | 0.01 |
| 2013 | 23,600 | 0.13 | 0.31 | 0.06 | 0.35 | 0.13 | 0.03 |
| 2014 | 8,331 | 0.06 | 0.31 | 0.03 | 0.38 | 0.19 | 0.02 |
| Mean | – | 0.09 | 0.34 | 0.05 | 0.36 | 0.14 | 0.02 |

cfs = cubic feet per second.

Each particle injection location was assigned to one or more SLS stations, and some SLS stations had multiple particle injection locations assigned to them, reflecting the relative distribution of the nearest SLS station to particle injection locations (e.g., station 919 had five injection locations assigned to it, whereas station 901 had one injection location assigned to it; Table 5D.14-4). The weight assigned to the particles injected at each PTM injection location reflected the mean proportion of larvae captured at the associated SLS station (Table 5D.14-2) divided by the number of injection locations at a given station. As an example, station 707 was assigned two particle injection locations: Threemile Slough (location no. 15) and Sacramento River at Rio Vista (location no. 31) (Table 5D.14-4). The overall mean proportion of larval longfin smelt at station 707 across all surveys in 2009–2014 was 0.078 (mean of values in the 707 column of Table 5D.14-2). This 0.078 (i.e., 7.8% of larvae) was then divided equally among the two particle injection locations assigned to SLS station 707, giving a weight of 0.039 (i.e., 3.9% of larvae) for the particles injected at both locations (Table 5D.14-4). Professional judgement was used to assign representative weights in situations where a broader area needed to be represented by relatively few stations in the geographic vicinity (i.e., Cache Slough Complex stations 22–26 represented by SLS stations 716 and 713).

**Table 5D.14-4. Particle Injection Locations, Associated Smelt Larvae Survey Stations, and Location Weight for the DSM2-PTM Analysis of Potential Larval Longfin Smelt Entrainment**

| PTM Injection Location Number | PTM Injection Location Name | SLS Station | Weight |
|---|---|---|---|
| 1 | San Joaquin River at Vernalis | 912 | 0.000014 |
| 2 | San Joaquin River at Mossdale | 912 | 0.000014 |
| 3 | San Joaquin River d/s of Rough and Ready Island | 910 | 0.000000 |
| 4 | San Joaquin River at Buckley Cove | 910 | 0.000000 |
| 5 | San Joaquin River near Medford Island | 906 | 0.000463 |
| 6 | San Joaquin River at Potato Slough | 815 | 0.003088 |
| 7 | San Joaquin River at Twitchell Island | 812 | 0.021832 |
| 8 | Old River near Victoria Canal | 918 | 0.000032 |
| 9 | Old River at Railroad Cut | 915 | 0.000191 |

| PTM Injection Location Number | PTM Injection Location Name | SLS Station | Weight |
|---|---|---|---|
| 10 | Old River near Quimby Island | 902 | 0.000957 |
| 11 | Middle River at Victoria Canal | 918 | 0.000032 |
| 12 | Middle River u/s of Mildred Island | 914 | 0.000094 |
| 13 | Grant Line Canal | 918 | 0.000032 |
| 14 | Frank's Tract East | 901 | 0.017578 |
| 15 | Threemile Slough | 707 | 0.038899 |
| 16 | Little Potato Slough | 919 | 0.000026 |
| 17 | Mokelumne River d/s of Cosumnes confluence | 919 | 0.000026 |
| 18 | South Fork Mokelumne | 919 | 0.000026 |
| 19 | Mokelumne River d/s of Georgiana confluence | 815 | 0.003088 |
| 20 | North Fork Mokelumne | 919 | 0.000026 |
| 21 | Georgiana Slough | 919 | 0.000026 |
| 22 | Miner Slough | 716+723 | 0.028025 |
| 23 | Sacramento Deep Water Ship Channel | 716+723 | 0.028025 |
| 24 | Cache Slough at Shag Slough | 716+723 | 0.028025 |
| 25 | Cache Slough at Liberty Island | 716+723 | 0.028025 |
| 26 | Cache Slough near Lindsey Slough | 716+723 | 0.028025 |
| 27 | Sacramento River at Sacramento | upstream | 0.000000 |
| 28 | Sacramento River at Sutter Slough | upstream | 0.000000 |
| 29 | Sacramento River at Ryde | 711 | 0.009815 |
| 30 | Sacramento River near Cache Slough confluence | 711 | 0.009815 |
| 31 | Sacramento River at Rio Vista | 707 | 0.038899 |
| 32 | Sacramento River d/s of Decker Island | 705+706 | 0.075899 |
| 33 | Sacramento River at Sherman Lake | 704 | 0.022743 |
| 34 | Sacramento River at Port Chicago | downstream | 0.000000 |
| 35 | Montezuma Slough near National Steel | downstream | 0.000000 |
| 36 | Montezuma Slough at Suisun Slough | downstream | 0.000000 |
| 37 | San Joaquin River d/s of Dutch Slough | 703+804 | 0.058814 |
| 38 | Sacramento River at Pittsburg | 801 | 0.048938 |
| 39 | San Joaquin River near Jersey Point | 809 | 0.026464 |

Note: See https://data.cnra.ca.gov/dataset/dsm2-georeferenced-model-grid for locations of DSM2 model nodes.
d/s = downstream; PTM = Particle Tracking Modeling; SLS = Smelt Larvae Survey; u/s = upstream.

SLS stations downstream of the Sacramento–San Joaquin River confluence (i.e., stations numbered 400s to 600s) were considered to be downstream of the influence of the SWP/CVP export facilities, and so were not included in the PTM analysis (but were used in the calculation of proportions; see Table 5D.14-2). Similarly, PTM injection locations downstream of the confluence were assigned zero

weight,7 because these particles would not be susceptible to entrainment at the locations of interest. In addition, particles injected in the Sacramento River at Sacramento and Sutter Slough were assigned zero weight because they are upstream of the range of the SLS (suggesting that this portion of the river is of minor concern for longfin smelt management). The summed weight of all the PTM injection locations in the analysis was 0.52, reflecting that 0.48 of the larval population was assumed to be downstream of the confluence and therefore not susceptible to entrainment in the Delta (see sum of the 400s, 500s, and 600s stations in Table 5D.14-4). As discussed further in Section 5D.14.3, *Note on Proportion of Larval Population outside the Delta and Suisun Marsh and Bay*, the spatial extent of the SLS data used in the present analysis includes only the Delta and Suisun Marsh and Bay, but the full extent of the distribution of larval longfin smelt may be considerably greater in wet years.

For each simulated month in the DSM2-PTM analysis, the percentage of particles from each particle injection location was output for several fates: entrainment (the SWP's Clifton Court Forebay, the CVP's Jones Pumping Plant, and the NBA Barker Slough Pumping Plant), and passing Chipps Island. These percentages were multiplied by the weight for each particle injection location (Table 5D.14-4), and then summed across all injection locations to give a relative comparison of the overall percentage of larvae that would have been entrained the modeled scenarios. Note that these percentages are not intended to represent an absolute estimate of the actual percentage of larvae that would be entrained and should be interpreted only as comparisons of operational scenarios. The latest version of DSM2-PTM allows the user to not allow particles to be entrained into small agricultural diversions; this option was used for the present analysis in order to represent the hypothesis that such losses may not be substantial for longfin smelt (based on observations for delta smelt (Nobriga et al. 2004) and because losses at agricultural diversions were not the focus of the present analysis. In addition to reporting of the above fates, the percentage of particles remaining in the DSM2-PTM modeling domain (i.e., neither entrained nor having left the domain) was also calculated.

## 5D.14.3 Note on Proportion of Larval Population outside the Delta and Suisun Marsh and Bay

The spatial distribution of newly hatched larvae determined from the SLS is likely much broader than observed during wet years. Grimaldo et al. (2017) showed that larval longfin smelt are hatching in shallow water and tidal marsh habitats in salinities up to 8 parts per thousand. Previously thought to concentrate spawning in freshwater (Rosenfield and Baxter 2007; California Department of Fish and Game 2009a, 2009b; Kimmerer et al. 2009), the analysis presented here and work by Grimaldo et al. (2017) shows that longfin smelt hatching is broadly distributed throughout Suisun Bay in most years (Table 5D.14-2). The proportion of newly hatched larvae from Delta stations was consistently lower than densities observed in Suisun Bay. Further, because overall larval longfin smelt abundance in the SLS is lowest during wet years, it is likely that spawning and hatching is occurring in San Pablo Bay and adjacent tributaries (e.g., Napa River, Petaluma River) when the area becomes suitable for spawning. Ultimately, this does not affect interpretation of results presented here because relative comparisons of the operational scenarios were made using data for observations of larvae.

[7] PTM results for injection locations assigned zero weight are available upon request.

## 5D.14.4 Results

Results for south Delta exports are discussed in Appendix 6C. Results for NBA are shown in Table 5D.14-5 and Table 5D.14-6.

**Table 5D.14-5. Percentage of Neutrally Buoyant Particles That Were Entrained over 90 Days into North Bay Aqueduct, Weighted by Longfin Smelt Larval Distribution**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 0.39 | 0.40 (1%) |
| January | Above normal | 0.43 | 0.44 (2%) |
| January | Below normal | 0.42 | 0.44 (6%) |
| January | Dry | 0.52 | 0.53 (2%) |
| January | Critical | 0.23 | 0.24 (3%) |
| February | Wet | 0.36 | 0.36 (1%) |
| February | Above normal | 0.40 | 0.40 (1%) |
| February | Below normal | 0.36 | 0.37 (3%) |
| February | Dry | 0.29 | 0.30 (2%) |
| February | Critical | 0.15 | 0.15 (1%) |
| March | Wet | 0.19 | 0.19 (1%) |
| March | Above normal | 0.20 | 0.21 (4%) |
| March | Below normal | 0.26 | 0.27 (3%) |
| March | Dry | 0.24 | 0.25 (4%) |
| March | Critical | 0.17 | 0.18 (7%) |

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions.

**Table 5D.14-6. Percentage of Surface-Oriented Particles That Were Entrained over 90 Days into North Bay Aqueduct, Weighted by Longfin Smelt Larval Distribution**

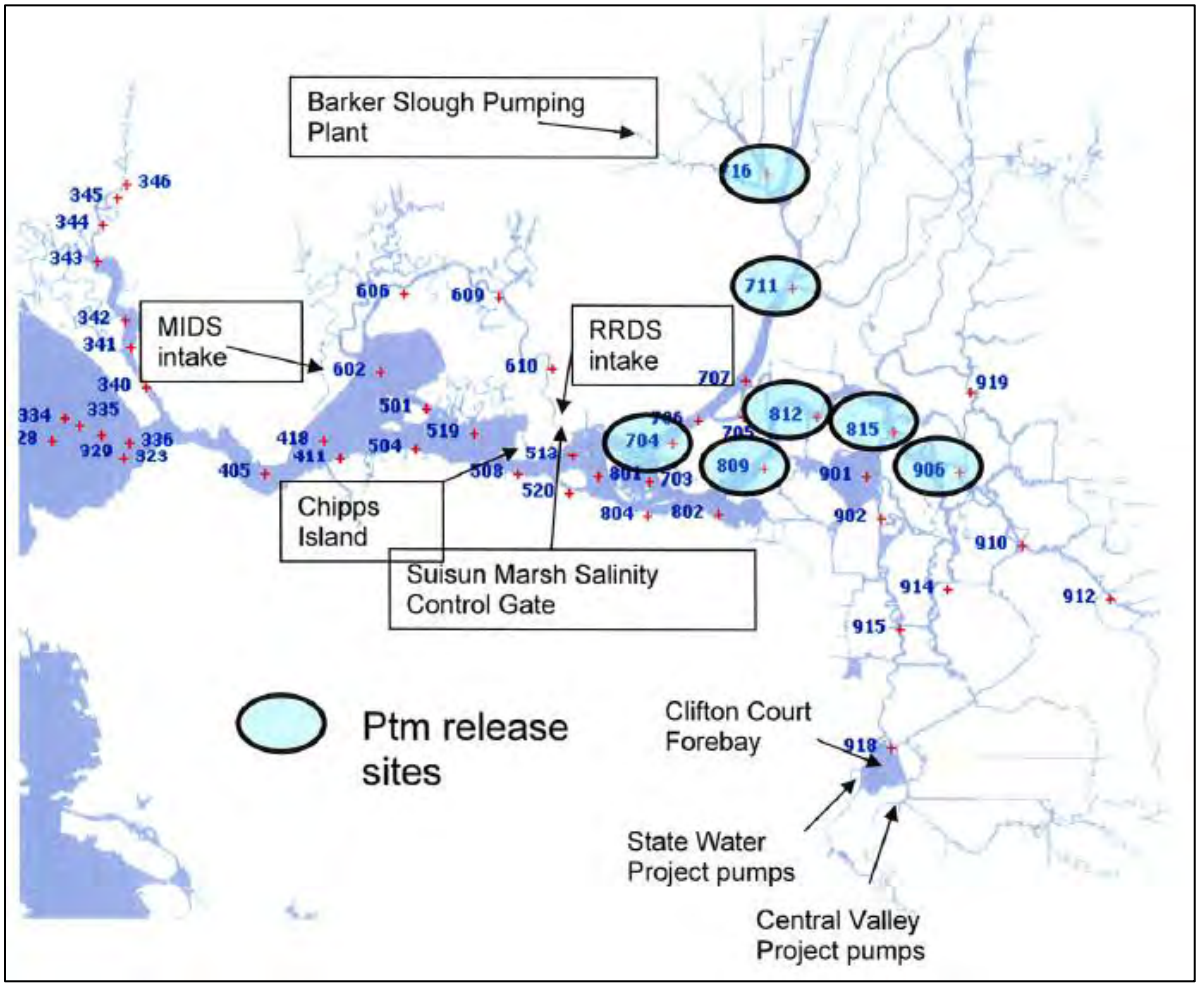
| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 0.39 | 0.40 (1%) |
| January | Above normal | 0.43 | 0.44 (3%) |
| January | Below normal | 0.43 | 0.45 (4%) |
| January | Dry | 0.52 | 0.53 (2%) |
| January | Critical | 0.23 | 0.23 (0%) |
| February | Wet | 0.36 | 0.36 (0%) |
| February | Above normal | 0.40 | 0.40 (1%) |
| February | Below normal | 0.36 | 0.37 (1%) |
| February | Dry | 0.28 | 0.29 (4%) |
| February | Critical | 0.14 | 0.14 (-2%) |
| March | Wet | 0.18 | 0.19 (4%) |
| March | Above normal | 0.20 | 0.20 (3%) |
| March | Below normal | 0.25 | 0.26 (5%) |

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| March | Dry | 0.22 | 0.24 (9%) |
| March | Critical | 0.16 | 0.16 (3%) |

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions.

## 5D.14.5 Detailed Results for California Department of Fish and Game (2009a) Stations of Interest

To supplement the above analysis and provide some comparability with the CDFG (2009a) effects analysis, PTM results were summarized for the seven particle injection stations analyzed by CDFG (2009a; Figure 5D.14-3). The results are presented below in Table 5D.14-7 through Table 5D.14-8.. Note that these are "raw" results, with no weighting as undertaken by CDFG (2009a).




Source: California Department of Fish and Game 2009a.

**Figure 5D.14-3. Particle Tracking Injection (Release) Locations Used by CDFG (2009a)**

**Table 5D.14-9. Percentage of Neutrally Buoyant Particles Injected at Station 716 (Cache Slough at Liberty Island) That Were Entrained over 90 Days into Clifton Court Forebay or Central Valley Project (Jones Pumping Plant)**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 0.51 | 0.63 (25%) |
| January | Above normal | 2.29 | 2.73 (19%) |
| January | Below normal | 7.20 | 7.67 (7%) |
| January | Dry | 12.54 | 13.11 (5%) |
| January | Critical | 14.14 | 14.49 (2%) |
| February | Wet | 0.15 | 0.16 (5%) |
| February | Above normal | 0.74 | 1.09 (48%) |
| February | Below normal | 3.11 | 3.28 (5%) |
| February | Dry | 3.97 | 4.66 (18%) |
| February | Critical | 7.03 | 6.76 (-4%) |
| March | Wet | 0.13 | 0.15 (11%) |
| March | Above normal | 0.27 | 0.41 (51%) |
| March | Below normal | 1.45 | 1.71 (18%) |
| March | Dry | 2.36 | 2.58 (9%) |
| March | Critical | 3.89 | 3.87 (-1%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-10. Percentage of Neutrally Buoyant Particles Injected at Station 716 (Cache Slough at Liberty Island) That Were Entrained over 90 Days into North Bay Aqueduct**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 2.68 | 2.72 (2%) |
| January | Above normal | 2.99 | 3.08 (3%) |
| January | Below normal | 3.02 | 3.22 (7%) |
| January | Dry | 3.99 | 4.09 (2%) |
| January | Critical | 1.73 | 1.86 (7%) |
| February | Wet | 2.55 | 2.56 (0%) |
| February | Above normal | 2.82 | 2.79 (-1%) |
| February | Below normal | 2.62 | 2.76 (5%) |
| February | Dry | 2.05 | 2.11 (3%) |
| February | Critical | 0.93 | 0.97 (4%) |
| March | Wet | 1.17 | 1.19 (2%) |
| March | Above normal | 1.32 | 1.38 (4%) |
| March | Below normal | 1.75 | 1.89 (8%) |
| March | Dry | 1.71 | 1.81 (5%) |
| March | Critical | 1.17 | 1.30 (11%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-11. Percentage of Neutrally Buoyant Particles Injected at Station 716 (Cache Slough at Liberty Island) That Passed Chipps Island over 90 Days**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 94.25 | 94.03 (0%) |
| January | Above normal | 90.17 | 88.53 (-2%) |
| January | Below normal | 79.80 | 78.59 (-2%) |
| January | Dry | 69.79 | 67.86 (-3%) |
| January | Critical | 66.89 | 64.43 (-4%) |
| February | Wet | 95.67 | 95.58 (0%) |
| February | Above normal | 94.42 | 94.04 (0%) |
| February | Below normal | 88.65 | 87.59 (-1%) |
| February | Dry | 84.88 | 83.28 (-2%) |
| February | Critical | 76.39 | 74.97 (-2%) |
| March | Wet | 96.59 | 96.58 (0%) |
| March | Above normal | 96.15 | 95.83 (0%) |
| March | Below normal | 93.04 | 92.75 (0%) |
| March | Dry | 90.43 | 89.88 (-1%) |
| March | Critical | 79.86 | 78.71 (-1%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-12. Percentage of Neutrally Buoyant Particles Injected at Station 711 (Sacramento River near Cache Slough confluence) That Were Entrained over 90 Days into Clifton Court Forebay or Central Valley Project (Jones Pumping Plant)**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 0.62 | 0.79 (28%) |
| January | Above normal | 2.88 | 3.17 (10%) |
| January | Below normal | 8.38 | 9.25 (10%) |
| January | Dry | 14.64 | 15.40 (5%) |
| January | Critical | 15.01 | 15.72 (5%) |
| February | Wet | 0.14 | 0.18 (30%) |
| February | Above normal | 0.78 | 1.01 (30%) |
| February | Below normal | 3.70 | 3.90 (5%) |
| February | Dry | 4.50 | 5.49 (22%) |
| February | Critical | 7.12 | 7.08 (-1%) |
| March | Wet | 0.12 | 0.15 (26%) |
| March | Above normal | 0.24 | 0.40 (69%) |
| March | Below normal | 1.48 | 1.77 (19%) |
| March | Dry | 2.70 | 3.03 (12%) |
| March | Critical | 3.65 | 3.62 (-1%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-13. Percentage of Neutrally Buoyant Particles Injected at Station 711 (Sacramento River near Cache Slough confluence) That Were Entrained over 90 Days into North Bay Aqueduct**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 0.07 | 0.08 (17%) |
| January | Above normal | 0.20 | 0.20 (-1%) |
| January | Below normal | 0.29 | 0.31 (8%) |
| January | Dry | 0.48 | 0.45 (-7%) |
| January | Critical | 0.25 | 0.29 (19%) |
| February | Wet | 0.02 | 0.03 (52%) |
| February | Above normal | 0.08 | 0.08 (6%) |
| February | Below normal | 0.23 | 0.22 (-4%) |
| February | Dry | 0.21 | 0.25 (20%) |
| February | Critical | 0.14 | 0.14 (4%) |
| March | Wet | 0.02 | 0.02 (0%) |
| March | Above normal | 0.04 | 0.07 (94%) |
| March | Below normal | 0.17 | 0.18 (5%) |
| March | Dry | 0.18 | 0.14 (-20%) |
| March | Critical | 0.13 | 0.14 (10%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-14. Percentage of Neutrally Buoyant Particles Injected at Station 711 (Sacramento River near Cache Slough confluence) That Passed Chipps Island over 90 Days**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 96.80 | 96.47 (0%) |
| January | Above normal | 92.28 | 90.42 (-2%) |
| January | Below normal | 81.51 | 79.95 (-2%) |
| January | Dry | 69.55 | 67.76 (-3%) |
| January | Critical | 67.86 | 64.89 (-4%) |
| February | Wet | 98.42 | 98.32 (0%) |
| February | Above normal | 97.27 | 96.99 (0%) |
| February | Below normal | 90.82 | 89.56 (-1%) |
| February | Dry | 86.45 | 84.64 (-2%) |
| February | Critical | 78.18 | 76.15 (-3%) |
| March | Wet | 98.37 | 98.37 (0%) |
| March | Above normal | 98.35 | 98.04 (0%) |
| March | Below normal | 96.12 | 96.03 (0%) |
| March | Dry | 93.90 | 93.23 (-1%) |
| March | Critical | 84.96 | 83.33 (-2%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-15. Percentage of Neutrally Buoyant Particles Injected at Station 704 (Sacramento River at Sherman Lake) That Were Entrained over 90 Days into Clifton Court Forebay or Central Valley Project (Jones Pumping Plant)**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 0.03 | 0.03 (24%) |
| January | Above normal | 0.37 | 0.51 (39%) |
| January | Below normal | 1.32 | 1.51 (15%) |
| January | Dry | 2.52 | 2.72 (8%) |
| January | Critical | 2.68 | 3.02 (13%) |
| February | Wet | 0.00 | 0.00 (200%) |
| February | Above normal | 0.01 | 0.03 (250%) |
| February | Below normal | 0.23 | 0.20 (-10%) |
| February | Dry | 0.33 | 0.41 (23%) |
| February | Critical | 0.65 | 0.68 (4%) |
| March | Wet | 0.00 | 0.00 (50%) |
| March | Above normal | 0.00 | 0.01 (150%) |
| March | Below normal | 0.04 | 0.07 (66%) |
| March | Dry | 0.13 | 0.12 (-7%) |
| March | Critical | 0.20 | 0.22 (9%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-16. Percentage of Neutrally Buoyant Particles Injected at Station 704 (Sacramento River at Sherman Lake) That Were Entrained over 90 Days into North Bay Aqueduct**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 0.00 | 0.00 (0%) |
| January | Above normal | 0.00 | 0.00 (0%) |
| January | Below normal | 0.00 | 0.00 (0%) |
| January | Dry | 0.00 | 0.00 (0%) |
| January | Critical | 0.00 | 0.00 (-100%) |
| February | Wet | 0.00 | 0.00 (0%) |
| February | Above normal | 0.00 | 0.00 (0%) |
| February | Below normal | 0.00 | 0.00 (0%) |
| February | Dry | 0.00 | 0.00 (0%) |
| February | Critical | 0.00 | 0.00 (0%) |
| March | Wet | 0.00 | 0.00 (0%) |
| March | Above normal | 0.00 | 0.00 (0%) |
| March | Below normal | 0.00 | 0.00 (0%) |
| March | Dry | 0.00 | 0.00 (0%) |
| March | Critical | 0.00 | 0.00 (0%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-17. Percentage of Neutrally Buoyant Particles Injected at Station 704 (Sacramento River at Sherman Lake) That Passed Chipps Island over 90 Days**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 97.52 | 97.41 (0%) |
| January | Above normal | 93.96 | 92.11 (-2%) |
| January | Below normal | 88.24 | 87.00 (-1%) |
| January | Dry | 78.45 | 76.69 (-2%) |
| January | Critical | 79.39 | 76.07 (-4%) |
| February | Wet | 98.44 | 98.41 (0%) |
| February | Above normal | 98.25 | 98.24 (0%) |
| February | Below normal | 94.37 | 93.13 (-1%) |
| February | Dry | 90.53 | 89.26 (-1%) |
| February | Critical | 84.77 | 82.46 (-3%) |
| March | Wet | 98.37 | 98.41 (0%) |
| March | Above normal | 98.39 | 98.40 (0%) |
| March | Below normal | 98.26 | 98.47 (0%) |
| March | Dry | 97.10 | 96.74 (0%) |
| March | Critical | 90.44 | 88.41 (-2%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-18. Percentage of Neutrally Buoyant Particles Injected at Station 809 (San Joaquin River near Jersey Point) That Were Entrained over 90 Days into Clifton Court Forebay or Central Valley Project (Jones Pumping Plant)**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 1.69 | 2.04 (21%) |
| January | Above normal | 5.81 | 6.38 (10%) |
| January | Below normal | 16.31 | 17.23 (6%) |
| January | Dry | 25.93 | 25.91 (0%) |
| January | Critical | 25.19 | 25.65 (2%) |
| February | Wet | 0.37 | 0.42 (13%) |
| February | Above normal | 2.33 | 2.84 (22%) |
| February | Below normal | 7.51 | 8.01 (7%) |
| February | Dry | 9.63 | 11.39 (18%) |
| February | Critical | 13.64 | 13.49 (-1%) |
| March | Wet | 0.27 | 0.35 (29%) |
| March | Above normal | 0.75 | 1.04 (38%) |
| March | Below normal | 3.21 | 3.82 (19%) |
| March | Dry | 5.30 | 5.62 (6%) |
| March | Critical | 6.73 | 6.49 (-3%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-19. Percentage of Neutrally Buoyant Particles Injected at Station 809 (San Joaquin River near Jersey Point) That Were Entrained over 90 Days into North Bay Aqueduct**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 0.00 | 0.00 (0%) |
| January | Above normal | 0.00 | 0.00 (0%) |
| January | Below normal | 0.00 | 0.00 (0%) |
| January | Dry | 0.00 | 0.00 (0%) |
| January | Critical | 0.00 | 0.00 (0%) |
| February | Wet | 0.00 | 0.00 (0%) |
| February | Above normal | 0.00 | 0.00 (0%) |
| February | Below normal | 0.00 | 0.00 (0%) |
| February | Dry | 0.00 | 0.00 (0%) |
| February | Critical | 0.00 | 0.00 (0%) |
| March | Wet | 0.00 | 0.00 (0%) |
| March | Above normal | 0.00 | 0.00 (0%) |
| March | Below normal | 0.00 | 0.00 (0%) |
| March | Dry | 0.00 | 0.00 (0%) |
| March | Critical | 0.00 | 0.00 (0%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-20. Percentage of Neutrally Buoyant Particles Injected at Station 809 (San Joaquin River near Jersey Point) That Passed Chipps Island over 90 Days**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 96.04 | 95.61 (0%) |
| January | Above normal | 90.26 | 88.20 (-2%) |
| January | Below normal | 75.23 | 73.48 (-2%) |
| January | Dry | 62.57 | 60.96 (-3%) |
| January | Critical | 59.48 | 57.34 (-4%) |
| February | Wet | 98.42 | 98.39 (0%) |
| February | Above normal | 95.88 | 95.43 (0%) |
| February | Below normal | 87.51 | 86.25 (-1%) |
| February | Dry | 82.10 | 79.69 (-3%) |
| February | Critical | 72.52 | 70.88 (-2%) |
| March | Wet | 98.50 | 98.42 (0%) |
| March | Above normal | 97.92 | 97.61 (0%) |
| March | Below normal | 94.68 | 94.27 (0%) |
| March | Dry | 91.42 | 90.72 (-1%) |
| March | Critical | 82.12 | 80.71 (-2%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-21. Percentage of Neutrally Buoyant Particles Injected at Station 812 (San Joaquin River at Twitchell Island) That Were Entrained over 90 Days into Clifton Court Forebay or Central Valley Project (Jones Pumping Plant)**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 10.68 | 11.70 (10%) |
| January | Above normal | 23.00 | 24.40 (6%) |
| January | Below normal | 44.79 | 46.20 (3%) |
| January | Dry | 61.56 | 61.77 (0%) |
| January | Critical | 60.33 | 59.80 (-1%) |
| February | Wet | 5.77 | 6.08 (5%) |
| February | Above normal | 16.39 | 18.18 (11%) |
| February | Below normal | 31.75 | 32.11 (1%) |
| February | Dry | 38.38 | 41.98 (9%) |
| February | Critical | 46.27 | 45.59 (-1%) |
| March | Wet | 3.77 | 3.99 (6%) |
| March | Above normal | 7.62 | 8.80 (15%) |
| March | Below normal | 18.99 | 20.34 (7%) |
| March | Dry | 25.67 | 26.53 (3%) |
| March | Critical | 27.94 | 27.67 (-1%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-22. Percentage of Neutrally Buoyant Particles Injected at Station 812 (San Joaquin River at Twitchell Island) That Were Entrained over 90 Days into North Bay Aqueduct**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 0.00 | 0.00 (0%) |
| January | Above normal | 0.00 | 0.00 (-100%) |
| January | Below normal | 0.00 | 0.00 (0%) |
| January | Dry | 0.00 | 0.00 (0%) |
| January | Critical | 0.00 | 0.00 (0%) |
| February | Wet | 0.00 | 0.00 (0%) |
| February | Above normal | 0.00 | 0.00 (0%) |
| February | Below normal | 0.00 | 0.00 (0%) |
| February | Dry | 0.00 | 0.00 (0%) |
| February | Critical | 0.00 | 0.00 (0%) |
| March | Wet | 0.00 | 0.00 (0%) |
| March | Above normal | 0.00 | 0.00 (0%) |
| March | Below normal | 0.00 | 0.00 (-100%) |
| March | Dry | 0.00 | 0.00 (-100%) |
| March | Critical | 0.00 | 0.00 (-100%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-23. Percentage of Neutrally Buoyant Particles Injected at Station 812 (San Joaquin River at Twitchell Island) That Passed Chipps Island over 90 Days**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 86.84 | 85.75 (-1%) |
| January | Above normal | 74.02 | 72.10 (-3%) |
| January | Below normal | 49.49 | 47.79 (-3%) |
| January | Dry | 32.68 | 31.67 (-3%) |
| January | Critical | 29.80 | 29.50 (-1%) |
| February | Wet | 92.76 | 92.40 (0%) |
| February | Above normal | 81.52 | 79.58 (-2%) |
| February | Below normal | 63.81 | 63.13 (-1%) |
| February | Dry | 55.53 | 51.54 (-7%) |
| February | Critical | 41.28 | 40.98 (-1%) |
| March | Wet | 94.84 | 94.56 (0%) |
| March | Above normal | 90.58 | 89.36 (-1%) |
| March | Below normal | 76.98 | 75.47 (-2%) |
| March | Dry | 67.70 | 66.30 (-2%) |
| March | Critical | 55.03 | 54.97 (0%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-24. Percentage of Neutrally Buoyant Particles Injected at Station 815 (San Joaquin River at Potato Slough) That Were Entrained over 90 Days into Clifton Court Forebay or Central Valley Project (Jones Pumping Plant)**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 18.45 | 19.41 (5%) |
| January | Above normal | 31.97 | 33.40 (4%) |
| January | Below normal | 51.71 | 52.85 (2%) |
| January | Dry | 68.16 | 67.88 (0%) |
| January | Critical | 66.18 | 65.29 (-1%) |
| February | Wet | 12.11 | 12.36 (2%) |
| February | Above normal | 25.23 | 26.71 (6%) |
| February | Below normal | 40.58 | 40.78 (0%) |
| February | Dry | 47.53 | 50.89 (7%) |
| February | Critical | 53.23 | 52.44 (-1%) |
| March | Wet | 8.19 | 8.13 (-1%) |
| March | Above normal | 14.37 | 15.37 (7%) |
| March | Below normal | 27.32 | 29.21 (7%) |
| March | Dry | 34.33 | 35.90 (5%) |
| March | Critical | 35.39 | 34.49 (-3%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-25. Percentage of Neutrally Buoyant Particles Injected at Station 815 (San Joaquin River at Potato Slough) That Were Entrained over 90 Days into North Bay Aqueduct**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 0.00 | 0.00 (0%) |
| January | Above normal | 0.00 | 0.00 (0%) |
| January | Below normal | 0.00 | 0.00 (0%) |
| January | Dry | 0.00 | 0.00 (0%) |
| January | Critical | 0.00 | 0.00 (-100%) |
| February | Wet | 0.00 | 0.00 (0%) |
| February | Above normal | 0.00 | 0.00 (0%) |
| February | Below normal | 0.00 | 0.00 (0%) |
| February | Dry | 0.00 | 0.00 (0%) |
| February | Critical | 0.00 | 0.00 (0%) |
| March | Wet | 0.00 | 0.00 (0%) |
| March | Above normal | 0.00 | 0.00 (0%) |
| March | Below normal | 0.00 | 0.00 (0%) |
| March | Dry | 0.00 | 0.00 (0%) |
| March | Critical | 0.00 | 0.00 (0%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-26. Percentage of Neutrally Buoyant Particles Injected at Station 815 (San Joaquin River at Potato Slough) That Passed Chipps Island over 90 Days**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 78.76 | 77.80 (-1%) |
| January | Above normal | 64.91 | 62.94 (-3%) |
| January | Below normal | 42.99 | 41.64 (-3%) |
| January | Dry | 26.72 | 26.45 (-1%) |
| January | Critical | 25.27 | 25.20 (0%) |
| February | Wet | 86.08 | 85.87 (0%) |
| February | Above normal | 72.41 | 70.97 (-2%) |
| February | Below normal | 55.19 | 54.59 (-1%) |
| February | Dry | 46.93 | 43.25 (-8%) |
| February | Critical | 35.66 | 35.58 (0%) |
| March | Wet | 90.37 | 90.26 (0%) |
| March | Above normal | 83.66 | 82.60 (-1%) |
| March | Below normal | 68.50 | 66.61 (-3%) |
| March | Dry | 59.46 | 57.34 (-4%) |
| March | Critical | 48.79 | 49.40 (1%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-27. Percentage of Neutrally Buoyant Particles Injected at Station 906 (San Joaquin River near Medford Island) That Were Entrained over 90 Days into Clifton Court Forebay or Central Valley Project (Jones Pumping Plant)**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 43.84 | 44.70 (2%) |
| January | Above normal | 63.86 | 65.08 (2%) |
| January | Below normal | 81.48 | 82.28 (1%) |
| January | Dry | 91.33 | 91.04 (0%) |
| January | Critical | 88.29 | 86.13 (-2%) |
| February | Wet | 32.22 | 32.27 (0%) |
| February | Above normal | 54.97 | 55.65 (1%) |
| February | Below normal | 72.37 | 71.95 (-1%) |
| February | Dry | 80.83 | 83.08 (3%) |
| February | Critical | 82.03 | 80.41 (-2%) |
| March | Wet | 22.10 | 21.21 (-4%) |
| March | Above normal | 36.29 | 37.96 (5%) |
| March | Below normal | 57.74 | 58.91 (2%) |
| March | Dry | 67.86 | 68.62 (1%) |
| March | Critical | 62.73 | 60.83 (-3%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-28. Percentage of Neutrally Buoyant Particles Injected at Station 906 (San Joaquin River near Medford Island) That Were Entrained over 90 Days into North Bay Aqueduct**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 0.00 | 0.00 (0%) |
| January | Above normal | 0.00 | 0.00 (0%) |
| January | Below normal | 0.00 | 0.00 (0%) |
| January | Dry | 0.00 | 0.00 (0%) |
| January | Critical | 0.00 | 0.00 (0%) |
| February | Wet | 0.00 | 0.00 (0%) |
| February | Above normal | 0.00 | 0.00 (0%) |
| February | Below normal | 0.00 | 0.00 (0%) |
| February | Dry | 0.00 | 0.00 (0%) |
| February | Critical | 0.00 | 0.00 (0%) |
| March | Wet | 0.00 | 0.00 (0%) |
| March | Above normal | 0.00 | 0.00 (0%) |
| March | Below normal | 0.00 | 0.00 (0%) |
| March | Dry | 0.00 | 0.00 (0%) |
| March | Critical | 0.00 | 0.00 (-100%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-29. Percentage of Neutrally Buoyant Particles Injected at Station 906 (San Joaquin River near Medford Island) That Passed Chipps Island over 90 Days**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 53.83 | 53.02 (-2%) |
| January | Above normal | 33.74 | 32.28 (-4%) |
| January | Below normal | 16.12 | 15.24 (-5%) |
| January | Dry | 6.52 | 6.45 (-1%) |
| January | Critical | 7.24 | 9.01 (24%) |
| February | Wet | 66.01 | 65.81 (0%) |
| February | Above normal | 43.09 | 42.24 (-2%) |
| February | Below normal | 24.90 | 25.30 (2%) |
| February | Dry | 16.45 | 14.29 (-13%) |
| February | Critical | 11.69 | 12.41 (6%) |
| March | Wet | 76.19 | 76.98 (1%) |
| March | Above normal | 61.12 | 59.50 (-3%) |
| March | Below normal | 37.99 | 36.79 (-3%) |
| March | Dry | 26.20 | 25.13 (-4%) |
| March | Critical | 23.38 | 25.11 (7%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-30. Percentage of Surface-Oriented Particles Injected at Station 716 (Cache Slough at Liberty Island) That Were Entrained over 90 Days into Clifton Court Forebay or Central Valley Project (Jones Pumping Plant)**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 0.68 | 0.86 (25%) |
| January | Above normal | 2.76 | 3.45 (25%) |
| January | Below normal | 8.57 | 9.15 (7%) |
| January | Dry | 14.35 | 15.38 (7%) |
| January | Critical | 16.67 | 17.13 (3%) |
| February | Wet | 0.21 | 0.28 (32%) |
| February | Above normal | 0.95 | 1.40 (47%) |
| February | Below normal | 3.75 | 4.26 (14%) |
| February | Dry | 4.66 | 5.85 (25%) |
| February | Critical | 8.07 | 8.51 (6%) |
| March | Wet | 0.19 | 0.24 (26%) |
| March | Above normal | 0.39 | 0.64 (62%) |
| March | Below normal | 1.82 | 2.40 (32%) |
| March | Dry | 3.20 | 3.60 (12%) |
| March | Critical | 4.60 | 5.25 (14%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-31. Percentage of Surface-Oriented Particles Injected at Station 716 (Cache Slough at Liberty Island) That Were Entrained over 90 Days into North Bay Aqueduct**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 2.55 | 2.51 (-1%) |
| January | Above normal | 2.78 | 2.78 (0%) |
| January | Below normal | 2.92 | 3.01 (3%) |
| January | Dry | 3.72 | 3.77 (1%) |
| January | Critical | 1.72 | 1.70 (-1%) |
| February | Wet | 2.36 | 2.27 (-4%) |
| February | Above normal | 2.55 | 2.65 (4%) |
| February | Below normal | 2.47 | 2.44 (-1%) |
| February | Dry | 1.91 | 1.86 (-2%) |
| February | Critical | 0.80 | 0.78 (-2%) |
| March | Wet | 1.00 | 0.98 (-2%) |
| March | Above normal | 1.22 | 1.15 (-6%) |
| March | Below normal | 1.65 | 1.69 (3%) |
| March | Dry | 1.43 | 1.54 (8%) |
| March | Critical | 1.01 | 1.01 (-1%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-32. Percentage of Surface-Oriented Particles Injected at Station 716 (Cache Slough at Liberty Island) That Passed Chipps Island over 90 Days**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 94.33 | 94.13 (0%) |
| January | Above normal | 90.12 | 88.27 (-2%) |
| January | Below normal | 79.10 | 77.64 (-2%) |
| January | Dry | 68.51 | 66.11 (-4%) |
| January | Critical | 65.96 | 62.57 (-5%) |
| February | Wet | 95.88 | 95.94 (0%) |
| February | Above normal | 94.51 | 94.08 (0%) |
| February | Below normal | 88.51 | 87.22 (-1%) |
| February | Dry | 84.45 | 82.74 (-2%) |
| February | Critical | 75.95 | 74.27 (-2%) |
| March | Wet | 96.99 | 97.01 (0%) |
| March | Above normal | 96.40 | 96.37 (0%) |
| March | Below normal | 93.45 | 92.96 (-1%) |
| March | Dry | 90.63 | 89.88 (-1%) |
| March | Critical | 80.35 | 78.82 (-2%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-33. Percentage of Surface-Oriented Particles Injected at Station 711 (Sacramento River near Cache Slough confluence) That Were Entrained over 90 Days into Clifton Court Forebay or Central Valley Project (Jones Pumping Plant)**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 0.80 | 1.03 (29%) |
| January | Above normal | 3.25 | 4.05 (25%) |
| January | Below normal | 9.95 | 10.76 (8%) |
| January | Dry | 16.95 | 17.95 (6%) |
| January | Critical | 18.10 | 18.54 (2%) |
| February | Wet | 0.16 | 0.18 (13%) |
| February | Above normal | 0.99 | 1.38 (39%) |
| February | Below normal | 4.37 | 4.78 (9%) |
| February | Dry | 5.75 | 6.98 (21%) |
| February | Critical | 8.71 | 9.18 (5%) |
| March | Wet | 0.15 | 0.24 (54%) |
| March | Above normal | 0.37 | 0.63 (72%) |
| March | Below normal | 1.93 | 2.46 (27%) |
| March | Dry | 3.51 | 3.95 (12%) |
| March | Critical | 4.45 | 4.95 (11%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-34. Percentage of Surface-Oriented Particles Injected at Station 711 (Sacramento River near Cache Slough confluence) That Were Entrained over 90 Days into North Bay Aqueduct**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 0.08 | 0.10 (25%) |
| January | Above normal | 0.21 | 0.25 (20%) |
| January | Below normal | 0.35 | 0.38 (9%) |
| January | Dry | 0.55 | 0.52 (-5%) |
| January | Critical | 0.25 | 0.32 (29%) |
| February | Wet | 0.03 | 0.04 (41%) |
| February | Above normal | 0.08 | 0.11 (52%) |
| February | Below normal | 0.24 | 0.25 (5%) |
| February | Dry | 0.25 | 0.28 (10%) |
| February | Critical | 0.14 | 0.15 (13%) |
| March | Wet | 0.01 | 0.01 (10%) |
| March | Above normal | 0.05 | 0.05 (-5%) |
| March | Below normal | 0.17 | 0.18 (7%) |
| March | Dry | 0.18 | 0.15 (-13%) |
| March | Critical | 0.15 | 0.15 (2%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-35. Percentage of Surface-Oriented Particles Injected at Station 711 (Sacramento River near Cache Slough confluence) That Passed Chipps Island over 90 Days**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 96.60 | 96.25 (0%) |
| January | Above normal | 91.93 | 89.76 (-2%) |
| January | Below normal | 79.89 | 78.43 (-2%) |
| January | Dry | 67.93 | 65.47 (-4%) |
| January | Critical | 66.69 | 63.03 (-5%) |
| February | Wet | 98.44 | 98.40 (0%) |
| February | Above normal | 97.16 | 96.65 (-1%) |
| February | Below normal | 90.46 | 88.79 (-2%) |
| February | Dry | 85.20 | 83.07 (-3%) |
| February | Critical | 76.73 | 74.28 (-3%) |
| March | Wet | 98.38 | 98.34 (0%) |
| March | Above normal | 98.22 | 98.02 (0%) |
| March | Below normal | 96.07 | 95.65 (0%) |
| March | Dry | 93.22 | 92.50 (-1%) |
| March | Critical | 84.35 | 82.26 (-2%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-36. Percentage of Surface-Oriented Particles Injected at Station 704 (Sacramento River at Sherman Lake) That Were Entrained over 90 Days into Clifton Court Forebay or Central Valley Project (Jones Pumping Plant)**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 0.04 | 0.07 (69%) |
| January | Above normal | 0.53 | 0.66 (25%) |
| January | Below normal | 1.92 | 2.17 (13%) |
| January | Dry | 3.61 | 4.03 (11%) |
| January | Critical | 4.04 | 4.19 (4%) |
| February | Wet | 0.00 | 0.01 (100%) |
| February | Above normal | 0.02 | 0.05 (132%) |
| February | Below normal | 0.28 | 0.39 (38%) |
| February | Dry | 0.48 | 0.69 (45%) |
| February | Critical | 0.95 | 1.10 (16%) |
| March | Wet | 0.00 | 0.01 (133%) |
| March | Above normal | 0.00 | 0.01 (100%) |
| March | Below normal | 0.08 | 0.11 (42%) |
| March | Dry | 0.21 | 0.24 (13%) |
| March | Critical | 0.37 | 0.42 (14%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-37. Percentage of Surface-Oriented Particles Injected at Station 704 (Sacramento River at Sherman Lake) That Were Entrained over 90 Days into North Bay Aqueduct**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 0.00 | 0.00 (0%) |
| January | Above normal | 0.00 | 0.00 (0%) |
| January | Below normal | 0.00 | 0.00 (0%) |
| January | Dry | 0.00 | 0.00 (0%) |
| January | Critical | 0.00 | 0.00 (0%) |
| February | Wet | 0.00 | 0.00 (0%) |
| February | Above normal | 0.00 | 0.00 (0%) |
| February | Below normal | 0.00 | 0.00 (0%) |
| February | Dry | 0.00 | 0.00 (0%) |
| February | Critical | 0.00 | 0.00 (0%) |
| March | Wet | 0.00 | 0.00 (0%) |
| March | Above normal | 0.00 | 0.00 (0%) |
| March | Below normal | 0.00 | 0.00 (0%) |
| March | Dry | 0.00 | 0.00 (0%) |
| March | Critical | 0.00 | 0.00 (0%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-38. Percentage of Surface-Oriented Particles Injected at Station 704 (Sacramento River at Sherman Lake) That Passed Chipps Island over 90 Days**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 97.59 | 97.46 (0%) |
| January | Above normal | 93.82 | 91.89 (-2%) |
| January | Below normal | 87.58 | 86.61 (-1%) |
| January | Dry | 77.71 | 75.78 (-2%) |
| January | Critical | 80.07 | 75.84 (-5%) |
| February | Wet | 98.46 | 98.47 (0%) |
| February | Above normal | 98.27 | 98.20 (0%) |
| February | Below normal | 94.57 | 93.20 (-1%) |
| February | Dry | 90.46 | 88.90 (-2%) |
| February | Critical | 84.55 | 82.33 (-3%) |
| March | Wet | 98.45 | 98.50 (0%) |
| March | Above normal | 98.50 | 98.57 (0%) |
| March | Below normal | 98.52 | 98.58 (0%) |
| March | Dry | 97.20 | 96.83 (0%) |
| March | Critical | 90.42 | 88.41 (-2%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-39. Percentage of Surface-Oriented Particles Injected at Station 809 (San Joaquin River near Jersey Point) That Were Entrained over 90 Days into Clifton Court Forebay or Central Valley Project (Jones Pumping Plant)**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 2.10 | 2.66 (27%) |
| January | Above normal | 6.66 | 7.79 (17%) |
| January | Below normal | 18.67 | 19.51 (4%) |
| January | Dry | 28.19 | 28.88 (2%) |
| January | Critical | 29.32 | 28.88 (-1%) |
| February | Wet | 0.49 | 0.65 (34%) |
| February | Above normal | 2.98 | 3.82 (28%) |
| February | Below normal | 9.06 | 10.07 (11%) |
| February | Dry | 11.61 | 13.80 (19%) |
| February | Critical | 16.27 | 16.36 (1%) |
| March | Wet | 0.43 | 0.51 (19%) |
| March | Above normal | 0.96 | 1.39 (46%) |
| March | Below normal | 3.93 | 5.09 (30%) |
| March | Dry | 6.46 | 7.29 (13%) |
| March | Critical | 7.96 | 8.43 (6%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-40. Percentage of Surface-Oriented Particles Injected at Station 809 (San Joaquin River near Jersey Point) That Were Entrained over 90 Days into North Bay Aqueduct**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 0.00 | 0.00 (0%) |
| January | Above normal | 0.00 | 0.00 (0%) |
| January | Below normal | 0.00 | 0.00 (0%) |
| January | Dry | 0.00 | 0.00 (0%) |
| January | Critical | 0.00 | 0.00 (0%) |
| February | Wet | 0.00 | 0.00 (0%) |
| February | Above normal | 0.00 | 0.00 (0%) |
| February | Below normal | 0.00 | 0.00 (-100%) |
| February | Dry | 0.00 | 0.00 (0%) |
| February | Critical | 0.00 | 0.00 (0%) |
| March | Wet | 0.00 | 0.00 (0%) |
| March | Above normal | 0.00 | 0.00 (0%) |
| March | Below normal | 0.00 | 0.00 (0%) |
| March | Dry | 0.00 | 0.00 (0%) |
| March | Critical | 0.00 | 0.00 (0%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-41. Percentage of Surface-Oriented Particles Injected at Station 809 (San Joaquin River near Jersey Point) That Passed Chipps Island over 90 Days**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 95.58 | 94.91 (-1%) |
| January | Above normal | 89.31 | 86.98 (-3%) |
| January | Below normal | 72.80 | 71.41 (-2%) |
| January | Dry | 60.06 | 57.93 (-4%) |
| January | Critical | 57.43 | 54.73 (-5%) |
| February | Wet | 98.30 | 98.13 (0%) |
| February | Above normal | 95.31 | 94.52 (-1%) |
| February | Below normal | 86.17 | 84.10 (-2%) |
| February | Dry | 80.33 | 77.56 (-3%) |
| February | Critical | 70.22 | 68.39 (-3%) |
| March | Wet | 98.37 | 98.32 (0%) |
| March | Above normal | 97.72 | 97.32 (0%) |
| March | Below normal | 94.20 | 93.05 (-1%) |
| March | Dry | 90.49 | 89.28 (-1%) |
| March | Critical | 81.40 | 79.17 (-3%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-42. Percentage of Surface-Oriented Particles Injected at Station 812 (San Joaquin River at Twitchell Island) That Were Entrained over 90 Days into Clifton Court Forebay or Central Valley Project (Jones Pumping Plant)**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 11.67 | 13.19 (13%) |
| January | Above normal | 23.67 | 25.63 (8%) |
| January | Below normal | 46.20 | 47.07 (2%) |
| January | Dry | 62.52 | 62.37 (0%) |
| January | Critical | 63.70 | 60.70 (-5%) |
| February | Wet | 6.38 | 6.95 (9%) |
| February | Above normal | 17.31 | 20.02 (16%) |
| February | Below normal | 33.32 | 34.32 (3%) |
| February | Dry | 40.22 | 44.05 (10%) |
| February | Critical | 48.43 | 47.36 (-2%) |
| March | Wet | 4.59 | 5.14 (12%) |
| March | Above normal | 8.89 | 10.48 (18%) |
| March | Below normal | 20.52 | 23.31 (14%) |
| March | Dry | 28.09 | 29.78 (6%) |
| March | Critical | 29.39 | 30.44 (4%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-43. Percentage of Surface-Oriented Particles Injected at Station 812 (San Joaquin River at Twitchell Island) That Were Entrained over 90 Days into North Bay Aqueduct**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 0.00 | 0.00 (0%) |
| January | Above normal | 0.00 | 0.00 (0%) |
| January | Below normal | 0.00 | 0.00 (0%) |
| January | Dry | 0.01 | 0.00 (-100%) |
| January | Critical | 0.00 | 0.00 (0%) |
| February | Wet | 0.00 | 0.00 (0%) |
| February | Above normal | 0.00 | 0.00 (0%) |
| February | Below normal | 0.00 | 0.00 (0%) |
| February | Dry | 0.00 | 0.00 (0%) |
| February | Critical | 0.00 | 0.00 (0%) |
| March | Wet | 0.00 | 0.00 (0%) |
| March | Above normal | 0.00 | 0.00 (0%) |
| March | Below normal | 0.00 | 0.00 (0%) |
| March | Dry | 0.00 | 0.00 (0%) |
| March | Critical | 0.00 | 0.00 (-33%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-44. Percentage of Surface-Oriented Particles Injected at Station 812 (San Joaquin River at Twitchell Island) That Passed Chipps Island over 90 Days**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 85.74 | 84.23 (-2%) |
| January | Above normal | 73.32 | 70.82 (-3%) |
| January | Below normal | 48.14 | 47.03 (-2%) |
| January | Dry | 31.98 | 31.04 (-3%) |
| January | Critical | 27.64 | 29.06 (5%) |
| February | Wet | 92.14 | 91.53 (-1%) |
| February | Above normal | 80.57 | 77.72 (-4%) |
| February | Below normal | 62.53 | 61.02 (-2%) |
| February | Dry | 53.91 | 49.95 (-7%) |
| February | Critical | 40.43 | 40.42 (0%) |
| March | Wet | 94.09 | 93.48 (-1%) |
| March | Above normal | 89.40 | 87.83 (-2%) |
| March | Below normal | 76.13 | 73.29 (-4%) |
| March | Dry | 66.43 | 64.51 (-3%) |
| March | Critical | 55.55 | 54.67 (-2%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-45. Percentage of Surface-Oriented Particles Injected at Station 815 (San Joaquin River at Potato Slough) That Were Entrained over 90 Days into Clifton Court Forebay or Central Valley Project (Jones Pumping Plant)**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 18.84 | 19.95 (6%) |
| January | Above normal | 32.04 | 34.00 (6%) |
| January | Below normal | 53.17 | 54.22 (2%) |
| January | Dry | 68.46 | 68.18 (0%) |
| January | Critical | 68.48 | 65.26 (-5%) |
| February | Wet | 12.62 | 12.85 (2%) |
| February | Above normal | 25.87 | 27.75 (7%) |
| February | Below normal | 41.23 | 41.62 (1%) |
| February | Dry | 48.09 | 51.50 (7%) |
| February | Critical | 54.78 | 53.31 (-3%) |
| March | Wet | 8.75 | 8.85 (1%) |
| March | Above normal | 14.96 | 16.49 (10%) |
| March | Below normal | 28.54 | 30.32 (6%) |
| March | Dry | 36.08 | 37.48 (4%) |
| March | Critical | 36.03 | 36.51 (1%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-46. Percentage of Surface-Oriented Particles Injected at Station 815 (San Joaquin River at Potato Slough) That Were Entrained over 90 Days into North Bay Aqueduct**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 0.00 | 0.00 (0%) |
| January | Above normal | 0.00 | 0.00 (0%) |
| January | Below normal | 0.00 | 0.00 (-50%) |
| January | Dry | 0.00 | 0.01 (300%) |
| January | Critical | 0.00 | 0.00 (-100%) |
| February | Wet | 0.00 | 0.00 (0%) |
| February | Above normal | 0.00 | 0.00 (0%) |
| February | Below normal | 0.00 | 0.00 (0%) |
| February | Dry | 0.00 | 0.00 (-100%) |
| February | Critical | 0.00 | 0.00 (0%) |
| March | Wet | 0.00 | 0.00 (0%) |
| March | Above normal | 0.00 | 0.00 (0%) |
| March | Below normal | 0.00 | 0.00 (0%) |
| March | Dry | 0.00 | 0.00 (0%) |
| March | Critical | 0.00 | 0.00 (0%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-47. Percentage of Surface-Oriented Particles Injected at Station 815 (San Joaquin River at Potato Slough) That Passed Chipps Island over 90 Days**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 78.40 | 77.24 (-1%) |
| January | Above normal | 64.77 | 62.37 (-4%) |
| January | Below normal | 41.74 | 40.42 (-3%) |
| January | Dry | 26.67 | 26.10 (-2%) |
| January | Critical | 23.99 | 25.68 (7%) |
| February | Wet | 85.67 | 85.40 (0%) |
| February | Above normal | 71.90 | 69.94 (-3%) |
| February | Below normal | 54.65 | 53.89 (-1%) |
| February | Dry | 46.54 | 43.04 (-8%) |
| February | Critical | 34.99 | 35.55 (2%) |
| March | Wet | 89.85 | 89.68 (0%) |
| March | Above normal | 83.23 | 81.73 (-2%) |
| March | Below normal | 68.04 | 66.16 (-3%) |
| March | Dry | 58.54 | 57.10 (-2%) |
| March | Critical | 49.61 | 49.07 (-1%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-48. Percentage of Surface-Oriented Particles Injected at Station 906 (San Joaquin River near Medford Island) That Were Entrained over 90 Days into Clifton Court Forebay or Central Valley Project (Jones Pumping Plant)**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 43.81 | 44.50 (2%) |
| January | Above normal | 63.51 | 64.80 (2%) |
| January | Below normal | 81.56 | 81.99 (1%) |
| January | Dry | 91.01 | 90.46 (-1%) |
| January | Critical | 89.74 | 85.78 (-4%) |
| February | Wet | 32.29 | 32.13 (0%) |
| February | Above normal | 54.39 | 56.13 (3%) |
| February | Below normal | 72.18 | 71.38 (-1%) |
| February | Dry | 80.54 | 82.90 (3%) |
| February | Critical | 82.65 | 79.95 (-3%) |
| March | Wet | 21.97 | 21.48 (-2%) |
| March | Above normal | 36.18 | 37.85 (5%) |
| March | Below normal | 57.42 | 58.98 (3%) |
| March | Dry | 67.50 | 68.73 (2%) |
| March | Critical | 62.18 | 60.98 (-2%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-49. Percentage of Surface-Oriented Particles Injected at Station 906 (San Joaquin River near Medford Island) That Were Entrained over 90 Days into North Bay Aqueduct**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 0.00 | 0.00 (0%) |
| January | Above normal | 0.00 | 0.00 (0%) |
| January | Below normal | 0.00 | 0.00 (0%) |
| January | Dry | 0.00 | 0.00 (0%) |
| January | Critical | 0.00 | 0.00 (0%) |
| February | Wet | 0.00 | 0.00 (0%) |
| February | Above normal | 0.00 | 0.00 (0%) |
| February | Below normal | 0.00 | 0.00 (0%) |
| February | Dry | 0.00 | 0.00 (0%) |
| February | Critical | 0.00 | 0.00 (-100%) |
| March | Wet | 0.00 | 0.00 (0%) |
| March | Above normal | 0.00 | 0.00 (0%) |
| March | Below normal | 0.00 | 0.00 (0%) |
| March | Dry | 0.00 | 0.00 (0%) |
| March | Critical | 0.00 | 0.00 (0%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

**Table 5D.14-50. Percentage of Surface-Oriented Particles Injected at Station 906 (San Joaquin River near Medford Island) That Passed Chipps Island over 90 Days**

| Month | Water Year Type | Existing Conditions | Proposed Action |
|---|---|---|---|
| January | Wet | 53.76 | 53.11 (-1%) |
| January | Above normal | 34.03 | 32.52 (-4%) |
| January | Below normal | 15.95 | 15.46 (-3%) |
| January | Dry | 6.88 | 6.96 (1%) |
| January | Critical | 6.15 | 9.41 (53%) |
| February | Wet | 65.89 | 65.96 (0%) |
| February | Above normal | 43.72 | 41.90 (-4%) |
| February | Below normal | 25.28 | 25.82 (2%) |
| February | Dry | 16.72 | 14.42 (-14%) |
| February | Critical | 11.40 | 13.16 (15%) |
| March | Wet | 76.47 | 76.85 (1%) |
| March | Above normal | 61.35 | 59.89 (-2%) |
| March | Below normal | 38.96 | 37.37 (-4%) |
| March | Dry | 27.28 | 26.07 (-4%) |
| March | Critical | 25.01 | 26.40 (6%) |

Note: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions.

# 5D.15 Longfin Smelt Salvage–Old and Middle River Flow Analysis Based on Grimaldo et al. (2009)

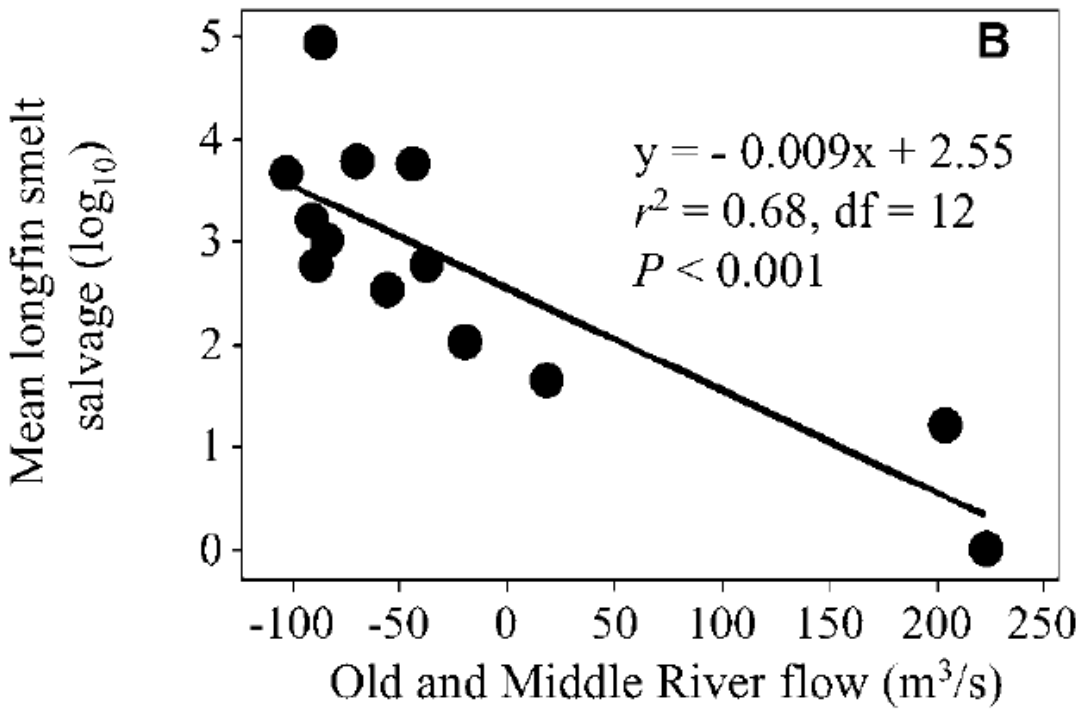
## 5D.15.1 Methods

Grimaldo et al. (2009: Figure 7B) found a significant relationship between juvenile Longfin Smelt salvage in April and May as a function of mean April–May Old and Middle River flows. In order to assess potential differences in salvage between the modeled scenarios, the regression of Grimaldo et al. (2009) was recreated in order to be able to fully account for sources of error in the predictions; this allowed calculation of prediction intervals from CalSim-derived estimates of Old and Middle River flows for the modeled scenarios, as recommended by Simenstad et al. (2016:49).

Longfin Smelt salvage data for April and May 1993–2005 were obtained from the California Department of Fish and Wildlife salvage monitoring website.[8] Consistent with Grimaldo et al. (2009), a record of 616 longfin smelt salvaged on April 7, 1998, was assumed to be in error, and was converted to zero for the analysis. Old and Middle River flow data were provided by Smith (pers. comm.) Following Grimaldo et al. (2009), $\log_{10}$(total salvage) was regressed against mean April–May Old and Middle River flow (converted to cubic meters/second). The resulting regression equation was very similar to that obtained by Grimaldo et al. (2009) (Figure 5D.15-1):

$\text{Log}_{10}$(April–May total Longfin Smelt salvage) = 2.5454 (± 0.2072 SE) – 0.0100 (± 0.0020 SE)* (Mean April–May Old and Middle River flow); $r^2 = 0.70$, 12 degrees of freedom.

[8] http://www.dfg.ca.gov/delta/apps/salvage/SalvageExportChart.aspx?Species=1&SampleDate=1%2f22%2f2016&Facility=1, accessed January 1, 2016, and August 17, 2016 (salvage for longfin smelt at both facilities was selected).




Source: Grimaldo et al. 2009.

**Figure 5D.15-1. Regression of April–May Longfin Smelt Salvage as a Function of Old and Middle River Flow**

For the comparison of the modeled scenarios, CalSim data outputs were used to calculate mean April–May Old and Middle River flows for each year of the 1922–2015 simulation. The salvage-Old and Middle River flow regression calculated as above was used to estimate salvage for the modeled scenarios. The log-transformed salvage estimates were back-transformed to a linear scale for comparison of the modeled scenarios. In order to illustrate the variability in predictions from the salvage-Old and Middle River flow regression, annual estimates were made for the mean and upper and lower 95% prediction limits of the salvage estimates, as recommended by Simenstad et al. (2016). Means and predictions limits giving negative estimates of salvage were converted to zero before statistical summary. Statistical analyses were conducted with PROC GLM and PROC PLM in SAS/STAT software, Version 9.4 of the SAS System for Windows.[9]

## 5D.15.2 Results

The results of the analysis based on water year type means are discussed in Appendix 6C. Table 5D.15-1 presents the mean and prediction intervals of the results by individual year.

[9] Copyright 2002–2010, SAS Institute Inc. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA.

**Table 5D.15-1. Mean and Upper and Lower 95% Prediction Limits of Juvenile Longfin Smelt April–May Salvage at the South Delta Export Facilities by Water Year Type, as Estimated by the Regression including Mean Old and Middle River Flows**

| Year | EC, Mean | EC, Lower 95% | EC, Upper 95% | Proposed Action, Mean | Proposed Action, Lower 95% | Proposed Action, Upper 95% |
|---|---|---|---|---|---|---|
| 1922 | 4,235 | 80 | 223,707 | 3,543 | 68 | 184,107 |
| 1923 | 3,514 | 68 | 182,440 | 3,682 | 71 | 191,982 |
| 1924 | 2,608 | 51 | 132,203 | 2,450 | 49 | 123,603 |
| 1925 | 3,374 | 65 | 174,558 | 3,133 | 61 | 161,087 |
| 1926 | 3,460 | 67 | 179,411 | 3,358 | 65 | 173,680 |
| 1927 | 3,667 | 70 | 191,091 | 3,749 | 72 | 195,799 |
| 1928 | 3,190 | 62 | 164,256 | 3,243 | 63 | 167,244 |
| 1929 | 2,823 | 55 | 143,913 | 2,867 | 56 | 146,339 |
| 1930 | 3,623 | 70 | 188,638 | 3,639 | 70 | 189,513 |
| 1931 | 2,071 | 42 | 103,302 | 2,029 | 41 | 101,072 |
| 1932 | 2,899 | 57 | 148,136 | 2,318 | 46 | 116,506 |
| 1933 | 2,472 | 49 | 124,781 | 2,458 | 49 | 124,039 |
| 1934 | 1,521 | 31 | 74,585 | 1,453 | 30 | 71,074 |
| 1935 | 3,131 | 61 | 160,979 | 3,551 | 68 | 184,519 |
| 1936 | 3,316 | 64 | 171,285 | 3,314 | 64 | 171,199 |
| 1937 | 2,105 | 42 | 105,126 | 2,137 | 43 | 106,810 |
| 1938 | 559 | 12 | 26,729 | 342 | 7 | 16,404 |
| 1939 | 3,464 | 67 | 179,655 | 3,322 | 64 | 171,633 |
| 1940 | 3,093 | 60 | 158,844 | 3,093 | 60 | 158,833 |
| 1941 | 3,575 | 69 | 185,883 | 2,942 | 58 | 150,470 |
| 1942 | 3,648 | 70 | 190,042 | 3,800 | 73 | 198,710 |
| 1943 | 2,819 | 55 | 143,731 | 2,536 | 50 | 128,260 |
| 1944 | 3,473 | 67 | 180,140 | 3,493 | 67 | 181,251 |
| 1945 | 3,623 | 70 | 188,604 | 3,671 | 70 | 191,368 |
| 1946 | 3,539 | 68 | 183,861 | 3,436 | 66 | 178,045 |
| 1947 | 3,694 | 71 | 192,655 | 3,726 | 71 | 194,491 |
| 1948 | 3,546 | 68 | 184,247 | 3,537 | 68 | 183,755 |
| 1949 | 3,411 | 66 | 176,636 | 4,140 | 79 | 218,218 |
| 1950 | 3,419 | 66 | 177,080 | 3,372 | 65 | 174,442 |
| 1951 | 3,171 | 62 | 163,196 | 3,161 | 61 | 162,637 |
| 1952 | 4,960 | 92 | 266,152 | 4,256 | 81 | 224,937 |
| 1953 | 3,431 | 66 | 177,775 | 3,800 | 73 | 198,706 |
| 1954 | 3,153 | 61 | 162,188 | 3,171 | 62 | 163,200 |
| 1955 | 3,656 | 70 | 190,502 | 4,026 | 77 | 211,646 |

| Year | EC, Mean | EC, Lower 95% | EC, Upper 95% | Proposed Action, Mean | Proposed Action, Lower 95% | Proposed Action, Upper 95% |
|---|---|---|---|---|---|---|
| 1956 | 3,697 | 71 | 192,846 | 3,709 | 71 | 193,482 |
| 1957 | 3,430 | 66 | 177,717 | 3,403 | 66 | 176,177 |
| 1958 | 3,486 | 67 | 180,855 | 3,567 | 69 | 185,456 |
| 1959 | 3,290 | 64 | 169,867 | 3,302 | 64 | 170,498 |
| 1960 | 3,876 | 74 | 203,035 | 3,279 | 64 | 169,223 |
| 1961 | 3,740 | 72 | 195,254 | 3,746 | 72 | 195,601 |
| 1962 | 3,988 | 76 | 209,445 | 3,932 | 75 | 206,262 |
| 1963 | 3,585 | 69 | 186,436 | 3,603 | 69 | 187,461 |
| 1964 | 3,044 | 59 | 156,131 | 3,055 | 60 | 156,773 |
| 1965 | 3,676 | 71 | 191,628 | 3,968 | 76 | 208,300 |
| 1966 | 3,032 | 59 | 155,460 | 3,119 | 61 | 160,310 |
| 1967 | 4,106 | 78 | 216,262 | 3,971 | 76 | 208,483 |
| 1968 | 3,146 | 61 | 161,819 | 3,155 | 61 | 162,308 |
| 1969 | 227 | 5 | 11,046 | 156 | 3 | 7,733 |
| 1970 | 2,934 | 57 | 150,031 | 2,558 | 51 | 129,437 |
| 1971 | 3,492 | 67 | 181,226 | 3,493 | 67 | 181,272 |
| 1972 | 3,301 | 64 | 170,447 | 3,267 | 63 | 168,558 |
| 1973 | 3,379 | 65 | 174,848 | 3,240 | 63 | 167,074 |
| 1974 | 3,689 | 71 | 192,345 | 3,689 | 71 | 192,336 |
| 1975 | 3,559 | 68 | 184,995 | 3,348 | 65 | 173,097 |
| 1976 | 2,249 | 45 | 112,800 | 1,962 | 39 | 97,560 |
| 1977 | 1,530 | 31 | 75,019 | 1,504 | 31 | 73,661 |
| 1978 | 3,852 | 74 | 201,683 | 3,169 | 62 | 163,065 |
| 1979 | 3,663 | 70 | 190,906 | 3,771 | 72 | 197,043 |
| 1980 | 714 | 15 | 34,166 | 716 | 15 | 34,265 |
| 1981 | 3,059 | 60 | 156,950 | 3,060 | 60 | 157,044 |
| 1982 | 1,844 | 37 | 91,357 | 1,499 | 31 | 73,424 |
| 1983 | 1 | 0 | 79 | 1 | 0 | 75 |
| 1984 | 2,932 | 57 | 149,958 | 2,836 | 56 | 144,674 |
| 1985 | 3,893 | 74 | 204,033 | 3,899 | 74 | 204,371 |
| 1986 | 1,767 | 36 | 87,331 | 1,204 | 25 | 58,432 |
| 1987 | 4,022 | 77 | 211,393 | 4,034 | 77 | 212,070 |
| 1988 | 2,267 | 45 | 113,755 | 2,544 | 50 | 128,680 |
| 1989 | 3,906 | 75 | 204,729 | 2,765 | 54 | 140,757 |
| 1990 | 3,207 | 62 | 165,230 | 3,297 | 64 | 170,243 |
| 1991 | 2,115 | 42 | 105,650 | 2,225 | 44 | 111,491 |
| 1992 | 1,830 | 37 | 90,582 | 1,754 | 36 | 86,628 |

| Year | EC, Mean | EC, Lower 95% | EC, Upper 95% | Proposed Action, Mean | Proposed Action, Lower 95% | Proposed Action, Upper 95% |
|---|---|---|---|---|---|---|
| 1993 | 3,425 | 66 | 177,411 | 3,380 | 65 | 174,904 |
| 1994 | 4,028 | 77 | 211,743 | 4,027 | 77 | 211,675 |
| 1995 | 3,131 | 61 | 160,953 | 1,774 | 36 | 87,698 |
| 1996 | 3,852 | 74 | 201,642 | 2,465 | 49 | 124,420 |
| 1997 | 110 | 2 | 5,582 | 98 | 2 | 5,031 |
| 1998 | 393 | 8 | 18,829 | 226 | 5 | 10,978 |
| 1999 | 3,686 | 71 | 192,194 | 3,844 | 73 | 201,219 |
| 2000 | 3,104 | 60 | 159,452 | 2,896 | 57 | 147,979 |
| 2001 | 3,658 | 70 | 190,586 | 3,653 | 70 | 190,296 |
| 2002 | 3,484 | 67 | 180,738 | 3,501 | 67 | 181,702 |
| 2003 | 3,466 | 67 | 179,767 | 3,462 | 67 | 179,523 |
| 2004 | 3,475 | 67 | 180,235 | 3,610 | 69 | 187,854 |
| 2005 | 3,683 | 71 | 192,004 | 3,674 | 70 | 191,540 |
| 2006 | 852 | 18 | 40,895 | 745 | 16 | 35,680 |
| 2007 | 3,707 | 71 | 193,361 | 3,711 | 71 | 193,629 |
| 2008 | 3,198 | 62 | 164,702 | 3,199 | 62 | 164,763 |
| 2009 | 3,354 | 65 | 173,440 | 3,231 | 63 | 166,541 |
| 2010 | 2,956 | 58 | 151,248 | 3,144 | 61 | 161,711 |
| 2011 | 1,443 | 30 | 70,547 | 1,486 | 30 | 72,781 |
| 2012 | 3,691 | 71 | 192,500 | 3,695 | 71 | 192,704 |
| 2013 | 3,449 | 67 | 178,776 | 4,010 | 76 | 210,737 |
| 2014 | 2,077 | 42 | 103,631 | 1,922 | 39 | 95,414 |
| 2015 | 1,412 | 29 | 68,981 | 1,426 | 29 | 69,695 |

EC = existing conditions.

# 5D.16 Longfin Smelt Delta Outflow–Abundance Index Analysis

## 5D.16.1 Methods

### 5D.16.1.1 Development of Statistical Relationship

The potential effect of the proposed action on longfin smelt was investigated through development of a statistical model relating the longfin smelt fall midwater trawl (FMWT) abundance index to Delta outflow, the FWMT abundance index 2 years earlier (as a representation of parental stock size), and ecological regime (i.e., 1967–1987, pre-*Potamocorbula amurensis* invasion; 1988–2002, post-*P. amurensis* invasion; and 2003–2020, Pelagic Organism Decline; to represent major ecological changepoints in the Bay-Delta, e.g., Nobriga and Rosenfield 2016). Total Delta outflow (thousand

acre-feet) was summed and examined for March through May and December through May, similar time periods to previous work by Mount et al. (2013:66–69) and Nobriga and Rosenfield (2016).

Twelve log-linear regression models were considered in the analysis. The models were fit using a Bayesian approach implemented in the R statistical computing language (R Core Team 2021) via the *brms* package (Bürkner 2017) with model weights for averaging posterior predictive distributions calculated using the *loo* package (Vehtari et al. 2020): three Markov Chain Monte Carlo chains were run; flat priors were assumed; there was a 2,000-sample warm-up; 10,000 samples were retained from each chain (30,000 samples total from the posterior); and the $\widehat{R}$ <1.01 on estimated parameters indicated sampling converged on the posterior probability distributions for all models.

Preliminary model comparison was performed using leave-one-out cross validation (LOO) (Vehtari et al. 2017). Measures of model predictive accuracy using LOO are asymptotically equal to the widely applicable information criteria (WAIC) (Watanabe 2010), but in the case of finite data, LOO has been shown to be more robust to influential observations like outliers (Vehtari et al. 2017). The preliminary model comparisons indicated there was a relatively high degree of similarity in terms of predictive ability between the top scoring individual models. The extent of model overlap in predictive accuracy was measured by the differences (and the standard errors of the differences) in expected log pointwise predictive densities: i.e., the differences in out-of-sample predictive accuracy between models.

Therefore, rather than selecting a single model for inference, the posterior predictive probability distributions were combined as a weighted average across models. This process involved taking draws from the posterior of each single model in proportion to its model weight. For example, if a single model's weight was 25% of the total model set, then 2,500 draws from its posterior were added to the averaged posterior predictive distribution, which again included 10,000 total draws across all models. The statistical approach used to calculate the model weights for averaging the posterior predictive distributions across models is known as "stacking" (Yao et al. 2018).

Compared to more traditional model averaging approaches, stacking differs in terms of how model weights are assigned. Instead of calculating model weights based on the relative predictive ability for each individual model—where the best model for prediction would be given the highest weight—the model weights estimated through stacking minimize the LOO mean squared error of the resulting averaged posterior predictive distribution across models. In other words, stacking was used to estimate the optimal linear combination of model weights (Yao et al. 2018).

Hence, the model with the largest stacking weight does not necessarily have the highest predictive score compared to other models in the set. For example, the models in this case can be divided into two subsets: one subset includes a covariate for Delta outflow during December–May and the other model subset includes a covariate for March–May Delta outflow. Comparing the predictive ability of each individual model using LOO resulted in a model with December–May outflow (the model with the third highest stacking weight in having the highest individual predictive accuracy of any single model considered. In contrast, stacking resulted in a model with March–May having the highest single model weight (36% of the total stacking weight). Nevertheless, because stacking optimizes the linear combination of model weights, the next three models (~64% of the stacking weight) all include December–May instead of March–May. Therefore, in this case, even though the model with highest stacking weight included March–May Delta outflow, the averaged posterior predictive distribution was ultimately weighted more heavily with models that include December–May Delta outflow compared to models with March–May Delta outflow. Of the twelve models considered, the

top four models by stacking weight accounted for 99.9% of the averaged posterior predictive distribution.

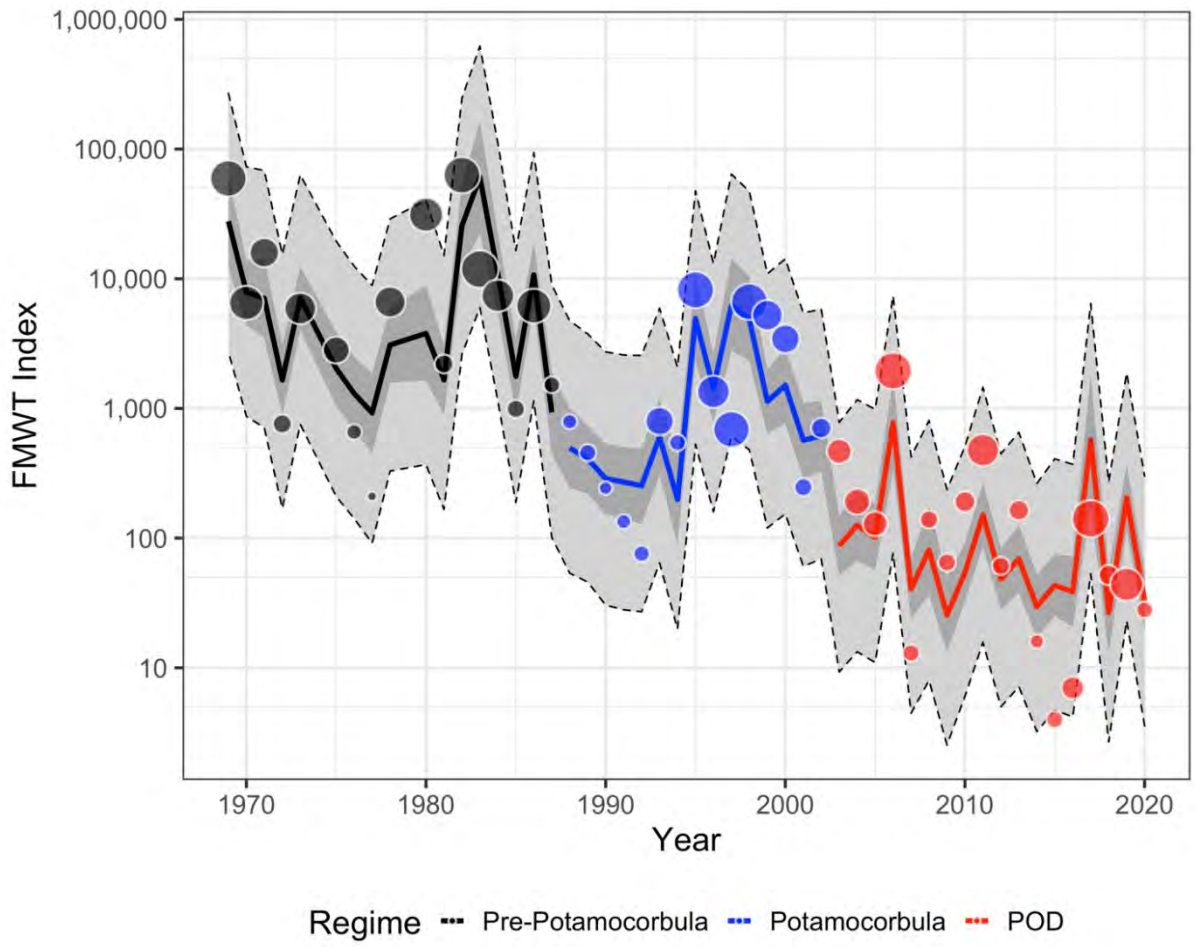
Several additional models were also examined, in addition to those in but they were ultimately not included in this analysis due to poor model fits and what would have been additional computational cost without an expected difference in results. The additional models included a squared term on Delta outflow and their examination was motivated by the modeling results of Nobriga and Rosenfield (2016). Those authors assessed the relationship between Delta outflow and the ratio of age-0 to age-2 longfin smelt abundance in the two-life-stage versions of the models included in their analyses. They found support for non-linearity in this relationship (i.e., there was a peak in productivity at more intermediate outflow values), which led to the inclusion of a second-order polynomial regression (i.e., a squared term) on Delta outflow (Nobriga and Rosenfield 2016:50). Given the approach taken here, which differs from the Nobriga and Rosenfield analysis in terms of (1) the survey data used for longfin smelt abundance, (2) how Delta outflow values were included as covariates, and (3) the overall time periods for available data included in the regression models, there was little to no support found for a second-order polynomial regression on Delta outflow. The aforementioned factors that differed between the two analyses are briefly described in the next paragraph for completeness; but, given the poor predictive ability of the second-order polynomial regressions under the current approach, that subset of models was ultimately not included because the preliminary results indicated the stacked model weights would be near zero. Hence the averaged posterior predictive distributions would not be expected to be sensitive to the exclusion of those models in this case, but their inclusion would have increased the computational time necessary to run and perform the averaging over a larger set of models.

As outlined above, there are several differences between these analyses and those of Nobriga and Rosenfield (2016) that might explain the discrepancy in terms of support (or lack thereof) found for dome shaped longfin smelt productivity as a function of Delta outflow. Firstly, Nobriga and Rosenfield (2016) found support for this relationship fitting models to catch data from the San Francisco Bay Study. In these analyses, on the other hand, the regression models have been fit to the FMWT index of abundance instead. Second, Nobriga and Rosenfield (2016) incorporated covariate values for Delta Outflow based on a principal component analysis (the first principal component values) of the *z*-scored monthly means from December to May. Here, the monthly total outflow (either from December to May, or March to May) were summed, resulting in a total outflow value during each time period each year, and the regression covariate values were calculated as the *z*-scores of the period-total outflow values taken across years. Third, in addition to examining indices of abundance from different surveys, the annual time periods that have been examined also differ. Nobriga and Rosenfield (2016) examined the relationship between annual indices of longfin smelt abundance-at-age and Delta outflow that were available from the Bay Study during 1980–2013. Whereas in these analyses this relationship was examined over a longer period, during 1967–2020, which includes 20 additional years in the comparison with Delta outflow.

### Table 5D.16-1. The Optimal Linear Combination of Model Weights based on Stacking

| **$Log_{10}$FMWT Linear Regression Model** [a] | **Stacking Weight** |
|---|---|
| Mar–May + Regime + $Log_{10}$ FMWT(yr – 2) | 0.3583 |
| Dec–May + Regime | 0.3154 |
| Dec–May + Regime + $Log_{10}$ FMWT(yr – 2) | 0.1995 |
| Dec–May + $Log_{10}$ FMWT(yr – 2) | 0.1260 |
| Dec–May + Regime + Dec–May * Regime | 0.0006 |
| Dec–May + Regime + Dec–May * Regime + $Log_{10}$ FMWT(yr – 2) | <0.0001 |
| Mar–May + Regime + Mar–May * Regime + $Log_{10}$ FMWT(yr – 2) | <0.0001 |
| Mar–May + $Log_{10}$ FMWT(yr – 2) | <0.0001 |
| Mar–May + Regime | <0.0001 |
| Mar–May + Regime + Mar–May * Regime | <0.0001 |
| Dec–May | <0.0001 |
| Mar–May | <0.0001 |

Note: The Optimal Linear Combination of Model Weights based on Stacking which Minimizes the Mean Squared Error of the Leave-One-Out Cross Validation for the Resulting Model Averaged Posterior Predictive Distribution across the Twelve Log-Linear Regressions of Longfin Smelt Fall Midwater Trawl Abundance Index. Models are a Function of Delta Outflow (December–May or March–May), Ecological Regime (1967–1987, pre-*Potamocorbula amurensis* invasion; 1988–2002, post-*P. amurensis* invasion; and 2003–2020, Pelagic Organism Decline), and Abundance Index 2 Years Earlier ($Log_{10}$ FMWT(yr – 2)).
FMWT = fall midwater trawl; yr = year.
[a] An asterisk "*" sign represents an interaction term between Regime and Delta Outflow.




Note: The circles represent the annual historical values of the FMWT abundance index, with diameter of each circle scaled relative to December through May Delta outflow in that year. The solid lines connect the annual medians from the Bayesian posterior distribution, and the darker gray ribbons around them represent the 95% posterior probability interval for the expected FMWT index value. Colors correspond to the three modeled regimes. The lighter gray ribbon with a dashed black outline represents the 95% posterior predictive probability interval.

FMWT = fall midwater trawl.

**Figure 5D.16-1. Fit of Best Log-Linear Regression of Longfin Smelt Fall Midwater Trawl Abundance Index as a Function of Delta Outflow (December–May), Ecological Regime (1967–1987, pre-*Potamocorbula amurensis* invasion; 1988–2002, post-*Potamocorbula* invasion [shown as *Potamocorbula*]; and 2003–2020, Pelagic Organism Decline [POD]), and Abundance Index 2 Years Earlier [Log10 FMWT(yr – 2)]**

### 5D.16.1.2 Assessment of Project Alternatives (including the Proposed Action)

Predictions of the FMWT abundance index under the alternative modeled CalSim 3 outflow scenarios (1922–2015) were generated using the model stacking approach described above to generate a weighted average Bayesian posterior predictive distribution across the set of models considered. Dropping subscripts denoting individual models for simplicity, the general form of the models can be written as:

$$Log_{10}[FMWT_{yr}] \sim N(\mu_{yr}, \sigma^2) \quad (1)$$

$$\mu_{yr} = \beta_{0,i} + \beta_1 Outflow_{yr,j} + \beta_2 Log_{10}\left[FMWT_{yr-2}\right] + \beta_3 Regime_i * Outflow_{yr,j} \quad (2)$$

where:

$Log_{10}[FMWT_{yr}]$ is the model predicted $Log_{10}$ value of the FMWT index in water year *yr*;

$\mu_{yr}$ is the expected FMWT index in water year *yr* (the stacked posterior predictive distribution for $\mu_{yr}$ is shown as the dark grey ribbon in Figure 5D.16-1);

$\sigma^2$ is the residual variance parameter (the stacked posterior predictive distribution including the residual variance is shown as the light grey ribbon in Figure 5D.16-1);

$\beta_{0,i}$ represents the intercept parameter estimated for each regime: Pre-*Potamocorbula* (*i* = 1); *Potamocorbula* (*i* = 2); and POD (*i* = 3). For models without a regime covariate, a single intercept is estimated across all years instead, i.e., $\beta_0$ is substituted for $\beta_{0,i}$;

$\beta_1$ represents the slope parameter estimated for the relationship between the FMWT index and Delta outflow;

$Outflow_{yr,j}$ is the normalized[10] outflow level during water year *yr*, and *j* denotes the outflow level during either the December through May, or the March through May period;

$\beta_2$ represents the slope parameter estimated for the relationship between the expected FMWT index and the value of that index 2 years prior. For models without the parental stock covariate, $\beta_2 = 0$, and;

$\beta_3$ represents the interaction covariate (the difference in slopes) with respect to the estimated effect of outflow on the FMWT index of abundance during different regimes. For models without this interaction term, $\beta_3 = 0$.

For those models that included the $Log_{10}$ FMWT(yr – 2) parental stock size covariate, the starting parental stock size in 1922 and 1923 was set at a FMWT index value of 99.4, corresponding to the mean index value from 2011 through 2020. Given the starting values for the FMWT index (in the relevant models), the recursive nature of the regression formula was used to generate the expected FMWT index value in successive years from the posterior predictive distribution 2 years prior. For all models, predictions were conditional on the estimated relationship between the FMWT index and Delta outflow (in December–May, or March–May, depending on the model), and for those models that included a regime covariate, draws from the posterior predictive distributions were conditioned on estimates during the Pelagic Organism Decline regime.

[10] Normalized outflow values for each CalSim 3 scenario were calculated by subtracting the mean and dividing by the standard deviation of observed Delta outflow values (1967–2020).

As an example, starting in 1924, draws from the posterior predictive distribution for models including the parental stock size covariate were generated by first substituting the normalized 1924 December through May (or March through May) CalSim 3 outflow value for each alternative. Draws from the posterior distributions for the regression parameters and the starting value for $Log_{10}[FMWT_{1922}]$ were then used to generate the posterior predictive distribution for the FMWT index in 1924 ($\mu_{1924}$). This value was then substituted into Equation 1, and the posterior distribution for the residual variance parameter was used to generate draws from the pointwise posterior predictive distributions for the FMWT index.[11] This process was iterated over each successive year, substituting the derived $\mu_{yr-2}$ values for $Log_{10}[FMWT_{yr-2}]$ to calculate $\mu_{yr}$, and to generate the annual posterior predictive distributions for the FMWT index under each alternative. For models that did not include the parental stock size covariate, the posterior predictive distributions were generated based on the corresponding CalSim 3 outflow values for the monthly period corresponding to the individual model estimates, and likewise conditioned on covariate estimates during the POD regime for models that included a regime covariate (or the constant intercept parameter $\beta_0$, for models without the regime covariate). As noted above in the description of the model stacking approach, draws from the posterior predictive distribution for each model were sampled in proportion to the stacking model weights, to generate a weighted average posterior predictive distribution across the models considered. Summaries were then calculated by grouping the stacked annual posterior predictive distributions by water year type and calculating the means and credible intervals for each aggregated water year type posterior predictive distribution.

### 5D.16.2 Results

## 5D.17 Smelt Tidal Habitat Restoration Mitigation Calculation

Tidal habitat restoration mitigation for delta smelt and longfin smelt was calculated based on the same method recently applied by California Department of Water Resources (2019:5-5). The method applied is that of Kratville (2010), who combined statistical relationships between E:I and proportion of particles entrained from various particle injection locations included in DSM2-PTM runs by Kimmerer and Nobriga (2008) with areas of habitat represented by groups of particle injection locations. The logistic equations for these particle injection locations that were applied in the analysis to mean CalSim-modeled E:I from February through June were as follows (Nobriga pers. comm.; see Kratville 2010 for further explanation of station codes):

- Antioch: Proportional entrainment = $1-(1/(1+ 0.00271028300855596*e^{6.84578776491213*E:I}))$
- Bacon Island: Proportional entrainment = $1-(1/(1+ 0.00360067831643248*e^{48.0279532945984*E:I}))$
- Collinsville: Proportional entrainment = $1-(1/(1+ 0.00122681735447479*e^{7.34600447344753*E:I}))$
- Franks Tract East: Proportional entrainment = $1-(1/(1+ 0.0882721350895259*e^{6.51283857598075*E:I}))$
- Franks West: Proportional entrainment = $1-(1/(1+ 0.0321221161869743*e^{5.5544157874989*E:I}))$

[11] "$\sim N$" in Eqn. 1 denotes a normal (Gaussian) distribution.

- Georgiana Slough: Proportional entrainment = $1-(1/(1+0.0556193254426028*e^{7.53188118299606*E:I}))$
- Hood: Proportional entrainment = $1-(1/(1+0.0370940945312037*e^{6.00721899458561*E:I}))$
- Medford Island: Proportional entrainment = $1-(1/(1+0.00592509281258315*e^{34.8002358833536*E:I}))$
- Mossdale: Proportional entrainment = $1-(1/(1+0.111111111111111*e^{26.6493233888825*E:I}))$
- North Fork Mokelumne: Proportional entrainment = $1-(1/(1+0.0610234435346189*e^{7.28620279196804*E:I}))$
- Potato Slough: Proportional entrainment = $1-(1/(1+0.0163841512024925*e^{23.708308398635*E:I}))$
- Rio Vista: Proportional entrainment = $1-(1/(1+0.0076755045686138*e^{6.69498358561645*E:I}))$
- Ryde: Proportional entrainment = $1-(1/(1+0.0117017438595754*e^{6.7207341005591*E:I}))$
- South Fork Mokelumne: Proportional entrainment = $1-(1/(1+0.0389615268878375*e^{14.4737516748024*E:I}))$
- Stockton: Proportional entrainment = $1-(1/(1+0.00840706847099802*e^{32.6988703978096*E:I}))$
- Three Mile Slough: Proportional entrainment = $1-(1/(1+0.0157935505682666*e^{6.10724605041376*E:I}))$
- Twitchell Island: Proportional entrainment = $1-(1/(1+0.0342441647821108*e^{6.37831755748149*E:I}))$
- Vernalis: Proportional entrainment = $1-(1/(1+0.111111111111111*e^{27.3073879175582*E:I}))$
- Victoria Canal: Proportional entrainment = $1-(1/(1+0.00000001283874368*e^{219.722457733622*E:I}))$

The mean estimate of particle proportional entrainment from application of these equations was calculated for four geographic zones, with this mean estimate of particle entrainment then being multiplied by the area of each zone.

- Lower Sacramento (Antioch, Collinsville, Rio Vista, Ryde, Three Mile Slough): 19,140.69 acres.
- Hood and West Dela San Joaquin (Hood, Twitchell Island): 6,080.929 acres.
- Georgiana Slough/North Fork Mokelumne (Georgiana Slough, North Fork Mokelumne): 2,704.28 acres.
- San Joaquin (Bacon Island, Franks Tract East, Franks Tract West, Medford Island, Mossdale, Potato Slough, South Fork Mokelumne, Stockton, Vernalis, Victoria Canal): 21,124.31 acres.

For delta smelt, the overall area of effect for each scenario was calculated as the full area of the above calculations. For longfin smelt, the overall area of effect for each scenario was calculated as 10% of the area of the above calculations, consistent with calculations for the mitigation requirements used by CDFG (2009a) and DWR (2019).

# 5D.18 Delta Smelt Occurrence Upstream of Freeport Regional Water Authority Intake

## 5D.18.1 Methods

To evaluate the potential influence of the Freeport Regional Water Authority Intake on upstream passage by delta smelt, delta smelt detection probability in Delta Juvenile Fish Monitoring Program beach seines during January–June upstream and downstream of the intake location were calculated. Delta Juvenile Fish Monitoring Program beach seine data from the monitoring stations listed in Table 5D.18-1 were used to convert delta smelt count data to presence/absence for all seine sets conducted between 1994 and 2019. Three periods of interest were defined: pre-construction (1994–2006); construction (2007–2009); and post-construction (2010–2019). The overall detection probability for each period and location combination (e.g., pre-construction/upstream; six combinations in total) was calculated as the proportion of beach seine sets with positive delta smelt detections. From these results, the ratio of upstream to downstream detection probability was calculated for each period.

**Table 5D.18-1. Delta Juvenile Fish Monitoring Program Beach Seine Stations and Location Relative to Freeport Regional Water Authority Intake**

| Station | Location Relative to Freeport Intake |
|---|---|
| SR012W (Sandy Beach) | Downstream |
| SR014W (Rio Vista) | Downstream |
| SR017E (Isleton) | Downstream |
| SR024E (Koket) | Downstream |
| XC001N (Delta Cross Channel) | Downstream |
| GS010E (Georgiana Slough) | Downstream |
| SS011N (Steamboat Slough (mouth) | Downstream |
| SR043W (Clarksburg) | Downstream |
| SR049E (Garcia Bend) | Upstream |
| SR055E (Sherwood Harbor) | Upstream |
| SR057E (Miller Park) | Upstream |
| SR060E (Discovery Park) | Upstream |
| AM001S (American River) | Upstream |
| SR062E (Sand Cove) | Upstream |
| SR071E (Elkhorn) | Upstream |
| SR080E (Verona) | Upstream |

To evaluate the statistical significance of any differences in delta smelt detection probability across locations and periods, a logistic regression model was fitted using the 'glm' function in the statistical software R (R Core Team 2021). Delta smelt detection was modeled as a function of the interaction of period and location (detection~period+location+period*location). It was assumed that catchability of delta smelt remained consistent during the study period, although this is not known.

The influence of potentially confounding variables, including overall delta smelt population abundance and river flow, was evaluated by initially including covariates in the logistic model. Delta smelt population abundance was represented by the prior year's FMWT index, while flow was calculated as the mean December through March flow reported by U.S. Geological Survey for the Freeport gaging station. Freeport flow was modeled as a second order polynomial to represent the hypothesis of a nonlinear influence of flow on upstream movement by delta smelt (i.e., impedance at high flow; less attraction at low flow). Neither of the covariates were found to be significant predictors of delta smelt detection, and a comparison of models including and excluding the covariates using AIC favored the more parsimonious model, so covariates were excluded from further analysis.

## 5D.18.2 Results

Overall, the probability of observing delta smelt in any Delta Juvenile Fish Monitoring Program beach seine conducted at the stations listed in Table 5D.18-2 was low (mean detection probability of 0.031). Detections were consistently higher at stations located downstream of the Freeport intake across all three periods. The ratio of upstream to downstream detection probability was highest during the pre-construction period, lowest during the construction period, and intermediate during the post-construction period (Table 5D.18-2), although the interaction between location and period was not statistically significant (Table 5D.18-3; Figure 5D.18-1). Logistic regression analysis indicated that differences in detection probability between upstream and downstream locations were highly statistically significant ($P$ <0.001; Table 5D.18-3). The odds ratio for the overall comparison of upstream and downstream indicated that the probability of detecting delta smelt in an upstream seine set was only 24% of that for a downstream seine set. Differences in detection probability between periods were marginally statistically significant ($P \sim 0.075$; Table 5D.18-3).

**Table 5D.18-2. Detection Probability of Delta Smelt in Beach Seines Upstream and Downstream of the Freeport Regional Water Authority Intake**

| Period | Upstream | Downstream | Ratio |
|---|---|---|---|
| Pre-construction | 0.007 | 0.030 | 0.245 |
| Construction | 0.004 | 0.020 | 0.187 |
| Post-construction | 0.005 | 0.023 | 0.231 |

**Table 5D.18-3. Summary of Logistic Regression of Delta Smelt Detection in Beach Seines Upstream and Downstream of the Freeport Regional Water Authority Intake**

| Comparison | Odds Ratio | *p*-value |
|---|---|---|
| Construction vs. pre-construction | 0.65 | 0.08 |
| Post- vs. pre-construction | 0.76 | 0.07 |
| Upstream vs. Downstream | 0.24 | <0.001 |
| Upstream, construction vs. downstream, pre-construction | 0.77 | 0.61 |
| Upstream, post-construction vs. downstream, pre-construction | 0.95 | 0.85 |

Note: Periods were pre-construction (1994–2006); construction (2007–2009); and post-construction (2010–2019).

Note: Periods were pre-construction (1994–2006); construction (2007–2009); and post-construction (2010–2019).

**Figure 5D.18-1. Predicted Probability of Delta Smelt Detection in Beach Seines Upstream and Downstream of the Freeport Regional Water Authority Intake**

These results indicate that the lower probability of detecting delta smelt at locations upstream vs. downstream of the Freeport intake predates the installation of the facility. The probability of detecting delta smelt in the DFJMP beach seines for these locations has decreased slightly relative to the pre-construction period, but this decrease is of marginal statistical significance, has occurred in both upstream and downstream sampling locations, and likely reflects the overall decrease in delta smelt abundance during the period investigated by this analysis.

# 5D.19 Delta Smelt Life Cycle Modeling

Attachment 5D.4, *Delta Smelt Life Cycle Modeling*, describes the methods and results from the delta smelt Life Cycle Model with Entrainment (LCME). Additional discussion of the results is provided in Chapter 6, *Effects Analysis for Delta Smelt, Longfin Smelt, and Terrestrial Species*.

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## 5D.20.2 Personal Communications

Jones, Gardner. Senior Environmental Scientist-Specialist. Mitigation and Restoration Branch, Division of Environmental Services, California Department of Water Resources, West Sacramento, California. August 5, 2015—Emails with fluorescence data (files ProductivityEntrainmentHoodData.xlsx and ProductivityEntrainmentAntiochData.xlsx) sent to Jennifer Pierre, Project Manager, and Lenny Grimaldo, Senior Fisheries Scientist, ICF International, Sacramento, CA.

Nobriga, Matthew. Fish Biologist, Bay Delta Fish and Wildlife Office, U.S. Fish and Wildlife Service, Sacramento, CA. May 14, 2012—Email containing Excel file: logistic_parameters.xls, sent to Marin Greenwood, Aquatic Ecologist, ICF, Sacramento, CA.

Smith, Peter. U.S. Geological Survey. 2012—Spreadsheet with Old and Middle River daily flows for WY 1979-2012, sent to Lenny Grimaldo, U.S. Bureau of Reclamation, Sacramento, CA.

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Attachment 5D.1

# Additional Information for Juvenile Winter-Run Chinook Salmon Salvage Analysis Based on Zeug and Cavallo (2014) and Hydrodynamic Effects Based on DSM2-HYDRO Data

## 5D.1.1 Introduction

This attachment provides additional information for the juvenile winter-run Chinook salmon salvage analysis based on Zeug and Cavallo (2014) and hydrodynamic effects based on DSM2-HYDRO data, described in Appendix 5D, *Bay-Delta Methods and Results*.

## 5D.1.2 Juvenile Winter-Run Chinook Salmon Salvage Analysis Based on Zeug and Cavallo (2014)

Figures 5D.1-1 through 5D.1-5 provide figures separated by water year type, to supplement a similar figures in Appendix 5D. Note that in the plots, Alt_5 = Alternative 5 = proposed action.

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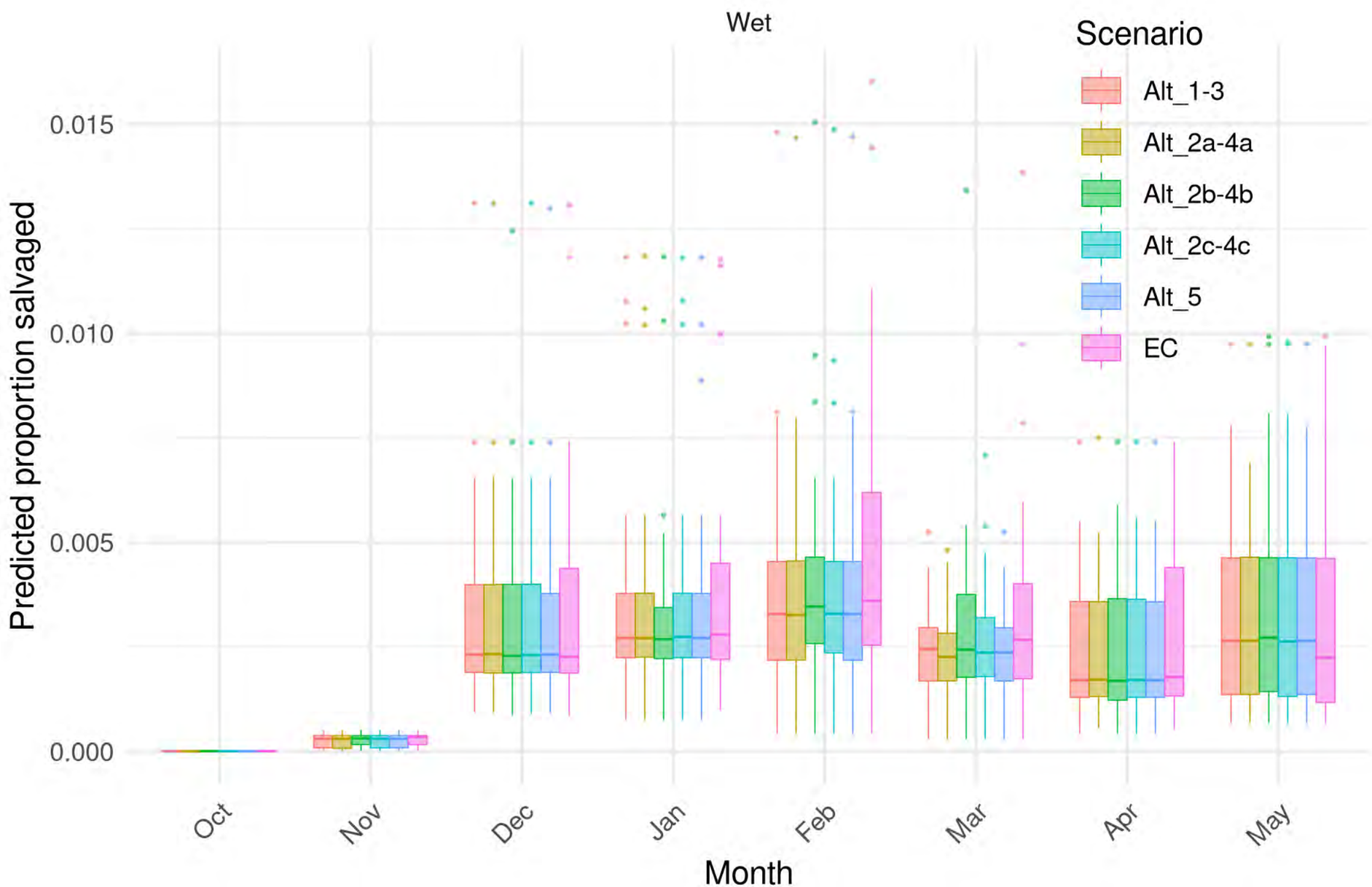



**Figure 5D.1-1. Box Plot of Proportional Juvenile Winter-Run Chinook Salmon Salvage by Month in Wet Water Years for the Analysis Based on Zeug and Cavallo (2014).**

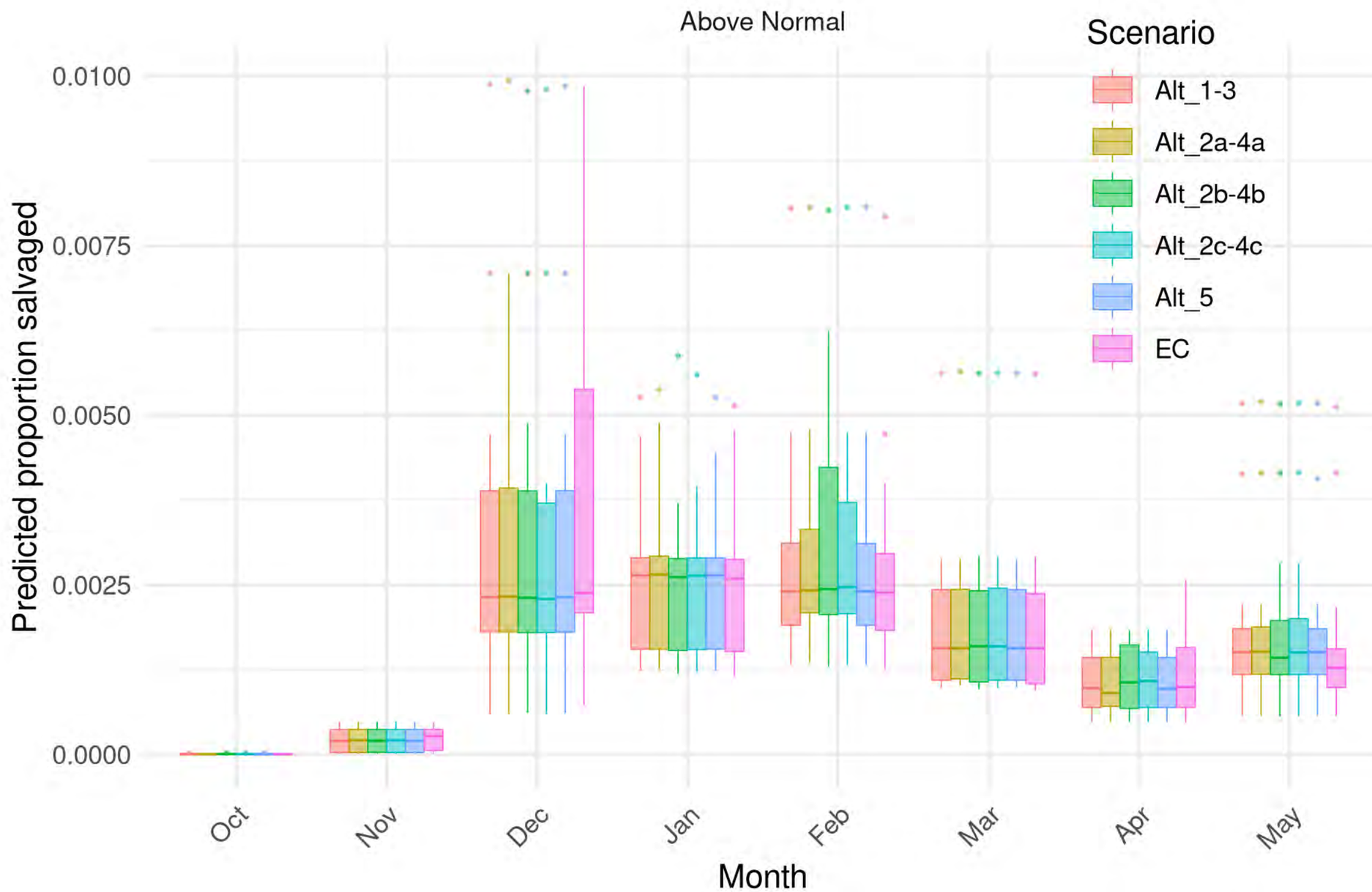



**Figure 5D.1-2. Box Plot of Proportional Juvenile Winter-Run Chinook Salmon Salvage by Month in Above Normal Water Years for the Analysis Based on Zeug and Cavallo (2014).**

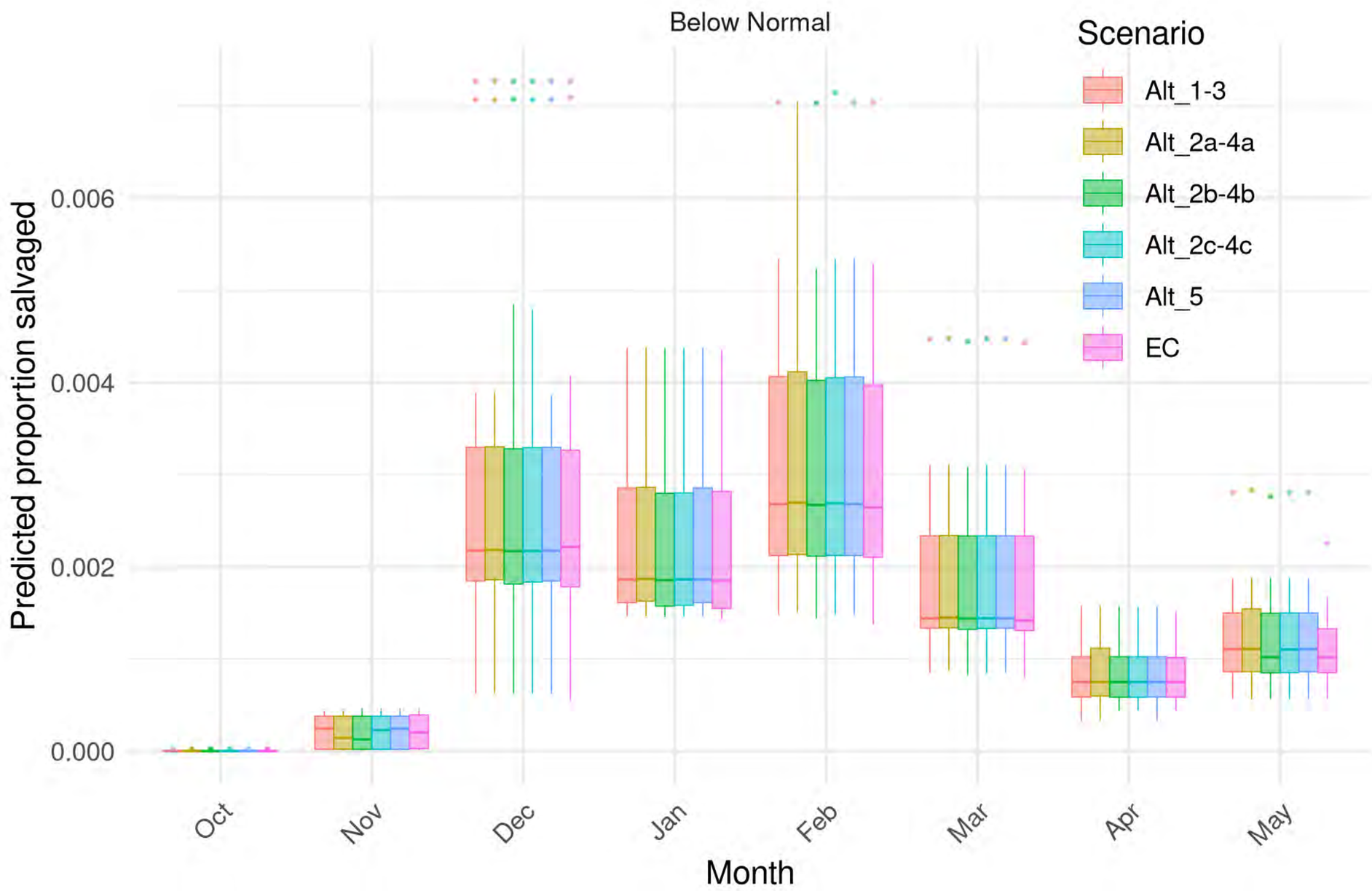



**Figure 5D.1-3. Box Plot of Proportional Juvenile Winter-Run Chinook Salmon Salvage by Month in Below Normal Water Years for the Analysis Based on Zeug and Cavallo (2014).**

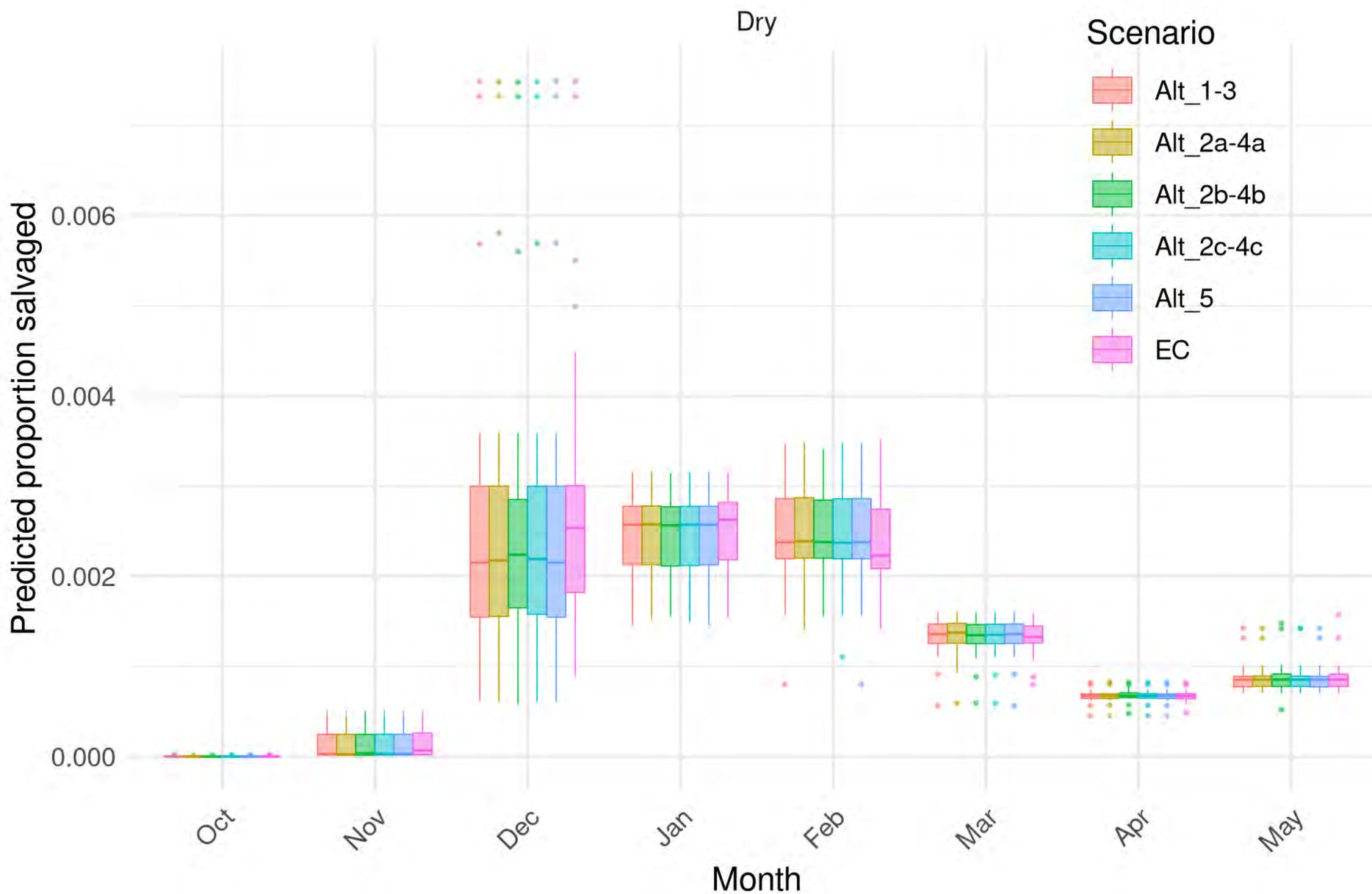



**Figure 5D.1-4. Box Plot of Proportional Juvenile Winter-Run Chinook Salmon Salvage by Month in Dry Water Years for the Analysis Based on Zeug and Cavallo (2014).**

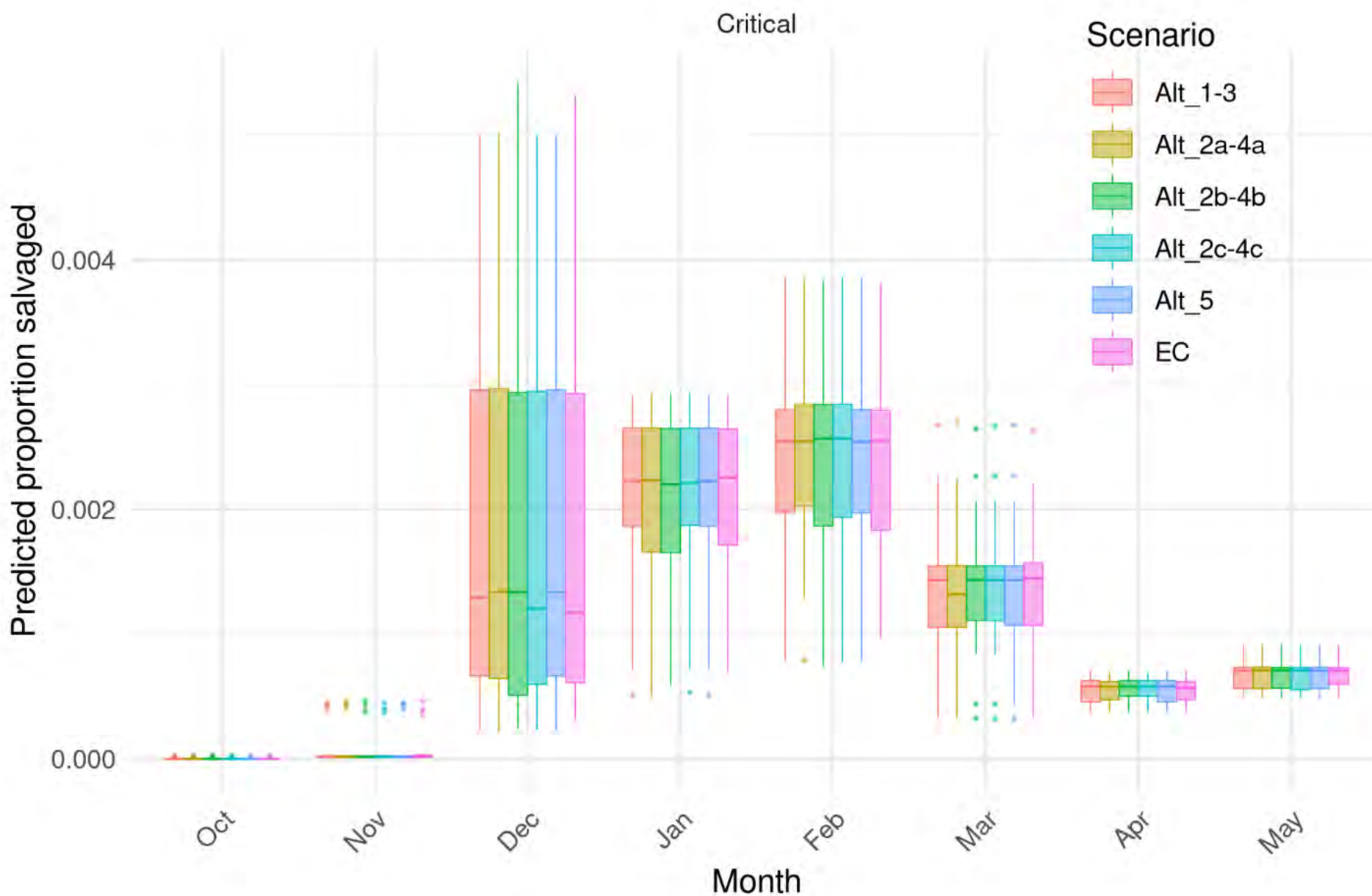



**Figure 5D.1-5. Box Plot of Proportional Juvenile Winter-Run Chinook Salmon Salvage by Month in Critically Dry Water Years for the Analysis Based on Zeug and Cavallo (2014).**

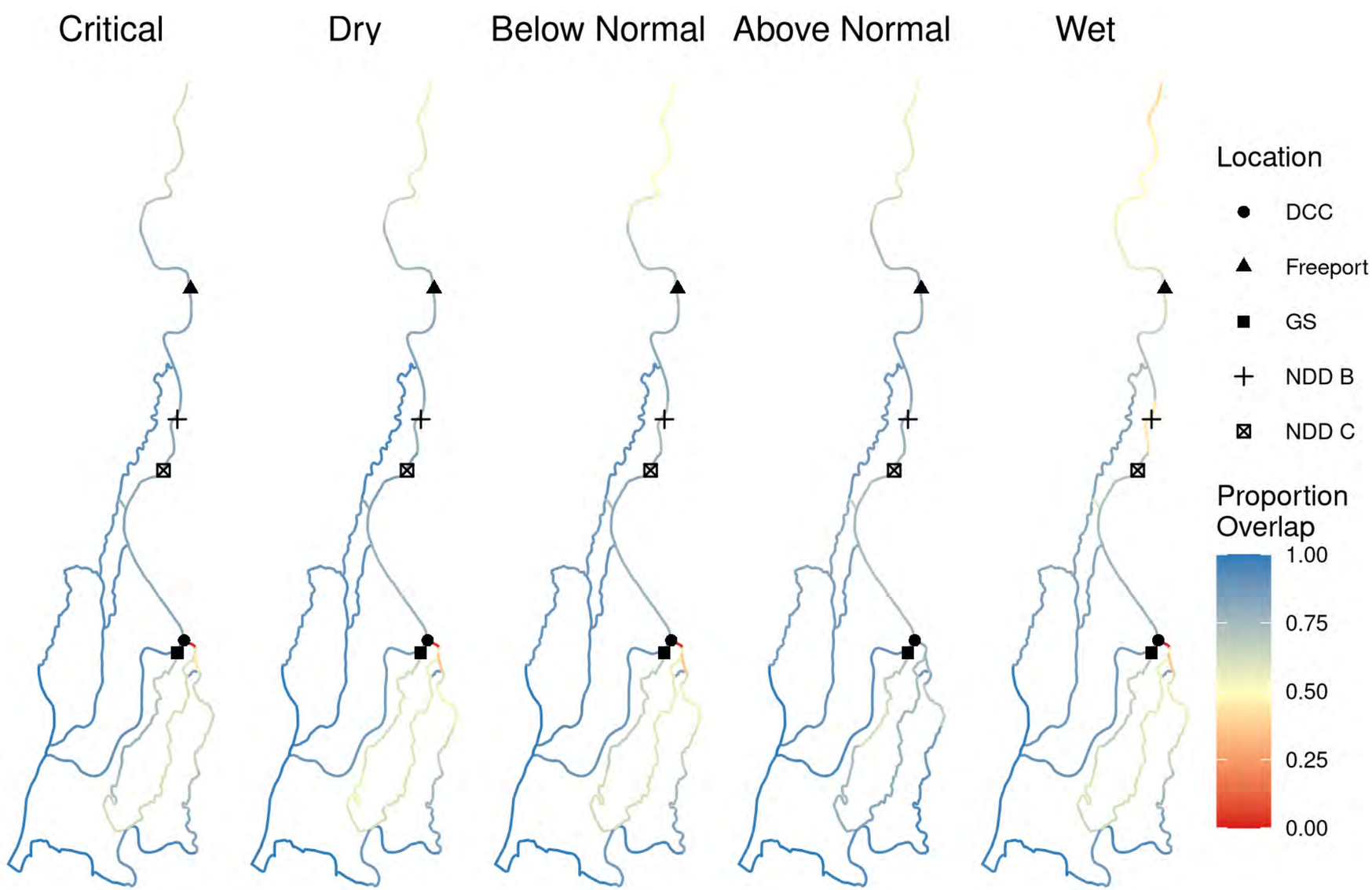
# 5D.1.3 Hydrodynamic Effects Based on DSM2-HYDRO Data

## 5D.1.3.1 Velocity

### 5D.1.3.1.1 Proportional Overlap of Velocity

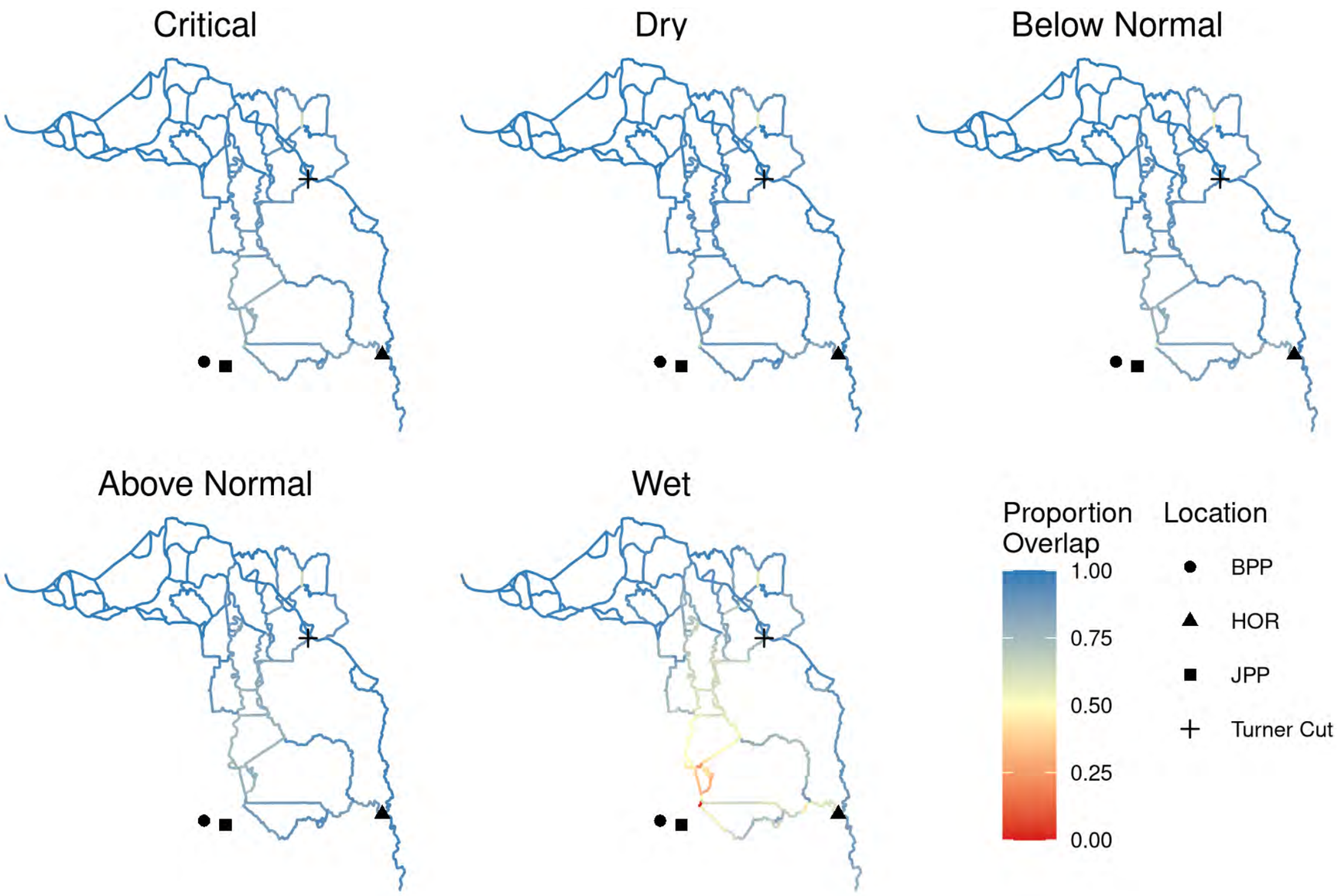
This section provides plots that supplement the plots provided in Appendix 5D; the plots herein are divided by month and include geographic points of interest such as the north Delta intakes.

**October**




Note: DCC = Delta Cross Channel; GS = Georgiana Slough; NDD B = Proposed North Delta Intake B; NDD C = Proposed North Delta Intake C.

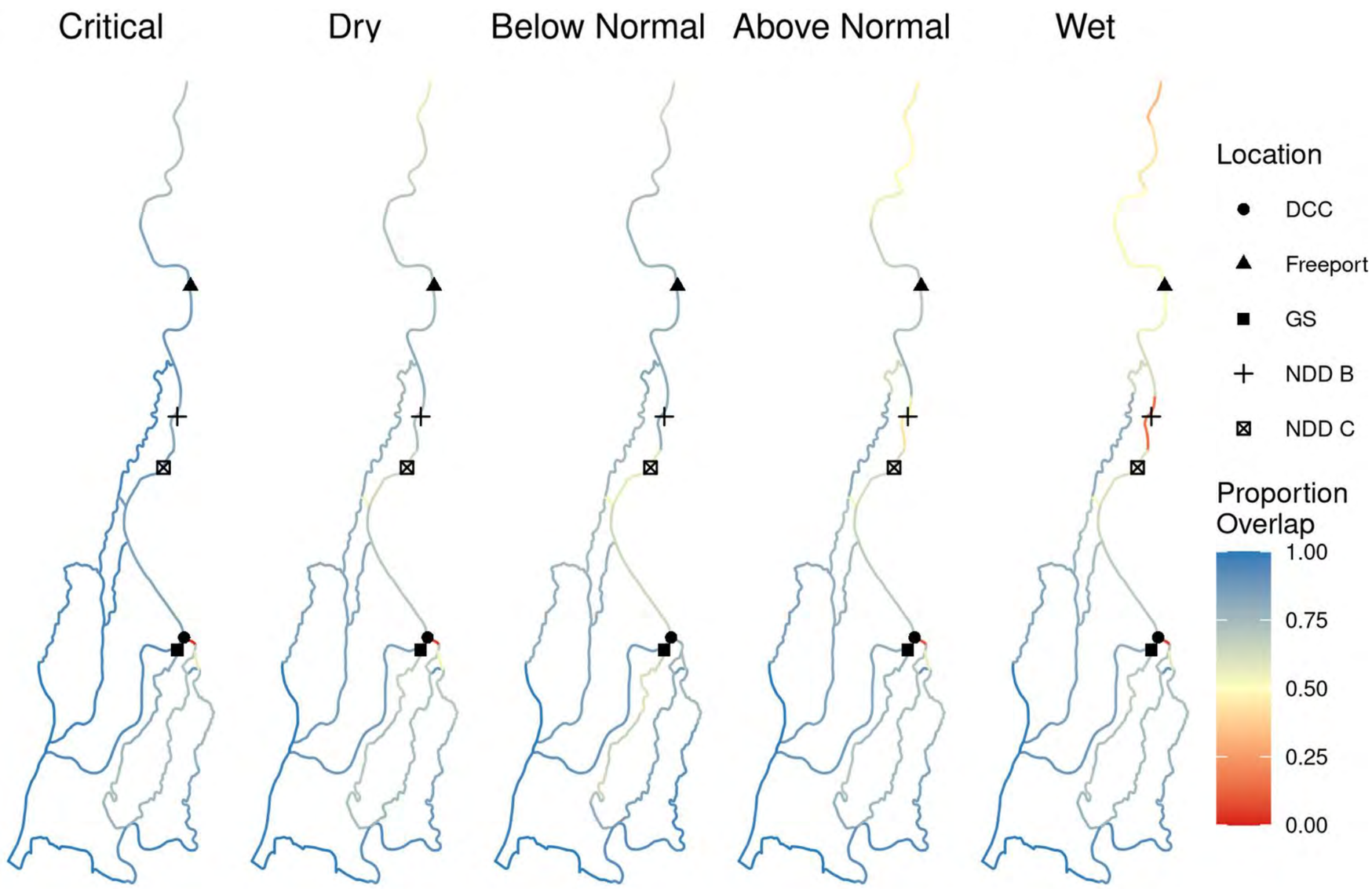
**Figure 5D.1-6. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the North Delta between Existing Conditions and Alternative 5 (Proposed Action), October**




Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant; Turner Cut.

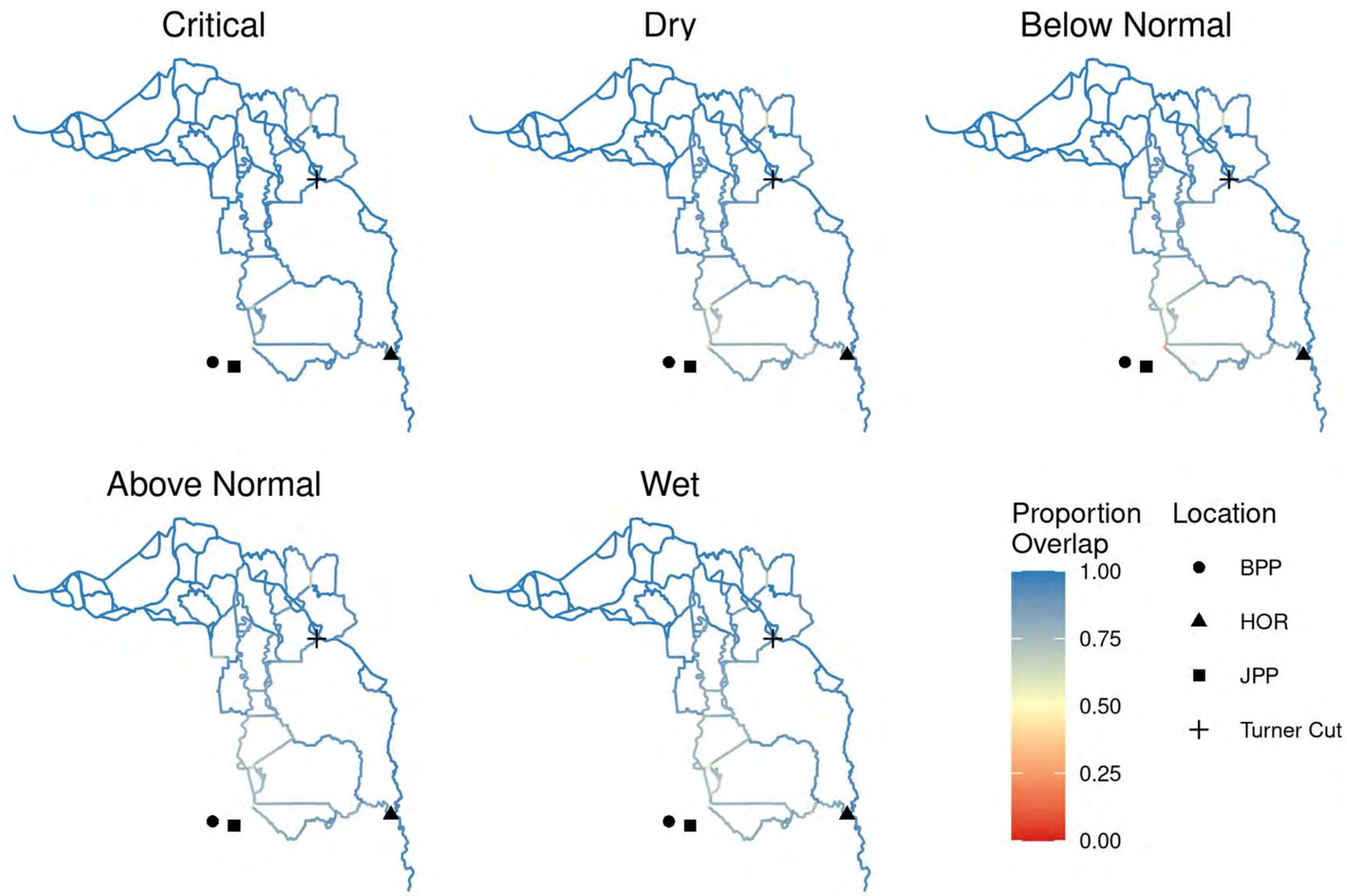
**Figure 5D.1-7. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the South Delta between Existing Conditions and Alternatives 5 (Proposed Action), October**

**November**




Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant; Turner Cut.

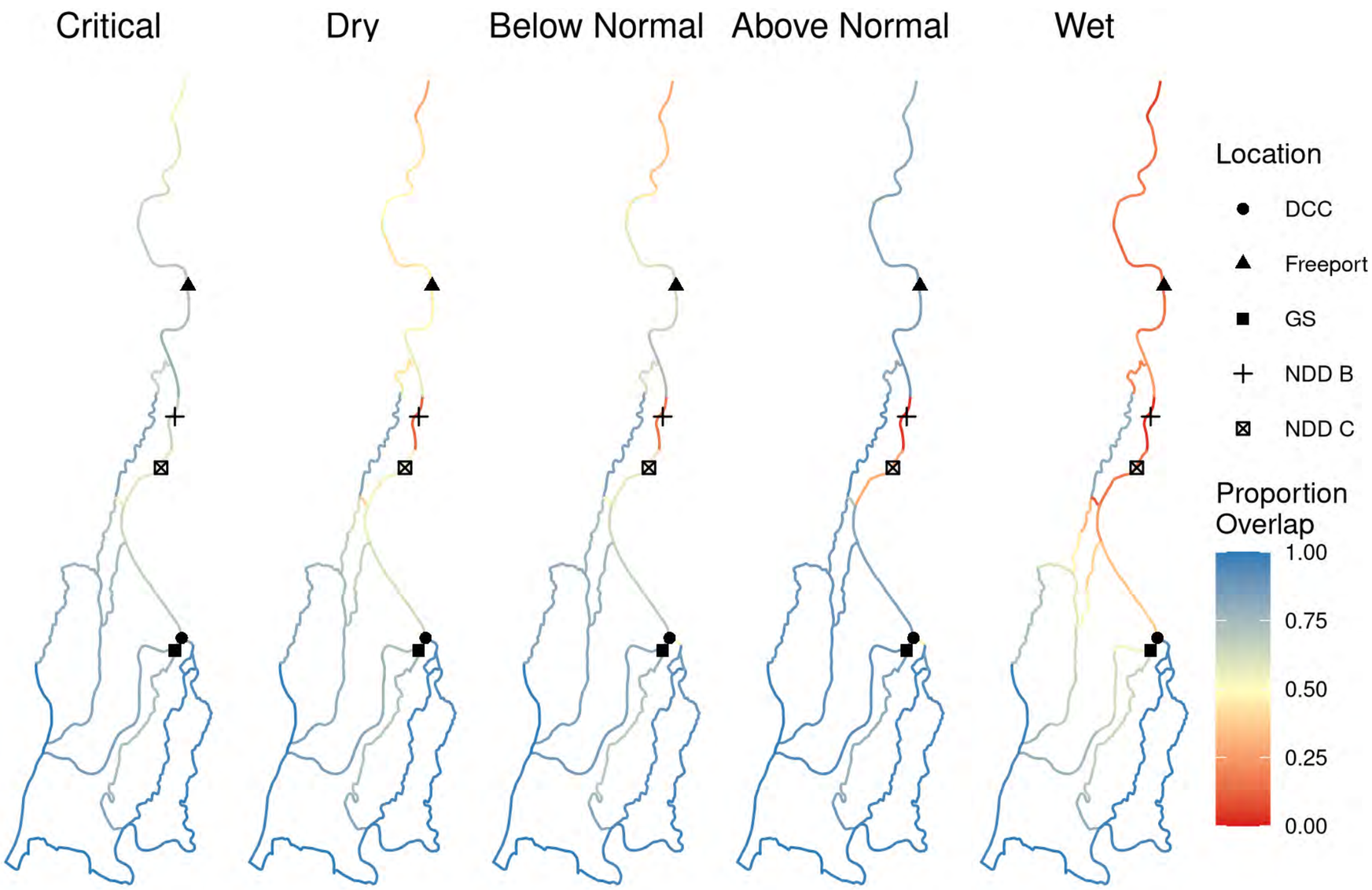
**Figure 5D.1-8. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the North Delta between Existing Conditions and Alternative 5 (Proposed Action), November**




Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant; Turner Cut.

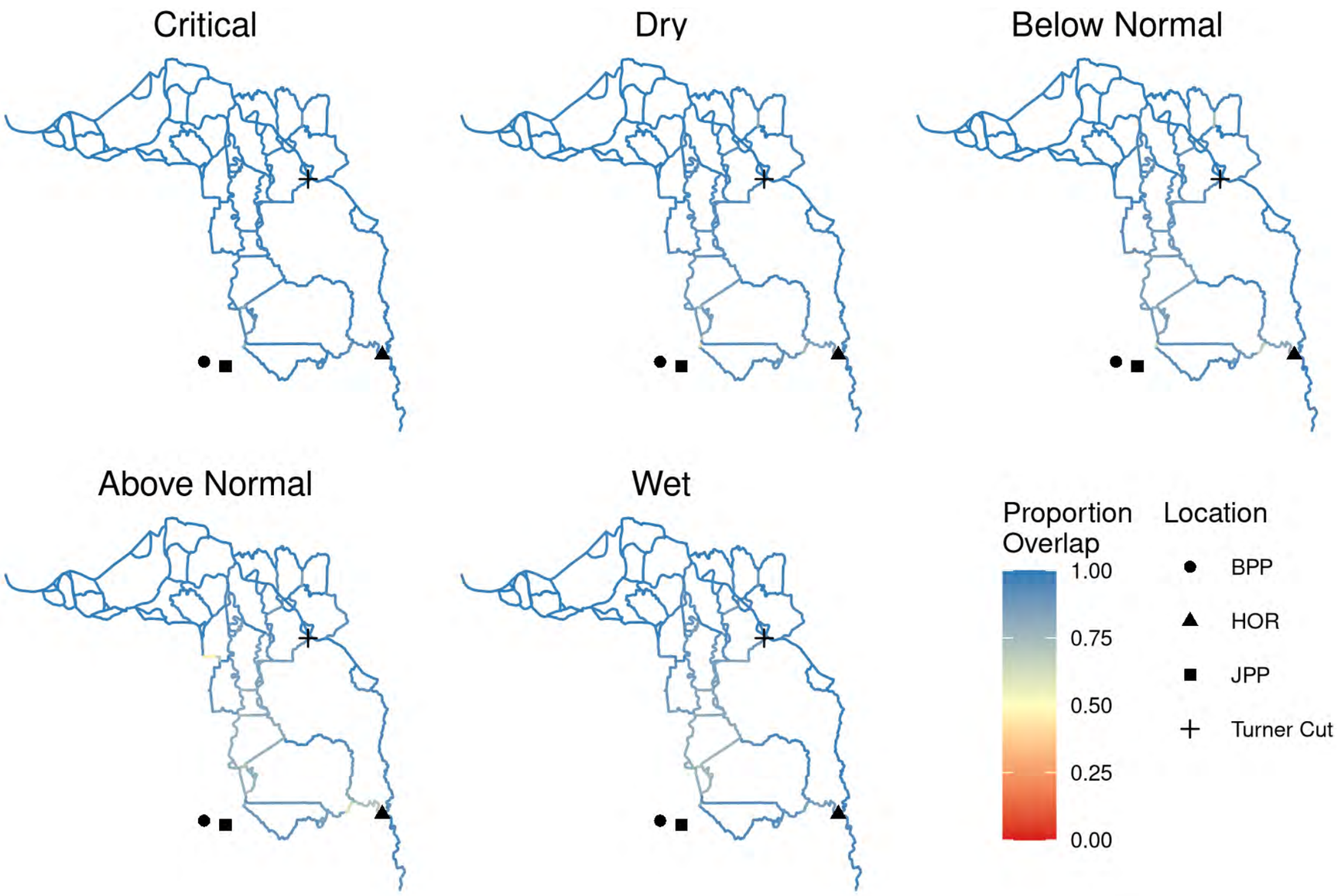
**Figure 5D.1-9. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the South Delta between Existing Conditions and Alternative 5 (Proposed Action), November**

**December**




Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant; Turner Cut.

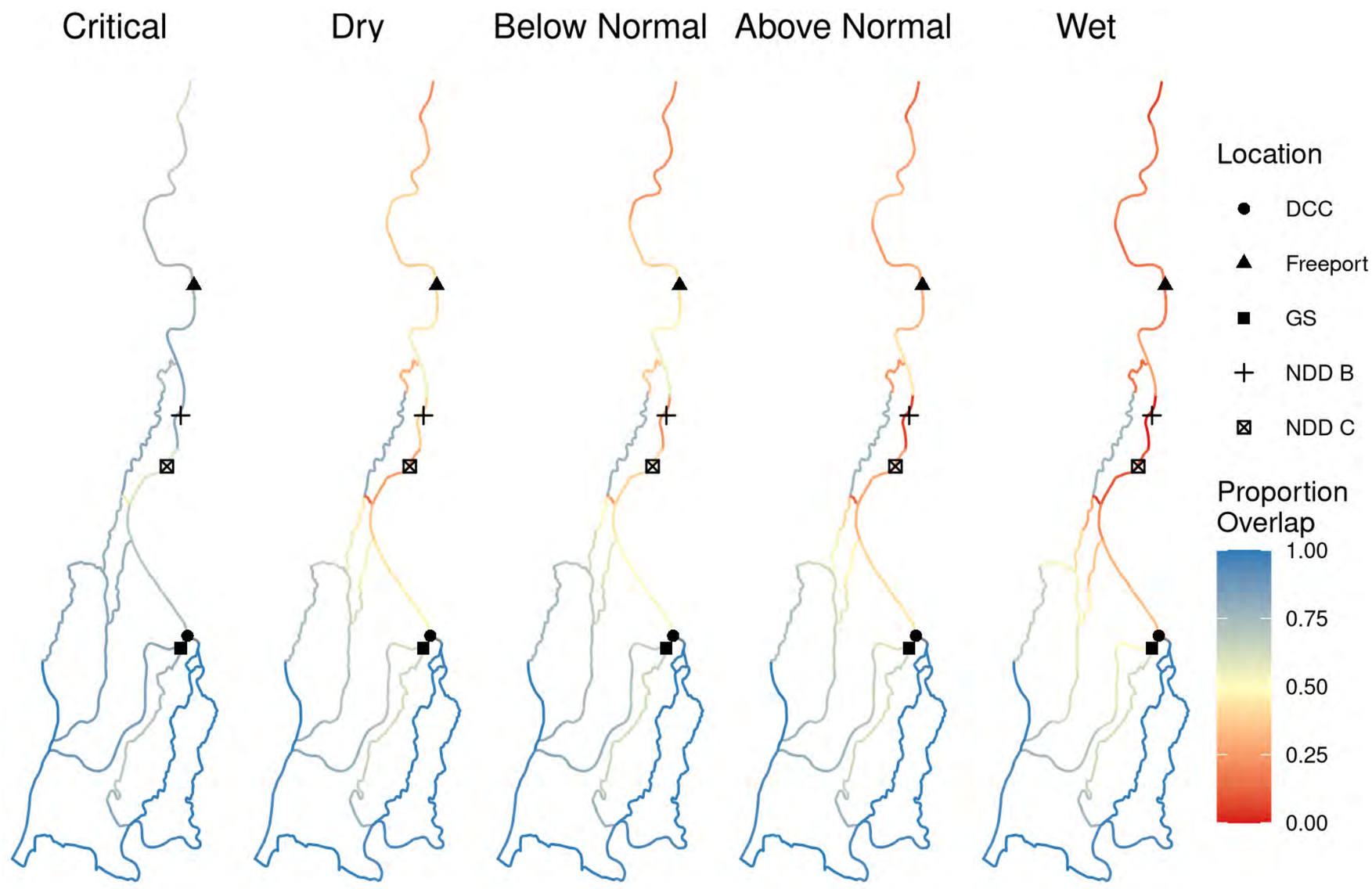
**Figure 5D.1-10. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the North Delta between Existing Conditions and Alternative 5 (Proposed Action), December**




Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant; Turner Cut.

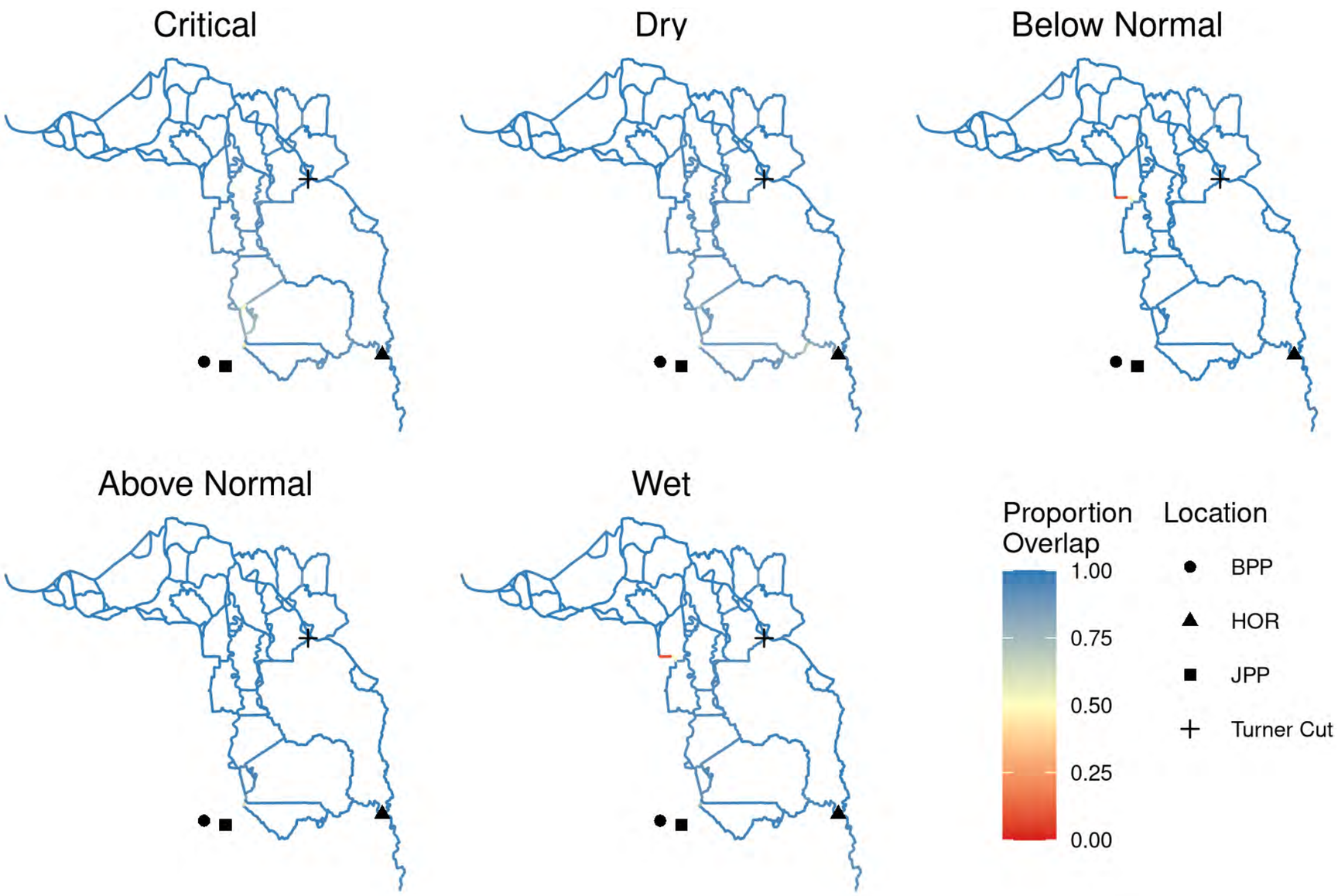
**Figure 5D.1-11. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the South Delta between Existing Conditions and Alternative 5 (Proposed Action), December**

**January**




Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant; Turner Cut.

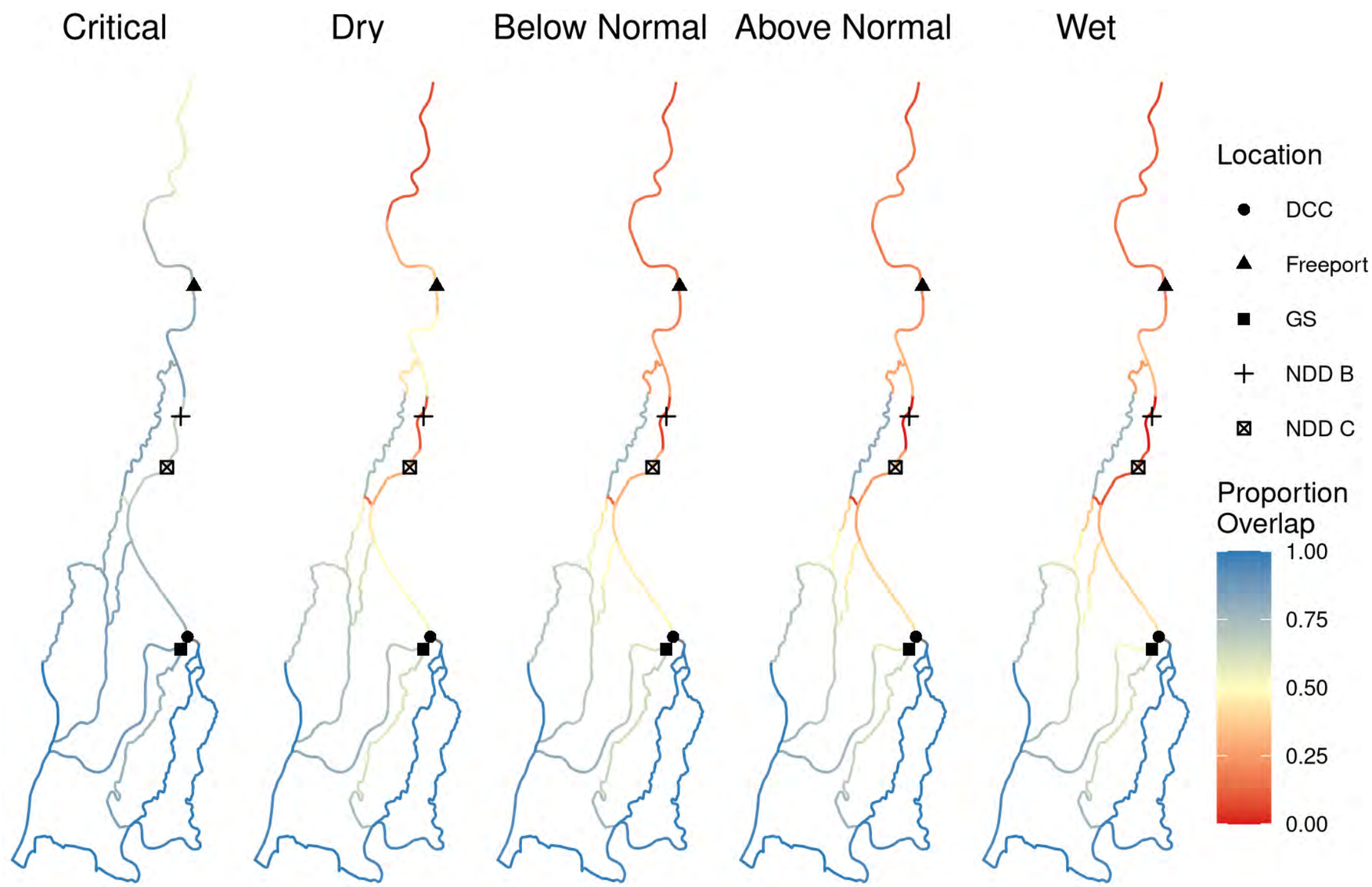
**Figure 5D.1-12. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the North Delta between Existing Conditions and Alternative 5 (Proposed Action), January**




Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant; Turner Cut.

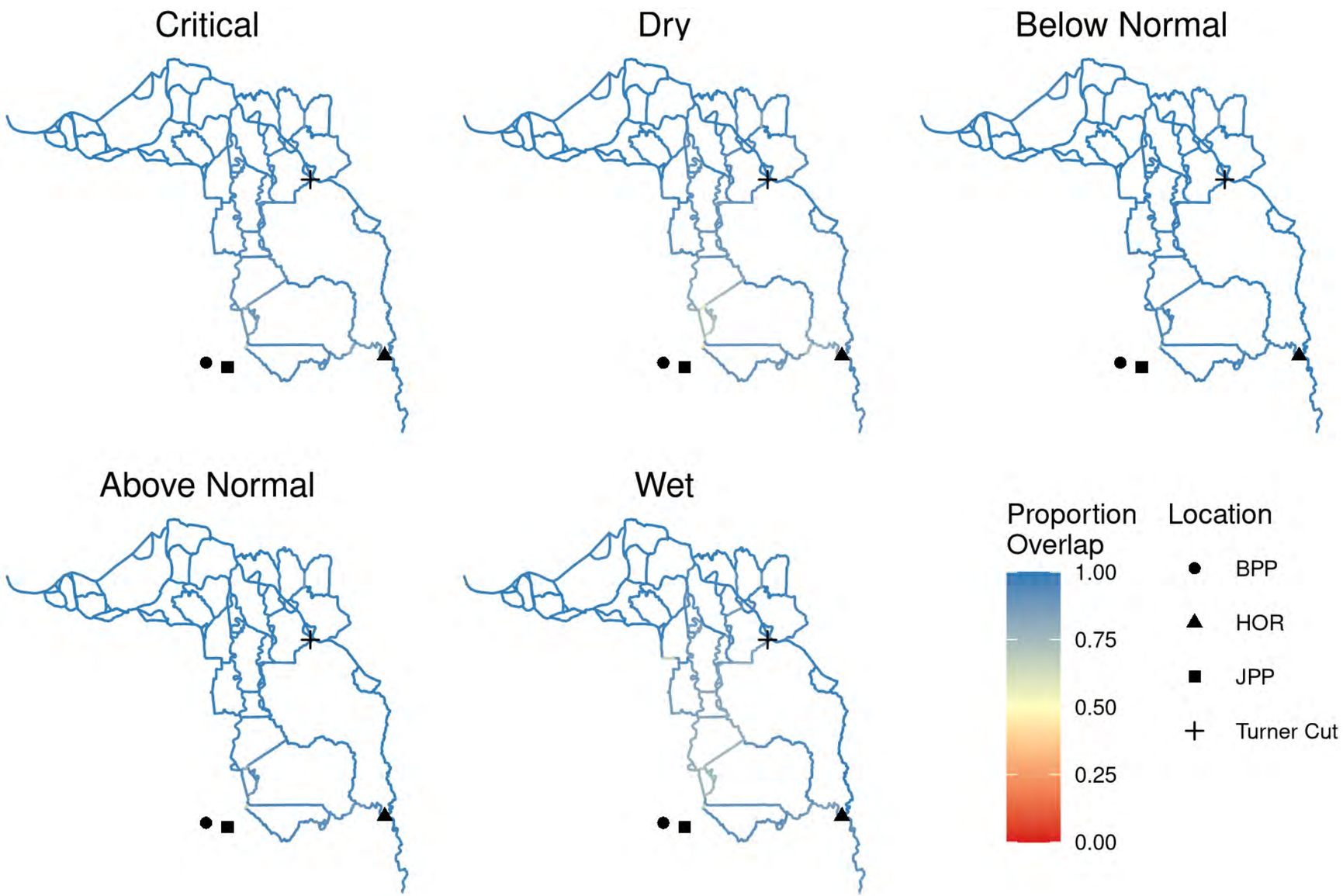
**Figure 5D.1-13. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the South Delta between Existing Conditions and Alternative 5 (Proposed Action), January**

**February**




Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant; Turner Cut.

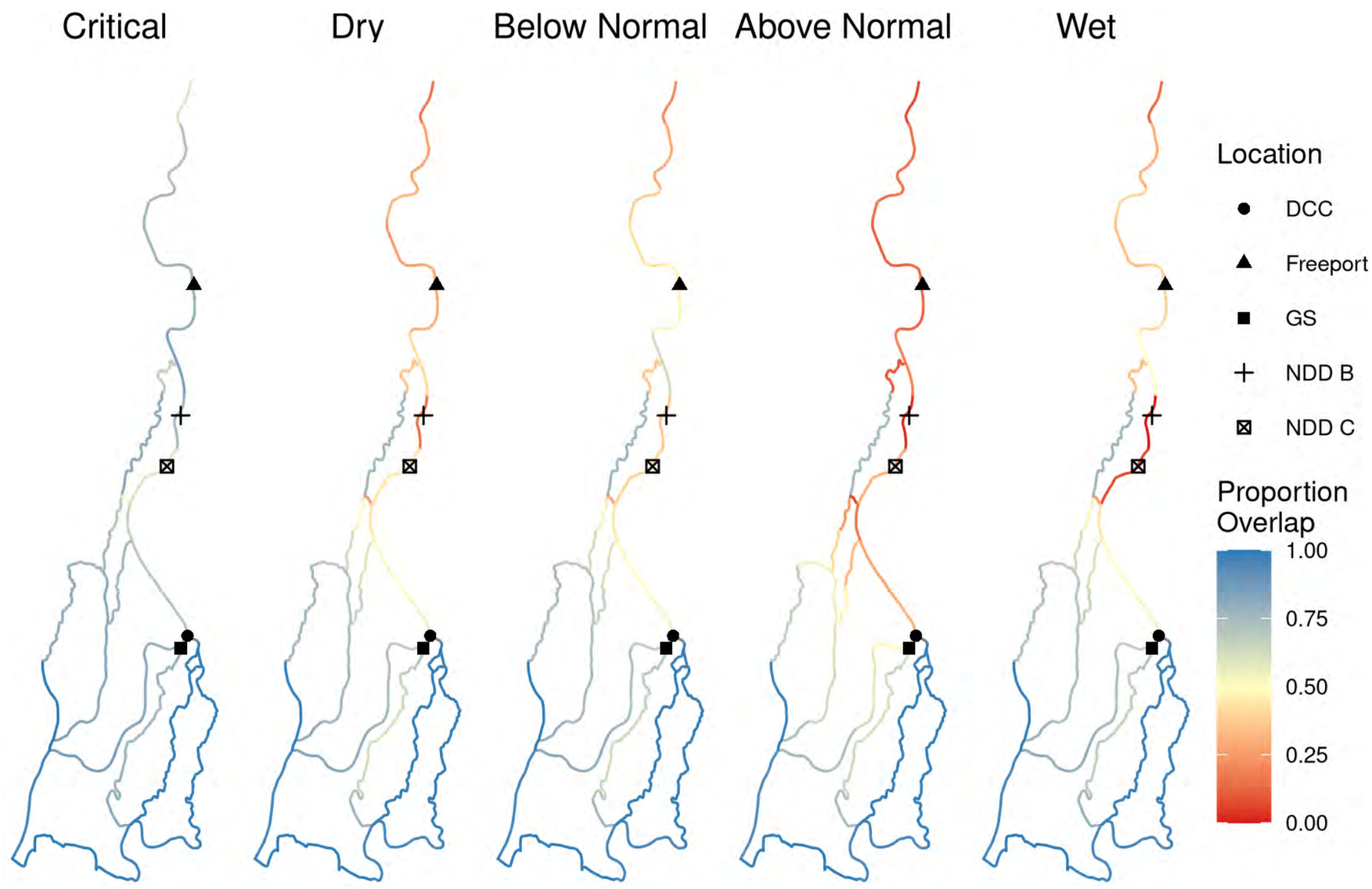
**Figure 5D.1-14. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the North Delta between Existing Conditions and Alternative 5 (Proposed Action), February**




Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant; Turner Cut.

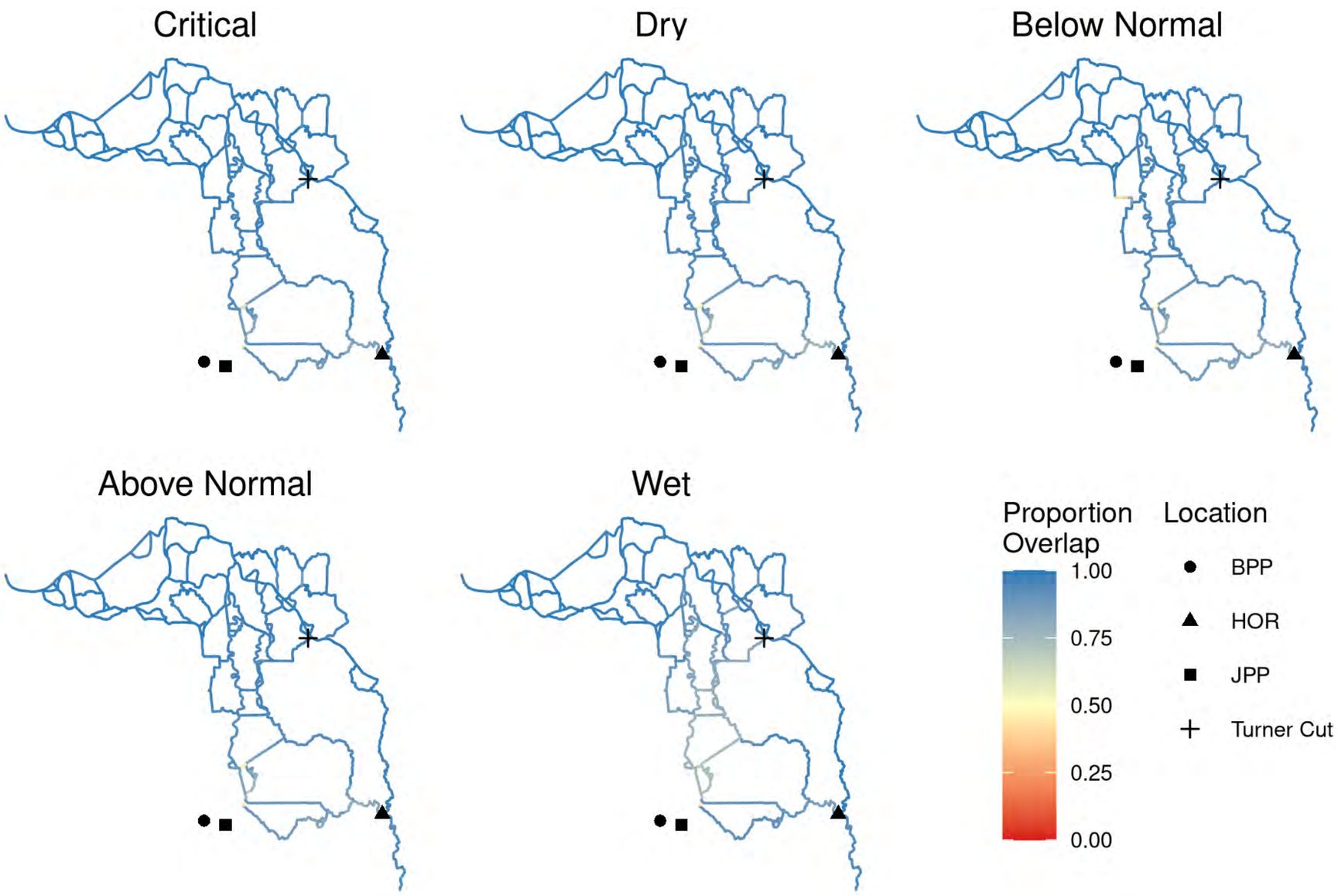
**Figure 5D.1-15. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the South Delta between Existing Conditions and Alternative 5 (Proposed Action), February**

**March**




Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant; Turner Cut.

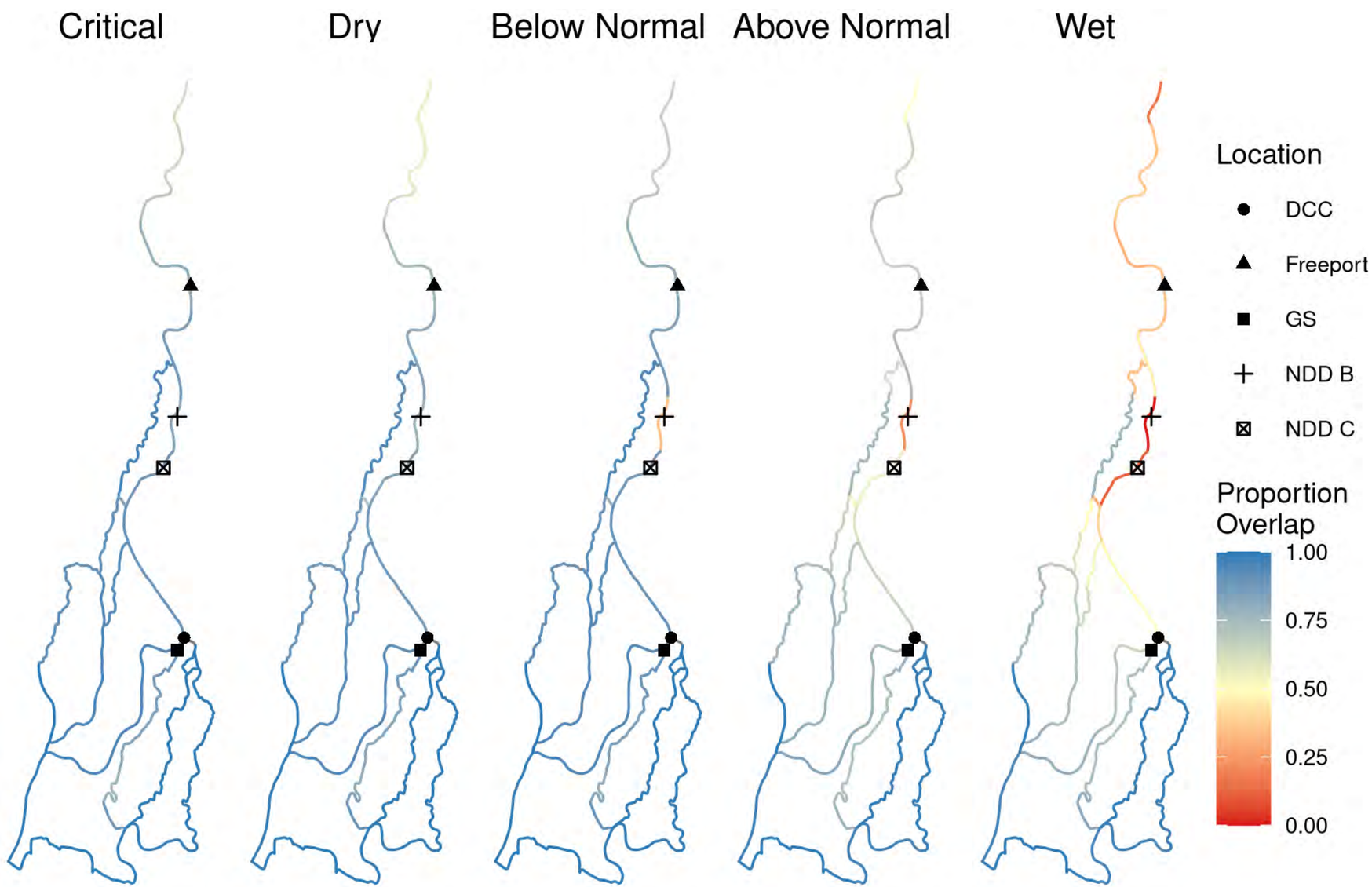
**Figure 5D.1-16. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the North Delta between Existing Conditions and Alternative 5 (Proposed Action), March**




Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant; Turner Cut.

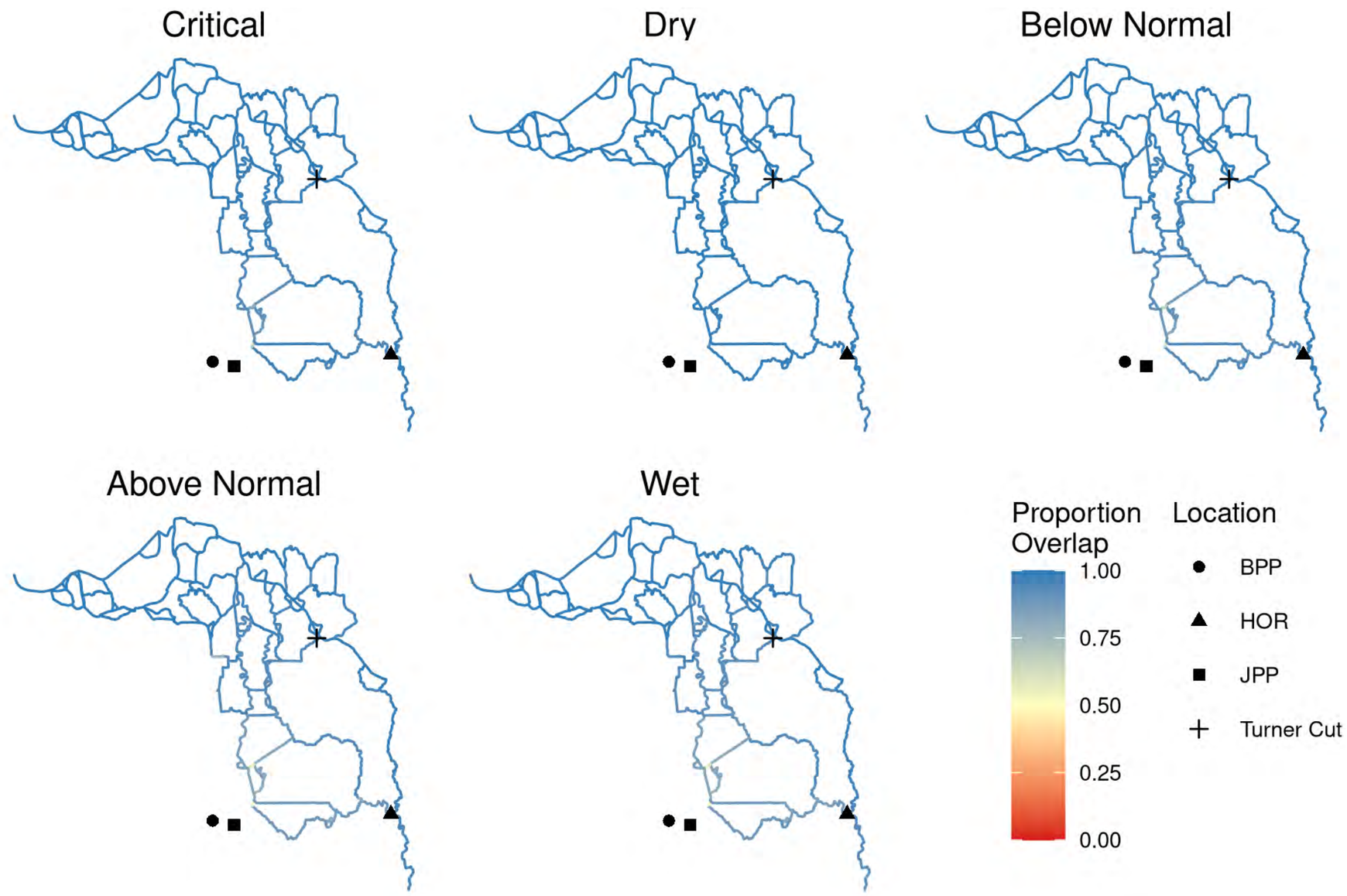
**Figure 5D.1-17. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the South Delta between Existing Conditions and Alternative 5 (Proposed Action), March**

**April**




Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant; Turner Cut.

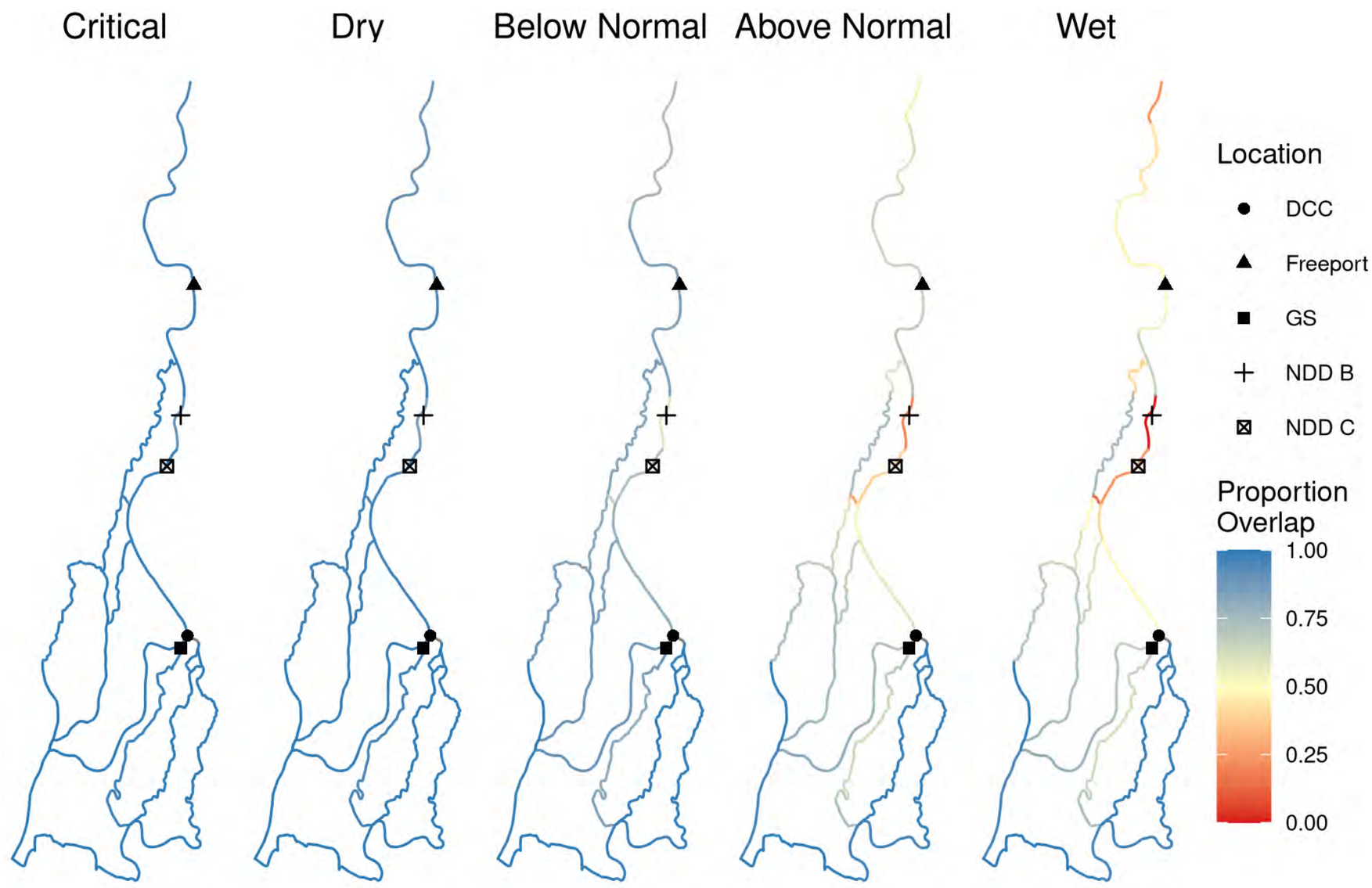
**Figure 5D.1-18. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the North Delta between Existing Conditions and Alternative 5 (Proposed Action), April**




Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant; Turner Cut.

