Effects Analysis

State Water Project Effects on White Sturgeon

November 2024

Prepared by California Department of Fish and Wildlife

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List of Acronyms and Abbreviations

7DADM	7-day average of the daily maximum
°C	degrees Celsius
°F	degrees Fahrenheit
AMP	Adaptive Management Plan
Banks Pumping Plant	Harvey O. Banks Pumping Plant
BO	Biological Opinion
BSOG	Butte Slough Outfall Gates
BSPP	Barker Slough Pumping Plant
CalSim	California Simulation
CAMT	Collaborative Adaptive Management Team
CCF	Clifton Court Forebay
CDEC	California Data Exchange Center
CDFG	California Department of Fish and Game
CDFW	California Department of Fish and Wildlife
CESA	California Endangered Species Act
CFPS	Clifton Court Forebay Predation Studies
cfs	cubic feet per second
CHNFR	fall-run Chinook Salmon
CHNLFR	late fall-run Chinook Salmon
CHNSR	spring-run Chinook Salmon
CHNWR	winter-run Chinook Salmon
cm	centimeter(s)
CNFH	Coleman National Fish Hatchery
CVP	Central Valley Project
CWT	coded-wire tag
D-1641	SWRCB Water Rights Decision 1641
DCC	Delta Cross Channel
DEIR	Draft Environmental Impact Report
Delta	Sacramento-San Joaquin Delta
DOSS	Delta Operations for Salmonids and Sturgeon
DPM	Delta Passage Model
DPS	Distinct Population Segment
DS	Delta Smelt
DSM2	Delta Simulation Model 2
DTUs	Daily Temperature Units
DWR	California Department of Water Resources
ESA	Endangered Species Act
Estuary	San Francisco Bay Estuary
ESU	Evolutionary Significant Unit

FEIR	Final Environmental Impact Report
FR	Federal Register
FRFH	Feather River Fish Hatchery
ft	foot (feet)
ft/s	foot (feet) per second
FNU	Formazin Nephelometric Units
GSA	Global Sensitivity Analysis
GYSO	Goodyear Slough Outfall
HAB	Harmful Algal Bloom
HRL	Healthy Rivers and Landscapes Program
IEP	Interagency Ecological Program
ITP	Incidental Take Permit
Jones Pumping Plant	C.W. Bill Jones Pumping Plant
JPE	Juvenile Production Estimate
JPI	Juvenile Production Index
km	kilometer(s)
LAD	length-at-date
LFS	Longfin Smelt
LSNFH	Livingston Stone National Fish Hatchery
m	meter(s)
MAF	million acre-feet
MIDS	Morrow Island Distribution System
mm	millimeter(s)
NAVD88	North American Vertical Datum of 1988
NFH	Nimbus Fish Hatchery
NMFS	National Marine Fisheries Service
NTU	nephelometric turbidity units
OMR	Old and Middle River
PATH	Pacific Aquatic Telemetry Hub
Permittee	California Department of Water Resources
POD	Pelagic Organism Decline
PPT	San Joaquin River at Prisoner's Point
Project	State Water Project
PTM	Particle Tracking Model
QA/QC	quality assurance/quality control
QWEST	Net flow on the San Joaquin River at Jersey Point
RBDD	Red Bluff Diversion Dam
Reclamation	United States Bureau of Reclamation
rkm	River kilometer
RM	River mile

RPA	Reasonable and Prudent Alternative
RRDS	Roaring River Distribution System
RST	Rotary Screw Trap
SacPAS	Central Valley Prediction and Assessment of Salmon
Salvage facilities	John E. Skinner Delta Fish Protective Facility and Tracy Fish Collection Facility
SDM	Structured Decision Making
Skinner Fish Facility	John E. Skinner Delta Fish Protective Facility
SJRRP	San Joaquin River Restoration Program
SMSCG	Suisun Marsh Salinity Control Gates
SST	Salmonid Scoping Team
STARS	Survival, Travel Time, and Routing Simulation
SWP	State Water Project
SWRCB	State Water Resources Control Board
TAF	thousand acre-feet
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
WOMT	Water Operations Management Team
WSMT	White Sturgeon Monitoring Team
WSSP	White Sturgeon Science Program
WSTT	White Sturgeon Technical Team
X2	The two ppt isohaline location in km from the Golden Gate Bridge
YOY	young-of-the-year

1. Introduction

In response to the California Department of Water Resources (DWR, Permittee) request for authorization for the incidental take of Longfin Smelt (*Spirinchus thaleichthys*, LFS), Delta Smelt (*Hypomesus transpacificus*, DS), Winter-run Chinook Salmon (*Oncorhynchus tshawytscha*, CHNWR), Spring-run Chinook Salmon (*Oncorhynchus tshawytscha*, CHNSR), and White Sturgeon (*Acipenser transmontanus*) under the California Endangered Species Act (CESA) for existing and future operations in the Sacramento-San Joaquin Bay-Delta (Delta) of the State Water Project (SWP; Project), California Department of Fish and Wildlife (CDFW) conducted effects analyses for each covered species based on DWR's Incidental Take Permit (ITP) Application for Long-term Operation of the Project dated November 1, 2023 and supplemental request to add White Sturgeon on August 2, 2024 (ITP Application), DWR's Draft and Final Environmental Impact Reports (DEIR and FEIR, SCH No. 2023060467), existing data, and literature. In this Effects Analysis, CDFW focuses analyses on White Sturgeon and provides background information, methodologies and approaches used, and discussions and definitions of the terminology and information available. Analyses conducted for LFS and DS are provided in a separate Effects Analysis dated October 2024. Additionally, analyses conducted for CHNWR and CHNSR are provided in a separate Effects Analysis dated October 2024. Together, the three effects analyses serve as companion analyses for the issuance of the ITP for Long-term Operation of the SWP in the Sacramento-San Joaquin Delta (No. 2081-2023-054-00; 2024 SWP ITP).

In the following White Sturgeon Effect Analysis, CDFW considered that Project operations will be consistent with existing water supply contracts, flood control needs, and certain operational criteria and other actions set forth in the FEIR, U.S. Fish and Wildlife Service (USFWS) Biological Opinion for the Reinitiation of Consultation on the Coordinated Operations of the Central Valley Project (CVP) and SWP issued on October 21, 2019 (2019 USFWS BO; USFWS 2019), and the National Marine Fisheries Service (NMFS) Endangered Species Act Section 7 Biological Opinion on Long-term Operation of the CVP and the SWP issued on October 21, 2019 (2019 NMFS BO; NMFS 2019a). However, given the limitations of California Simulation (CalSim) 3 modeling, modeled Proposed Project operations provided in this Effects Analysis include CVP and SWP joint operations in the Delta, specifically Old and Middle River (OMR) flow management measures. In addition, CDFW considered that the Project will comply with all applicable State, federal, and local laws and regulations in existence or adopted after the issuance of the 2024 SWP ITP as well as State Water Resources Control Board (SWRCB) Water Rights Decision 1641 (D-1641).

2. Project Description Summary

Under the 2024 SWP ITP, DWR will continue to operate the SWP facilities in the Delta and Suisun Marsh. The SWP includes water, power, and conveyance systems, conveying an annual average of 2.9 million acre-feet (MAF) of water for agricultural, municipal, industrial, recreational, and environmental purposes while also providing flood control. The principal facilities of the SWP are Oroville Reservoir and related facilities, San Luis Dam and related facilities, facilities in the Delta, the Suisun Marsh Salinity Control Gates (SMSCG), the California Aqueduct including its terminal reservoirs and the Delta-Mendota Canal/California Aqueduct Intertie (DCI), and the North and South Bay Aqueducts. Water stored in the Oroville facilities, along with water available in the Delta (consistent with applicable regulations), is captured in the Delta and conveyed through several facilities to SWP contractors. DWR holds contracts with 29 public agencies in northern, central, and southern California for water supplies from the SWP.

The Project includes operations of the following facilities in the Delta: Harvey O. Banks Pumping Plant (Banks Pumping Plant), the Clifton Court Forebay (CCF), the John E. Skinner Delta Fish Protective Facility (Skinner Fish Facility), the Barker Slough Pumping Plant (BSPP), the South Delta Temporary Barriers Project, San Luis Reservoir, the Delta-Mendota Canal/California Aqueduct Intertie, the Georgiana Slough Salmonid Migratory Barrier, and Suisun Marsh facilities including the SMSCG , Roaring River Distribution System (RRDS), Morrow Island Distribution System (MIDS), and Goodyear Slough Outfall (GYSO).

The Project is located within the following geographic area (Project Area, see Figure 1 attached to the 2024 SWP ITP):

- Sacramento River from its confluence with the Feather River downstream to the legal Delta boundary at the I Street Bridge in the City of Sacramento;
- Sacramento-San Joaquin Delta (i.e., upstream to Vernalis and downstream to Chipps Island); and
- Suisun Marsh and Bay.

Project operations will be in all fish-bearing waterways within the Project Area. The northern edge of the Project Area is located approximately 8.56 km northeast of Knights Landing in Yolo County at approximately 38.785281 latitude, -121.621825 longitude and extends downstream on the Sacramento River to the Delta. To the south and east, the Project Area is bounded by the legal boundary of the Delta. To the west, the Project Area is bounded by the legal Delta, Suisun Marsh, and Suisun Bay.

Covered Activities contemplated under the 2024 SWP ITP are detailed in the permit and include operations of the Banks Pumping Plant (including water transfers), Skinner Fish Facility, CCF (including herbicide and algaecide application and mechanical aquatic weed removal), South Delta Temporary Barriers Project, Georgiana Slough Salmonid Migratory Barrier, BSPP (including fish screen cleaning, sediment removal, and aquatic weed removal), and the Suisun Marsh Facilities that include the SMSCG, the RRDS, the MIDS, and GYSO.

3. List of Covered Species

The 2024 SWP ITP provides DWR with incidental take authorization for the Project for the following species, referred to collectively as "Covered Species":

1. Longfin Smelt (*Spirinchus thaleichthys*), CESA-listed as Threatened
2. Delta Smelt (*Hypomesus transpacificus*), CESA-listed as Endangered
3. Spring-run Chinook Salmon of the Sacramento River drainage (*Oncorhynchus tshawytscha*), CESA-listed as Threatened
4. Winter-run Chinook Salmon (*Oncorhynchus tshawytscha*), CESA-listed as Endangered
5. White Sturgeon (*Acipenser transmontanus*), Candidate for CESA listing

4. Covered Species Life History

4.1. White Sturgeon

4.1.1. Listing History and Proposed Critical Habitat

On November 29, 2023, the Fish and Game Commission (Commission) received a Petition from San Francisco Baykeeper, The Bay Institute, Restore the Delta, and California Sportfishing Protection Alliance to list White Sturgeon as threatened under CESA (Petition; Rosenfield, 2023). On December 6, 2023, the Commission referred the Petition to CDFW for evaluation. On June 19, 2024, the Commission voted to accept White Sturgeon as candidate for threatened status under CESA (Fish & G. Code, §2074.2, subd. (e)(2)). Subsequently, CDFW is in the process of developing a peer-reviewed report utilizing the best scientific information available to advise the Commission on whether the petitioned action is warranted (Fish & G. Code, § 2074.6). The Commission must utilize the report and other information in the administrative record, to determine whether the petitioned action to list White Sturgeon as threatened is warranted (Fish & G. Code, § 2075.5). Additionally, on November 29, 2023, pursuant to Section 4(b) of the Endangered Species Act, 16. U.S.C. § 1533(b); Section 553(e) of the Administrative Procedure Act, 5. U.S.C. § 553(e); and 50 C.F.R. § 424.14(a), San Francisco Baykeeper, The Bay Institute, Restore the Delta, and California Sportfishing Protection Alliance provided notice in accordance with 50 C.F.R. § 424.14(b) and (c)(9) of their intention to petition the Secretary of Commerce, through the NMFS, to list the San Francisco Estuary (SFE) White Sturgeon (*Acipenser transmontanus*) Distinct Population Segment as a threatened species. The petition was subsequently passed to the USFWS to maintain consistency with the listing of the Kootenai White Sturgeon population. On October 9, 2024, the USFWS posted their 90-Day Finding on the Federal Register with the decision that the petition presented substantial information that the SFE White Sturgeon population may be a listable entity (Federal Docket No. FWS-R8-ES-2024-0049). Critical habitat for White Sturgeon has been proposed from below all the Central Valley dams to the waters and fringing marshes of San Francisco Bay and its sub-embayments, along with the nearshore ocean off San Francisco Bay (Gulf of the Farallones) and nearby coastal embayments (e.g., Bodega Bay, Tomales Bay). The proposed critical habitat includes spawning sites on the San Joaquin and Sacramento rivers, as well as anticipated spawning and rearing habitats on the San Joaquin and Sacramento rivers major tributaries, including waterways used for migration to and from these spawning/rearing areas in and upstream of the Delta.

4.1.2. Population Status and Trends

Sturgeon and Paddlefishes comprise the order Acipenseriformes, of which twenty-two species are categorized as "extinct in the wild", ''critically endangered',' or ''endangered'' by the International Union for Conservation of Nature (IUCN, 2024). Recently, White Sturgeon range-wide have been changed to "vulnerable", uplisted from "least concern" by the IUCN, reflecting the declining status range-wide. Populations in the Columbia River above Grand Coulee Dam, Kootenai River, Fraser River, and Nechako River are recognized as threatened or endangered by the United States and/or Canadian governments (Hildebrand et al., 2016; Ulaski et al., 2022). The American Fisheries Society considers White Sturgeon to be "endangered" (Hildebrand et al., 2016; Jelks et al., 2008; Ulaski et al., 2022).

In California, the only reproducing population of White Sturgeon is found in the SFE and is currently considered a Species of Special Concern (Hildebrand et al., 2016; Moyle et al., 2015) A combination of life-history traits such as iteroparity, high fecundity, and longevity may help buffer populations through short periods of low recruitment (Hildebrand et al., 2016; Ulaski et al., 2022). However, other traits like delayed maturation, multi-year intervals between egg clutches, and low intrinsic population growth rate make White Sturgeon particularly vulnerable to sustained anthropogenic modification of river and estuarine flow regimes, overharvest, catastrophic adult mortality events, and degradation of other habitat conditions (Blackburn et al. 2019; Boreman 1997). Additionally, White Sturgeon recruitment has been strongly correlated with flow (Blackburn et al., 2019; Fish, 2010; Kohlhorst et al., 1991; SWRCB, 2017) and as a result, persistent reductions in the frequency of high magnitude Delta outflow from prolonged periods of drought, climate change, and anthropogenic river modifications lead to prolonged intervals between successful cohorts, further reducing the population's resilience and viability.

White Sturgeon populations have been declining for decades (Figure 2) and four primary factors have been repeatedly identified in the literature (Blackburn et al., 2019; CDFW, 2023; Fish, 2010; Heublein et al., 2017; Kohlhorst et al., 1991; Moyle et al., 2015; Pyros and Culberson 2023; SWRCB, 2017; Ulaski et al., 2022): (1) mortality related to entrainment and salvage at the water export facilities operated in the south Delta; (2) previous high rates of harvest in the recreational fishery; (3) catastrophic mortality from events such as harmful algal blooms (HABs); and (4) the low frequency and declining magnitude of substantial juvenile recruitment related to Central Valley river flow conditions. While other stressors on the SFE White Sturgeon population do exist, these four represent the largest negative anthropogenic effects on the population and are supported with multiple data sources which can contextualize recent population trends.

South Delta water export operations are known to cause entrainment of juvenile White Sturgeon, with those less than ~5 years of age being at the highest risk (Afentoulis et al., 2024). Currently, there is no loss calculations associated with salvage at either the south Delta CVP or SWP facilities, so it is unknown how many White Sturgeon mortalities occur each year. Jackson et al. (2016) stated that water diversions throughout the SFE may also entrain biologically significant portions of the annual White Sturgeon juvenile production. Additionally, salvage is also strongly correlated with the annual recruitment of juveniles (Gingras et al. 2013, see Section 5.3.3 below). Recent trends in White Sturgeon salvage data (since the 1990's) suggest declining trend in abundance (see Section 5.3), including zero (0) fish detected in five (5) of the last ten (10) years (Figure 3), while White Sturgeon salvage during the mid-1900's was reported to be in the hundreds or thousands of fish per year (CDFG, 1981). Larger numbers of salvaged fish are likely a reflection of more successful recruitment of young-of-the-year (YOY) White Sturgeon following a large precipitation year (see Section 5.3.3 below). High salvage has been associated with high loss of entrained individuals for Chinook Salmon and DS, which suggests this association may also occur for White Sturgeon (Kimmerer, 2008).

Catch and keep sportfishing has also been a source of mortality for sub-adult and adult White Sturgeon from the SFE population, with estimates of fishery harvest rate between 2007 and 2015 averaged 13.6%, with a range of 8-29.6% of harvestable slot-limit White Sturgeon (i.e., a length range for legal harvest) (Blackburn et al., 2019). More recent harvest rates from 2016 through 2021 have been estimated around 8.1%, with a range of 3.5-14.2%, which best available science indicates to be above the sustainable level (CDFW, 2023). Mark-recapture abundance estimates of slot-limit fish in the 1980s were as high as 150,000 but have been declining since (Figure 2). The estimated slot-limit population has since declined by ~78% to a 5-year average of approximately 33,000 fish, however this estimate does not account for the potential effect of massive fish kills related to red-tide blooms of the harmful algae, *Heterosigma akashiwo* (CDFW, 2023). In response to White Sturgeon becoming a CESA candidate species, sportfishing in the SFE was temporarily closed, but has since reopened for Catch and Release only fishing as of October 1, 2024 which will reduce take resulting from fishing should these regulations be permanently adopted.

Another chronic driver of declining abundance in the SFE White Sturgeon population is catastrophic loss from harmful algal blooms (HABs) in the Bay and Delta. A major HAB event occurred during July and August 2022 which was caused by the spread of *H. akashiwo* across San Pablo, Central, and South San Francisco Bays. Harmful algal blooms such as those caused by *H. akashiwo* have been linked to fish kills elsewhere in the world (CDFW, 2023) and this HAB even lead to the rapid die-off of large numbers of fish in San Francisco and San Pablo Bays

(August, 2022) and at least one of its estuarine lagoons, (Lake Merritt, in Oakland California; September, 2022) (Schreier et al., 2022).

Finally, the most frequently identified driver of White Sturgeon population decline in the SFE is poor juvenile recruitment due to low Delta outflow (Blackburn et al., 2019; Fish, 2010; Kohlhorst, 1976; Kohlhorst et al., 1991; Schaffter and Kohlhorst, 1999; Stevens and Miller, 1970; SWRCB, 2017). Stevens and Miller (1970) followed by (Kohlhorst, 1976) first noticed patterns of flow-depended juvenile White Sturgeon recruitment back in the 1960's and 1970's, however, the underlying ecological mechanism as to why this relationship exist is still unknown. Several studies hypothesize that low river flows and reductions in Delta outflow resulting from water diversion and storage operations have played a part in poor juvenile recruitment and ultimately, the decline of White Sturgeon (Jackson et al., 2016; Moyle et al., 2015; SWRCB, 2017). Data shows that successful cohorts are infrequent for White Sturgeon, corresponding to years of high Delta outflow (Fish, 2010; Kohlhorst et al., 1991; Schaffter and Kohlhorst, 1999; SWRCB, 2017). When evaluating the relationship between juvenile White Sturgeon recruitment and March-July Delta outflow, (SWRCB, 2017) found that recruitment rarely occurred when average flows were below 37,000 cfs. From 1980-1999, average March-July Delta outflows >37,000 cfs occurred during 30% of years (6 out of 20 years) (Rosenfield, 2023). Since 1999, flows of this magnitude have occurred only during 17.4% of years (4 out of 23 years) (Rosenfield, 2023). Juvenile recruitment during optimal conditions may also be constrained by declines in the spawning stock of adults (Blackburn et al., 2019; SWRCB, 2017), reduced adult fecundity, or both.

Figure 1. Current and historic distribution of White Sturgeon (*Acipenser transmontanus*). The San Francisco Estuary (SFE) is the only known spawning population in California; detection of White Sturgeon in rivers north of the SFE is not believed to reflect presence of a current spawning population (CDFW 2023).

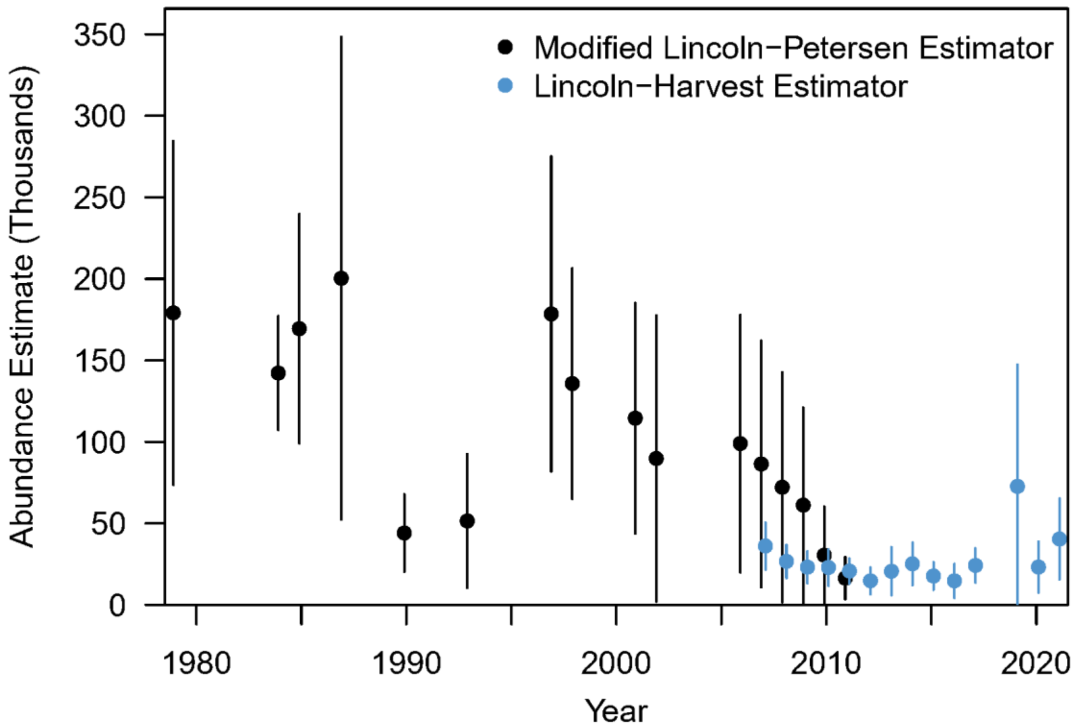

Figure 2. Estimated abundance of "slot-sized" White Sturgeon based on CDFW mark-recapture studies. Whiskers represent error bounds. The latest year of data (2021) precedes fish kills related to harmful algal blooms in 2022 and 2023. CDFW 2023, slide 28.

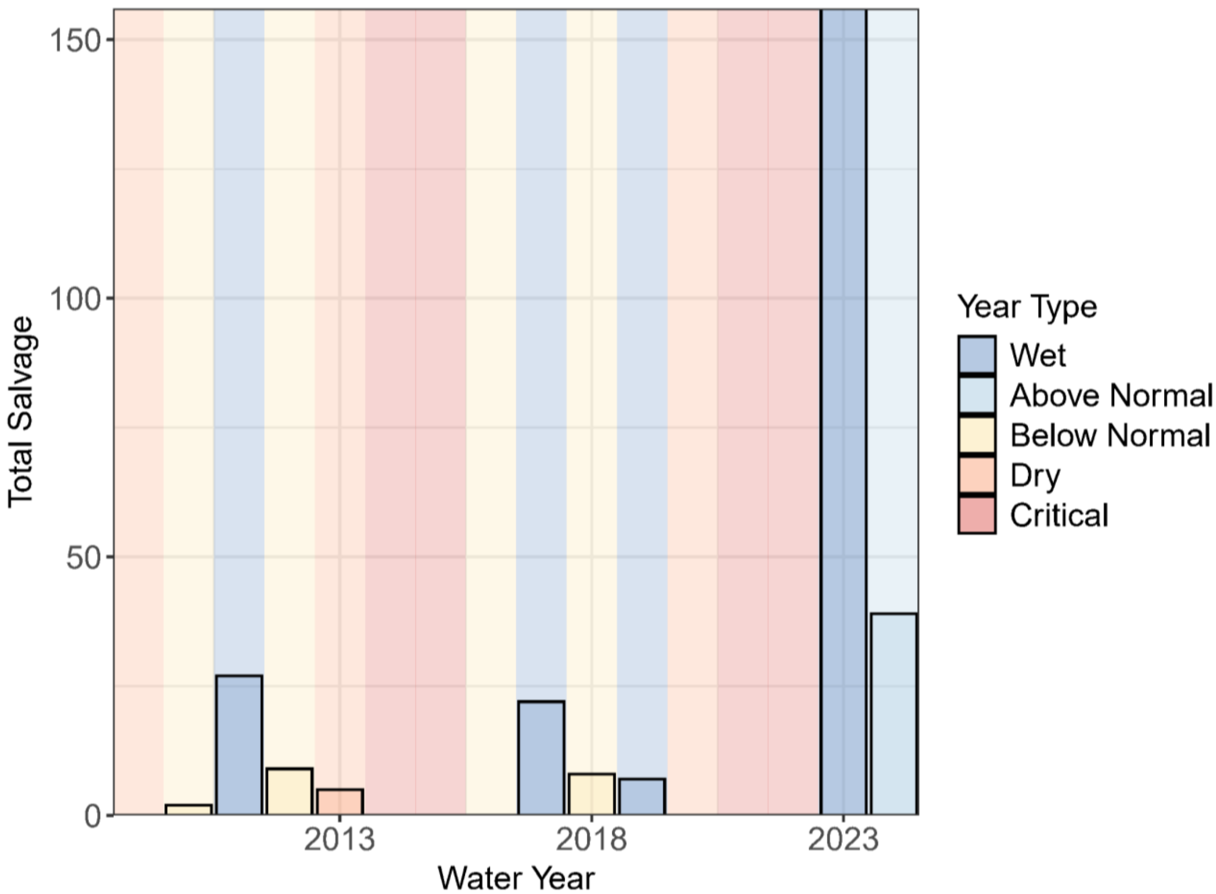

Figure 3. Annual combined salvage of White Sturgeon at the Central Valley Project and State Water Project facilities from water years 2009 to 2024, with each colored region representing Water Year Type based on the Sacramento River Index.

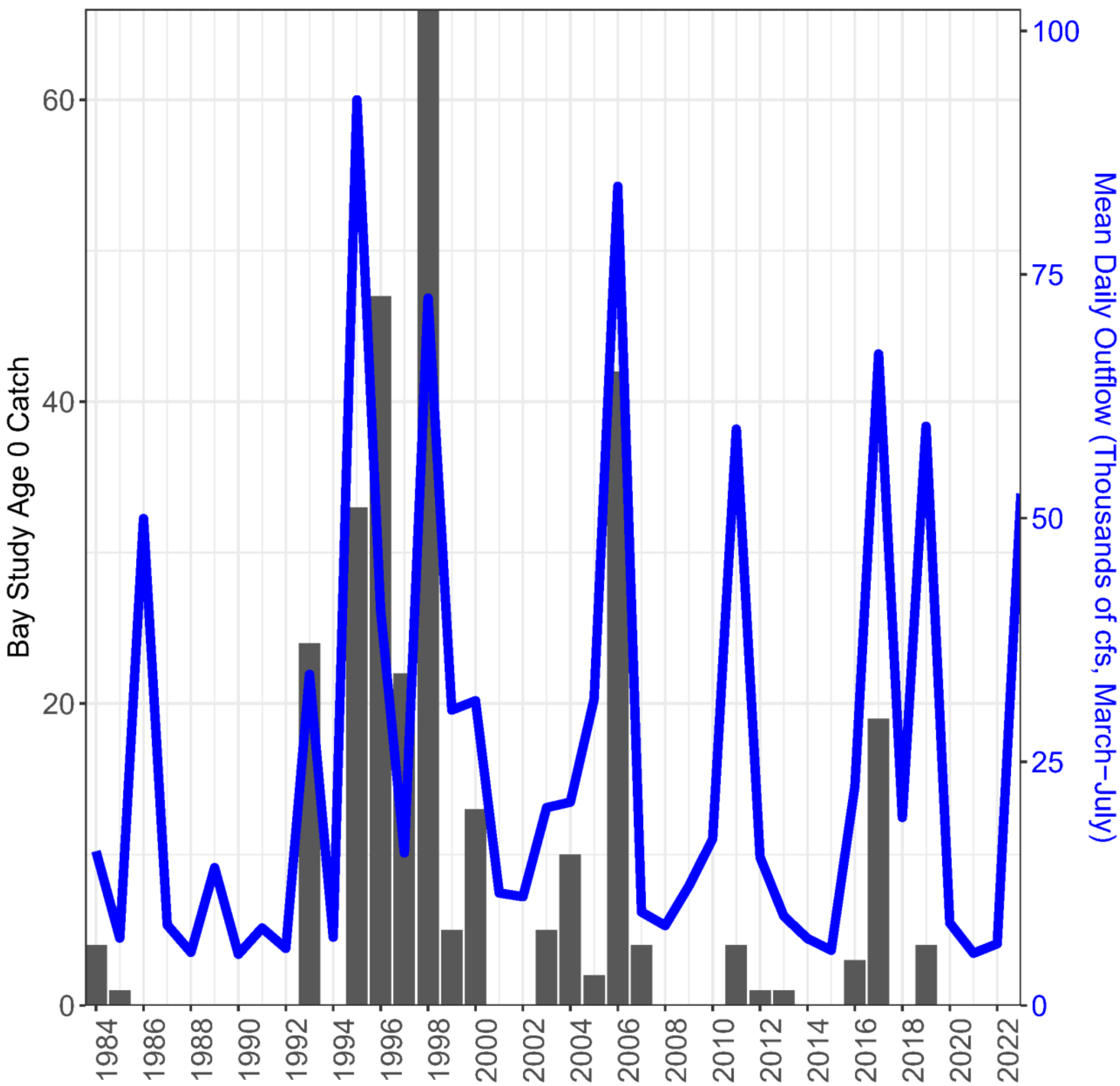

Figure 4. Relationship of spring-summer Delta outflow and White Sturgeon juvenile recruitment. Left axis: Bay Study index of Age 0 White Sturgeon caught in the San Francisco Estuary (source: Bashevkin et al. (2024)). Right axis: Mean daily Delta outflow during March-July, in thousands of cfs (source: DWR (2024)). Abundance is strongly correlated with March-July Delta outflow.

4.1.3. Primary Stressors

The White Sturgeon population consists of a primary spawning population in the Sacramento River and a secondary spawning population on the San Joaquin River (Figure 1). The secondary spawning population has likely been displaced from its historical spawning habitat upstream of the Central Valley Rim dams and persists in a section of the San Joaquin River where suitable habitat is artificially maintained by releases from reservoirs. A landlocked population of White Sturgeon also persists in Shasta Reservoir after construction of Shasta Dam, suggesting that White Sturgeon historically migrated and spawned upstream of the current damsite, which is supported by historic sightings of spawning activity in the Pit River (Moyle, 2002; Moyle et al., 2015). This highlights the impact of reservoir construction on the decreased habitat of White Sturgeon. Reports of spawning activity outside of the Sacramento River and San Joaquin River mainstems has been sparse and likely reflect a lack of recent systematic sampling in other Central Valley rivers. Water infrastructure development has also limited the frequency and spatial extent of successful White Sturgeon spawning in the San Joaquin River (Jackson et al., 2016). Additional stressors such as low flow river flows, high nutrient inputs, and operations in the Stockton Deepwater Shipping Channel contribute to low dissolved oxygen conditions and frequent HABs (Berg and Sutula, 2015), which likely impair White Sturgeon migrations to and from spawning grounds in the San Joaquin River and its tributaries (CBDA and CV RWQCB, 2006; Moyle et al., 2015). Conditions for spawning in the Feather River are also likely to be much less suitable due to changes in flow, temperature, and upstream passage ability after the construction of Oroville Dam (Heublein et al., 2017).

During the July and August 2022 HAB event, at least 850 sturgeon carcasses were observed, most of which were White Sturgeon (>90% of the carcasses with species identification confirmed) (CDFW, 2023). Of these 850 carcasses, 86% were 40 inches or greater, representing mature, spawning broodstock (CDFW, 2023). This estimate represents the minimum mortality experienced, which may have been up to eight (8) to twelve (12) times greater based on data from other sturgeon populations (Fox et al. 2020) (CDFW, 2023). The documented mortality from the HAB event (i.e., not including undocumented mortality such as individuals that did not float upon mortality or were not documented by citizen scientists) was equivalent to 62% of the mortality due to harvest in 2022, which has historically been better documented than mortality due to water operations or other species stressors (CDFW, 2023). The abundance of spawning sized White Sturgeon has declined considerably in the past forty (40) years, and the 2022 HAB fish kill is expected to have exacerbated the decline considerably.

4.1.4. Spawning Migration of Adults in the Upper Sacramento River

White Sturgeon in the SFE start maturation at approximately ten (10) years of age and close to 100% of the population reaches maturity by age 20 (Devore et al., 1995). Some mature White Sturgeon visit spawning sites in the Upper Sacramento River every water year during the spawning season from December-June (Klimley et al., 2015). The spawning sites in the Sacramento River are located approximately between river kilometers (rkm) 239-317, and mainly between Knights Landing and Colusa (Miller et al., 2020), as well as above the mouth of the Feather River (Kohlhorst, 1976). Adults spend anywhere from three weeks to over two months in their spawning reach before returning downstream to the Delta (Miller et al., 2020). The telemetry data on the UC Davis Pacific Aquatic Telemetry Hub (PATH) dataset shows most detections near the town of Colusa (approximately rkm 280) occur between March and April (Table 1). The PATH dataset consists of 259 unique White Sturgeon detected which are observed a total of 12,528,265 times at different stations located throughout the Sacramento River basin from calendar years 2010 to 2023.

Table 1. Percentage of detections of adult White Sturgeon within 20km of the city of Colusa for any given month in the telemetry dataset of UC Davis PATH.

Month	Percentage of Detections 20km of Colusa	Cumulative Percentage
December	1.09	1.09
January	6.37	7.46
February	12.1	19.56
March	32.6	52.16
April	39.0	91.16
May	6.68	97.84
June	2.17	100.00

Adult and juvenile White Sturgeon have been detected upstream of this core spawning ground in some years, suggesting a larger spawning distribution, but lack of monitoring precludes confirmation of the frequency and density of fish in the upper sections of the Sacramento River. Nevertheless, adult White Sturgeon have been reported by anglers near the confluence of the Sacramento River and Deer Creek (rkm 354) and have been observed and collected during summer and early fall near the Glenn-Colusa Irrigation District (GCID) oxbow (rkm 332.5) (Heublein et al., 2017). Juvenile White Sturgeon have been collected in the rotary screw traps at GCID and reported by anglers in the area (Heublein et al., 2017). Given these observations, spawning White Sturgeon and eggs presumably occur upstream from the GCID oxbow in some years. Egg distribution upstream of GCID requires verification by egg or larval collections as juveniles collected in the GCID trap could have migrated from downstream.

Adult White Sturgeon have been documented spawning in the San Joaquin River basin. Spawning on the mainstem San Joaquin River has been recorded between rkms 115–138 (Jackson et al., 2016). In the San Joaquin River basin, fertilized eggs were collected downstream of Grayson at rkm 138 (measured from the Sacramento River confluence) in late April 2011 and downstream of Vernalis between rkm 115 and 140 from late March through mid-May in 2012 (Jackson et al., 2016). In March and April of 2016, fertilized eggs were collected between rkm

115 and 140, though collection of a single larvae approximately 1-day post-hatch (dph) at rkm 101, which indicates that spawning occurs further downstream than previously known (Heublein et al., 2017).

4.1.5. Egg and Fry Development

Adult White Sturgeon have been documented depositing eggs following an increase in Sacramento River flow at near Colusa in the Sacramento River (Schaffter, 1997). Increased river flow is hypothesized to be a requirement for successful reproduction of the species Adult White Sturgeon have been documented depositing eggs following an increase in Sacramento River flow at near Colusa in the Sacramento River (Schaffter, 1997). Increased river flow is hypothesized to be a requirement for successful reproduction of the species (Blackburn et al., 2019; Coutant, 2004; Fish, 2010). High flows also correspond to increases in sturgeon larvae observations in the Delta (Stevens and Miller 1970). White Sturgeon deposit their eggs mainly on substrate dominated by gravel and cobble in depths ranging from 1.5-10.5 m and with water velocities greater than 1.0 meters per second (Jackson et al., 2016; Schaffter, 1997). Fine substrate and lack of interstitial space in spawning habitat can decrease survival and hatch rates of White Sturgeon eggs (Hildebrand et al., 2016). Thus, minimal suitable substrate in SFE, especially in the San Joaquin River, may limit recruitment to the larval or juvenile life stages.

Fecundity of female White Sturgeon averages 5,648 eggs per kilogram of body weight, which translates to hundreds of thousands of eggs per female at maturity (Blackburn et al., 2019; Ulaski et al., 2022; Willis et al., 2022). Eggs are negatively buoyant and become adhesive upon (Hildebrand et al., 2016; Israel et al., 2009; Moyle, 2002). Wang et al. (1985) found that development and survival of White Sturgeon embryos were temperature dependent. Optimal survival to hatching was observed when water temperatures during incubation in the hatchery were between 14°C (88.6% ± 2.2% survival) and 17°C (83.6% ± 1.9% survival). Embryo mortality increased as water temperatures increased to 20°C (49.1% ± 3.2% survival), and water temperatures of more than 20°C were lethal to developing embryos (Wang et al., 1985). Water temperatures in spawning habitat on the Sacramento River typically remain below this 20°C, but median daily water temperatures in excess of 20°C were recorded in Sacramento River incubation habitat during drought conditions such as in April 2015 (DWR 2024). Water temperatures in the spring (March-May) regularly reach or exceed suitable levels for egg incubation in the San Joaquin River (Jackson et al. 2016). White Sturgeon egg incubation duration is also temperature-dependent (Wang et al., 1985). Under an optimal incubation water temperature of 15.7 ± 0.2°C, Deng et al. (2002) found that development time to hatching ranged from 152 to 200 hours, which results in an average of 176 hours. Understanding hatch time is important for defining timelines to mitigate potentially variable habitat conditions (e.g., inundation levels, temperature) during egg development.

White Sturgeon yolk-sac larvae are 10-11 mm in total length at hatch. At temperatures between 14° C and 17° C, the yolk-sac is completely absorbed approximately 20-23 days post-fertilization (Wang et al. 1985). Larvae are photonegative upon hatching and swim near the bottom of rivers (Kynard and Parker 2005). In a laboratory study, the presence of physical cover in well-lit mesocosms decreased predation on White Sturgeon larvae that were < 17 mm in total length; however, larger individuals did not benefit from the presence of cover and other studies have observed that White Sturgeon leave cover at the size where exogenous feeding begins (Gadmoski and Parsley 2005).

4.1.6. Rearing and Outmigrating Juveniles in the Sacramento River

Little is known about the timing of outmigration and rearing habitat of White Sturgeon larvae in the Sacramento River system between GCID and the city of Sacramento (Israel et al. 2009). However, juvenile White Sturgeon are believed to initiate a secondary dispersal (the primary dispersal occurring at the larval stage) in spring (March-May) by actively swimming downstream at night (Kynard and Parker 2005). Dispersal duration is unknown, but observed swimming intensity and duration in laboratory studies indicate dispersal likely lasts several days and may span many kilometers (Kynard and Parker 2005). Small juvenile White Sturgeon are likely preyed upon by a variety of native and invasive piscivores (Hildebrand et al. 2016). Karp and Bridges (2015) conducted a mark-recapture study using hatchery juvenile White Sturgeon (approximately 200 mm fork length) to test the efficiency of louvers intended to prevent juvenile fish entrainment at the Tracy Fish Collection Facility. During this study, White Sturgeon were observed in the stomachs of Striped Bass collected at the facility. For example, juvenile White Sturgeon grew quickly in laboratory studies with ample food at 20 and 25°C but growth was negatively affected by reductions in dissolved oxygen (DO) at all temperature treatments of 15°C, 20°C and 25°C (Cech et al. 1984).

4.1.7. Rearing and Outmigrating Juveniles in the San Joaquin River

Very little is known about the rearing and outmigration of juvenile White Sturgeon from the San Joaquin River, but evidence of spawning in the San Joaquin Basin has been documented. Confirmation of White Sturgeon spawning in the San Joaquin River occurred for the first time in 2011 and again in 2012 via egg mat studies (Jackson et al. 2016). In water year 2023, the 20-mm Survey, a survey conducted by CDFW to monitor post larval-juvenile DS throughout the SFE, detected White Sturgeon larvae for the first time at the mouth of the Calaveras River. On March 11, 2024, the Larval Entrainment Study, a survey that samples the south Delta to better understand larval entrainment, found White Sturgeon larvae (12-13mm) north of Jersey Point and west of Oulton Point (Gilbert and Malinich, 2024). In addition, recent monitoring efforts showed that adult White Sturgeon migrate as far up the San Joaquin River as the Tuolumne

River, possibly for spawning (Diviney and Dahl. 2024). Collectively, this evidence indicates that adult White Sturgeon migrate upstream into the San Joaquin River with reproduction apparent given the presence of eggs and small larvae.

4.1.8. Rearing and Outmigrating Juveniles in the Bay-Delta

White Sturgeon larvae begin appearing south of the city of Sacramento during the first 20-mm Survey of the year in March and, subsequently are recruited by the San Francisco Bay Study (Bay Study) gear mainly between the months of April and May (Table 2). During high outflow years, White Sturgeon larvae can be observed as far downstream as Suisun Bay (Stevens and Miller 1970). Juvenile White Sturgeon increase their tolerance to salinity as they age, allowing White Sturgeon to occupy a wider range of habitats within the Bay-Delta as they become young adult sturgeon (Vaz et al. 2015). In laboratory studies, juvenile White Sturgeon are able to tolerate abrupt transfer from freshwater (0-ppt salinity) to 15-ppt-salinity water for up to five (5) days but experienced high mortality rates in abrupt transfers from freshwater to 25-ppt and 35-ppt-salinity water (Vaz et al. 2015). Miller et al. (2020) found that tagged juvenile White Sturgeon (defined as having a total length between 50 cm and 90 cm) were most often detected in Suisun Bay and the Delta and infrequently observed as far west as San Pablo Bay. Subadult White Sturgeon (defined as having a total length between 90 cm and 140 cm) were most frequently detected in San Pablo Bay, Suisun Bay, San Francisco Bay, and the Delta, while a small number of individuals venture out into coastal waters for a short period of time (Miller et al. 2020).