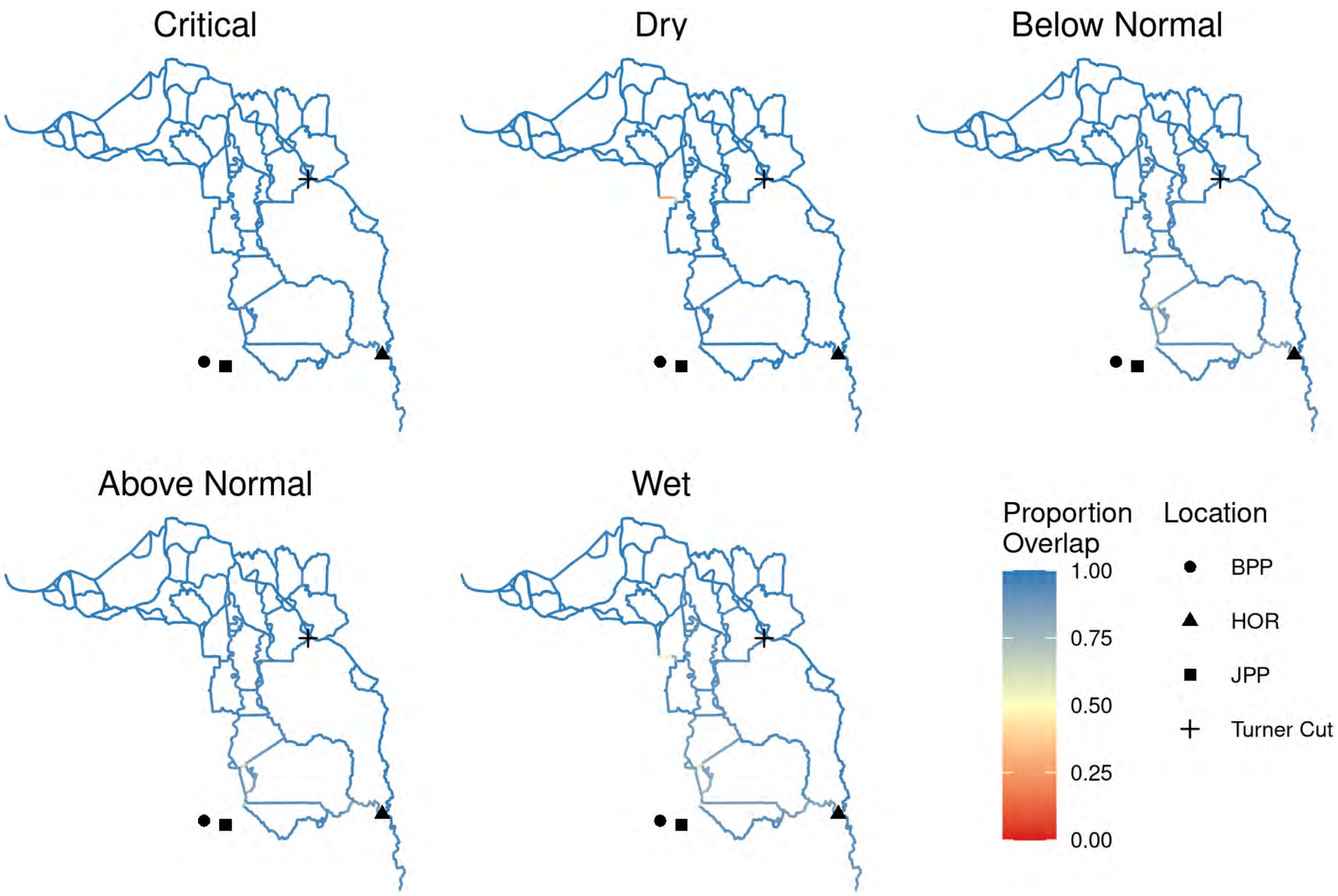
**Figure 5D.1-19. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the South Delta between Existing Conditions and Alternative 5 (Proposed Action), April**

**May**




Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant; Turner Cut.

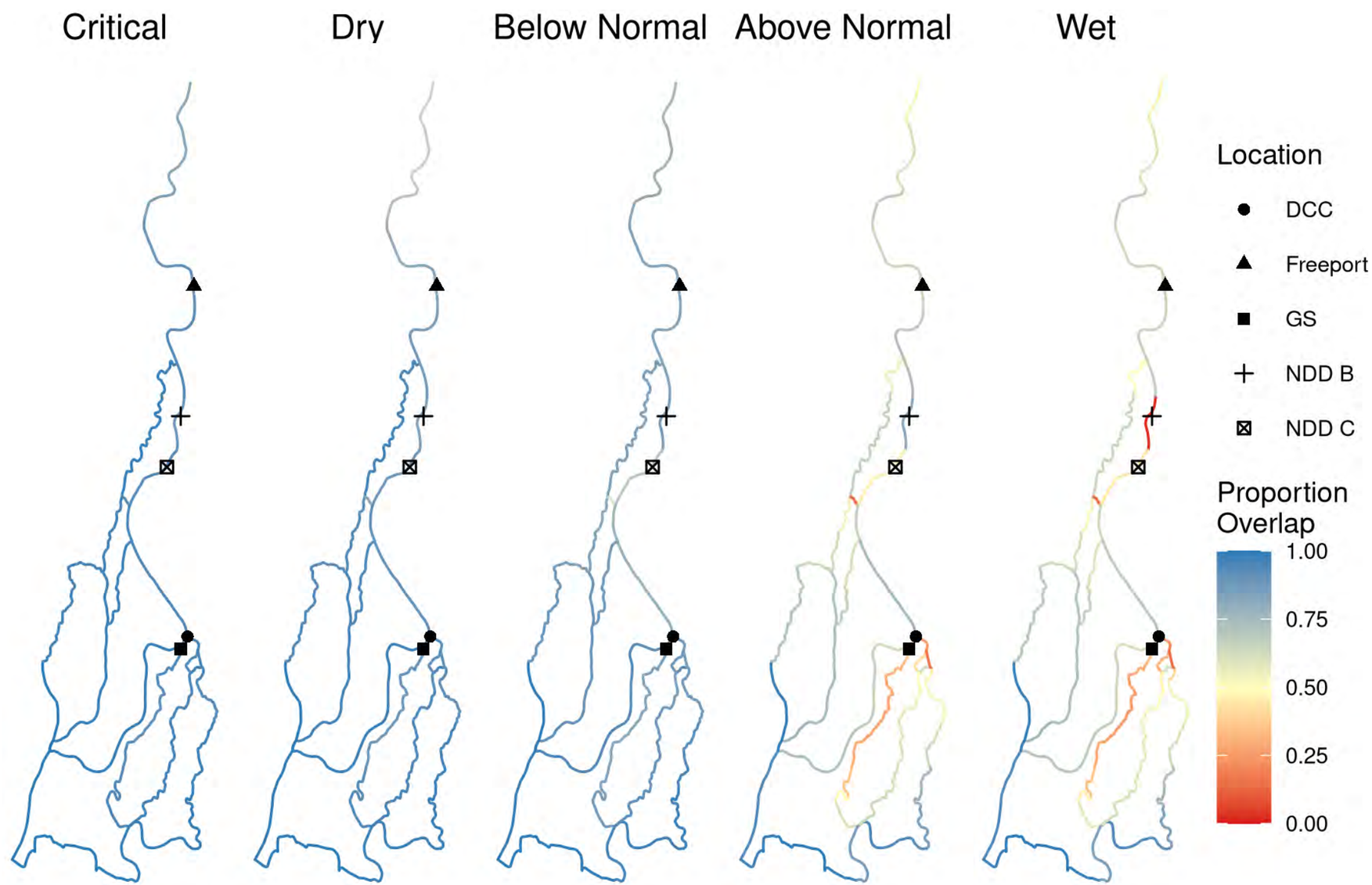
**Figure 5D.1-20. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the North Delta between Existing Conditions and Alternative 5 (Proposed Action), May**




Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant; Turner Cut.

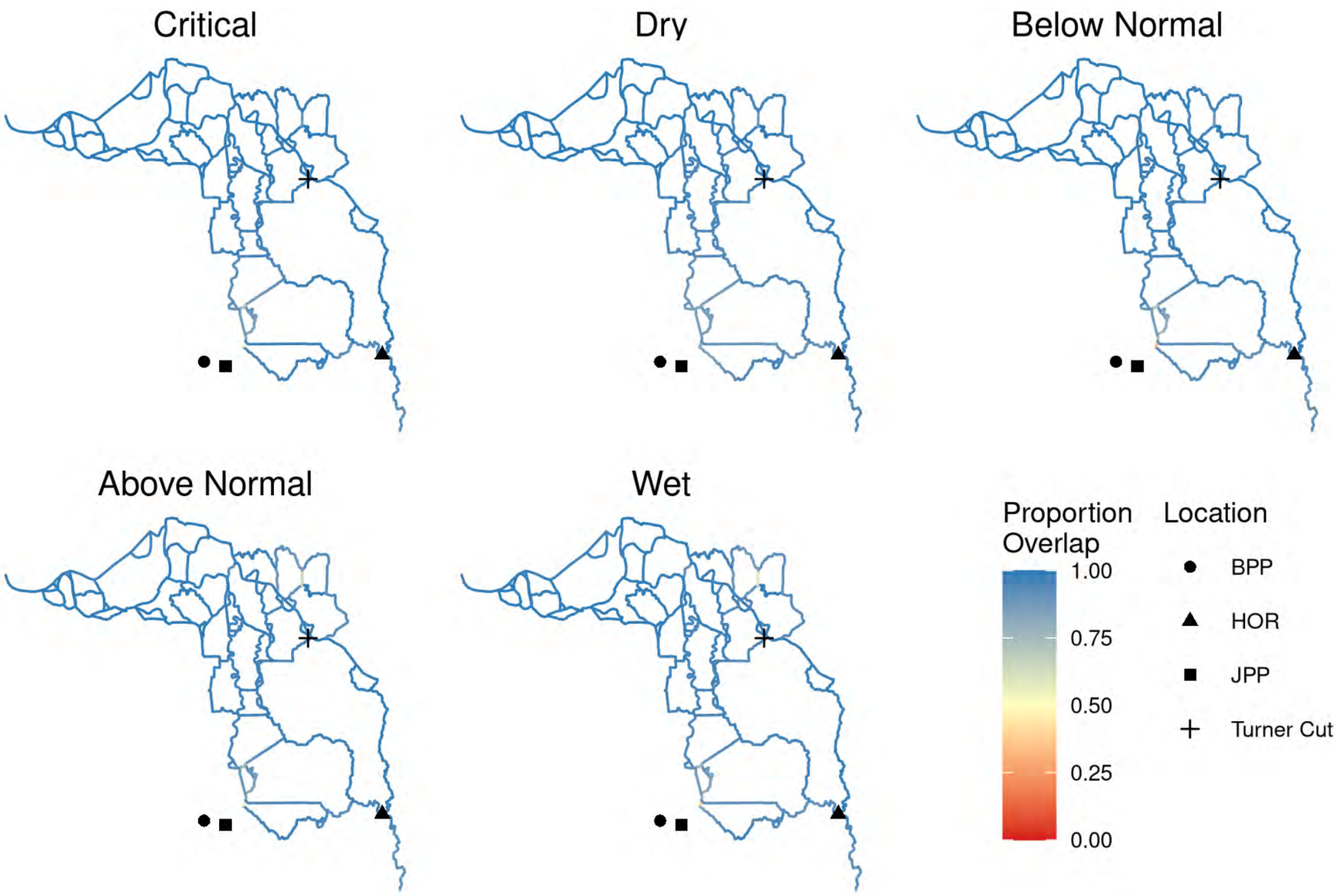
**Figure 5D.1-21. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the South Delta between Existing Conditions and Alternative 5 (Proposed Action), May**

**June**




Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant; Turner Cut.

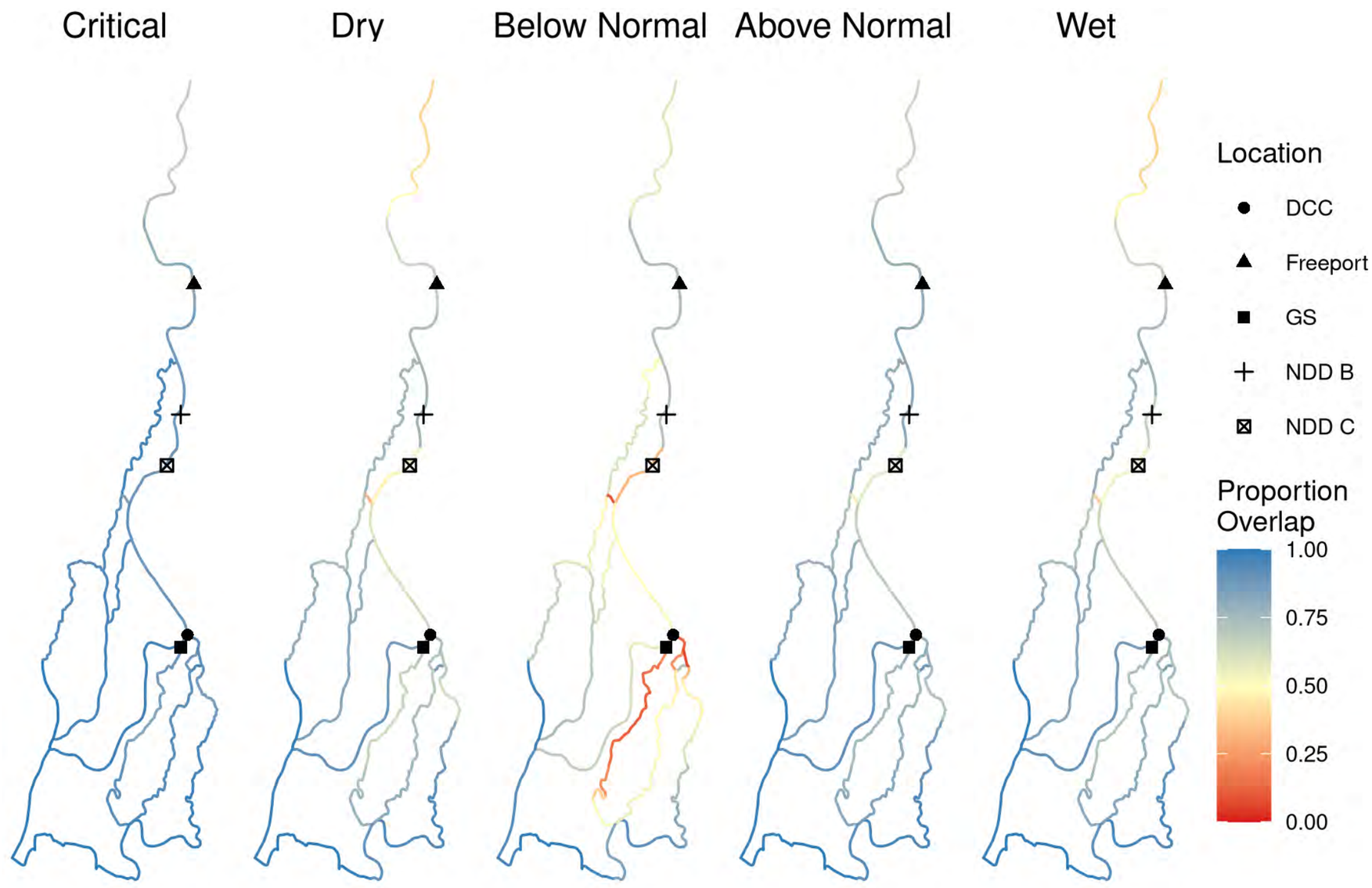
**Figure 5D.1-22. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the North Delta between Existing Conditions and Alternative 5 (Proposed Action), June**




Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant; Turner Cut.

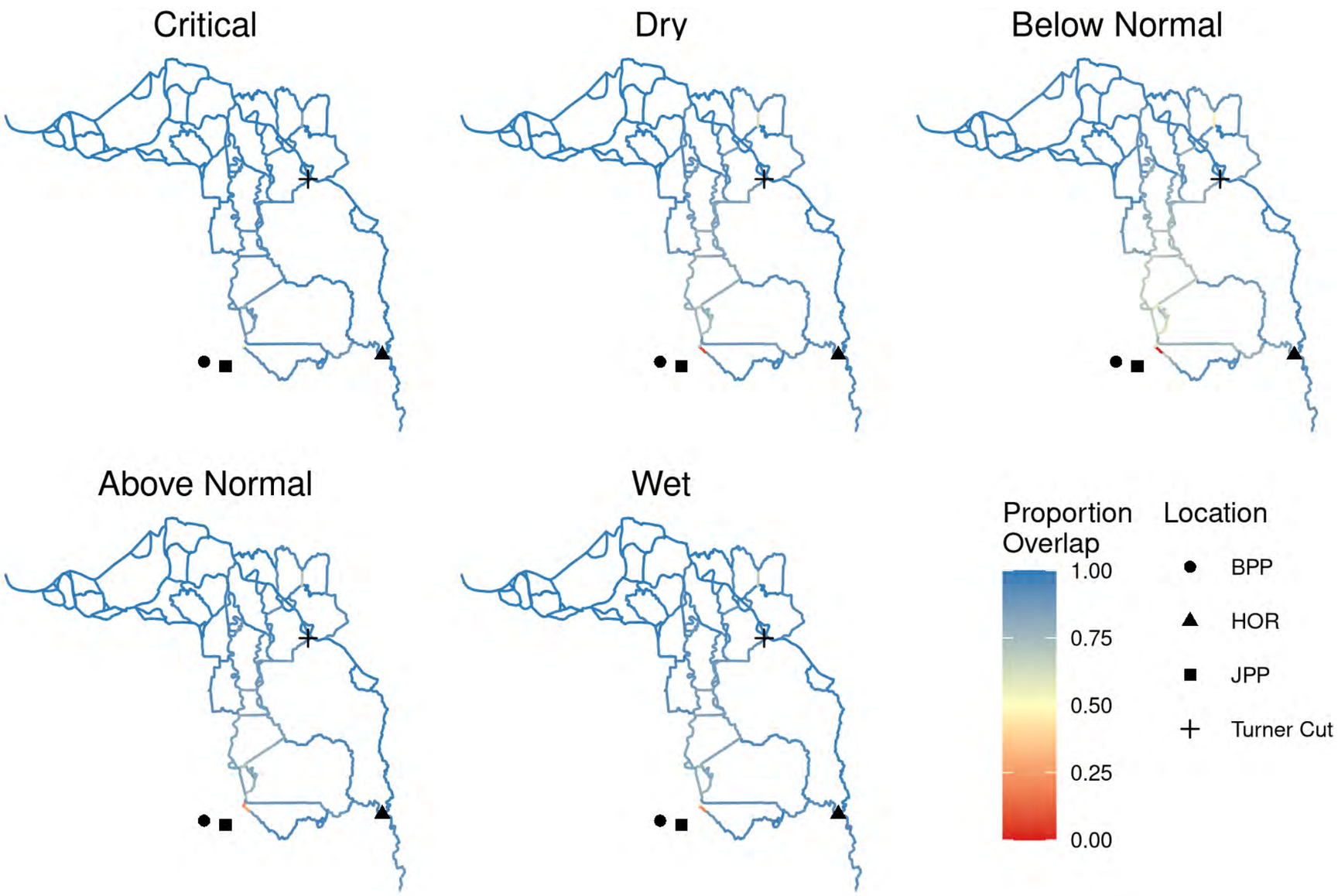
**Figure 5D.1-23. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the South Delta between Existing Conditions and Alternative 5 (Proposed Action), June**

**July**




Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant; Turner Cut.

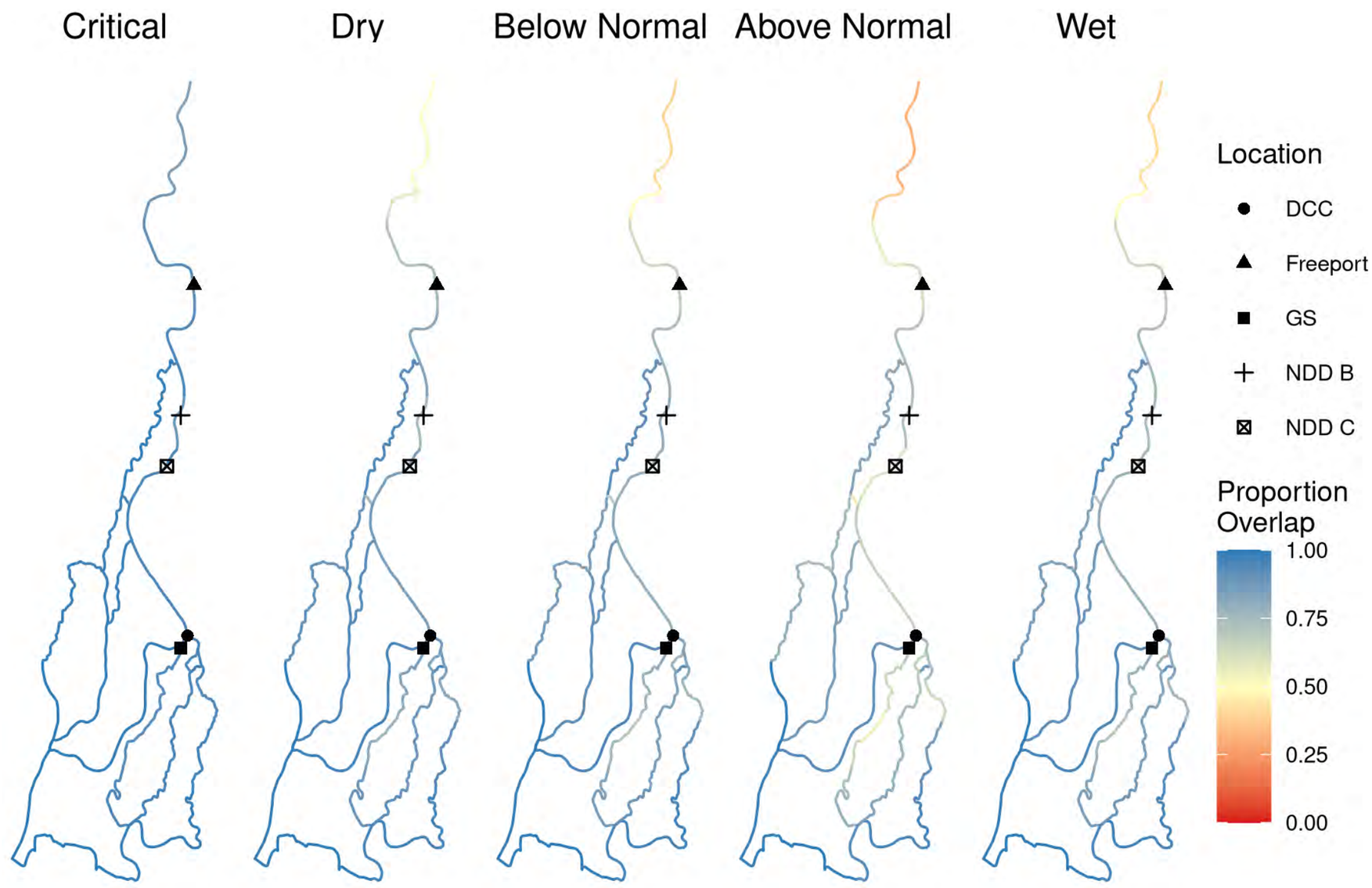
**Figure 5D.1-24. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the North Delta between Existing Conditions and Alternative 5 (Proposed Action), July**




Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant; Turner Cut.

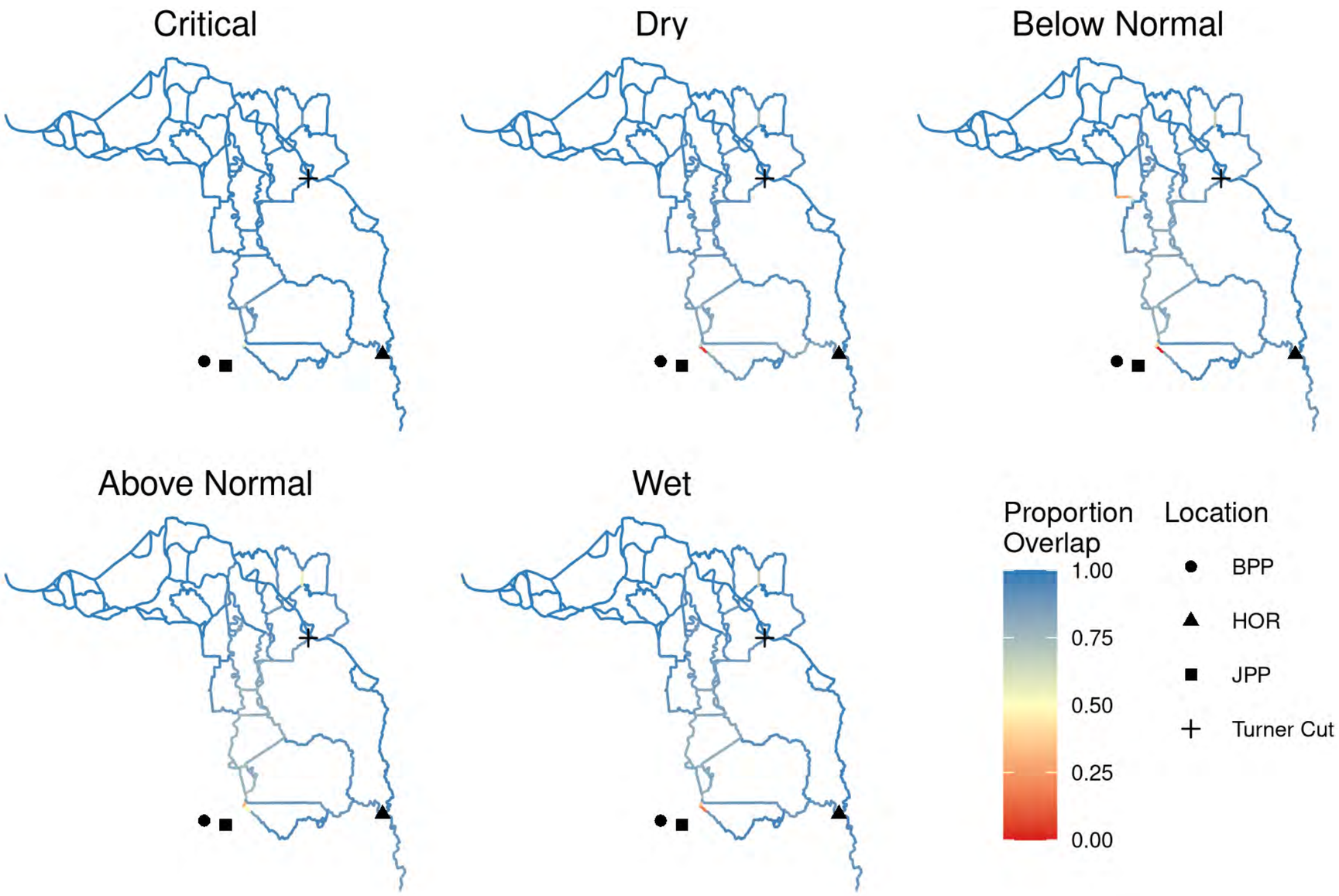
**Figure 5D.1-25. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the South Delta between Existing Conditions and Alternative 5 (Proposed Action), July**

**August**




Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant; Turner Cut.

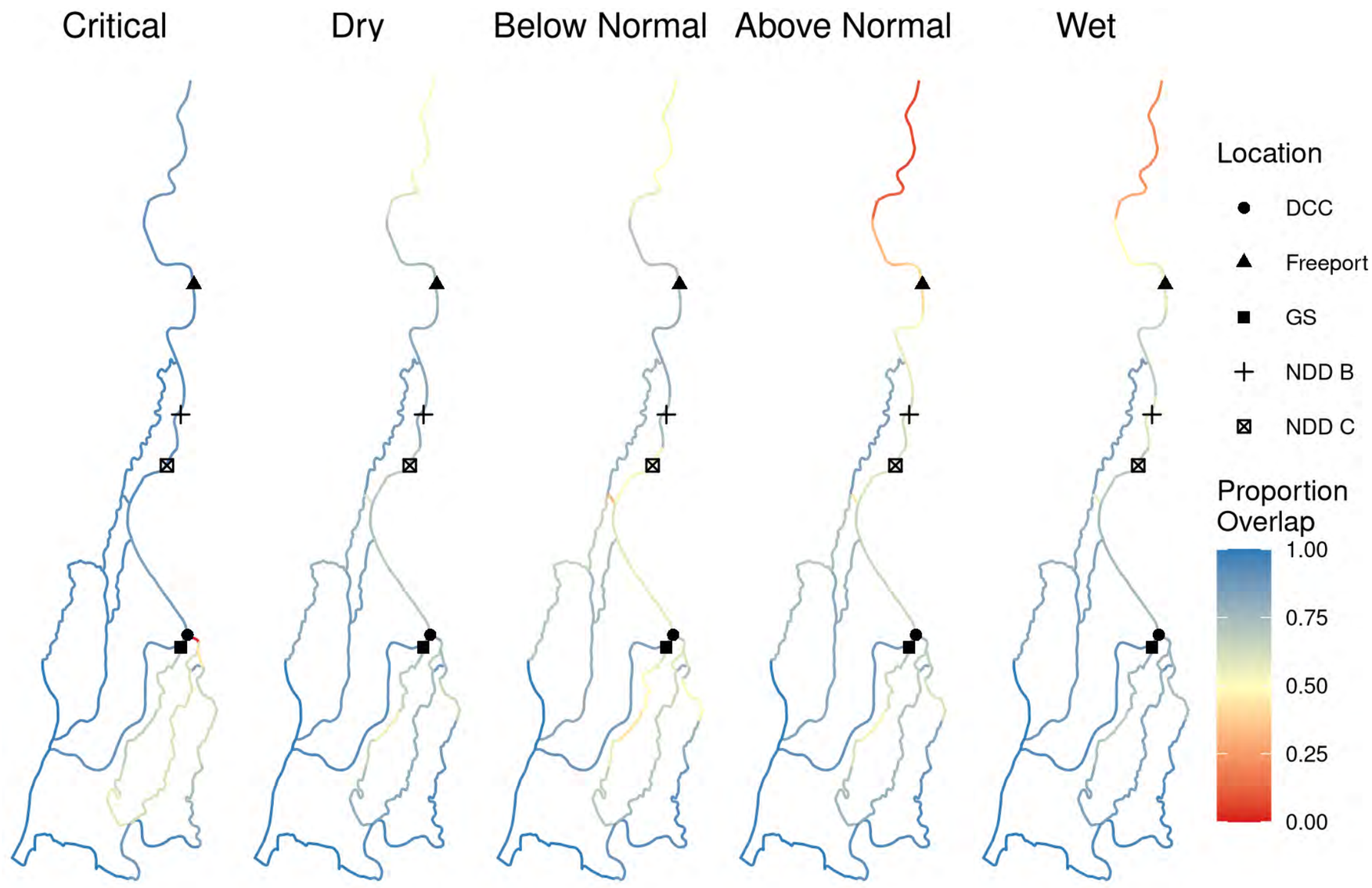
**Figure 5D.1-26. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the North Delta between Existing Conditions and Alternative 5 (Proposed Action), August**




Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant; Turner Cut.

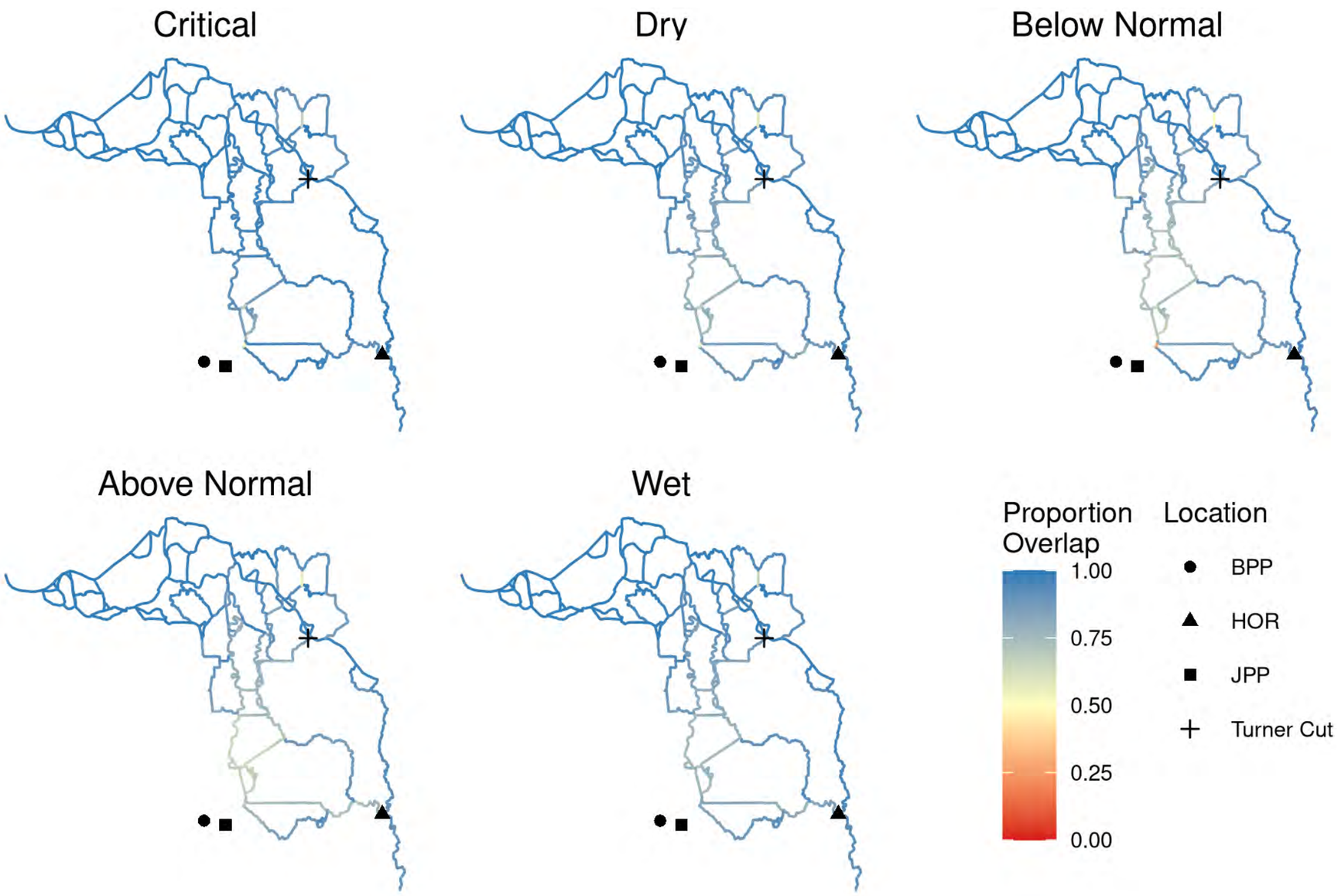
**Figure 5D.1-27. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the South Delta between Existing Conditions and Alternative 5 (Proposed Action), August**

**September**




Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant; Turner Cut.

**Figure 5D.1-28. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the North Delta between Existing Conditions and Alternative 5 (Proposed Action), September**




Note: BPP = Banks Pumping Plant; HOR = Head of Old River; JPP = Jones Pumping Plant; Turner Cut.

**Figure 5D.1-29. Minimum Proportional Overlap of DSM2-HYDRO Velocity in the South Delta between Existing Conditions and Alternative 5 (Proposed Action), September**

#### 5D.1.3.1.2 Velocity Density Distribution

This section provides plots of 15-minute velocity density distribution for a number of locations within the Delta based on DSM2-HYDRO data, comparing each alternative to existing conditions. Figure 5D.1-30 provides an overview of the locations included in the analysis. The plots are arranged by Sacramento River Delta and San Joaquin River Delta, generally beginning upstream and moving downstream.

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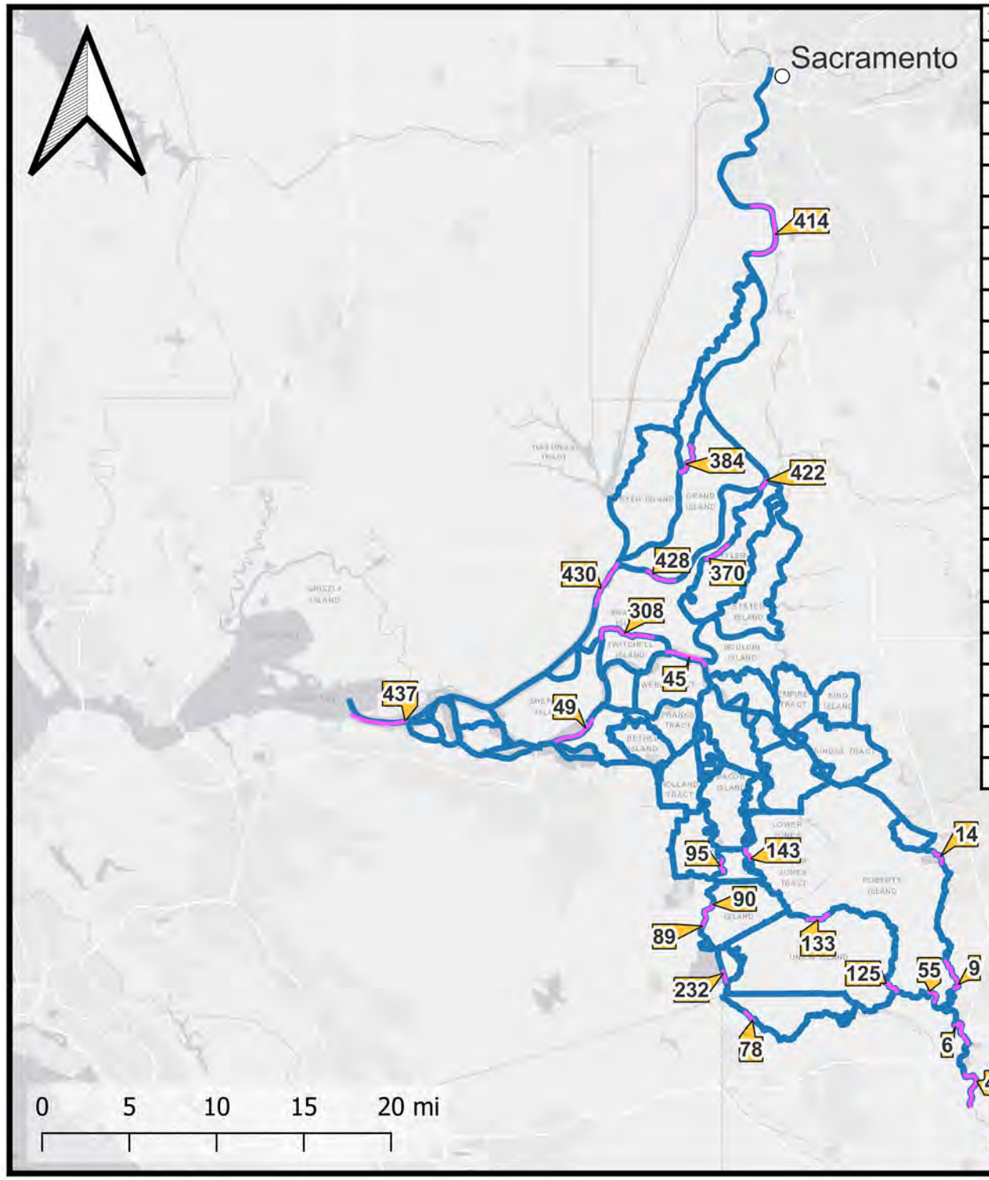
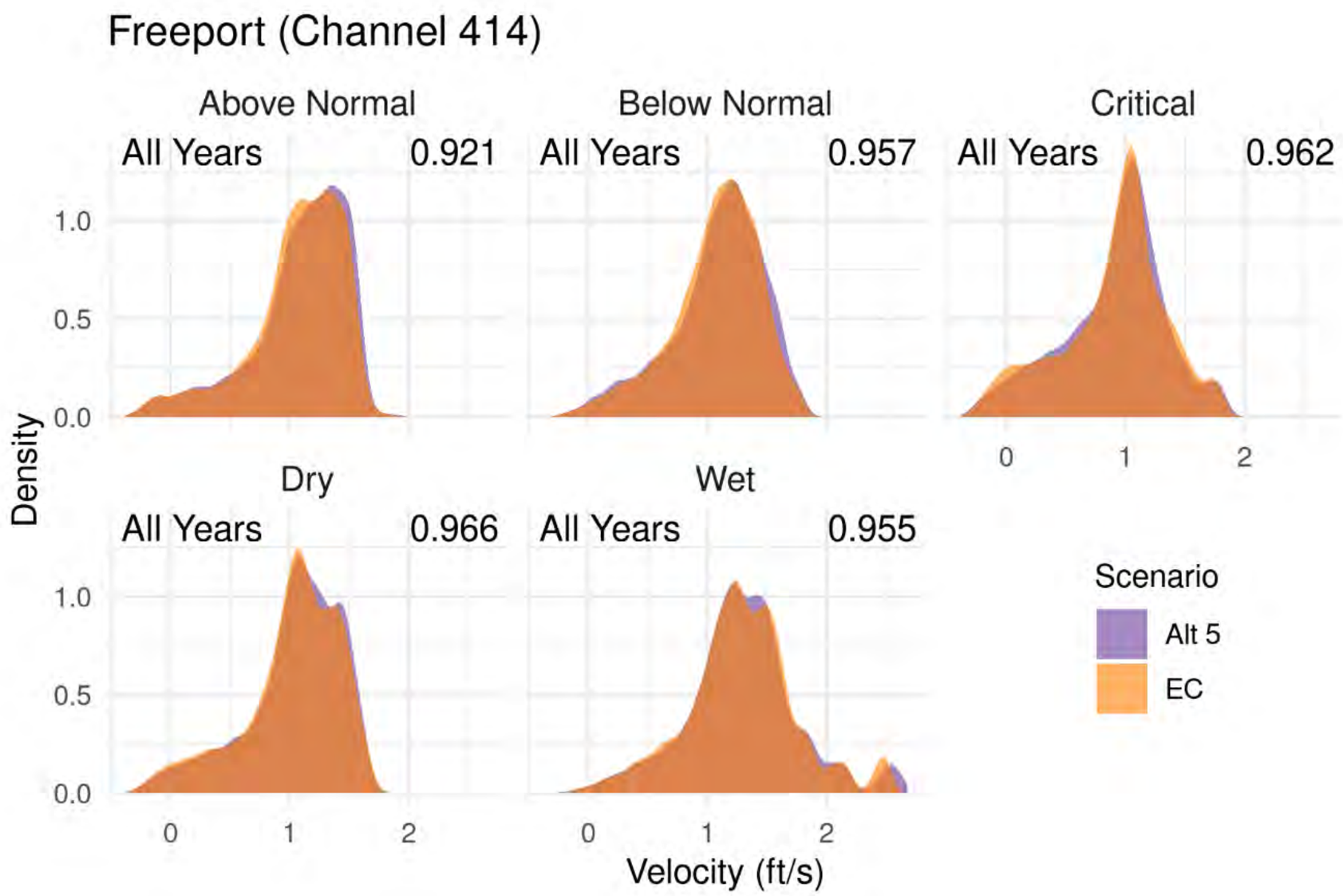



| DSM2 Channel Number | Name |
|---|---|
| 1 | Vernalis |
| 4 | SJR upstream of HOR |
| 6 | Mossdale |
| 9 | SJR near HOR |
| 14 | San Joquin River @ Hwy 4 |
| 45 | SJR near Mokelumne |
| 49 | SJR near Jersey Point |
| 55 | Old River near HOR |
| 78 | Old River upstream of facilities |
| 89 | Old River downstream of facilities |
| 90 | Old River@ Hwy 4 |
| 95 | Old River Woodward Island |
| 125 | Head of Middle River |
| 133 | Middle River near Victoria Canal |
| 143 | Middle River near Woodward Island |
| 232 | SWP |
| 308 | Sevenmile Slough |
| 370 | Georgiana Slough |
| 384 | Streamboat Slough |
| 414 | Freeport |
| 422 | Walnut Grove |
| 428 | Isleton |
| 430 | Rio Vista |
| 437 | Chipps Island |

**Figure 5D.1-30. Overview of Locations Included in Velocity Density Distribution Analysis.**

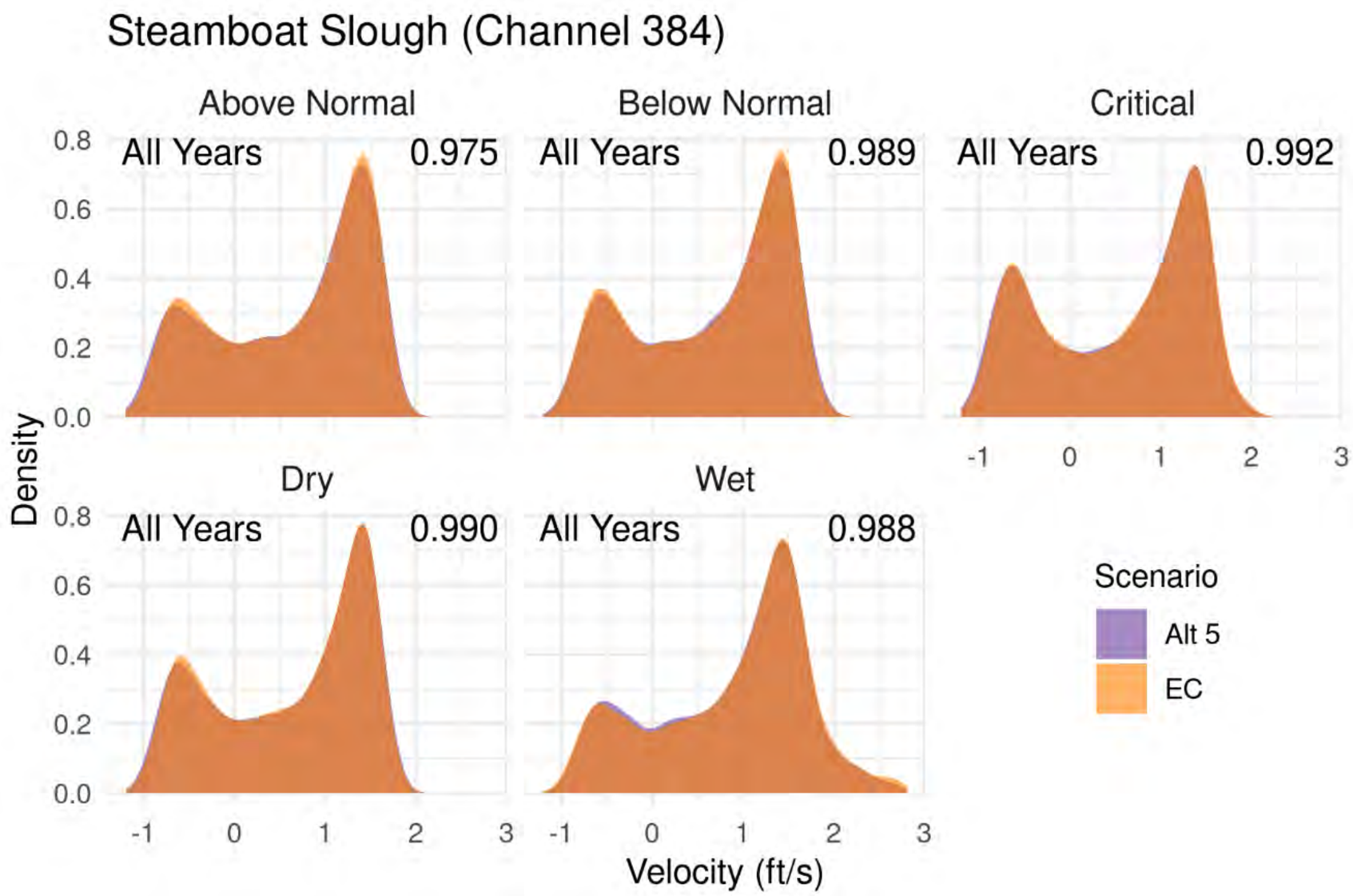
**October**

***Sacramento River Delta***



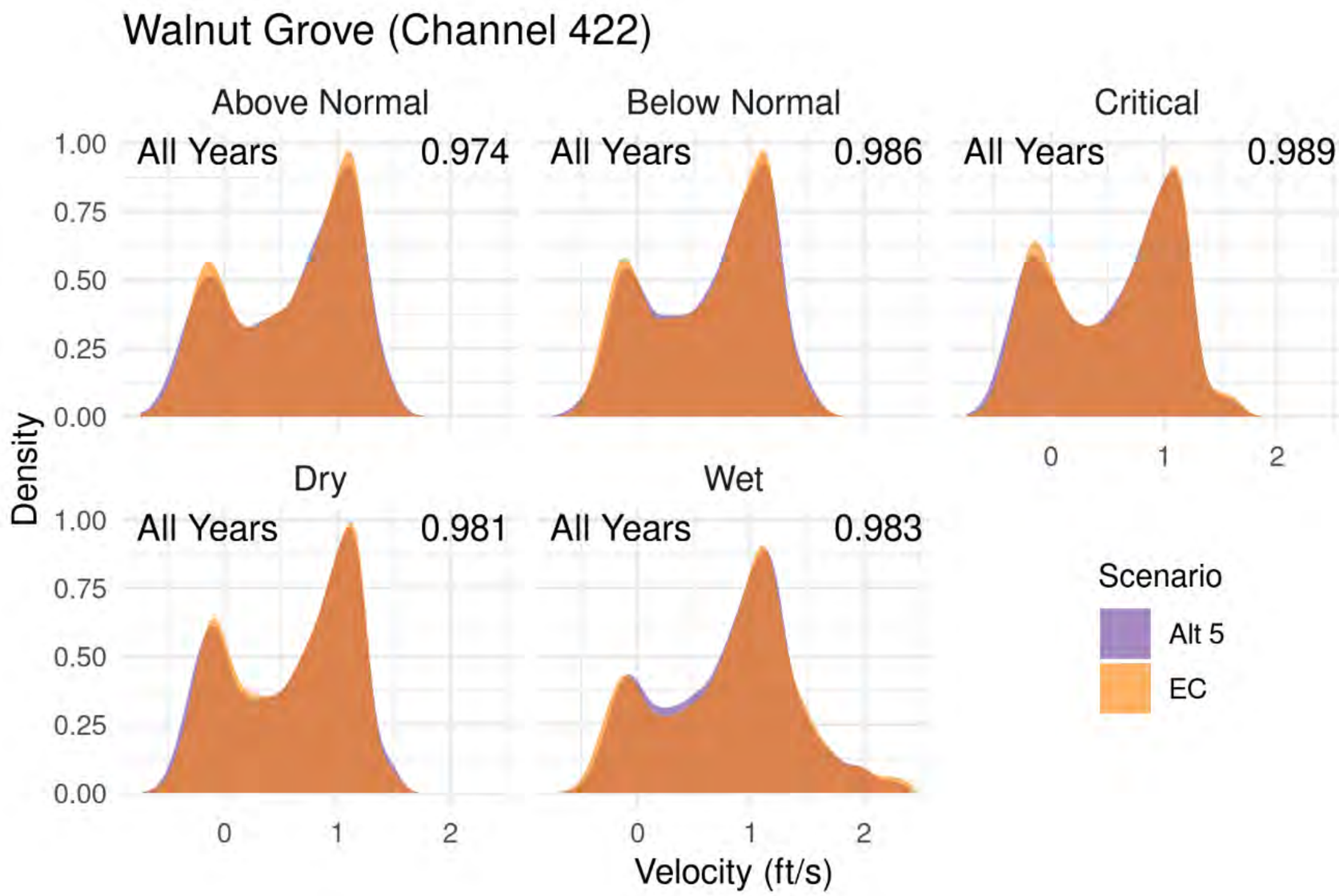

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-31. Velocity Density Distribution for Freeport, October.**



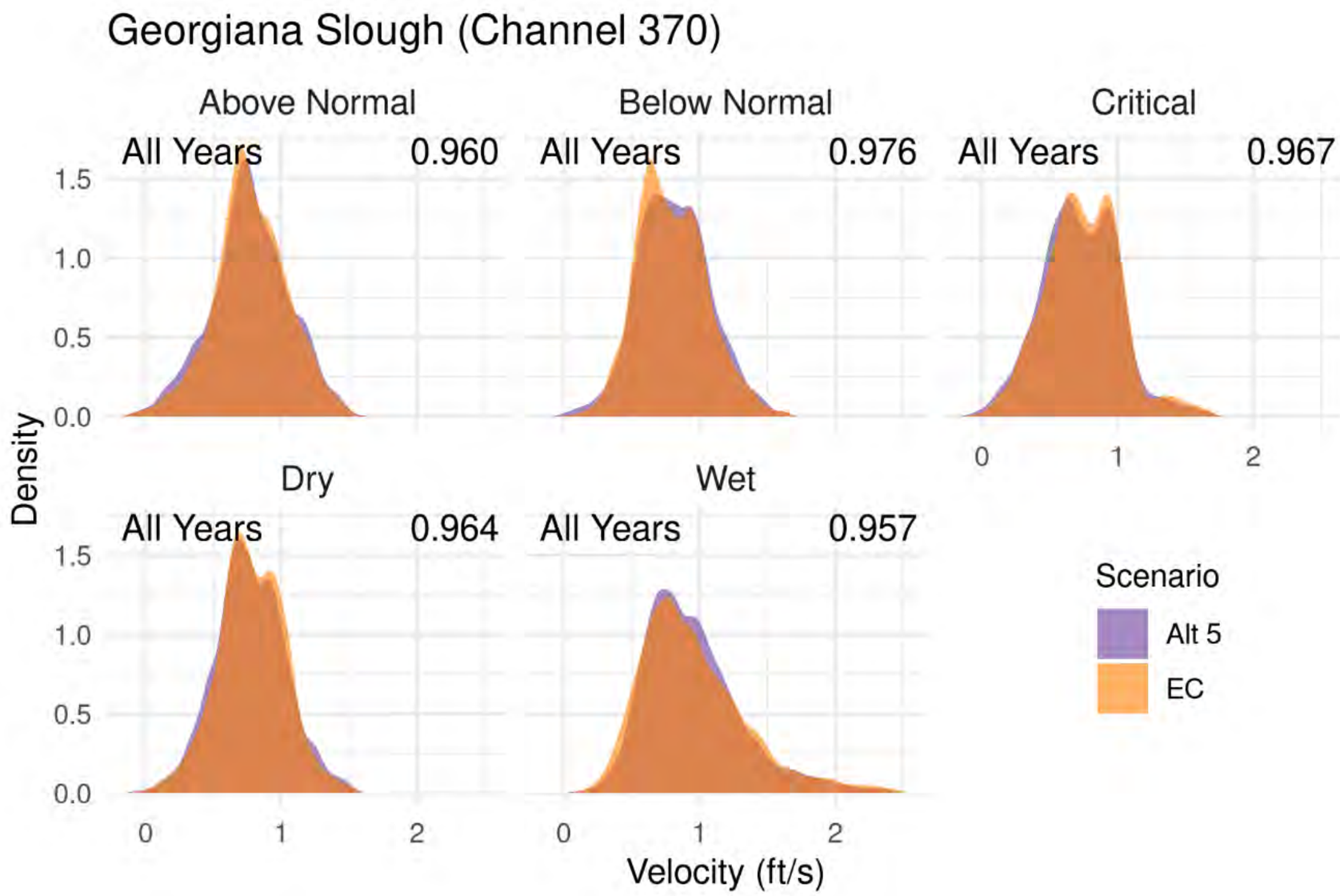

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-32. Velocity Density Distribution for Steamboat Slough, October.**



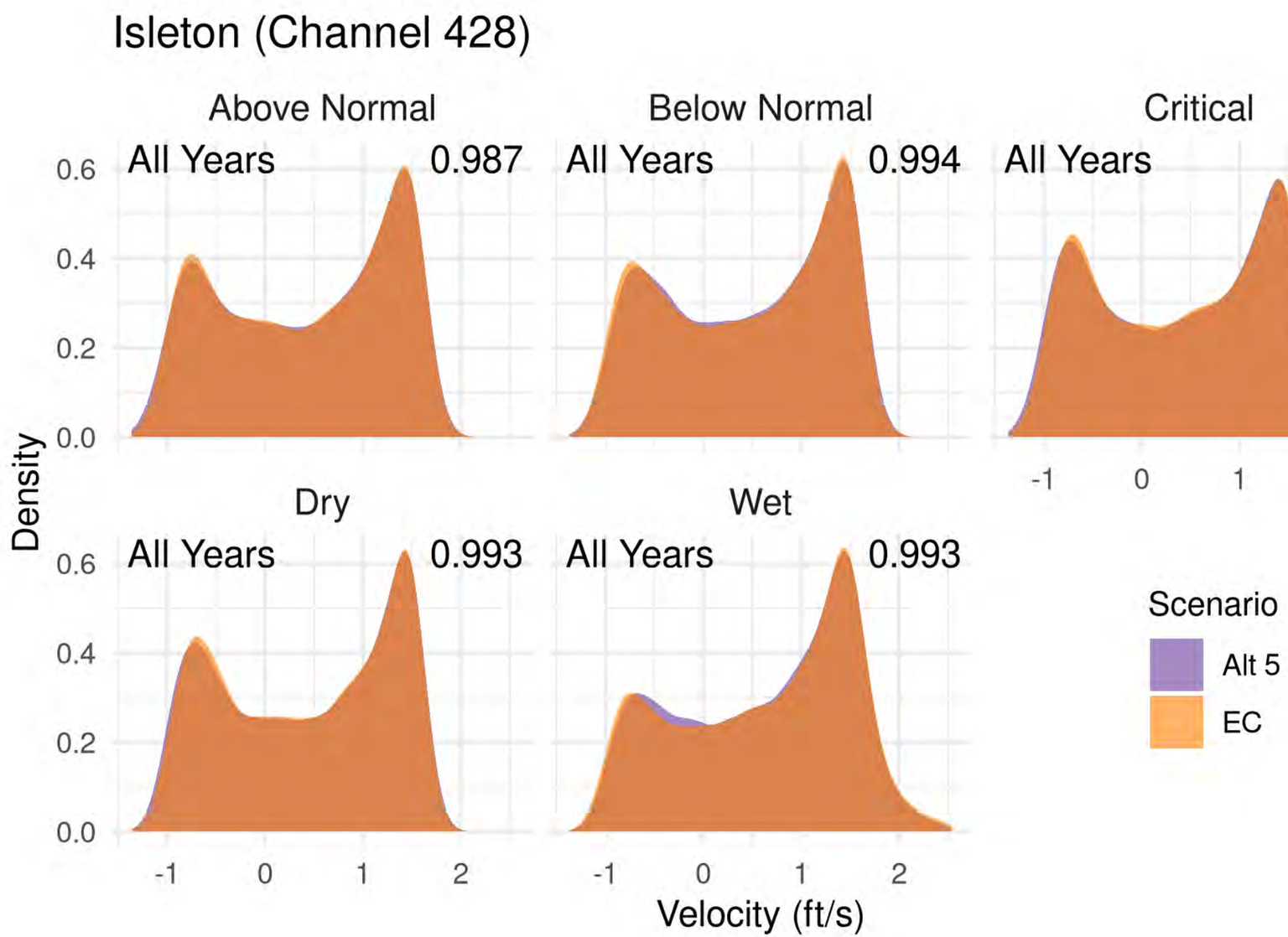

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-33. Velocity Density Distribution for Walnut Grove (Sacramento River), October.**



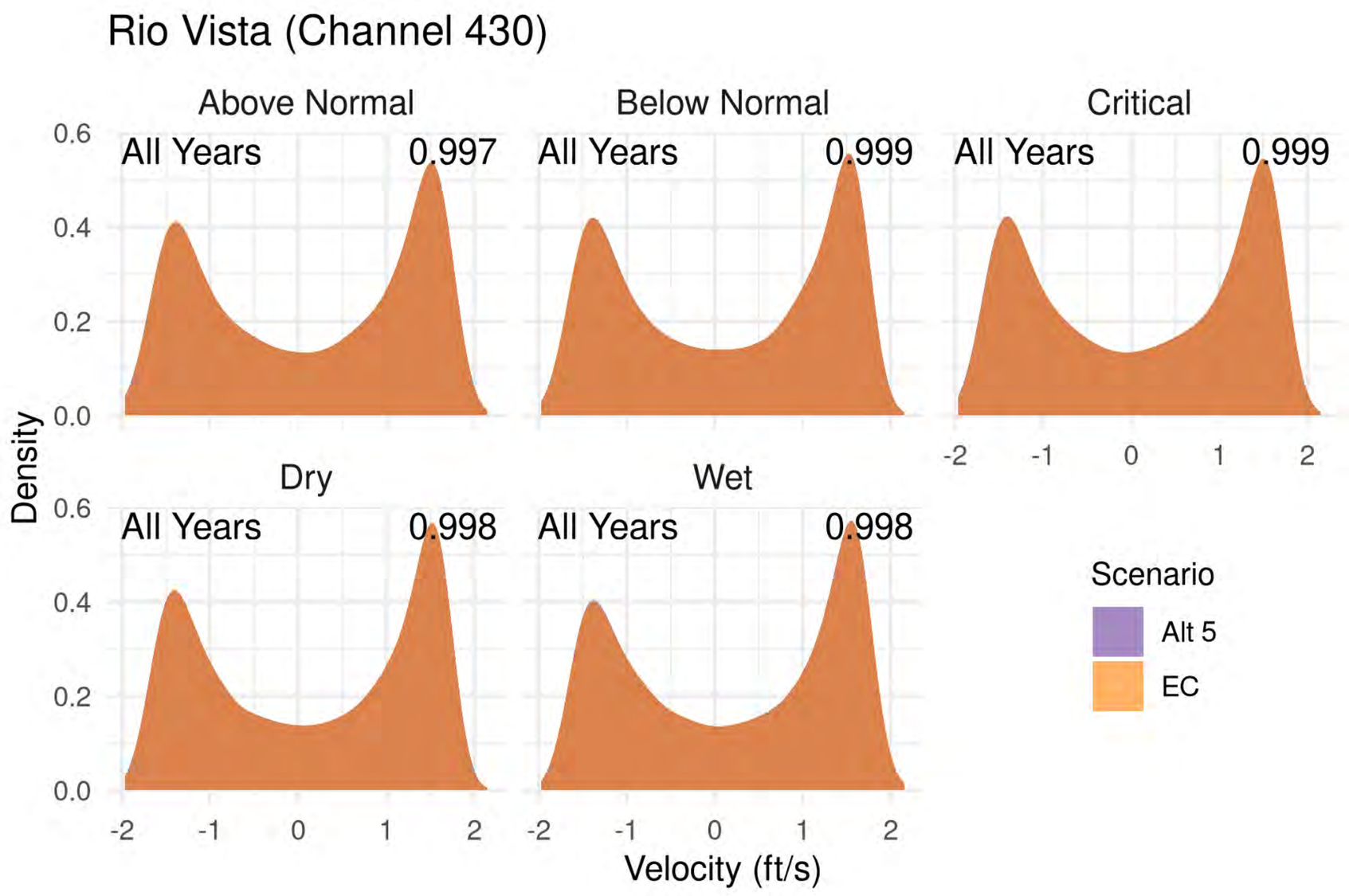

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-34. Velocity Density Distribution for Georgiana Slough, October.**



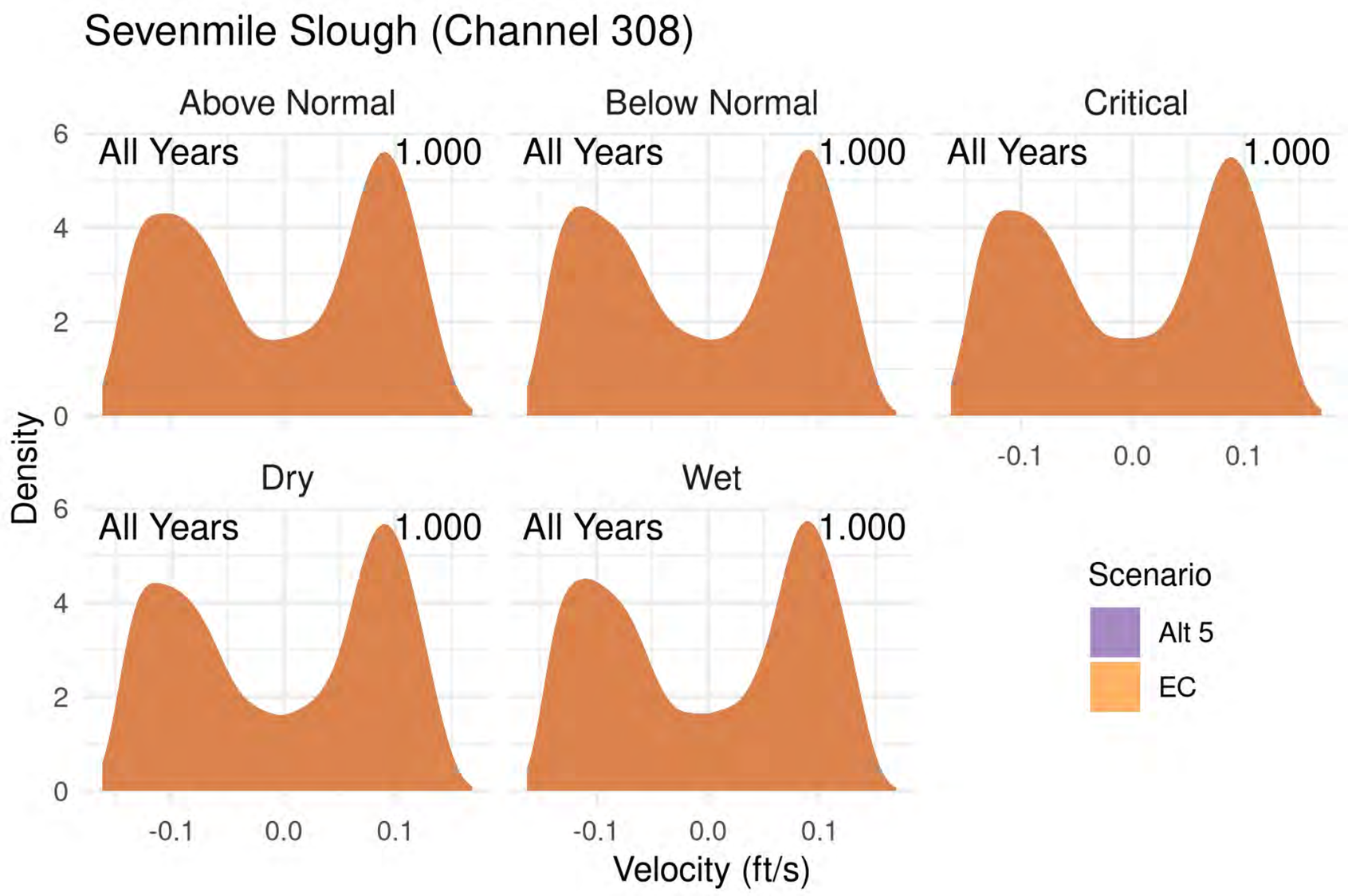

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-35. Velocity Density Distribution for Isleton (Sacramento River), October.**



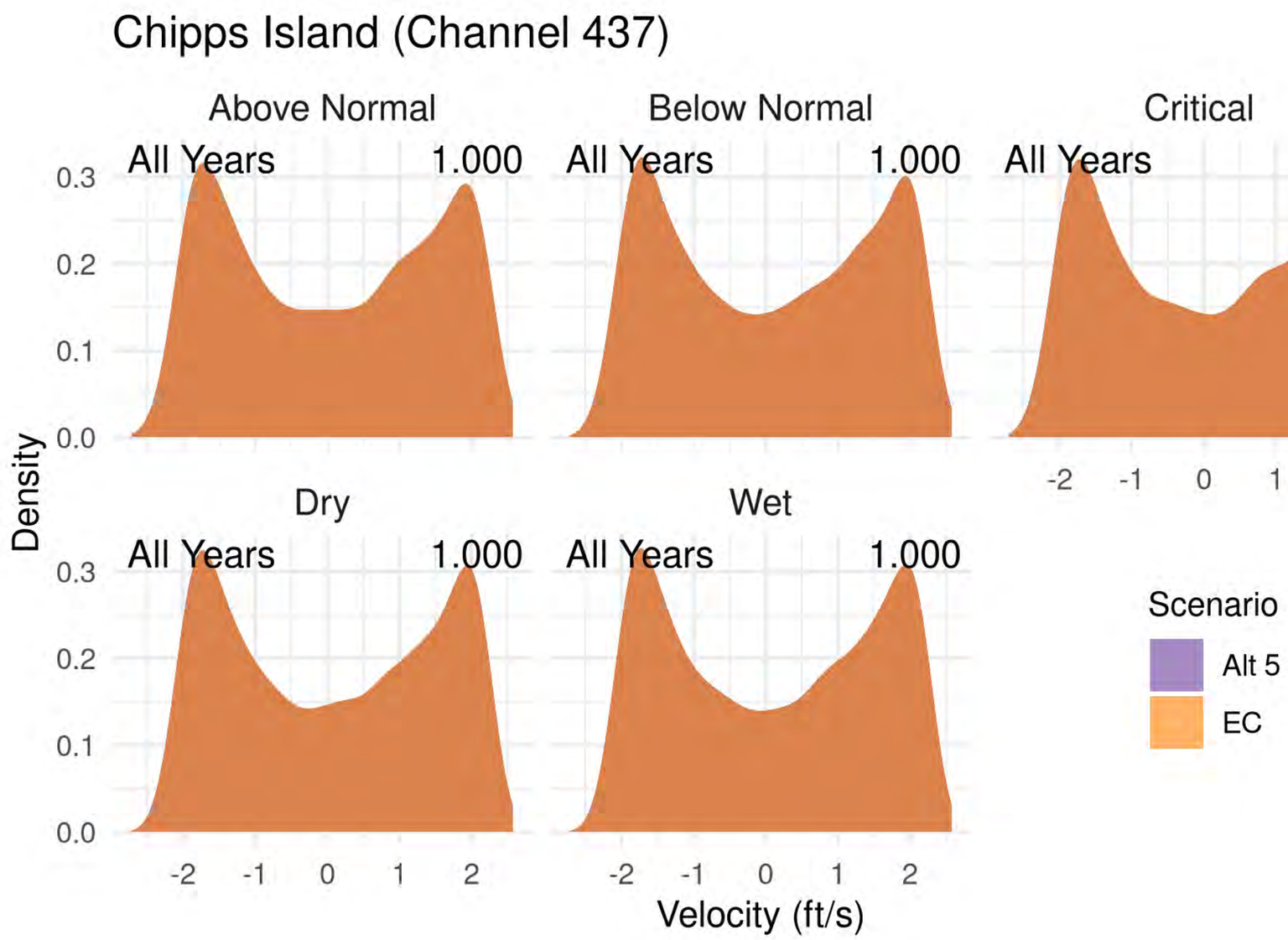

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-36. Velocity Density Distribution for Rio Vista (Sacramento River), October.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

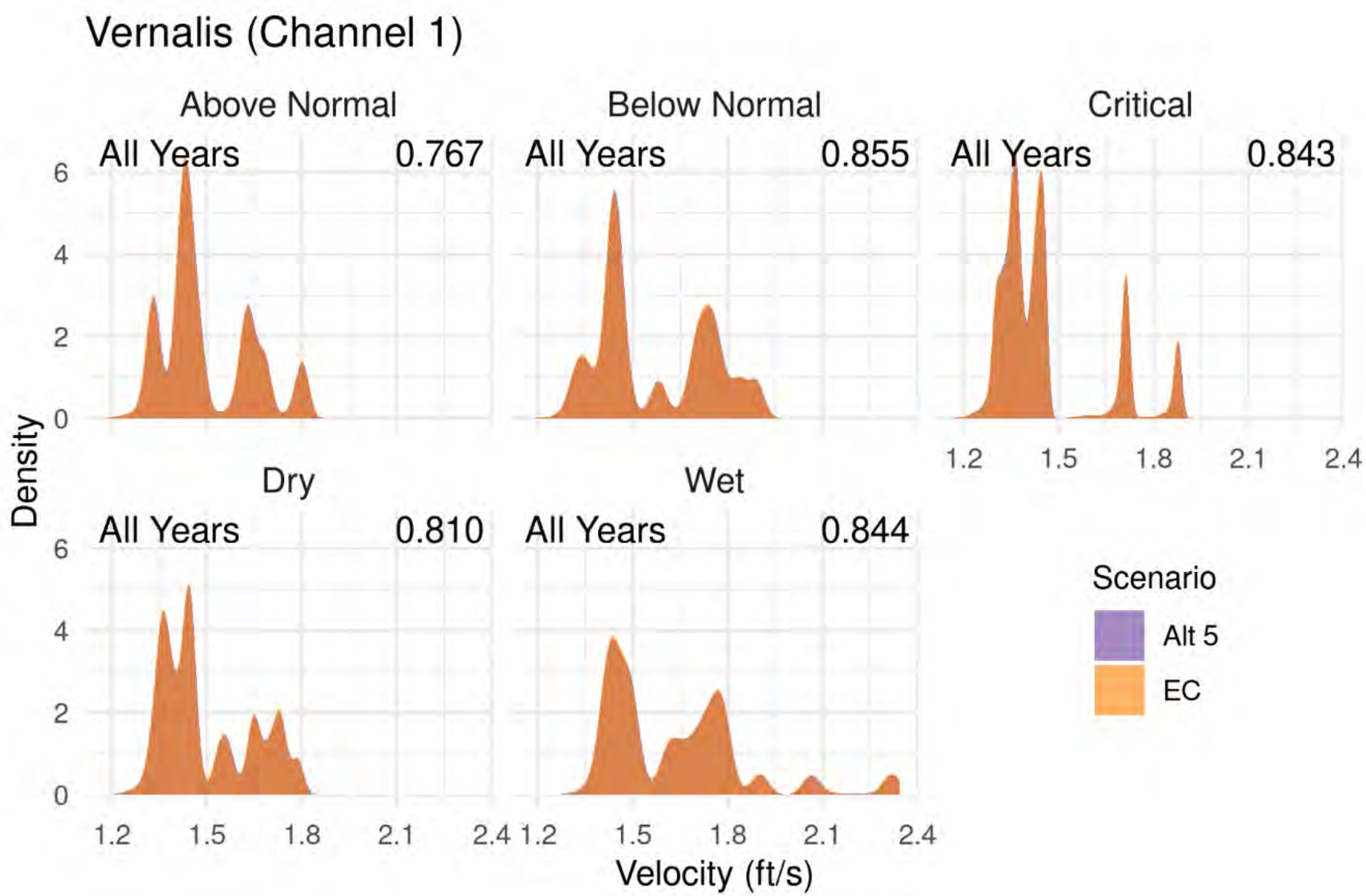
**Figure 5D.1-37. Velocity Density Distribution for Sevenmile Slough, October.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

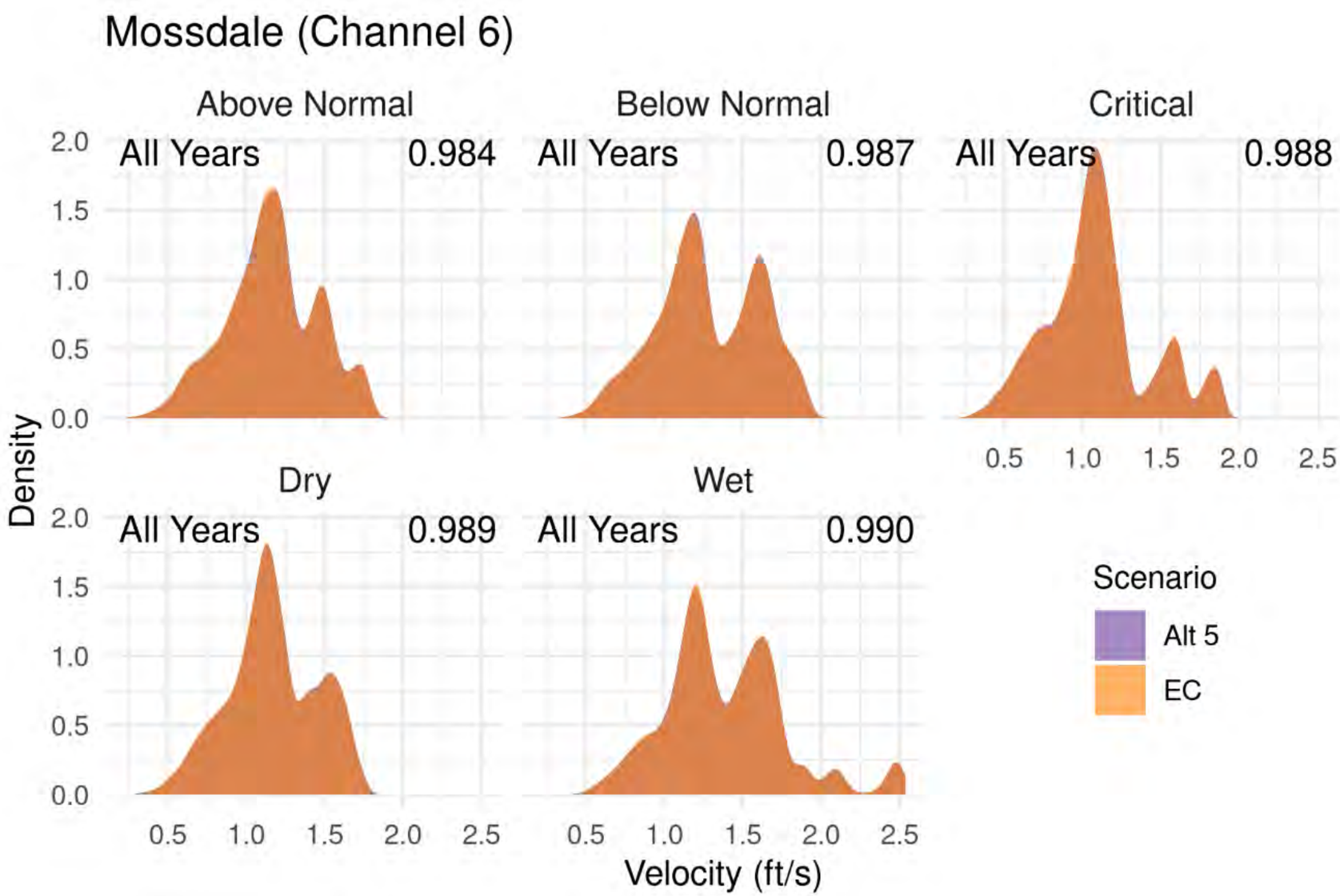
**Figure 5D.1-38. Velocity Density Distribution for Chipps Island (Sacramento River–San Joaquin River Confluence), October.**

***San Joaquin River Delta***



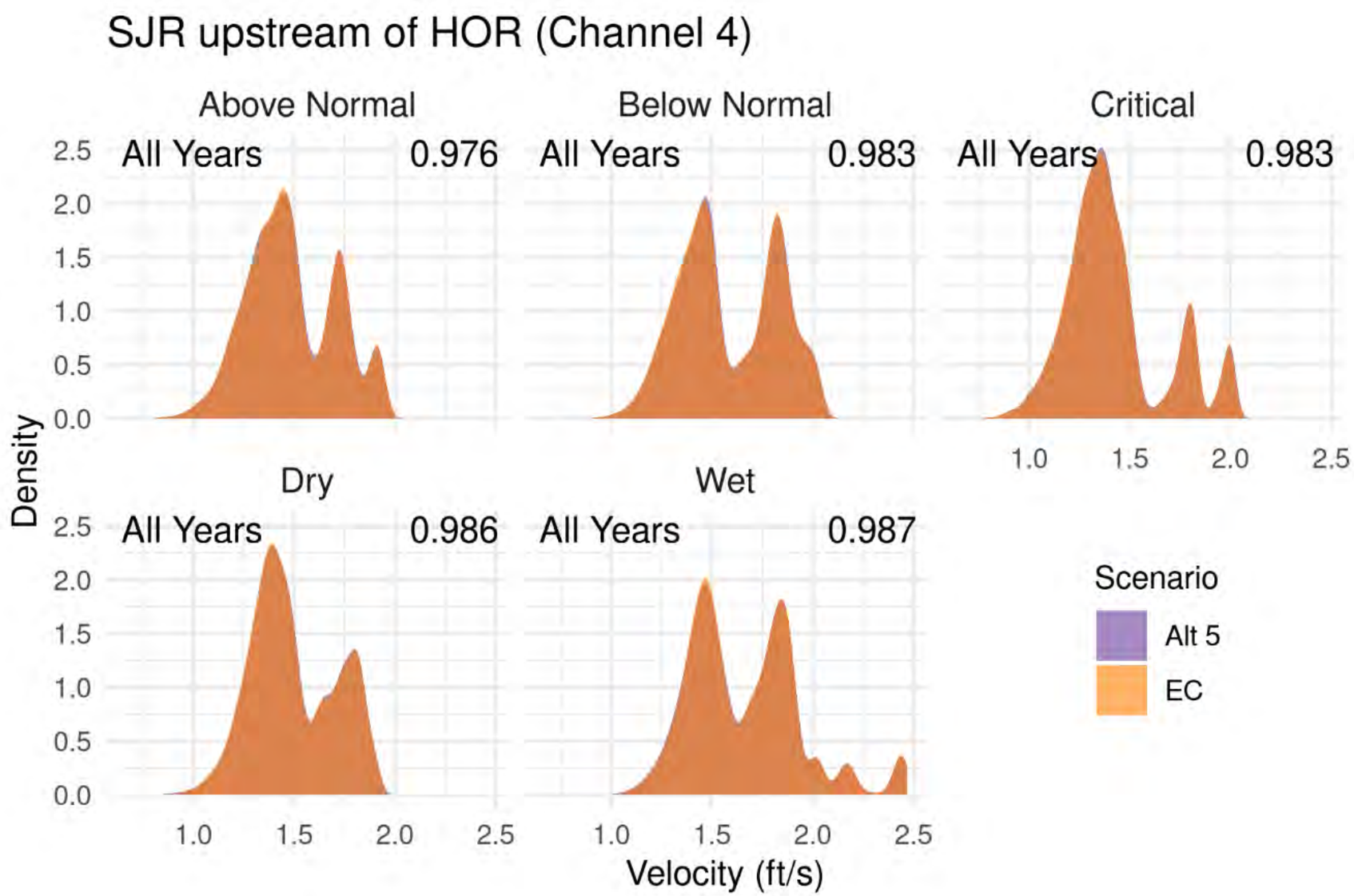

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-39. Velocity Density Distribution for Vernalis (San Joaquin River), October.**



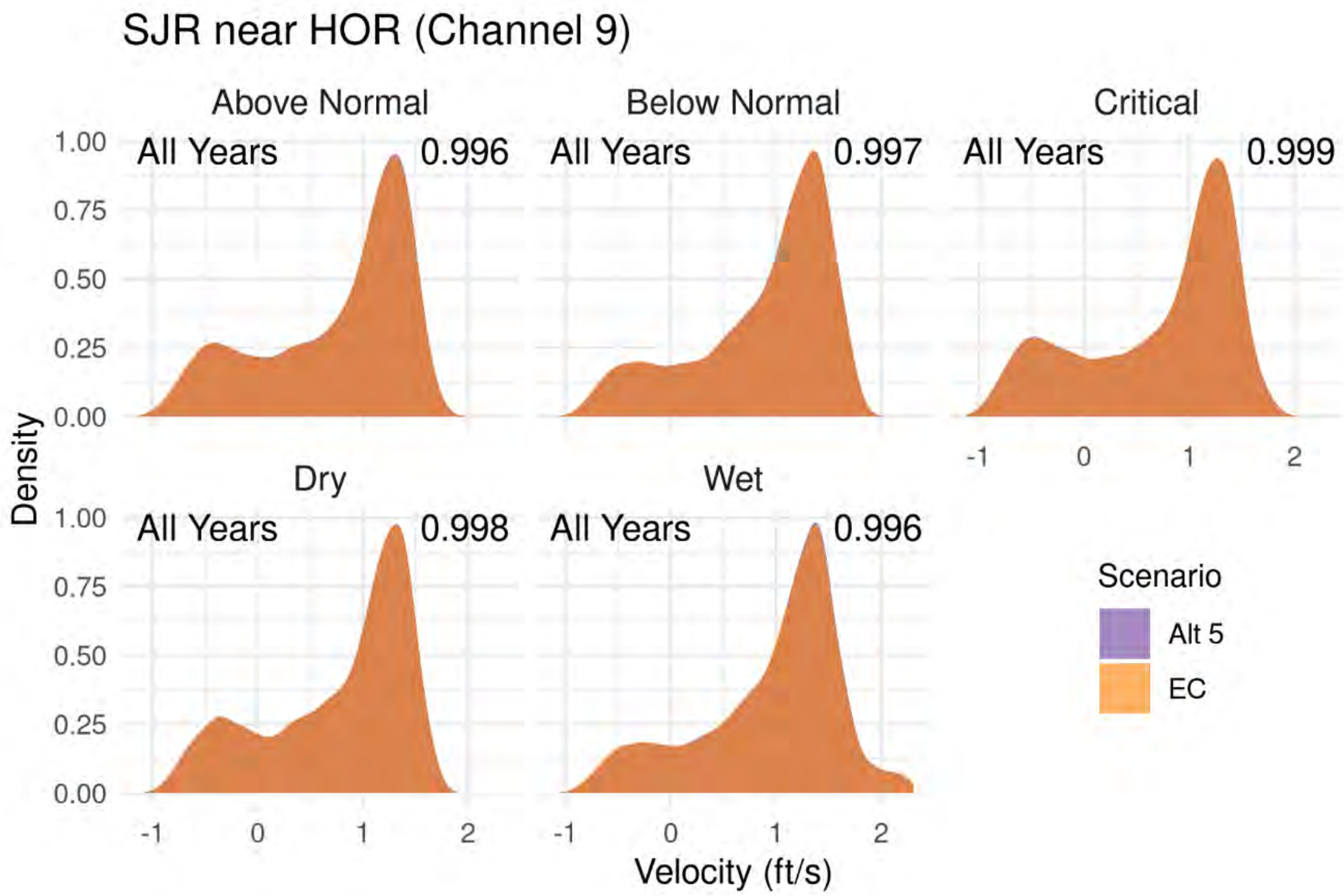

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-40. Velocity Density Distribution for Mossdale (San Joaquin River), October.**



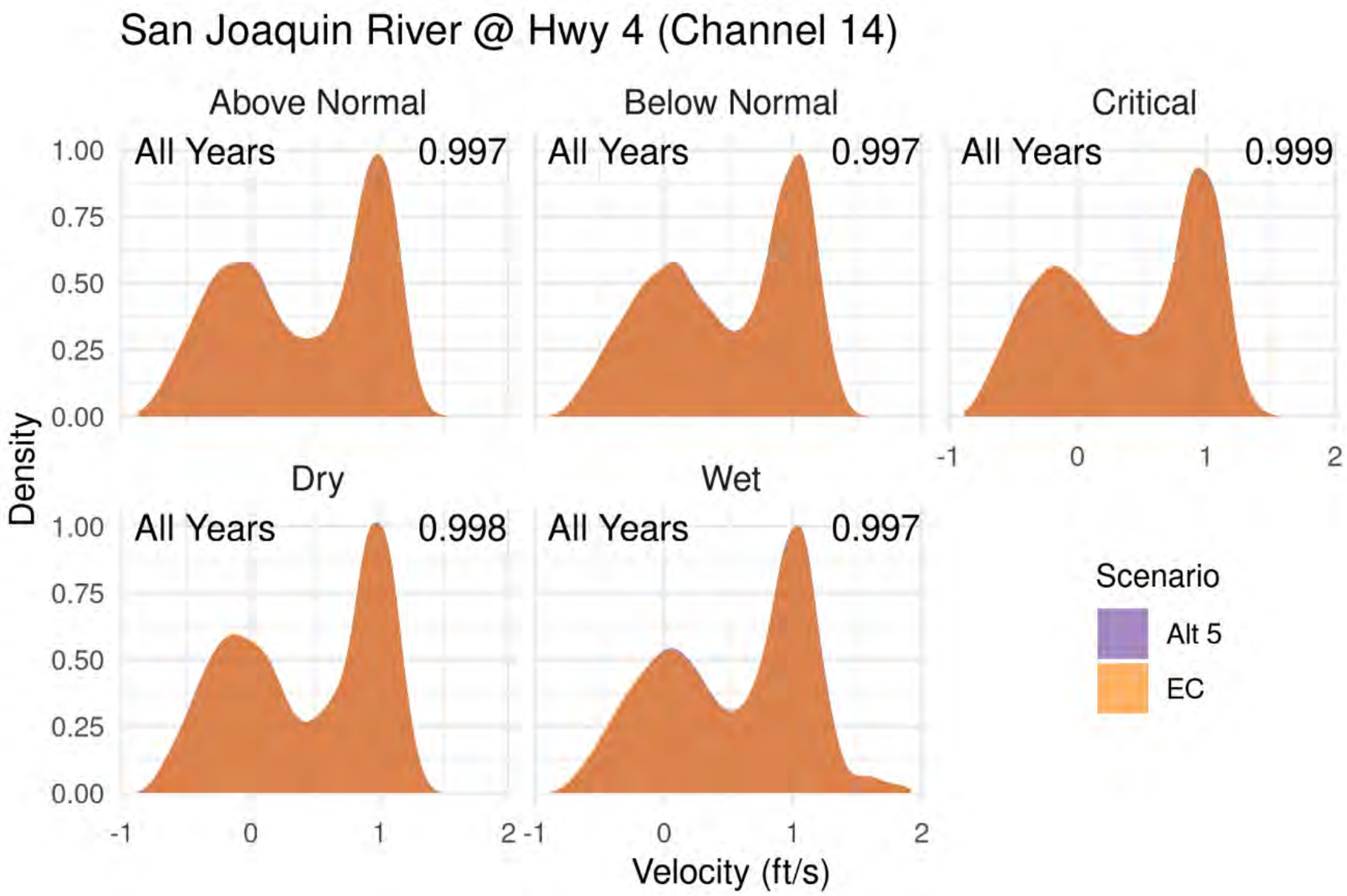

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-41. Velocity Density Distribution for San Joaquin River upstream of Head of Old River, October.**



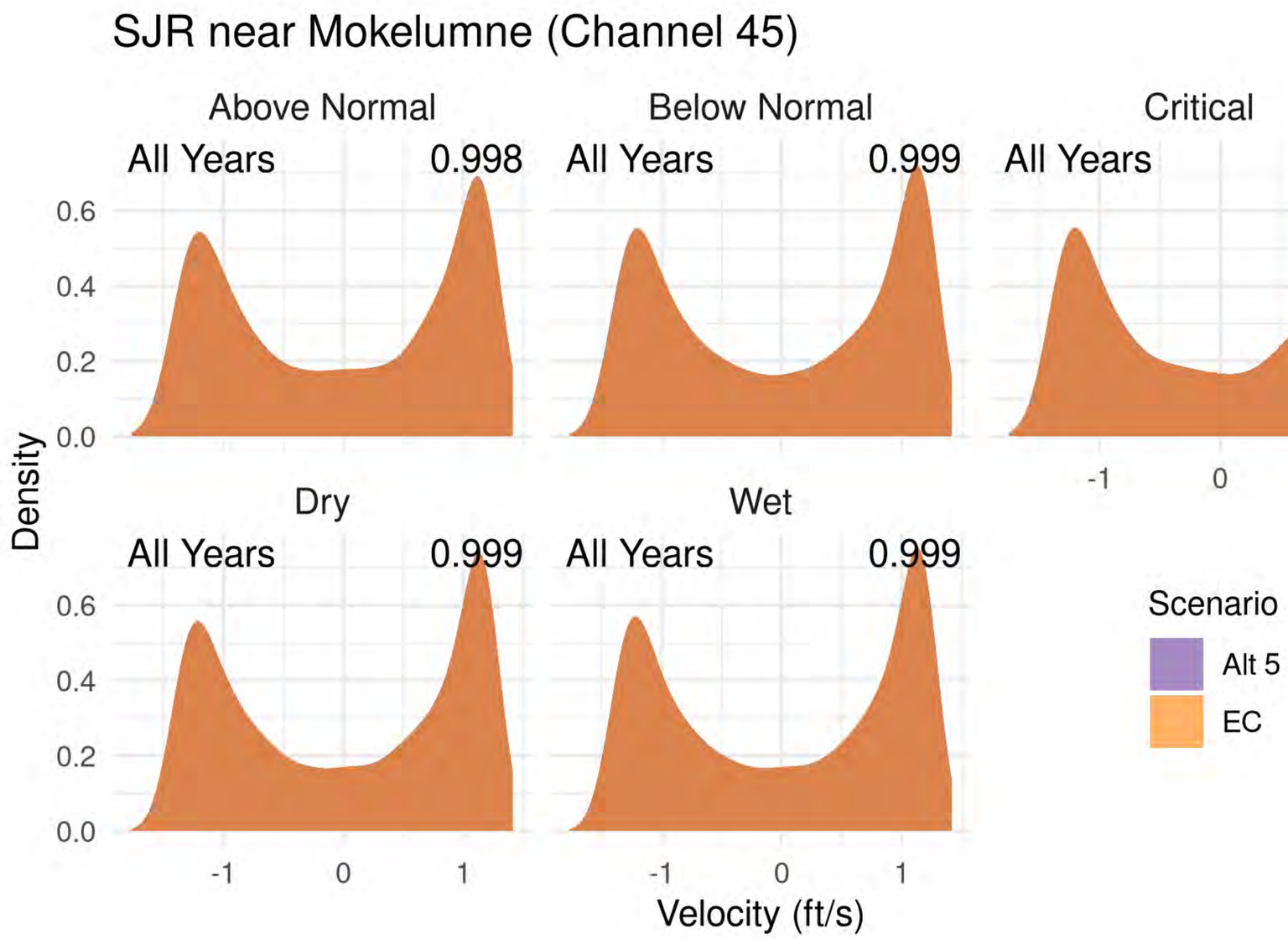

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-42. Velocity Density Distribution for San Joaquin River near Head of Old River, October.**



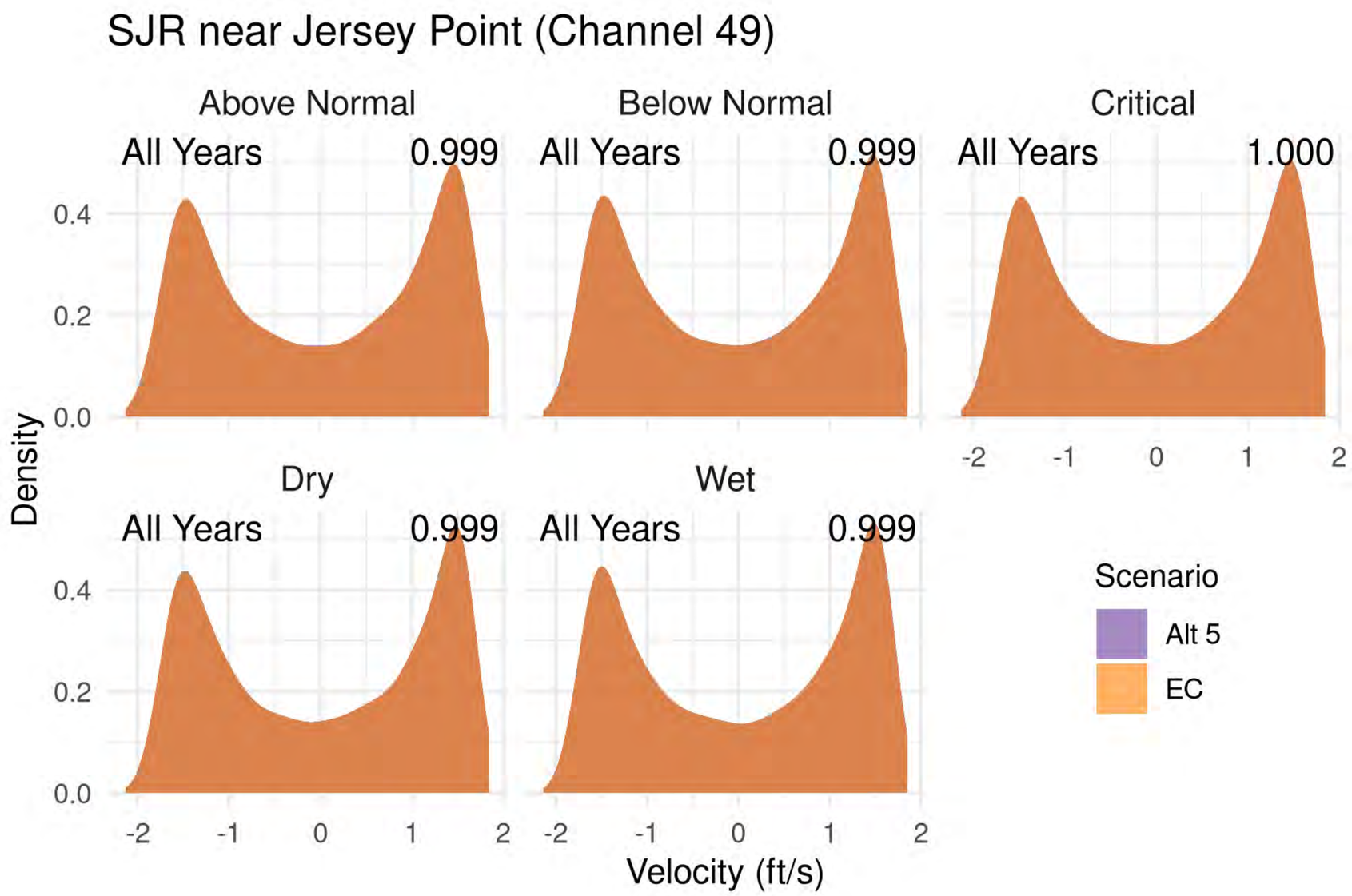

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-43. Velocity Density Distribution for San Joaquin River at Highway 4, October.**



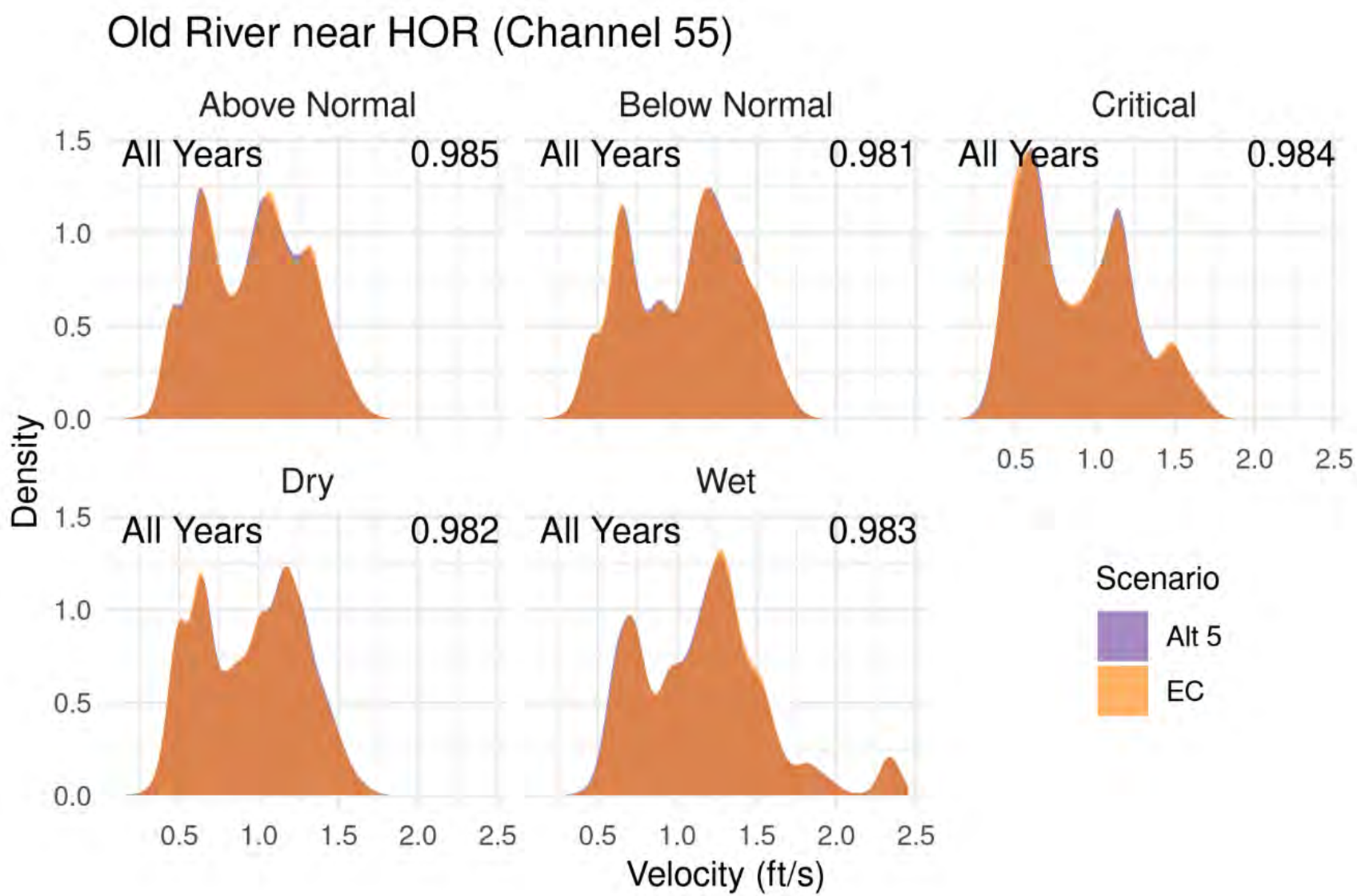

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-44. Velocity Density Distribution for San Joaquin River near Mokelumne River, October.**



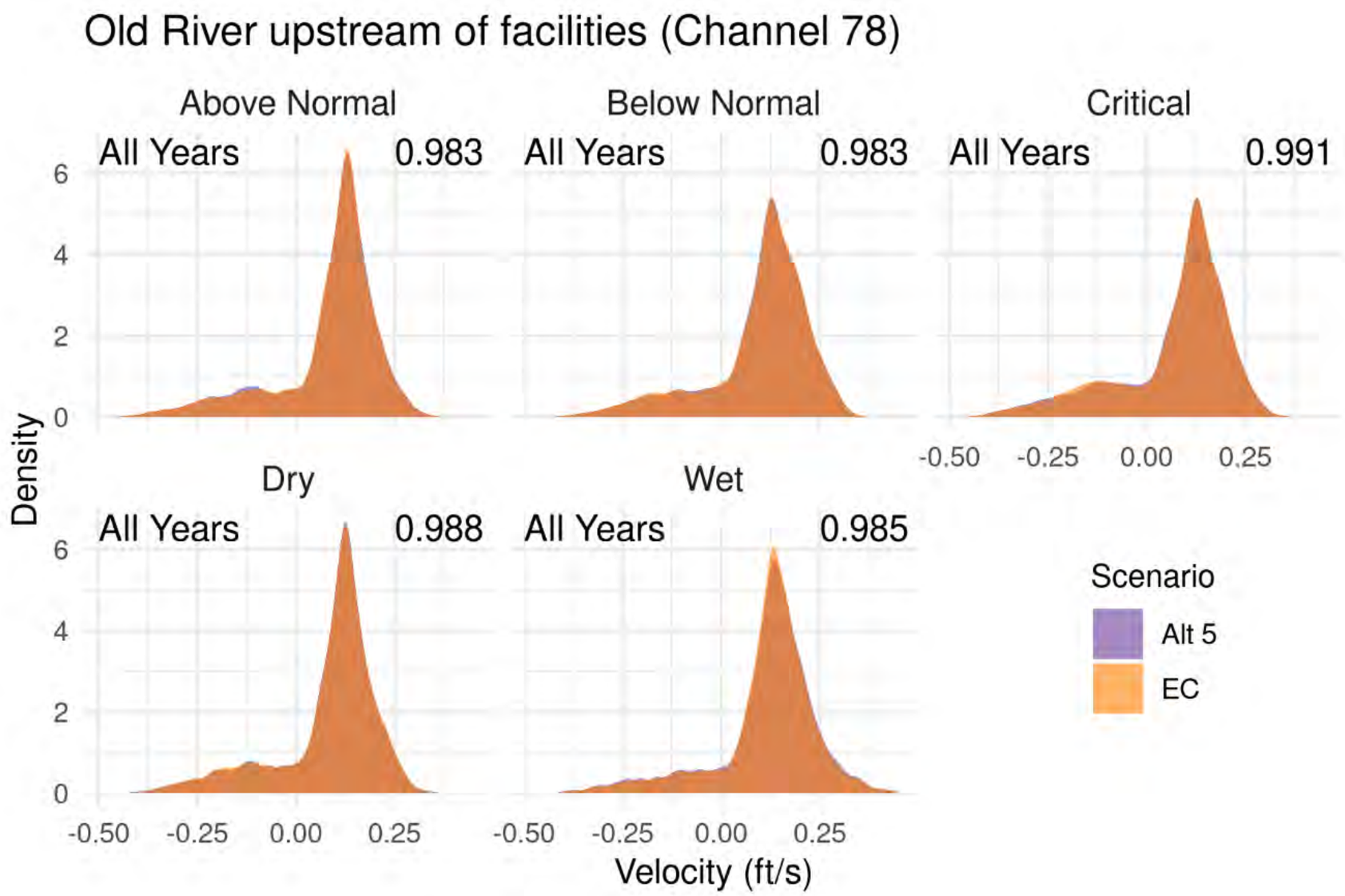

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-45. Velocity Density Distribution for San Joaquin River near Jersey Point, October.**



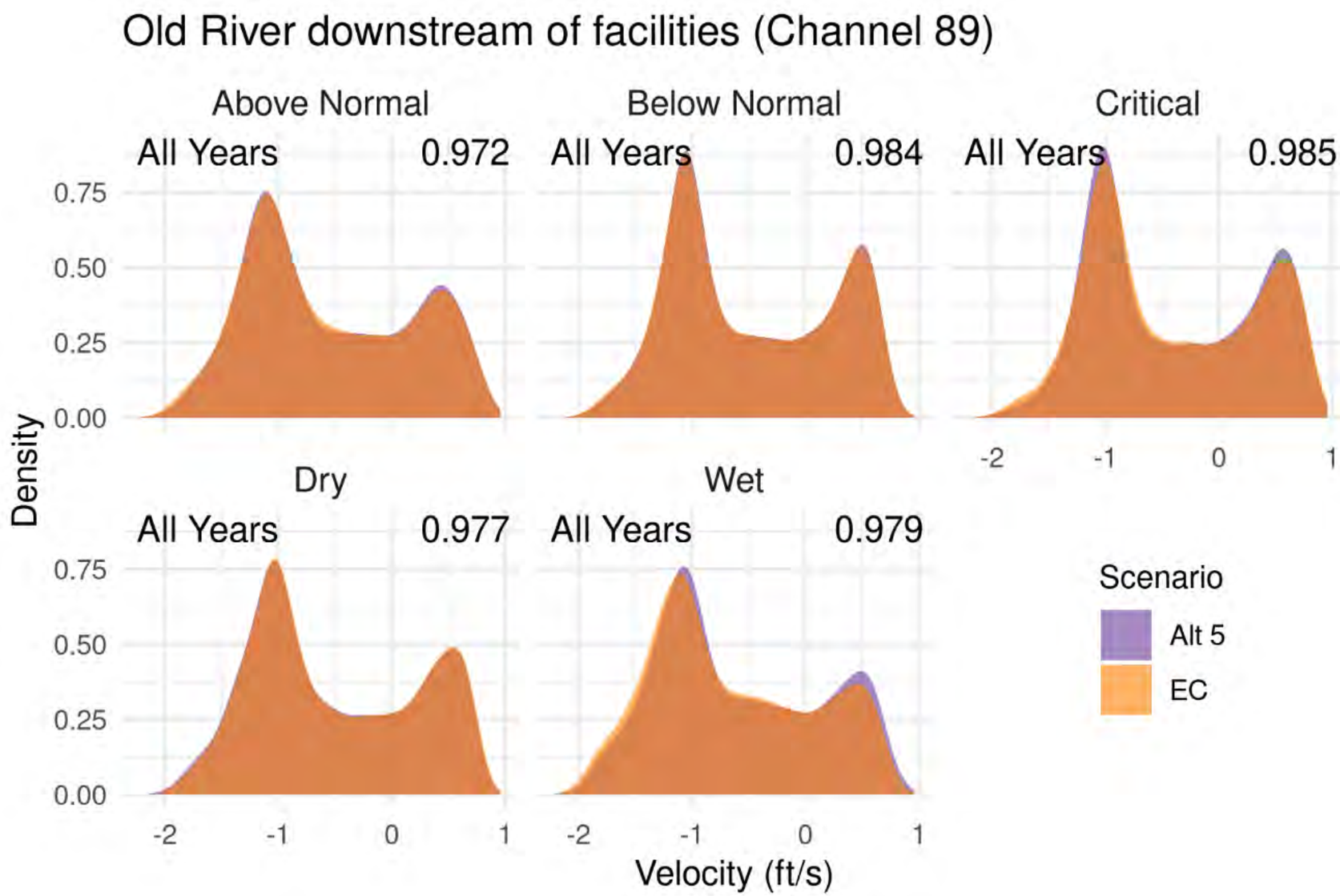

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-46. Velocity Density Distribution for Old River near Head of Old River, October.**



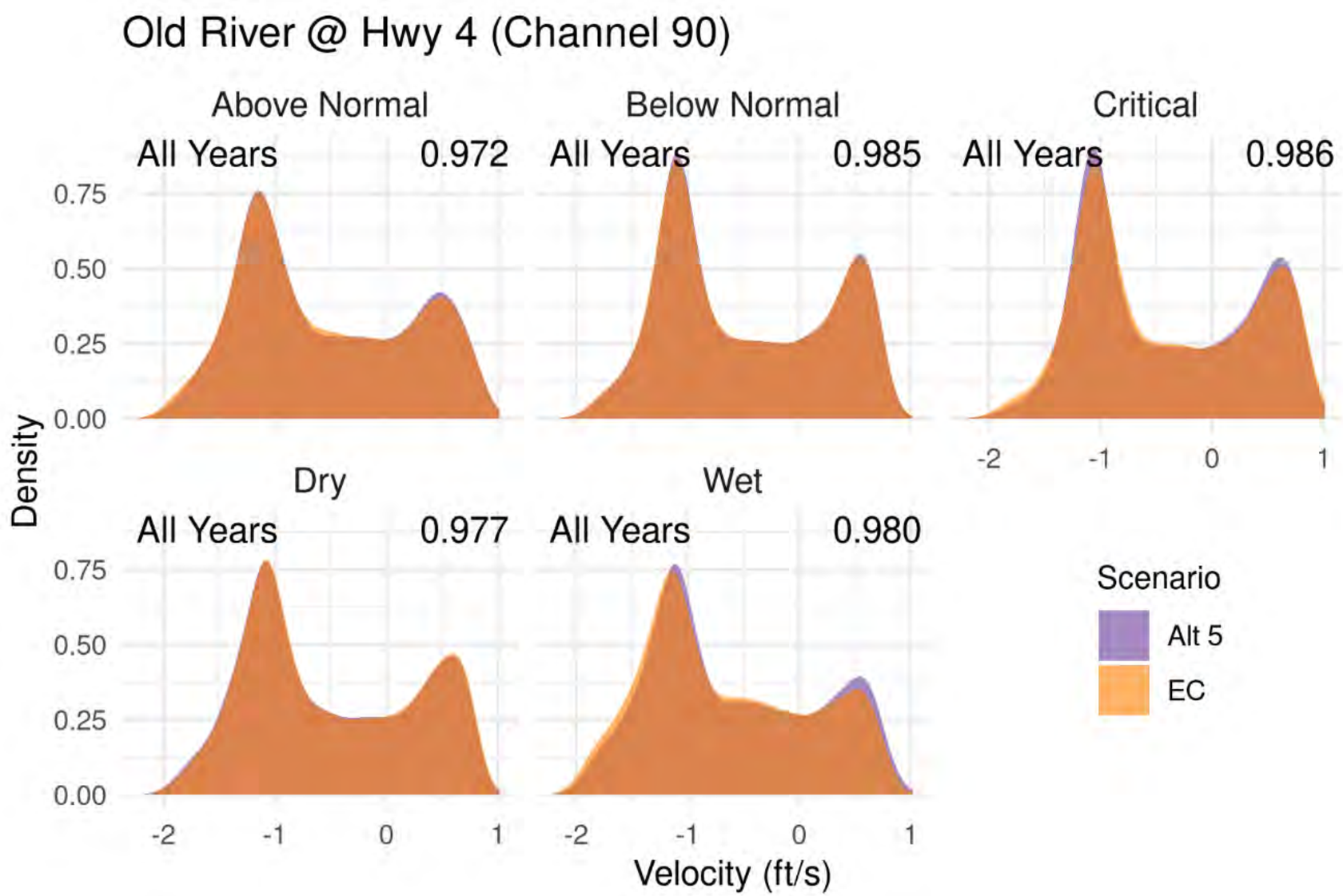

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-47. Velocity Density Distribution for Old River upstream of the South Delta Export Facilities, October.**



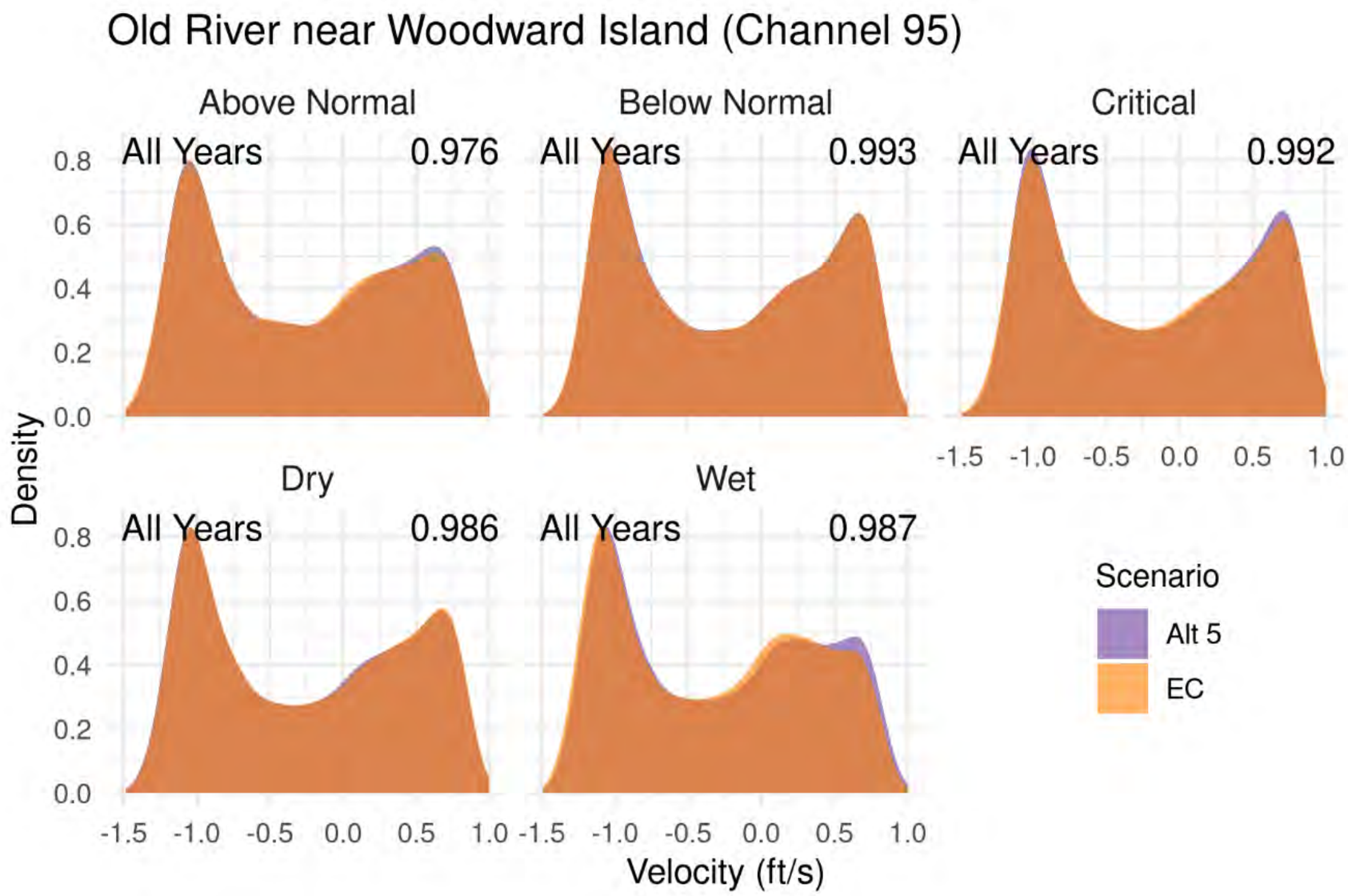

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-48. Velocity Density Distribution for Old River Downstream of the South Delta Export Facilities, October.**



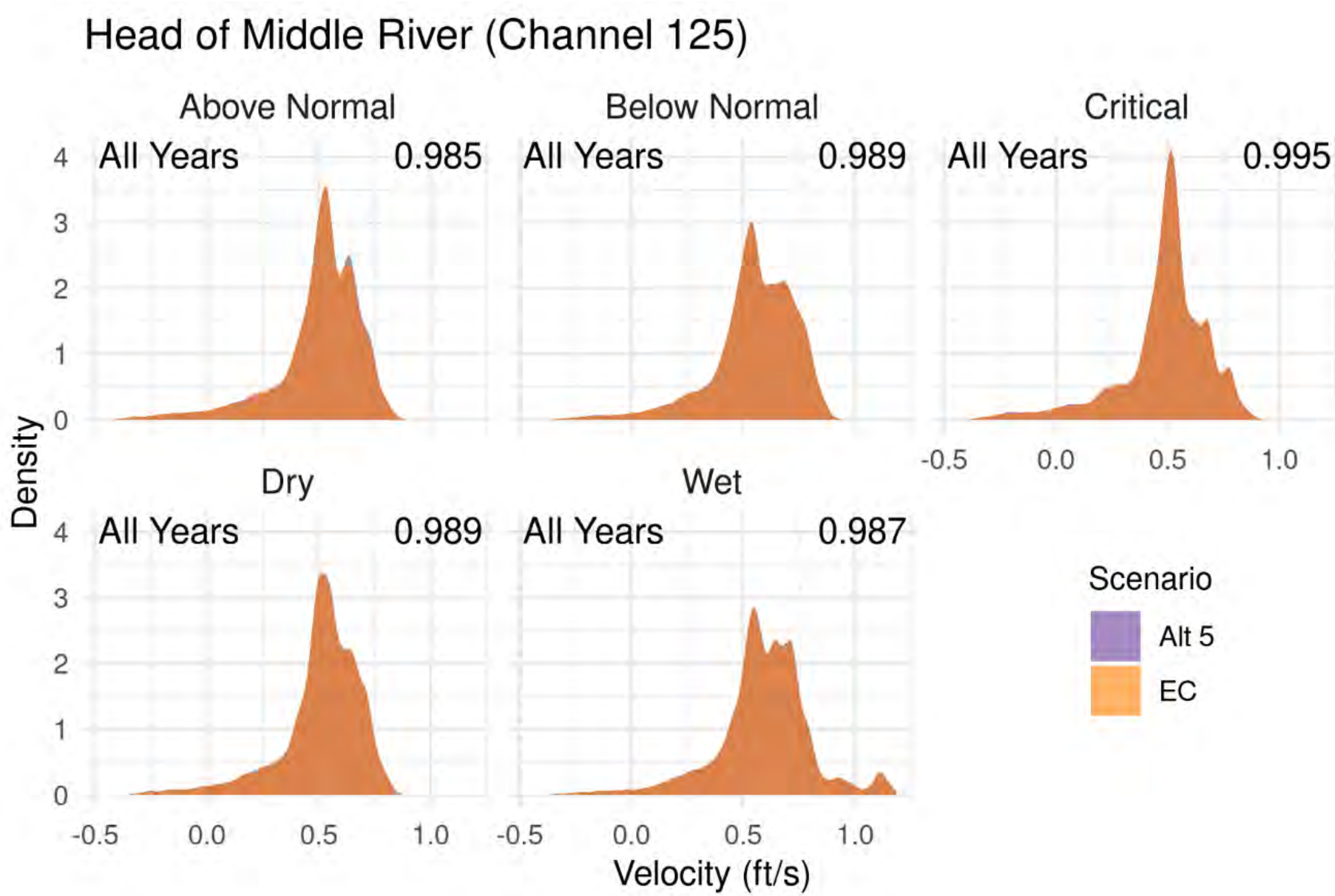

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-49. Velocity Density Distribution for Old River at Highway 4, October.**



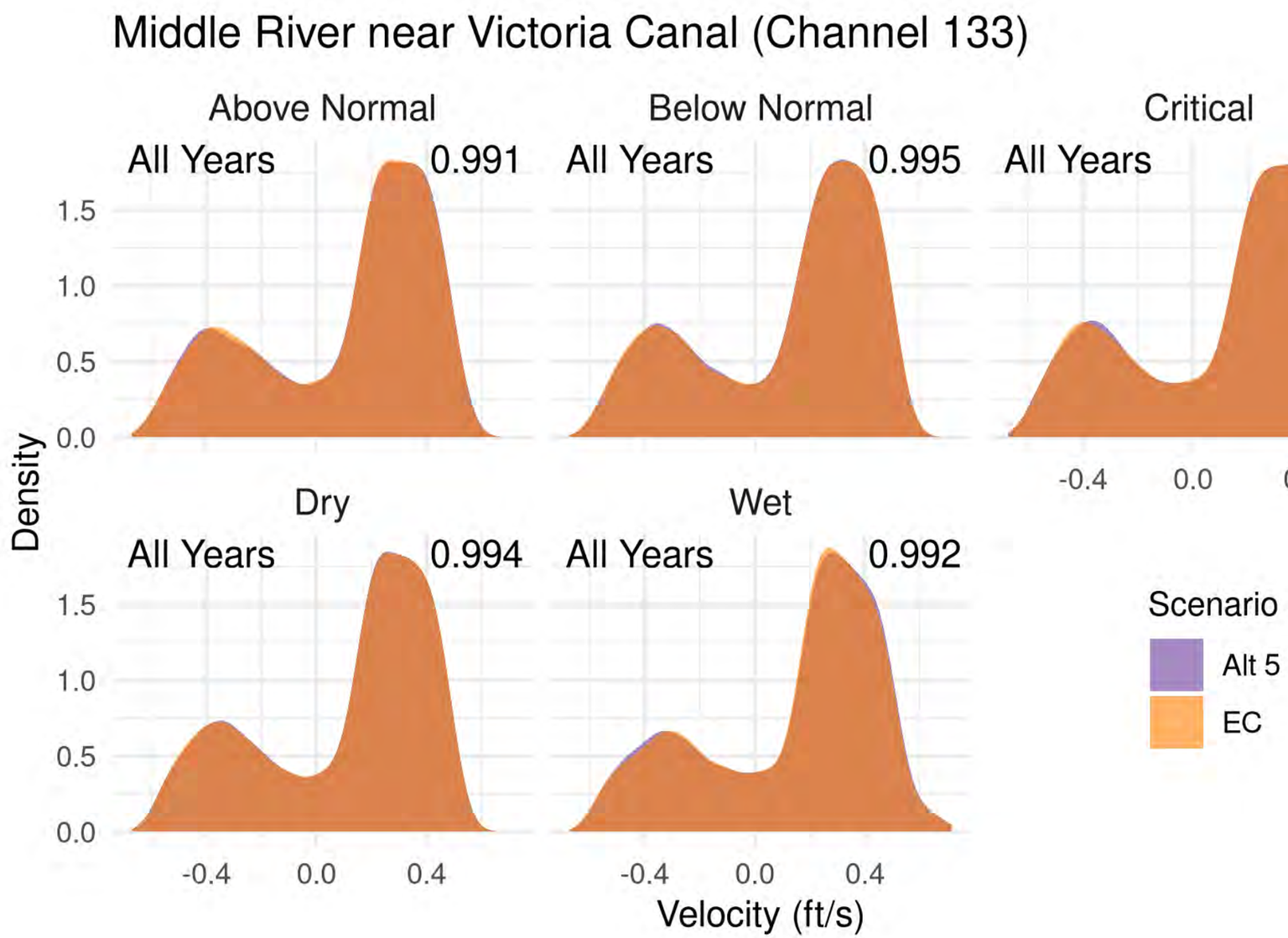

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-50. Velocity Density Distribution for Old River near Woodward Island, October.**



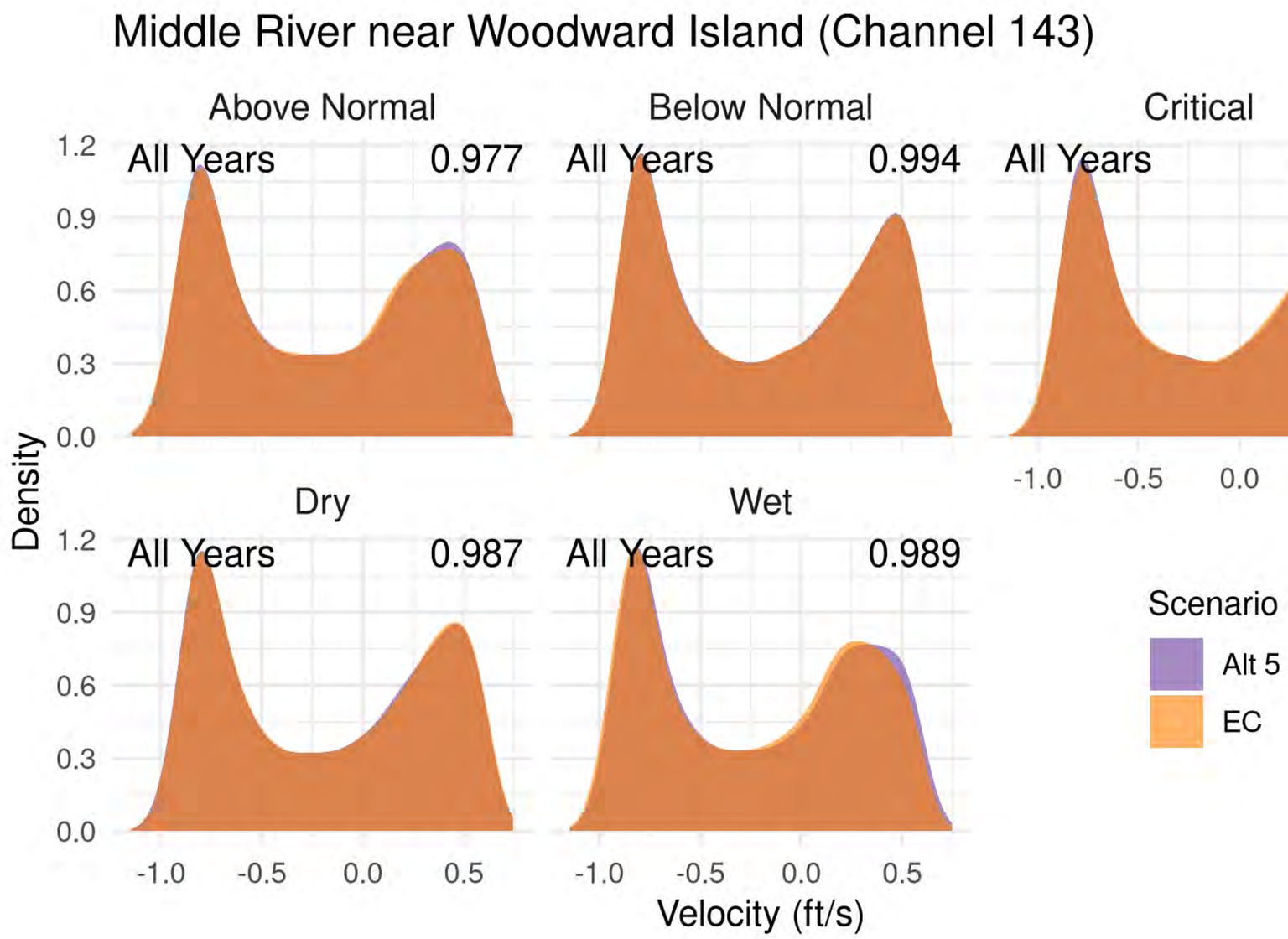

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-51. Velocity Density Distribution for Head of Middle River, October.**



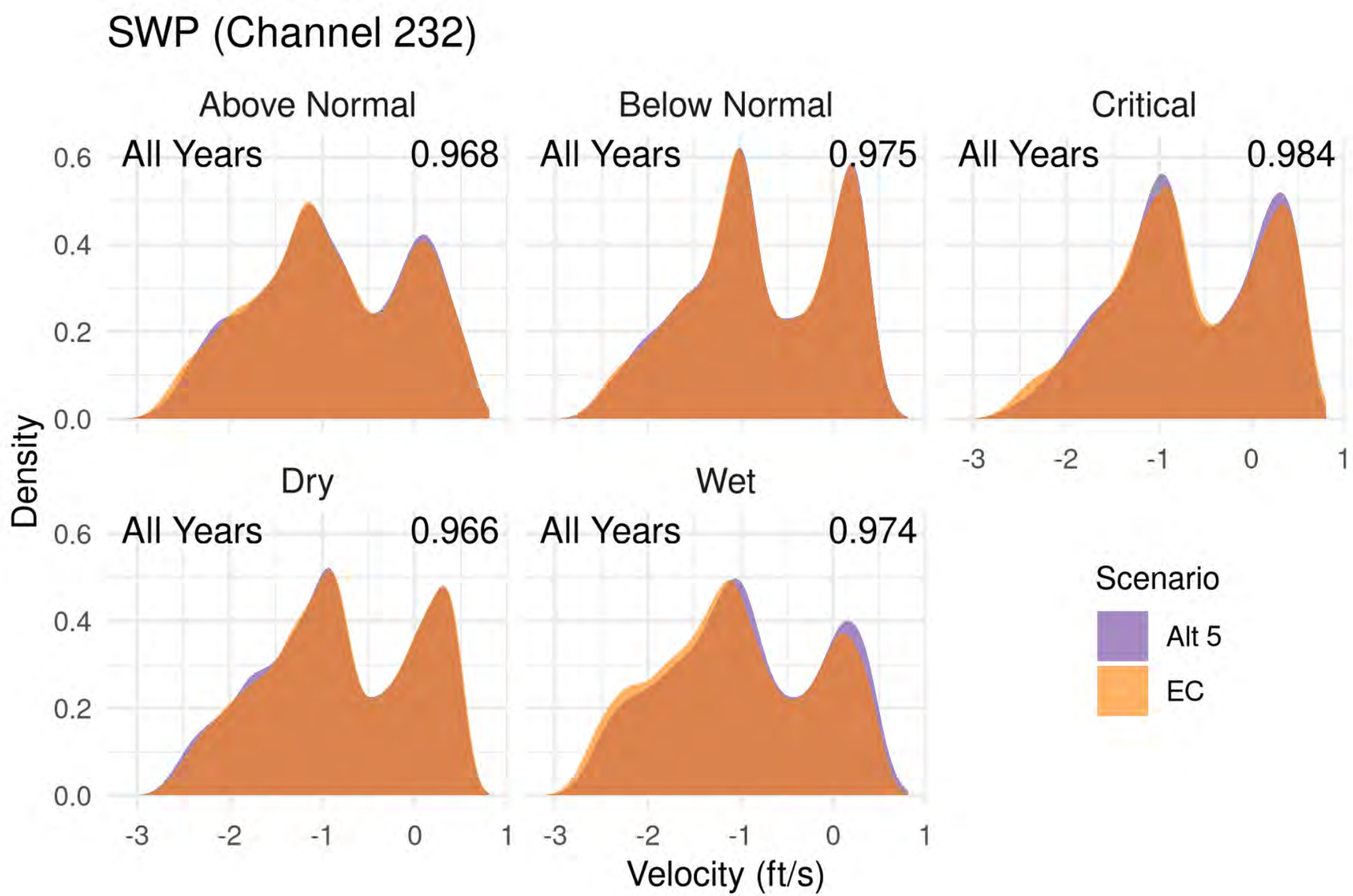

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-52. Velocity Density Distribution for Middle River near Victoria Canal, October.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-53. Velocity Density Distribution for Middle River near Woodward Island, October.**

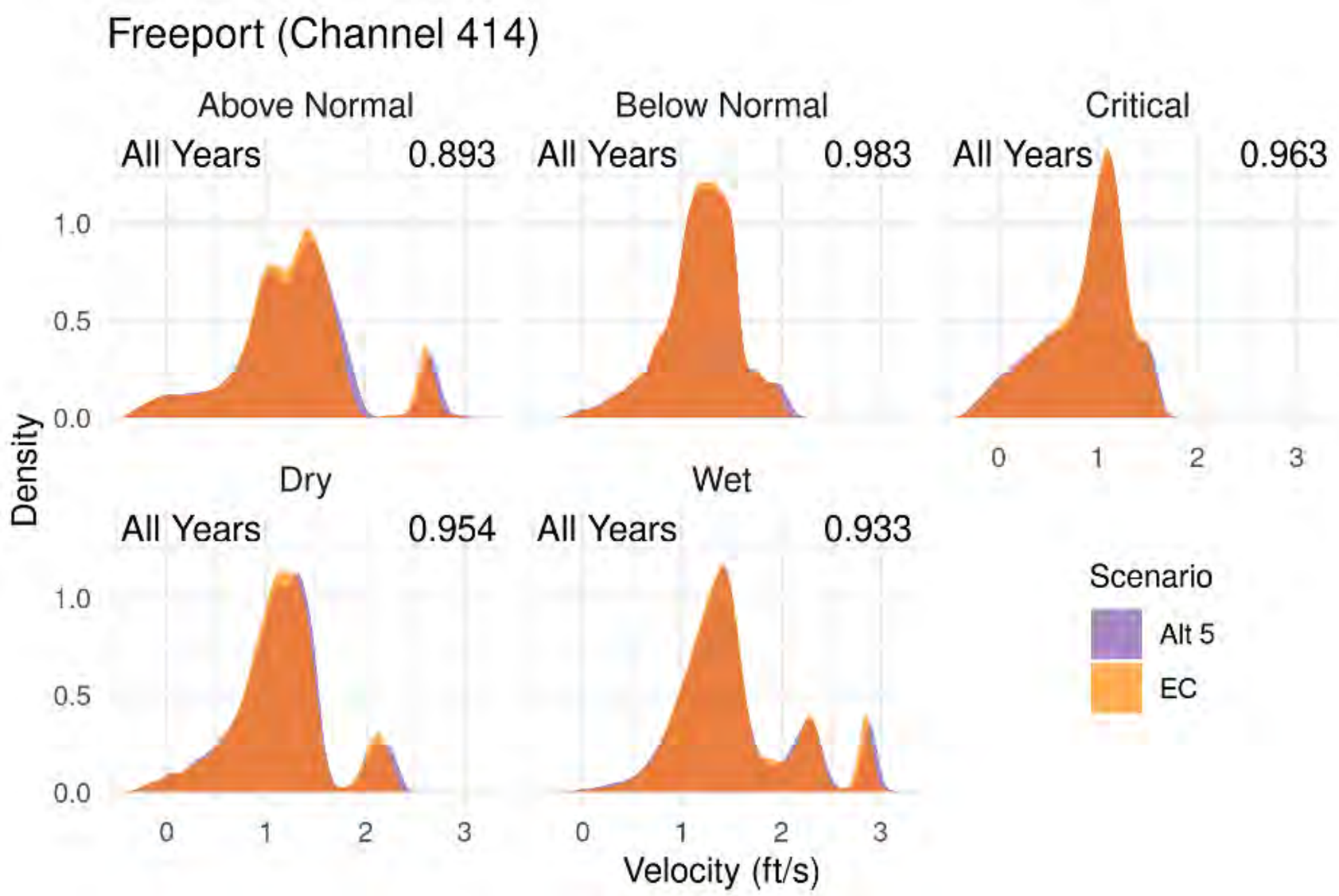



Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-54. Velocity Density Distribution for State Water Project (West Canal near Entrance to Clifton Court Forebay), October.**

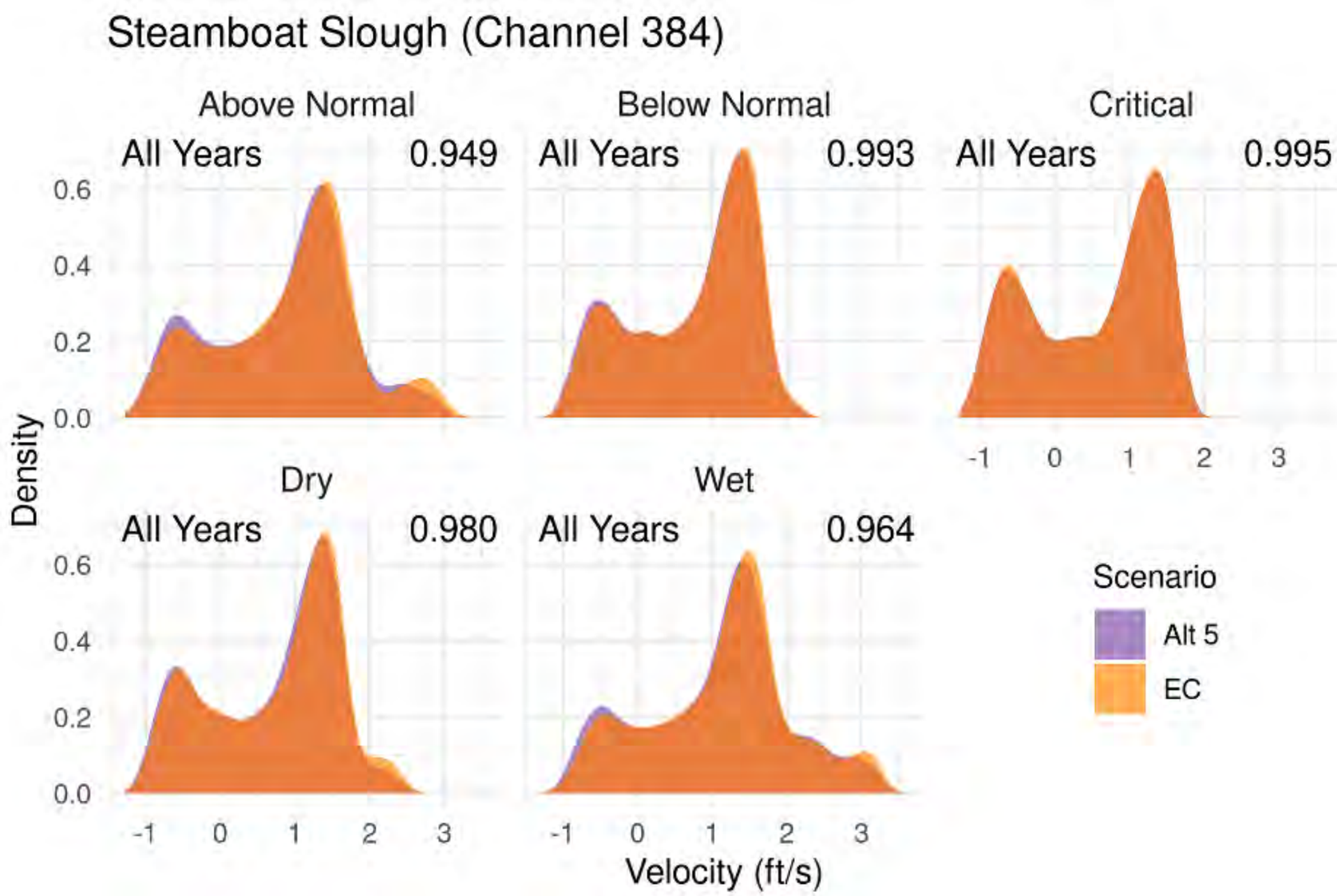
**November**

***Sacramento River Delta***



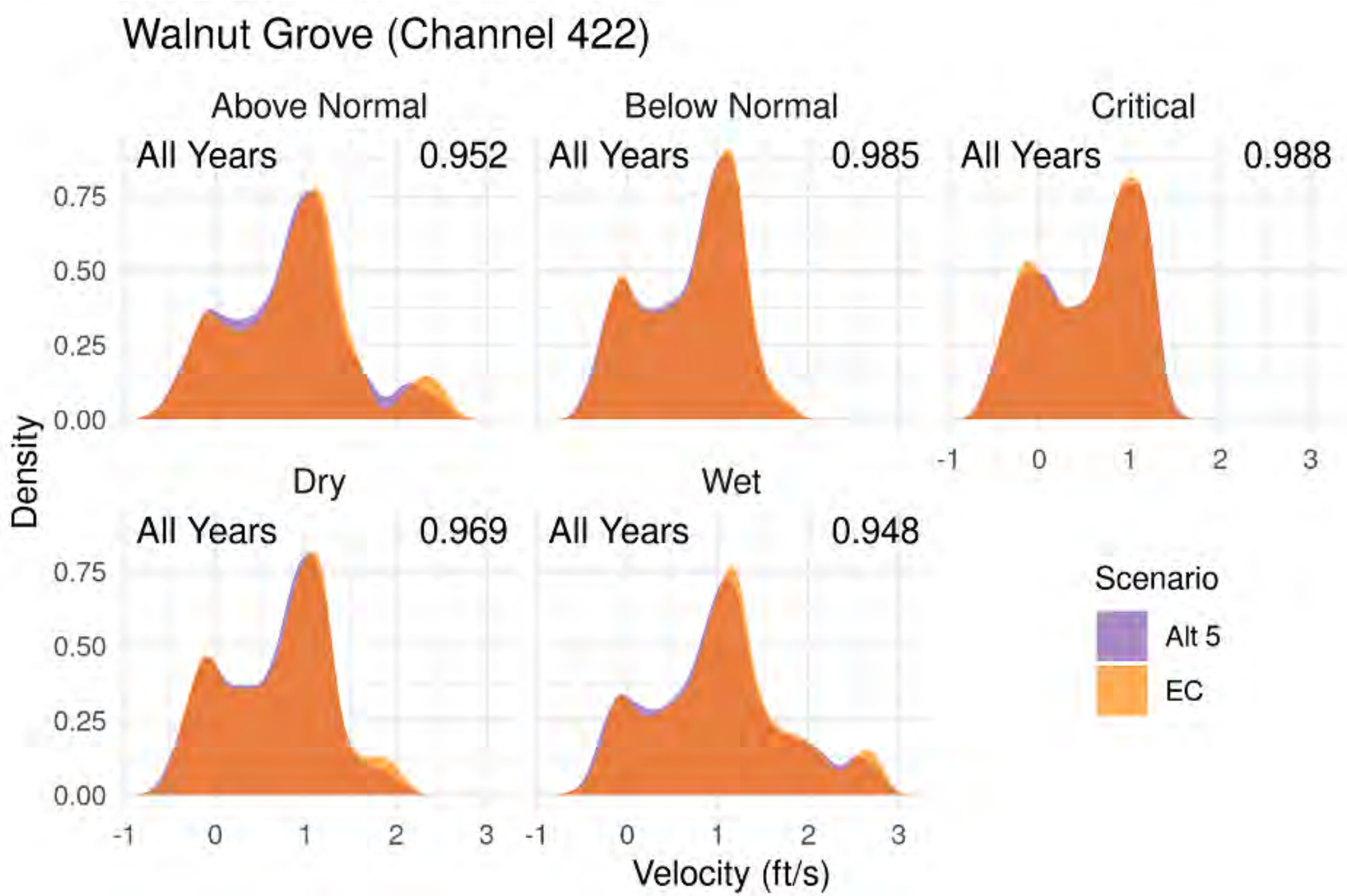

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-55. Velocity Density Distribution for Freeport, November.**



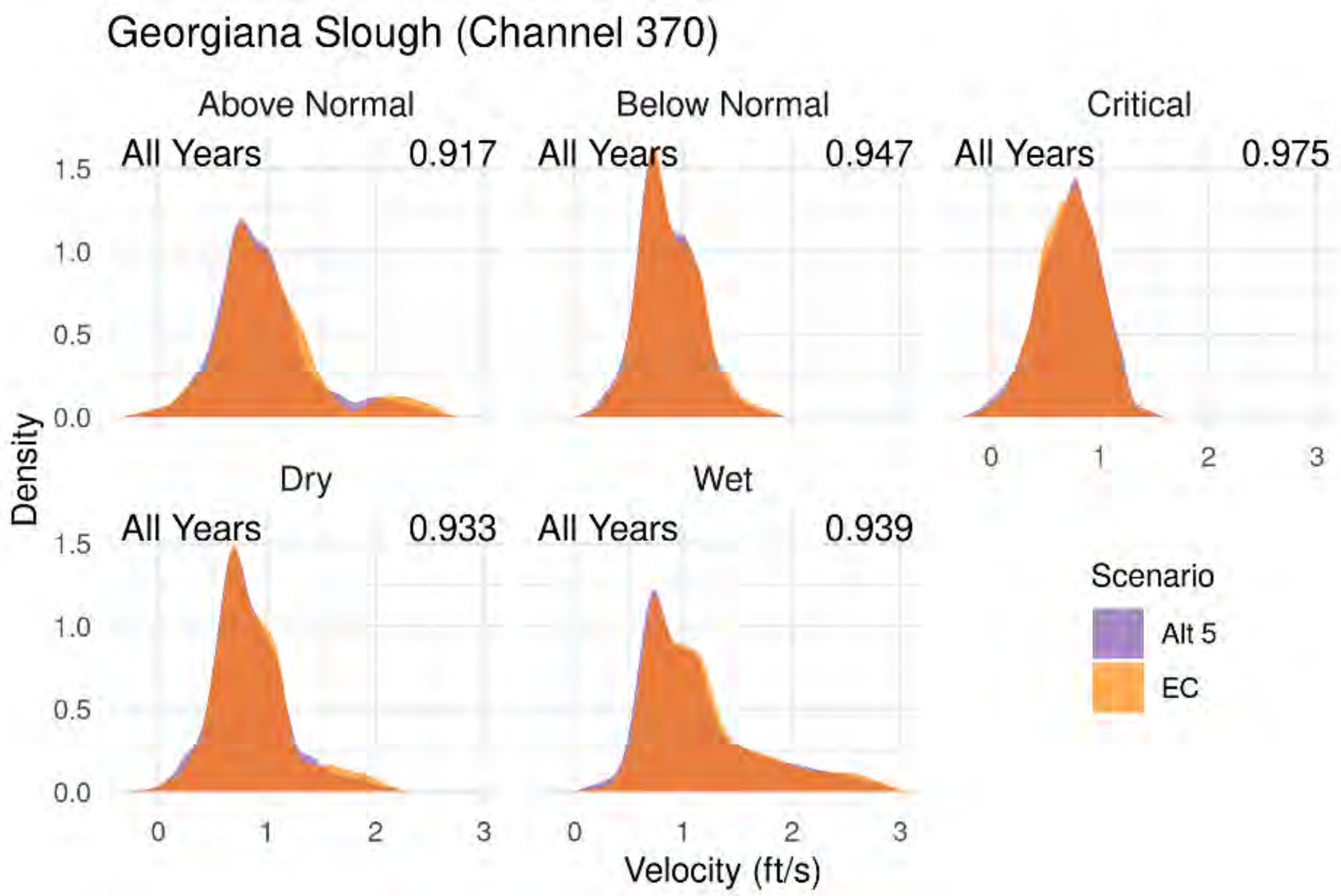

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-56. Velocity Density Distribution for Steamboat Slough, November.**



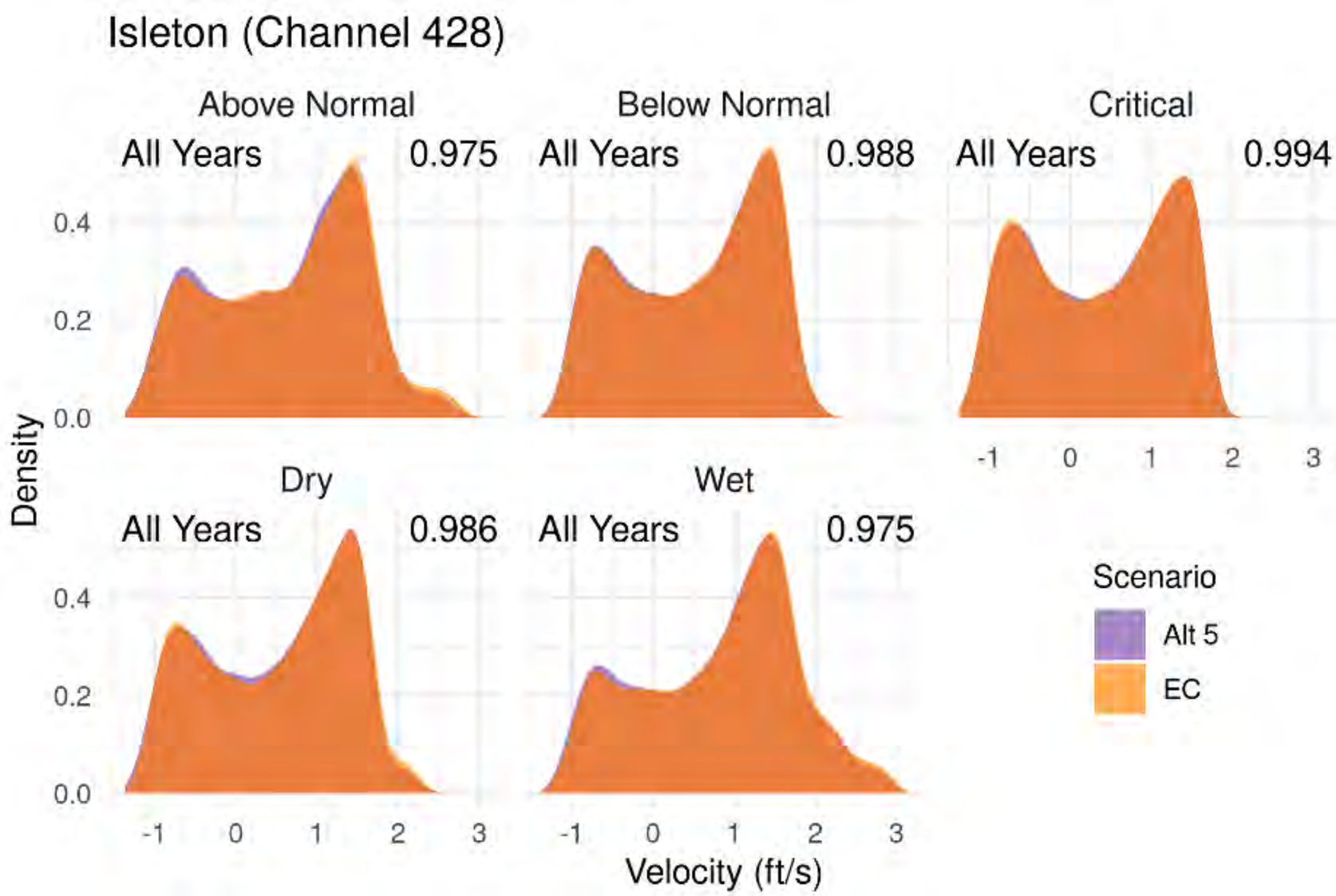

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-57. Velocity Density Distribution for Walnut Grove (Sacramento River), November.**



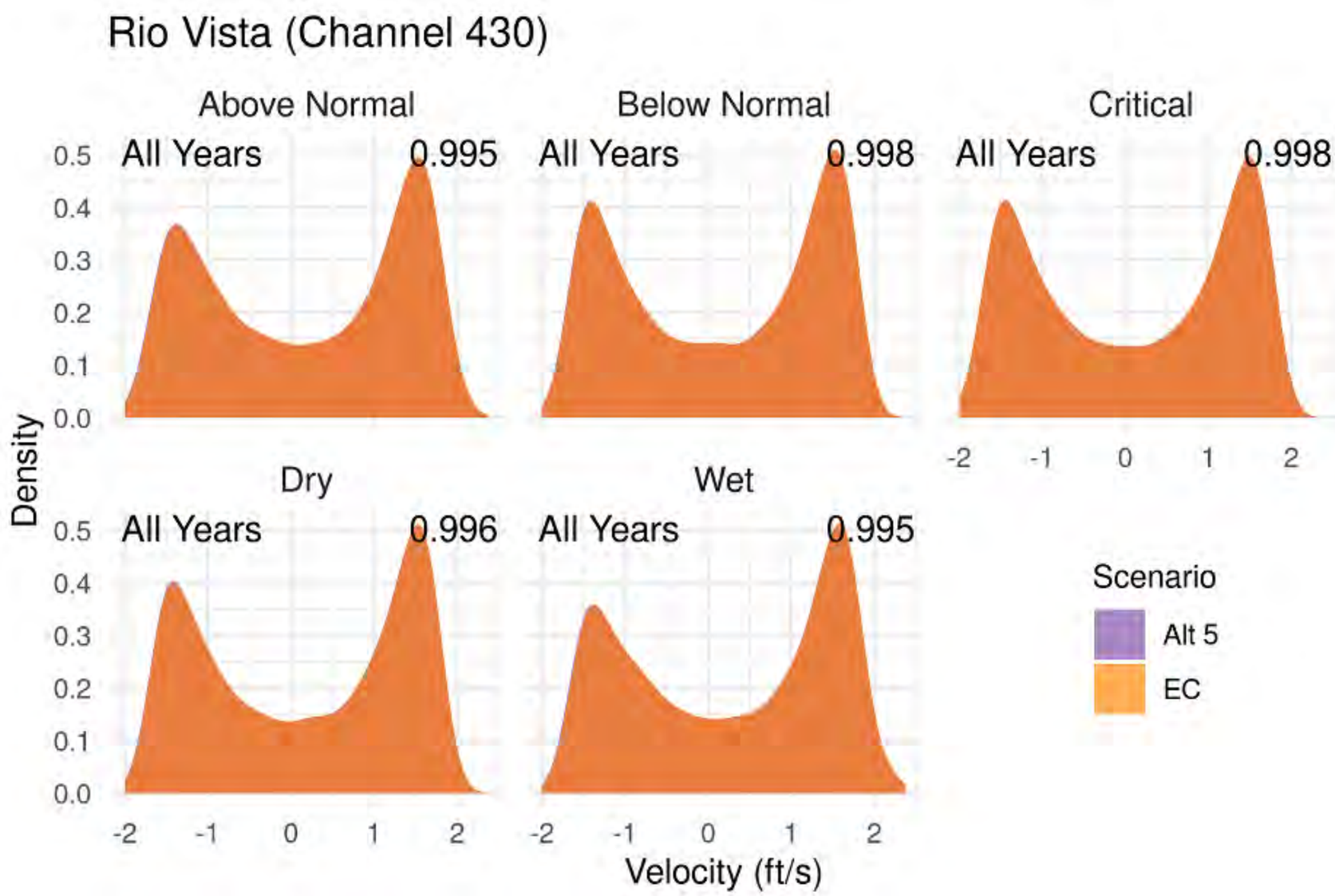

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-58. Velocity Density Distribution for Georgiana Slough, November.**



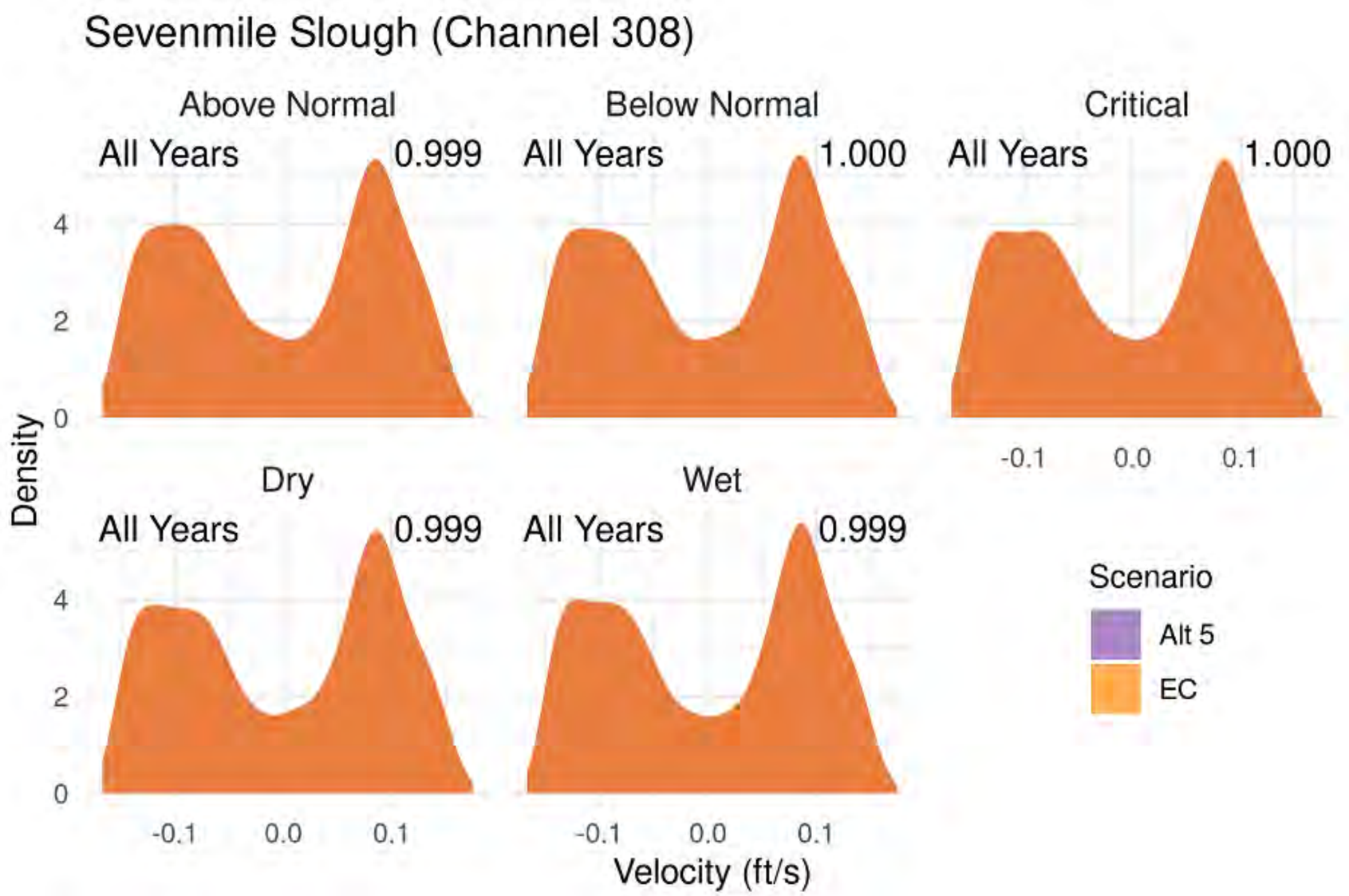

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-59. Velocity Density Distribution for Isleton (Sacramento River), November.**



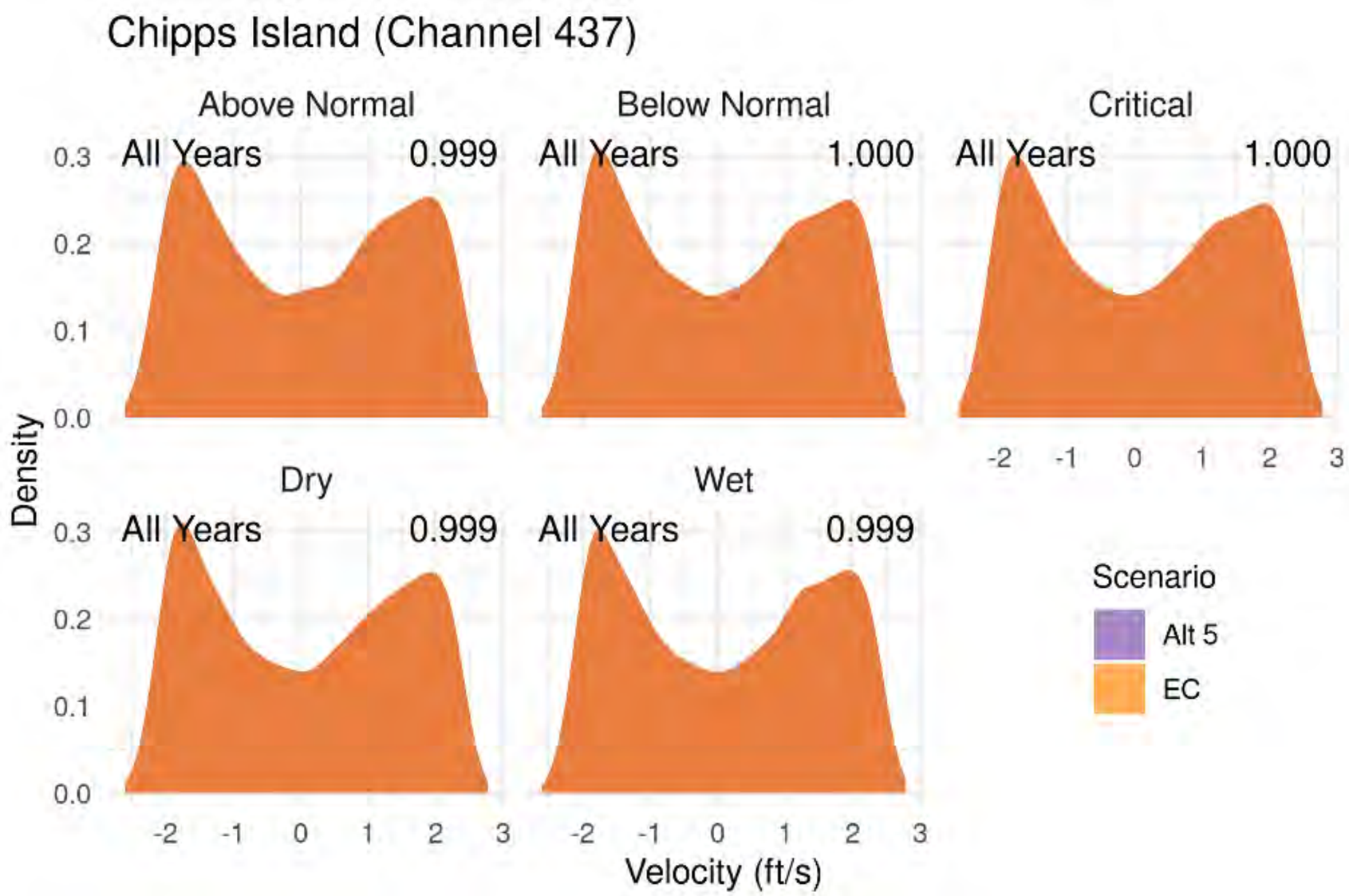

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-60. Velocity Density Distribution for Rio Vista (Sacramento River), November.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

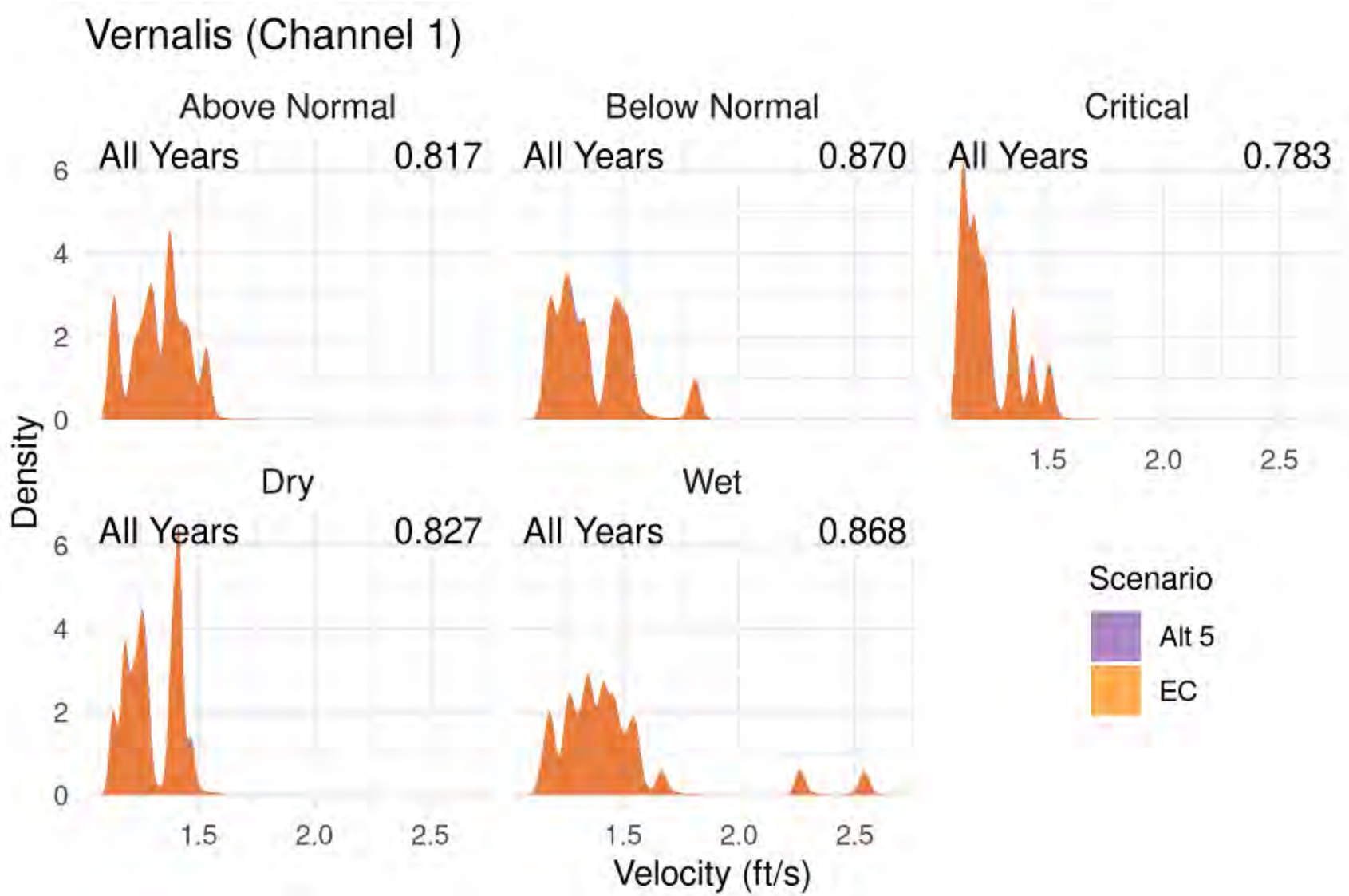
**Figure 5D.1-61. Velocity Density Distribution for Sevenmile Slough, November.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

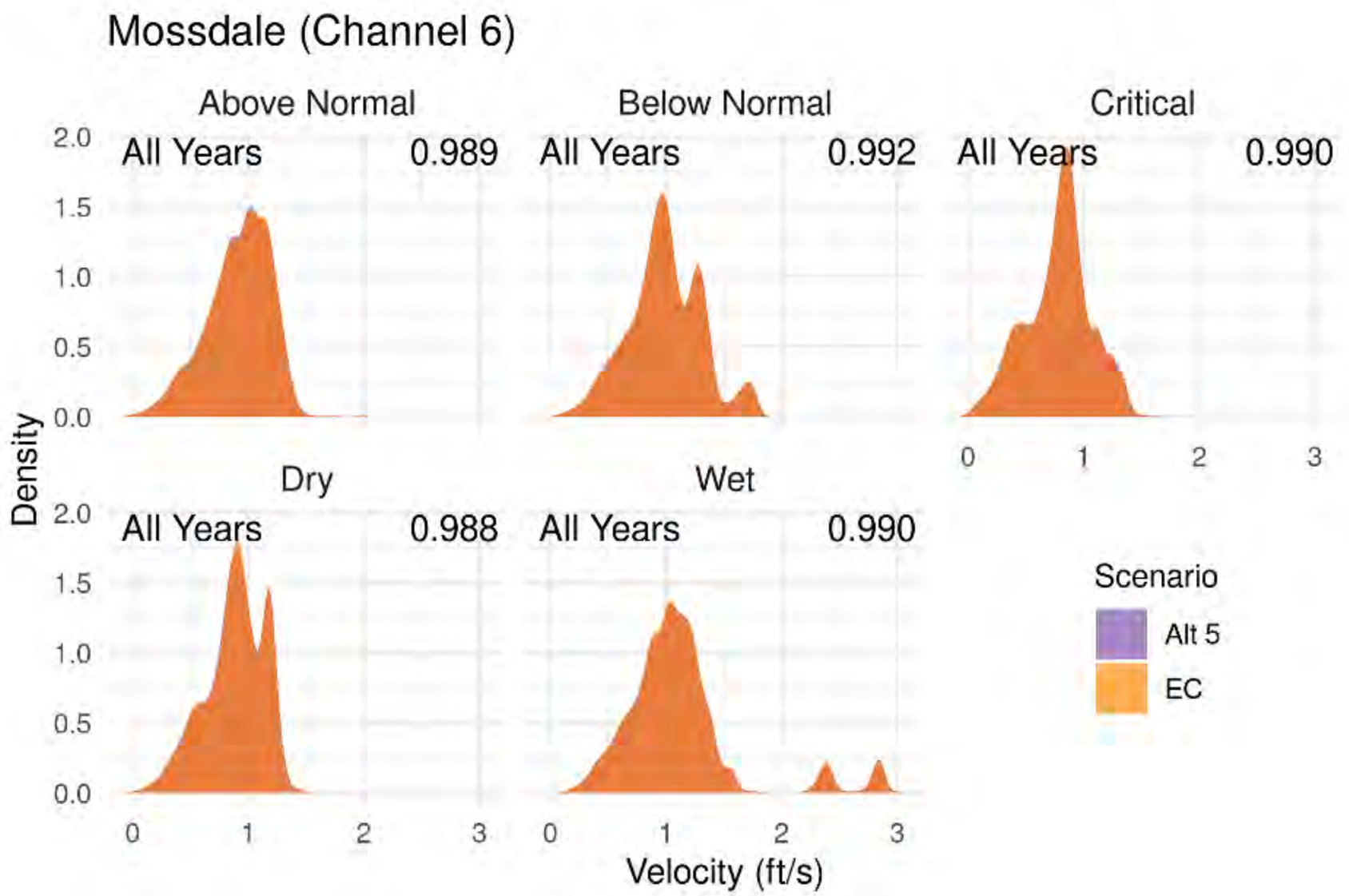
**Figure 5D.1-62. Velocity Density Distribution for Chipps Island (Sacramento River–San Joaquin River Confluence), November.**

***San Joaquin River Delta***



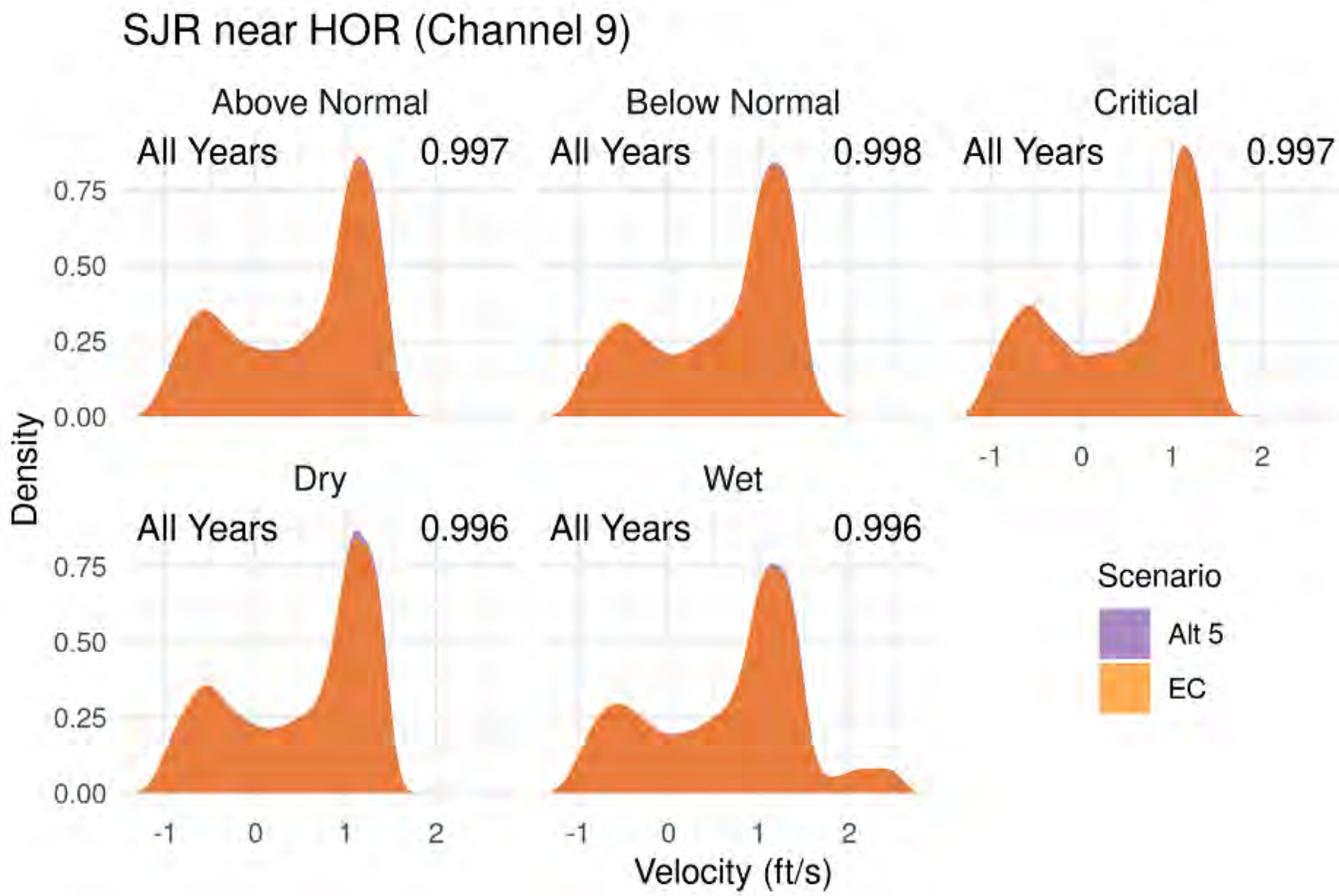

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-63. Velocity Density Distribution for Vernalis (San Joaquin River), November.**



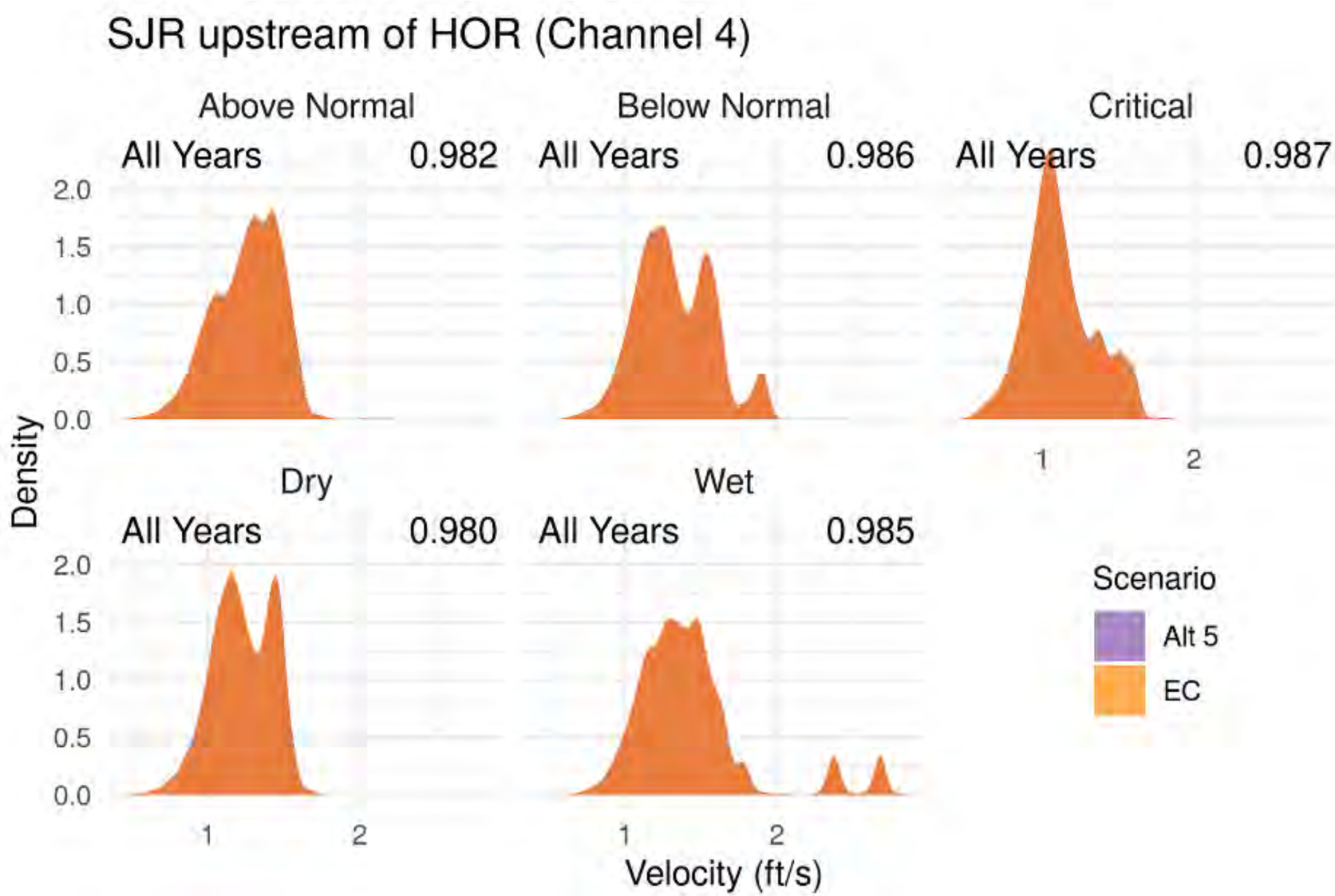

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-64. Velocity Density Distribution for Mossdale (San Joaquin River), November.**



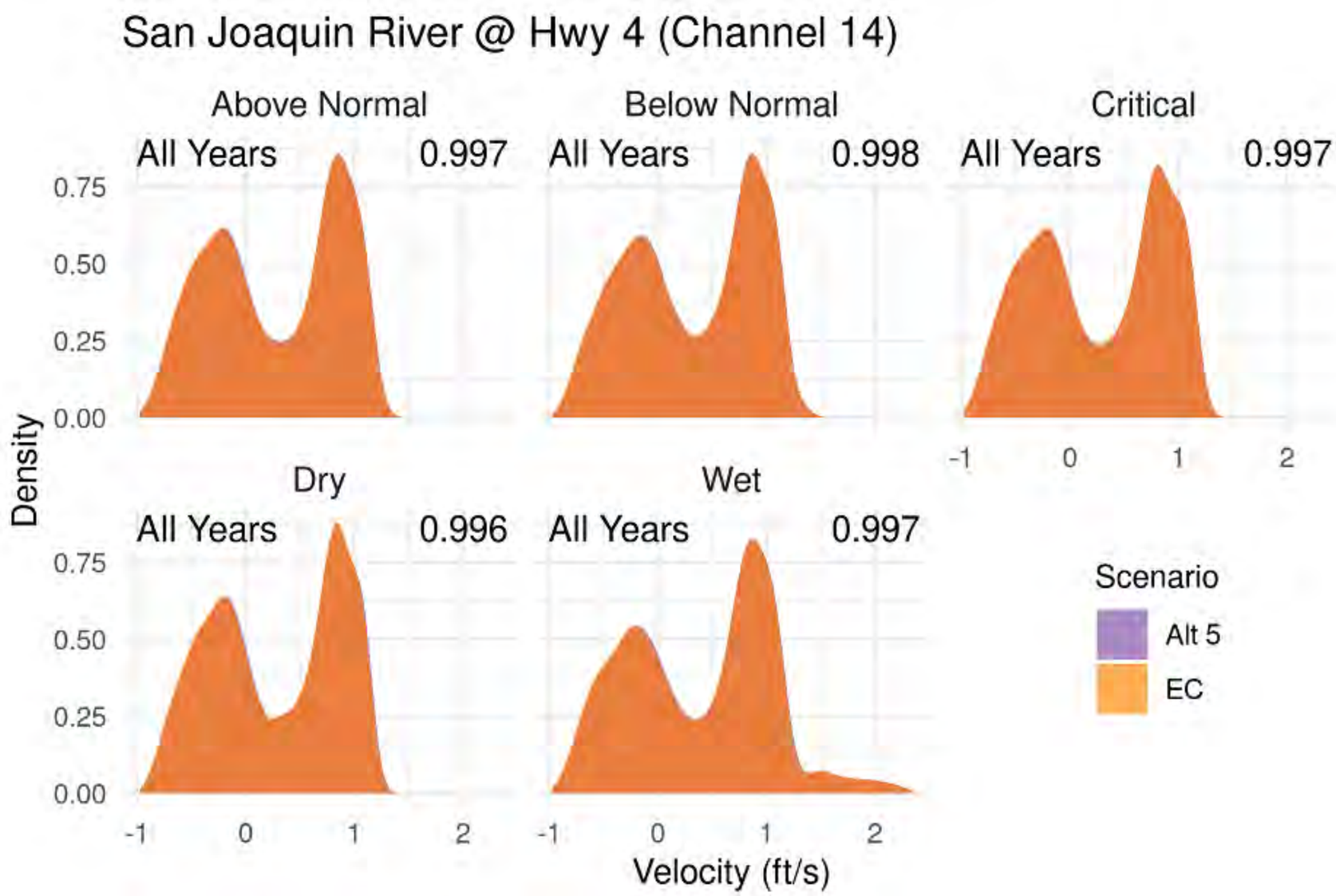

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-65. Velocity Density Distribution for San Joaquin River upstream of Head of Old River, November.**