Table 2. Month of first detection of a White Sturgeon smaller than 100 mm during water years 1993-2024 in 20-mm Survey and San Francisco Bay Study surveys. Horizontal lines at any given water year represent surveys when no White Sturgeon smaller than 100 mm were detected during that year.

Water Year	**First Month of Detection**
1993	May
1994	April
1995	April
1996	April
1997	April
1998	April
1999	May
2000	March
2001	N/A

Water Year	First Month of Detection
2002	N/A
2003	March
2004	April
2005	July
2006	April
2007	N/A
2008	N/A
2009	N/A
2010	N/A
2011	March
2012	May
2013	May
2014	N/A
2015	N/A
2016	March
2017	March
2018	March
2019	March
2020	N/A
2021	N/A
2022	N/A
2023	March
2024	May

4.2. Additional White Sturgeon Stressors

4.2.1. Harmful Algal Blooms

Currently, cyanobacterial HABs in the Delta are typically dominated by the genus *Microcystis*, though mixed assemblages that include *Planktothrix, Aphanizomenon,* Dolichospermum and other genera are increasingly observed (Lehman et al. 2005, Lehman et al. 2008, Spier et al. 2013, Lehman et al. 2017, Lehman et al. 2022, Perry et al. 2023). These blooms tend to occur in low salinity and their cyanotoxins can travel downstream. In 2022 and 2023 HABs dominated by the raphidophyte, *H. akashiwo*, resulted in mass fish kills in the higher-salinity lower San Francisco Bay Estuary (Senn et al. 2023). Overall, phytoplankton, of which there are many bloom forming types in the SFE, are complex organisms that have species-specific growth requirements.

Generally, water temperature of 19°C or higher is used as a threshold above which *Microcystis* begins to bloom (Lehman et al. 2013). Historically, *Microcystis* in the Delta may have been light limited, since *Microcystis* requires ample light, but data have shown a reduction in turbidity may be reducing this limitation (Wu et al. 2009, Berg and Sutula 2015, Hellweger et al. 2022, Schoellhamer 2011). Nutrients are typically plentiful in the Delta, but nitrogen-limitations can occur during large blooms and nitrogen to phosphorus ratios can advantage certain plankton species over others (Jassby et al. 2002, Cloern 2019, Wilhelm et al. 2020, Dahm et al. 2016, Glibert et al. 2016, Wan et al. 2019). Low flow events that increase water residence times favor *Microcystis* blooms as they allow the cyanobacteria cells time to reproduce before being flushed out of the system (Monsen et al. 2002, Bricker et al. 2007). *Microcystis* is tolerant of fresh, brackish, and saltwater conditions (Paerl 1988, Sellner et al. 1988). See Bouma–Gregson et al. (2024) for a thorough summary of conditions and drivers that may lead to *Microcystis* blooms in the Delta.

Research is still ongoing related to the *H. akashiwo* HAB strain occurring in the lower SFE. White Sturgeon mortalities have been observed to correspond with the timing of the *H. akashiwo* blooms and are considered a factor in listing White Sturgeon as a threatened species under CESA (Rosenfield 2023). A strain from the Pacific Northwest was shown to live at a wide range of salinities (10-32 ppt) but the organisms may be deadlier to fish in lower salinities (10-20 ppt) or when in competition with another alga (Ikeda et al. 2016).

Given the known relationship between HABs and White Sturgeon mortality, we attempted to quantify the potential effects of HAB events on the growth of White Sturgeon population by incorporating HAB mortality into a model that follows the methodology of the Blackburn et al. (2019) model. This modeling exercise incorporated HABs as mass mortality events driven by intense HABs that manifest as varying degrees of mortality across all age classes. The model is an age-structured model that keeps track of female sturgeons of different ages a at year t denoted by $N_{a,t}$. This model follows the dynamics of a Leslie matrix structure given by Equation 1:

Equation 1

$$\begin{pmatrix} N_{0,t+1} \\ N_{1,t+1} \\ N_{2,t+1} \\ \vdots \\ N_{20+,t+1} \end{pmatrix} = \begin{pmatrix} R_0 & R_1 & \dots & \dots & R_{20+} \\ S_0 & 0 & \dots & \dots & 0 \\ 0 & S_1 & & \dots & \vdots \\ \vdots & \vdots & \ddots & \dots & \vdots \\ 0 & 0 & \dots & S_{19} & S_{20+} \end{pmatrix} \begin{pmatrix} N_{0,t} \\ N_{1,t} \\ N_{2,t} \\ \vdots \\ N_{20+,t} \end{pmatrix}$$

where R_a is the reproductive rate of female sturgeon at age a and S_a is the probability of a sturgeon of age a to survive to the next year. The reproductive rate is estimated as half of the product of the probability of spawning at age a P_a, its fecundity f_a, and the annual survival probability S_a:

$$R_a = \frac{1}{2} P_a f_a S_a$$

The half represents the assumption that the sex-ratio of recruits is 1:1.

The Blackburn et al. (2019) methodology describes deterministic Leslie matrix models, which do not properly describe dynamics of sturgeon as they are periodic species that have sporadic successful reproductive events (Gross et al, 2002). To overcome this, the simulations reported here follow a stochastic Leslie matrix model, where the reproductive rates of sturgeon R_a have a probability of being zero (0) in seven (7) out of every eight (8) years.

In addition to the stochastic nature of reproductive events, we add stochastic mass mortality events caused by intense HABs to our model. To do this, we reduce the survival probabilities of the different age classes in our model. The Mardones et al. (2021) empirical study with salmon suggest there is no correlation between fish size and direct mortality from HABs and because of the lack of evidence of age-dependent mortality caused directly by HABs, we made the simplified assumption that all age classes of White Sturgeon experience a reduction in survival, with survival reduced by a severity factor γ_{HAB}.

Equation 2

$$S_a \rightarrow S_a \left(1 - \gamma_{HAB} \mathbf{1}_{HAB}\right)$$

where $\mathbf{1}_{HAB}$ is the indicator function of whether an intense HAB event occurred during the year. Due to a lack of severity of HAB events regarding sturgeon mortality, we treat the severity of HAB events γ_{HAB} as a free parameter.

We model intense HAB events as independent events with a probability p_{HAB}. We model this probability in terms of the odds of HAB events occurring (i.e., a frequency of HAB events occurring every 20 years has odds of 20 to 1 of occurring).

Similar to Blackburn et al. (2019), we estimate the population growth rate of the modeled White Sturgeon population as the geometric mean of year-over-year ratios of total population abundance modeled by iterating the stochastic model defined by Equation 1. We vary the severity of HAB events γ_{HAB} and probability of intense HAB events p_{HAB} and report the mean population growth rate obtained after iterating the simulations for 5,000 repetitions per combination of parameters. This analysis indicates that intense HAB events that cause mass mortality can decrease the population growth rate of White Sturgeon by half (Figure 5). The severity and probability of HAB events like those observed in water years 2022 and 2023 is unknown. Therefore, the trajectory of White Sturgeon population when considering mortality directly caused by HABs is currently unknown. Nevertheless, the simulation reported here highlights the potential for HAB events to be detrimental to the population. Furthermore, the model reported here does not account for increased mortality caused by nonlethal effects of HABs, which may further decrease the growth rate of White Sturgeon populations.

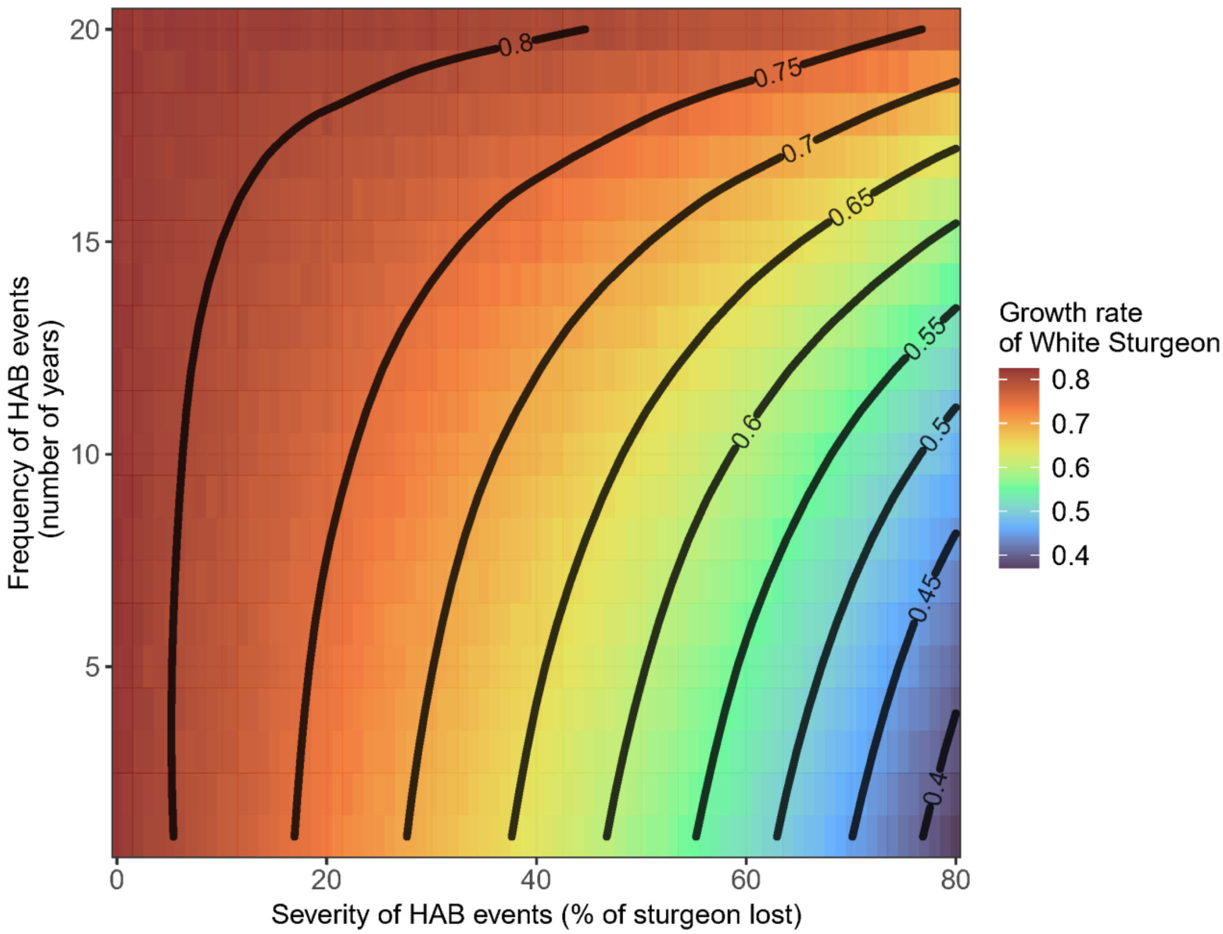

Figure 5. Population growth rate of White Sturgeon based on the extension of the model by Blackburn et al (2019) to incorporate the effects of intense harmful algal bloom (HAB) events as the severity and frequency of HAB events vary. Black lines represent isoclines, i.e. parameter combinations where the growth rate equals a certain value.

To elucidate the relative importance of different parameters on the growth rate of the White Sturgeon population, we perform a Global Sensitivity Analysis (GSA) following the procedure of Harper et al (2011). The GSA algorithm consists of sampling the parameters of the model from a given distribution, which are then used to measure the growth rate of the White Sturgeon population. We sample and utilize 2,000 combinations of parameters to train a random forest that predicts the growth rate of the White Sturgeon population by taking the parameters of the model as inputs. The most important parameters for determining the growth rate of the White Sturgeon population are identified using the importance metric of the random forest. The importance metric of a random forest is a relative measure of how much varying each individual parameter leads to a difference in the value of the growth rate predicted by the trained random forest.

We sample the original parameters of the model of Blackburn et al. (2019) using normal distributions with the baseline value as mean and the standard error as standard deviation. We sample the probability of a HAB event p_{HAB}, the severity of HAB events γ_{HAB}, and the probability of a successful reproduction event randomly from a uniform distribution between 0 and 1.

From our GSA, we find that the probability and severity of HAB events, as well as the probability of successful reproductive events have an importance several orders of magnitude than the survival, spawning probability, or fecundity of any age class of White Sturgeon in our model (Figure 6). Following the guidelines of Harper et al (2011), better estimates of the severity and probability of HAB events would provide more accurate estimates of the White Sturgeon population growth rate.

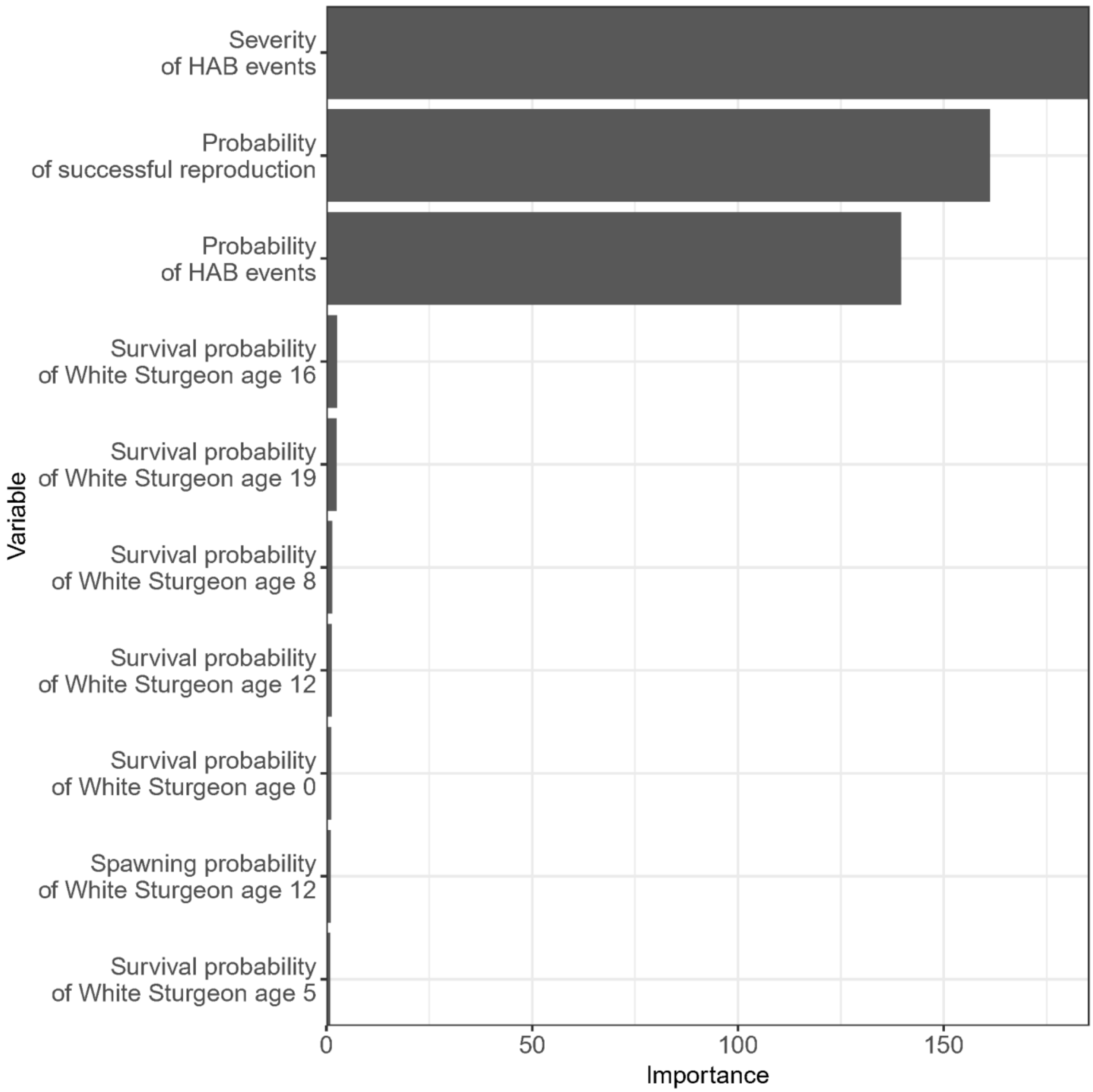

Figure 6. Importance metrics for the top 10 most important variables determined by fitting a random forest that predicts the growth rate of a model White Sturgeon population using our extension of the model of Blackburn et al. (2019).

4.2.2. Predation Risk to Adult and Juvenile White Sturgeon

White Sturgeon can experience predation at all life stages; however, they are disproportionately more vulnerable to predation during the egg, larval, and juvenile stages (McAdam 2011; Hildebrand et al. 2016). Species such as Sacramento Pikeminnow (*Ptychocheilus grandis*), Channel Catfish (*Ictalurus punctatus*), Prickly Sculpin (*Cottus asper*), Common Carp (*Cyprinus carpio*), Largemouth Bass (*Micropterus salmoides*), and Striped Bass (*Morone saxatalis*) have all been documented predating upon these early life stages (Israel et al. 2009; Hildebrand et al. 2016; Steel et al. 2020, Rosenfield 2023). Juvenile sturgeon become less vulnerable with increased length and are only predated upon by larger piscivores such as Striped and Largemouth Bass (Steel et al. 2020). An experimental study using Green Sturgeon showed that once juveniles reached roughly 20–22 cm total length, or between 38% and 58% of predator total length, predation risk decreased substantially from Striped Bass and Largemouth Bass (Steel et al. 2020). Once sturgeon outgrow these piscivorous fish predators, California sea lions remain the dominant source of predation in the SFE (Hildebrand et al. 2016; Heublein et al. 2017). While estimated numbers are not available for sea lion predation in the SFE, other watersheds can offer insight into the impact on sturgeon populations. In the Columbia River basin, the estimated consumption of White Sturgeon by sea lions in the Bonneville Dam tailrace ranged from approximately 150 to 3,000 individuals annually between 2006 and 2014 (Stansell et al. 2014). Recent reports found an approximate number of 80-200 sea lions in the Bonneville Dam trailrace (Tidwell et al. 2018), which would translate to an annual predation of between 1 and38 White Sturgeon per sea lion. In the SFE, sea lion predation has been observed from the San Francisco Bay through the spawning areas around Knights Landing (Israel et al. 2009; Hildebrand et al. 2016).

4.2.3. Vessel Strike Risk on Adult White Sturgeon

White Sturgeon have been reported to be impacted by vessel strikes in the SFE, both by direct eyewitness (Demetras et al. 2020) as well as anecdotal evidence (Hildebrand et al. 2016). The SFE is heavily trafficked by vessels, which increases the risk of these impacts. During recent years, tens of cases of sturgeon struck by vessels have been anecdotally reported, and under the assumption that observed floating to sink carcasses follow a ratio of 1:8 (CDFW 2023), this could imply at least hundreds of sturgeon are struck by vessels every year (Figure 7). However, the observation effort of these reports is unknown and likely varies greatly among years. As a result, the number of White Sturgeon struck by vessels every year, or the associated impact to White Sturgeon, are currently unknown.

Impacts of vessel strikes on the population of White Sturgeon are unknown. However, evaluation of Brown and Murphy (2010) using an egg-per-recruit analysis and found that if 2.5% of Atlantic Sturgeon (*Acipenser oxyrinchus*) females in the Delaware estuary were struck by vessels, the egg-per-recruit of this Atlantic Sturgeon population would decrease by more than 50%, when compared to a scenario where no sturgeon were struck by vessels. Further data collection is required in order to use similar analyses that could elucidate the impacts of vessel strikes in White Sturgeon in the SFE.

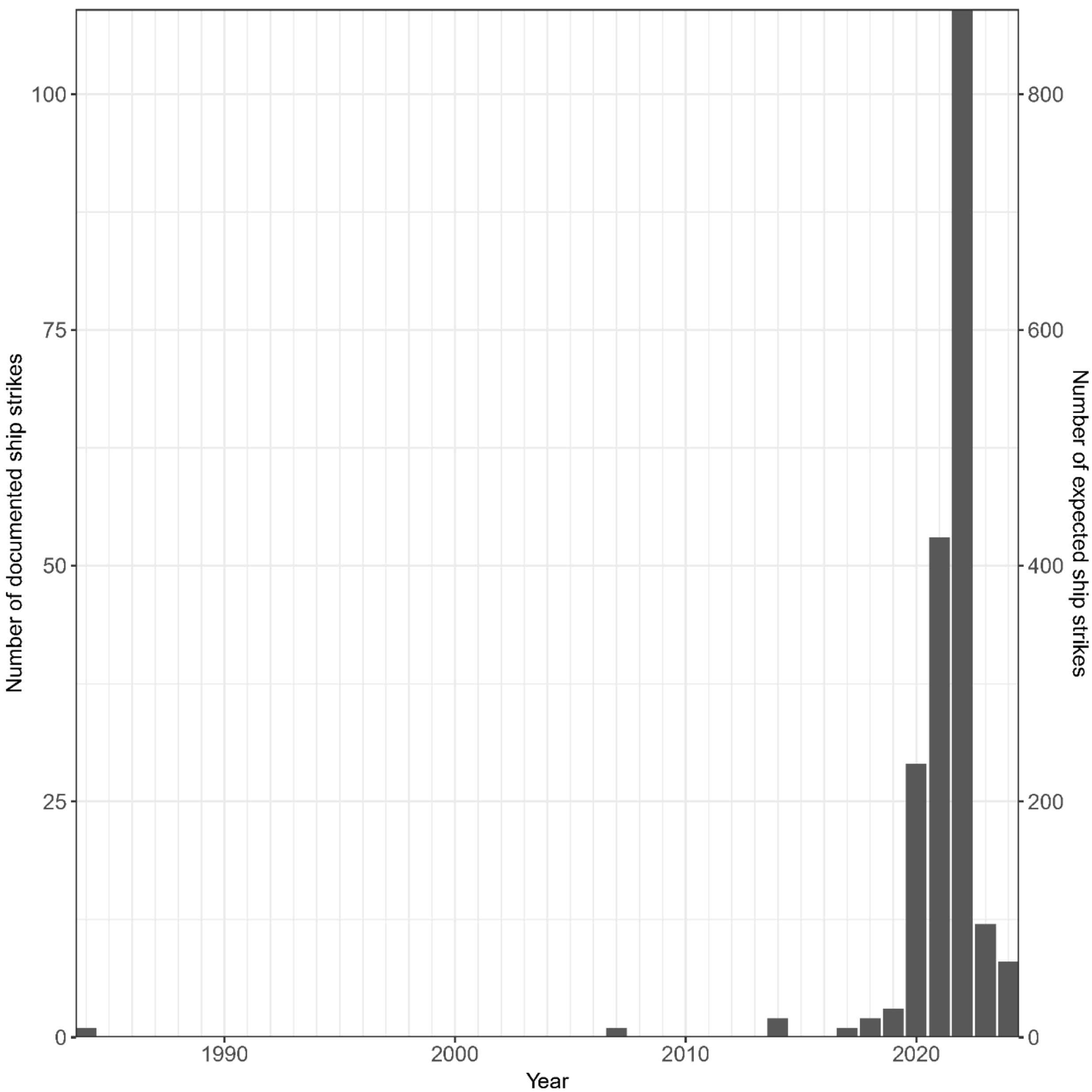

Figure 7. Number of vessel strikes with White Sturgeon documented by year (left axis) and its respective number of expected strikes (8 times the observed number of strikes; right axis) using the assumption that most sturgeon carcasses sink (data provided by Nicholas Demetras, Associate Specialist in the NOAA Southwest Fisheries Science Center on 8/26/2024).