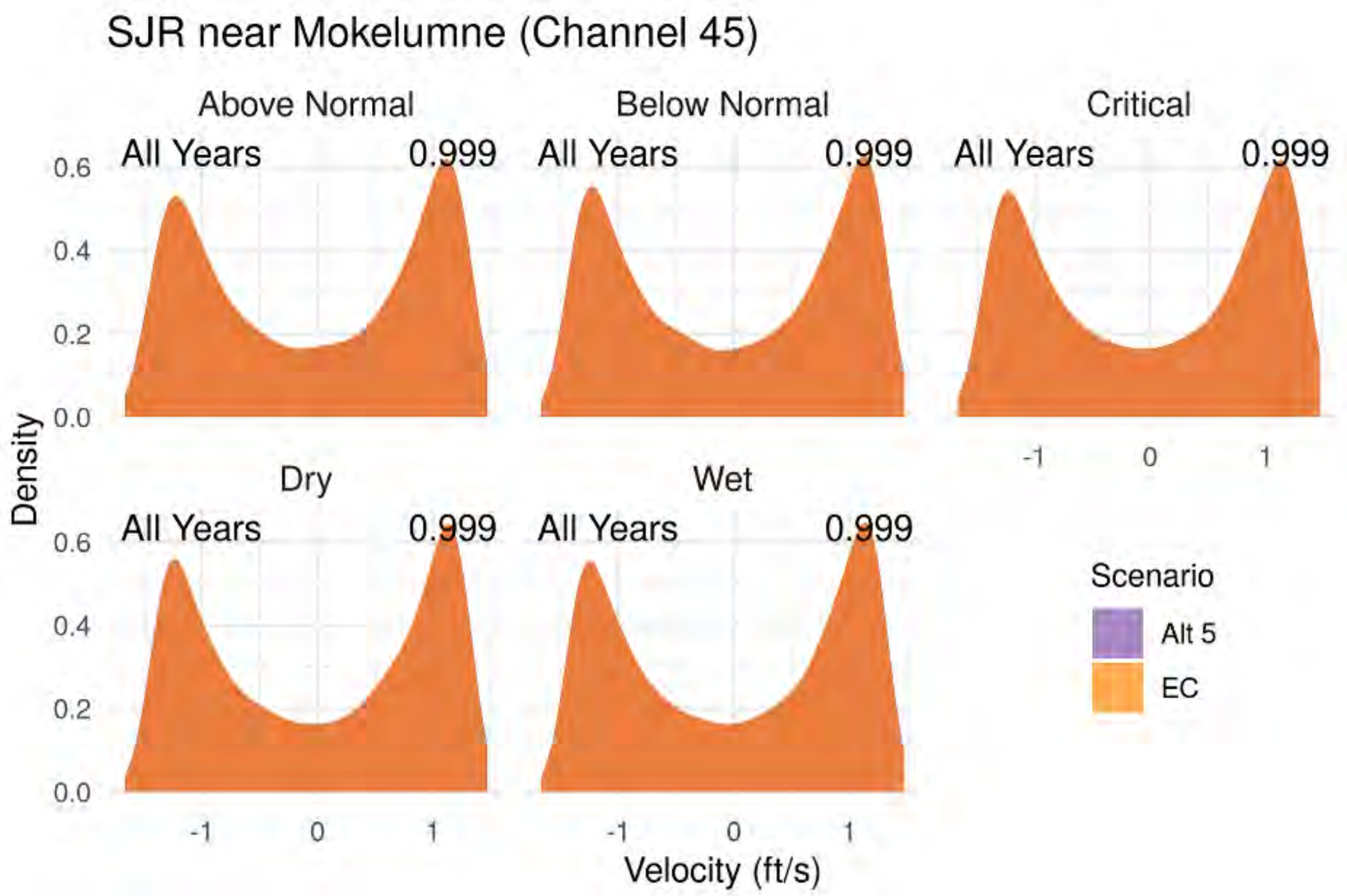

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-66. Velocity Density Distribution for San Joaquin River near Head of Old River, November.**



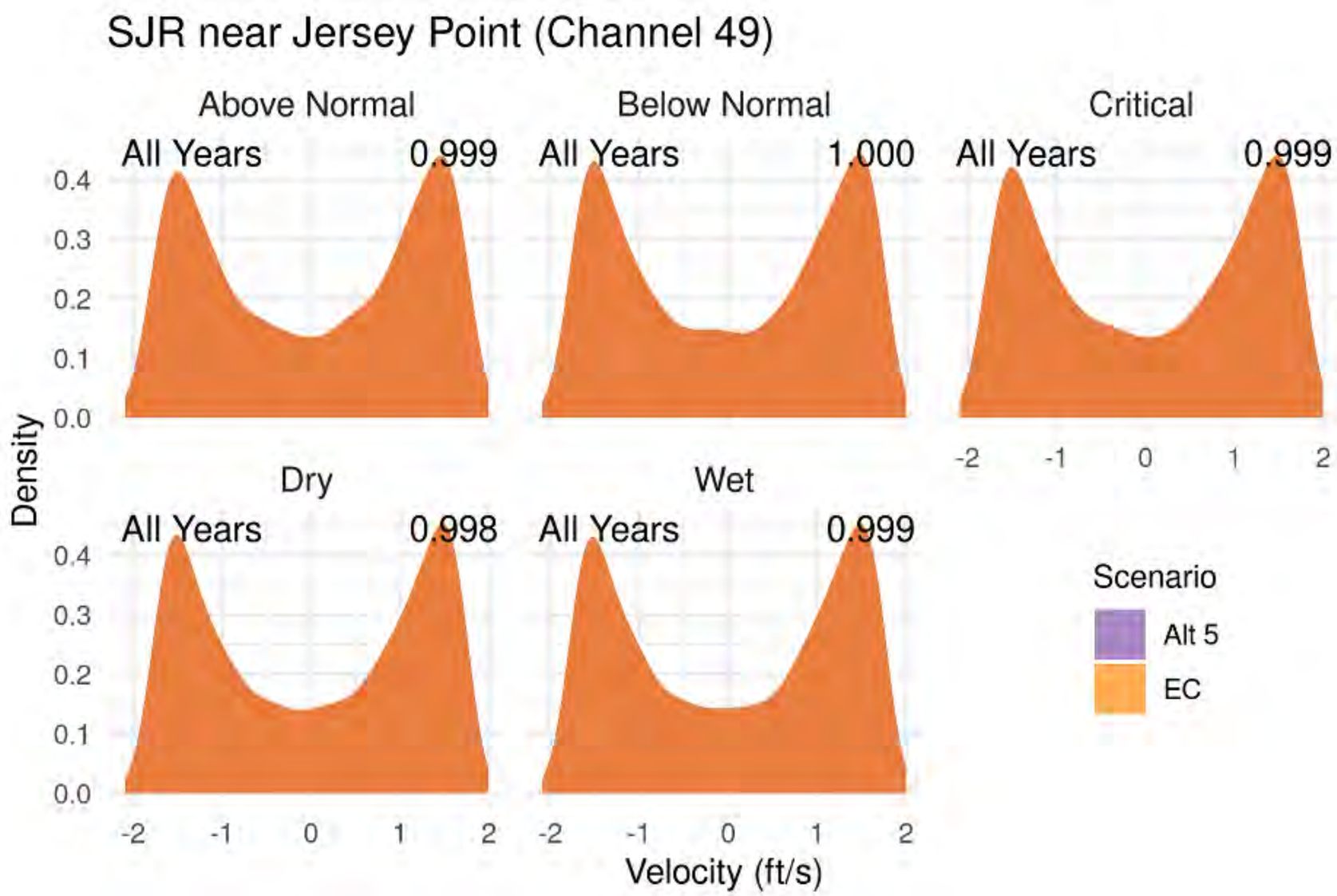

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-67. Velocity Density Distribution for San Joaquin River at Highway 4, November.**



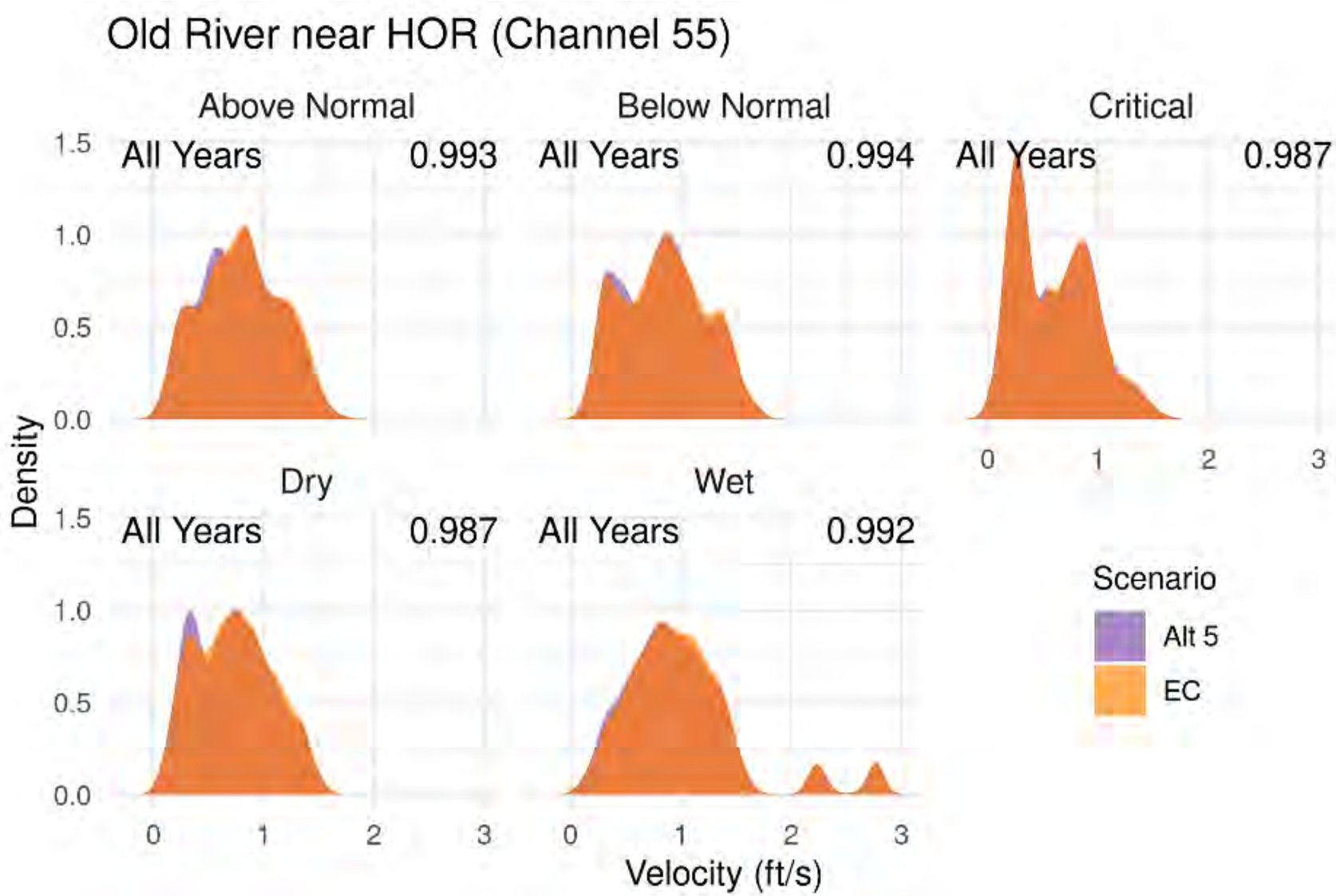

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-68. Velocity Density Distribution for San Joaquin River near Mokelumne River, November.**



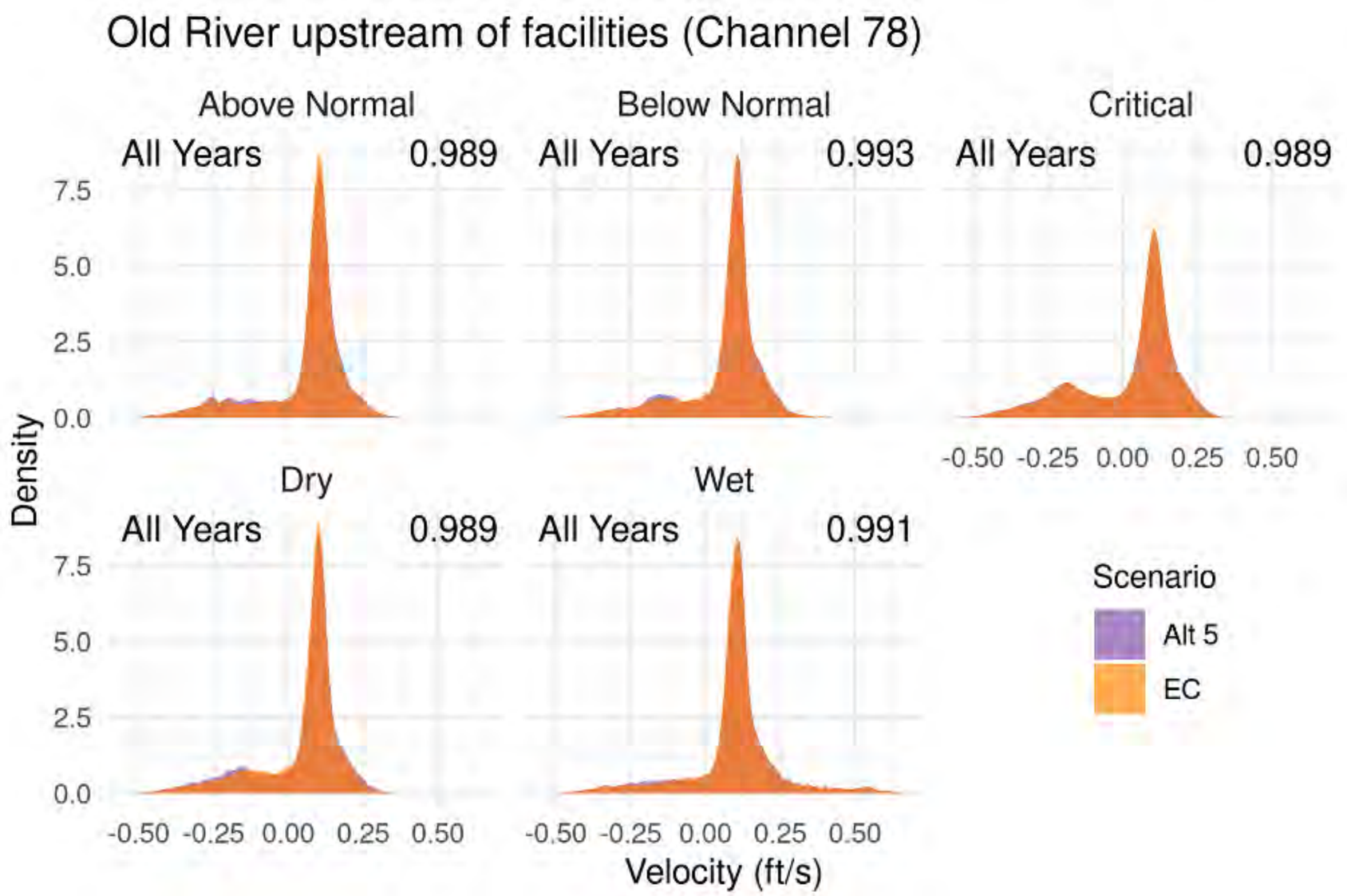

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-69. Velocity Density Distribution for San Joaquin River near Jersey Point, November.**



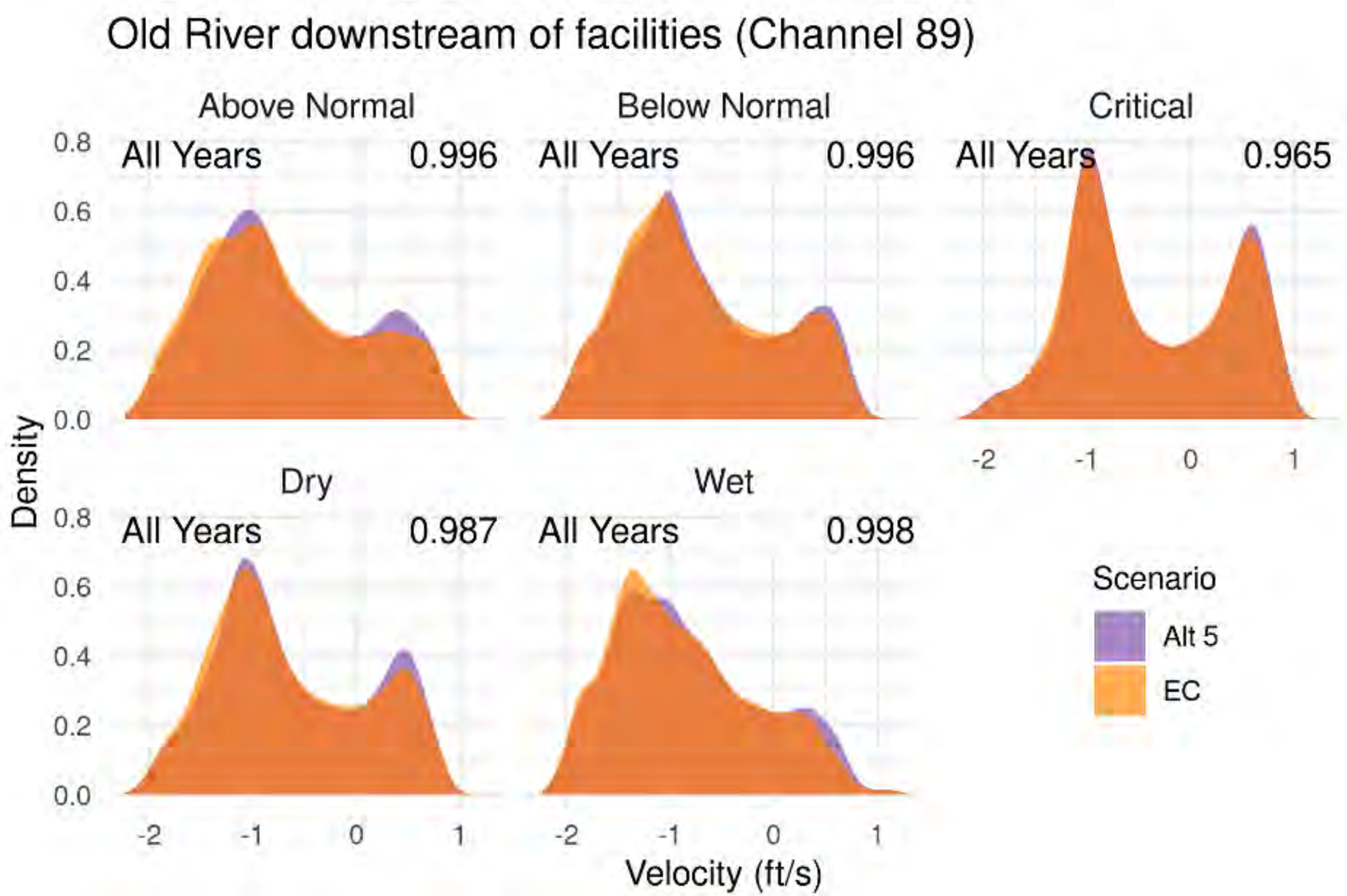

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-70. Velocity Density Distribution for Old River near Head of Old River, November.**



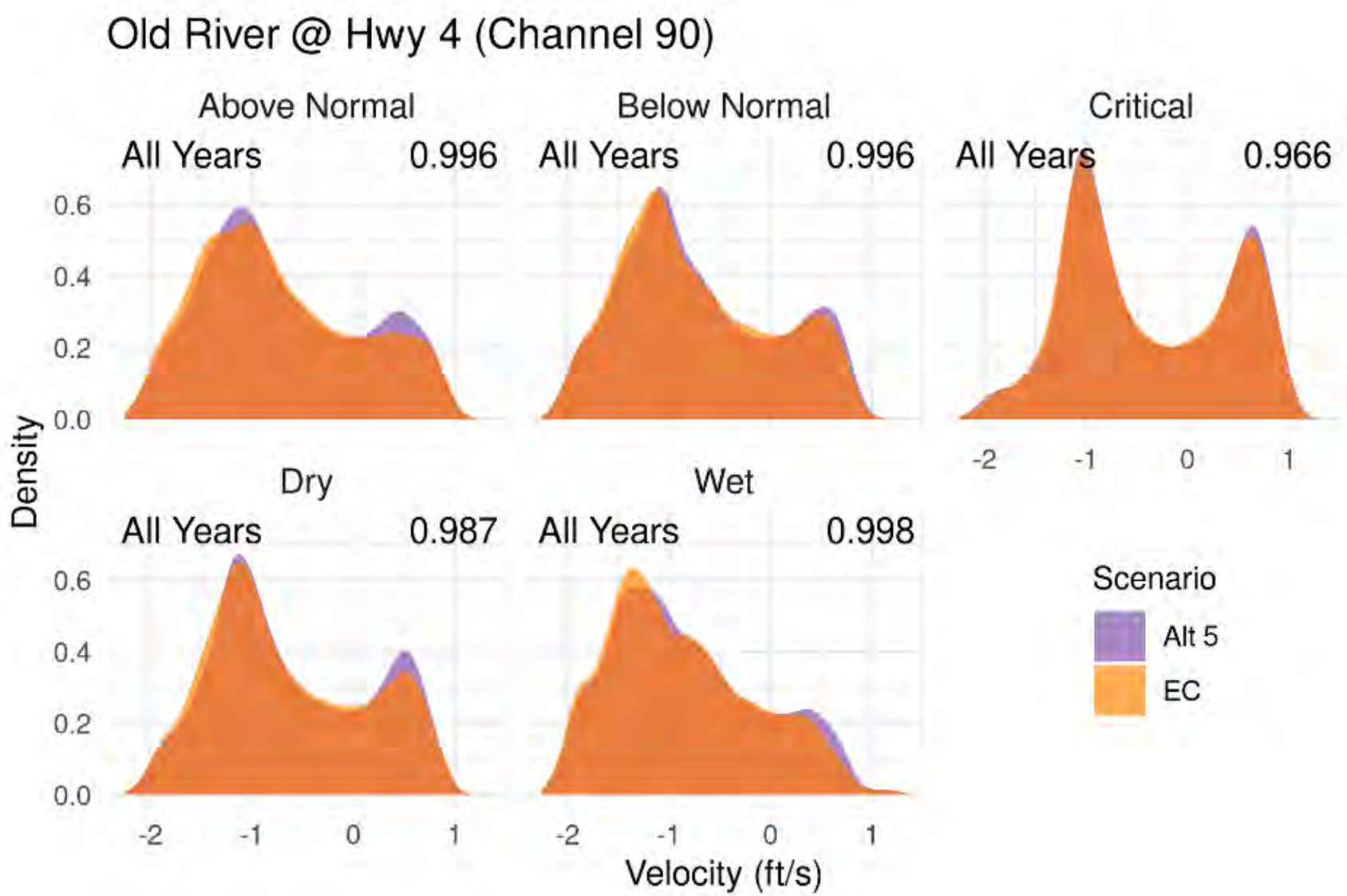

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-71. Velocity Density Distribution for Old River upstream of the South Delta Export Facilities, November.**



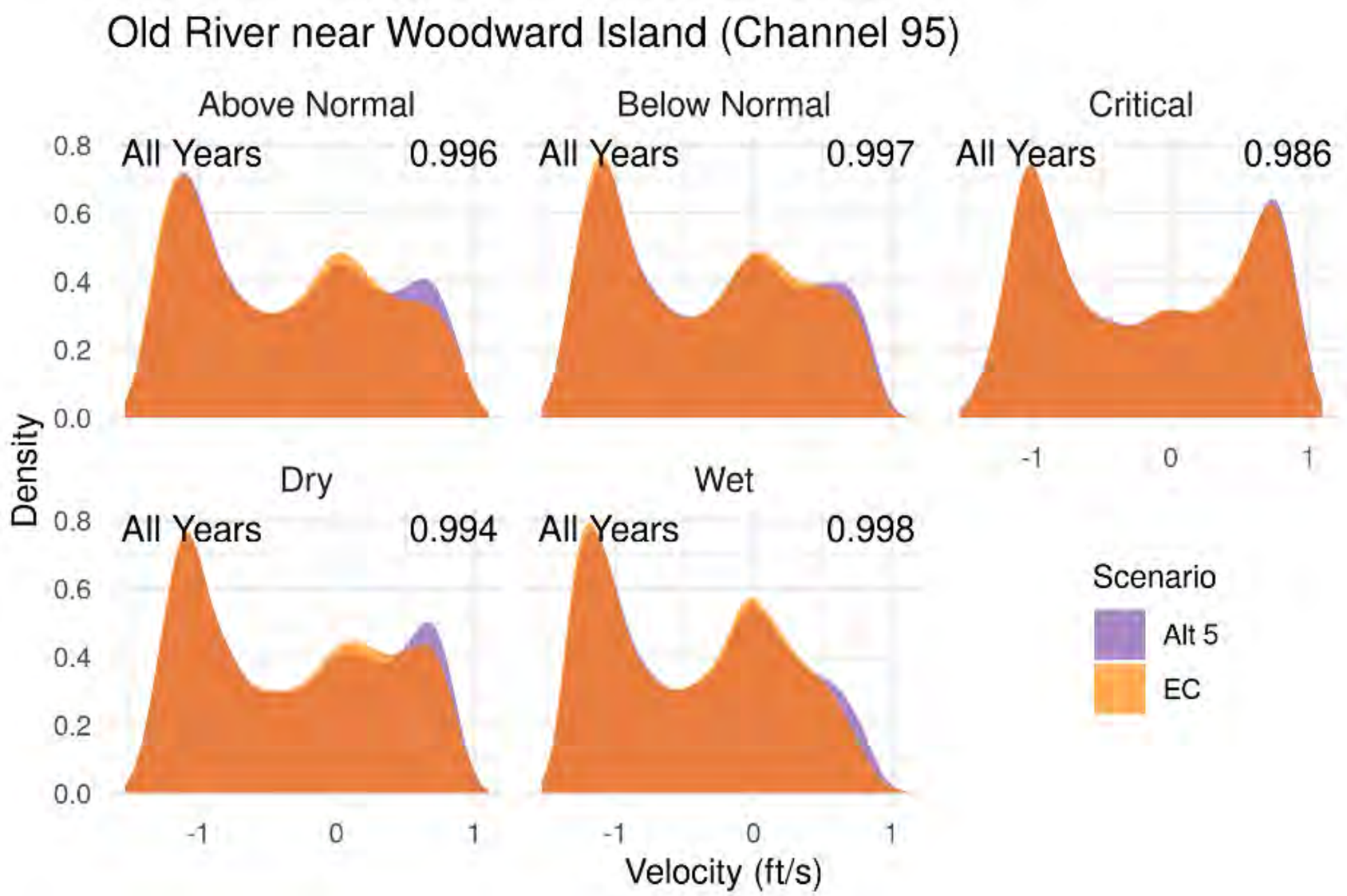

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-72. Velocity Density Distribution for Old River Downstream of the South Delta Export Facilities, November.**



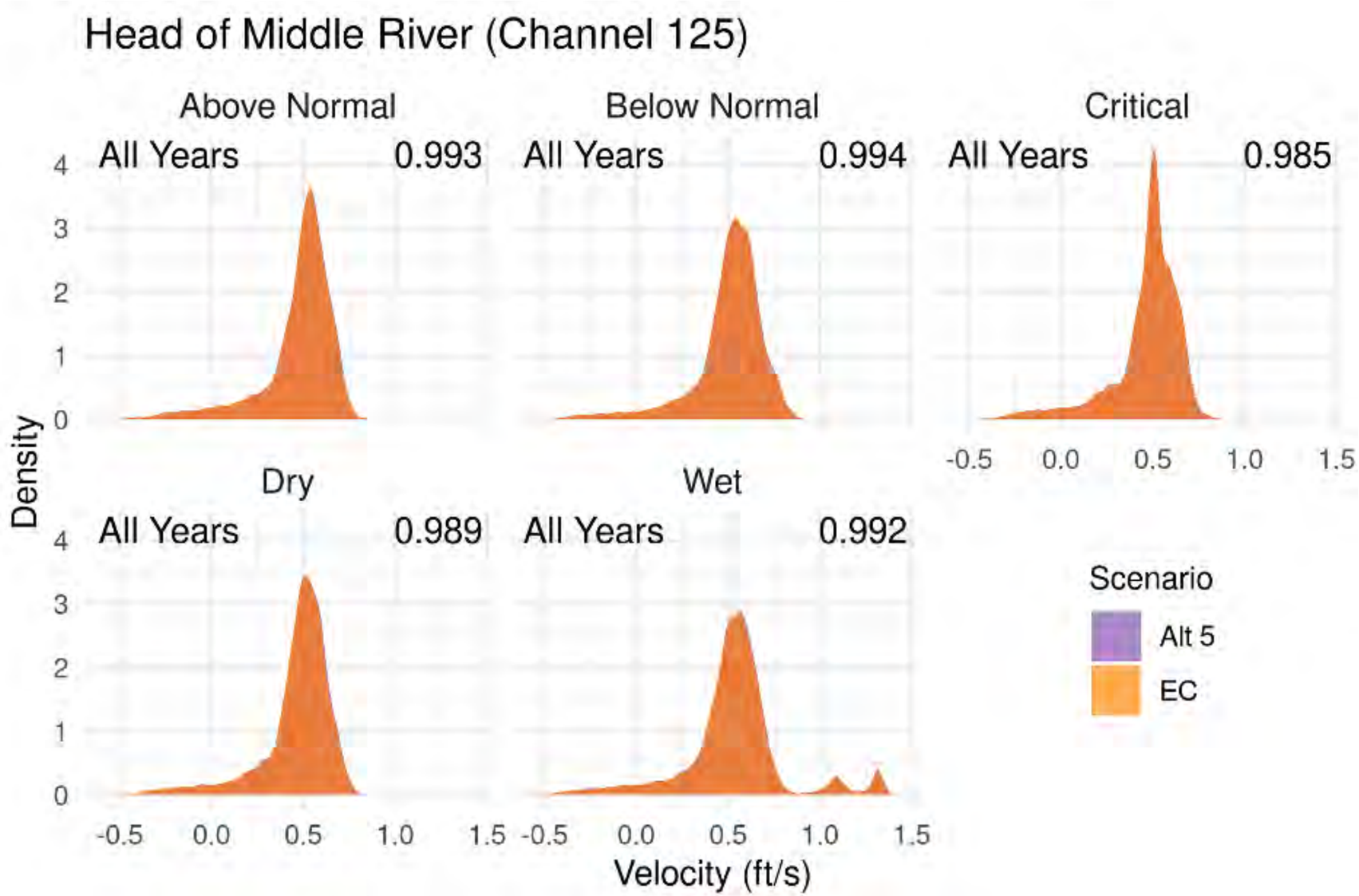

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-73. Velocity Density Distribution for Old River at Highway 4, November.**



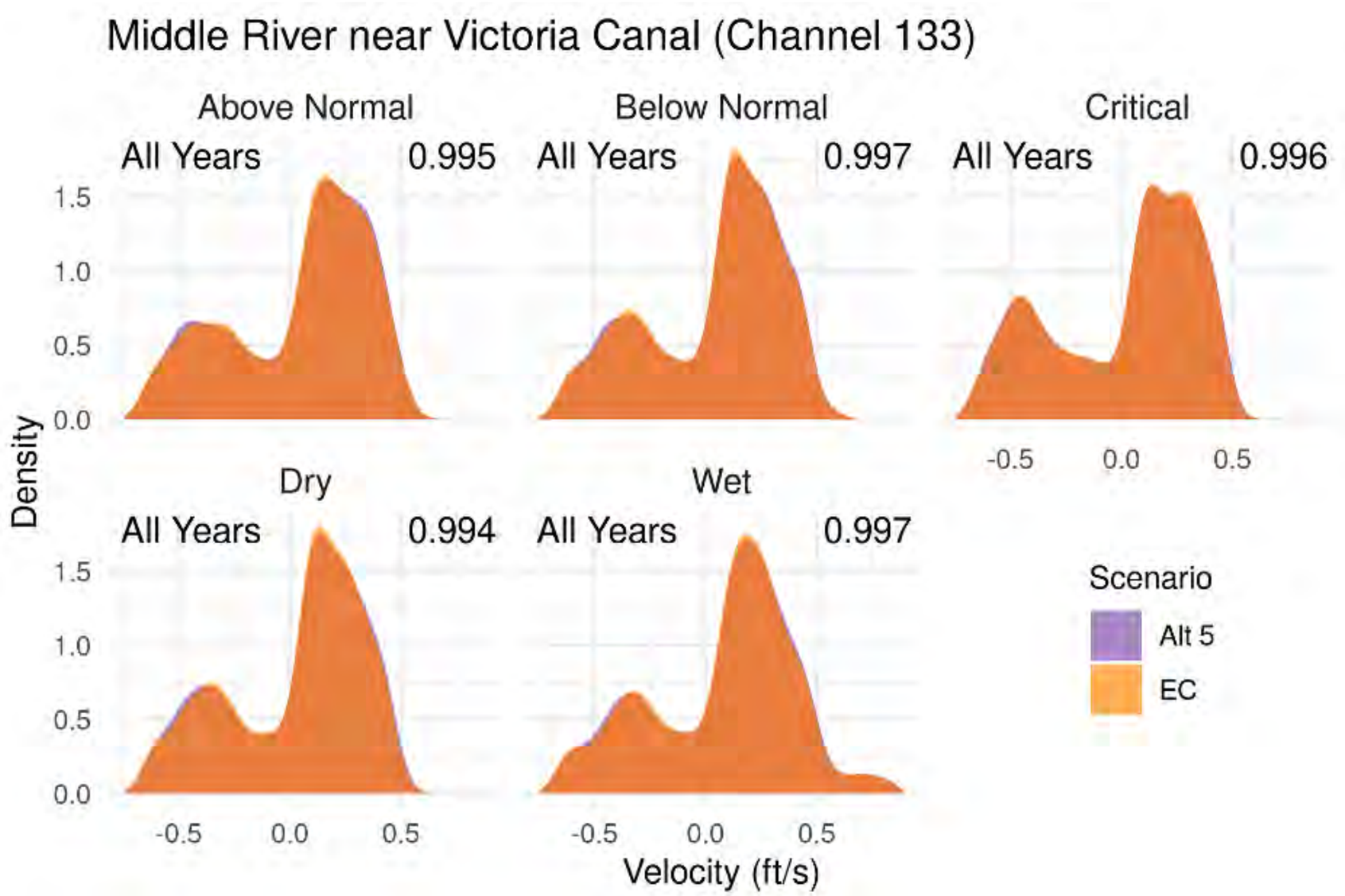

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-74. Velocity Density Distribution for Old River near Woodward Island, November.**



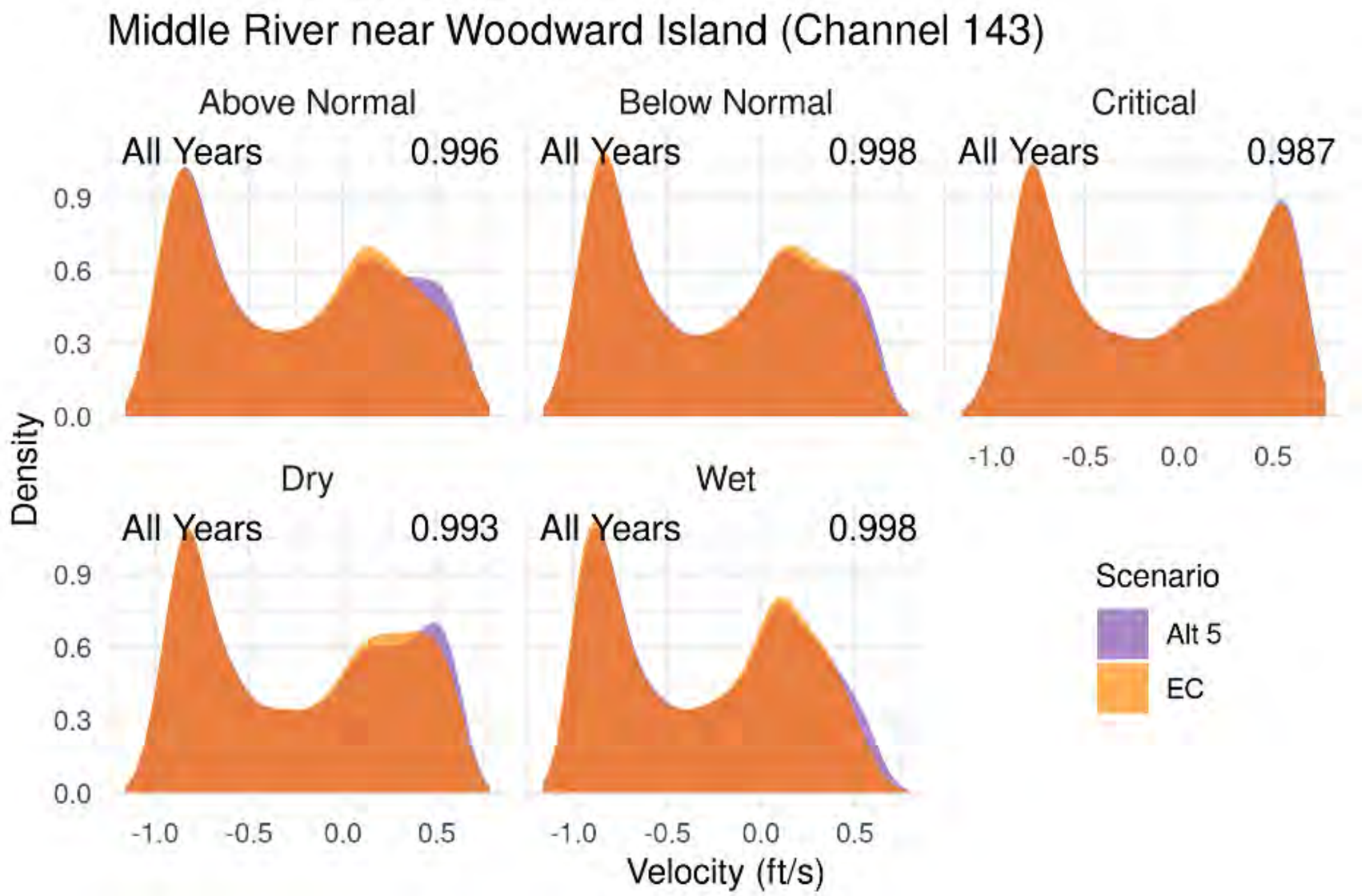

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-75. Velocity Density Distribution for Head of Middle River, November.**



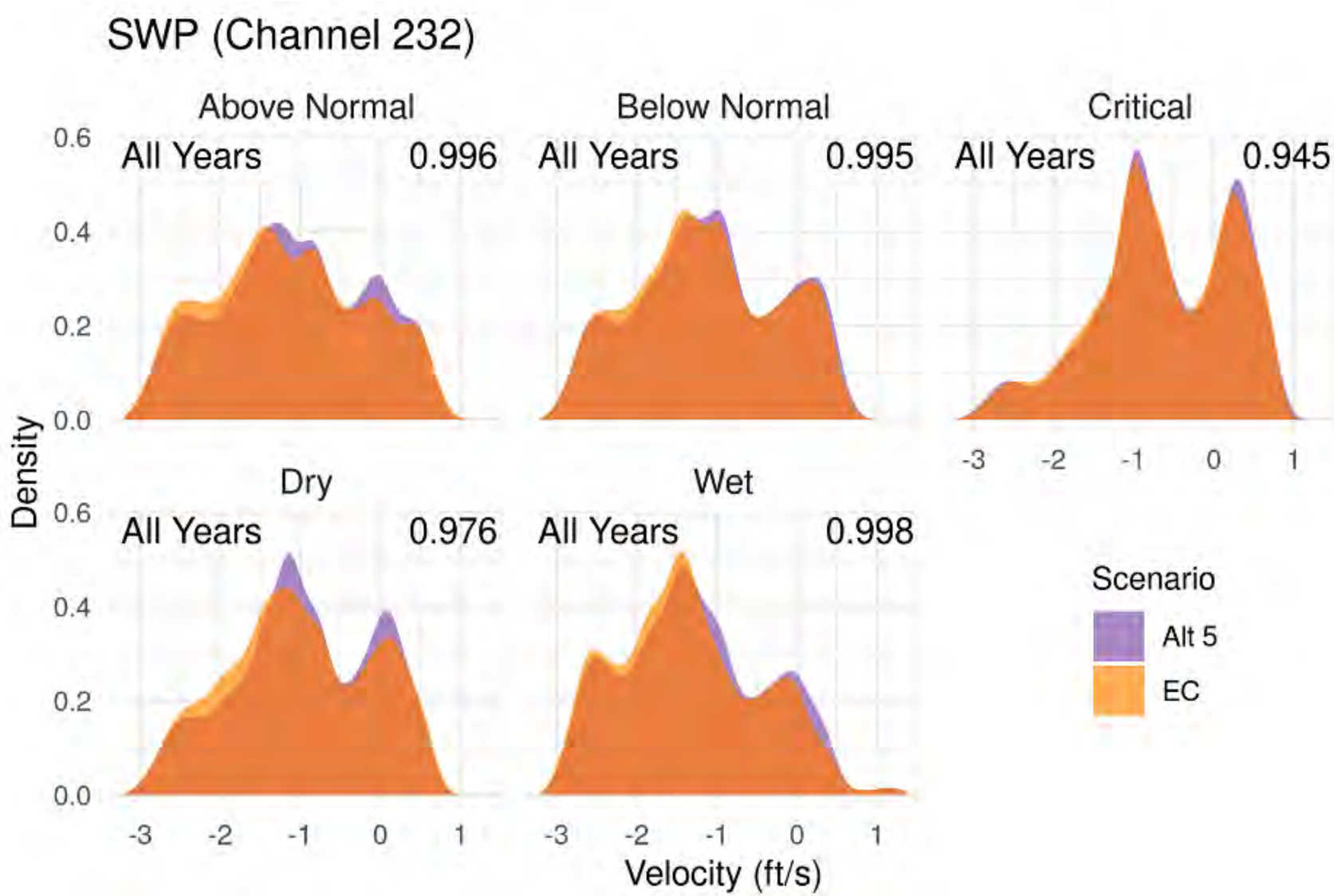

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-76. Velocity Density Distribution for Middle River near Victoria Canal, November.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-77. Velocity Density Distribution for Middle River near Woodward Island, November.**

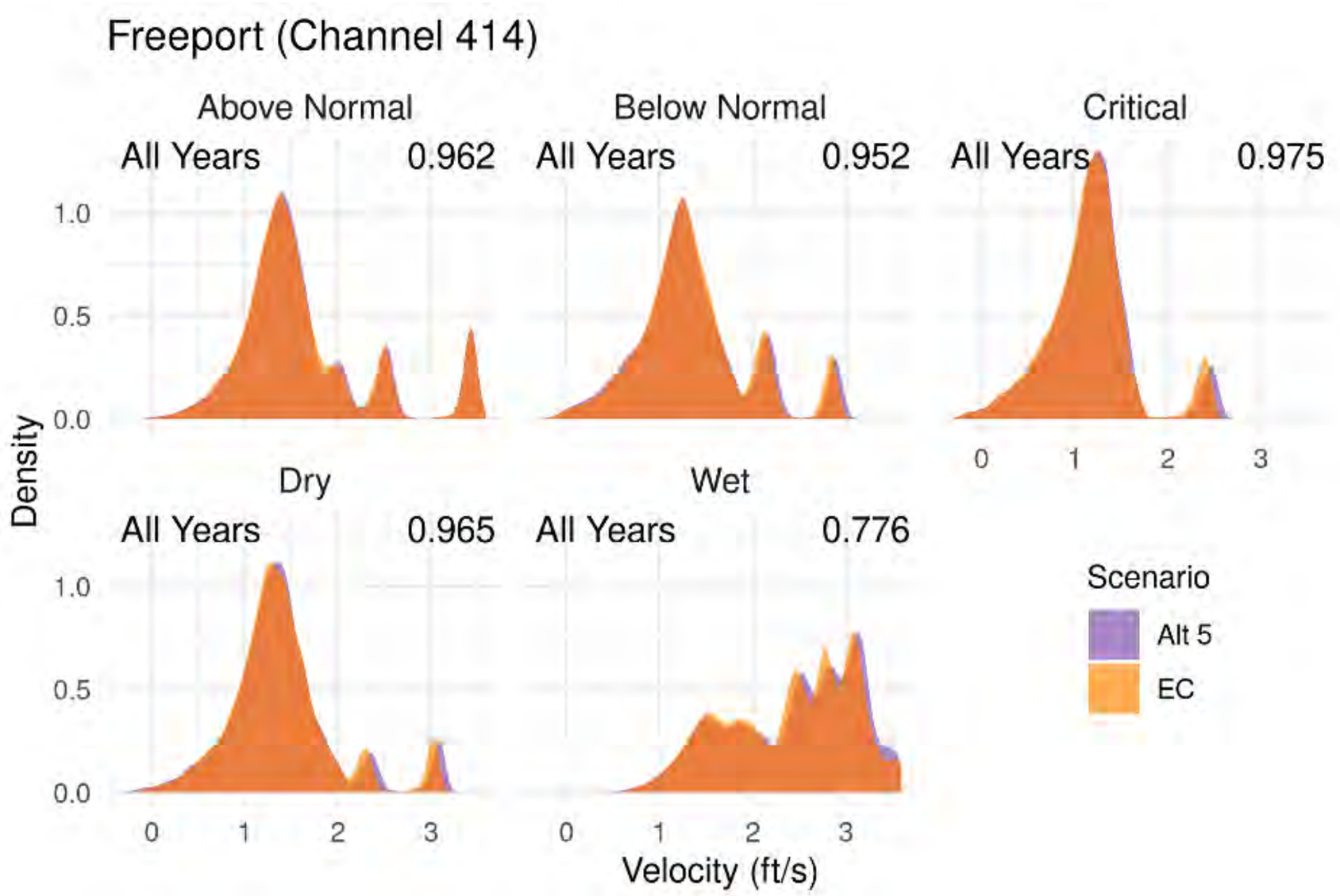



Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-78. Velocity Density Distribution for State Water Project (West Canal near Entrance to Clifton Court Forebay), November.**

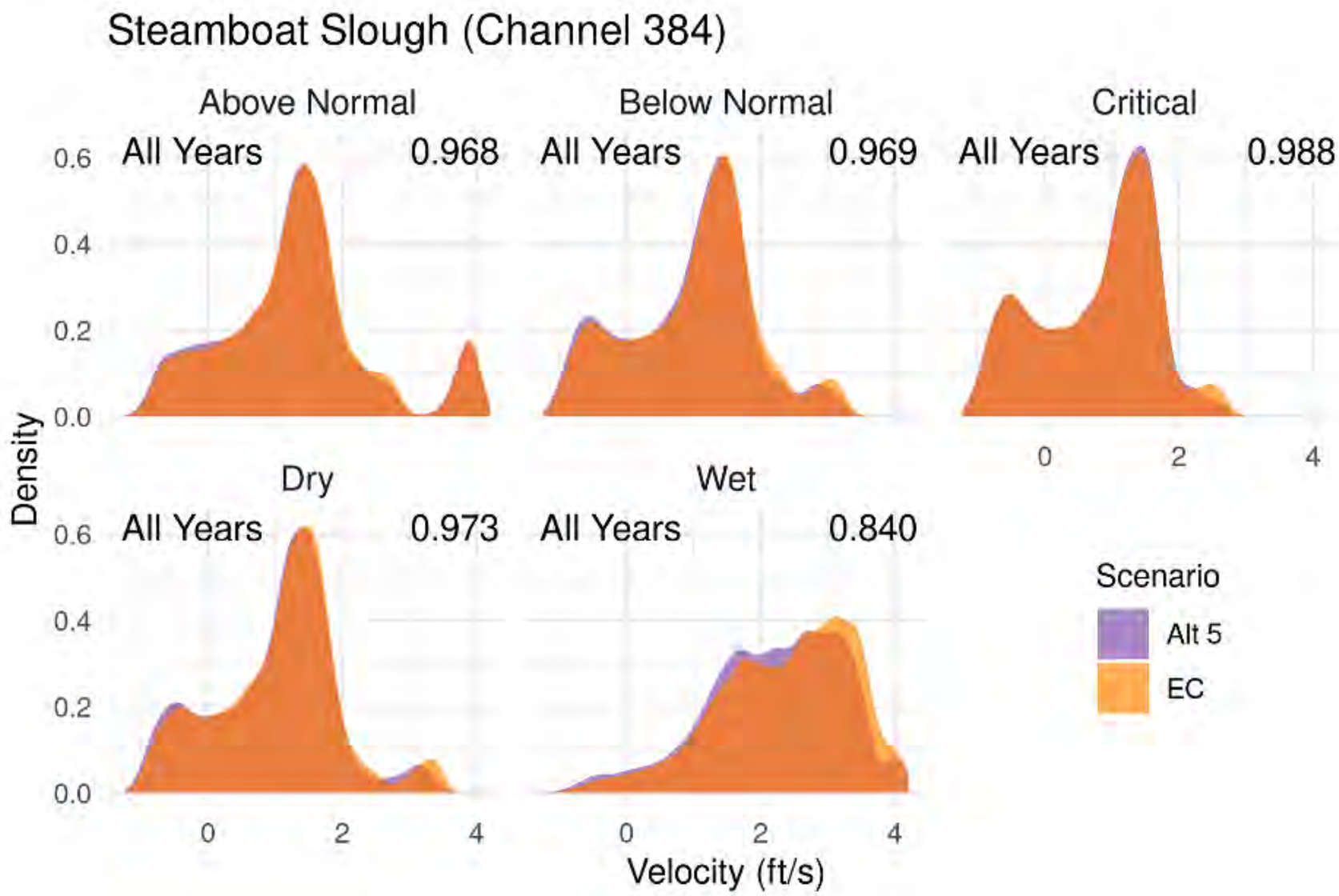
**December**

***Sacramento River Delta***



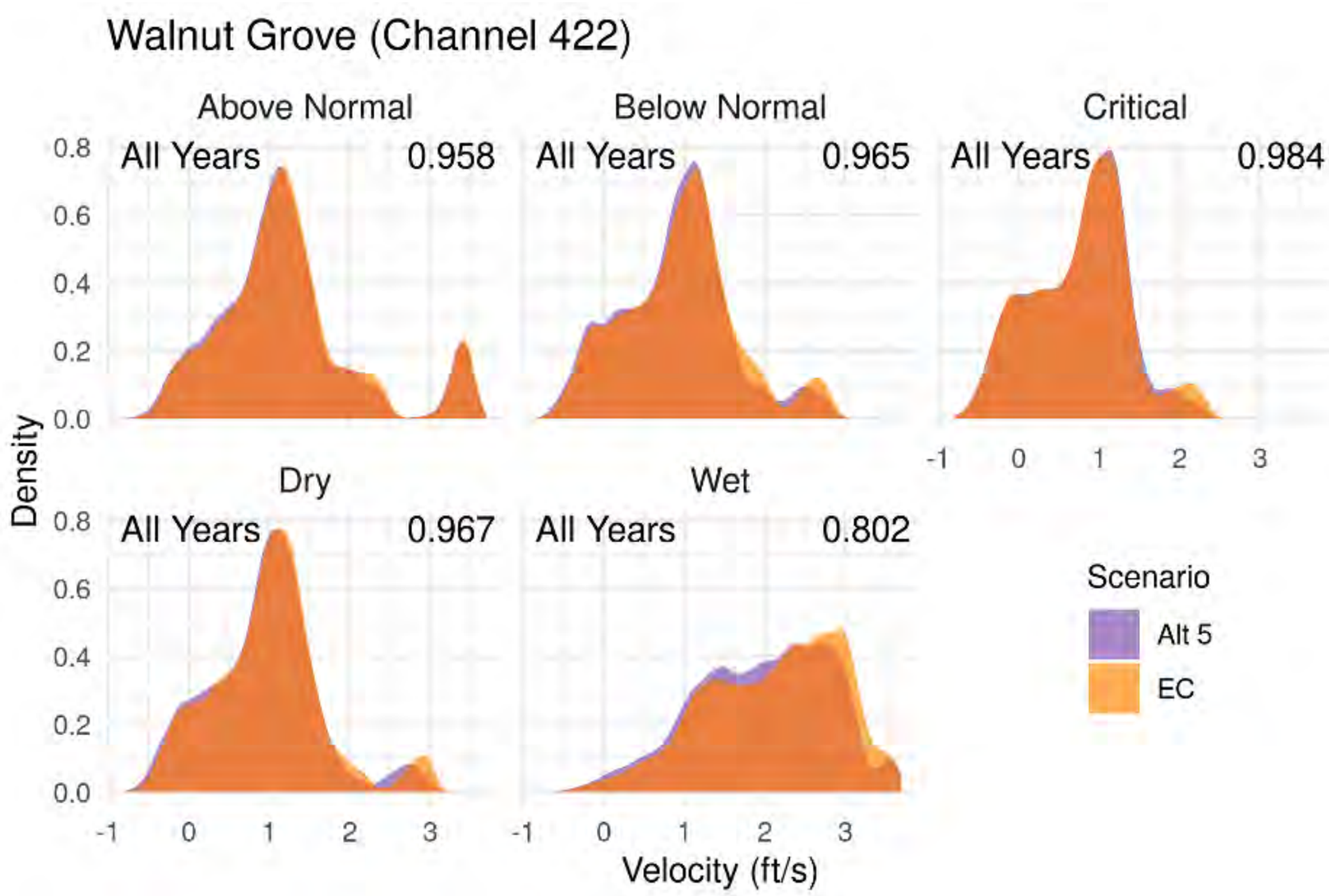

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-79. Velocity Density Distribution for Freeport, December.**



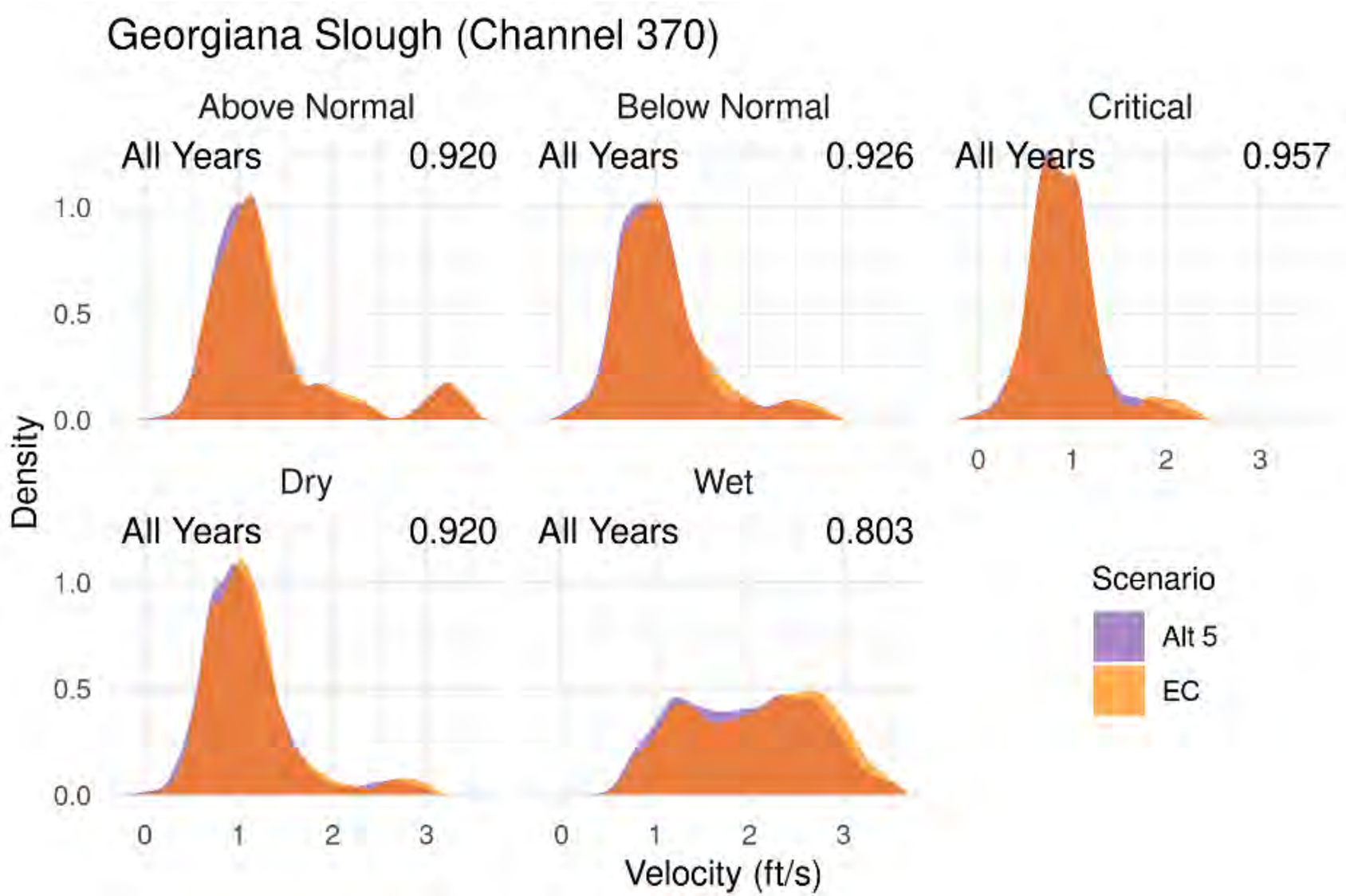

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-80. Velocity Density Distribution for Steamboat Slough, December.**



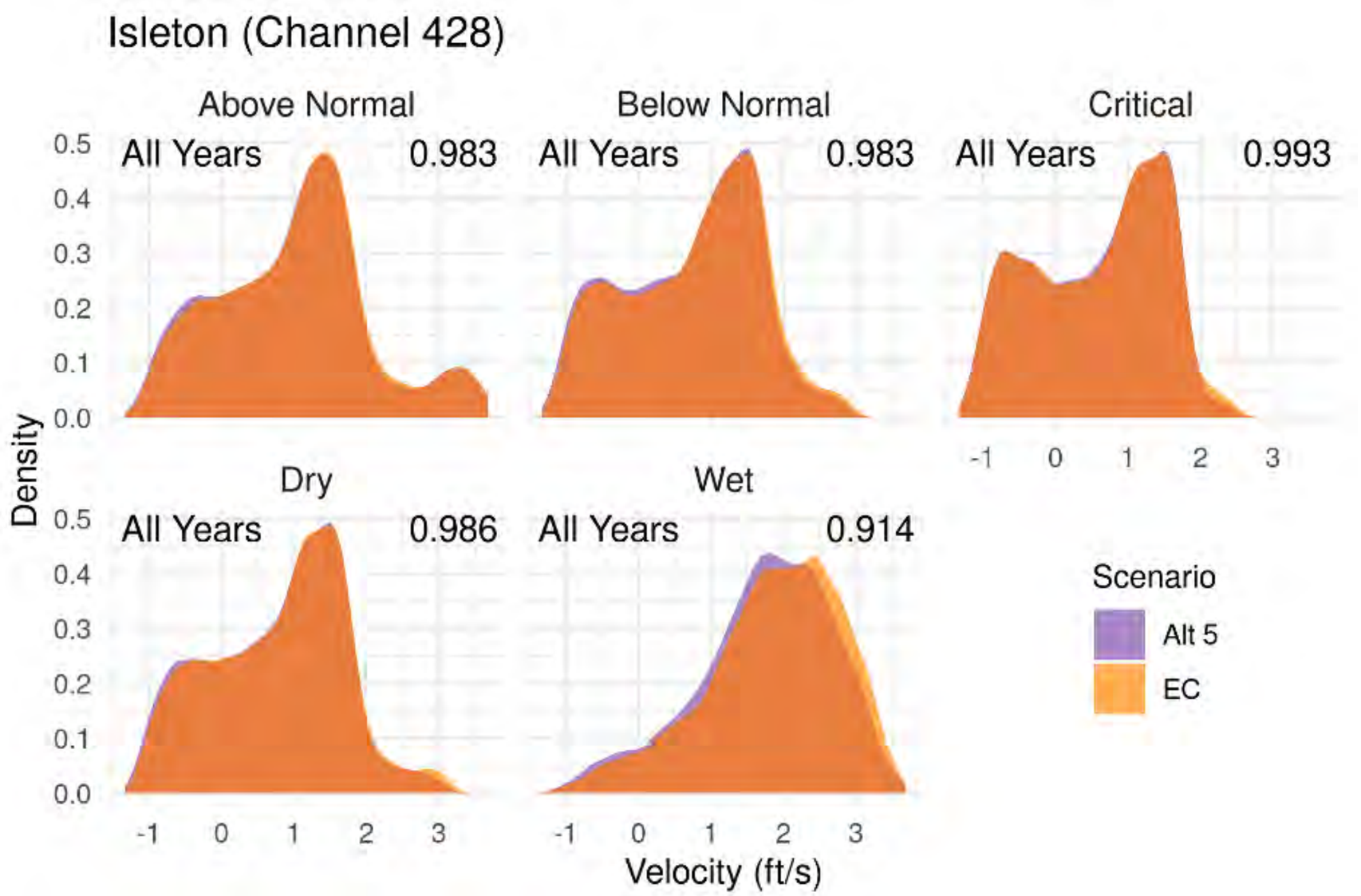

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-81. Velocity Density Distribution for Walnut Grove (Sacramento River), December.**



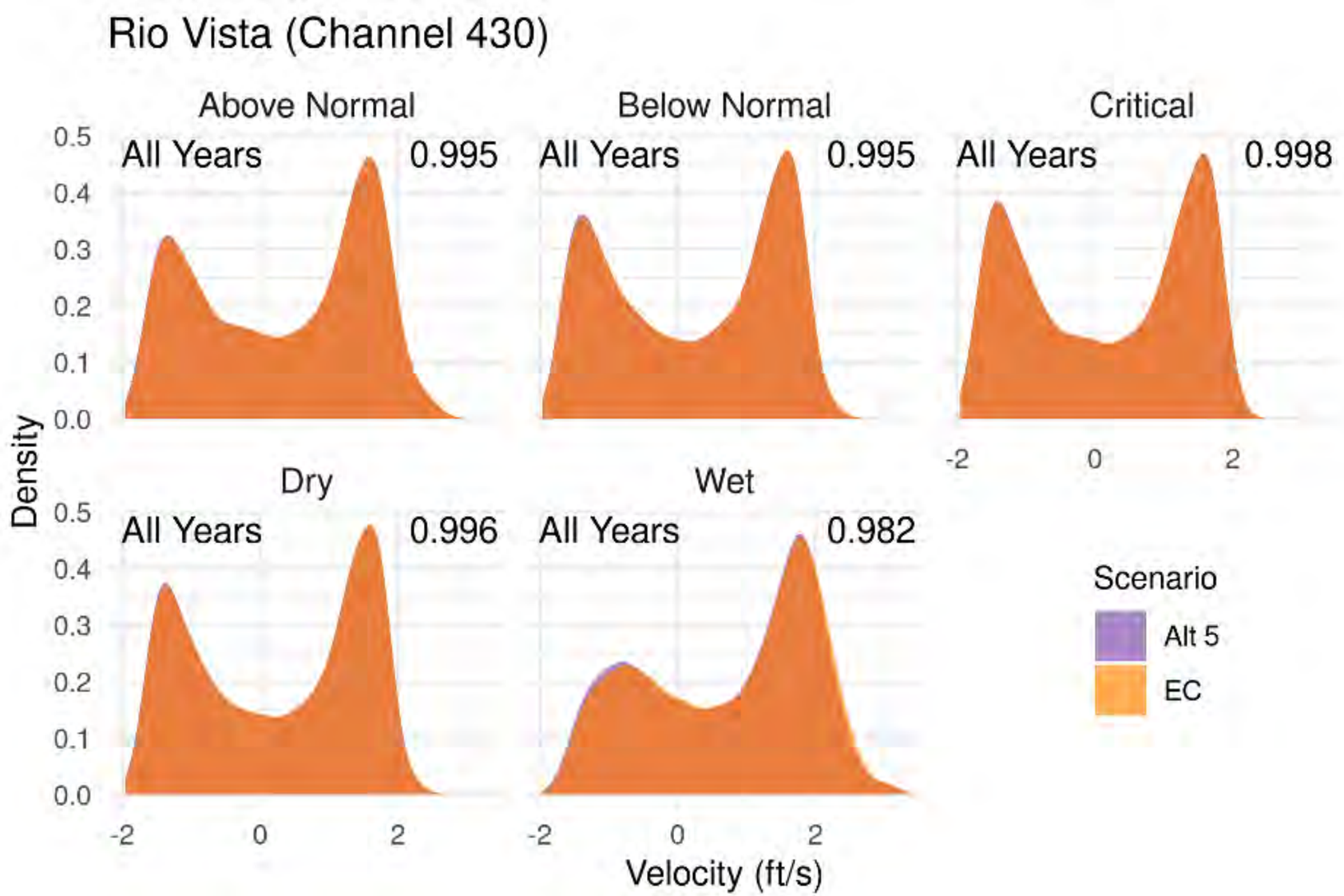

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-82. Velocity Density Distribution for Georgiana Slough, December.**



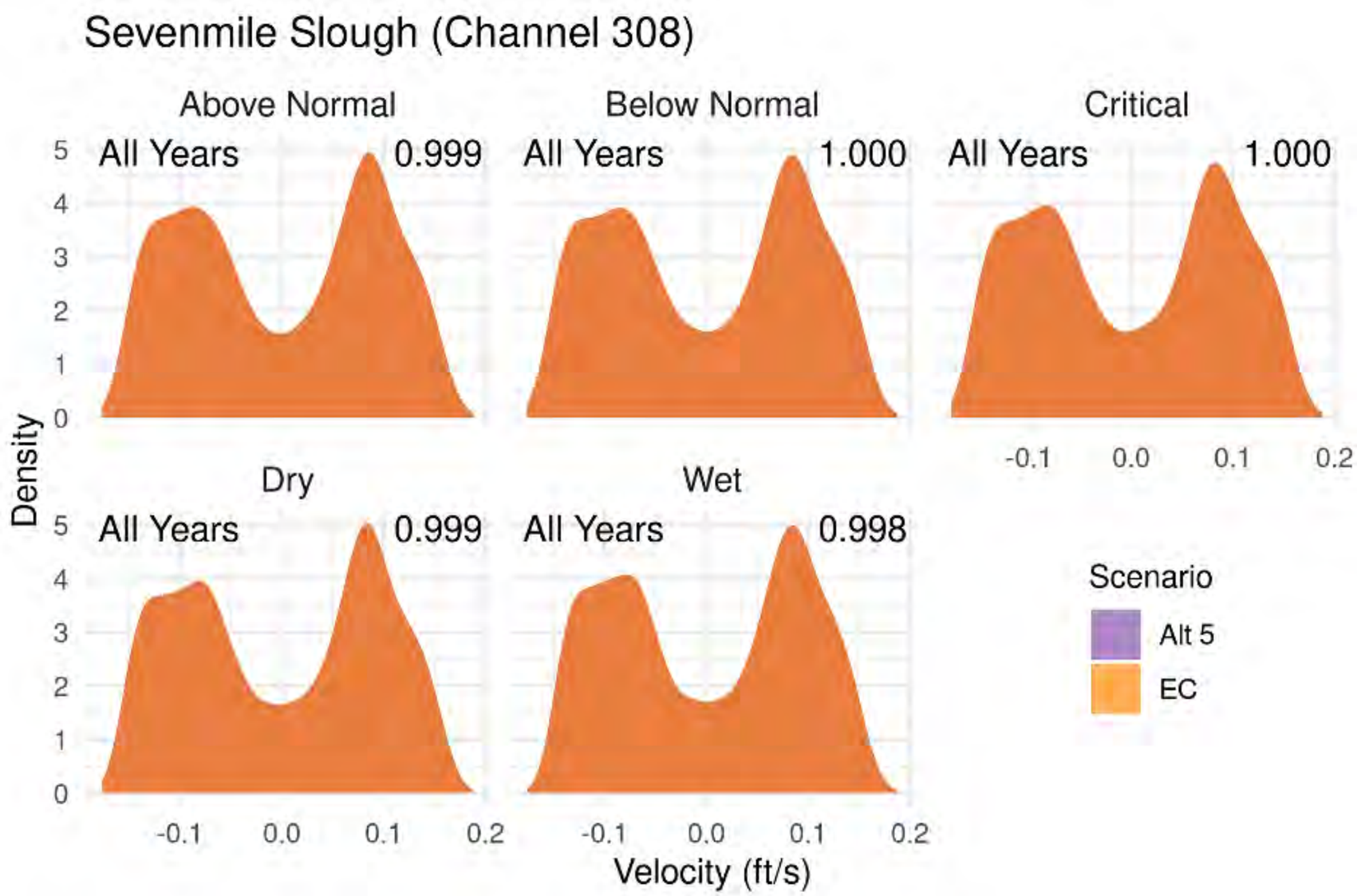

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-83. Velocity Density Distribution for Isleton (Sacramento River), December.**



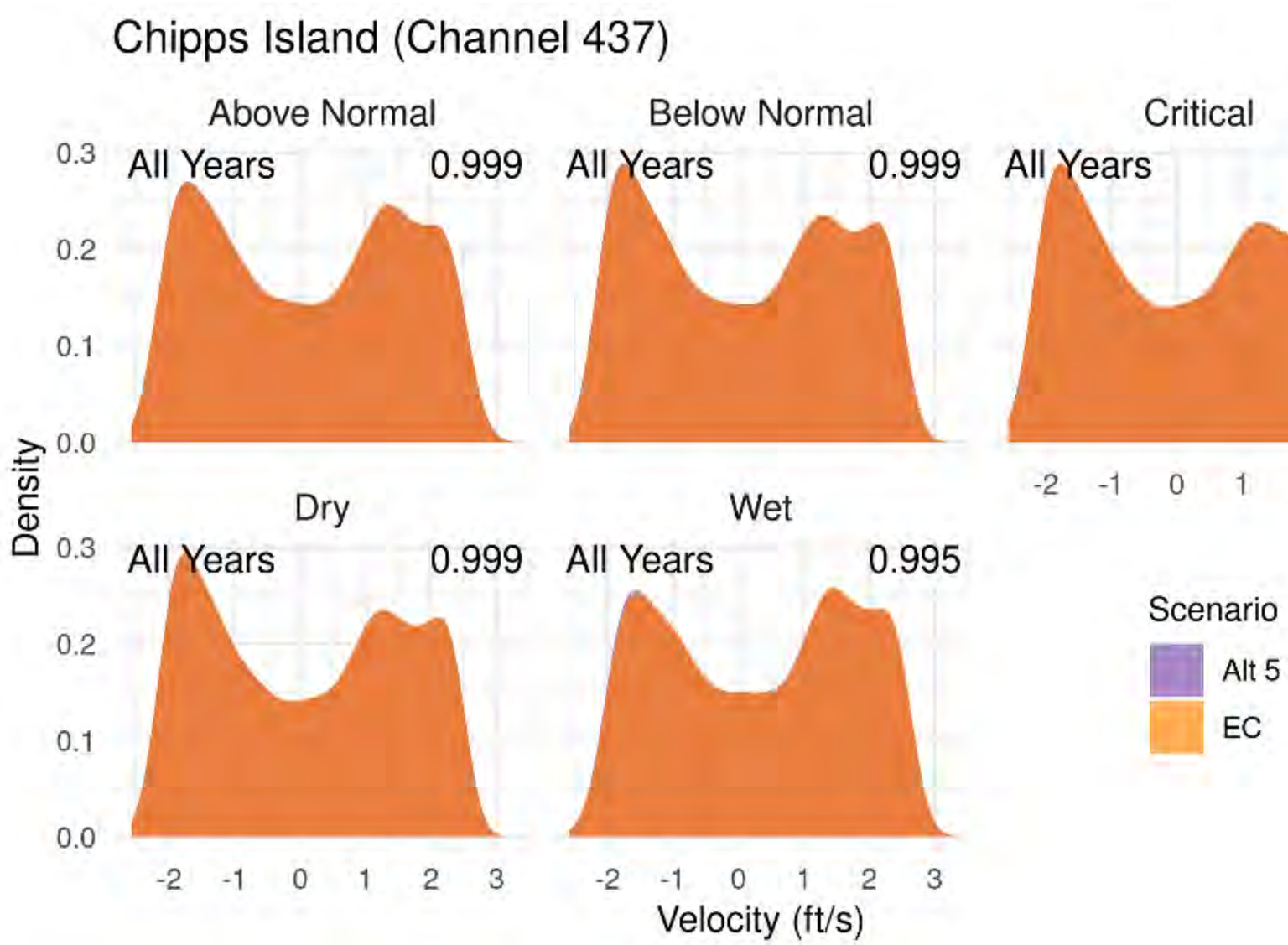

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-84. Velocity Density Distribution for Rio Vista (Sacramento River), December.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

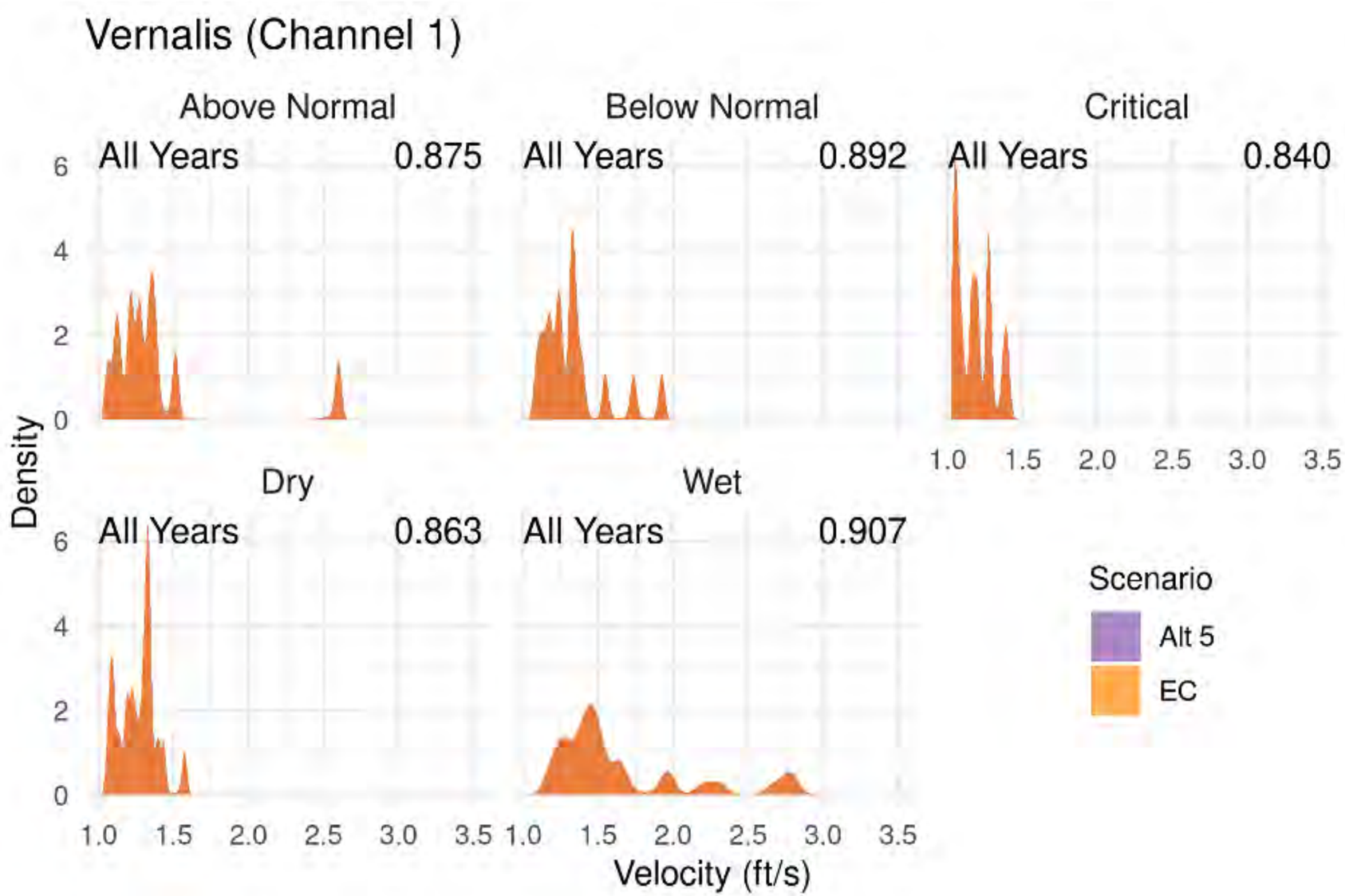
**Figure 5D.1-85. Velocity Density Distribution for Sevenmile Slough, December.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

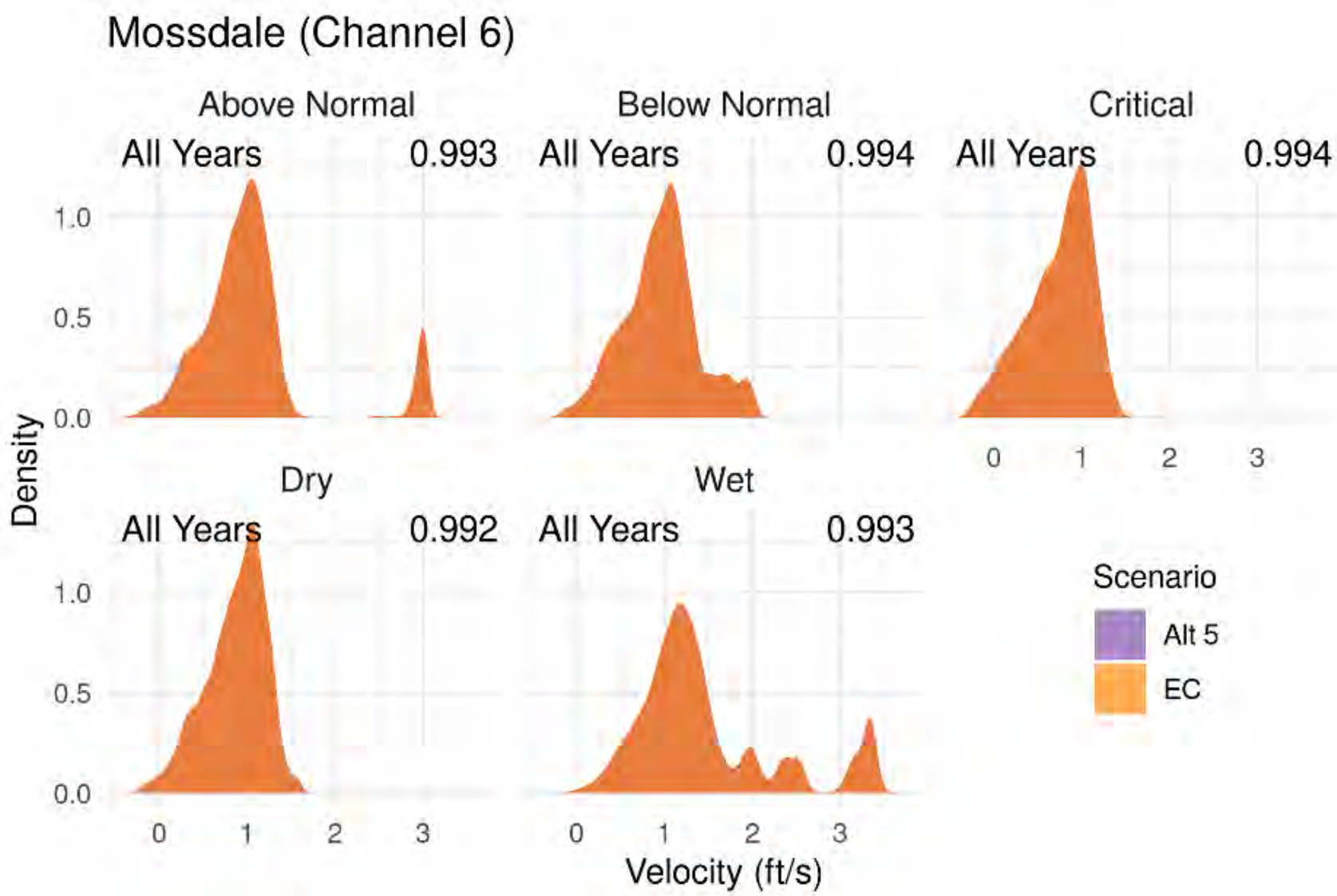
**Figure 5D.1-86. Velocity Density Distribution for Chipps Island (Sacramento River–San Joaquin River Confluence), December.**

***San Joaquin River Delta***



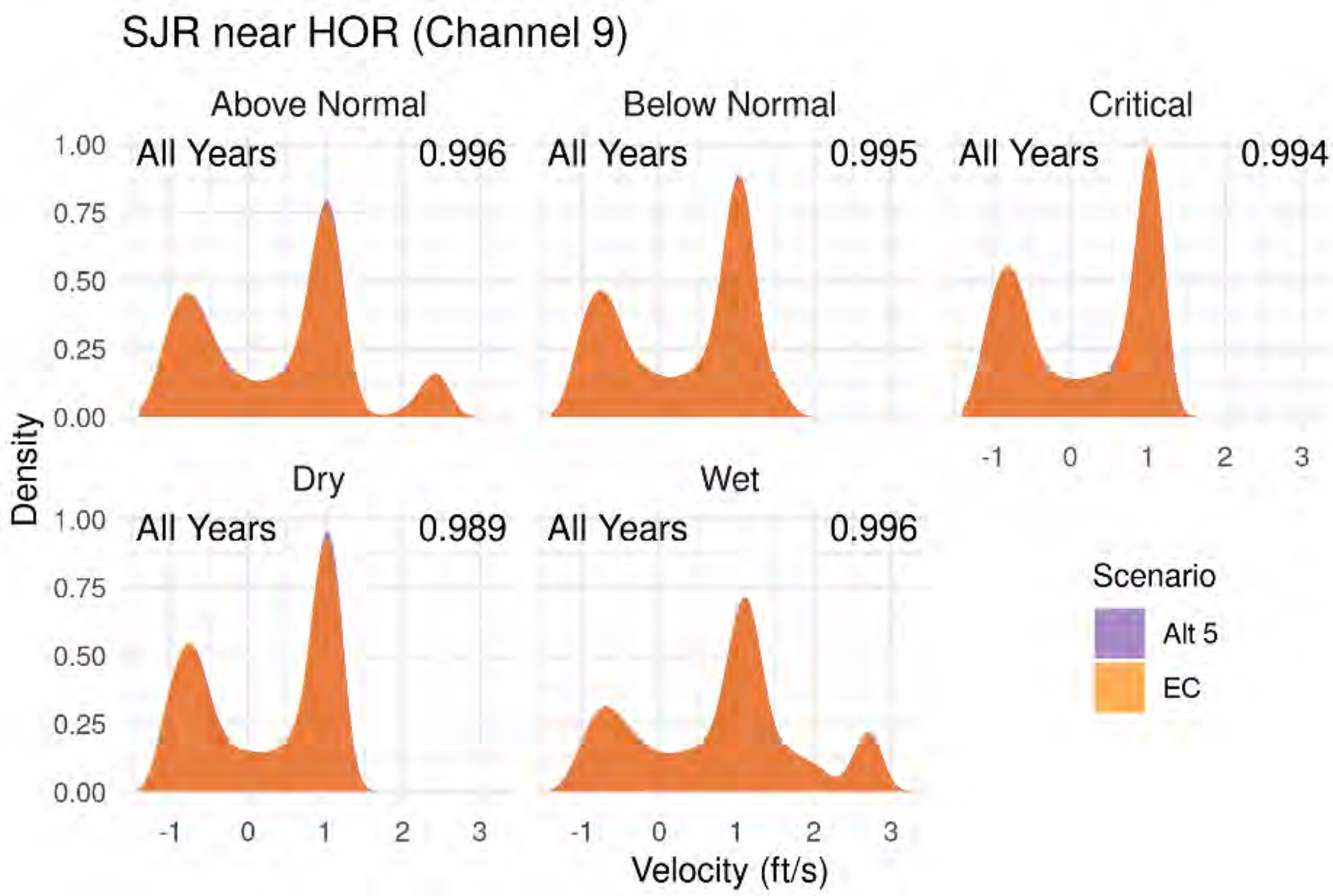

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-87. Velocity Density Distribution for Vernalis (San Joaquin River), December.**



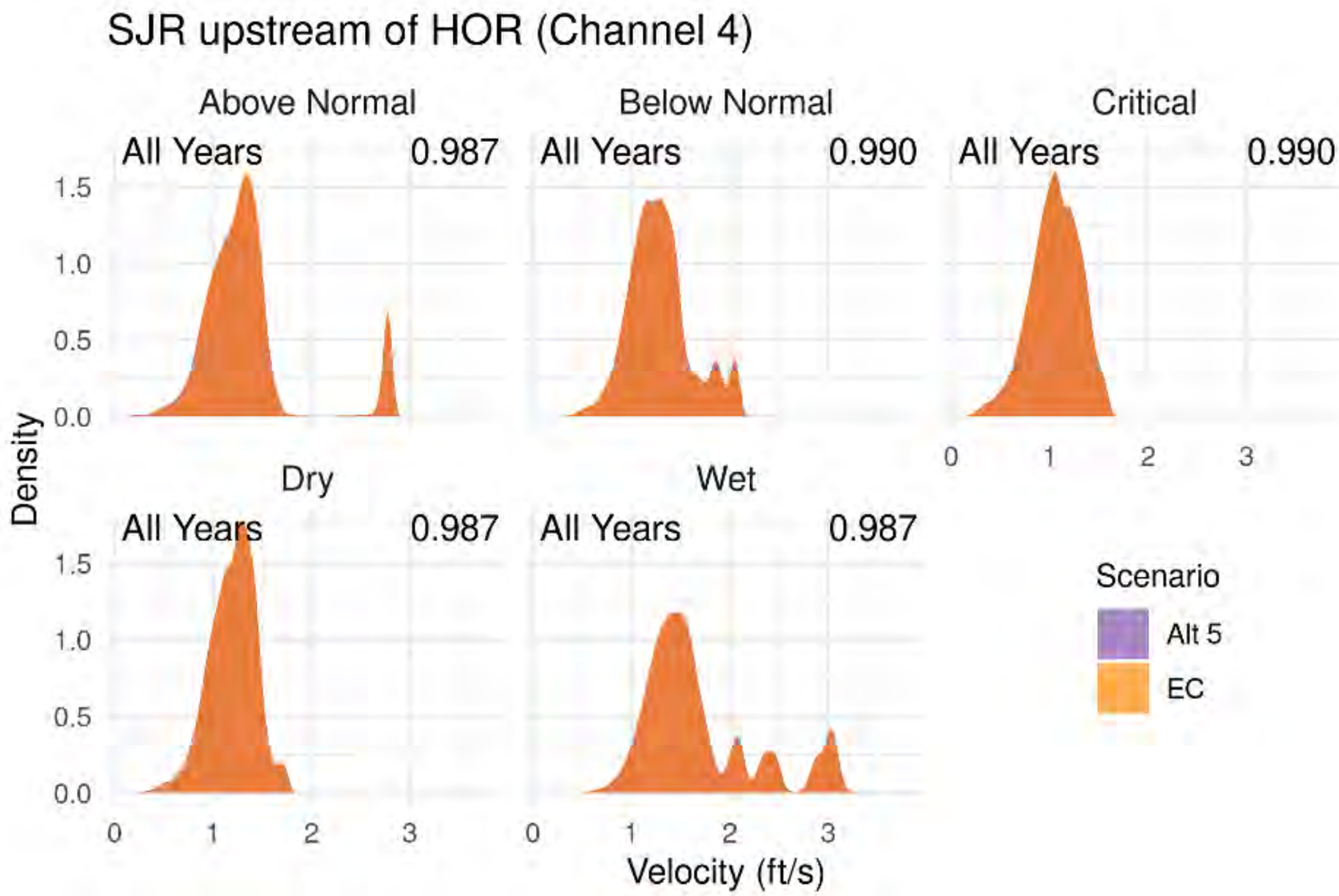

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-88. Velocity Density Distribution for Mossdale (San Joaquin River), December.**



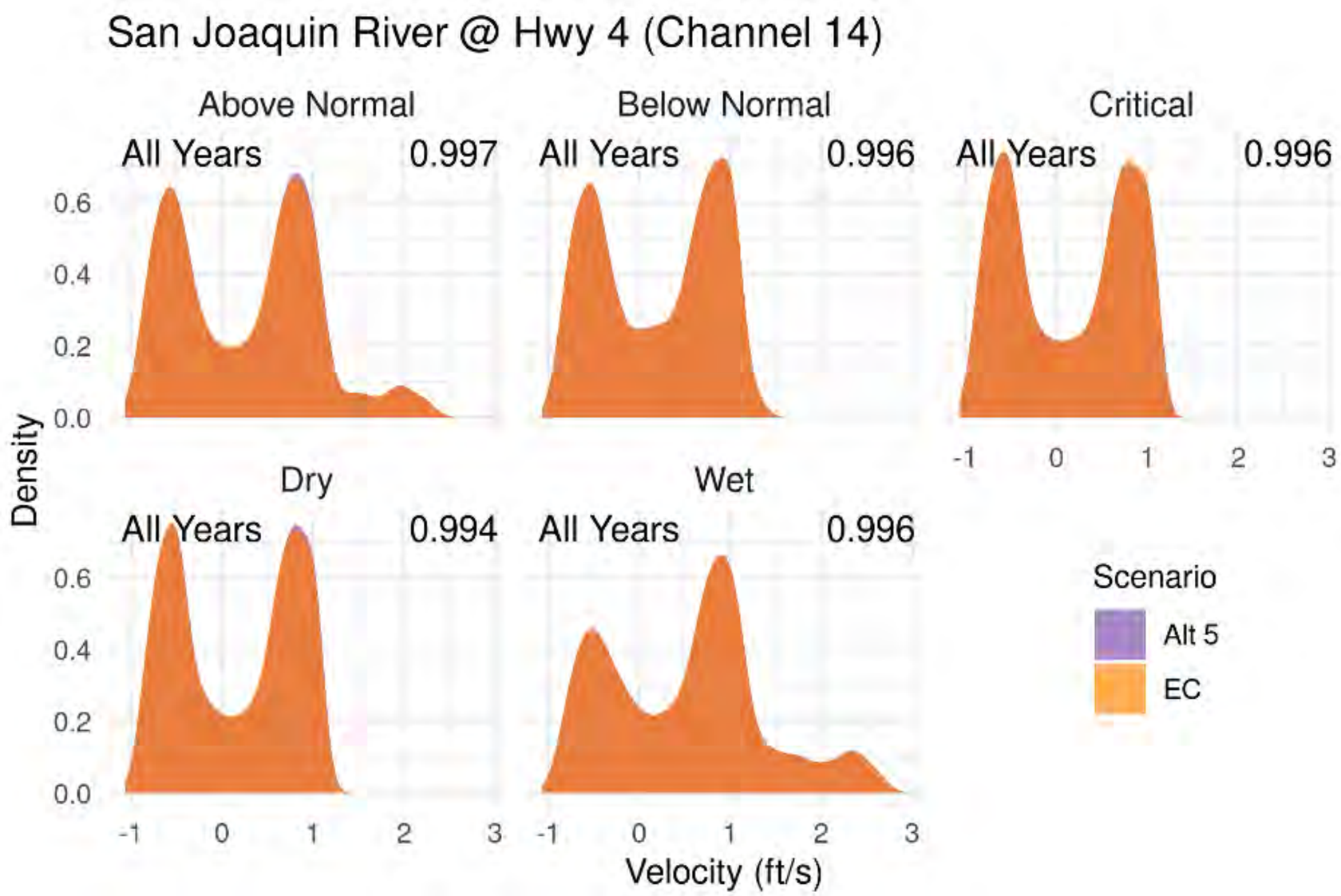

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-89. Velocity Density Distribution for San Joaquin River near Head of Old River, December.**



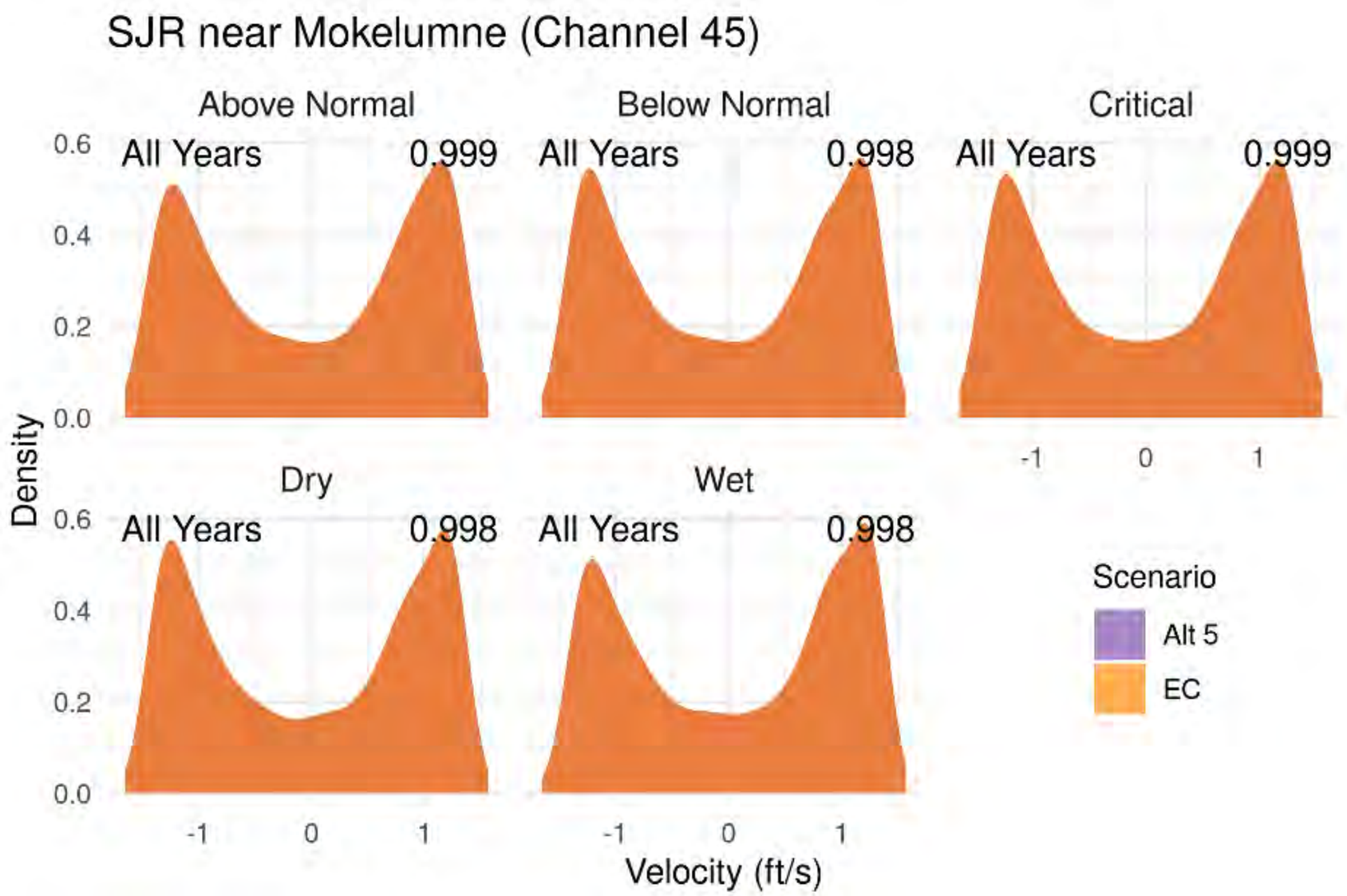

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-90. Velocity Density Distribution for San Joaquin River upstream of Head of Old River, December.**



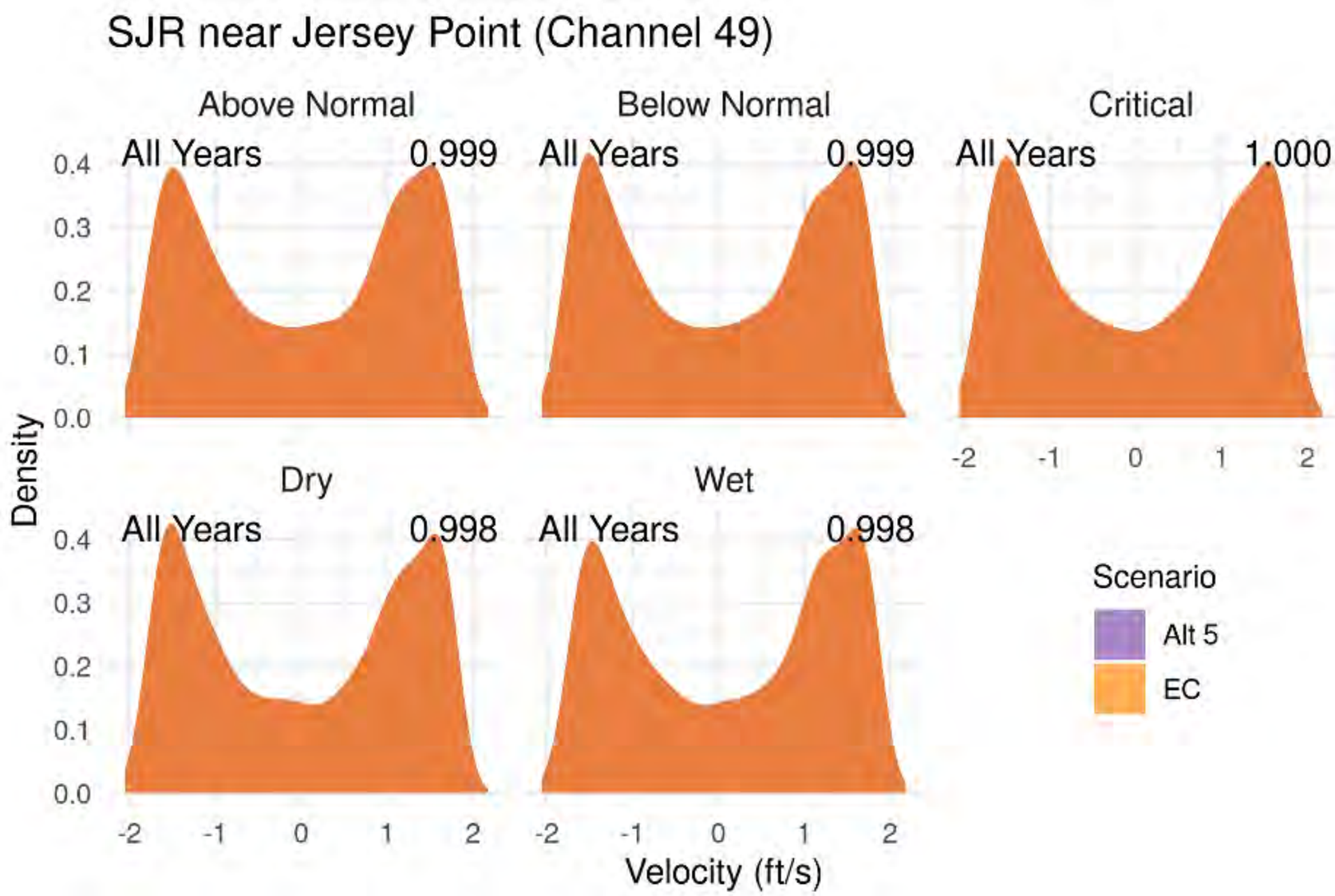

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-91. Velocity Density Distribution for San Joaquin River at Highway 4, December.**



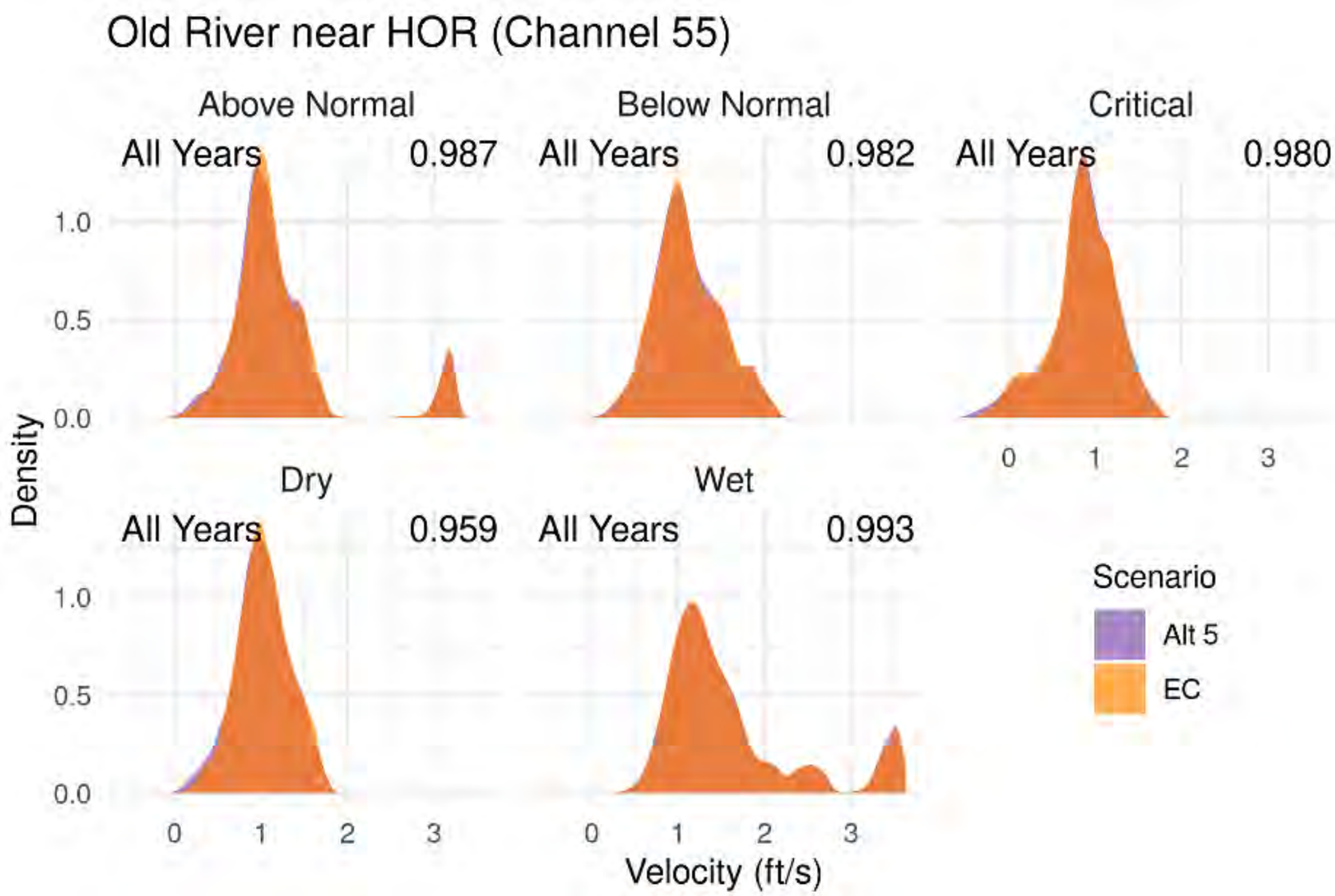

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-92. Velocity Density Distribution for San Joaquin River near Mokelumne River, December.**



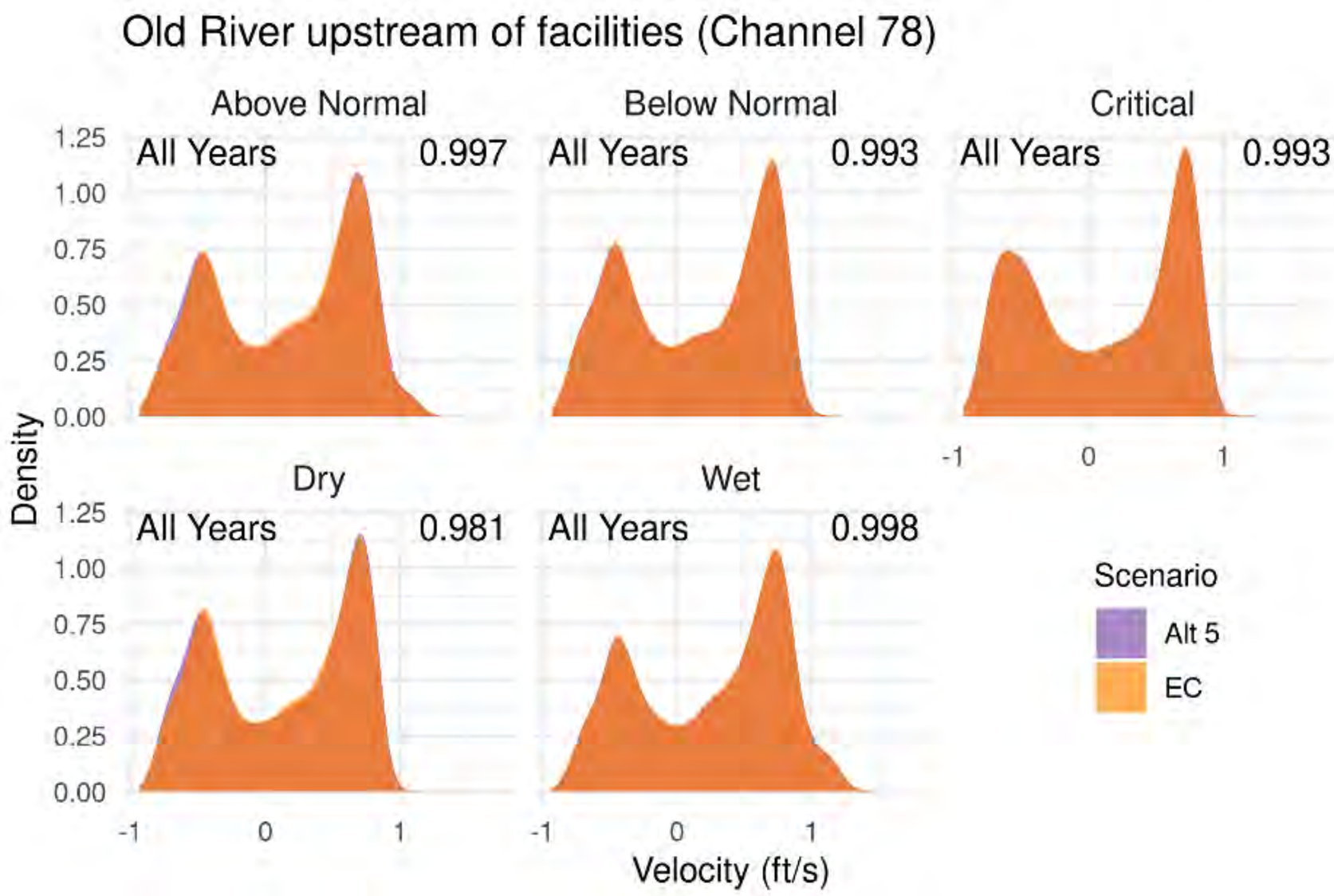

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-93. Velocity Density Distribution for San Joaquin River near Jersey Point, December.**



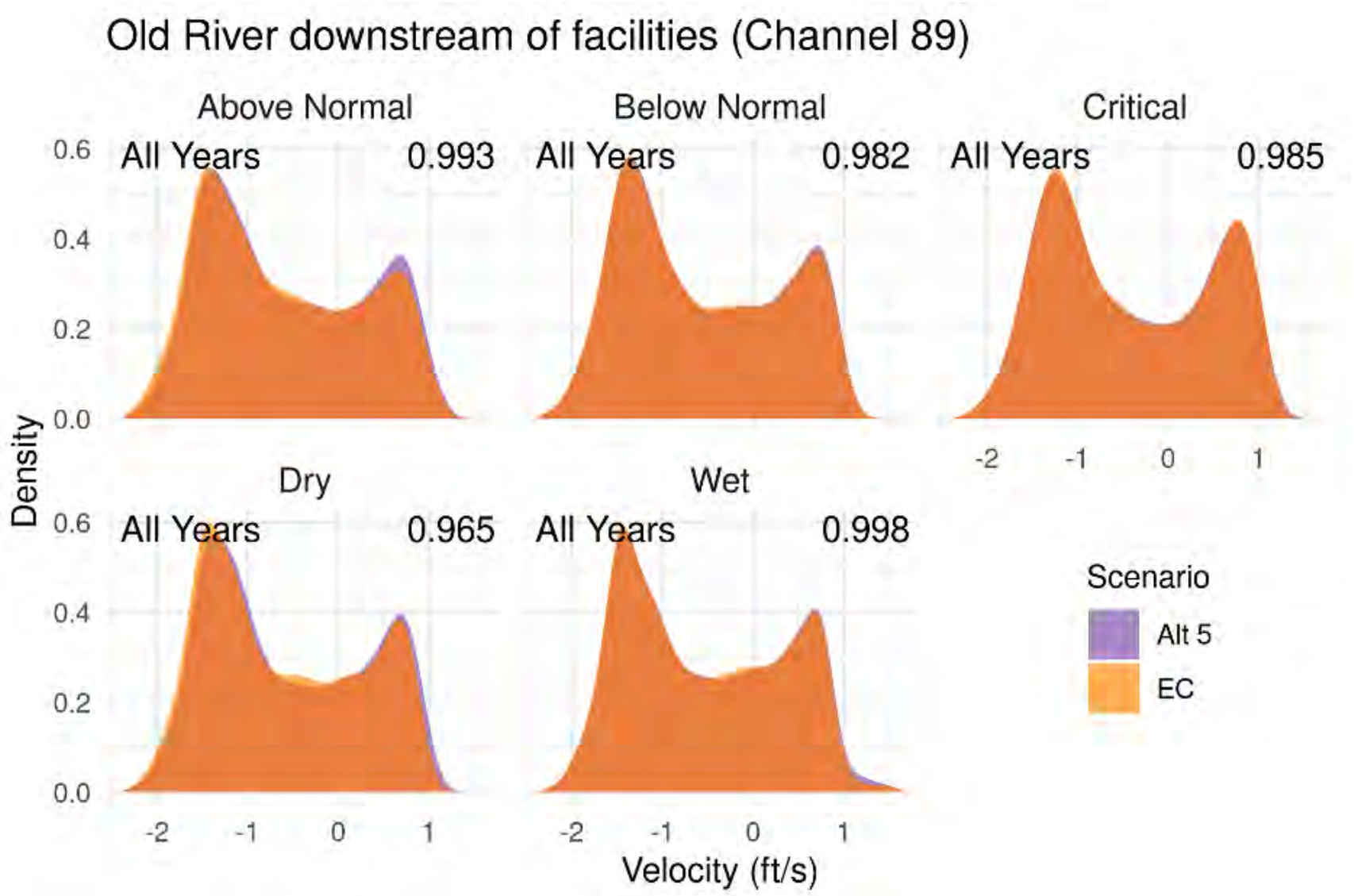

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-94. Velocity Density Distribution for Old River near Head of Old River, December.**



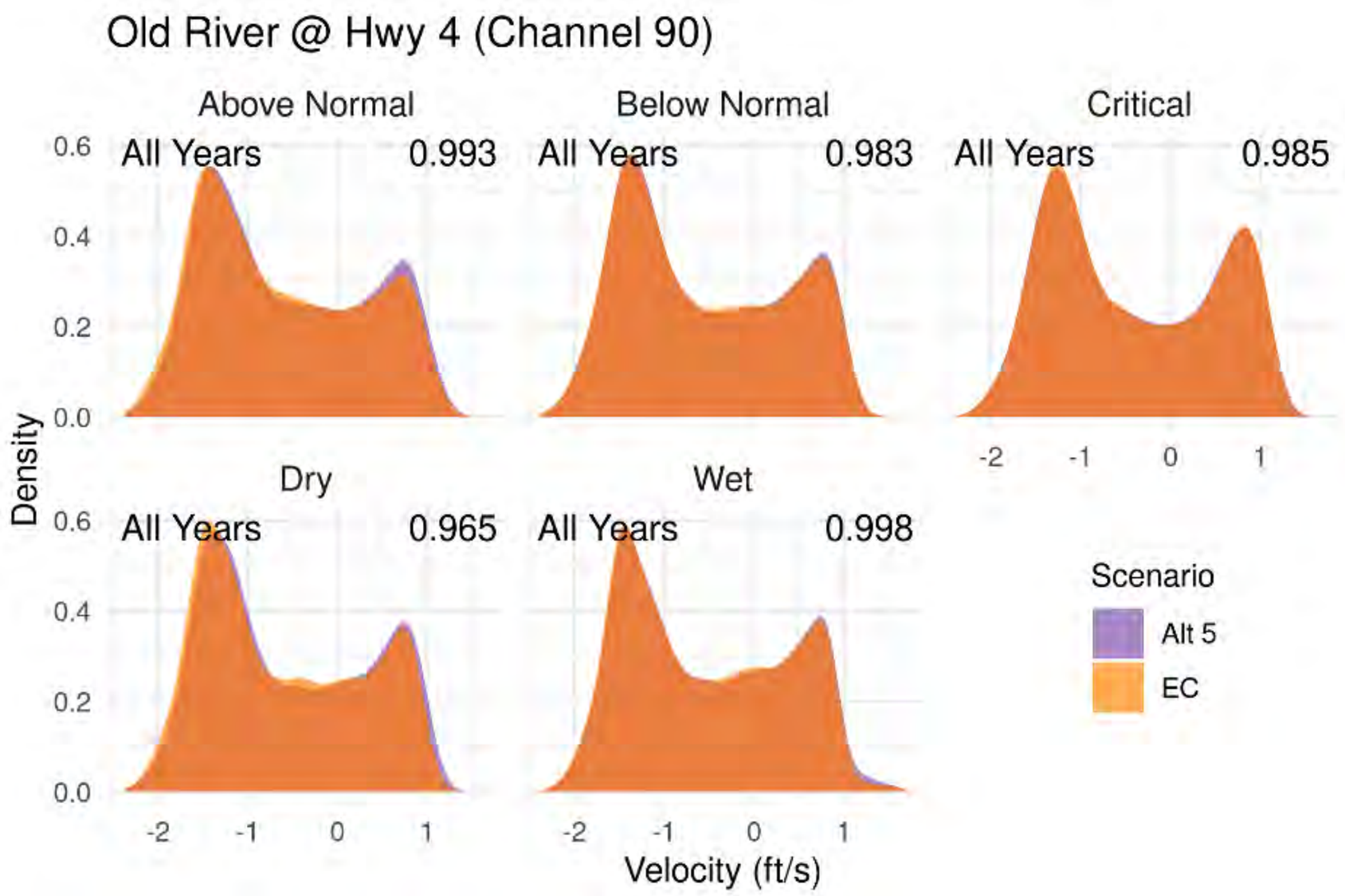

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-95. Velocity Density Distribution for Old River upstream of the South Delta Export Facilities, December.**



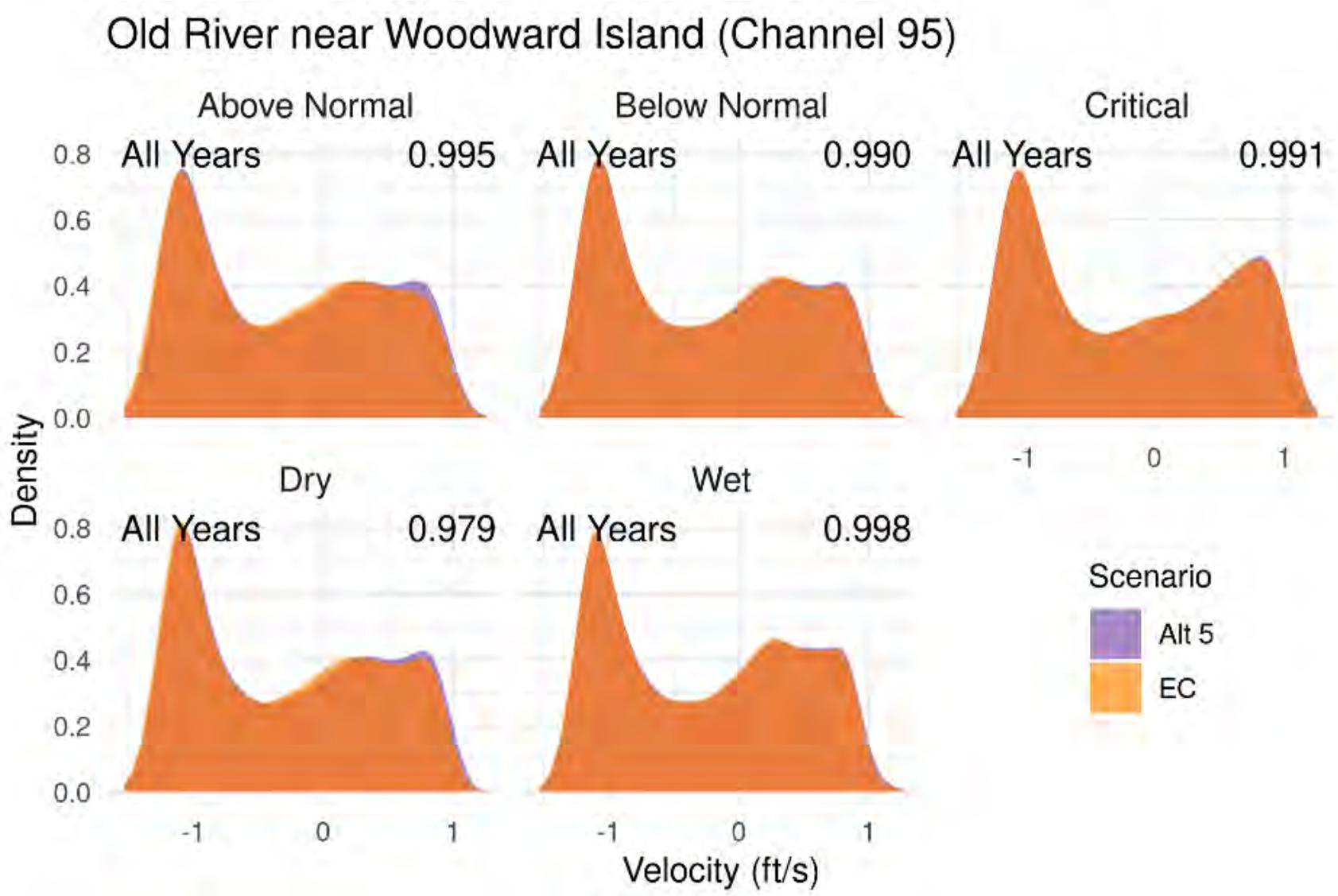

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-96. Velocity Density Distribution for Old River Downstream of the South Delta Export Facilities, December.**



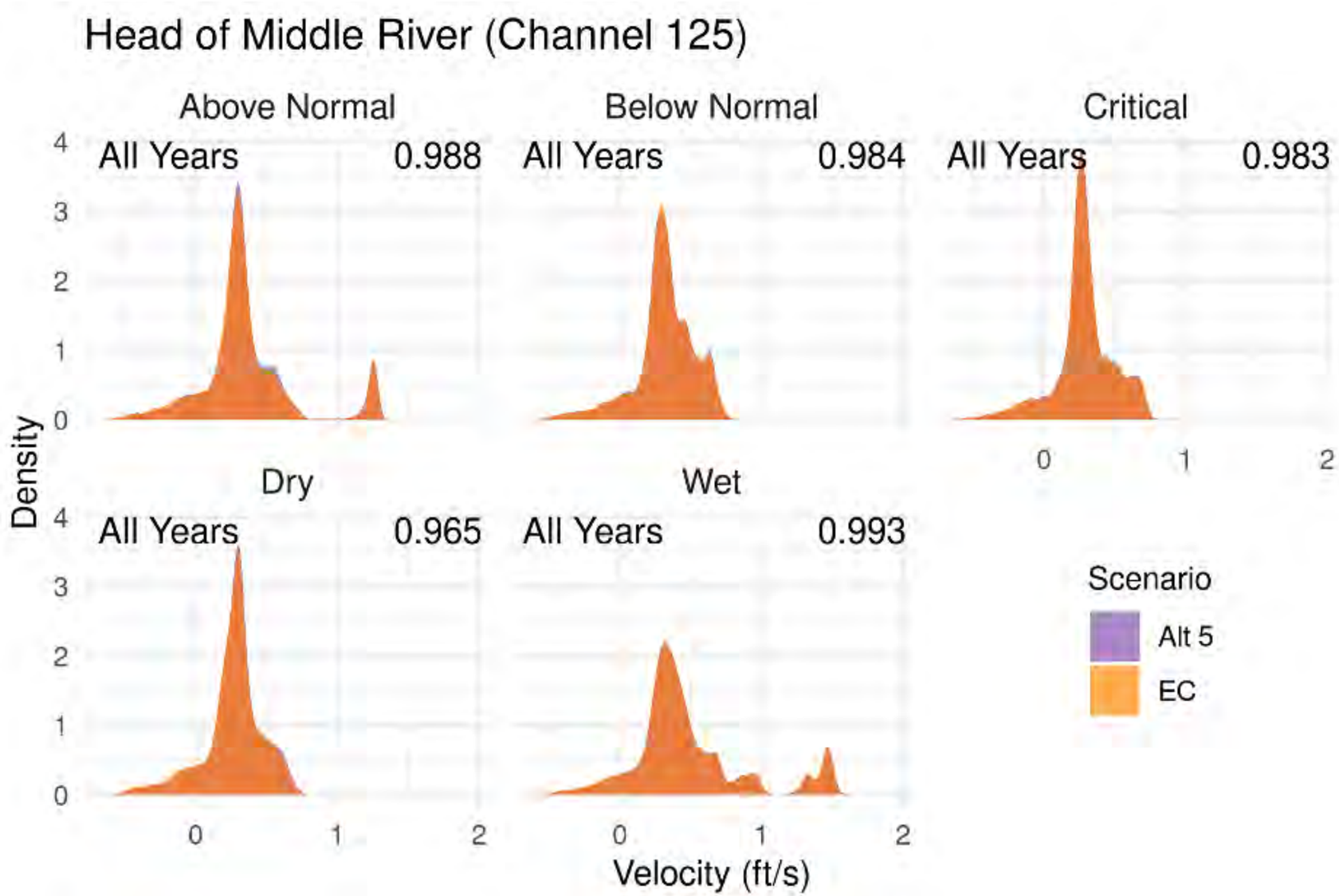

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-97. Velocity Density Distribution for Old River at Highway 4, December.**



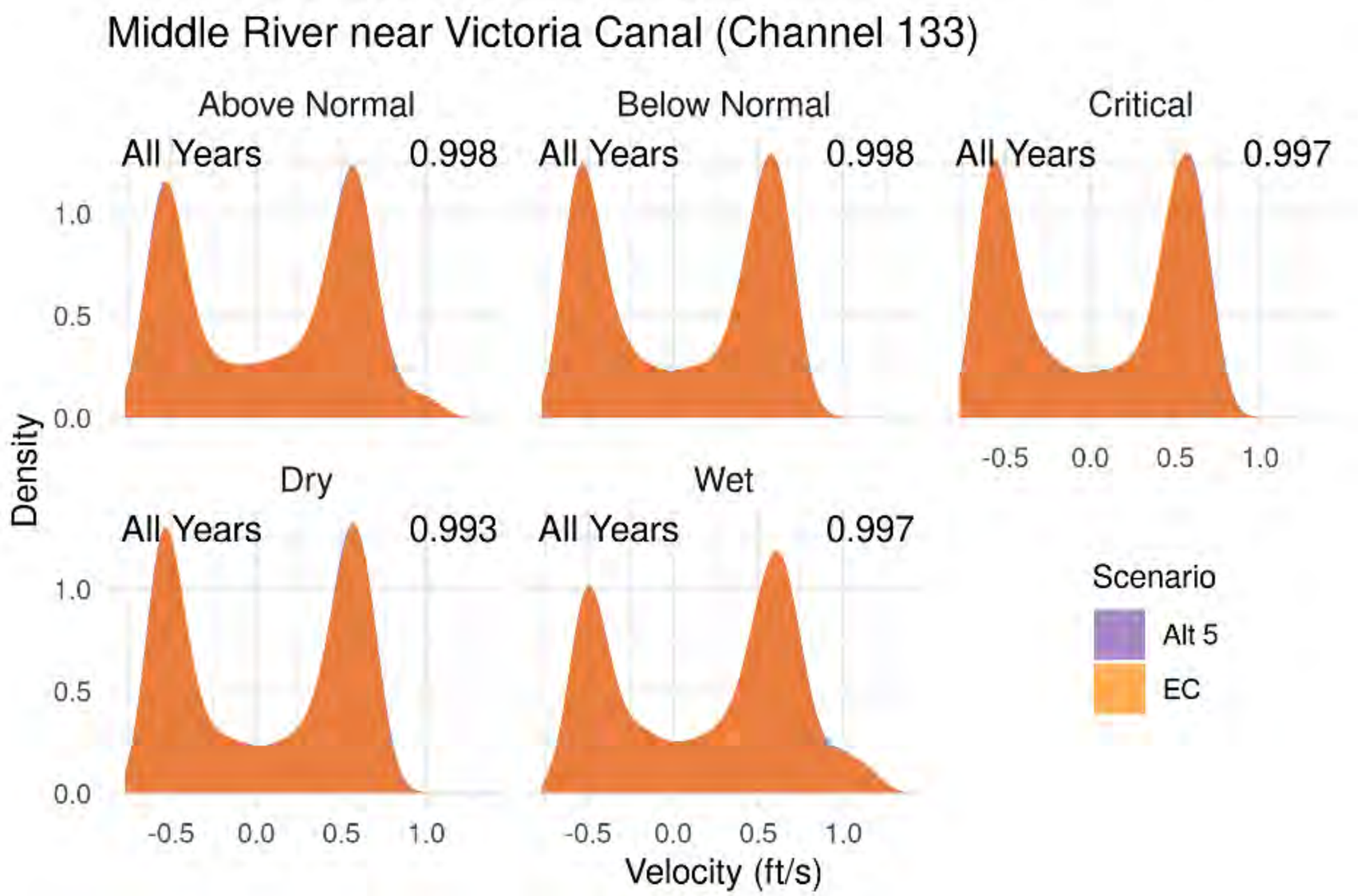

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-98. Velocity Density Distribution for Old River near Woodward Island, December.**



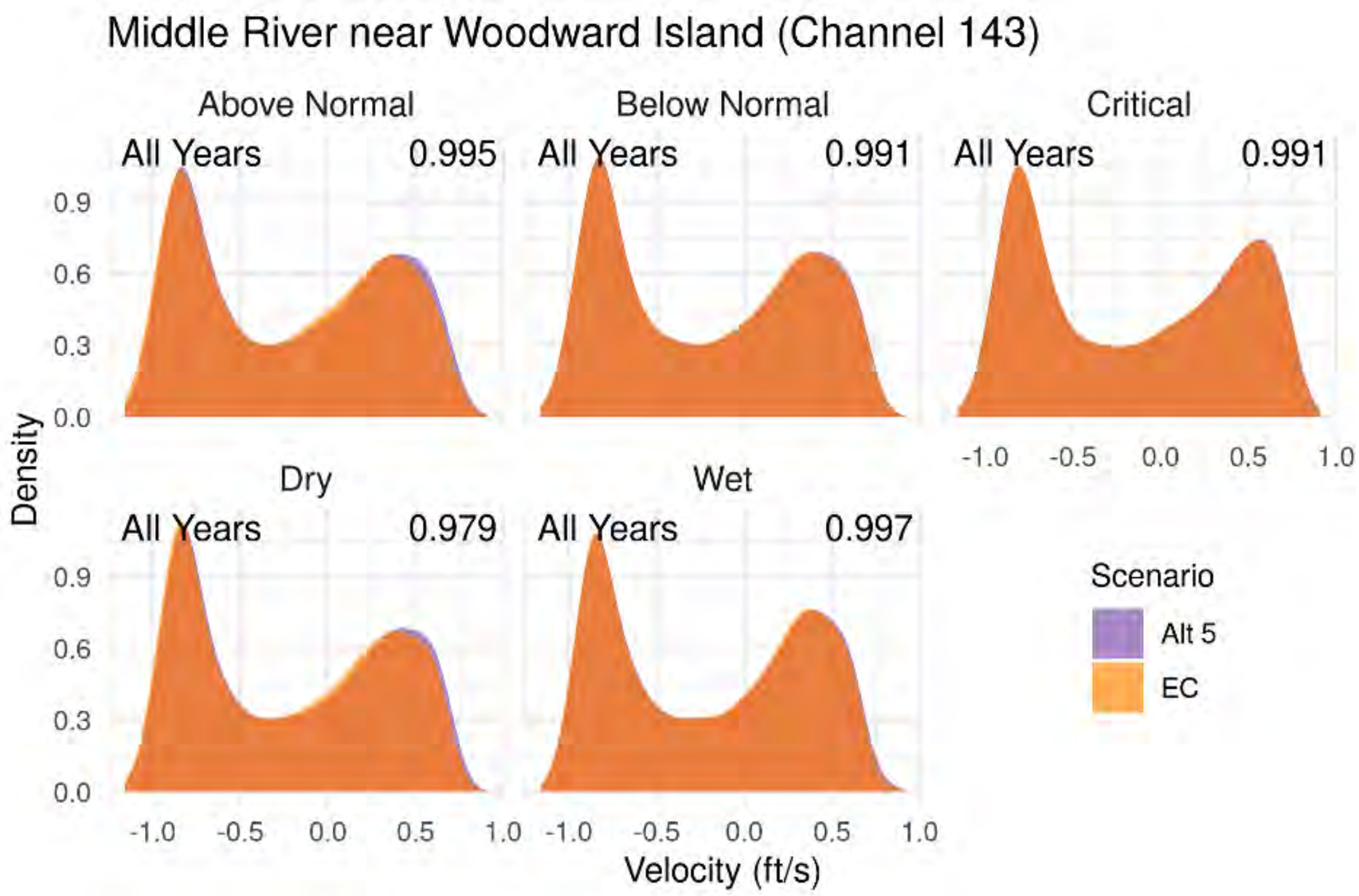

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-99. Velocity Density Distribution for Head of Middle River, December.**



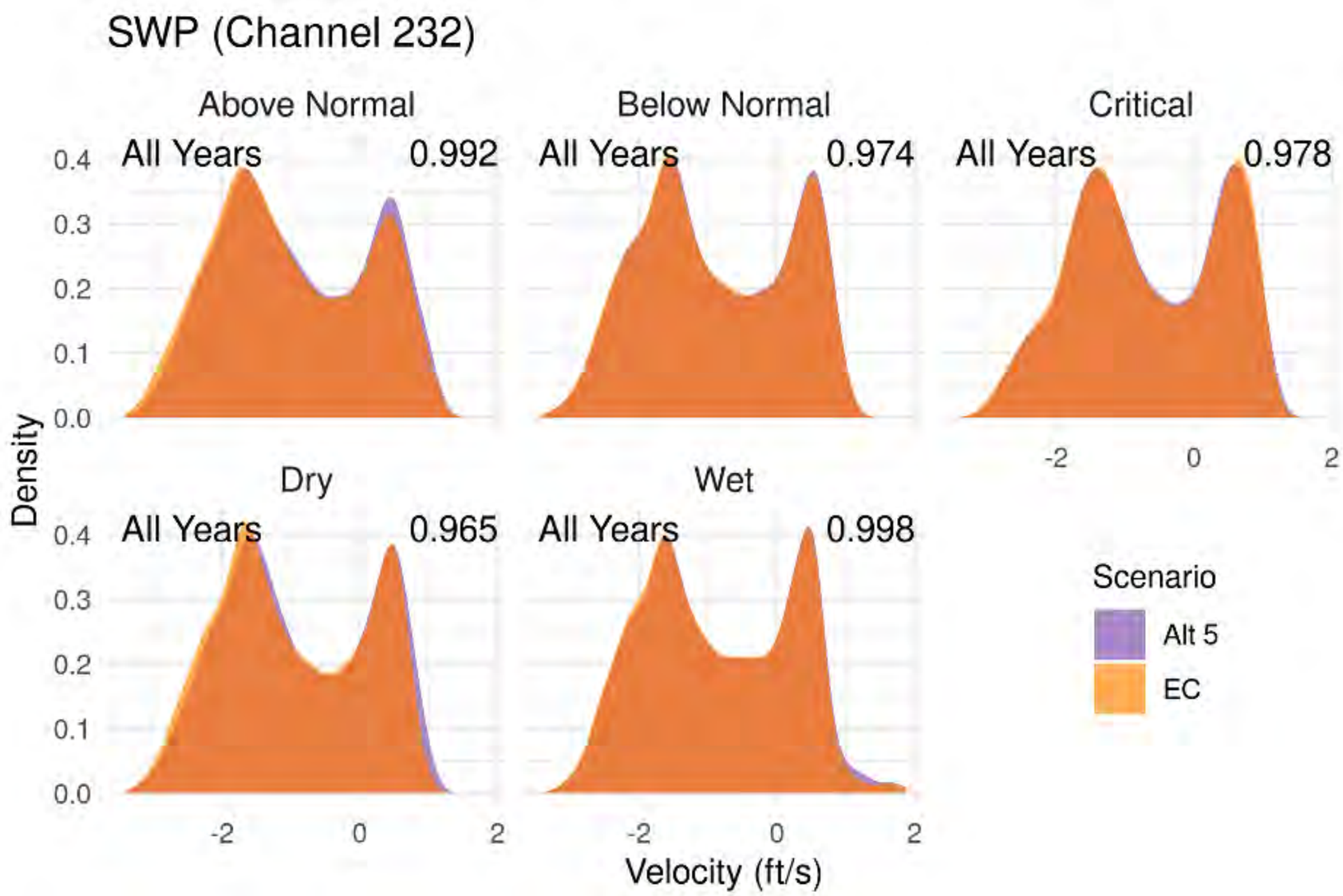

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-100. Velocity Density Distribution for Middle River near Victoria Canal, December.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-101. Velocity Density Distribution for Middle River near Woodward Island, December.**

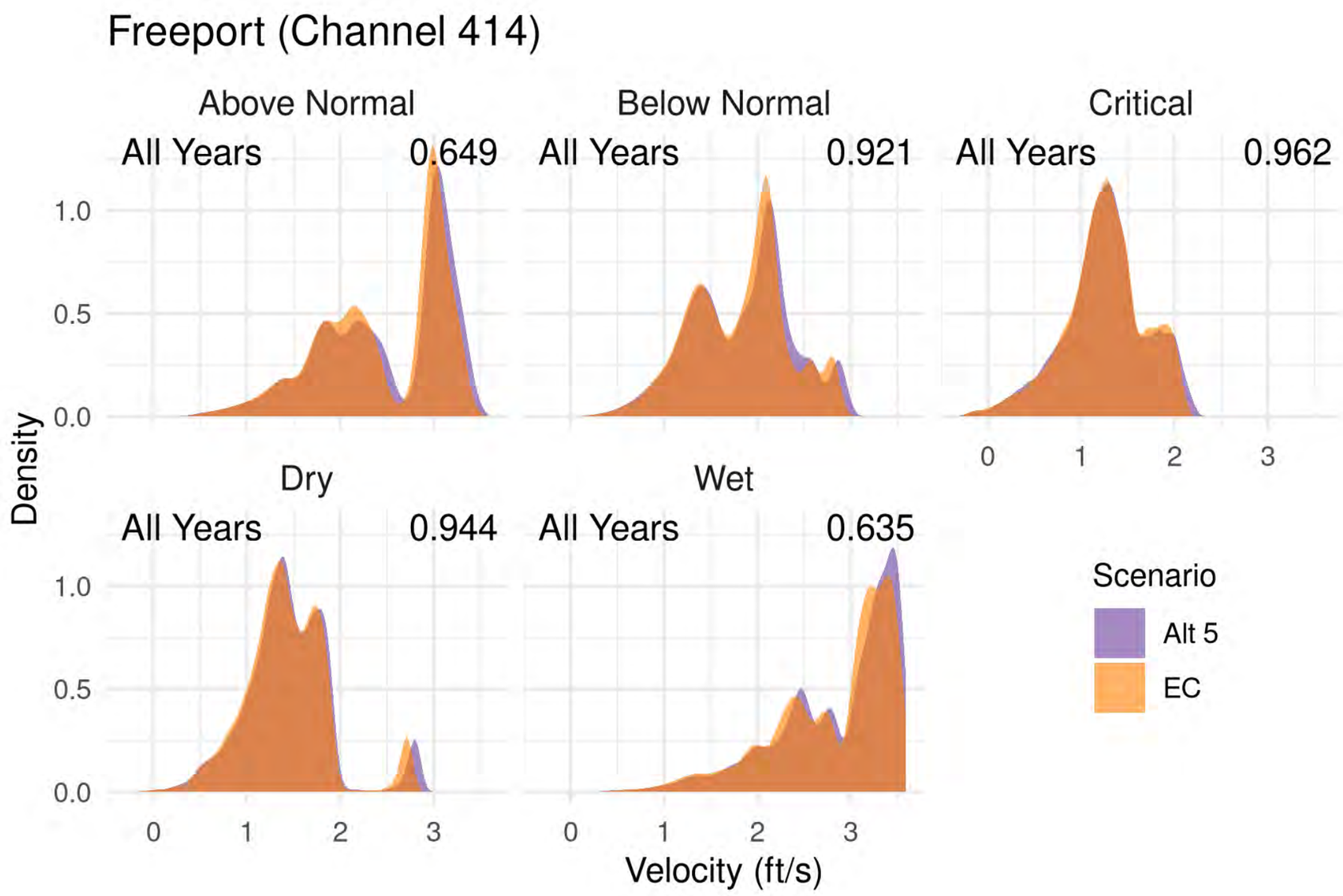



Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-102. Velocity Density Distribution for State Water Project (West Canal near Entrance to Clifton Court Forebay), December.**

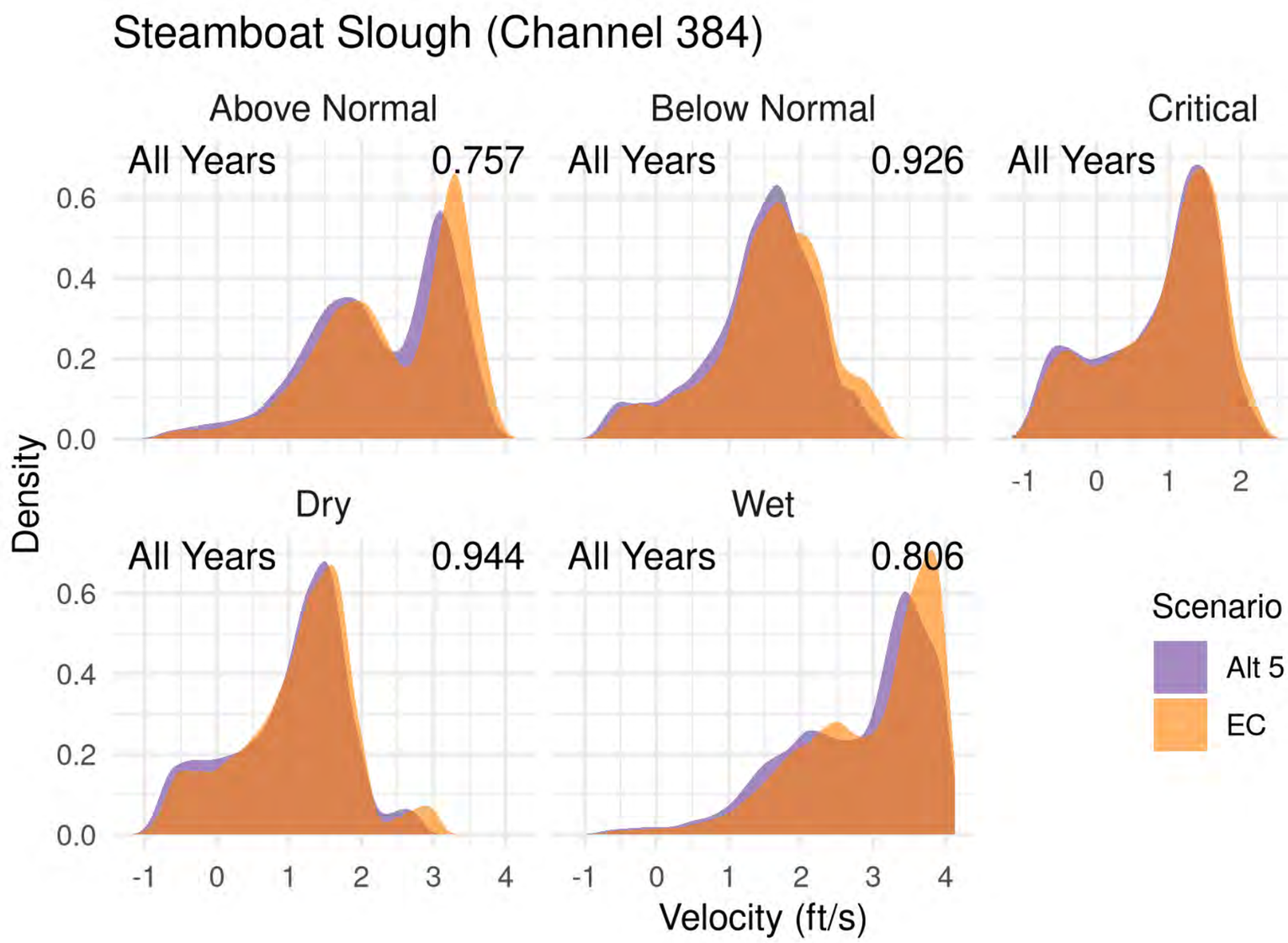
**January**

***Sacramento River Delta***



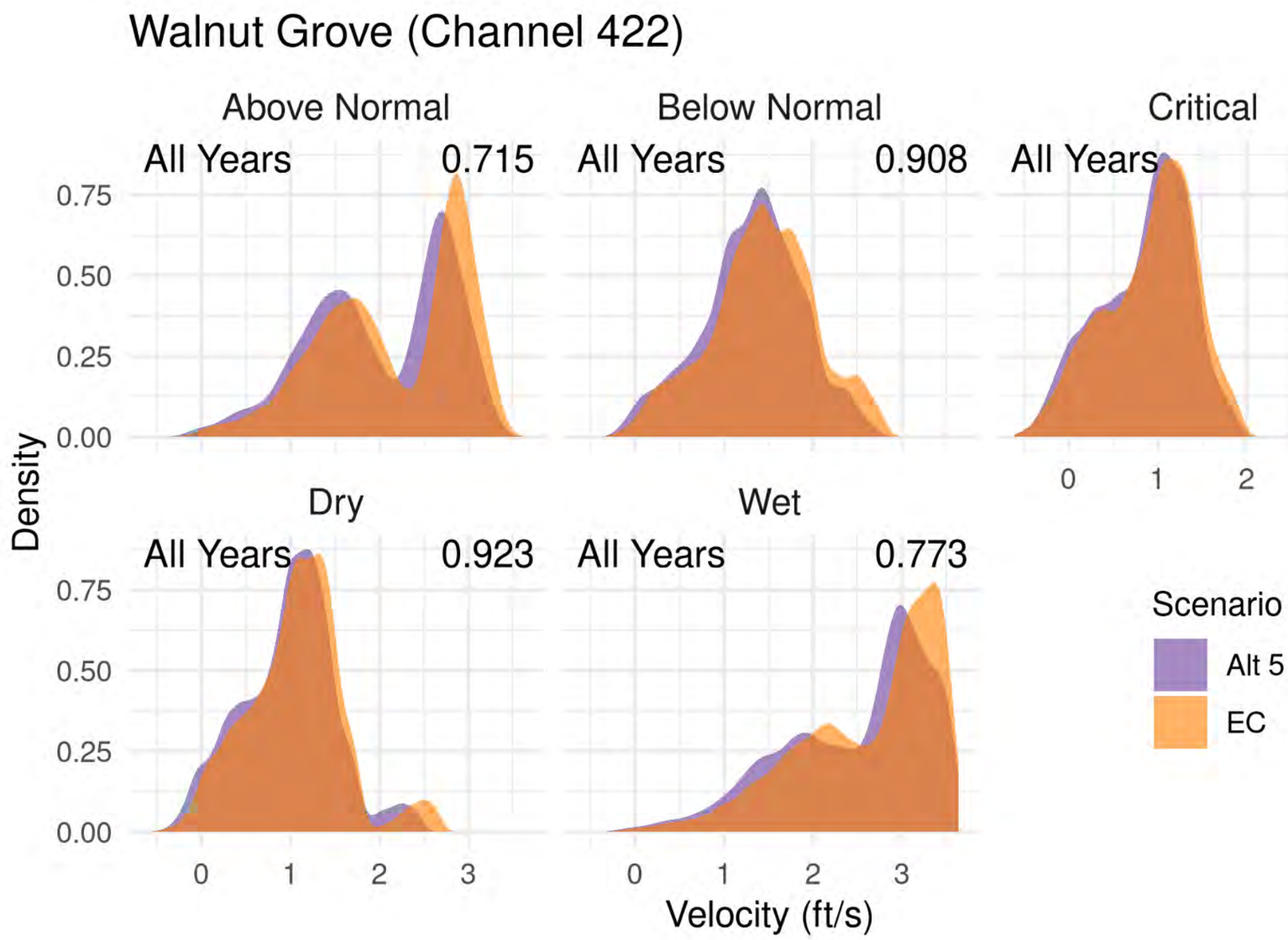

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-103. Velocity Density Distribution for Freeport, January.**



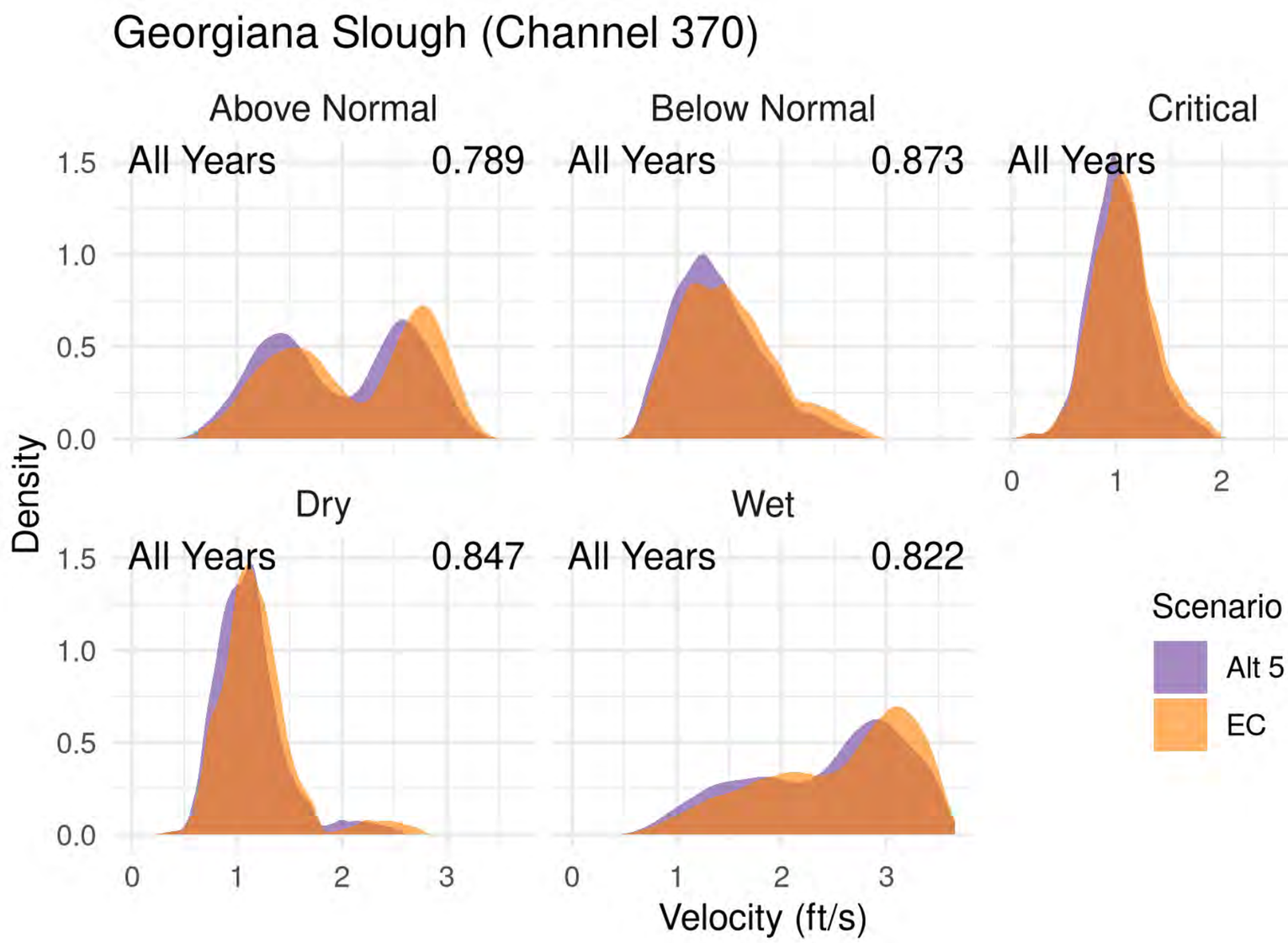

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-104. Velocity Density Distribution for Steamboat Slough, January.**



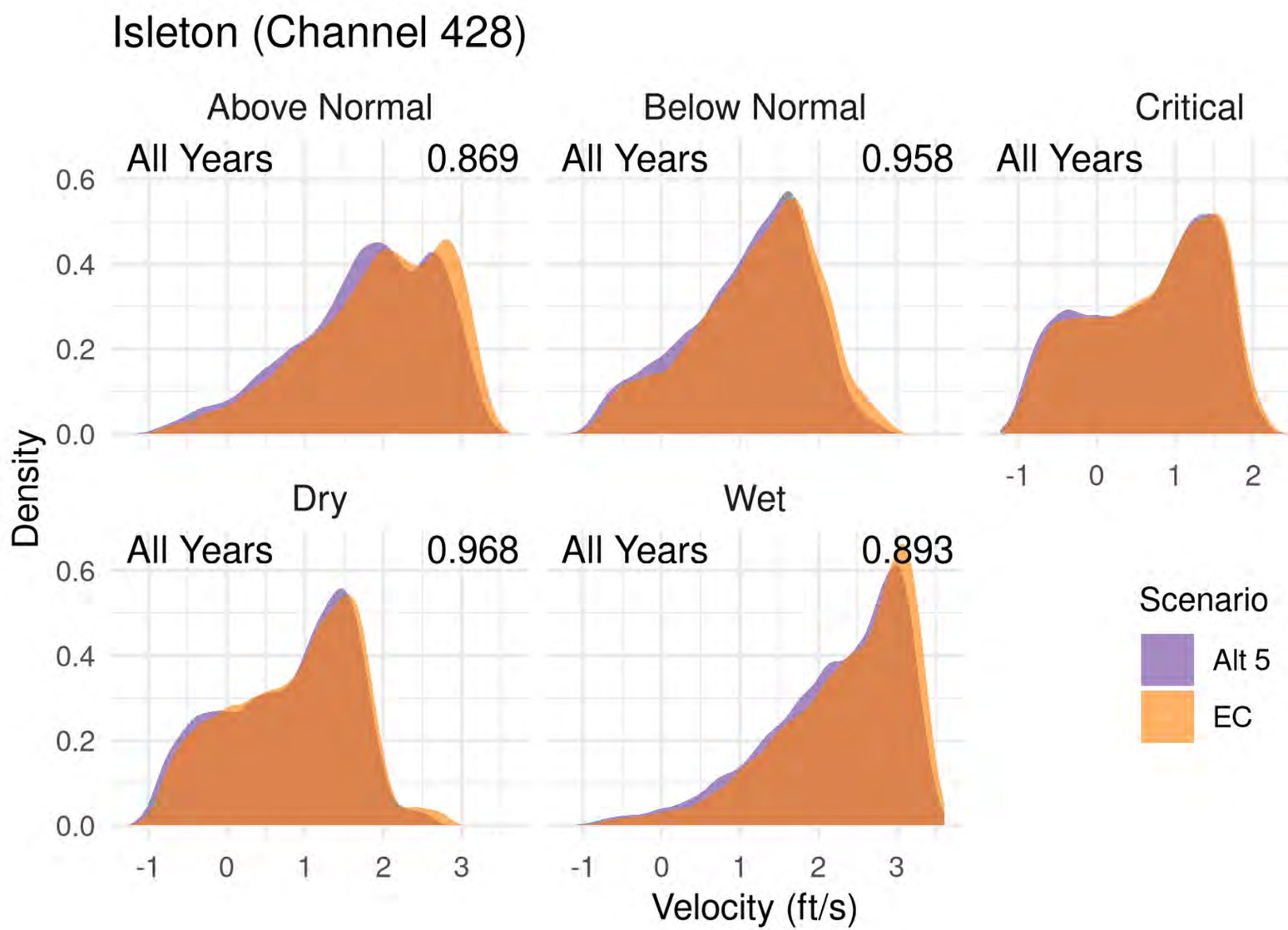

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-105. Velocity Density Distribution for Walnut Grove (Sacramento River), January.**



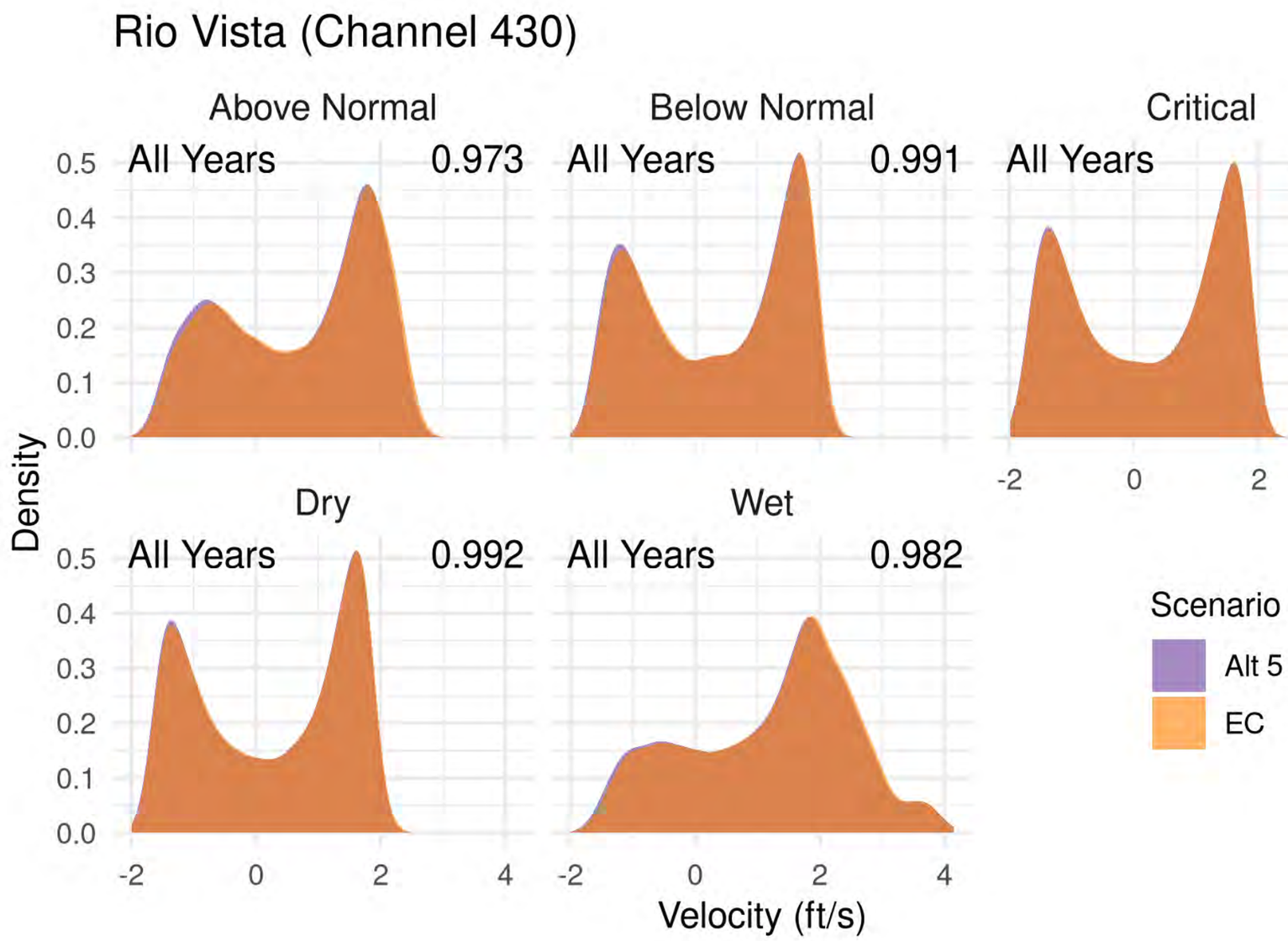

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-106. Velocity Density Distribution for Georgiana Slough, January.**



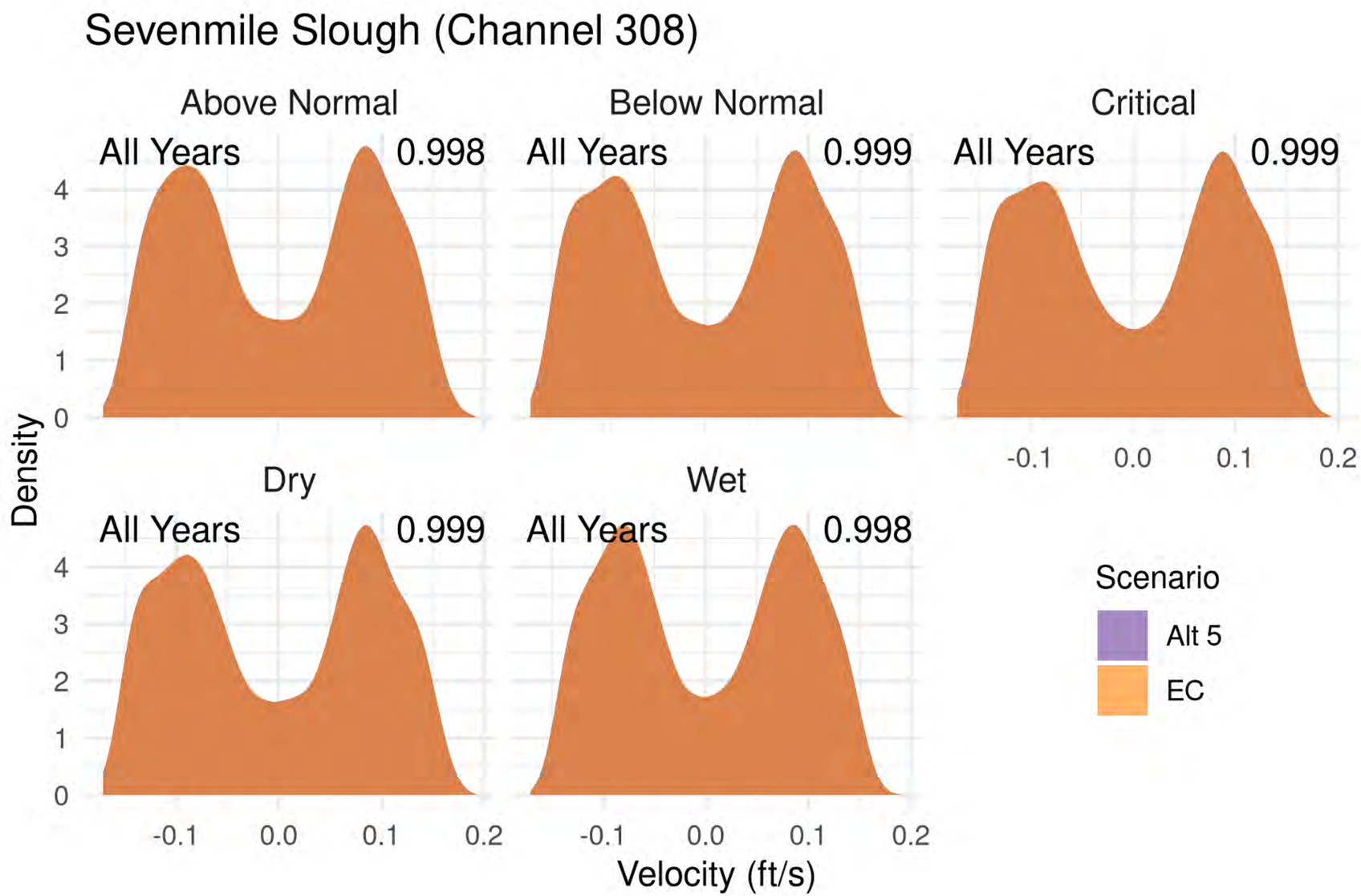

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-107. Velocity Density Distribution for Isleton (Sacramento River), January.**



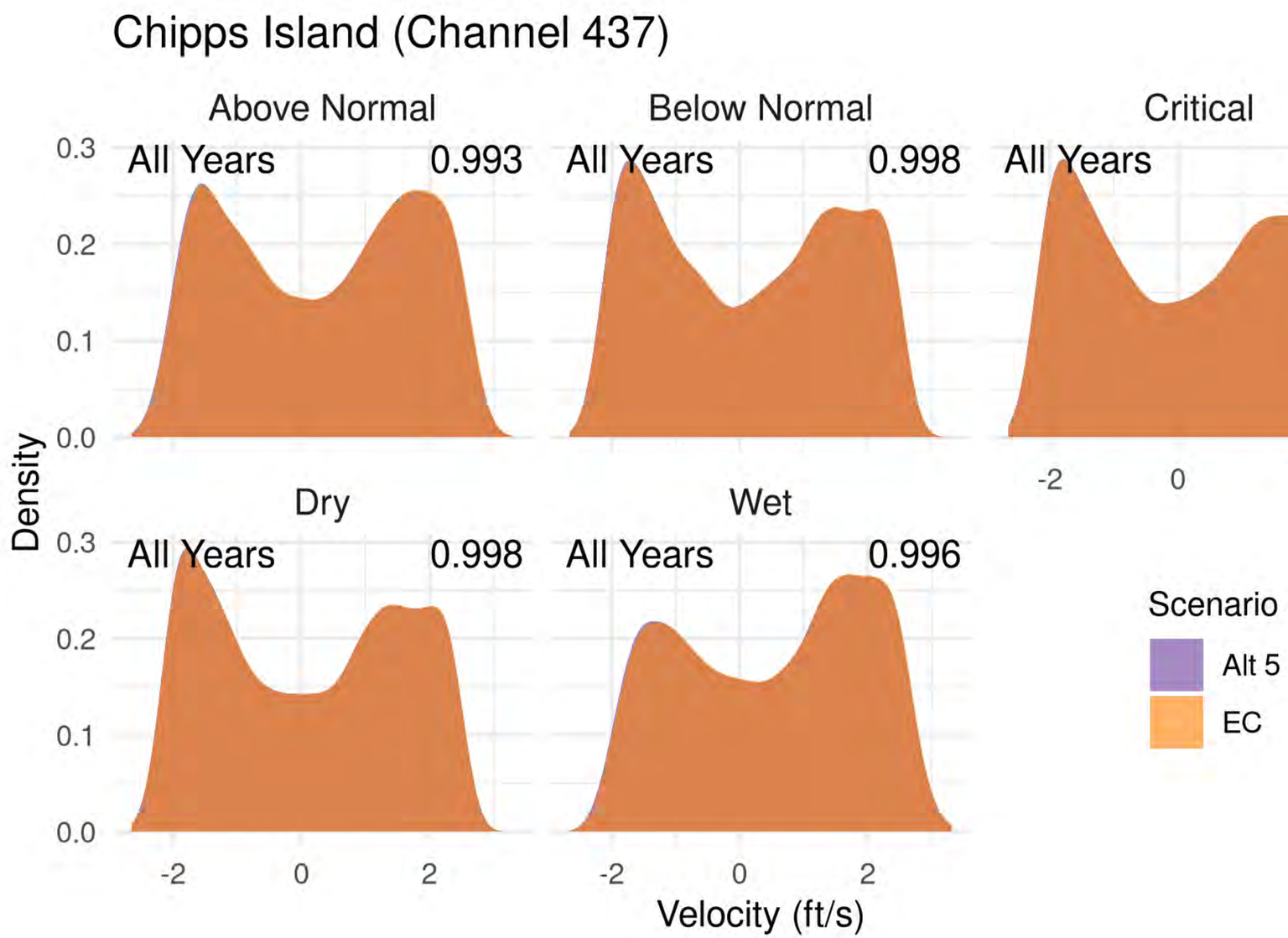

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-108. Velocity Density Distribution for Rio Vista (Sacramento River), January.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

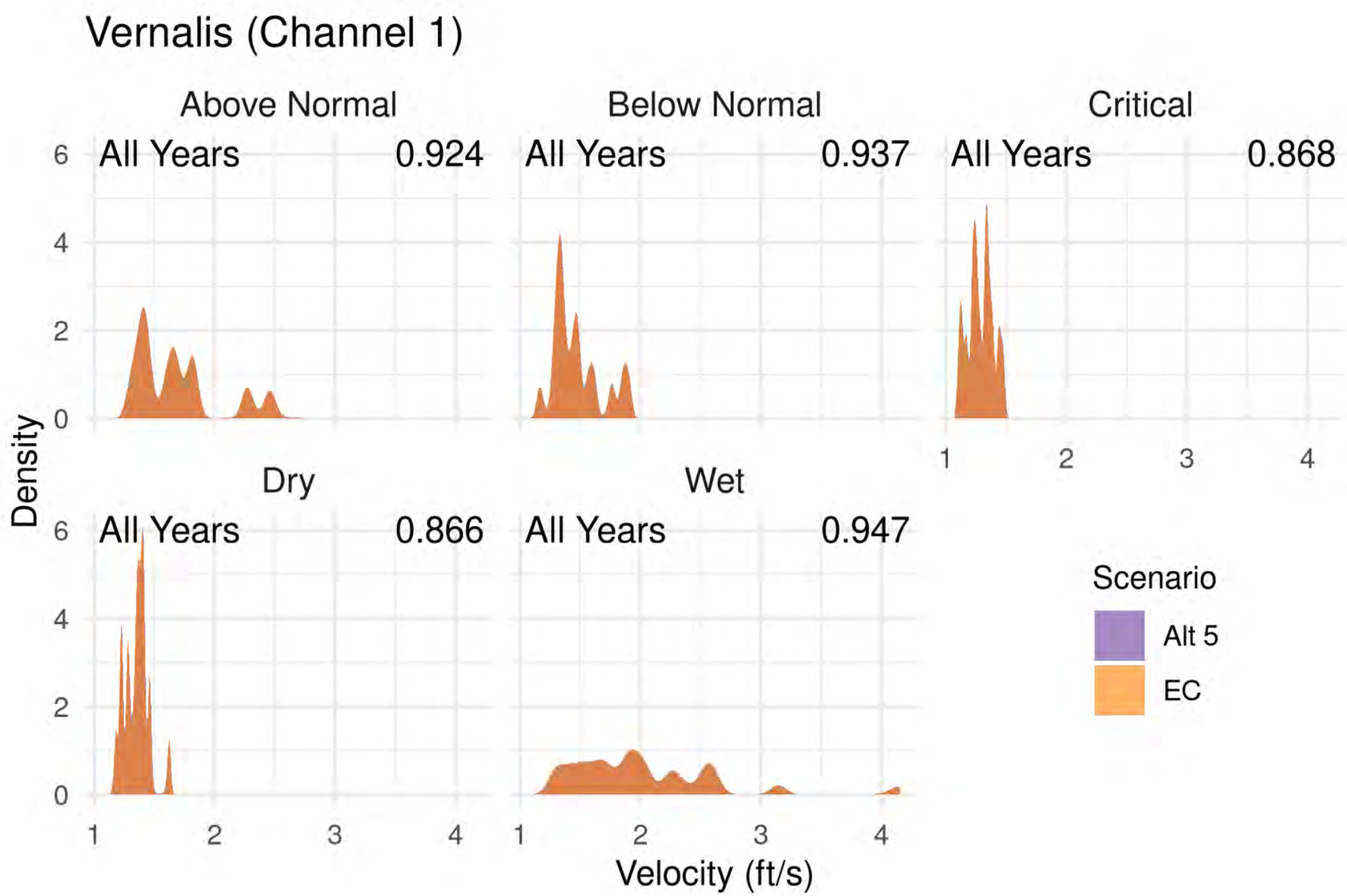
**Figure 5D.1-109. Velocity Density Distribution for Sevenmile Slough, January.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

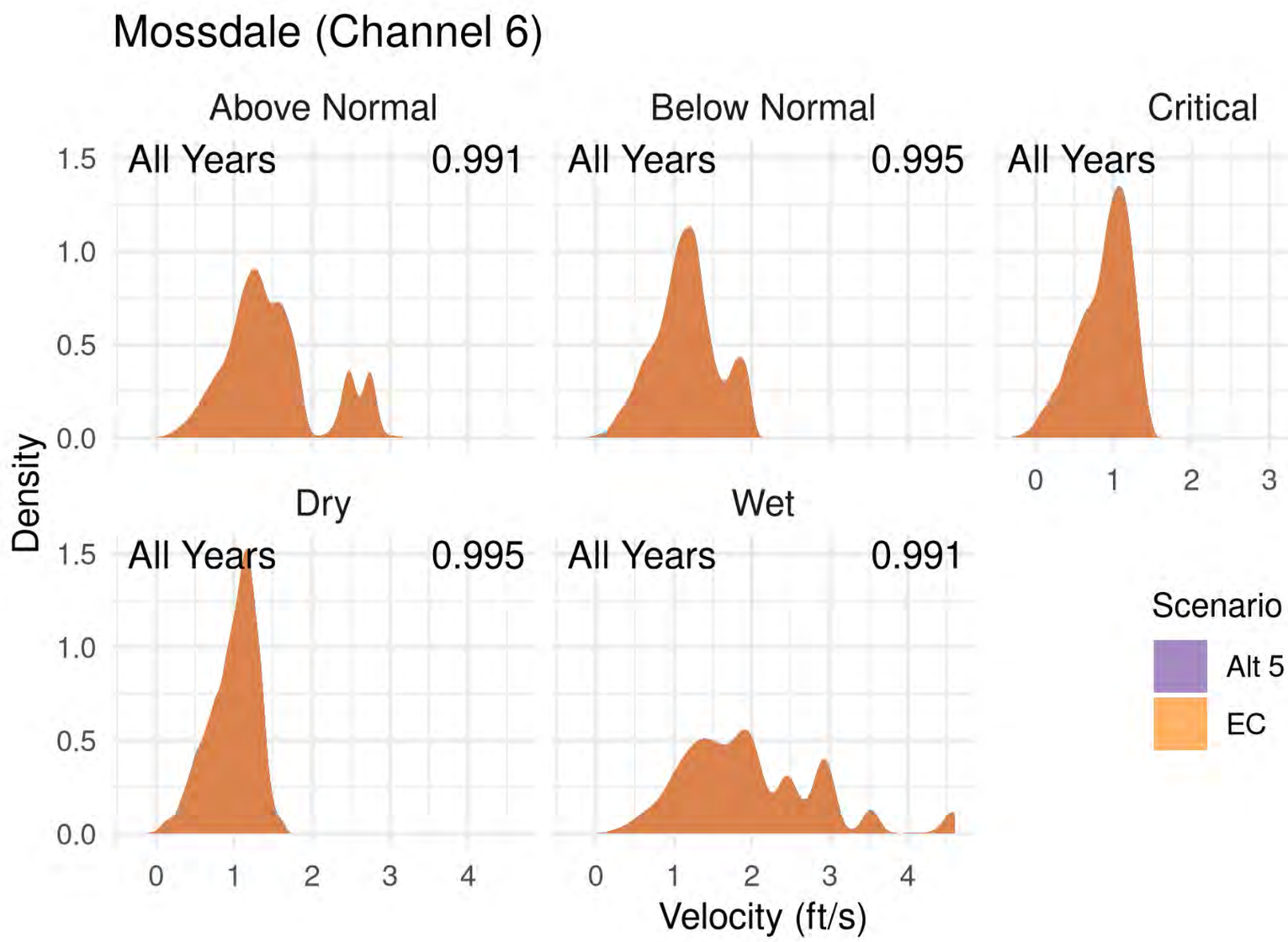
**Figure 5D.1-110. Velocity Density Distribution for Chipps Island (Sacramento River–San Joaquin River Confluence), January.**

***San Joaquin River Delta***



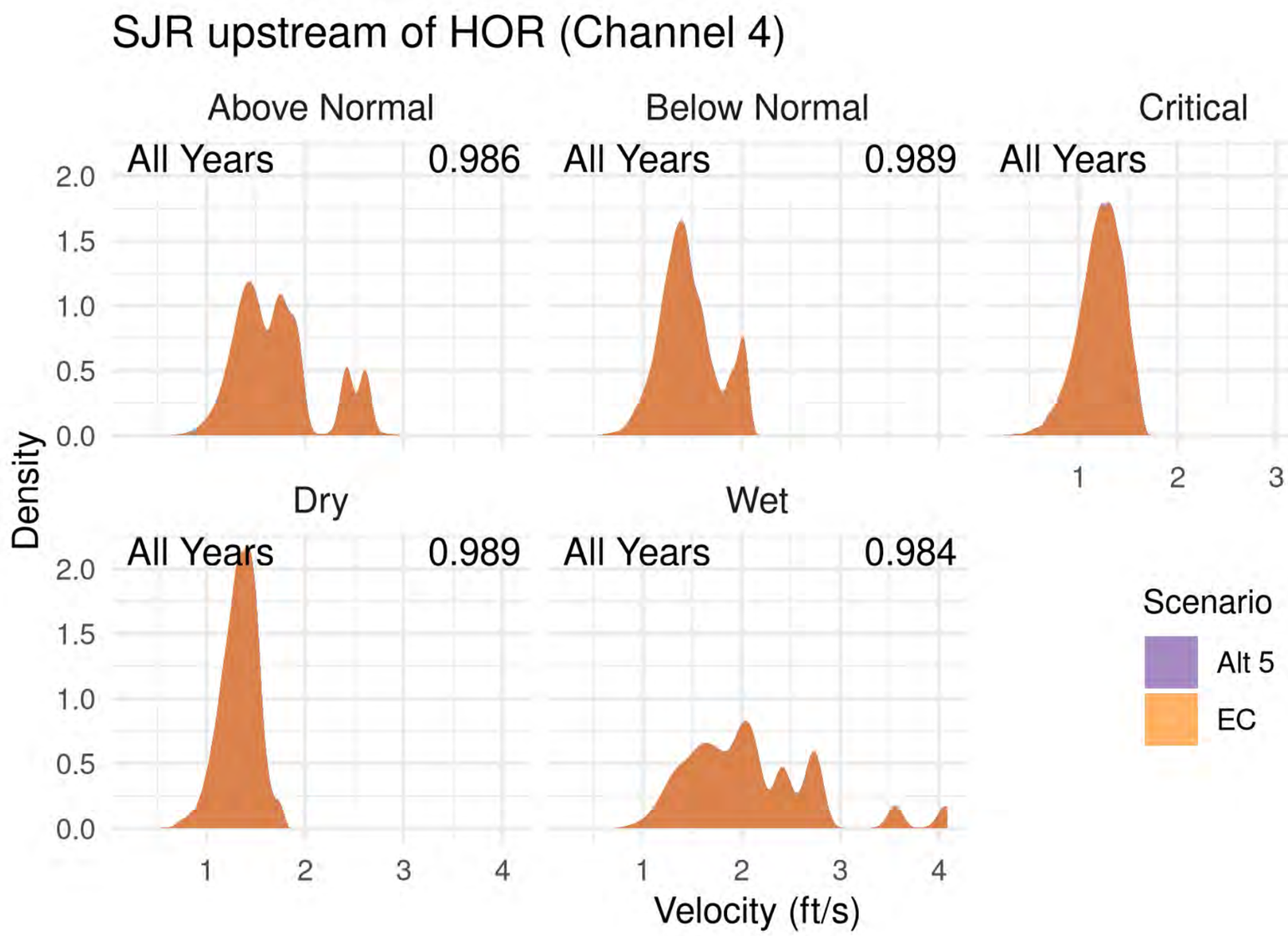

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-111. Velocity Density Distribution for Vernalis (San Joaquin River), January.**



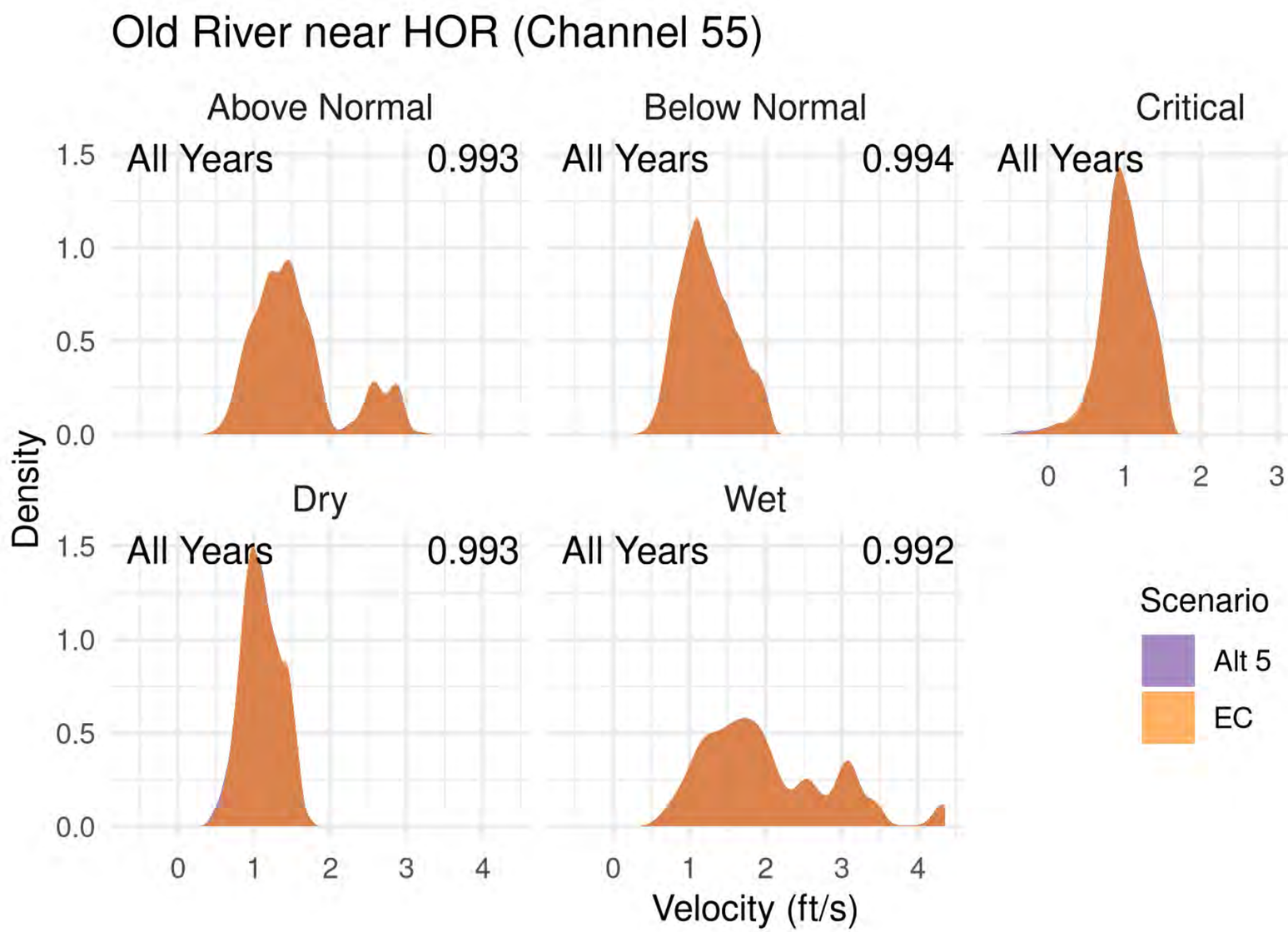

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-112. Velocity Density Distribution for Mossdale (San Joaquin River), January.**



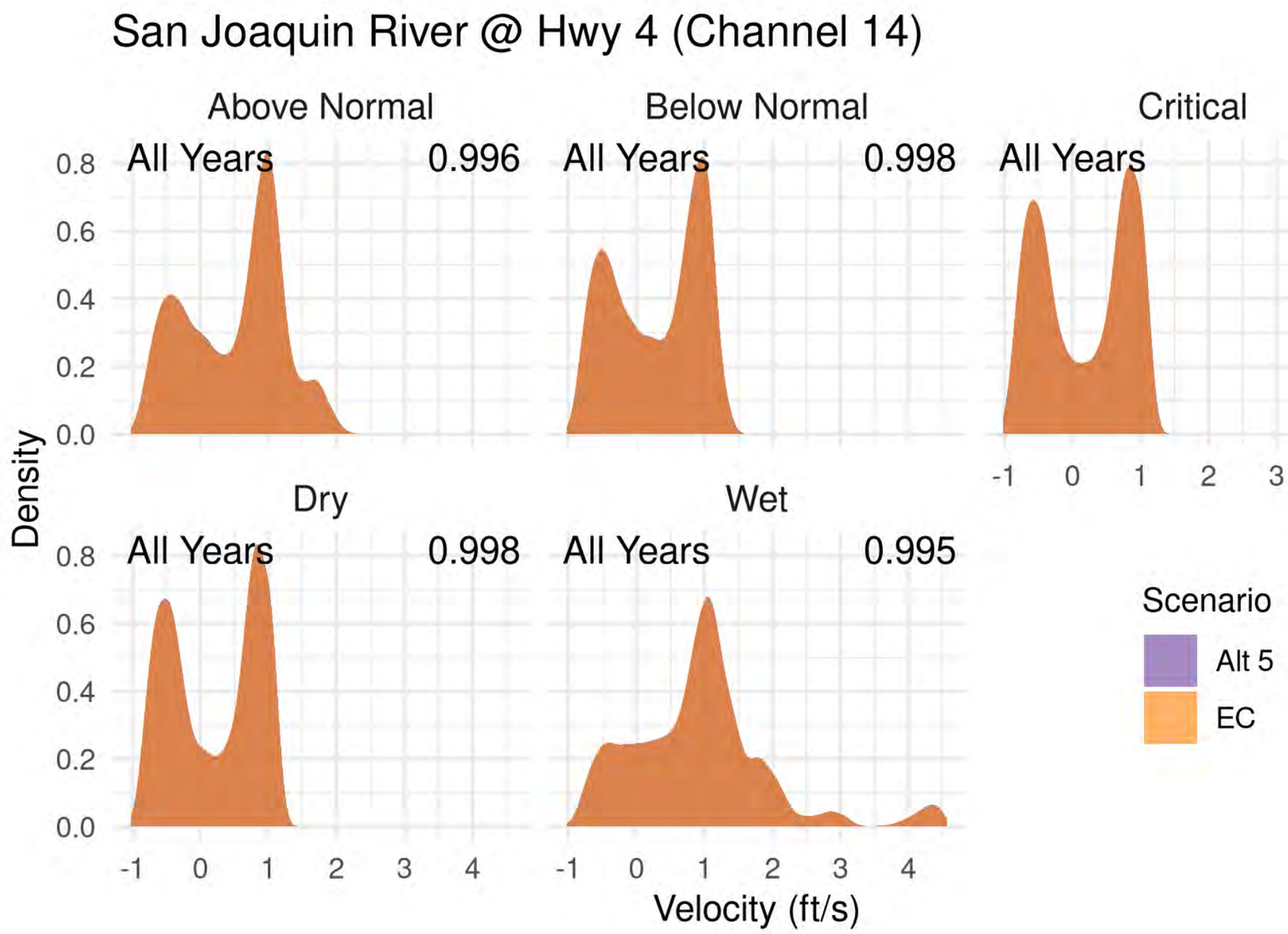

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-113. Velocity Density Distribution for San Joaquin River upstream of Head of Old River, January.**