4.2.4. Stranding

Water infrastructure projects in the SFE have inadvertently led to conditions that periodically strand White Sturgeon during winter and spring high-flow events (Israel et al. 2009; Johnston et al. 2020; Miller et al. 2020). Historically, sturgeon losses have occurred near the Yolo and Tisdale Bypasses, prompting occasional rescues by CDFW since the 1950s (Pyros & Culberson 2023). Recent efforts, including the "Big Notch" project and modifications to the Tisdale Weir, aim to minimize future strandings by improving flood management structures. Similar incidents have been reported at the Wallace Weir and the Bear River, often linked to local agricultural diversions and water management practices (Johnston et al. 2020). Thomas et al. (2013) modeled the potential impact of stranding events on sturgeon populations and concluded they could have long-term negative effect on the overall sturgeon population size. Monitoring and rescue operations within the SFE are crucial to understanding the impact of stranding on White Sturgeon and mitigating stranding effects on White Sturgeon within the region.

4.2.5. Heavy Metals and Contaminants

There are a number of prevalent contaminants and heavy metals found in the SFE that affect White Sturgeon at all life stages (Gunther et al. 1991). Polychlorinated biphenyls (PCBs), mercury, chlorinated pesticides, selenium, polycyclic aromatic hydrocarbons (PAHs), polybrominated biphenyl ethers (PBDEs), dioxins, and various metals are just a few examples of the most common or impactful forms (Gunther et al. 1991). These chemicals have been shown to contribute to the decline of fish populations through impairment and direct mortality, with some specifically affecting liver and gonad function in White Sturgeon (Gundersen et al. 2017). Selenium, in particular, is known to cause larval defects and has been documented to pass negative health effects from mother to offspring during reproduction (Linares-Casenave et al. 2015). These contaminants present significant challenges for the recovery and sustainability of sturgeon populations in the SFE. Additionally, selenium uptake through ingestion of the invasive clam *Potamocorbula amurensis* has been observed in White Sturgeon in the SFE (Linville et al 2002).

4.2.6. Pathogens

White Sturgeon in the SFE are vulnerable to bacterial and parasitic diseases, though these sources of mortality have not been found to be widespread (Pyros & Culberson 2023). However, viral outbreaks are a significant concern in commercial sturgeon aquaculture, particularly in farms producing meat and caviar (Mugetti et al. 2020). White Sturgeon are susceptible to several viruses, including White Sturgeon iridovirus (WSIV), British Columbia White Sturgeon virus (BCWSV), acipenserid herpesvirus 1 (AciHV-1), acipenserid herpesvirus 2 (AciHV-2), White

Sturgeon adenovirus 1 (WSAdV-1), infectious hematopoietic necrosis virus (IHNV), and Papova-like virus (Mugetti et al 2020).

5. Take and Impacts of Taking on White Sturgeon

The following sections describe take and impacts of taking White Sturgeon by Project infrastructure and operations. “Take” is defined by California Fish and Game Code Section 86 as “hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture, or kill.” Take of juvenile and adult White Sturgeon by the Project can occur either directly or indirectly in the form of “capture” and “kill”. South Delta export operations may result in take of juvenile White Sturgeon through impacts on the recruitment of White Sturgeon by affecting the number of spawning individuals visiting spawning sites (see Section 5.1 – Effects of South Delta Export Operations on Timing and Likelihood of Visitation of Spawning Sites on Adult White Sturgeon) and the year class strength of White Sturgeon (see Section 5.2 – Effects of South Delta Export Operations on Year Class Strength of White Sturgeon). South Delta export operations may also result in take through entrainment of juvenile White Sturgeon into the interior Delta and south Delta CVP and SWP export facilities (see Section 5.3 – Effects of South Delta Export Operations on Salvage of White Sturgeon). South Delta export operations may result in White Sturgeon mortality through changes in habitat condition including reductions in turbidity and low Delta flows which may exacerbate the frequency and severity of HABs (see Section 5.4 – Effects of South Delta Export Operations on Potential Mortality of White Sturgeon Driven by Harmful Algal Blooms). Finally, operations and/or maintenance activities associated with other Project facilities that may pose a threat to White Sturgeon are also described including maintenance at CCF, operations and maintenance at BSPP, the South Delta Temporary Barriers Project, water transfers, and operations at the SMSCG (see Sections 5.5-5.11).

5.1. Effects of South Delta Export Operations on Timing and Likelihood of Visitation of Spawning Sites on Adult White Sturgeon

CDFW used telemetry data of White Sturgeon provided by the UC Davis PATH to identify the timing and likelihood of adult White Sturgeon visiting their spawning sites. The PATH dataset consists of a grand total of 259 unique White Sturgeon detected a total of 12,528,265 times spanning from calendar years 2010 to 2023 in stations located throughout the Sacramento River basin. Telemetry data was used to determine which detections correspond to a visitation of spawning sites. It was determined that a detection corresponds to a visitation of spawning sites if the approximate rkm of the detection is higher than 230 km to account for possible uncertainties in the location of the stations and the spawning sites.

To account for the effects of age in the visitation of spawning sites, the approximate age of each tagged White Sturgeon was incorporated into the models. The fork length of each of the fish in the PATH dataset was recorded at the time of tagging. Initial age was approximated from the fork length measurements using the inverse von Bertalanffy growth model using the parameters identified by Blackburn et al. (2019). Age at detection was then calculated by adding the initial age and the number of years that have passed since the initial detection.

The correlation between visitation of spawning sites and hydrological covariates was identified using Generalized Linear Mixed Models (GLMMs). GLMMs are flexible statistical models that account for nonnormal distributions in a response variable while also accounting for the impacts of possible random effects (Bolker et al. 2009). GLMMs were constructed where the response is the number of individuals that visit a spawning site, separated by (1) numerical age a and (2) categorical month t denoted by $n_{a,t}$. Hydrological covariates were compiled from Dayflow (DWR 2024) including measurements of X2 ($X2$), Sacramento River flow (SAC) and total outflow in the Sacramento Delta (OUT). For any given day and covariate, the mean covariate lagged by the last 30, 60, and 90 days was calculated.

The GLMMs constructed in this section follow a similar structure between one another. At any month t, all the tagged White Sturgeon with current age a denoted by $N_{a,t}$ have a probability $p_{a,t}$ of visiting spawning sites. This probability depends both on current age and month, as well as one of the mean covariates previously determined (for either $X2$, SAC, or OUT) with a lag l and denoted by X_{t-l}. This covariate is taken at the last day of any given calendar month. Finally, sources of uncertainty not accounted for by the previously mentioned covariates were accounted for by separating time by brood years as a random effect z_{BY}. A previous study showed White Sturgeon tend to visit spawning sites more often starting between February and April (Miller et al. 2020). Based on these observations, the brood year for White Sturgeon was assumed to begin on February 1.

In equation form, our GLMMs follow a binomial regression denoted by:

Equation 3

$$\begin{aligned} n_{a,t} &\sim Binomial(p_{a,t}, N_{a,t}) \\ \text{logit}(p_{a,t}) &\sim \beta_0 + \beta_a a + \beta_t + \beta_X X_{t-l} + z_{BY} \\ z_{BY} &\sim Normal(0, \sigma_{BY}) \end{aligned}$$

The models presented in this section were fitted using Bayesian regression with the brms package in R (Burkner et al. 2017). Bayesian modeling is a powerful method to quantify different sources of uncertainty in the correlations between a response variable and its possible covariates. The best model was determined by using the Leave-One-Out cross validation (LOO) (Vehtari et al. 2016). LOO is a method to evaluate the performance of a Bayesian model by measuring the likelihood of a data point given the Bayesian model was trained with the rest of the data.

Based on the log-likelihoods presented in Table 3, the model with the highest log-likelihood is the model using the mean Sacramento River flow of the last 30 days. However, none of the models had a difference in expected likelihood with this model higher than 4. This implies that determining any level of statistical significance for best model is not practical (Sivula et al. 2020).

Table 3. Expected log-likelihood of models of probability of visiting a spawning site dependent on different hydrological covariates estimated using the Leave-One-Out cross validation method. The expected difference of log-likelihoods between a given model and the model with the highest log-likelihood, as well as its standard error (SE).

Hydrological Covariate	Expected Log-Likelihood	Expected difference with highest likelihood model	SE of difference
SAC Lag 30	-719.27	N/A	N/A
OUT Lag 30	-719.40	0.12	0.81
OUT Lag 60	-719.94	0.67	1.30
X2 Lag 30	-720.24	0.96	1.24
SAC Lag 60	-720.77	1.49	1.33
OUT Lag 90	-721.07	1.80	1.42
SAC Lag 90	-721.35	2.07	1.66
X2 Lag 90	-721.41	2.12	1.89
X2 Lag 60	-721.73	2.45	1.81

The posterior distributions of the best-fit model were normalized to study the effect size of each covariate in predicting their corresponding response. These distributions were normalized by dividing each of their parameter values by the difference between the maximum and the minimum parameter values sampled during the fitting process. A distribution that has an effect size further away from zero would imply that the covariate has a stronger effect (either positive or negative) on the response. On the other hand, a covariate with a posterior distribution that intersects zero at a point with higher density would have almost no impact in predicting the response.

The effect size plot of the model using the 30-day mean Sacramento River flow as the hydrological covariate shows a strong positive effect of age, which corresponds to the increase in maturity as White Sturgeon age (Figure 8) (Devore et al. 1995). In addition, the effect size shows a smaller but significant positive effect of the 30-day mean Sacramento River flow. With regards to the month, the effect size shows that the probability of visiting a spawning site relative to January increases from the months of February-April and decreases during June-November. This model matches the spawning season of White Sturgeon and their swimming behavior reported in the literature (Klimley et al. 2015).

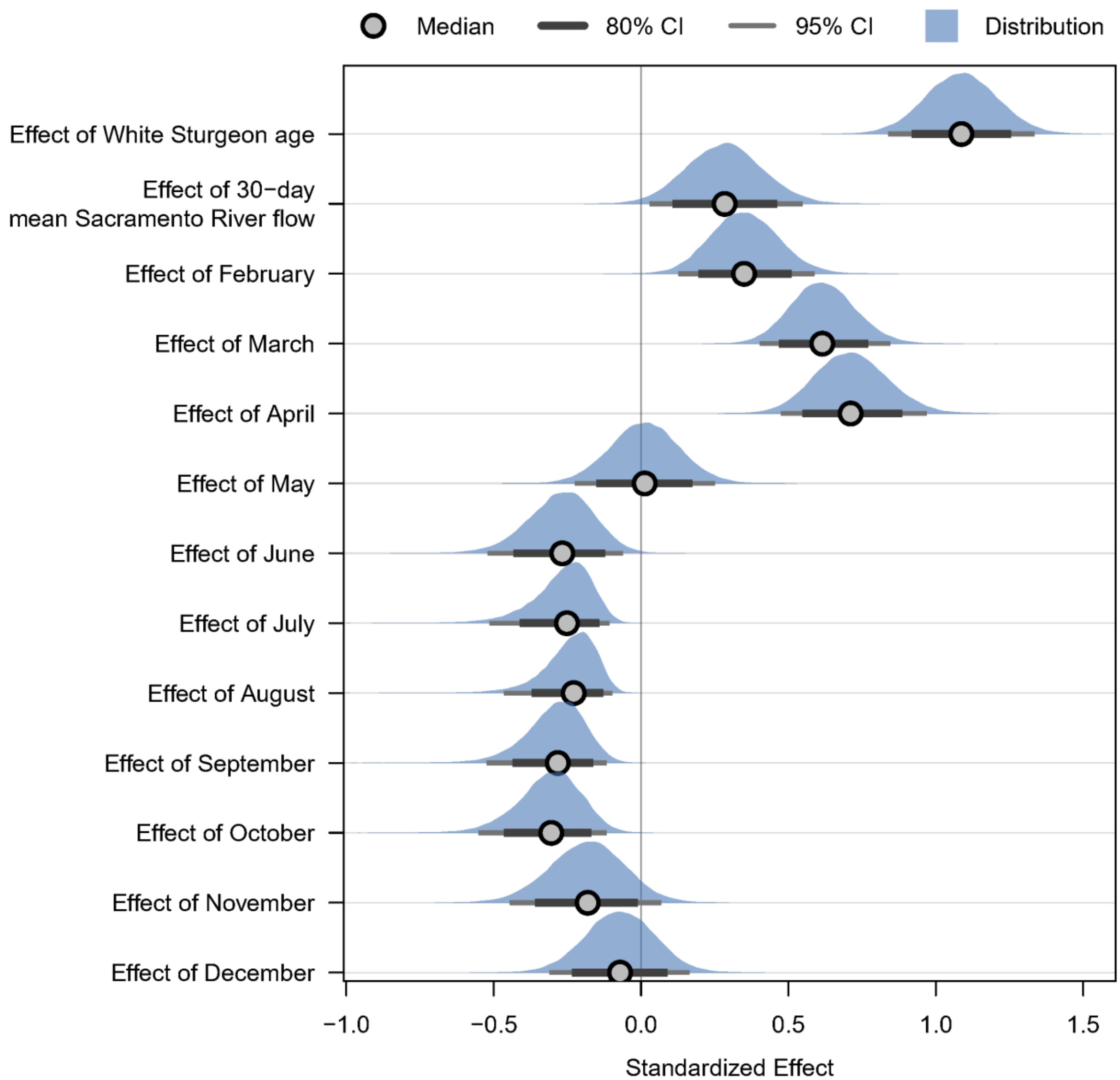

Figure 8. Effect size of the posterior distributions of the parameters of the best model for the probability of visiting spawning sites, with its 80 and 95% confidence intervals (CI). The vertical line corresponds to an effect size of 0, i.e. there is no effect of the variable. The effect size of months uses January as a reference, which means the effect size of a given month is relative to January.

When predicting the probability of White Sturgeon spawning visitation using the observed Sacramento River flows during water years 2003-2023, the probability of visiting a spawning site has a small variation throughout the water years, with most water years having a probability of visitation around approximately 20%, with some outlier years, such as water years 2011 and

2022 (Figure 9). In addition, when separating these simulations by water year type, there is a slightly higher median probability of visitation for wet water years, with no clear difference in the median probability for the other water year types (Figure 10). This is consistent with the literature (e.g., Miller et al. 2020) reporting that some White Sturgeon visit spawning sites at any given water year.

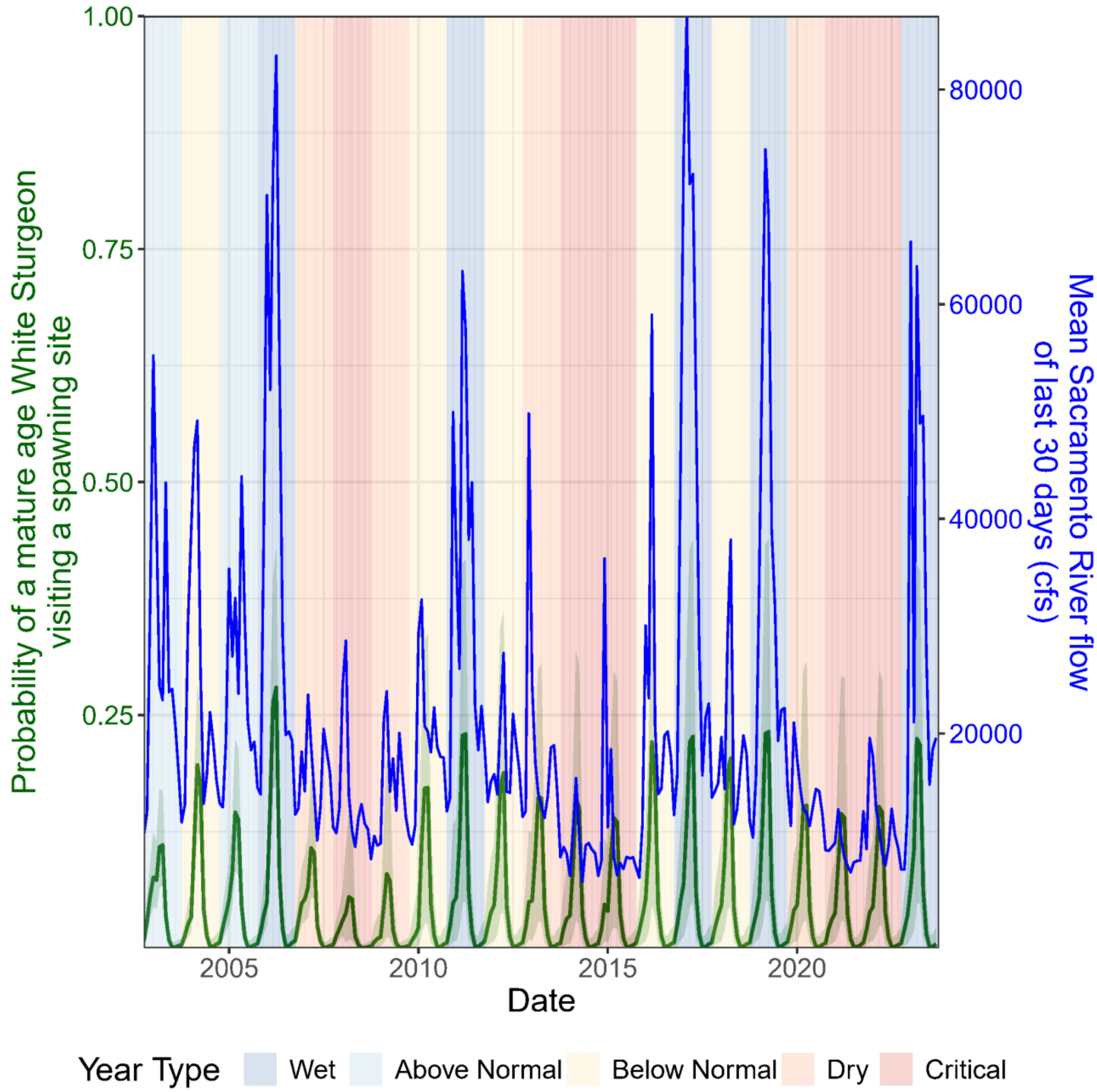

Figure 9. Green: Mean probability of a White Sturgeon from ages 10 to 30 visiting a spawning site from water years 2003-2023 based on the model which uses 30-day mean Sacramento River flow as its hydrological covariate. Confidence intervals are on the 95%. Blue: 30-day mean

Sacramento River flow through months from water years 2003-2023. The background color of each water year corresponds to the water year type based on the Sacramento Valley Index.