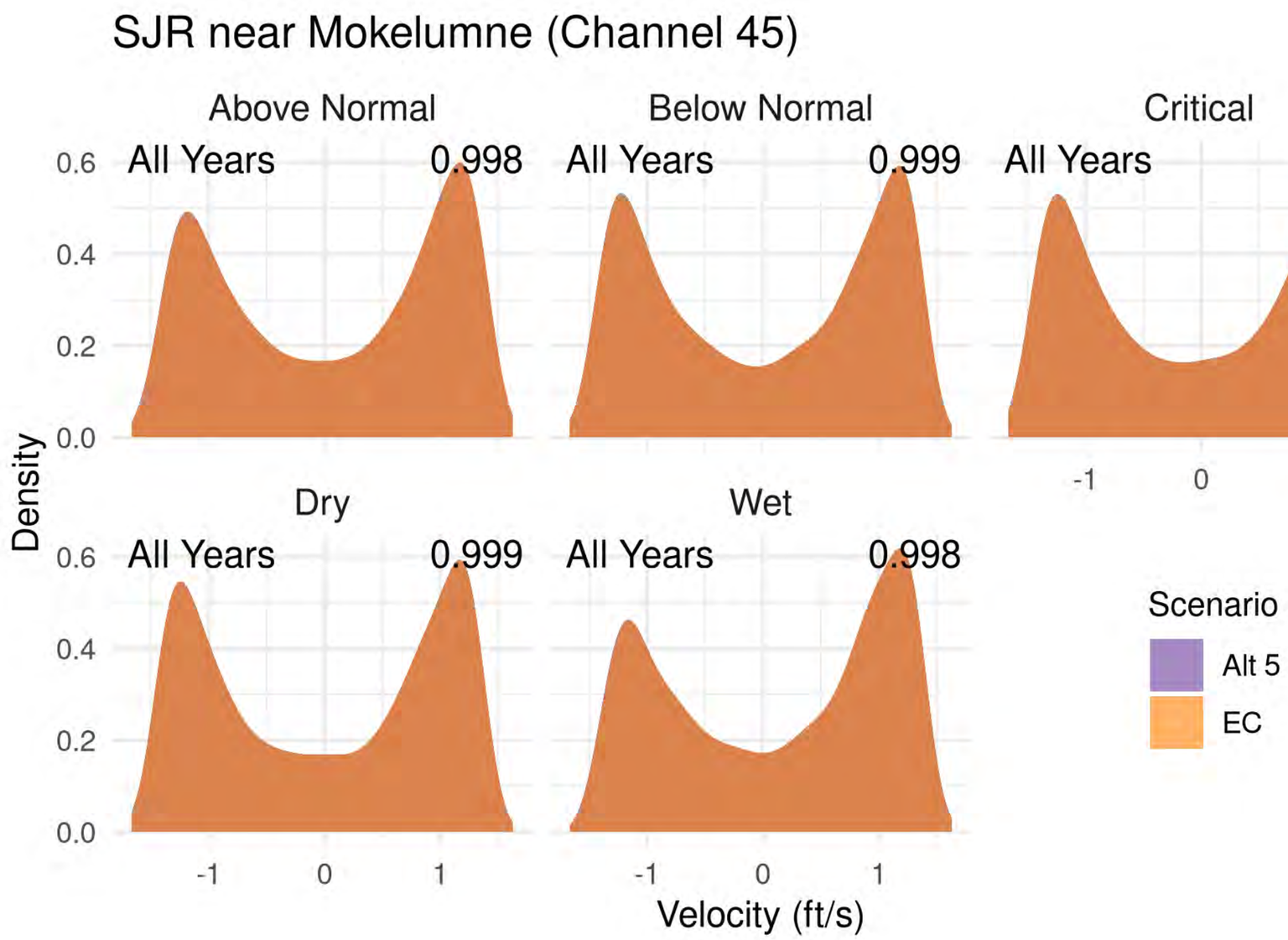

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-114. Velocity Density Distribution for San Joaquin River near Head of Old River, January.**



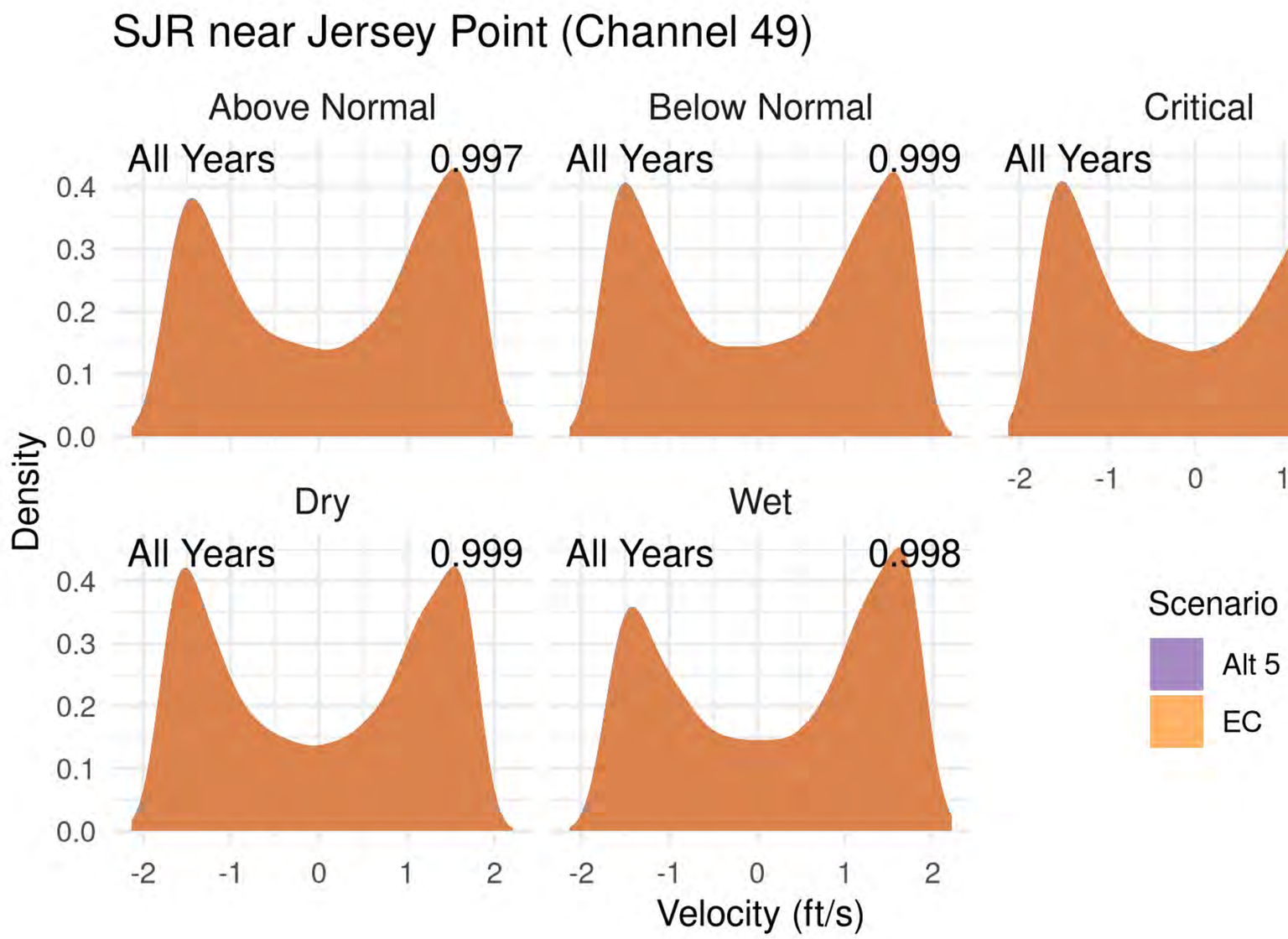

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-115. Velocity Density Distribution for San Joaquin River at Highway 4, January.**



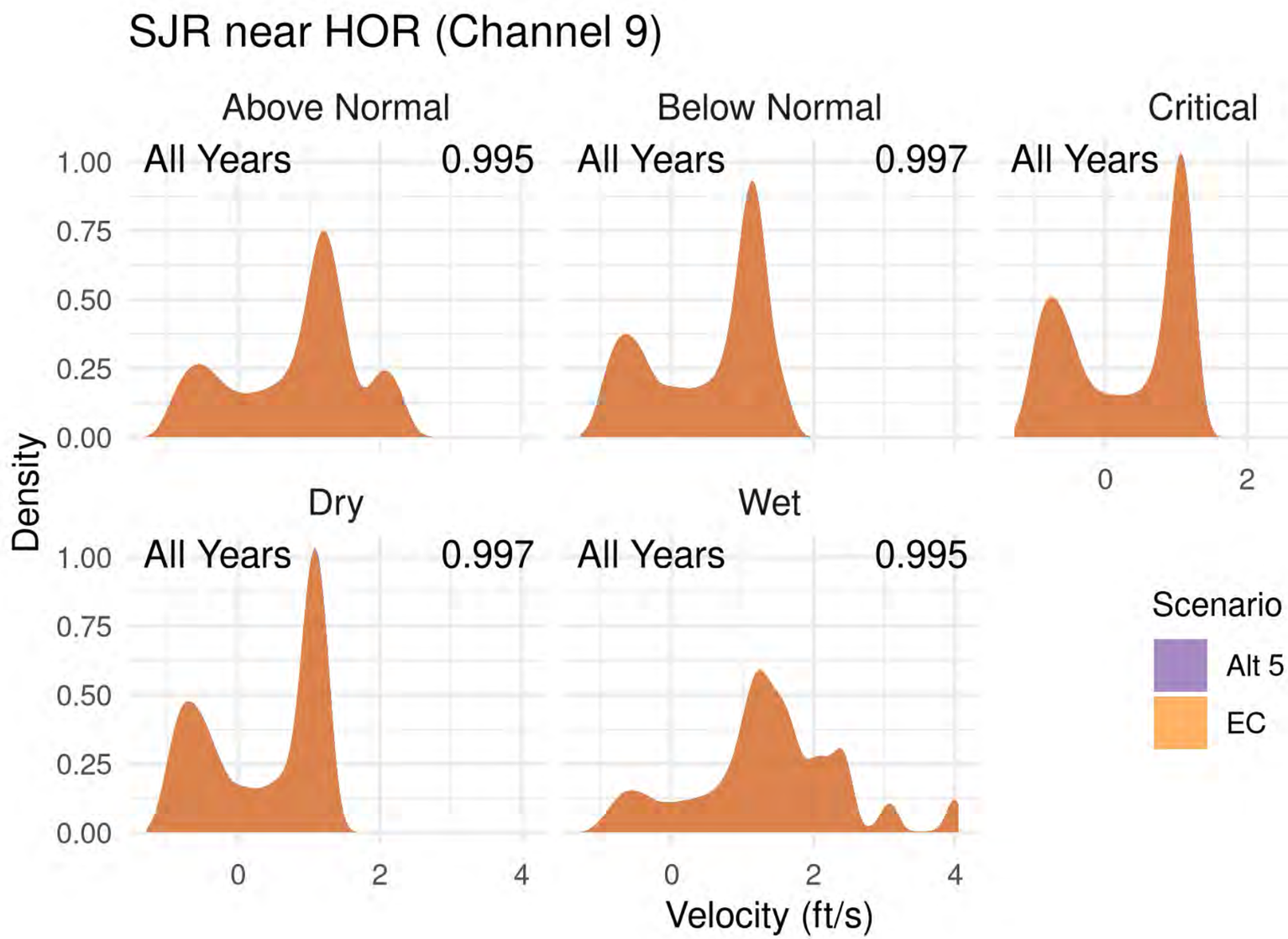

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-116. Velocity Density Distribution for San Joaquin River near Mokelumne River, January.**



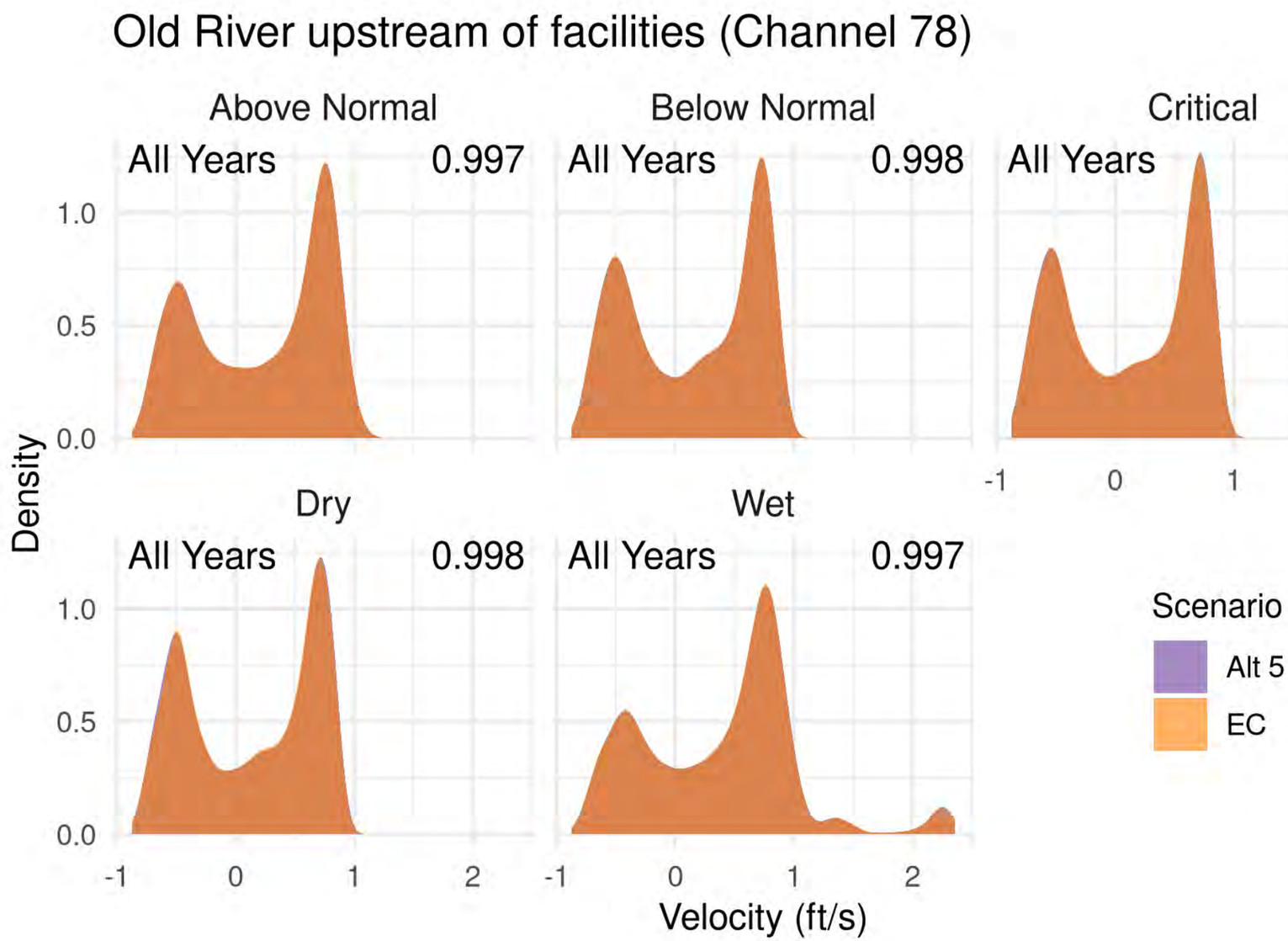

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-117. Velocity Density Distribution for San Joaquin River near Jersey Point, January.**



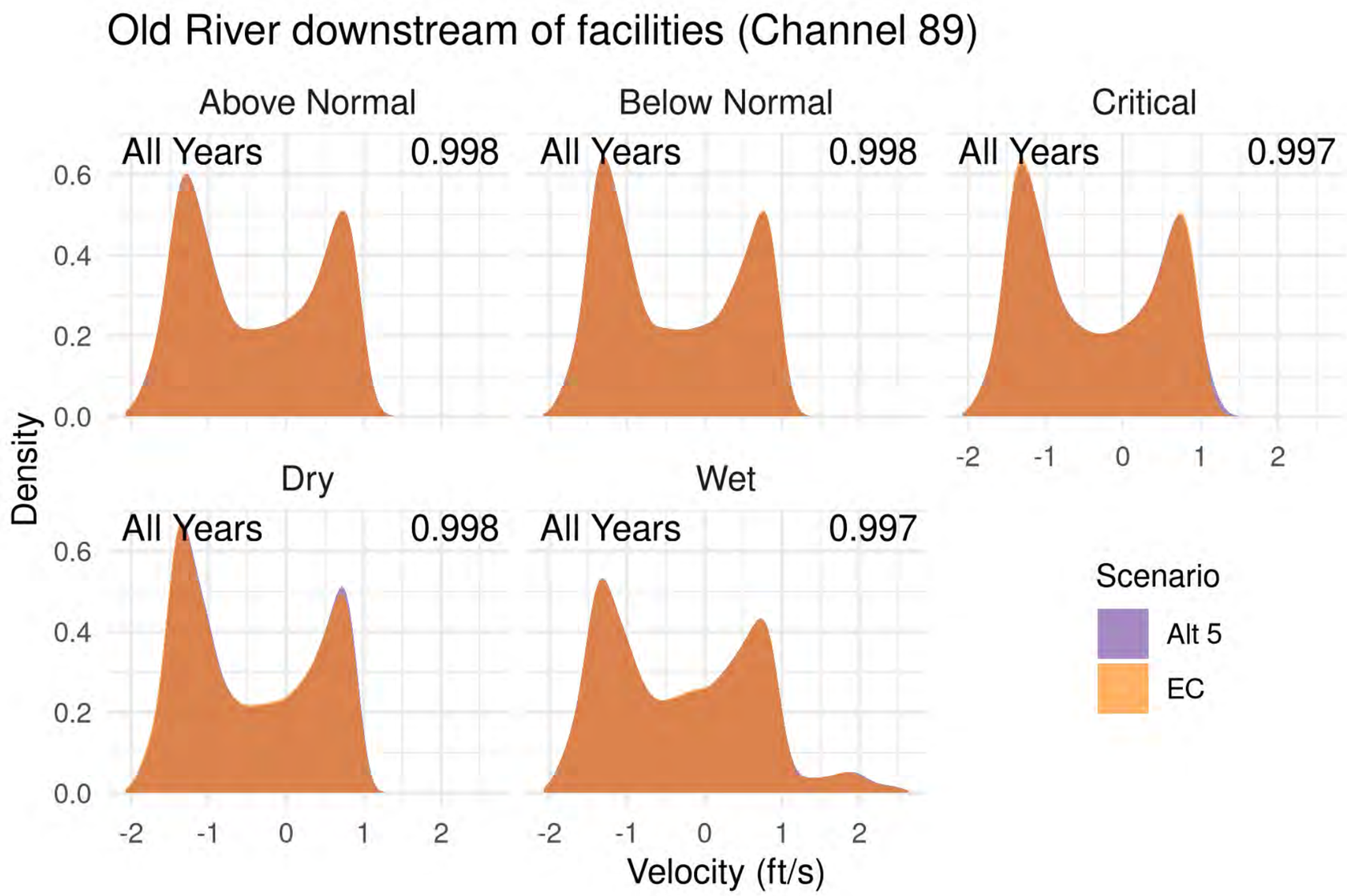

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-118. Velocity Density Distribution for Old River near Head of Old River, January.**



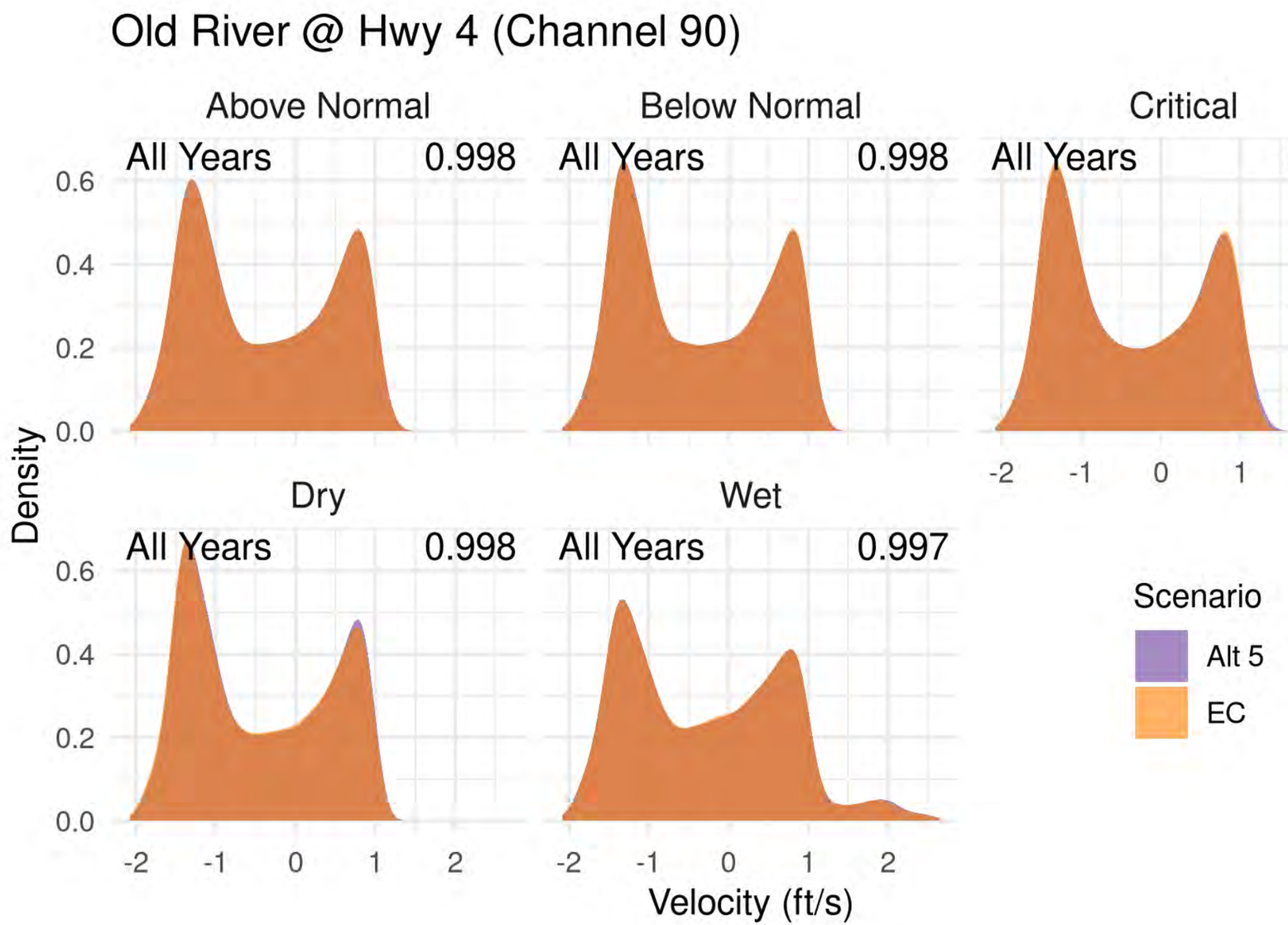

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-119. Velocity Density Distribution for Old River upstream of the South Delta Export Facilities, January.**



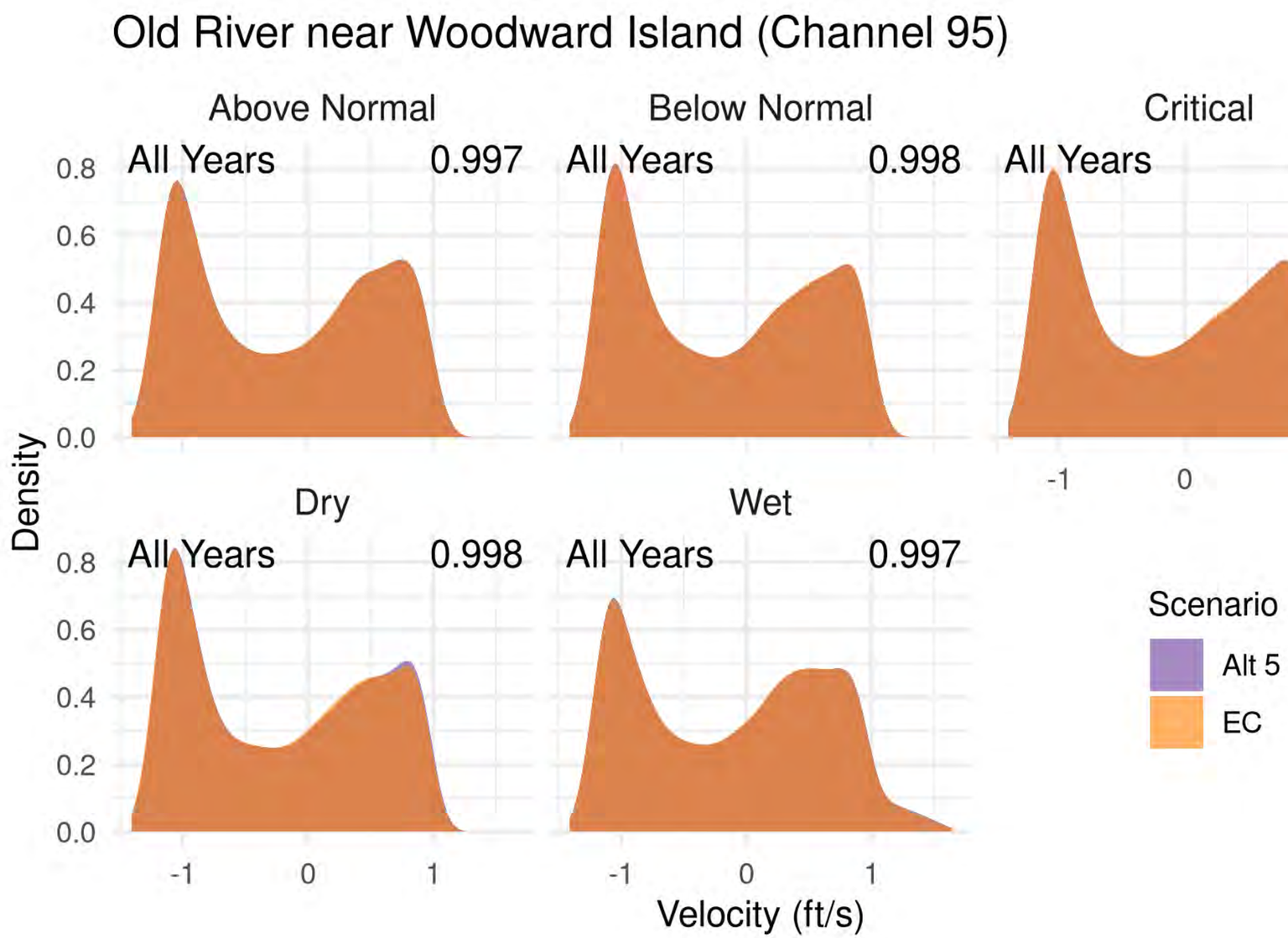

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-120. Velocity Density Distribution for Old River Downstream of the South Delta Export Facilities, January.**



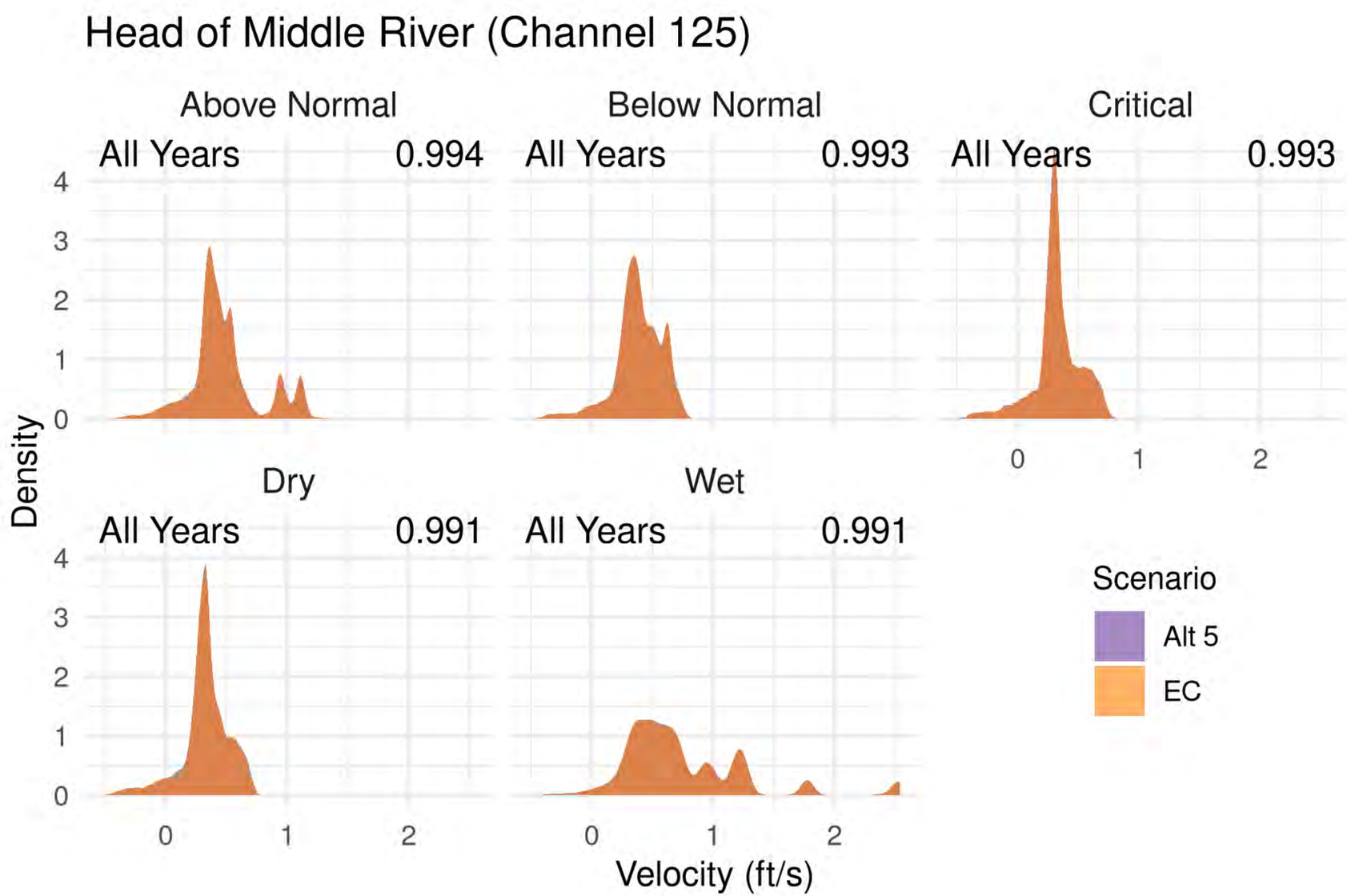

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-121. Velocity Density Distribution for Old River at Highway 4, January.**



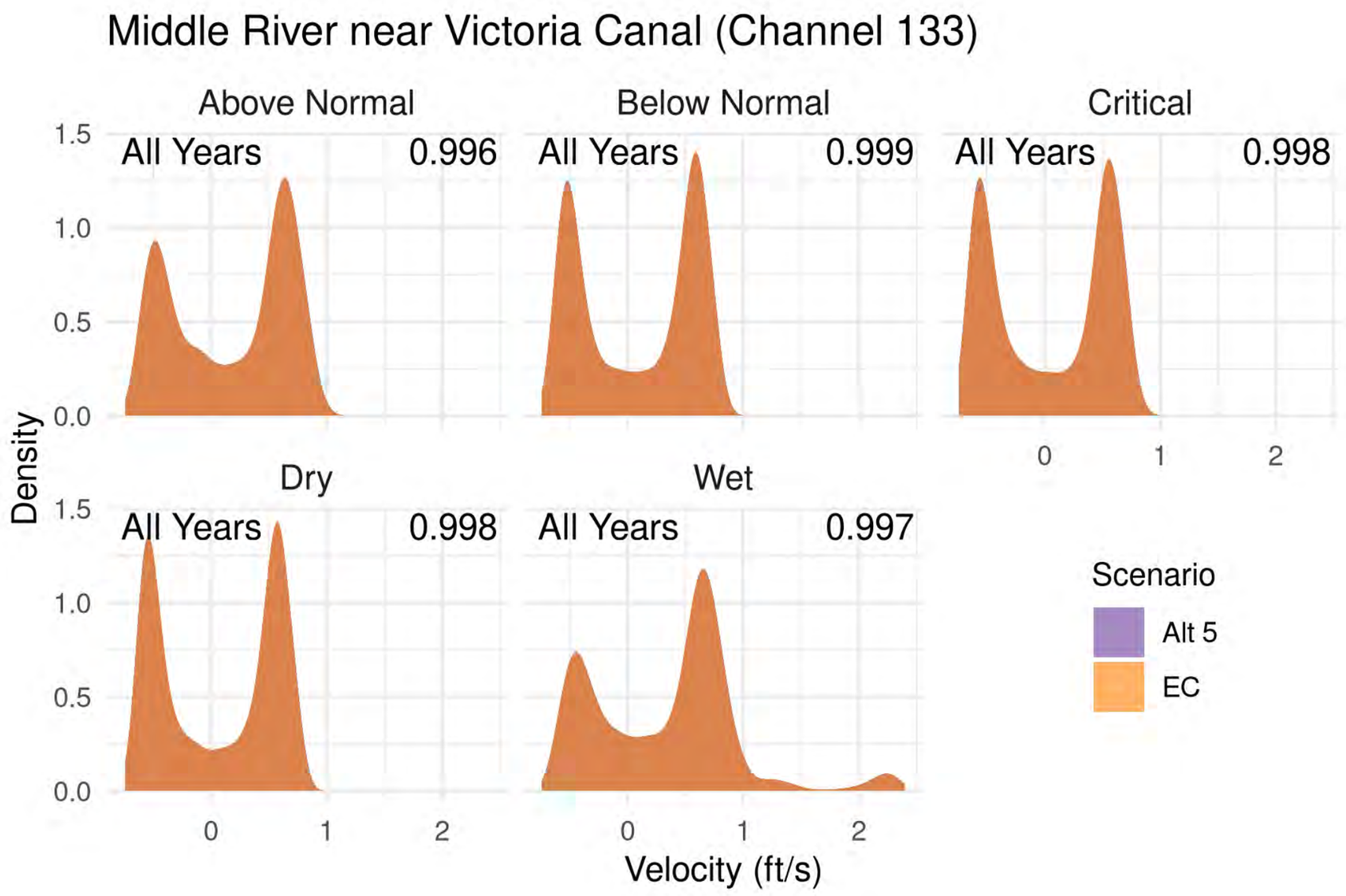

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-122. Velocity Density Distribution for Old River near Woodward Island, January.**



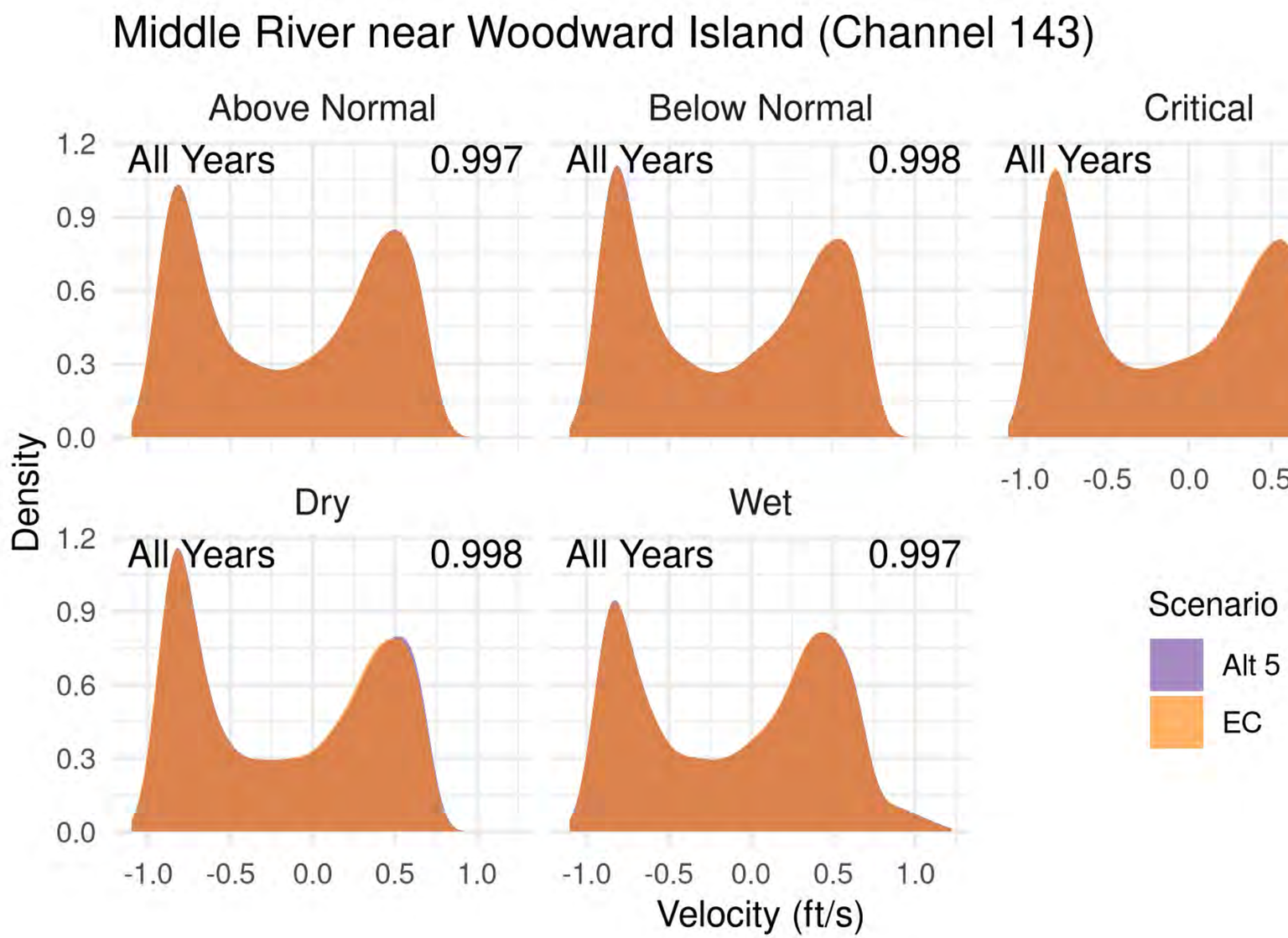

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-123. Velocity Density Distribution for Head of Middle River, January.**



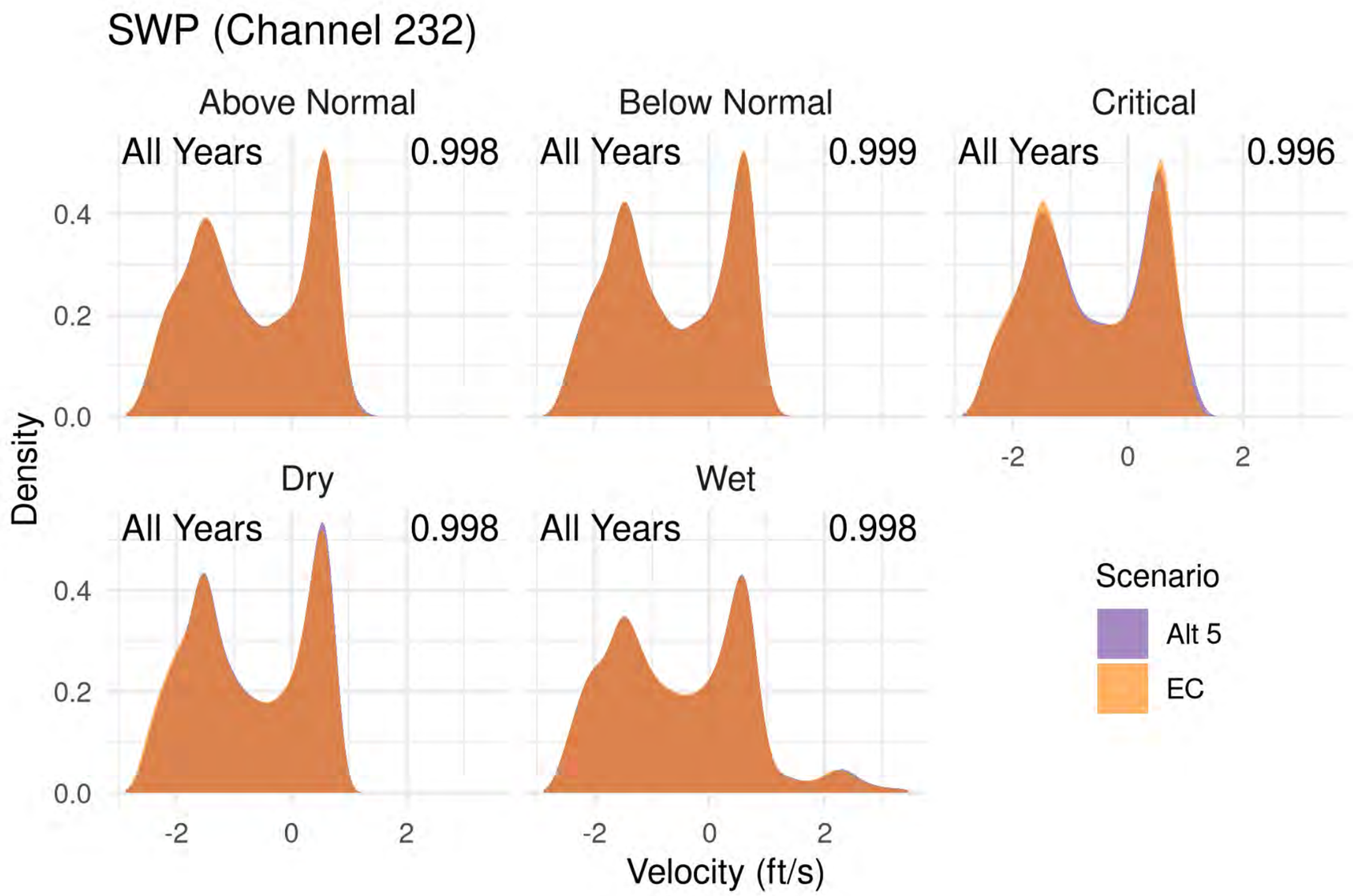

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-124. Velocity Density Distribution for Middle River near Victoria Canal, January.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-125. Velocity Density Distribution for Middle River near Woodward Island, January.**

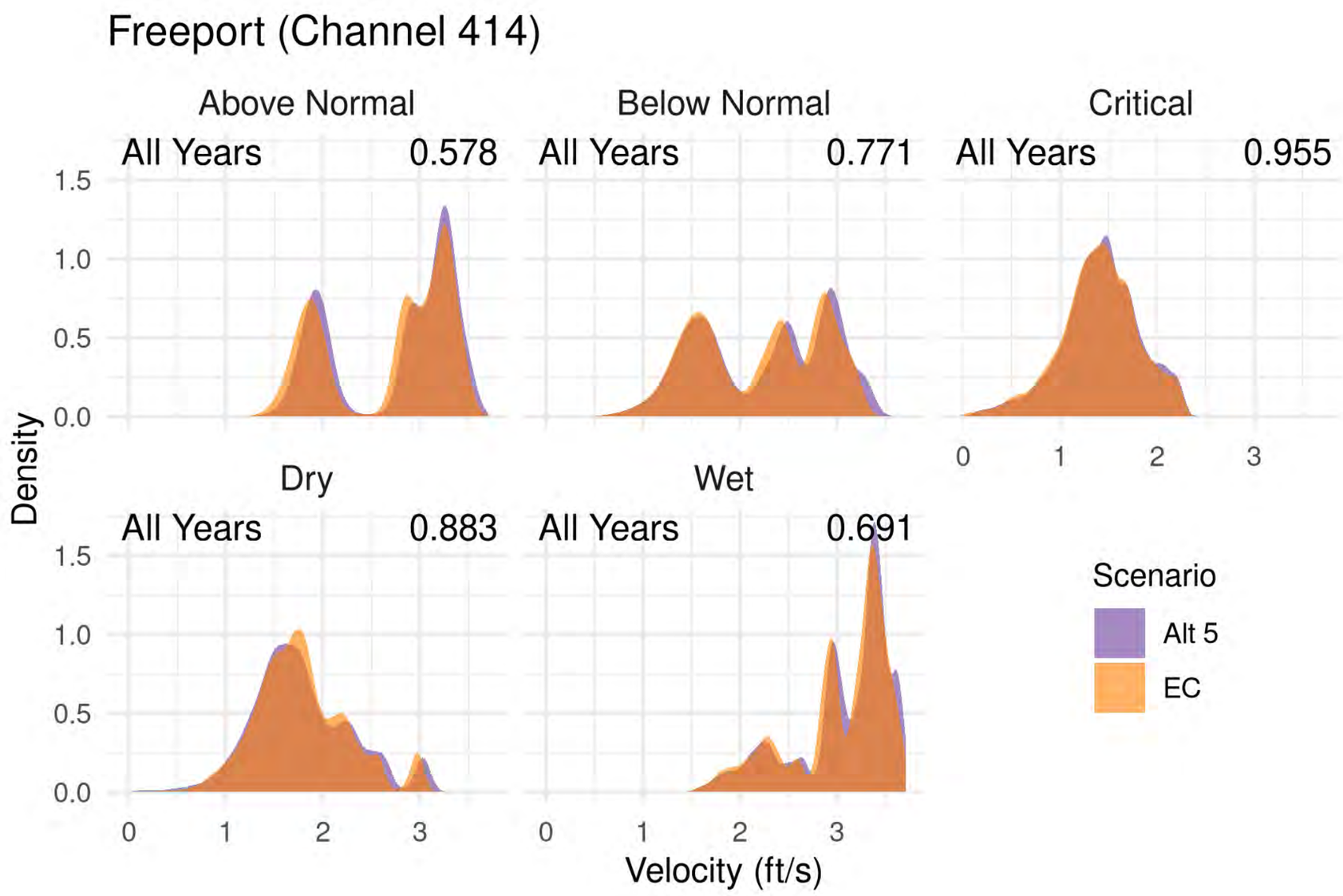



Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-126. Velocity Density Distribution for State Water Project (West Canal near Entrance to Clifton Court Forebay), January.**

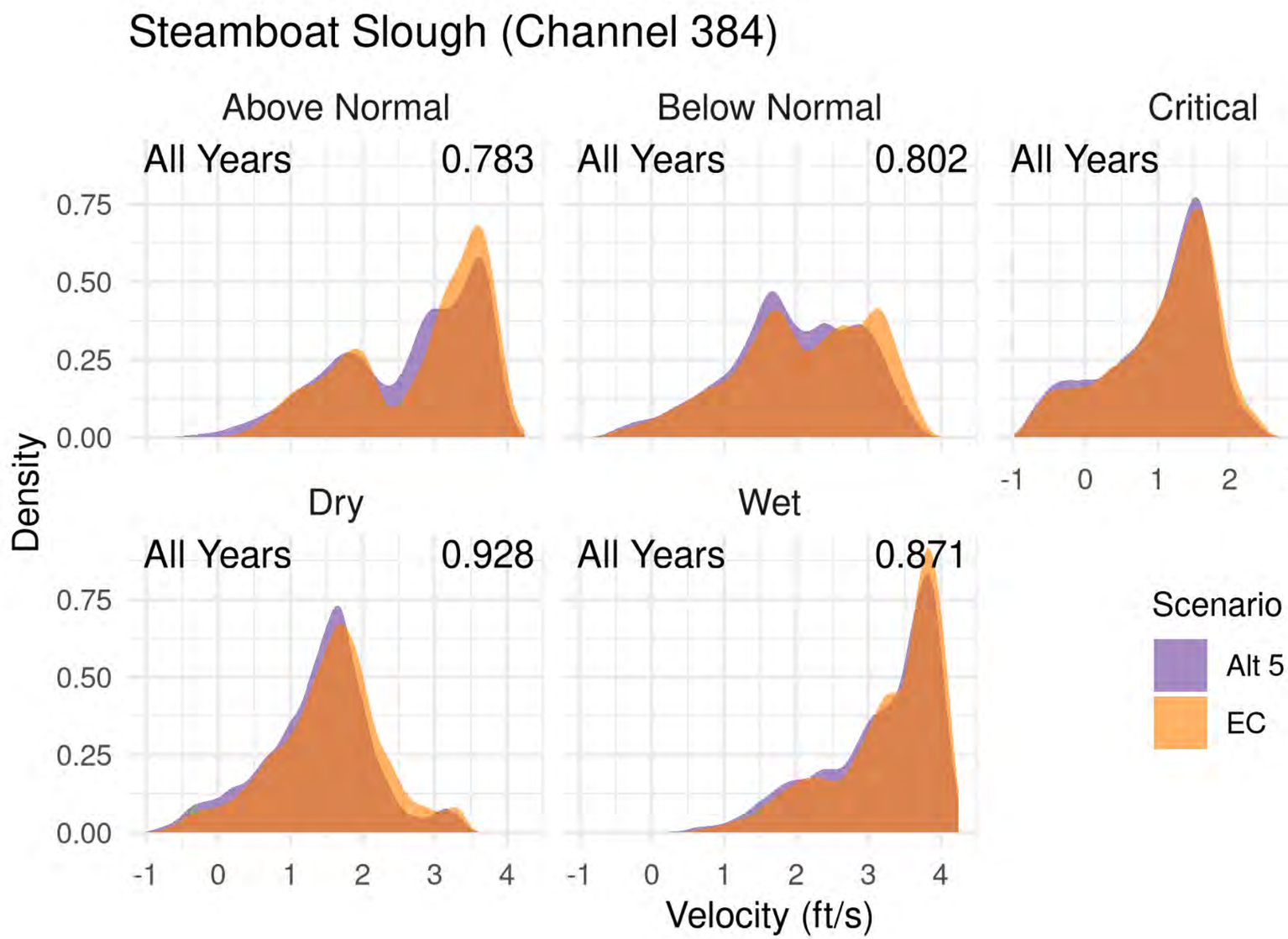
**February**

***Sacramento River Delta***



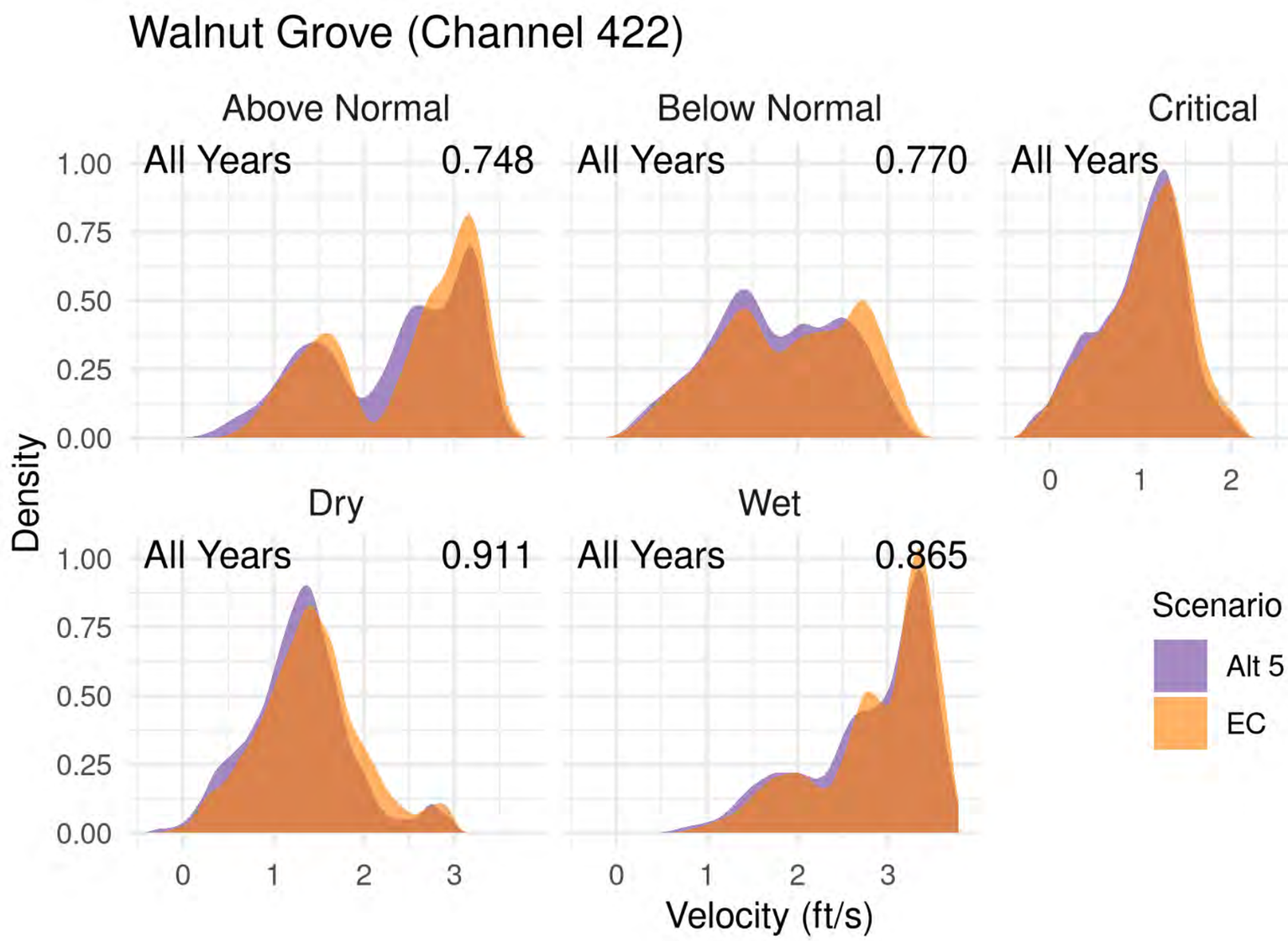

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-127. Velocity Density Distribution for Freeport, February.**



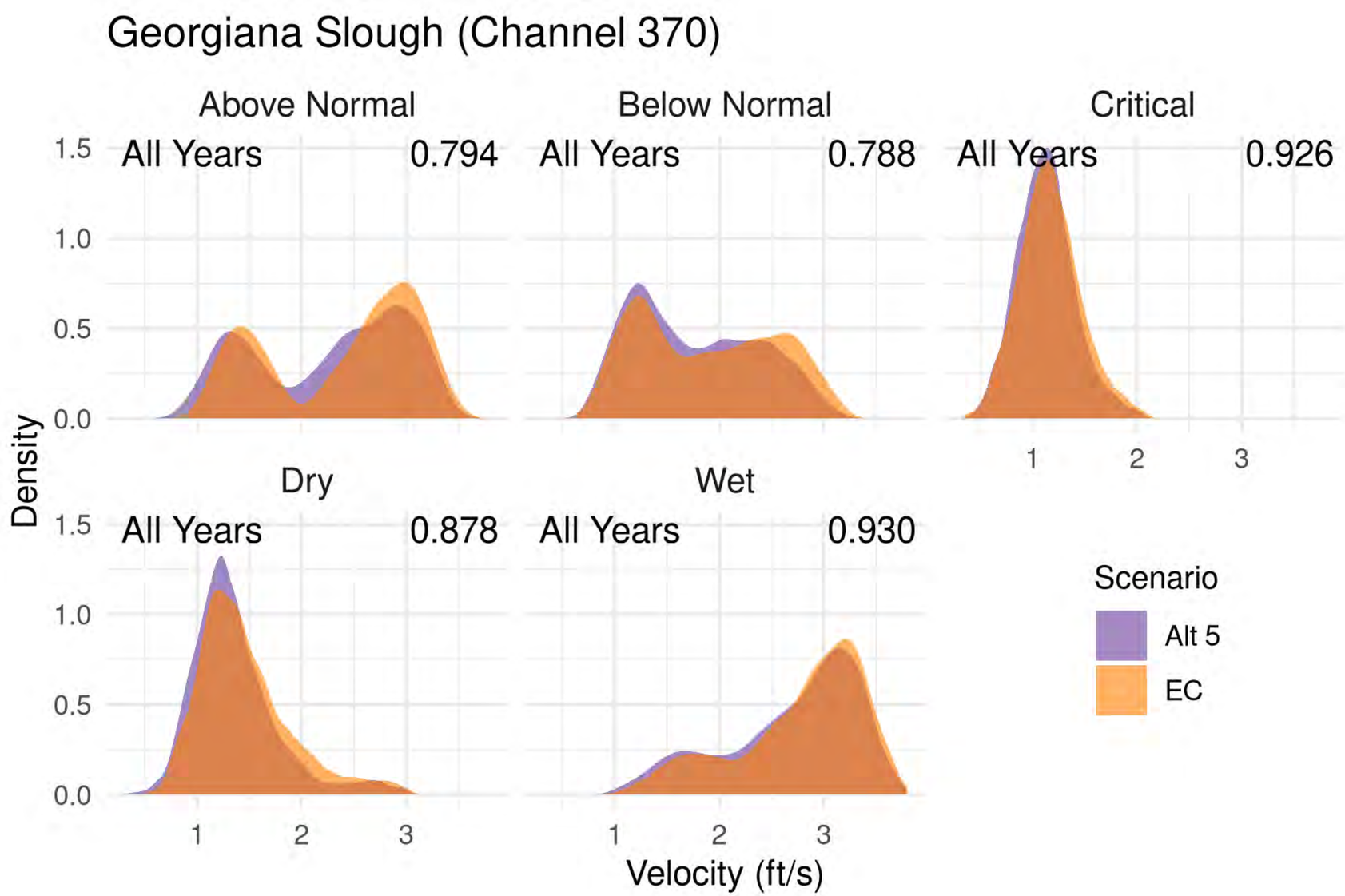

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-128. Velocity Density Distribution for Steamboat Slough, February.**



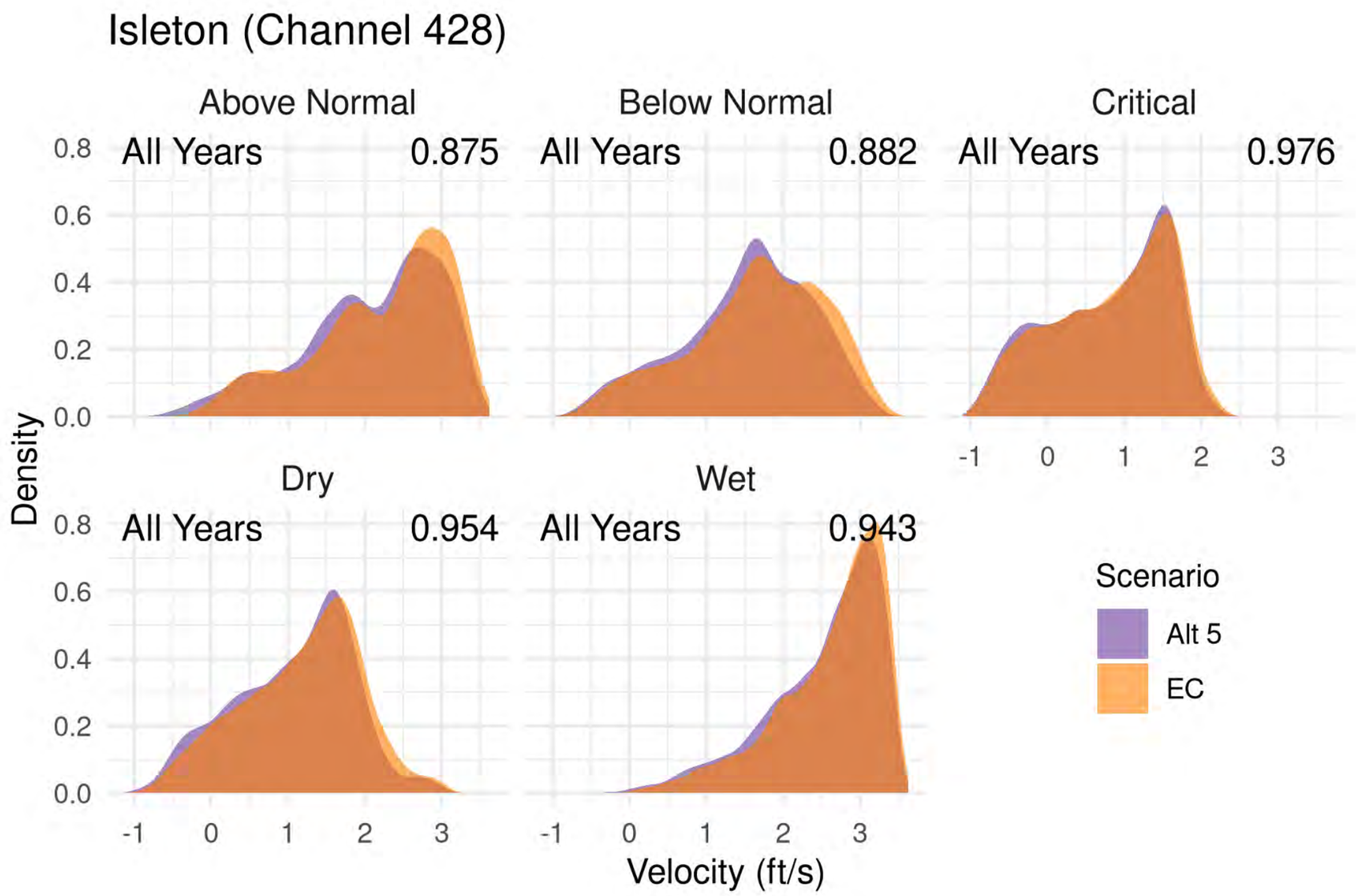

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-129. Velocity Density Distribution for Walnut Grove (Sacramento River), February.**



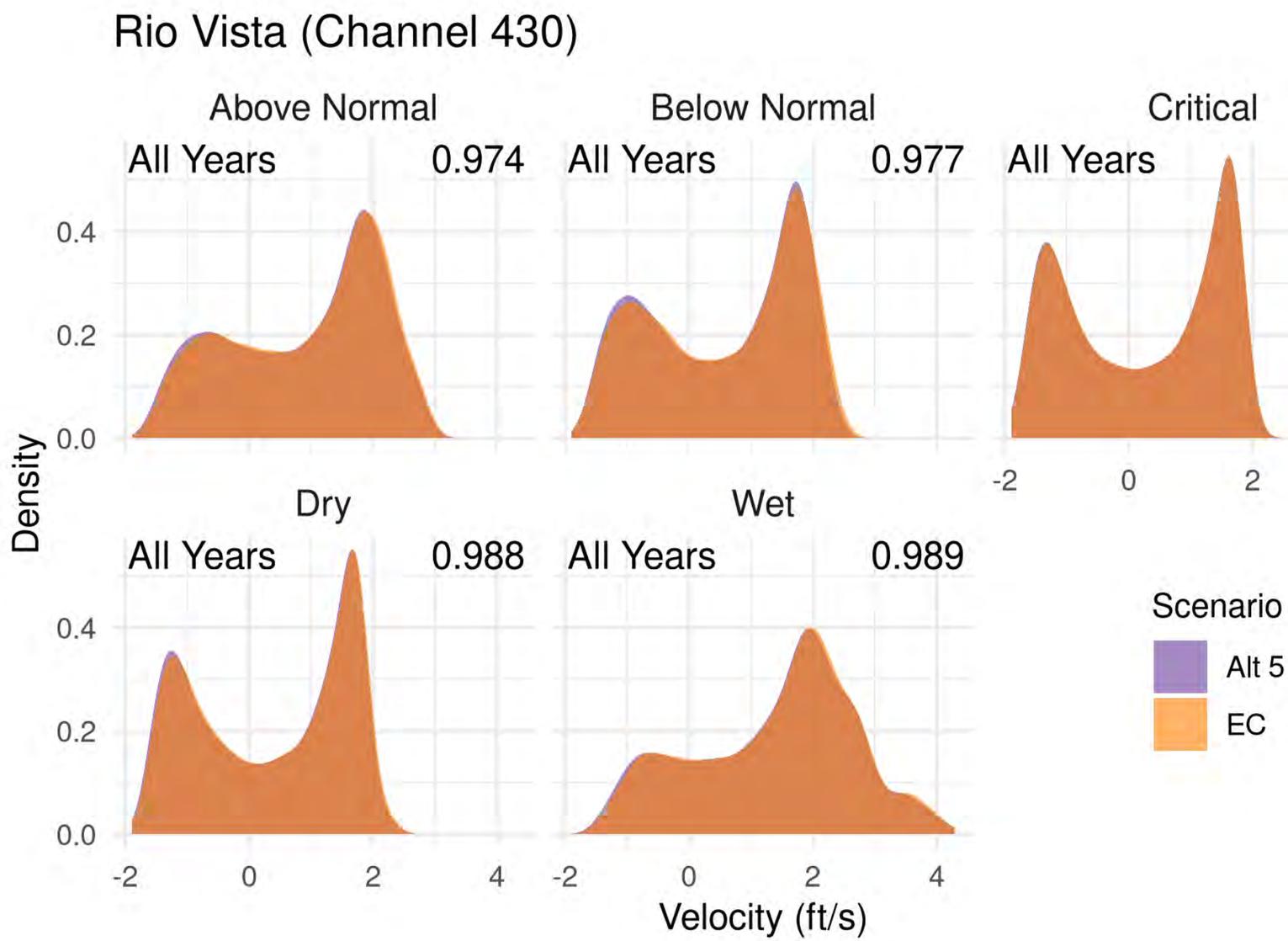

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-130. Velocity Density Distribution for Georgiana Slough, February.**



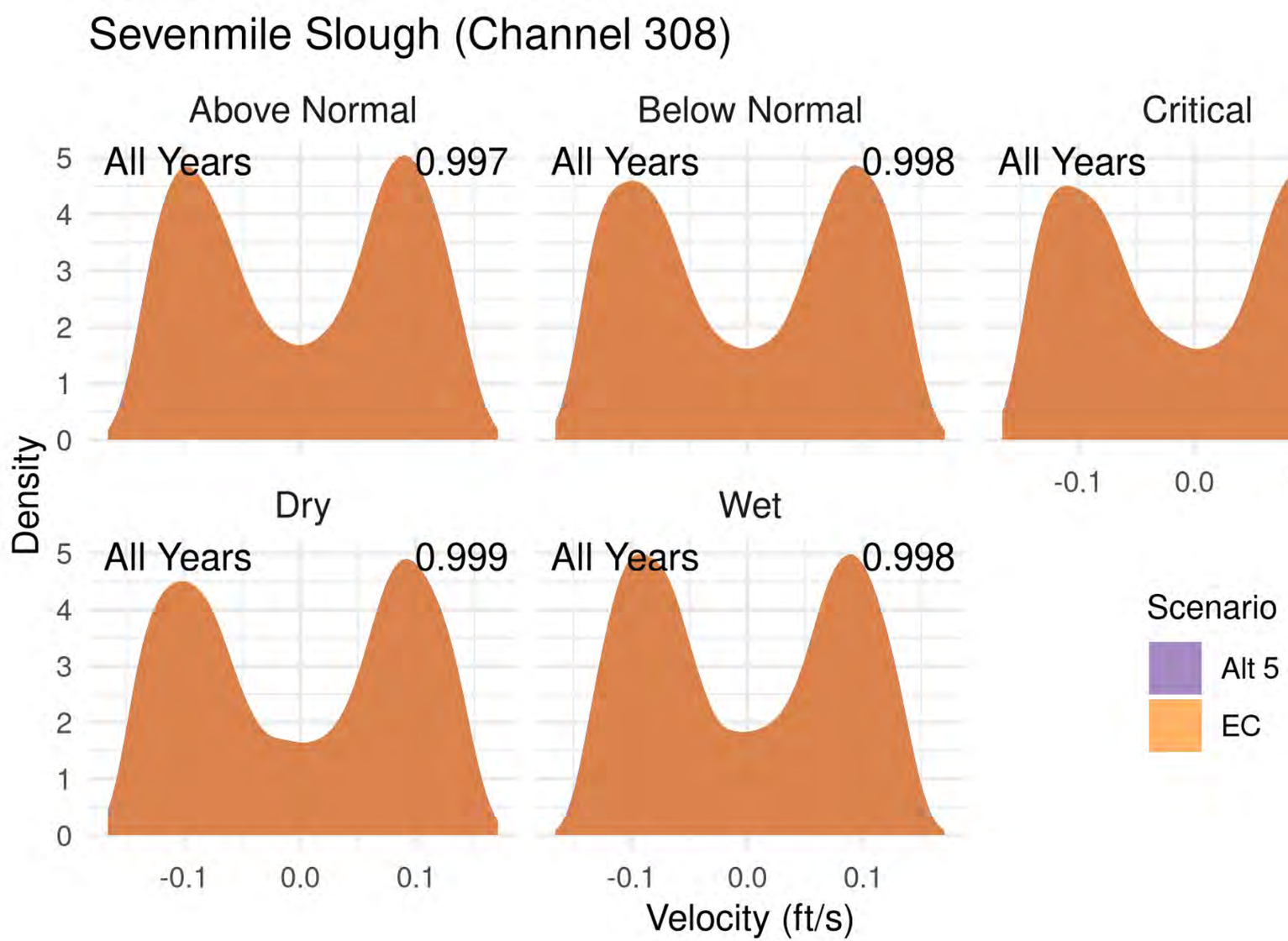

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-131. Velocity Density Distribution for Isleton (Sacramento River), February.**



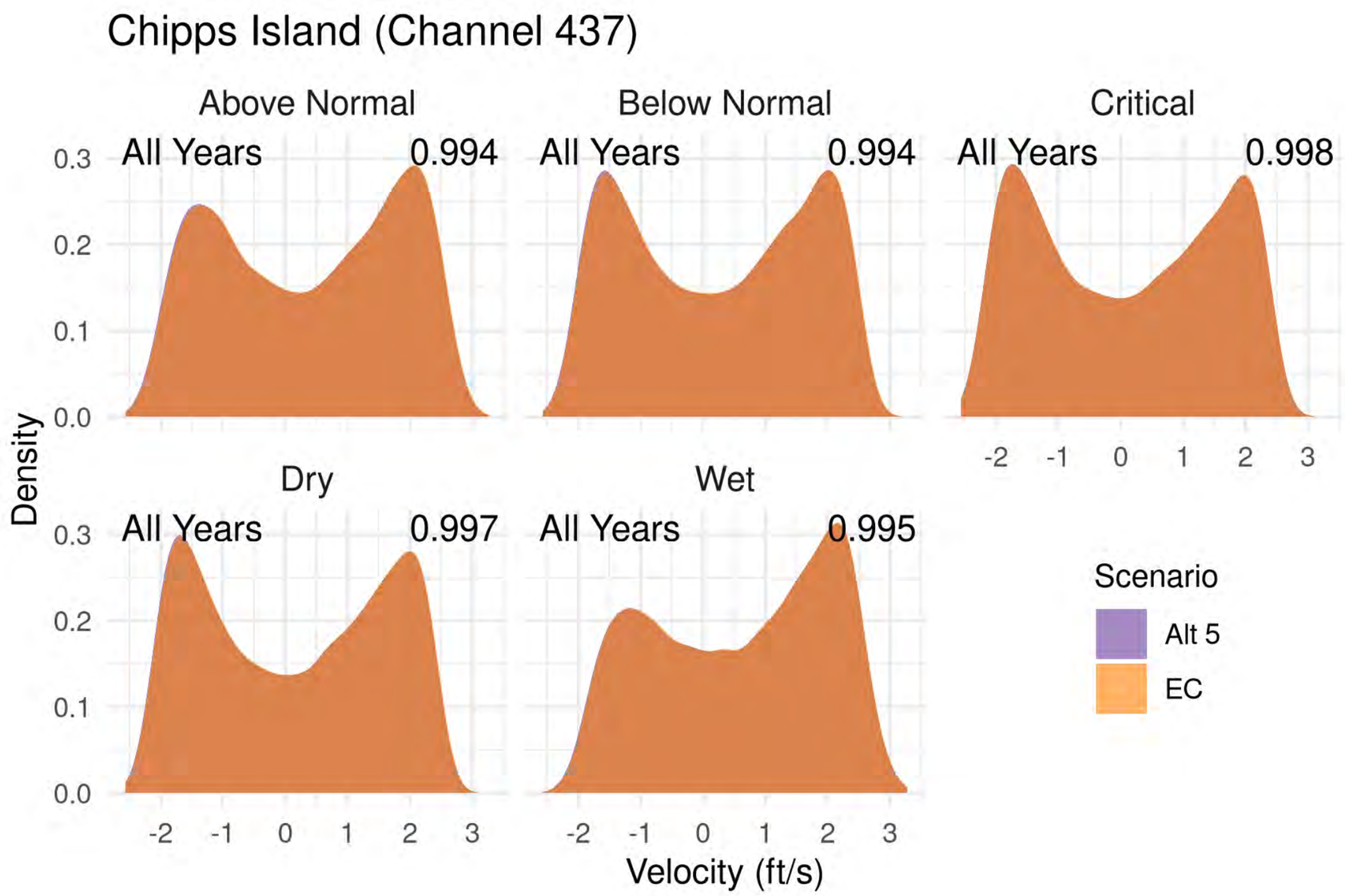

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-132. Velocity Density Distribution for Rio Vista (Sacramento River), February.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

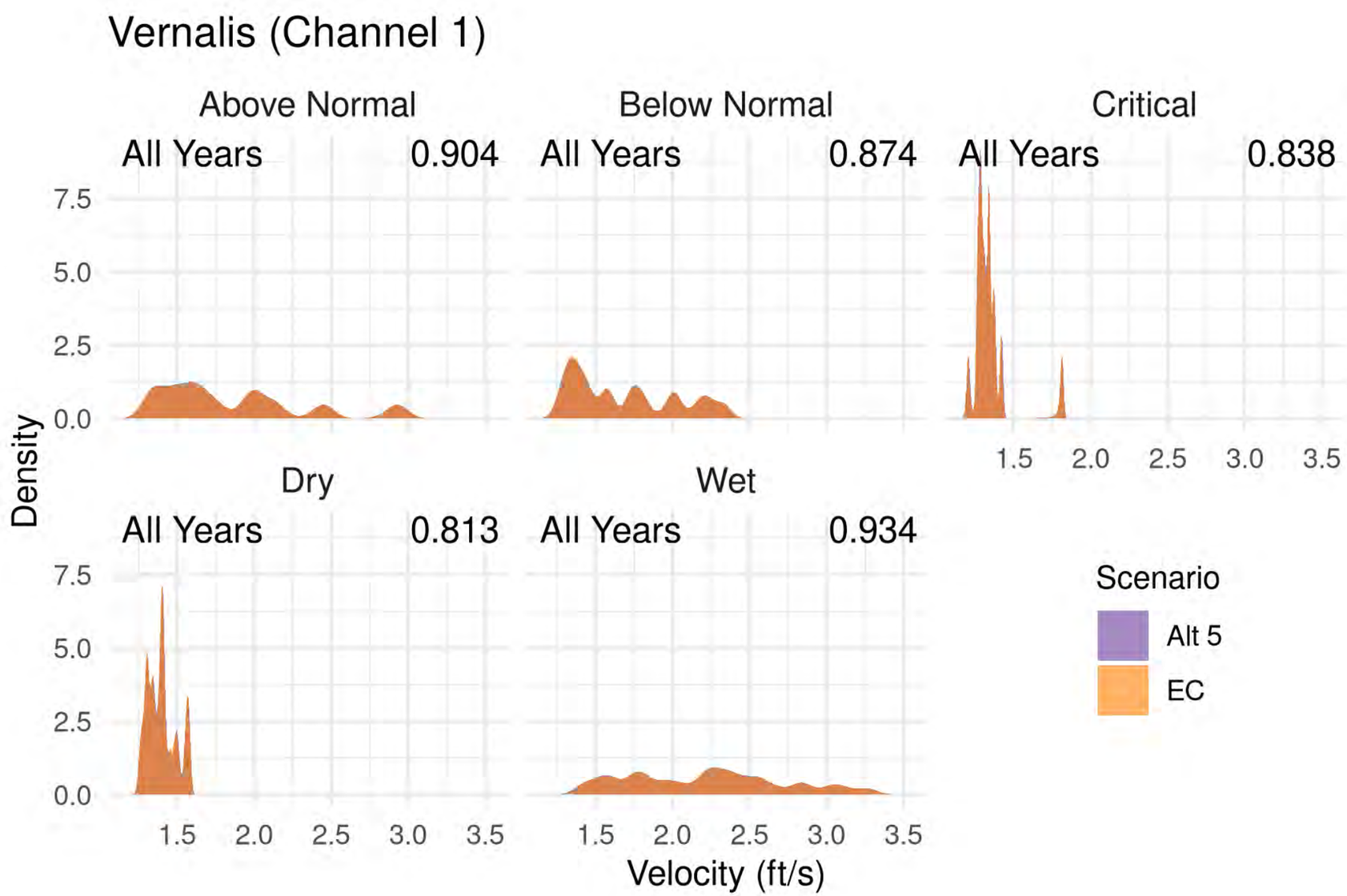
**Figure 5D.1-133. Velocity Density Distribution for Sevenmile Slough, February.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

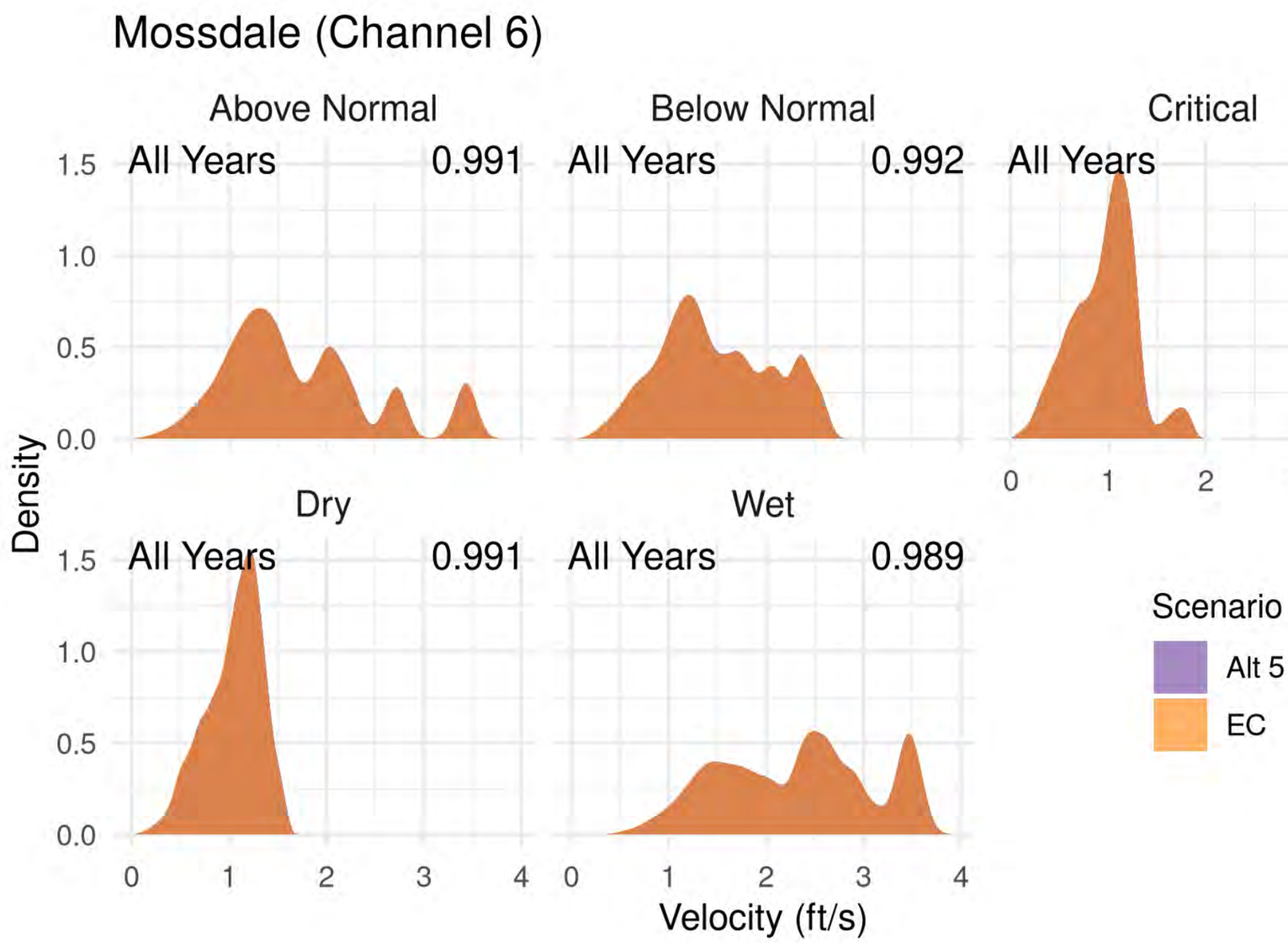
**Figure 5D.1-134. Velocity Density Distribution for Chipps Island (Sacramento River–San Joaquin River Confluence), February.**

***San Joaquin River Delta***



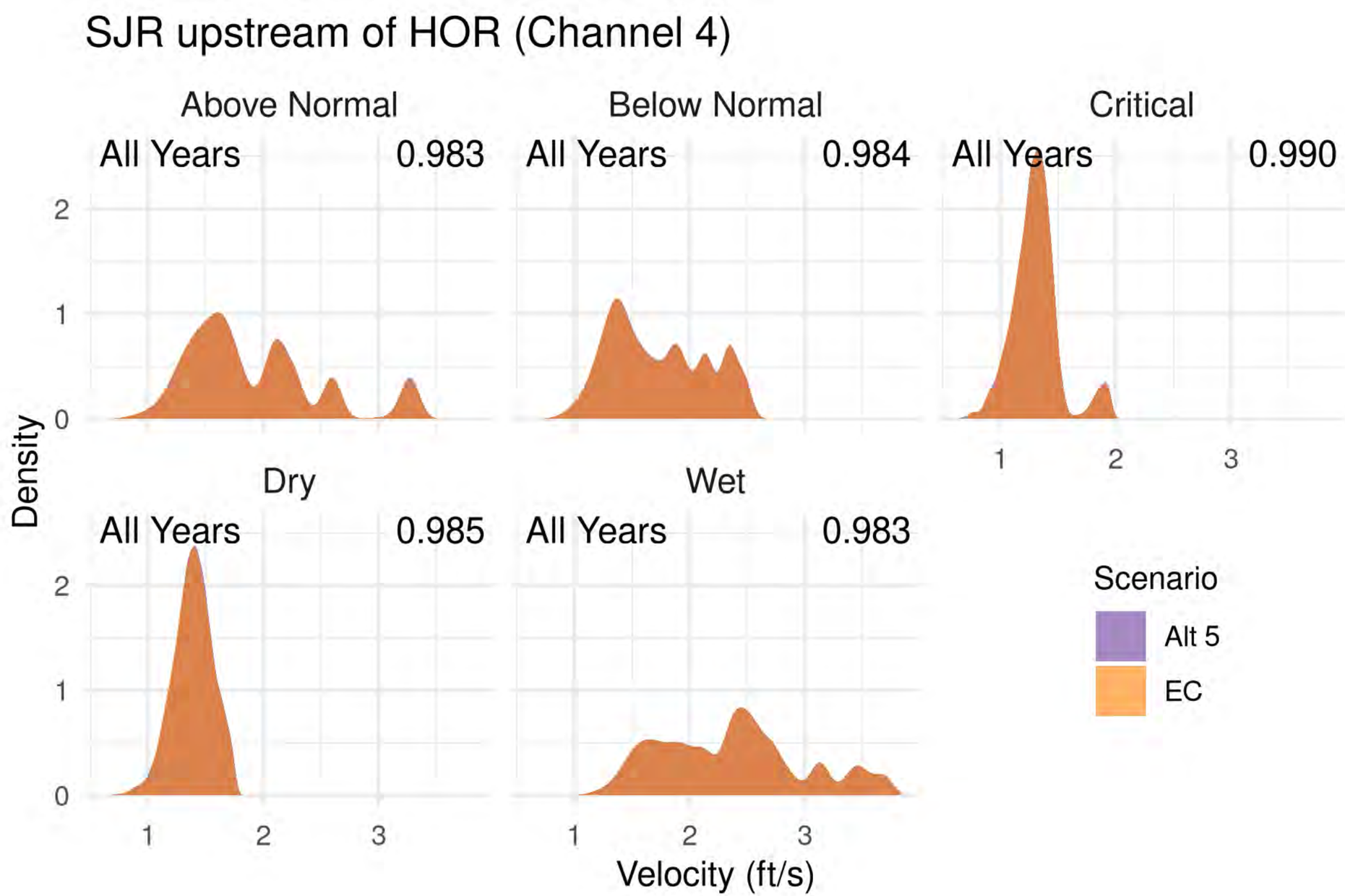

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-135. Velocity Density Distribution for Vernalis (San Joaquin River), February.**



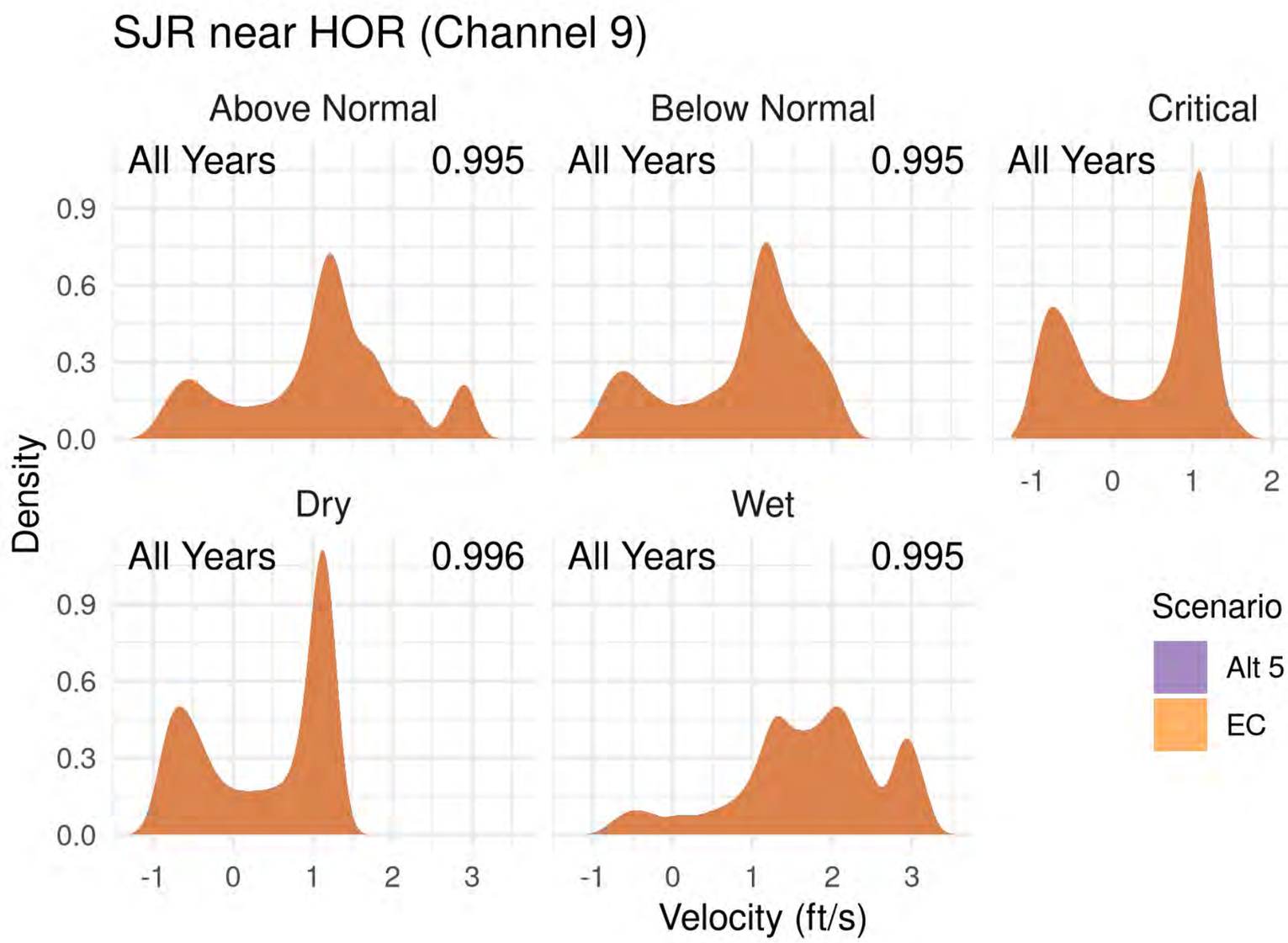

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-136. Velocity Density Distribution for Mossdale (San Joaquin River), February.**



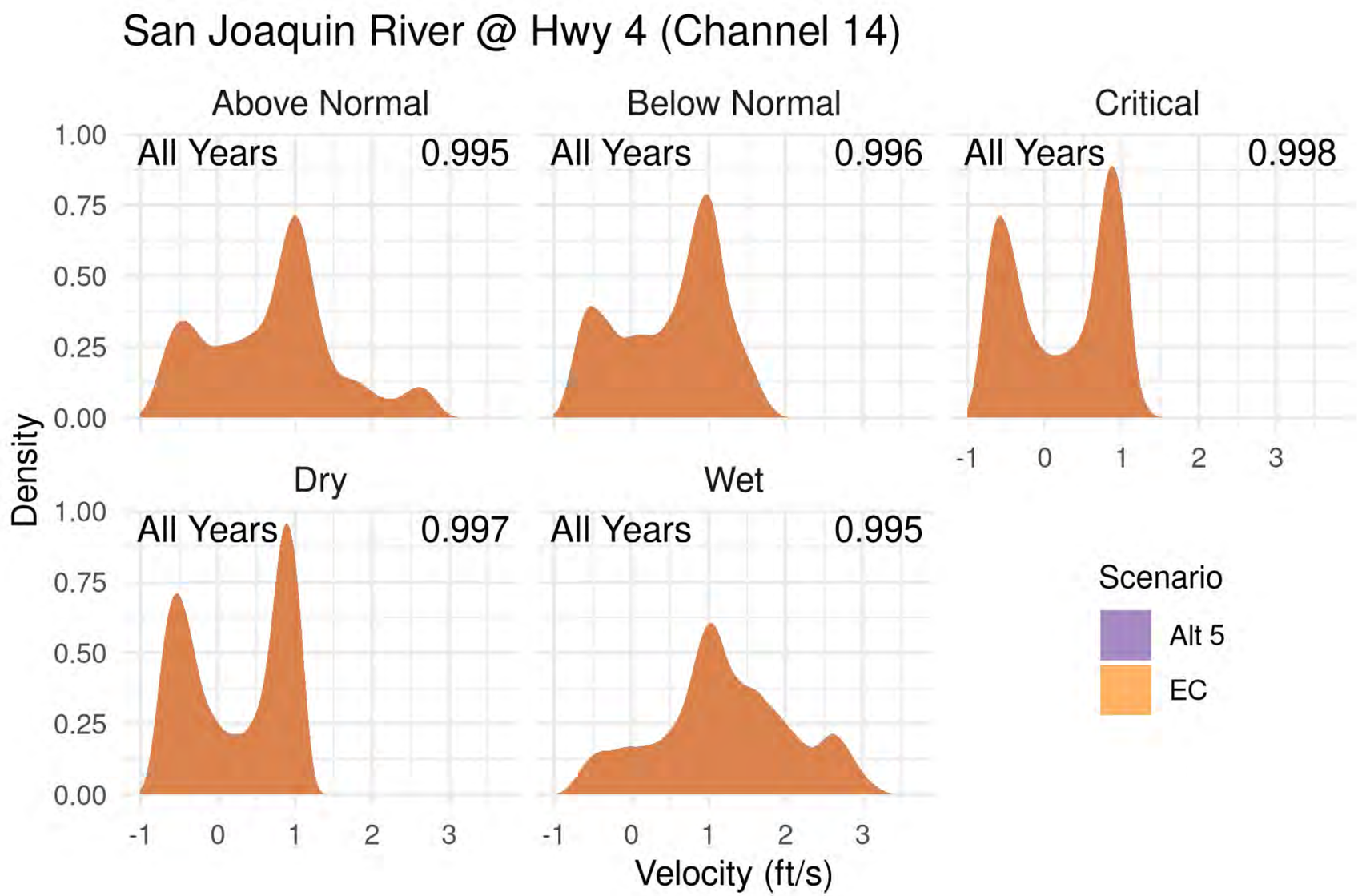

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-137. Velocity Density Distribution for San Joaquin River upstream of Head of Old River, February.**



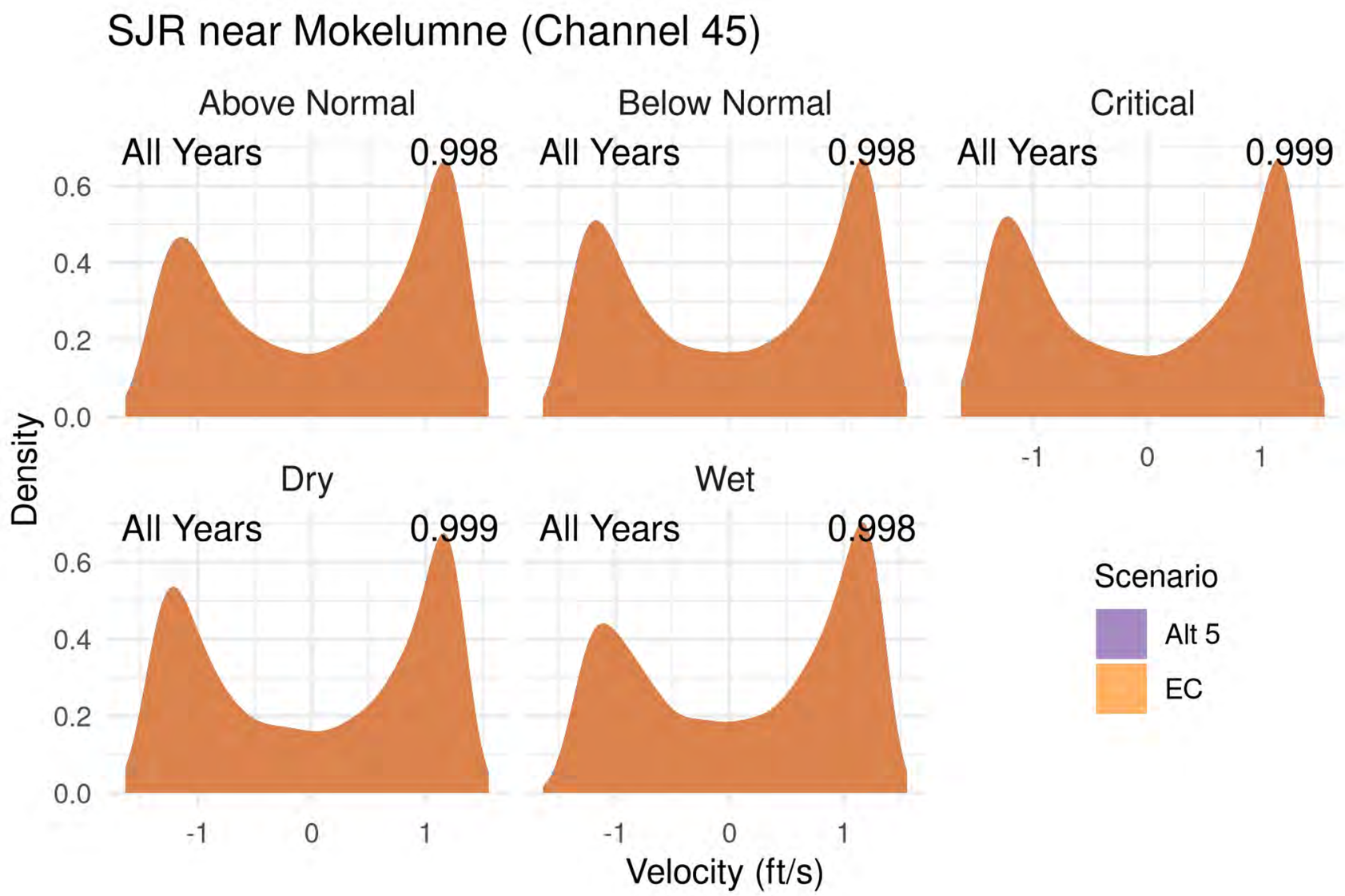

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-138. Velocity Density Distribution for San Joaquin River near Head of Old River, February.**



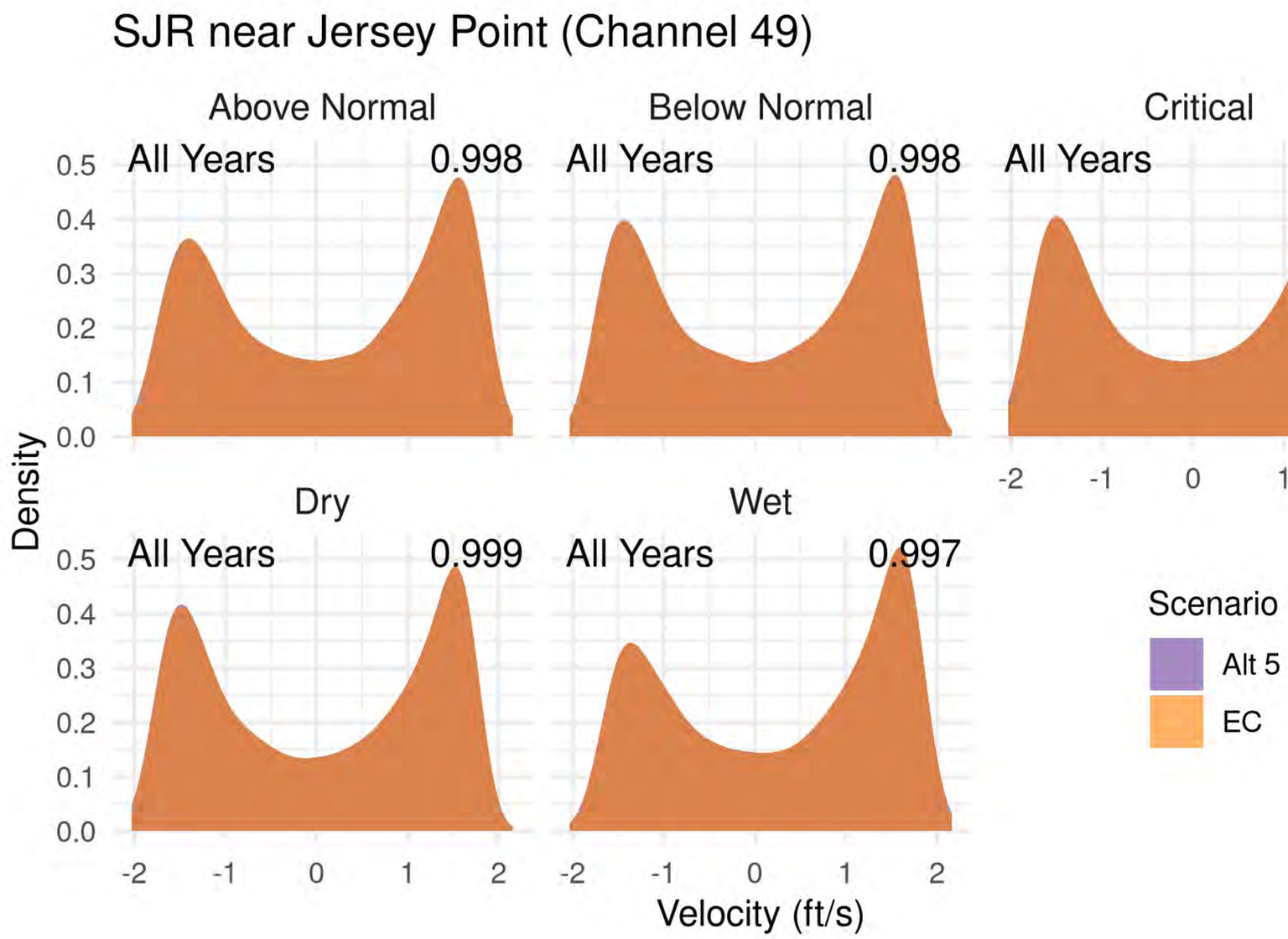

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-139. Velocity Density Distribution for San Joaquin River at Highway 4, February.**



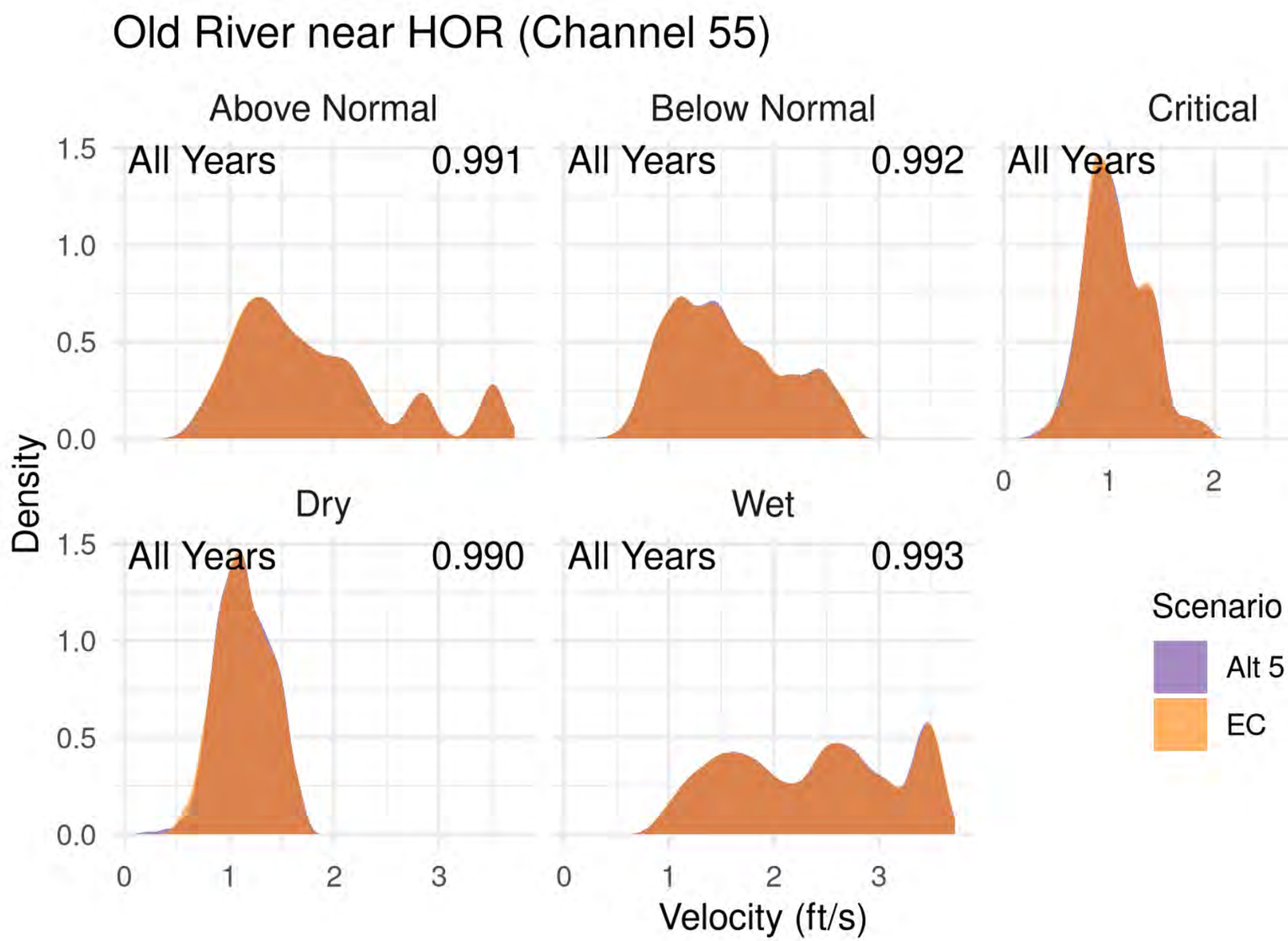

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-140. Velocity Density Distribution for San Joaquin River near Mokelumne River, February.**



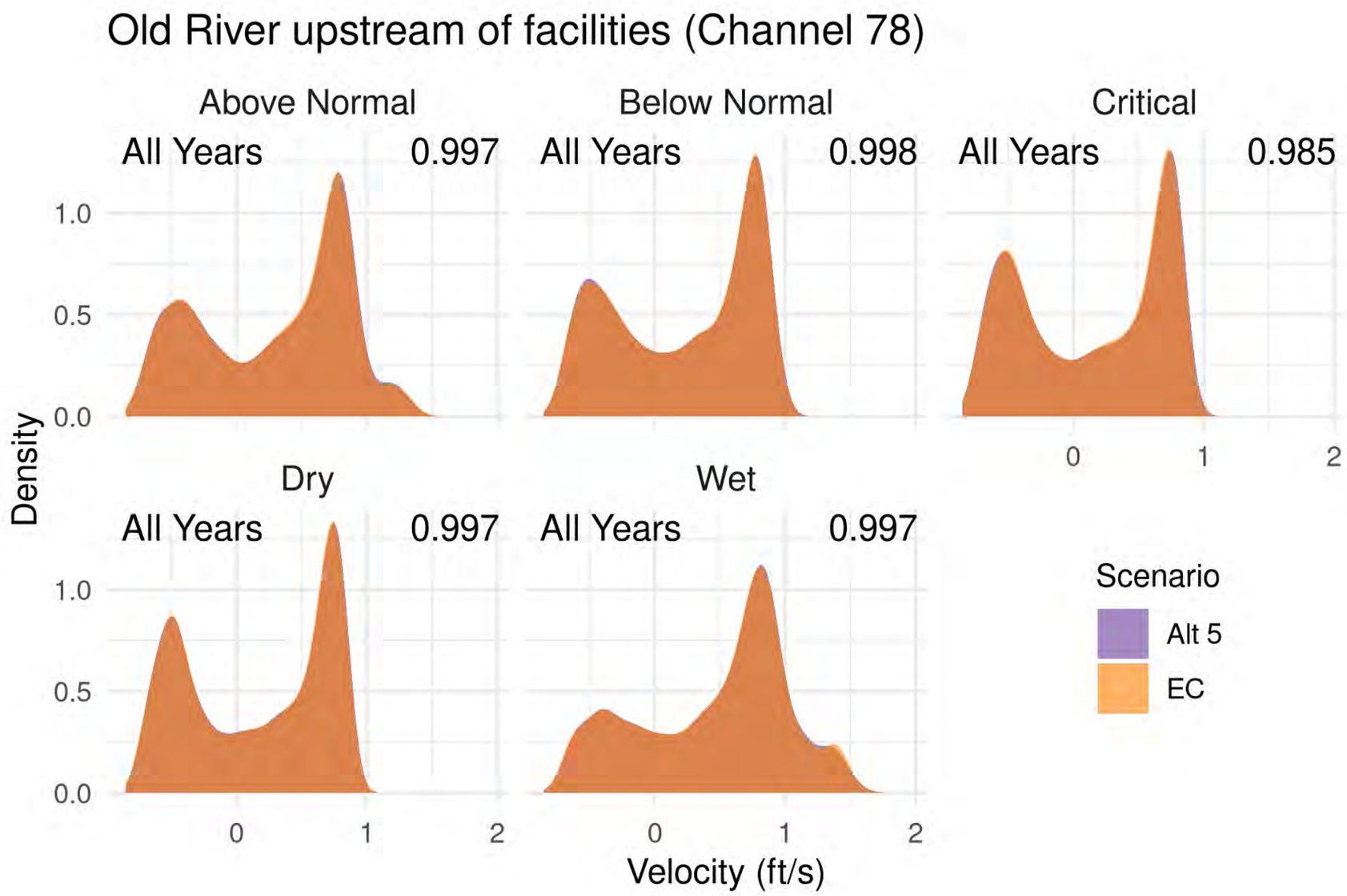

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-141. Velocity Density Distribution for San Joaquin River near Jersey Point, February.**



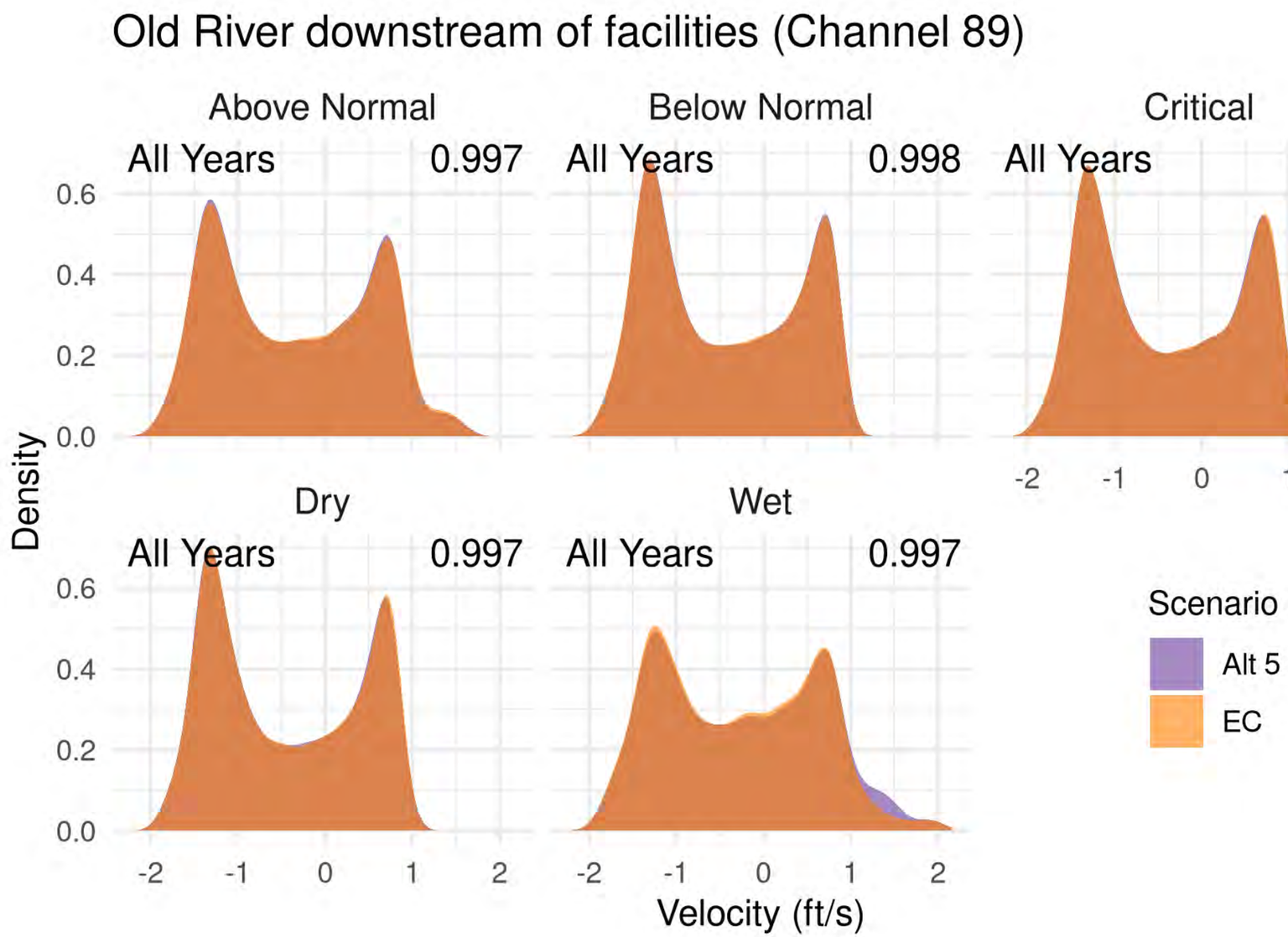

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-142. Velocity Density Distribution for Old River near Head of Old River, February.**



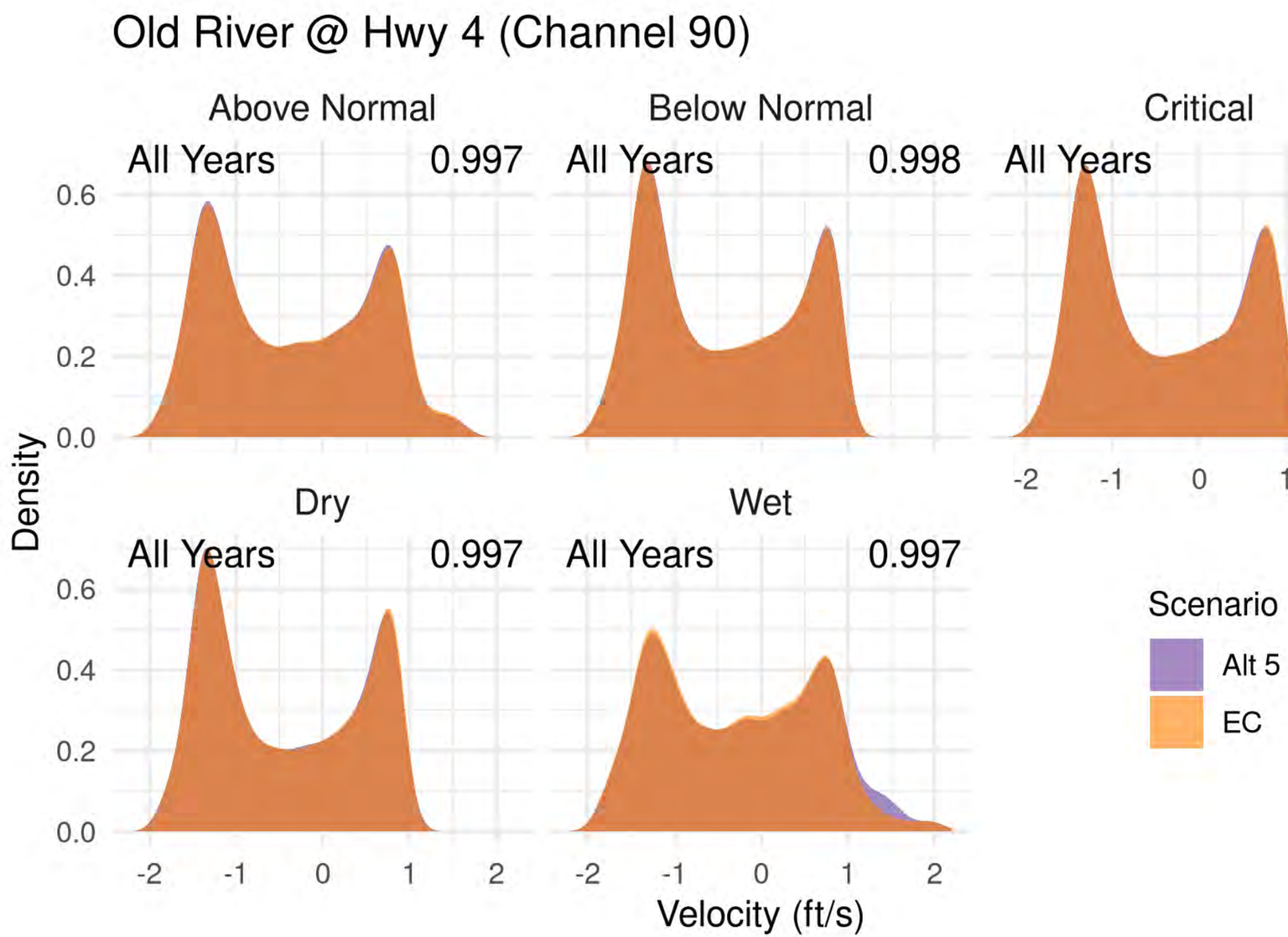

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-143. Velocity Density Distribution for Old River upstream of the South Delta Export Facilities, February.**



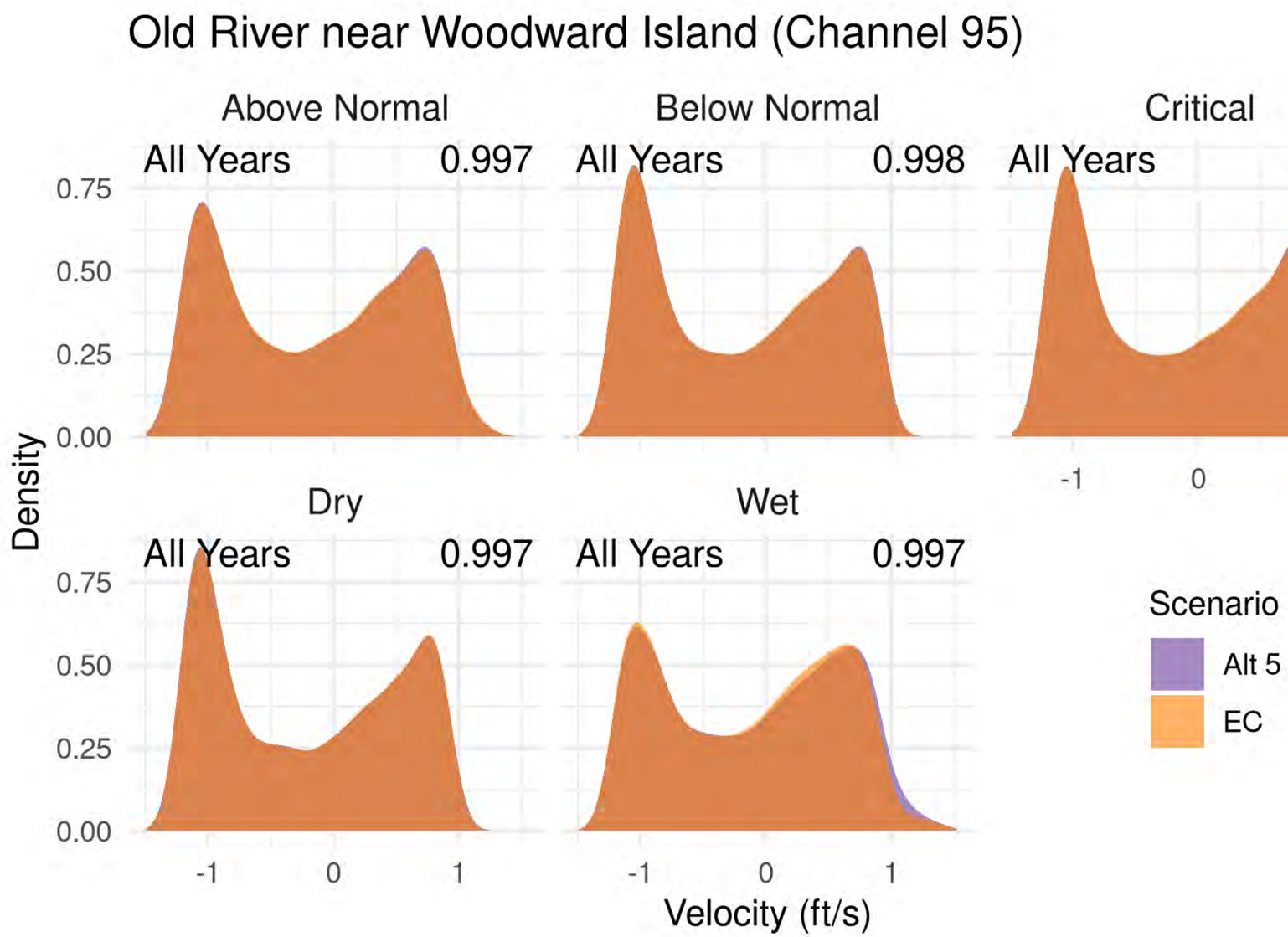

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-144. Velocity Density Distribution for Old River Downstream of the South Delta Export Facilities, February.**



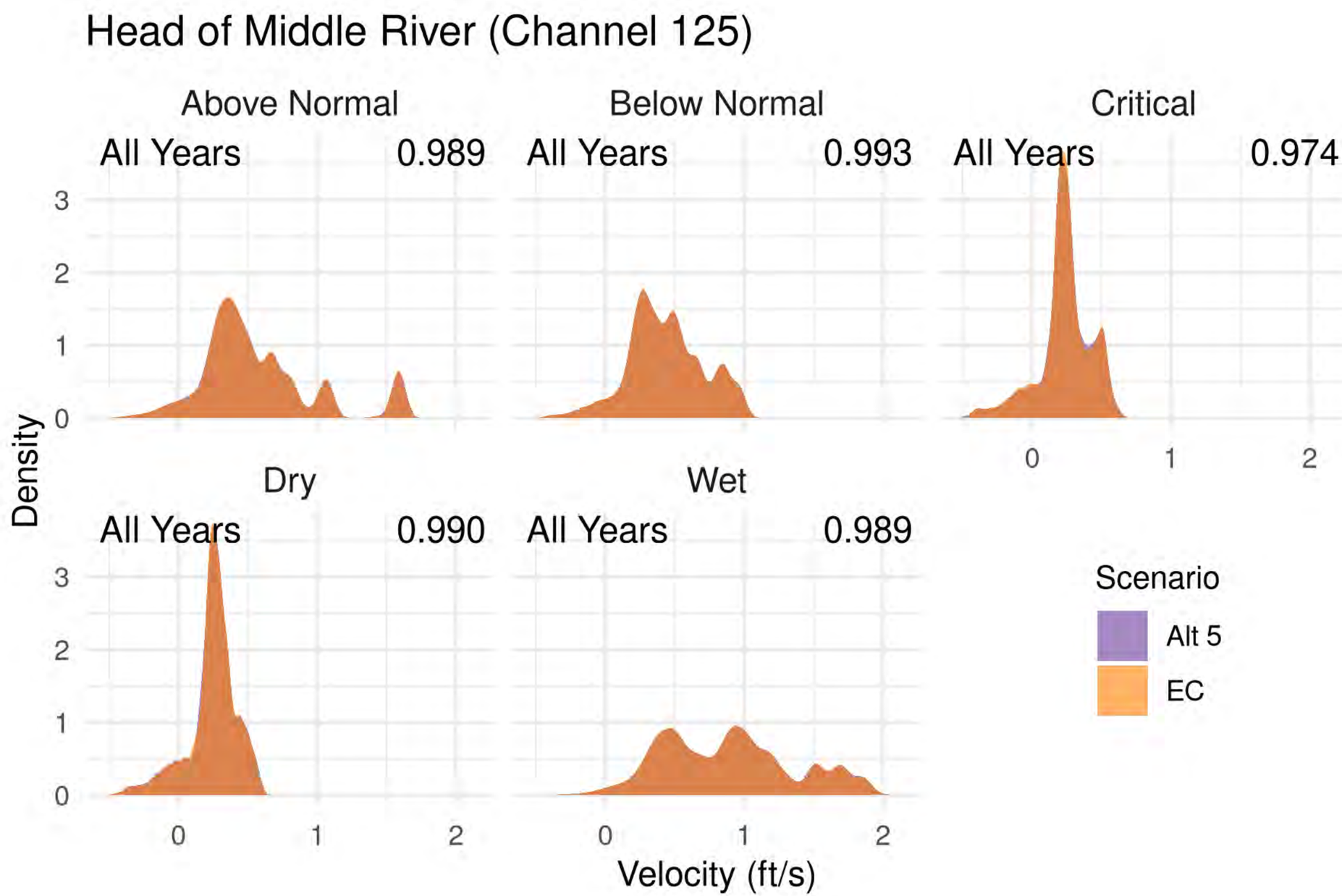

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-145. Velocity Density Distribution for Old River at Highway 4, February.**



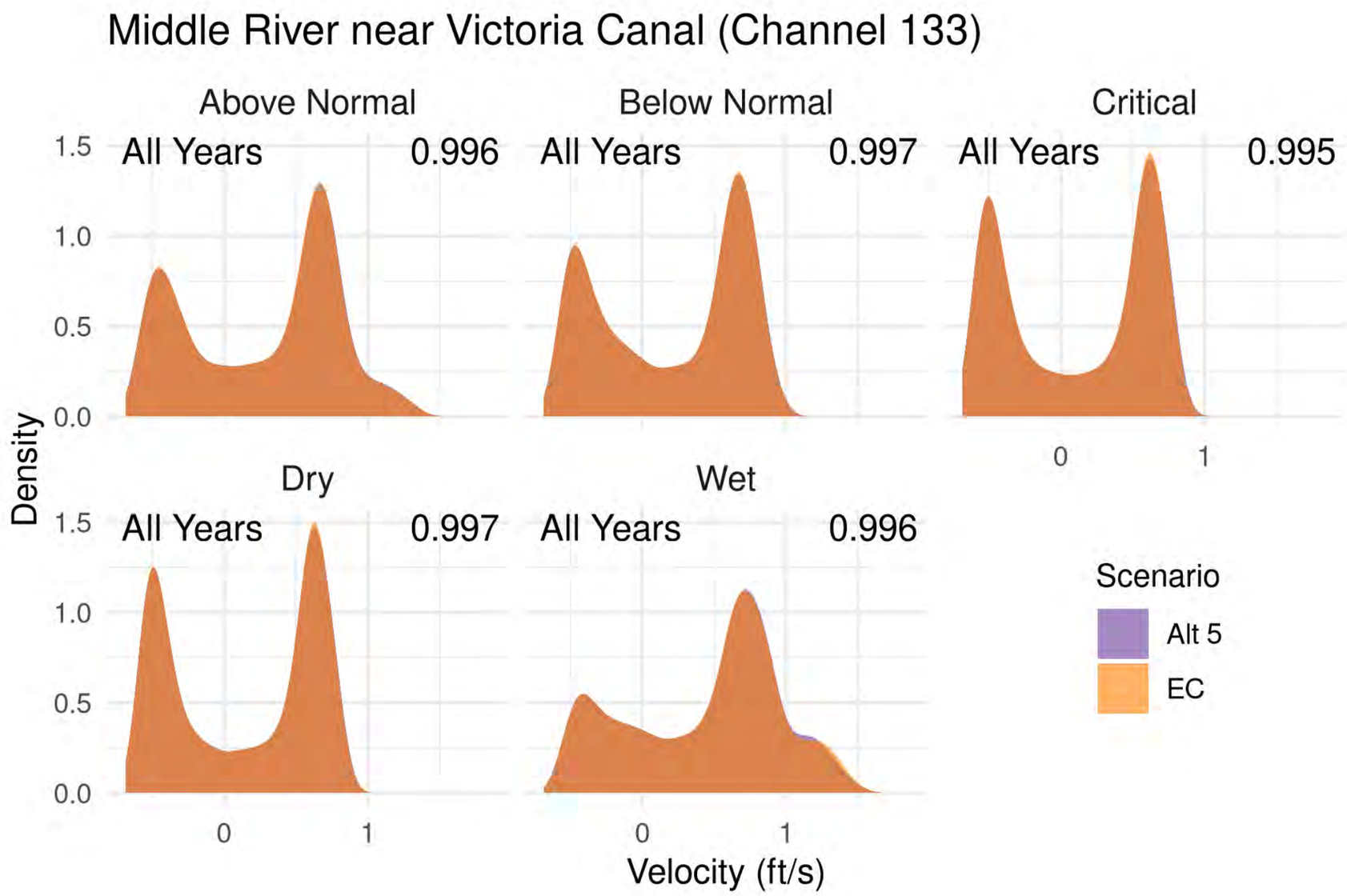

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-146. Velocity Density Distribution for Old River near Woodward Island, February.**



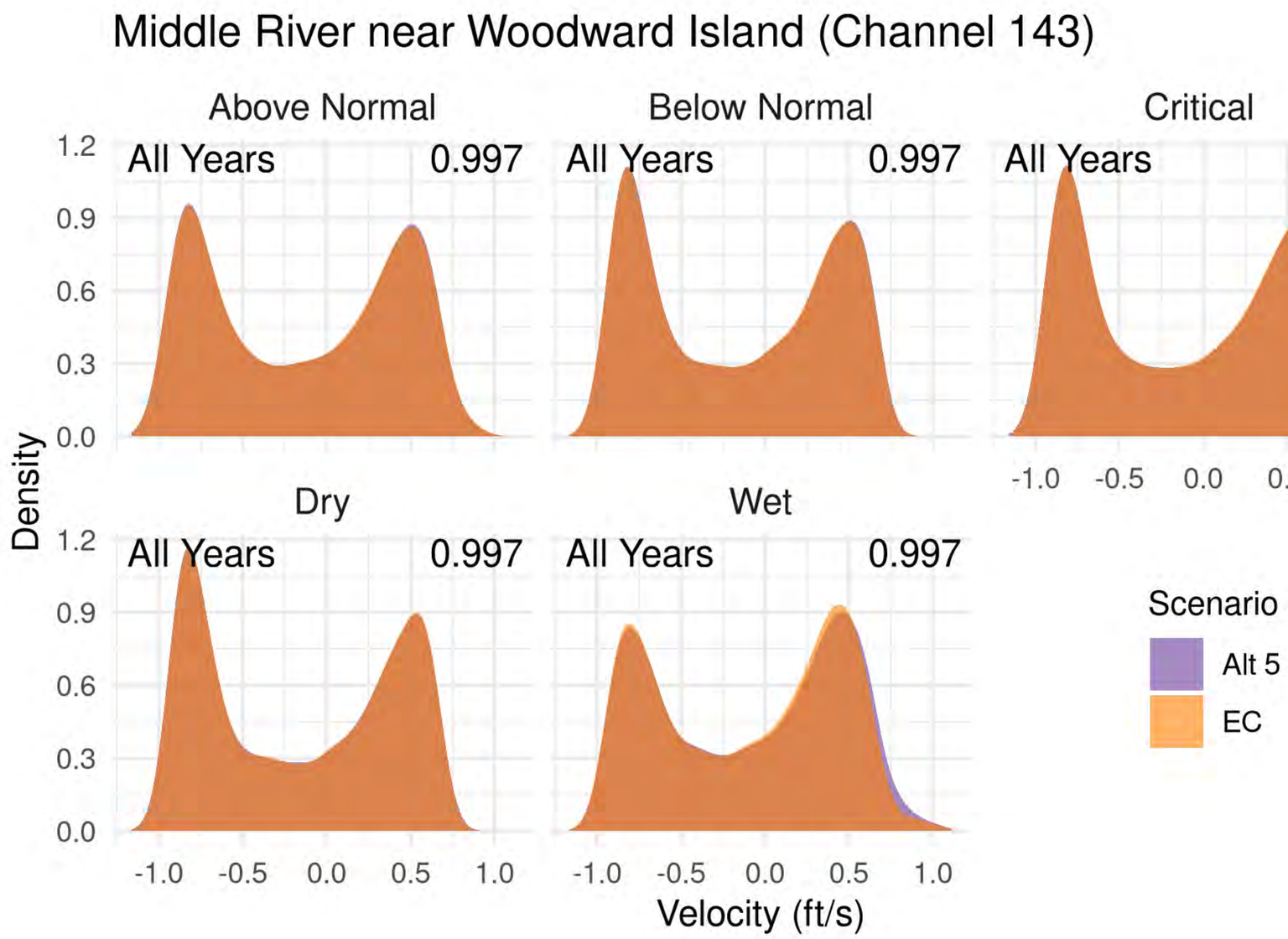

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-147. Velocity Density Distribution for Head of Middle River, February.**



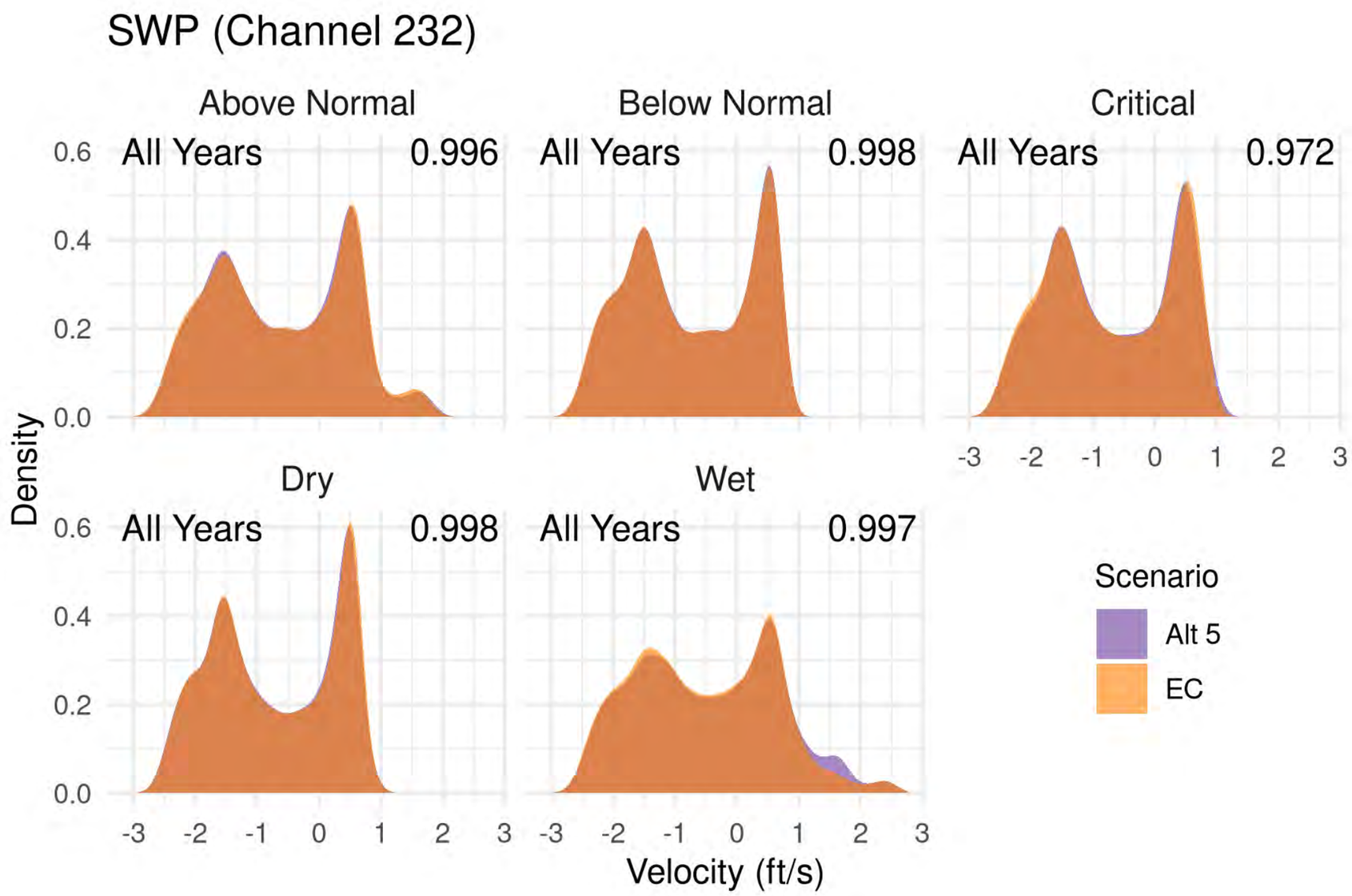

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-148. Velocity Density Distribution for Middle River near Victoria Canal, February.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-149. Velocity Density Distribution for Middle River near Woodward Island, February.**

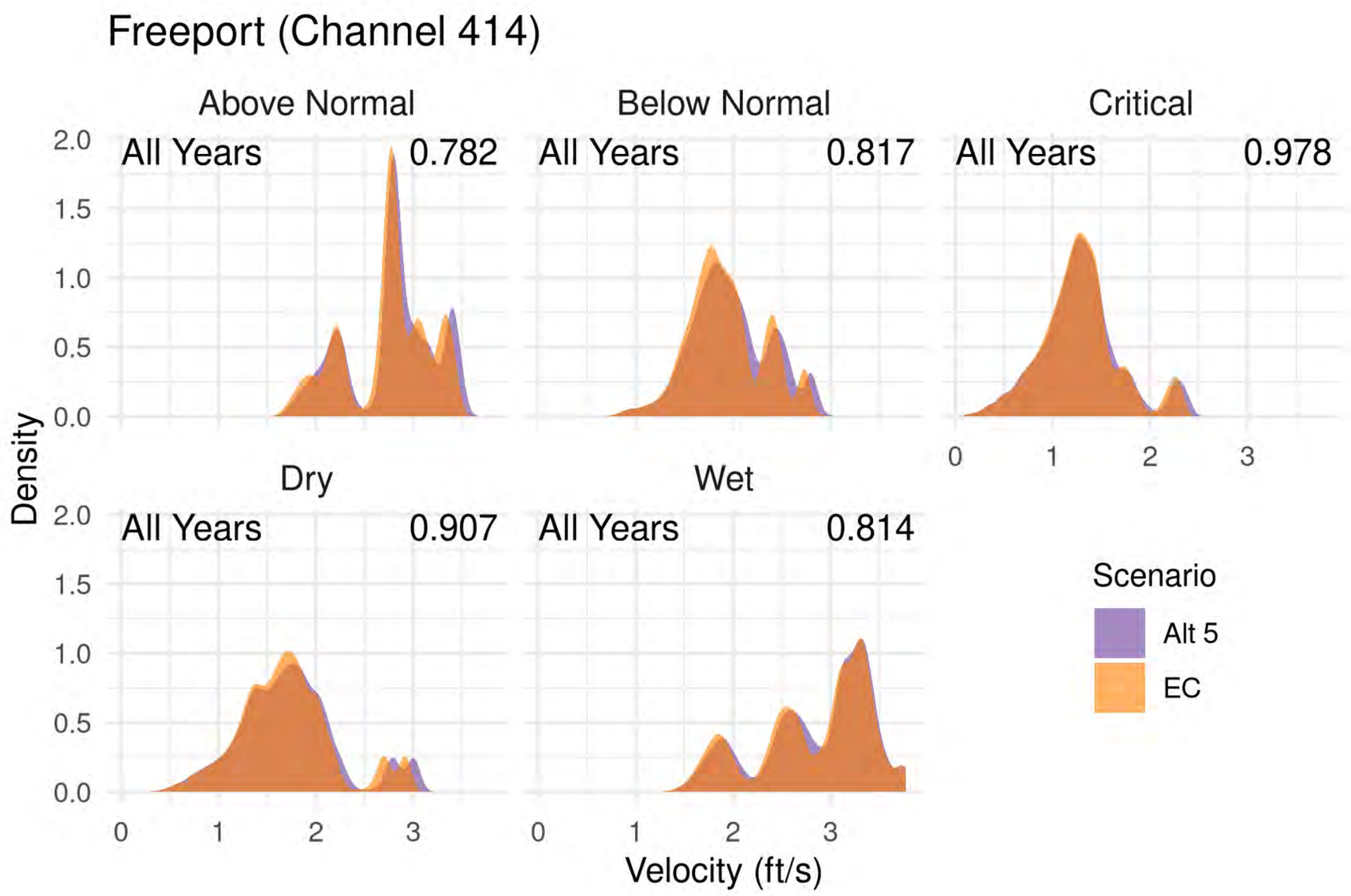



Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-150. Velocity Density Distribution for State Water Project (West Canal near Entrance to Clifton Court Forebay), February.**

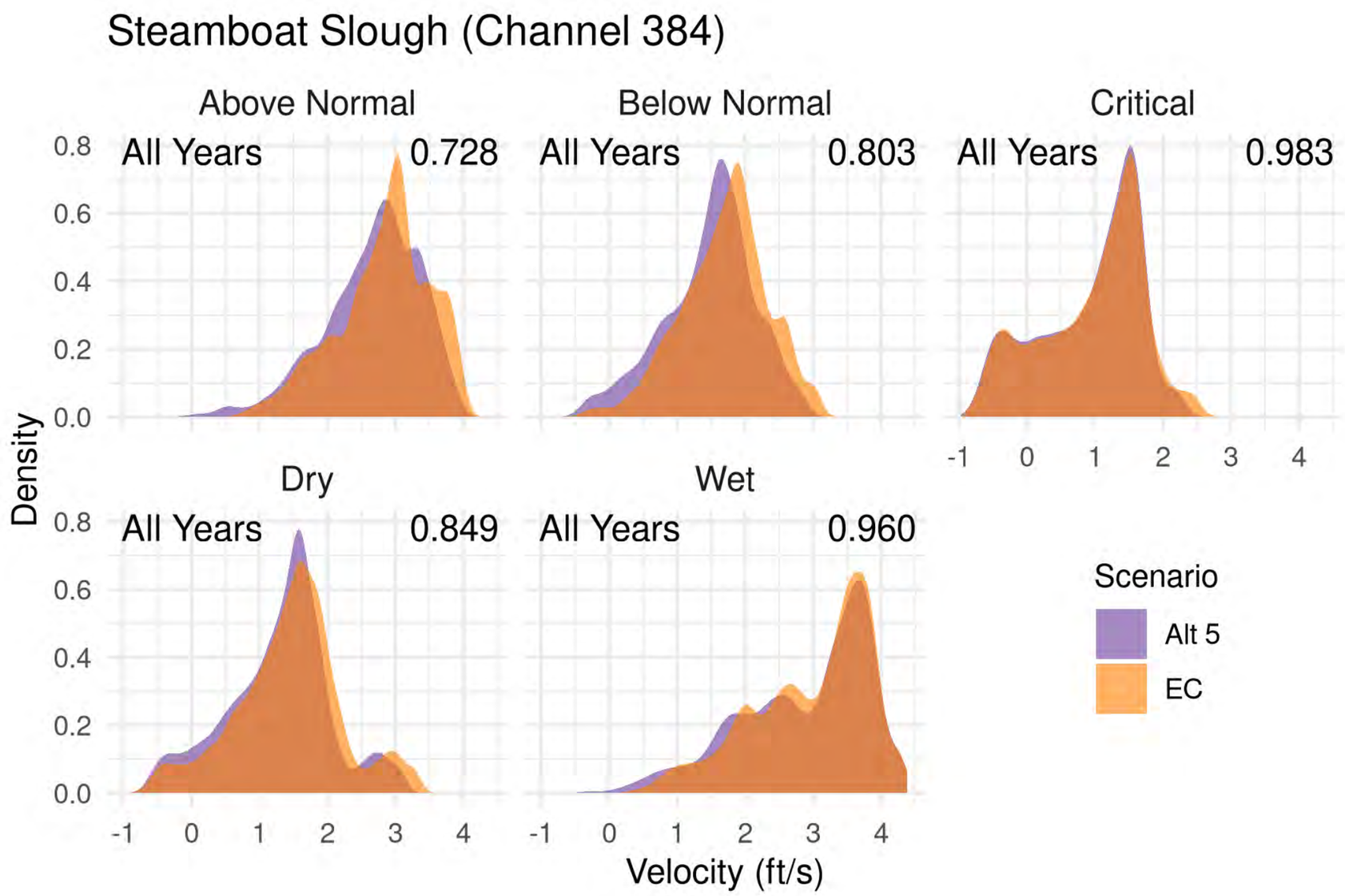
**March**

***Sacramento River Delta***



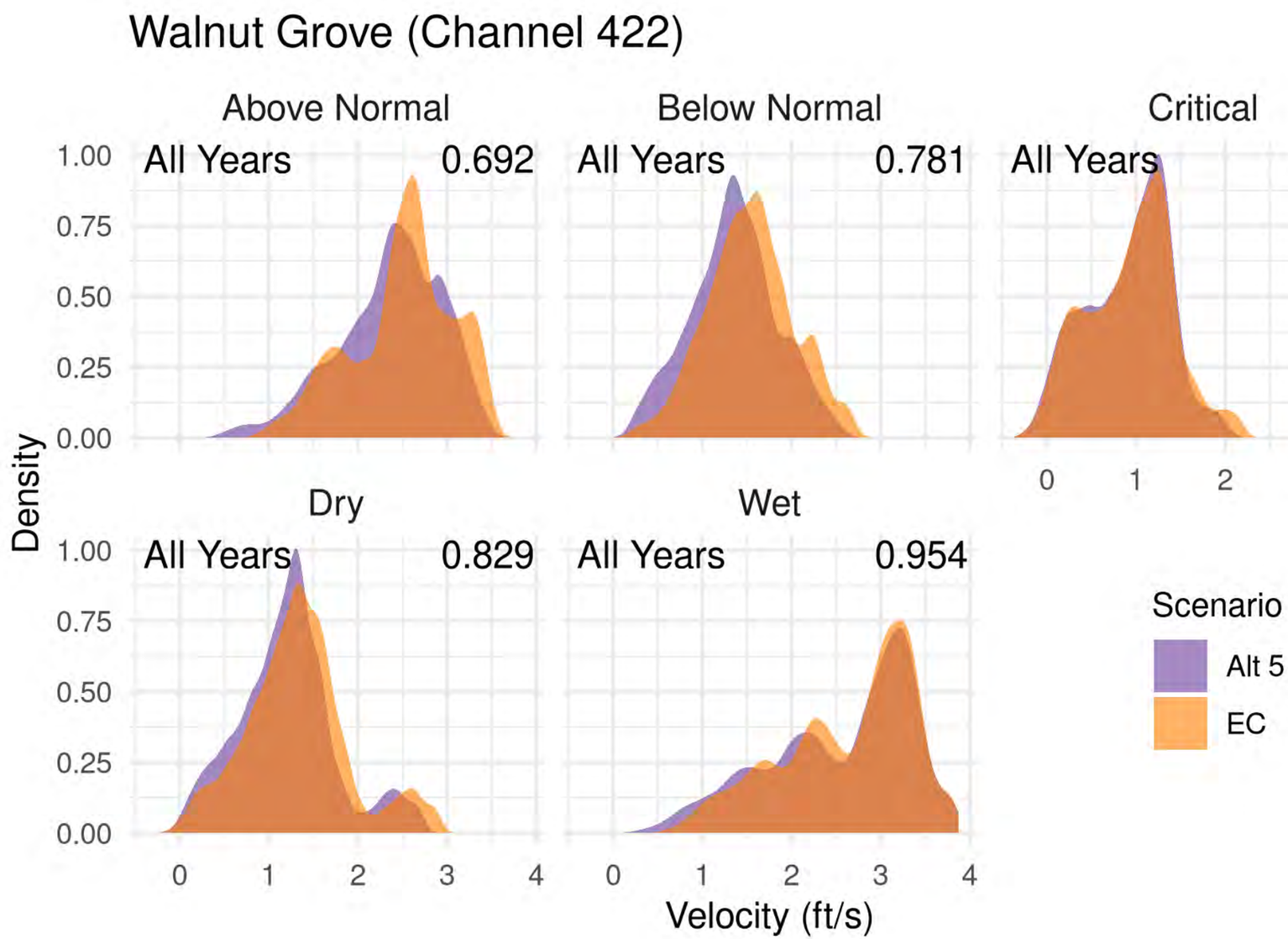

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-151. Velocity Density Distribution for Freeport, March.**



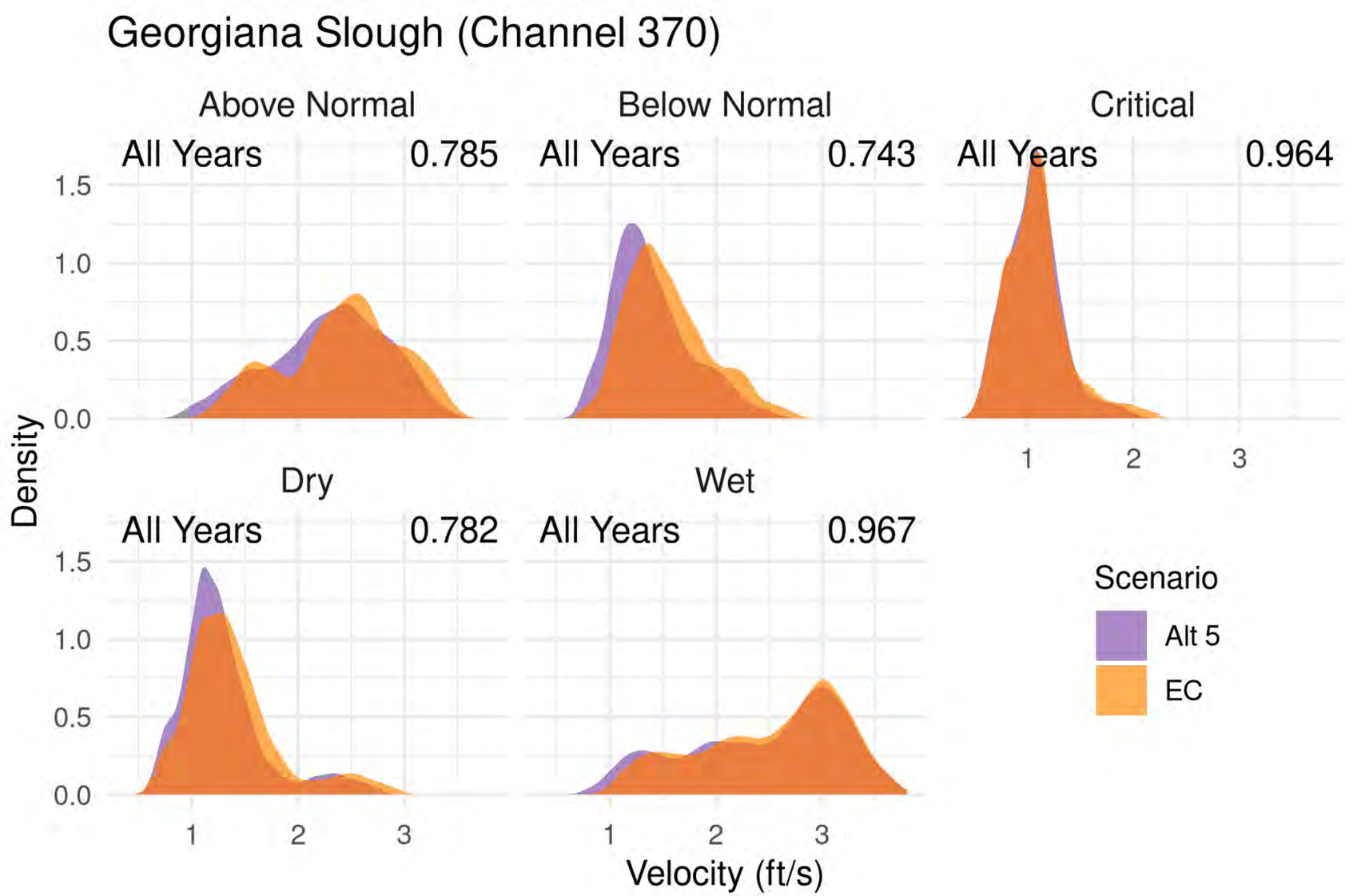

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-152. Velocity Density Distribution for Steamboat Slough, March.**



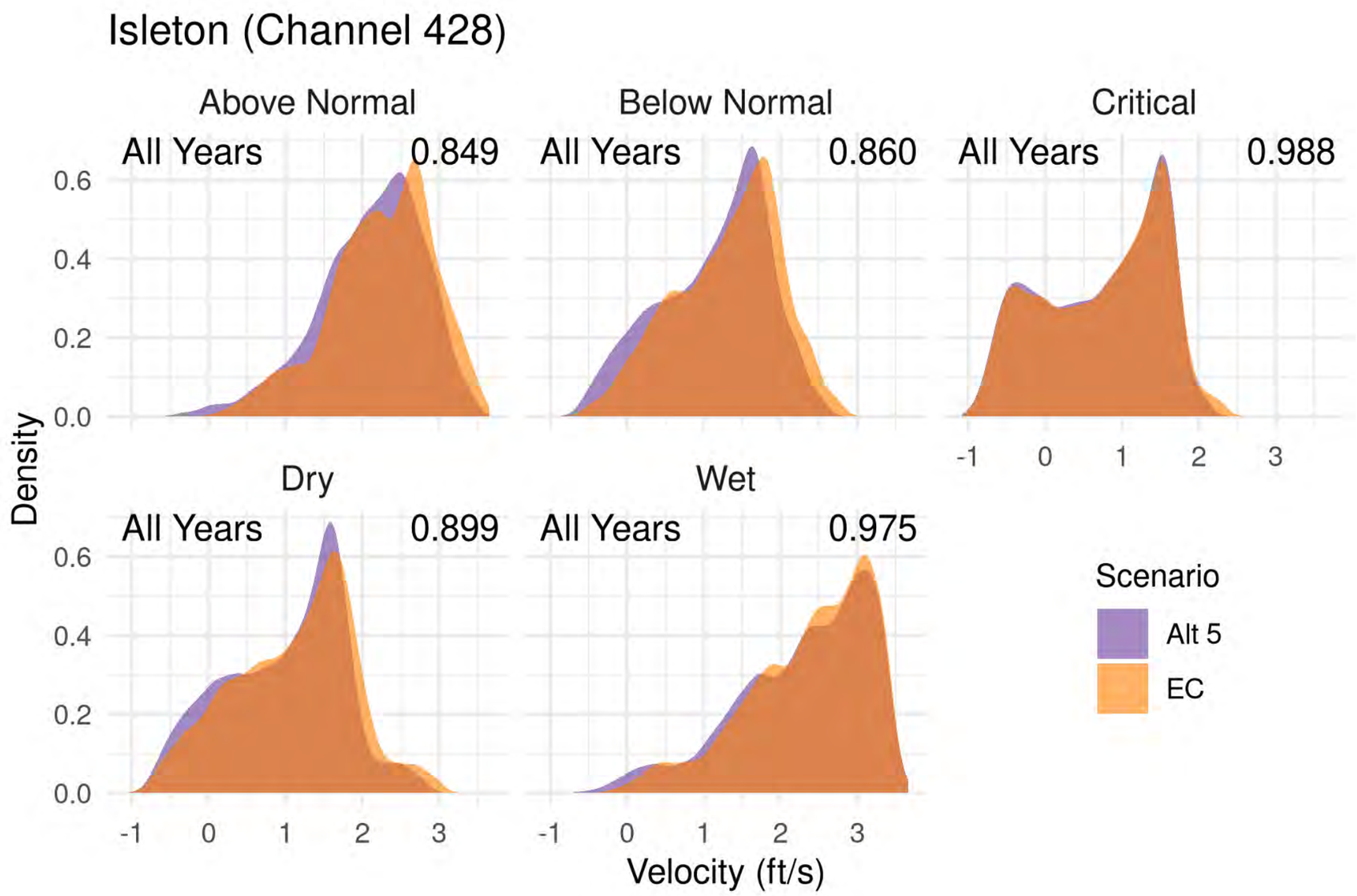

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-153. Velocity Density Distribution for Walnut Grove (Sacramento River), March.**



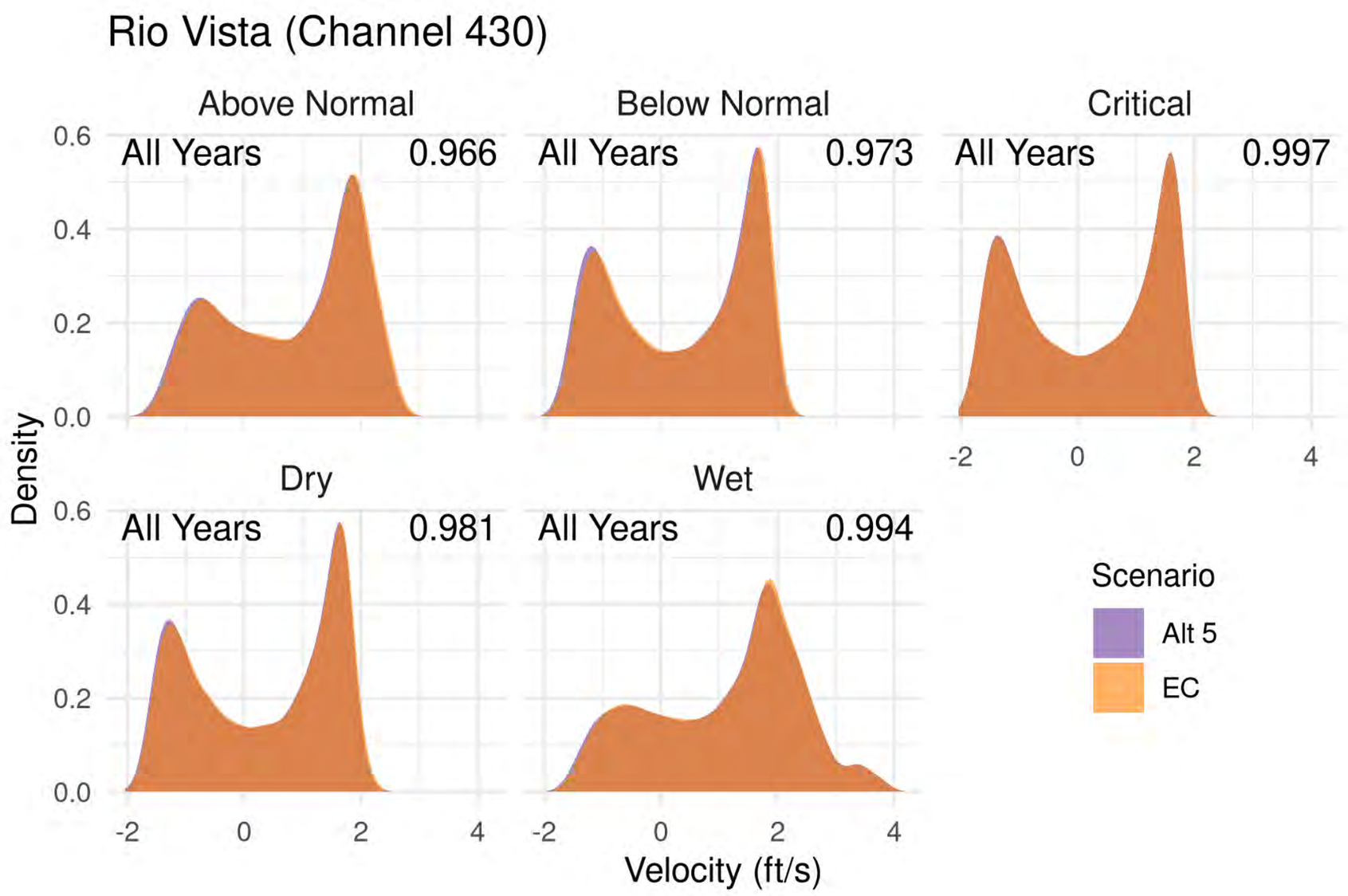

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-154. Velocity Density Distribution for Georgiana Slough, March.**



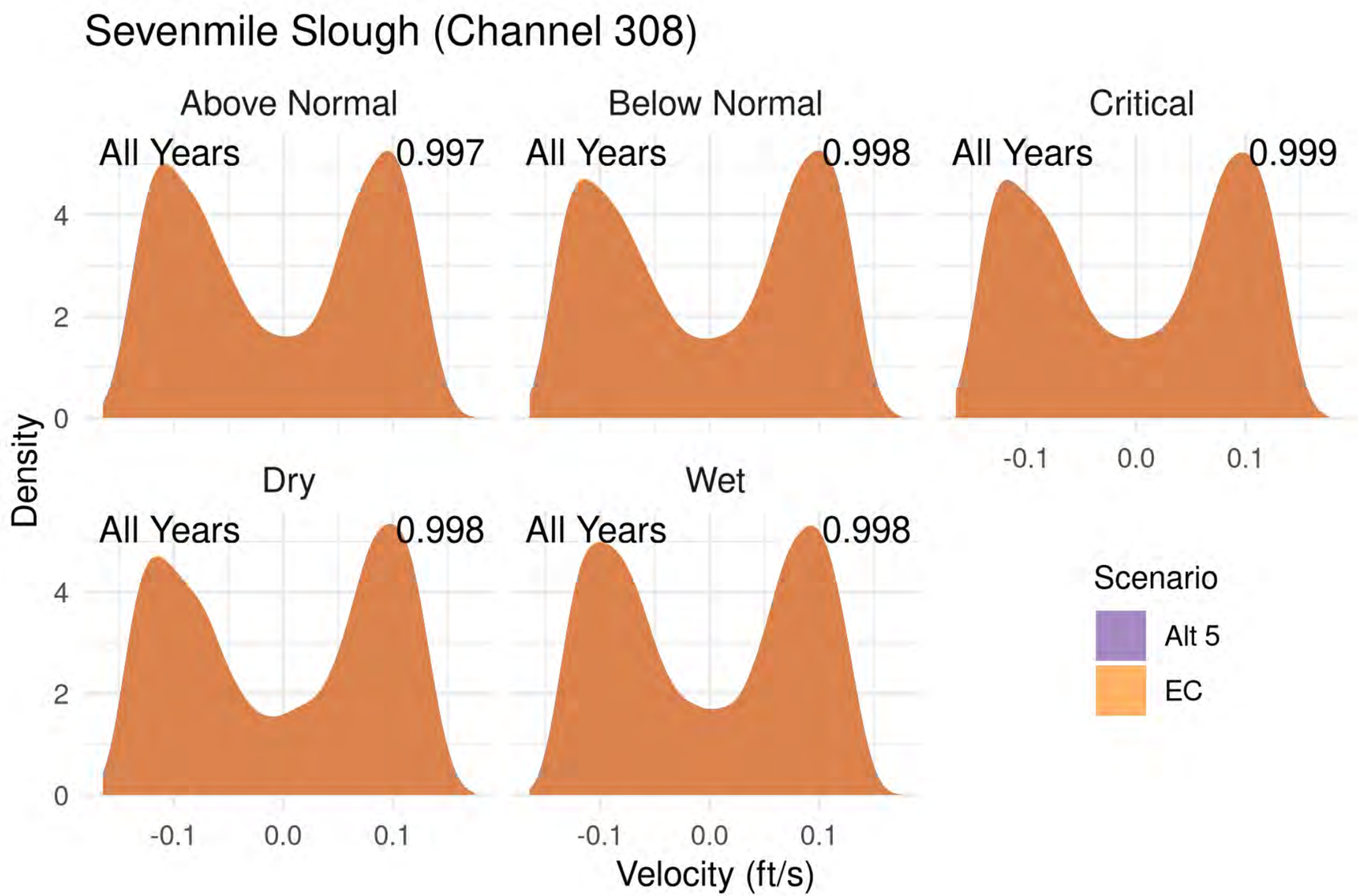

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-155. Velocity Density Distribution for Isleton (Sacramento River), March.**



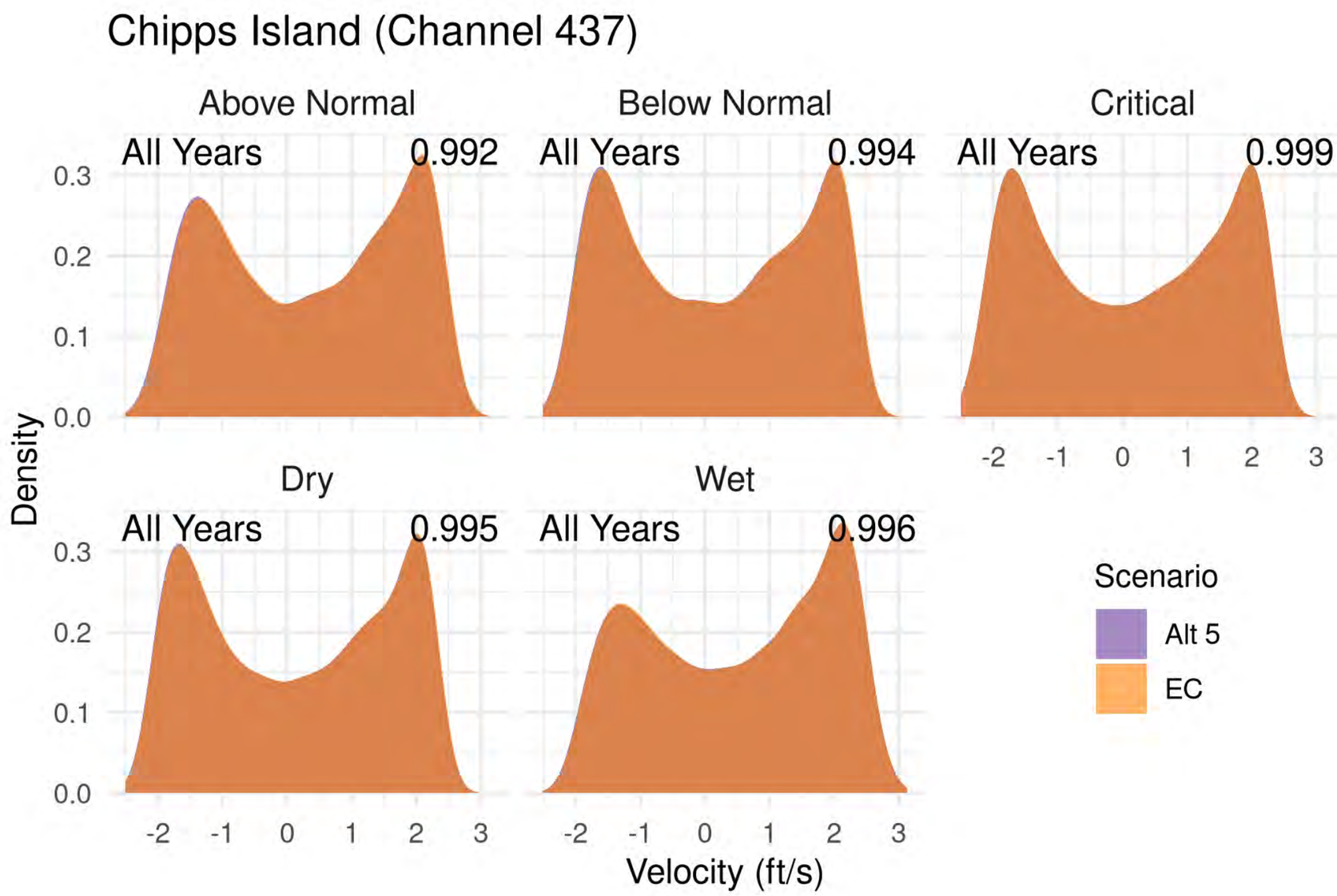

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-156. Velocity Density Distribution for Rio Vista (Sacramento River), March.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

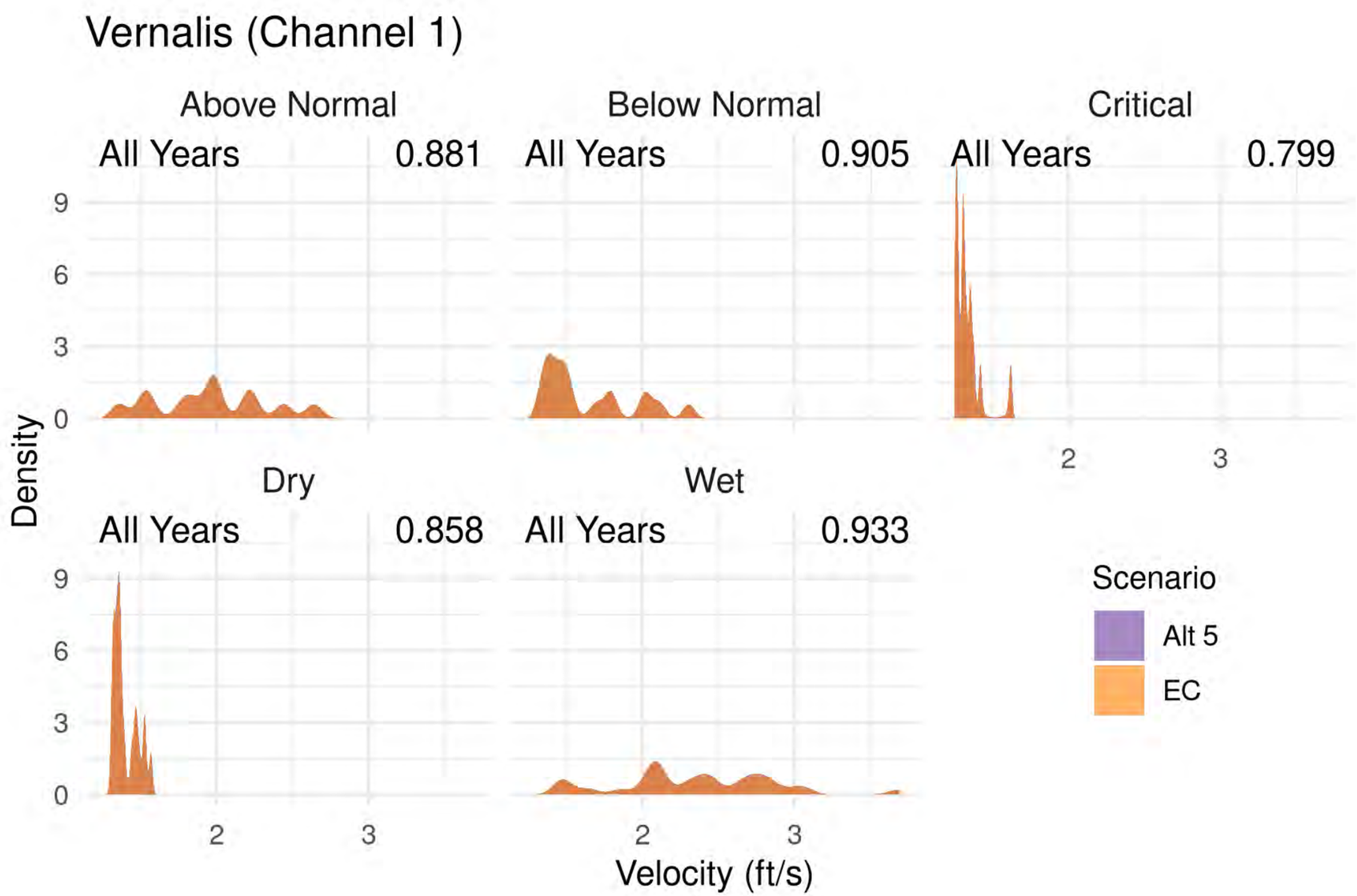
**Figure 5D.1-157. Velocity Density Distribution for Sevenmile Slough, March.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

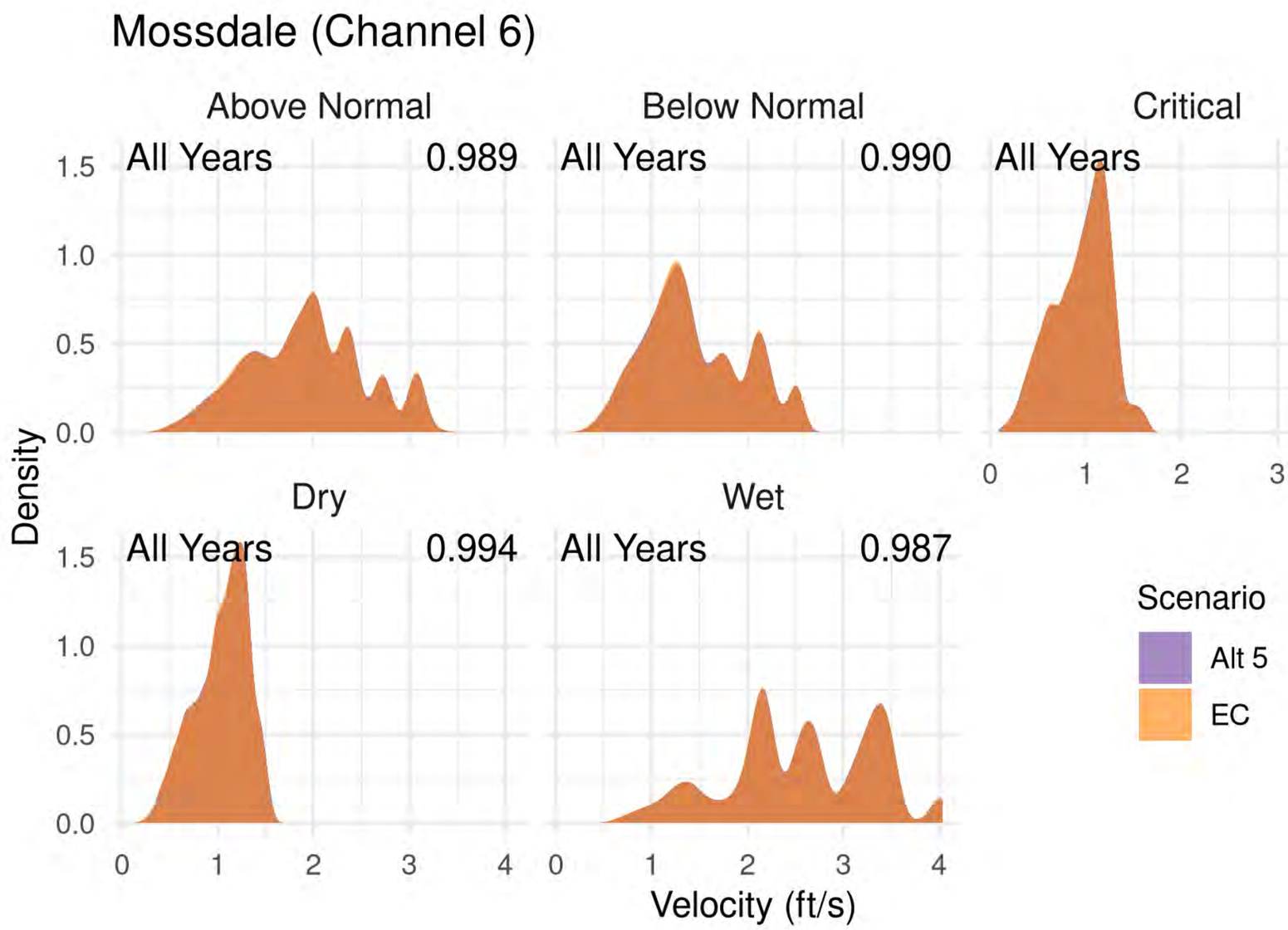
**Figure 5D.1-158. Velocity Density Distribution for Chipps Island (Sacramento River–San Joaquin River Confluence), March.**

***San Joaquin River Delta***



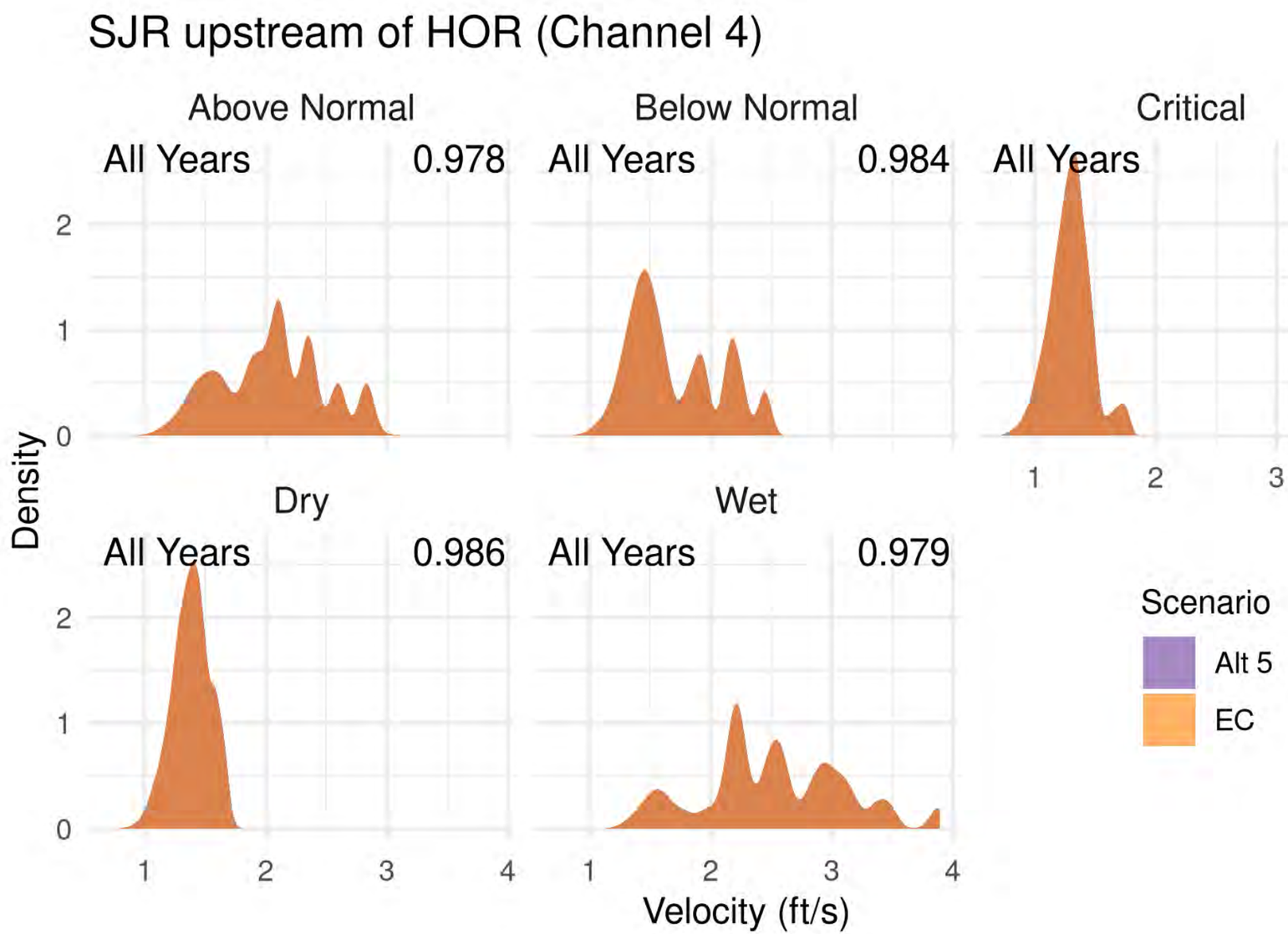

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-159. Velocity Density Distribution for Vernalis (San Joaquin River), March.**



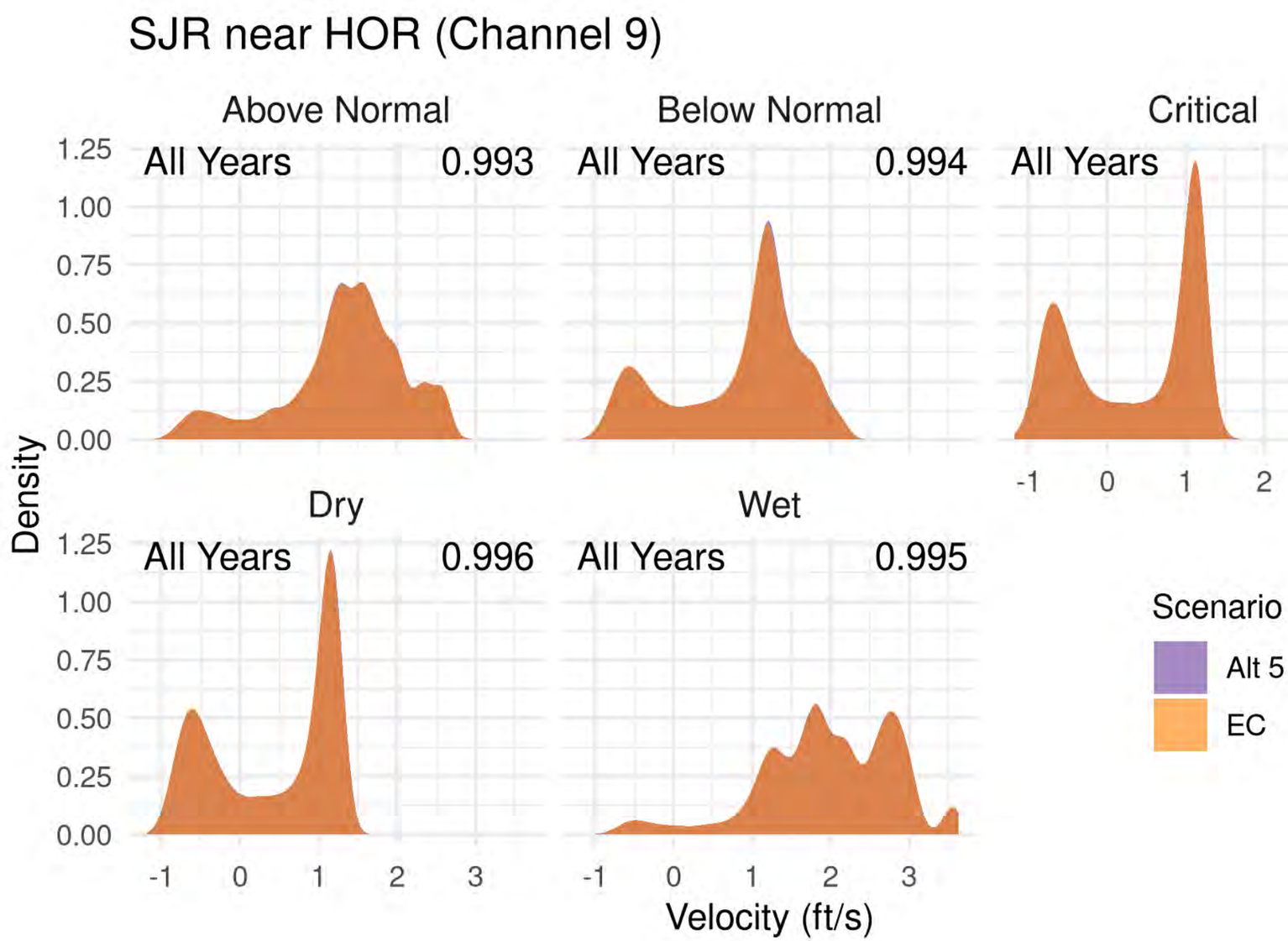

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-160. Velocity Density Distribution for Mossdale (San Joaquin River), March.**



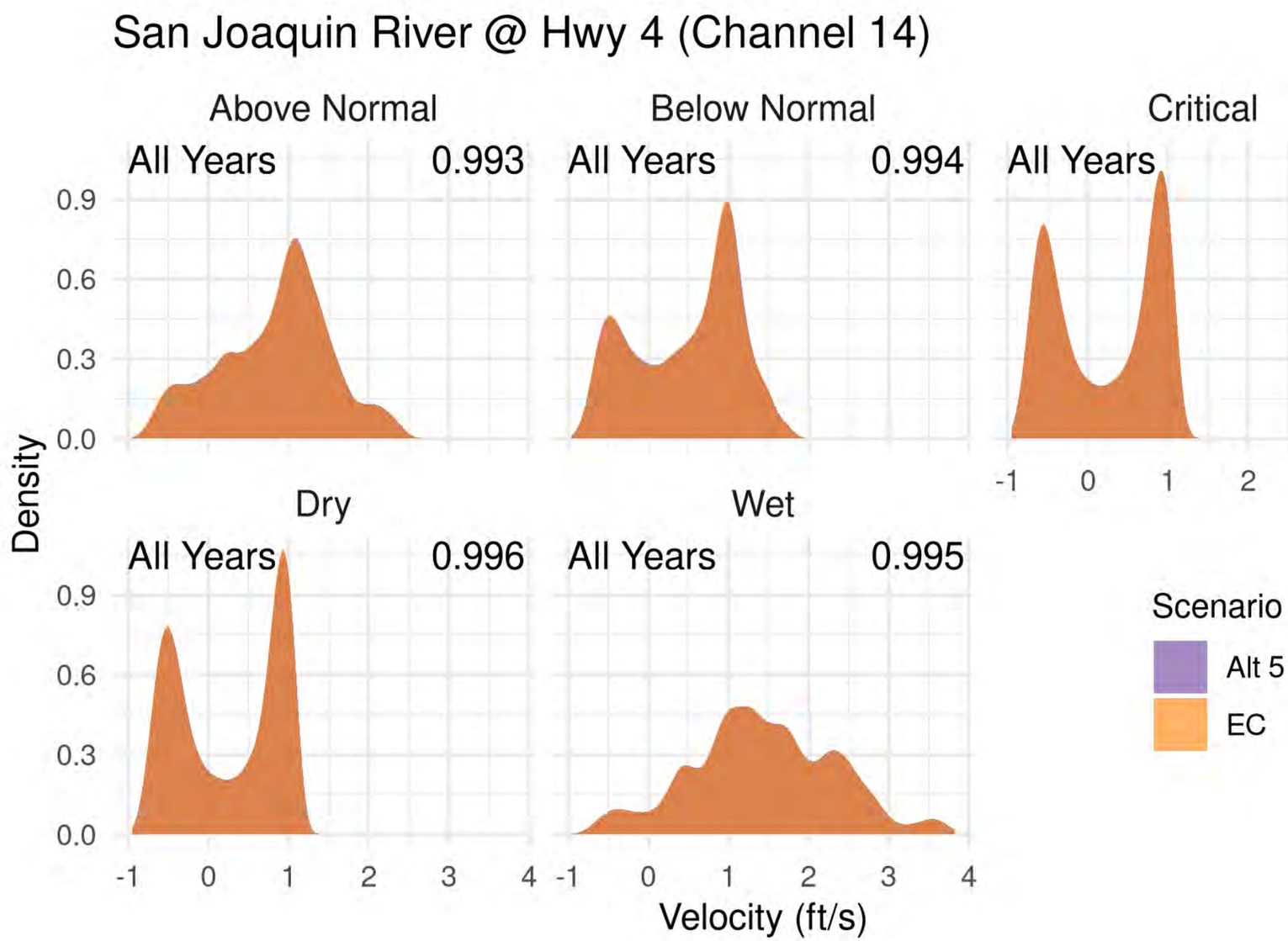

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-161. Velocity Density Distribution for San Joaquin River upstream of Head of Old River, March.**



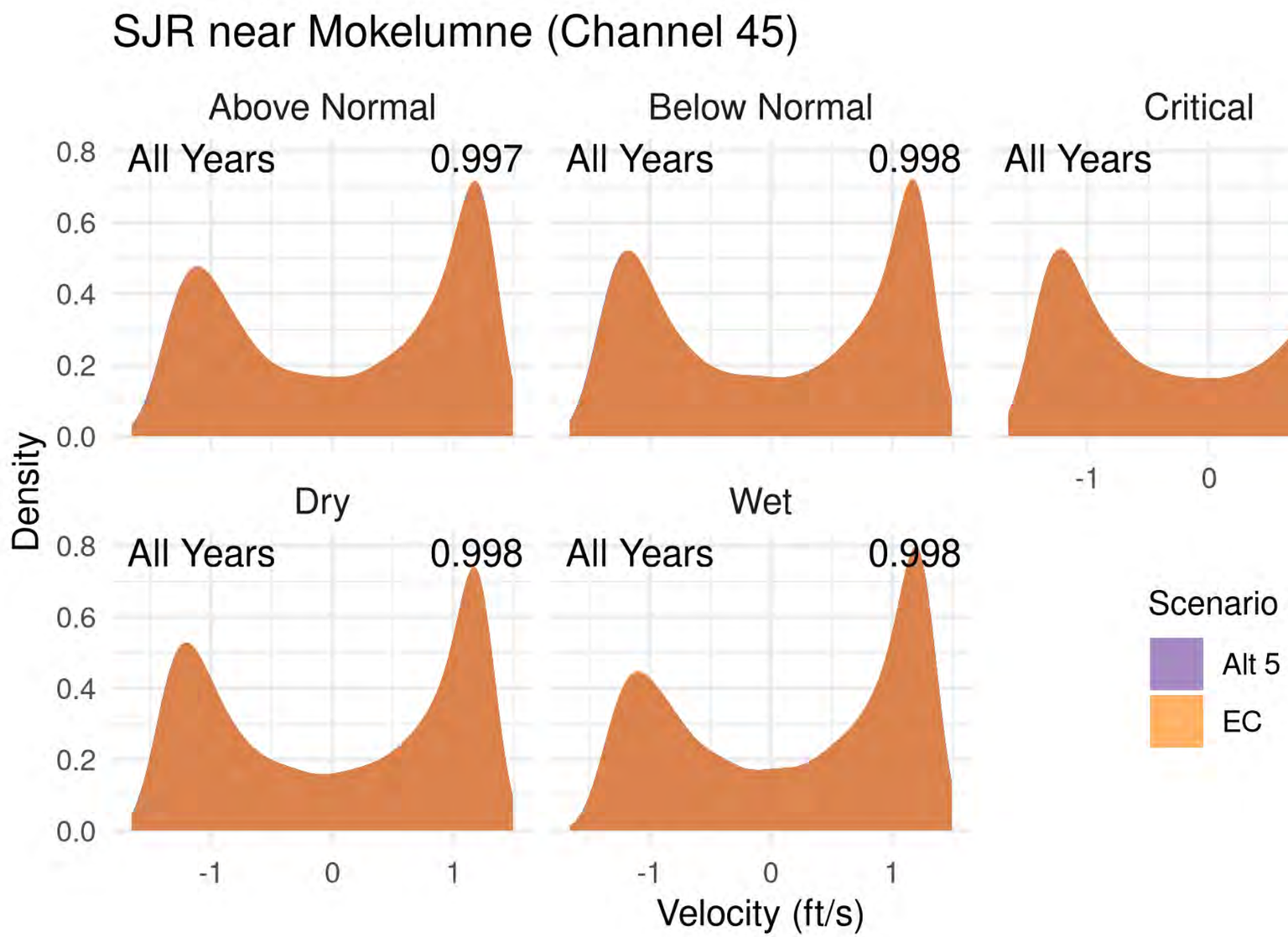

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-162. Velocity Density Distribution for San Joaquin River near Head of Old River, March.**



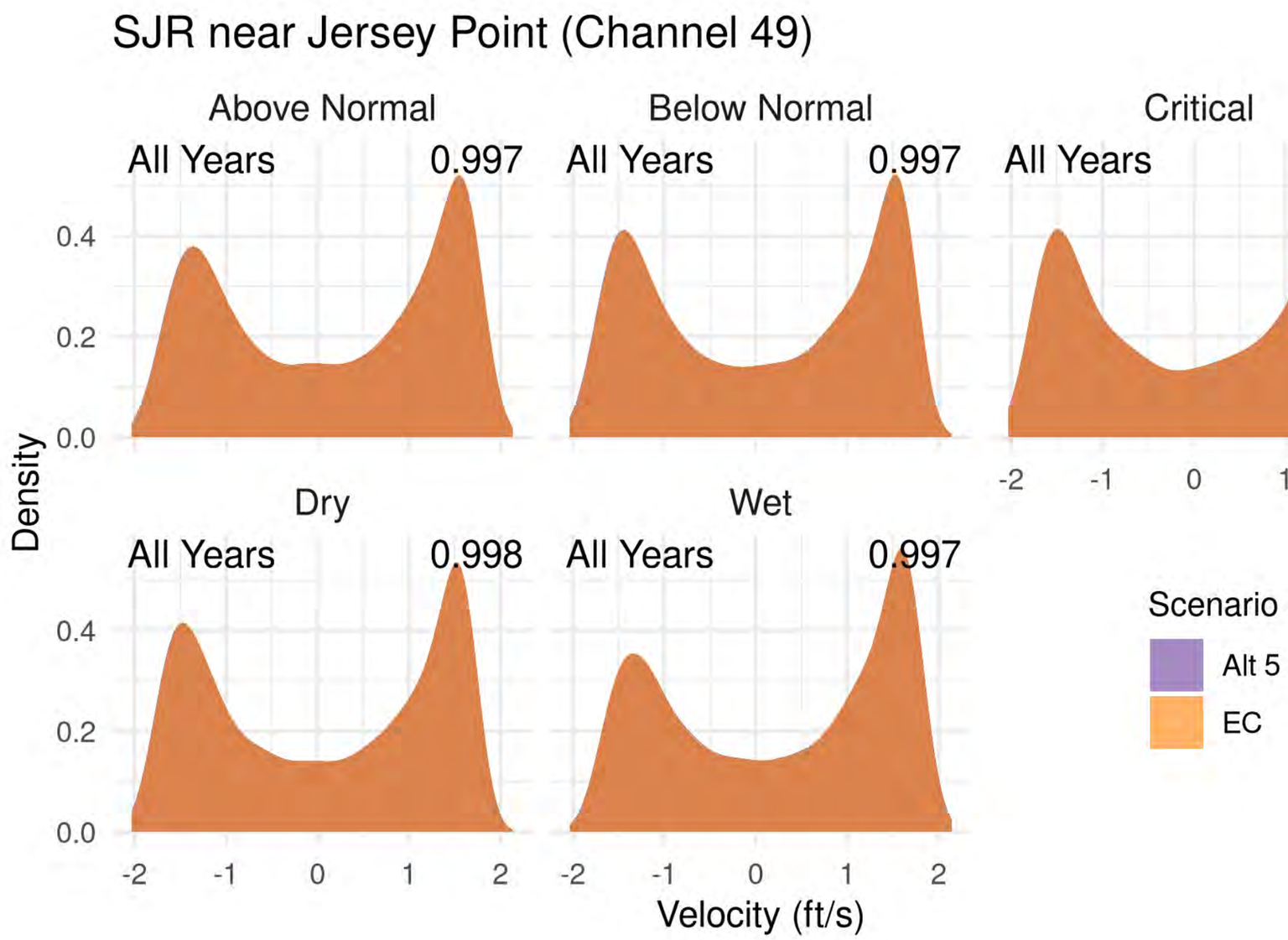

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-163. Velocity Density Distribution for San Joaquin River at Highway 4, March.**



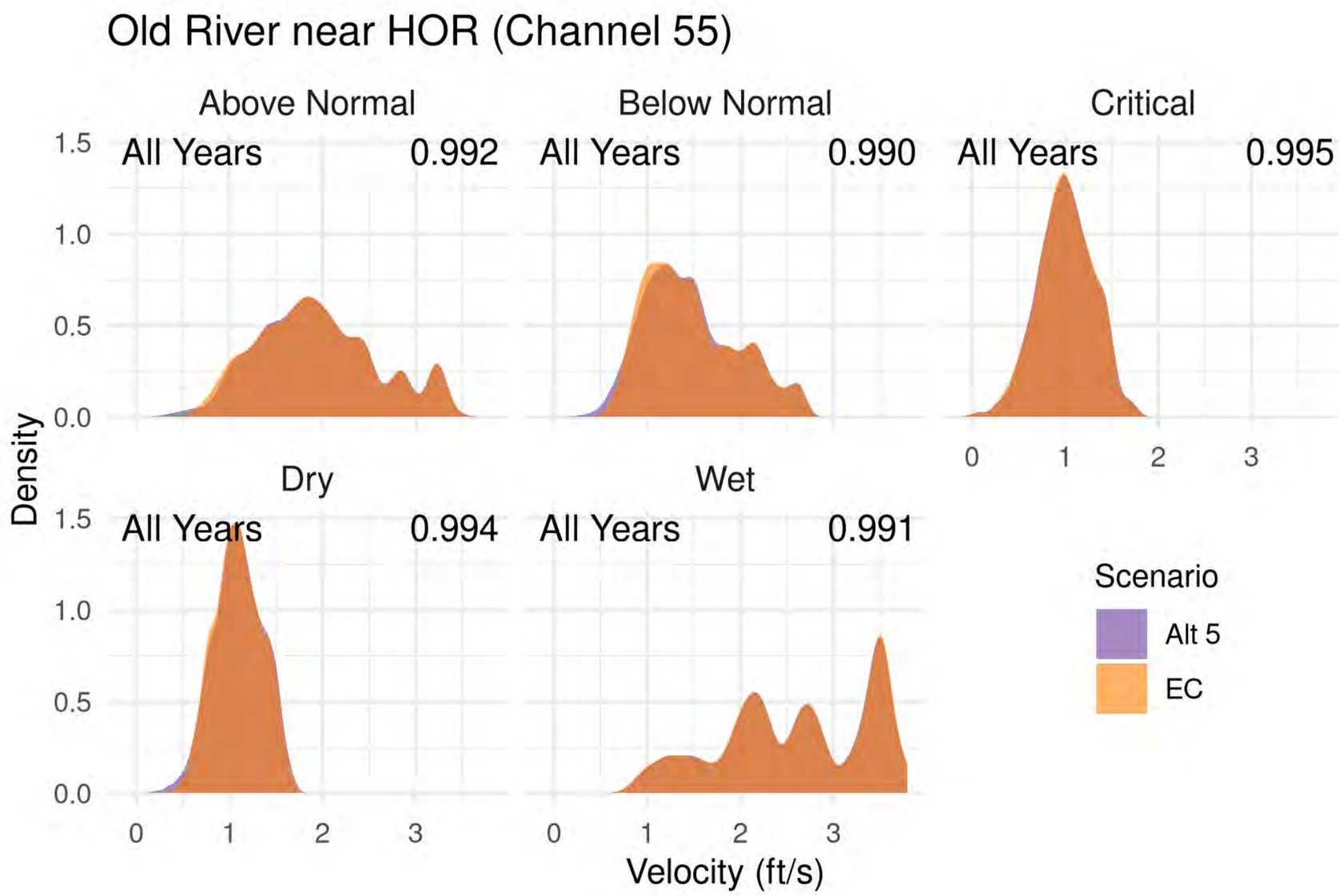

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-164. Velocity Density Distribution for San Joaquin River near Mokelumne River, March.**



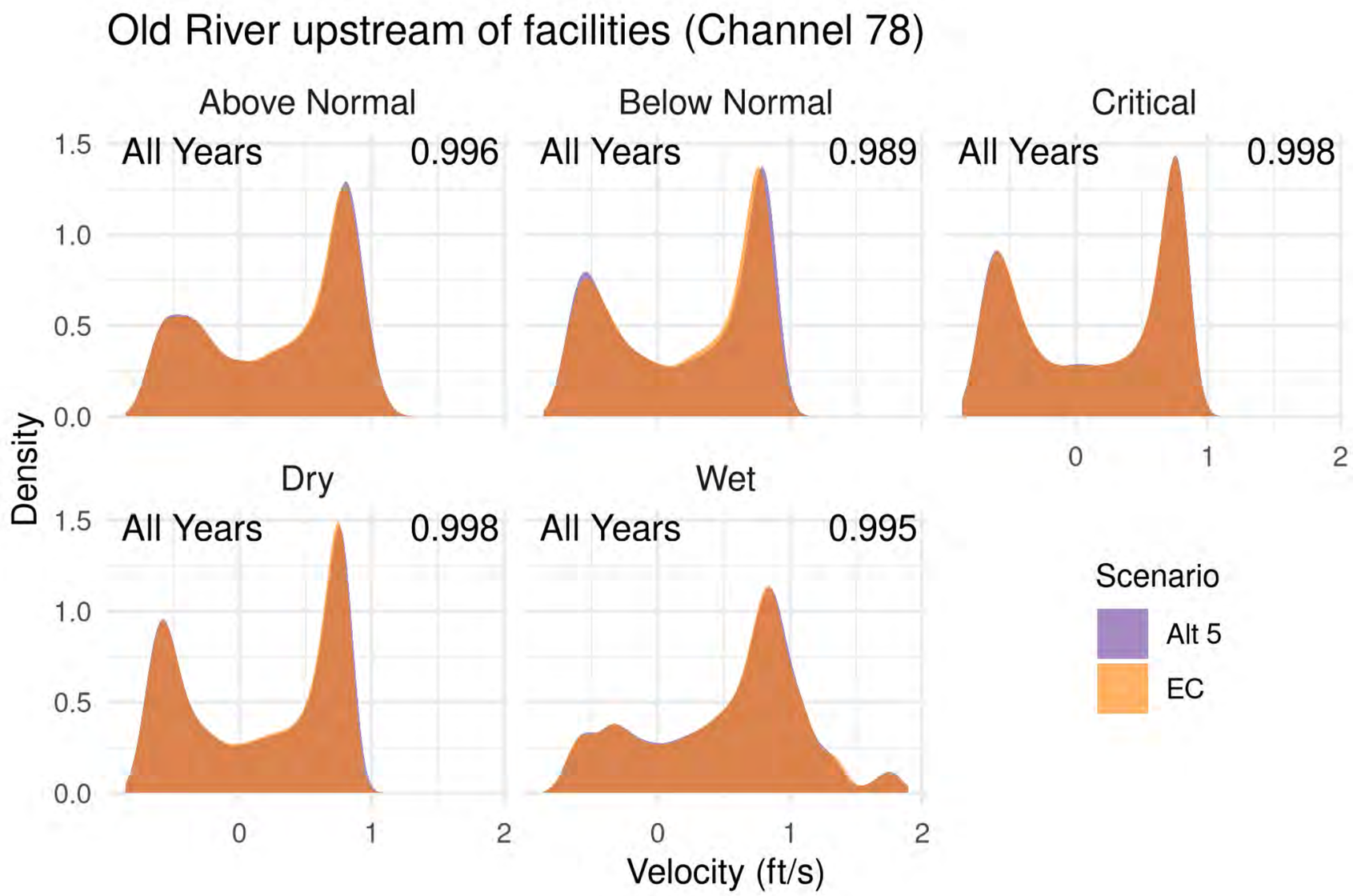

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-165. Velocity Density Distribution for San Joaquin River near Jersey Point, March.**



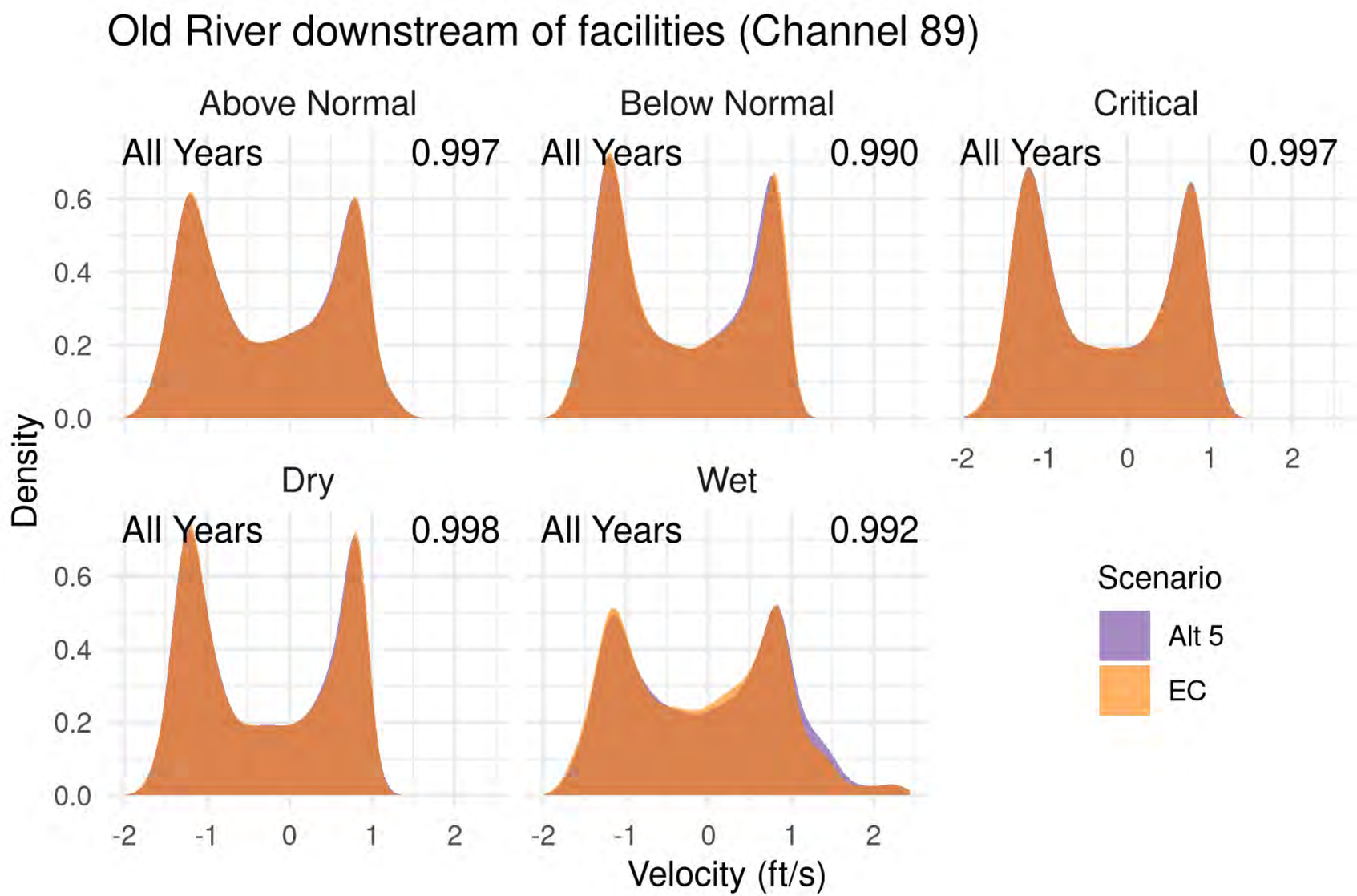

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-166. Velocity Density Distribution for Old River near Head of Old River, March.**



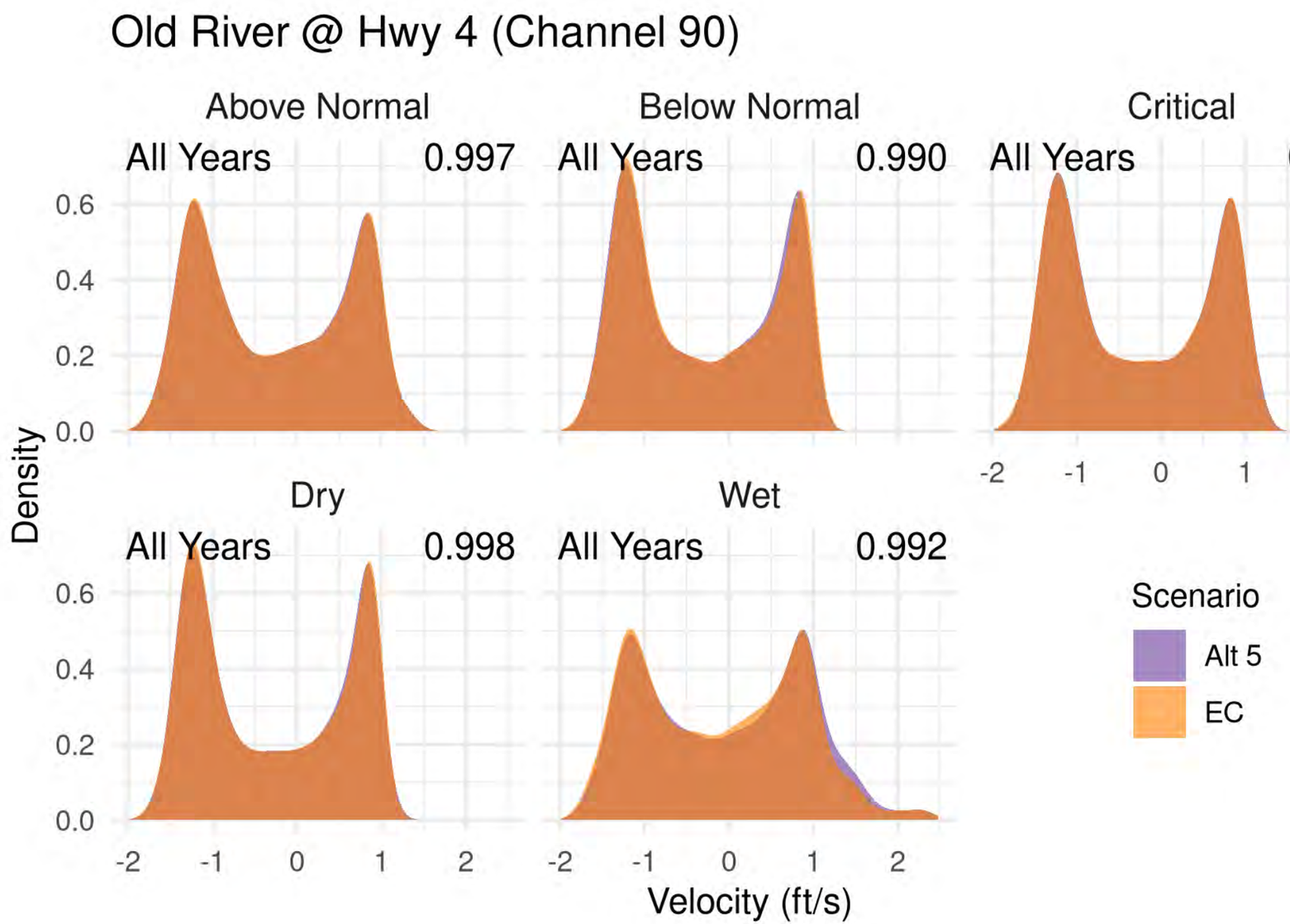

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-167. Velocity Density Distribution for Old River upstream of the South Delta Export Facilities, March.**



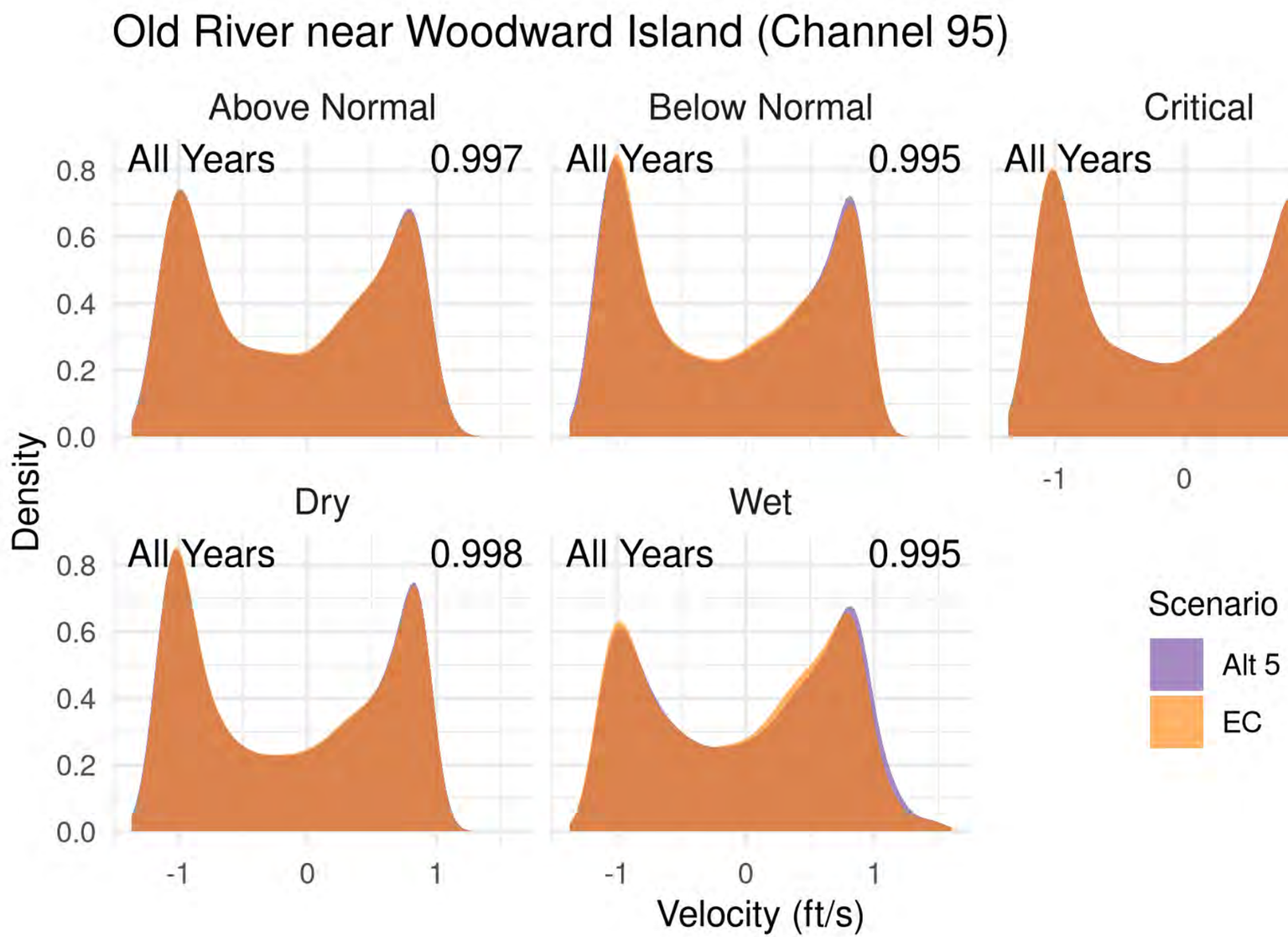

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-168. Velocity Density Distribution for Old River Downstream of the South Delta Export Facilities, March.**



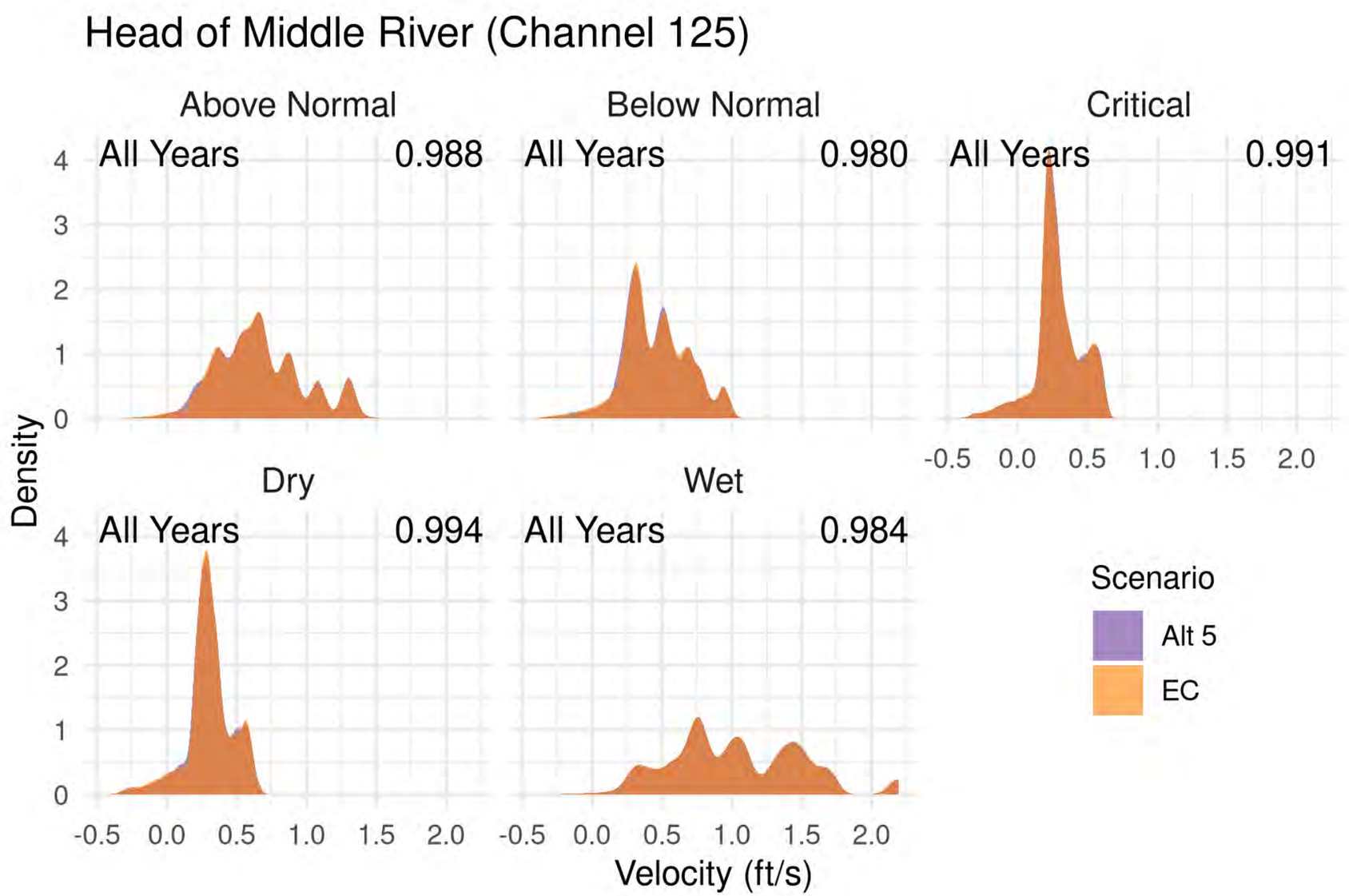

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-169. Velocity Density Distribution for Old River at Highway 4, March.**



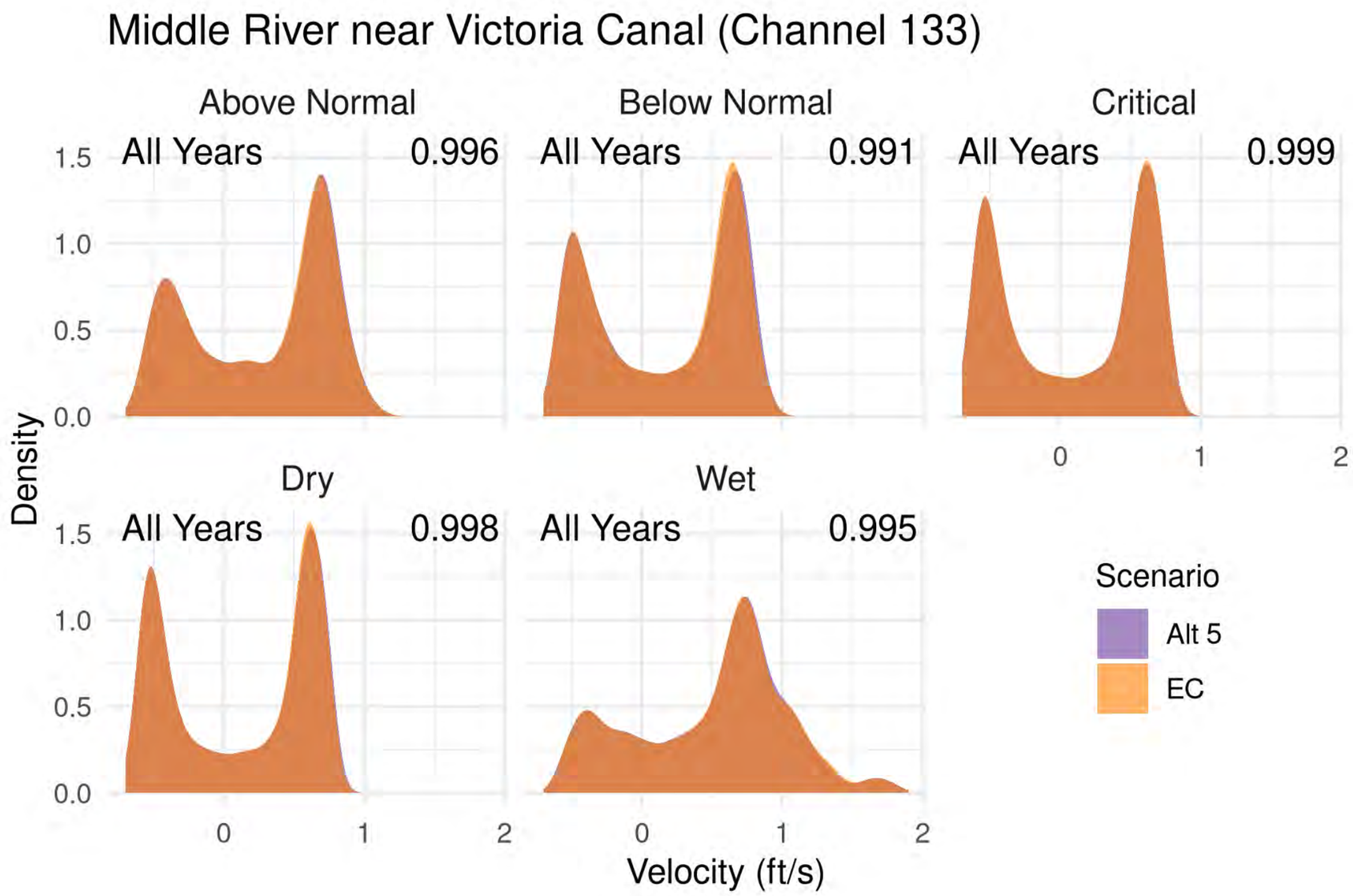

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-170. Velocity Density Distribution for Old River near Woodward Island, March.**



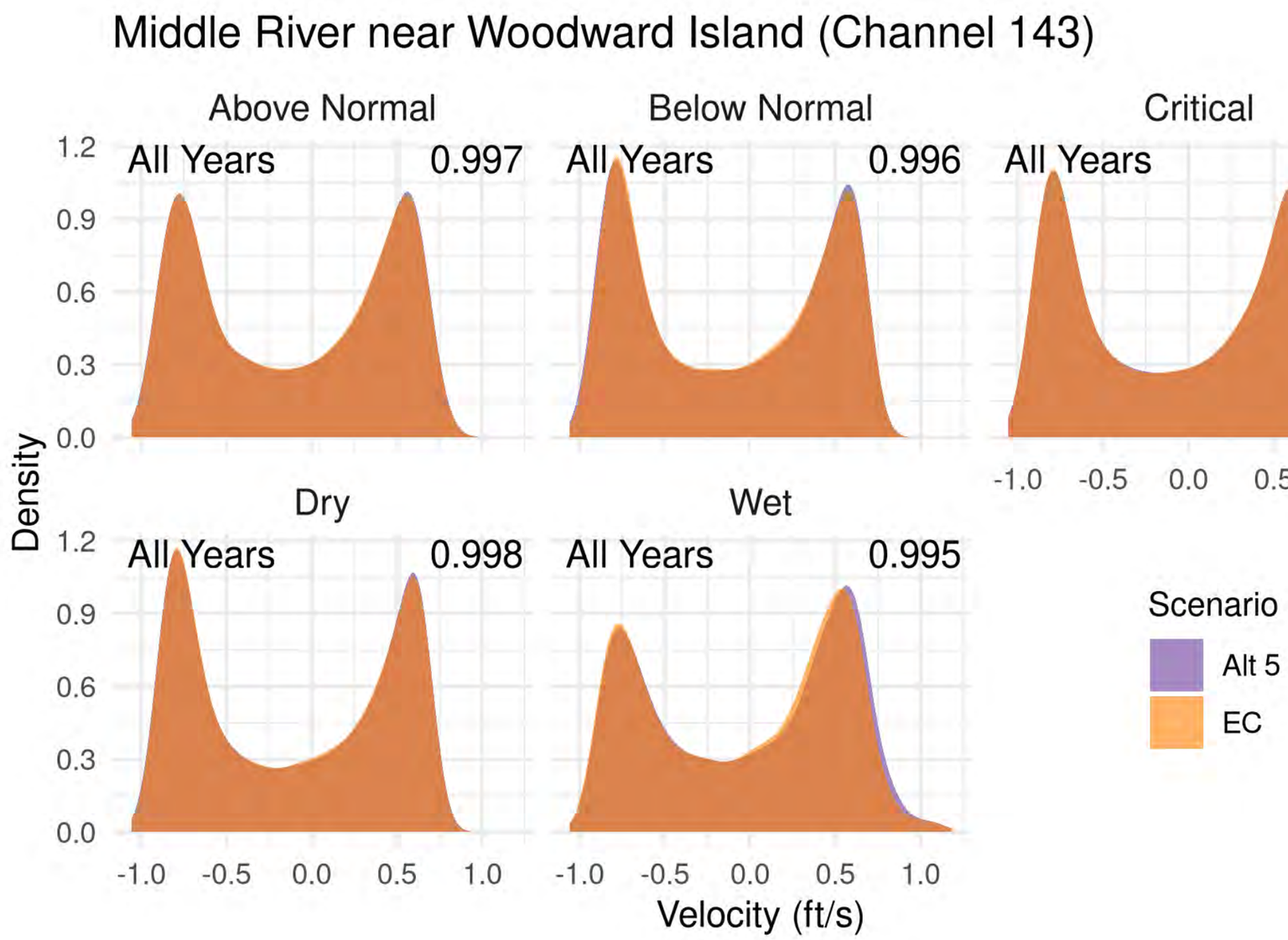

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-171. Velocity Density Distribution for Head of Middle River, March.**



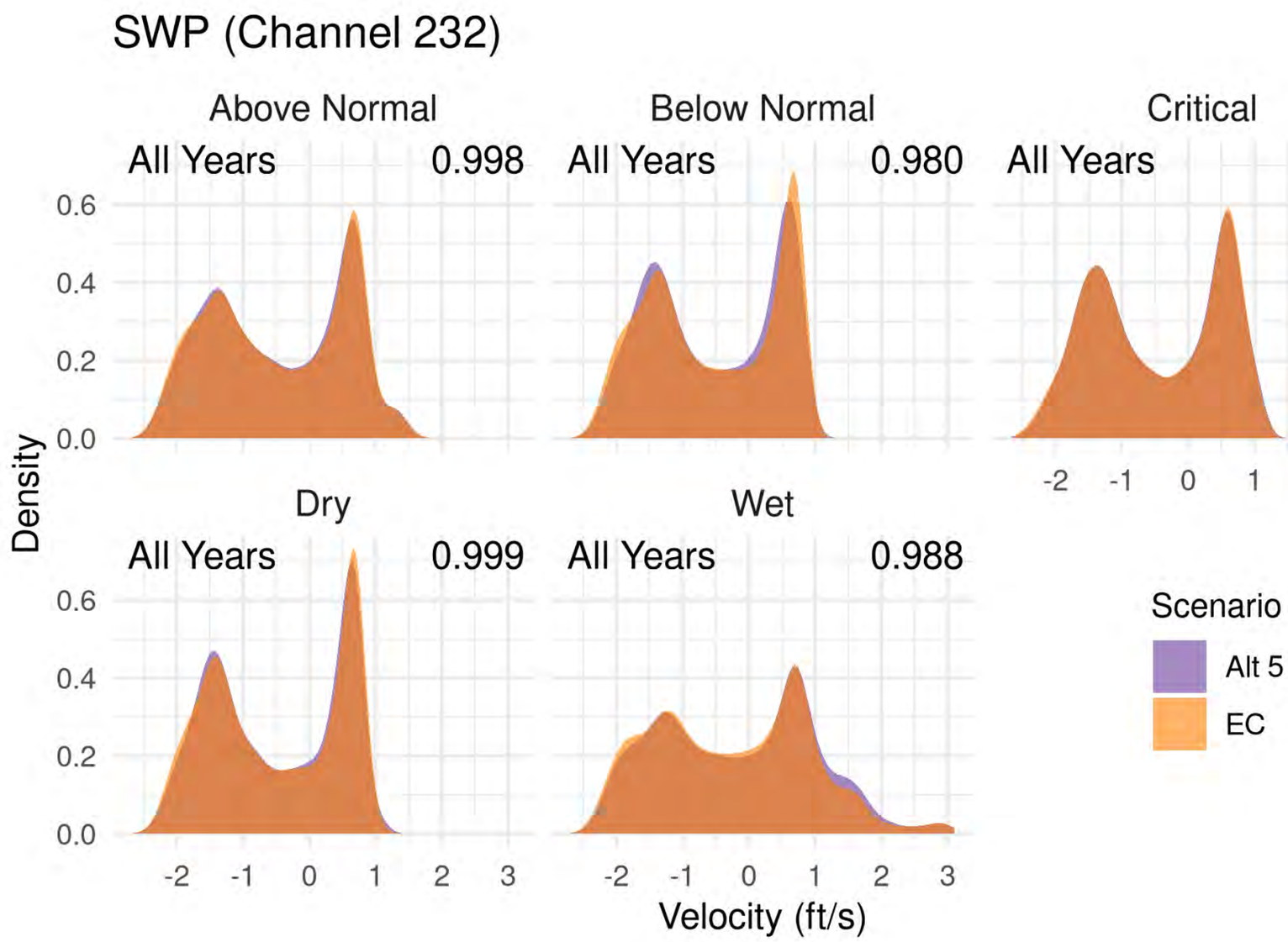

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-172. Velocity Density Distribution for Middle River near Victoria Canal, March.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-173. Velocity Density Distribution for Middle River near Woodward Island, March.**

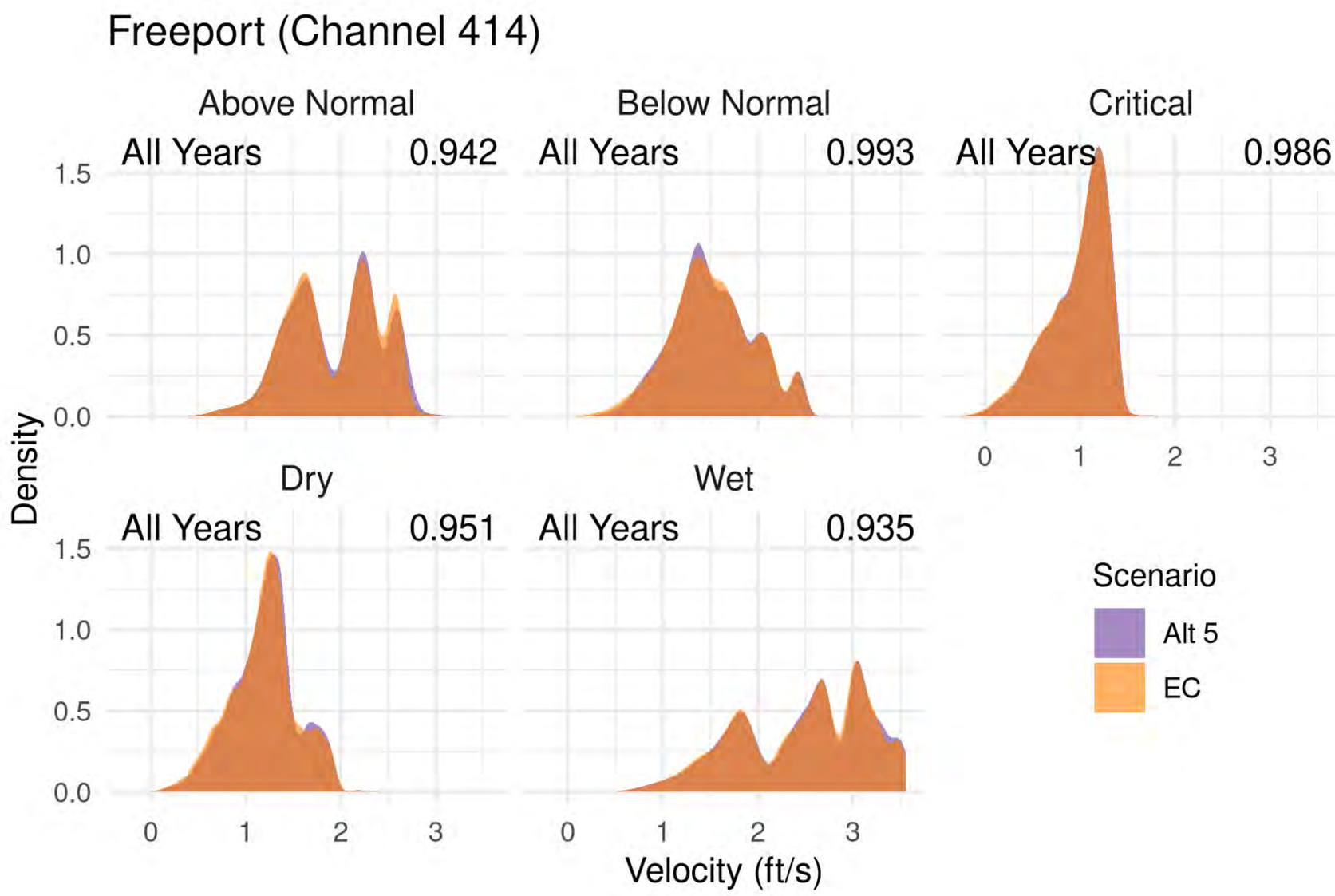



Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-174. Velocity Density Distribution for State Water Project (West Canal near Entrance to Clifton Court Forebay), March.**

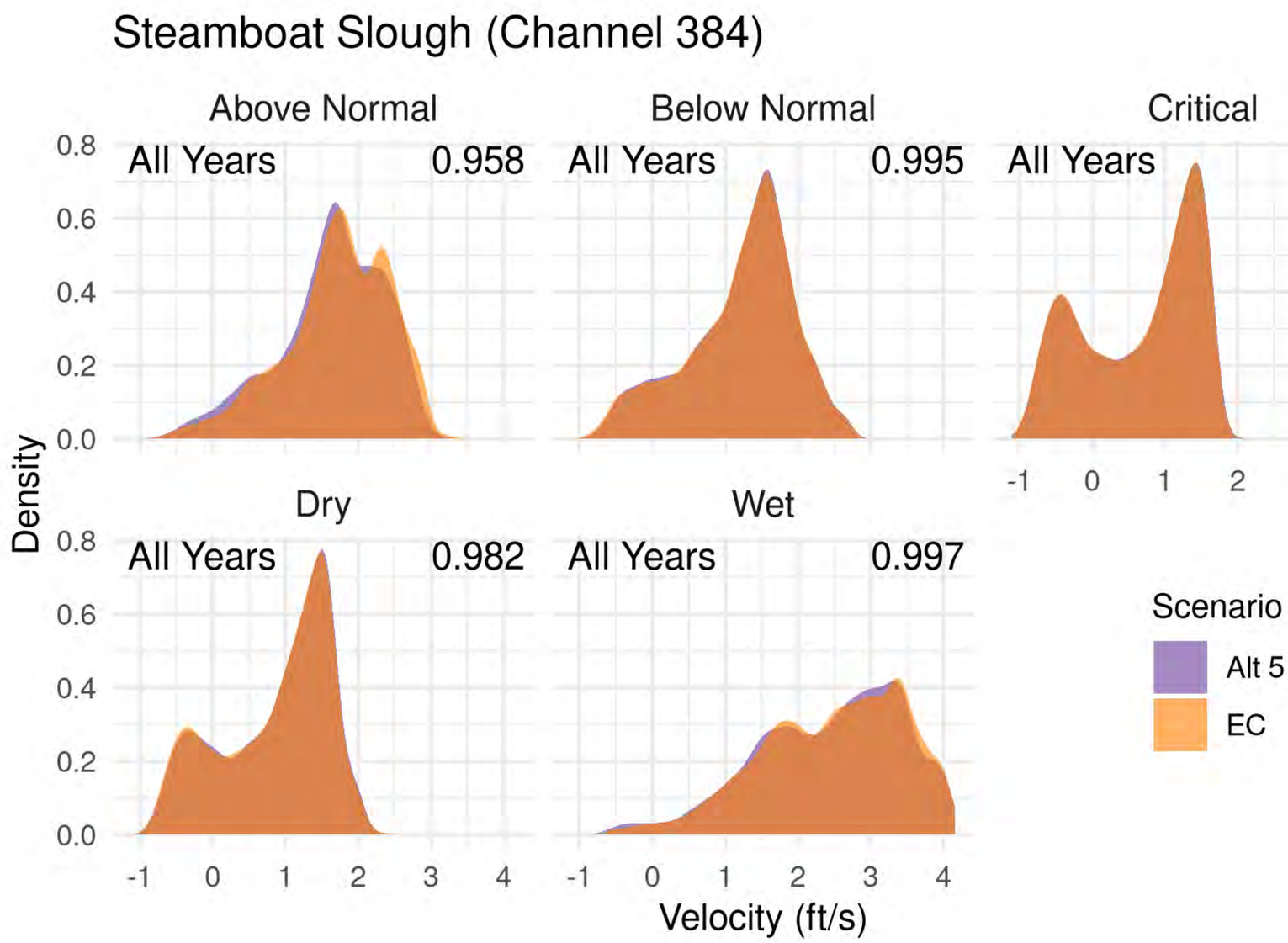
**April**

***Sacramento River Delta***



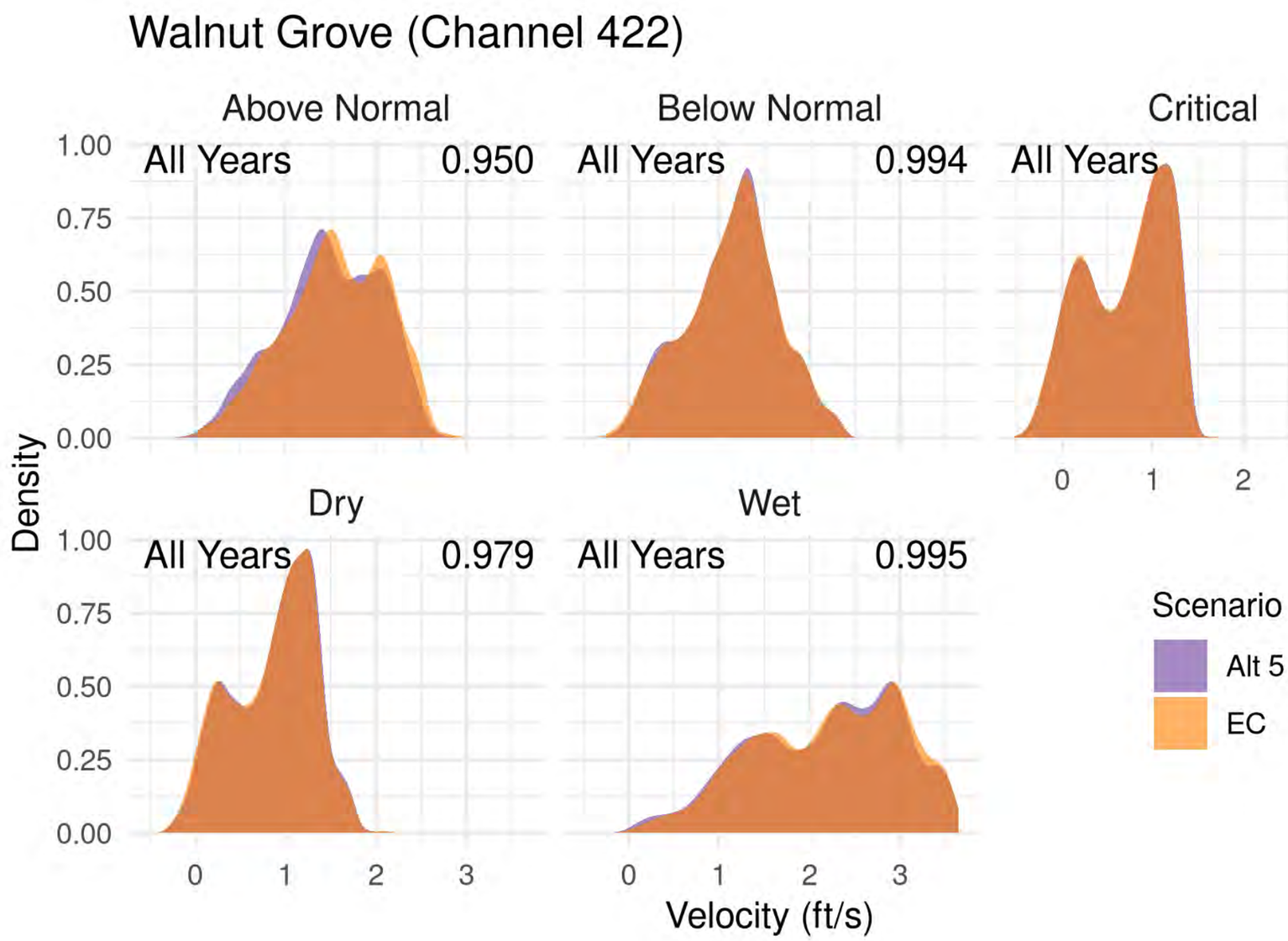

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-175. Velocity Density Distribution for Freeport, April.**



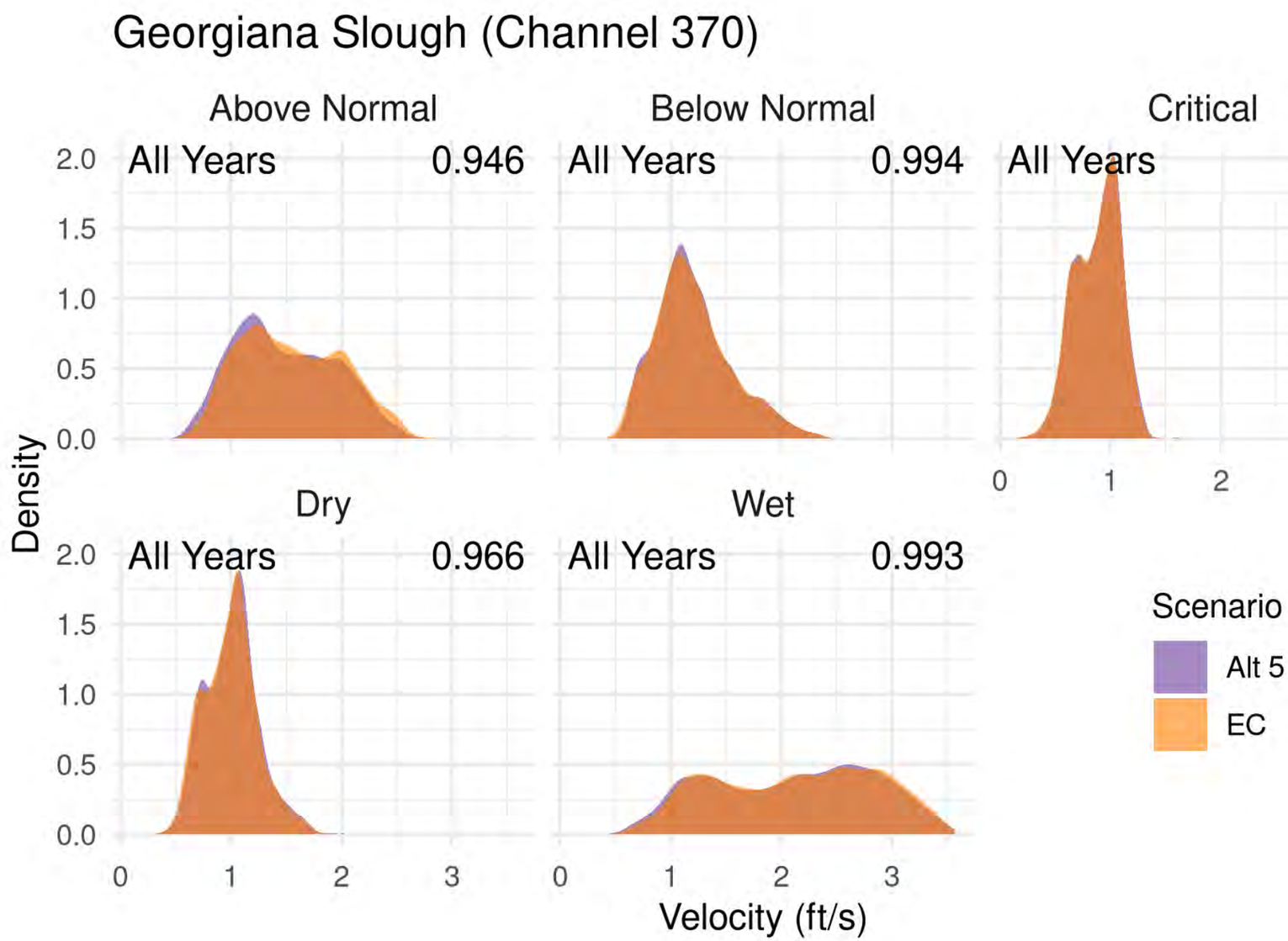

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-176. Velocity Density Distribution for Steamboat Slough, April.**



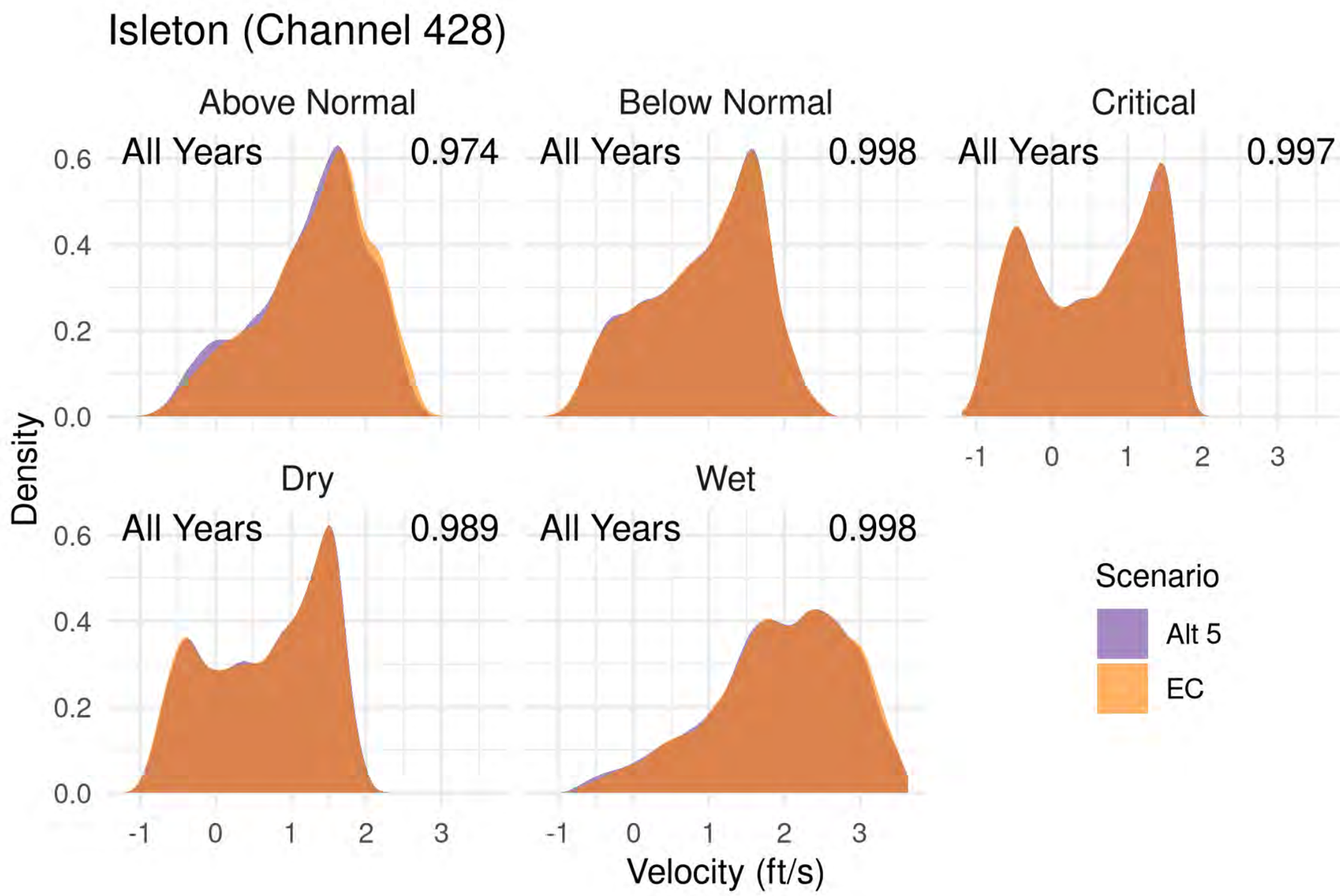

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-177. Velocity Density Distribution for Walnut Grove (Sacramento River), April.**



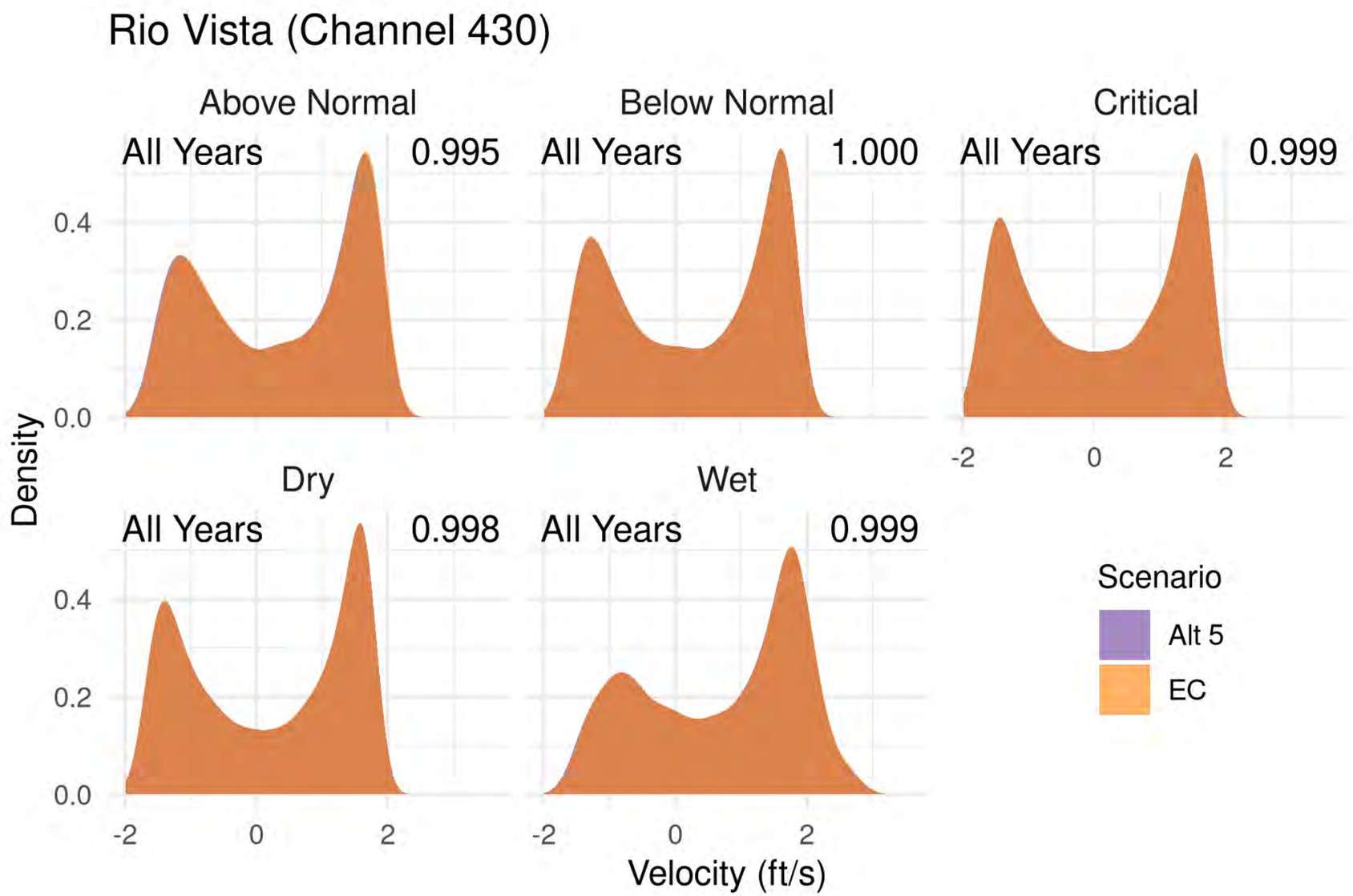

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-178. Velocity Density Distribution for Georgiana Slough, April.**



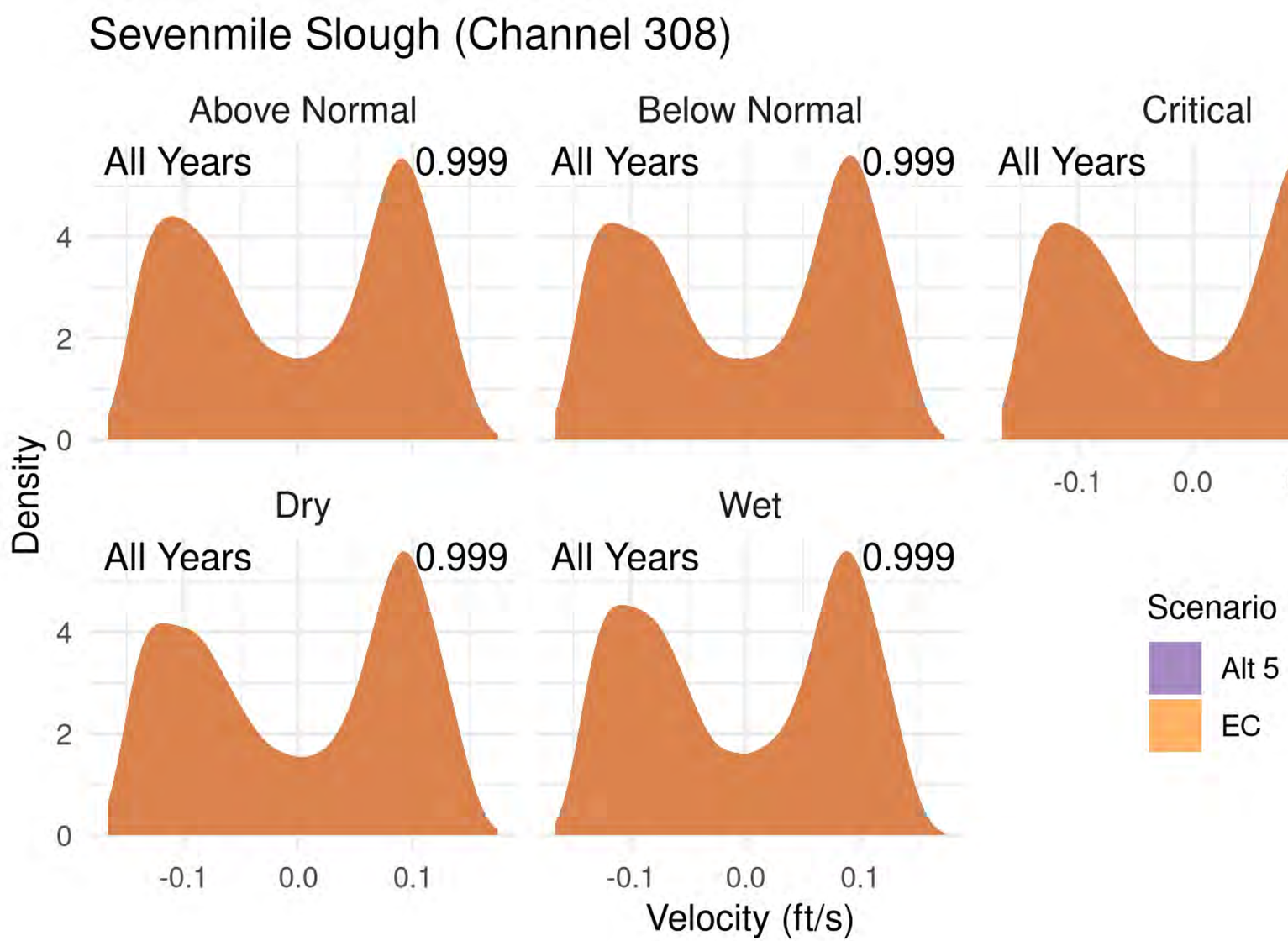

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-179. Velocity Density Distribution for Isleton (Sacramento River), April**



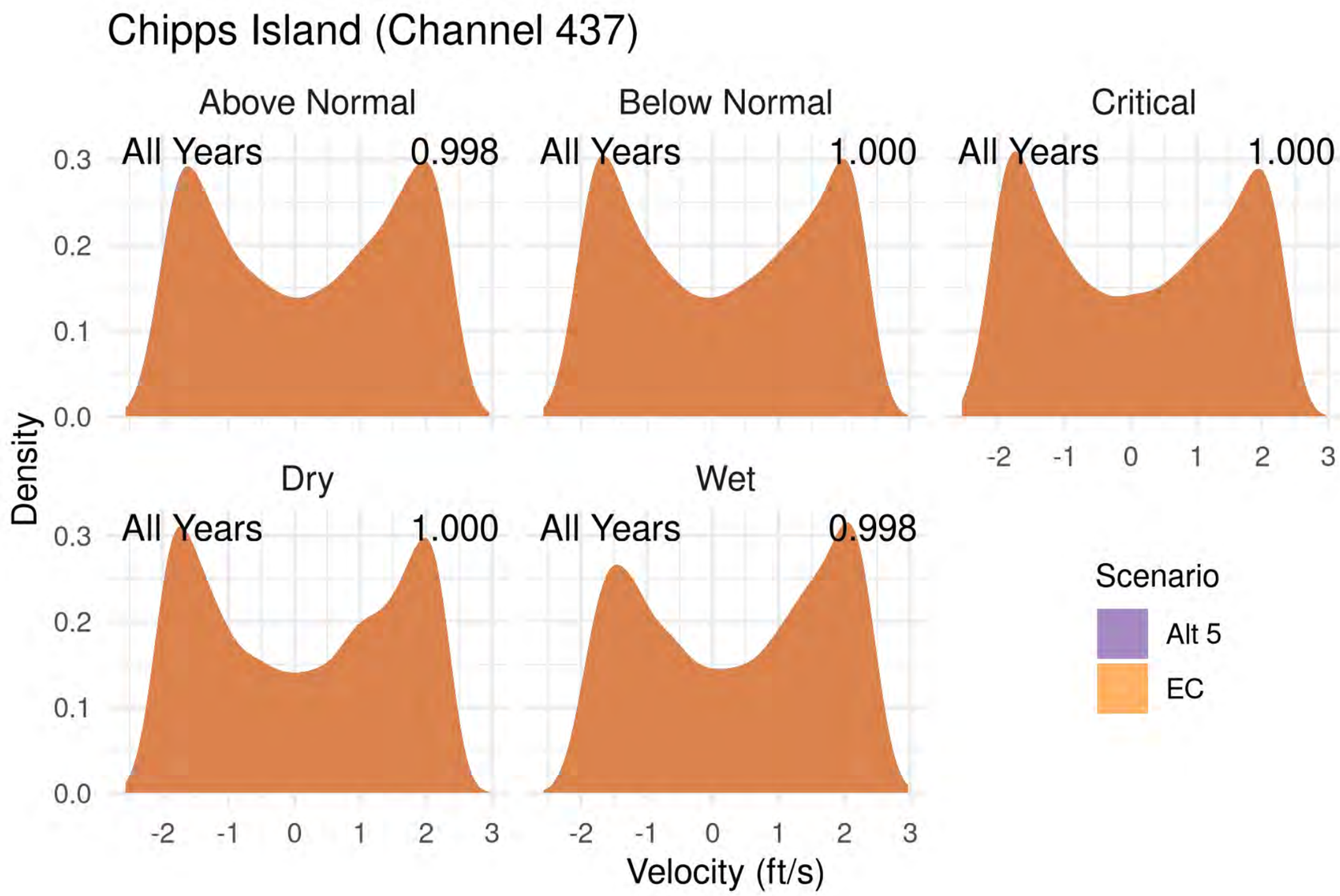

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-180. Velocity Density Distribution for Rio Vista (Sacramento River), April.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

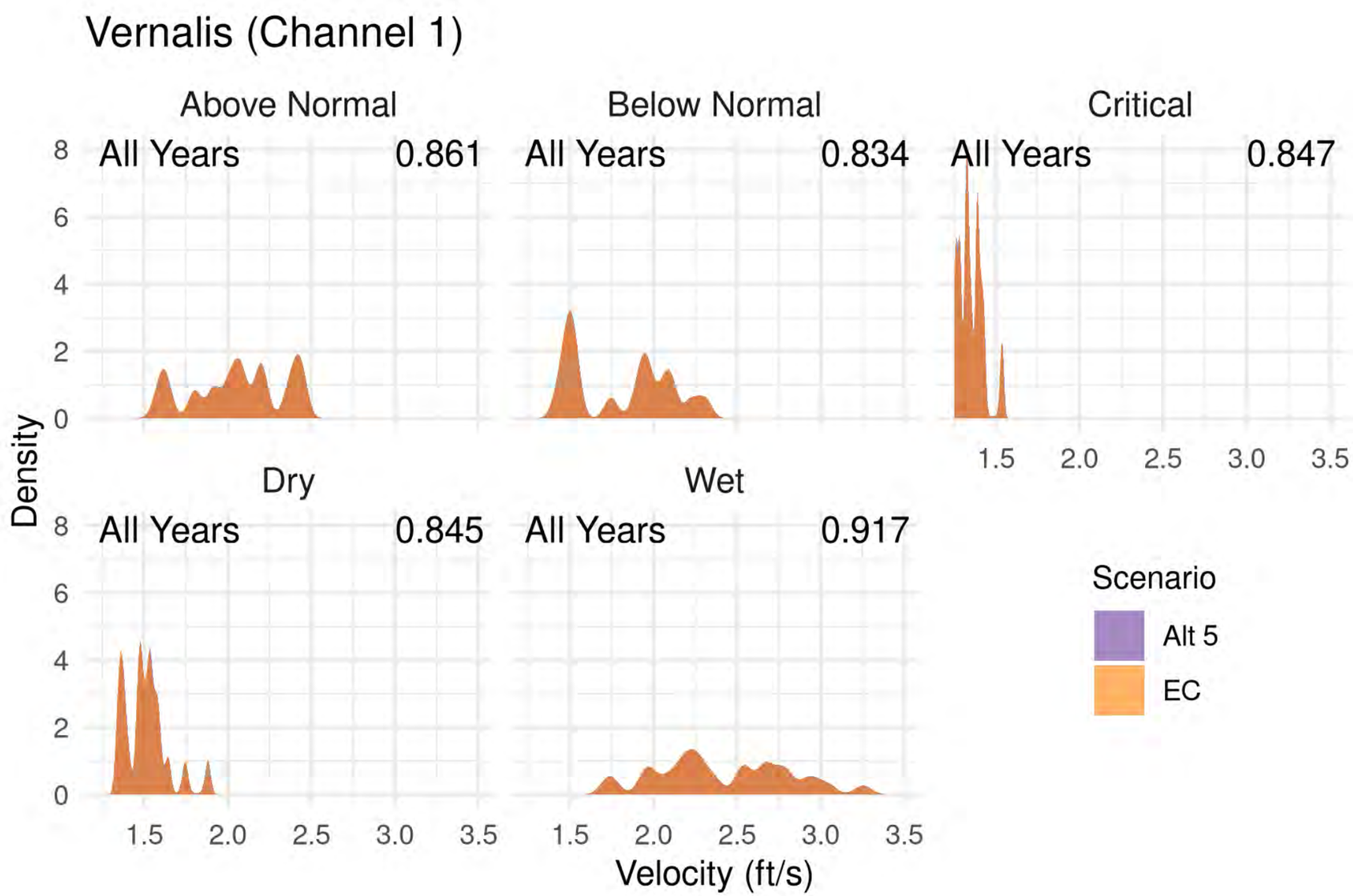
**Figure 5D.1-181. Velocity Density Distribution for Sevenmile Slough, April.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

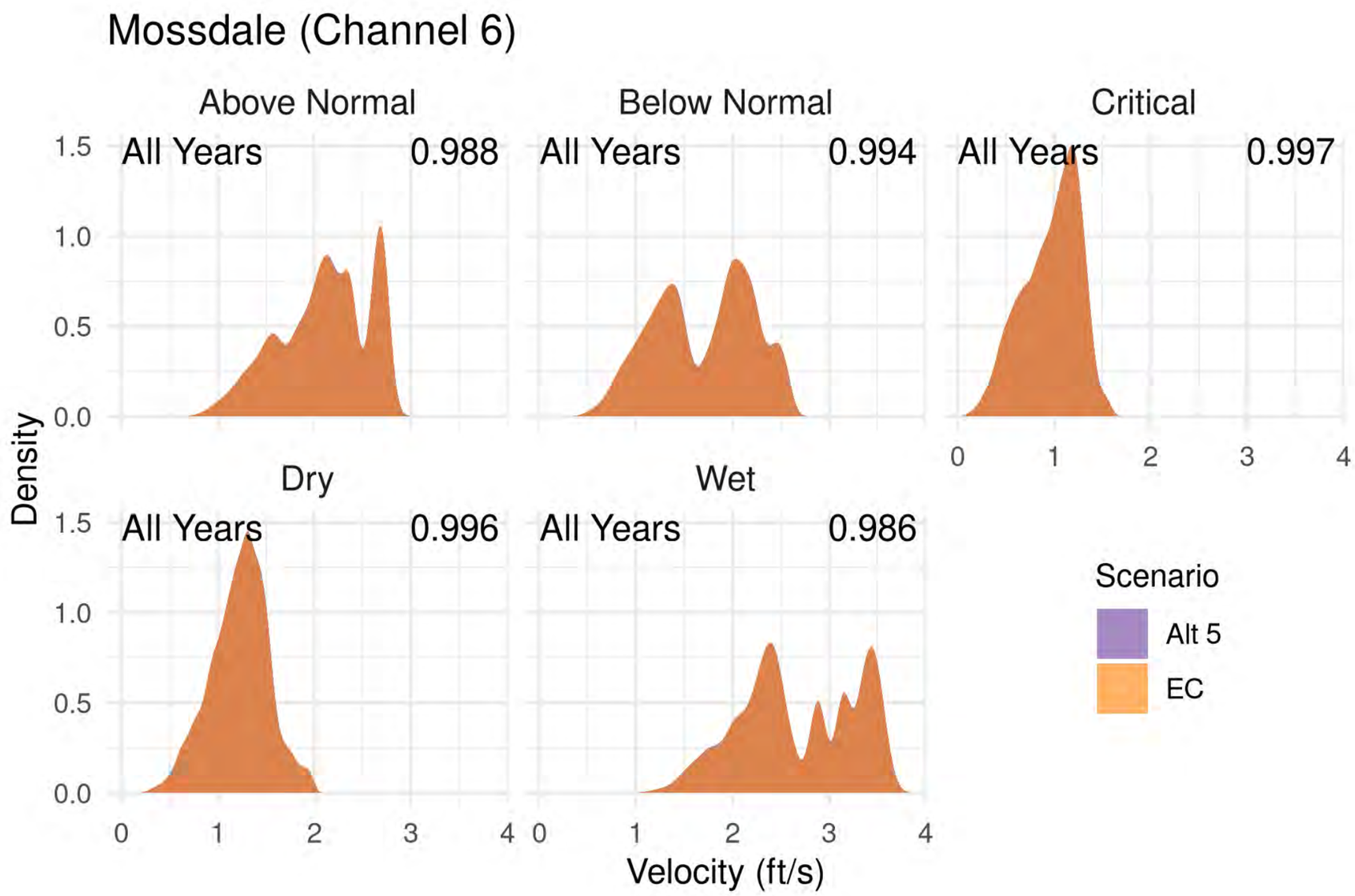
**Figure 5D.1-182. Velocity Density Distribution for Chipps Island (Sacramento River–San Joaquin River Confluence), April.**

***San Joaquin River Delta***



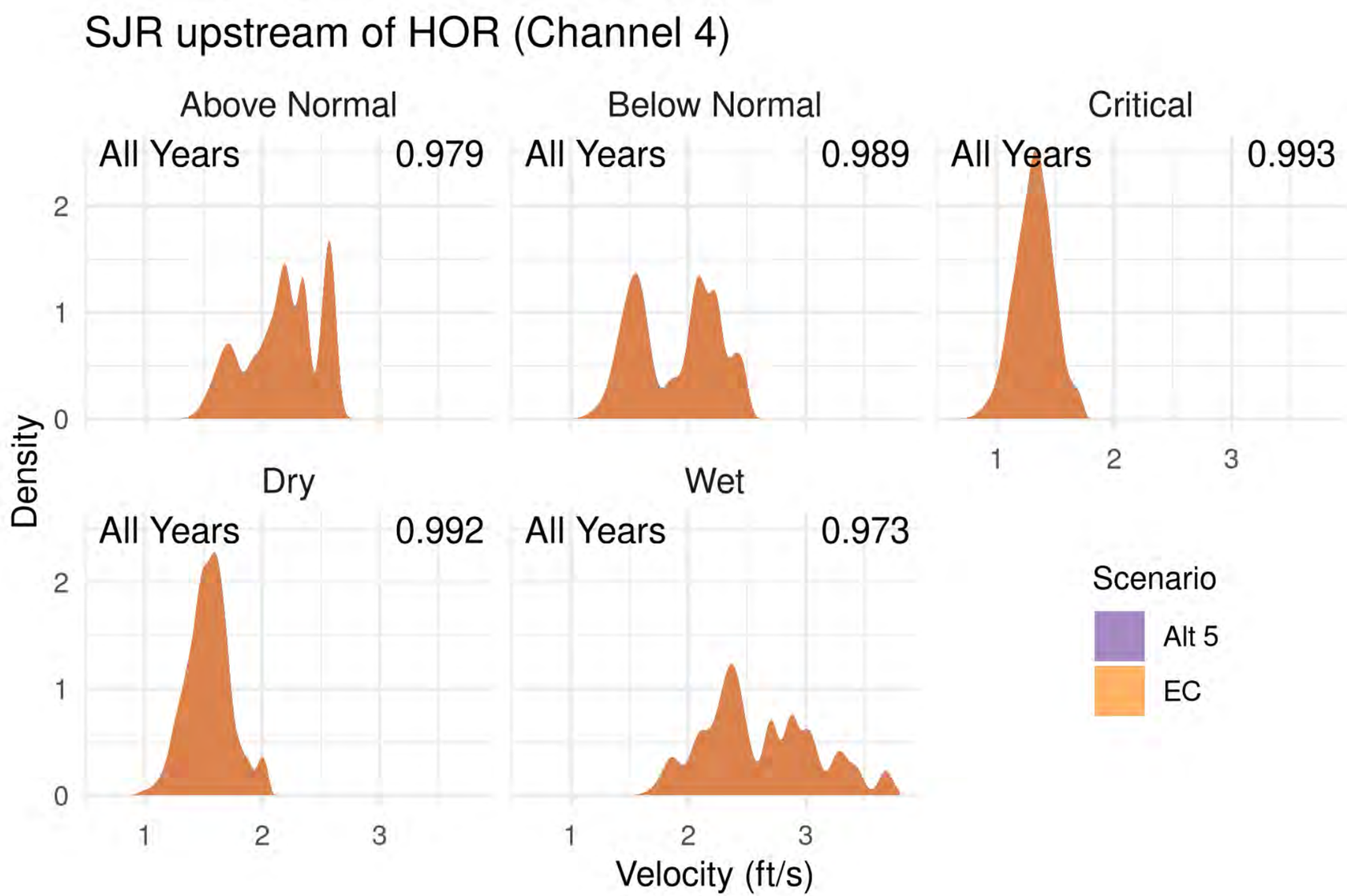

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-183. Velocity Density Distribution for Vernalis (San Joaquin River), April.**



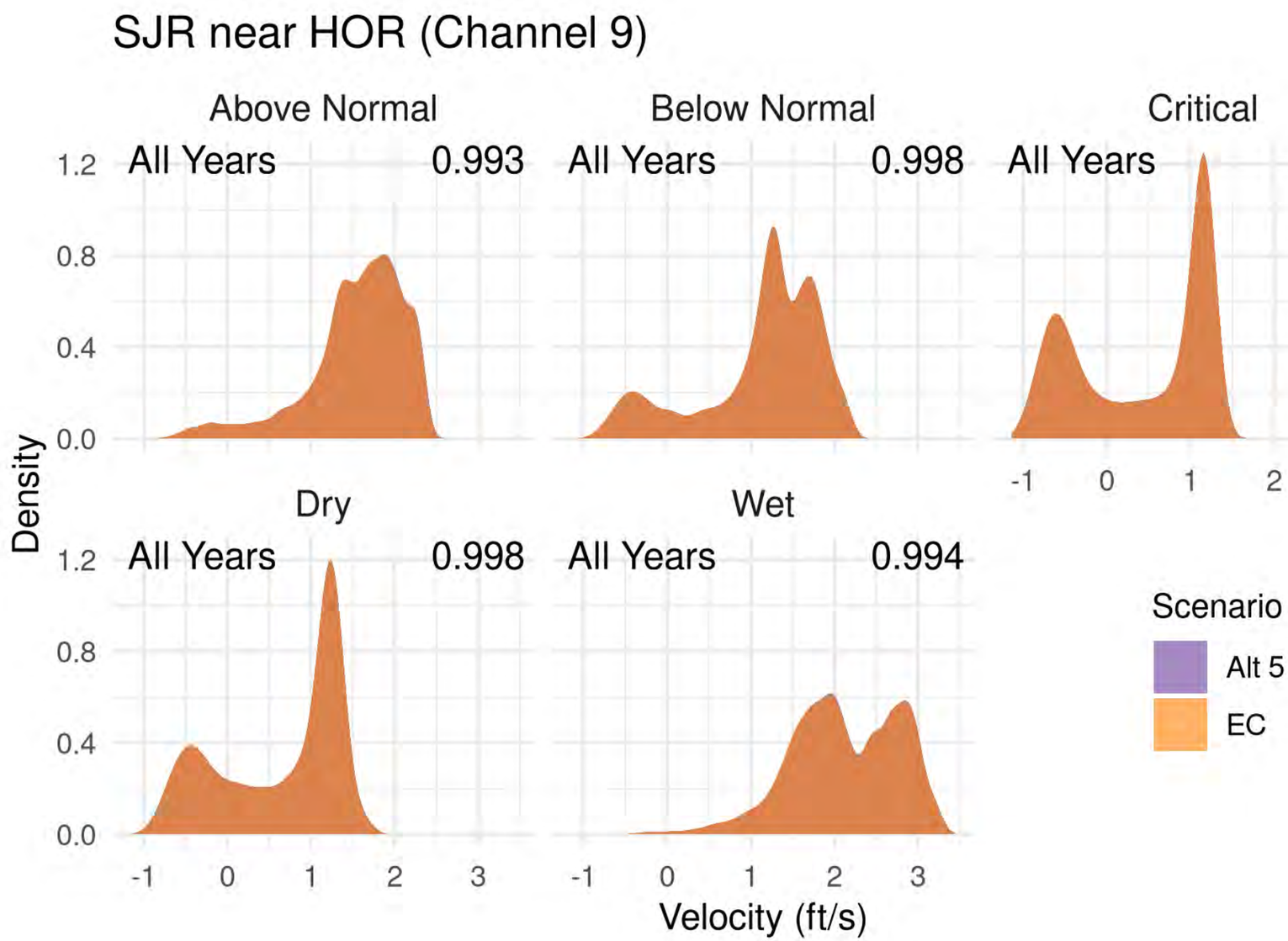

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-184. Velocity Density Distribution for Mossdale (San Joaquin River), April.**



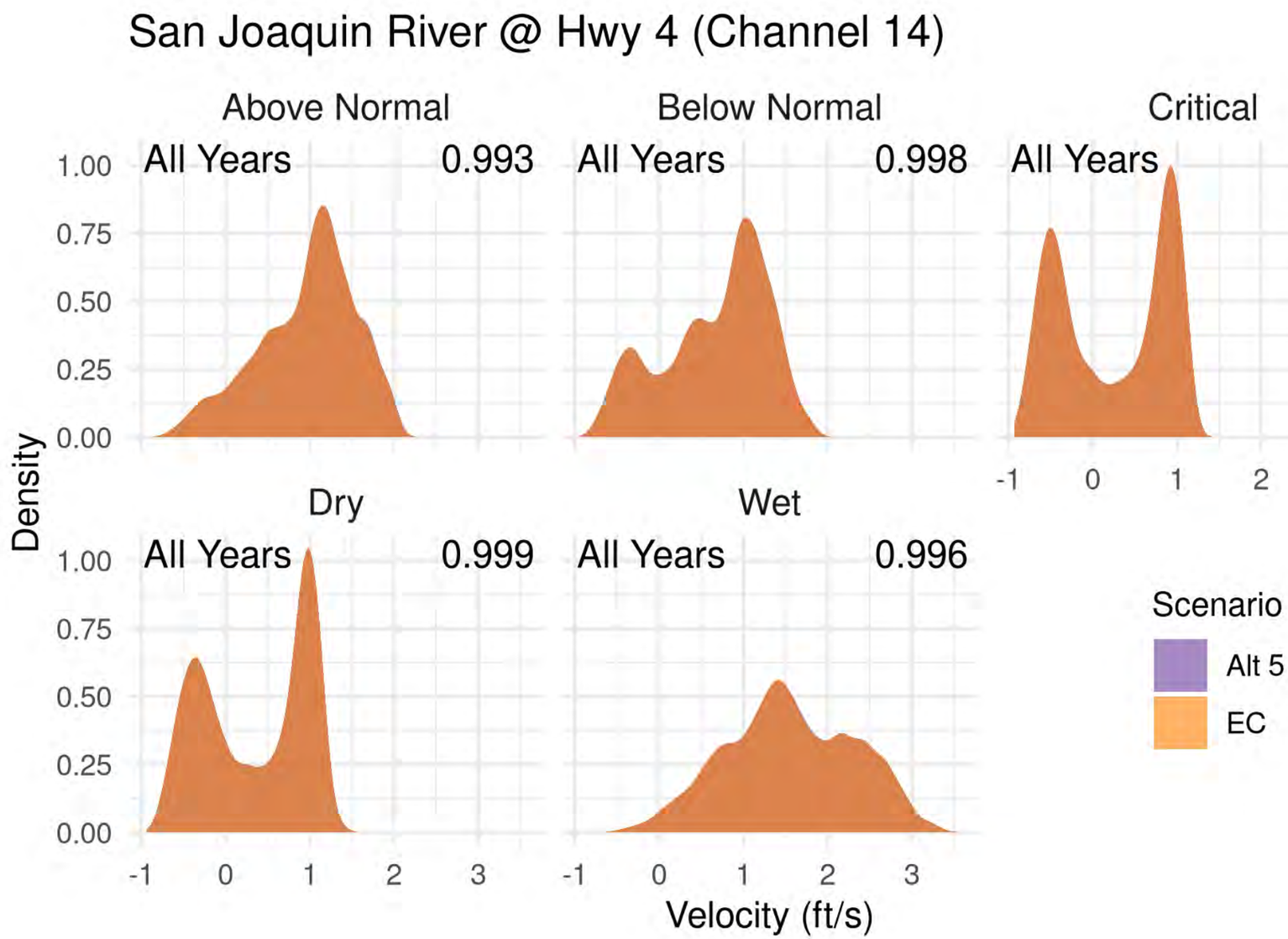

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-185. Velocity Density Distribution for San Joaquin River upstream of Head of Old River, April.**



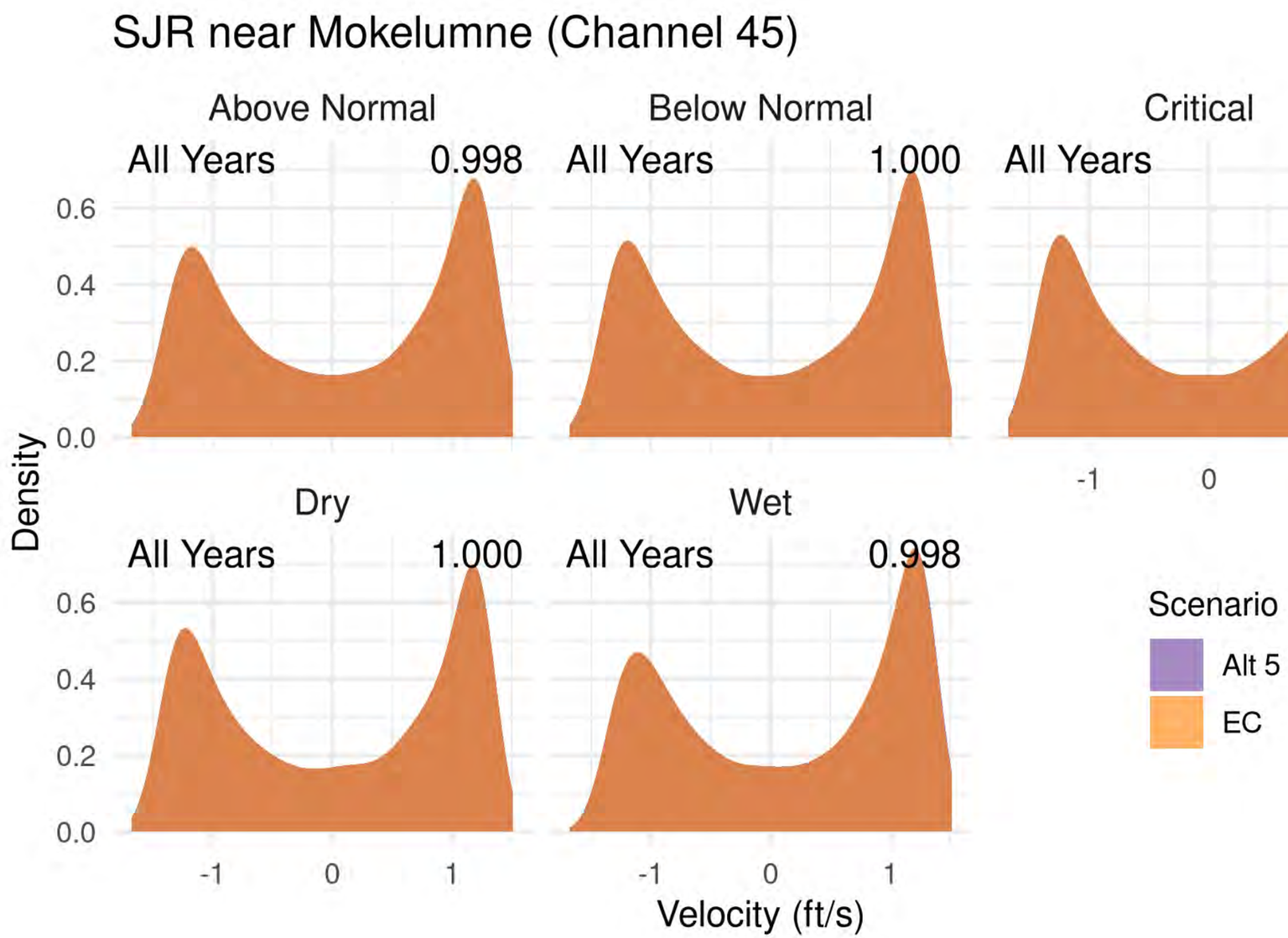

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-186. Velocity Density Distribution for San Joaquin River near Head of Old River, April.**



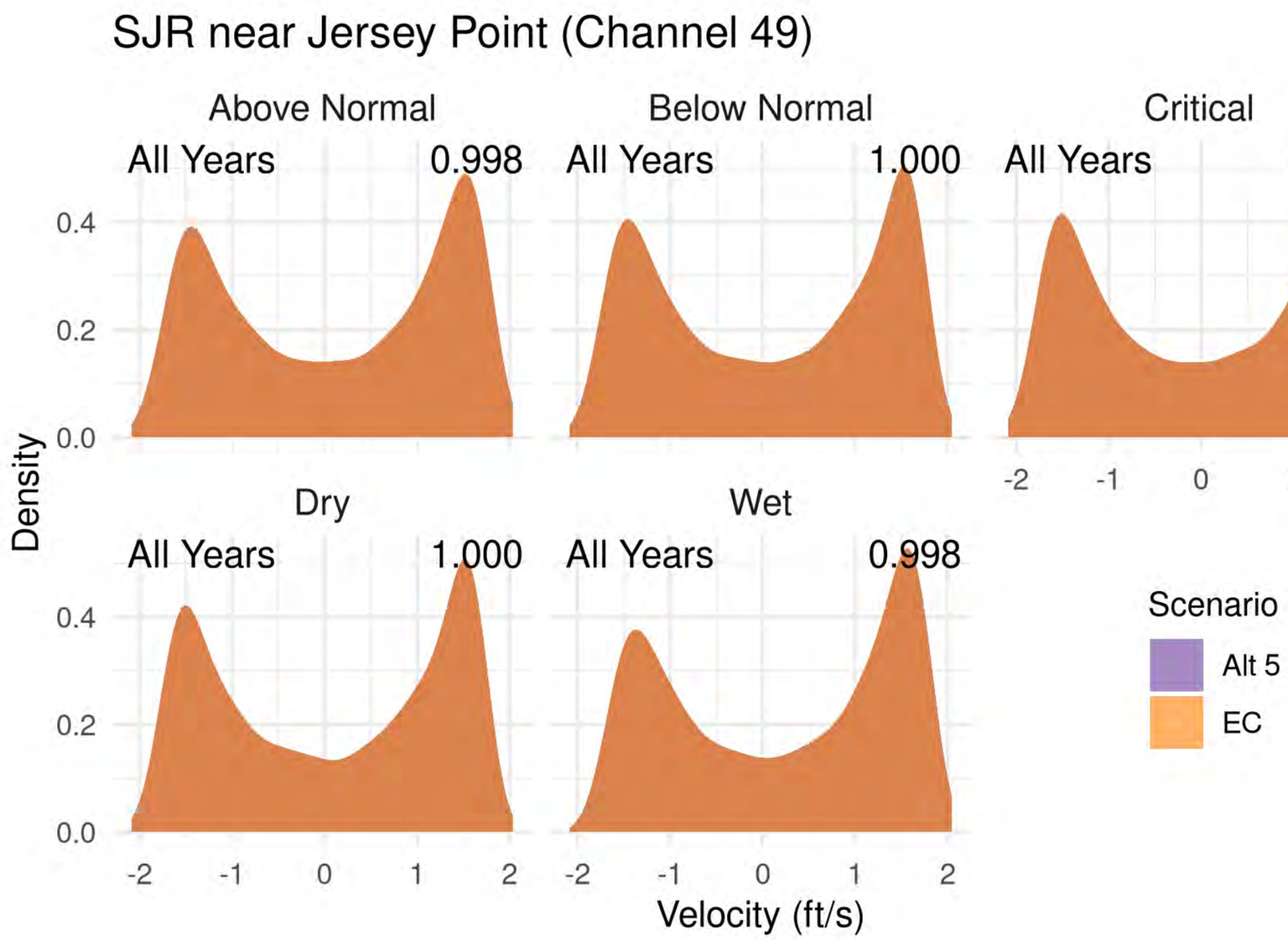

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-187. Velocity Density Distribution for San Joaquin River at Highway 4, April.**



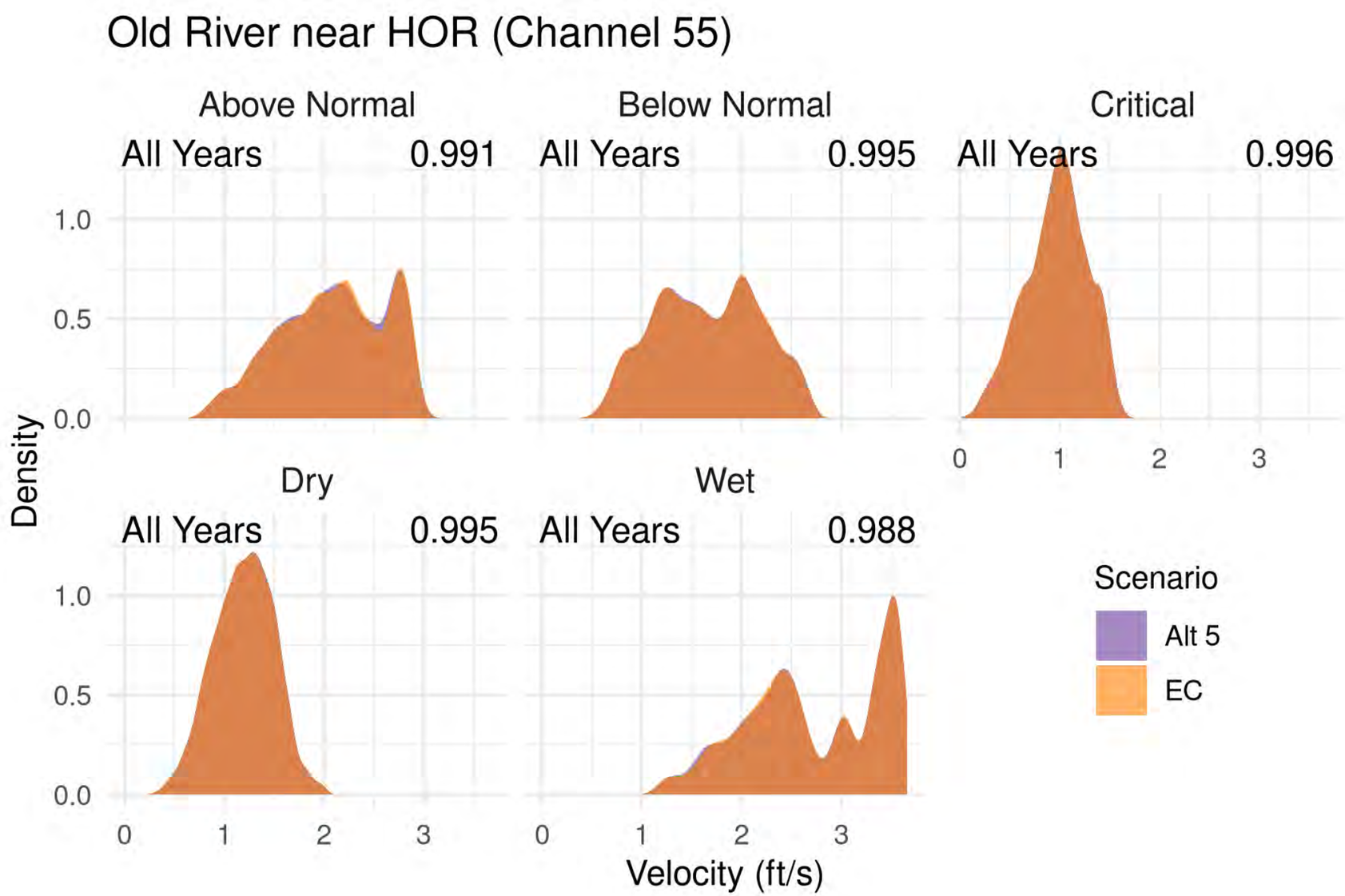

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-188. Velocity Density Distribution for San Joaquin River near Mokelumne River, April.**



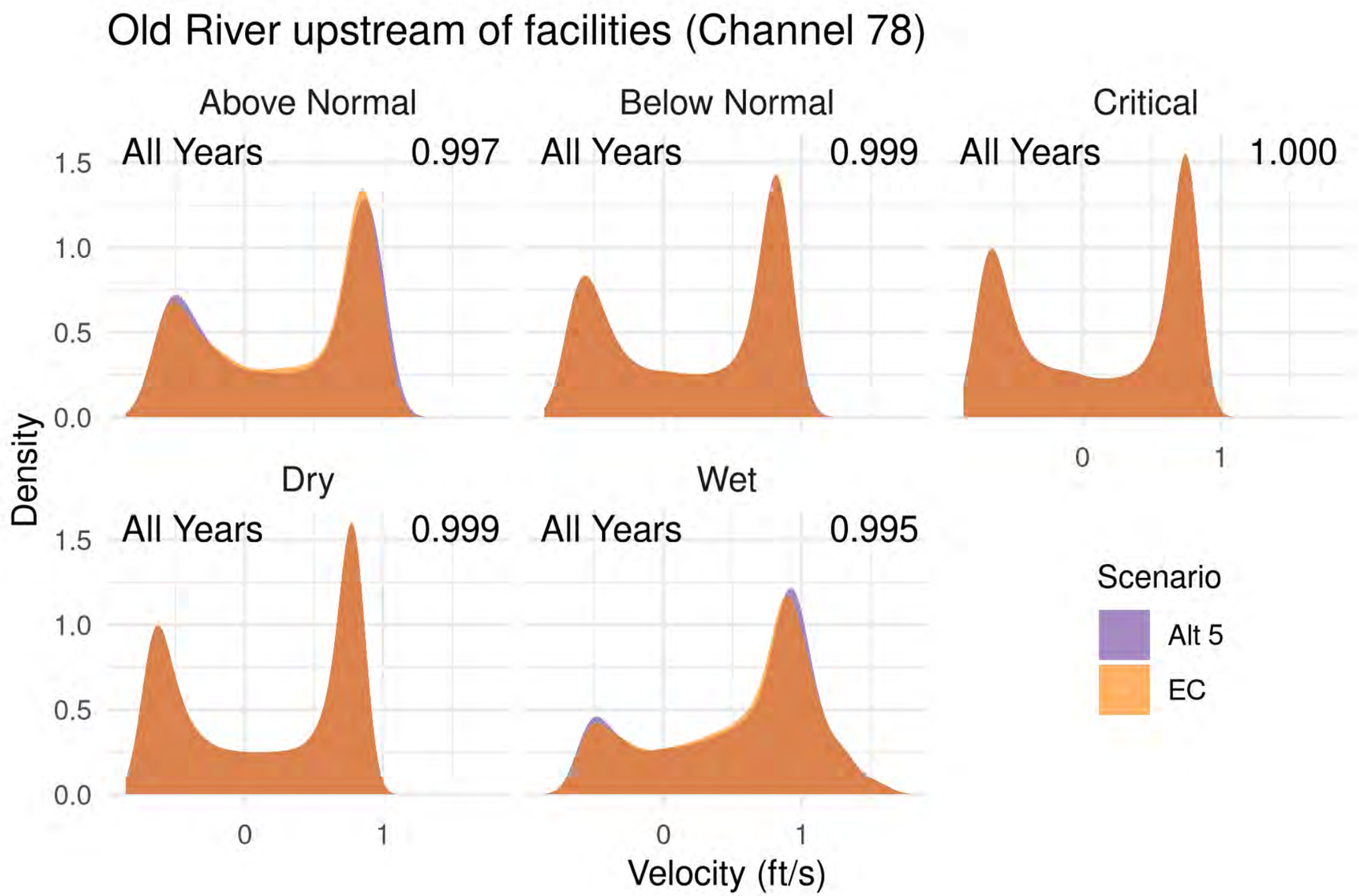

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-189. Velocity Density Distribution for San Joaquin River near Jersey Point, April.**



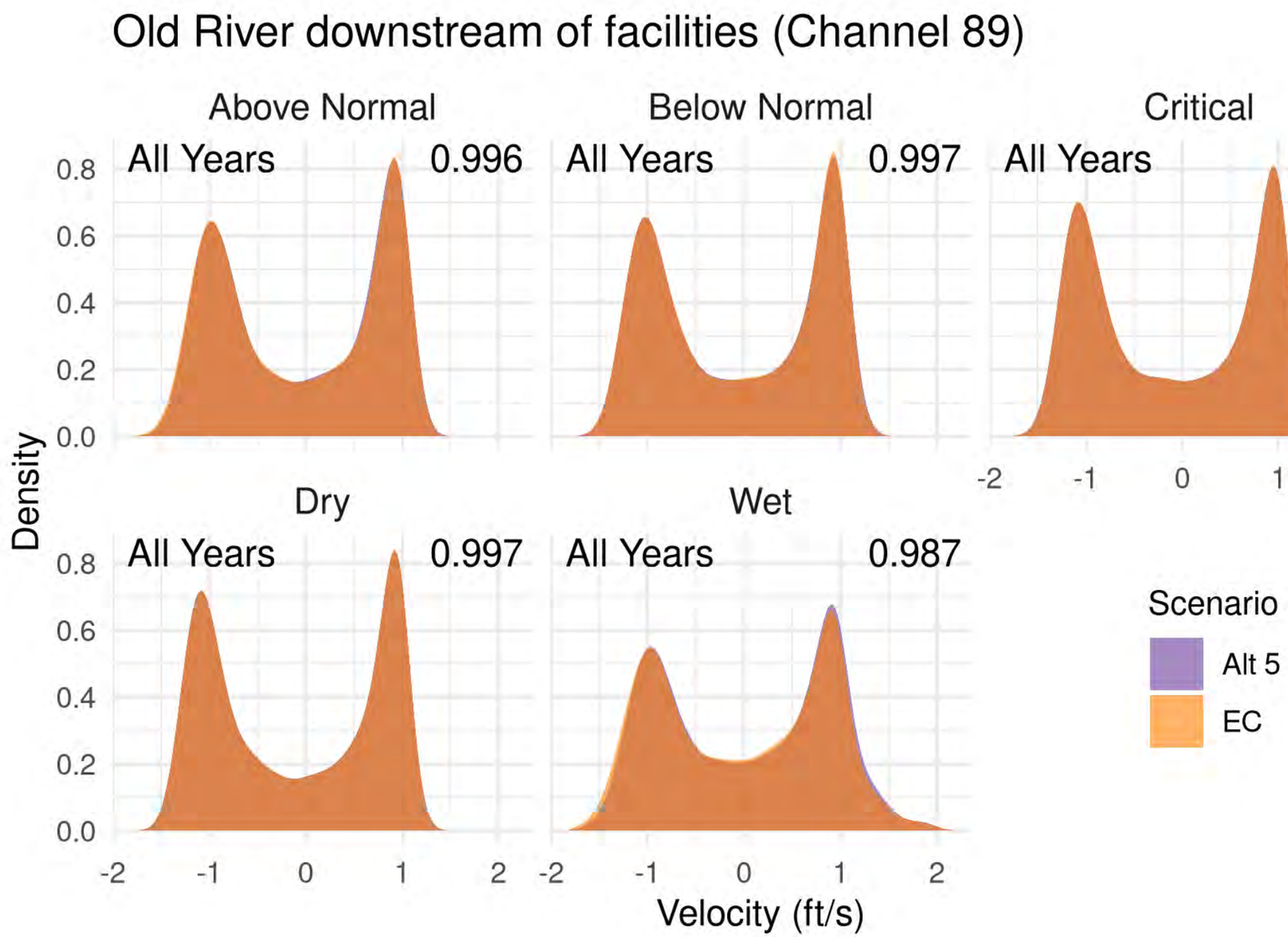

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-190. Velocity Density Distribution for Old River near Head of Old River, April.**



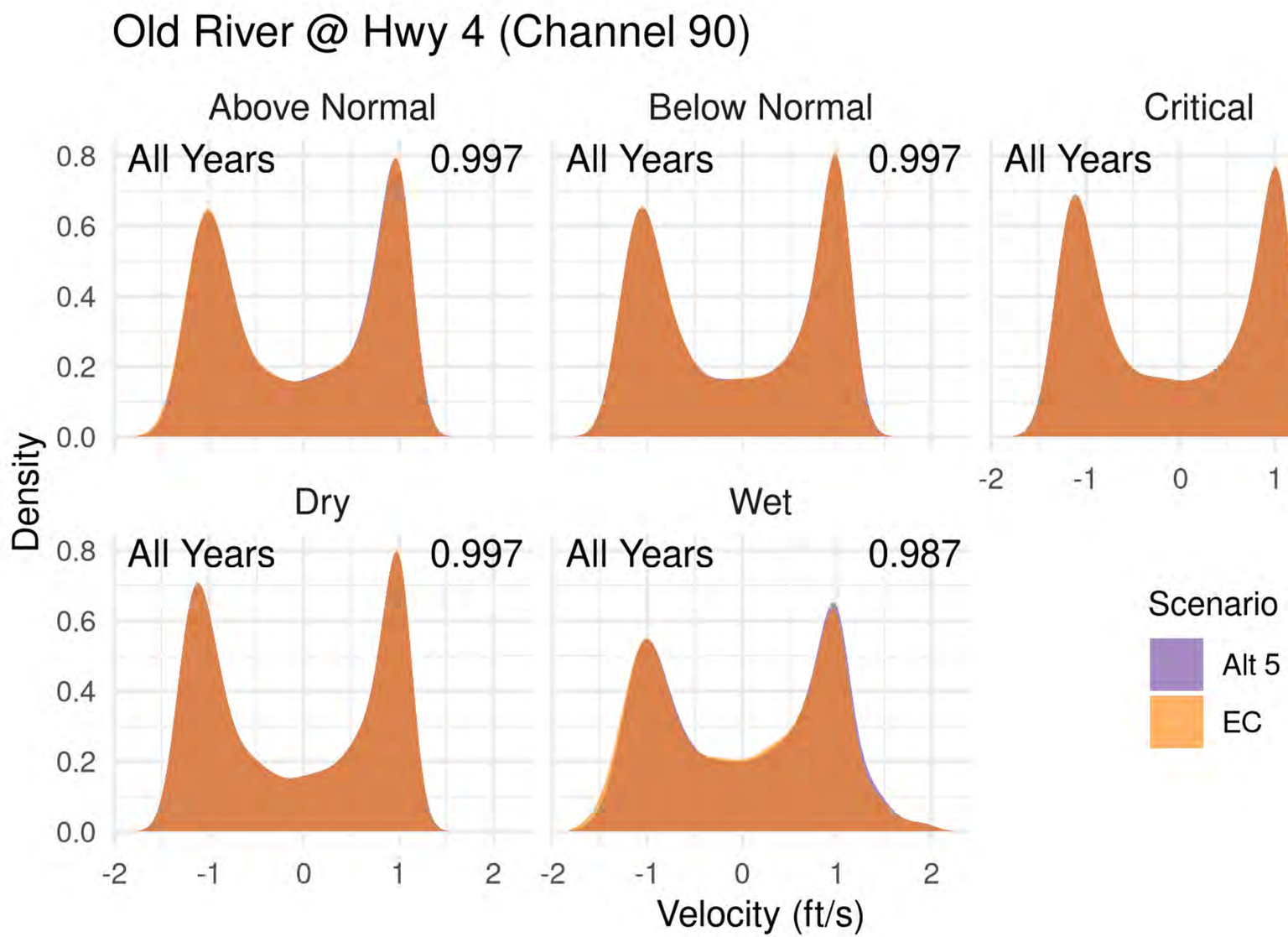

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-191. Velocity Density Distribution for Old River upstream of the South Delta Export Facilities, April.**



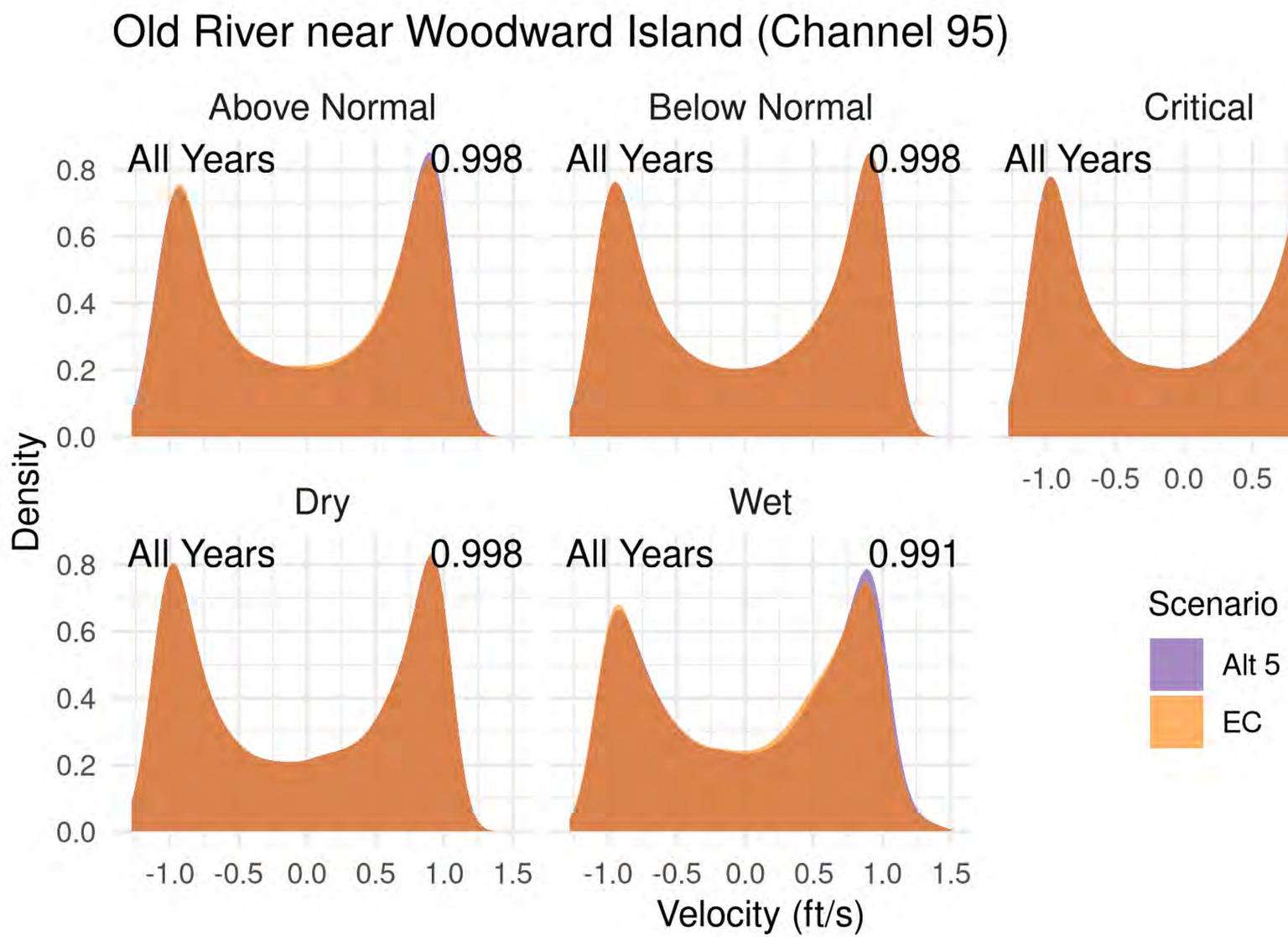

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-192. Velocity Density Distribution for Old River Downstream of the South Delta Export Facilities, April.**



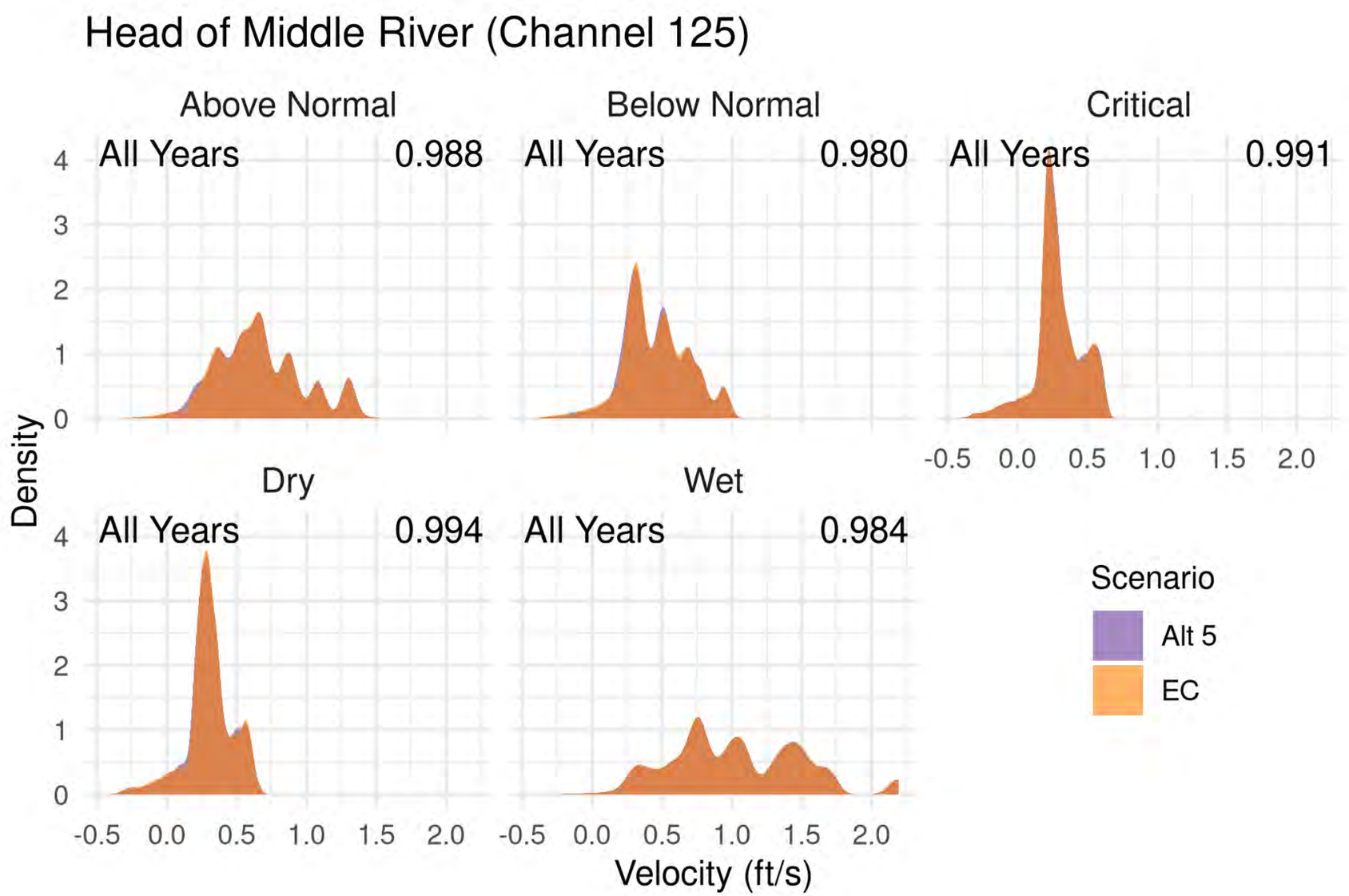

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-193. Velocity Density Distribution for Old River at Highway 4, April.**



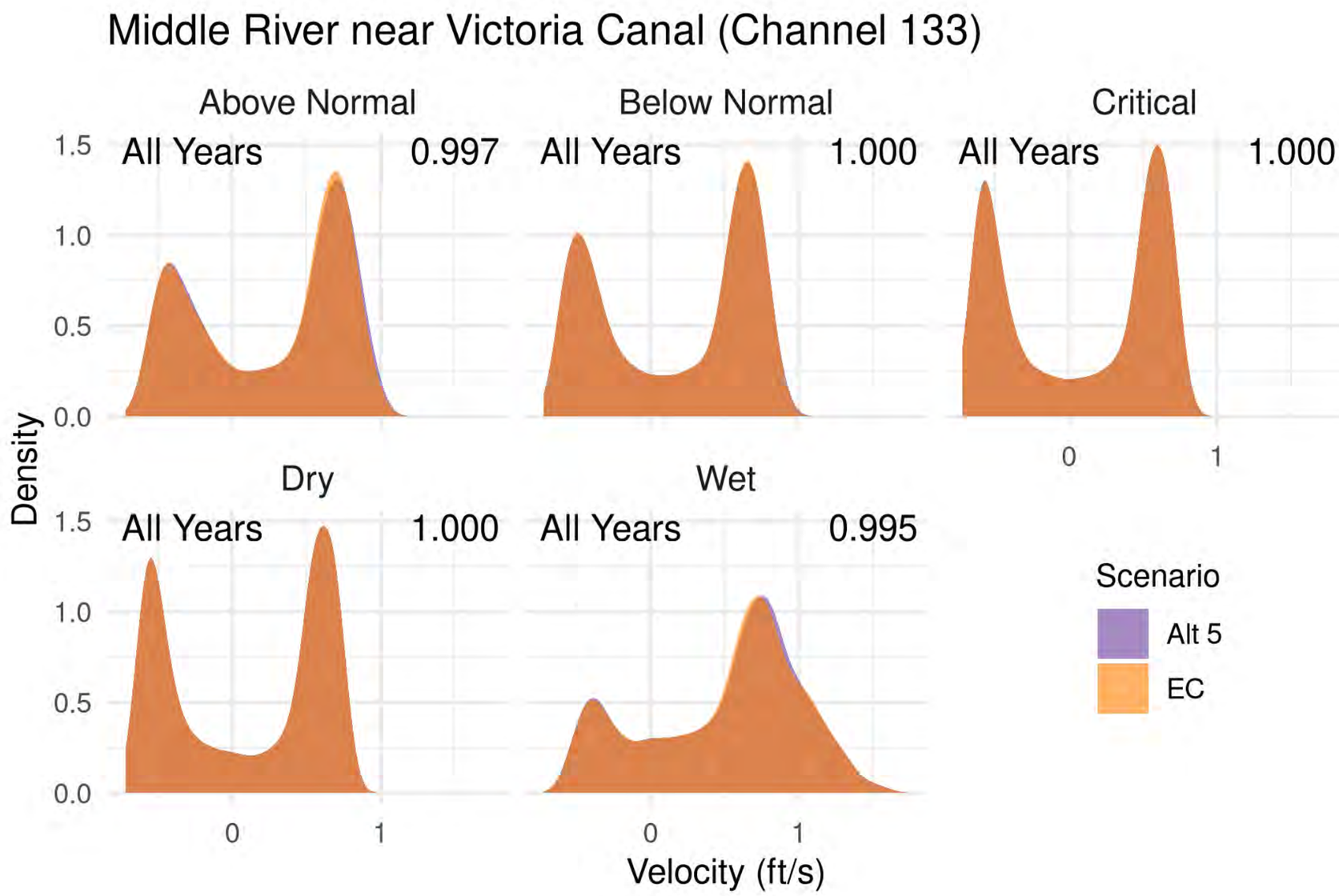

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-194. Velocity Density Distribution for Old River near Woodward Island, April.**



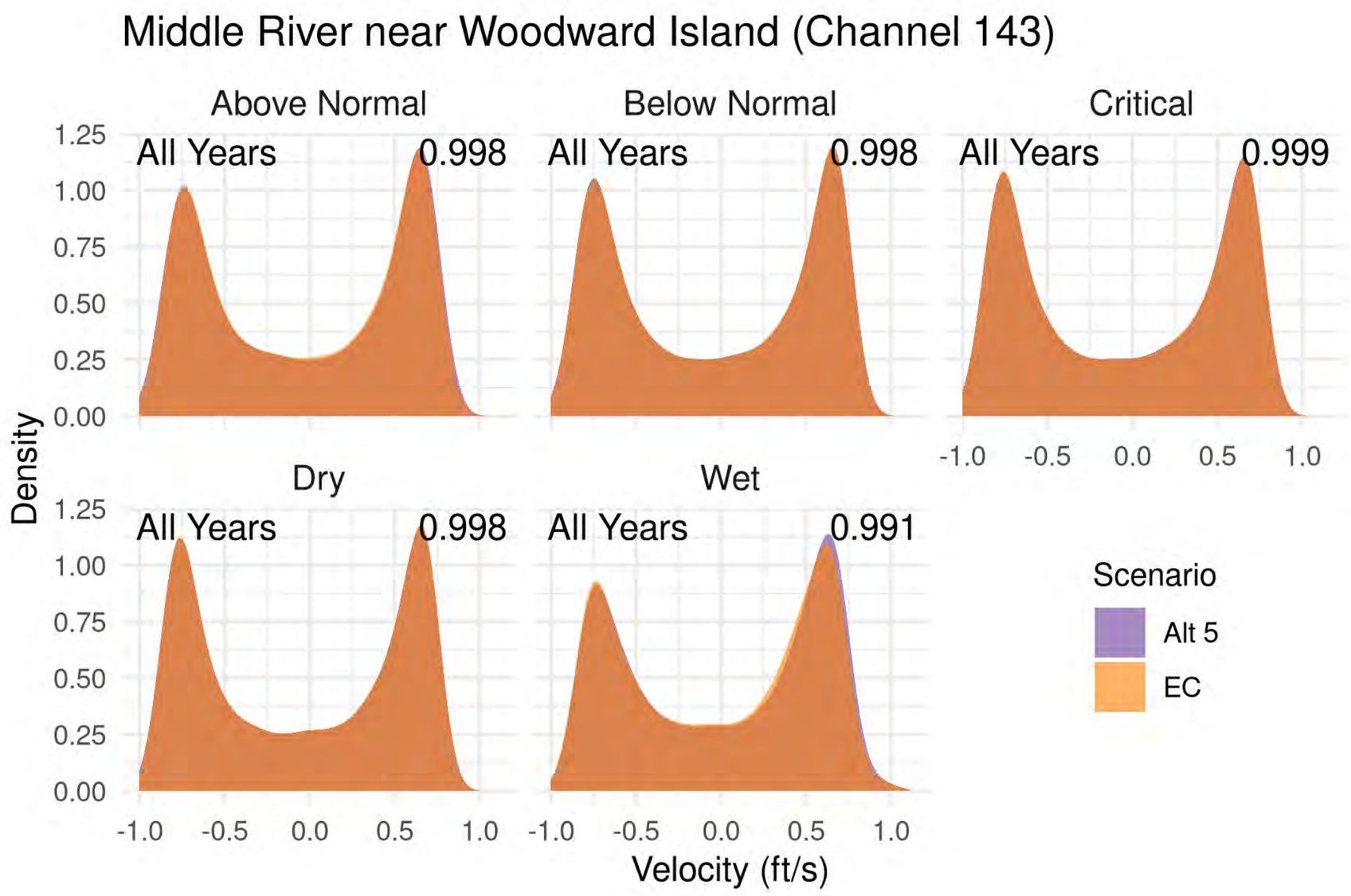

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-195. Velocity Density Distribution for Head of Middle River, April.**



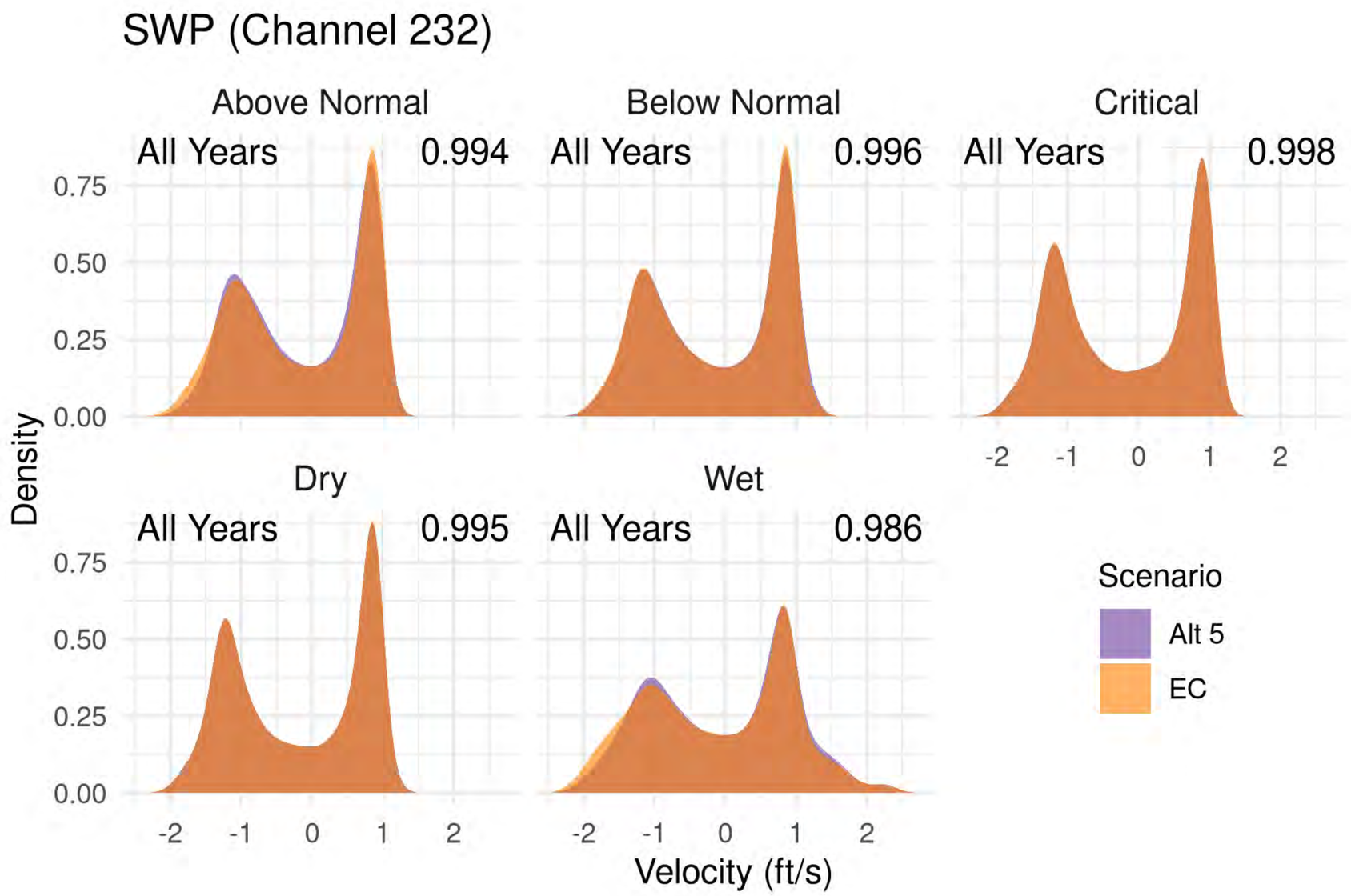

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-196. Velocity Density Distribution for Middle River near Victoria Canal, April.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-197. Velocity Density Distribution for Middle River near Woodward Island, April.**

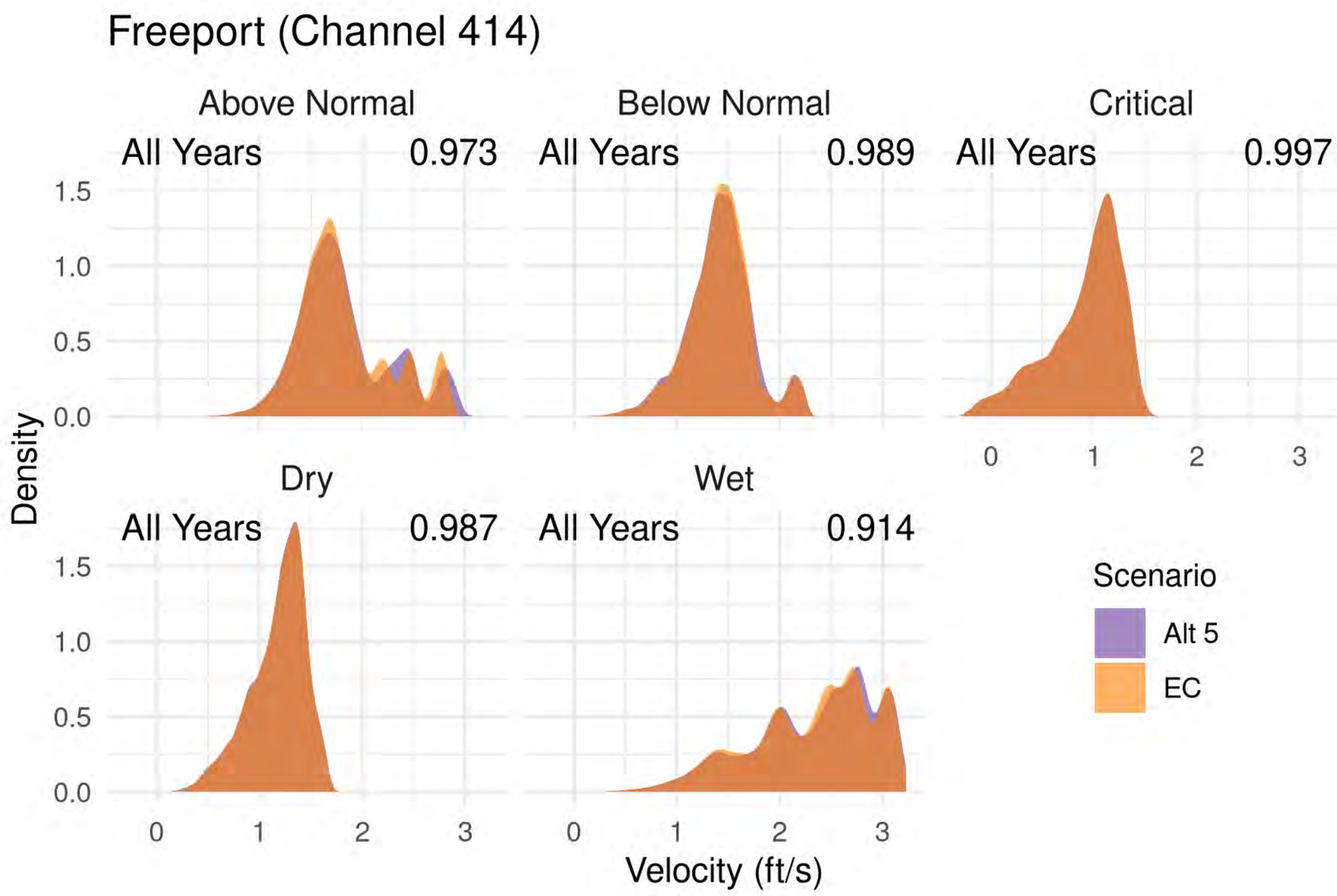



Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-198. Velocity Density Distribution for State Water Project (West Canal near Entrance to Clifton Court Forebay), April.**

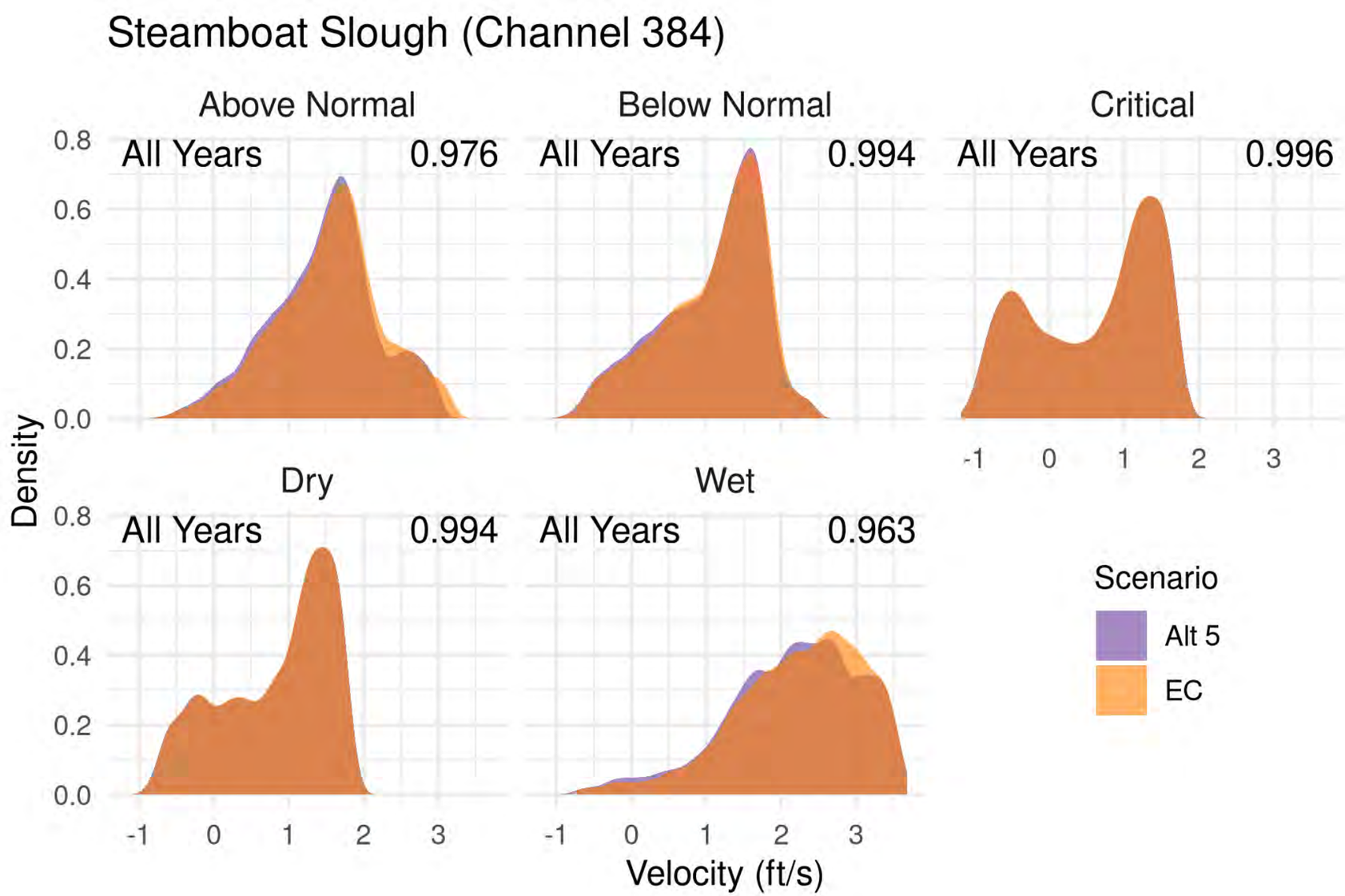
**May**

***Sacramento River Delta***



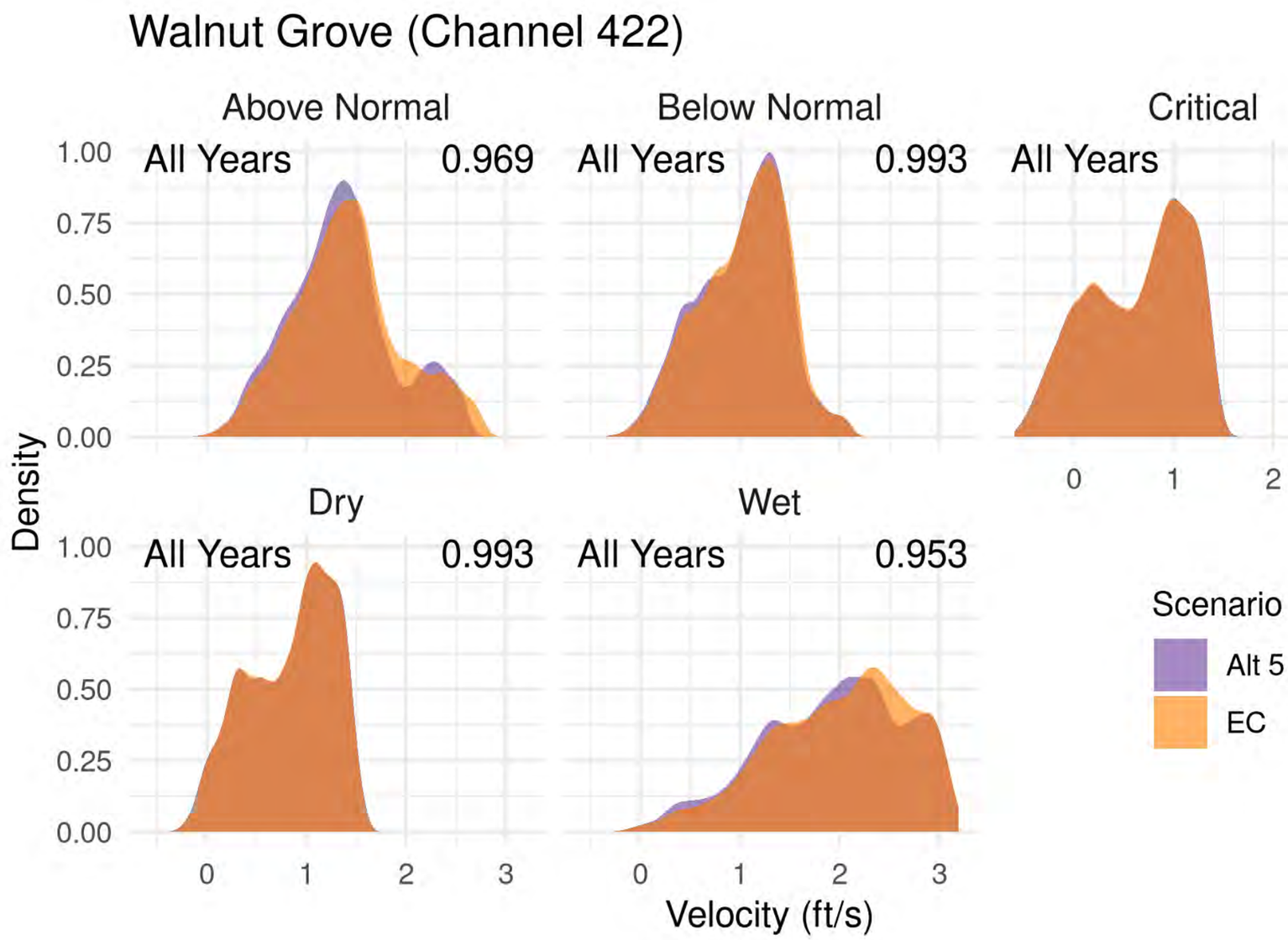

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-199. Velocity Density Distribution for Freeport, May.**



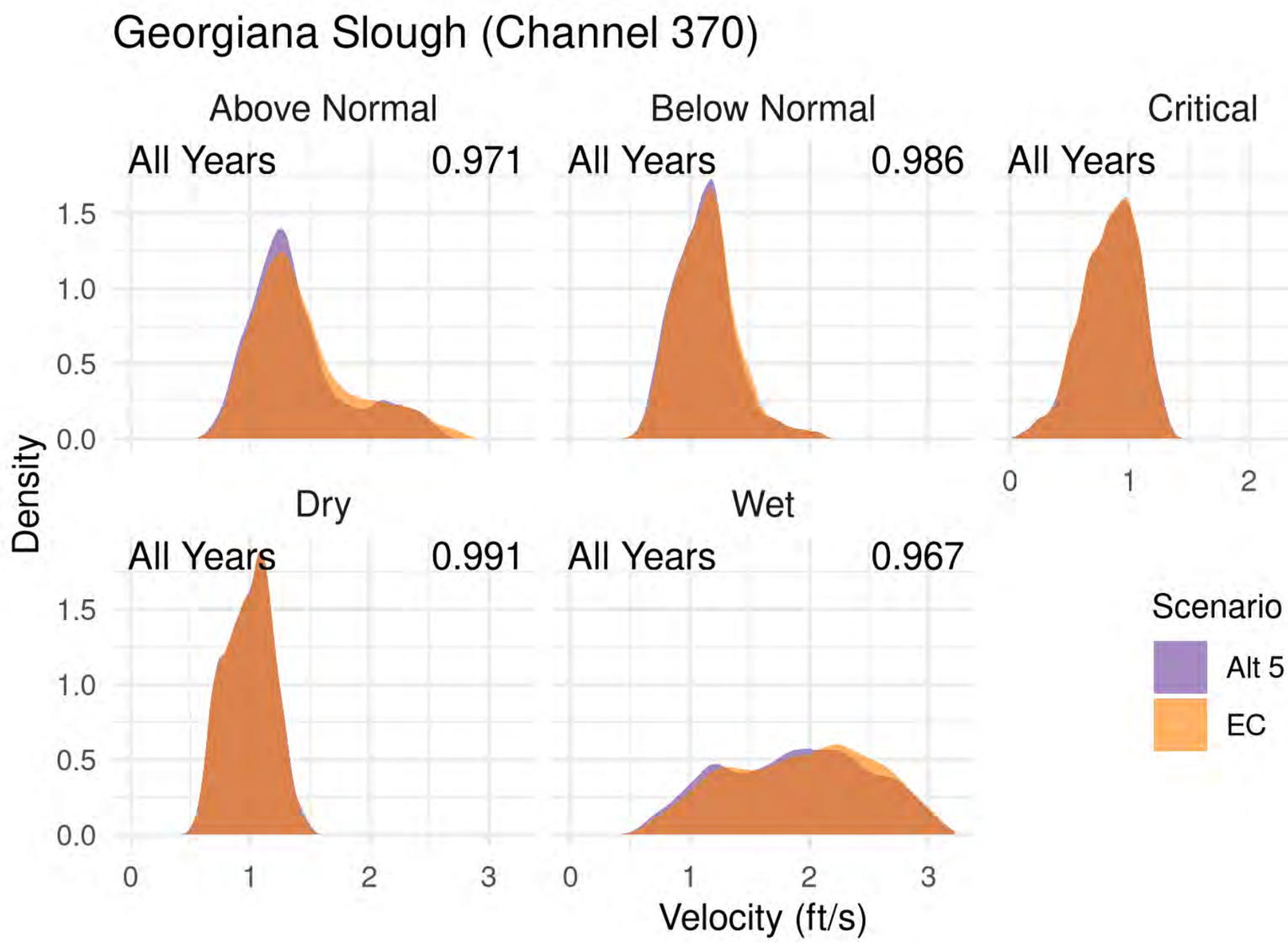

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-200. Velocity Density Distribution for Steamboat Slough, May.**



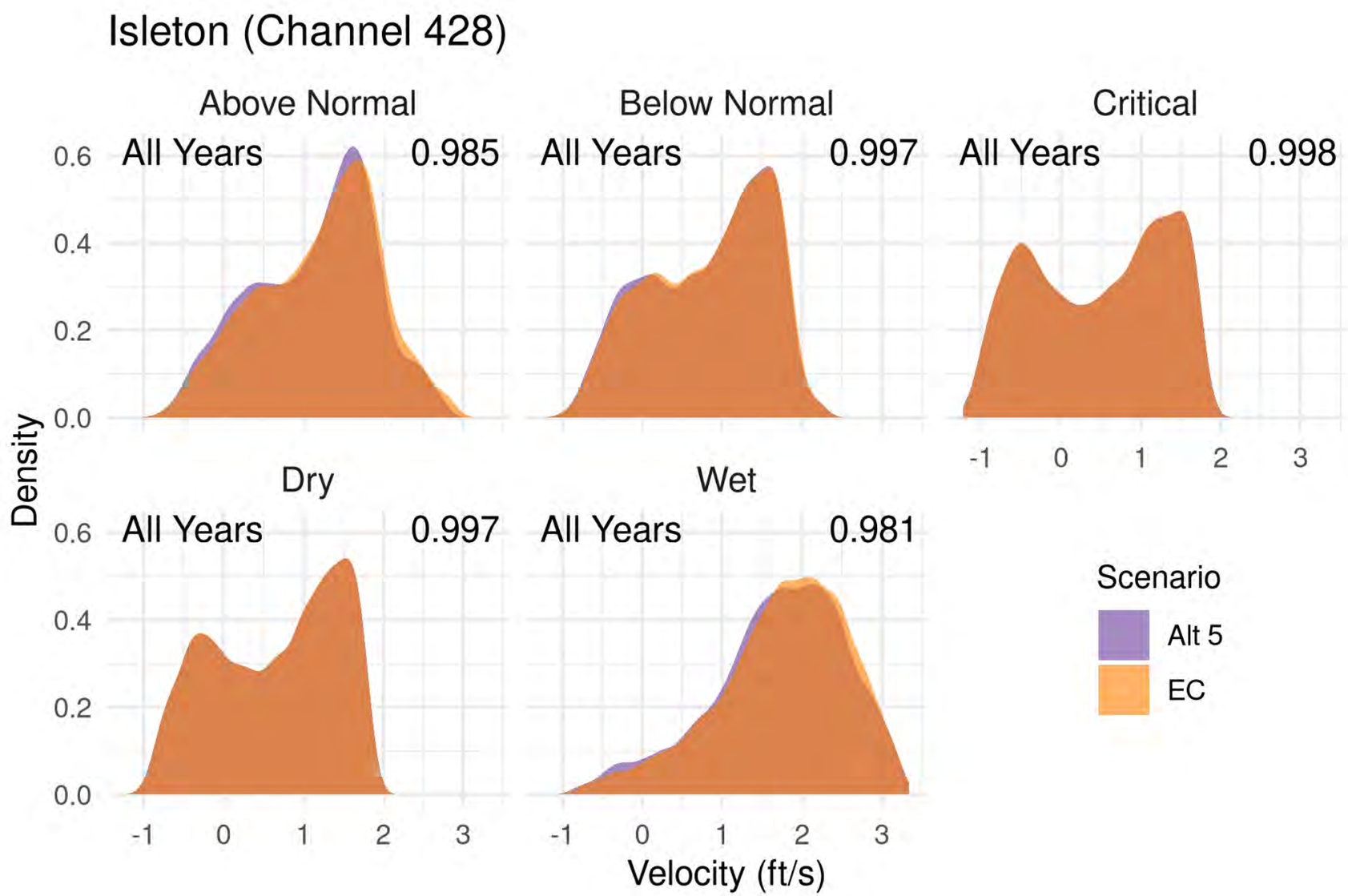

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-201. Velocity Density Distribution for Walnut Grove (Sacramento River), May.**



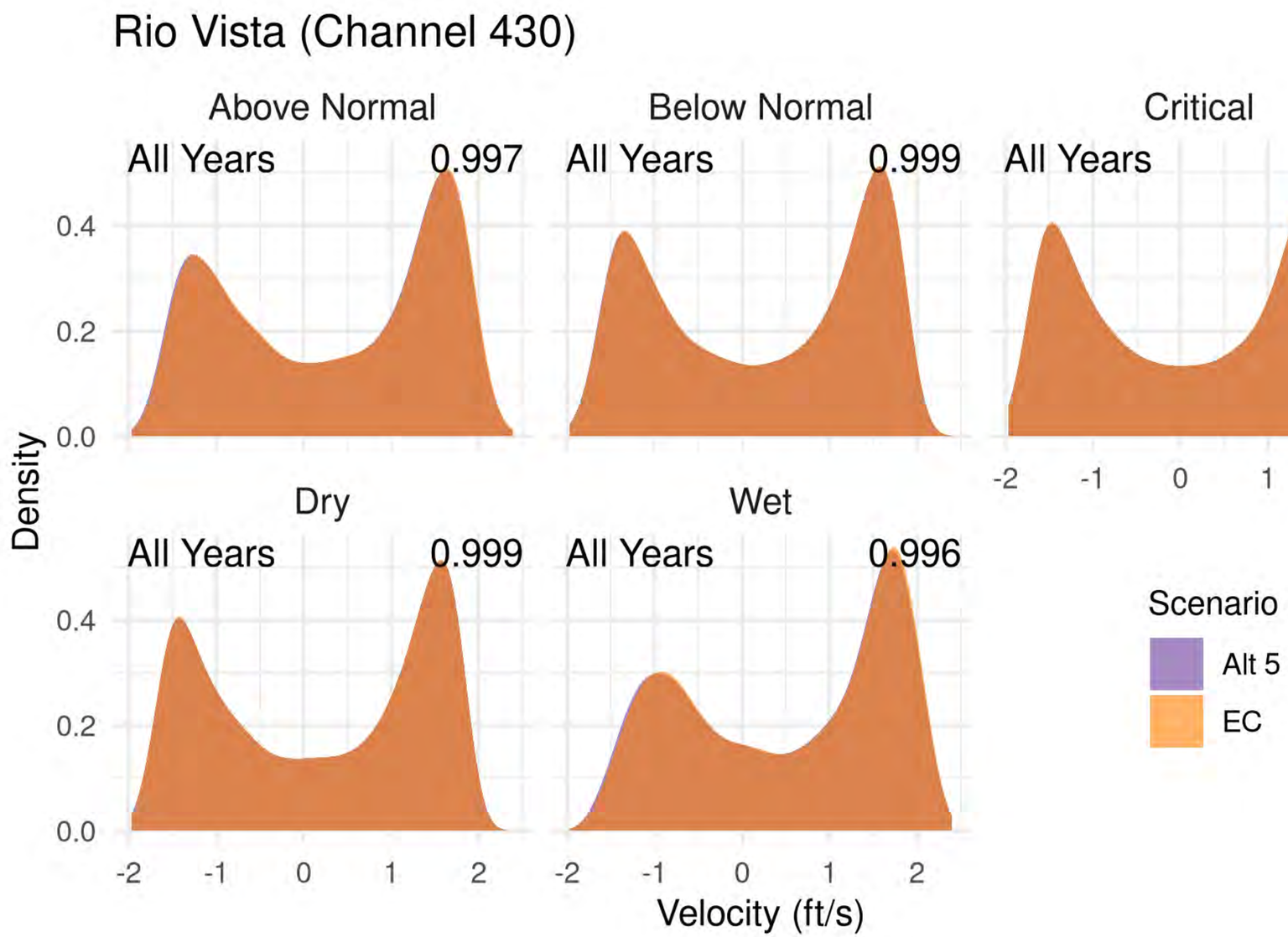

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-202. Velocity Density Distribution for Georgiana Slough, May.**



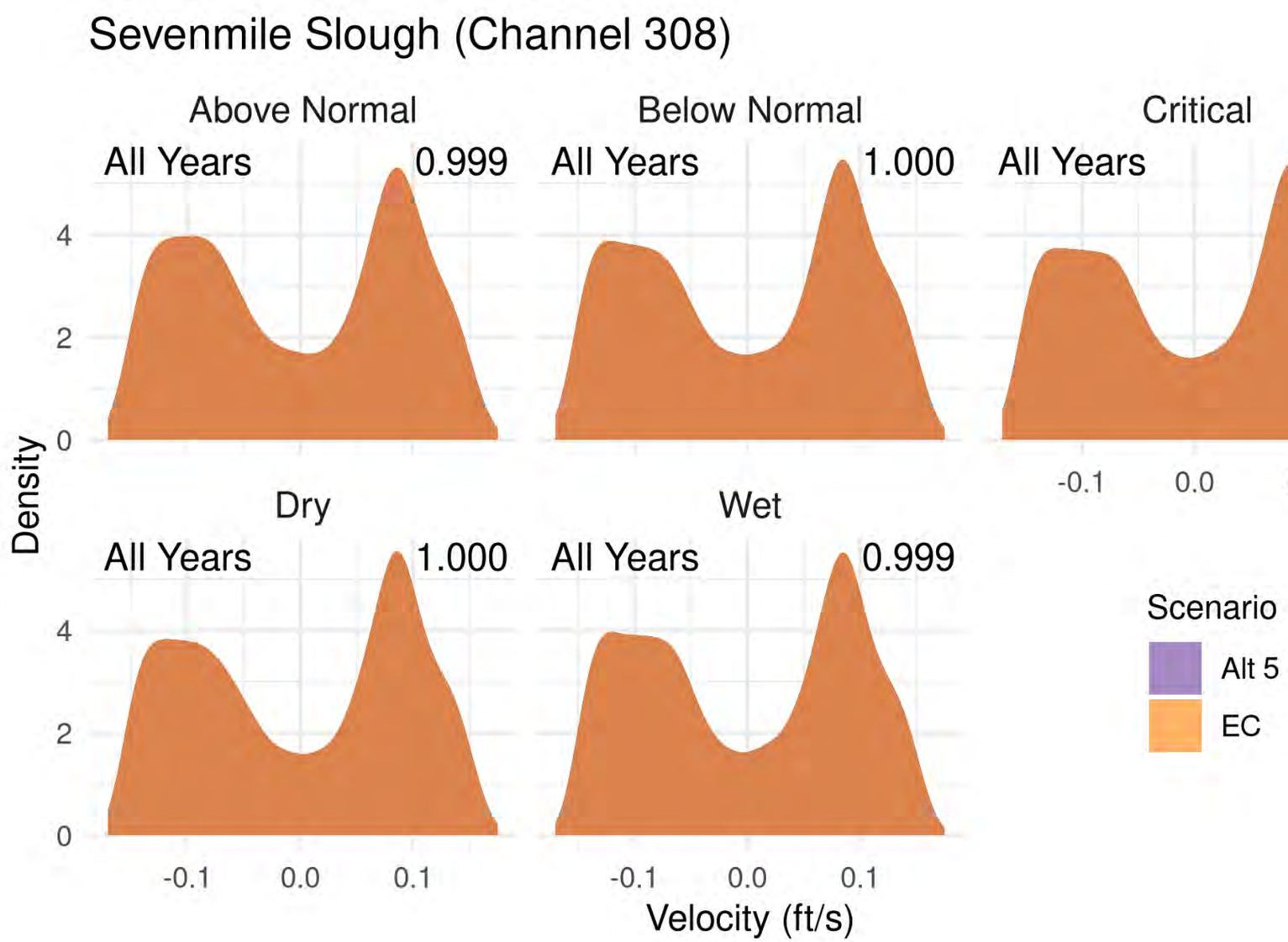

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-203. Velocity Density Distribution for Isleton (Sacramento River), May**



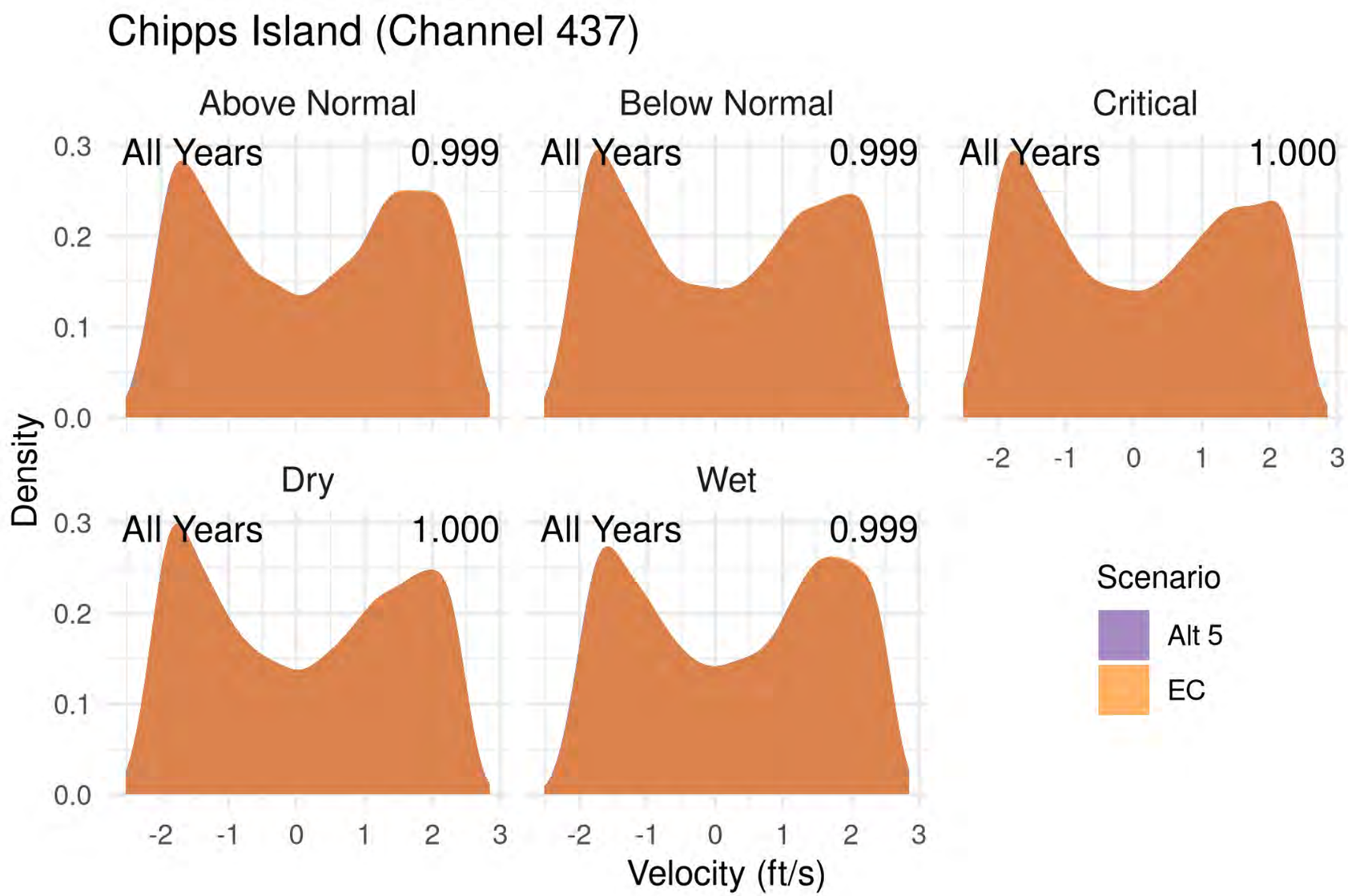

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-204. Velocity Density Distribution for Rio Vista (Sacramento River), May.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

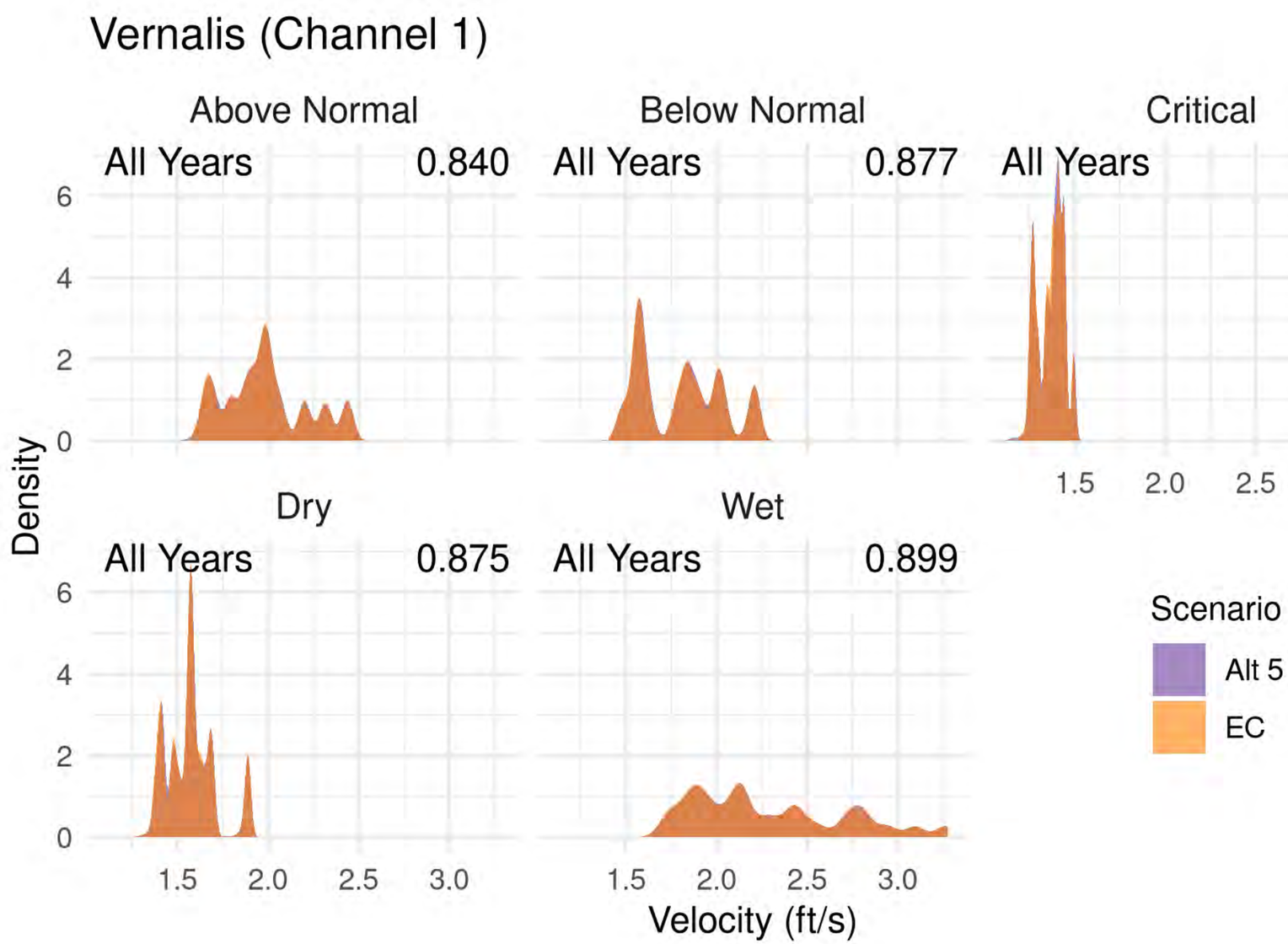
**Figure 5D.1-205. Velocity Density Distribution for Sevenmile Slough, May.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

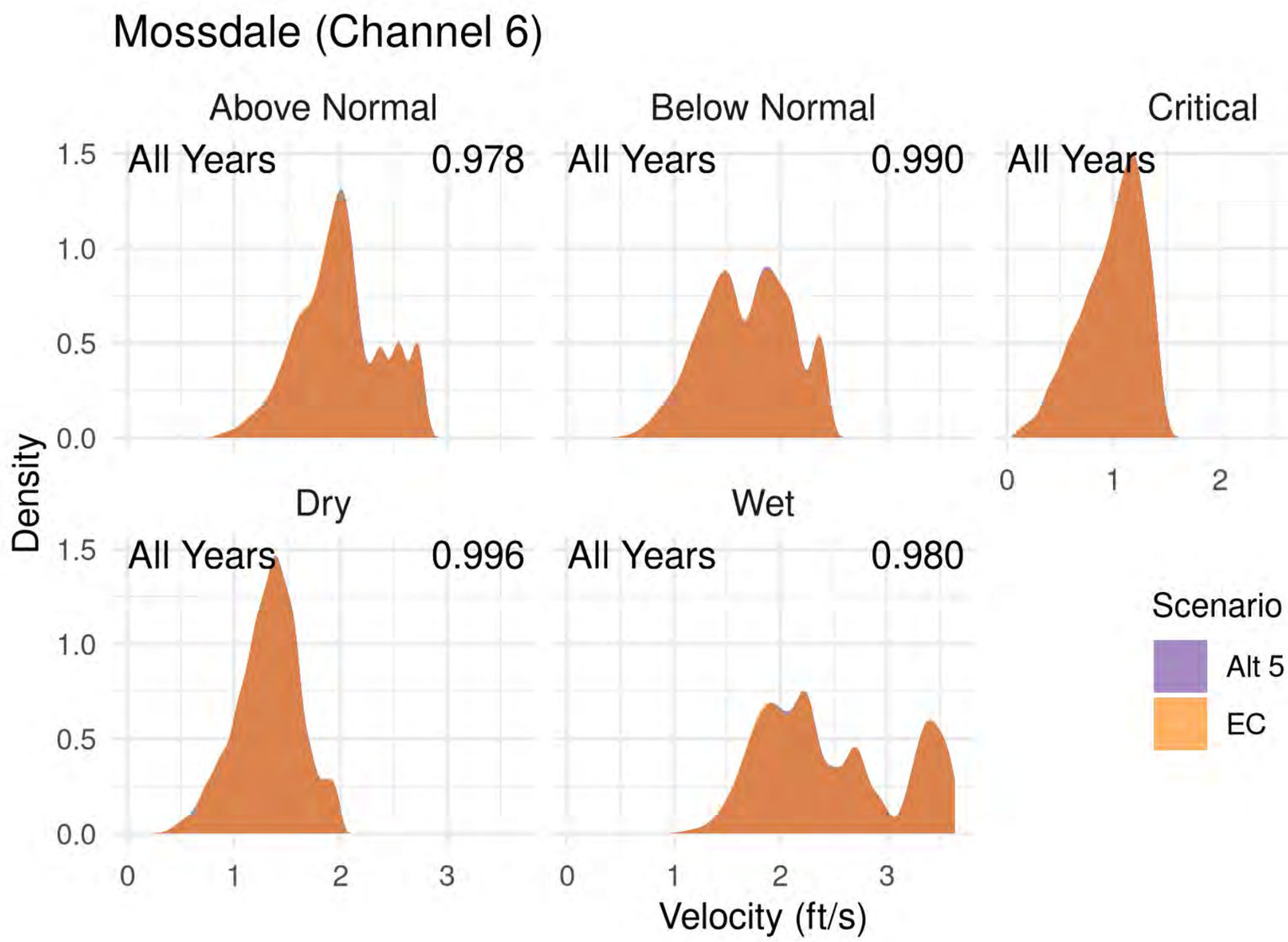
**Figure 5D.1-206. Velocity Density Distribution for Chipps Island (Sacramento River–San Joaquin River Confluence), May.**

***San Joaquin River Delta***



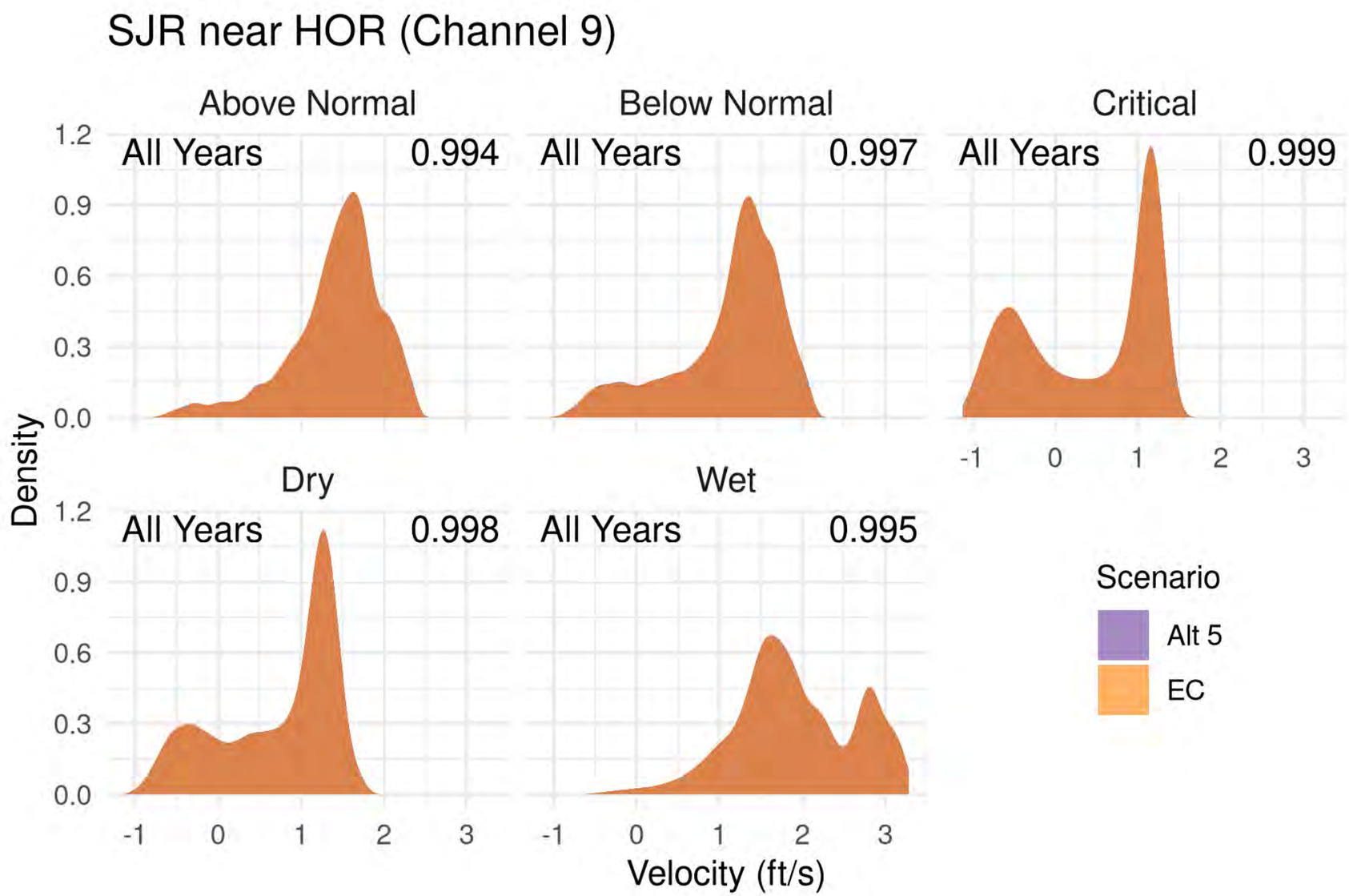

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-207. Velocity Density Distribution for Vernalis (San Joaquin River), May.**



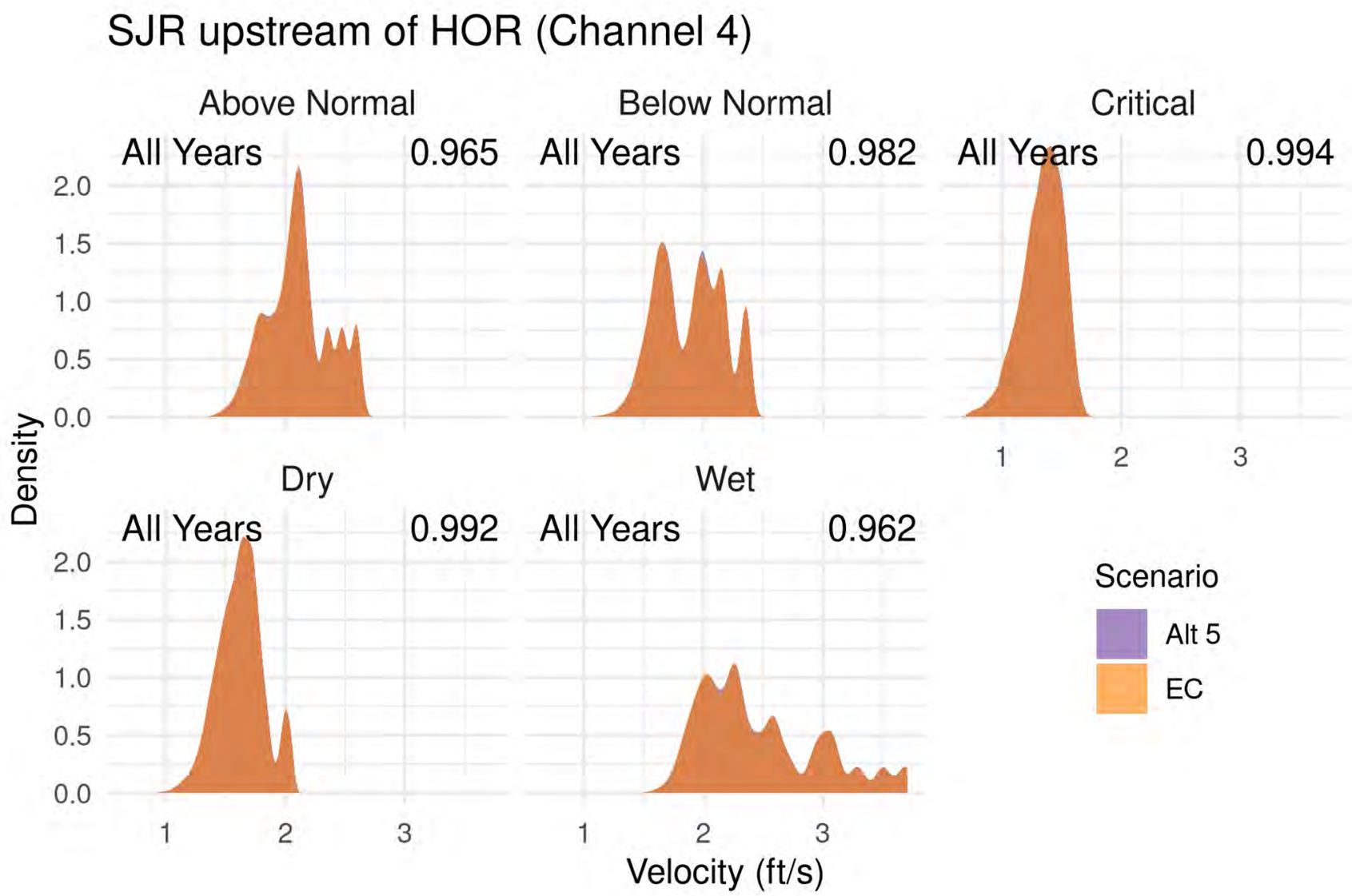

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-208. Velocity Density Distribution for Mossdale (San Joaquin River), May.**