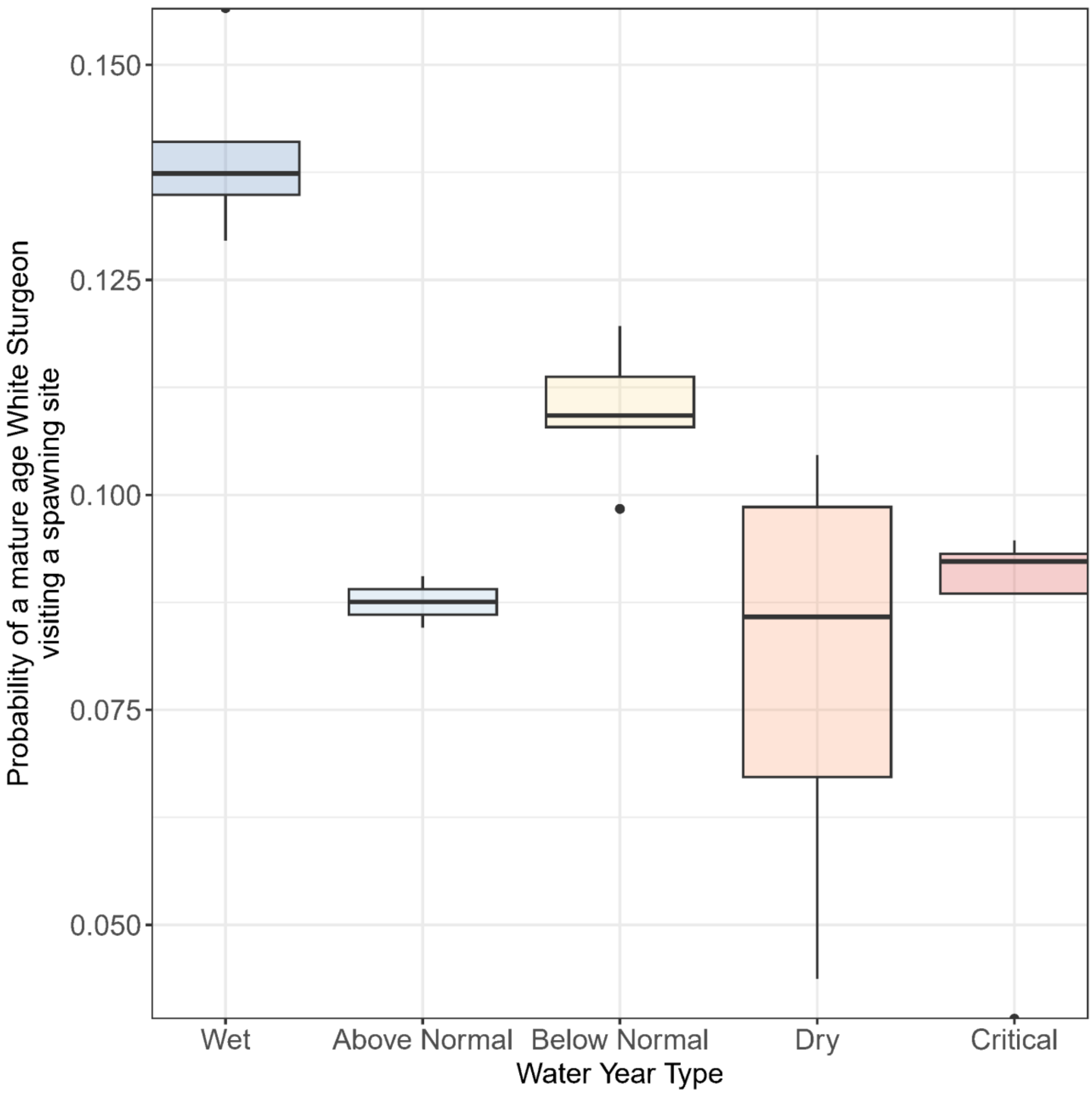

Figure 10. Boxplots of mean probability of a White Sturgeon from ages 10 to 30 visiting a spawning site from water years 2003-2023 based on the model which uses 30-day mean Sacramento River flow as its hydrological covariate. Each data point is separated by water year type.

The probability of a spawning site visitation was simulated across the entire observed range of Sacramento River flows at the age of 10, 20, and 30 years old. A slight increase in the probability for small Sacramento River flows was observed, followed by a leveling out where the probability does not change as much for intermediate and high Sacramento River flows (Figure 11). As suggested by the effect size plot (Figure 8), age has a higher effect in the probability of visiting a spawning site than the mean Sacramento River flow of the last 30 days. This can be observed in the model, where the mean probability of an age 30 White Sturgeon visiting a spawning site is one order of magnitude bigger than that of an age 10 White Sturgeon.

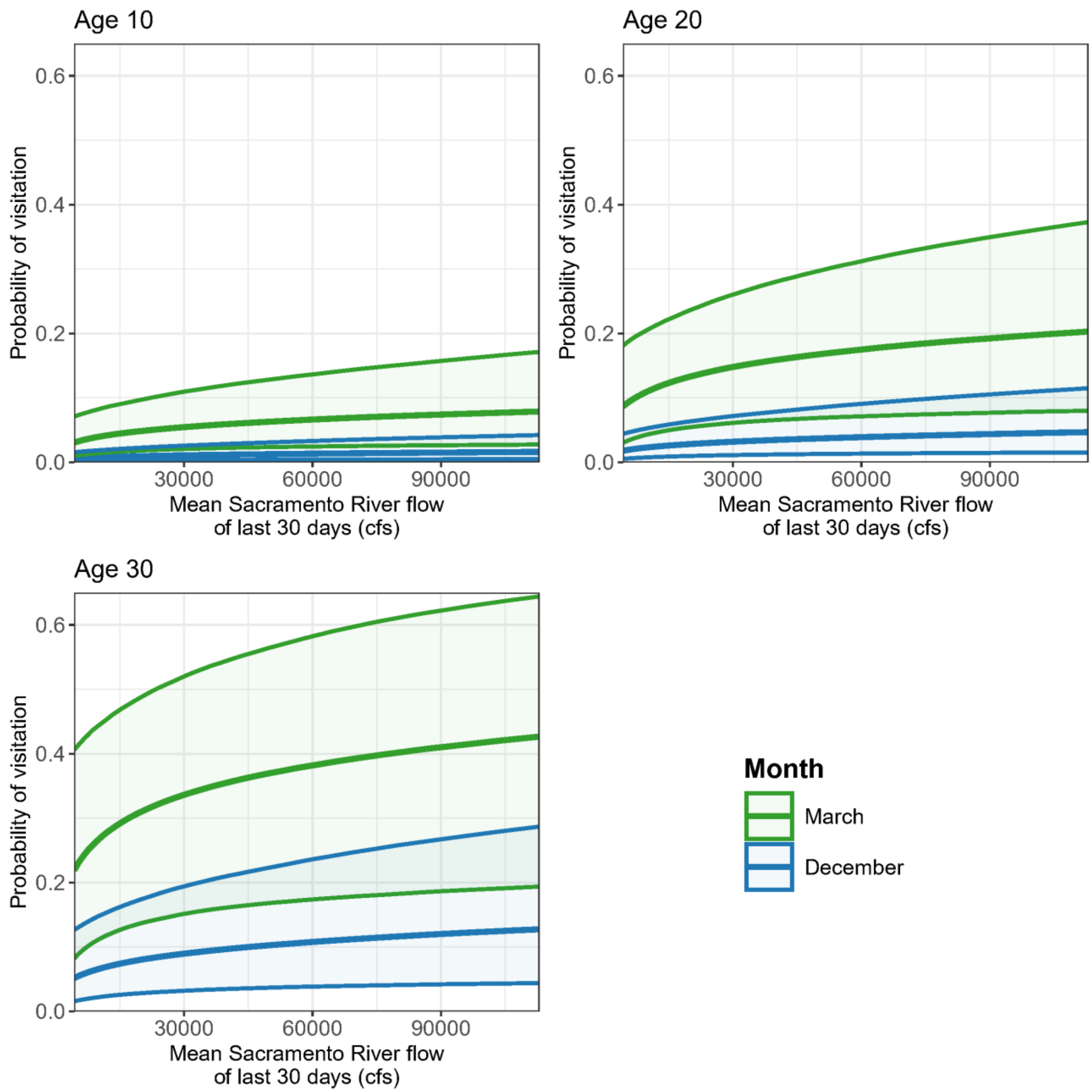

Figure 11. Model probability visitation of spawning site by a White Sturgeon during the months of March and December as a function of the mean Sacramento River flow of last 30 days within the observed range of mean Sacramento River flows from calendar years 1997 to 2023 and separated at ages 10, 20, and 30. Confidence intervals are at the 95%.

Using the GLMM model with the mean Sacramento River flow as its hydrological covariate, the changes in the number of individual White Sturgeon visiting spawning sites under the different proposed Project scenarios were evaluated. The two Spring Delta Outflow options are represented in CalSim 3 modeling as two different Proposed Project scenarios. The ITP_Spring modeling scenario incorporates all proposed SWP operations and continued implementation of 2020 SWP ITP Condition of Approval 8.17 -Export Curtailments for Spring Outflow (CDFW 2020). The 9A_V2A modeling scenario incorporates all proposed SWP operations and DWR's contribution to the Healthy Rivers and Landscapes Program (HRL) through export reductions and facilitating upstream land fallowing and subsequent reservoir releases as described above. See Section 5.2 – Effects of South Delta Export Operations on Year Class Strength of White Sturgeon and Appendix C – CalSim Modeling Results for additional details on CalSim 3 modeling of the Proposed Project.

Scenario 9A_V2A shows a trend of decreasing number of individuals visiting spawning sites relative to the baseline during dry and critical years (Figure 12), while scenario ITP_Spring shows a trend of decreasing number of individuals visiting spawning sites during critical years with smaller variations during other water year types (Figure 13). A difference in the number of White Sturgeon visiting spawning sites was not observed in the absolute number of estimated total age-20 White Sturgeon per 120 that visit spawning sites during the spawning season (Table 4). The age chosen for this metric to evaluate the difference between scenarios was 20 as previous modeling efforts assumed all sturgeon reach sexual maturity at age 20 (Blackburn et al. 2019). The number of sturgeon chosen for this metric was 120 to make the total number of sturgeon modeled in a year divisible by 12, the number of months in a year. As suggested by effect size plot (Figure 8) and our numerical exploration across the possible ranges of the covariates of the model (Figure 11), visitation of spawning sites is largely driven by White Sturgeon age and the months of their spawning season, which are not affected by the proposed Project scenarios.

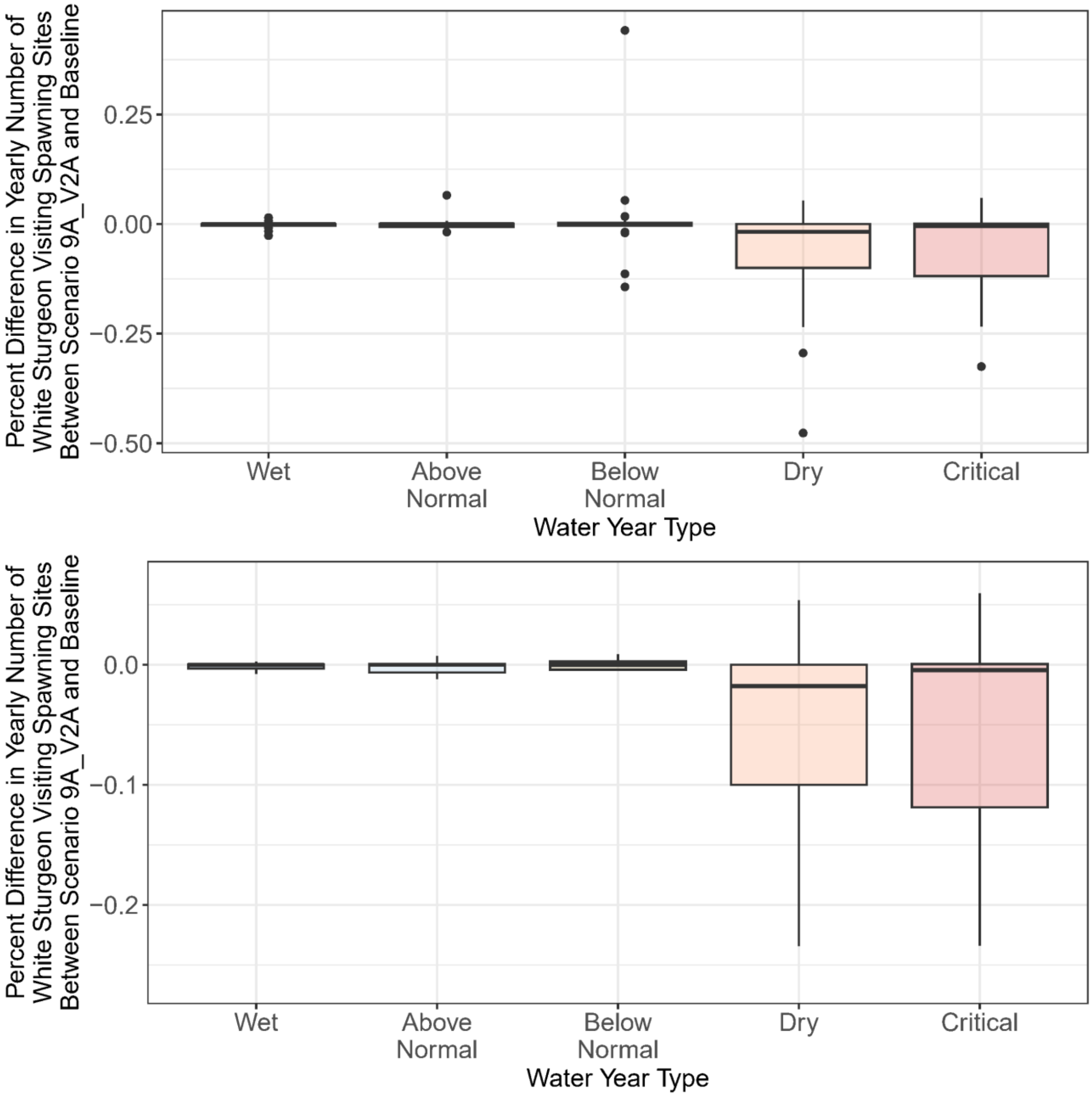

Figure 12. Percent difference in yearly number of age-20 White Sturgeon visiting spawning sites between scenario 9A_V2A and baseline. Top panel represents the distribution of all water years. Bottom panel represents the distribution of water years within 1.5 times the interquartile range of all water years.

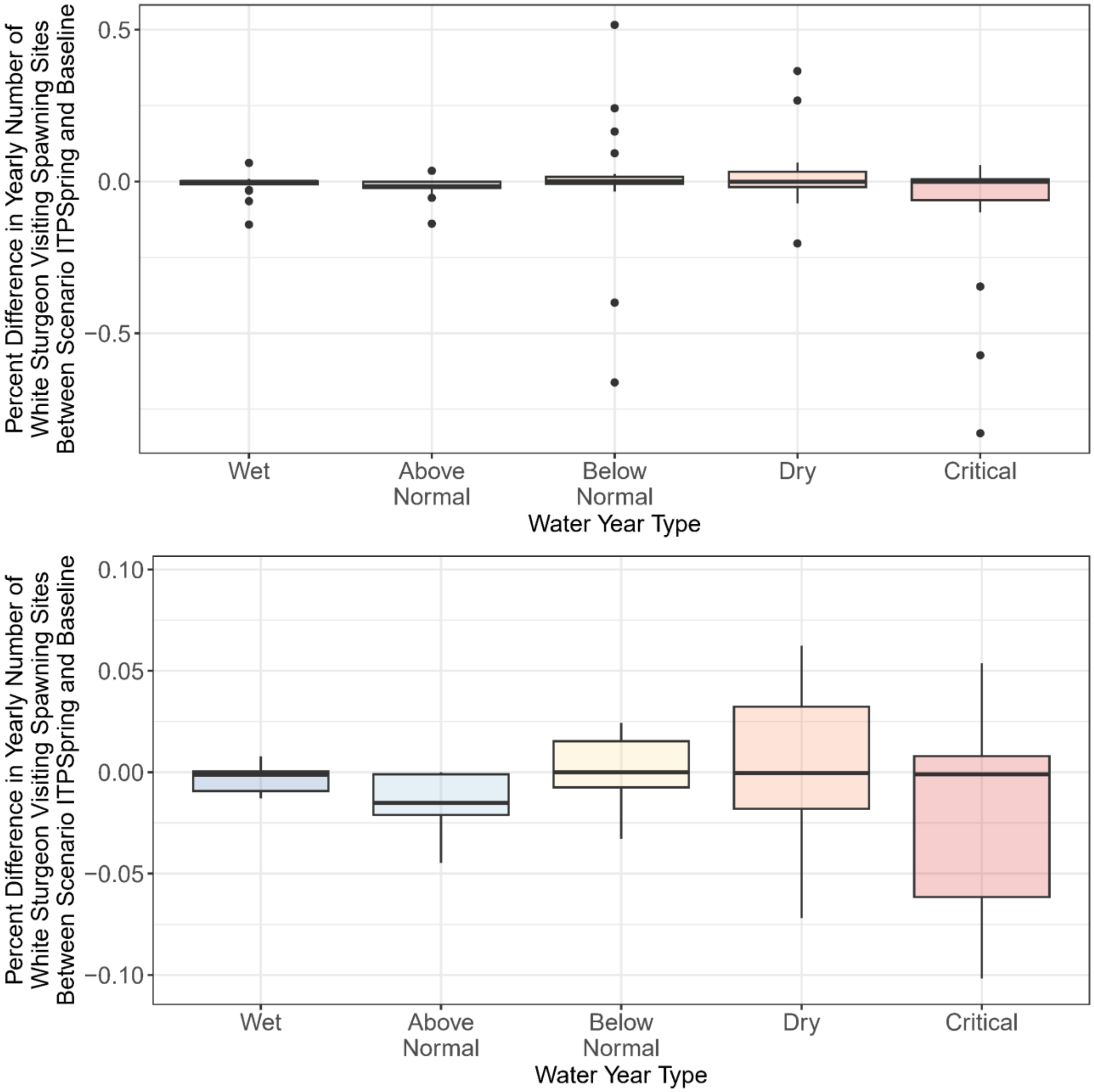

Figure 13. Percent difference in yearly number of age-20 White Sturgeon visiting spawning sites between scenario ITP_Spring and baseline. Top panel represents the distribution of all water years. Bottom panel represents the distribution of water years within 1.5 times the interquartile range of all water years.

Table 4. Total age-20 White Sturgeon per 120 age-20 White Sturgeon that visit spawning sites during December-May of a given water year under different scenarios.

Water Year	Baseline	9A_V2A	ITP_Spring
1922	9	9	9
1923	9	9	9

Water Year	Baseline	9A_V2A	ITP_Spring
1924	7	7	7
1925	9	9	9
1926	9	9	9
1927	10	10	10
1928	10	10	10
1929	7	7	7
1930	9	9	9
1931	7	7	7
1932	8	8	8
1933	8	8	8
1934	8	8	8
1935	9	9	9
1936	10	10	10
1937	9	9	9
1938	12	12	12
1939	8	8	8
1940	11	11	11
1941	11	11	11
1942	10	10	10
1943	11	11	11
1944	9	9	9
1945	9	9	9
1946	9	9	9
1947	8	8	8
1948	9	9	9
1949	9	9	9
1950	9	9	9
1951	10	10	10
1952	12	12	12
1953	10	10	10
1954	10	10	10
1955	8	8	8
1956	10	10	10
1957	9	9	9
1958	12	12	12
1959	8	8	9
1960	9	9	9
1961	8	8	8
1962	9	9	9
1963	11	11	11
1964	8	8	8

Water Year	Baseline	9A_V2A	ITP_Spring
1965	10	10	10
1966	9	9	9
1967	11	11	11
1968	9	9	9
1969	11	11	11
1970	10	10	10
1971	10	10	10
1972	9	9	9
1973	10	10	10
1974	11	11	11
1975	10	10	10
1976	8	8	8
1977	7	7	7
1978	10	10	10
1979	9	9	9
1980	11	11	11
1981	8	8	8
1982	12	12	12
1983	12	12	12
1984	10	10	10
1985	8	8	8
1986	11	11	11
1987	8	8	8
1988	8	8	8
1989	9	9	9
1990	8	8	8
1991	8	8	8
1992	9	9	9
1993	10	10	10
1994	8	8	8
1995	12	12	12
1996	11	11	11
1997	9	9	9
1998	11	11	11
1999	11	11	11
2000	10	10	10
2001	8	8	8
2002	8	8	8
2003	10	10	10
2004	10	10	10
2005	10	10	10

Water Year	Baseline	9A_V2A	ITP_Spring
2006	12	12	12
2007	8	8	8
2008	8	8	8
2009	9	9	9
2010	7	7	7
2011	19	19	19
2012	13	13	13
2013	9	9	9
2014	12	12	12
2015	11	11	11
2016	11	11	11
2017	8	8	8
2018	8	8	8
2019	9	9	9
2020	9	9	9
2021	5	5	5

5.2. Effects of South Delta Export Operations on Year Class Strength of White Sturgeon

Year class strength of White Sturgeon was quantified as the catch per unit effort (CPUE) of YOY White Sturgeon in several Interagency Ecological Program (IEP) long-term monitoring surveys (Hayman et al. 1980). Based on the von Bertalanffy growth curve provided by Blackburn et al. (2019), a YOY was defined as any White Sturgeon with a fork length smaller than 234 mm. Using this definition, data was compiled of YOY White Sturgeon from the 20 mm Survey, Bay Study Midwater Trawl (MWT), and Bay Study Otter Trawl (OT) collected by the IEP between water years 2003 and 2023 (Gaeta et al. 2021). These studies are known to have consistently caught YOY White Sturgeon since the Pelagic Organism Decline (POD) that occurred in the early 2000s (Figure 14) (Baxter et al. 2008). Each station in the surveys was labeled with a region dependent on its relative position within the Delta: Far West Delta, West Delta, Central Delta, and South Delta (Figure 15).

To quantify effort, the tow volume in cubic meters (m^3) of water towed was used. For the San Francisco Bay Study Otter Trawl (OT), tow area of square meters (m^2) of water towed is reported. To get the total volume of water towed, the tow area of San Francisco Bay Study Otter Trawl was multiplied by the height of the otter net of 2.31 m (Gaeta et al. 2021). To quantify the CPUE, the catch of YOYs within a region in a month were added and divided that number by the sum of the towed volumes for each survey within that region in that month:

Equation 4

$$CPUE_{region,month} = \frac{catch_{20mm,region,month} + catch_{BayMWT,region,month} + catch_{BayOT,region,month}}{volume_{20mm,region,month} + volume_{BayMWT,region,month} + volume_{BayOT,region,month}}$$

The correlation between year class strength and hydrological covariates was identified using GLMMs. Models where $CPUE_{region,month}$ is the response variable were conducted. Two hydrological covariates were compiled: daily measurements of X2 and outflow from Dayflow (DWR 2024). For each month, the mean X2 and mean outflow was quantified as the hydrological covariates for the models.