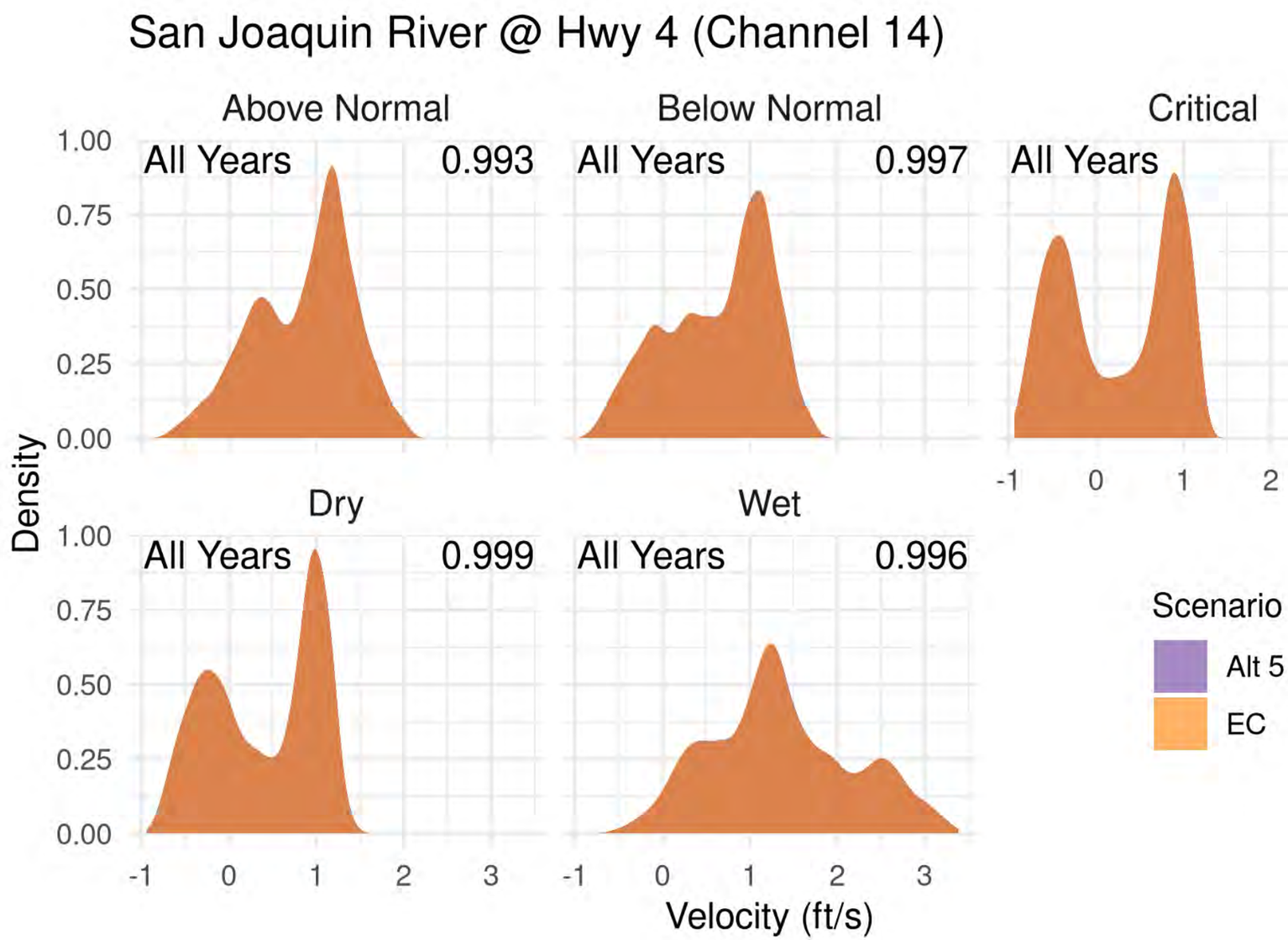

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-209. Velocity Density Distribution for San Joaquin River near Head of Old River, May.**



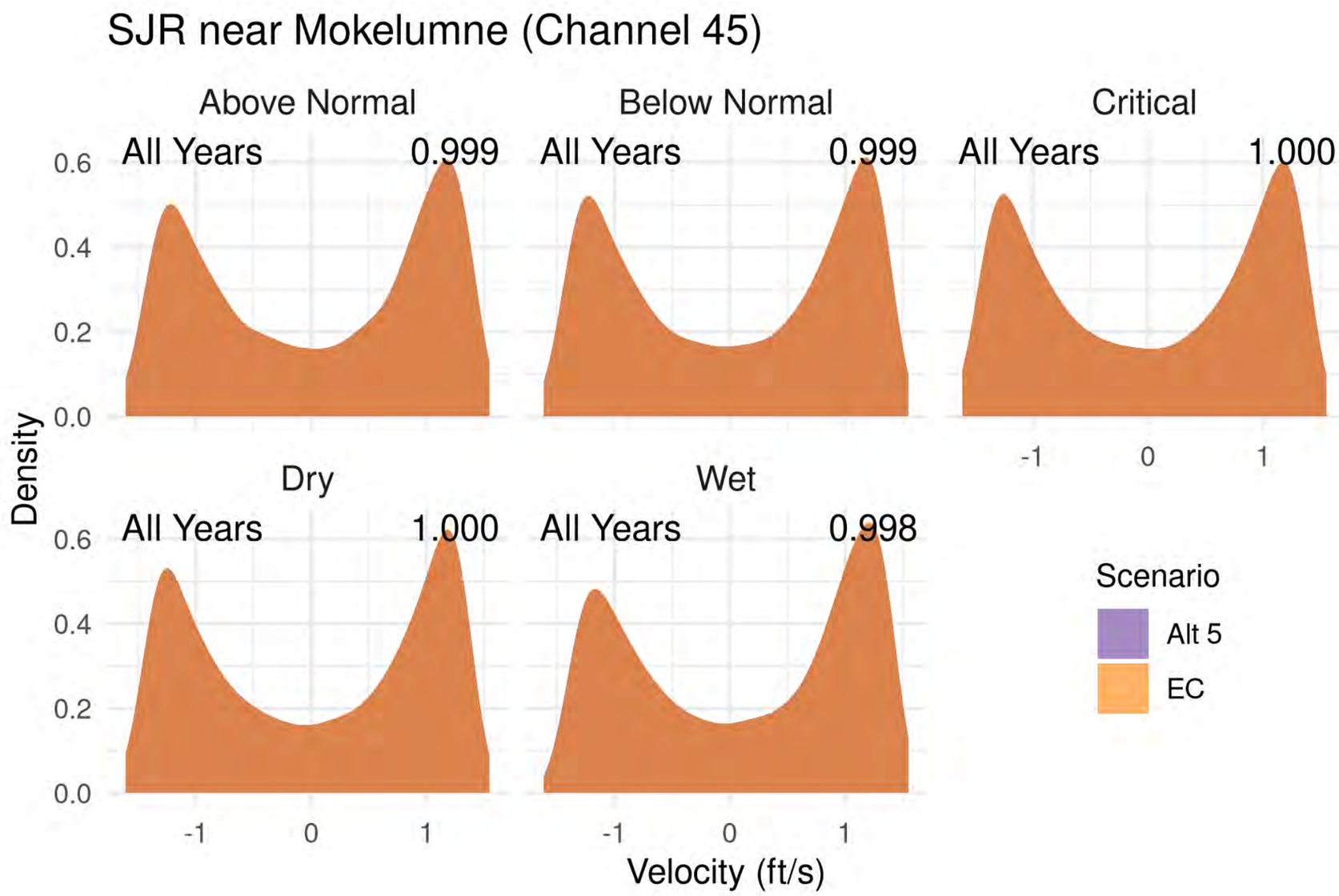

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-210. Velocity Density Distribution for San Joaquin River upstream of Head of Old River, May.**



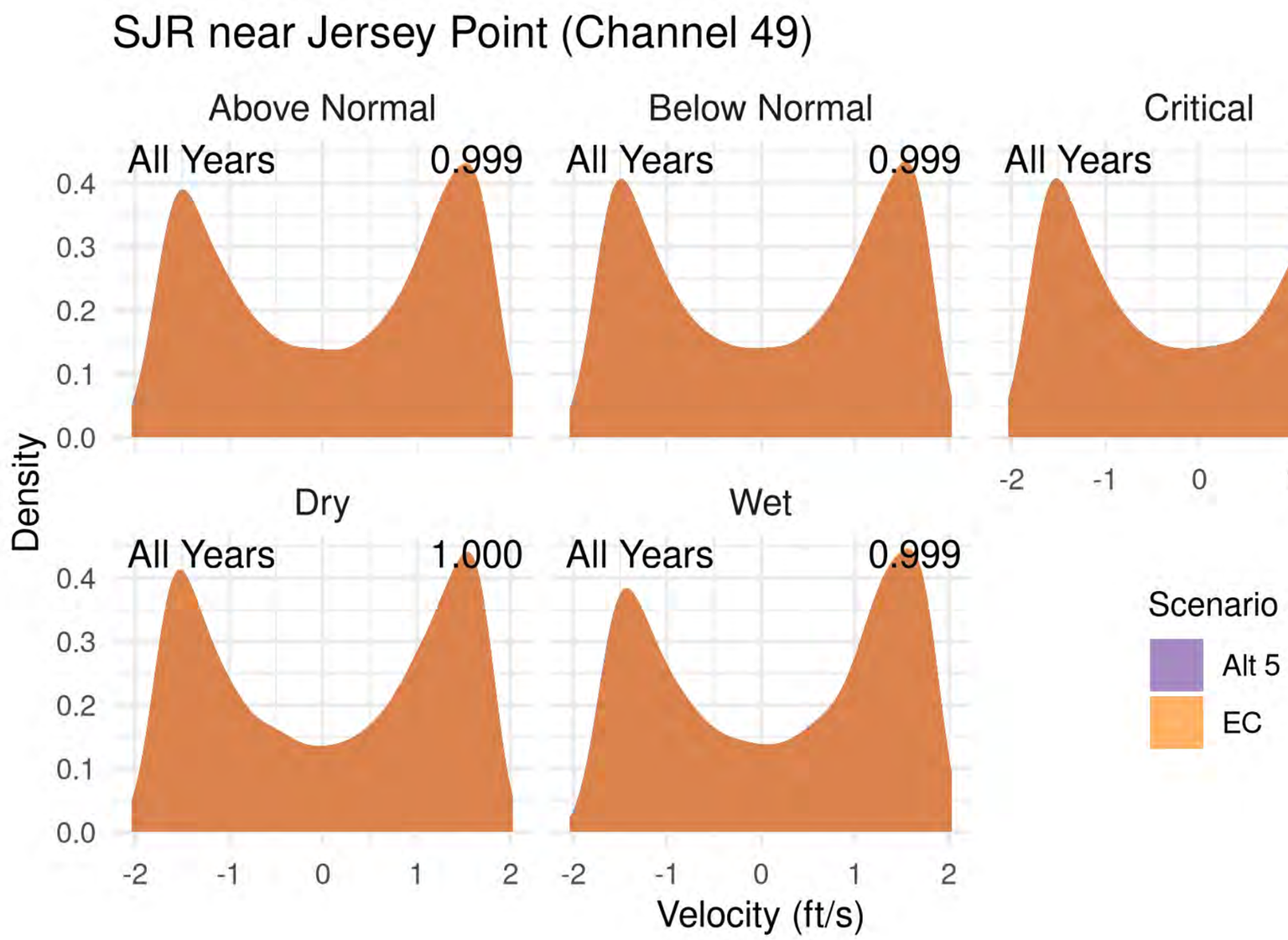

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-211. Velocity Density Distribution for San Joaquin River at Highway 4, May.**



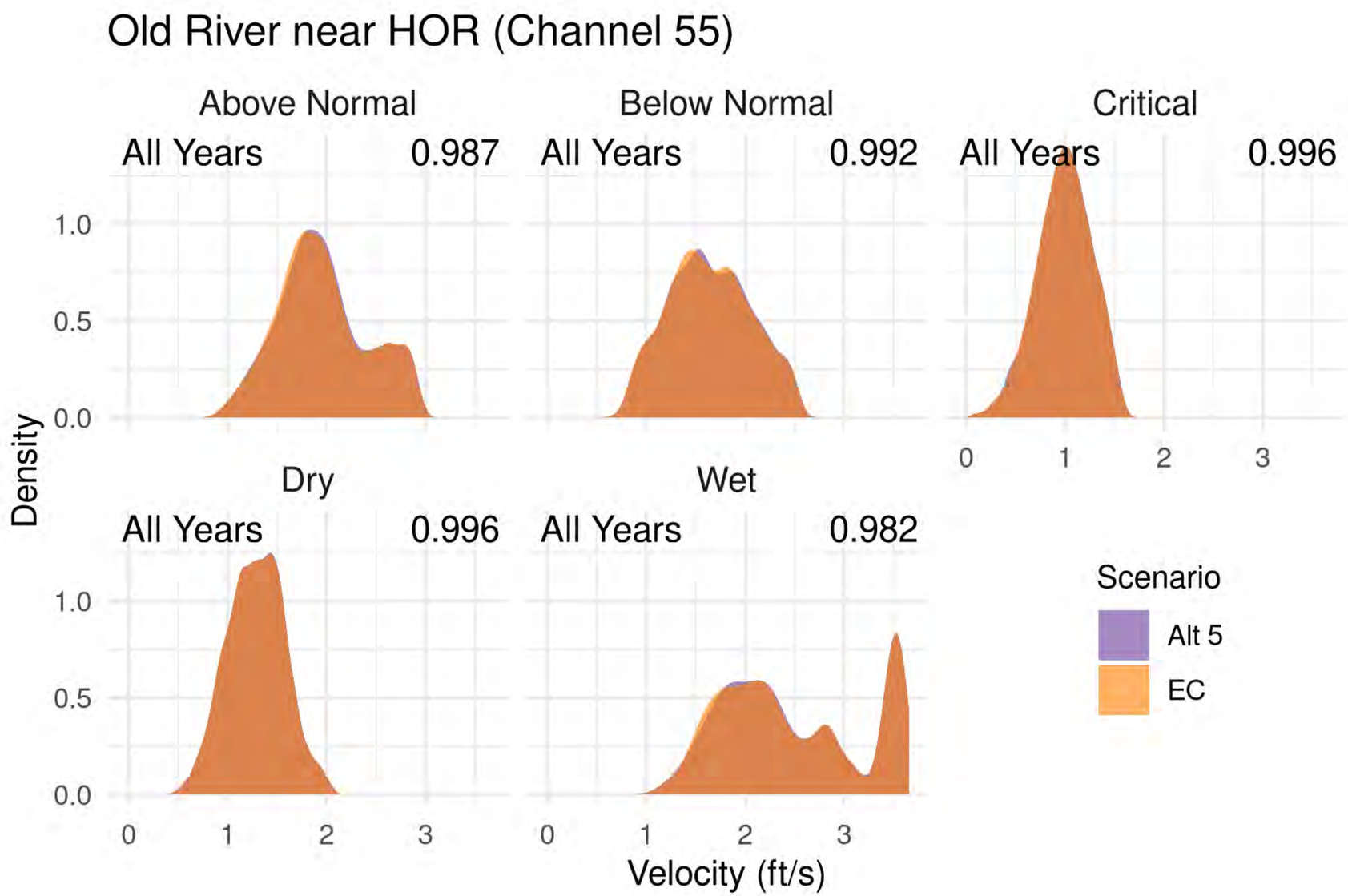

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-212. Velocity Density Distribution for San Joaquin River near Mokelumne River, May.**



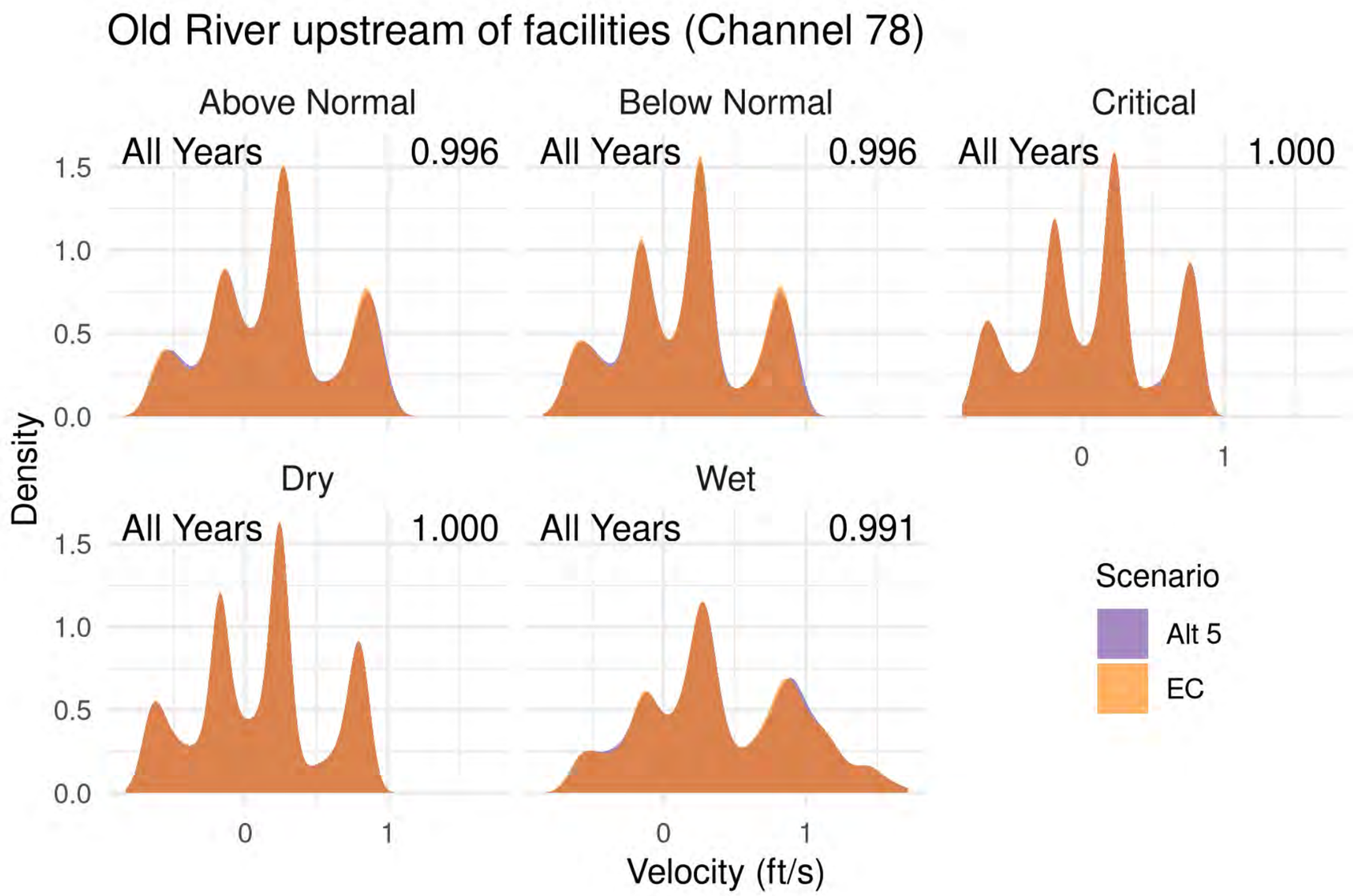

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-213. Velocity Density Distribution for San Joaquin River near Jersey Point, May.**



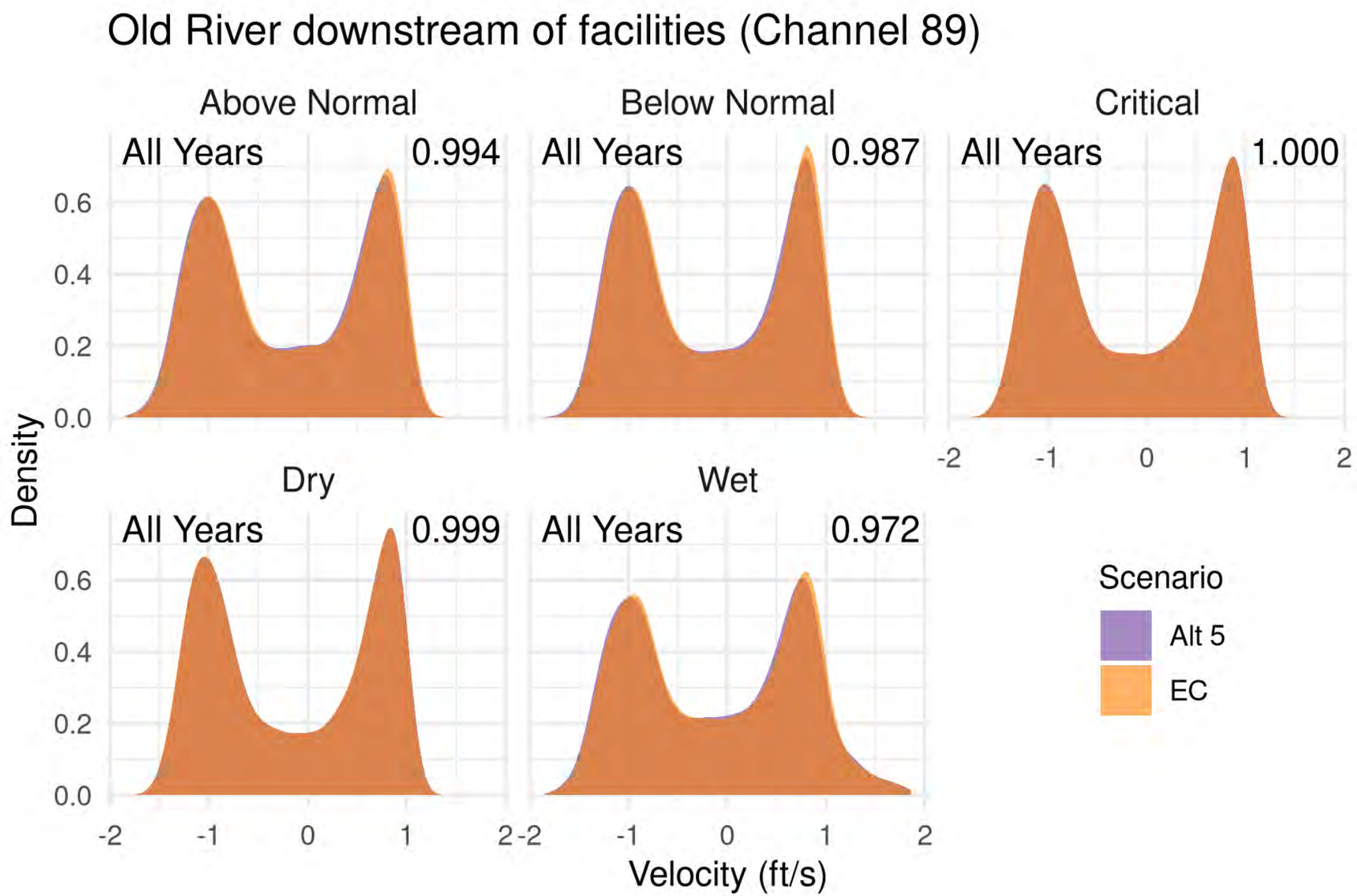

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-214. Velocity Density Distribution for Old River near Head of Old River, May.**



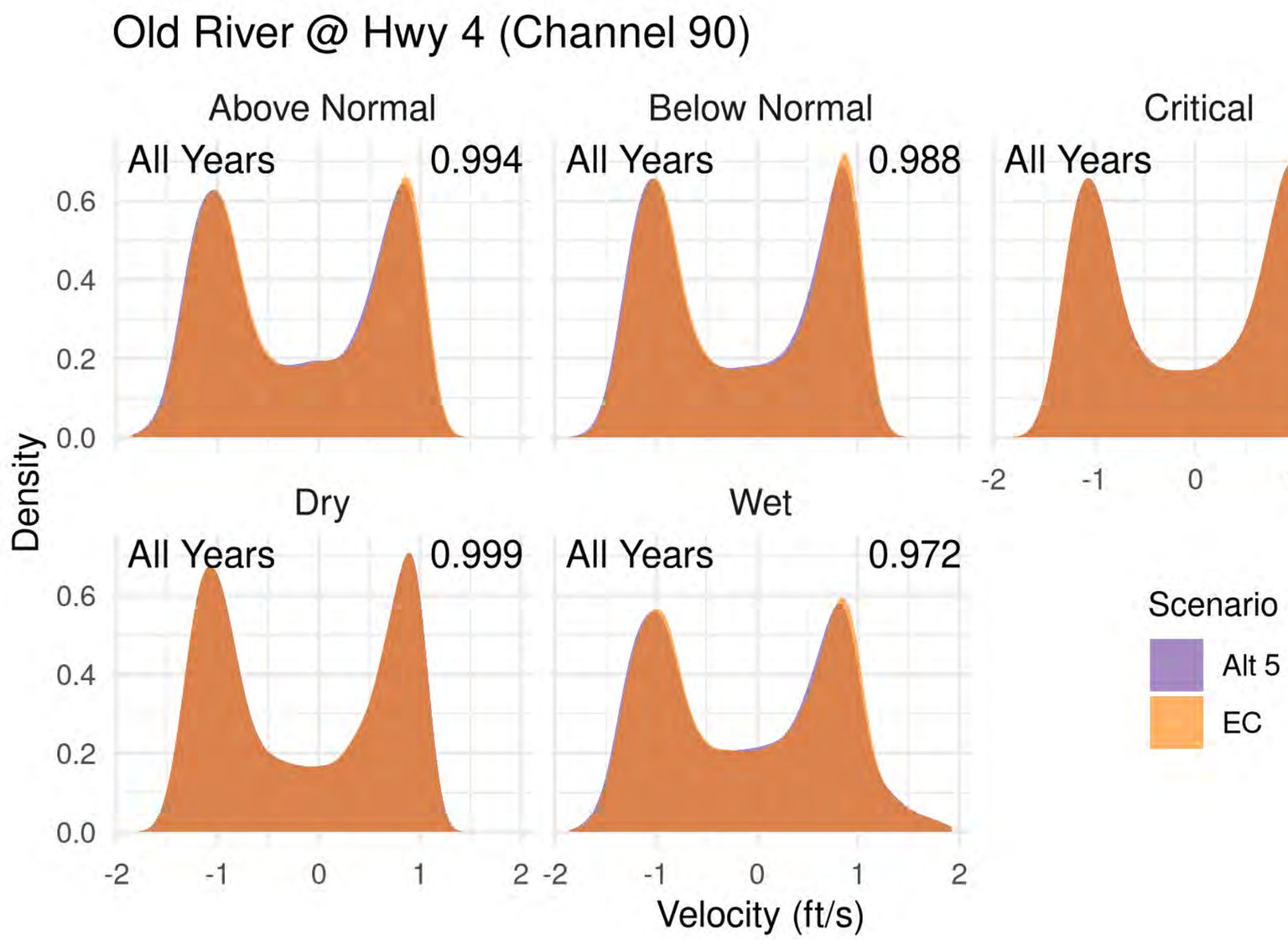

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-215. Velocity Density Distribution for Old River upstream of the South Delta Export Facilities, May.**



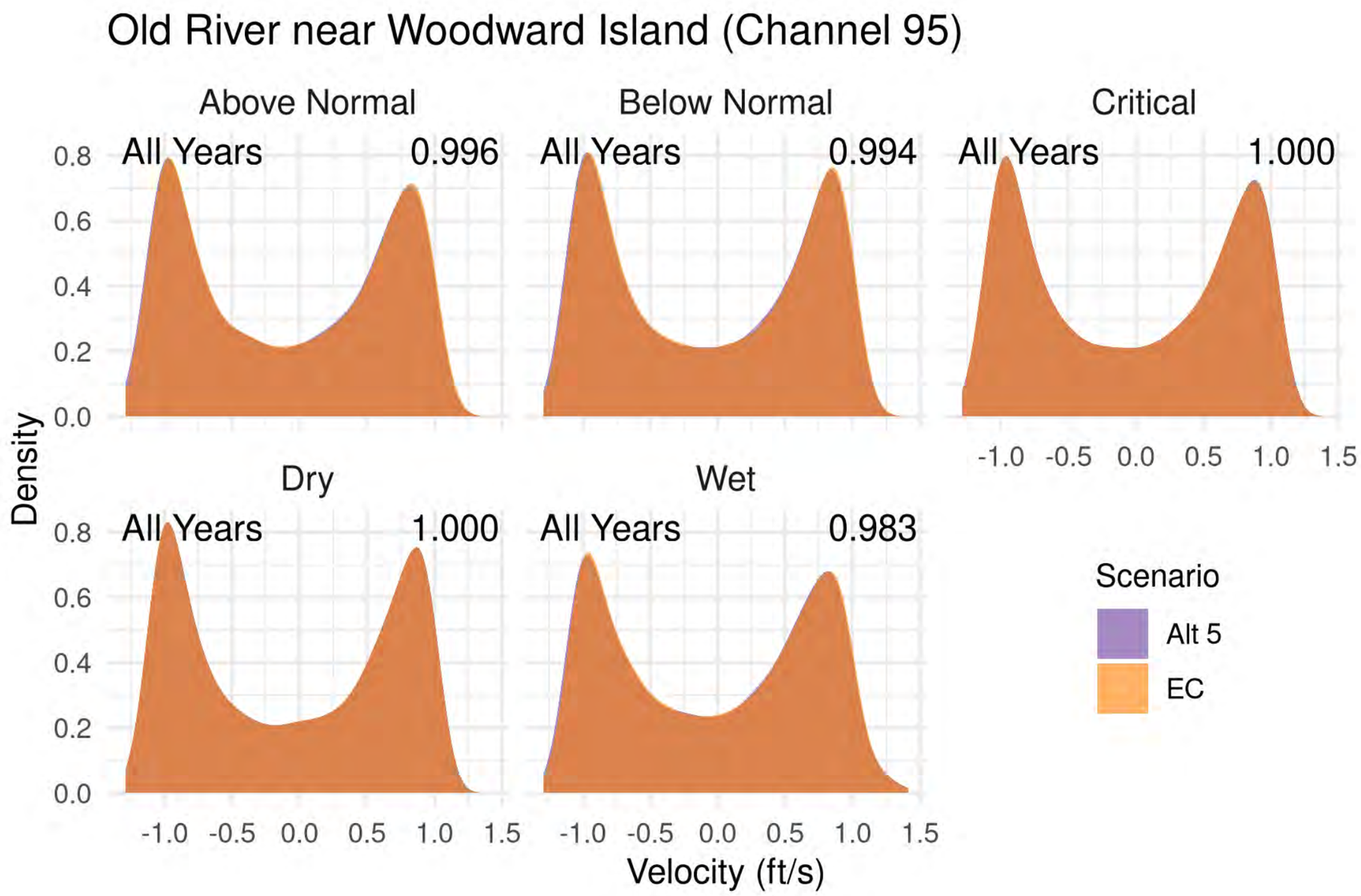

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-216. Velocity Density Distribution for Old River Downstream of the South Delta Export Facilities, May.**



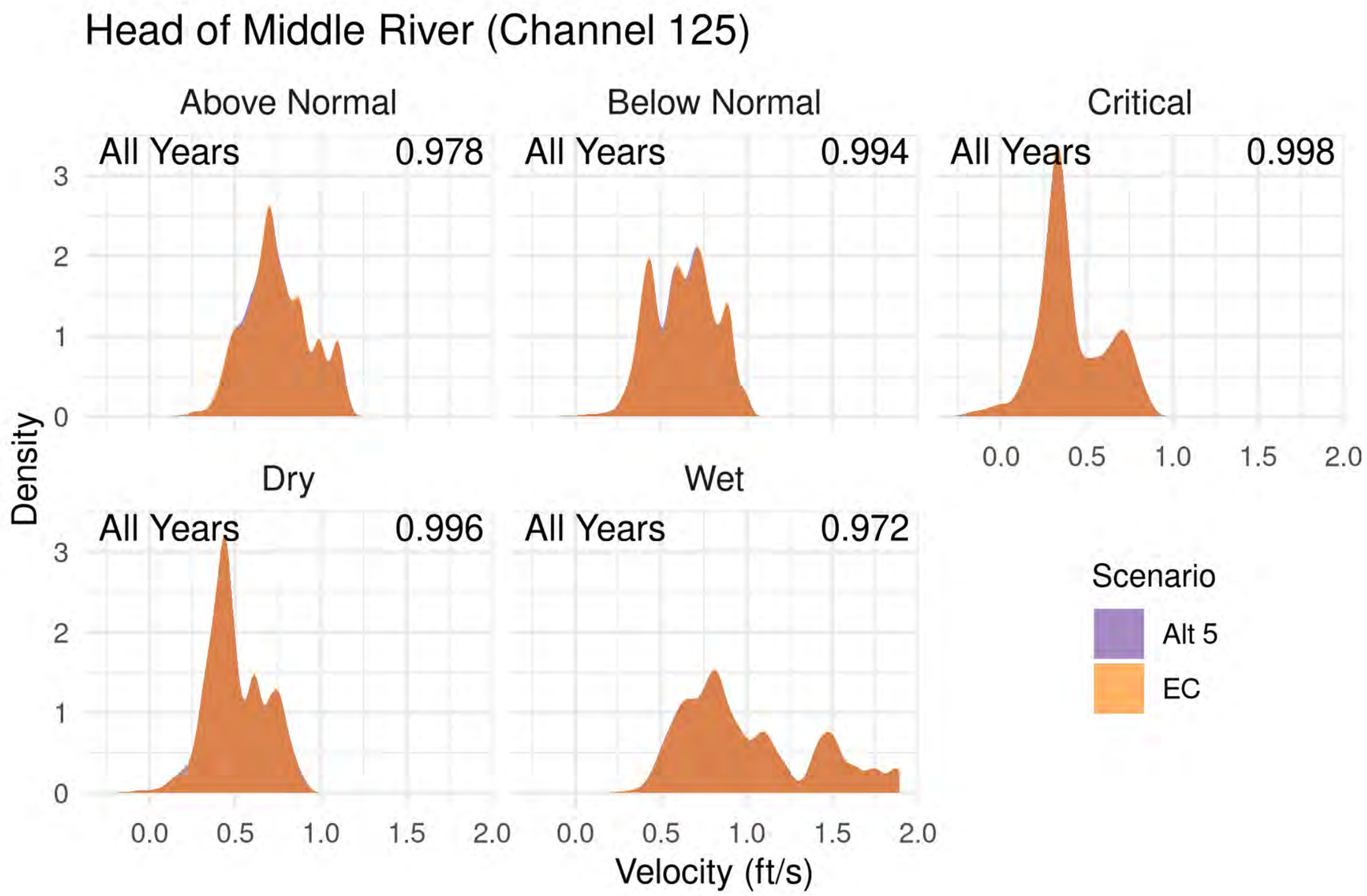

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-217. Velocity Density Distribution for Old River at Highway 4, May.**



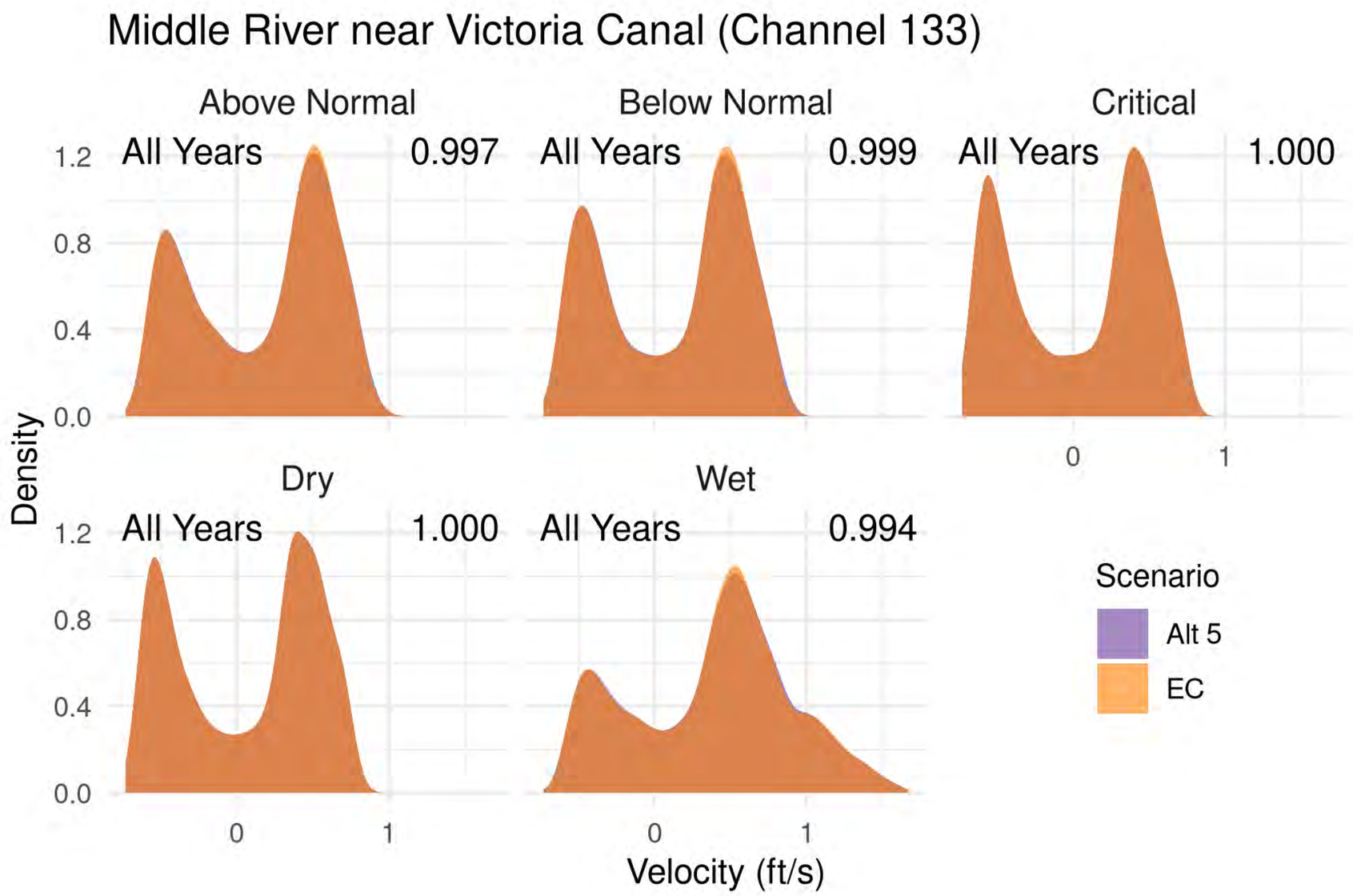

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-218. Velocity Density Distribution for Old River near Woodward Island, May.**



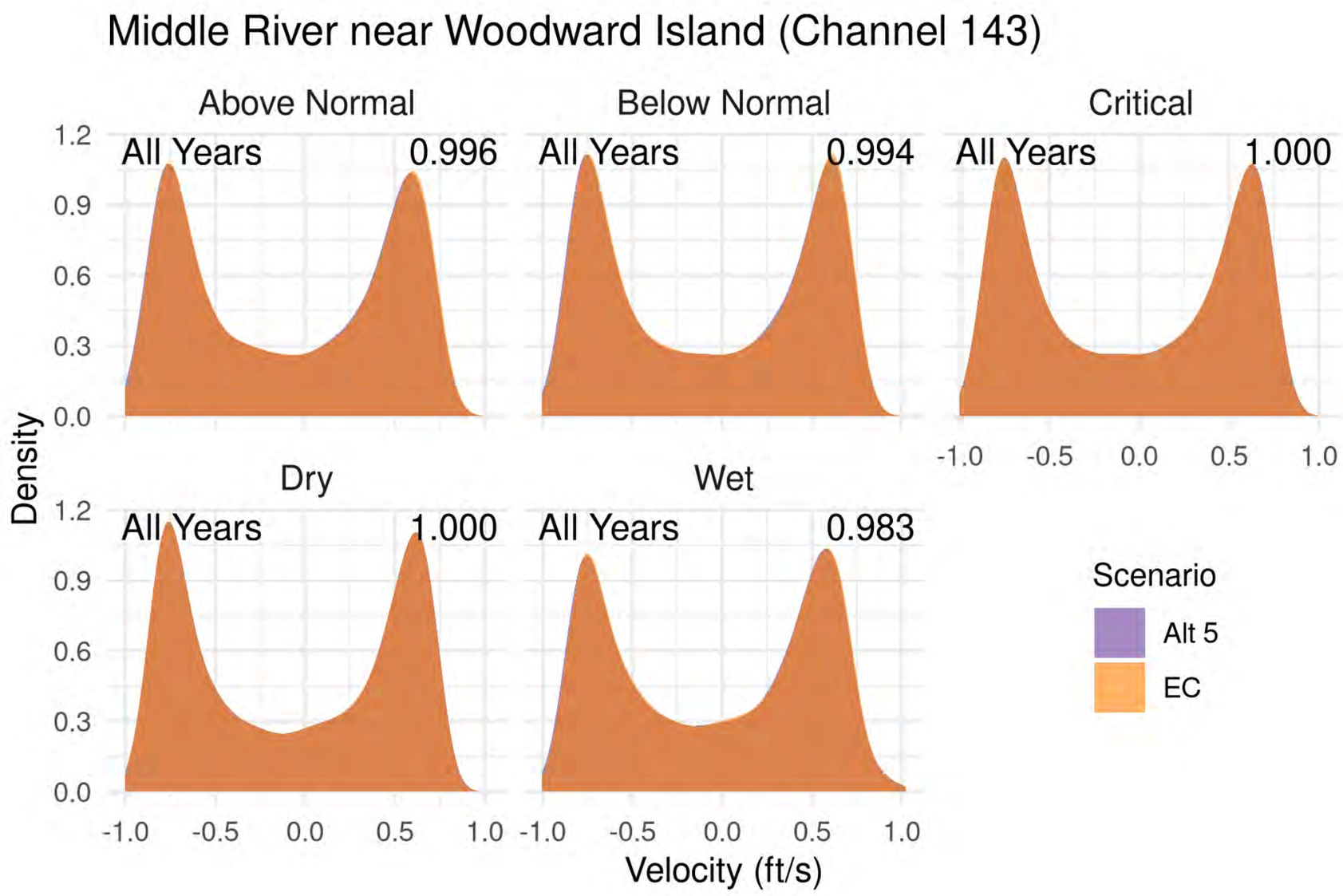

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-219. Velocity Density Distribution for Head of Middle River, May.**



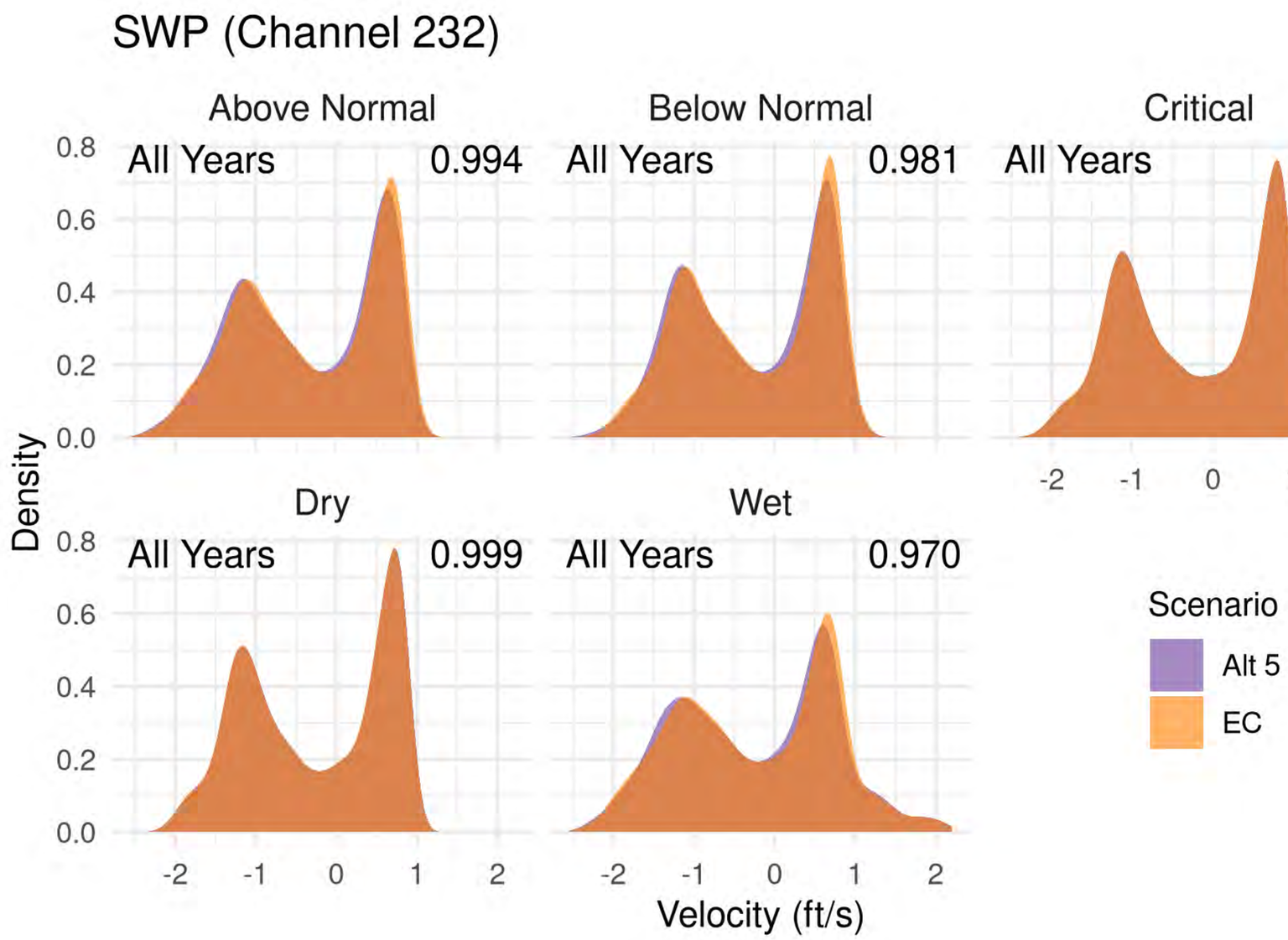

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-220. Velocity Density Distribution for Middle River near Victoria Canal, May.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-221. Velocity Density Distribution for Middle River near Woodward Island, May.**

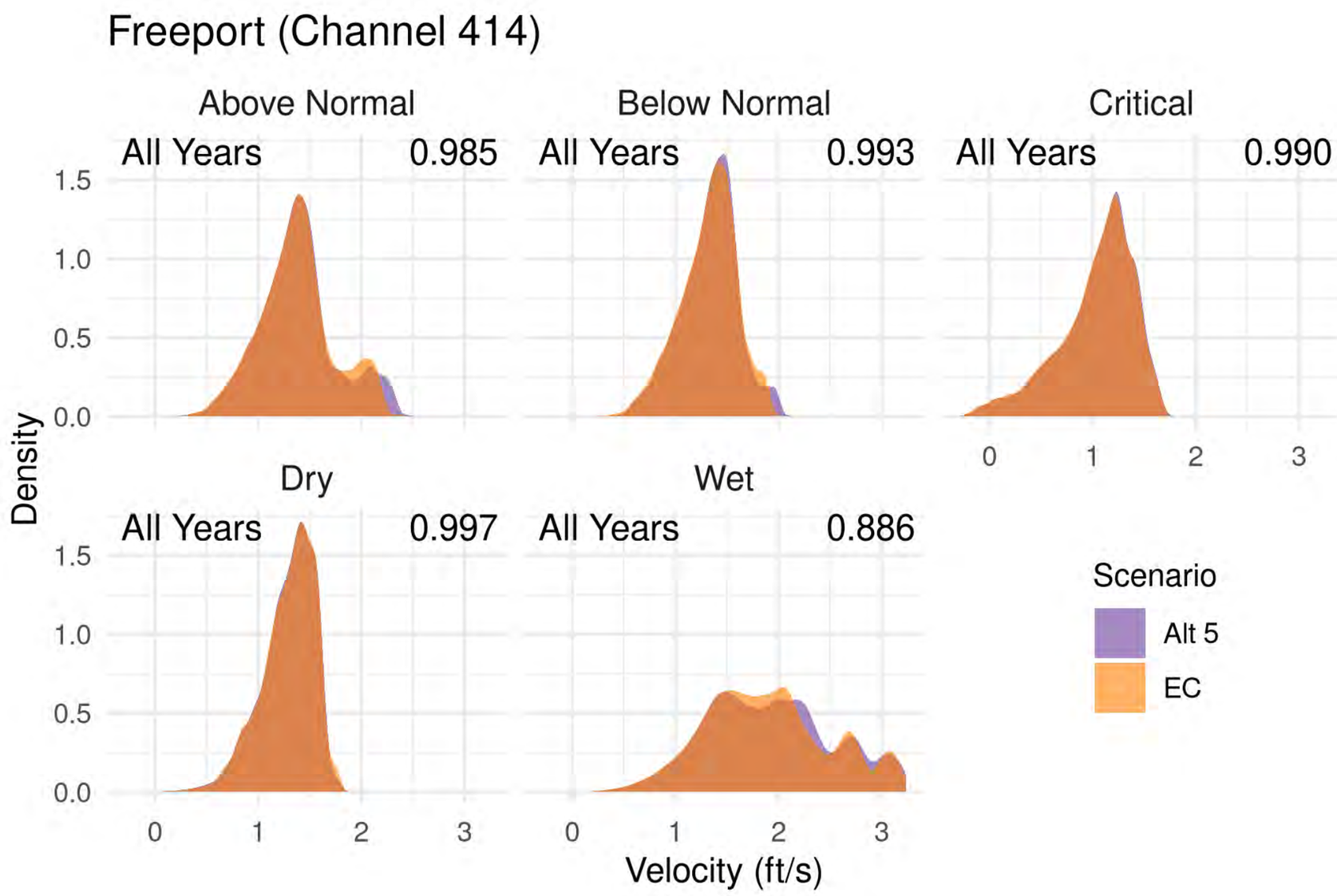



Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-222. Velocity Density Distribution for State Water Project (West Canal near Entrance to Clifton Court Forebay), May.**

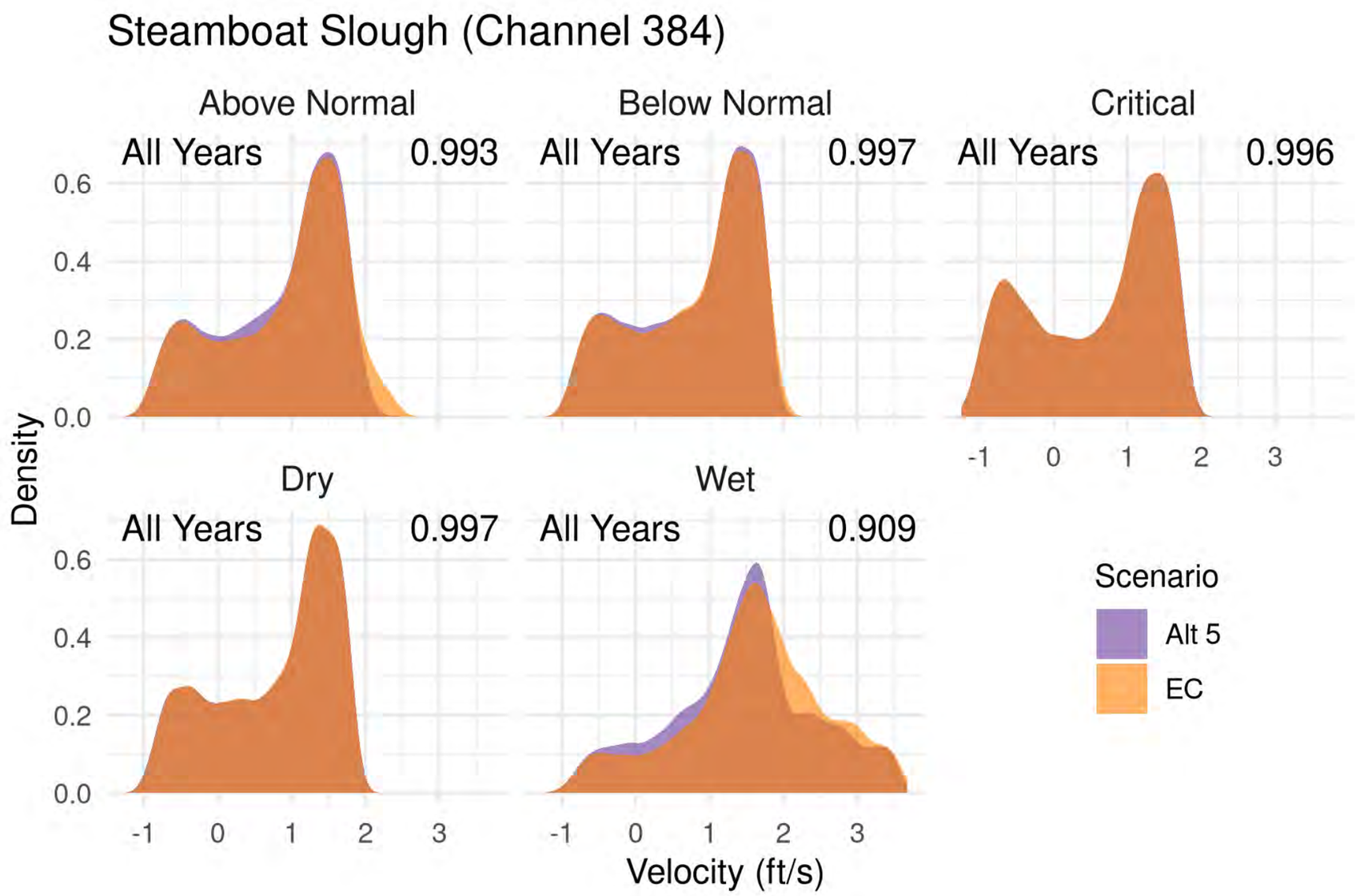
**June**

***Sacramento River Delta***



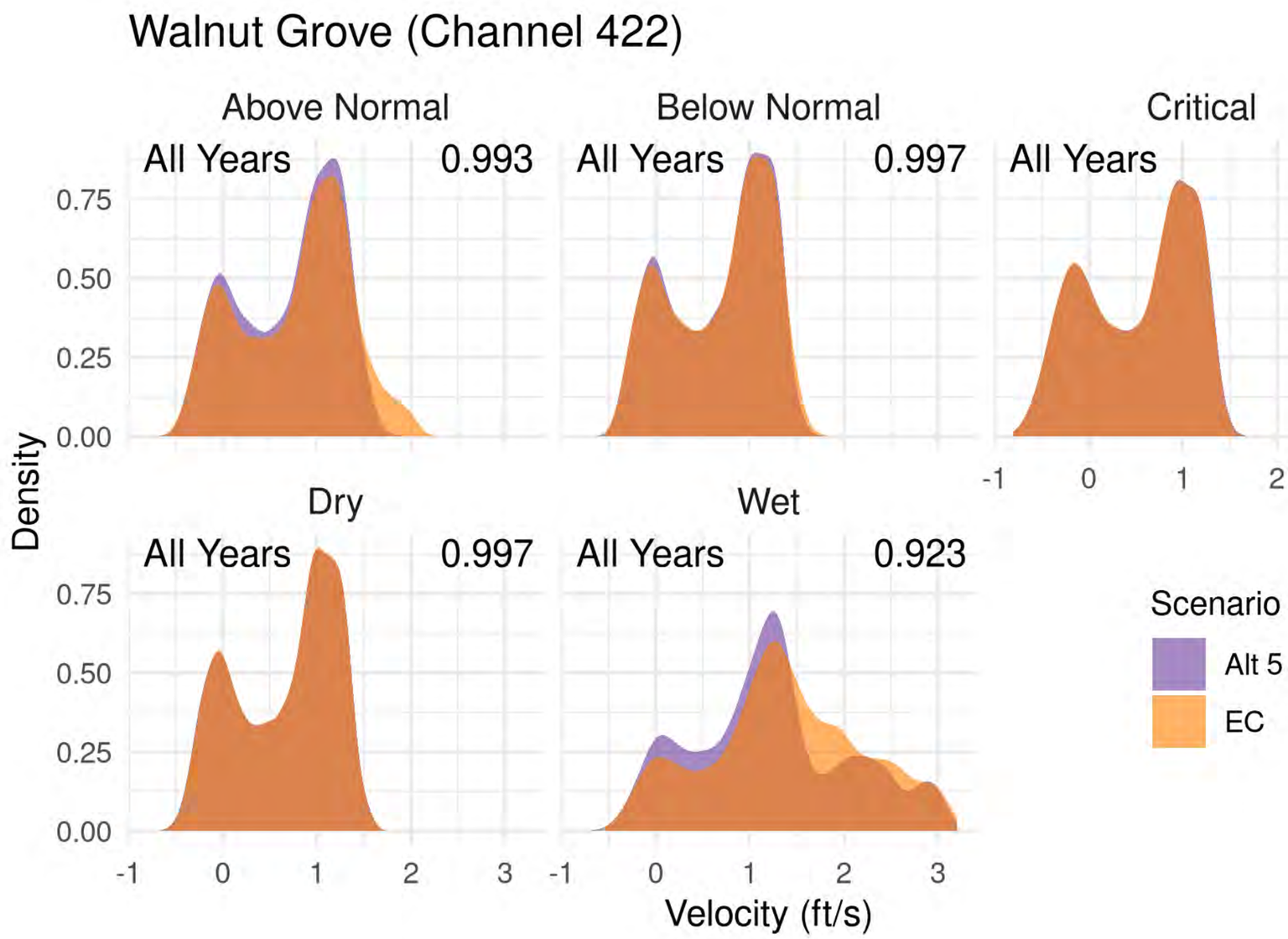

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-223. Velocity Density Distribution for Freeport, June.**



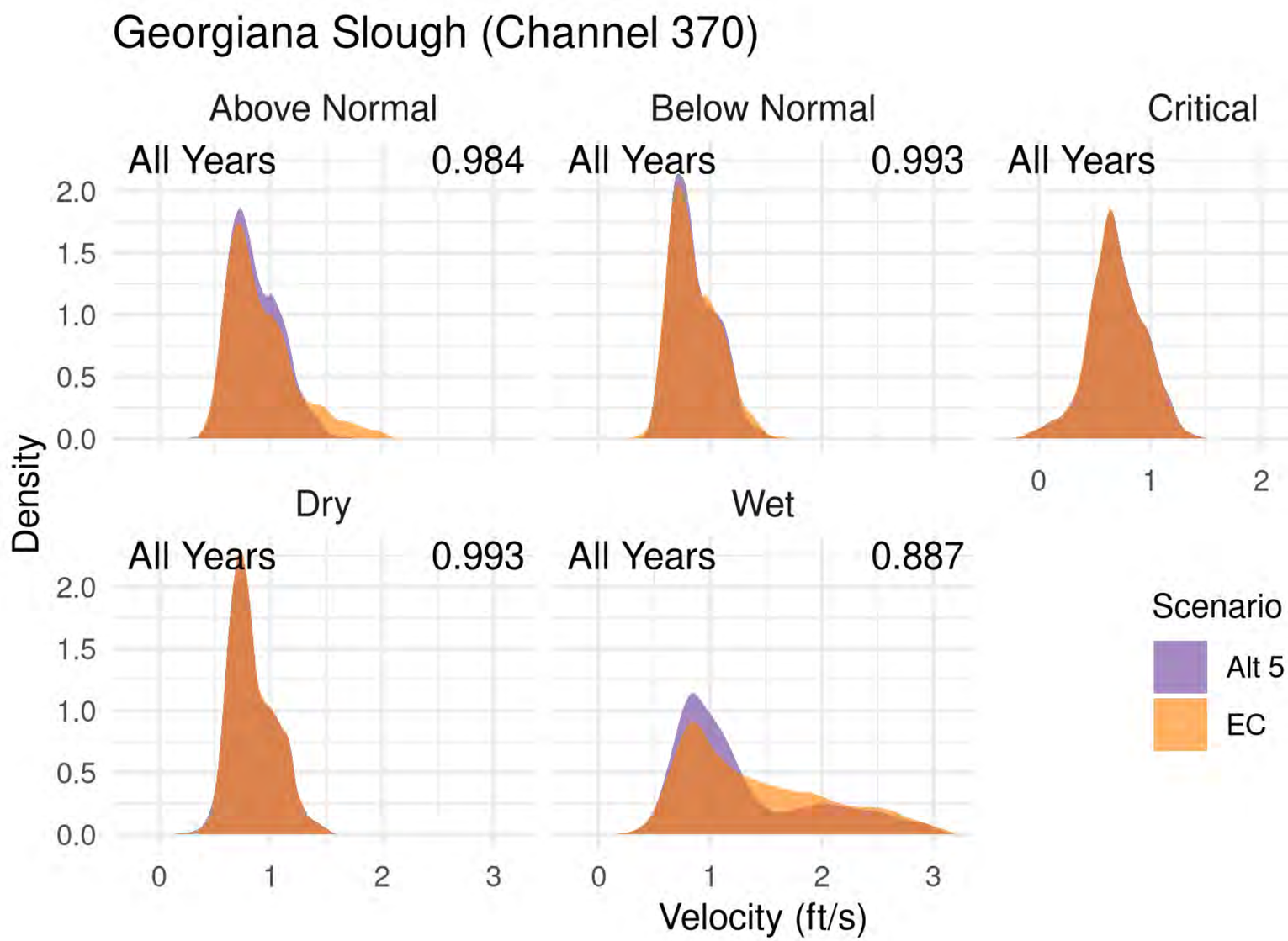

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-224. Velocity Density Distribution for Steamboat Slough, June.**



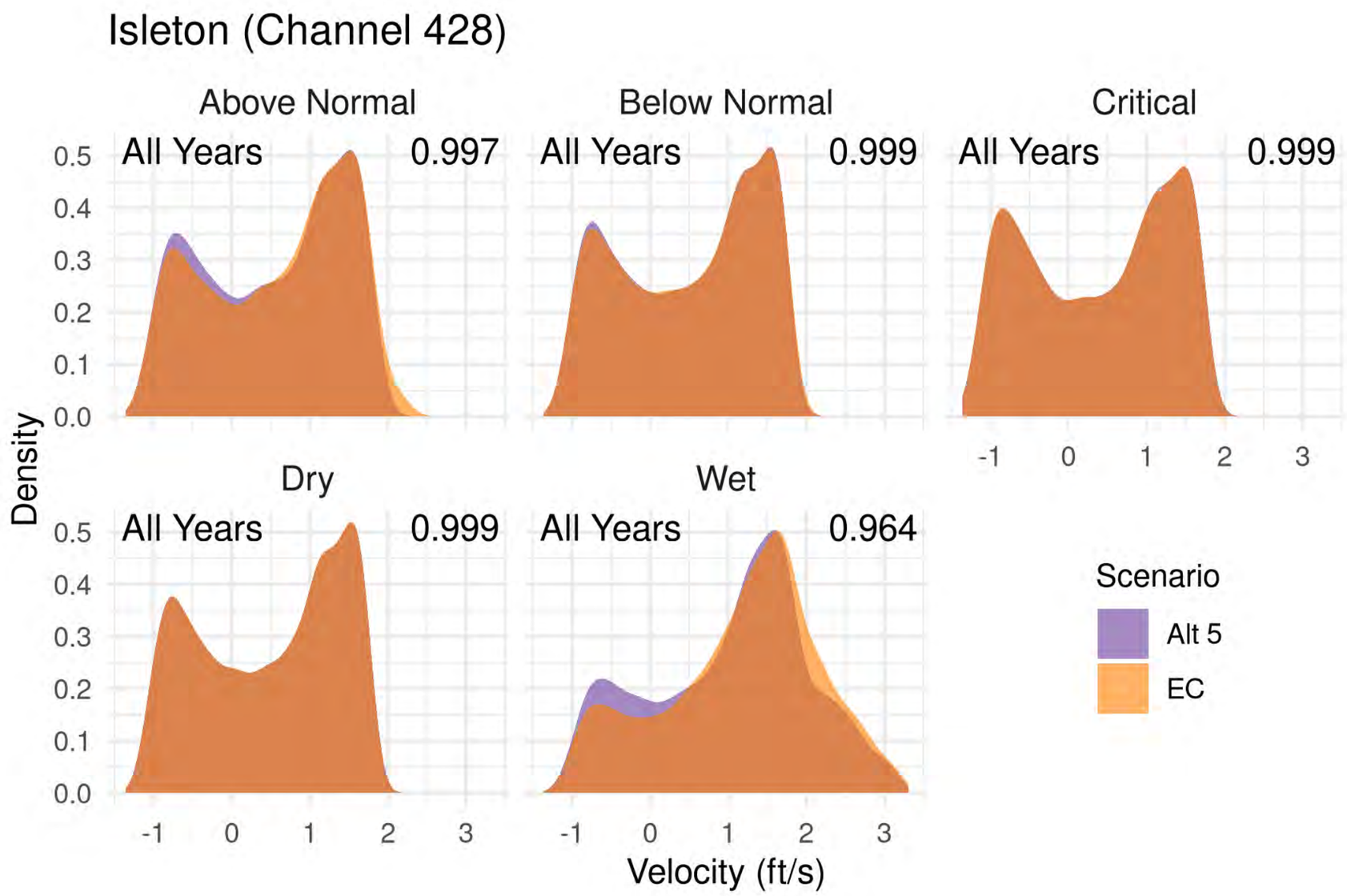

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-225. Velocity Density Distribution for Walnut Grove (Sacramento River), June.**



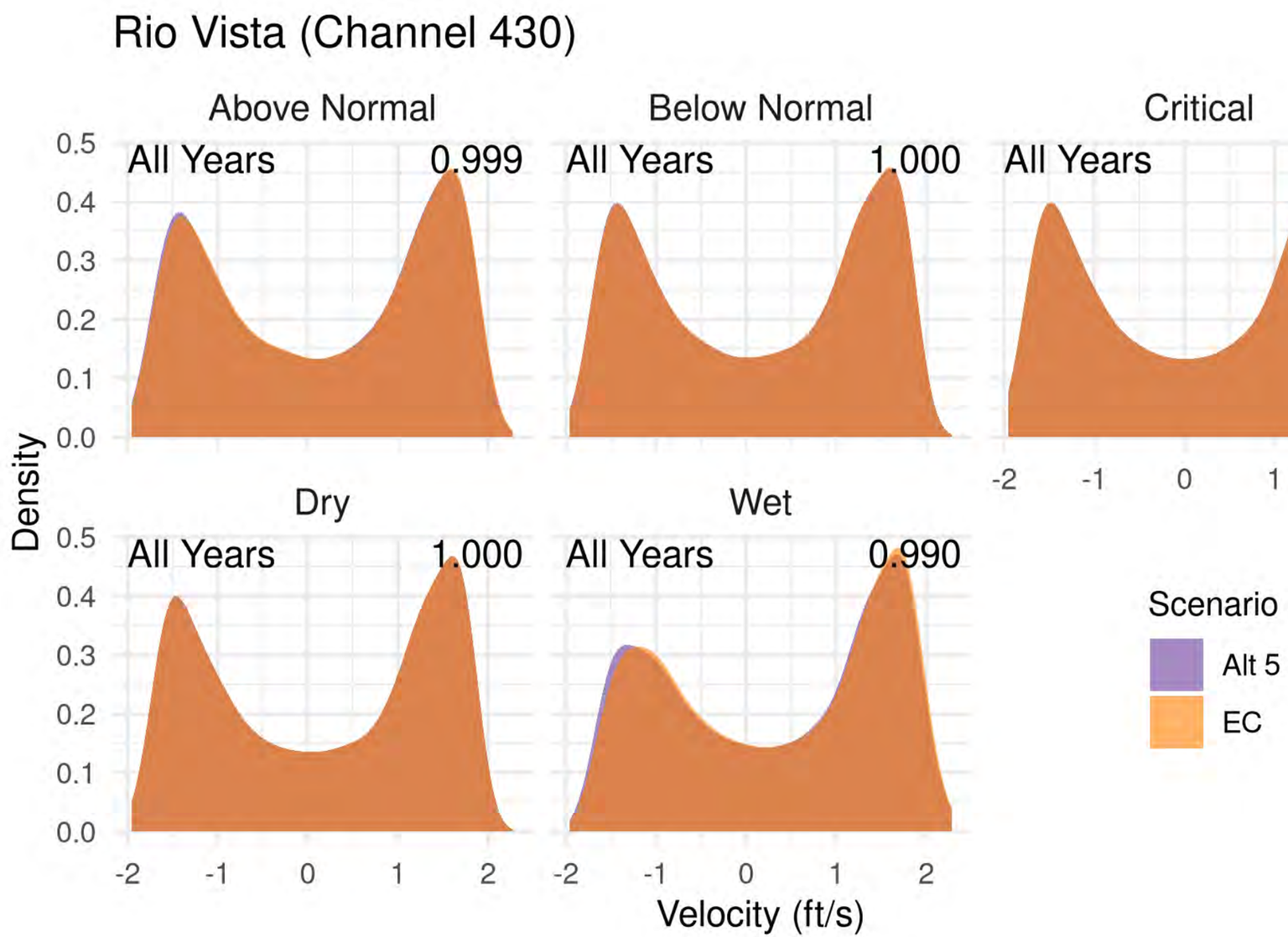

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-226. Velocity Density Distribution for Georgiana Slough, June.**



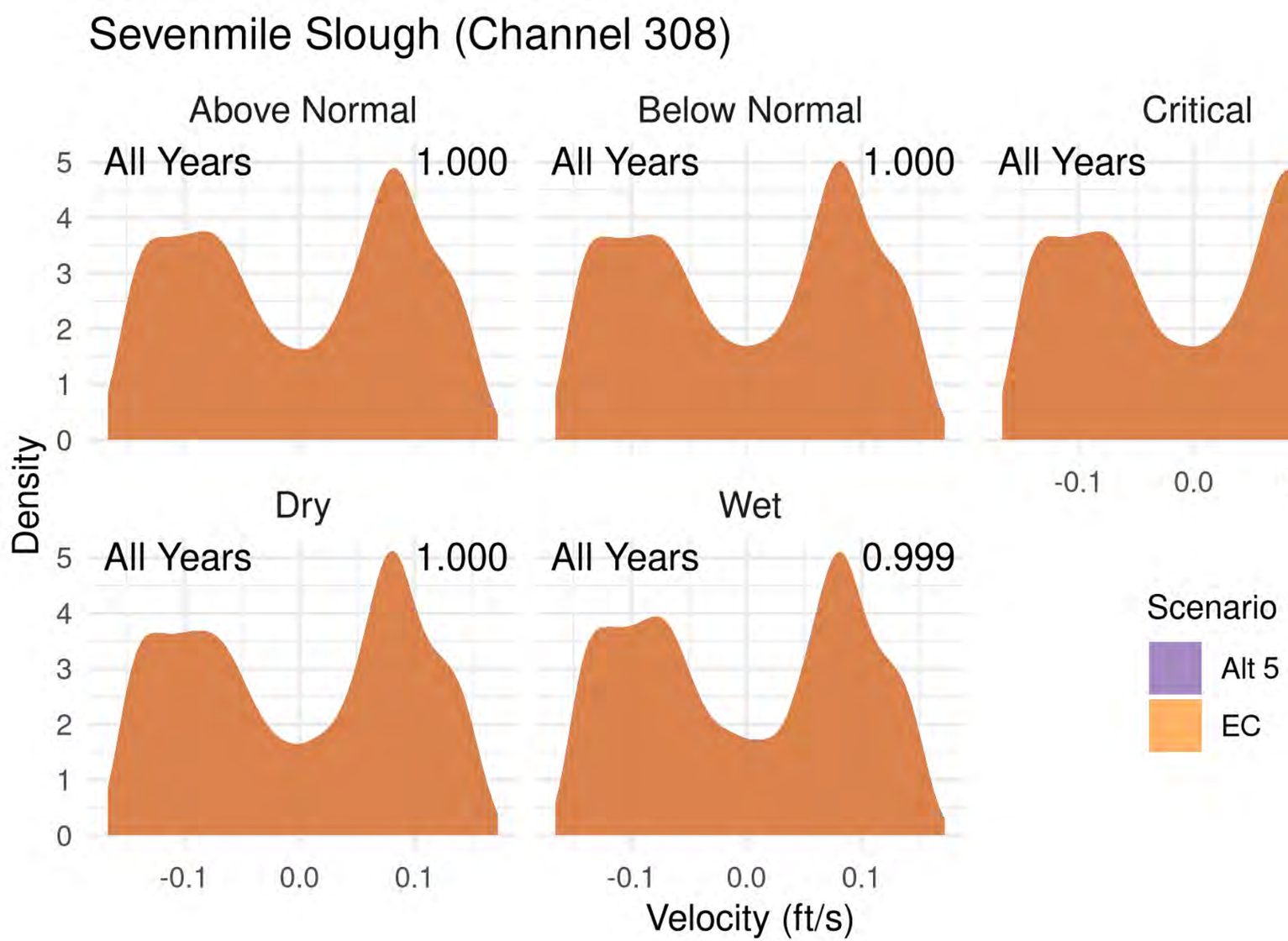

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-227. Velocity Density Distribution for Isleton (Sacramento River), June**



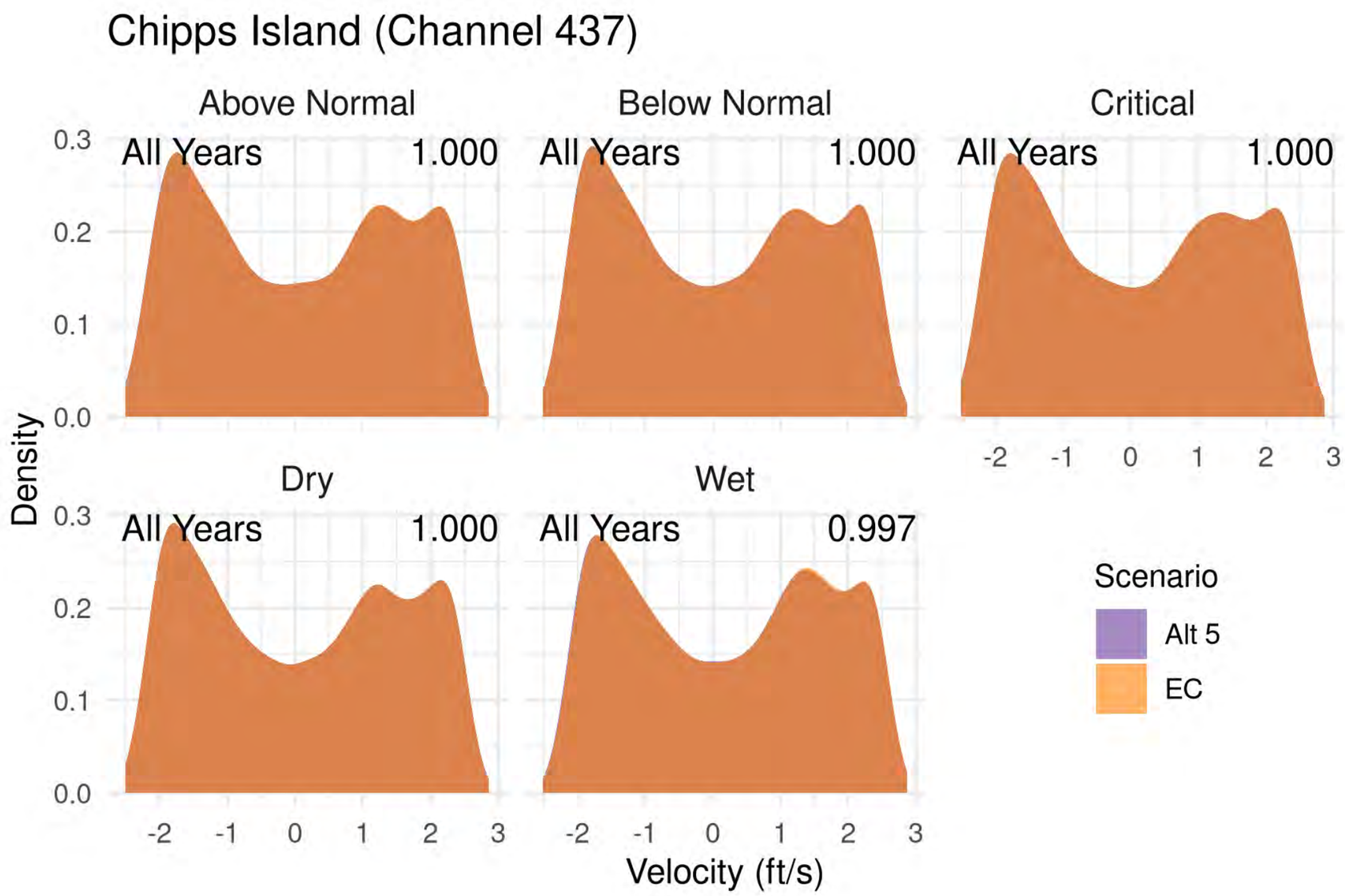

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-228. Velocity Density Distribution for Rio Vista (Sacramento River), June.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

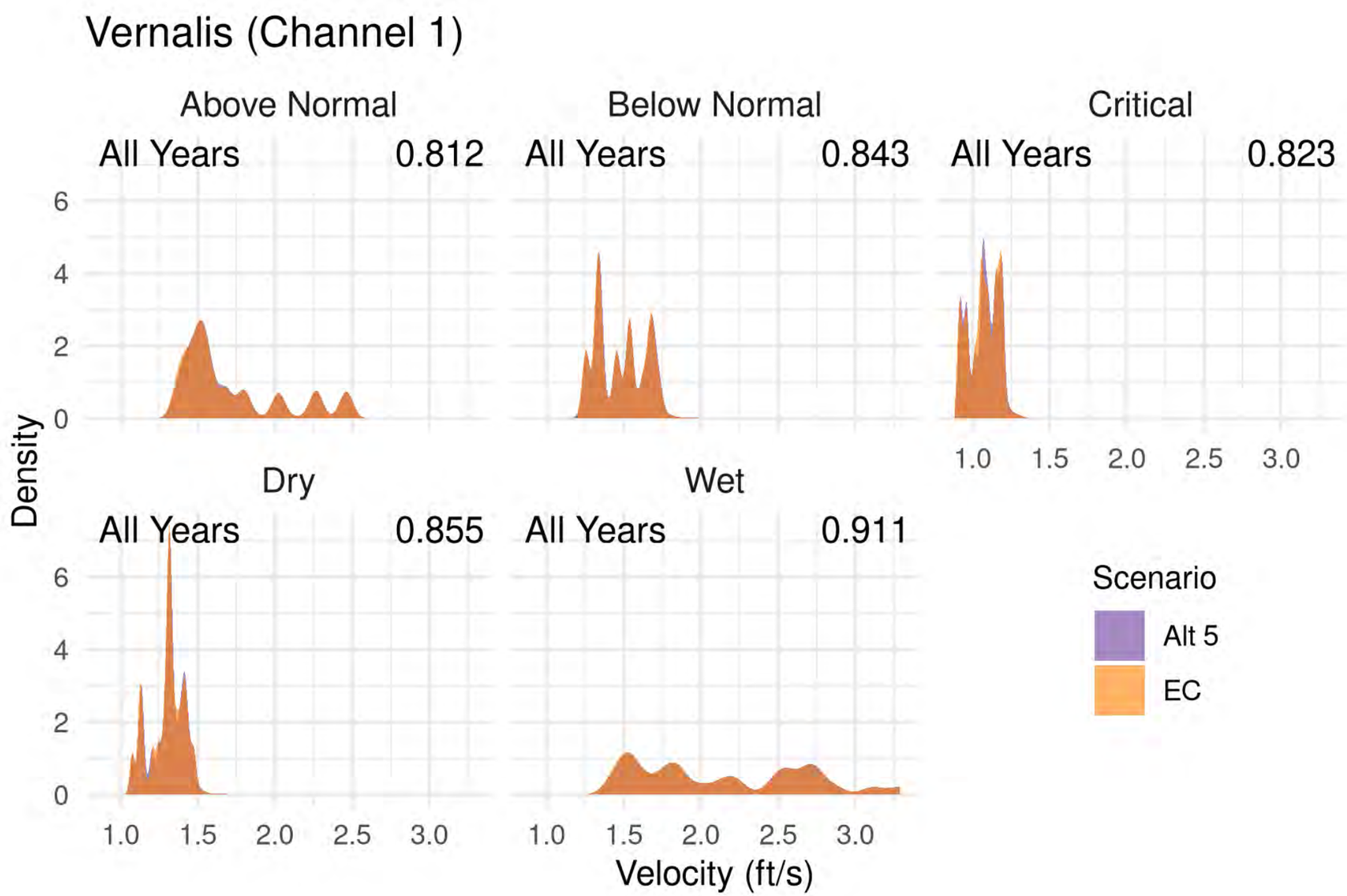
**Figure 5D.1-229. Velocity Density Distribution for Sevenmile Slough, June.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

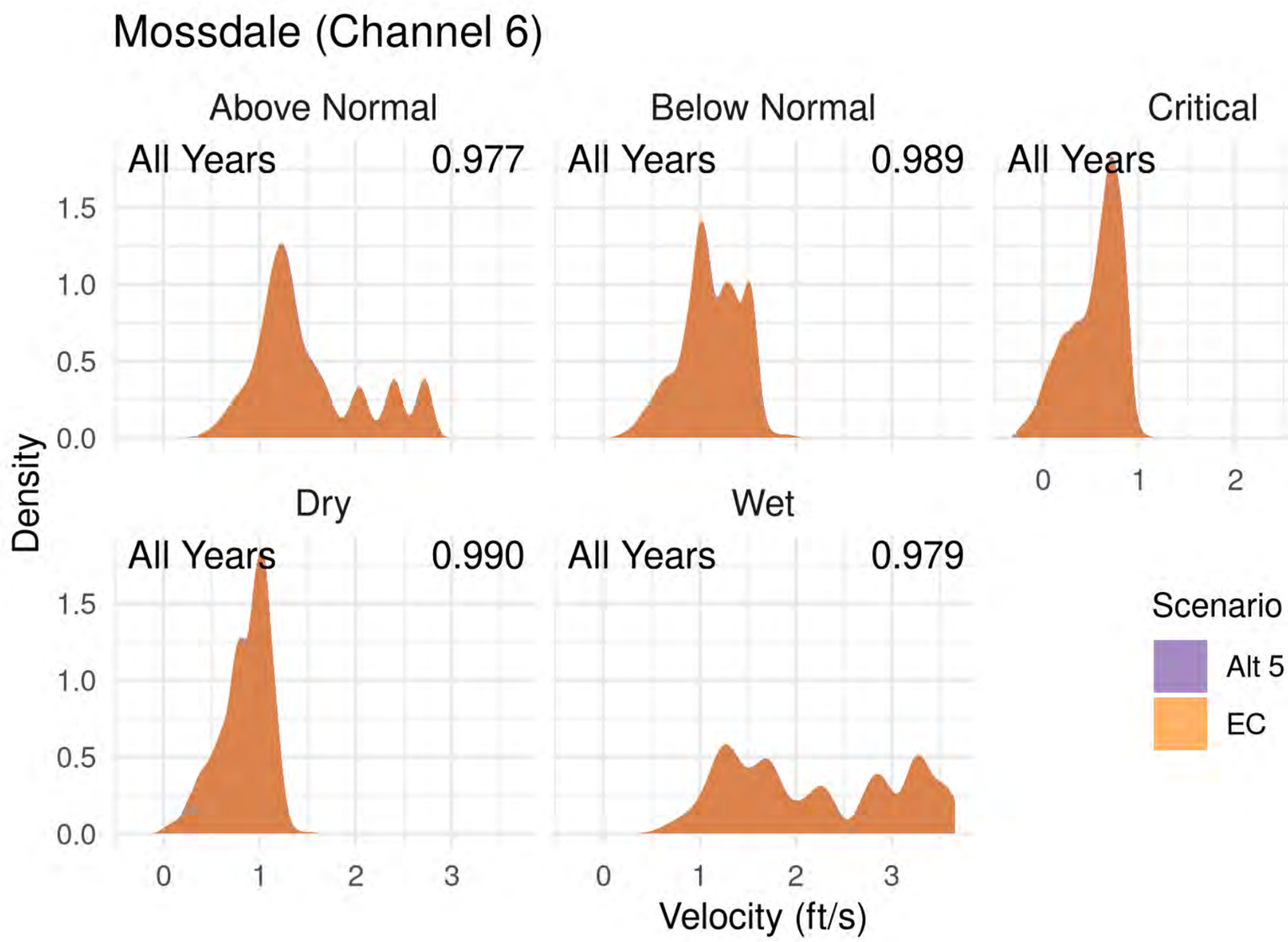
**Figure 5D.1-230. Velocity Density Distribution for Chipps Island (Sacramento River–San Joaquin River Confluence), June.**

***San Joaquin River Delta***



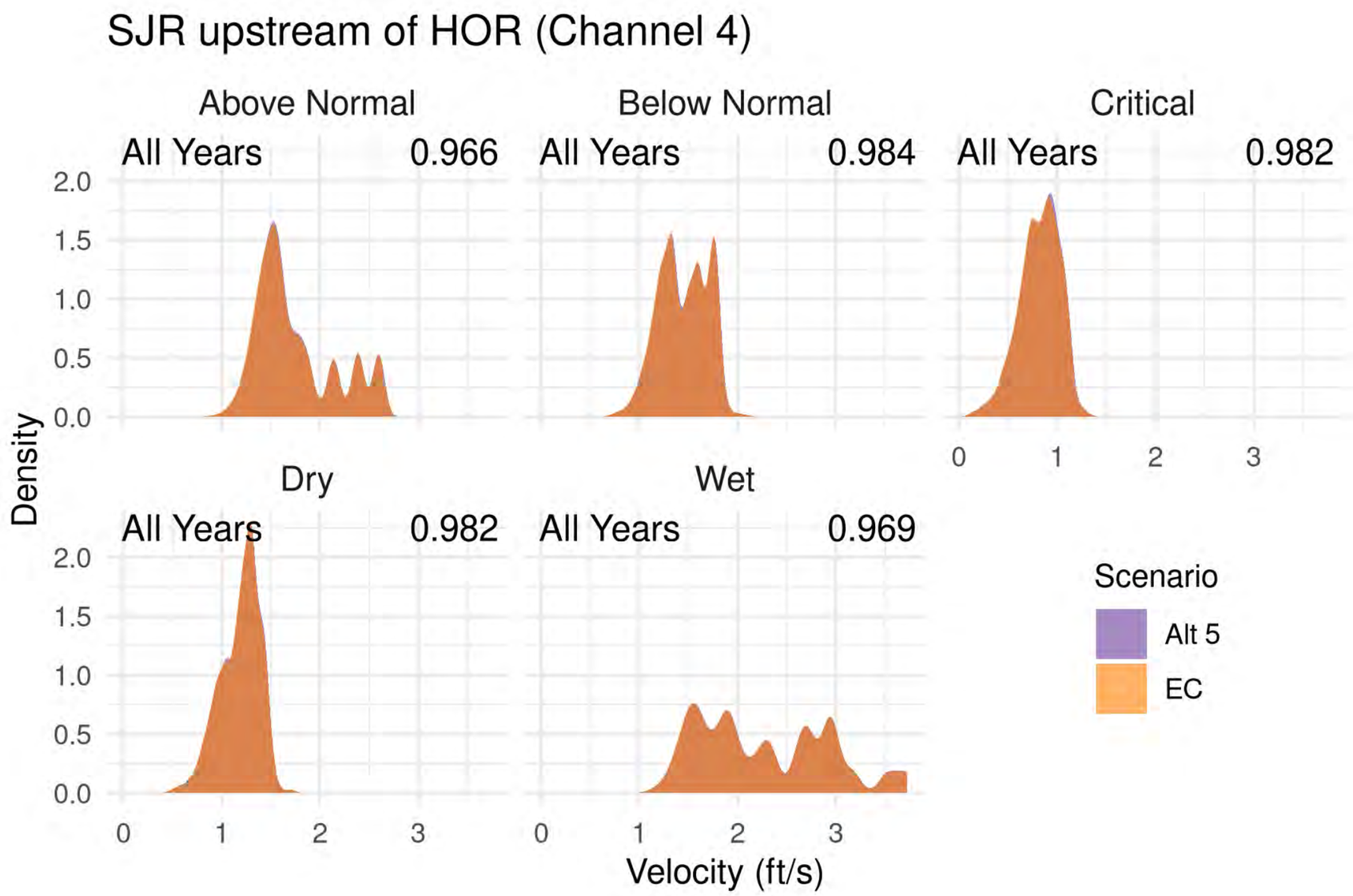

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-231. Velocity Density Distribution for Vernalis (San Joaquin River), June.**



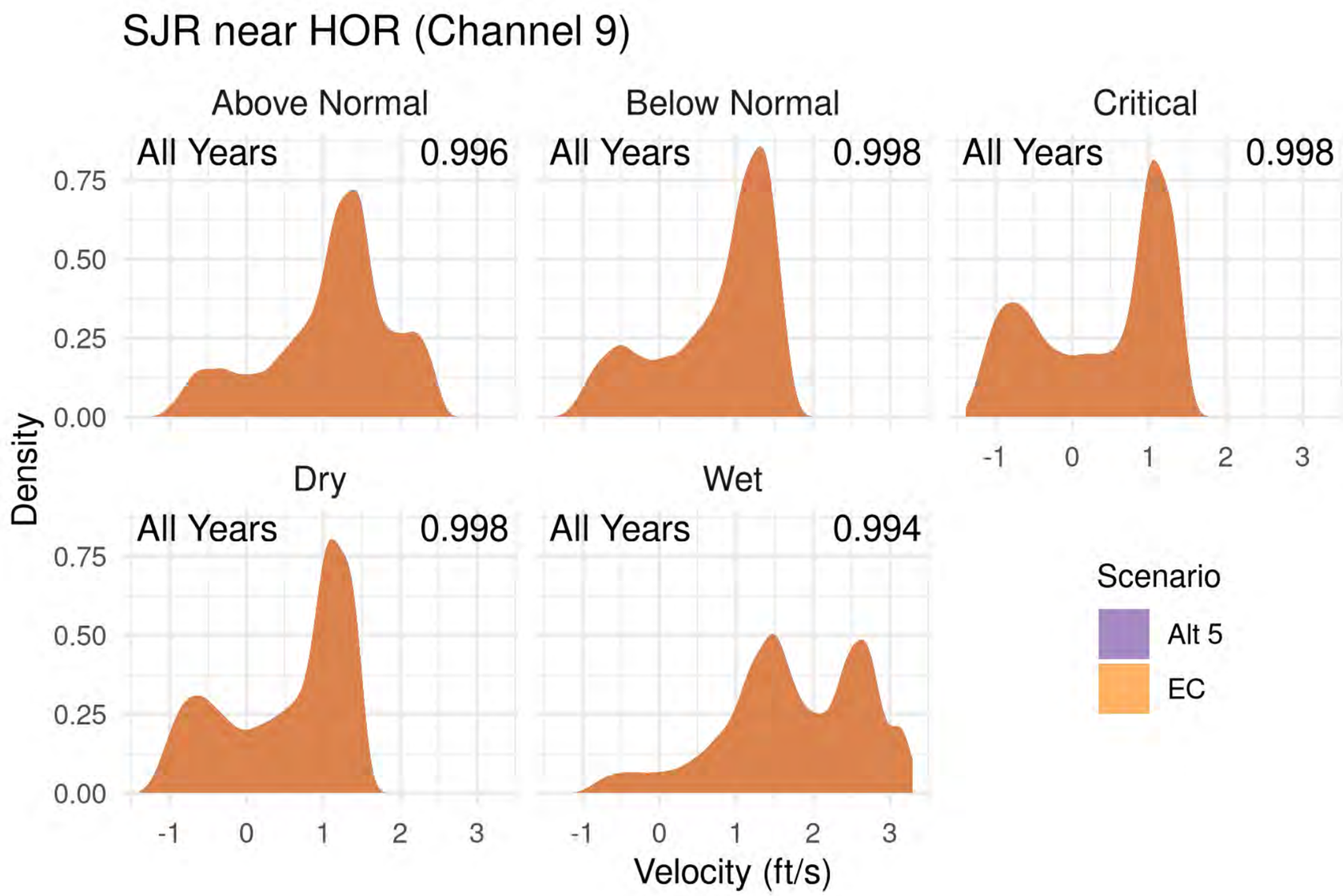

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-232. Velocity Density Distribution for Mossdale (San Joaquin River), June.**



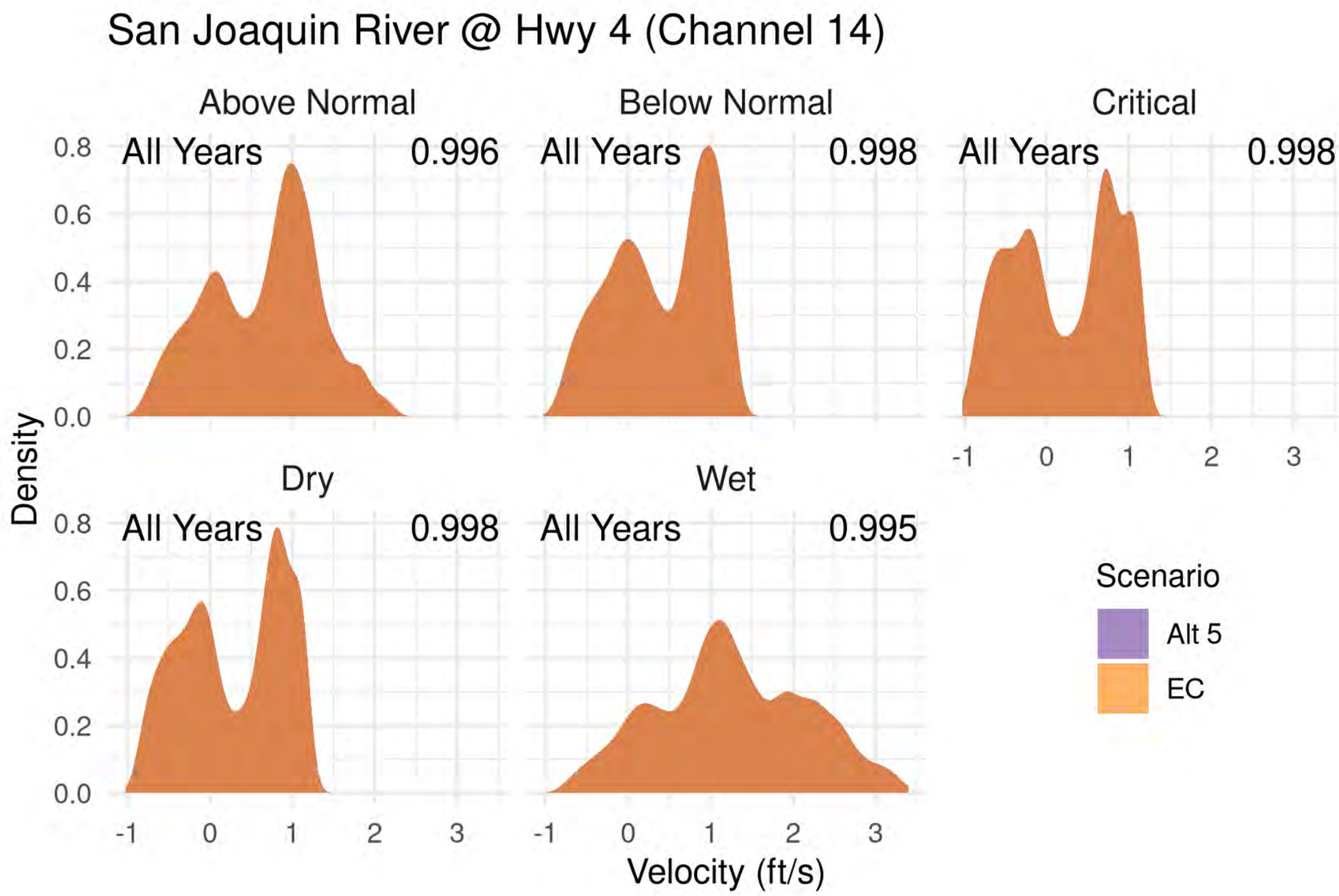

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-233. Velocity Density Distribution for San Joaquin River upstream of Head of Old River, June.**



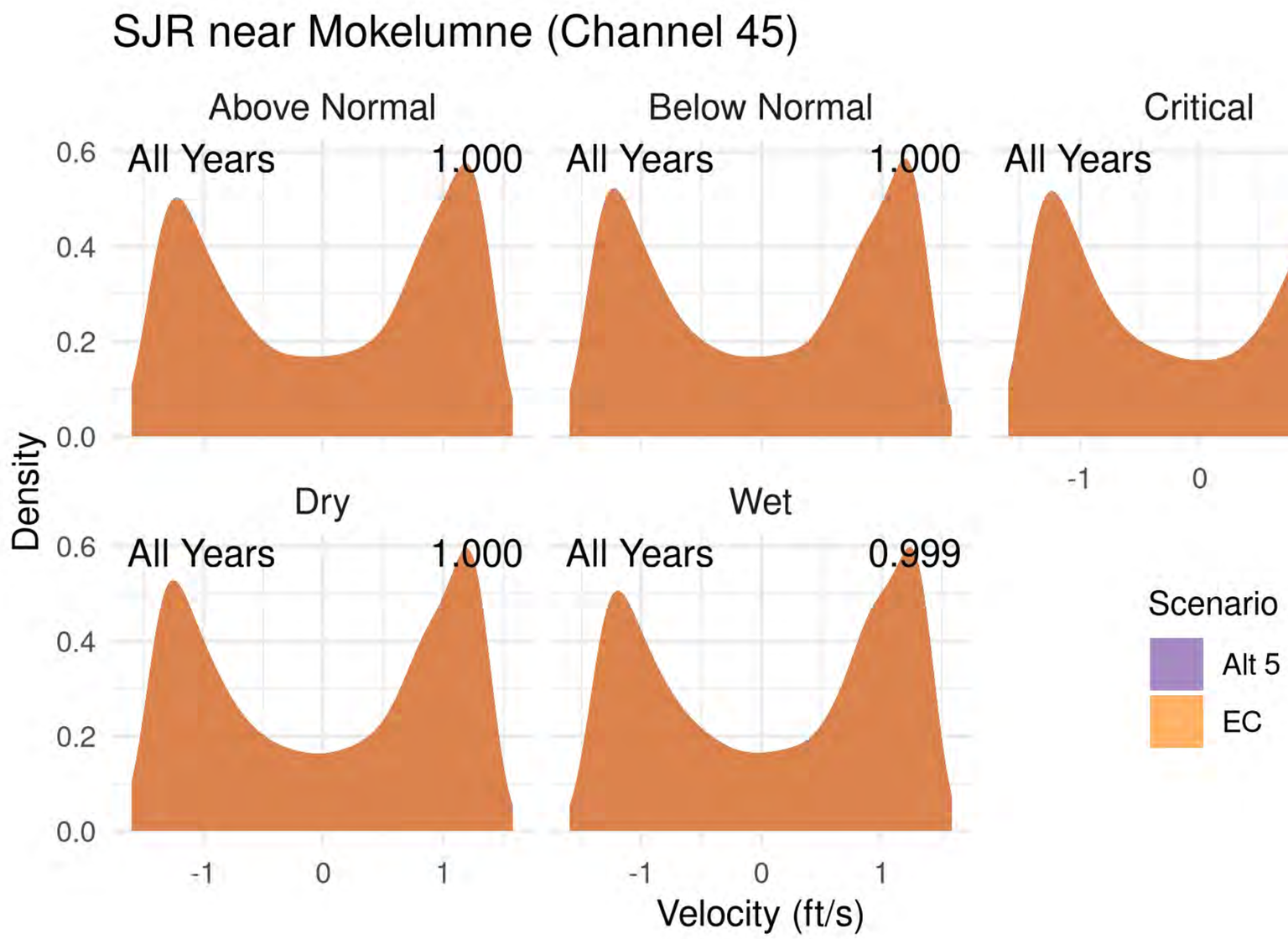

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-234. Velocity Density Distribution for San Joaquin River near Head of Old River, June.**



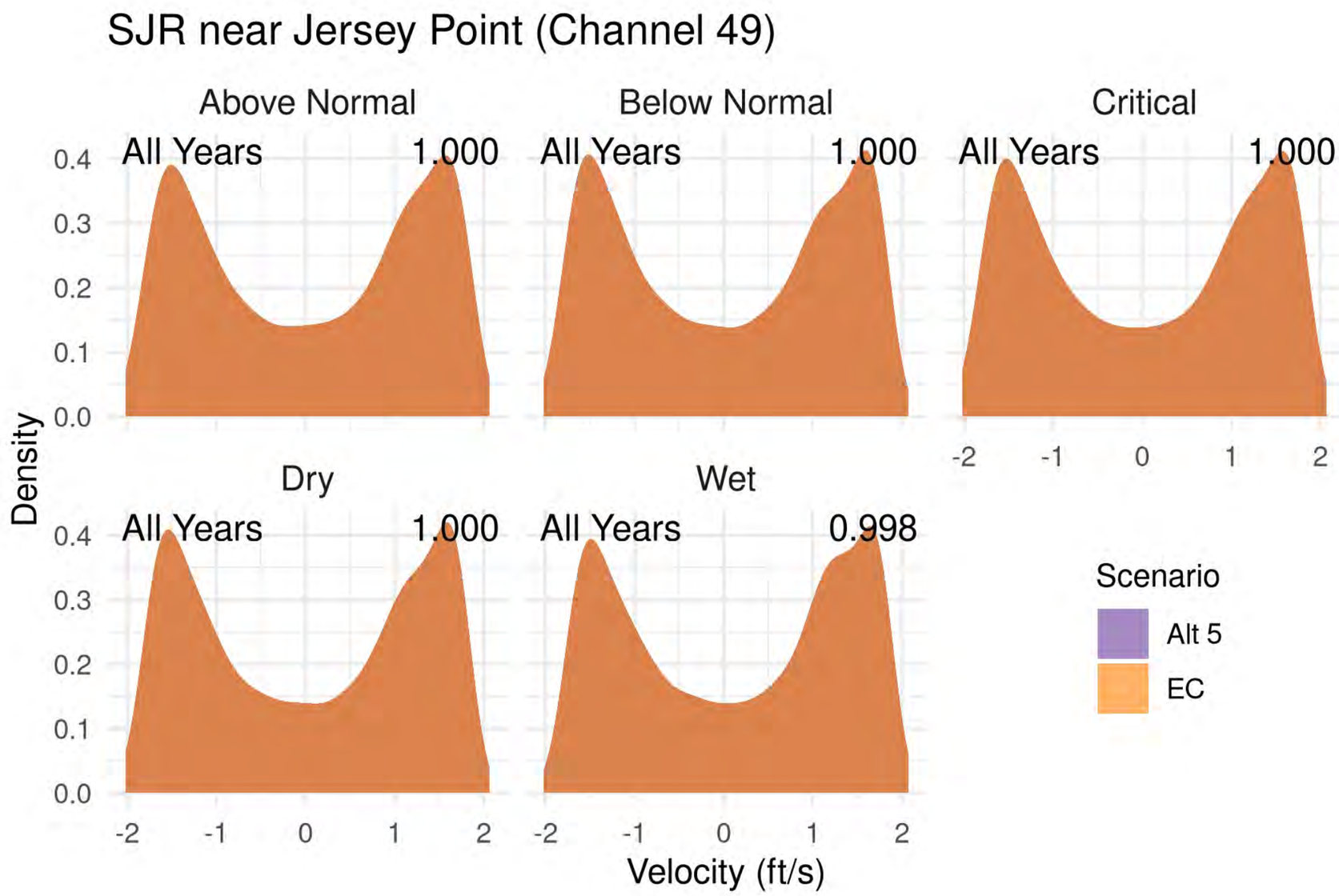

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-235. Velocity Density Distribution for San Joaquin River at Highway 4, June.**



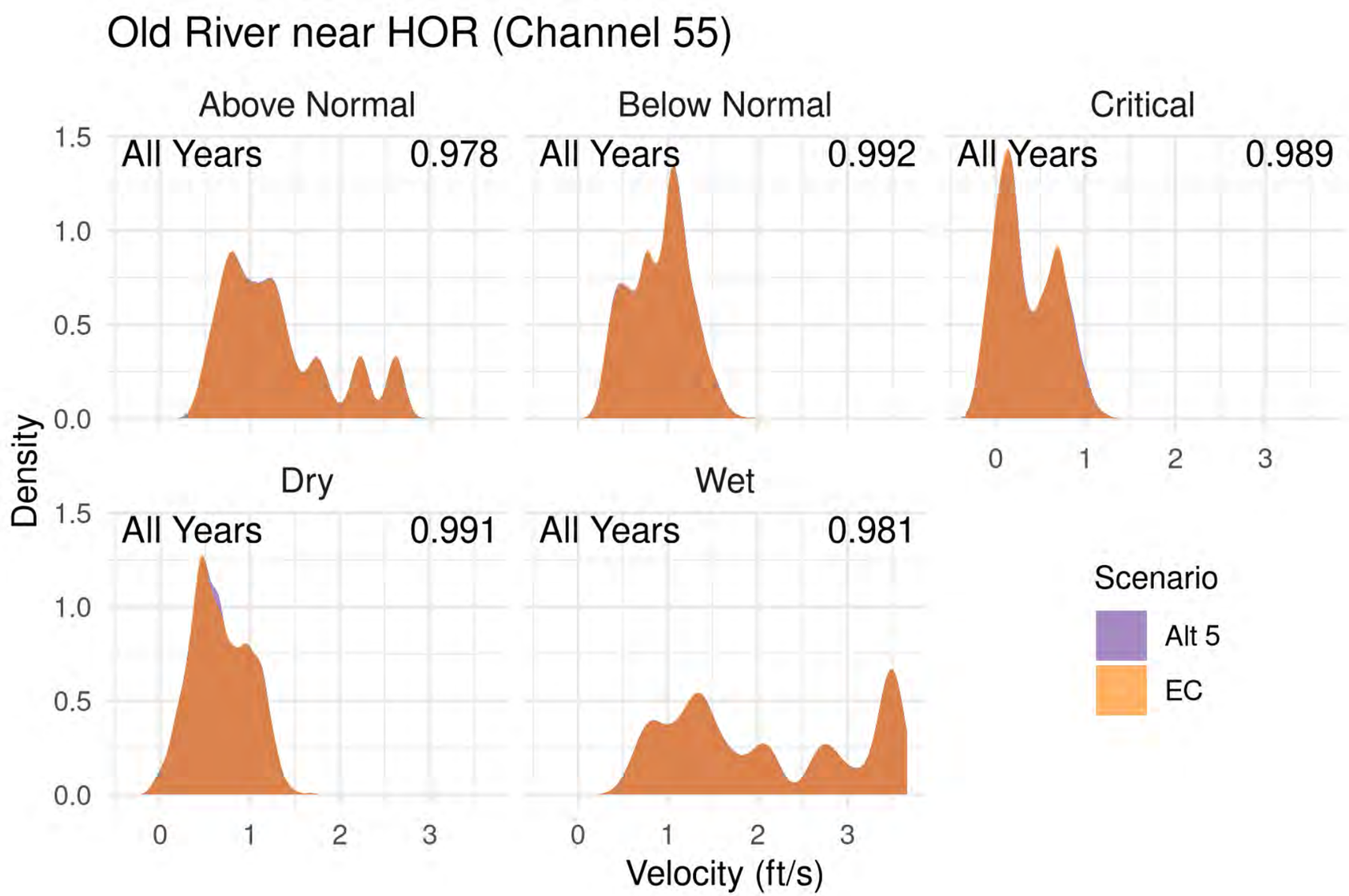

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-236. Velocity Density Distribution for San Joaquin River near Mokelumne River, June.**



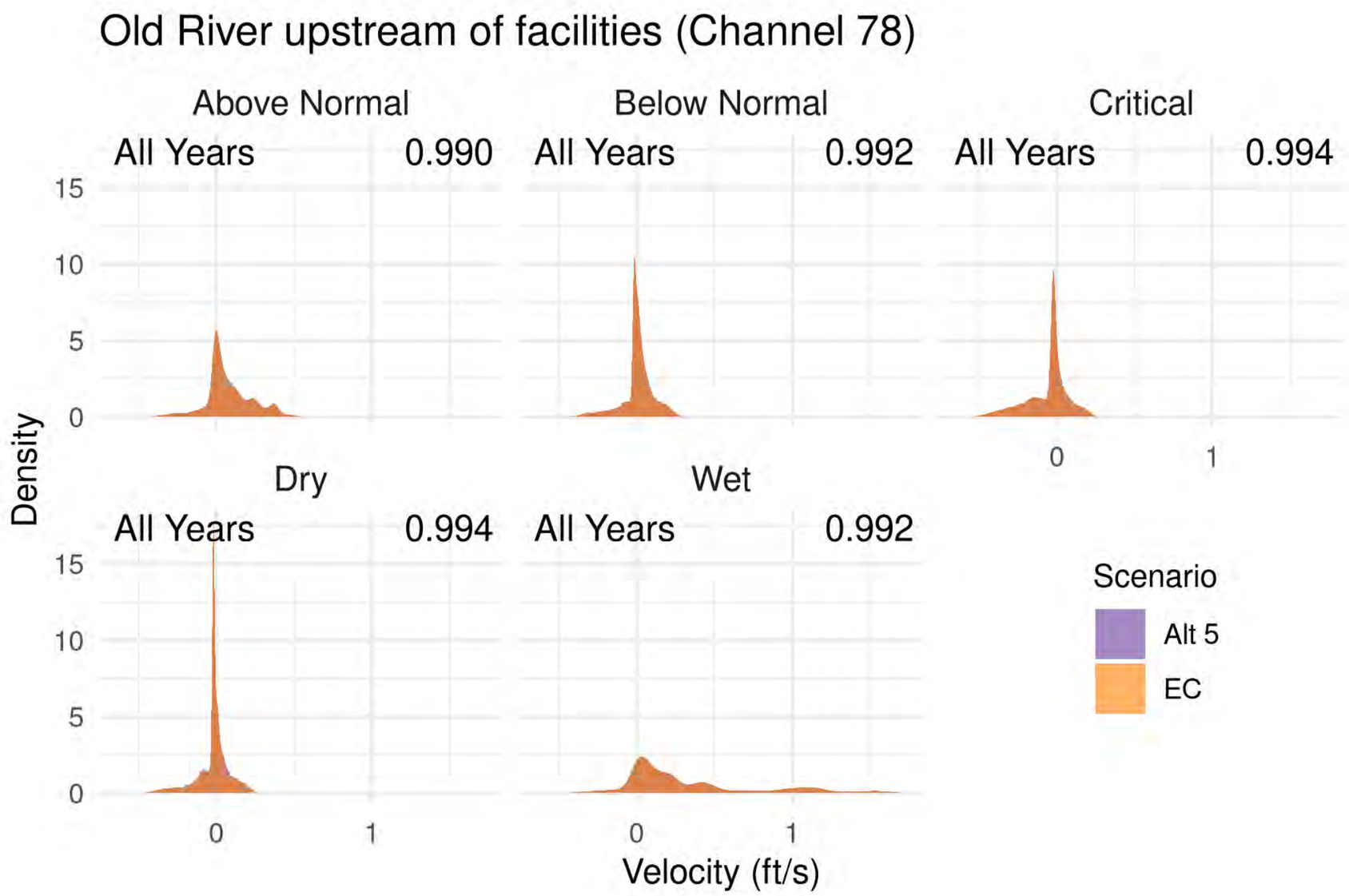

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-237. Velocity Density Distribution for San Joaquin River near Jersey Point, June.**



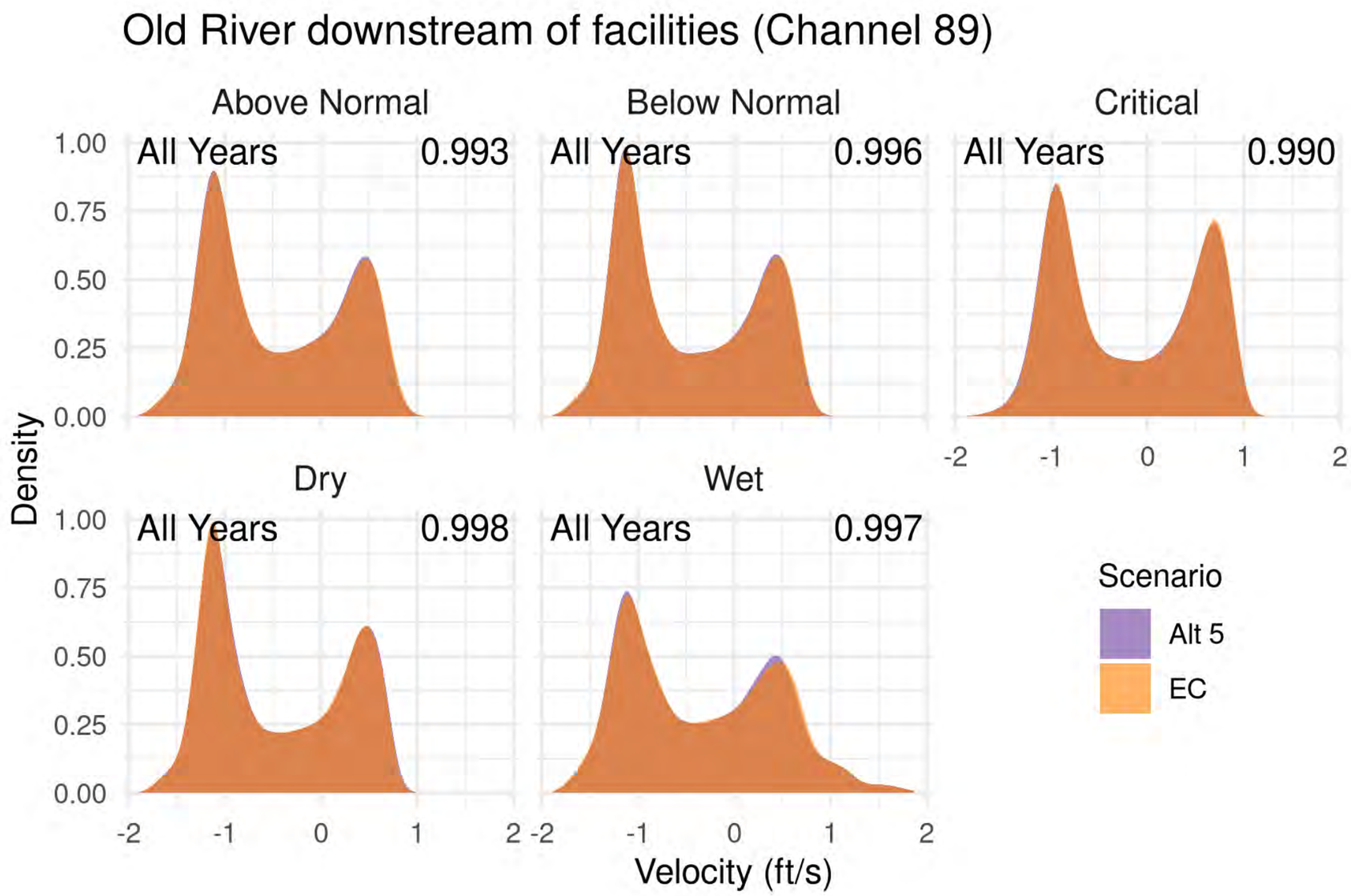

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-238. Velocity Density Distribution for Old River near Head of Old River, June.**



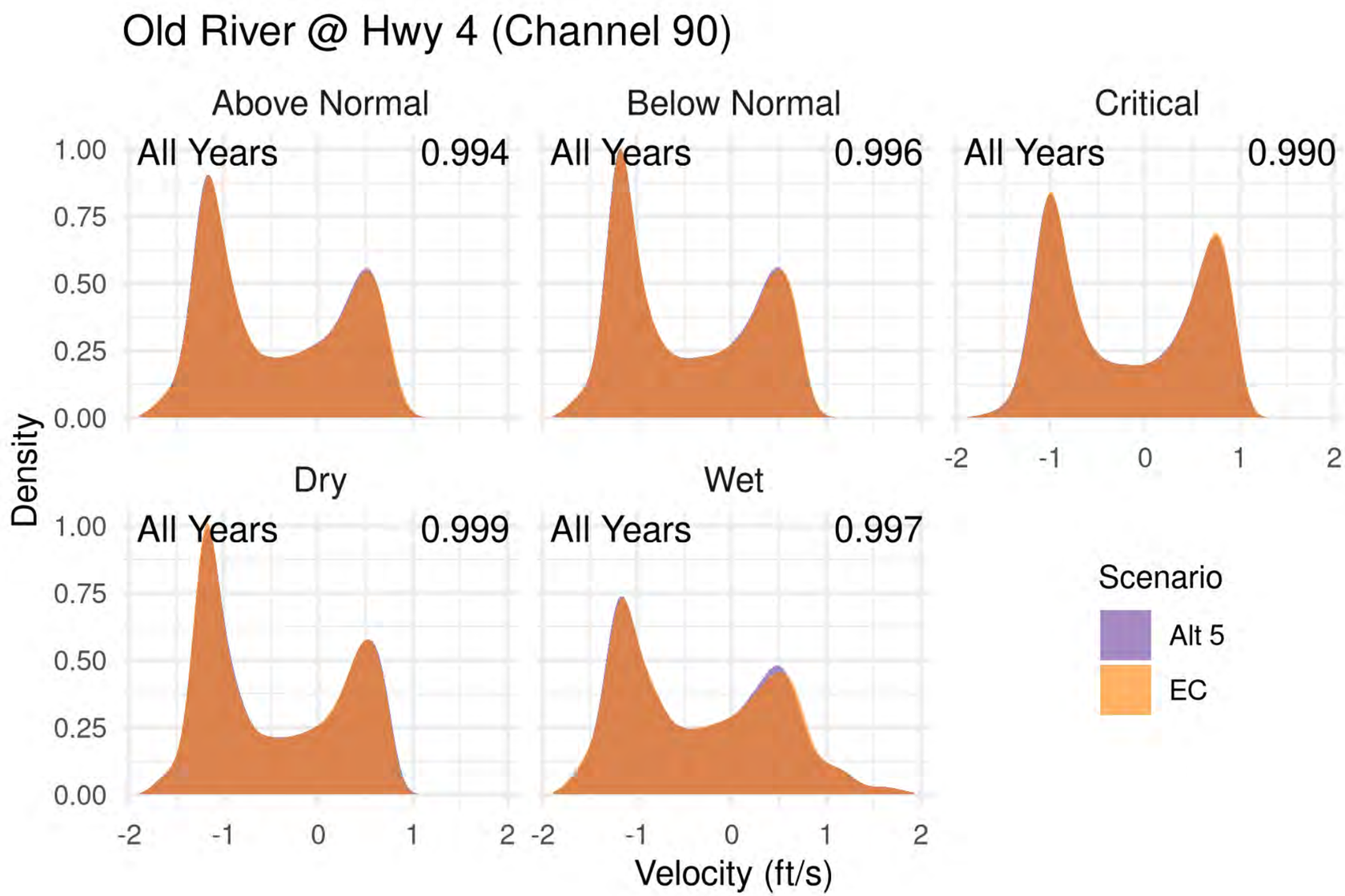

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-239. Velocity Density Distribution for Old River upstream of the South Delta Export Facilities, June.**



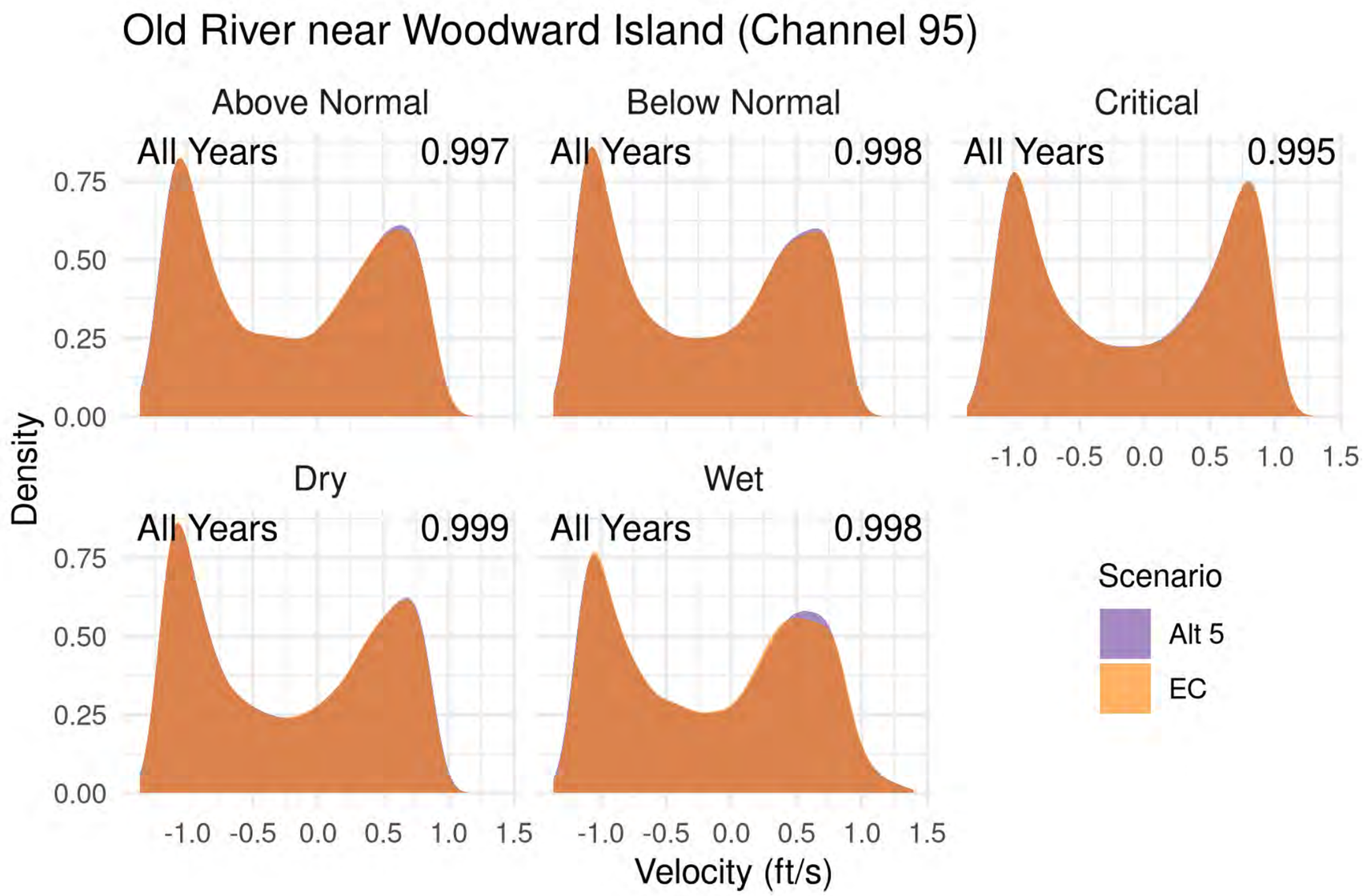

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-240. Velocity Density Distribution for Old River Downstream of the South Delta Export Facilities, June.**



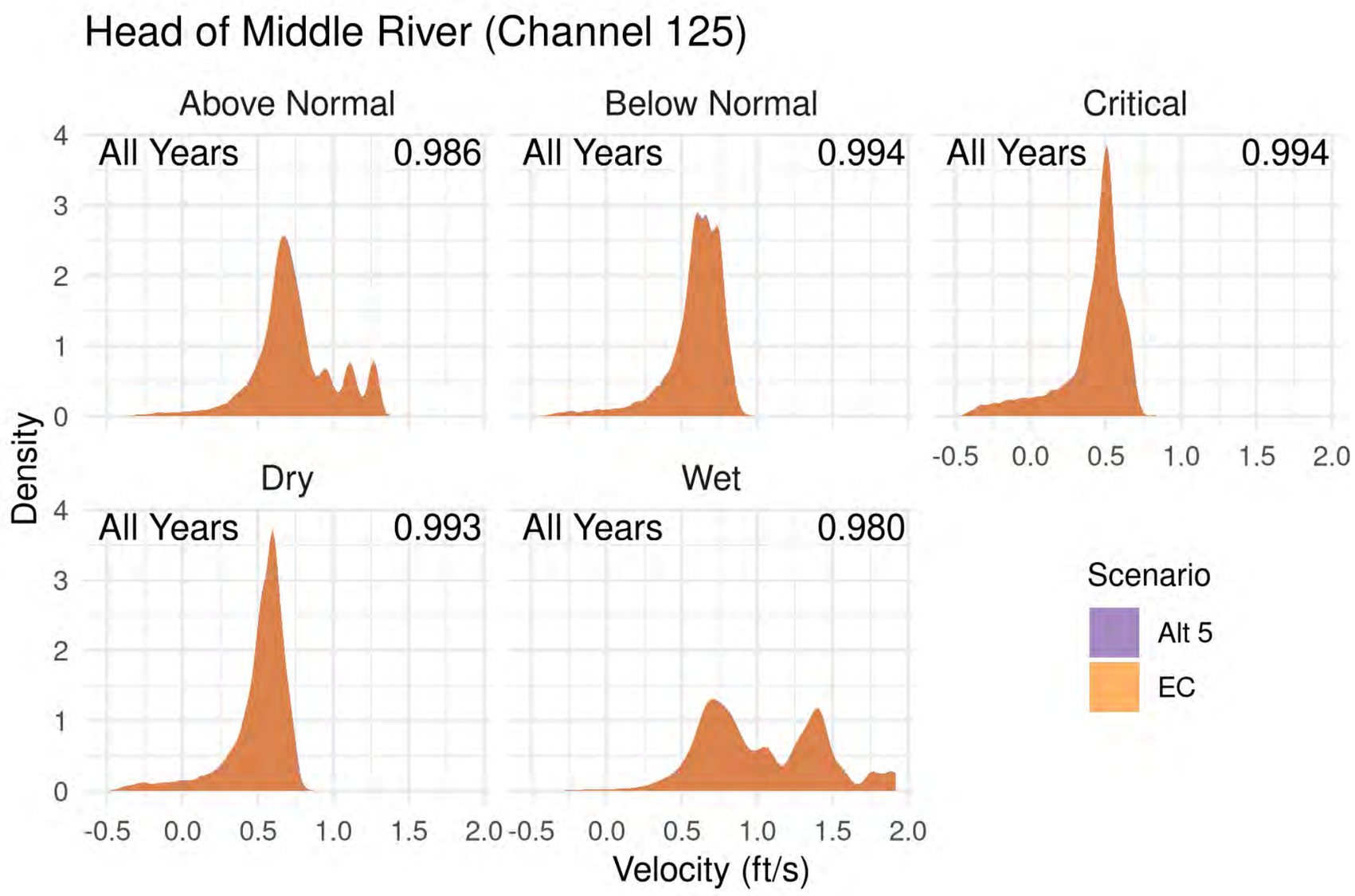

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-241. Velocity Density Distribution for Old River at Highway 4, June.**



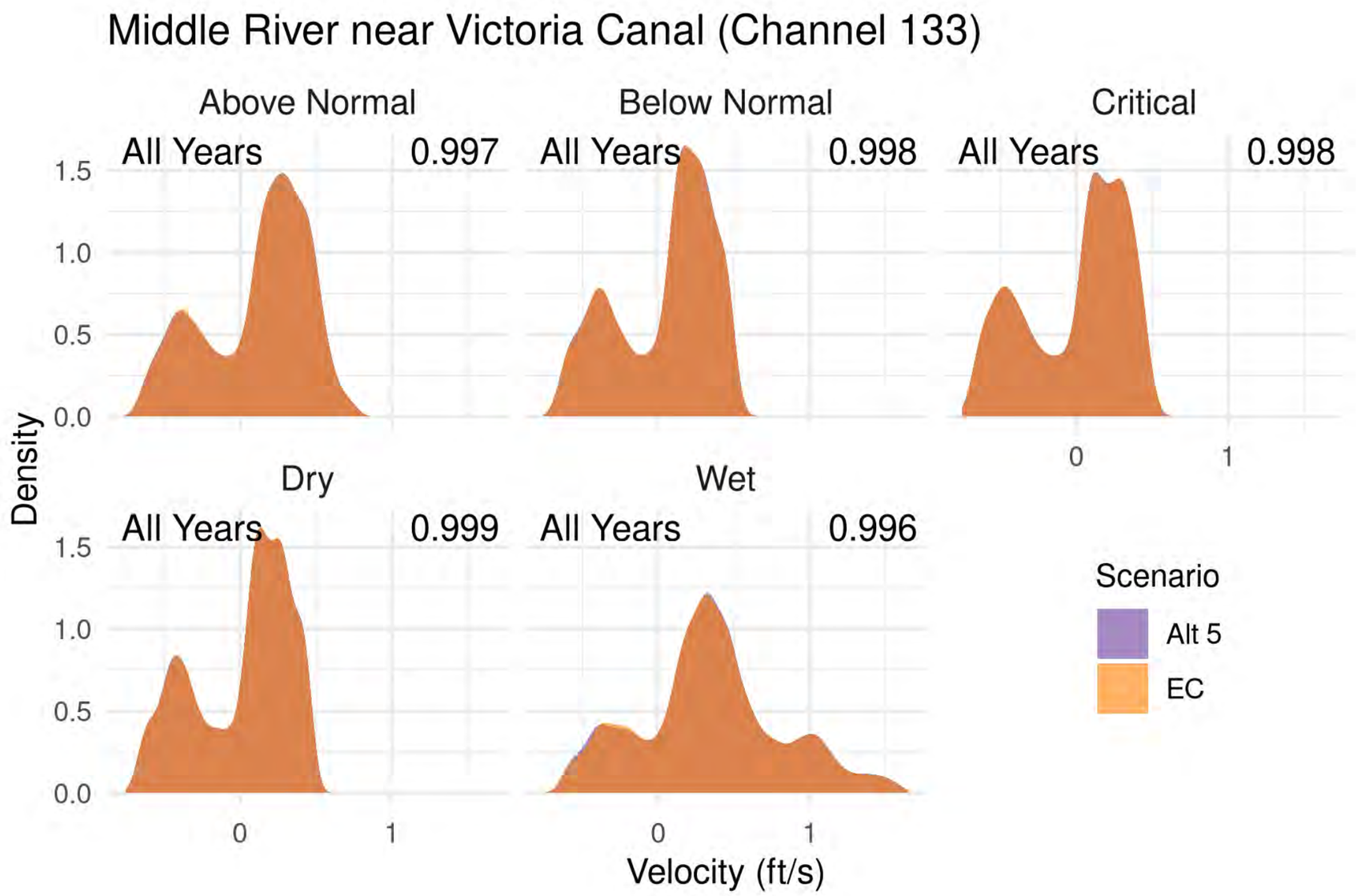

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-242. Velocity Density Distribution for Old River near Woodward Island, June.**



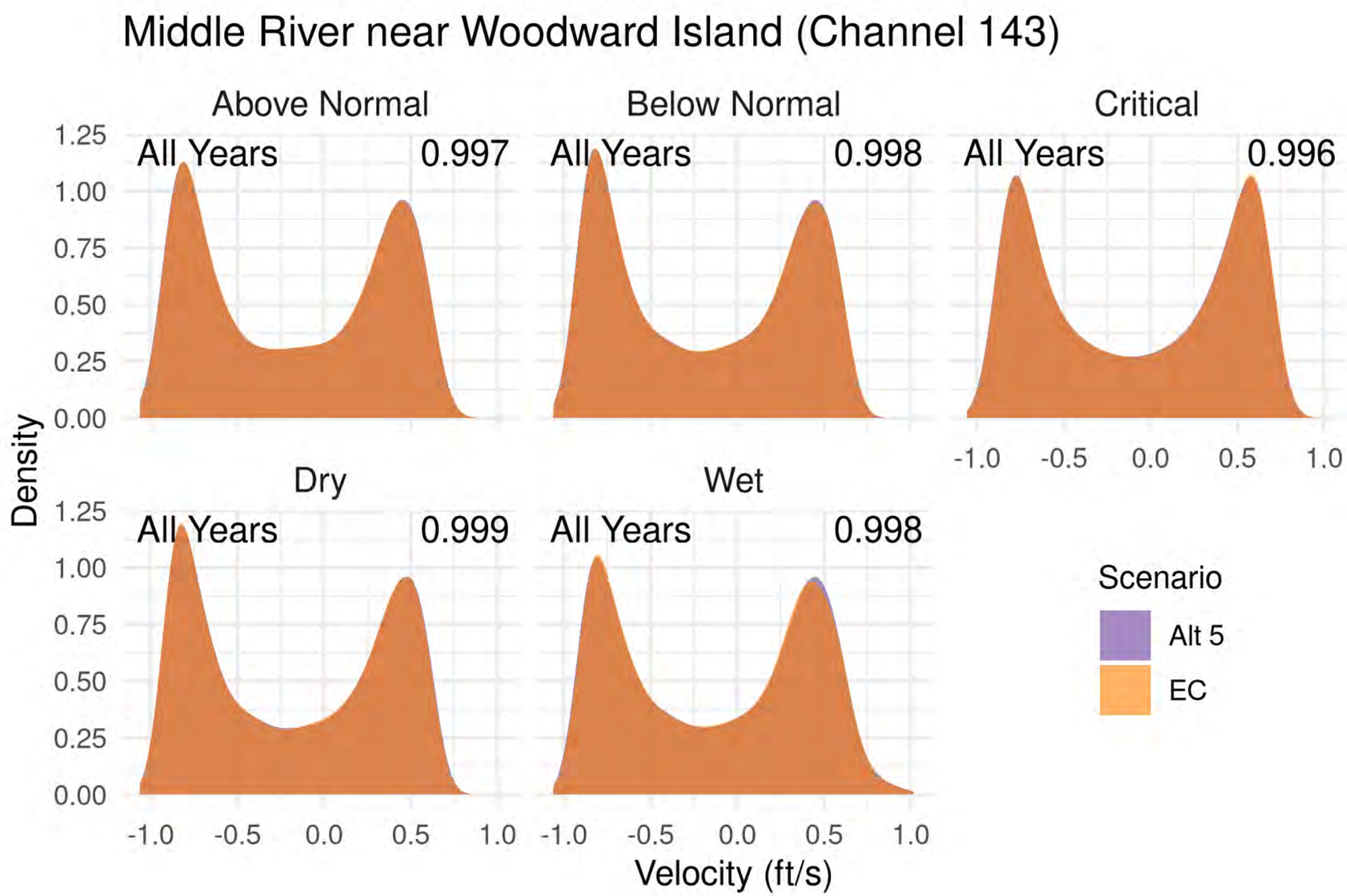

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-243. Velocity Density Distribution for Head of Middle River, June.**



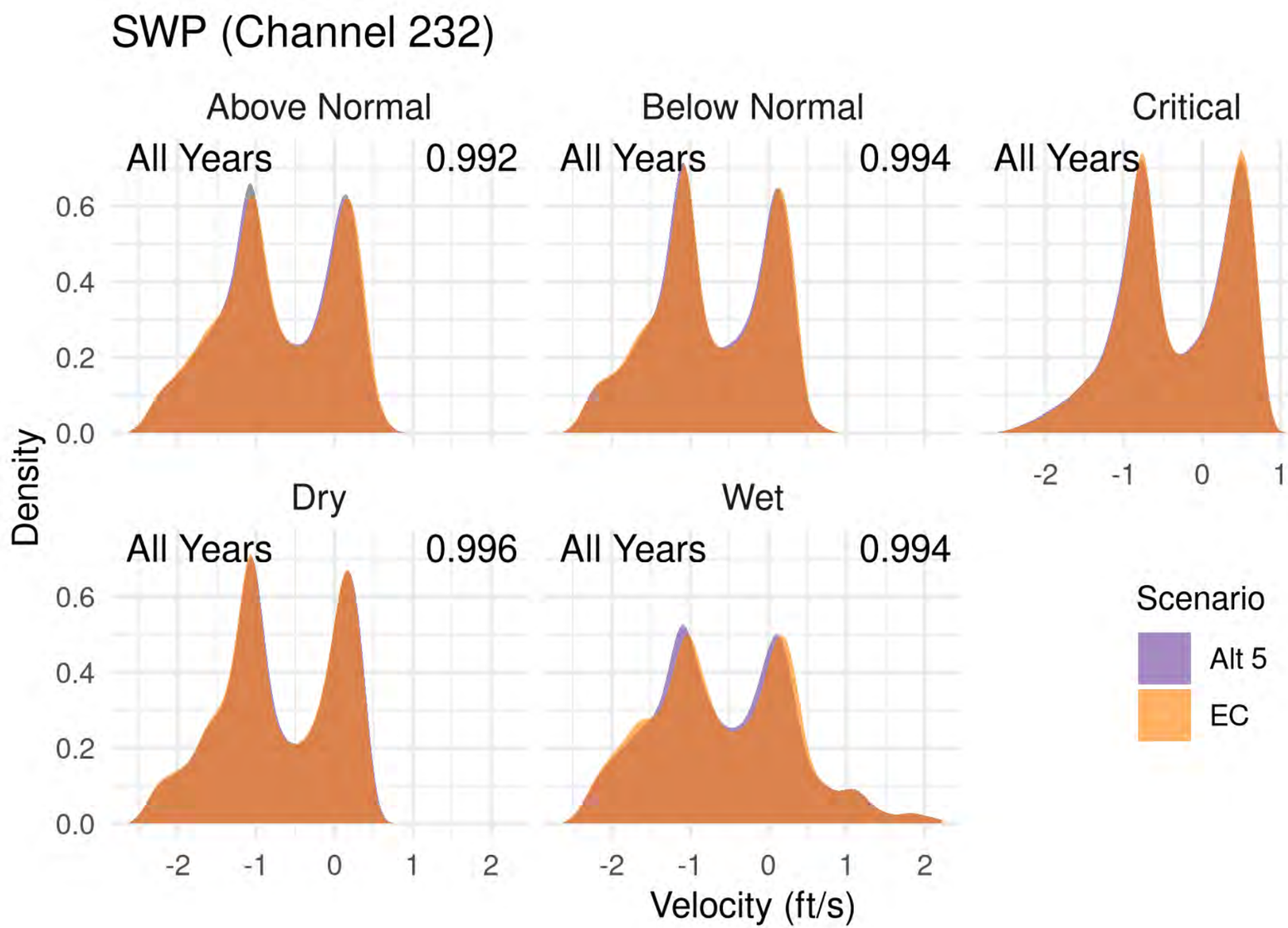

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-244. Velocity Density Distribution for Middle River near Victoria Canal, June.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-245. Velocity Density Distribution for Middle River near Woodward Island, June.**

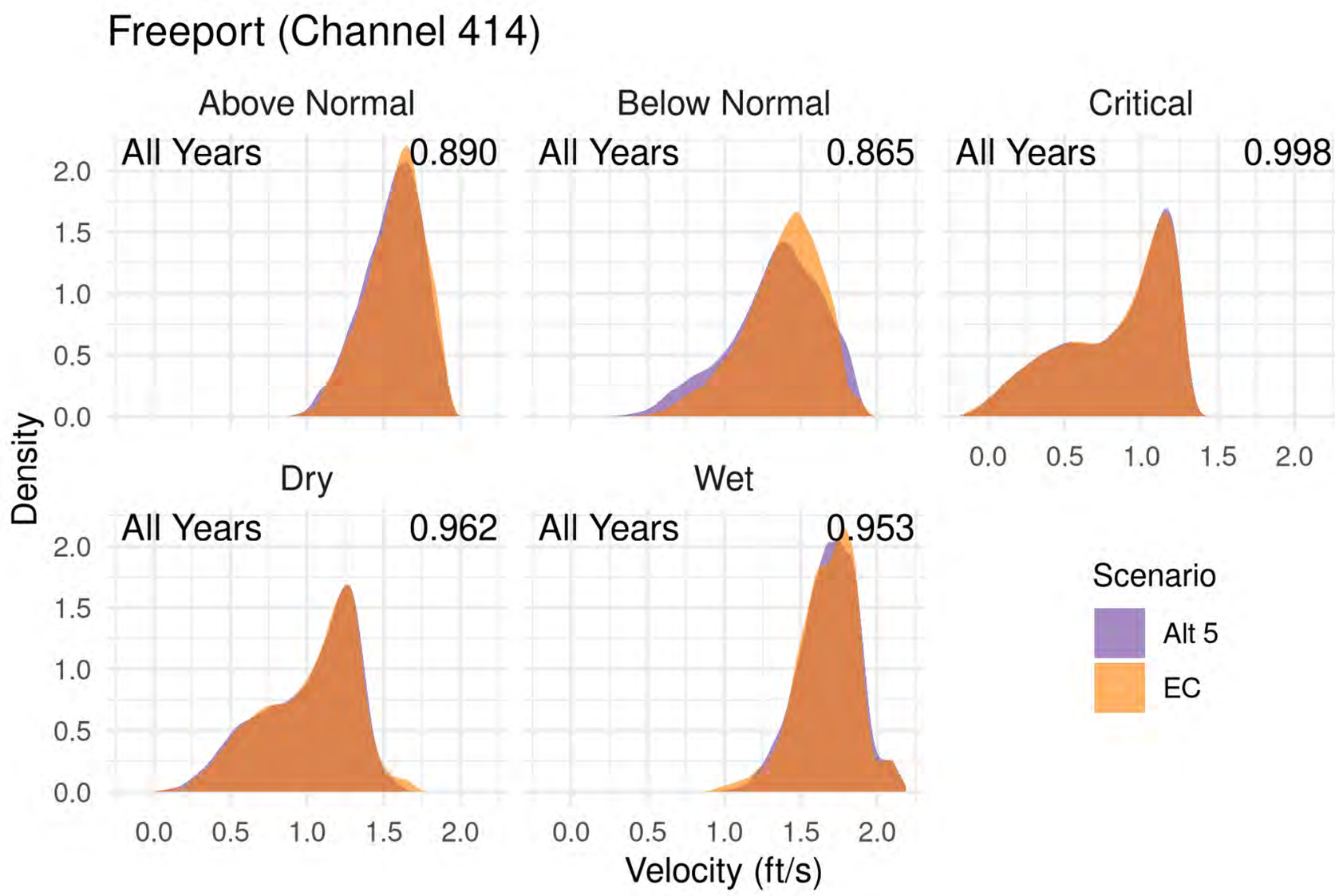



Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-246. Velocity Density Distribution for State Water Project (West Canal near Entrance to Clifton Court Forebay), June.**

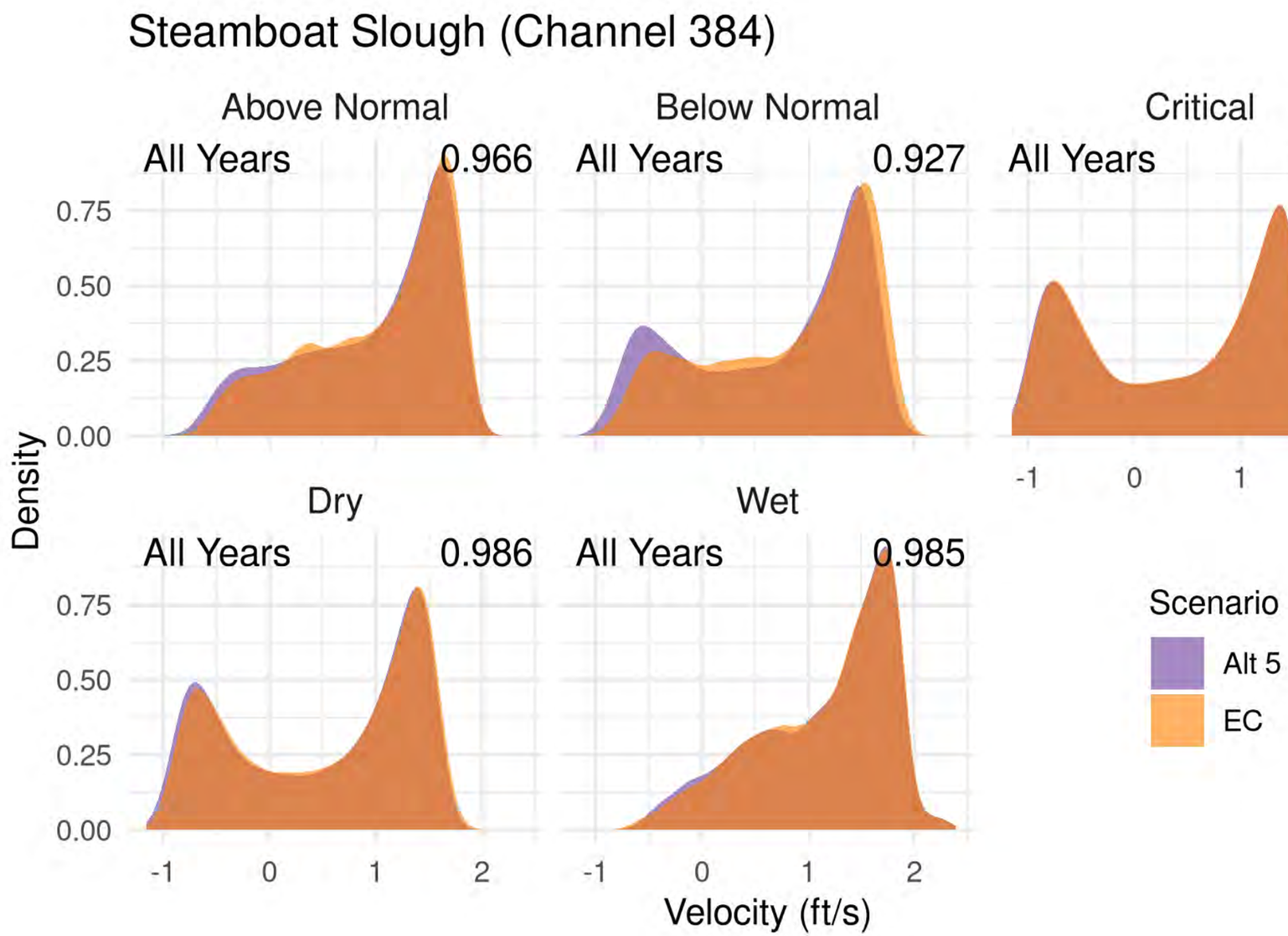
**September**

***Sacramento River Delta***



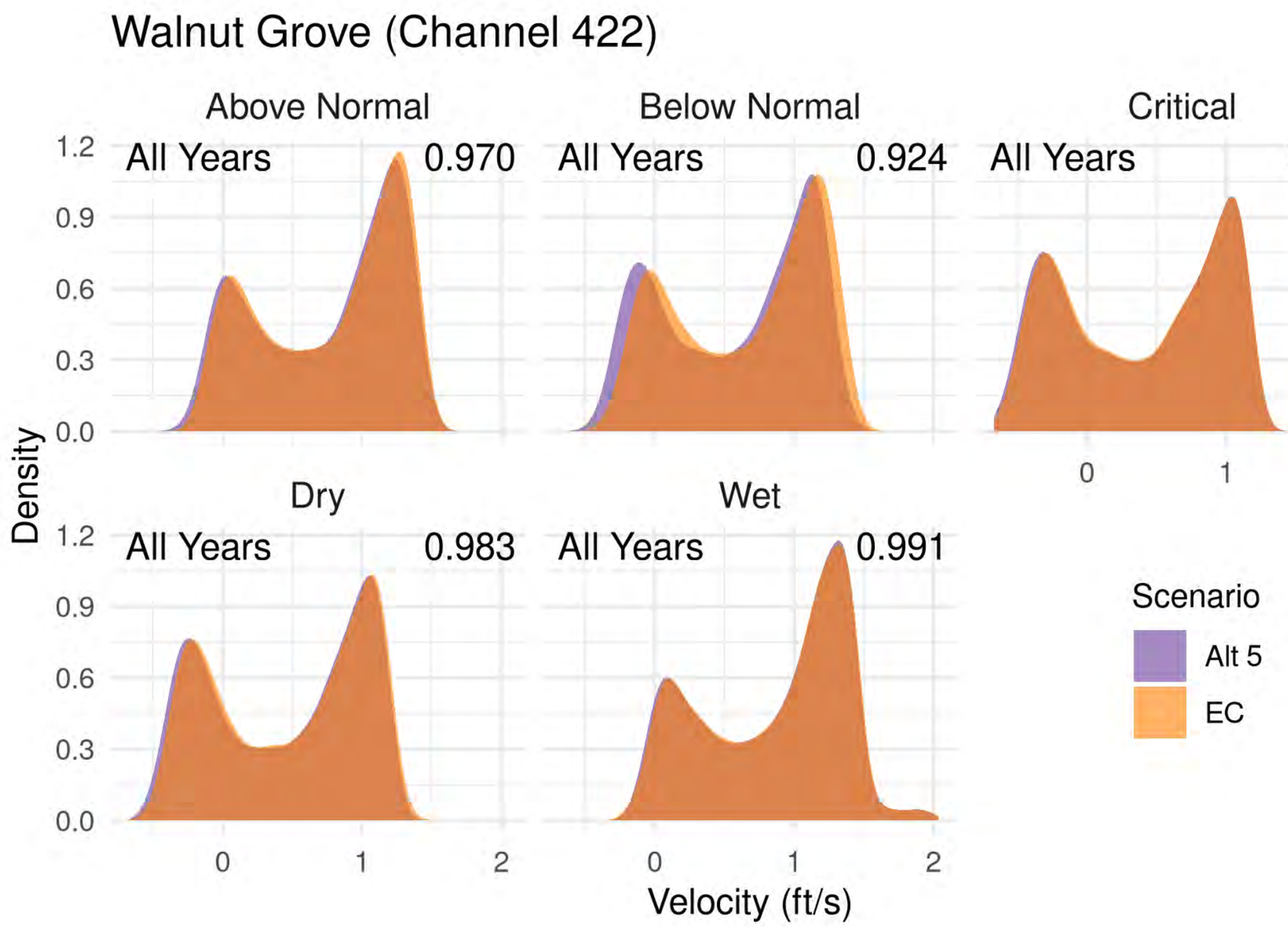

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-247. Velocity Density Distribution for Freeport, September.**



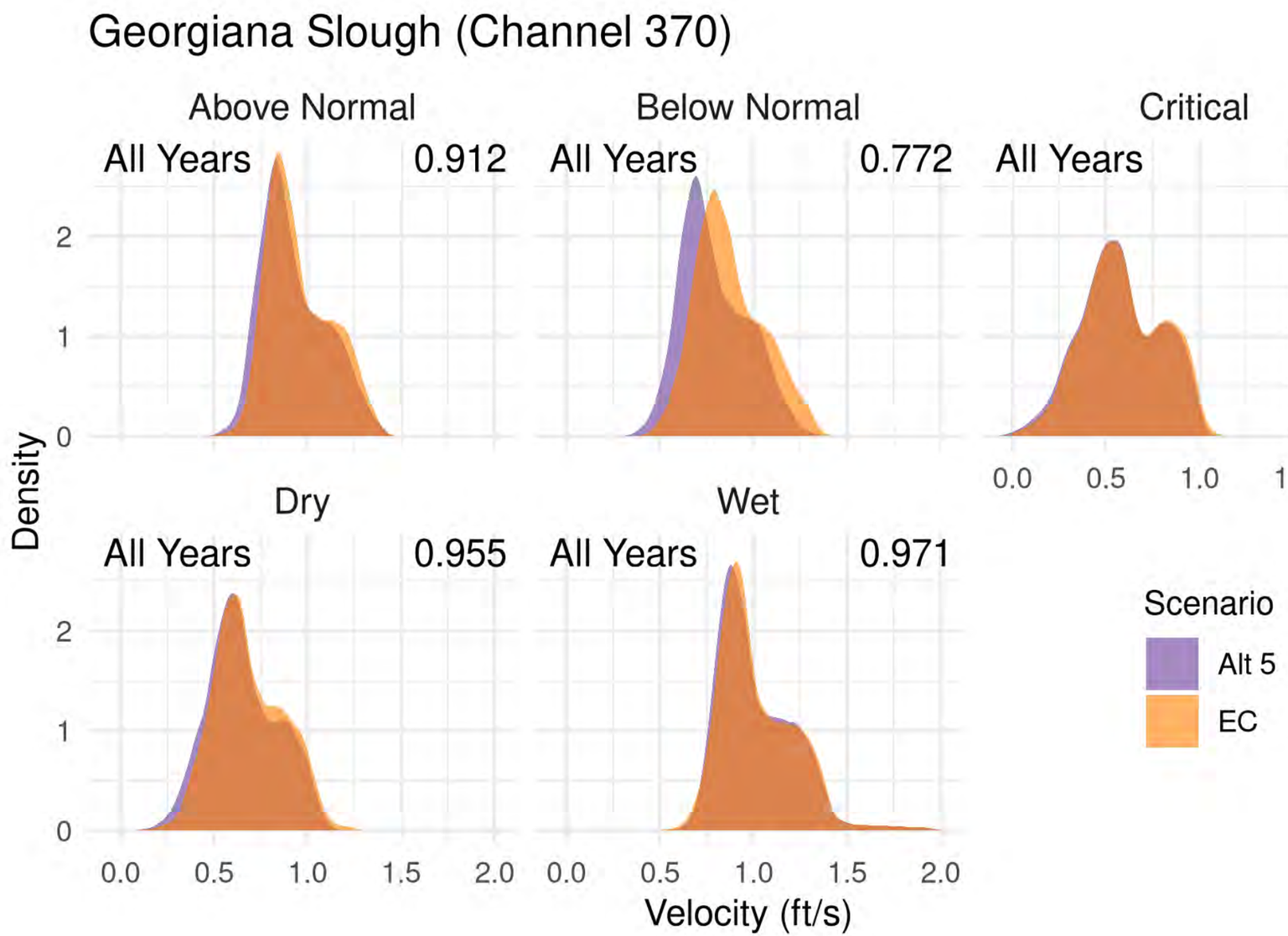

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-248. Velocity Density Distribution for Steamboat Slough, September.**



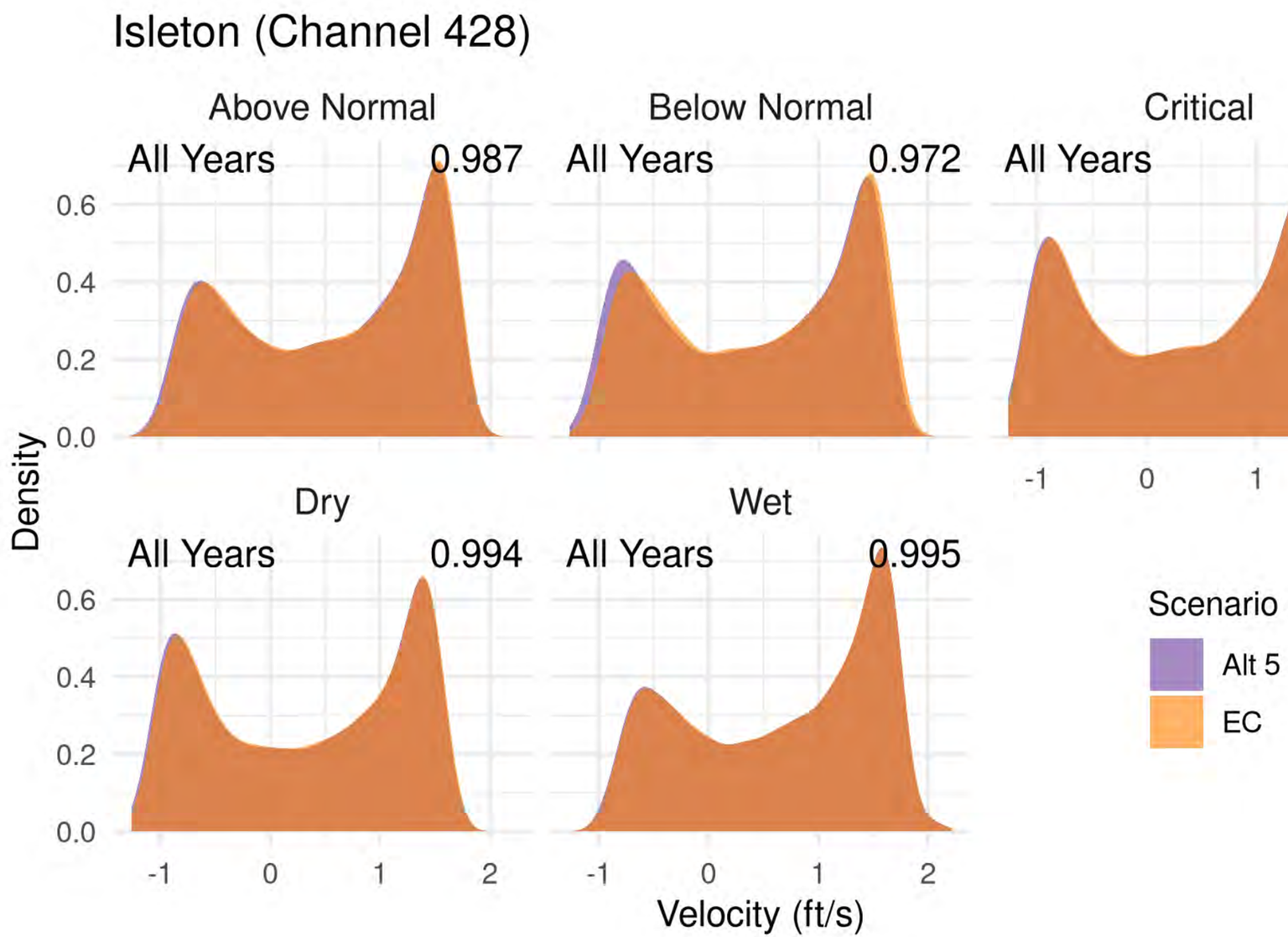

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-249. Velocity Density Distribution for Walnut Grove (Sacramento River), September.**



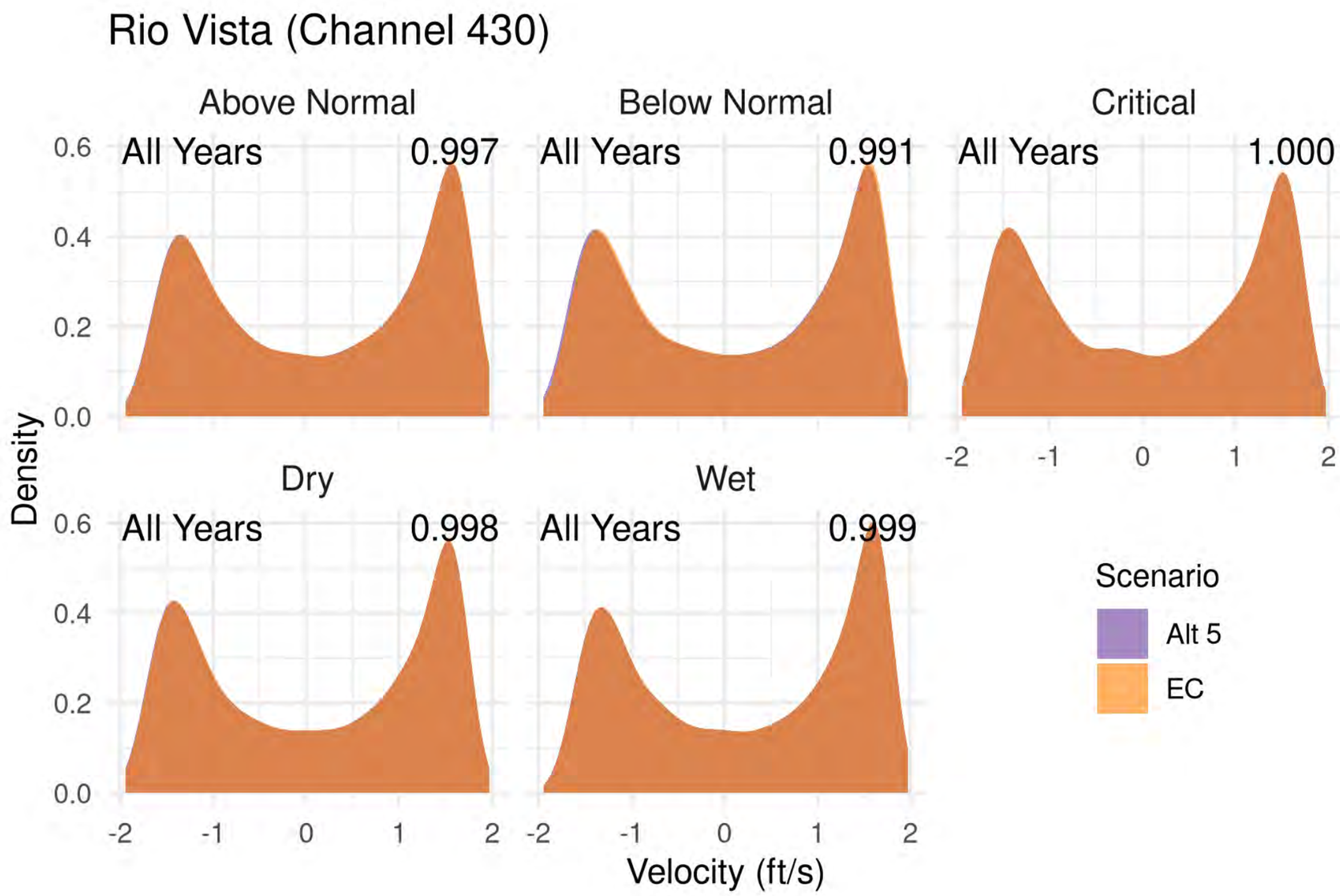

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-250. Velocity Density Distribution for Georgiana Slough, September.**



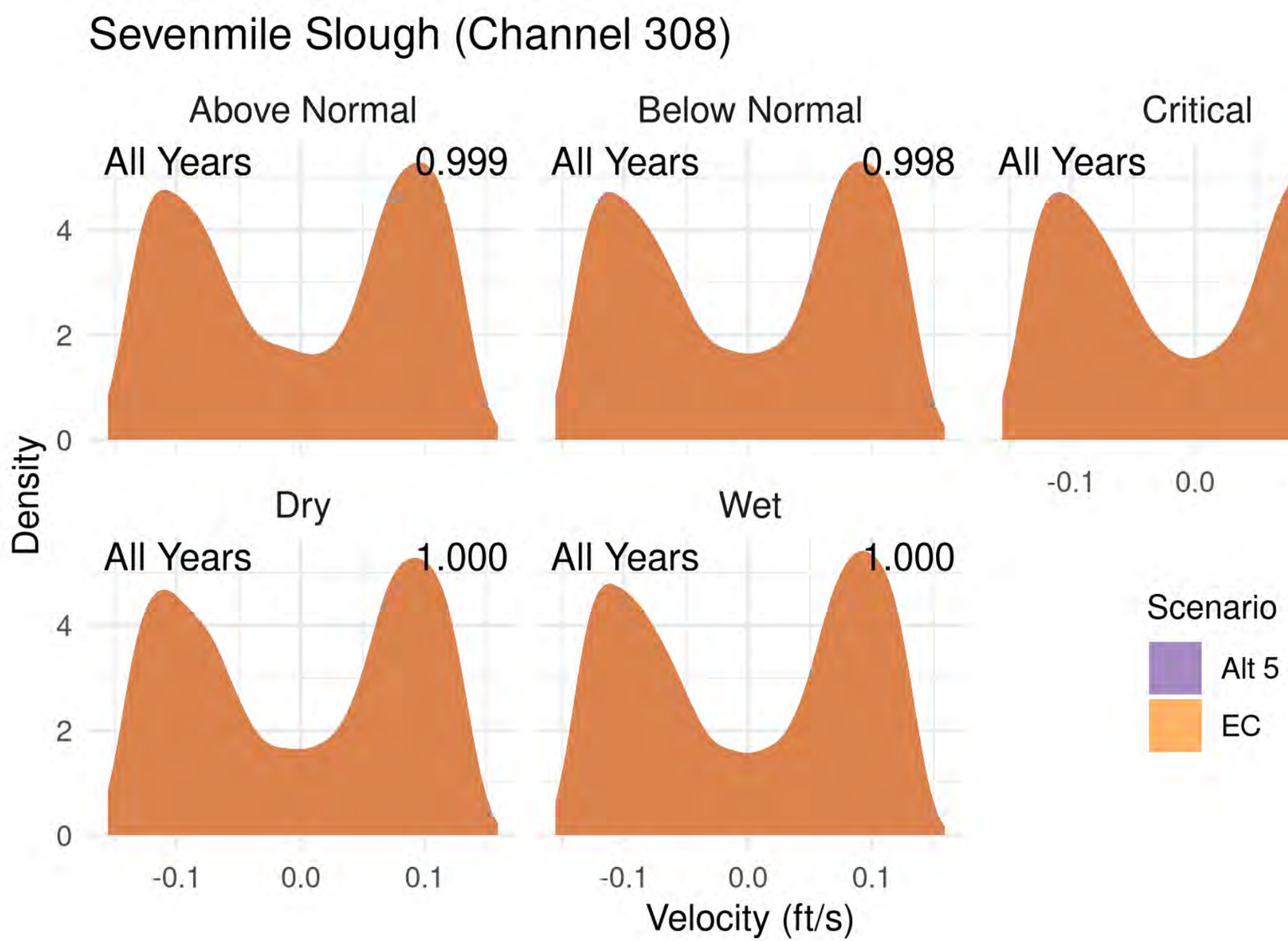

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-251. Velocity Density Distribution for Isleton (Sacramento River), September.**



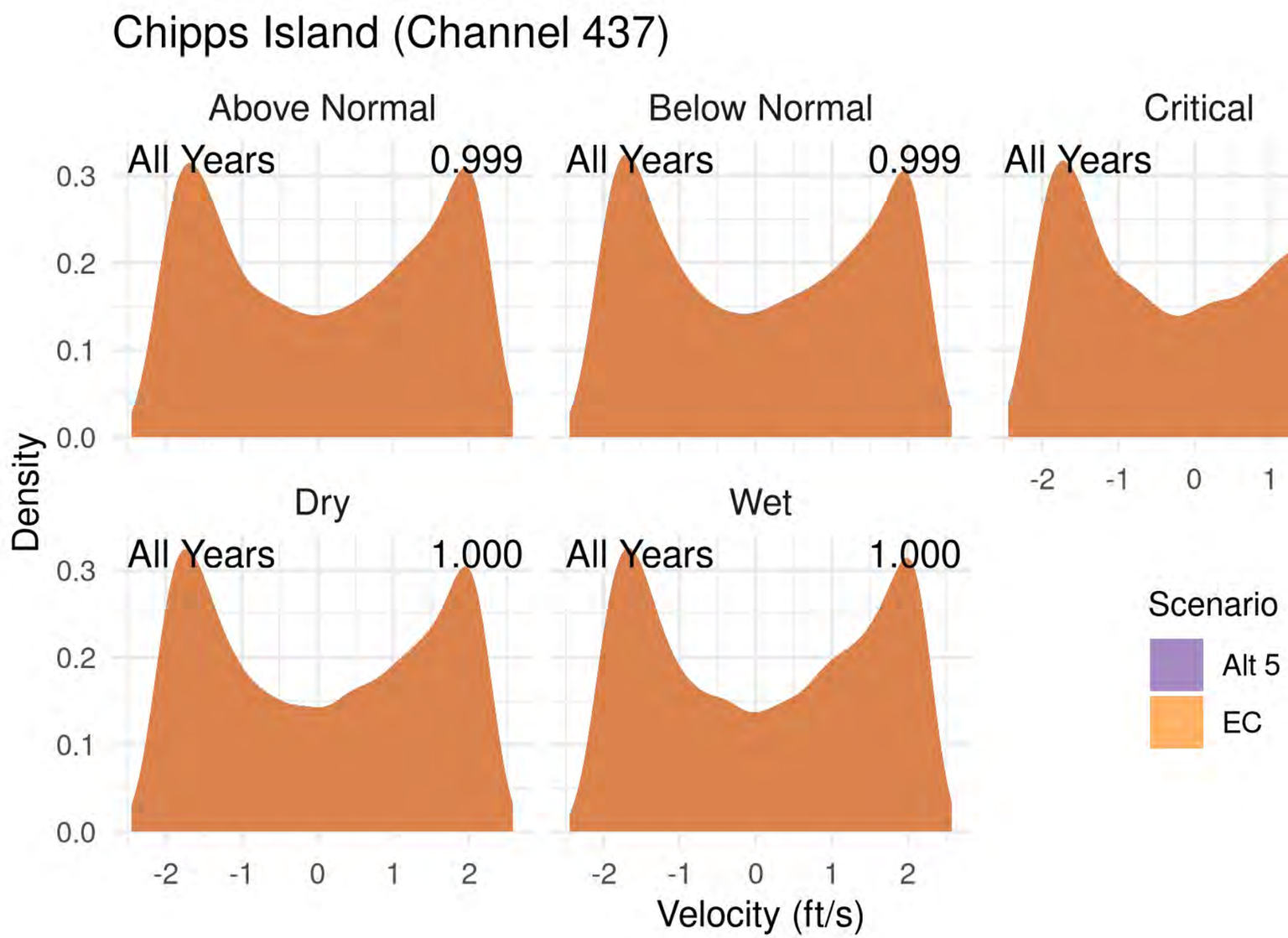

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-252. Velocity Density Distribution for Rio Vista (Sacramento River), September.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

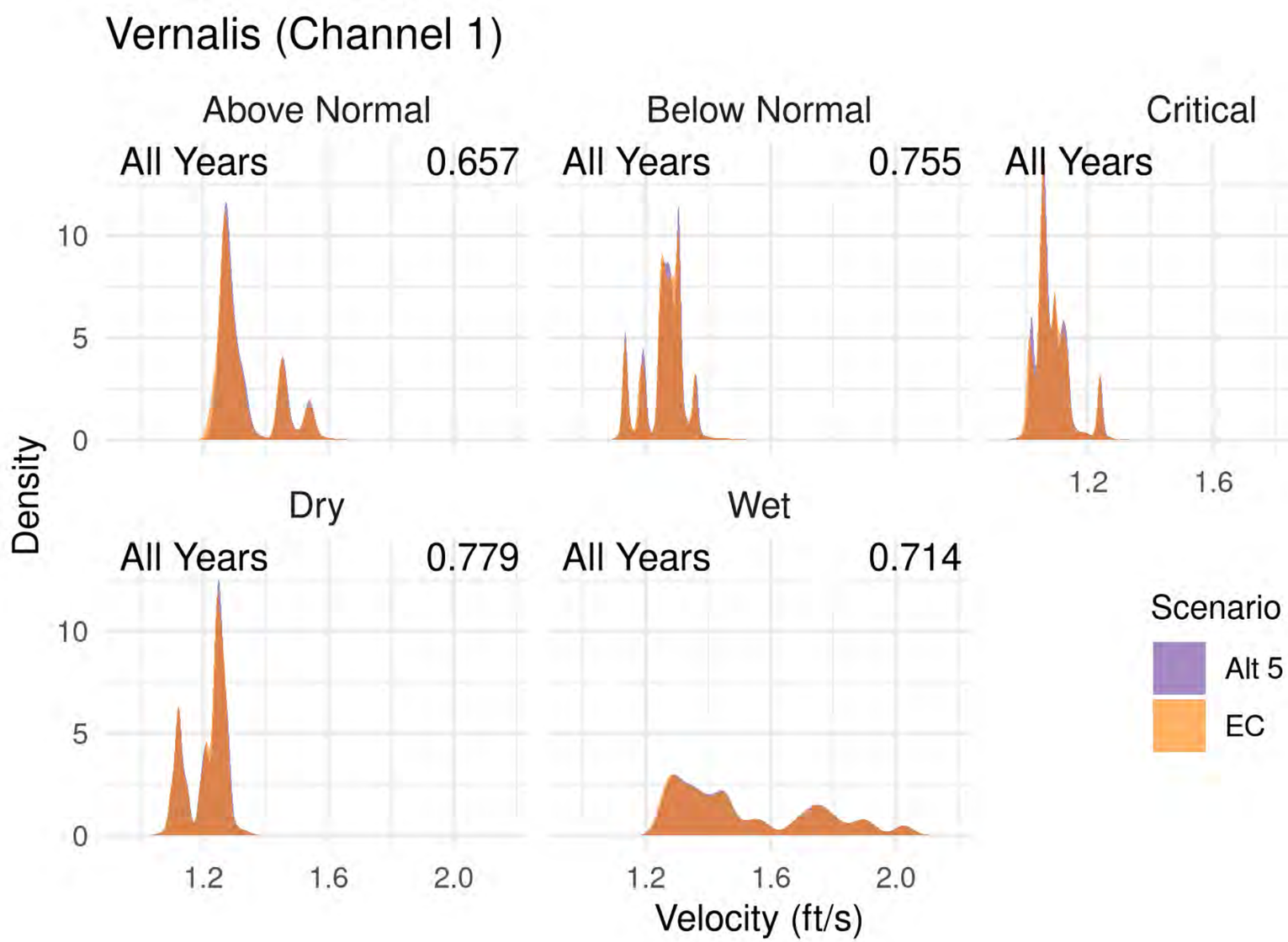
**Figure 5D.1-253. Velocity Density Distribution for Sevenmile Slough, September.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

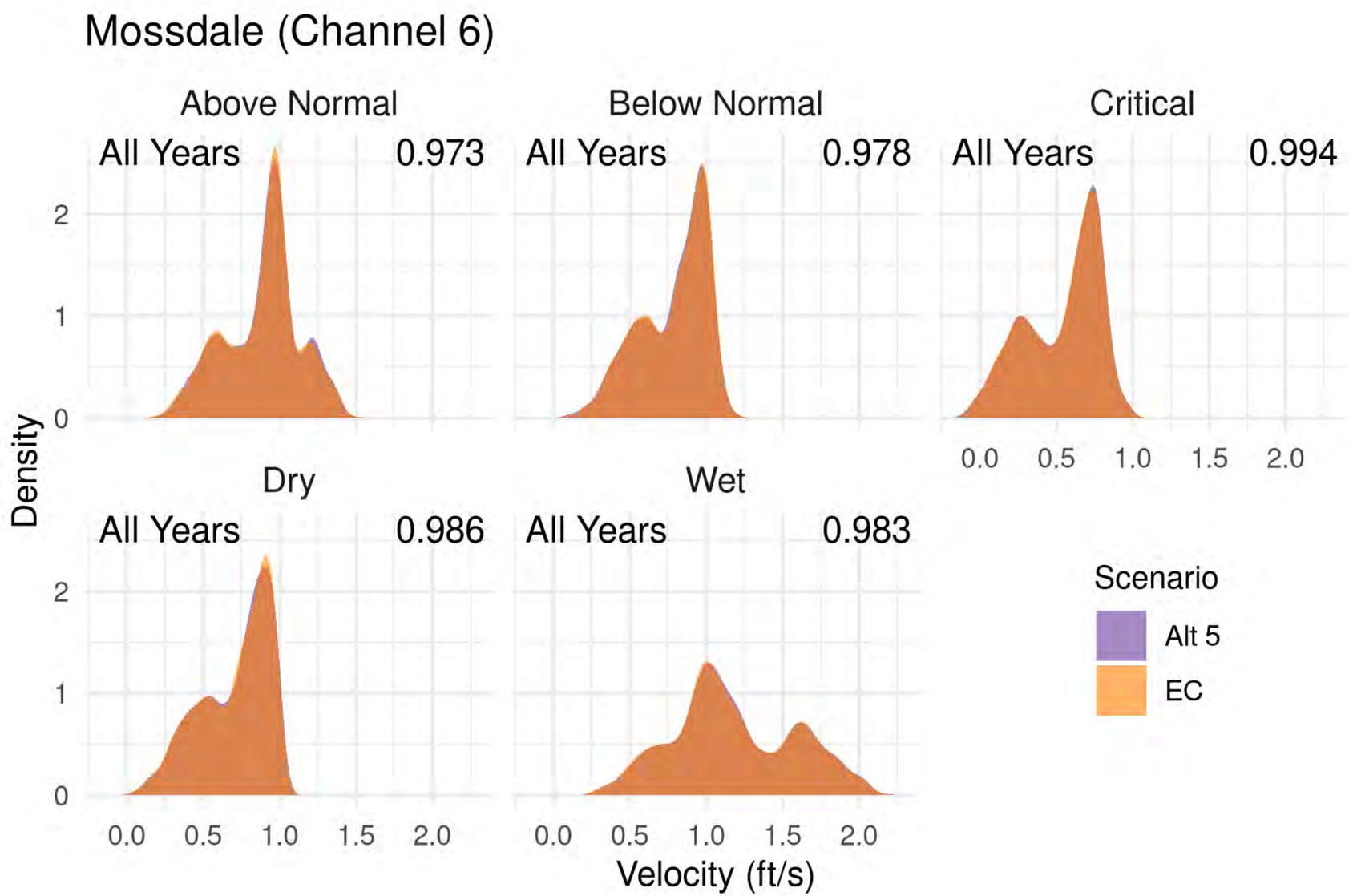
**Figure 5D.1-254. Velocity Density Distribution for Chipps Island (Sacramento River–San Joaquin River Confluence), September.**

***San Joaquin River Delta***



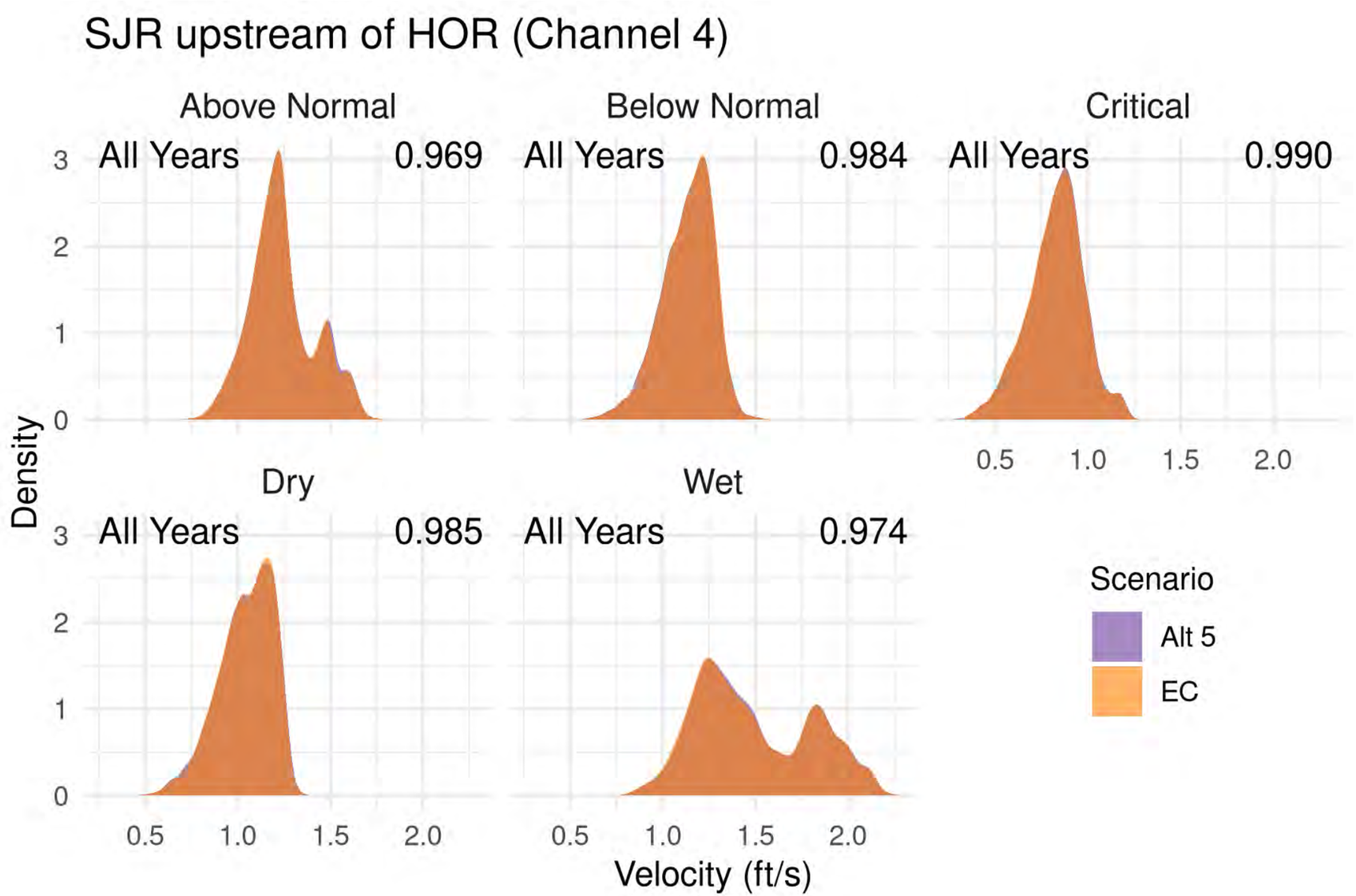

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-255. Velocity Density Distribution for Vernalis (San Joaquin River), September.**



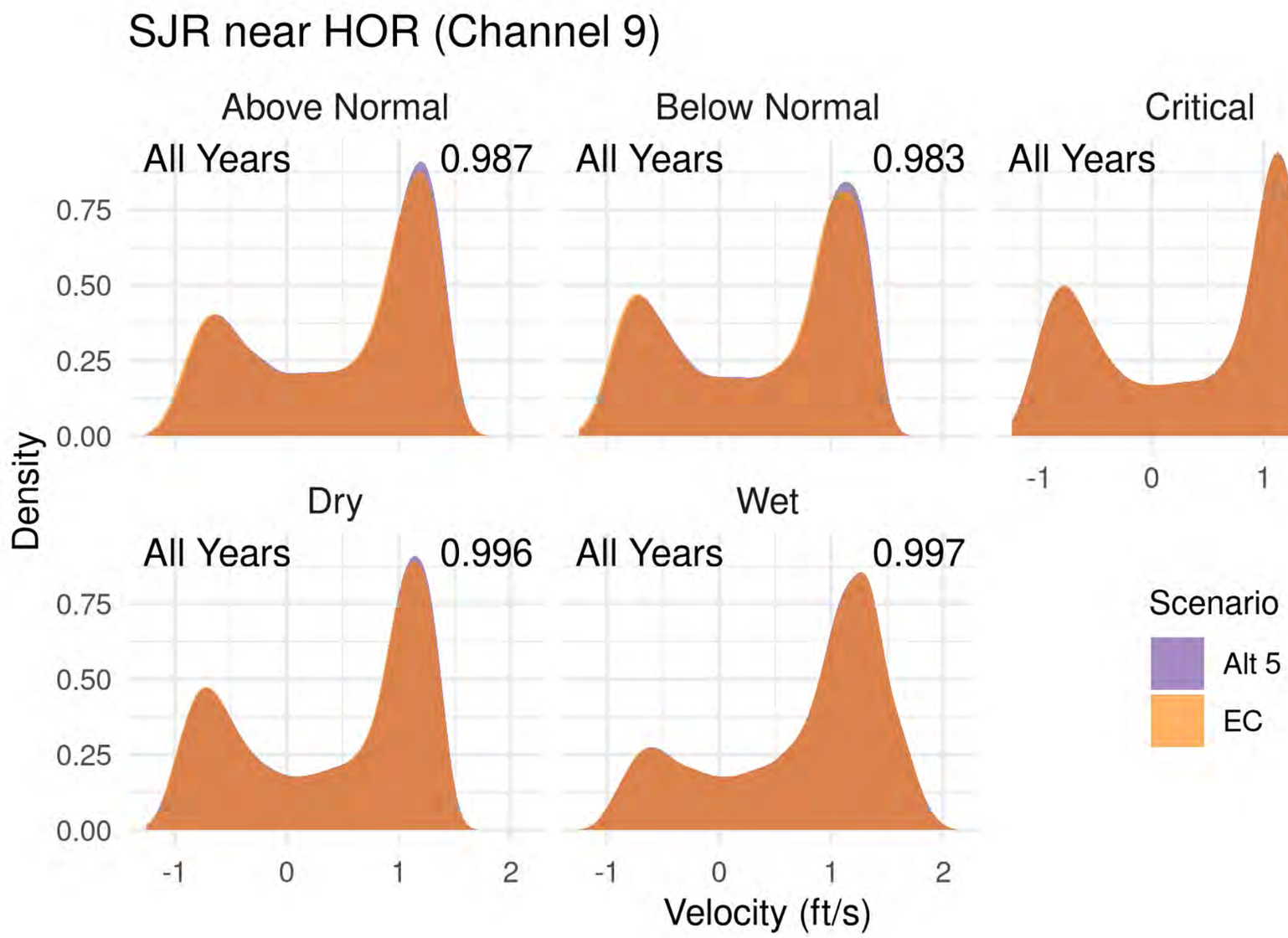

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-256. Velocity Density Distribution for Mossdale (San Joaquin River), September.**



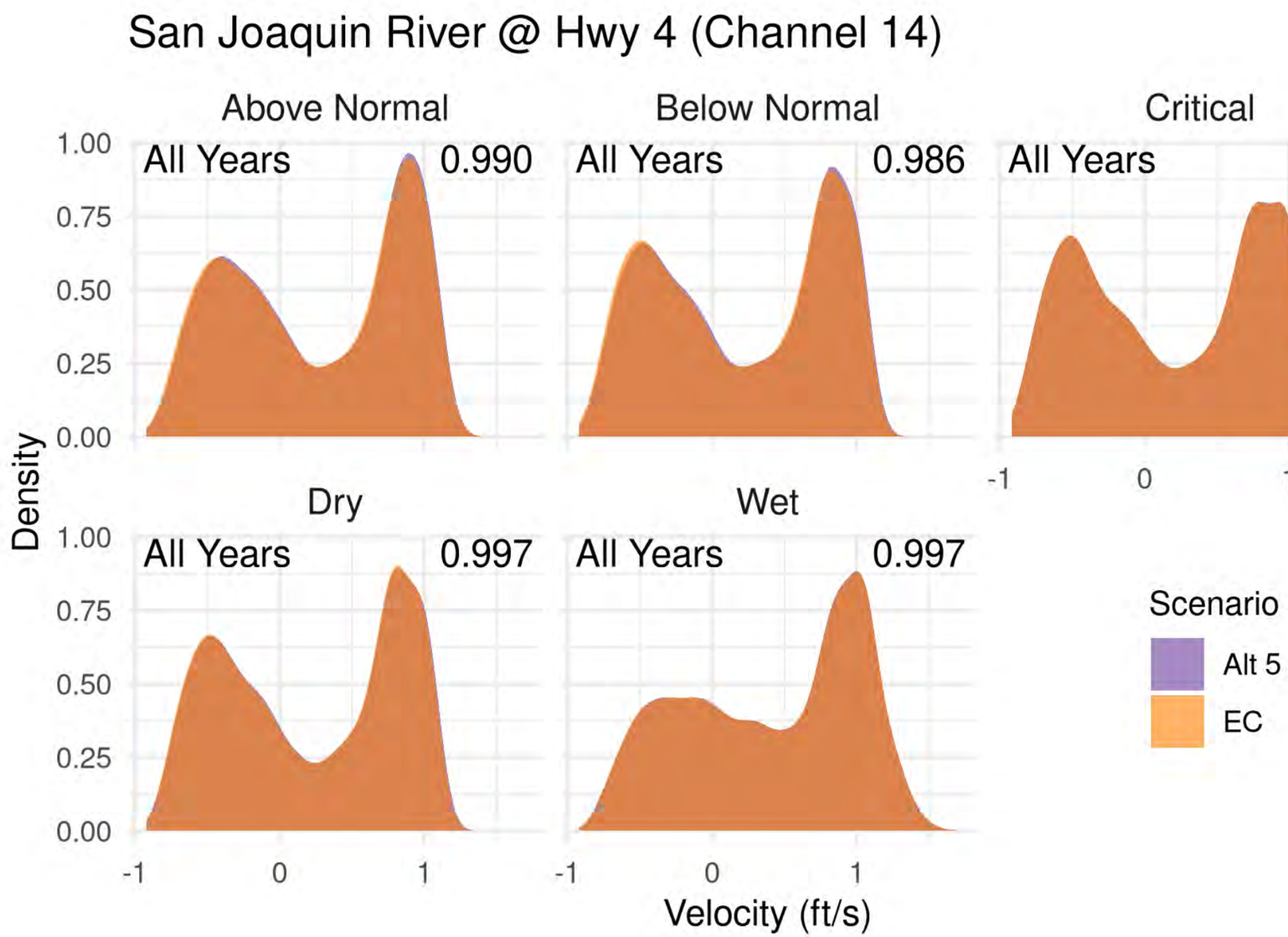

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-257. Velocity Density Distribution for San Joaquin River upstream of Head of Old River, September.**



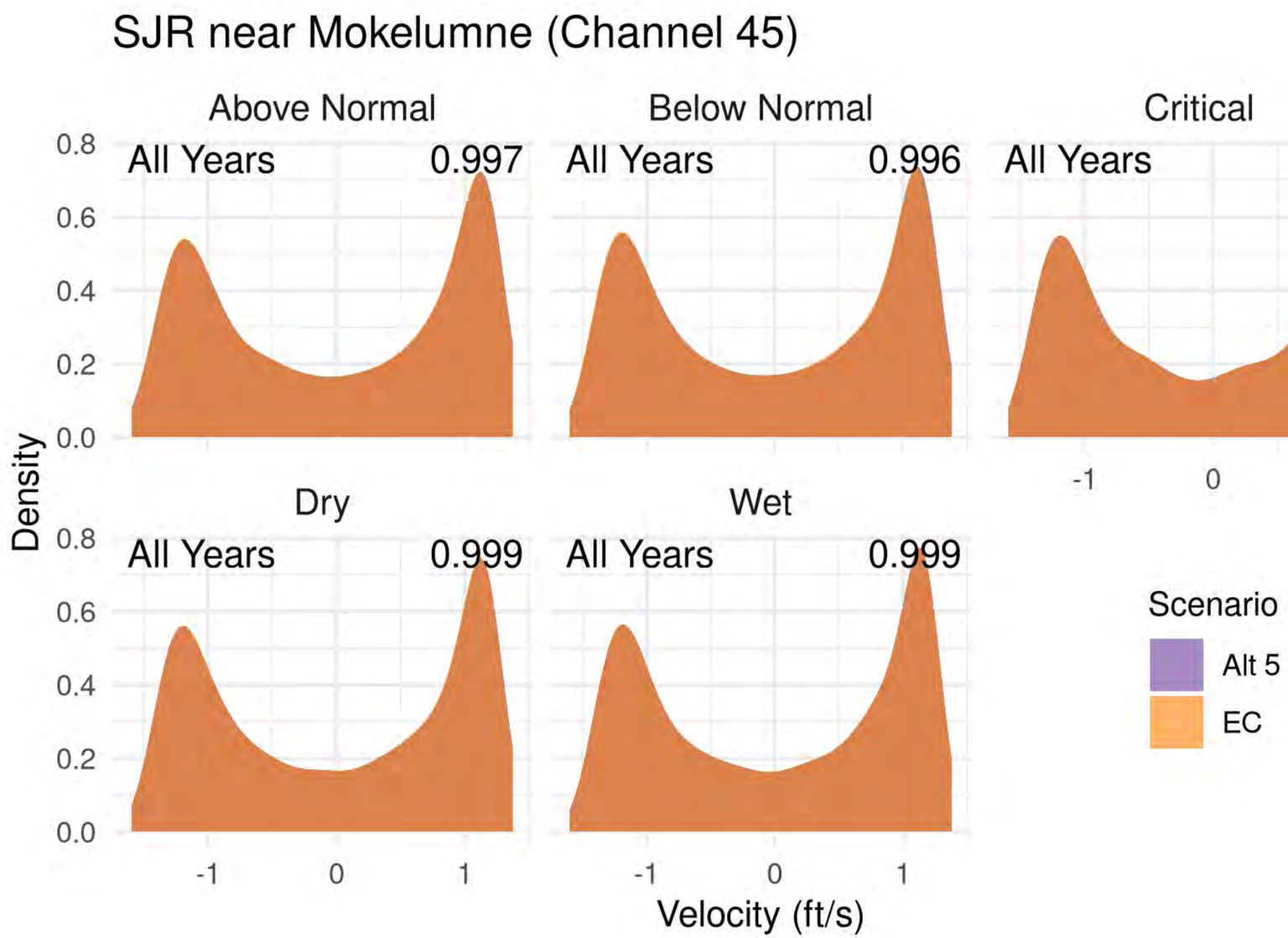

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-258. Velocity Density Distribution for San Joaquin River near Head of Old River, September.**



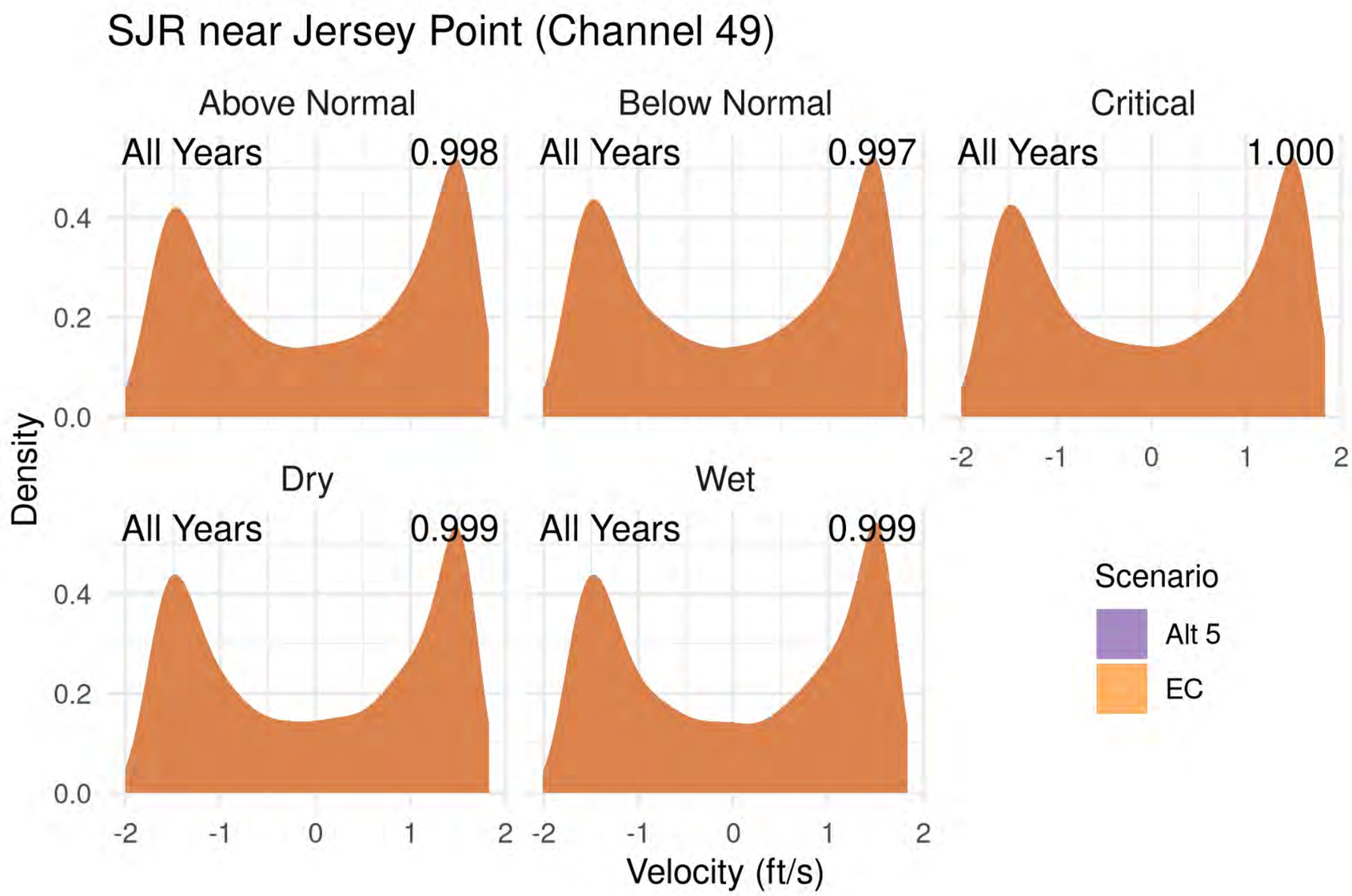

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-259. Velocity Density Distribution for San Joaquin River at Highway 4, September.**



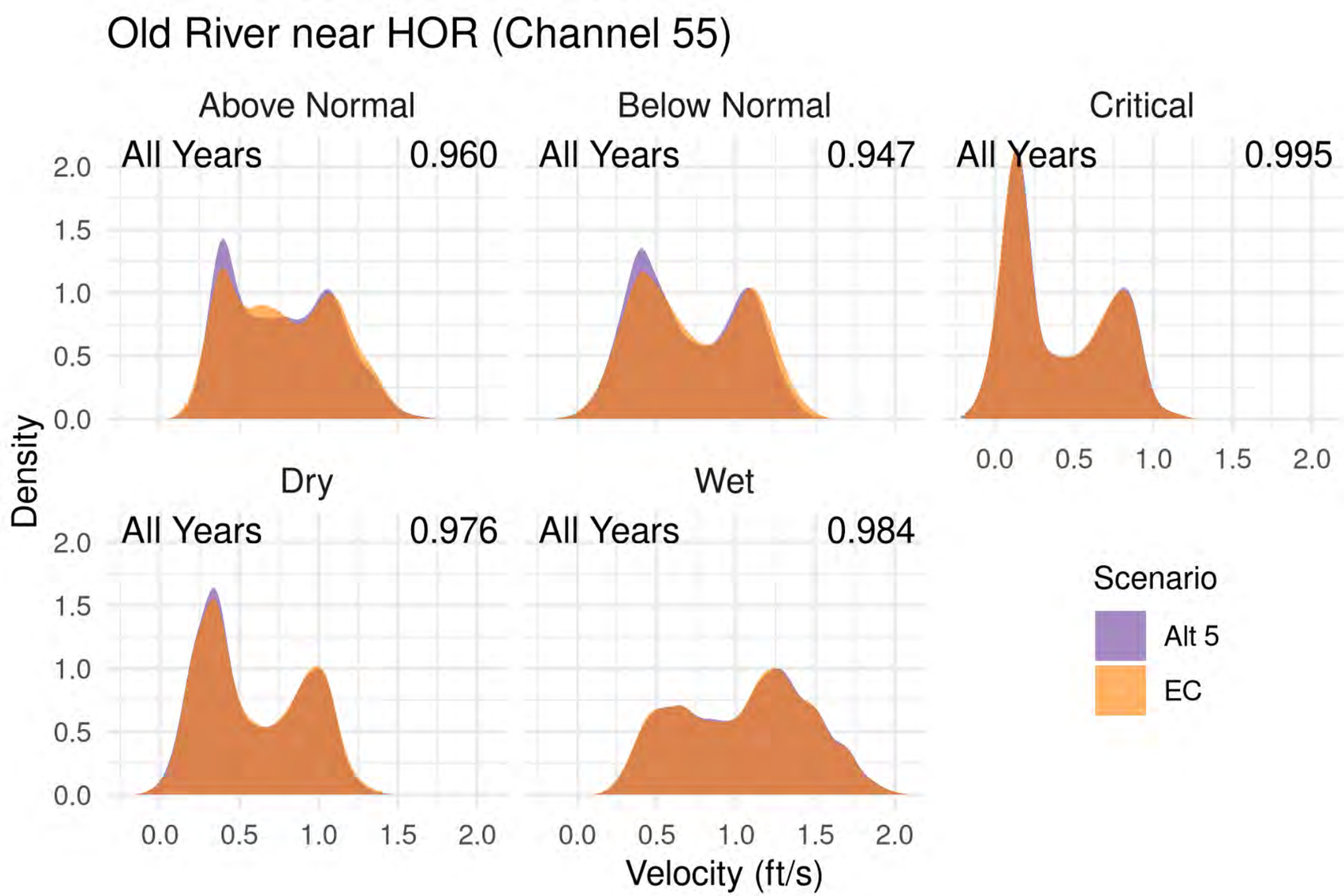

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-260. Velocity Density Distribution for San Joaquin River near Mokelumne River, September.**



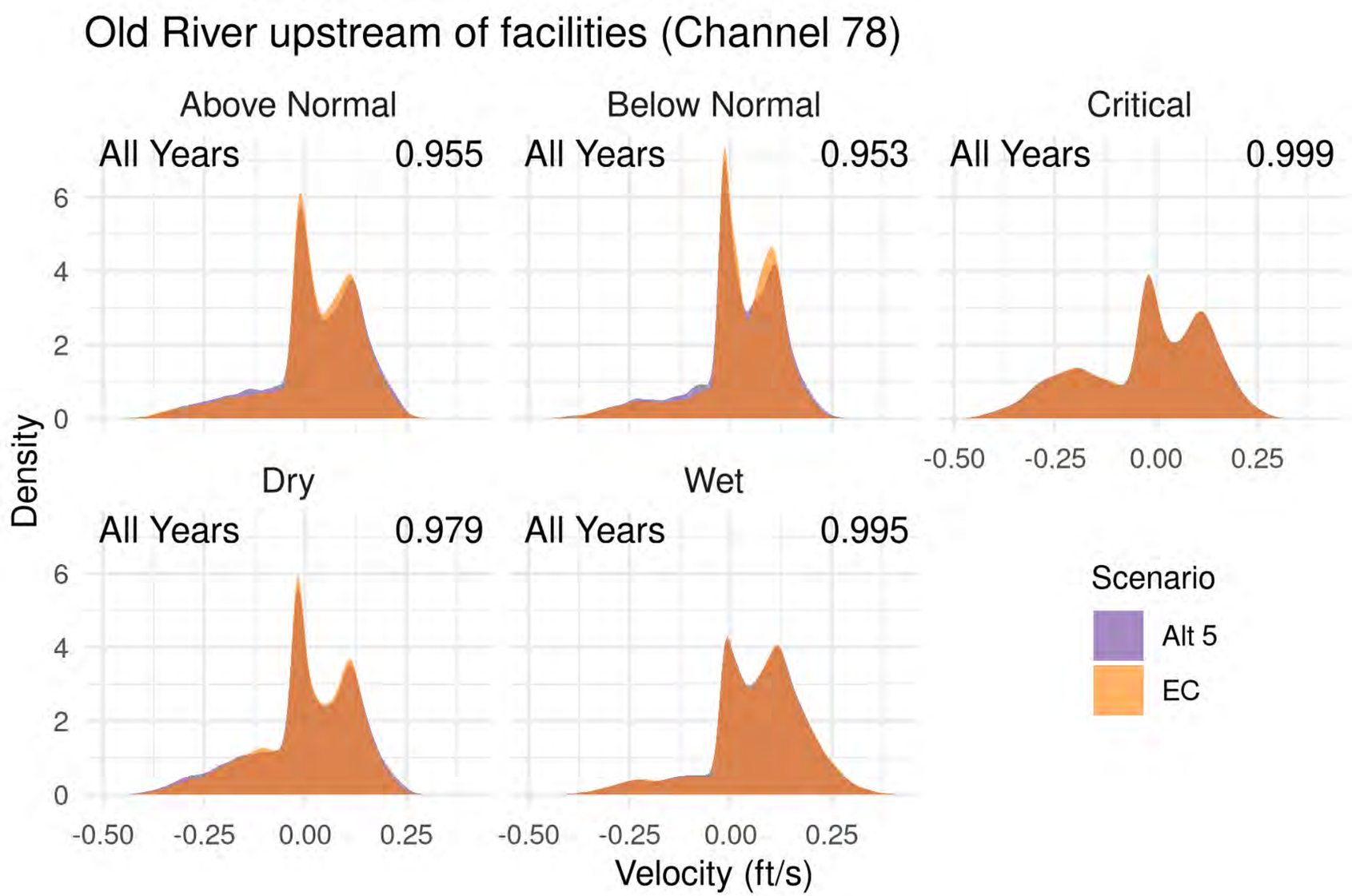

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-261. Velocity Density Distribution for San Joaquin River near Jersey Point, September.**



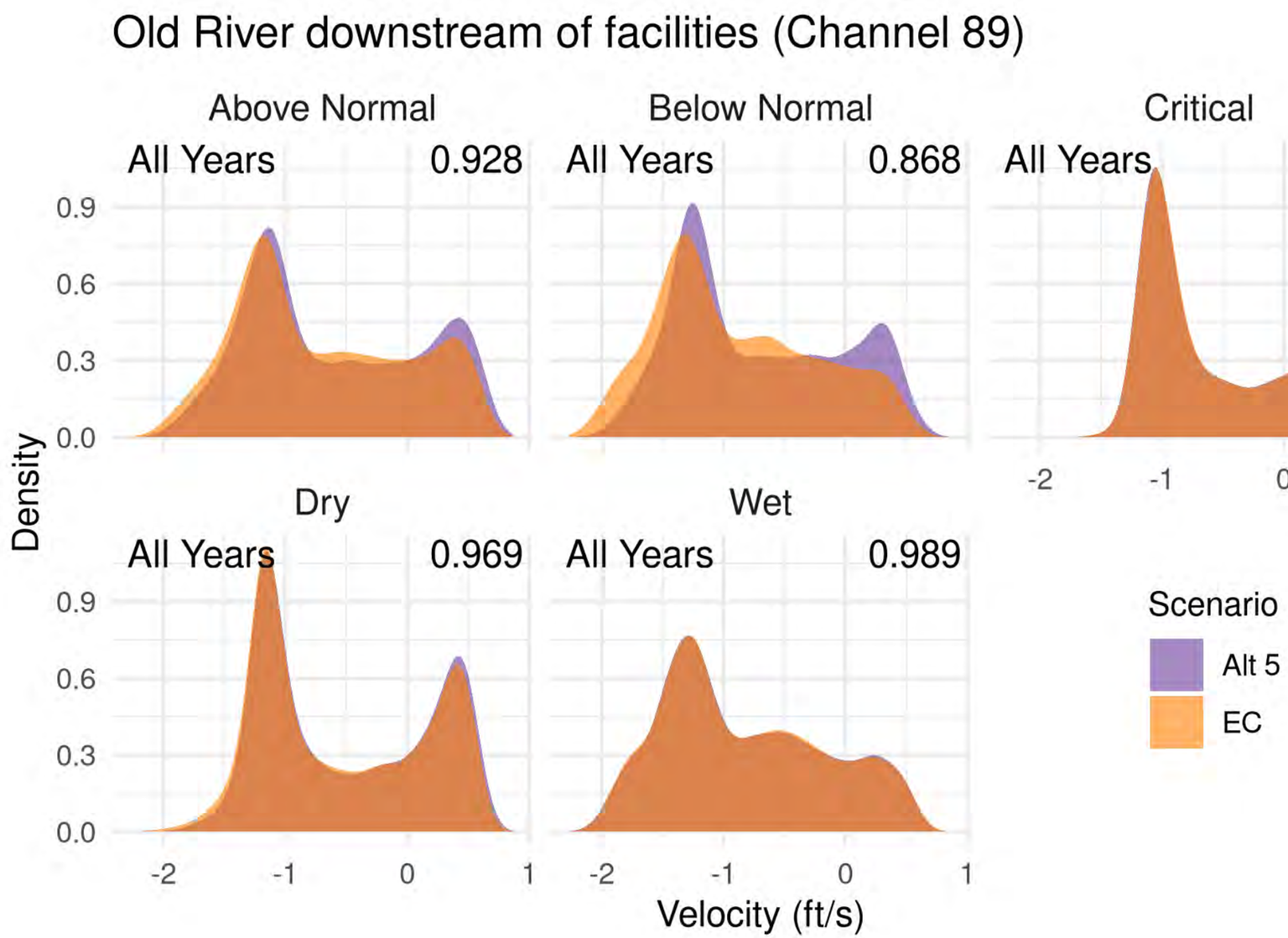

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-262. Velocity Density Distribution for Old River near Head of Old River, September.**



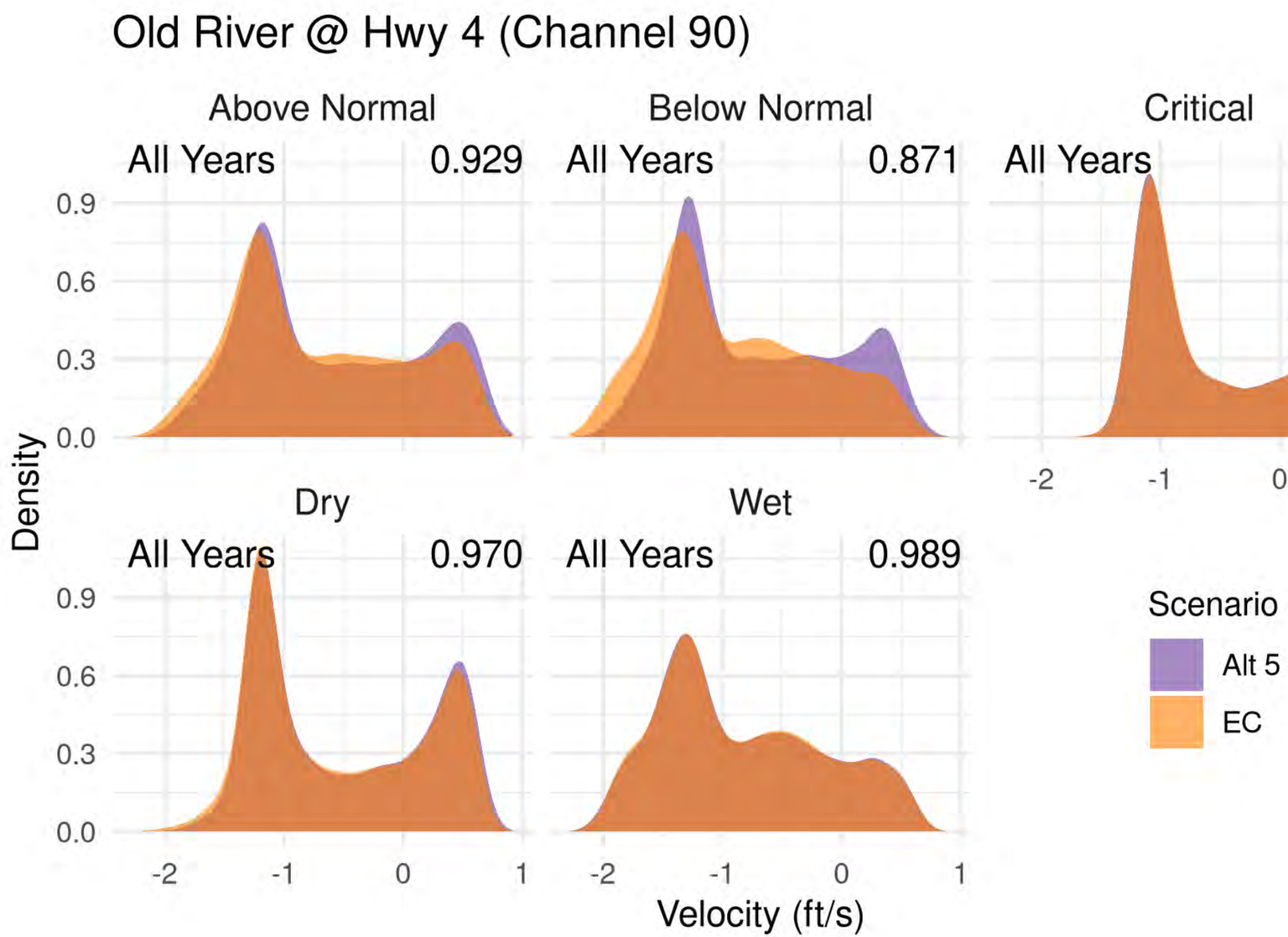

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-263. Velocity Density Distribution for Old River upstream of the South Delta Export Facilities, September.**



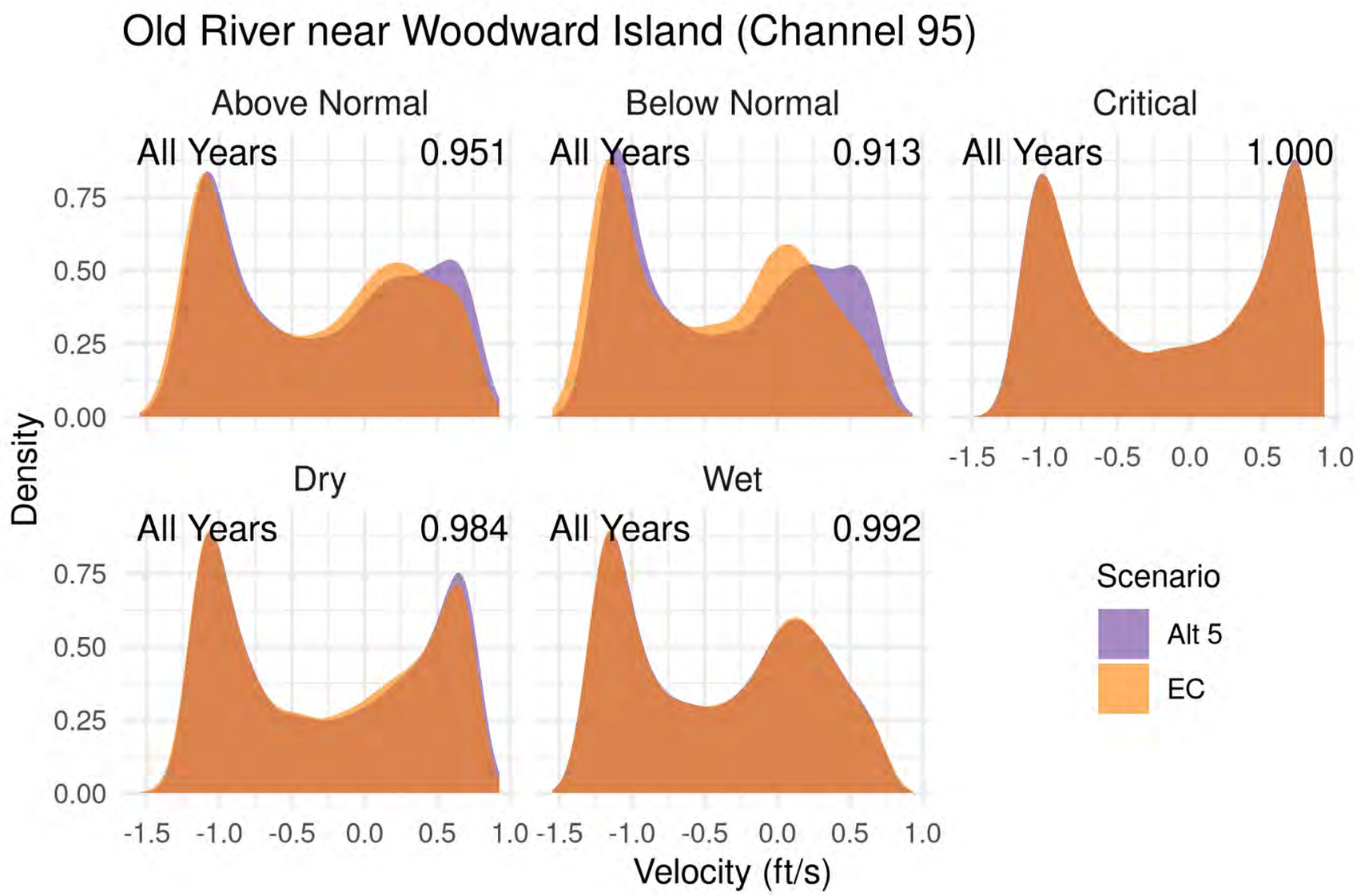

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-264. Velocity Density Distribution for Old River Downstream of the South Delta Export Facilities, September.**



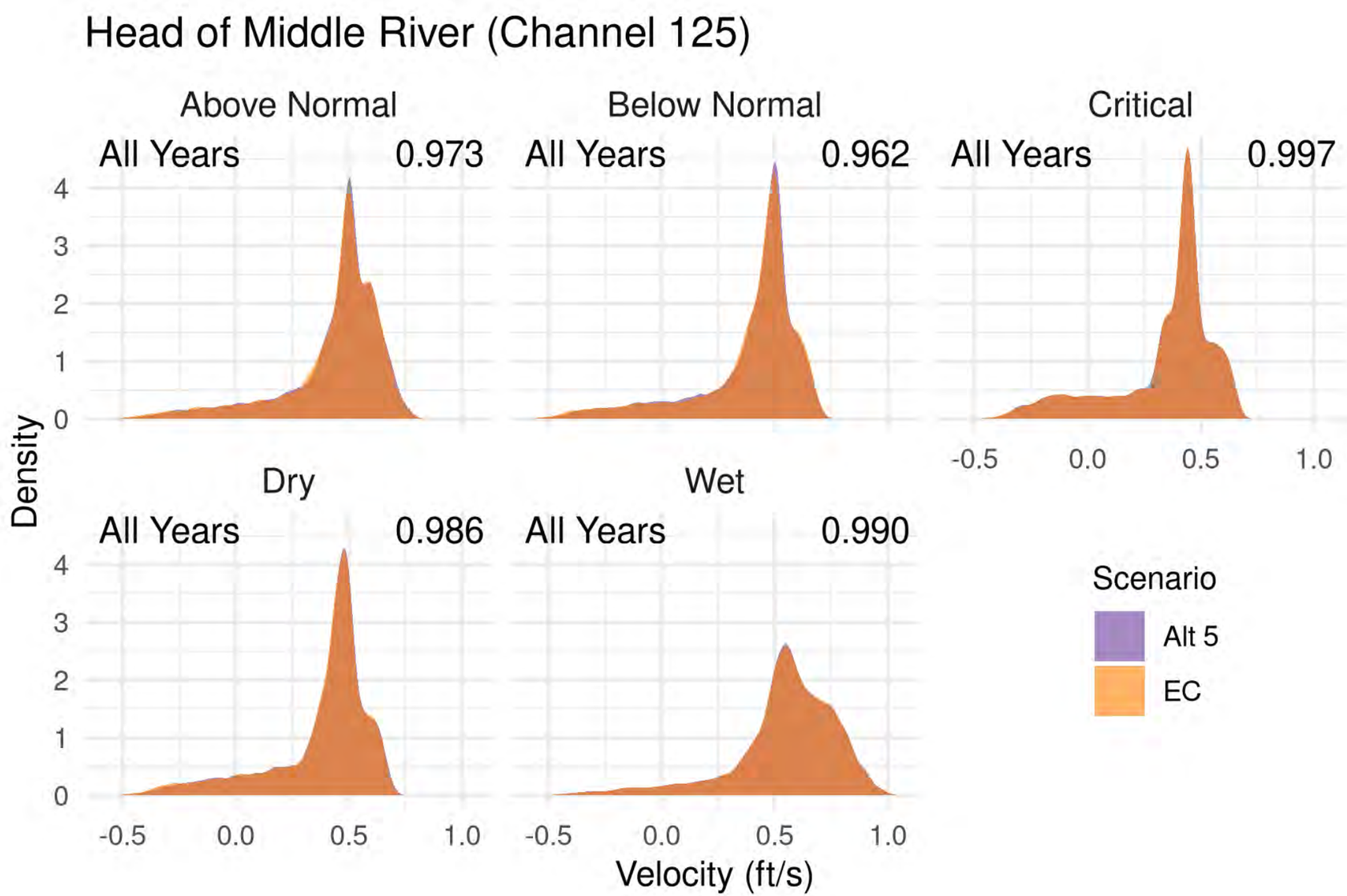

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-265. Velocity Density Distribution for Old River at Highway 4, September.**



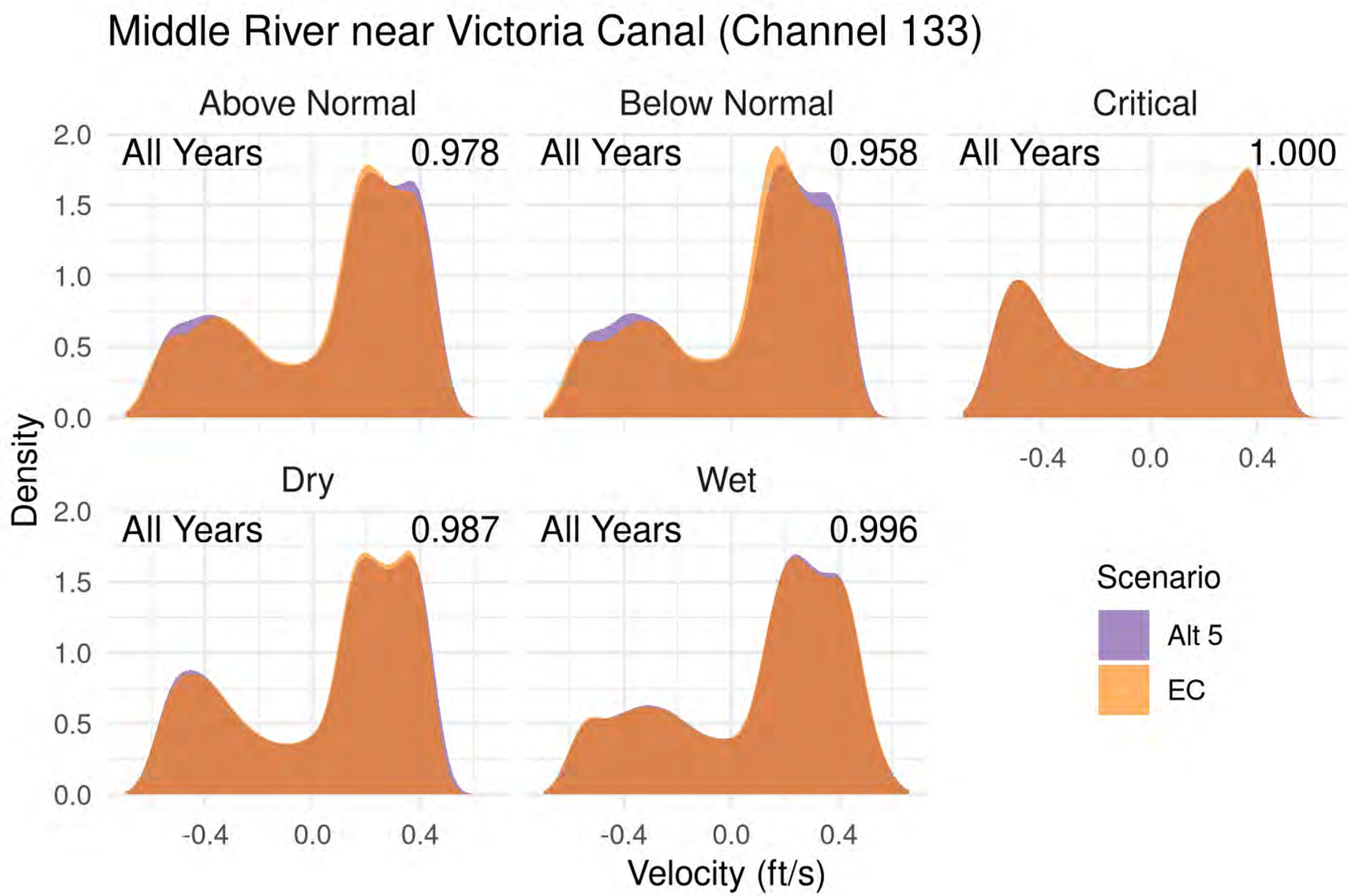

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-266. Velocity Density Distribution for Old River near Woodward Island, September.**



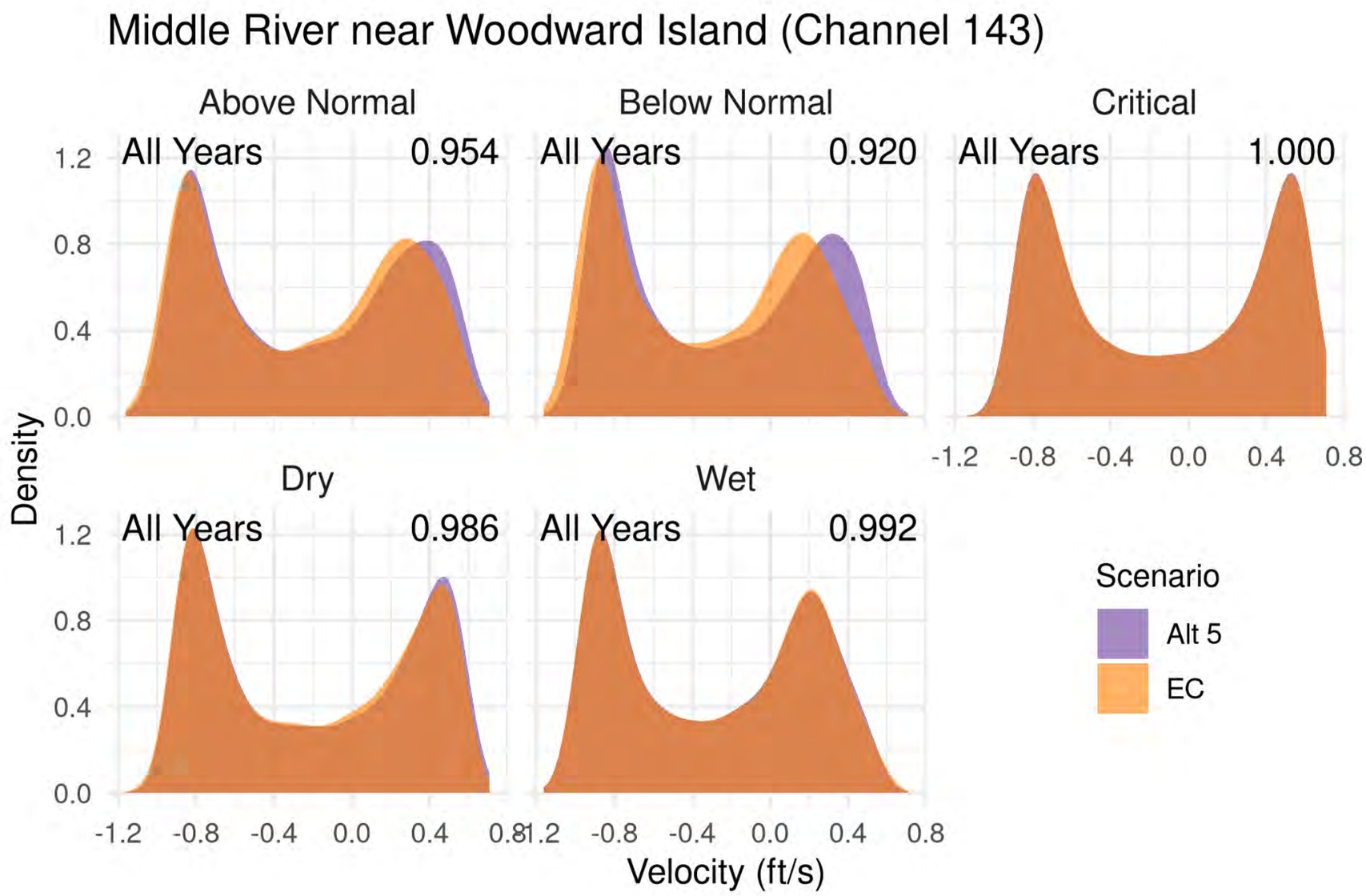

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-267. Velocity Density Distribution for Head of Middle River, September.**



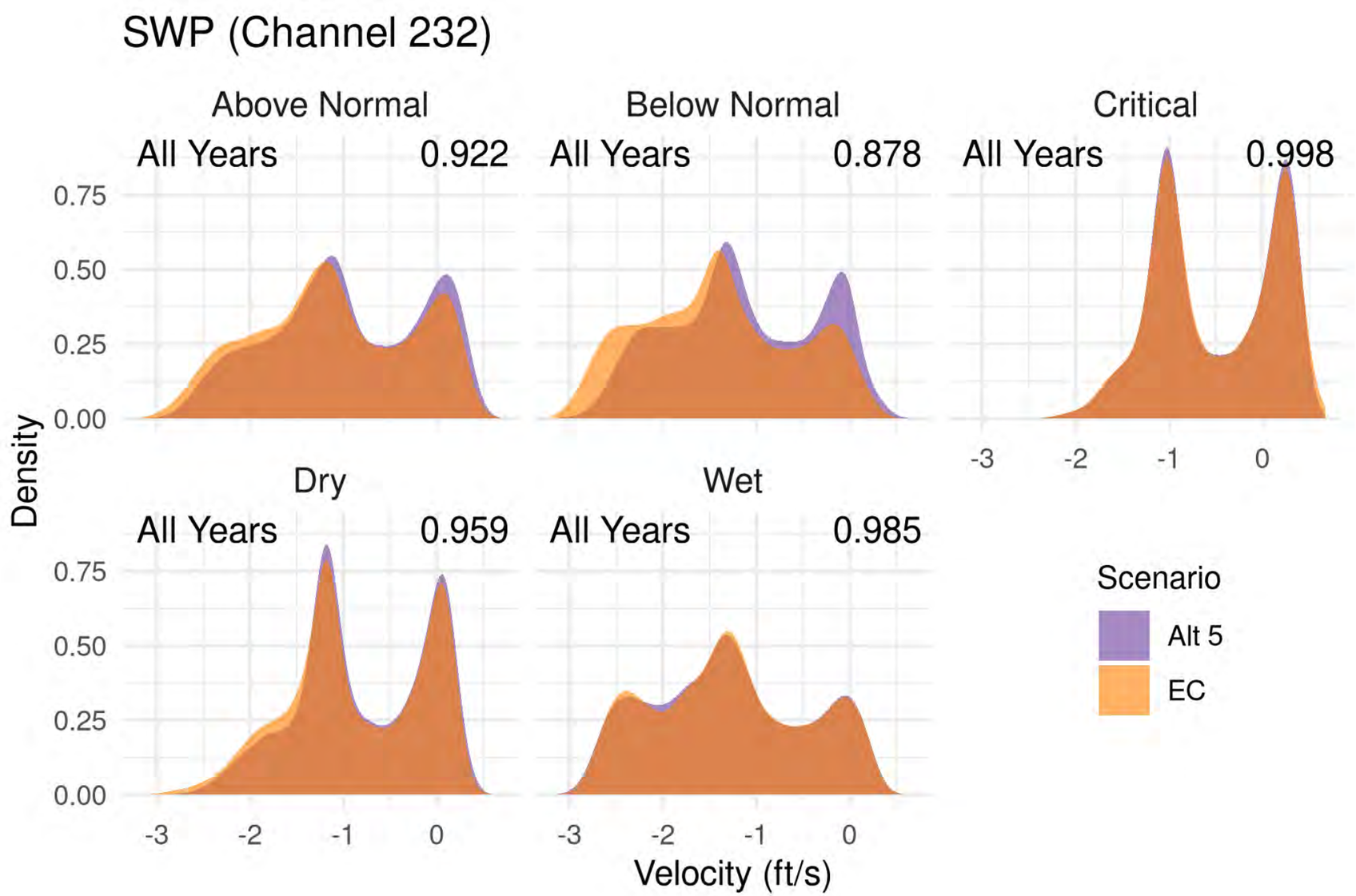

Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-268. Velocity Density Distribution for Middle River near Victoria Canal, September.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-269. Velocity Density Distribution for Middle River near Woodward Island, September.**




Note: The number on each plot represents the median overlap of density distribution between existing conditions (EC) and proposed action (Alt 5) for a given water year type.

**Figure 5D.1-270. Velocity Density Distribution for State Water Project (West Canal near Entrance to Clifton Court Forebay), September.**

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## 5D.1.3.2 Flow into Junctions

Table 5D.1-1 provides the mean proportion of flow entering the various junctions described for *Flow Into Junctions* analysis in Appendix 5D: that is, Sutter Slough, Steamboat Slough, the Delta Cross Channel, Georgiana Slough, the head of Old River, Turner Cut, Columbia Cut, the mouth of Middle River, the mouth of Old River, Fisherman's Cut, False River, and Jersey Point.

**Table 5D.1-1. Mean Daily Proportion of Flow Entering Delta Junctions by Month and Water Year Type.**

| Junction | Month | Water Year Type | Existing Conditions | Proposed Action (Alternative 5) |
|---|---|---|---|---|
| Columbia Cut | Nov | Wet | 0.135 | 0.134 (-1%) |
| Columbia Cut | Nov | Above normal | 0.130 | 0.128 (-1%) |
| Columbia Cut | Nov | Below normal | 0.130 | 0.129 (-1%) |
| Columbia Cut | Nov | Dry | 0.127 | 0.126 (-1%) |
| Columbia Cut | Nov | Critical | 0.120 | 0.120 (-1%) |
| Columbia Cut | Dec | Wet | 0.132 | 0.132 (0%) |
| Columbia Cut | Dec | Above normal | 0.128 | 0.127 (-1%) |
| Columbia Cut | Dec | Below normal | 0.126 | 0.126 (0%) |
| Columbia Cut | Dec | Dry | 0.125 | 0.123 (-1%) |
| Columbia Cut | Dec | Critical | 0.121 | 0.121 (0%) |
| Columbia Cut | Jan | Wet | 0.130 | 0.130 (0%) |
| Columbia Cut | Jan | Above normal | 0.128 | 0.128 (0%) |
| Columbia Cut | Jan | Below normal | 0.123 | 0.123 (0%) |
| Columbia Cut | Jan | Dry | 0.122 | 0.121 (0%) |
| Columbia Cut | Jan | Critical | 0.121 | 0.120 (0%) |
| Columbia Cut | Feb | Wet | 0.136 | 0.135 (-1%) |
| Columbia Cut | Feb | Above normal | 0.131 | 0.131 (0%) |
| Columbia Cut | Feb | Below normal | 0.131 | 0.131 (0%) |
| Columbia Cut | Feb | Dry | 0.123 | 0.122 (0%) |
| Columbia Cut | Feb | Critical | 0.120 | 0.120 (0%) |
| Columbia Cut | Mar | Wet | 0.129 | 0.128 (-1%) |
| Columbia Cut | Mar | Above normal | 0.128 | 0.128 (0%) |
| Columbia Cut | Mar | Below normal | 0.123 | 0.123 (0%) |
| Columbia Cut | Mar | Dry | 0.119 | 0.119 (0%) |
| Columbia Cut | Mar | Critical | 0.117 | 0.117 (0%) |
| Columbia Cut | Apr | Wet | 0.129 | 0.128 (-1%) |
| Columbia Cut | Apr | Above normal | 0.121 | 0.121 (0%) |
| Columbia Cut | Apr | Below normal | 0.119 | 0.119 (0%) |
| Columbia Cut | Apr | Dry | 0.115 | 0.115 (0%) |
| Columbia Cut | Apr | Critical | 0.111 | 0.111 (0%) |
| Columbia Cut | May | Wet | 0.129 | 0.130 (0%) |

| Junction | Month | Water Year Type | Existing Conditions | Proposed Action (Alternative 5) |
|---|---|---|---|---|
| Columbia Cut | May | Above normal | 0.123 | 0.123 (0%) |
| Columbia Cut | May | Below normal | 0.119 | 0.120 (1%) |
| Columbia Cut | May | Dry | 0.117 | 0.117 (0%) |
| Columbia Cut | May | Critical | 0.111 | 0.111 (0%) |
| Columbia Cut | Jun | Wet | 0.132 | 0.132 (0%) |
| Columbia Cut | Jun | Above normal | 0.128 | 0.129 (0%) |
| Columbia Cut | Jun | Below normal | 0.127 | 0.127 (0%) |
| Columbia Cut | Jun | Dry | 0.124 | 0.124 (0%) |
| Columbia Cut | Jun | Critical | 0.113 | 0.114 (1%) |
| Delta Cross Channel | Nov | Wet | 0.195 | 0.170 (-13%) |
| Delta Cross Channel | Nov | Above normal | 0.140 | 0.100 (-28%) |
| Delta Cross Channel | Nov | Below normal | 0.262 | 0.238 (-9%) |
| Delta Cross Channel | Nov | Dry | 0.229 | 0.183 (-20%) |
| Delta Cross Channel | Nov | Critical | 0.200 | 0.162 (-19%) |
| Delta Cross Channel | Dec | Wet | 0.024 | 0.024 (0%) |
| Delta Cross Channel | Dec | Above normal | 0.100 | 0.101 (2%) |
| Delta Cross Channel | Dec | Below normal | 0.133 | 0.135 (1%) |
| Delta Cross Channel | Dec | Dry | 0.129 | 0.127 (-2%) |
| Delta Cross Channel | Dec | Critical | 0.171 | 0.168 (-2%) |
| Delta Cross Channel | Jan | Wet | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Jan | Above normal | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Jan | Below normal | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Jan | Dry | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Jan | Critical | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Feb | Wet | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Feb | Above normal | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Feb | Below normal | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Feb | Dry | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Feb | Critical | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Mar | Wet | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Mar | Above normal | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Mar | Below normal | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Mar | Dry | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Mar | Critical | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Apr | Wet | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Apr | Above normal | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Apr | Below normal | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Apr | Dry | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Apr | Critical | 0.000 | 0.000 (0%) |
| Delta Cross Channel | May | Wet | 0.000 | 0.000 (0%) |

| Junction | Month | Water Year Type | Existing Conditions | Proposed Action (Alternative 5) |
|---|---|---|---|---|
| Delta Cross Channel | May | Above normal | 0.000 | 0.000 (0%) |
| Delta Cross Channel | May | Below normal | 0.000 | 0.000 (0%) |
| Delta Cross Channel | May | Dry | 0.000 | 0.000 (0%) |
| Delta Cross Channel | May | Critical | 0.000 | 0.000 (0%) |
| Delta Cross Channel | Jun | Wet | 0.198 | 0.249 (26%) |
| Delta Cross Channel | Jun | Above normal | 0.309 | 0.337 (9%) |
| Delta Cross Channel | Jun | Below normal | 0.373 | 0.374 (0%) |
| Delta Cross Channel | Jun | Dry | 0.384 | 0.384 (0%) |
| Delta Cross Channel | Jun | Critical | 0.358 | 0.359 (0%) |
| Fisherman's Cut | Nov | Wet | 0.014 | 0.014 (-3%) |
| Fisherman's Cut | Nov | Above normal | 0.013 | 0.013 (-1%) |
| Fisherman's Cut | Nov | Below normal | 0.013 | 0.013 (0%) |
| Fisherman's Cut | Nov | Dry | 0.013 | 0.013 (0%) |
| Fisherman's Cut | Nov | Critical | 0.012 | 0.012 (0%) |
| Fisherman's Cut | Dec | Wet | 0.016 | 0.016 (-3%) |
| Fisherman's Cut | Dec | Above normal | 0.014 | 0.014 (-1%) |
| Fisherman's Cut | Dec | Below normal | 0.013 | 0.013 (2%) |
| Fisherman's Cut | Dec | Dry | 0.013 | 0.013 (-1%) |
| Fisherman's Cut | Dec | Critical | 0.013 | 0.013 (-1%) |
| Fisherman's Cut | Jan | Wet | 0.020 | 0.020 (-1%) |
| Fisherman's Cut | Jan | Above normal | 0.016 | 0.016 (-5%) |
| Fisherman's Cut | Jan | Below normal | 0.015 | 0.014 (-2%) |
| Fisherman's Cut | Jan | Dry | 0.014 | 0.014 (0%) |
| Fisherman's Cut | Jan | Critical | 0.013 | 0.014 (2%) |
| Fisherman's Cut | Feb | Wet | 0.022 | 0.022 (-2%) |
| Fisherman's Cut | Feb | Above normal | 0.018 | 0.017 (-3%) |
| Fisherman's Cut | Feb | Below normal | 0.015 | 0.016 (2%) |
| Fisherman's Cut | Feb | Dry | 0.014 | 0.014 (-1%) |
| Fisherman's Cut | Feb | Critical | 0.013 | 0.013 (-1%) |
| Fisherman's Cut | Mar | Wet | 0.019 | 0.019 (1%) |
| Fisherman's Cut | Mar | Above normal | 0.017 | 0.017 (-2%) |
| Fisherman's Cut | Mar | Below normal | 0.014 | 0.014 (-4%) |
| Fisherman's Cut | Mar | Dry | 0.014 | 0.014 (-3%) |
| Fisherman's Cut | Mar | Critical | 0.013 | 0.013 (0%) |
| Fisherman's Cut | Apr | Wet | 0.016 | 0.016 (-1%) |
| Fisherman's Cut | Apr | Above normal | 0.014 | 0.014 (1%) |
| Fisherman's Cut | Apr | Below normal | 0.014 | 0.014 (2%) |
| Fisherman's Cut | Apr | Dry | 0.013 | 0.013 (-1%) |
| Fisherman's Cut | Apr | Critical | 0.013 | 0.013 (0%) |
| Fisherman's Cut | May | Wet | 0.015 | 0.015 (1%) |

| Junction | Month | Water Year Type | Existing Conditions | Proposed Action (Alternative 5) |
|---|---|---|---|---|
| Fisherman's Cut | May | Above normal | 0.014 | 0.014 (1%) |
| Fisherman's Cut | May | Below normal | 0.013 | 0.013 (-1%) |
| Fisherman's Cut | May | Dry | 0.013 | 0.013 (-1%) |
| Fisherman's Cut | May | Critical | 0.013 | 0.013 (0%) |
| Fisherman's Cut | Jun | Wet | 0.014 | 0.014 (0%) |
| Fisherman's Cut | Jun | Above normal | 0.014 | 0.014 (1%) |
| Fisherman's Cut | Jun | Below normal | 0.013 | 0.013 (0%) |
| Fisherman's Cut | Jun | Dry | 0.013 | 0.013 (-1%) |
| Fisherman's Cut | Jun | Critical | 0.013 | 0.013 (0%) |
| False River | Nov | Wet | 0.185 | 0.185 (0%) |
| False River | Nov | Above normal | 0.184 | 0.184 (0%) |
| False River | Nov | Below normal | 0.185 | 0.185 (0%) |
| False River | Nov | Dry | 0.184 | 0.184 (0%) |
| False River | Nov | Critical | 0.183 | 0.183 (0%) |
| False River | Dec | Wet | 0.183 | 0.183 (0%) |
| False River | Dec | Above normal | 0.185 | 0.184 (0%) |
| False River | Dec | Below normal | 0.185 | 0.185 (0%) |
| False River | Dec | Dry | 0.185 | 0.185 (0%) |
| False River | Dec | Critical | 0.184 | 0.184 (0%) |
| False River | Jan | Wet | 0.178 | 0.179 (0%) |
| False River | Jan | Above normal | 0.182 | 0.182 (0%) |
| False River | Jan | Below normal | 0.184 | 0.184 (0%) |
| False River | Jan | Dry | 0.184 | 0.184 (0%) |
| False River | Jan | Critical | 0.184 | 0.184 (0%) |
| False River | Feb | Wet | 0.178 | 0.178 (0%) |
| False River | Feb | Above normal | 0.181 | 0.181 (0%) |
| False River | Feb | Below normal | 0.183 | 0.183 (0%) |
| False River | Feb | Dry | 0.183 | 0.183 (0%) |
| False River | Feb | Critical | 0.182 | 0.182 (0%) |
| False River | Mar | Wet | 0.177 | 0.176 (0%) |
| False River | Mar | Above normal | 0.180 | 0.180 (0%) |
| False River | Mar | Below normal | 0.182 | 0.182 (0%) |
| False River | Mar | Dry | 0.182 | 0.182 (0%) |
| False River | Mar | Critical | 0.181 | 0.181 (0%) |
| False River | Apr | Wet | 0.177 | 0.177 (0%) |
| False River | Apr | Above normal | 0.179 | 0.179 (0%) |
| False River | Apr | Below normal | 0.180 | 0.180 (0%) |
| False River | Apr | Dry | 0.181 | 0.181 (0%) |
| False River | Apr | Critical | 0.181 | 0.181 (0%) |
| False River | May | Wet | 0.179 | 0.179 (0%) |

| Junction | Month | Water Year Type | Existing Conditions | Proposed Action (Alternative 5) |
|---|---|---|---|---|
| False River | May | Above normal | 0.180 | 0.181 (0%) |
| False River | May | Below normal | 0.182 | 0.182 (0%) |
| False River | May | Dry | 0.182 | 0.182 (0%) |
| False River | May | Critical | 0.182 | 0.182 (0%) |
| False River | Jun | Wet | 0.182 | 0.181 (0%) |
| False River | Jun | Above normal | 0.183 | 0.183 (0%) |
| False River | Jun | Below normal | 0.184 | 0.184 (0%) |
| False River | Jun | Dry | 0.184 | 0.184 (0%) |
| False River | Jun | Critical | 0.182 | 0.182 (0%) |
| Georgiana Slough | Nov | Wet | 0.389 | 0.390 (0%) |
| Georgiana Slough | Nov | Above normal | 0.381 | 0.386 (1%) |
| Georgiana Slough | Nov | Below normal | 0.410 | 0.409 (0%) |
| Georgiana Slough | Nov | Dry | 0.392 | 0.395 (1%) |
| Georgiana Slough | Nov | Critical | 0.389 | 0.390 (0%) |
| Georgiana Slough | Dec | Wet | 0.319 | 0.326 (2%) |
| Georgiana Slough | Dec | Above normal | 0.389 | 0.391 (1%) |
| Georgiana Slough | Dec | Below normal | 0.390 | 0.390 (0%) |
| Georgiana Slough | Dec | Dry | 0.402 | 0.401 (0%) |
| Georgiana Slough | Dec | Critical | 0.410 | 0.410 (0%) |
| Georgiana Slough | Jan | Wet | 0.297 | 0.301 (1%) |
| Georgiana Slough | Jan | Above normal | 0.318 | 0.325 (2%) |
| Georgiana Slough | Jan | Below normal | 0.353 | 0.364 (3%) |
| Georgiana Slough | Jan | Dry | 0.399 | 0.408 (2%) |
| Georgiana Slough | Jan | Critical | 0.417 | 0.425 (2%) |
| Georgiana Slough | Feb | Wet | 0.286 | 0.288 (1%) |
| Georgiana Slough | Feb | Above normal | 0.295 | 0.303 (3%) |
| Georgiana Slough | Feb | Below normal | 0.320 | 0.325 (2%) |
| Georgiana Slough | Feb | Dry | 0.356 | 0.366 (3%) |
| Georgiana Slough | Feb | Critical | 0.402 | 0.406 (1%) |
| Georgiana Slough | Mar | Wet | 0.290 | 0.295 (2%) |
| Georgiana Slough | Mar | Above normal | 0.288 | 0.295 (2%) |
| Georgiana Slough | Mar | Below normal | 0.326 | 0.350 (7%) |
| Georgiana Slough | Mar | Dry | 0.357 | 0.373 (4%) |
| Georgiana Slough | Mar | Critical | 0.425 | 0.428 (1%) |
| Georgiana Slough | Apr | Wet | 0.305 | 0.307 (1%) |
| Georgiana Slough | Apr | Above normal | 0.326 | 0.329 (1%) |
| Georgiana Slough | Apr | Below normal | 0.380 | 0.382 (0%) |
| Georgiana Slough | Apr | Dry | 0.427 | 0.427 (0%) |
| Georgiana Slough | Apr | Critical | 0.452 | 0.452 (0%) |
| Georgiana Slough | May | Wet | 0.311 | 0.315 (2%) |

| Junction | Month | Water Year Type | Existing Conditions | Proposed Action (Alternative 5) |
|---|---|---|---|---|
| Georgiana Slough | May | Above normal | 0.342 | 0.348 (2%) |
| Georgiana Slough | May | Below normal | 0.389 | 0.394 (2%) |
| Georgiana Slough | May | Dry | 0.434 | 0.434 (0%) |
| Georgiana Slough | May | Critical | 0.425 | 0.423 (0%) |
| Georgiana Slough | Jun | Wet | 0.360 | 0.381 (6%) |
| Georgiana Slough | Jun | Above normal | 0.398 | 0.409 (3%) |
| Georgiana Slough | Jun | Below normal | 0.422 | 0.425 (0%) |
| Georgiana Slough | Jun | Dry | 0.423 | 0.422 (0%) |
| Georgiana Slough | Jun | Critical | 0.365 | 0.367 (1%) |
| Head of Old River | Nov | Wet | 0.568 | 0.561 (-1%) |
| Head of Old River | Nov | Above normal | 0.548 | 0.542 (-1%) |
| Head of Old River | Nov | Below normal | 0.551 | 0.545 (-1%) |
| Head of Old River | Nov | Dry | 0.537 | 0.529 (-1%) |
| Head of Old River | Nov | Critical | 0.497 | 0.495 (0%) |
| Head of Old River | Dec | Wet | 0.657 | 0.656 (0%) |
| Head of Old River | Dec | Above normal | 0.665 | 0.658 (-1%) |
| Head of Old River | Dec | Below normal | 0.668 | 0.667 (0%) |
| Head of Old River | Dec | Dry | 0.677 | 0.667 (-2%) |
| Head of Old River | Dec | Critical | 0.612 | 0.611 (0%) |
| Head of Old River | Jan | Wet | 0.610 | 0.610 (0%) |
| Head of Old River | Jan | Above normal | 0.638 | 0.638 (0%) |
| Head of Old River | Jan | Below normal | 0.651 | 0.651 (0%) |
| Head of Old River | Jan | Dry | 0.675 | 0.672 (0%) |
| Head of Old River | Jan | Critical | 0.657 | 0.654 (0%) |
| Head of Old River | Feb | Wet | 0.587 | 0.586 (0%) |
| Head of Old River | Feb | Above normal | 0.627 | 0.627 (0%) |
| Head of Old River | Feb | Below normal | 0.622 | 0.621 (0%) |
| Head of Old River | Feb | Dry | 0.671 | 0.669 (0%) |
| Head of Old River | Feb | Critical | 0.662 | 0.659 (0%) |
| Head of Old River | Mar | Wet | 0.570 | 0.570 (0%) |
| Head of Old River | Mar | Above normal | 0.595 | 0.593 (0%) |
| Head of Old River | Mar | Below normal | 0.620 | 0.616 (-1%) |
| Head of Old River | Mar | Dry | 0.657 | 0.654 (0%) |
| Head of Old River | Mar | Critical | 0.647 | 0.647 (0%) |
| Head of Old River | Apr | Wet | 0.556 | 0.555 (0%) |
| Head of Old River | Apr | Above normal | 0.567 | 0.566 (0%) |
| Head of Old River | Apr | Below normal | 0.586 | 0.586 (0%) |
| Head of Old River | Apr | Dry | 0.625 | 0.625 (0%) |
| Head of Old River | Apr | Critical | 0.622 | 0.623 (0%) |
| Head of Old River | May | Wet | 0.560 | 0.561 (0%) |

| Junction | Month | Water Year Type | Existing Conditions | Proposed Action (Alternative 5) |
|---|---|---|---|---|
| Head of Old River | May | Above normal | 0.571 | 0.571 (0%) |
| Head of Old River | May | Below normal | 0.587 | 0.588 (0%) |
| Head of Old River | May | Dry | 0.620 | 0.619 (0%) |
| Head of Old River | May | Critical | 0.632 | 0.631 (0%) |
| Head of Old River | Jun | Wet | 0.532 | 0.531 (0%) |
| Head of Old River | Jun | Above normal | 0.532 | 0.532 (0%) |
| Head of Old River | Jun | Below normal | 0.530 | 0.530 (0%) |
| Head of Old River | Jun | Dry | 0.512 | 0.511 (0%) |
| Head of Old River | Jun | Critical | 0.398 | 0.403 (1%) |
| Jersey Point | Nov | Wet | 0.071 | 0.071 (0%) |
| Jersey Point | Nov | Above normal | 0.071 | 0.071 (0%) |
| Jersey Point | Nov | Below normal | 0.071 | 0.071 (0%) |
| Jersey Point | Nov | Dry | 0.071 | 0.071 (0%) |
| Jersey Point | Nov | Critical | 0.070 | 0.070 (0%) |
| Jersey Point | Dec | Wet | 0.072 | 0.072 (0%) |
| Jersey Point | Dec | Above normal | 0.071 | 0.071 (0%) |
| Jersey Point | Dec | Below normal | 0.071 | 0.071 (0%) |
| Jersey Point | Dec | Dry | 0.071 | 0.071 (0%) |
| Jersey Point | Dec | Critical | 0.071 | 0.071 (0%) |
| Jersey Point | Jan | Wet | 0.072 | 0.072 (0%) |
| Jersey Point | Jan | Above normal | 0.072 | 0.072 (0%) |
| Jersey Point | Jan | Below normal | 0.072 | 0.072 (0%) |
| Jersey Point | Jan | Dry | 0.071 | 0.071 (0%) |
| Jersey Point | Jan | Critical | 0.071 | 0.071 (0%) |
| Jersey Point | Feb | Wet | 0.071 | 0.071 (0%) |
| Jersey Point | Feb | Above normal | 0.072 | 0.072 (0%) |
| Jersey Point | Feb | Below normal | 0.072 | 0.072 (0%) |
| Jersey Point | Feb | Dry | 0.071 | 0.071 (0%) |
| Jersey Point | Feb | Critical | 0.071 | 0.071 (0%) |
| Jersey Point | Mar | Wet | 0.072 | 0.072 (0%) |
| Jersey Point | Mar | Above normal | 0.072 | 0.072 (0%) |
| Jersey Point | Mar | Below normal | 0.071 | 0.071 (0%) |
| Jersey Point | Mar | Dry | 0.071 | 0.071 (0%) |
| Jersey Point | Mar | Critical | 0.071 | 0.071 (0%) |
| Jersey Point | Apr | Wet | 0.071 | 0.071 (0%) |
| Jersey Point | Apr | Above normal | 0.071 | 0.071 (0%) |
| Jersey Point | Apr | Below normal | 0.071 | 0.071 (0%) |
| Jersey Point | Apr | Dry | 0.070 | 0.070 (0%) |
| Jersey Point | Apr | Critical | 0.071 | 0.071 (0%) |
| Jersey Point | May | Wet | 0.072 | 0.072 (0%) |

| Junction | Month | Water Year Type | Existing Conditions | Proposed Action (Alternative 5) |
|---|---|---|---|---|
| Jersey Point | May | Above normal | 0.071 | 0.071 (0%) |
| Jersey Point | May | Below normal | 0.071 | 0.071 (0%) |
| Jersey Point | May | Dry | 0.071 | 0.071 (0%) |
| Jersey Point | May | Critical | 0.071 | 0.071 (0%) |
| Jersey Point | Jun | Wet | 0.072 | 0.072 (0%) |
| Jersey Point | Jun | Above normal | 0.071 | 0.071 (0%) |
| Jersey Point | Jun | Below normal | 0.071 | 0.071 (0%) |
| Jersey Point | Jun | Dry | 0.071 | 0.071 (0%) |
| Jersey Point | Jun | Critical | 0.071 | 0.071 (0%) |
| Mouth of Middle River | Nov | Wet | 0.201 | 0.199 (-1%) |
| Mouth of Middle River | Nov | Above normal | 0.195 | 0.193 (-1%) |
| Mouth of Middle River | Nov | Below normal | 0.195 | 0.193 (-1%) |
| Mouth of Middle River | Nov | Dry | 0.190 | 0.189 (-1%) |
| Mouth of Middle River | Nov | Critical | 0.180 | 0.180 (0%) |
| Mouth of Middle River | Dec | Wet | 0.192 | 0.191 (0%) |
| Mouth of Middle River | Dec | Above normal | 0.190 | 0.189 (-1%) |
| Mouth of Middle River | Dec | Below normal | 0.190 | 0.189 (0%) |
| Mouth of Middle River | Dec | Dry | 0.186 | 0.184 (-1%) |
| Mouth of Middle River | Dec | Critical | 0.181 | 0.181 (0%) |
| Mouth of Middle River | Jan | Wet | 0.186 | 0.185 (0%) |
| Mouth of Middle River | Jan | Above normal | 0.185 | 0.185 (0%) |
| Mouth of Middle River | Jan | Below normal | 0.180 | 0.180 (0%) |
| Mouth of Middle River | Jan | Dry | 0.180 | 0.179 (0%) |
| Mouth of Middle River | Jan | Critical | 0.177 | 0.177 (0%) |
| Mouth of Middle River | Feb | Wet | 0.190 | 0.188 (-1%) |
| Mouth of Middle River | Feb | Above normal | 0.185 | 0.185 (0%) |
| Mouth of Middle River | Feb | Below normal | 0.188 | 0.188 (0%) |
| Mouth of Middle River | Feb | Dry | 0.180 | 0.180 (0%) |
| Mouth of Middle River | Feb | Critical | 0.176 | 0.176 (0%) |
| Mouth of Middle River | Mar | Wet | 0.182 | 0.181 (-1%) |
| Mouth of Middle River | Mar | Above normal | 0.184 | 0.184 (0%) |
| Mouth of Middle River | Mar | Below normal | 0.179 | 0.179 (0%) |
| Mouth of Middle River | Mar | Dry | 0.174 | 0.175 (0%) |
| Mouth of Middle River | Mar | Critical | 0.174 | 0.174 (0%) |
| Mouth of Middle River | Apr | Wet | 0.182 | 0.181 (0%) |
| Mouth of Middle River | Apr | Above normal | 0.176 | 0.177 (1%) |
| Mouth of Middle River | Apr | Below normal | 0.174 | 0.173 (0%) |
| Mouth of Middle River | Apr | Dry | 0.169 | 0.170 (0%) |
| Mouth of Middle River | Apr | Critical | 0.168 | 0.168 (0%) |
| Mouth of Middle River | May | Wet | 0.184 | 0.185 (0%) |

| Junction | Month | Water Year Type | Existing Conditions | Proposed Action (Alternative 5) |
|---|---|---|---|---|
| Mouth of Middle River | May | Above normal | 0.178 | 0.178 (0%) |
| Mouth of Middle River | May | Below normal | 0.175 | 0.176 (1%) |
| Mouth of Middle River | May | Dry | 0.172 | 0.172 (0%) |
| Mouth of Middle River | May | Critical | 0.169 | 0.169 (0%) |
| Mouth of Middle River | Jun | Wet | 0.191 | 0.192 (1%) |
| Mouth of Middle River | Jun | Above normal | 0.189 | 0.190 (0%) |
| Mouth of Middle River | Jun | Below normal | 0.187 | 0.187 (0%) |
| Mouth of Middle River | Jun | Dry | 0.185 | 0.184 (0%) |
| Mouth of Middle River | Jun | Critical | 0.172 | 0.173 (1%) |
| Mouth of Old River | Nov | Wet | 0.174 | 0.171 (-2%) |
| Mouth of Old River | Nov | Above normal | 0.164 | 0.160 (-2%) |
| Mouth of Old River | Nov | Below normal | 0.163 | 0.160 (-2%) |
| Mouth of Old River | Nov | Dry | 0.156 | 0.154 (-2%) |
| Mouth of Old River | Nov | Critical | 0.144 | 0.142 (-1%) |
| Mouth of Old River | Dec | Wet | 0.183 | 0.179 (-2%) |
| Mouth of Old River | Dec | Above normal | 0.164 | 0.161 (-2%) |
| Mouth of Old River | Dec | Below normal | 0.156 | 0.155 (-1%) |
| Mouth of Old River | Dec | Dry | 0.152 | 0.149 (-2%) |
| Mouth of Old River | Dec | Critical | 0.146 | 0.146 (0%) |
| Mouth of Old River | Jan | Wet | 0.205 | 0.202 (-2%) |
| Mouth of Old River | Jan | Above normal | 0.175 | 0.172 (-1%) |
| Mouth of Old River | Jan | Below normal | 0.151 | 0.149 (-1%) |
| Mouth of Old River | Jan | Dry | 0.145 | 0.144 (-1%) |
| Mouth of Old River | Jan | Critical | 0.142 | 0.141 (-1%) |
| Mouth of Old River | Feb | Wet | 0.224 | 0.220 (-2%) |
| Mouth of Old River | Feb | Above normal | 0.186 | 0.184 (-1%) |
| Mouth of Old River | Feb | Below normal | 0.173 | 0.171 (-1%) |
| Mouth of Old River | Feb | Dry | 0.151 | 0.150 (-1%) |
| Mouth of Old River | Feb | Critical | 0.143 | 0.142 (0%) |
| Mouth of Old River | Mar | Wet | 0.194 | 0.191 (-2%) |
| Mouth of Old River | Mar | Above normal | 0.177 | 0.175 (-1%) |
| Mouth of Old River | Mar | Below normal | 0.151 | 0.150 (-1%) |
| Mouth of Old River | Mar | Dry | 0.145 | 0.144 (-1%) |
| Mouth of Old River | Mar | Critical | 0.139 | 0.139 (0%) |
| Mouth of Old River | Apr | Wet | 0.175 | 0.173 (-1%) |
| Mouth of Old River | Apr | Above normal | 0.150 | 0.149 (0%) |
| Mouth of Old River | Apr | Below normal | 0.143 | 0.143 (0%) |
| Mouth of Old River | Apr | Dry | 0.134 | 0.135 (0%) |
| Mouth of Old River | Apr | Critical | 0.128 | 0.129 (0%) |
| Mouth of Old River | May | Wet | 0.171 | 0.171 (0%) |

| Junction | Month | Water Year Type | Existing Conditions | Proposed Action (Alternative 5) |
|---|---|---|---|---|
| Mouth of Old River | May | Above normal | 0.149 | 0.149 (0%) |
| Mouth of Old River | May | Below normal | 0.142 | 0.143 (1%) |
| Mouth of Old River | May | Dry | 0.136 | 0.136 (0%) |
| Mouth of Old River | May | Critical | 0.128 | 0.128 (0%) |
| Mouth of Old River | Jun | Wet | 0.170 | 0.170 (1%) |
| Mouth of Old River | Jun | Above normal | 0.159 | 0.160 (0%) |
| Mouth of Old River | Jun | Below normal | 0.157 | 0.157 (0%) |
| Mouth of Old River | Jun | Dry | 0.153 | 0.153 (0%) |
| Mouth of Old River | Jun | Critical | 0.138 | 0.139 (1%) |
| Sutter Slough | Nov | Wet | 0.196 | 0.196 (0%) |
| Sutter Slough | Nov | Above normal | 0.188 | 0.192 (2%) |
| Sutter Slough | Nov | Below normal | 0.186 | 0.187 (1%) |
| Sutter Slough | Nov | Dry | 0.182 | 0.186 (2%) |
| Sutter Slough | Nov | Critical | 0.175 | 0.180 (3%) |
| Sutter Slough | Dec | Wet | 0.216 | 0.216 (0%) |
| Sutter Slough | Dec | Above normal | 0.208 | 0.207 (0%) |
| Sutter Slough | Dec | Below normal | 0.197 | 0.196 (-1%) |
| Sutter Slough | Dec | Dry | 0.201 | 0.200 (0%) |
| Sutter Slough | Dec | Critical | 0.193 | 0.194 (0%) |
| Sutter Slough | Jan | Wet | 0.220 | 0.220 (0%) |
| Sutter Slough | Jan | Above normal | 0.219 | 0.219 (0%) |
| Sutter Slough | Jan | Below normal | 0.219 | 0.219 (0%) |
| Sutter Slough | Jan | Dry | 0.221 | 0.222 (1%) |
| Sutter Slough | Jan | Critical | 0.219 | 0.220 (0%) |
| Sutter Slough | Feb | Wet | 0.221 | 0.221 (0%) |
| Sutter Slough | Feb | Above normal | 0.219 | 0.219 (0%) |
| Sutter Slough | Feb | Below normal | 0.218 | 0.217 (0%) |
| Sutter Slough | Feb | Dry | 0.218 | 0.217 (0%) |
| Sutter Slough | Feb | Critical | 0.218 | 0.219 (0%) |
| Sutter Slough | Mar | Wet | 0.220 | 0.220 (0%) |
| Sutter Slough | Mar | Above normal | 0.219 | 0.218 (0%) |
| Sutter Slough | Mar | Below normal | 0.217 | 0.217 (0%) |
| Sutter Slough | Mar | Dry | 0.219 | 0.219 (0%) |
| Sutter Slough | Mar | Critical | 0.223 | 0.223 (0%) |
| Sutter Slough | Apr | Wet | 0.220 | 0.220 (0%) |
| Sutter Slough | Apr | Above normal | 0.219 | 0.219 (0%) |
| Sutter Slough | Apr | Below normal | 0.221 | 0.222 (0%) |
| Sutter Slough | Apr | Dry | 0.225 | 0.225 (0%) |
| Sutter Slough | Apr | Critical | 0.222 | 0.224 (0%) |
| Sutter Slough | May | Wet | 0.220 | 0.220 (0%) |

| Junction | Month | Water Year Type | Existing Conditions | Proposed Action (Alternative 5) |
|---|---|---|---|---|
| Sutter Slough | May | Above normal | 0.219 | 0.219 (0%) |
| Sutter Slough | May | Below normal | 0.222 | 0.223 (0%) |
| Sutter Slough | May | Dry | 0.227 | 0.227 (0%) |
| Sutter Slough | May | Critical | 0.203 | 0.203 (0%) |
| Sutter Slough | Jun | Wet | 0.202 | 0.199 (-1%) |
| Sutter Slough | Jun | Above normal | 0.187 | 0.186 (-1%) |
| Sutter Slough | Jun | Below normal | 0.182 | 0.182 (0%) |
| Sutter Slough | Jun | Dry | 0.180 | 0.180 (0%) |
| Sutter Slough | Jun | Critical | 0.164 | 0.164 (0%) |
| Steamboat Slough | Nov | Wet | 0.199 | 0.197 (-1%) |
| Steamboat Slough | Nov | Above normal | 0.197 | 0.195 (-1%) |
| Steamboat Slough | Nov | Below normal | 0.182 | 0.180 (-1%) |
| Steamboat Slough | Nov | Dry | 0.184 | 0.184 (0%) |
| Steamboat Slough | Nov | Critical | 0.181 | 0.184 (2%) |
| Steamboat Slough | Dec | Wet | 0.247 | 0.243 (-2%) |
| Steamboat Slough | Dec | Above normal | 0.209 | 0.207 (-1%) |
| Steamboat Slough | Dec | Below normal | 0.199 | 0.196 (-1%) |
| Steamboat Slough | Dec | Dry | 0.196 | 0.195 (-1%) |
| Steamboat Slough | Dec | Critical | 0.185 | 0.185 (0%) |
| Steamboat Slough | Jan | Wet | 0.264 | 0.261 (-1%) |
| Steamboat Slough | Jan | Above normal | 0.249 | 0.245 (-2%) |
| Steamboat Slough | Jan | Below normal | 0.229 | 0.224 (-2%) |
| Steamboat Slough | Jan | Dry | 0.212 | 0.206 (-2%) |
| Steamboat Slough | Jan | Critical | 0.203 | 0.199 (-2%) |
| Steamboat Slough | Feb | Wet | 0.272 | 0.271 (-1%) |
| Steamboat Slough | Feb | Above normal | 0.263 | 0.259 (-2%) |
| Steamboat Slough | Feb | Below normal | 0.246 | 0.243 (-1%) |
| Steamboat Slough | Feb | Dry | 0.228 | 0.224 (-2%) |
| Steamboat Slough | Feb | Critical | 0.210 | 0.207 (-1%) |
| Steamboat Slough | Mar | Wet | 0.264 | 0.262 (-1%) |
| Steamboat Slough | Mar | Above normal | 0.261 | 0.258 (-1%) |
| Steamboat Slough | Mar | Below normal | 0.236 | 0.228 (-3%) |
| Steamboat Slough | Mar | Dry | 0.227 | 0.222 (-2%) |
| Steamboat Slough | Mar | Critical | 0.200 | 0.199 (-1%) |
| Steamboat Slough | Apr | Wet | 0.252 | 0.251 (0%) |
| Steamboat Slough | Apr | Above normal | 0.237 | 0.235 (-1%) |
| Steamboat Slough | Apr | Below normal | 0.216 | 0.215 (0%) |
| Steamboat Slough | Apr | Dry | 0.197 | 0.197 (0%) |
| Steamboat Slough | Apr | Critical | 0.184 | 0.185 (0%) |
| Steamboat Slough | May | Wet | 0.247 | 0.245 (-1%) |

| Junction | Month | Water Year Type | Existing Conditions | Proposed Action (Alternative 5) |
|---|---|---|---|---|
| Steamboat Slough | May | Above normal | 0.233 | 0.231 (-1%) |
| Steamboat Slough | May | Below normal | 0.215 | 0.213 (-1%) |
| Steamboat Slough | May | Dry | 0.196 | 0.195 (0%) |
| Steamboat Slough | May | Critical | 0.185 | 0.186 (0%) |
| Steamboat Slough | Jun | Wet | 0.214 | 0.206 (-4%) |
| Steamboat Slough | Jun | Above normal | 0.184 | 0.180 (-2%) |
| Steamboat Slough | Jun | Below normal | 0.172 | 0.171 (-1%) |
| Steamboat Slough | Jun | Dry | 0.169 | 0.169 (0%) |
| Steamboat Slough | Jun | Critical | 0.175 | 0.175 (0%) |
| Turner Cut | Nov | Wet | 0.181 | 0.180 (-1%) |
| Turner Cut | Nov | Above normal | 0.171 | 0.169 (-1%) |
| Turner Cut | Nov | Below normal | 0.172 | 0.172 (0%) |
| Turner Cut | Nov | Dry | 0.166 | 0.166 (0%) |
| Turner Cut | Nov | Critical | 0.158 | 0.157 (0%) |
| Turner Cut | Dec | Wet | 0.169 | 0.168 (0%) |
| Turner Cut | Dec | Above normal | 0.162 | 0.161 (-1%) |
| Turner Cut | Dec | Below normal | 0.158 | 0.158 (0%) |
| Turner Cut | Dec | Dry | 0.154 | 0.153 (-1%) |
| Turner Cut | Dec | Critical | 0.151 | 0.151 (0%) |
| Turner Cut | Jan | Wet | 0.170 | 0.169 (0%) |
| Turner Cut | Jan | Above normal | 0.165 | 0.164 (0%) |
| Turner Cut | Jan | Below normal | 0.156 | 0.156 (0%) |
| Turner Cut | Jan | Dry | 0.152 | 0.151 (0%) |
| Turner Cut | Jan | Critical | 0.151 | 0.150 (0%) |
| Turner Cut | Feb | Wet | 0.178 | 0.177 (-1%) |
| Turner Cut | Feb | Above normal | 0.169 | 0.170 (0%) |
| Turner Cut | Feb | Below normal | 0.172 | 0.172 (0%) |
| Turner Cut | Feb | Dry | 0.152 | 0.152 (0%) |
| Turner Cut | Feb | Critical | 0.149 | 0.149 (0%) |
| Turner Cut | Mar | Wet | 0.177 | 0.175 (-1%) |
| Turner Cut | Mar | Above normal | 0.169 | 0.170 (0%) |
| Turner Cut | Mar | Below normal | 0.162 | 0.163 (1%) |
| Turner Cut | Mar | Dry | 0.148 | 0.149 (0%) |
| Turner Cut | Mar | Critical | 0.147 | 0.147 (0%) |
| Turner Cut | Apr | Wet | 0.184 | 0.183 (0%) |
| Turner Cut | Apr | Above normal | 0.170 | 0.170 (0%) |
| Turner Cut | Apr | Below normal | 0.162 | 0.162 (0%) |
| Turner Cut | Apr | Dry | 0.148 | 0.148 (0%) |
| Turner Cut | Apr | Critical | 0.141 | 0.141 (0%) |
| Turner Cut | May | Wet | 0.181 | 0.182 (1%) |

| Junction | Month | Water Year Type | Existing Conditions | Proposed Action (Alternative 5) |
|---|---|---|---|---|
| Turner Cut | May | Above normal | 0.169 | 0.170 (0%) |
| Turner Cut | May | Below normal | 0.163 | 0.164 (1%) |
| Turner Cut | May | Dry | 0.153 | 0.153 (0%) |
| Turner Cut | May | Critical | 0.142 | 0.142 (0%) |
| Turner Cut | Jun | Wet | 0.185 | 0.186 (0%) |
| Turner Cut | Jun | Above normal | 0.172 | 0.172 (0%) |
| Turner Cut | Jun | Below normal | 0.164 | 0.165 (0%) |
| Turner Cut | Jun | Dry | 0.158 | 0.158 (0%) |
| Turner Cut | Jun | Critical | 0.145 | 0.146 (0%) |

# 5D.1.4References Cited

## 5D.1.4.1 Printed References

Zeug, S. C., and B. J. Cavallo. 2014. Controls on the Entrainment of Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) into Large Water Diversions and Estimates of Population-Level Loss. *PLoS ONE* 9(7):e101479.

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Attachment 5D.2

# Results of OBAN Analysis of Delta Conveyance Project Alternatives 2020

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QEDα

# Technical Memorandum

**To:** Marin Greenwood, ICF
**From:** Noble Hendrix, QEDA Consulting
**Date:** April 8, 2022
**Subject: Results of OBAN analysis of Delta Conveyance Project Alternatives 2020**

## Executive Summary

This technical memorandum describes results from running the winter-run Oncorhynchus Bayesian Analysis (OBAN) model for an existing condition (EC) and several alternatives (Alt 1/3, Alt 2a/4a, Alt 2b/4b, Alt 2c/4c, and Alt 5) during 2020 climate conditions.

For the 2020 model runs, the modeled median abundances were highest under Alt 2a/4a relative to the EC and all other alternatives. The Alt 2a/4a alternative had median abundances greater than the EC when averaged across the timeseries, whereas all other alternatives had median abundances less than the EC. These results were due in large part to the initial ten years of the modeling time-period, and comparisons among the remaining years indicated median abundances below the EC for all alternatives. Rankings of the alternatives from highest to lowest abundance on average from the period excluding the first ten years was Alt 2a/4a, Alt 2c/4c, Alt 2b/4b, Alt 5, and Alt 1/3. The probability of quasi-extinction (spawner abundance < 100) also followed this general pattern, in which Alt 2a/4a had the lowest probability and Alt 1/3 had the highest probability over the period excluding the first ten years. Differences in the performance of the alternatives were due mostly to the egg through fry survival stage of the OBAN model, which uses temperature at Bend Bridge and minimum flow at Bend Bridge as physical drivers. Temperatures and minimum flows were similar among alternatives, but temperatures were slightly lower on average in Alt2a/4a and flows were slightly higher relative to the other alternatives. In addition, the OBAN model was run for the 2020 climate condition with two mortality assumptions (5% and 10%) to evaluate the sensitivity of model results to additional potential mortality associated with the north Delta diversions. All of the alternatives, including the Alt 2a/4a, had median abundance less than the EC under a mortality assumption of 5% and 10% over the full time period of the model.

## OBAN Model Description

The Oncorhynchus Bayesian Analysis (OBAN) model uses statistical approaches to understand how a series of environmental driver variables (e.g., temperature and flow) that are under management control may affect winter-run Chinook salmon population dynamics. The model was developed by first determining which of a suite of parameters (e.g., water temperature,

harvest, exports, striped bass abundance, and offshore upwelling) covaried with historical abundance data. The OBAN model incorporates uncertainty by estimating the influence of covariates on population abundance in a Bayesian estimation framework. The set of covariates that provided the best model fit were then retained for the predictive model. The OBAN model can be used to evaluate the effect of project operations on winter-run Chinook. The OBAN model uses values of the covariates under climate or operational alternatives, which are produced primarily from CALSIM and HEC 5Q outputs, to predict patterns in winter-run Chinook salmon population dynamics. Furthermore, uncertainty in the predicted winter-run abundance is then incorporated into model output through Monte Carlo simulations (1,000 simulations per model run). The alternatives are compared to a baseline condition to provide inference on the relative performance of the alternatives to the baseline, which is a more robust approach for evaluating alternatives than absolute prediction.

Specifically, the OBAN model:

- Accounts for mortality during all phases of the Chinook salmon life history, including environmental and anthropogenic factors;
- Evaluates covariates that may explain dynamic vital rates (e.g., thermal mortality reduces alevin survival rates in spawning reaches);
- Estimates model coefficients by fitting predictions of the population dynamics model to observed indices of abundance in a Bayesian framework.

<u>Model Structure</u>

The winter-run Chinook salmon OBAN model is composed of several life history stages:

- Alevin – incubation in the gravel below Keswick Dam
- Fry – rearing above Red Bluff Diversion Dam (RBDD)
- Delta – from RBDD to Chipps Island
- Bay – from Chipps Island to the Golden Gate
- Gulf – Gulf of Farrallones
- Ocean 1 – first year in the ocean, return to spawn as 2 year olds
- Ocean 2 – second year in the ocean, return to spawn as 3 year olds
- Ocean 3 – third and final year in the ocean, return to spawn as 4 year olds
- Escapement – composed of all spawners on the spawning ground

The winter run Chinook OBAN model has been developed from the conceptual life-cycle model of winter run, and uses a Bayesian statistical estimation algorithm to find a statistical “best fit” to empirical trends by matching model predictions to empirically observed juvenile and adult abundances. The model is capable of fitting any number of abundance data sources and estimating any number of coefficient values to find the best statistical prediction.

The transition between life history stages occurs with a Beverton-Holt recruitment function:

$$N_{j+1} = N_j \times \frac{p_j}{1 + \frac{p_j N_j}{K_j}}$$

where $N_j$ is the abundance at stage *j*, $p_j$ is the productivity in the absence of density dependence for stage *j*, $K_j$ is the capacity at stage *j*. The two parameters of the Beverton-Holt transition equation are $p_j$ and $K_j$ , and they can be user defined constants, estimated parameters fixed across all years, or dynamic, i.e., $p_{j,t}$ and $K_{j,t}$ can be modeled as changing in each year *t*. Note that density dependence can be effectively removed from the formulation by setting $K_j$ to a very large value.

In the case of dynamic productivity ($p_{j,t}$ ) and capacity ($K_{j,t}$), parameter values, the values of the productivities and capacities in a given year are modeled from a set of time-varying covariates. By using this formulation, the influence of anthropogenic and environmental factors on specific life history stages can be incorporated. Each productivity parameter can be influenced by independent covariates acting simultaneously on the life history stage to drive demographic rates.

The dynamic productivities used a logit transformation, which caused the productivities to remain between 0 and 1. This interval is the sample space for the survival for all stages from alevin to spawner.

$$\text{logit}(p_{j,t}) = \beta_{0,j} + \beta_{1,j}X_{1,t} + \beta_{2,j}X_{2,t} + \cdots + \beta_{5,j}X_{5,t}$$

The dynamic capacities used a natural log transformation, which caused the capacities to remain between 0 and infinity. This interval is the sample space for the abundance for all stages from alevin to spawner.

$$\ln(K_{j,t}) = \beta_{0,j} + \beta_{1,j}X_{1,t} + \beta_{2,j}X_{2,t} + \cdots + \beta_{5,j}X_{5,t}$$

The estimation of $p_{j,t}$ and $K_{j,t}$ involves estimating the $\beta$ coefficients on the right hand sides of the equations. The $X_{1:5,t}$ are environmental covariates that represent water conditions such as temperature or flow, biotic factors such as predator abundance, food abundance, or anthropogenic factors such as water export levels or harvest rates. The model has the ability to estimate as few or as many of the parameters as desired, and covariates were used in the OBAN model based on their ability to explain historical patterns in winter-run escapement and juvenile abundance at Red Bluff Diversion Dam data.

Covariates

The following covariates were retained in the model and their coefficients estimated:

*STEMP*: July through September mean daily water temperature (degrees Fahrenheit) in the Sacramento River at Bend Bridge. This covariate affects survival of the alevin life history stage.

*FLMIN*: August through November minimum monthly flow (cubic feet per second) in the Sacramento River at Bend Bridge (USGS Gauge 11377100 data). This covariate affects survival of the fry life history stage.

*EXPT*: Total water exports in the south Delta (CVP and SWP) during December through June, derived by taking average daily export rate (cubic feet per second), multiplying by the number of days in the month, and then summing over December-June (IEP Dayflow data). This covariate affects survival in the Delta life history stage.

*YOLO*: Number of days during December through March with minimum flows of 100 cfs over the Fremont Weir, which is enough for positive flows onto the Yolo Bypass (December of the brood year and January – March of the year following) (Reclamation data). The 100 cfs minimum flow threshold was chosen to distinguish days with an actual inundation event from the rest of the days with year-round 100 cfs flows into the Bypass to maintain positive flows for adult fish passage under the via the preliminary proposal. Although this flow is much lower than the suggested flows needed for juveniles salmonids to gain survival benefits in the Yolo Bypass (~4,000 cfs, T. Sommer pers. comm.), the parameter used to fit the data is number of days of flooding, and not flow rate during flooding. This covariate affects survival in the Delta life history stage.

*DCC*: Proportion of time that the Delta Cross Channel gates were open between December and March (December of the brood year and January – March of the year following) (US Bureau of Reclamation data). This covariate affects survival in the Delta life history stage.

*CURL*: a wind stress curl index that is correlated with coastal productivity off California (Chelton 1982) (Pascals per meter) (Pacific Fisheries Environmental Laboratory, Pacific Grove data). Persistent longshore equatorward wind stress during spring and summer forces surface waters offshore via Eckman transport drawing nutrient-rich water to the euphotic zone to replace surface waters pushed offshore (Rykaczewski and Checkley 2008). Once nutrient-rich water reaches the euphotic zone, primary productivity increases. Positive effects of the CURL index on Chinook salmon growth and maturation have been observed (Wells et al. 2007). This covariate affects survival in the Gulf life history stage.

*Harvest*: Ocean harvest of Ocean 2 and Ocean 3 individuals (Ocean 1 are assumed to be too small to be vulnerable to the fishery) as the proportion of the total Ocean 2 and Ocean 3 individuals available for harvest. The harvest rate index was constructed by using the California Department of Fish and Game ocean and recreational fishing regulations. Until 1987, there was little regulation of the Central Valley Chinook fishery and estimates of the mortality rate on winter run Chinook in the ocean fishery was approximately 0.7 of the mortality rate experienced by fall run Chinook. The harvest rate of fall-run Chinook is calculated annually as the Central Valley Index (CVI) by calculating the proportion of the fall run that were captured in the fishery (harvested/(harvested + escaped) ). In 1989, winter-run were listed as threatened and the following year the ocean fishery regulations were shifted to open two weeks later

(NMFS 1997). It was assumed that this had an effect on the winter-run harvest mortality and reduced the impact to 0.5 of the CVI. In 1994, winter-run were listed as endangered and, in 1997, a biological opinion was released by NMFS (1997) initiating a delayed opening of the ocean fishery from mid-March to mid-April and eventually to late April in 2001. Using coded wire tagged winter run from 1998 through 2000 cohorts, Grover et al. (2004) estimated ocean harvest rates of 0.22. The effect of the fishery is not the same for Ocean 2 and Ocean 3 stages, however. The rates described above were generated for the Ocean 2 stage. Ocean 2 and Ocean 3 fish are not captured at the same rate. Most winter-run Chinook return to spawn as three-year olds (after the Ocean 2 phase); however, the Ocean 3 stages are more likely to be captured in the commercial fishery due to their larger size. Grover et al. (2004) found that the harvest related mortality of Ocean 3 winter run Chinook was 2.5 to 3.7 times the rate of Ocean 2 winter run. For OBAN, it assumed that the harvest rates experienced by Ocean 3 stage winter run were 2.7 times the harvest rates experienced by Ocean 2 stage. In order to make sure that the harvest rate could not surpass 1, a logistic regression approach was used to incorporate the harvest rates. Harvest also occurs in the Sacramento River, and the best available published rates were used. Between 1967 and 1975, estimates of winter-run harvest in the recreational river fishery varied from 0.04 to 0.14 (Hallock and Fisher 1985). For OBAN, it was assumed that the in-river fishery harvest rates were 0.09 from 1975 to 1982, which was the average of the Hallock and Fisher (1985) estimates. NMFS (1997) published in-river harvest rates from 1983 to 1990 that varied between 0.013 and 0.087. For OBAN, it was assumed that the in-river harvest was constant at 0.05 from 1991 to 2007. The 0.05 river harvest rate was used in combination with the 0.22 ocean harvest rate to equal the average harvest impact rate identified by Grover et al. (2004) for the 1998, 1999, and 2000 cohorts.

**Using the OBAN model for Evaluating Delta Conveyance Project alternatives**

In order to simulate winter-run Chinook salmon population dynamics under each of the alternatives, covariate data were required for each alternative. These covariates were produced for each alternative by using hydrological (CalSim) and water quality models (HEC 5Q). In addition, DCC position does not differ between model scenarios during the period of winter-run presence in the Delta, as it is assumed to be closed during winter-run presence. All covariates were normalized by subtracting the mean and dividing by the standard deviation of empirical data used to estimate the OBAN model coefficients.

The OBAN model was modified to be able to run for the full CalSim 3 period of hydrologic outputs (1922 – 2014) by making two modifications to the model. The first was the inclusion of a harvest control rule for calculating harvest rates as a function of spawning abundance. The harvest control rule is consistent with the rule used in the NMFS winter-run life cycle model (WRLCM) and has a maximum harvest rate of 0.2 when the three-year geometric average is greater than 3500 spawners (Hendrix et al. 2014). The second modification was the need to resample from the ocean productivity indices (CURL). The historical 1967 – 2014 CURL values were resampled with replacement in each iteration to provide variability in ocean productivity across the 1000 Monte Carlo simulations for each alternative.

**OBAN Model Results**

Median abundance was the highest under Alt 2a/4a relative to the existing condition (EC) and to all other alternatives (Figure 1). When averaging across the model years 1922 - 2014, Alt 2a/4a had the highest average abundance of all the alternatives, and all alternatives except Alt 2a/4a had median abundances lower than the EC on average. This result for Alt 2a/4a was due to largely to the escapement in model years 1928 – 1932. All alternatives had the largest differences in the early model years, which may reflect differences in the production during the initialization of the model. As a result, the period of evaluation for the abundances was truncated to 1932 – 2014 to allow comparisons between alternatives and the EC to occur during more representative conditions. Average median abundance from 1932 to the end of the time series was lower in Alt2a/4a than the EC (Figure 1). Rankings of the alternatives from highest to lowest abundance on average over the 1932 – 2014 period was Alt 2a/4a, Alt 2c/4c, Alt 2b/4b, Alt 5, and Alt 1/3.

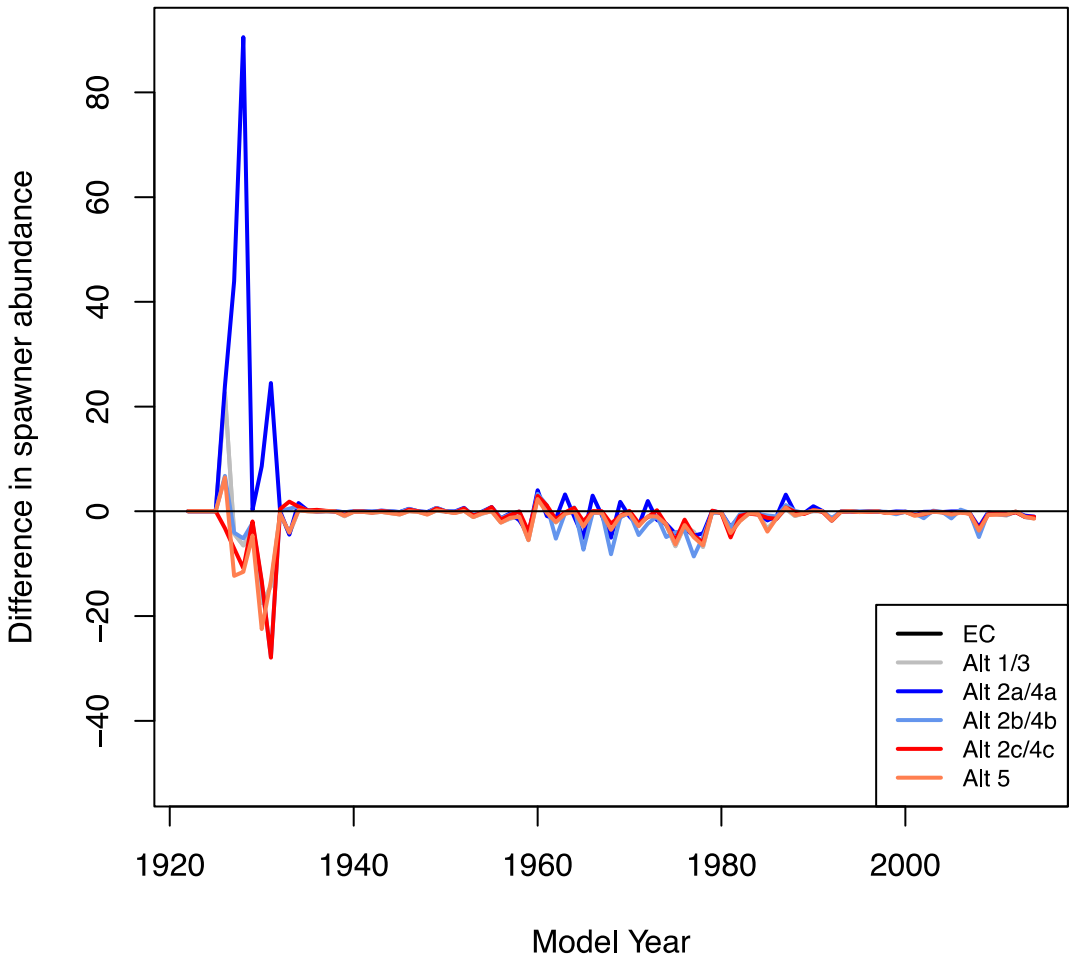


*Figure 1. Difference (Alternative – EC) in median spawner abundance for model years 1922 – 2014. Positive values indicate higher abundances under alternatives relative to the baseline existing condition (EC).*

There were periods in which the spawner abundances were similar among the alternatives and the EC, such as during the modeled 1940's and 1990's (Figure 1). Other periods showed variability among the alternatives and the EC, such as during the modeled 1960's to 1980's (Figure 1), and it was during these periods of variability that the alternatives could be evaluated for their relative performance. Uncertainty in the abundances followed these general patterns in which the spawner abundances in the alternatives and the EC were consistently equivalent during the 1940's and 1990's (Figure 2). Generally, these periods of low variability and low uncertainty across Monte Carlo simulations were years of low abundance in both the alternatives and the EC.

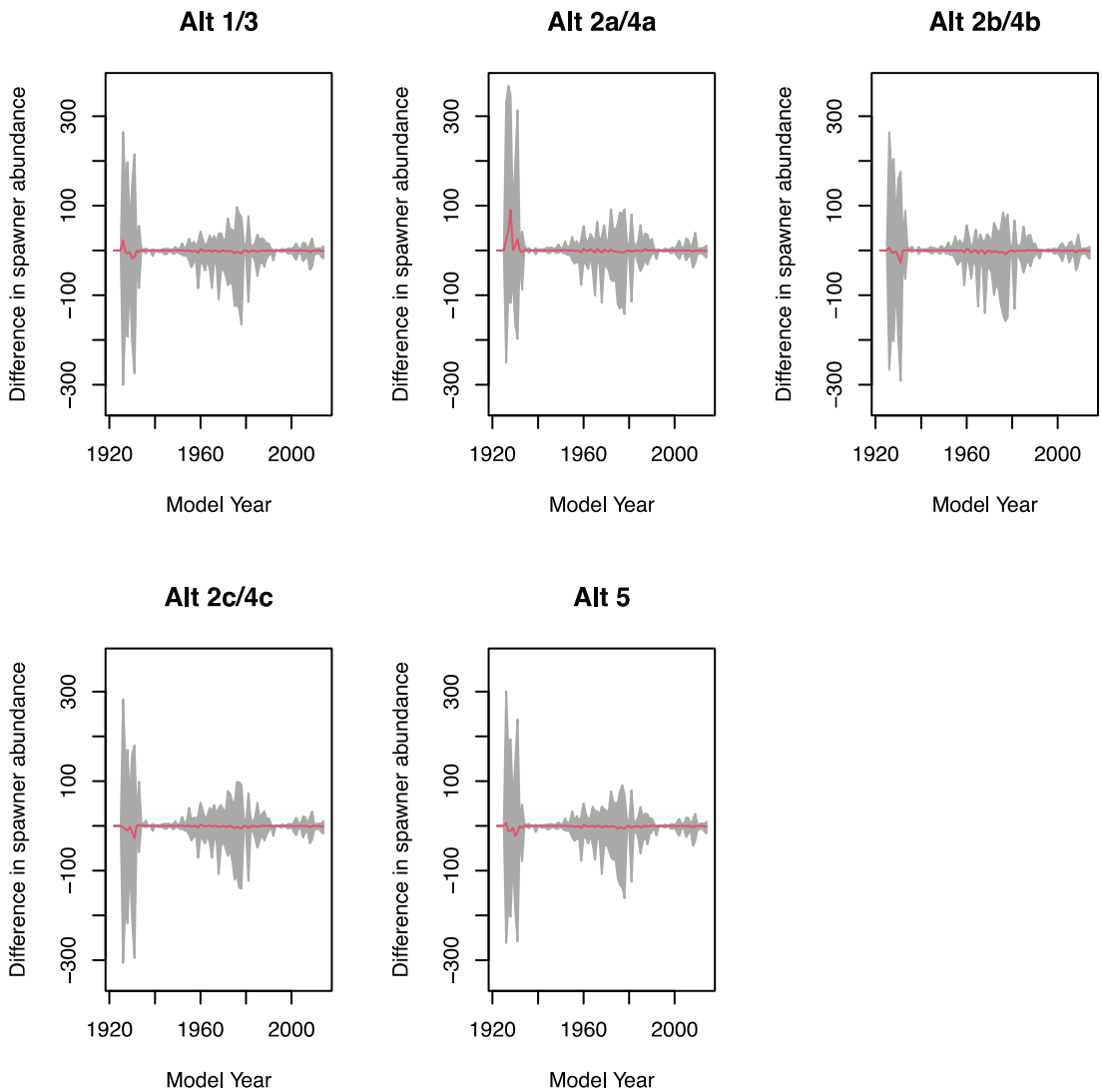


*Figure 2a. Difference (Alt - EC) in spawner abundance for model years 1922 – 2014. Positive values indicate higher abundances under alternatives relative to the existing condition (EC). Median (red line) and 80% intervals (gray) across 1000 Monte Carlo simulations are presented.*

The probability of quasi-extinction (probability that spawner abundance < 100) was another metric that indicated the years in which spawner abundance was low. Temporal patterns in quasi-extinction were similar among alternatives and the existing condition (Figure 3 left). High probability of quasi-extinction coincided with years of little variation between alternatives and the EC identified in Figure 1. Performance of the alternatives relative to the EC indicated that Alt 2a/4a had consistently lower probabilities of quasi-extinction than the EC (Figure 3, right). The rankings of the alternatives from the greatest to least probability of quasi-extinction was Alt 2a/4a, Alt 2c/4c, Alt 5, Alt 1/3, and Alt 2b/4b (Figure 3, right).

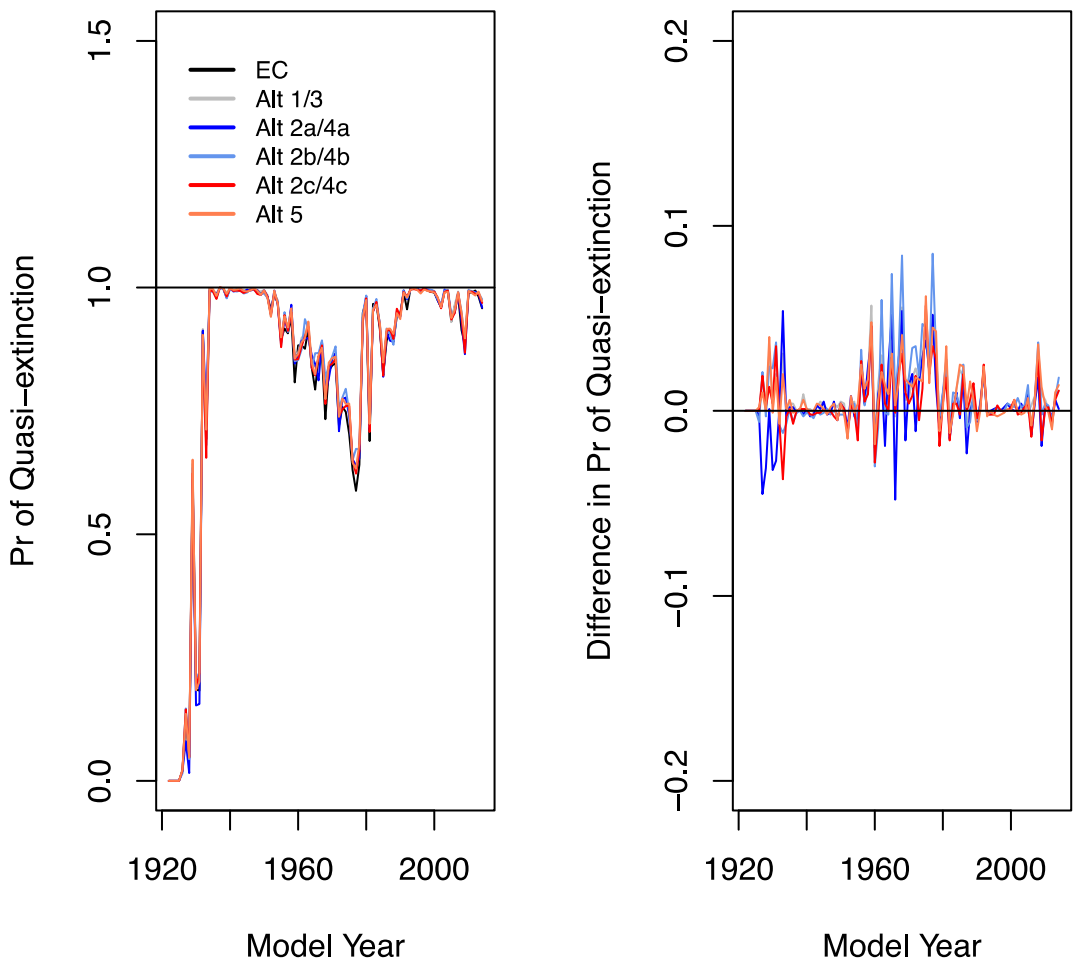


*Figure 3. Probability of quasi-extinction (spawner abundance < 100) showing the existing condition (EC) (black) and alternatives (left). Difference (Alt – EC) in the probability of quasi-extinction (right); thus, negative values indicate lower probability of quasi-extinction.*

The survival rates in the egg through fry stage provided an indicator of how operations affect the early winter-run life history stages. The difference in survival rates of the alternatives

relative to the EC was calculated to understand how the alternatives differed compared to the EC, and to identify the model years in which those differences were occurring. Average egg through fry survival was lower in all alternatives relative to the EC, but the egg to fry survival were highest for alternative Alt2a/4a relative to the other alternatives (Figure 4).

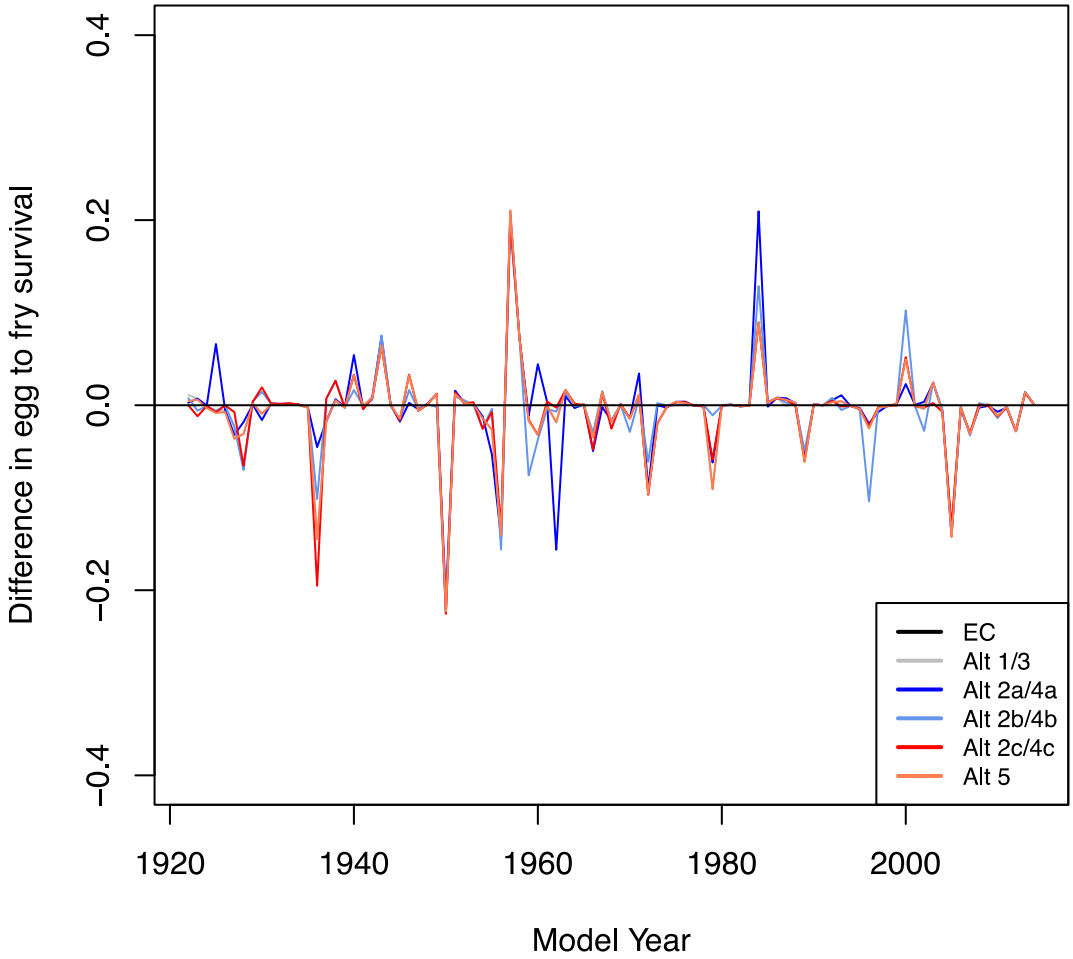


*Figure 4. Median difference (Alt – EC) in survival of the egg through fry stages which includes thermal mortality and Bend Bridge flow effects.*

The relative survival of egg through fry in the alternatives compared to the EC varied in their temporal patterns (Figure 4, Figure 5). In most years, the survival of the alternatives and EC were similar, with a few years having large positive or negative differences (Figure 5). The number of years with negative median survival differences provides insight into the different levels of performance of the alternatives. Alt 2a/4a had six years with survival differences > 0.05 (i.e., positive effects) and eight years with survival differences < -0.05 (i.e., negative effects). The number of years with positive and negative survival differences for Alt 2b/4b and Alt 2c/4c was five positive and eight negative, whereas Alt 1/3 had five positive and seven negative and Alt 5 had four positive and seven negative.

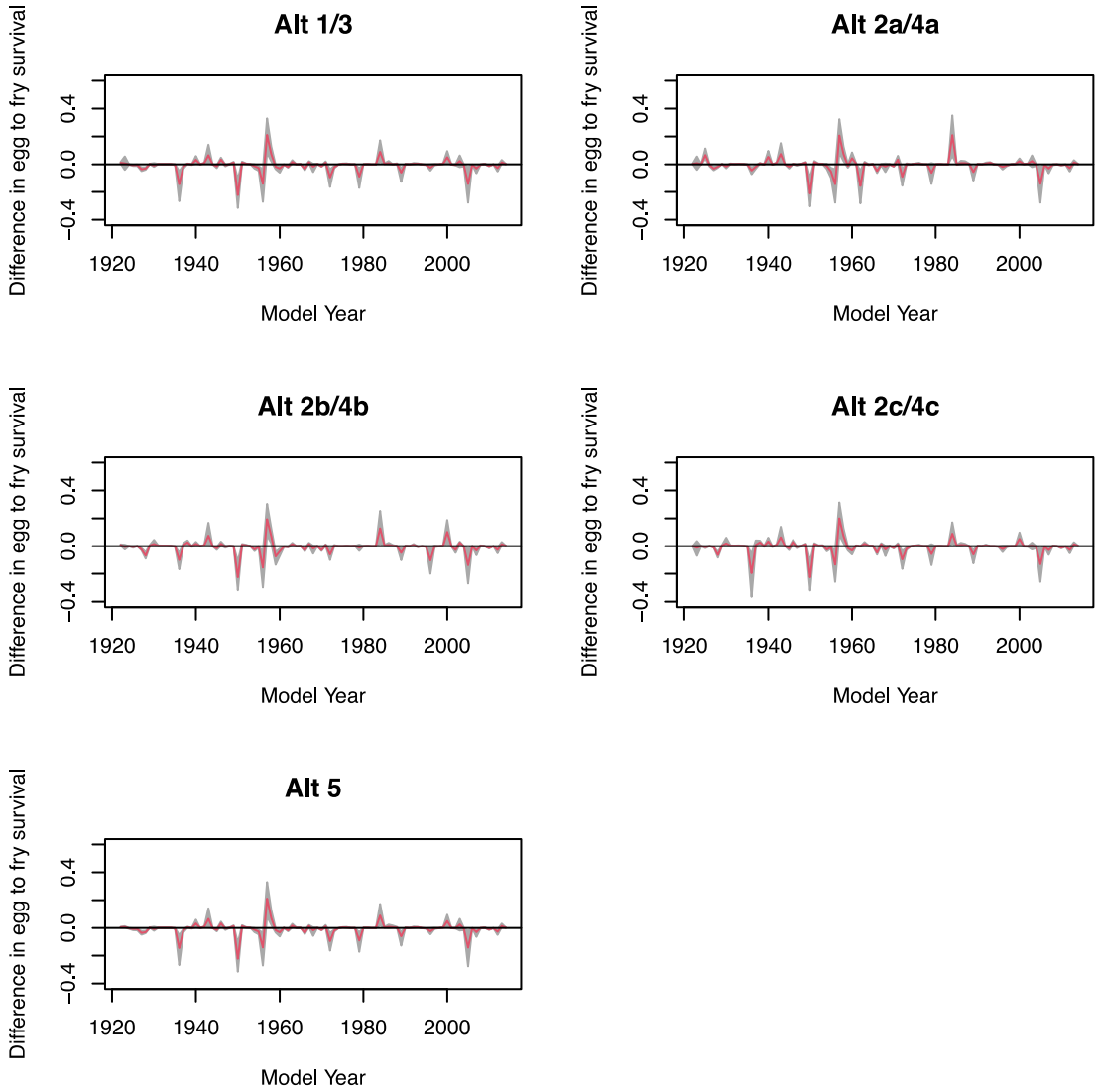


*Figure 5. Difference (ALT – NAA) in survival of the egg through fry stages which includes thermal mortality and Bend Bridge flow effects. Median (red line) and 80% intervals (gray) across 1000 Monte Carlo simulations are presented.*

There was little difference in the survival rates of the alternatives relative to the EC in the delta (Figure 6, Figure 7), and median differences between the alternatives and the EC were within +/- 5e-04 (Figure 6). Uncertainty in the estimates was also small and 80th percentile intervals were consistently within +/- 5 e-03 (Figure 7).

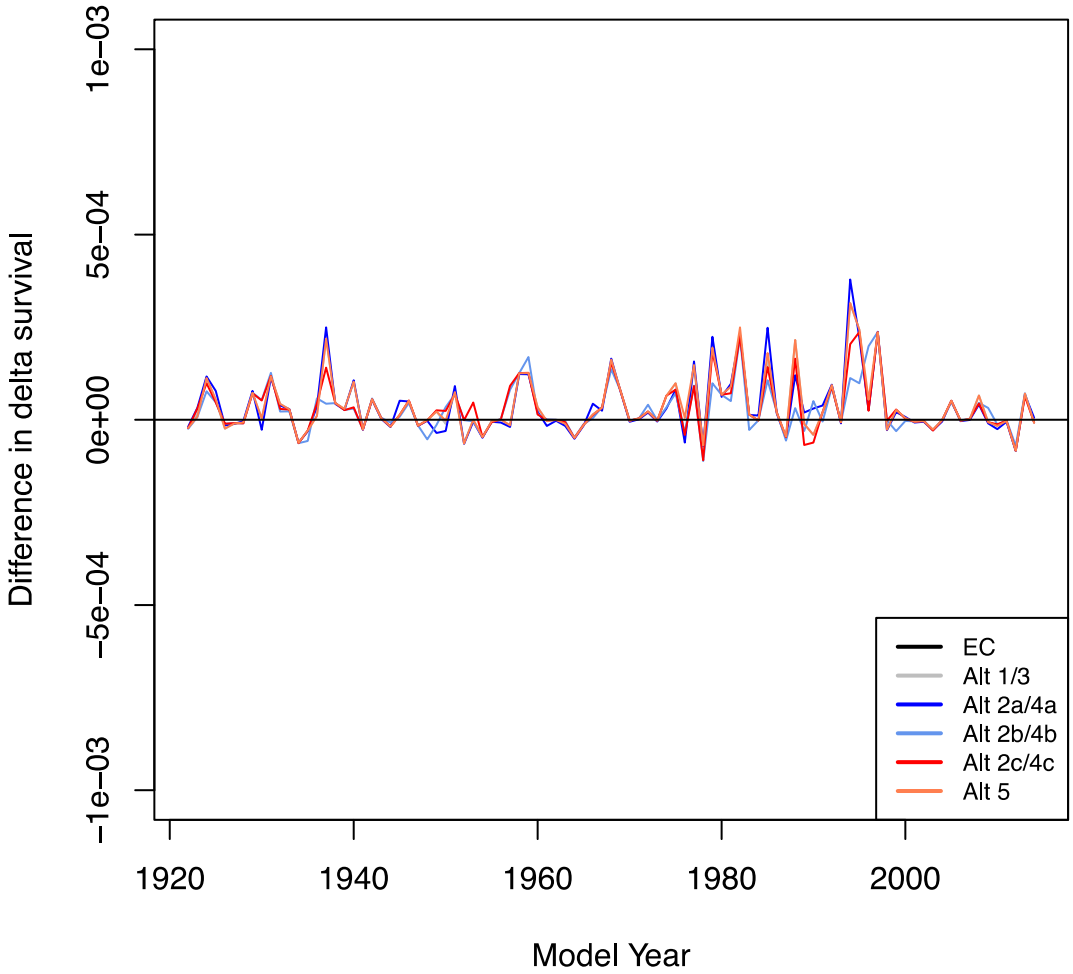


*Figure 6. Median difference (Alt – EC) in survival of the delta stage which includes access to Yolo bypass and export effects.*

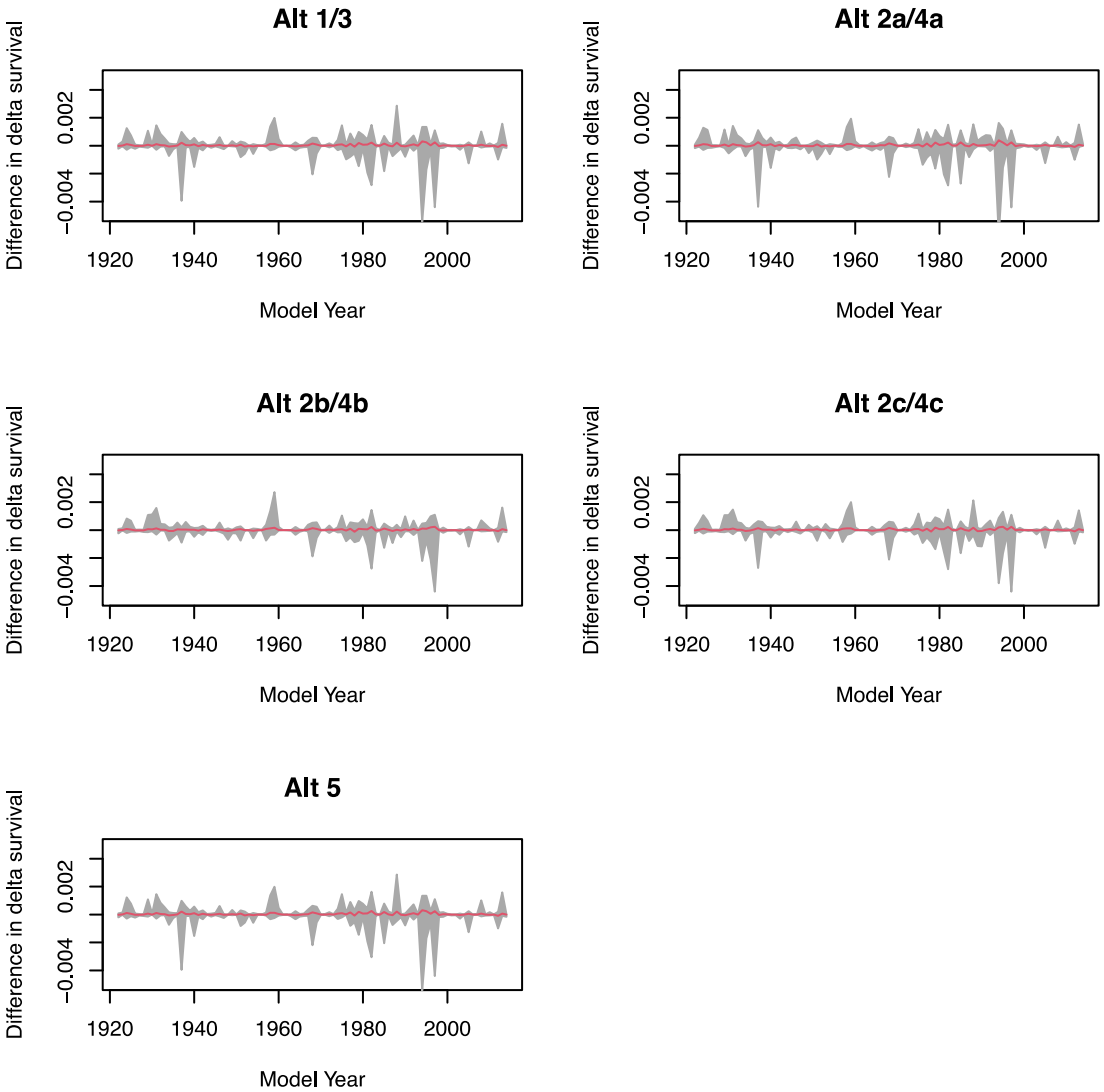


*Figure 7. Difference (Alt – EC) in survival of the delta stage which includes access to Yolo bypass and export effects. Median (red line) and 80% intervals (gray) across 1000 Monte Carlo simulations are presented.*

Evaluation of Physical Data Affecting Performance

Of the alternatives, Alt 2a/4a provided the only improvement over the existing condition (EC) in average abundance, but this was due largely to the first ten modeled years. Egg through fry survival, which differed among alternatives and the EC, was on average negative for all alternatives. The two physical drivers that affect the egg through fry survival in the OBAN model are the temperatures at Bend Bridge during egg incubation and the minimum flow at Bend Bridge during fry rearing and outmigration (Figure 8 and 9). The average difference in temperatures was similar across alternatives and the EC (less than 0.1 F on average). Still, alternatives Alt 2a/4a, Alt 2b/4b and Alt2c/4c had slightly lower average temperatures relative to the EC, whereas Alt 1/3 and Alt 5 had higher temperatures when averaged across model

years (Figure 8). In contrast, median temperature values for all alternatives were all very slightly higher (differences less than 0.01 F) than the EC. Ranking of the alternatives in order of the coolest to warmest average temperatures is Alt 2a/4a, Alt 2c/4c, Alt 2b/4b, Alt 5, and Alt 1/3.

Differences in minimum flow between the alternatives and the EC showed unique patterns and differences among years (Figure 9). The average minimum flow was lower than the EC for all alternatives, but on average the highest average flows were in alternative Alt 2a/4a. The ranks of the alternatives in order of the least to greatest average flow differences (i.e., most like the EC to least like the EC) are Alt 2a/4a, Alt 2b/4b, Alt 1/3, Alt 5, Alt 2c/4c.

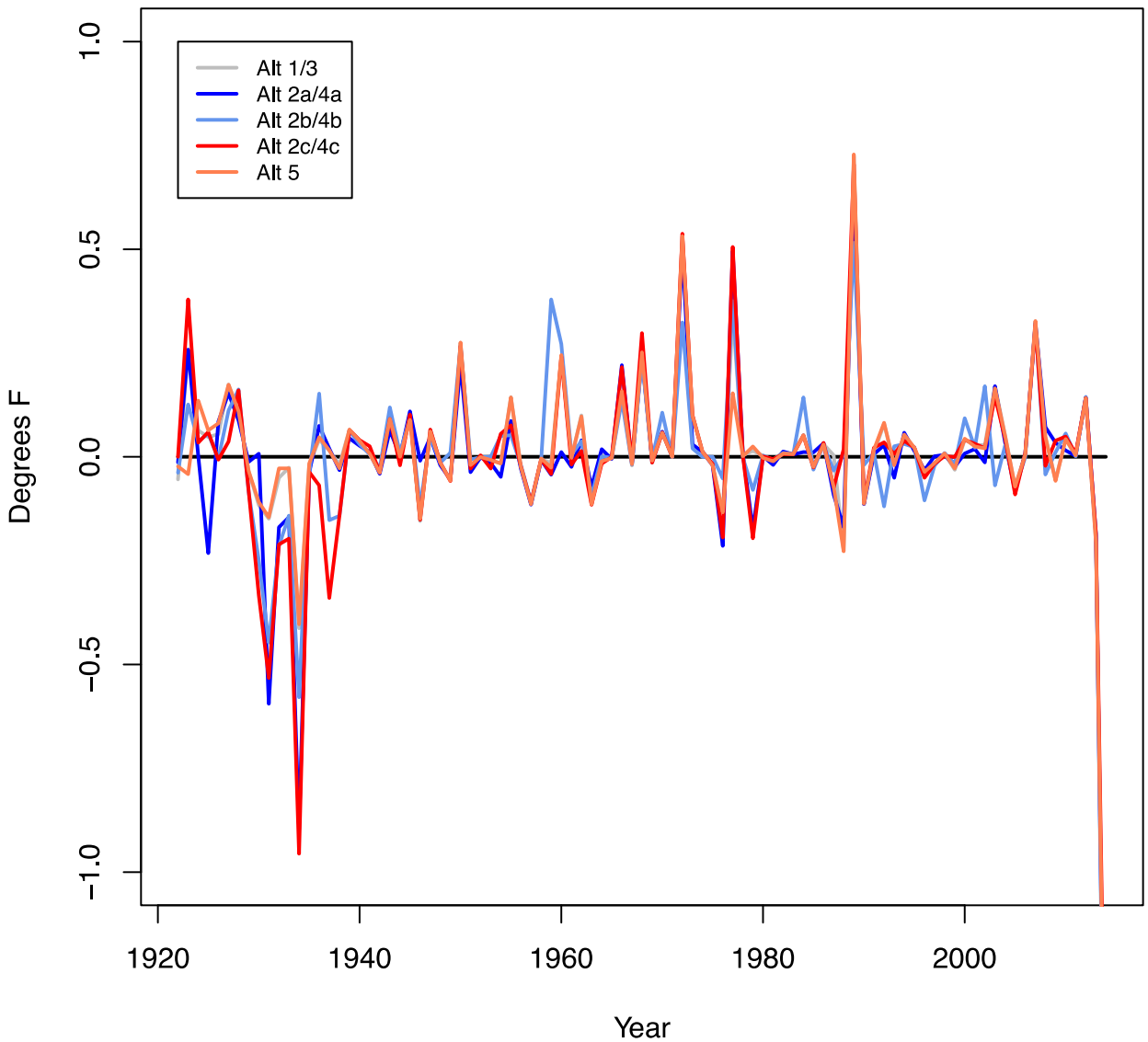


*Figure 8. Difference (Alt – EC) in temperature (degrees F) between the existing condition (EC) and the alternatives.*

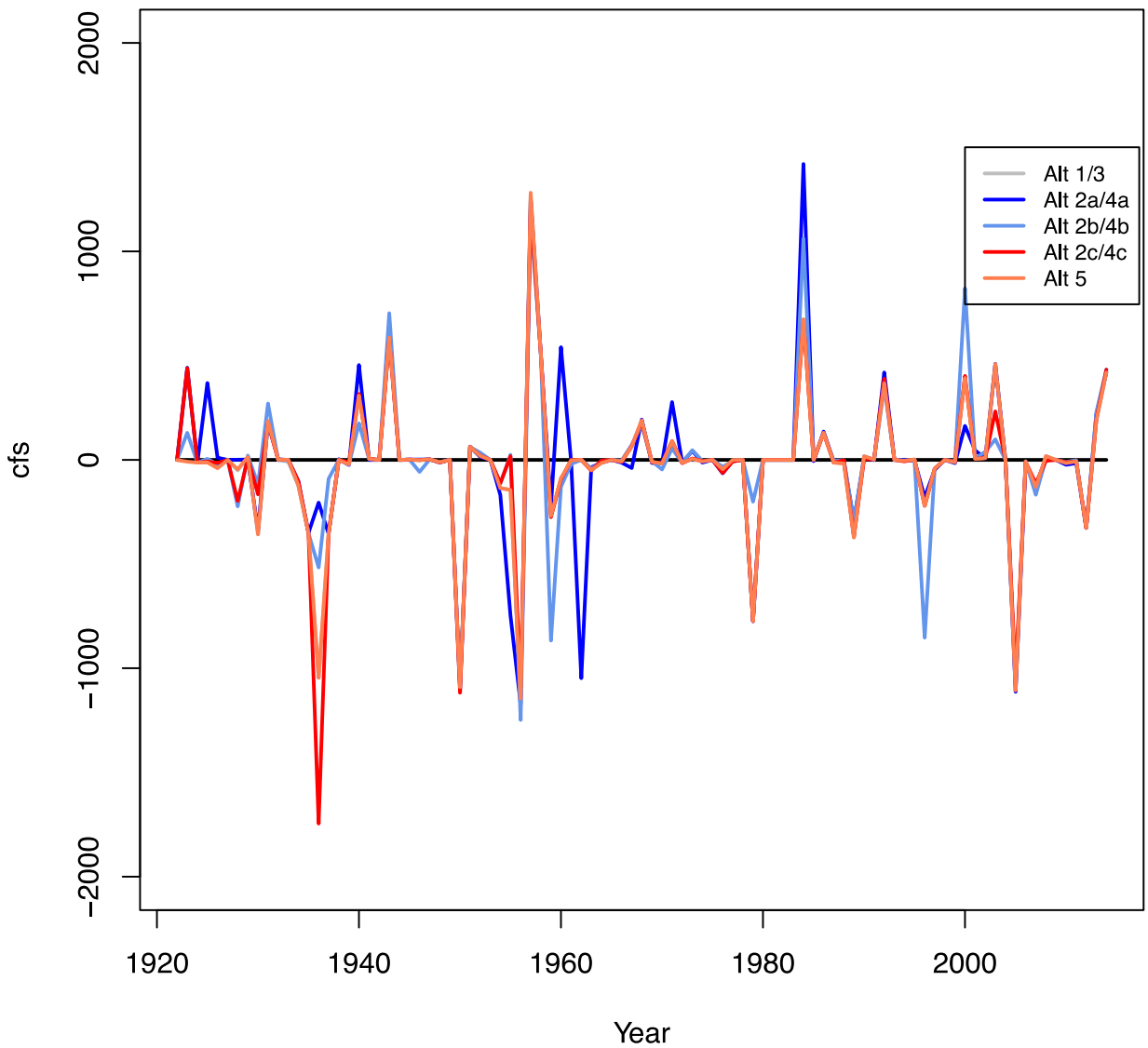


*Figure 9. Difference (Alt – EC) in flow (cubic feet per second, cfs) between the existing condition (EC) and the alternatives.*

The delta survival rates did not vary appreciably between the alternatives and the EC (Figure 6 and 7); therefore, we did not explore the role of those driver variables further.

**Sensitivity Analyses**

To understand the potential for effects associated with additional potential mortality associated with the north Delta diversions, the OBAN model was run with an assumed 5% and

10% mortality rates. The levels of mortality (5% and 10%) were implemented in the delta survival stage of the OBAN model. These levels of mortality were evaluated to understand how sensitive the population metrics of spawner abundance and quasi-extinction were to these different mortality assumptions. Of particular interest is the role that the additional mortality will have on the results of the Alt 2a/4a alternative, so we begin with this alternative.

Alt 2a/4a

The difference in median abundance was sensitive to the level of mortality associated with the diversion. The median difference in spawner abundance was greater than the EC on average under Alt 2a/4a with 0% mortality over the 1928 – 2014 period, whereas the median difference was less than the EC on average under the 5% and 10% mortality level (Figure 10).

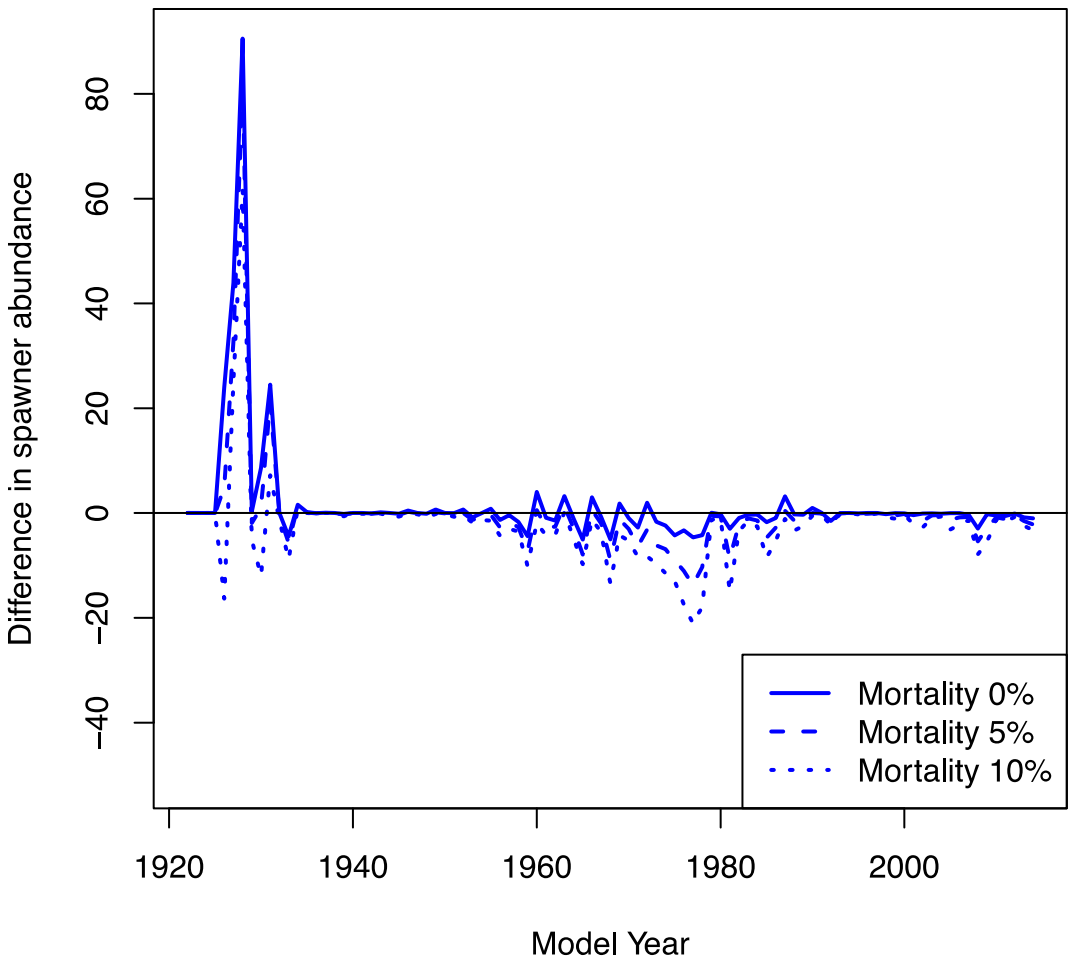


*Figure 10. Difference (Alternative – EC) in median spawner abundance for model years 1922 – 2014 with mortality sensitivities. Positive values indicate higher abundances under alternatives relative to the baseline existing condition (EC).*

The lower spawner abundances calculated in the OBAN model for the 5% and 10% additional mortality levels also affected the probability of quasi-extinction (Figure 11). The assumed mortality associated with the diversions reduced the spawner abundance below the quasi-extinction threshold of 100 spawners. The effects of the additional mortality were most pronounced during the more productive periods of the 1950's – 1970's in spawner abundance (Figure 10) and also increased the probability of quasi-extinction in those years (Figure 11).

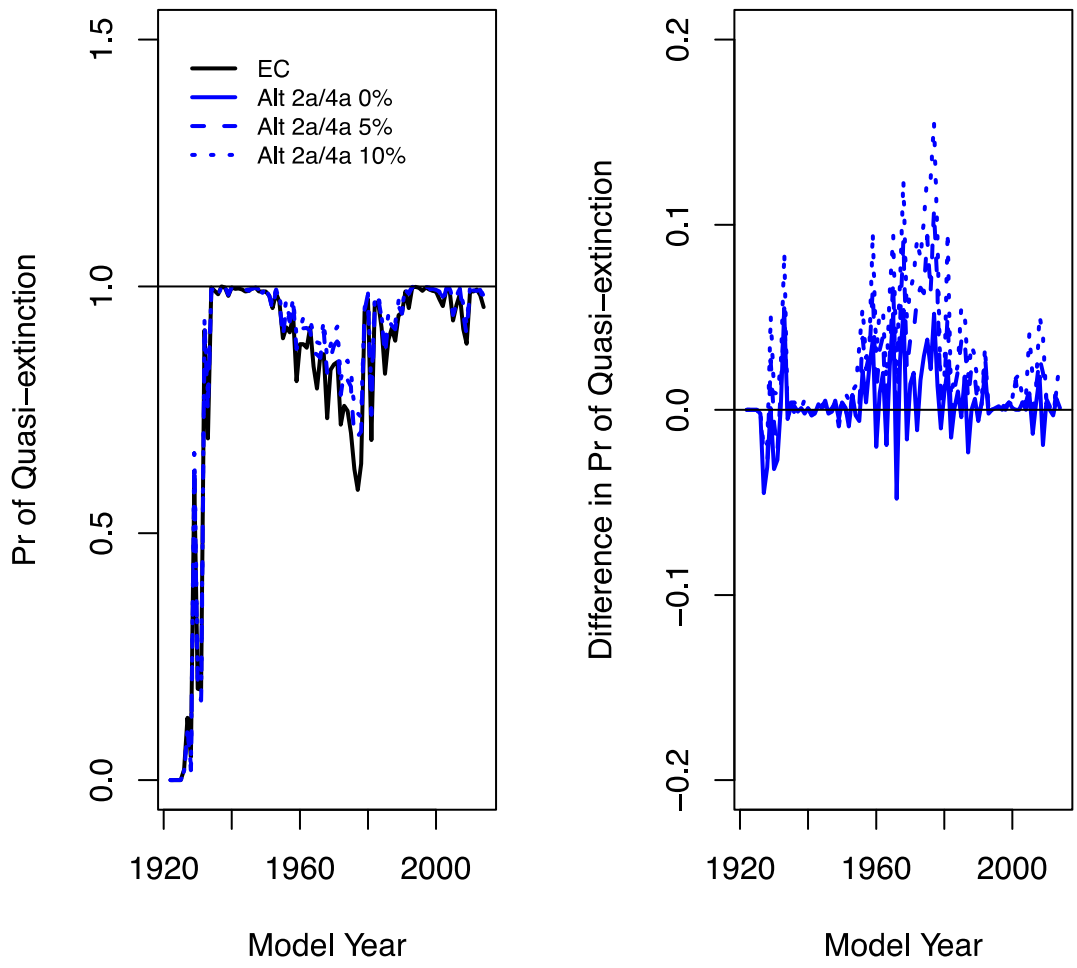


*Figure 11. Probability of quasi-extinction (spawner abundance < 100) showing the existing condition (EC) (black) and alternatives (left). Difference (Alt – EC) in the probability of quasi-extinction (right); thus, negative values indicate lower probability of quasi-extinction.*

Alt 1/3

The sensitivity analysis for Alt 1/3 gave lower abundances with the additional mortality assumptions included. As a result, the spawner abundances were lower than the EC for the 5% and 10% mortality levels (Figure 12). The levels of spawner abundance often decreased to levels below the quasi-extinction threshold of 100 spawners, which increased the probability of quasi-extinction relative to the EC (Figure 13).

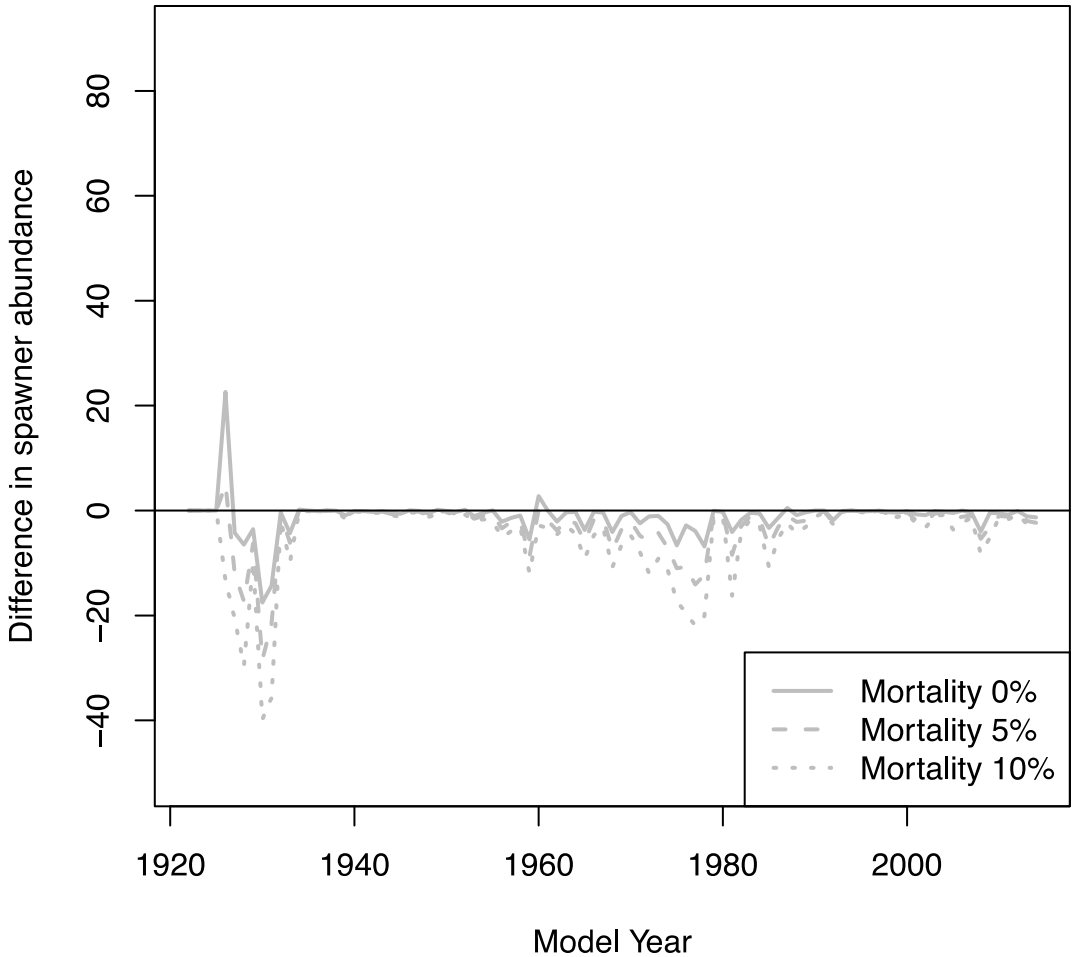


*Figure 12. Difference (Alternative – EC) in median spawner abundance for model years 1922 – 2014 with mortality sensitivities. Positive values indicate higher abundances under alternatives relative to the baseline existing condition (EC).*

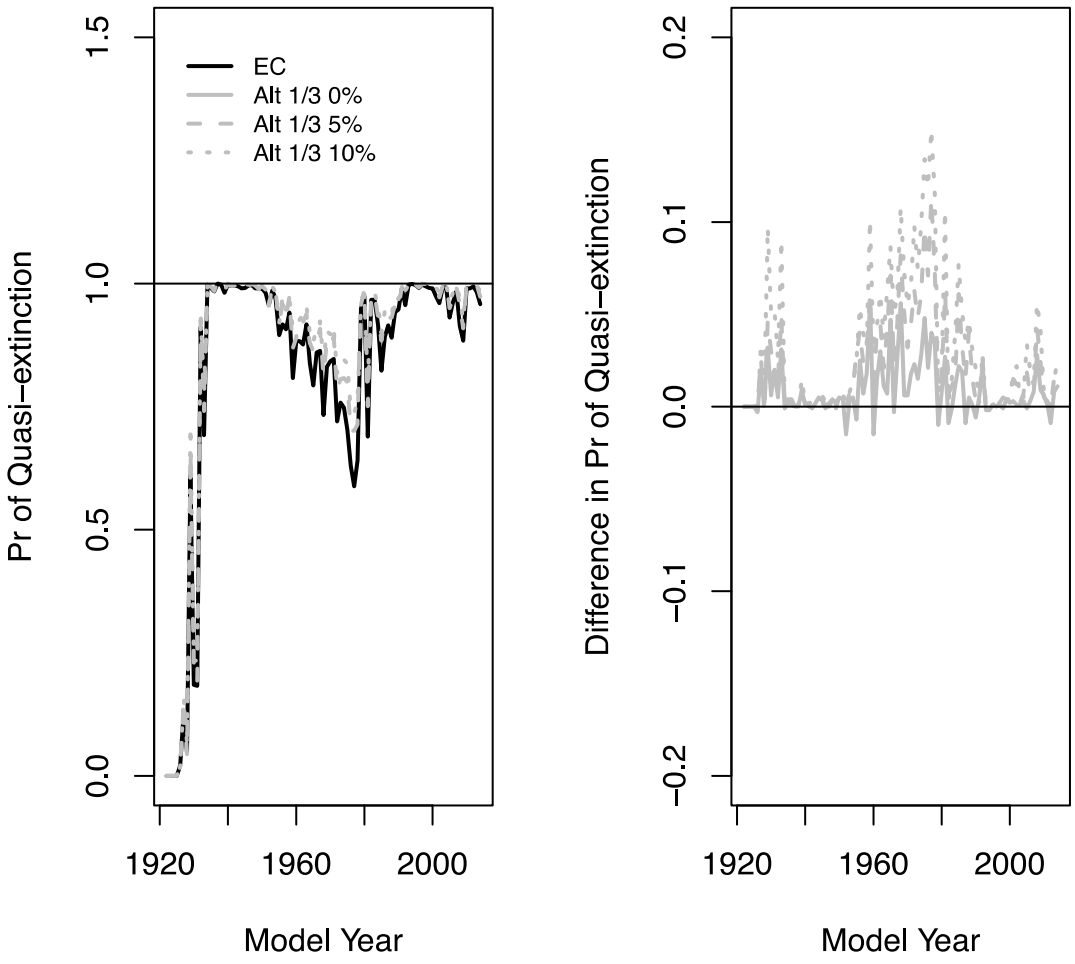


*Figure 13. Probability of quasi-extinction (spawner abundance < 100) showing the existing condition (EC) (black) and alternatives (left). Difference (Alt – EC) in the probability of quasi-extinction (right); thus, negative values indicate lower probability of quasi-extinction.*

Alt 2b/4b

The model results for Alt 2b/4b with the assumption of no mortality due to diversion indicated spawner abundances were lower under Alt 2b/4b compared to the EC. The results for Alt 2b/4b under increased mortality were likewise lower than the EC (Figure 14). The additional mortality decreased the abundance to below 100 spawners in many of the Monte Carlo iterations, thus increasing the probability of quasi-extinction (Figure 15).

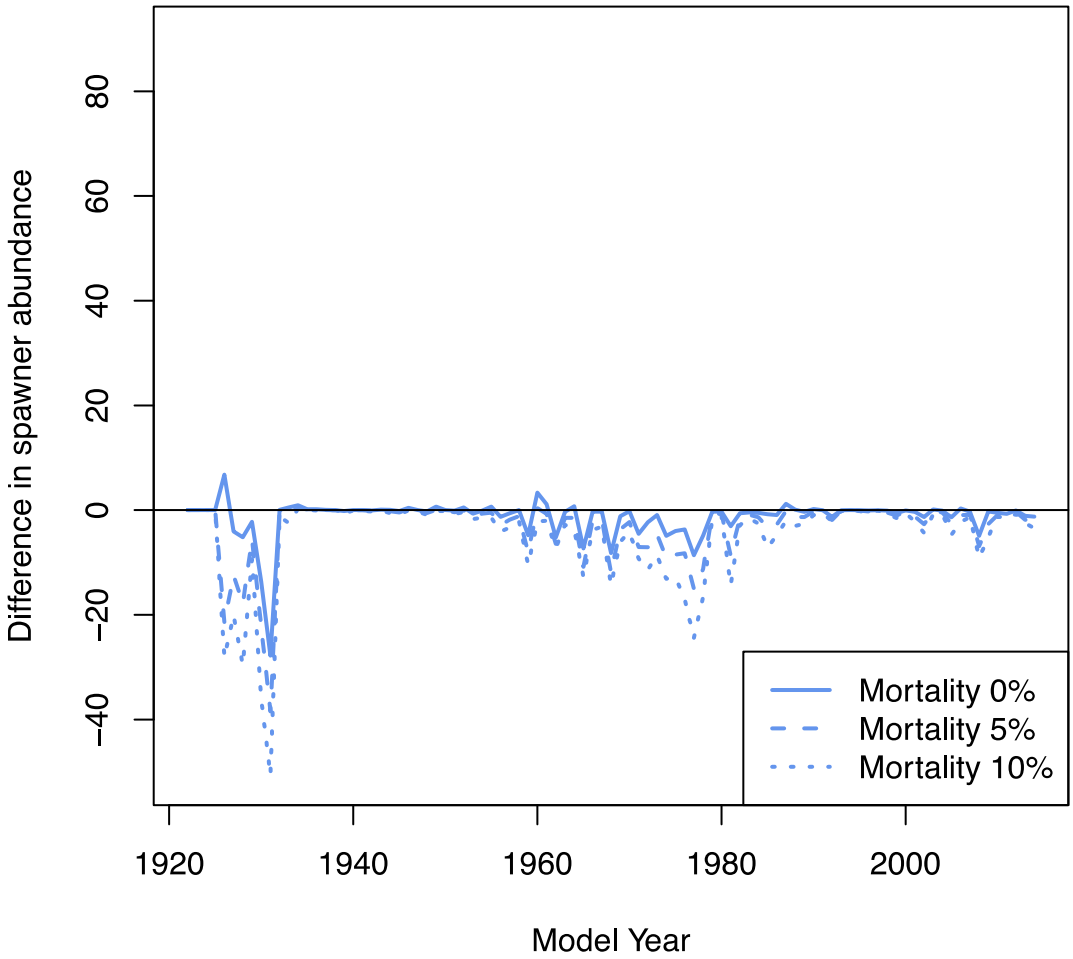


*Figure 14. Difference (Alternative – EC) in median spawner abundance for model years 1922 – 2014 with mortality sensitivities. Positive values indicate higher abundances under alternatives relative to the baseline existing condition (EC).*

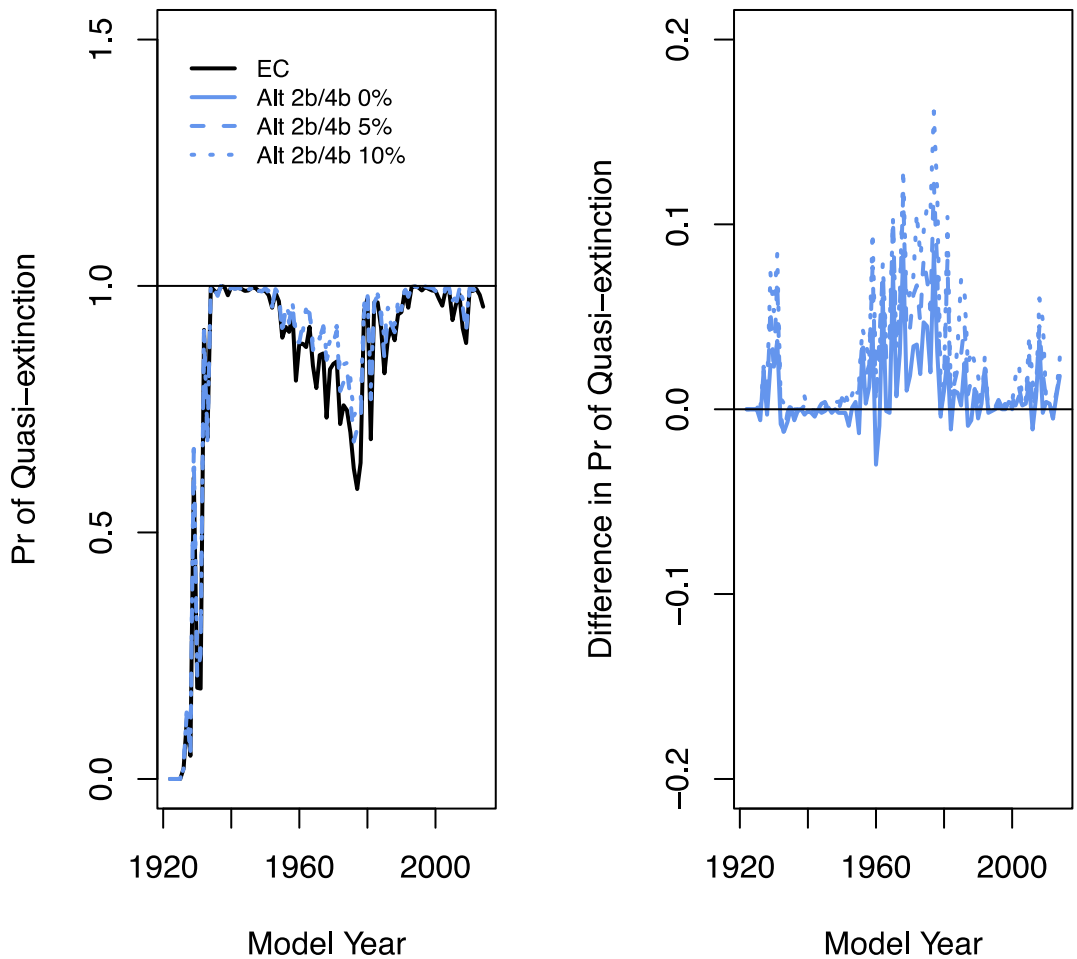


*Figure 15. Probability of quasi-extinction (spawner abundance < 100) showing the existing condition (EC) (black) and alternatives (left). Difference (Alt – EC) in the probability of quasi-extinction (right); thus, negative values indicate lower probability of quasi-extinction.*

Alt 2c/4c

The model results for Alt 2c/4c were similar in magnitude to Alt 1/3.. The results of the sensitivity analysis for Alt 2c/4c indicated decreases in the spawner abundance relative to the EC as the additional mortality rate increased (Figure 16). As a result of the lower abundance, the probability of quasi-extinction increased under the higher mortality levels (Figure 17).

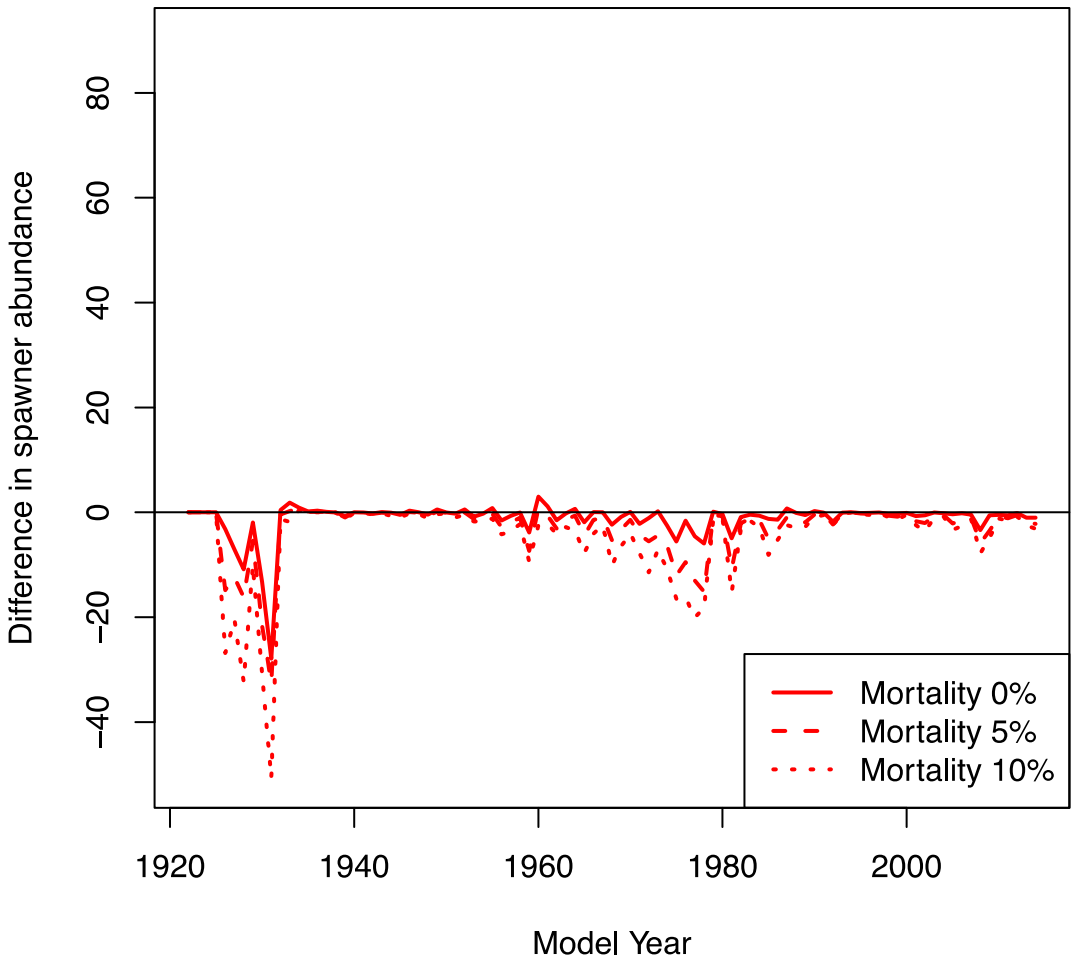


*Figure 16. Difference (Alternative – EC) in median spawner abundance for model years 1922 – 2014 with mortality sensitivities. Positive values indicate higher abundances under alternatives relative to the baseline existing condition (EC).*

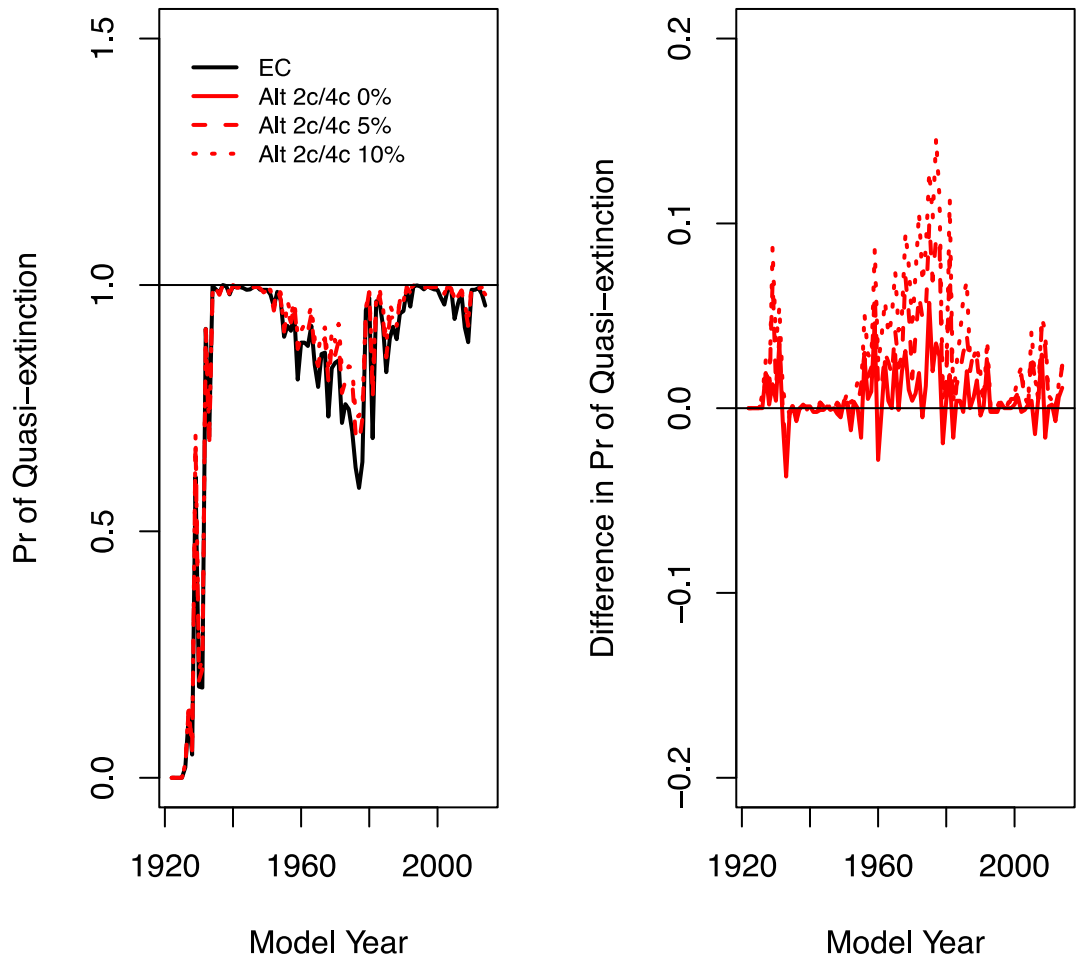


*Figure 17. Probability of quasi-extinction (spawner abundance < 100) showing the existing condition (EC) (black) and alternatives (left). Difference (Alt – EC) in the probability of quasi-extinction (right); thus, negative values indicate lower probability of quasi-extinction.*

Alt 5

The final alternative, Alt 5, had average spawner abundances that were below the EC with additional mortality assumed to be 0%. When the additional mortality rate was assumed to be 5% and 10%, the average Alt 5 spawner abundances decreased to levels below the EC on average, but particularly for years 1960 - 1985 (Figure 18). As in previous evaluations of the additional mortality, the decrease in spawner abundances resulted in increased probabilities of quasi-extinction due to the additional mortality levels (Figure 19).

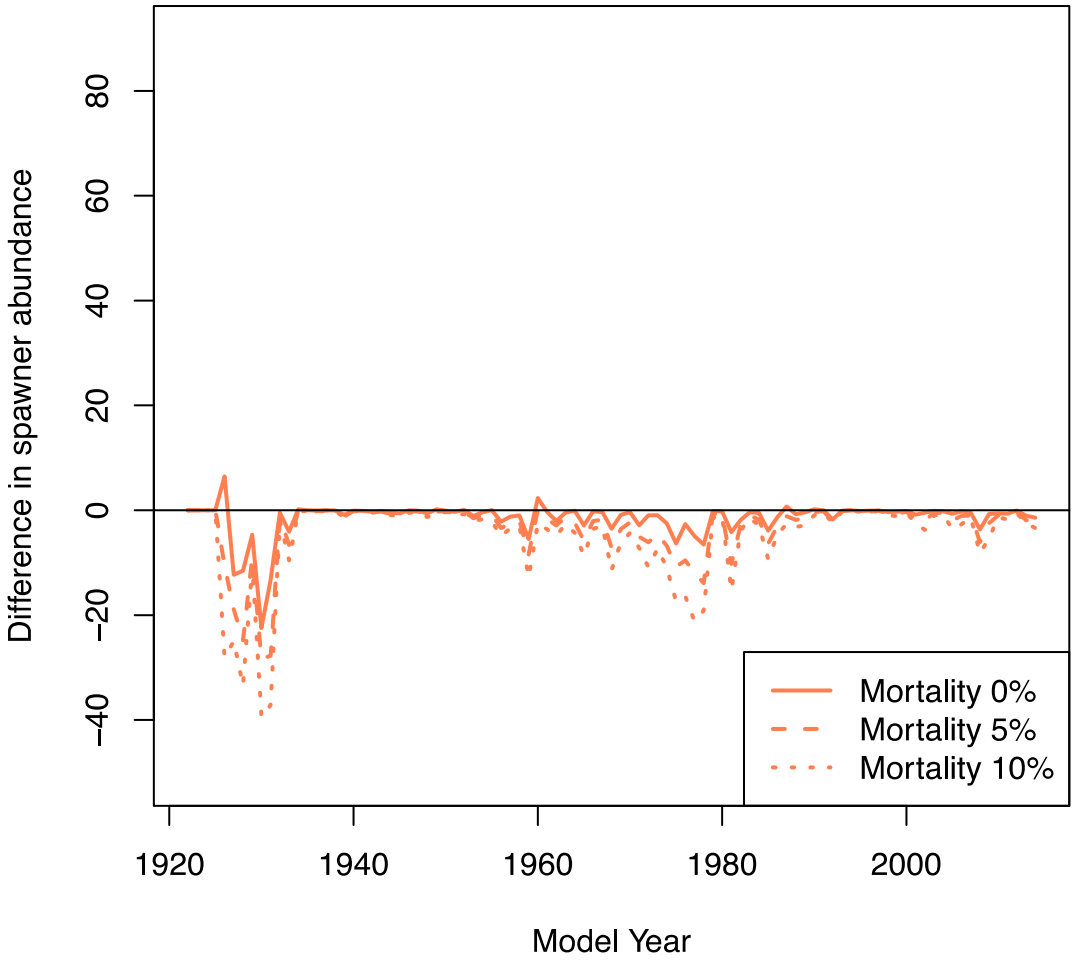


*Figure 18. Difference (Alternative – EC) in median spawner abundance for model years 1922 – 2014 with mortality sensitivities. Positive values indicate higher abundances under alternatives relative to the baseline existing condition (EC).*

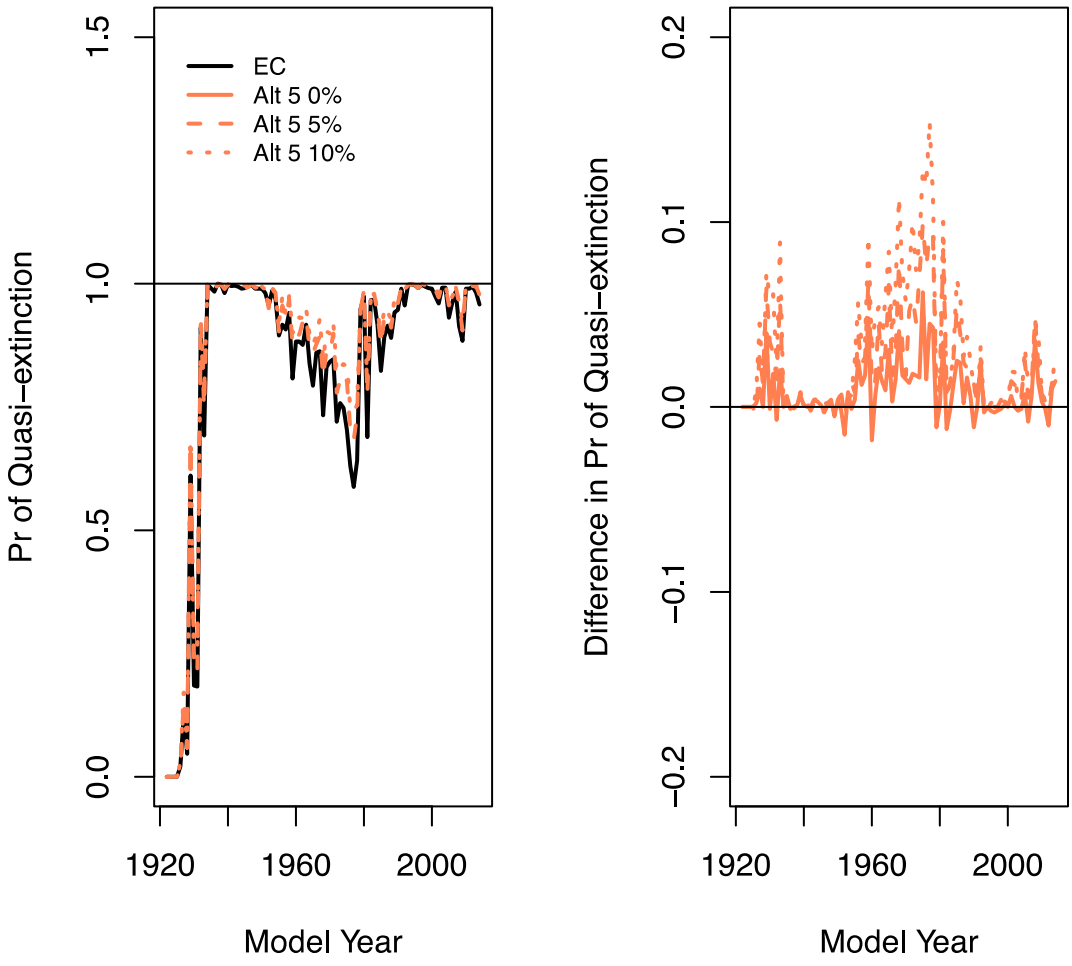


*Figure 19. Probability of quasi-extinction (spawner abundance < 100) showing the existing condition (EC) (black) and alternatives (left). Difference (Alt – EC) in the probability of quasi-extinction (right); thus, negative values indicate lower probability of quasi-extinction.*

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Attachment 5D.3

# Raw DSM2 Particle Tracking Modeling Output

## 5D.3.1 Introduction

File <postp2020np30d.xlsx> provided with this attachment includes the raw DSM2 particle tracking model (DSM2-PTM) outputs used in the analysis of delta smelt larval entrainment provided in Appendix 5D, *Bay-Delta Methods and Results* (see Section 5D.10, *Delta Smelt Larval Entrainment [DSM2 Particle Tracking Model]*). The sheets included in this file are as follows:

- 'insert': locations of particle insertion points, with the 'loc' in column A corresponding to the location used in other sheets
- 'output': a summary of some of the additional output locations computed, beyond standard outputs
- 'ex': results for the existing conditions scenario; columns include 'SimPeriod' (the insertion month of particles), 'SimLoc' (equivalent to 'loc' from 'insert' sheet), 'Export_CVP' (percentage of particles entrained at the Central Valley Project Jones Pumping Plant), 'Export_CCF' (percentage of particles entrained at the State Water Project Clifton Court Forebay), 'Export_IF' (percentage of particles entrained at the proposed north Delta intakes*), 'Past_MTZ' (percentage of particles that moved past Martinez), 'Past_Chipps' (percentage of particles that moved past Chipps Island), 'Diversion_Ag' (percentage of particles entrained by agricultural diversions*), 'To_NBA' (percentage of particles entrained at the State Water Project North Bay Aqueduct Barker Slough Pumping Plant), 'Other_Div' (percentage of particles entrained at other diversions), 'In_Delta' (percentage of particles remaining within the Delta), 'Total' (total percentage of particles), 'East_Chipps' (percentage of particles east of Chipps Island), 'SJR_to_South_Delta' (percentage of particles moving from San Joaquin River into the south Delta), 'mon' (month), 'node' (DSM2 node; see 'insert' sheet), and 'insert' (name of insertion location; see also 'insert' sheet)
- 'pa3k': results for EIR/EIS Alternatives 2b/4b, with columns as described above for the existing conditions scenario
- 'pa4k5': results for EIR/EIS Alternatives 2c/4c, with columns as described above for the existing conditions scenario
- 'pa6k': results for EIR/EIS Alternatives 1/3, with columns as described above for the existing conditions scenario
- 'pa6kb': results for EIR/EIS Alternative 5, corresponding to the proposed action, with columns as described above for the existing conditions scenario
- 'pa7k5': results for EIR/EIS Alternatives 2a/4a, with columns as described above for the existing conditions scenario
- 'pa3k-ex' through 'pa7k5-ex': absolute differences between each alternative and existing conditions, using the naming scheme for scenarios as above

* These locations were turned off as sources of entrainment, but the hydrodynamic effects of their diversions on channel flows and particle movement were retained.

Attachment 5D.4
# Delta Smelt Life Cycle Modeling

## 5.D4.1 Introduction

This attachment discusses analysis of potential effects on delta smelt of the proposed action compared to existing conditions using the Life Cycle Model with Entrainment (LCME) (Smith et al. 2021).