CPUE is usually assumed to follow a lognormal distribution (Gruss et al. 2019). However, catch of White Sturgeon is rare in these surveys, which leads to a distribution with a high count of zeros that violates the assumption of a lognormal distribution. To overcome this, the CPUE was assumed to follow a hurdle-lognormal distribution instead (Santos et al. 2021). Distributions with hurdles assume that the probability of an observation being zero is a value called the hurdle and denoted by η. For nonzero values x, the probability of an observation being x follows some distribution (lognormal in our case) truncated at zero.

Both the nonzero CPUE and the hurdle were modeled using a similar structure of covariates. Months were classified into four seasons for incorporation into the models: Spring (March-May), Summer (June-August), Fall (September-November), and Winter (December-February). Subsequently, each month in the data uses its season and the mean hydrological covariate as predictors. In addition, we incorporated the region z_{region} and the survey z_{survey}, as well as the brood year z_{BY} starting in the month of February as random effects possibly affecting year class strength due to unexplained processes.

The model, using X2 as the hydrological covariate, follows the following equation:

Equation 5

$$\begin{aligned} \log(CPUE_{region,month}) \sim & \beta_{CPUE,0} + \beta_{CPUE,X2}X2 + \beta_{CPUE,season} + \\ & z_{CPUE,BY} + z_{CPUE,Region} + z_{CPUE,Survey}, \\ \text{logit}(\eta_{region,month}) \sim & \beta_{\eta,0} + \beta_{\eta,X2}X2 + \beta_{\eta,season} + \\ & z_{\eta,BY} + z_{\eta,Region} + z_{\eta,Survey}, \\ z_{i,j} \sim & Normal(0, \sigma_{i,j}) \end{aligned}$$

For $i = CPUE, \eta$ and $j = BY, Region, Survey$. A similar equation was used for the model using outflow as the hydrological covariate:

Equation 6

$$\begin{aligned}
\log(CPUE_{region,month}) \sim & \beta_{CPUE,0} + \beta_{CPUE,OUT}OUT + \beta_{CPUE,season} + \\
& z_{CPUE,BY} + z_{CPUE,Region} + z_{CPUE,Survey}, \\
\text{logit}(\eta_{region,month}) \sim & \beta_{\eta,0} + \beta_{\eta,OUT}OUT + \beta_{\eta,season} + \\
& z_{\eta,BY} + z_{\eta,Region} + z_{\eta,Survey}, \\
z_{i,j} \sim & Normal(0, \sigma_{i,j})
\end{aligned}$$

We fitted the models presented in this section using Bayesian regression with the brms package in R (Burkner et al. 2017). The best model was determined using LOO (Vehtari et al. 2016).

Based on the log-likelihoods presented in Table 5, the model with the highest log-likelihood is the model using the mean daily X2 at a given month. However, similar to the models of the probability of visiting a spawning site, a small, expected difference in log-likelihood, as well as the high standard error relative to the mean difference suggests that the model using outflow as a hydrological covariate does not perform significantly differently than the model using X2.

The posterior distributions of the best fit model were normalized to study the effect size of each covariate in predicting their corresponding response. These distributions were normalized by dividing each of their parameter values by the difference between the maximum and the minimum parameter values sampled during the fitting process. A distribution that has an effect size further away from zero would imply that the covariate has a stronger effect (either positive or negative) on the response. In contrast, a covariate with a posterior distribution that intersects zero at a point with higher density would have almost no impact in predicting the response.

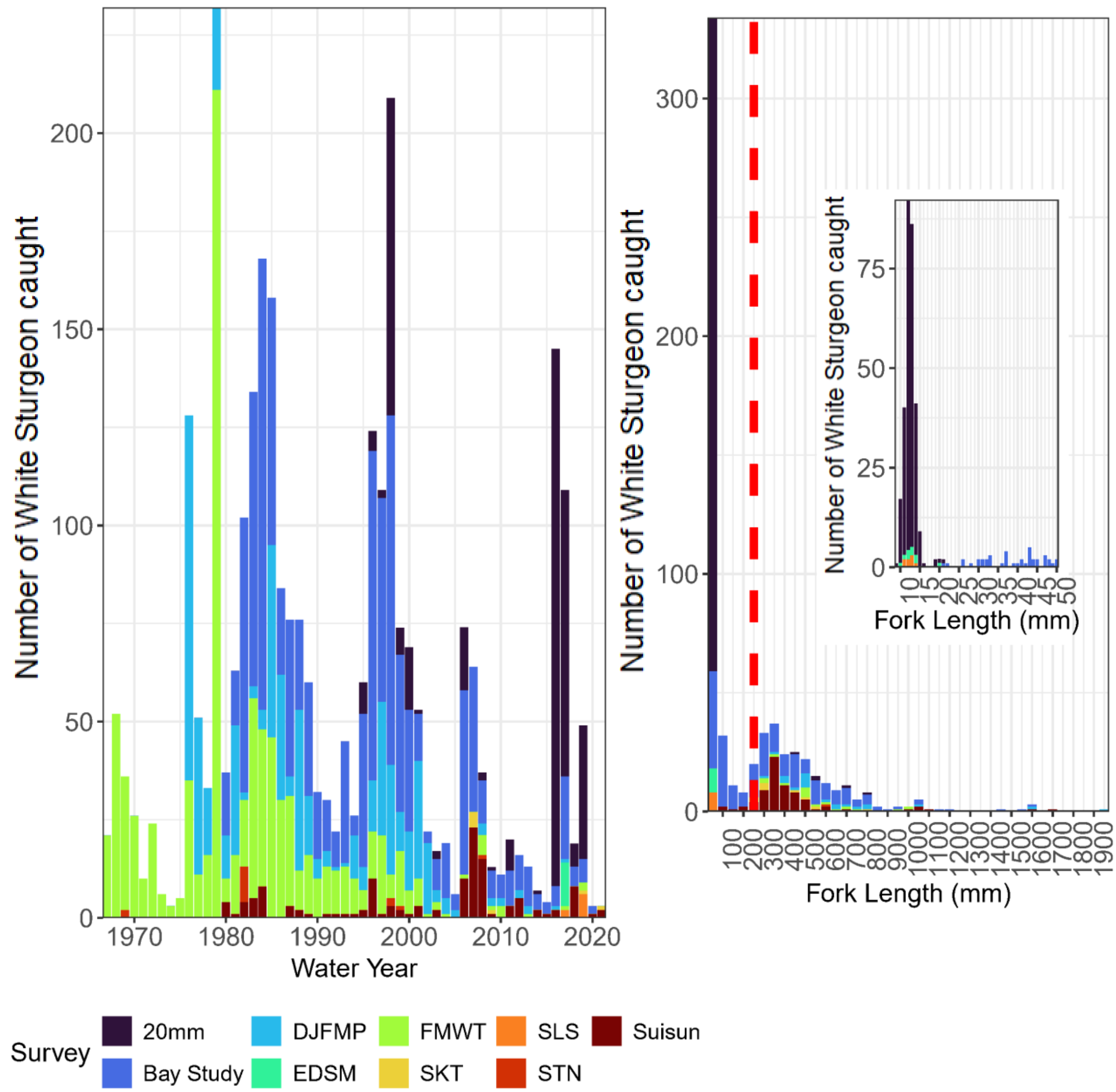

Figure 14. Left: Total number of White Sturgeon caught by water year and survey. Right: Distribution of fork lengths of White Sturgeon caught from water year 2003 to water year 2021. The red dashed line represents the fork length of 234 mm, which corresponds to our threshold fork length to determine a YOY White Sturgeon based on the von Bertalanffy growth curve provided by Blackburn et al. (2019). Survey abbreviations correspond to: 20mm (20-mm Survey), DJFMP (Delta Juvenile Fish Monitoring Program), FMWT (Fall Midwater Trawl), SLS (Smelt Larva Survey), Bay Study (San Francsico Bay Study, both Otter and Midwater Trawls),

EDSM (Enhanced Delta Smelt Monitoring), SKT (Spring Kodiak Trawl), STN (Summer Townet Survey), and Suisun (Suisun Survey).

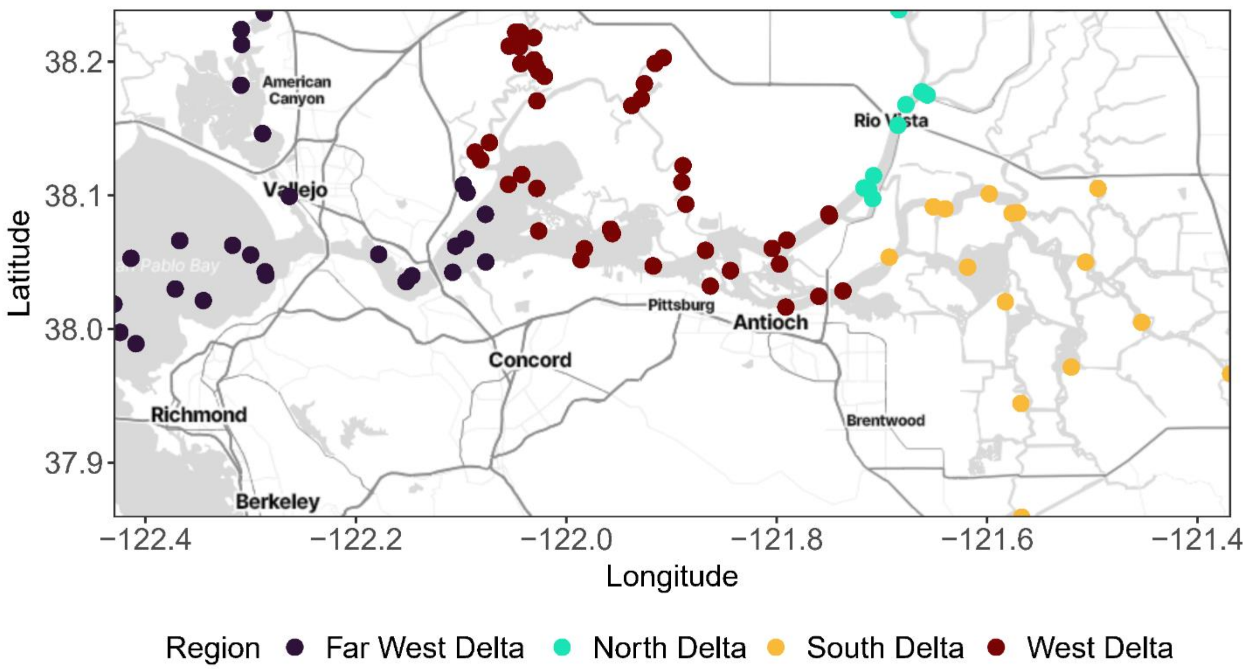

Figure 15. Location of the survey stations of the 20-mm Survey, San Francisco Bay Study Midwater Trawl Survey, and San Francisco Bay Study Otter Trawl Survey within the San Francisco Estuary separated by region. The color of each dot represents the Region where the station is located.

Table 5. Expected log-likelihood of models of year class strength dependent on different hydrological covariates estimated using Leave-One-Out cross validation. The expected difference of log-likelihoods between a given model and the model with the highest log-likelihood, as well as its standard error (SE).

Hydrological Covariate	**Expected Log-Likelihood**	**Expected difference with highest likelihood model**	**SE of difference**
Mean Monthly X2	309.03	N/A	N/A
Mean Monthly Outflow	307.58	1.45	3.19

The effect size of the model using mean outflow as its hydrological covariate shows that the probability of catching a YOY White Sturgeon has a strong correlation with mean outflow and spring, summer, and fall have a higher probability of catching a YOY White Sturgeon than winter

(Figure 16). Outflow has a bigger influence than seasons in determining the mean CPUE of YOY White Sturgeon. Based on the effect size, YOY White Sturgeon are more likely to be caught in surveys during Spring and Summer and more YOY White Sturgeon are likely to be caught per volume of water towed during months with a higher mean outflow.

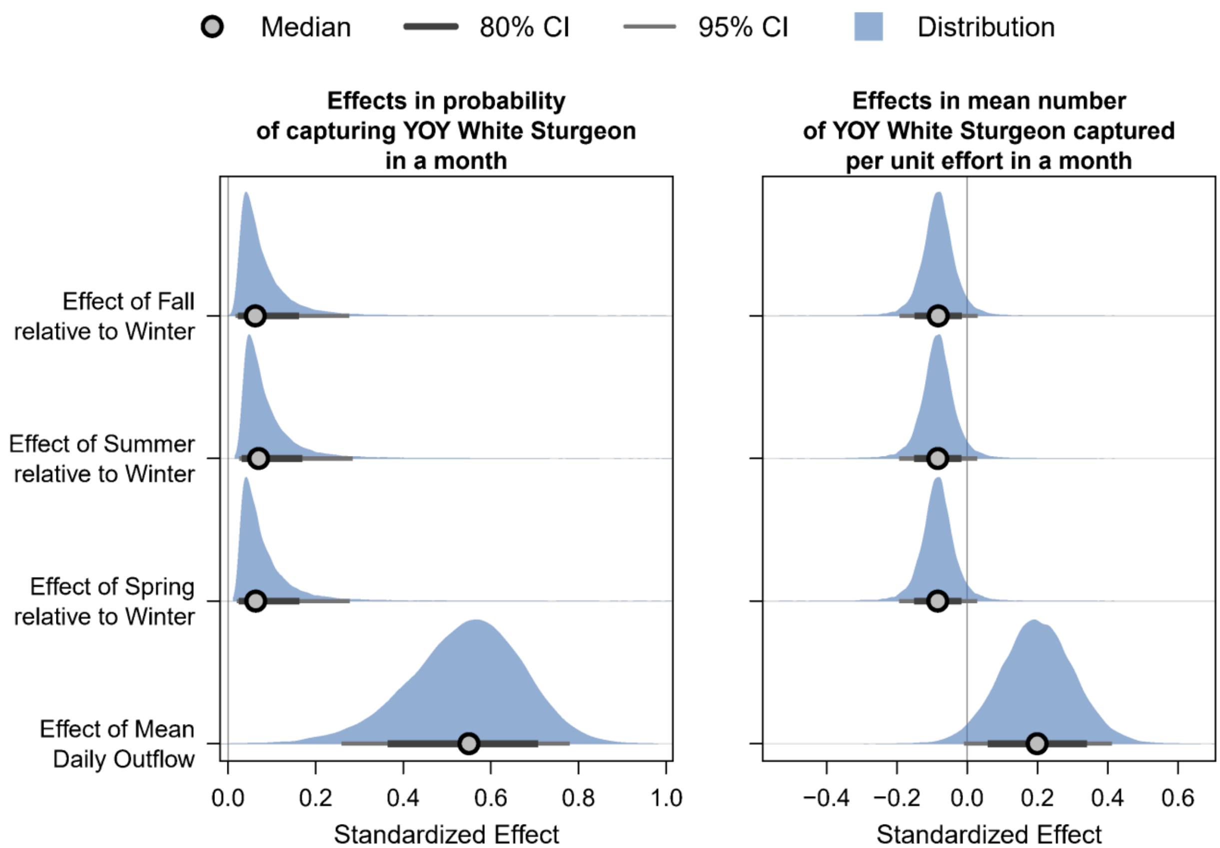

Figure 16. Effect size of the posterior distributions of the parameters of the model for the year class strength of White Sturgeon as a function of mean outflow with 80% and 95% confidence intervals (CI). The vertical line corresponds to an effect size of zero; therefore, there is no effect of the variable. The effect size of seasons uses Winter as a reference, which means the effect size of a given month is relative to Winter.

Based on the outflow model, we observed a higher probability of catching YOY White Sturgeon during surveys occurring during high outflows (Figure 17), particularly during wet water years. When looking at the probabilities by water year type, we observed an increasing trend in probability as water years become wetter (Figure 18).

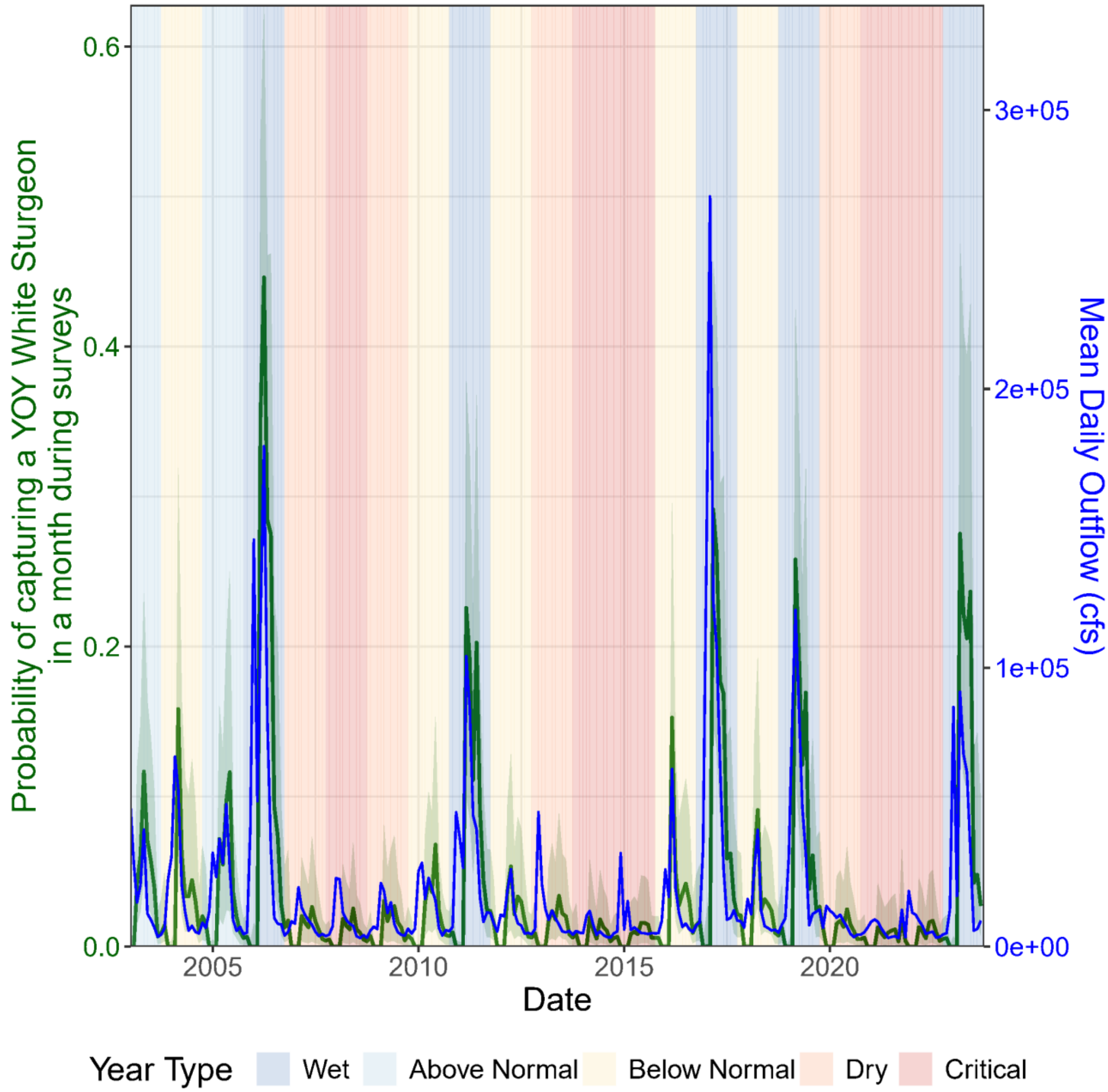

Figure 17. Green: Probability of catching a young-of-year (YOY) White Sturgeon during surveys per month from water years 2003-2023 based on the model which uses the mean outflow of each month as its hydrological covariate. Confidence intervals are at the 95%. Blue: Mean outflow for each month during water years 2003-2023. The background color of each water year corresponds to the water year type based on the Sacramento Valley Index.

When the mean daily outflow was allowed to vary throughout the historical ranges observed, an upward trend in the mean probability of catching a YOY White Sturgeon was observed (Figure 19). However, in Figure 19, the uncertainty of this probability increases at higher outflows, which can be caused by the trend of higher outflow observed during wetter water years (where the probability of capturing a YOY White Sturgeon increases). Nevertheless, the increase across outflow is apparent in spring.

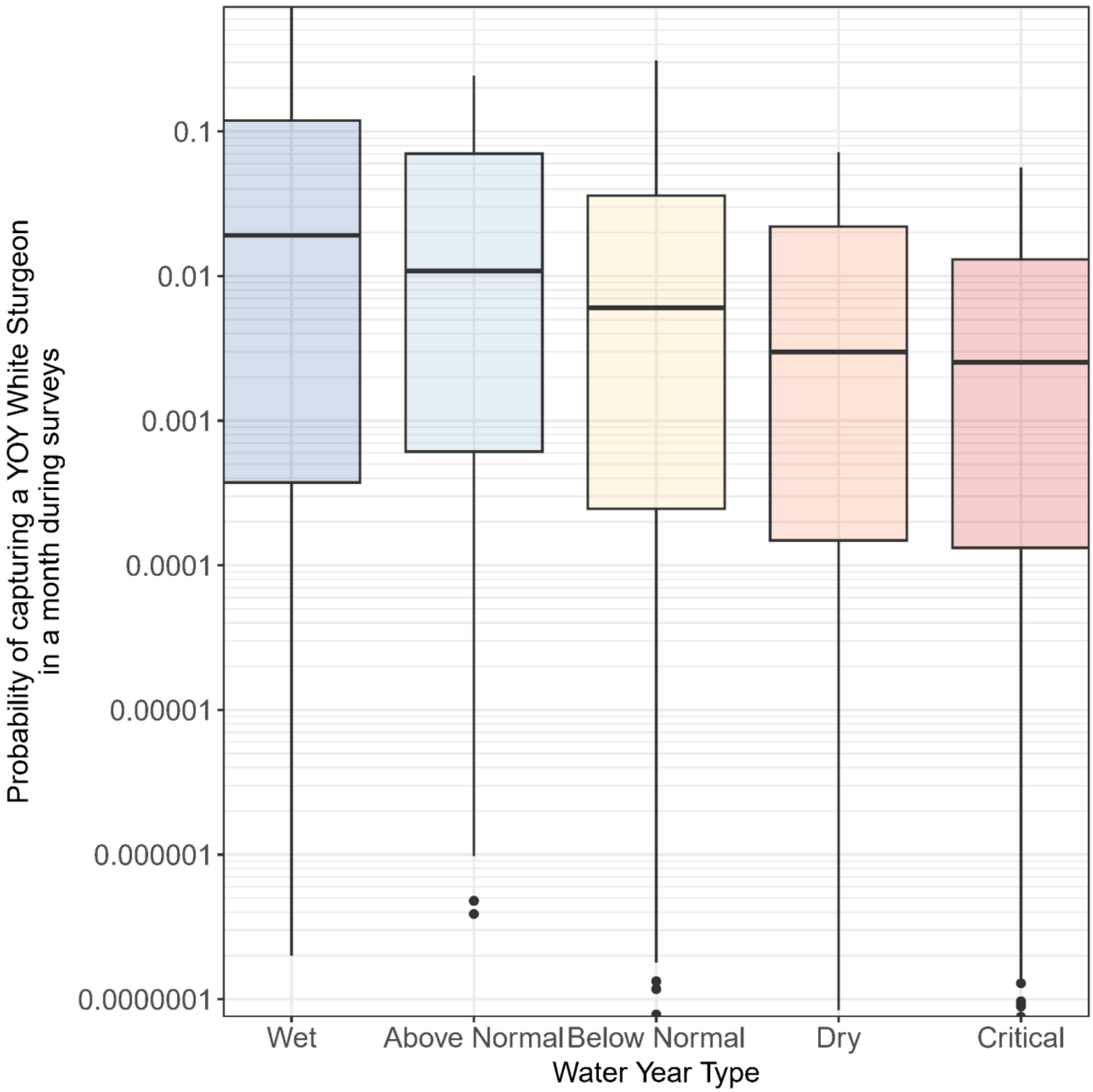

Figure 18. Boxplots of probability of catching a young-of-year (YOY) White Sturgeon during surveys from water years 2003-2023 based on the model which uses the mean outflow of each month as its hydrological covariate. Each data point is separated by water year type based on the Sacramento Valley Index.

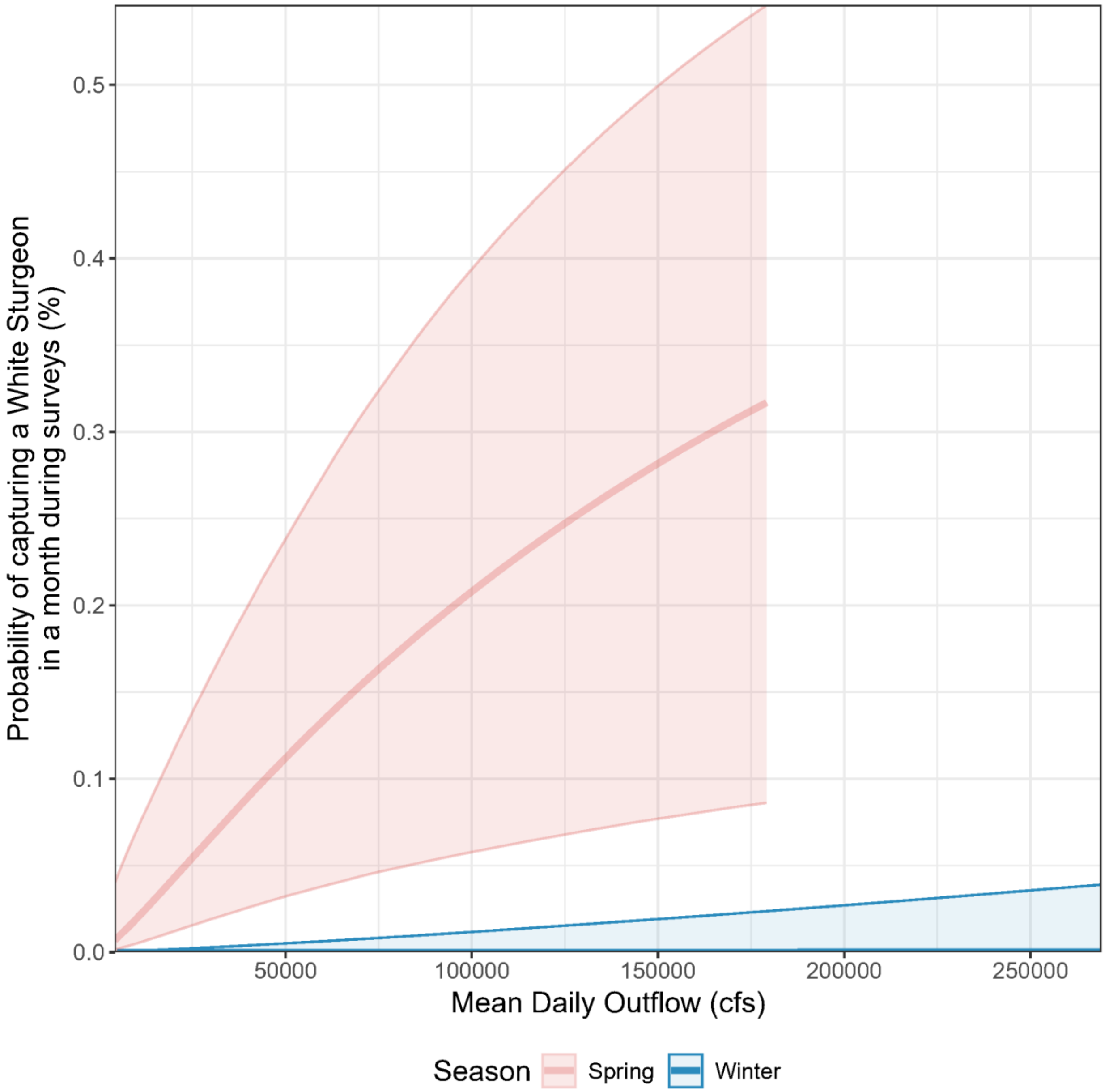

Figure 19. Model probability of catching a young-of-year (YOY) White Sturgeon during surveys as a function of the mean X2 over a calendar month within the observed range of mean outflow between calendar years 1981-2024. The presented confidence intervals are at a 95% level.

Using the model that includes the mean monthly outflow as its hydrological covariate, the changes in expected number of YOY White Sturgeon caught in surveys under the different proposed scenarios were evaluated. Scenario 9A_V2A shows a trend of increased expected number of YOY White Sturgeon caught in surveys relative to the baseline during all water year types (Figure 20), while Scenario ITP_Spring shows this trend only during wet and critical water years, with a decreased expected number of YOY White Sturgeon caught in other water year types (Figure 21). When looking at absolute numbers, a difference in the expected number of YOY White Sturgeon caught in surveys under the different surveys was not observed (Table 6). As evidenced in Figure 19, the impact of mean daily outflow during spring months on the probability of catching a White Sturgeon in surveys is uncertain. Reduction of this uncertainty may require surveys designed for White Sturgeon and a higher temporal resolution of the different modeled scenarios.

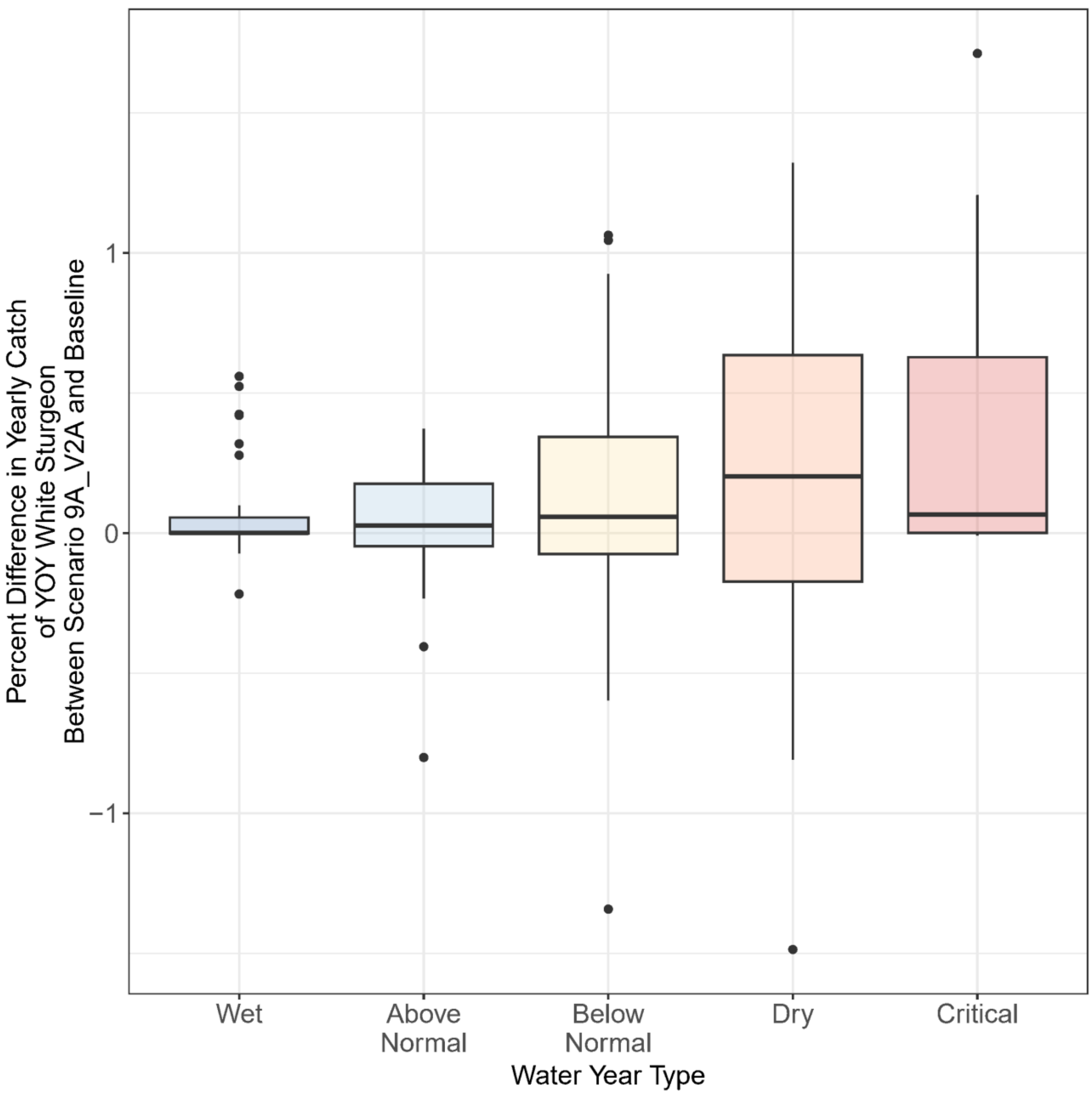

Figure 20. Percent difference in expected yearly number of young-of-year (YOY) White Sturgeon caught in surveys between Scenario 9A_V2A and Baseline. Each data point is separated by water year type based on the Sacramento Valley Index.

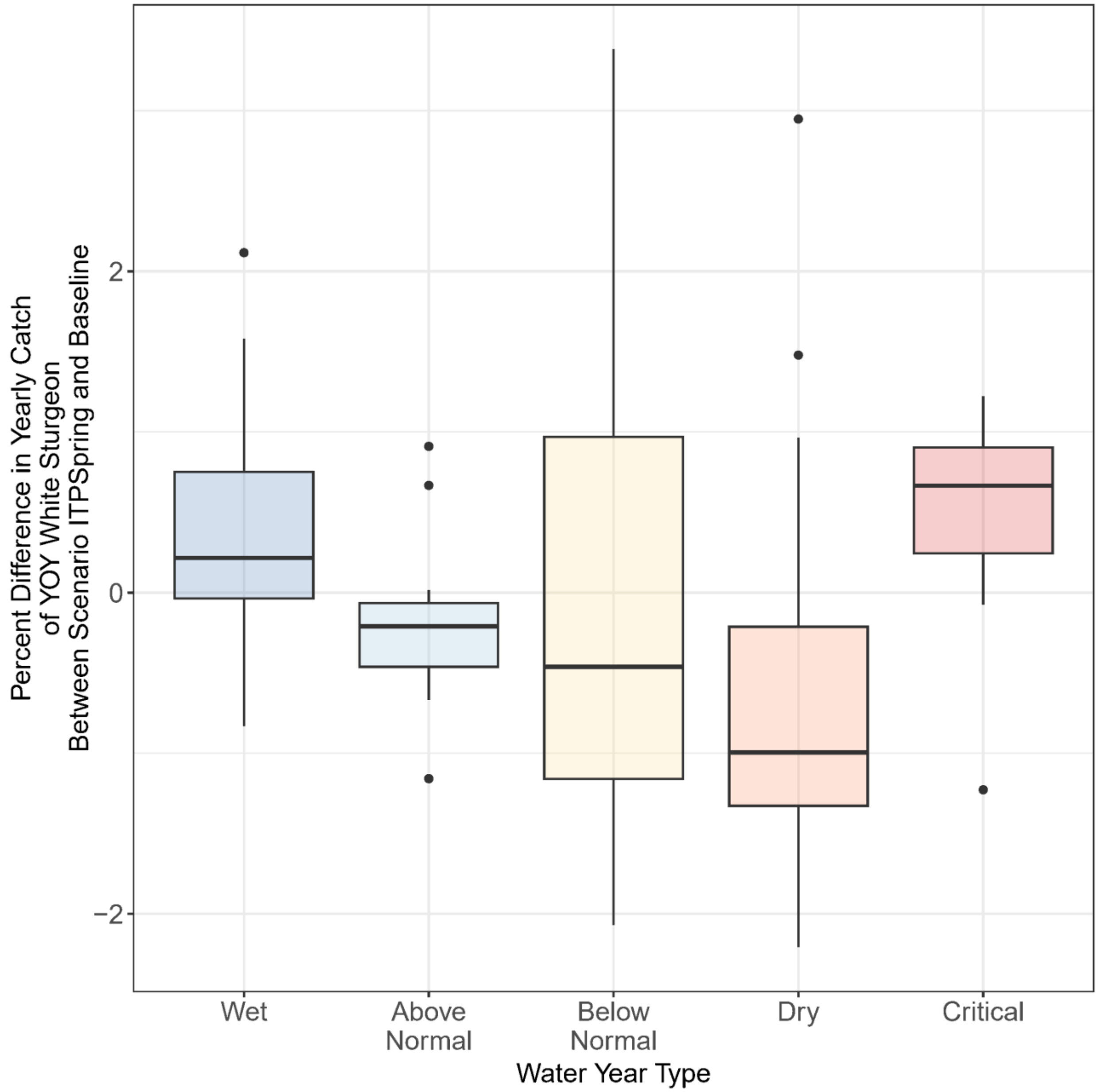

Figure 21. Percent difference in expected yearly number of young-of-year (YOY) White Sturgeon caught in surveys between Scenario ITP_Spring and Baseline. Each data point is separated by water year type based on the Sacramento Valley Index.

Table 6. Total yearly expected number of young-of-year (YOY) White Sturgeon caught in surveys under different scenarios.

Water Year	Baseline	9A_V2A	ITP_Spring
1922	8	8	8
1923	3	3	3
1924	1	1	1
1925	3	3	3
1926	2	2	2
1927	7	7	7
1928	7	7	7
1929	1	1	1
1930	2	2	2
1931	1	1	1
1932	2	2	2
1933	1	1	1
1934	1	1	1
1935	4	4	4
1936	4	4	4
1937	4	4	4
1938	16	16	16
1939	2	2	2
1940	8	8	8
1941	11	11	11
1942	7	7	7
1943	7	7	7
1944	2	2	2
1945	3	3	3
1946	3	3	3
1947	2	2	2
1948	4	4	4
1949	3	3	3
1950	2	2	2
1951	6	6	6
1952	12	12	12
1953	5	5	5
1954	5	5	5
1955	2	2	2
1956	6	6	6
1957	4	4	4
1958	13	13	13
1959	2	2	2

Water Year	Baseline	9A_V2A	ITP_Spring
1960	2	2	2
1961	2	2	2
1962	2	2	2
1963	8	8	8
1964	2	2	2
1965	5	5	5
1966	3	3	3
1967	11	11	11
1968	3	3	3
1969	11	11	11
1970	4	4	4
1971	6	6	6
1972	3	3	2
1973	5	5	5
1974	13	13	13
1975	8	8	8
1976	2	2	2
1977	1	1	1
1978	7	7	7
1979	3	3	3
1980	5	5	5
1981	2	2	2
1982	14	14	14
1983	30	30	30
1984	8	8	8
1985	3	3	3
1986	9	9	9
1987	2	2	2
1988	1	1	1
1989	4	4	4
1990	1	1	1
1991	2	2	2
1992	2	2	2
1993	7	7	7
1994	1	1	1
1995	19	19	19
1996	8	8	8
1997	3	3	3
1998	17	17	17
1999	7	7	7
2000	6	6	6

Water Year	Baseline	9A_V2A	ITP_Spring
2001	2	2	2
2002	2	2	2
2003	6	6	6
2004	5	5	5
2005	6	6	6
2006	42	42	42
2007	3	3	3
2008	1	1	1
2009	2	2	2
2010	3	3	3
2011	10	10	10
2012	4	4	4
2013	2	2	2
2014	1	1	1
2015	1	1	1
2016	12	12	12
2017	23	23	24
2018	4	4	4
2019	12	12	12
2020	2	2	2
2021	1	1	1

5.3. Effects of South Delta Export Operations on Salvage of White Sturgeon

White Sturgeon salvage data was collected at the export facilities, compiled and curated by CDFW, and then used in this analysis to evaluate the effects of south Delta export operations on salvage of White Sturgeon (Afentoulis et al, 2024). The dataset spans October 1, 1993 to May 14, 2024 and consists of daily number and fork length of White Sturgeon caught at the Skinner Fish Facility and the Tracy Fish Collection Facility. Following the threshold of 234 mm determined by the von Bertalanffy growth curve in Blackburn et al (2019), fork length measurements were used to separate salvage of YOY and non-YOY White Sturgeon. The number of YOY and non-YOY White Sturgeon captured in a single month were aggregated. The total sampled time at each salvage facility was also added as a monthly aggregation.

Two different sets of hydrological covariates were used to evaluate how changes in hydrology affect the salvage of White Sturgeon: combined Old and Middle River (OMR) net flow and total water exports combined with Vernalis Gage Discharge. OMR is a well-known predictor of fish entrainment in the Delta as it accounts for hydrodynamic pulls near the salvage facilities (Grimaldo et al. 2011). Total water exports and Vernalis Gage Discharge are two principle hydrological covariates contributing to the commonly used OMR Flow metric for salvage (Andrews et al. 2016). As such, these covariates were utilized to build the model that does not use OMR as its hydrological covariate.

5.3.1. Modeling salvage as a function of Old and Middle River net flow

OMR flow data were obtained from USGS gauges 11313405 (Old River at Bacon Island) and 11312676 (Middle River at Middle River), respectively, from 1993 through 2021. Approximately 25% of the days were missing observations for Old River (4.5%), Middle River (17.8%), or both (2.6%). Linear mixed effects regression were used to predict either river when data was available for the other. For both models, a random intercept of month within water year was included. The Old River included Middle River as a predictor whereas the Middle River model included Old River and the daily change in Old River as predictors. The Old River model had an R^2 of 0.988 and the Middle River model had an R^2 of 0.987; the correlation between observed and predicted flows were 0.994 for both models. OMR was aggregated on a monthly scale using two metrics: mean OMR and max OMR.

Preliminary data analyses showed that salvage of YOY White Sturgeon occurs in higher numbers in wetter water years (Figure 22). To account for water year type, the Sacramento Valley Index (SVI) of the water year was included as an additional hydrological covariate.