## 5.D4.2 Methods

The LCME estimates annual population replacement rate (lambda) as a function of various covariates acting on six different life stages. R statistical software (R Core Team 2023) model code was provided by the lead author (Smith pers. comm.). Coordination was undertaken with the model authors to establish the appropriate application of the model for the comparison of the proposed action to existing conditions modeling scenarios. Although the LCME includes numerous covariates (see Table 1 of Smith et al. 2021), the appropriate use of the model indicated by the authors was to focus on CalSim-modeled inputs for several Old and Middle River flow covariates (Tables 5D.4-1 and 5D.4-2) and June–August Delta outflow (Table 5D.4-3), leaving other covariates at historical values for the 1995–2015 modeling period.

**Table 5D.4-1. Old and Middle River Flow Inputs (cubic feet per second) for Delta Smelt LCME Modeling, Existing Conditions**

| Cohort Year | Early Postlarval (PL1); April–May | Late Postlarval (PL2); June | Early Subadult (SA1); December–January | Late Subadult (SA2); February | Early Adult (A1); March |
|---|---|---|---|---|---|
| 1995 | -2,165 | -4,593 | -4,903 | -4,061 | -3,258 |
| 1996 | -2,567 | -5,000 | 7,854 | 2,263 | -3,258 |
| 1997 | -1,967 | -4,646 | -6,600 | 2,697 | 2,274 |
| 1998 | 303 | -2,968 | -4,903 | -4,464 | -3,258 |
| 1999 | -2,143 | -5,000 | -5,387 | -4,483 | -3,258 |
| 2000 | -1,912 | -4,746 | -5,593 | -4,464 | -3,258 |
| 2001 | -1,756 | -5,000 | -4,903 | -4,464 | -3,258 |
| 2002 | -1,891 | -5,000 | -4,903 | -4,464 | -3,258 |
| 2003 | -1,868 | -5,000 | -4,903 | -4,483 | -3,258 |
| 2004 | -1,869 | -5,000 | -4,903 | -4,464 | -3,258 |
| 2005 | -2,167 | -5,000 | -4,903 | -4,464 | -1,408 |
| 2006 | 3,229 | -4,206 | -7,383 | -4,464 | -3,258 |
| 2007 | -1,933 | -5,000 | -3,918 | -4,483 | -3,258 |
| 2008 | -1,930 | -5,000 | -3,784 | -4,464 | -3,258 |
| 2009 | -1,911 | -5,000 | -3,636 | -4,464 | -3,258 |

| Cohort Year | Early Postlarval (PL1); April–May | Late Postlarval (PL2); June | Early Subadult (SA1); December–January | Late Subadult (SA2); February | Early Adult (A1); March |
|---|---|---|---|---|---|
| 2010 | -1,577 | -5,000 | -4,903 | -2,525 | 2,321 |
| 2011 | -1,976 | -4,250 | -5,195 | -4,192 | -3,258 |
| 2012 | -2,052 | -5,000 | -5,266 | -3,573 | -3,258 |
| 2013 | -1,930 | -5,000 | -1,652 | -5,000 | -4,516 |
| 2014 | -1,631 | -1,984 | -4,689 | -4,464 | -289 |
| 2015 | -1,285 | -1,339 | - | - | - |

**Table 5D.4-2. Old and Middle River Flow (cubic feet per second) Inputs for Delta Smelt LCME Modeling, Proposed Action**

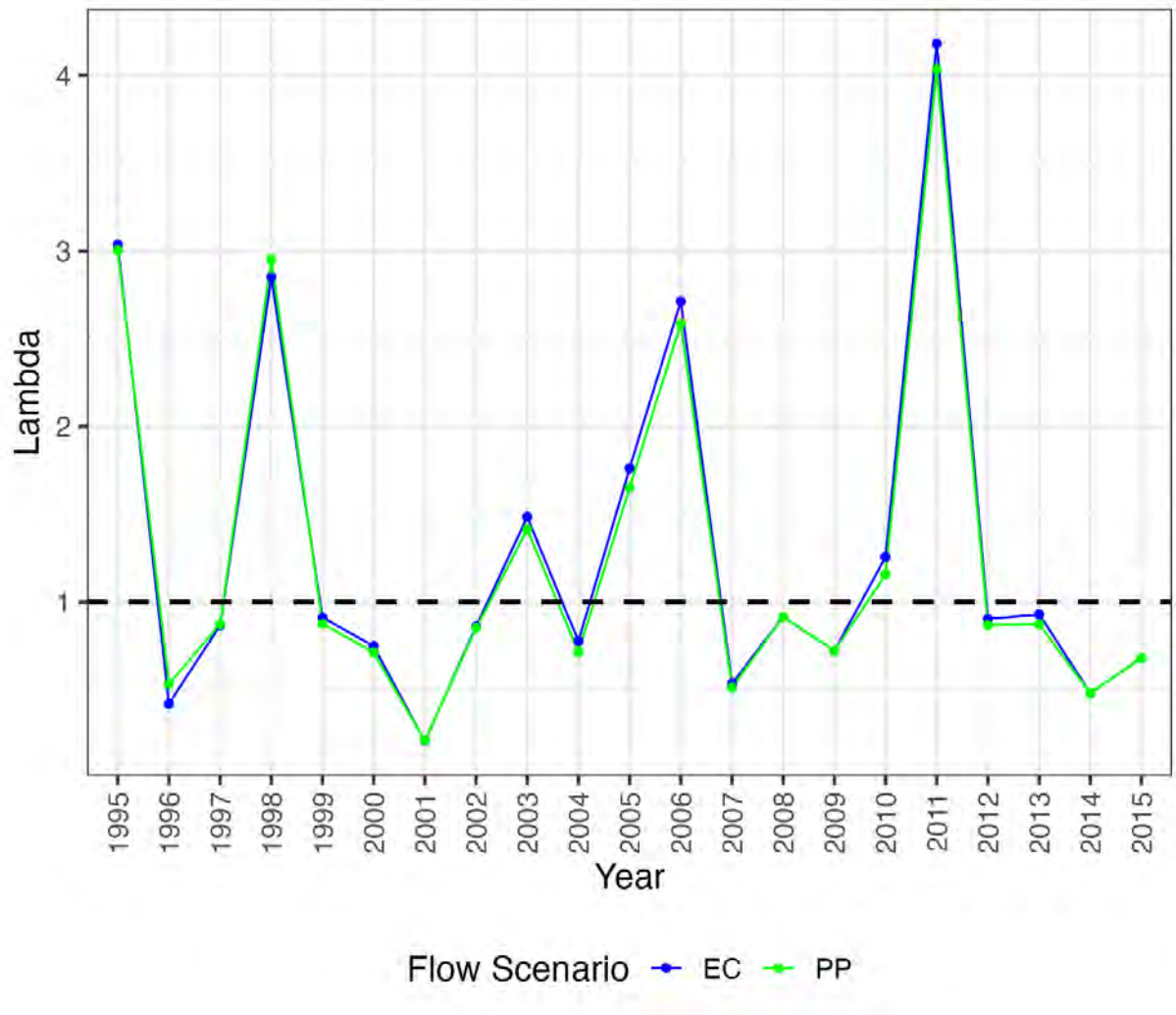
| Cohort Year | Early Postlarval (PL1); April–May | Late Postlarval (PL2); June | Early Subadult (SA1); December–January | Late Subadult (SA2); February | Early Adult (A1); March |
|---|---|---|---|---|---|
| 1995 | -1,389 | -4,586 | -4,903 | -2,117 | -3,074 |
| 1996 | -1,571 | -5,000 | 7,762 | 2,194 | -3,258 |
| 1997 | -1,677 | -4,484 | -6,599 | 5,617 | 2,730 |
| 1998 | 1,147 | -2,960 | -4,903 | -4,464 | -3,258 |
| 1999 | -2,339 | -5,000 | -5,448 | -4,483 | -3,258 |
| 2000 | -1,568 | -4,825 | -5,542 | -4,464 | -3,258 |
| 2001 | -1,750 | -5,000 | -4,903 | -4,464 | -3,248 |
| 2002 | -1,917 | -5,000 | -4,903 | -4,464 | -3,250 |
| 2003 | -1,867 | -5,000 | -4,903 | -4,483 | -3,258 |
| 2004 | -2,074 | -4,943 | -4,903 | -4,464 | -3,258 |
| 2005 | -2,158 | -5,000 | -4,903 | -4,236 | -454 |
| 2006 | 3,247 | -4,196 | -7,382 | -4,464 | -3,246 |
| 2007 | -1,945 | -5,000 | -3,886 | -4,483 | -3,258 |
| 2008 | -1,931 | -5,000 | -3,189 | -4,464 | -3,258 |
| 2009 | -1,933 | -5,000 | -3,379 | -4,464 | -3,236 |
| 2010 | -1,876 | -5,000 | -4,903 | -2,647 | 2,150 |
| 2011 | -1,971 | -4,239 | -5,201 | -4,198 | -3,258 |
| 2012 | -2,053 | -5,000 | -5,266 | -4,925 | -3,253 |
| 2013 | -1,947 | -5,000 | -1,471 | -5,000 | -4,509 |
| 2014 | -1,581 | -1,307 | -4,728 | -4,464 | -286 |
| 2015 | -1,293 | -1,334 | - | - | - |

**Table 5D.4-3. June–August Delta Outflow (1,000 cubic meters) Inputs for Delta Smelt LCME Modeling**

| Cohort Year | Existing Conditions | Proposed Action |
|---|---|---|
| 1995 | 5,220,530 | 4,944,108 |
| 1996 | 1,578,651 | 1,524,948 |
| 1997 | 1,525,580 | 1,496,027 |
| 1998 | 7,873,416 | 7,627,768 |
| 1999 | 1,638,299 | 1,532,051 |
| 2000 | 1,507,053 | 1,419,177 |
| 2001 | 978,750 | 978,705 |
| 2002 | 1,106,312 | 1,086,791 |
| 2003 | 1,502,987 | 1,395,495 |
| 2004 | 1,792,315 | 1,603,048 |
| 2005 | 2,481,072 | 2,282,283 |
| 2006 | 2,723,588 | 2,551,726 |
| 2007 | 1,200,302 | 1,114,516 |
| 2008 | 896,899 | 897,182 |
| 2009 | 1,255,605 | 1,255,543 |
| 2010 | 1,604,832 | 1,431,273 |
| 2011 | 5,642,130 | 5,300,240 |
| 2012 | 1,222,161 | 1,140,155 |
| 2013 | 1,240,842 | 1,126,271 |
| 2014 | 964,121 | 964,111 |
| 2015 | 974,468 | 974,529 |

# 5.D4.3 Results

The results of the LCME modeling showed that median population growth rate generally ranged from similar to 8% lower under the proposed action compared to existing conditions (Figure 5D.4-1, Table 5D.4-4). The proportion of the proposed action population growth rate posterior distribution that was lower than existing conditions was generally close to 0.500, ranging from 0.463 in 1996 to over 0.51 in several years (Table 5D.4-4). The model authors suggested during coordination on use of the method that particular focus be placed on the years following implementation of the 2009 Biological Opinion, during which factors such as Old and Middle River flow management changed. During this time period, the difference between scenarios ranged from 0% to 8% lower under the proposed action, with around 0.500 to 0.51 of the posterior distribution being lower under the proposed action than existing conditions (Figure 5D.4-1, Table 5D.4-4).




Note: EC = existing conditions; PP = proposed action; median is 50th percentile of posterior distribution by year.

**Figure 5D.4-1. Median Population Growth Rate (Lambda) from Delta Smelt LCME Modeling**

**Table 5D.4-4. Median, Percentage Difference (Proposed Action minus Existing Conditions), and Proportion of Posterior Distribution with Proposed Action Less than Existing Conditions in Population Growth Rate from Delta Smelt LCME Modeling**

| Cohort Year | Existing Conditions | Proposed Action | Percentage Difference | Proportion of Posterior Distribution Less Under Proposed Action |
|---|---|---|---|---|
| 1995 | 3.04 | 3.00 | -1% | 0.501 |
| 1996 | 0.42 | 0.53 | 27% | 0.463 |
| 1997 | 0.87 | 0.87 | 1% | 0.499 |
| 1998 | 2.85 | 2.95 | 4% | 0.493 |
| 1999 | 0.91 | 0.87 | -4% | 0.503 |
| 2000 | 0.75 | 0.71 | -5% | 0.512 |
| 2001 | 0.21 | 0.21 | 1% | 0.499 |

| Cohort Year | Existing Conditions | Proposed Action | Percentage Difference | Proportion of Posterior Distribution Less Under Proposed Action |
|---|---|---|---|---|
| 2002 | 0.86 | 0.85 | -1% | 0.500 |
| 2003 | 1.48 | 1.41 | -5% | 0.510 |
| 2004 | 0.78 | 0.71 | -8% | 0.516 |
| 2005 | 1.76 | 1.65 | -6% | 0.513 |
| 2006 | 2.71 | 2.59 | -5% | 0.508 |
| 2007 | 0.53 | 0.51 | -4% | 0.506 |
| 2008 | 0.91 | 0.91 | 0% | 0.500 |
| 2009 | 0.72 | 0.72 | 0% | 0.499 |
| 2010 | 1.26 | 1.16 | -8% | 0.511 |
| 2011 | 4.18 | 4.04 | -3% | 0.507 |
| 2012 | 0.90 | 0.87 | -4% | 0.507 |
| 2013 | 0.93 | 0.87 | -6% | 0.512 |
| 2014 | 0.48 | 0.48 | 0% | 0.500 |
| 2015 | 0.68 | 0.68 | 0% | 0.500 |

# 5.D4.4 References Cited

## 5D.4.4.1 Printed References

R Core Team. 2023. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. Available: https://www.R-project.org.

Smith, W. E., L. Polansky, and M. L. Nobriga. 2021. Disentangling Risks to an Endangered Fish: Using a State-Space Life Cycle Model to Separate Natural Mortality from Anthropogenic Losses. *Canadian Journal of Fisheries and Aquatic Sciences* 78(8):1008–1029.

## 5D.4.4.2 Personal Communications

Smith, William. Statistician, San Francisco Bay-Delta Fish and Wildlife Office, US Fish and Wildlife Service, Sacramento, CA. February 13, 2023—Email containing R code (<LCME postprocessing predictions for DCP.R>) for LCME sent to Marin Greenwood, Aquatic Ecologist, ICF, Sacramento, CA.

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# Appendix 5E
# Fish and Aquatic Resources Year 2040 Analysis

This appendix compares existing conditions at 2040 to the proposed action at 2040 using modeling tools and methods appropriate for the evaluation of impacts on fish and aquatic resources. Modeling for the existing conditions at 2040 and proposed action at 2040 incorporates assumptions regarding changes to hydrology and sea level rise as a result of climate change. Information regarding how climate change was considered in the modeling is provided in the *Delta Conveyance Project Final Environmental Impact Report* (Final EIR) Appendix 5A, *Modeling Technical Appendix* (California Department of Water Resources 2023). The analysis in this appendix is provided for informational purposes to help decision-makers better understand the effects analyses.

## 5E.1 Impacts Analysis

### 5E.1.1 Effects of Construction of Water Conveyance Facilities on Special-Status Fish Species

The effects of construction of water conveyance facilities on special-status fish species are described in Chapter 5, *Effects Analysis for Chinook Salmon, California Central Valley Steelhead, Green Sturgeon, and Killer Whale,* Section 5.4, *Effects of Water Facility Construction on Chinook Salmon, Central Valley Steelhead, and Green Sturgeon,* and for delta smelt described in Chapter 6, *Effects Analysis for Delta Smelt, Longfin Smelt, and Terrestrial Species,* Section 6.1.1, *Effects of Construction Activities on Delta Smelt,* and Section 6.2.1, *Effects of Construction Activities on Longfin Smelt.* Construction of the proposed action would be complete by 2039; thus, there would be no construction-related impacts on fish and aquatic species at 2040.

### 5E.1.2 Effects of Water Facility Construction on Designated Critical Habitat

The effects of construction of water conveyance facilities on critical habitat for winter-run Chinook salmon, spring-run Chinook salmon, steelhead, and green sturgeon are described in Chapter 5, Section 5.5, *Effects of Water Facility Construction on Designated Critical Habitat*, and for delta smelt and longfin smelt are described in Chapter 6, Section 6.1.2, *Effects of Construction Activities on Delta Smelt Critical Habitat.* Construction of the proposed action would be complete by 2039; thus, there would be no construction-related impacts on fish and aquatic species at 2040.

### 5E.1.3 Effects of Operations and Maintenance of Water Conveyance Facilities on Sacramento River Winter-Run Chinook Salmon

The effects of operations and maintenance of water conveyance facilities on winter-run Chinook salmon are described in Appendix 5C, *Operations and Maintenance Effects Analysis for Chinook Salmon, California Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5C.7, *Effects of*

*Operations and Maintenance of Water Conveyance Facilities on Sacramento River Winter-Run Chinook Salmon*. The impact mechanisms at 2040 remains the same as at 2020. Table 5E.1-1 summarizes quantitative analyses and differences between 2040 (i.e., existing conditions vs. the proposed action) and 2020 (i.e., existing conditions vs. the proposed action).

**Table 5E.1-1. Summary of Winter-Run Chinook Salmon Quantitative Analyses and Differences at 2040 Relative to 2020**

| Effect/Method | 2040 Results [a] | 2020 Results [b] | Differences |
|---|---|---|---|
| Juvenile south Delta entrainment/ salvage-density method | Tables 5E.1-2 and 5E.1-3 | Tables 5C.7-8 and 5C.7-9 | Generally similar,[c] with some slightly lower differences at 2040. In spring, exports at CVP Jones Pumping Plant are greater because regulatory control has shifted to Delta export/inflow ratio due to north Delta exports, leading to a shift in exports in the south Delta from SWP Banks Pumping Plant to CVP Jones Pumping Plant to satisfy Coordinated Operation Agreement sharing requirements. This occurs especially in March of below-normal and dry years. In this case, overall south Delta exports do not change, but there is a shift from SWP Banks Pumping Plant to CVP Jones Pumping Plant. |
| Juvenile south Delta entrainment/ Zeug and Cavallo (2014) | Table 5E.1-6 | Table 5C.7-10 | Similar |
| Channel velocity/DSM2 | Table 5E.1-7 | Table 5C.7-11 | Generally similar, with some exceptions (e.g., smaller differences at 2040 in September of dry years, November and January of critically dry years, and June of wet and above normal years; larger difference at 2040 in February, March, and April of dry years) |
| Reverse flow downstream of Georgiana Slough/DSM2 | Table 5E.1-8 | Table 5C.7-12 | Generally similar, with some exceptions (e.g., smaller differences at 2040 in June of wet years; larger differences at 2040 in January, February, and May of dry years, and December and March of dry years) |
| Juvenile through-Delta survival/Perry et al. (2018) | Table 5E.1-9 | Table 5C.7-13 | Generally similar, except smaller differences at 2040 (September in below normal years, June in wet and above normal years) and larger differences at 2040 (October in below normal years, February in dry years) |
| Juvenile through-Delta survival/Delta Passage Model | Table 5E.1-10 | Table 5C.7-15 | Generally similar, except slightly larger differences at 2040 in dry years |
| Riparian and wetland bench inundation/DSM2 | Tables 5E.1-11 and 5E.1-12 | Tables 5C.7-16 and 5C.7-17 | Generally similar or smaller difference at 2040 than 2020 |
| Water temperature/DSM2 | Tables 5E.1-13, 5E.1-14, and 5E.1-15 | Tables 5C.7-18, 5C.7-19, and 5C.7-20 | Same (zero difference) |
| Adult female escapement/IOS | Table 5E.1-16 | Table 5C.7-21 | Generally similar or larger differences at 2040 than 2020 |

| Effect/Method | 2040 Results [a] | 2020 Results [b] | Differences |
|---|---|---|---|
| Juvenile through-Delta survival/IOS | Table 5E.1-17 | Table 5C.7-22 | Generally similar with larger differences at 2040 in dry years |
| Egg survival/IOS | Table 5E.1-18 | Table 5C.7-23 | Generally similar or slightly larger differences at 2040 in critically dry years |
| Fry survival/IOS | Table 5E.1-19 | Table 5C.7-24 | Similar |
| River survival/IOS | Table 5E.1-20 | Table 5C.7-25 | Similar |
| Adult escapement/OBAN | Table 5E.1-21 | Table 5C.7-26 | Lower relative difference at 2040 than 2020, somewhat different ranking of mean difference (e.g., proposed action has the largest negative difference at 2020 but similar/low positive at 2040) |
| Spawner abundance, freshwater productivity, and cohort replacement rate/Winter-Run Chinook Salmon Life Cycle Model | Table 5E.1-22 | Table 5C.7-27 | Similar or slightly lower difference at 2040 than 2020 |

[a] Results for 2040 are provided in this appendix.

[b] Results for 2020 are provided in Appendix 5C, *Operations and Maintenance Effects Analysis for Chinook Salmon, California Central Valley Steelhead, Green Sturgeon, and Killer Whale.*

[c] Throughout this appendix, the term *similar* is generally taken to mean differences within a few percentage points (i.e., relative percentage difference between the proposed action and existing conditions at 2040 compared to relative percentage difference between the proposed action and existing conditions at 2020 generally is no more than 5% or so), although this is not necessarily applied in situations where small changes to low absolute differences may give relatively large relative changes.

### Table 5E.1-2. Entrainment Loss of Juvenile Winter-Run Chinook Salmon at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 2,246 | 2,050 (-9%) |
| Above normal | N/A | (-1%) |
| Below normal | 1,589 | 1,560 (-2%) |
| Dry | 918 | 868 (-5%) |
| Critically dry | 924 | 880 (-5%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions.

EC = existing conditions; N/A = not applicable; SWP = State Water Project.

### Table 5E.1-3. Entrainment Loss of Juvenile Winter-Run Chinook Salmon At CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 222 | 220 (-1%) |
| Above normal | N/A | (0%) |
| Below normal | 464 | 491 (6%) |
| Dry | 271 | 288 (6%) |
| Critically dry | 72 | 72 (0%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between

percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions.
CVP = Central Valley Project; EC = existing conditions; N/A = not applicable.

### Table 5E.1-4. Entrainment Loss of Juvenile Winter-Run Chinook Salmon at SWP Banks Pumping Plant, Averaged by Water Year Type and Month, Based on the Salvage-Density Method

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Wet | Jan | 196 | 196 (0%) |
| Wet | Feb | 521 | 497 (-5%) |
| Wet | Mar | 1,246 | 1,088 (-13%) |
| Wet | Apr | 102 | 88 (-13%) |
| Wet | May | 3 | 3 (1%) |
| Wet | Jun | 0 | 0 (0%) |
| Wet | Jul | 0 | 0 (0%) |
| Wet | Aug | 0 | 0 (0%) |
| Wet | Sep | 0 | 0 (0%) |
| Wet | Oct | 0 | 0 (0%) |
| Wet | Nov | 0 | 0 (0%) |
| Wet | Dec | 178 | 178 (0%) |
| Above normal | Jan | N/A | (0%) |
| Above normal | Feb | N/A | (6%) |
| Above normal | Mar | N/A | (-4%) |
| Above normal | Apr | N/A | (0%) |
| Above normal | May | N/A | (0%) |
| Above normal | Jun | N/A | (0%) |
| Above normal | Jul | N/A | (0%) |
| Above normal | Aug | N/A | (0%) |
| Above normal | Sep | N/A | (0%) |
| Above normal | Oct | N/A | (0%) |
| Above normal | Nov | N/A | (0%) |
| Above normal | Dec | N/A | (-3%) |
| Below normal | Jan | 201 | 200 (0%) |
| Below normal | Feb | 622 | 635 (2%) |
| Below normal | Mar | 718 | 680 (-5%) |
| Below normal | Apr | 33 | 29 (-12%) |
| Below normal | May | 11 | 12 (6%) |
| Below normal | Jun | 0 | 0 (0%) |
| Below normal | Jul | 0 | 0 (0%) |
| Below normal | Aug | 0 | 0 (0%) |
| Below normal | Sep | 0 | 0 (0%) |
| Below normal | Oct | 0 | 0 (0%) |
| Below normal | Nov | 0 | 0 (0%) |
| Below normal | Dec | 4 | 4 (-5%) |
| Dry | Jan | 103 | 103 (0%) |

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Dry | Feb | 115 | 118 (3%) |
| Dry | Mar | 543 | 503 (-7%) |
| Dry | Apr | 16 | 16 (0%) |
| Dry | May | 0 | 0 (0%) |
| Dry | Jun | 0 | 0 (0%) |
| Dry | Jul | 0 | 0 (0%) |
| Dry | Aug | 0 | 0 (0%) |
| Dry | Sep | 0 | 0 (0%) |
| Dry | Oct | 0 | 0 (0%) |
| Dry | Nov | 0 | 0 (0%) |
| Dry | Dec | 140 | 128 (-9%) |
| Critically dry | Jan | 79 | 86 (9%) |
| Critically dry | Feb | 107 | 105 (-1%) |
| Critically dry | Mar | 639 | 589 (-8%) |
| Critically dry | Apr | 15 | 15 (2%) |
| Critically dry | May | 0 | 0 (0%) |
| Critically dry | Jun | 0 | 0 (0%) |
| Critically dry | Jul | 0 | 0 (0%) |
| Critically dry | Aug | 0 | 0 (0%) |
| Critically dry | Sep | 0 | 0 (0%) |
| Critically dry | Oct | 0 | 0 (0%) |
| Critically dry | Nov | 0 | 0 (0%) |
| Critically dry | Dec | 84 | 85 (1%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to the existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions.
EC = existing conditions; N/A = not applicable; SWP = State Water Project.

### Table 5E.1-5. Entrainment Loss of Juvenile Winter-Run Chinook Salmon at CVP Jones Pumping Plant, Averaged by Water Year Type and Month, Based on the Salvage-Density Method

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Wet | Jan | 33 | 32 (-3%) |
| Wet | Feb | 48 | 46 (-3%) |
| Wet | Mar | 88 | 89 (0%) |
| Wet | Apr | 2 | 2 (1%) |
| Wet | May | 0 | 0 (0%) |
| Wet | Jun | 0 | 0 (0%) |
| Wet | Jul | 0 | 0 (0%) |
| Wet | Aug | 0 | 0 (0%) |
| Wet | Sep | 0 | 0 (0%) |
| Wet | Oct | 0 | 0 (0%) |
| Wet | Nov | 0 | 0 (0%) |

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Wet | Dec | 51 | 50 (-1%) |
| Above normal | Jan | N/A | (-1%) |
| Above normal | Feb | N/A | (0%) |
| Above normal | Mar | N/A | (0%) |
| Above normal | Apr | N/A | (0%) |
| Above normal | May | N/A | (0%) |
| Above normal | Jun | N/A | (0%) |
| Above normal | Jul | N/A | (0%) |
| Above normal | Aug | N/A | (0%) |
| Above normal | Sep | N/A | (0%) |
| Above normal | Oct | N/A | (0%) |
| Above normal | Nov | N/A | (0%) |
| Above normal | Dec | N/A | (2%) |
| Below normal | Jan | 113 | 112 (0%) |
| Below normal | Feb | 161 | 164 (2%) |
| Below normal | Mar | 166 | 190 (15%) |
| Below normal | Apr | 23 | 23 (0%) |
| Below normal | May | 0 | 0 (0%) |
| Below normal | Jun | 0 | 0 (0%) |
| Below normal | Jul | 0 | 0 (0%) |
| Below normal | Aug | 0 | 0 (0%) |
| Below normal | Sep | 0 | 0 (0%) |
| Below normal | Oct | 0 | 0 (0%) |
| Below normal | Nov | 0 | 0 (0%) |
| Below normal | Dec | 1 | 1 (3%) |
| Dry | Jan | 78 | 77 (0%) |
| Dry | Feb | 73 | 74 (2%) |
| Dry | Mar | 100 | 115 (15%) |
| Dry | Apr | 4 | 4 (0%) |
| Dry | May | 0 | 0 (0%) |
| Dry | Jun | 0 | 0 (0%) |
| Dry | Jul | 0 | 0 (0%) |
| Dry | Aug | 0 | 0 (0%) |
| Dry | Sep | 0 | 0 (0%) |
| Dry | Oct | 0 | 0 (0%) |
| Dry | Nov | 0 | 0 (0%) |
| Dry | Dec | 16 | 17 (3%) |
| Critically dry | Jan | 27 | 25 (-7%) |
| Critically dry | Feb | 0 | 0 (0%) |
| Critically dry | Mar | 34 | 36 (5%) |
| Critically dry | Apr | 3 | 3 (7%) |
| Critically dry | May | 0 | 0 (0%) |
| Critically dry | Jun | 0 | 0 (0%) |

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Critically dry | Jul | 0 | 0 (0%) |
| Critically dry | Aug | 0 | 0 (0%) |
| Critically dry | Sep | 0 | 0 (0%) |
| Critically dry | Oct | 0 | 0 (0%) |
| Critically dry | Nov | 0 | 0 (0%) |
| Critically dry | Dec | 9 | 9 (1%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to the existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions.
CVP = Central Valley Project; EC = existing conditions; N/A = not applicable.

### Table 5E.1-6. Proportion of Juvenile Winter-Run Chinook Salmon Entering the Delta Salvaged at the South Delta Export Facilities, Averaged by Water Year Type, Based on Zeug and Cavallo (2014)

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 0.0038 | 0.0032 (-15%) |
| Above normal | 0.0025 | 0.0024 (-2%) |
| Below normal | 0.0020 | 0.0020 (0%) |
| Dry | 0.0016 | 0.0017 (2%) |
| Critically dry | 0.0014 | 0.0014 (1%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty. Results are not future predictions.
EC = existing conditions.

### Table 5E.1-7. Mean Channel Velocity (feet per second) in the Sacramento River Downstream of Intake C

| Water Year Type | EC | Proposed Action |
|---|---|---|
| **September** | | |
| Wet | 1.26 | 1.27 (0%) |
| Above normal | 1.17 | 1.17 (0%) |
| Below normal | 0.82 | 0.76 (-8%) |
| Dry | 0.68 | 0.68 (0%) |
| Critically dry | 0.63 | 0.63 (0%) |
| **October** | | |
| Wet | 0.89 | 0.85 (-4%) |
| Above normal | 0.84 | 0.81 (-3%) |
| Below normal | 0.78 | 0.77 (0%) |
| Dry | 0.71 | 0.71 (-1%) |
| Critically dry | 0.62 | 0.60 (-3%) |
| **November** | | |
| Wet | 1.30 | 1.22 (-6%) |
| Above normal | 1.05 | 0.95 (-10%) |

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Below normal | 0.91 | 0.83 (-8%) |
| Dry | 0.77 | 0.74 (-3%) |
| Critically dry | 0.66 | 0.66 (0%) |
| **December** | | |
| Wet | 2.52 | 2.43 (-3%) |
| Above normal | 1.69 | 1.59 (-6%) |
| Below normal | 1.23 | 1.18 (-4%) |
| Dry | 1.02 | 0.97 (-5%) |
| Critically dry | 0.92 | 0.88 (-4%) |
| **January** | | |
| Wet | 3.26 | 3.20 (-2%) |
| Above normal | 2.65 | 2.55 (-4%) |
| Below normal | 1.52 | 1.41 (-8%) |
| Dry | 1.25 | 1.14 (-8%) |
| Critically dry | 0.97 | 0.94 (-4%) |
| **February** | | |
| Wet | 3.47 | 3.51 (1%) |
| Above normal | 3.00 | 2.95 (-2%) |
| Below normal | 2.02 | 1.91 (-6%) |
| Dry | 1.69 | 1.50 (-11%) |
| Critically dry | 1.17 | 1.11 (-5%) |
| **March** | | |
| Wet | 3.15 | 3.16 (1%) |
| Above normal | 2.91 | 2.81 (-3%) |
| Below normal | 1.74 | 1.59 (-9%) |
| Dry | 1.61 | 1.45 (-10%) |
| Critically dry | 1.08 | 1.04 (-4%) |
| **April** | | |
| Wet | 2.40 | 2.43 (1%) |
| Above normal | 1.49 | 1.49 (0%) |
| Below normal | 1.34 | 1.32 (-2%) |
| Dry | 1.08 | 1.03 (-5%) |
| Critically dry | 0.85 | 0.83 (-3%) |
| **May** | | |
| Wet | 1.64 | 1.63 (-1%) |
| Above normal | 1.16 | 1.16 (0%) |
| Below normal | 1.07 | 1.07 (1%) |
| Dry | 0.87 | 0.90 (4%) |
| Critically dry | 0.63 | 0.64 (0%) |
| **June** | | |
| Wet | 1.14 | 1.15 (1%) |
| Above normal | 1.20 | 1.20 (1%) |
| Below normal | 1.03 | 1.03 (0%) |

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Dry | 0.99 | 0.96 (-3%) |
| Critically dry | 0.81 | 0.81 (0%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

EC = existing conditions.

### Table 5E.1-8. Number of Hours within Each Month with Reversing Flow in the Sacramento River Downstream of Georgiana Slough (DSM2 Channel 423)

| Water Year Type | EC | Proposed Action |
|---|---|---|
| **September** | | |
| Wet (720) | 7.5 | 10.4 (2.8/37%) |
| Above normal (720) | 5.2 | 11.5 (6.3/121%) |
| Below normal (720) | 81.4 | 100.7 (19.2/24%) |
| Dry (720) | 123.5 | 143.7 (20.2/16%) |
| Critically dry (720) | 179.4 | 192.3 (13.0/7%) |
| **October** | | |
| Wet (744) | 255.4 | 260.3 (5.0/2%) |
| Above normal (744) | 286.8 | 273.1 (-13.6/-5%) |
| Below normal (744) | 281.1 | 279.2 (-2.0/-1%) |
| Dry (744) | 287.9 | 285.9 (-2.0/-1%) |
| Critically dry (744) | 285.2 | 281.1 (-4.1/-1%) |
| **November** | | |
| Wet (720) | 180.8 | 190.8 (10.0/6%) |
| Above normal (720) | 204.5 | 224.1 (19.6/10%) |
| Below normal (720) | 240.8 | 249.4 (8.6/4%) |
| Dry (720) | 269.7 | 272.4 (2.7/1%) |
| Critically dry (720) | 276.7 | 276.5 (-0.2/0%) |
| **December** | | |
| Wet (744) | 65.6 | 69.7 (4.1/6%) |
| Above normal (744) | 154.1 | 155.4 (1.3/1%) |
| Below normal (744) | 169.0 | 169.1 (0.1/0%) |
| Dry (744) | 215.4 | 207.0 (-8.4/-4%) |
| Critically dry (744) | 272.0 | 271.8 (-0.2/0%) |
| **January** | | |
| Wet (744) | 0.0 | 0.2 (0.2) |
| Above normal (744) | 5.5 | 17.1 (11.6/212%) |
| Below normal (744) | 47.4 | 59.3 (11.9/25%) |
| Dry (744) | 33.0 | 68.8 (35.8/108%) |
| Critically dry (744) | 132.6 | 151.8 (19.2/14%) |
| **February** | | |
| Wet (676) | 2.9 | 7.1 (4.2/145%) |
| Above normal (684) | 0.0 | 2.9 (2.9) |
| Below normal (678) | 37.9 | 55.5 (17.6/46%) |

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Dry (679) | 49.3 | 79.8 (30.5/62%) |
| Critically dry (678) | 152.5 | 161.3 (8.8/6%) |
| **March** | | |
| Wet (744) | 244.6 | 246.0 (1.4/1%) |
| Above normal (744) | 255.4 | 255.8 (0.4/0%) |
| Below normal (744) | 298.6 | 304.4 (5.8/2%) |
| Dry (744) | 313.1 | 313.1 (0.0/0%) |
| Critically dry (744) | 316.7 | 316.5 (-0.2/0%) |
| **April** | | |
| Wet (720) | 245.0 | 247.4 (2.4/1%) |
| Above normal (720) | 262.1 | 259.1 (-3.0/-1%) |
| Below normal (720) | 281.1 | 279.9 (-1.1/0%) |
| Dry (720) | 300.8 | 298.3 (-2.5/-1%) |
| Critically dry (720) | 304.8 | 305.6 (0.9/0%) |
| **May** | | |
| Wet (744) | 30.2 | 30.6 (0.4/1%) |
| Above normal (744) | 60.3 | 63.8 (3.5/6%) |
| Below normal (744) | 105.8 | 113.9 (8.2/8%) |
| Dry (744) | 155.4 | 174.4 (19.0/12%) |
| Critically dry (744) | 223.6 | 231.6 (8.0/4%) |
| **June** | | |
| Wet (720) | 225.6 | 225.5 (-0.1/0%) |
| Above normal (720) | 229.3 | 229.1 (-0.1/0%) |
| Below normal (720) | 252.3 | 252.8 (0.5/0%) |
| Dry (720) | 259.9 | 262.7 (2.9/1%) |
| Critically dry (720) | 281.0 | 281.4 (0.4/0%) |

Notes: Numbers in parentheses after water year type indicate total number of hours by month. Absolute and percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Absolute differences only are shown in parentheses when existing conditions percentage is zero.

EC = existing conditions.

### Table 5E.1-9. Probability of Juvenile Chinook Salmon Through-Delta Survival, Averaged by Month and Water Year Type, Based on Perry et al. (2018)

| Water Year Type | EC | Proposed Action |
|---|---|---|
| **September** | | |
| Wet | 0.34 | 0.34 (0%) |
| Above normal | 0.33 | 0.33 (0%) |
| Below normal | 0.28 | 0.27 (-3%) |
| Dry | 0.26 | 0.26 (0%) |
| Critically dry | 0.25 | 0.25 (0%) |
| **October** | | |
| Wet | 0.32 | 0.32 (0%) |

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Above normal | 0.29 | 0.29 (1%) |
| Below normal | 0.33 | 0.35 (8%) |
| Dry | 0.33 | 0.33 (0%) |
| Critically dry | 0.32 | 0.32 (0%) |
| **November** | | |
| Wet | 0.38 | 0.37 (-1%) |
| Above normal | 0.37 | 0.36 (-1%) |
| Below normal | 0.37 | 0.36 (-2%) |
| Dry | 0.33 | 0.34 (2%) |
| Critically dry | 0.29 | 0.29 (-1%) |
| **December** | | |
| Wet | 0.47 | 0.46 (-2%) |
| Above normal | 0.48 | 0.47 (-2%) |
| Below normal | 0.49 | 0.48 (-2%) |
| Dry | 0.38 | 0.38 (-2%) |
| Critically dry | 0.41 | 0.40 (-2%) |
| **January** | | |
| Wet | 0.62 | 0.61 (-2%) |
| Above normal | 0.58 | 0.57 (-2%) |
| Below normal | 0.48 | 0.47 (-3%) |
| Dry | 0.45 | 0.43 (-3%) |
| Critically dry | 0.41 | 0.41 (-1%) |
| **February** | | |
| Wet | 0.63 | 0.63 (-1%) |
| Above normal | 0.60 | 0.59 (-2%) |
| Below normal | 0.53 | 0.51 (-2%) |
| Dry | 0.50 | 0.48 (-5%) |
| Critically dry | 0.44 | 0.43 (-2%) |
| **March** | | |
| Wet | 0.61 | 0.61 (-1%) |
| Above normal | 0.61 | 0.59 (-2%) |
| Below normal | 0.50 | 0.49 (-4%) |
| Dry | 0.49 | 0.47 (-4%) |
| Critically dry | 0.43 | 0.42 (-1%) |
| **April** | | |
| Wet | 0.56 | 0.56 (0%) |
| Above normal | 0.48 | 0.48 (0%) |
| Below normal | 0.46 | 0.46 (-1%) |
| Dry | 0.43 | 0.42 (-2%) |
| Critically dry | 0.40 | 0.39 (-1%) |
| **May** | | |
| Wet | 0.49 | 0.49 (-1%) |
| Above normal | 0.44 | 0.44 (0%) |

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Below normal | 0.43 | 0.43 (0%) |
| Dry | 0.40 | 0.40 (1%) |
| Critically dry | 0.36 | 0.36 (0%) |
| **June** | | |
| Wet | 0.34 | 0.34 (0%) |
| Above normal | 0.35 | 0.35 (0%) |
| Below normal | 0.32 | 0.32 (0%) |
| Dry | 0.32 | 0.31 (-1%) |
| Critically dry | 0.29 | 0.29 (0%) |

Notes: Percentage values in parentheses indicate differences of the proposed actions compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The main period of juvenile winter-run Chinook salmon occurrence in the Delta is December–April. Table only includes mean responses and does not consider model uncertainty. Results are not future predictions.

EC = existing conditions.

### Table 5E.1-10. Through-Delta Survival of Juvenile Winter-Run Chinook Salmon, Averaged by Water Year Type, Based on the Delta Passage Model

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 0.33 | 0.33 (-1%) |
| Above normal | 0.27 | 0.26 (-2%) |
| Below normal | 0.20 | 0.19 (-3%) |
| Dry | 0.18 | 0.17 (-4%) |
| Critically dry | 0.15 | 0.14 (-2%) |

Notes: Percentage values in parentheses indicate differences of the proposed actions compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty. Results are not future predictions.

EC = existing conditions.

**Table 5E.1-11. Mean Riparian and Wetland Bench Inundation Index by Geographic Group, Season, and Water Year Type**

| Geographic Group | Bench Type | WYT | Season | EC | Proposed Action |
|---|---|---|---|---|---|
| Cache Slough | Riparian | W | Winter | 0.58 | 0.58 (-1%) |
| Cache Slough | Riparian | AN | Winter | 0.51 | 0.51 (-1%) |
| Cache Slough | Riparian | BN | Winter | 0.43 | 0.42 (-1%) |
| Cache Slough | Riparian | D | Winter | 0.41 | 0.41 (-1%) |
| Cache Slough | Riparian | C | Winter | 0.40 | 0.40 (0%) |
| Cache Slough | Wetland | W | Winter | 0.62 | 0.62 (0%) |
| Cache Slough | Wetland | AN | Winter | 0.66 | 0.67 (0%) |
| Cache Slough | Wetland | BN | Winter | 0.69 | 0.69 (0%) |
| Cache Slough | Wetland | D | Winter | 0.69 | 0.69 (0%) |
| Cache Slough | Wetland | C | Winter | 0.69 | 0.69 (0%) |
| Sacramento River above north Delta intakes | Riparian | W | Winter | 0.23 | 0.24 (4%) |
| Sacramento River above north Delta intakes | Riparian | AN | Winter | 0.35 | 0.35 (1%) |
| Sacramento River above north Delta intakes | Riparian | BN | Winter | 0.35 | 0.35 (-1%) |
| Sacramento River above north Delta intakes | Riparian | D | Winter | 0.37 | 0.35 (-6%) |
| Sacramento River above north Delta intakes | Riparian | C | Winter | 0.25 | 0.24 (-3%) |
| Sacramento River above north Delta intakes | Wetland | W | Winter | 0.10 | 0.10 (3%) |
| Sacramento River above north Delta intakes | Wetland | AN | Winter | 0.15 | 0.16 (4%) |
| Sacramento River above north Delta intakes | Wetland | BN | Winter | 0.31 | 0.32 (4%) |
| Sacramento River above north Delta intakes | Wetland | D | Winter | 0.36 | 0.38 (6%) |
| Sacramento River above north Delta intakes | Wetland | C | Winter | 0.47 | 0.48 (2%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | W | Winter | 0.44 | 0.46 (4%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | AN | Winter | 0.46 | 0.45 (-1%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | BN | Winter | 0.40 | 0.38 (-5%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | D | Winter | 0.34 | 0.30 (-11%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | C | Winter | 0.26 | 0.25 (-4%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | W | Winter | 0.25 | 0.28 (10%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | AN | Winter | 0.41 | 0.44 (7%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | BN | Winter | 0.61 | 0.63 (4%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | D | Winter | 0.68 | 0.70 (3%) |

| Geographic Group | Bench Type | WYT | Season | EC | Proposed Action |
|---|---|---|---|---|---|
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | C | Winter | 0.70 | 0.71 (1%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | W | Winter | 0.59 | 0.61 (2%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | AN | Winter | 0.61 | 0.61 (0%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | BN | Winter | 0.56 | 0.54 (-3%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | D | Winter | 0.51 | 0.48 (-5%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | C | Winter | 0.46 | 0.45 (-2%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | W | Winter | 0.31 | 0.33 (7%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | AN | Winter | 0.44 | 0.47 (5%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | BN | Winter | 0.61 | 0.62 (3%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | D | Winter | 0.65 | 0.66 (2%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | C | Winter | 0.67 | 0.67 (1%) |
| Sutter/Steamboat Sloughs | Riparian | W | Winter | 0.55 | 0.56 (3%) |
| Sutter/Steamboat Sloughs | Riparian | AN | Winter | 0.59 | 0.60 (1%) |
| Sutter/Steamboat Sloughs | Riparian | BN | Winter | 0.59 | 0.58 (-1%) |
| Sutter/Steamboat Sloughs | Riparian | D | Winter | 0.57 | 0.55 (-3%) |
| Sutter/Steamboat Sloughs | Riparian | C | Winter | 0.53 | 0.53 (-1%) |
| Sutter/Steamboat Sloughs | Wetland | W | Winter | 0.26 | 0.27 (6%) |
| Sutter/Steamboat Sloughs | Wetland | AN | Winter | 0.37 | 0.39 (5%) |
| Sutter/Steamboat Sloughs | Wetland | BN | Winter | 0.51 | 0.53 (3%) |
| Sutter/Steamboat Sloughs | Wetland | D | Winter | 0.56 | 0.57 (2%) |
| Sutter/Steamboat Sloughs | Wetland | C | Winter | 0.58 | 0.59 (1%) |
| Cache Slough | Riparian | W | Spring | 0.48 | 0.48 (0%) |
| Cache Slough | Riparian | AN | Spring | 0.43 | 0.43 (0%) |
| Cache Slough | Riparian | BN | Spring | 0.40 | 0.40 (0%) |
| Cache Slough | Riparian | D | Spring | 0.40 | 0.40 (0%) |
| Cache Slough | Riparian | C | Spring | 0.39 | 0.39 (0%) |
| Cache Slough | Wetland | W | Spring | 0.68 | 0.68 (0%) |
| Cache Slough | Wetland | AN | Spring | 0.69 | 0.69 (0%) |
| Cache Slough | Wetland | BN | Spring | 0.69 | 0.69 (0%) |
| Cache Slough | Wetland | D | Spring | 0.69 | 0.69 (0%) |

| Geographic Group | Bench Type | WYT | Season | EC | Proposed Action |
|---|---|---|---|---|---|
| Cache Slough | Wetland | C | Spring | 0.69 | 0.69 (0%) |
| Sacramento River above north Delta intakes | Riparian | W | Spring | 0.33 | 0.33 (-1%) |
| Sacramento River above north Delta intakes | Riparian | AN | Spring | 0.32 | 0.33 (1%) |
| Sacramento River above north Delta intakes | Riparian | BN | Spring | 0.33 | 0.32 (-3%) |
| Sacramento River above north Delta intakes | Riparian | D | Spring | 0.27 | 0.25 (-5%) |
| Sacramento River above north Delta intakes | Riparian | C | Spring | 0.19 | 0.18 (-2%) |
| Sacramento River above north Delta intakes | Wetland | W | Spring | 0.22 | 0.22 (1%) |
| Sacramento River above north Delta intakes | Wetland | AN | Spring | 0.29 | 0.30 (1%) |
| Sacramento River above north Delta intakes | Wetland | BN | Spring | 0.38 | 0.39 (3%) |
| Sacramento River above north Delta intakes | Wetland | D | Spring | 0.44 | 0.46 (3%) |
| Sacramento River above north Delta intakes | Wetland | C | Spring | 0.55 | 0.55 (1%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | W | Spring | 0.42 | 0.42 (-2%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | AN | Spring | 0.39 | 0.39 (1%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | BN | Spring | 0.31 | 0.29 (-5%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | D | Spring | 0.26 | 0.25 (-5%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | C | Spring | 0.21 | 0.20 (-3%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | W | Spring | 0.50 | 0.51 (2%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | AN | Spring | 0.59 | 0.61 (2%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | BN | Spring | 0.69 | 0.70 (1%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | D | Spring | 0.70 | 0.71 (1%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | C | Spring | 0.72 | 0.72 (0%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | W | Spring | 0.58 | 0.58 (-1%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | AN | Spring | 0.55 | 0.56 (1%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | BN | Spring | 0.49 | 0.48 (-2%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | D | Spring | 0.46 | 0.45 (-2%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | C | Spring | 0.41 | 0.40 (-1%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | W | Spring | 0.51 | 0.52 (1%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | AN | Spring | 0.59 | 0.60 (2%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | BN | Spring | 0.66 | 0.67 (1%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | D | Spring | 0.67 | 0.68 (1%) |

| Geographic Group | Bench Type | WYT | Season | EC | Proposed Action |
|---|---|---|---|---|---|
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | C | Spring | 0.69 | 0.69 (0%) |
| Sutter/Steamboat Sloughs | Riparian | W | Spring | 0.59 | 0.59 (0%) |
| Sutter/Steamboat Sloughs | Riparian | AN | Spring | 0.59 | 0.59 (1%) |
| Sutter/Steamboat Sloughs | Riparian | BN | Spring | 0.55 | 0.55 (-1%) |
| Sutter/Steamboat Sloughs | Riparian | D | Spring | 0.53 | 0.52 (-1%) |
| Sutter/Steamboat Sloughs | Riparian | C | Spring | 0.50 | 0.50 (0%) |
| Sutter/Steamboat Sloughs | Wetland | W | Spring | 0.43 | 0.43 (1%) |
| Sutter/Steamboat Sloughs | Wetland | AN | Spring | 0.50 | 0.51 (1%) |
| Sutter/Steamboat Sloughs | Wetland | BN | Spring | 0.57 | 0.57 (1%) |
| Sutter/Steamboat Sloughs | Wetland | D | Spring | 0.58 | 0.59 (1%) |
| Sutter/Steamboat Sloughs | Wetland | C | Spring | 0.61 | 0.61 (0%) |
| Cache Slough | Riparian | W | Fall | 0.41 | 0.41 (0%) |
| Cache Slough | Riparian | AN | Fall | 0.40 | 0.40 (0%) |
| Cache Slough | Riparian | BN | Fall | 0.39 | 0.39 (0%) |
| Cache Slough | Riparian | D | Fall | 0.38 | 0.38 (0%) |
| Cache Slough | Riparian | C | Fall | 0.39 | 0.39 (0%) |
| Cache Slough | Wetland | W | Fall | 0.70 | 0.70 (0%) |
| Cache Slough | Wetland | AN | Fall | 0.70 | 0.70 (0%) |
| Cache Slough | Wetland | BN | Fall | 0.70 | 0.70 (0%) |
| Cache Slough | Wetland | D | Fall | 0.70 | 0.70 (0%) |
| Cache Slough | Wetland | C | Fall | 0.70 | 0.70 (0%) |
| Sacramento River above north Delta intakes | Riparian | W | Fall | 0.23 | 0.23 (-1%) |
| Sacramento River above north Delta intakes | Riparian | AN | Fall | 0.20 | 0.20 (-1%) |
| Sacramento River above north Delta intakes | Riparian | BN | Fall | 0.18 | 0.17 (-2%) |
| Sacramento River above north Delta intakes | Riparian | D | Fall | 0.15 | 0.15 (-1%) |
| Sacramento River above north Delta intakes | Riparian | C | Fall | 0.14 | 0.14 (0%) |
| Sacramento River above north Delta intakes | Wetland | W | Fall | 0.47 | 0.48 (2%) |
| Sacramento River above north Delta intakes | Wetland | AN | Fall | 0.52 | 0.52 (1%) |
| Sacramento River above north Delta intakes | Wetland | BN | Fall | 0.56 | 0.56 (1%) |
| Sacramento River above north Delta intakes | Wetland | D | Fall | 0.59 | 0.60 (0%) |

| Geographic Group | Bench Type | WYT | Season | EC | Proposed Action |
|---|---|---|---|---|---|
| Sacramento River above north Delta intakes | Wetland | C | Fall | 0.61 | 0.61 (0%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | W | Fall | 0.27 | 0.26 (-4%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | AN | Fall | 0.21 | 0.21 (-3%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | BN | Fall | 0.19 | 0.18 (-3%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | D | Fall | 0.17 | 0.17 (-1%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Riparian | C | Fall | 0.17 | 0.17 (0%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | W | Fall | 0.69 | 0.69 (1%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | AN | Fall | 0.72 | 0.72 (0%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | BN | Fall | 0.72 | 0.72 (0%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | D | Fall | 0.72 | 0.72 (0%) |
| Sacramento River below north Delta intakes to Sutter/Steamboat Slough | Wetland | C | Fall | 0.73 | 0.73 (0%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | W | Fall | 0.46 | 0.45 (-2%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | AN | Fall | 0.42 | 0.42 (-1%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | BN | Fall | 0.39 | 0.39 (-1%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | D | Fall | 0.37 | 0.37 (0%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Riparian | C | Fall | 0.38 | 0.38 (0%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | W | Fall | 0.66 | 0.66 (1%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | AN | Fall | 0.68 | 0.68 (0%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | BN | Fall | 0.69 | 0.69 (0%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | D | Fall | 0.70 | 0.70 (0%) |
| Sacramento River from Sutter/Steamboat Slough to Rio Vista | Wetland | C | Fall | 0.70 | 0.70 (0%) |
| Sutter/Steamboat Sloughs | Riparian | W | Fall | 0.54 | 0.53 (-1%) |
| Sutter/Steamboat Sloughs | Riparian | AN | Fall | 0.52 | 0.51 (-1%) |
| Sutter/Steamboat Sloughs | Riparian | BN | Fall | 0.50 | 0.49 (-1%) |
| Sutter/Steamboat Sloughs | Riparian | D | Fall | 0.48 | 0.48 (0%) |
| Sutter/Steamboat Sloughs | Riparian | C | Fall | 0.49 | 0.49 (0%) |
| Sutter/Steamboat Sloughs | Wetland | W | Fall | 0.57 | 0.58 (1%) |
| Sutter/Steamboat Sloughs | Wetland | AN | Fall | 0.60 | 0.60 (0%) |
| Sutter/Steamboat Sloughs | Wetland | BN | Fall | 0.61 | 0.62 (0%) |
| Sutter/Steamboat Sloughs | Wetland | D | Fall | 0.62 | 0.62 (0%) |

| Geographic Group | Bench Type | WYT | Season | EC | Proposed Action |
|---|---|---|---|---|---|
| Sutter/Steamboat Sloughs | Wetland | C | Fall | 0.62 | 0.62 (0%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Results are not future predictions.

EC = existing conditions; WYT = water year type (W = wet, AN = above normal, BN = below normal, D = dry, C = critically dry).

**Table 5E.1-12. Riparian Bench Length and Total Deficit Compared to Existing Conditions (linear feet)**

| Geographic Location | Bench Type | Length | Proposed Action |
|---|---|---|---|
| Cache Slough | Riparian | 2,950 | -27 |
| Cache Slough | Wetland | 3,992 | 0 |
| Sacramento River above north Delta intakes | Riparian | 18,251 | -1,114 |
| Sacramento River above north Delta intakes | Wetland | 3,766 | -3 |
| Sacramento River below north Delta intakes to Sutter/ Steamboat Slough | Riparian | 3,037 | -343 |
| Sacramento River below north Delta intakes to Sutter/ Steamboat Slough | Wetland | 3,115 | -11 |
| Sacramento River from Sutter/ Steamboat Slough to Rio Vista | Riparian | 1,685 | -84 |
| Sacramento River from Sutter/ Steamboat Slough to Rio Vista | Wetland | 2,430 | 1 |
| Sutter/Steamboat Sloughs | Riparian | 5,235 | -142 |
| Sutter/Steamboat Sloughs | Wetland | 2,670 | 0 |
| Total | Both | 47,131 | -1,724 |

Note: Results are not future predictions.

**Table 5E.1-13. Mean Water Temperature (degrees Celsius) by Water Year Type and Month from DSM2-QUAL Modeling, Sacramento River Immediately Downstream of Intake C**

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Wet | Jan | 10.1 | 10.1 (0.0) |
| Wet | Feb | 11.5 | 11.5 (0.0) |
| Wet | Mar | 13.1 | 13.1 (0.0) |
| Wet | Apr | 15.1 | 15.1 (0.0) |
| Wet | May | 18.0 | 18.0 (0.0) |
| Wet | Jun | 19.6 | 19.7 (0.0) |
| Wet | Jul | 21.1 | 21.1 (0.0) |
| Wet | Aug | 21.1 | 21.1 (0.0) |
| Wet | Sep | 20.2 | 20.2 (0.0) |
| Wet | Oct | 17.1 | 17.1 (0.0) |
| Wet | Nov | 13.3 | 13.3 (0.0) |
| Wet | Dec | 10.7 | 10.7 (0.0) |
| Above normal | Jan | 10.0 | 10.0 (0.0) |
| Above normal | Feb | 11.3 | 11.3 (0.0) |
| Above normal | Mar | 13.4 | 13.4 (0.0) |
| Above normal | Apr | 15.8 | 15.8 (0.0) |
| Above normal | May | 18.0 | 18.0 (0.0) |
| Above normal | Jun | 19.8 | 19.8 (0.0) |
| Above normal | Jul | 21.2 | 21.2 (0.0) |
| Above normal | Aug | 20.9 | 21.0 (0.0) |
| Above normal | Sep | 19.8 | 19.8 (0.0) |
| Above normal | Oct | 17.5 | 17.5 (0.0) |

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Above normal | Nov | 13.0 | 13.0 (0.0) |
| Above normal | Dec | 10.2 | 10.2 (0.0) |
| Below normal | Jan | 9.3 | 9.3 (0.0) |
| Below normal | Feb | 11.0 | 11.0 (0.0) |
| Below normal | Mar | 13.0 | 13.0 (0.0) |
| Below normal | Apr | 15.4 | 15.4 (0.0) |
| Below normal | May | 17.5 | 17.5 (0.0) |
| Below normal | Jun | 19.9 | 19.9 (0.0) |
| Below normal | Jul | 21.1 | 21.1 (0.0) |
| Below normal | Aug | 20.7 | 20.7 (0.0) |
| Below normal | Sep | 19.6 | 19.6 (0.0) |
| Below normal | Oct | 17.0 | 17.0 (0.0) |
| Below normal | Nov | 12.8 | 12.8 (0.0) |
| Below normal | Dec | 9.8 | 9.8 (0.0) |
| Dry | Jan | 9.0 | 9.0 (0.0) |
| Dry | Feb | 11.0 | 11.0 (0.0) |
| Dry | Mar | 13.4 | 13.4 (0.0) |
| Dry | Apr | 15.6 | 15.5 (0.0) |
| Dry | May | 17.7 | 17.7 (0.0) |
| Dry | Jun | 19.8 | 19.8 (0.0) |
| Dry | Jul | 20.7 | 20.8 (0.0) |
| Dry | Aug | 20.5 | 20.6 (0.0) |
| Dry | Sep | 19.6 | 19.6 (0.0) |
| Dry | Oct | 16.6 | 16.6 (0.0) |
| Dry | Nov | 12.8 | 12.8 (0.0) |
| Dry | Dec | 10.0 | 10.0 (0.0) |
| Critically dry | Jan | 9.3 | 9.3 (0.0) |
| Critically dry | Feb | 11.4 | 11.4 (0.0) |
| Critically dry | Mar | 13.4 | 13.4 (0.0) |
| Critically dry | Apr | 15.4 | 15.4 (0.0) |
| Critically dry | May | 17.4 | 17.4 (0.0) |
| Critically dry | Jun | 19.6 | 19.6 (0.0) |
| Critically dry | Jul | 21.2 | 21.2 (0.0) |
| Critically dry | Aug | 20.8 | 20.8 (0.0) |
| Critically dry | Sep | 19.6 | 19.6 (0.0) |
| Critically dry | Oct | 17.1 | 17.1 (0.0) |
| Critically dry | Nov | 13.3 | 13.3 (0.0) |
| Critically dry | Dec | 9.6 | 9.6 (0.0) |

Note: Values in parentheses indicate absolute differences of the proposed action compared to existing conditions.
EC = existing conditions.

**Table 5E.1-14. Mean Water Temperature (degrees Celsius) by Water Year Type and Month from DSM2-QUAL Modeling, Sacramento River at Rio Vista**

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Wet | Jan | 10.0 | 10.0 (0.0) |
| Wet | Feb | 11.6 | 11.6 (0.0) |
| Wet | Mar | 13.4 | 13.4 (0.0) |
| Wet | Apr | 15.2 | 15.2 (0.0) |
| Wet | May | 17.9 | 17.9 (0.0) |
| Wet | Jun | 19.7 | 19.7 (0.0) |
| Wet | Jul | 21.5 | 21.5 (0.0) |
| Wet | Aug | 21.6 | 21.6 (0.0) |
| Wet | Sep | 20.3 | 20.3 (0.0) |
| Wet | Oct | 17.3 | 17.3 (0.0) |
| Wet | Nov | 13.8 | 13.8 (0.0) |
| Wet | Dec | 10.7 | 10.7 (0.0) |
| Above normal | Jan | 10.0 | 10.0 (0.0) |
| Above normal | Feb | 11.4 | 11.4 (0.0) |
| Above normal | Mar | 13.7 | 13.7 (0.0) |
| Above normal | Apr | 15.9 | 15.9 (0.0) |
| Above normal | May | 18.0 | 18.0 (0.0) |
| Above normal | Jun | 19.7 | 19.7 (0.0) |
| Above normal | Jul | 21.6 | 21.6 (0.0) |
| Above normal | Aug | 21.7 | 21.7 (0.0) |
| Above normal | Sep | 19.9 | 19.9 (0.0) |
| Above normal | Oct | 17.8 | 17.8 (0.0) |
| Above normal | Nov | 13.6 | 13.7 (0.1) |
| Above normal | Dec | 10.1 | 10.1 (0.0) |
| Below normal | Jan | 9.0 | 9.0 (0.0) |
| Below normal | Feb | 11.0 | 11.0 (0.0) |
| Below normal | Mar | 13.4 | 13.4 (0.0) |
| Below normal | Apr | 15.4 | 15.4 (0.0) |
| Below normal | May | 17.3 | 17.3 (0.0) |
| Below normal | Jun | 20.0 | 20.0 (0.0) |
| Below normal | Jul | 21.6 | 21.6 (0.0) |
| Below normal | Aug | 21.3 | 21.3 (0.0) |
| Below normal | Sep | 20.1 | 20.1 (0.0) |
| Below normal | Oct | 17.3 | 17.3 (0.0) |
| Below normal | Nov | 13.4 | 13.4 (0.0) |
| Below normal | Dec | 9.7 | 9.7 (0.0) |
| Dry | Jan | 8.5 | 8.5 (0.0) |
| Dry | Feb | 11.0 | 11.0 (0.0) |
| Dry | Mar | 13.9 | 13.9 (0.0) |
| Dry | Apr | 15.7 | 15.7 (0.0) |
| Dry | May | 17.4 | 17.4 (0.0) |

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Dry | Jun | 19.7 | 19.7 (0.0) |
| Dry | Jul | 21.3 | 21.3 (0.0) |
| Dry | Aug | 21.2 | 21.2 (0.0) |
| Dry | Sep | 20.2 | 20.2 (0.0) |
| Dry | Oct | 16.9 | 16.9 (0.0) |
| Dry | Nov | 13.6 | 13.6 (0.0) |
| Dry | Dec | 10.0 | 10.0 (0.0) |
| Critically dry | Jan | 8.9 | 8.9 (0.0) |
| Critically dry | Feb | 11.5 | 11.5 (0.0) |
| Critically dry | Mar | 14.0 | 14.0 (0.0) |
| Critically dry | Apr | 15.4 | 15.4 (0.0) |
| Critically dry | May | 17.5 | 17.5 (0.0) |
| Critically dry | Jun | 19.8 | 19.7 (0.0) |
| Critically dry | Jul | 22.2 | 22.2 (0.0) |
| Critically dry | Aug | 22.0 | 22.0 (0.0) |
| Critically dry | Sep | 20.6 | 20.6 (0.0) |
| Critically dry | Oct | 17.8 | 17.8 (0.0) |
| Critically dry | Nov | 14.0 | 14.0 (0.0) |
| Critically dry | Dec | 9.7 | 9.7 (0.0) |

Note: Values in parentheses indicate absolute differences of the proposed action compared to existing conditions.
EC = existing conditions.

### Table 5E.1-15. Mean Water Temperature (degrees Celsius) by Water Year Type and Month from DSM2-QUAL Modeling, San Joaquin River at Jersey Point

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Wet | Jan | 9.9 | 9.9 (0.0) |
| Wet | Feb | 11.8 | 11.8 (0.0) |
| Wet | Mar | 13.8 | 13.9 (0.0) |
| Wet | Apr | 15.4 | 15.4 (0.0) |
| Wet | May | 17.9 | 17.9 (0.0) |
| Wet | Jun | 19.7 | 19.7 (0.0) |
| Wet | Jul | 21.6 | 21.6 (0.0) |
| Wet | Aug | 21.8 | 21.8 (0.0) |
| Wet | Sep | 20.4 | 20.4 (0.0) |
| Wet | Oct | 17.5 | 17.5 (0.0) |
| Wet | Nov | 14.3 | 14.3 (0.0) |
| Wet | Dec | 10.9 | 11.0 (0.0) |
| Above normal | Jan | 9.8 | 9.8 (0.0) |
| Above normal | Feb | 11.4 | 11.4 (0.0) |
| Above normal | Mar | 14.2 | 14.2 (0.0) |
| Above normal | Apr | 16.0 | 16.0 (0.0) |
| Above normal | May | 18.0 | 18.0 (0.0) |
| Above normal | Jun | 19.7 | 19.7 (0.0) |
| Above normal | Jul | 21.7 | 21.7 (0.0) |

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Above normal | Aug | 22.0 | 22.0 (0.0) |
| Above normal | Sep | 20.0 | 20.0 (0.0) |
| Above normal | Oct | 17.9 | 17.9 (0.0) |
| Above normal | Nov | 14.3 | 14.3 (0.0) |
| Above normal | Dec | 10.2 | 10.2 (0.0) |
| Below normal | Jan | 8.7 | 8.7 (0.0) |
| Below normal | Feb | 10.8 | 10.8 (0.0) |
| Below normal | Mar | 13.7 | 13.7 (0.0) |
| Below normal | Apr | 15.5 | 15.5 (0.0) |
| Below normal | May | 17.1 | 17.1 (0.0) |
| Below normal | Jun | 20.0 | 20.0 (0.0) |
| Below normal | Jul | 21.8 | 21.8 (0.0) |
| Below normal | Aug | 21.5 | 21.5 (0.0) |
| Below normal | Sep | 20.2 | 20.2 (0.0) |
| Below normal | Oct | 17.5 | 17.5 (0.0) |
| Below normal | Nov | 13.9 | 13.9 (0.0) |
| Below normal | Dec | 10.0 | 10.0 (0.0) |
| Dry | Jan | 8.3 | 8.2 (0.0) |
| Dry | Feb | 10.8 | 10.7 (0.0) |
| Dry | Mar | 14.1 | 14.1 (0.0) |
| Dry | Apr | 15.8 | 15.8 (0.0) |
| Dry | May | 17.3 | 17.3 (0.0) |
| Dry | Jun | 19.6 | 19.6 (0.0) |
| Dry | Jul | 21.3 | 21.3 (0.0) |
| Dry | Aug | 21.3 | 21.3 (0.0) |
| Dry | Sep | 20.3 | 20.3 (0.0) |
| Dry | Oct | 17.1 | 17.1 (0.0) |
| Dry | Nov | 14.1 | 14.1 (0.0) |
| Dry | Dec | 10.3 | 10.3 (0.0) |
| Critically dry | Jan | 8.6 | 8.6 (0.0) |
| Critically dry | Feb | 11.3 | 11.3 (0.0) |
| Critically dry | Mar | 14.3 | 14.3 (0.0) |
| Critically dry | Apr | 15.5 | 15.5 (0.0) |
| Critically dry | May | 17.4 | 17.4 (0.0) |
| Critically dry | Jun | 19.7 | 19.7 (0.0) |
| Critically dry | Jul | 22.3 | 22.3 (0.0) |
| Critically dry | Aug | 22.2 | 22.2 (0.0) |
| Critically dry | Sep | 20.7 | 20.8 (0.0) |
| Critically dry | Oct | 18.0 | 18.0 (0.0) |
| Critically dry | Nov | 14.5 | 14.5 (0.0) |
| Critically dry | Dec | 10.2 | 10.2 (0.0) |

Note: Values in parentheses indicate absolute differences of the proposed action compared to existing conditions.
EC = existing conditions.

### Table 5E.1-16. Mean Adult Female Winter-Run Chinook Salmon Escapement (Number of Fish) Based on the IOS Model

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 4,315 | 3,920 (-9%) |
| Above normal | 4,880 | 4,449 (-9%) |
| Below normal | 4,223 | 3,819 (-10%) |
| Dry | 3,557 | 3,220 (-9%) |
| Critically dry | 2,630 | 2,306 (-12%) |
| All | 3,997 | 3,610 (-10%) |

Notes: Percentage values in parentheses indicate differences of the proposed actions compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty. Results are not future predictions.

EC = existing conditions.

### Table 5E.1-17. Mean Juvenile Winter-Run Chinook Salmon Through-Delta Proportional Survival Based on the IOS Model

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 0.36 | 0.35 (-1%) |
| Above normal | 0.33 | 0.32 (-3%) |
| Below normal | 0.24 | 0.23 (-4%) |
| Dry | 0.22 | 0.20 (-7%) |
| Critically dry | 0.17 | 0.16 (-5%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty. Results are not future predictions.

EC = existing conditions.

### Table 5E.1-18. Mean Winter-Run Chinook Salmon Egg Proportional Survival Based on the IOS Model

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 1.00 | 1.00 (0%) |
| Above normal | 1.00 | 1.00 (0%) |
| Below normal | 1.00 | 1.00 (0%) |
| Dry | 1.00 | 1.00 (0%) |
| Critically dry | 0.83 | 0.87 (5%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty. Results are not future predictions.

EC = existing conditions.

### Table 5E.1-19. Mean Winter-Run Chinook Salmon Fry Proportional Survival Based on the IOS Model

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 0.95 | 0.95 (0%) |
| Above normal | 0.96 | 0.96 (0%) |
| Below normal | 0.95 | 0.95 (0%) |
| Dry | 0.95 | 0.95 (0%) |
| Critically dry | 0.77 | 0.80 (3%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty. Results are not future predictions.

EC = existing conditions.

### Table 5E.1-20. Mean Juvenile Winter-Run Chinook Salmon Riverine Proportional Survival Based on the IOS Model

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 0.28 | 0.28 (0%) |
| Above normal | 0.27 | 0.27 (0%) |
| Below normal | 0.25 | 0.25 (0%) |
| Dry | 0.25 | 0.25 (0%) |
| Critically dry | 0.25 | 0.25 (0%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty. Results are not future predictions.

EC = existing conditions.

### Table 5E.1-21. OBAN Winter-Run Chinook Salmon Escapement Results: Mean Difference (Proposed Action Minus Existing Conditions, Based on Annual Median) and Mean Probability of Greater Escapement under the Proposed Action Compared to Existing Conditions

| Proposed Action | Mean Escapement % Difference | Mean Probability > EC |
|---|---|---|
| Proposed action 0% | 2 | 0.51 |
| Proposed action 5% | -12 | 0.41 |
| Proposed action 10% | -25 | 0.31 |

Notes: Table only includes mean responses and does not consider model uncertainty. Additional results are provided in Attachment 5D.2, *Results of OBAN Analysis of Delta Conveyance Project 2020*.

EC = existing conditions.

### Table 5E.1-22. Summary of Winter-Run Chinook Salmon Life Cycle Model Results.

| Output | Proposed Action |
|---|---|
| Spawner abundance (mean % difference relative to EC) | 5.22% |
| Probability of spawner abundance > EC | 1.00 |
| Freshwater productivity (mean % difference in gulf smolts per spawner relative to EC) | 0.24% |
| Cohort replacement rate (mean % difference relative to EC) | 0.42% |
| Probability of cohort replacement rate > EC | 0.81 |

EC= existing conditions.

## 5E.1.4 Effects of Operations and Maintenance of Water Conveyance Facilities on Central Valley Spring-Run Chinook Salmon

The effects of operations and maintenance of water conveyance facilities on spring-run Chinook salmon are described in Appendix 5C, Section 5C.8, *Effects of Operations and Maintenance of Water Conveyance Facilities on Central Valley Spring-Run Chinook Salmon*. The impact mechanisms at 2040 remain the same as at 2020. Table 5E.1-23 summarizes quantitative analyses and differences between 2040 (i.e., existing conditions vs. the proposed action) and 2020 (i.e., existing conditions vs. the proposed action).

**Table 5E.1-23. Summary of Spring-Run Chinook Salmon Quantitative Analyses and Differences at 2040 Relative to 2020**

| Effect/Method | 2040 Results [a] | 2020 Results [b] | Differences |
|---|---|---|---|
| Juvenile south Delta entrainment/salvage-density method | Tables 5E.1-25 and 5E.1-26 | Tables 5C.8-1 and 5C.8-2 | Generally similar, except somewhat smaller difference in wet years at SWP Banks Pumping Plant (see also summary in Table 5E.1-1 for winter-run Chinook salmon); differences in the interaction of north Delta |
| Channel velocity/DSM2 | Table 5E.1-7 | Table 5C.7-11 | Generally similar, with some exceptions (e.g., smaller differences at 2040 in September of dry years, November and January of critically dry years, and June of wet and above normal years; larger difference at 2040 in February, March, and April of dry years) |
| Reverse flow downstream of Georgiana Slough/DSM2 | Table 5E.1-8 | Table 5C.7-12 | Generally similar, with some exceptions (e.g., smaller differences at 2040 in June of wet years; larger differences at 2040 in January, February, and May of dry years, and December and March of dry years) |
| Juvenile through-Delta survival/Perry et al. (2018) | Table 5E.1-9 | Table 5C.7-13 | Generally similar, except smaller differences at 2040 (September in below normal years, June in wet and above normal years) and larger differences at 2040 (October in below normal years, February in dry years) |
| Juvenile through-Delta survival/Delta Passage Model | Table 5E.1-24 | Table 5C.7-15 | Generally similar, except slightly larger difference at 2040 in dry years |
| Juvenile through-Delta survival (San Joaquin River basin spring-run)/Structured Decision Model | Table 5E.1-29 | Table 5C.8-4 | Similar (greater relative difference at 2040 than 2020 in wet and above normal years but low absolute survival under all scenarios) |
| Riparian and wetland bench inundation/DSM2 | Tables 5E.1-11 and 5E.1-12 | Tables 5C.7-16 and 5C.7-17 | Generally similar or smaller difference at 2040 than 2020 |

| Effect/Method | 2040 Results [a] | 2020 Results [b] | Differences |
|---|---|---|---|
| Water temperature/DSM2 | Tables 5E.1-13, 5E.1-14, and 5E.1-15 | Tables 5C.7-18, 5C.7-19, and 5C.7-20 | Same (zero difference) |

CVP = Central Valley Project; SWP = State Water Project.

[a] Results for 2040 are provided in this appendix.

[b] Results for 2020 are provided in Appendix 5C, *Operations and Maintenance Effects Analysis for Chinook Salmon, California Central Valley Steelhead, Green Sturgeon, and Killer Whale.*

### Table 5E.1-24. Through-Delta Survival of Juvenile Spring-Run Chinook Salmon, Averaged by Water Year Type, Based on the Delta Passage Model

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 0.33 | 0.33 (-1%) |
| Above normal | 0.27 | 0.27 (-1%) |
| Below normal | 0.21 | 0.21 (-3%) |
| Dry | 0.19 | 0.18 (-4%) |
| Critically dry | 0.15 | 0.15 (-2%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.

EC = existing conditions.

### Table 5E.1-25. Entrainment Loss of Juvenile Spring-Run Chinook Salmon at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 40,215 | 38,571 (-4%) |
| Above normal | N/A | (0%) |
| Below normal | 4,002 | 3,808 (-5%) |
| Dry | 3,038 | 2,981 (-2%) |
| Critically dry | 2,829 | 2,848 (1%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

EC = existing conditions; N/A = not applicable; SWP = State Water Project.

### Table 5E.1-26. Entrainment Loss of Juvenile Spring-Run Chinook Salmon at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 6,736 | 6,958 (3%) |
| Above normal | N/A | (1%) |
| Below normal | 2,111 | 2,172 (3%) |
| Dry | 1,959 | 1,976 (1%) |
| Critically dry | 109 | 116 (6%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between

percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

CVP = Central Valley Project; EC = existing conditions; N/A = not applicable.

### Table 5E.1-27. Entrainment Loss of Juvenile Spring-Run Chinook Salmon at SWP Banks Pumping Plant, Averaged by Water Year Type and Month, Based on the Salvage-Density Method

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Wet | Jan | 6 | 6 (0%) |
| Wet | Feb | 60 | 57 (-5%) |
| Wet | Mar | 1,593 | 1,391 (-13%) |
| Wet | Apr | 13,303 | 11,510 (-13%) |
| Wet | May | 22,795 | 23,087 (1%) |
| Wet | Jun | 2,459 | 2,521 (3%) |
| Wet | Jul | 0 | 0 (0%) |
| Wet | Aug | 0 | 0 (0%) |
| Wet | Sep | 0 | 0 (0%) |
| Wet | Oct | 0 | 0 (0%) |
| Wet | Nov | 0 | 0 (0%) |
| Wet | Dec | 0 | 0 (0%) |
| Above normal | Jan | N/A | (0%) |
| Above normal | Feb | N/A | (6%) |
| Above normal | Mar | N/A | (-4%) |
| Above normal | Apr | N/A | (0%) |
| Above normal | May | N/A | (0%) |
| Above normal | Jun | N/A | (0%) |
| Above normal | Jul | N/A | (0%) |
| Above normal | Aug | N/A | (0%) |
| Above normal | Sep | N/A | (0%) |
| Above normal | Oct | N/A | (0%) |
| Above normal | Nov | N/A | (0%) |
| Above normal | Dec | N/A | (0%) |
| Below normal | Jan | 0 | 0 (0%) |
| Below normal | Feb | 0 | 0 (0%) |
| Below normal | Mar | 599 | 567 (-5%) |
| Below normal | Apr | 2,040 | 1,796 (-12%) |
| Below normal | May | 1,320 | 1,403 (6%) |
| Below normal | Jun | 43 | 42 (-1%) |
| Below normal | Jul | 0 | 0 (0%) |
| Below normal | Aug | 0 | 0 (0%) |
| Below normal | Sep | 0 | 0 (0%) |
| Below normal | Oct | 0 | 0 (0%) |
| Below normal | Nov | 0 | 0 (0%) |

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Below normal | Dec | 0 | 0 (0%) |
| Dry | Jan | 0 | 0 (0%) |
| Dry | Feb | 0 | 0 (0%) |
| Dry | Mar | 104 | 96 (-7%) |
| Dry | Apr | 2,181 | 2,181 (0%) |
| Dry | May | 753 | 704 (-7%) |
| Dry | Jun | 0 | 0 (0%) |
| Dry | Jul | 0 | 0 (0%) |
| Dry | Aug | 0 | 0 (0%) |
| Dry | Sep | 0 | 0 (0%) |
| Dry | Oct | 0 | 0 (0%) |
| Dry | Nov | 0 | 0 (0%) |
| Dry | Dec | 0 | 0 (0%) |
| Critically dry | Jan | 0 | 0 (0%) |
| Critically dry | Feb | 0 | 0 (0%) |
| Critically dry | Mar | 122 | 112 (-8%) |
| Critically dry | Apr | 1,994 | 2,043 (2%) |
| Critically dry | May | 713 | 692 (-3%) |
| Critically dry | Jun | 0 | 0 (0%) |
| Critically dry | Jul | 0 | 0 (0%) |
| Critically dry | Aug | 0 | 0 (0%) |
| Critically dry | Sep | 0 | 0 (0%) |
| Critically dry | Oct | 0 | 0 (0%) |
| Critically dry | Nov | 0 | 0 (0%) |
| Critically dry | Dec | 0 | 0 (0%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to the existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions.
EC = existing conditions; N/A = not applicable; SWP = State Water Project.

### Table 5E.1-28. Entrainment Loss of Juvenile Spring-Run Chinook Salmon at CVP Jones Pumping Plant, Averaged by Water Year Type and Month, Based on the Salvage-Density Method

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Wet | Jan | 3 | 3 (-3%) |
| Wet | Feb | 11 | 11 (-3%) |
| Wet | Mar | 137 | 138 (0%) |
| Wet | Apr | 1,435 | 1,445 (1%) |
| Wet | May | 4,901 | 5,113 (4%) |
| Wet | Jun | 240 | 239 (-1%) |
| Wet | Jul | 0 | 0 (0%) |
| Wet | Aug | 0 | 0 (0%) |

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Wet | Sep | 0 | 0 (0%) |
| Wet | Oct | 0 | 0 (0%) |
| Wet | Nov | 0 | 0 (0%) |
| Wet | Dec | 8 | 8 (-1%) |
| Above normal | Jan | N/A | (-1%) |
| Above normal | Feb | N/A | (0%) |
| Above normal | Mar | N/A | (0%) |
| Above normal | Apr | N/A | (0%) |
| Above normal | May | N/A | (1%) |
| Above normal | Jun | N/A | (0%) |
| Above normal | Jul | N/A | (0%) |
| Above normal | Aug | N/A | (0%) |
| Above normal | Sep | N/A | (0%) |
| Above normal | Oct | N/A | (0%) |
| Above normal | Nov | N/A | (0%) |
| Above normal | Dec | N/A | (2%) |
| Below normal | Jan | 1 | 1 (0%) |
| Below normal | Feb | 6 | 6 (2%) |
| Below normal | Mar | 427 | 490 (15%) |
| Below normal | Apr | 1,130 | 1,125 (0%) |
| Below normal | May | 545 | 547 (0%) |
| Below normal | Jun | 3 | 3 (0%) |
| Below normal | Jul | 0 | 0 (0%) |
| Below normal | Aug | 0 | 0 (0%) |
| Below normal | Sep | 0 | 0 (0%) |
| Below normal | Oct | 0 | 0 (0%) |
| Below normal | Nov | 0 | 0 (0%) |
| Below normal | Dec | 0 | 0 (0%) |
| Dry | Jan | 0 | 0 (0%) |
| Dry | Feb | 0 | 0 (0%) |
| Dry | Mar | 144 | 165 (15%) |
| Dry | Apr | 1,381 | 1,376 (0%) |
| Dry | May | 432 | 434 (0%) |
| Dry | Jun | 2 | 2 (0%) |
| Dry | Jul | 0 | 0 (0%) |
| Dry | Aug | 0 | 0 (0%) |
| Dry | Sep | 0 | 0 (0%) |
| Dry | Oct | 0 | 0 (0%) |
| Dry | Nov | 0 | 0 (0%) |
| Dry | Dec | 0 | 0 (0%) |
| Critically dry | Jan | 0 | 0 (0%) |
| Critically dry | Feb | 0 | 0 (0%) |
| Critically dry | Mar | 44 | 46 (5%) |

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Critically dry | Apr | 55 | 59 (7%) |
| Critically dry | May | 10 | 10 (4%) |
| Critically dry | Jun | 0 | 0 (0%) |
| Critically dry | Jul | 0 | 0 (0%) |
| Critically dry | Aug | 0 | 0 (0%) |
| Critically dry | Sep | 0 | 0 (0%) |
| Critically dry | Oct | 0 | 0 (0%) |
| Critically dry | Nov | 0 | 0 (0%) |
| Critically dry | Dec | 0 | 0 (0%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to the existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions.
CVP = Central Valley Project; EC = existing conditions; N/A = not applicable.

**Table 5E.1-29. Through-Delta Survival of Juvenile Spring-Run Chinook Salmon from the San Joaquin River Basin, Averaged by Water Year Type, Based on the Structured Decision Model Routing Application**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 0.026 | 0.025 (-4%) |
| Above normal | 0.021 | 0.020 (-4%) |
| Below normal | 0.022 | 0.022 (-1%) |
| Dry | 0.021 | 0.022 (2%) |
| Critically dry | 0.016 | 0.016 (1%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.
EC = existing conditions.

## 5E.1.5 Effects of Operations and Maintenance of Water Conveyance Facilities on Central Valley Fall-Run/Late Fall–Run Chinook Salmon

The effects of operations and maintenance of water conveyance facilities on fall- and late fall–run Chinook salmon are described in Appendix 5C, Section 5C.9, *Effects of Operations and Maintenance of Water Conveyance Facilities on Central Valley Fall-Run/Late Fall–Run Chinook Salmon*. The impact mechanisms at 2040 remain the same as at 2020. Table 5E.1-30 summarizes quantitative analyses and differences between 2040 (i.e., existing conditions vs. the proposed action) and 2020 (i.e., existing conditions vs. the proposed action).

**Table 5E.1-30. Summary of Fall- and Late Fall–Run Chinook Salmon Quantitative Analyses and Differences at 2040 Relative to 2020**

| Effect/Method | 2040 Results [a] | 2020 Results [b] | Differences |
|---|---|---|---|
| Juvenile south Delta entrainment/salvage-density method | Tables 5E.1-33, 5E.1-34, 5E.1-37, and 5E.1-38 | Tables 5C.9-3 through 5C.9-6 | Generally similar, with less difference at 2040 (fall-run in wet/above normal years; late fall–run at CVP in dry years) and greater difference at 2040 (fall-run in critically dry years at CVP) |
| Channel velocity/DSM2 | Table 5E.1-7 | Table 5C.7-11 | Generally similar, with some exceptions (e.g., smaller differences at 2040 in September of dry years, November and January of critically dry years, and June of wet and above normal years; larger difference at 2040 in February, March, and April of dry years) |
| Reverse flow downstream of Georgiana Slough/DSM2 | Table 5E.1-8 | Table 5C.7-12 | Generally similar, with some exceptions (e.g., smaller differences at 2040 in June of wet years; larger differences at 2040 in January, February, and May of dry years, and December and March of dry years) |
| Juvenile through-Delta survival/Perry et al. (2018) | Table 5E.1-9 | Table 5C.7-13 | Generally similar, except smaller differences at 2040 (September in below normal years, June in wet and above normal years) and larger differences at 2040 (October in below normal years, February in dry years) |
| Juvenile through-Delta survival/Delta Passage Model | Tables 5E.1-31 and 5E.1-32 | Tables 5C.9-1 and 5C.9-2 | Similar |
| Juvenile through-Delta survival (San Joaquin River basin fall-run)/Structured Decision Model | Table 5E.1-41 | Table 5C.9-7 | Similar (greater relative difference at 2040 in wet/above normal years but low absolute survival under all scenarios) |
| San Joaquin River basin adult fall-run straying/Marston et al. (2012) | Table 5E.1-42 | Table 5C.9-8 | Similar or greater differences at 2040 |
| Riparian and wetland bench inundation/DSM2 | Tables 5E.1-11 and 5E.1-12 | Tables 5C.7-16 and 5C.7-17 | Generally similar or less difference at 2040 than 2020 |
| Water temperature/DSM2 | Tables 5E.1-13, 5E.1-14, and 5E.1-15 | Tables 5C.7-18, 5C.7-19, and 5C.7-20 | Same (zero difference) |
| Juvenile Mokelumne River fall-run south Delta entrainment/CalSim | Tables 5E.1-43, 5E.1-44, 5E.1-45, and 5E.1-46 | Tables 5C.9-9, 5C.9-10, 5C.9-11, and 5C.9-12 | Similar (greater positive or negative involve relatively small absolute differences of no more than a few hundred cfs) |
| Juvenile Mokelumne River fall-run south Delta entrainment/DSM2 | Figures 5E.1-1 through 5E.1-4 | Figures 5D.4-34 through 5D.4-37 | Similar |
| Adult Mokelumne River fall-run straying/CalSim | Tables 5E.1-47 and 5E.1-48 | Tables 5C.9-13 and 5C.9-14 | Generally similar or less openings at 2040 |

cfs = cubic feet per second; CVP = Central Valley Project.

[a] Results for 2040 are provided in this appendix.

[b] Results for 2020 are provided in Appendix 5C, *Operations and Maintenance Effects Analysis for Chinook Salmon, California Central Valley Steelhead, Green Sturgeon, and Killer Whale,* and Appendix 5D, *Bay-Delta Methods and Results.*

### Table 5E.1-31. Through-Delta Survival of Juvenile Fall-Run Chinook Salmon, Averaged by Water Year Type, Based on the Delta Passage Model

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 0.25 | 0.25 (-1%) |
| Above normal | 0.21 | 0.20 (-1%) |
| Below normal | 0.18 | 0.18 (-1%) |
| Dry | 0.16 | 0.16 (-2%) |
| Critically dry | 0.14 | 0.13 (-1%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.
EC = existing conditions.

### Table 5E.1-32. Through-Delta Survival of Juvenile Late Fall–Run Chinook Salmon, Averaged by Water Year Type, Based on the Delta Passage Model

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 0.27 | 0.26 (-2%) |
| Above normal | 0.22 | 0.22 (-2%) |
| Below normal | 0.17 | 0.16 (-3%) |
| Dry | 0.15 | 0.14 (-3%) |
| Critically dry | 0.13 | 0.13 (-2%) |

Notes: Percentage values in parentheses indicate differences of proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.
EC = existing conditions.

### Table 5E.1-33. Entrainment Loss of Juvenile Fall-Run Chinook Salmon at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 22,228 | 22,351 (1%) |
| Above normal | N/A | (1%) |
| Below normal | 3,902 | 3,953 (1%) |
| Dry | 3,772 | 3,580 (-5%) |
| Critically dry | 3,339 | 3,300 (-1%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.
EC = existing conditions; N/A = not applicable; SWP = State Water Project.

**Table 5E.1-34. Entrainment Loss of Juvenile Fall-Run Chinook Salmon at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 7,120 | 7,246 (2%) |
| Above normal | N/A | (1%) |
| Below normal | 1,540 | 1,554 (1%) |
| Dry | 2,365 | 2,368 (0%) |
| Critically dry | 113 | 119 (6%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

CVP = Central Valley Project; EC = existing conditions; N/A = not applicable.

**Table 5E.1-35. Entrainment Loss of Juvenile Fall-Run Chinook Salmon at SWP Banks Pumping Plant, Averaged by Water Year Type and Month, Based on the Salvage-Density Method**

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Wet | Jan | 1,220 | 1,218 (0%) |
| Wet | Feb | 2,676 | 2,554 (-5%) |
| Wet | Mar | 337 | 294 (-13%) |
| Wet | Apr | 413 | 357 (-13%) |
| Wet | May | 7,904 | 8,005 (1%) |
| Wet | Jun | 9,605 | 9,848 (3%) |
| Wet | Jul | 11 | 11 (-4%) |
| Wet | Aug | 0 | 0 (0%) |
| Wet | Sep | 0 | 0 (0%) |
| Wet | Oct | 0 | 0 (0%) |
| Wet | Nov | 0 | 0 (0%) |
| Wet | Dec | 63 | 63 (0%) |
| Above normal | Jan | N/A | (0%) |
| Above normal | Feb | N/A | (6%) |
| Above normal | Mar | N/A | (-4%) |
| Above normal | Apr | N/A | (0%) |
| Above normal | May | N/A | (0%) |
| Above normal | Jun | N/A | (0%) |
| Above normal | Jul | N/A | (-4%) |
| Above normal | Aug | N/A | (0%) |
| Above normal | Sep | N/A | (0%) |
| Above normal | Oct | N/A | (0%) |
| Above normal | Nov | N/A | (0%) |
| Above normal | Dec | N/A | (-3%) |
| Below normal | Jan | 0 | 0 (0%) |
| Below normal | Feb | 7 | 8 (2%) |
| Below normal | Mar | 75 | 71 (-5%) |

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Below normal | Apr | 750 | 660 (-12%) |
| Below normal | May | 2,432 | 2,585 (6%) |
| Below normal | Jun | 627 | 620 (-1%) |
| Below normal | Jul | 4 | 4 (-4%) |
| Below normal | Aug | 0 | 0 (0%) |
| Below normal | Sep | 0 | 0 (0%) |
| Below normal | Oct | 0 | 0 (0%) |
| Below normal | Nov | 0 | 0 (0%) |
| Below normal | Dec | 6 | 5 (-5%) |
| Dry | Jan | 0 | 0 (0%) |
| Dry | Feb | 10 | 11 (3%) |
| Dry | Mar | 32 | 29 (-7%) |
| Dry | Apr | 1,048 | 1,048 (0%) |
| Dry | May | 2,146 | 2,005 (-7%) |
| Dry | Jun | 55 | 48 (-12%) |
| Dry | Jul | 0 | 0 (0%) |
| Dry | Aug | 0 | 0 (0%) |
| Dry | Sep | 0 | 0 (0%) |
| Dry | Oct | 0 | 0 (0%) |
| Dry | Nov | 0 | 0 (0%) |
| Dry | Dec | 480 | 438 (-9%) |
| Critically dry | Jan | 0 | 0 (0%) |
| Critically dry | Feb | 10 | 10 (-1%) |
| Critically dry | Mar | 37 | 34 (-8%) |
| Critically dry | Apr | 958 | 982 (2%) |
| Critically dry | May | 2,033 | 1,972 (-3%) |
| Critically dry | Jun | 12 | 11 (-13%) |
| Critically dry | Jul | 0 | 0 (0%) |
| Critically dry | Aug | 0 | 0 (0%) |
| Critically dry | Sep | 0 | 0 (0%) |
| Critically dry | Oct | 0 | 0 (0%) |
| Critically dry | Nov | 0 | 0 (0%) |
| Critically dry | Dec | 289 | 292 (1%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to the existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions.
EC = existing conditions; N/A = not applicable; SWP = State Water Project.

**Table 5E.1-36. Entrainment Loss of Juvenile Fall-Run Chinook Salmon at CVP Jones Pumping Plant, Averaged by Water Year Type and Month, Based on the Salvage-Density Method**

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Wet | Jan | 672 | 654 (-3%) |
| Wet | Feb | 623 | 606 (-3%) |
| Wet | Mar | 142 | 142 (0%) |
| Wet | Apr | 64 | 65 (1%) |
| Wet | May | 3,935 | 4,106 (4%) |
| Wet | Jun | 1,647 | 1,638 (-1%) |
| Wet | Jul | 19 | 18 (-2%) |
| Wet | Aug | 1 | 1 (0%) |
| Wet | Sep | 0 | 0 (0%) |
| Wet | Oct | 0 | 0 (0%) |
| Wet | Nov | 1 | 1 (2%) |
| Wet | Dec | 15 | 15 (-1%) |
| Above normal | Jan | N/A | (-1%) |
| Above normal | Feb | N/A | (0%) |
| Above normal | Mar | N/A | (0%) |
| Above normal | Apr | N/A | (0%) |
| Above normal | May | N/A | (1%) |
| Above normal | Jun | N/A | (0%) |
| Above normal | Jul | N/A | (0%) |
| Above normal | Aug | N/A | (-2%) |
| Above normal | Sep | N/A | (0%) |
| Above normal | Oct | N/A | (0%) |
| Above normal | Nov | N/A | (-1%) |
| Above normal | Dec | N/A | (2%) |
| Below normal | Jan | 7 | 7 (0%) |
| Below normal | Feb | 16 | 17 (2%) |
| Below normal | Mar | 88 | 101 (15%) |
| Below normal | Apr | 493 | 491 (0%) |
| Below normal | May | 890 | 893 (0%) |
| Below normal | Jun | 44 | 44 (0%) |
| Below normal | Jul | 0 | 0 (-7%) |
| Below normal | Aug | 0 | 0 (0%) |
| Below normal | Sep | 0 | 0 (0%) |
| Below normal | Oct | 0 | 0 (0%) |
| Below normal | Nov | 0 | 0 (0%) |
| Below normal | Dec | 0 | 0 (0%) |
| Dry | Jan | 4 | 4 (0%) |
| Dry | Feb | 5 | 5 (2%) |
| Dry | Mar | 16 | 19 (15%) |
| Dry | Apr | 1,195 | 1,190 (0%) |
| Dry | May | 1,105 | 1,109 (0%) |

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Dry | Jun | 10 | 10 (0%) |
| Dry | Jul | 0 | 0 (0%) |
| Dry | Aug | 0 | 0 (0%) |
| Dry | Sep | 0 | 0 (0%) |
| Dry | Oct | 0 | 0 (0%) |
| Dry | Nov | 0 | 0 (0%) |
| Dry | Dec | 29 | 30 (3%) |
| Critically dry | Jan | 0 | 0 (0%) |
| Critically dry | Feb | 8 | 9 (5%) |
| Critically dry | Mar | 10 | 10 (5%) |
| Critically dry | Apr | 55 | 59 (7%) |
| Critically dry | May | 40 | 41 (4%) |
| Critically dry | Jun | 0 | 0 (0%) |
| Critically dry | Jul | 0 | 0 (0%) |
| Critically dry | Aug | 0 | 0 (0%) |
| Critically dry | Sep | 0 | 0 (0%) |
| Critically dry | Oct | 0 | 0 (0%) |
| Critically dry | Nov | 0 | 0 (0%) |
| Critically dry | Dec | 0 | 0 (0%) |

Notes: Percentage values in parentheses indicate differences of the proposed actions compared to the existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions.

CVP = Central Valley Project; EC = existing conditions; N/A = not applicable.

### Table 5E.1-37. Entrainment Loss of Juvenile Late Fall–Run Chinook Salmon at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 1,443 | 1,436 (0%) |
| Above normal | N/A | (-1%) |
| Below normal | 376 | 373 (-1%) |
| Dry | 1,043 | 952 (-9%) |
| Critically dry | 630 | 637 (1%) |

Notes: Percentage values in parentheses indicate differences of proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

EC = existing conditions; N/A = not applicable; SWP = State Water Project.

**Table 5E.1-38. Entrainment Loss of Juvenile Late Fall–Run Chinook Salmon at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 271 | 268 (-1%) |
| Above normal | N/A | (1%) |
| Below normal | 69 | 69 (1%) |
| Dry | 91 | 94 (3%) |
| Critically dry | 26 | 26 (-1%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

CVP = Central Valley Project; EC = existing conditions; N/A = not applicable.

**Table 5E.1-39. Entrainment Loss of Juvenile Late Fall–Run Chinook Salmon at SWP Banks Pumping Plant, Averaged by Water Year Type and Month, Based on the Salvage-Density Method**

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Wet | Jan | 661 | 660 (0%) |
| Wet | Feb | 86 | 83 (-5%) |
| Wet | Mar | 9 | 8 (-13%) |
| Wet | Apr | 0 | 0 (0%) |
| Wet | May | 0 | 0 (0%) |
| Wet | Jun | 0 | 0 (0%) |
| Wet | Jul | 0 | 0 (0%) |
| Wet | Aug | 0 | 0 (0%) |
| Wet | Sep | 0 | 0 (0%) |
| Wet | Oct | 0 | 0 (0%) |
| Wet | Nov | 0 | 0 (0%) |
| Wet | Dec | 686 | 686 (0%) |
| Above normal | Jan | N/A | (0%) |
| Above normal | Feb | N/A | (6%) |
| Above normal | Mar | N/A | (-4%) |
| Above normal | Apr | N/A | (0%) |
| Above normal | May | N/A | (0%) |
| Above normal | Jun | N/A | (0%) |
| Above normal | Jul | N/A | (0%) |
| Above normal | Aug | N/A | (0%) |
| Above normal | Sep | N/A | (0%) |
| Above normal | Oct | N/A | (0%) |
| Above normal | Nov | N/A | (0%) |
| Above normal | Dec | N/A | (-3%) |
| Below normal | Jan | 156 | 156 (0%) |
| Below normal | Feb | 107 | 109 (2%) |

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Below normal | Mar | 17 | 16 (-5%) |
| Below normal | Apr | 0 | 0 (-12%) |
| Below normal | May | 0 | 0 (0%) |
| Below normal | Jun | 0 | 0 (0%) |
| Below normal | Jul | 0 | 0 (0%) |
| Below normal | Aug | 0 | 0 (0%) |
| Below normal | Sep | 0 | 0 (0%) |
| Below normal | Oct | 0 | 0 (0%) |
| Below normal | Nov | 0 | 0 (0%) |
| Below normal | Dec | 96 | 91 (-5%) |
| Dry | Jan | 19 | 19 (0%) |
| Dry | Feb | 0 | 0 (0%) |
| Dry | Mar | 0 | 0 (0%) |
| Dry | Apr | 0 | 0 (0%) |
| Dry | May | 0 | 0 (0%) |
| Dry | Jun | 0 | 0 (0%) |
| Dry | Jul | 0 | 0 (0%) |
| Dry | Aug | 0 | 0 (0%) |
| Dry | Sep | 0 | 0 (0%) |
| Dry | Oct | 0 | 0 (0%) |
| Dry | Nov | 0 | 0 (0%) |
| Dry | Dec | 1,023 | 933 (-9%) |
| Critically dry | Jan | 15 | 16 (9%) |
| Critically dry | Feb | 0 | 0 (0%) |
| Critically dry | Mar | 0 | 0 (0%) |
| Critically dry | Apr | 0 | 0 (0%) |
| Critically dry | May | 0 | 0 (0%) |
| Critically dry | Jun | 0 | 0 (0%) |
| Critically dry | Jul | 0 | 0 (0%) |
| Critically dry | Aug | 0 | 0 (0%) |
| Critically dry | Sep | 0 | 0 (0%) |
| Critically dry | Oct | 0 | 0 (0%) |
| Critically dry | Nov | 0 | 0 (0%) |
| Critically dry | Dec | 615 | 621 (1%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to the existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions.
EC = existing conditions; N/A = not applicable; SWP = State Water Project.

**Table 5E.1-40. Entrainment Loss of Juvenile Late Fall–Run Chinook Salmon at CVP Jones Pumping Plant, Averaged by Water Year Type and Month, Based on the Salvage-Density Method**

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Wet | Jan | 66 | 64 (-3%) |
| Wet | Feb | 2 | 2 (-3%) |
| Wet | Mar | 0 | 0 (0%) |
| Wet | Apr | 0 | 0 (0%) |
| Wet | May | 0 | 0 (0%) |
| Wet | Jun | 0 | 0 (0%) |
| Wet | Jul | 0 | 0 (0%) |
| Wet | Aug | 0 | 0 (0%) |
| Wet | Sep | 0 | 0 (0%) |
| Wet | Oct | 1 | 1 (-2%) |
| Wet | Nov | 1 | 1 (2%) |
| Wet | Dec | 203 | 201 (-1%) |
| Above normal | Jan | N/A | (-1%) |
| Above normal | Feb | N/A | (0%) |
| Above normal | Mar | N/A | (0%) |
| Above normal | Apr | N/A | (0%) |
| Above normal | May | N/A | (0%) |
| Above normal | Jun | N/A | (0%) |
| Above normal | Jul | N/A | (0%) |
| Above normal | Aug | N/A | (0%) |
| Above normal | Sep | N/A | (0%) |
| Above normal | Oct | N/A | (4%) |
| Above normal | Nov | N/A | (-1%) |
| Above normal | Dec | N/A | (2%) |
| Below normal | Jan | 53 | 53 (0%) |
| Below normal | Feb | 8 | 8 (2%) |
| Below normal | Mar | 1 | 1 (15%) |
| Below normal | Apr | 0 | 0 (0%) |
| Below normal | May | 0 | 0 (0%) |
| Below normal | Jun | 0 | 0 (0%) |
| Below normal | Jul | 0 | 0 (0%) |
| Below normal | Aug | 0 | 0 (0%) |
| Below normal | Sep | 0 | 0 (0%) |
| Below normal | Oct | 0 | 0 (0%) |
| Below normal | Nov | 0 | 0 (0%) |
| Below normal | Dec | 7 | 7 (3%) |
| Dry | Jan | 7 | 7 (0%) |
| Dry | Feb | 0 | 0 (0%) |
| Dry | Mar | 0 | 0 (0%) |
| Dry | Apr | 0 | 0 (0%) |
| Dry | May | 0 | 0 (0%) |

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Dry | Jun | 0 | 0 (0%) |
| Dry | Jul | 0 | 0 (0%) |
| Dry | Aug | 0 | 0 (0%) |
| Dry | Sep | 0 | 0 (0%) |
| Dry | Oct | 0 | 0 (0%) |
| Dry | Nov | 0 | 0 (0%) |
| Dry | Dec | 84 | 87 (3%) |
| Critically dry | Jan | 5 | 5 (-7%) |
| Critically dry | Feb | 0 | 0 (0%) |
| Critically dry | Mar | 0 | 0 (0%) |
| Critically dry | Apr | 0 | 0 (0%) |
| Critically dry | May | 0 | 0 (0%) |
| Critically dry | Jun | 0 | 0 (0%) |
| Critically dry | Jul | 0 | 0 (0%) |
| Critically dry | Aug | 0 | 0 (0%) |
| Critically dry | Sep | 0 | 0 (0%) |
| Critically dry | Oct | 0 | 0 (0%) |
| Critically dry | Nov | 0 | 0 (0%) |
| Critically dry | Dec | 21 | 21 (1%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to the existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions.

CVP = Central Valley Project; EC = existing conditions; N/A = not applicable.

### Table 5E.1-41. Through-Delta Survival of Juvenile Fall-Run Chinook Salmon from the San Joaquin River Basin, Averaged by Water Year Type, Based on the Structured Decision Model Routing Application

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 0.022 | 0.021 (-5%) |
| Above normal | 0.016 | 0.016 (-3%) |
| Below normal | 0.022 | 0.021 (-1%) |
| Dry | 0.019 | 0.018 (-1%) |
| Critically dry | 0.014 | 0.013 (-2%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.

EC = existing conditions.

### Table 5E.1-42. Straying Rate (Percent) of San Joaquin River Basin Fall-Run Chinook Salmon to the Sacramento River Basin, Averaged by Water Year Type, Based on Marston et al. (2012)

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 19% | 17% (-9%) |
| Above normal | 23% | 19% (-17%) |
| Below normal | 15% | 14% (-11%) |
| Dry | 12% | 11% (-9%) |
| Critically dry | 9% | 8% (-10%) |

Notes: Percentage values in parentheses indicate relative differences of the proposed action compared to existing conditions (relative differences are larger than absolute differences). Table only includes mean responses and does not consider model uncertainty.

EC = existing conditions.

### Table 5E.1-43. Mean South Delta Exports (cubic feet per second) by Water Year Type, March

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 7,617 | 7,015 (-8%) |
| Above normal | 6,643 | 6,497 (-2%) |
| Below normal | 4,976 | 4,966 (0%) |
| Dry | 3,748 | 3,963 (6%) |
| Critically dry | 4,109 | 4,089 (0%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

EC = existing conditions.

### Table 5E.1-44. Mean South Delta Exports (cubic feet per second) by Water Year Type, April

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 6,374 | 6,004 (-6%) |
| Above normal | 4,359 | 4,335 (-1%) |
| Below normal | 3,422 | 3,349 (-2%) |
| Dry | 2,366 | 2,370 (0%) |
| Critically dry | 1,569 | 1,675 (7%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

EC = existing conditions.

### Table 5E.1-45. Mean South Delta Exports (cubic feet per second) by Water Year Type, May

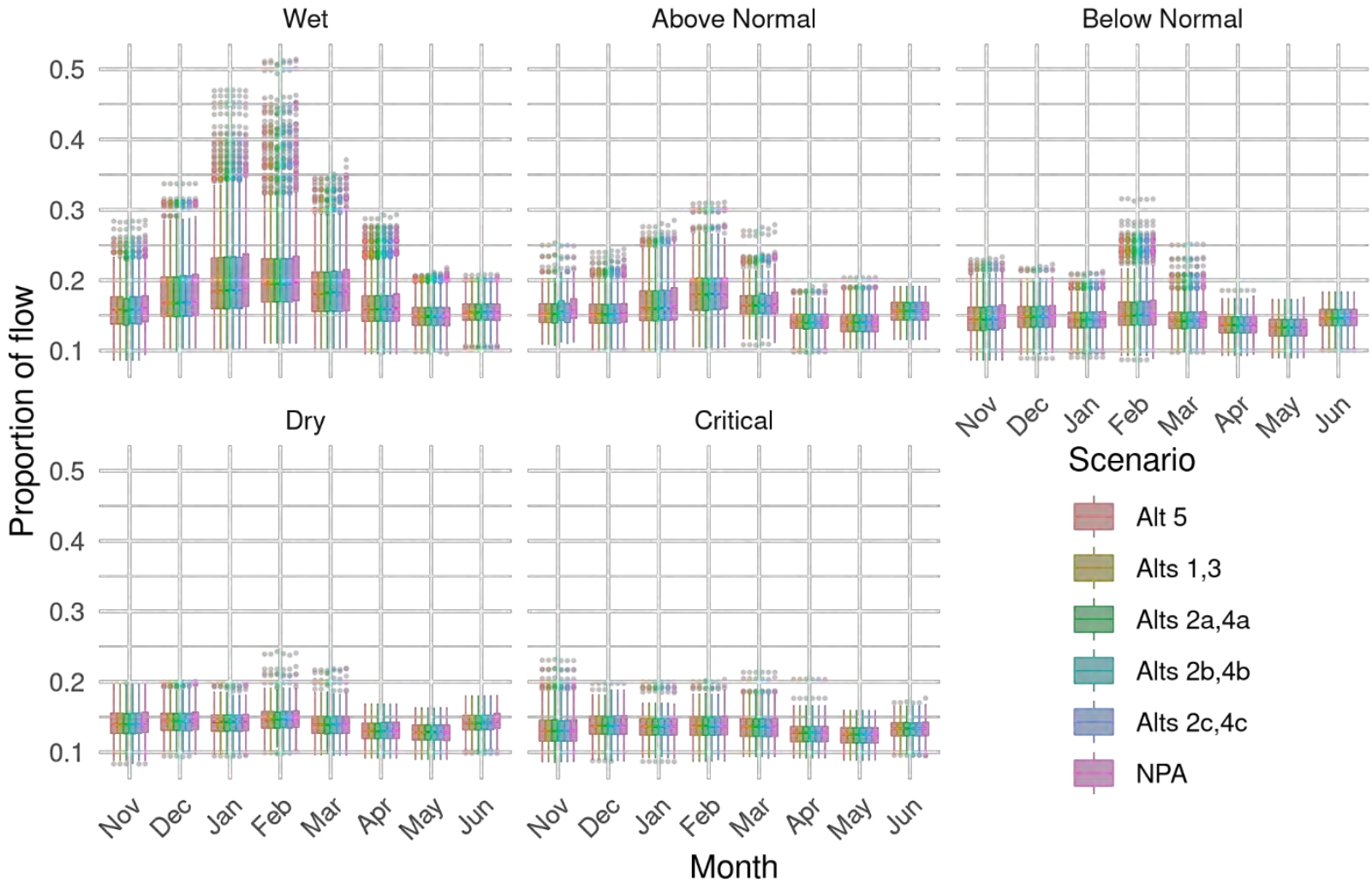
| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 5,673 | 5,791 (2%) |
| Above normal | 4,280 | 4,307 (1%) |
| Below normal | 2,569 | 2,592 (1%) |
| Dry | 1,885 | 1,847 (-2%) |
| Critically dry | 1,719 | 1,742 (1%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
EC = existing conditions.

### Table 5E.1-46. Mean South Delta Exports (cubic feet per second) by Water Year Type, June

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 7,156 | 7,259 (1%) |
| Above normal | 6,393 | 6,389 (0%) |
| Below normal | 5,192 | 5,145 (-1%) |
| Dry | 4,115 | 3,703 (-10%) |
| Critically dry | 1,560 | 1,442 (-8%) |

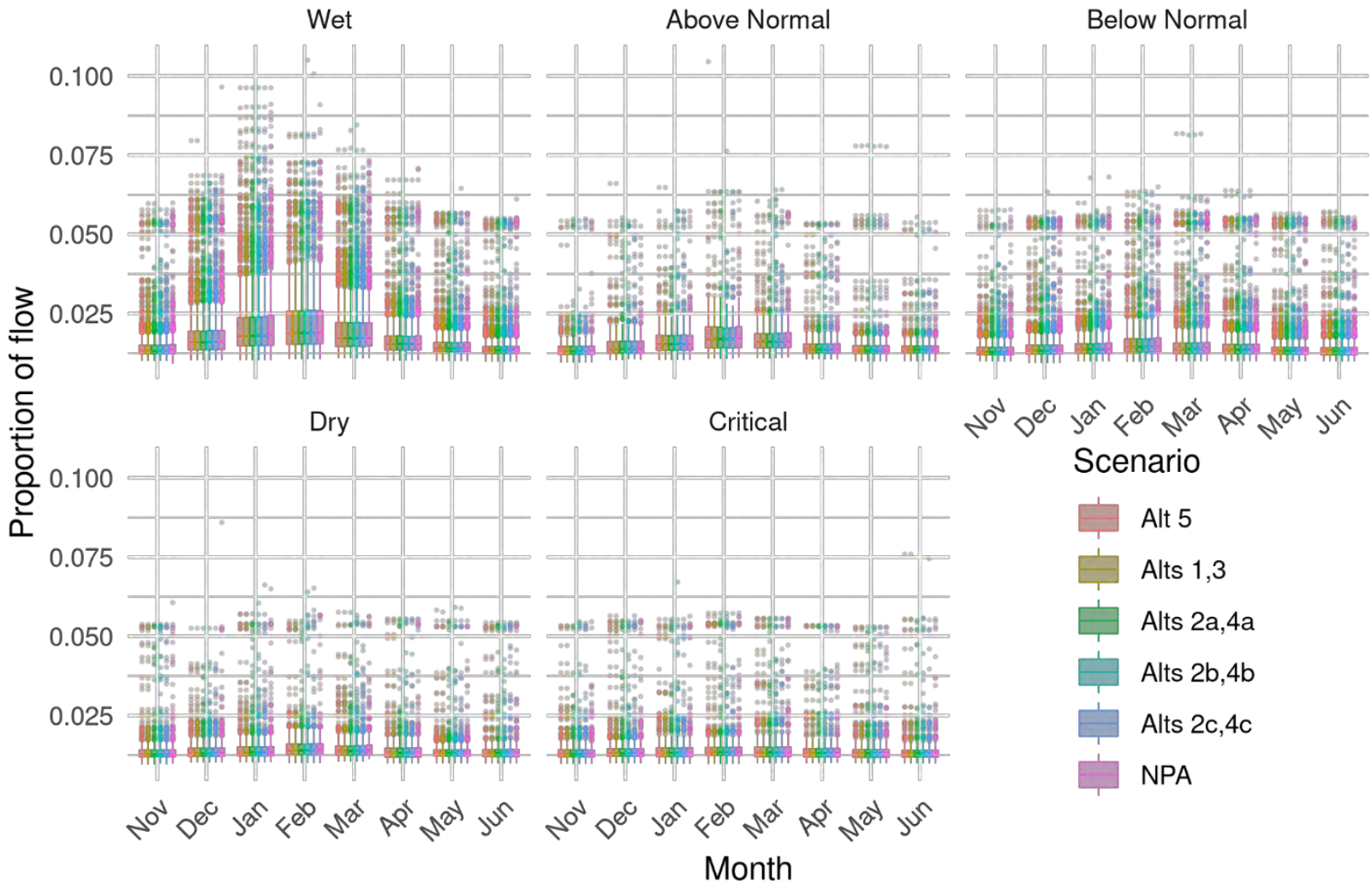
Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
EC = existing conditions.




Note: Boxes represent median (horizontal line) and 25th/75th percentiles; whiskers represent 5th/95th percentiles; points represent additional observations outside this range.

Alt = alternative; Alt 5 = proposed action; NPA = No Project Alternative (existing conditions)

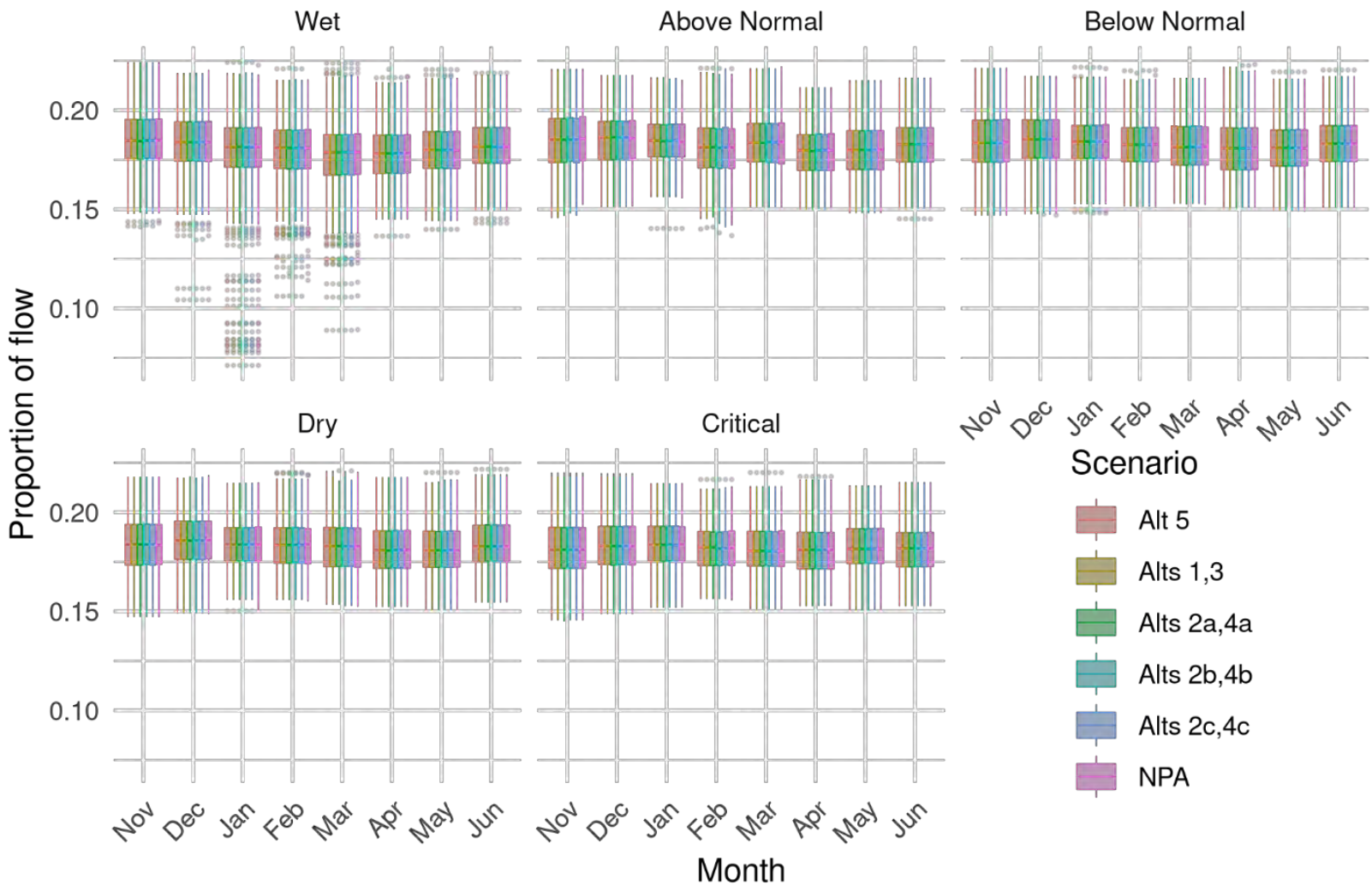
**Figure 5E.1-1. Proportion of Flow Entering the Mouth of Old River from DSM2-HYDRO Modeling Data**




Note: Boxes represent median (horizontal line) and 25th/75th percentiles; whiskers represent 5th/95th percentiles; points represent additional observations outside this range.

Alt = alternative; Alt 5 = proposed action; NPA = No Project Alternative (existing conditions).

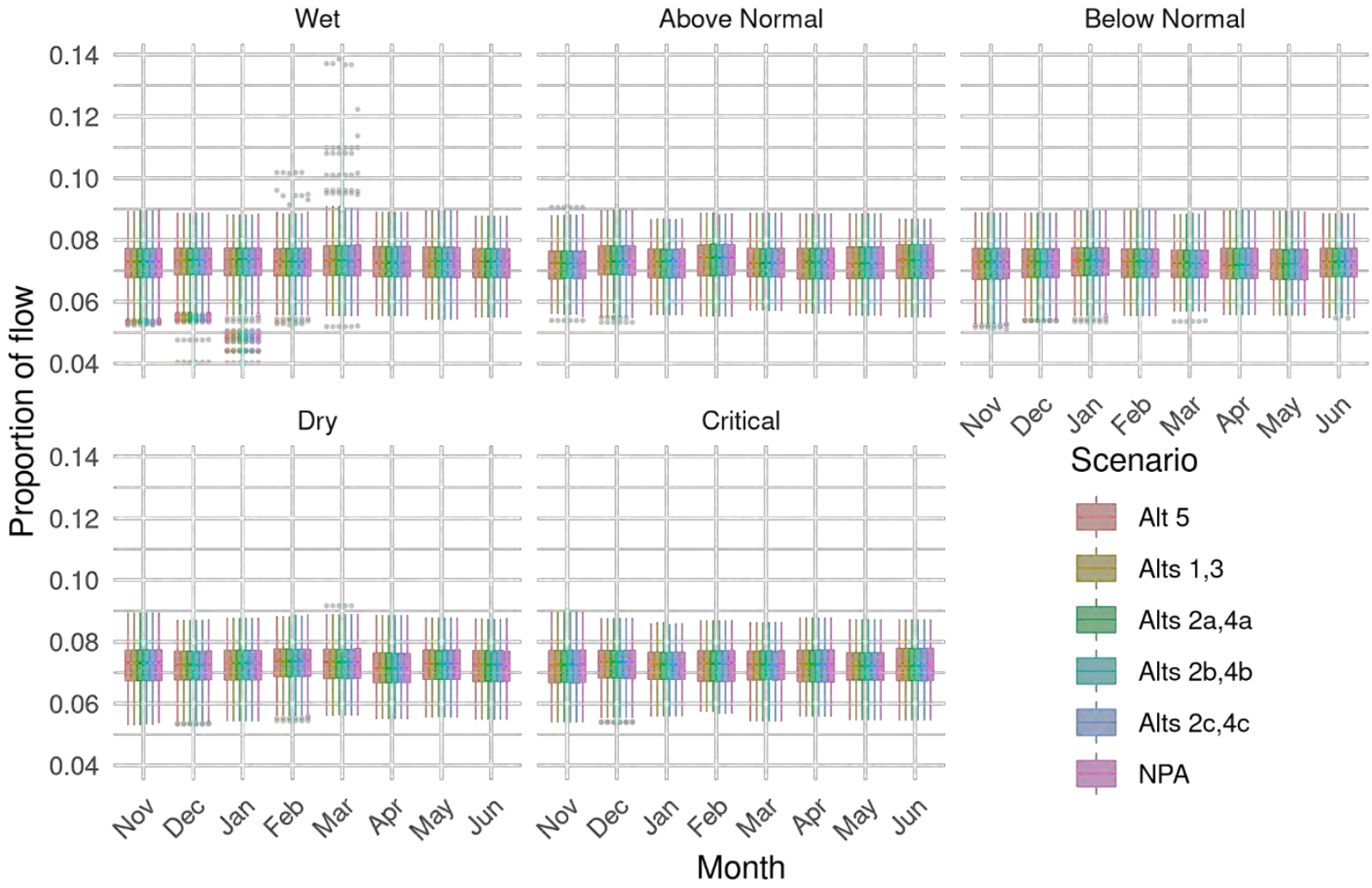
**Figure 5E.1-2. Proportion of Flow Entering Fisherman's Cut from DSM2-HYDRO Modeling Data**




Note: Boxes represent median (horizontal line) and 25th/75th percentiles; whiskers represent 5th/95th percentiles; points represent additional observations outside this range.

Alt = alternative; Alt 5 = proposed action; NPA = No Project Alternative (existing conditions).

**Figure 5E.1-3. Proportion of Flow Entering False River from DSM2-HYDRO Modeling Data**



Notes: Boxes represent median (horizontal line) and 25th/75th percentiles; whiskers represent 5th/95th percentiles; points represent additional observations outside this range.

Alt = alternative; Alt 5 = proposed action; NPA = No Project Alternative (existing conditions).

**Figure 5E.1-4. Proportion of Flow Entering Jersey Point from DSM2-HYDRO Modeling Data**

**Table 5E.1-47. Mean Number of Days with Delta Cross Channel Open by Water Year Type, October**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 17 | 16 (-5%) |
| Above normal | 28 | 17 (-38%) |
| Below normal | 21 | 18 (-11%) |
| Dry | 15 | 13 (-14%) |
| Critically dry | 10 | 5 (-53%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
EC = existing conditions.

**Table 5E.1-48. Mean Number of Days with Delta Cross Channel Open by Water Year Type, November**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 14 | 12 (-13%) |
| Above normal | 15 | 16 (1%) |
| Below normal | 17 | 14 (-16%) |
| Dry | 19 | 19 (-2%) |
| Critically dry | 12 | 13 (7%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
EC = existing conditions.

## 5E.1.6 Effects of Operations and Maintenance of Water Conveyance Facilities on California Central Valley Steelhead

The effects of operations and maintenance of water conveyance facilities on steelhead are described in Appendix 5C, Section 5C.10, *Effects of Operations and Maintenance of Water Conveyance Facilities on California Central Valley Steelhead*. The impact mechanisms at 2040 remain the same as at 2020. Table 5E.1-49 summarizes quantitative analyses and differences between 2040 (i.e., existing conditions vs. the proposed action) and 2020 (i.e., existing conditions vs. the proposed action).

**Table 5E.1-49. Summary of Central Valley Steelhead Quantitative Analyses and Differences at 2040 Relative to 2020**

| Effect/Method | 2040 Results [a] | 2020 Results [b] | Differences |
|---|---|---|---|
| Juvenile south Delta entrainment/salvage-density method | Tables 5E.1-50 and 5E.1-51 | Tables 5C.10-5 and 5C.10-6 | Generally similar, with somewhat less difference at 2040 for SWP |
| Channel velocity/DSM2 | Table 5E.1-7 | Table 5C.7-11 | Generally similar, with some exceptions (e.g., smaller differences at 2040 in September of dry years, November and January of critically dry years, and June of wet and above normal years; larger |

| Effect/Method | 2040 Results [a] | 2020 Results [b] | Differences |
|---|---|---|---|
| | | | difference at 2040 in February, March, and April of dry years) |
| Reverse flow downstream of Georgiana Slough/DSM2 | Table 5E.1-8 | Table 5C.7-12 | Generally similar, with some exceptions (e.g., smaller differences at 2040 in June of wet years; larger differences at 2040 in January, February, and May of dry years, and December and March of dry years) |
| Riparian and wetland bench inundation/ DSM2 | Tables 5E.1-11 and 5E.1-12 | Tables 5C.7-16 and 5C.7-17 | Generally similar or smaller difference at 2040 than 2020 |
| Water temperature/DSM2 | Tables 5E.1-13, 5E.1-14, and 5E.1-15 | Tables 5C.7-18, 5C.7-19, and 5C.7-20 | Same (zero difference) |
| Juvenile Mokelumne River south Delta entrainment/CalSim | Tables 5E.1-43 through 5E.1-46 | Tables 5E.1-50 through 5E.1-12 | Similar (greater positive or negative involve relatively small absolute differences no more than a few hundred cfs) |
| Juvenile Mokelumne River south Delta entrainment/DSM2-HYDRO | Figures 5E.1-1 through 5E.1-4 | Figures 5E.1-5 through 5E.1-6 | Similar |
| Juvenile San Joaquin River basin through-Delta survival/CalSim | Tables 5E.1-54, 5E.1-55, 5E.1-56 and 5E.1-57 | Tables 5C.10-1, 5C.10-2, 5C.10-3, and 5C.10-4 | Same (no difference between EC and the project alternatives) |

EC = existing conditions; SWP = State Water Project.

[a] Results for 2040 are provided in this appendix.

[b] Results for 2020 are provided in Chapter 5, Appendix 5C, *Operations and Maintenance Effects Analysis for Chinook Salmon, California Central Valley Steelhead, Green Sturgeon, and Killer Whale.* and Appendix 5D, *Bay-Delta Methods and Results.*

### Table 5E.1-51. Entrainment Loss of Juvenile Steelhead at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 5,142 | 4,786 (-7%) |
| Above normal | N/A | (2%) |
| Below normal | 3,546 | 3,466 (-2%) |
| Dry | 2,177 | 2,105 (-3%) |
| Critically dry | 2,103 | 2,036 (-3%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

EC = existing conditions; N/A = not applicable; SWP = State Water Project.

### Table 5E.1-52. Entrainment Loss of Juvenile Steelhead at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 268 | 264 (-1%) |
| Above normal | N/A | (0%) |
| Below normal | 813 | 849 (5%) |
| Dry | 522 | 557 (7%) |
| Critically dry | 156 | 165 (5%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

CVP = Central Valley Project; EC = existing conditions; N/A = not applicable.

### Table 5E.1-53. Entrainment Loss of Juvenile Steelhead at SWP Banks Pumping Plant, Averaged by Water Year Type and Month, Based on the Salvage-Density Method

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Wet | Jan | 313 | 312 (0%) |
| Wet | Feb | 2,025 | 1,933 (-5%) |
| Wet | Mar | 985 | 860 (-13%) |
| Wet | Apr | 1,113 | 963 (-13%) |
| Wet | May | 387 | 392 (1%) |
| Wet | Jun | 303 | 310 (3%) |
| Wet | Jul | 0 | 0 (0%) |
| Wet | Aug | 0 | 0 (0%) |
| Wet | Sep | 2 | 2 (1%) |
| Wet | Oct | 3 | 3 (-4%) |
| Wet | Nov | 5 | 4 (-10%) |
| Wet | Dec | 7 | 7 (0%) |
| Above normal | Jan | N/A | (0%) |
| Above normal | Feb | N/A | (6%) |
| Above normal | Mar | N/A | (-4%) |
| Above normal | Apr | N/A | (0%) |
| Above normal | May | N/A | (0%) |
| Above normal | Jun | N/A | (0%) |
| Above normal | Jul | N/A | (0%) |
| Above normal | Aug | N/A | (0%) |
| Above normal | Sep | N/A | (-2%) |
| Above normal | Oct | N/A | (-10%) |
| Above normal | Nov | N/A | (-30%) |
| Above normal | Dec | N/A | (-3%) |
| Below normal | Jan | 265 | 264 (0%) |
| Below normal | Feb | 1,330 | 1,358 (2%) |
| Below normal | Mar | 1,262 | 1,194 (-5%) |

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Below normal | Apr | 392 | 345 (-12%) |
| Below normal | May | 158 | 168 (6%) |
| Below normal | Jun | 127 | 126 (-1%) |
| Below normal | Jul | 6 | 5 (-4%) |
| Below normal | Aug | 0 | 0 (0%) |
| Below normal | Sep | 0 | 0 (0%) |
| Below normal | Oct | 0 | 0 (0%) |
| Below normal | Nov | 0 | 0 (0%) |
| Below normal | Dec | 6 | 6 (-5%) |
| Dry | Jan | 140 | 139 (0%) |
| Dry | Feb | 483 | 496 (3%) |
| Dry | Mar | 787 | 729 (-7%) |
| Dry | Apr | 445 | 445 (0%) |
| Dry | May | 176 | 165 (-7%) |
| Dry | Jun | 103 | 91 (-12%) |
| Dry | Jul | 7 | 8 (15%) |
| Dry | Aug | 0 | 0 (0%) |
| Dry | Sep | 0 | 0 (0%) |
| Dry | Oct | 0 | 0 (0%) |
| Dry | Nov | 5 | 4 (-12%) |
| Dry | Dec | 31 | 28 (-9%) |
| Critically dry | Jan | 106 | 116 (9%) |
| Critically dry | Feb | 449 | 443 (-1%) |
| Critically dry | Mar | 926 | 854 (-8%) |
| Critically dry | Apr | 407 | 417 (2%) |
| Critically dry | May | 167 | 162 (-3%) |
| Critically dry | Jun | 23 | 20 (-13%) |
| Critically dry | Jul | 3 | 3 (-1%) |
| Critically dry | Aug | 0 | 0 (0%) |
| Critically dry | Sep | 0 | 0 (0%) |
| Critically dry | Oct | 0 | 0 (0%) |
| Critically dry | Nov | 3 | 3 (-7%) |
| Critically dry | Dec | 18 | 19 (1%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to the existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions. EC = existing conditions; N/A = not applicable; SWP = State Water Project.

**Table 5E.1-54. Entrainment Loss of Juvenile Steelhead at CVP Jones Pumping Plant, Averaged by Water Year Type and Month, Based on the Salvage-Density Method**

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Wet | Jan | 45 | 43 (-3%) |
| Wet | Feb | 131 | 128 (-3%) |
| Wet | Mar | 32 | 33 (0%) |
| Wet | Apr | 10 | 10 (1%) |
| Wet | May | 29 | 30 (4%) |
| Wet | Jun | 18 | 18 (-1%) |
| Wet | Jul | 0 | 0 (0%) |
| Wet | Aug | 0 | 0 (0%) |
| Wet | Sep | 1 | 1 (-2%) |
| Wet | Oct | 0 | 0 (0%) |
| Wet | Nov | 0 | 0 (0%) |
| Wet | Dec | 2 | 2 (-1%) |
| Above normal | Jan | N/A | (-1%) |
| Above normal | Feb | N/A | (0%) |
| Above normal | Mar | N/A | (0%) |
| Above normal | Apr | N/A | (0%) |
| Above normal | May | N/A | (1%) |
| Above normal | Jun | N/A | (0%) |
| Above normal | Jul | N/A | (0%) |
| Above normal | Aug | N/A | (0%) |
| Above normal | Sep | N/A | (0%) |
| Above normal | Oct | N/A | (0%) |
| Above normal | Nov | N/A | (0%) |
| Above normal | Dec | N/A | (2%) |
| Below normal | Jan | 49 | 49 (0%) |
| Below normal | Feb | 471 | 481 (2%) |
| Below normal | Mar | 186 | 213 (15%) |
| Below normal | Apr | 73 | 73 (0%) |
| Below normal | May | 30 | 30 (0%) |
| Below normal | Jun | 3 | 3 (0%) |
| Below normal | Jul | 0 | 0 (0%) |
| Below normal | Aug | 0 | 0 (0%) |
| Below normal | Sep | 0 | 0 (0%) |
| Below normal | Oct | 0 | 0 (0%) |
| Below normal | Nov | 0 | 0 (0%) |
| Below normal | Dec | 0 | 0 (0%) |
| Dry | Jan | 32 | 31 (0%) |
| Dry | Feb | 153 | 156 (2%) |
| Dry | Mar | 218 | 251 (15%) |
| Dry | Apr | 74 | 74 (0%) |
| Dry | May | 35 | 35 (0%) |

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Dry | Jun | 3 | 3 (0%) |
| Dry | Jul | 0 | 0 (0%) |
| Dry | Aug | 0 | 0 (0%) |
| Dry | Sep | 0 | 0 (0%) |
| Dry | Oct | 0 | 0 (0%) |
| Dry | Nov | 0 | 0 (0%) |
| Dry | Dec | 7 | 7 (3%) |
| Critically dry | Jan | 0 | 0 (0%) |
| Critically dry | Feb | 64 | 67 (5%) |
| Critically dry | Mar | 68 | 72 (5%) |
| Critically dry | Apr | 19 | 21 (7%) |
| Critically dry | May | 5 | 5 (4%) |
| Critically dry | Jun | 0 | 0 (0%) |
| Critically dry | Jul | 0 | 0 (0%) |
| Critically dry | Aug | 0 | 0 (0%) |
| Critically dry | Sep | 0 | 0 (0%) |
| Critically dry | Oct | 0 | 0 (0%) |
| Critically dry | Nov | 0 | 0 (0%) |
| Critically dry | Dec | 0 | 0 (0%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions.
CVP = Central Valley Project; EC = existing conditions; N/A = not applicable.

### Table 5E.1-55. Mean San Joaquin River Flow at Vernalis (cubic feet per second) by Water Year Type, February

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 10,124 | 10,130 (0%) |
| Above normal | 7,413 | 7,415 (0%) |
| Below normal | 3,568 | 3,569 (0%) |
| Dry | 2,017 | 2,016 (0%) |
| Critically dry | 1,885 | 1,887 (0%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
EC = existing conditions.

**Table 5E.1-56. Mean San Joaquin River Flow at Vernalis (cubic feet per second) by Water Year Type, March**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 11,640 | 11,642 (0%) |
| Above normal | 6,997 | 6,998 (0%) |
| Below normal | 2,985 | 2,986 (0%) |
| Dry | 1,936 | 1,935 (0%) |
| Critically dry | 1,837 | 1,840 (0%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

EC = existing conditions.

**Table 5E.1-57. Mean San Joaquin River Flow at Vernalis (cubic feet per second) by Water Year Type, April**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 11,112 | 11,115 (0%) |
| Above normal | 6,617 | 6,619 (0%) |
| Below normal | 3,778 | 3,779 (0%) |
| Dry | 2,509 | 2,513 (0%) |
| Critically dry | 1,838 | 1,838 (0%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

EC = existing conditions.

**Table 5E.1-58. Mean San Joaquin River Flow at Vernalis (cubic feet per second) by Water Year Type, May**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 9,726 | 9,728 (0%) |
| Above normal | 6,161 | 6,163 (0%) |
| Below normal | 3,812 | 3,816 (0%) |
| Dry | 2,699 | 2,702 (0%) |
| Critically dry | 1,928 | 1,929 (0%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

EC = existing conditions.

## 5E.1.7 Effects of Operations and Maintenance of Water Conveyance Facilities on Delta Smelt

The effects of operations and maintenance of water conveyance facilities on delta smelt are described in Appendix 6C, *Operations and Maintenance Effects Analysis for Delta Smelt, Longfin Smelt, and Terrestrial Species,* Section 6C.1.1, *Effects of Water Facility Operations and Maintenance on Delta Smelt*. The impact mechanisms at 2040 remain the same as at 2020. Table 5E.1-59 summarizes

quantitative analyses and differences between 2040 (i.e., existing conditions vs. the proposed action) and 2020 (i.e., existing conditions vs. the proposed action).

**Table 5E.1-59. Summary of Delta Smelt Quantitative Analyses and Differences at 2040 Relative to 2020**

| Effect/Method | 2040 Results [a] | 2020 Results [b] | Differences |
|---|---|---|---|
| Larval NDD entrainment/CalSim | Table 5E.1-59 | Table 6C.1-2 | Similar or less at 2040 than 2020 (particularly May/June) |
| Adult south Delta entrainment/CalSim | Tables 5E.1-60, 5E.1-61, 5E.1-62, and 5E.1-63 | Tables 6C.1-5, 6C.1-6, 6C.1-7, and 6C.1-8 | Similar (although there are some differences more than a few percentage points, existing assumed regulatory entrainment restrictions would occur) |
| Larval/early juvenile south Delta entrainment/CalSim | Tables 5E.1-63, 5E.1-64, 5E.1-65, and 5E.1-66 | Tables 6C.1-8, 6C.1-9, 6C.1-10, and 6C.1-11 | Similar (although there are some differences more than a few percentage points, existing assumed regulatory entrainment restrictions would occur) |
| Larval/early juvenile south Delta entrainment/DSM2-PTM | Table 5E.1-67 and 5E.1-68 | Table 6C.1-12 | Similar (although there are some differences more than a few percentage points, existing assumed regulatory entrainment restrictions would occur) |
| NDD suspended sediment entrainment/CalSim | Table 5E.1-69 | Table 6C.1-13 | Similar |
| *Eurytemora affinis* food availability/X2-abundance regression | Table 5E.1-70 | Table 6C.1-14 | Generally similar (marginally greater negative difference in dry years at 2040) |
| *Pseudodiaptomus forbesi* food availability/CalSim | Tables 5E.1-71 through 5E.1-76 | Tables 6C.1-15 through 6C.1-24 | Generally similar, with less difference at 2040 in some cases, (e.g., June and July outflow in above normal years) and somewhat greater difference at 2040 in October of wet years; greater differences for QWEST percentage of years with positive flow at 2040 in August and October |
| NDD phytoplankton carbon entrainment/DSM2 | Tables 5E.1-77 | Table 6C.1-25 | Similar |
| Juvenile/subadult habitat extent/CalSim | Tables 5E.1-78 and 5E.1-79 | Tables 6C.1-26 and 6C.1-27 | Generally similar, but with greater difference in November and December at 2040 for X2 < 85 km |
| Predator abundance (silversides)/CalSim | Tables 5E.1-80 and 5E.1-81 | Tables 6C.1-31 and 6C.1-32 | Similar |

| Effect/Method | 2040 Results [a] | 2020 Results [b] | Differences |
|---|---|---|---|
| Cyanobacteria harmful algal blooms | See Impact WQ-14: *Effects on Cyanobacteria Harmful Algal Blooms Resulting from Facility Operations and Maintenance* in Appendix 9L, *Water Quality 2040 Analysis,* of the *Delta Conveyance Project Final Environmental Impact Report* (Department of Water Resources 2023) | See Appendix 6B | Similar |
| Selenium | Quantitative analysis not undertaken but would remain well within toxicity thresholds based on 2020 results (relative magnitude of different selenium sources does not change appreciably from 2020 to 2040) | See Appendix 6B | Similar (results would remain well below toxicity thresholds) |

km = kilometers; NDD = north Delta diversions.

[a] Results for 2040 are provided in this appendix.

[b] Results for 2020 are provided in Appendix 6B, *Water Quality,* and Appendix 6C, *Operations and Maintenance Effects Analysis for Delta Smelt, Longfin Smelt, and Terrestrial Species.*

### Table 5E.1-60. Percentage of Sacramento River Flow Diverted by the North Delta Diversions, March–June

| Percentile | Proposed Action |
|---|---|
| Minimum | 0% |
| 10% | 0% |
| 20% | 0% |
| 30% | 0% |
| 40% | 0% |
| 50% | 5% |
| 60% | 8% |
| 70% | 11% |
| 80% | 13% |
| 90% | 18% |
| Maximum | 23% |
| Minimum | 0% |
| 10% | 0% |
| 20% | 0% |
| 30% | 0% |
| 40% | 0% |
| 50% | 0% |
| 60% | 0% |

| Percentile | Proposed Action |
|---|---|
| 70% | 0% |
| 80% | 0% |
| 90% | 3% |
| Maximum | 16% |
| Minimum | 0% |
| 10% | 0% |
| 20% | 0% |
| 30% | 0% |
| 40% | 0% |
| 50% | 0% |
| 60% | 0% |
| 70% | 0% |
| 80% | 0% |
| 90% | 3% |
| Maximum | 21% |
| Minimum | 0% |
| 10% | 0% |
| 20% | 0% |
| 30% | 0% |
| 40% | 0% |
| 50% | 0% |
| 60% | 0% |
| 70% | 0% |
| 80% | 0% |
| 90% | 0% |
| Maximum | 10% |

### Table 5E.1-61. Mean Old and Middle River Flow (cubic feet per second) by Water Year Type, December

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | -4,705 | -4,674 (1%) |
| Above normal | -5,831 | -5,788 (1%) |
| Below normal | -5,639 | -5,565 (1%) |
| Dry | -5,442 | -5,267 (3%) |
| Critically dry | -3,775 | -3,818 (-1%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
EC = existing conditions.

### Table 5E.1-62. Mean Old and Middle River Flow (cubic feet per second) by Water Year Type, January

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | -2,779 | -2,673 (4%) |
| Above normal | -4,029 | -4,010 (0%) |
| Below normal | -4,362 | -4,362 (0%) |
| Dry | -4,776 | -4,759 (0%) |
| Critically dry | -3,752 | -3,759 (0%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

EC = existing conditions.

### Table 5E.1-63. Mean Old and Middle River Flow (cubic feet per second) by Water Year Type, February

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | -2,427 | -2,111 (13%) |
| Above normal | -2,797 | -3,067 (-10%) |
| Below normal | -3,864 | -3,920 (-1%) |
| Dry | -4,317 | -4,444 (-3%) |
| Critically dry | -3,477 | -3,574 (-3%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

EC = existing conditions.

### Table 5E.1-64. Mean Old and Middle River Flow (cubic feet per second) by Water Year Type, March

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | -805 | -245 (70%) |
| Above normal | -2,620 | -2,487 (5%) |
| Below normal | -3,016 | -3,006 (0%) |
| Dry | -2,423 | -2,619 (-8%) |
| Critically dry | -2,800 | -2,780 (1%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

EC = existing conditions.

### Table 5E.1-65. Mean Old and Middle River Flow (cubic feet per second) by Water Year Type, April

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | -529 | -188 (65%) |
| Above normal | -1,164 | -1,142 (2%) |
| Below normal | -1,510 | -1,443 (4%) |
| Dry | -1,124 | -1,126 (0%) |
| Critically dry | -753 | -849 (-13%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
EC = existing conditions.

### Table 5E.1-66. Mean Old and Middle River Flow (cubic feet per second) by Water Year Type, May

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | -769 | -876 (-14%) |
| Above normal | -1,360 | -1,384 (-2%) |
| Below normal | -880 | -899 (-2%) |
| Dry | -750 | -714 (5%) |
| Critically dry | -941 | -962 (-2%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
EC = existing conditions.

### Table 5E.1-67. Mean Old and Middle River Flow (cubic feet per second) by Water Year Type, June

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | -4,301 | -4,396 (-2%) |
| Above normal | -4,766 | -4,761 (0%) |
| Below normal | -4,537 | -4,491 (1%) |
| Dry | -3,753 | -3,372 (10%) |
| Critically dry | -1,648 | -1,539 (7%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
EC = existing conditions.

### Table 5E.1-68. Entrainment of Particles at the South Delta Export Facilities and North Bay Aqueduct from DSM2 Particle Tracking Modeling, Weighted by Delta Smelt Larval/Early Juvenile Distribution

| Water Year Type | EC | Proposed Action |
|---|---|---|
| **March** | | |
| Wet | 4.20 | 4.17 (-1%) |
| Above normal | 0.62 | 0.62 (1%) |
| Below normal | 12.82 | 12.89 (1%) |
| Dry | 12.50 | 14.13 (13%) |
| Critically dry | 13.19 | 13.17 (0%) |
| **April** | | |
| Wet | 2.87 | 2.77 (-4%) |
| Above normal | 5.74 | 5.74 (0%) |
| Below normal | 5.96 | 6.19 (4%) |
| Dry | 6.28 | 6.26 (0%) |
| Critically dry | 4.72 | 5.21 (10%) |

| Water Year Type | EC | Proposed Action |
|---|---|---|
| **May** | | |
| Wet | 6.10 | 7.30 (20%) |
| Above normal | 4.27 | 4.31 (1%) |
| Below normal | 4.21 | 4.26 (1%) |
| Dry | 3.96 | 3.74 (-6%) |
| Critically dry | 7.46 | 7.53 (1%) |
| **June** | | |
| Wet | 16.45 | 16.83 (2%) |
| Above normal | 18.85 | 18.83 (0%) |
| Below normal | 23.61 | 23.40 (-1%) |
| Dry | 20.41 | 18.65 (-9%) |
| Critically dry | 10.07 | 9.54 (-5%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
EC = existing conditions.

### Table 5E.1-69. Entrainment of Particles at North Bay Aqueduct from DSM2 Particle Tracking Modeling, Weighted by Delta Smelt Larval/Early Juvenile Distribution

| Water Year Type | EC | Proposed Action |
|---|---|---|
| **March** | | |
| Wet | 0.02 | 0.02 (20%) |
| Above normal | 0.08 | 0.07 (-5%) |
| Below normal | 0.08 | 0.09 (12%) |
| Dry | 0.04 | 0.04 (3%) |
| Critically dry | 0.04 | 0.04 (-3%) |
| **April** | | |
| Wet | 0.00 | 0.00 (3%) |
| Above normal | 0.00 | 0.00 (51%) |
| Below normal | 0.04 | 0.04 (-2%) |
| Dry | 0.05 | 0.05 (4%) |
| Critically dry | 0.03 | 0.03 (2%) |
| **May** | | |
| Wet | 0.14 | 0.14 (0%) |
| Above normal | 0.21 | 0.20 (-2%) |
| Below normal | 0.21 | 0.21 (0%) |
| Dry | 0.14 | 0.14 (-1%) |
| Critically dry | 0.09 | 0.09 (0%) |
| **June** | | |
| Wet | 0.22 | 0.21 (-3%) |
| Above normal | 0.22 | 0.24 (9%) |
| Below normal | 0.19 | 0.19 (1%) |
| Dry | 0.19 | 0.19 (2%) |
| Critically dry | 0.14 | 0.14 (0%) |

Notes: Percentage values in parentheses indicate differences of proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
EC = existing conditions.

### Table 5E.1-70. Mean Annual Percentage of Suspended Sediment in the Sacramento River at Freeport Entrained by the North Delta Diversions by Water Year Type and Total Percentage Entrained over Full CalSim Modeling Period (Water Years 1922–2015)

| Water Year Type | Proposed Action |
|---|---|
| Wet | 3% |
| Above normal | 7% |
| Below normal | 7% |
| Dry | 6% |
| Critically dry | 4% |
| Total | 5% |

### Table 5E.1-71. Mean *Eurytemora affinis* Density (adults per cubic meter) in the Low Salinity Zone by Water Year Type

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 154 | 153 (-1%) |
| Above normal | 137 | 136 (-1%) |
| Below normal | 113 | 110 (-3%) |
| Dry | 101 | 97 (-4%) |
| Critically dry | 76 | 74 (-3%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty. Results are not predictions of actual values.
EC = existing conditions.

### Table 5E.1-72. Mean Delta Outflow (cubic feet per second) by Water Year Type, June

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 11,628 | 11,523 (-1%) |
| Above normal | 10,093 | 10,109 (0%) |
| Below normal | 6,390 | 6,385 (0%) |
| Dry | 6,100 | 6,081 (0%) |
| Critically dry | 5,671 | 5,724 (1%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
EC = existing conditions.

### Table 5E.1-73. Mean Delta Outflow (cubic feet per second) by Water Year Type, July

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 7,933 | 7,956 (0%) |
| Above normal | 7,048 | 7,067 (0%) |

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Below normal | 5,312 | 5,314 (0%) |
| Dry | 4,258 | 4,166 (-2%) |
| Critically dry | 3,348 | 3,345 (0%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

EC = existing conditions.

### Table 5E.1-74. Mean Delta Outflow (cubic feet per second) by Water Year Type, August

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 4,991 | 4,977 (0%) |
| Above normal | 5,588 | 5,597 (0%) |
| Below normal | 3,284 | 3,215 (-2%) |
| Dry | 3,576 | 3,688 (3%) |
| Critically dry | 3,022 | 3,044 (1%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

EC = existing conditions.

### Table 5E.1-75. Mean Delta Outflow (cubic feet per second) by Water Year Type, September

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 11,500 | 11,468 (0%) |
| Above normal | 11,791 | 11,757 (0%) |
| Below normal | 2,699 | 2,396 (-11%) |
| Dry | 2,200 | 2,205 (0%) |
| Critically dry | 2,347 | 2,347 (0%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

EC = existing conditions.

### Table 5E.1-76. Mean Delta Outflow (cubic feet per second) by Water Year Type, October

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 7,379 | 6,971 (-6%) |
| Above normal | 7,735 | 7,522 (-3%) |
| Below normal | 5,865 | 5,824 (-1%) |
| Dry | 5,365 | 5,330 (-1%) |
| Critically dry | 4,120 | 4,089 (-1%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

EC = existing conditions.

### Table 5E.1-77. Percentage of Years with Positive QWEST Flow, July–October

| Month | EC | Proposed Action |
|---|---|---|
| July | 55% | 62% (12%) |
| August | 51% | 41% (-19%) |
| September | 64% | 69% (8%) |
| October | 78% | 72% (-7%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions (these are percentage point differences as opposed to absolute percentage differences).
EC = existing conditions.

### Table 5E.1-78. Estimated 5th, 50th, and 95th Percentile Entrainment of Phytoplankton Carbon at the North Delta Diversions Based on Minimum and Maximum Delta Phytoplankton Carbon Stock Size

| Month | Min. Stock Size: 5th Percentile Entrainment | Min. Stock Size: 50th Percentile Entrainment | Min. Stock Size: 95th Percentile Entrainment | Max. Stock Size: 5th Percentile Entrainment | Max. Stock Size: 50th Percentile Entrainment | Max. Stock Size: 95th Percentile Entrainment |
|---|---|---|---|---|---|---|
| January | 0.0% | 0.7% | 4.1% | 0.0% | 0.3% | 1.8% |
| February | 0.0% | 0.5% | 3.1% | 0.0% | 0.3% | 1.7% |
| March | 0.0% | 0.3% | 2.6% | 0.0% | 0.1% | 1.2% |
| April | 0.0% | 0.0% | 1.3% | 0.0% | 0.0% | 0.4% |
| May | 0.0% | 0.0% | 0.7% | 0.0% | 0.0% | 0.1% |
| June | 0.0% | 0.0% | 0.1% | 0.0% | 0.0% | 0.0% |
| July | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| August | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| September | 0.0% | 0.0% | 0.7% | 0.0% | 0.0% | 0.2% |
| October | 0.0% | 0.0% | 1.1% | 0.0% | 0.0% | 0.3% |
| November | 0.0% | 0.0% | 1.9% | 0.0% | 0.0% | 0.7% |
| December | 0.0% | 1.3% | 8.1% | 0.0% | 0.2% | 1.5% |

Notes: Max. and min. stock size = maximum and minimum stock size based on multiplying observed maximum and minimum phytoplankton carbon density at Antioch by the volume of the Delta. Entrainment percentiles represent the range of entrainment based on modeled north Delta intake diversion rates (Appendix 5D, *Bay-Delta Methods and Results*, Section 5D.12, *Phytoplankton Carbon Entrainment by North Delta Diversions*).

### Table 5E.1-79. Percentage of Years with X2 Less than 85 km (Low Salinity Zone within Honker Bay), June–December

| Month | EC | Proposed Action |
|---|---|---|
| June | 90% | 89% (-1%) |
| July | 49% | 50% (2%) |
| August | 37% | 38% (3%) |
| September | 45% | 45% (0%) |
| October | 48% | 47% (-2%) |
| November | 22% | 19% (-14%) |
| December | 54% | 50% (-8%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions (these are percentage point differences as opposed to absolute percentage differences).

EC = existing conditions; km = kilometers.

**Table 5E.1-80. Mean September–November X2 By Water Year Type**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 80.6 | 80.8 (0.2) |
| Above normal | 82.0 | 82.2 (0.1) |
| Below normal | 89.8 | 90.3 (0.5) |
| Dry | 92.7 | 92.8 (0.1) |
| Critically dry | 93.5 | 93.6 (0.0) |

Notes: Values in parentheses indicate differences of the proposed action compared to existing conditions.
EC = existing conditions.

**Table 5E.1-81. Mean South Delta Exports (cubic feet per second) by Water Year Type, March–May**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 6,555 | 6,270 (-4%) |
| Above normal | 5,094 | 5,046 (-1%) |
| Below normal | 3,656 | 3,636 (-1%) |
| Dry | 2,666 | 2,727 (2%) |
| Critically dry | 2,466 | 2,502 (1%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
EC = existing conditions.

**Table 5E.1-82. Mean Delta Inflow (cubic feet per second) by Water Year Type, June–September**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 20,731 | 20,634 (0%) |
| Above normal | 18,384 | 18,398 (0%) |
| Below normal | 14,269 | 14,243 (0%) |
| Dry | 11,472 | 11,501 (0%) |
| Critically dry | 9,719 | 9,645 (-1%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The Sacramento River flow term in the Delta inflow calculation is downstream of the north Delta diversions.
EC = existing conditions.

## 5E.1.8 Effects of Operations and Maintenance of Water Conveyance Facilities on Longfin Smelt

The effects of operations and maintenance of water conveyance facilities on longfin smelt are described in *Operations and Maintenance Effects on Longfin Smelt*, in Section 6C.2.1.1. The impact mechanisms at 2040 remain the same as at 2020. Table 5E.1-83 summarizes quantitative analyses and differences between 2040 (i.e., existing conditions vs. the proposed action) and 2020 (i.e., existing conditions vs. the proposed action).

**Table 5E.1-83. Summary of Longfin Smelt Quantitative Analyses and Differences at 2040 Relative to 2020**

| Effect/Method | 2040 Results [a] | 2020 Results [b] | Differences |
|---|---|---|---|
| Larval entrainment/DSM2-PTM | Tables 5E.1-83, 5E.1-84 | Tables 6C.2-35 and 6C.2-36 | Similar (although there are some differences more than a few percentage points, existing assumed regulatory entrainment restrictions would occur, and absolute percentage would remain low) |
| Larval entry into south Delta/DSM2-PTM | Tables 5E.1-87 and 5E.1-88 | Tables I and 6C.2-38 | Generally similar (although there are some differences more than a few percentage points, existing assumed regulatory entrainment restrictions would occur, and absolute percentage would remain low) |
| Larval passage past Chipps Island/DSM2-PTM | Tables 5E.1-89 and 5E.1-90 | Tables 6C.2-39 and 6C.2-40 | Similar |
| Juvenile south Delta entrainment/OMR-salvage regression | Table 5E.1-91 | Table 6C.2-41 | Similar |
| *Eurytemora affinis* food availability/X2-abundance regression | Table 5E.1-70 | Table 6C.1-14 | Generally similar (marginally greater negative difference in dry years at 2040) |
| Delta outflow-abundance/Delta outflow-abundance index method | Figures 5E.1-5; Tables 5E.1-92 and 5E.1-93 | Figure 6C.2-2; Tables 6C.2-42 and 6C.2-43 | Generally similar |

[a] Results for 2040 are provided in this appendix.

[b] Results for 2020 are provided in Appendix 5D, *Bay-Delta Methods and Results*, and Appendix 6C*, Operations and Maintenance Effects Analysis for Delta Smelt, Longfin Smelt, and Terrestrial Species.*

**Table 5E.1-84. Entrainment of Neutrally Buoyant Particles at the South Delta Export Facilities and North Bay Aqueduct from DSM2 Particle Tracking Modeling, Weighted by Longfin Smelt Larval Distribution**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| **January** | | |
| Wet | 1.33 | 1.43 (7%) |
| Above normal | 1.81 | 1.93 (7%) |
| Below normal | 4.91 | 5.20 (6%) |
| Dry | 7.01 | 7.48 (7%) |
| Critically dry | 6.22 | 6.55 (5%) |
| **February** | | |
| Wet | 0.83 | 0.84 (2%) |
| Above normal | 1.45 | 1.53 (6%) |
| Below normal | 2.37 | 2.54 (7%) |
| Dry | 3.15 | 3.58 (14%) |
| Critically dry | 3.38 | 3.56 (6%) |
| **March** | | |

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 0.62 | 0.60 (-4%) |
| Above normal | 0.71 | 0.71 (-1%) |
| Below normal | 1.56 | 1.64 (5%) |
| Dry | 1.40 | 1.62 (16%) |
| Critically dry | 2.15 | 2.19 (2%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

EC = existing conditions.

### Table 5E.1-85. Entrainment of Neutrally Buoyant Particles at the North Bay Aqueduct from DSM2 Particle Tracking Modeling, Weighted by Longfin Smelt Larval Distribution

| Water Year Type | EC | Proposed Action |
|---|---|---|
| **January** | | |
| Wet | 0.35 | 0.35 (0%) |
| Above normal | 0.39 | 0.41 (5%) |
| Below normal | 0.38 | 0.39 (3%) |
| Dry | 0.47 | 0.49 (3%) |
| Critically dry | 0.22 | 0.23 (3%) |
| **February** | | |
| Wet | 0.33 | 0.33 (0%) |
| Above normal | 0.36 | 0.38 (6%) |
| Below normal | 0.34 | 0.34 (1%) |
| Dry | 0.27 | 0.27 (2%) |
| Critically dry | 0.14 | 0.15 (7%) |
| **March** | | |
| Wet | 0.17 | 0.17 (0%) |
| Above normal | 0.17 | 0.16 (-4%) |
| Below normal | 0.19 | 0.20 (4%) |
| Dry | 0.19 | 0.20 (5%) |
| Critically dry | 0.16 | 0.16 (0%) |

Notes: Percentage values in parentheses indicate differences of proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

EC = existing conditions.

### Table 5E.1-86. Entrainment of Surface-Oriented Particles at the South Delta Export Facilities from DSM2 Particle Tracking Modeling, Weighted by Longfin Smelt Larval Distribution

| Water Year Type | EC | Proposed Action |
|---|---|---|
| **January** | | |
| Wet | 1.48 | 1.58 (7%) |
| Above normal | 1.98 | 2.14 (8%) |
| Below normal | 5.57 | 5.92 (6%) |
| Dry | 7.93 | 8.44 (6%) |

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Critically dry | 7.15 | 7.54 (5%) |
| **February** | | |
| Wet | 0.91 | 0.92 (2%) |
| Above normal | 1.62 | 1.71 (6%) |
| Below normal | 2.70 | 2.90 (7%) |
| Dry | 3.57 | 4.09 (15%) |
| Critically dry | 3.97 | 4.25 (7%) |
| **March** | | |
| Wet | 0.69 | 0.67 (-4%) |
| Above normal | 0.79 | 0.80 (2%) |
| Below normal | 1.83 | 1.93 (5%) |
| Dry | 1.65 | 1.93 (17%) |
| Critically dry | 2.64 | 2.68 (1%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
EC = existing conditions.

### Table 5E.1-87. Entrainment of Surface-Oriented Particles at the North Bay Aqueduct from DSM2 Particle Tracking Modeling, Weighted by Longfin Smelt Larval Distribution

| Water Year Type | EC | Proposed Action |
|---|---|---|
| **January** | | |
| Wet | 0.35 | 0.35 (1%) |
| Above normal | 0.40 | 0.39 (-4%) |
| Below normal | 0.38 | 0.39 (2%) |
| Dry | 0.47 | 0.49 (4%) |
| Critically dry | 0.22 | 0.22 (-1%) |
| **February** | | |
| Wet | 0.33 | 0.33 (1%) |
| Above normal | 0.36 | 0.37 (0%) |
| Below normal | 0.33 | 0.34 (1%) |
| Dry | 0.25 | 0.27 (6%) |
| Critically dry | 0.13 | 0.14 (6%) |
| **March** | | |
| Wet | 0.16 | 0.16 (3%) |
| Above normal | 0.16 | 0.15 (-1%) |
| Below normal | 0.18 | 0.18 (3%) |
| Dry | 0.18 | 0.19 (5%) |
| Critically dry | 0.15 | 0.15 (3%) |

Notes: Percentage values in parentheses indicate differences of proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
EC = existing conditions.

**Table 5E.1-88. South Delta Flux of Neutrally Buoyant Particles from DSM2 Particle Tracking Modeling, Weighted by Longfin Smelt Larval Distribution**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| **January** | | |
| Wet | -0.46 | -0.37 (21%) |
| Above normal | 0.01 | 0.15 (1081%) |
| Below normal | 3.27 | 3.59 (10%) |
| Dry | 5.44 | 5.95 (10%) |
| Critically dry | 5.05 | 5.41 (7%) |
| **February** | | |
| Wet | -1.01 | -0.99 (2%) |
| Above normal | -0.35 | -0.26 (25%) |
| Below normal | 0.69 | 0.89 (30%) |
| Dry | 1.52 | 2.01 (32%) |
| Critically dry | 2.10 | 2.34 (11%) |
| **March** | | |
| Wet | -1.22 | -1.24 (-2%) |
| Above normal | -1.10 | -1.11 (0%) |
| Below normal | -0.04 | 0.07 (254%) |
| Dry | -0.13 | 0.16 (226%) |
| Critically dry | 1.20 | 1.26 (5%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
EC = existing conditions.

**Table 5E.1-89. South Delta Flux of Surface-Oriented Particles from DSM2 Particle Tracking Modeling, Weighted by Longfin Smelt Larval Distribution**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| **January** | | |
| Wet | -0.31 | -0.21 (35%) |
| Above normal | 0.20 | 0.36 (85%) |
| Below normal | 3.93 | 4.30 (9%) |
| Dry | 6.34 | 6.90 (9%) |
| Critically dry | 5.97 | 6.42 (7%) |
| **February** | | |
| Wet | -0.93 | -0.91 (2%) |
| Above normal | -0.19 | -0.09 (50%) |
| Below normal | 1.03 | 1.27 (22%) |
| Dry | 1.94 | 2.53 (30%) |
| Critically dry | 2.74 | 3.06 (11%) |
| **March** | | |
| Wet | -1.15 | -1.17 (-2%) |
| Above normal | -1.02 | -1.00 (2%) |

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Below normal | 0.23 | 0.38 (67%) |
| Dry | 0.17 | 0.50 (197%) |
| Critically dry | 1.79 | 1.85 (3%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

EC = existing conditions.

### Table 5E.1-90. Passage Past Chipps Island of Neutrally Buoyant Particles from DSM2 Particle Tracking Modeling, Weighted by Longfin Smelt Larval Distribution

| Water Year Type | EC | Proposed Action |
|---|---|---|
| **January** | | |
| Wet | 47.35 | 47.24 (0%) |
| Above normal | 45.23 | 44.97 (-1%) |
| Below normal | 39.11 | 38.25 (-2%) |
| Dry | 34.51 | 33.67 (-2%) |
| Critically dry | 31.12 | 30.26 (-3%) |
| **February** | | |
| Wet | 47.95 | 47.92 (0%) |
| Above normal | 47.36 | 47.27 (0%) |
| Below normal | 44.10 | 43.37 (-2%) |
| Dry | 41.70 | 40.89 (-2%) |
| Critically dry | 37.25 | 35.81 (-4%) |
| **March** | | |
| Wet | 47.69 | 47.69 (0%) |
| Above normal | 47.04 | 47.08 (0%) |
| Below normal | 45.73 | 45.26 (-1%) |
| Dry | 45.07 | 44.61 (-1%) |
| Critically dry | 39.67 | 38.84 (-2%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

EC = existing conditions.

### Table 5E.1-91. Passage Past Chipps Island of Surface-Oriented Particles from DSM2 Particle Tracking Modeling, Weighted by Longfin Smelt Larval Distribution

| Water Year Type | EC | Proposed Action |
|---|---|---|
| **January** | | |
| Wet | 48.02 | 47.87 (0%) |
| Above normal | 45.79 | 45.51 (-1%) |
| Below normal | 39.09 | 38.18 (-2%) |
| Dry | 34.25 | 33.34 (-3%) |
| Critically dry | 30.90 | 29.90 (-3%) |
| **February** | | |

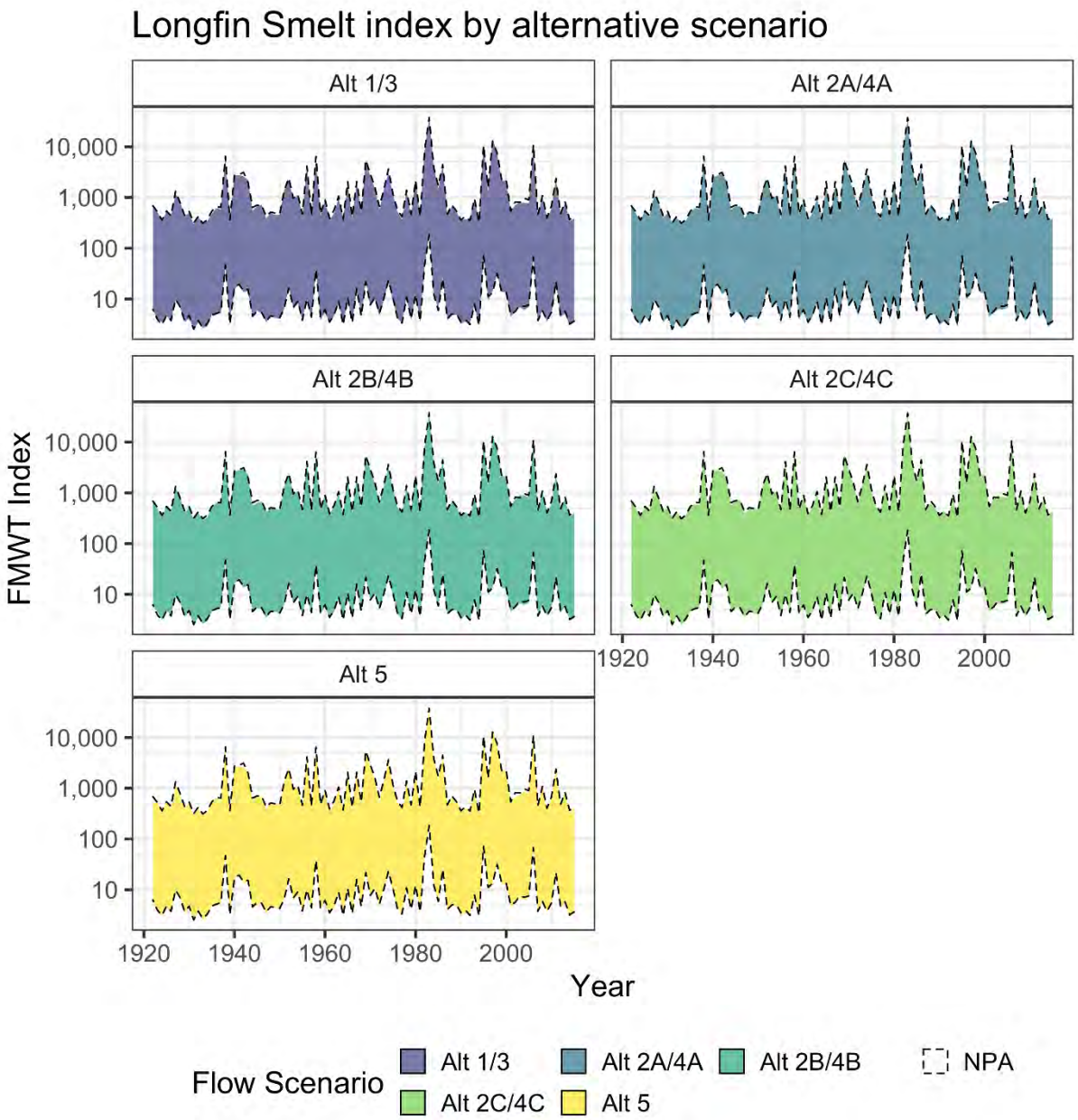
| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 48.77 | 48.72 (0%) |
| Above normal | 48.02 | 47.92 (0%) |
| Below normal | 44.41 | 43.67 (-2%) |
| Dry | 41.87 | 40.99 (-2%) |
| Critically dry | 37.22 | 35.73 (-4%) |
| **March** | | |
| Wet | 48.55 | 48.55 (0%) |
| Above normal | 47.96 | 47.95 (0%) |
| Below normal | 46.17 | 45.65 (-1%) |
| Dry | 45.44 | 44.92 (-1%) |
| Critically dry | 39.90 | 39.04 (-2%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
EC = existing conditions.

### Table 5E.1-92. Mean Juvenile Longfin Smelt April–May Salvage at the South Delta Export Facilities by Water Year Type, as Estimated by the Regression Including Mean Old and Middle River Flows

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 2,233 | 2,076 (-7%) |
| Above normal | 2,579 | 2,511 (-3%) |
| Below normal | 2,624 | 2,610 (-1%) |
| Dry | 2,371 | 2,310 (-3%) |
| Critically dry | 1,541 | 1,546 (0%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty. Results are not future predictions.
EC = existing conditions.




Notes: Alt = alternative; Alt 5 = proposed action; NPA = No Project Alternative (existing conditions).

**Figure 5E.1-7. Time Series Plots of Predicted Longfin Smelt Fall Midwater Trawl Index from Application of the Delta Outflow-Abundance Index Method**

**Table 5E.1-93. Predicted Mean Longfin Smelt Fall Midwater Trawl Index Averaged by Water Year Type, Based on Delta Outflow-Abundance Index Method**

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 559 | 530 (-5%) |
| Above normal | 161 | 147 (-9%) |
| Below normal | 72 | 67 (-7%) |
| Dry | 72 | 66 (-8%) |
| Critically dry | 46 | 44 (-5%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty. Results are not future predictions.
EC = existing conditions.

**Table 5E.1-94. Probability of Longfin Smelt Fall Midwater Trawl Index Smaller than Existing Conditions Averaged by Water Year Type, Based on Delta Outflow-Abundance Index Method**

| Water Year Type | Proposed Action |
|---|---|
| Wet | 0.560 |
| Above normal | 0.580 |
| Below normal | 0.559 |
| Dry | 0.559 |
| Critically dry | 0.538 |

Note: Probability of 0.500 indicates equal probability of fall midwater trawl index being smaller or larger than existing conditions.

## 5E.1.9 Effects of Operations and Maintenance of Water Conveyance Facilities on Southern DPS Green Sturgeon

The effects of operations and maintenance of water conveyance facilities on green sturgeon are described in Appendix 5C, Section 5C.11, *Effects of Operations and Maintenance of Water Conveyance Facilities on Southern DPS Green Sturgeon*. The impact mechanisms at 2040 remain the same as at 2020. Table 5E.1-95 summarizes quantitative analyses and differences between 2040 (i.e., existing conditions vs. the proposed action) and 2020 (i.e., existing conditions vs. the proposed action).

**Table 5E.1-95. Summary of Green Sturgeon Quantitative Analyses and Differences at 2040 Relative to 2020**

| Effect/Method | 2040 Results [a] | 2020 Results [b] | Differences |
|---|---|---|---|
| South Delta entrainment/Salvage-density method | Tables 5E.1-95 and 5E.1-96 | Tables 5C.11-2 and 5C.11-3 | Similar |

[a] Results for 2040 are provided in this appendix.
[b] Results for 2020 are provided in Appendix 5C, *Operations and Maintenance Effects Analysis for Chinook Salmon, California Central Valley Steelhead, Green Sturgeon, and Killer Whale.*

### Table 5E.1-96. Salvage of Green Sturgeon at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 1 | 1 (-13%) |
| Above normal | N/A | (-4%) |
| Below normal | 1 | 1 (0%) |
| Dry | 0 | 0 (0%) |
| Critically dry | 0 | 0 (0%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.
EC = existing conditions; N/A = not applicable; SWP = State Water Project.

### Table 5E.1-97. Salvage of Green Sturgeon at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

| Water Year Type | EC | Proposed Action |
|---|---|---|
| Wet | 4 | 4 (-1%) |
| Above normal | N/A | (0%) |
| Below normal | 0 | 0 (0%) |
| Dry | 0 | 0 (0%) |
| Critically dry | 0 | 0 (0%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.
CVP = Central Valley Project; EC = existing conditions; N/A = not applicable.

### Table 5E.1-98. Salvage of Green Sturgeon at SWP Banks Pumping Plant, Averaged by Water Year Type and Month, Based on the Salvage-Density Method

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Wet | Jan | 0 | 0 (0%) |
| Wet | Feb | 0 | 0 (0%) |
| Wet | Mar | 1 | 1 (-13%) |
| Wet | Apr | 0 | 0 (0%) |
| Wet | May | 0 | 0 (0%) |
| Wet | Jun | 0 | 0 (0%) |
| Wet | Jul | 0 | 0 (0%) |
| Wet | Aug | 0 | 0 (0%) |
| Wet | Sep | 0 | 0 (0%) |
| Wet | Oct | 0 | 0 (0%) |
| Wet | Nov | 0 | 0 (0%) |
| Wet | Dec | 0 | 0 (0%) |
| Above normal | Jan | N/A | (0%) |
| Above normal | Feb | N/A | (0%) |

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Above normal | Mar | N/A | (-4%) |
| Above normal | Apr | N/A | (0%) |
| Above normal | May | N/A | (0%) |
| Above normal | Jun | N/A | (0%) |
| Above normal | Jul | N/A | (0%) |
| Above normal | Aug | N/A | (0%) |
| Above normal | Sep | N/A | (0%) |
| Above normal | Oct | N/A | (0%) |
| Above normal | Nov | N/A | (0%) |
| Above normal | Dec | N/A | (0%) |
| Below normal | Jan | 1 | 1 (0%) |
| Below normal | Feb | 0 | 0 (0%) |
| Below normal | Mar | 0 | 0 (0%) |
| Below normal | Apr | 0 | 0 (0%) |
| Below normal | May | 0 | 0 (0%) |
| Below normal | Jun | 0 | 0 (0%) |
| Below normal | Jul | 0 | 0 (0%) |
| Below normal | Aug | 0 | 0 (0%) |
| Below normal | Sep | 0 | 0 (0%) |
| Below normal | Oct | 0 | 0 (0%) |
| Below normal | Nov | 0 | 0 (0%) |
| Below normal | Dec | 0 | 0 (0%) |
| Dry | Jan | 0 | 0 (0%) |
| Dry | Feb | 0 | 0 (0%) |
| Dry | Mar | 0 | 0 (0%) |
| Dry | Apr | 0 | 0 (0%) |
| Dry | May | 0 | 0 (0%) |
| Dry | Jun | 0 | 0 (0%) |
| Dry | Jul | 0 | 0 (0%) |
| Dry | Aug | 0 | 0 (0%) |
| Dry | Sep | 0 | 0 (0%) |
| Dry | Oct | 0 | 0 (0%) |
| Dry | Nov | 0 | 0 (0%) |
| Dry | Dec | 0 | 0 (0%) |
| Critically dry | Jan | 0 | 0 (0%) |
| Critically dry | Feb | 0 | 0 (0%) |
| Critically dry | Mar | 0 | 0 (0%) |
| Critically dry | Apr | 0 | 0 (0%) |
| Critically dry | May | 0 | 0 (0%) |
| Critically dry | Jun | 0 | 0 (0%) |
| Critically dry | Jul | 0 | 0 (0%) |
| Critically dry | Aug | 0 | 0 (0%) |
| Critically dry | Sep | 0 | 0 (0%) |

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Critically dry | Oct | 0 | 0 (0%) |
| Critically dry | Nov | 0 | 0 (0%) |
| Critically dry | Dec | 0 | 0 (0%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to the existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions.
EC = existing conditions; N/A = not applicable; SWP = State Water Project.

### Table 5E.1-99. Salvage of Green Sturgeon at CVP Jones Pumping Plant, Averaged by Water Year Type and Month, Based on the Salvage-Density Method

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Wet | Jan | 0 | 0 (0%) |
| Wet | Feb | 0 | 0 (0%) |
| Wet | Mar | 0 | 0 (0%) |
| Wet | Apr | 0 | 0 (0%) |
| Wet | May | 0 | 0 (0%) |
| Wet | Jun | 4 | 4 (-1%) |
| Wet | Jul | 0 | 0 (0%) |
| Wet | Aug | 0 | 0 (0%) |
| Wet | Sep | 0 | 0 (0%) |
| Wet | Oct | 0 | 0 (0%) |
| Wet | Nov | 0 | 0 (0%) |
| Wet | Dec | 0 | 0 (0%) |
| Above normal | Jan | N/A | (0%) |
| Above normal | Feb | N/A | (0%) |
| Above normal | Mar | N/A | (0%) |
| Above normal | Apr | N/A | (0%) |
| Above normal | May | N/A | (0%) |
| Above normal | Jun | N/A | (0%) |
| Above normal | Jul | N/A | (0%) |
| Above normal | Aug | N/A | (0%) |
| Above normal | Sep | N/A | (0%) |
| Above normal | Oct | N/A | (0%) |
| Above normal | Nov | N/A | (0%) |
| Above normal | Dec | N/A | (0%) |
| Below normal | Jan | 0 | 0 (0%) |
| Below normal | Feb | 0 | 0 (0%) |
| Below normal | Mar | 0 | 0 (0%) |
| Below normal | Apr | 0 | 0 (0%) |
| Below normal | May | 0 | 0 (0%) |
| Below normal | Jun | 0 | 0 (0%) |
| Below normal | Jul | 0 | 0 (0%) |

| Water Year Type | Month | EC | Proposed Action |
|---|---|---|---|
| Below normal | Aug | 0 | 0 (0%) |
| Below normal | Sep | 0 | 0 (0%) |
| Below normal | Oct | 0 | 0 (0%) |
| Below normal | Nov | 0 | 0 (0%) |
| Below normal | Dec | 0 | 0 (0%) |
| Dry | Jan | 0 | 0 (0%) |
| Dry | Feb | 0 | 0 (0%) |
| Dry | Mar | 0 | 0 (0%) |
| Dry | Apr | 0 | 0 (0%) |
| Dry | May | 0 | 0 (0%) |
| Dry | Jun | 0 | 0 (0%) |
| Dry | Jul | 0 | 0 (0%) |
| Dry | Aug | 0 | 0 (0%) |
| Dry | Sep | 0 | 0 (0%) |
| Dry | Oct | 0 | 0 (0%) |
| Dry | Nov | 0 | 0 (0%) |
| Dry | Dec | 0 | 0 (0%) |
| Critically dry | Jan | 0 | 0 (0%) |
| Critically dry | Feb | 0 | 0 (0%) |
| Critically dry | Mar | 0 | 0 (0%) |
| Critically dry | Apr | 0 | 0 (0%) |
| Critically dry | May | 0 | 0 (0%) |
| Critically dry | Jun | 0 | 0 (0%) |
| Critically dry | Jul | 0 | 0 (0%) |
| Critically dry | Aug | 0 | 0 (0%) |
| Critically dry | Sep | 0 | 0 (0%) |
| Critically dry | Oct | 0 | 0 (0%) |
| Critically dry | Nov | 0 | 0 (0%) |
| Critically dry | Dec | 0 | 0 (0%) |

Notes: Percentage values in parentheses indicate differences of the proposed action compared to the existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions.
CVP = Central Valley Project; EC = existing conditions; N/A = not applicable.

## 5E.1.10 Effects on Southern Resident Killer Whale and Southern Resident DPS Killer Whale Critical Habitat

The effects of operations and maintenance of water conveyance facilities on southern resident killer whale are described in Appendix 5C, Section 5C.13, *Effects on Southern Resident Killer Whale and Southern Resident DPS Killer Whale Critical Habitat*. As described therein, Chinook salmon form the primary diet of southern resident killer whales, with a portion of this diet from Central Valley salmon. Refer to the Chinook salmon summaries in this appendix describe generally similar magnitude of differences between the proposed action and existing conditions as discussed in

Chapter 5. As such the proposed action at 2040 relative to the existing conditions would have generally similar effects on southern resident killer whales as at 2020 relative to existing conditions.

# 5E.2 References Cited

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