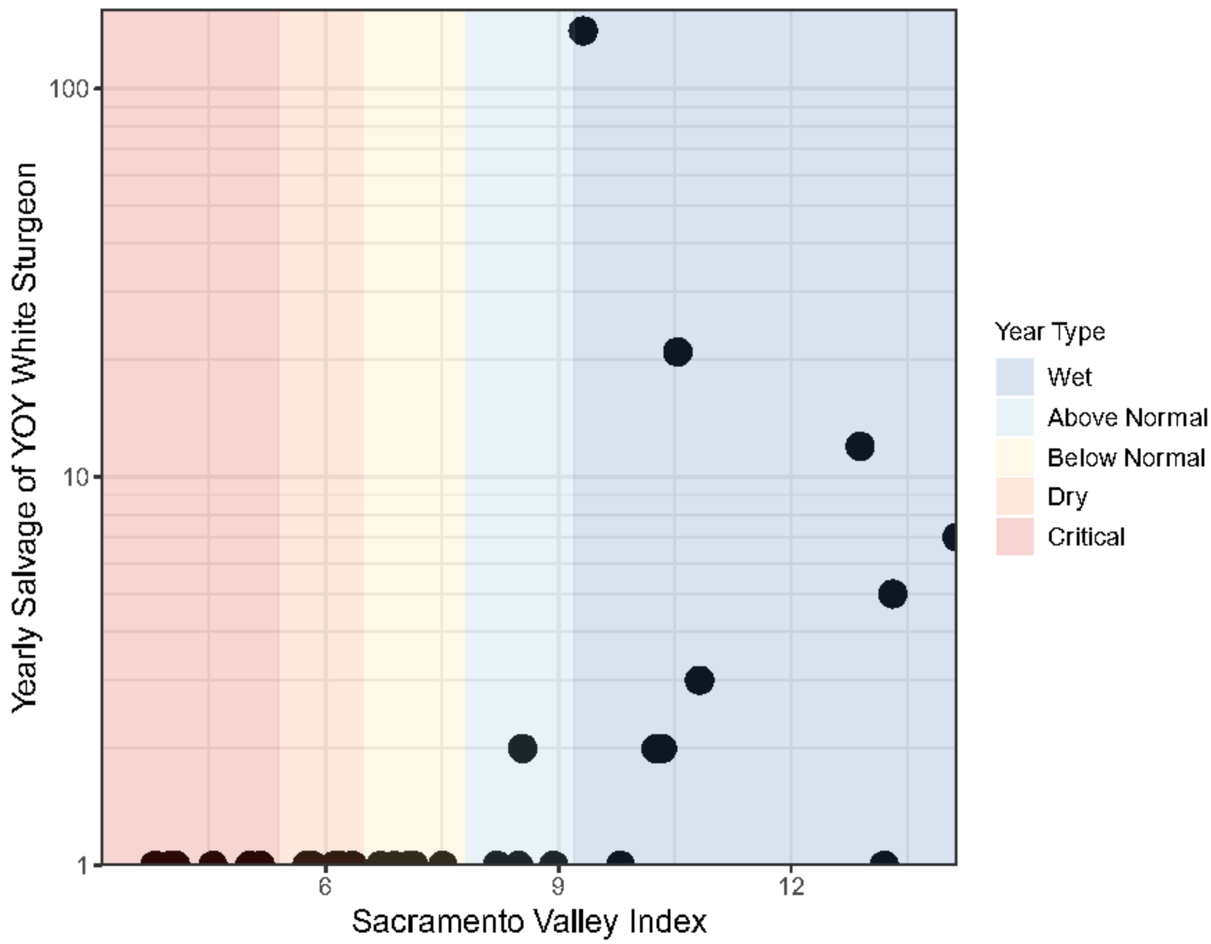

Figure 22. Scatter plot of yearly salvage of young-of-year (YOY) White Sturgeon depending on Sacramento Valley Index. Data ranges from water years 1993 to 2023, with each colored region representing different water year types based on the Sacramento Valley Index.

The relationship between monthly salvage of both YOY and non-YOY White Sturgeon and hydrological covariates using multivariable GLMMs where the number of YOY (S_{YOY}) and non-YOY ($S_{Non-YOY}$) salvaged are the response variables (Kettermann and Fartmann 2023). Because salvage numbers are counts of total fish, the regular assumption is that salvage follows a Poisson distribution. However, salvage of White Sturgeon is rare, which implies that many of the months in the processed dataset do not observe any salvage. Similar to the models for the year class strength analyses in Section 5.2, the issue of excess zeros in the distribution of the data was overcome using a hurdle Poisson distribution with hurdles $\eta_{YOY}, \eta_{Non-YOY}$.

For both classes of White Sturgeon, an aggregation of OMR, either the monthly mean OMR or the monthly maximum OMR, was included. For salvage of YOY White Sturgeon, current year's Sacramento Valley Index (SVI) was included as a predictor. Most of the non-YOY White Sturgeon that were captured were no older than 2 years old (Figure 23). To account for possible effects of the Sacramento Valley Index during the years these juvenile White Sturgeon were YOYs, the Sacramento Valley Index of the previous year (SVI_{-1}) and two years ago (SVI_{-2}) were included. Brood year and the salvage facility were included as random effects. In addition, total time sampling (T) was included as an offset. Offsets provide a proxy for effort and provide more accurate estimates of the parameters in a Poisson distribution (Gagnon et al. 2008).

In equation form, the model for salvage has the following structure:

Equation 7

$$
\begin{aligned}
S_{YOY} &\sim Poisson(\lambda_{YOY}) \\
\log(\lambda_{YOY}) &\sim \beta_{YOY,0} + \beta_{YOY,OMR}OMR + \beta_{YOY,SVI}SVI + \beta_{YOY,season} + \\
&\quad z_{YOY,BY} + z_{YOY,Facility} + \log(T) \\
\operatorname{logit}(\eta_{YOY}) &\sim \alpha_{YOY,0} + \alpha_{YOY,OMR}OMR + \alpha_{YOY,SVI}SVI + \alpha_{YOY,season} + \\
&\quad z_{YOY,BY} + z_{YOY,Facility} + \log(T) \\
S_{Non-YOY} &\sim Poisson(\lambda_{Non-YOY}) \\
\log(\lambda_{Non-YOY}) &\sim \beta_{Non-YOY,0} + \beta_{Non-YOY,OMR}OMR + \beta_{Non-YOY,SVI_{-1}}SVI_{-1} + \beta_{Non-YOY,SVI_{-2}}SVI_{-2} + \\
&\quad \beta_{Non-YOY,season} + z_{Non-YOY,BY} + z_{Non-YOY,Facility} + \log(T) \\
\operatorname{logit}(\eta_{Non-YOY}) &\sim \alpha_{Non-YOY,0} + \alpha_{Non-YOY,OMR}OMR + \alpha_{Non-YOY,SVI_{-1}}SVI_{-1} + \alpha_{Non-YOY,SVI_{-2}}SVI_{-2} + \\
&\quad \alpha_{Non-YOY,season} + z_{Non-YOY,BY} + z_{Non-YOY,Facility} + \log(T) \\
z_{i,j} &\sim Normal(0, \sigma_{i,j})
\end{aligned}
$$

For $i = YOY, Non - YOY$ and $j = BY, Facility$. The models presented in this section were fit using Bayesian regression with the brms package in R (Burkner et al. 2017). Bayesian modeling is a powerful method to quantify different sources of uncertainty in the correlations between a response variable and its possible covariates. To determine which aggregation of OMR produces a better performing model, the complexity of this model makes LOO unreliable (Vehtari et al. 2016). To overcome this issue, salvage models were compared using the Bayesian R^2 introduced in Gelman et al. (2019). Both mean and max OMR have a similar predictive performance for number of YOYs salvaged in a month, while the mean OMR tends to produce higher R^2 values more frequently for non-YOYs (Figure 24). This is evidence that, although both models have a comparable performance, the mean OMR model performs slightly better.

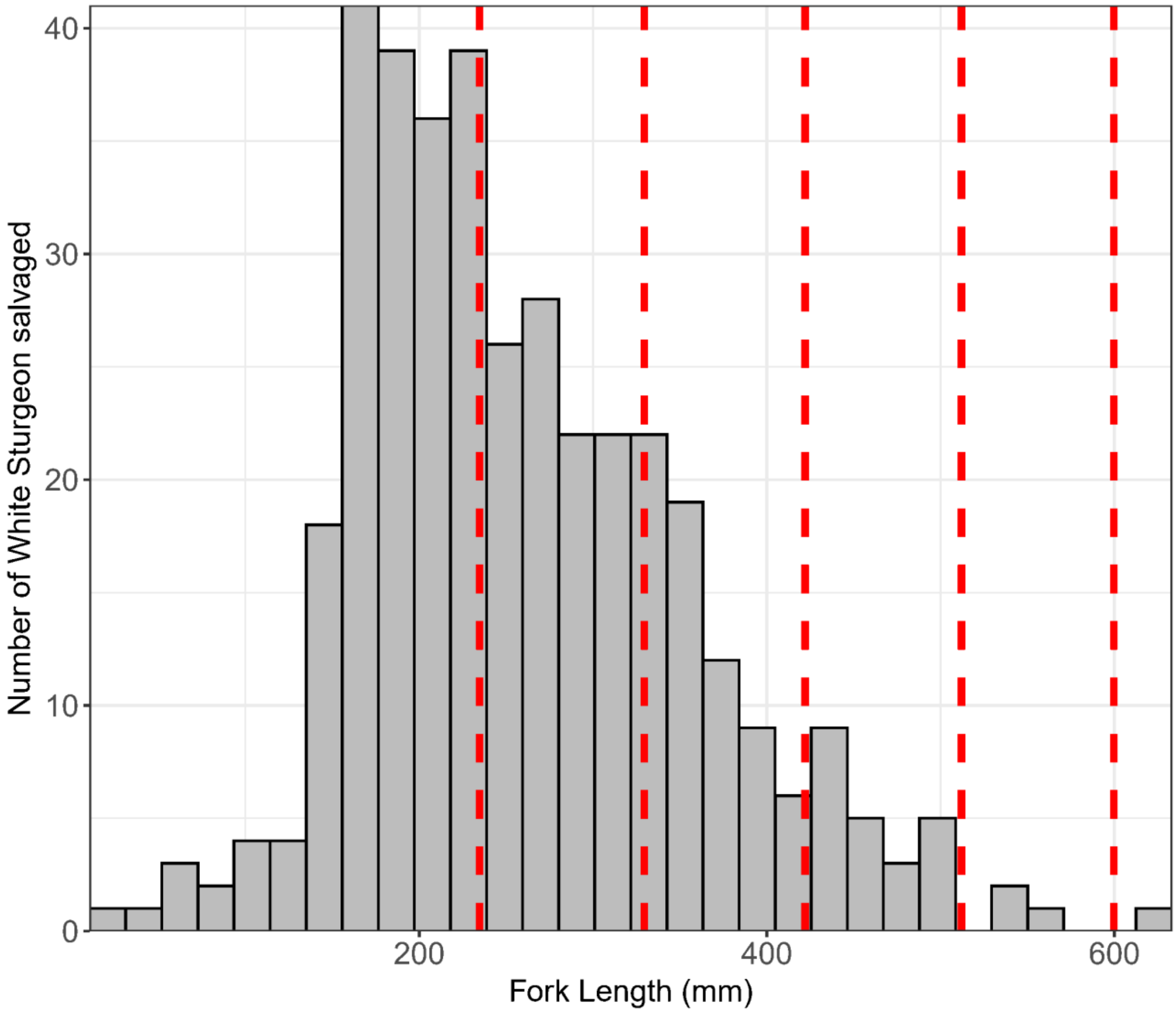

Figure 23. Distribution of fork lengths of White Sturgeon captured in salvage facilities. The red dashed lines represent the length at age upper thresholds for age 0, 1, 2, 3, and 4 years of age for White Sturgeon based on the von Bertalanffy growth curve of Blackburn et al. (2019).

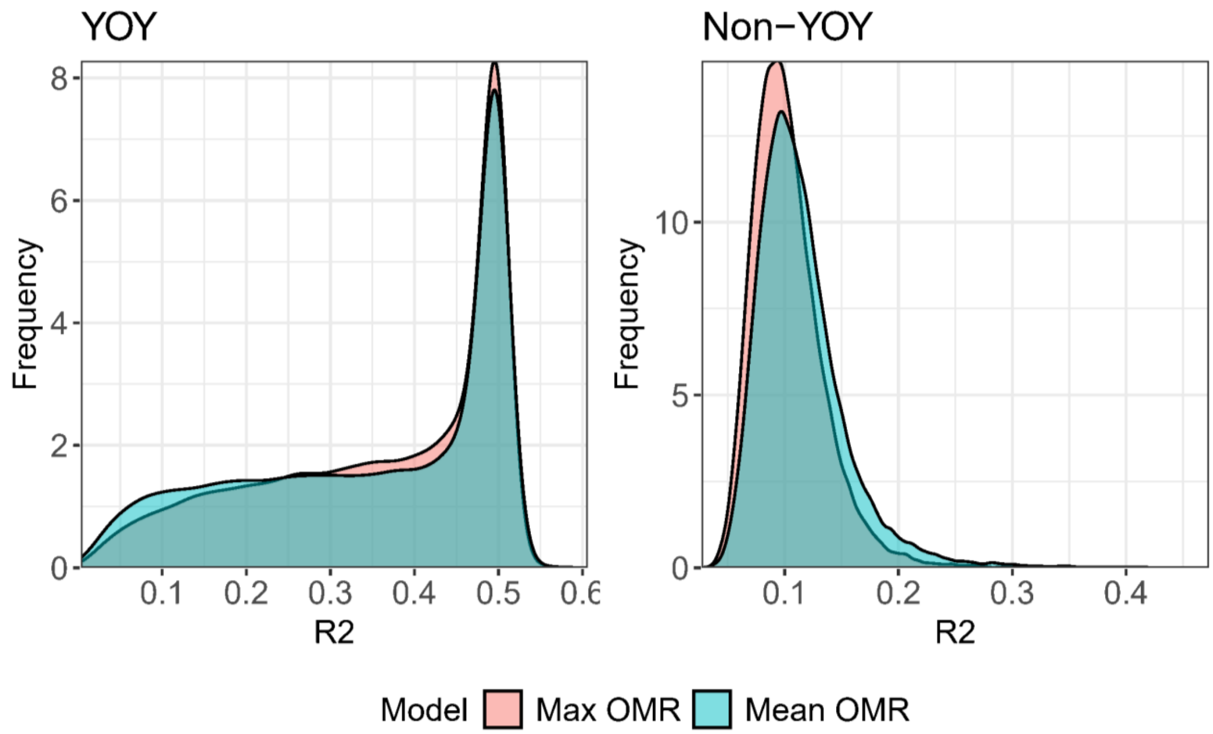

Figure 24. Distribution of Bayesian R2 values for models of number of salvage of young-of-year (YOY; left) and non-YOY (right) White Sturgeon using either max or mean Old and Middle River (OMR) flow as hydrological covariates.

When looking at the mean OMR model, the probability of capturing YOY White Sturgeon in salvage is correlated with the current year's Sacramento Valley Index. (Figure 25). The season that YOY White Sturgeon are captured has a small effect on the probability of capturing White Sturgeon in a particular month. When observing the total number of YOY White Sturgeon salvaged, there is a strong negative correlation with mean OMR. This is interpreted to indicate that it is more likely to have a higher number of White Sturgeon in salvage when the mean OMR of the month is lower. When considering non-YOY White Sturgeon, a lower mean OMR was observed to lead to a higher probability of non-YOY White Sturgeon caught during salvage (Figure 26). In addition, non-YOY White Sturgeon were more likely to be caught following years with higher Sacramento Valley Index, and this likelihood decreases during summer. Furthermore, the effect size shows the mean number of non-YOY White Sturgeon caught in salvage during a month does not depend on any of the factors considered.

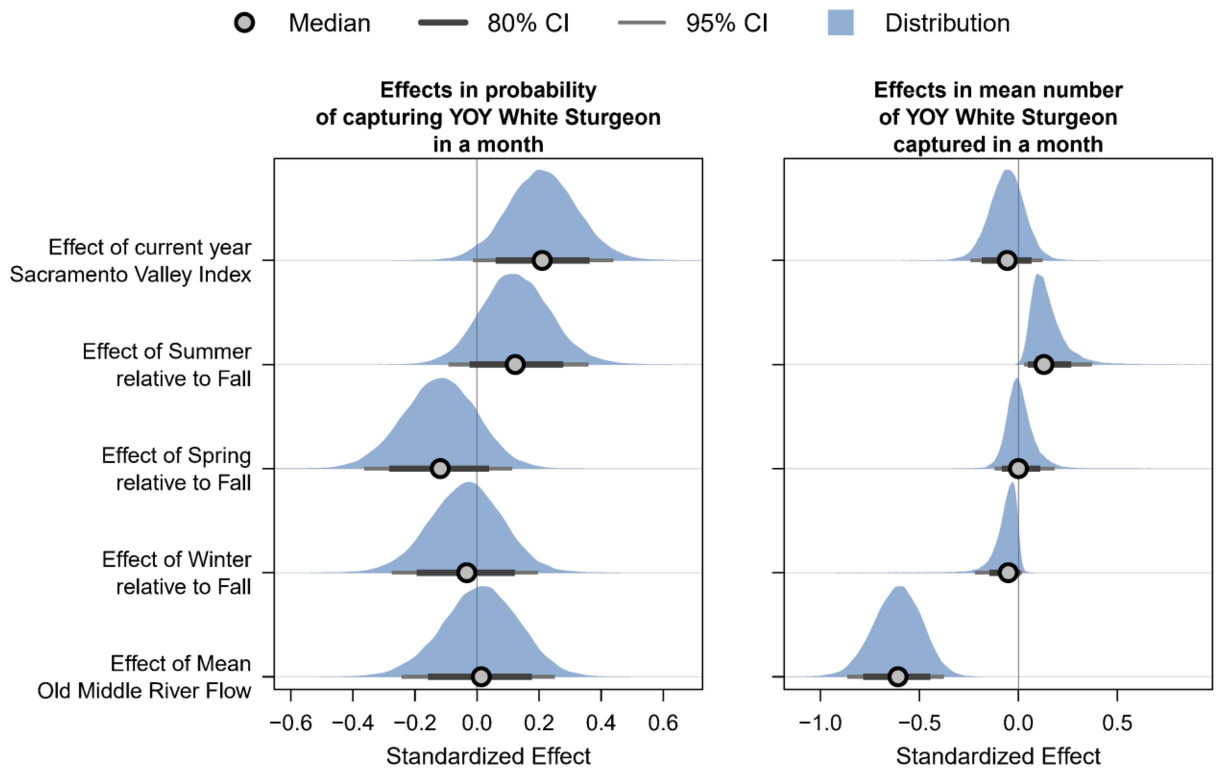

Figure 25. Effect size of the posterior distributions of the parameters of the model for the number of young-of-year (YOY) White Sturgeon salvaged in a month as a function of mean Old and Middle River (OMR) flow with 80% and 95% confidence intervals (CI). The vertical line corresponds to an effect size of zero, which indicates there is no effect of the variable. The effect size of seasons uses fall as a reference, which indicates the effect size of a given month is relative to fall.

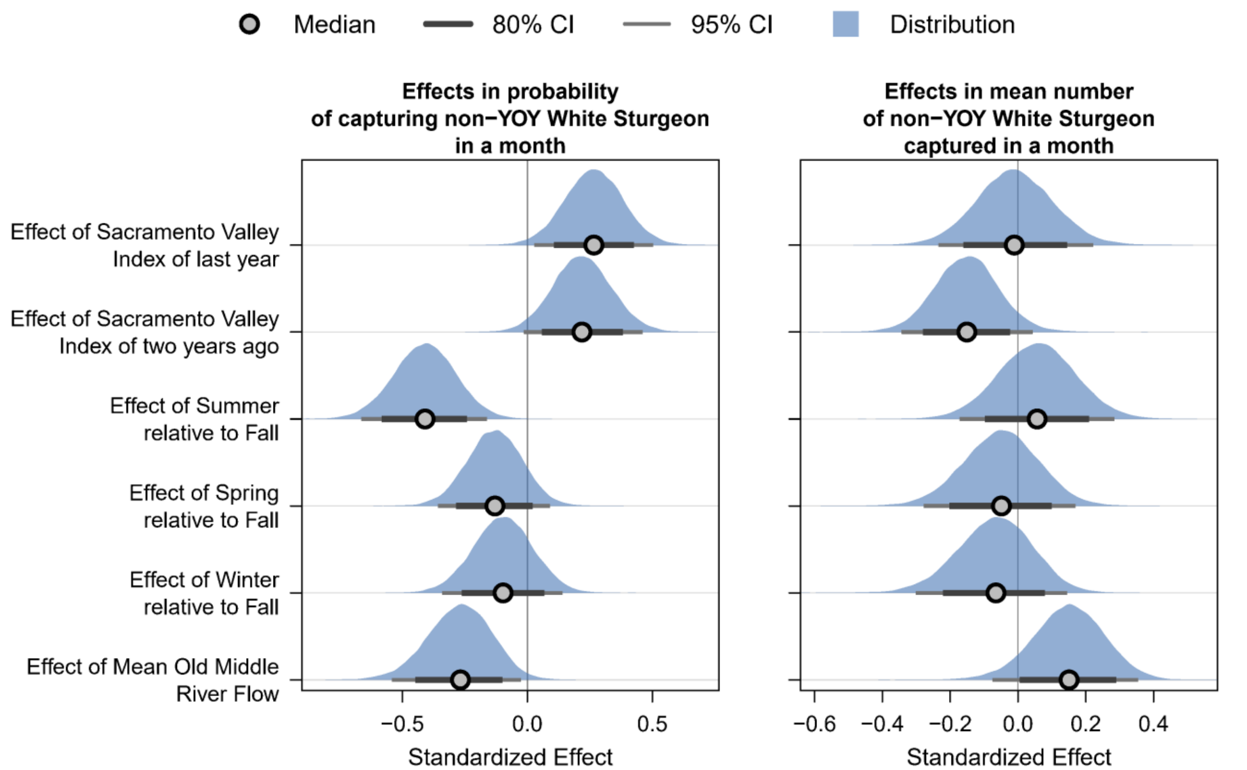

Figure 26. Effect size of the posterior distributions of the parameters of the model for the number of non-young-of-year (YOY) White Sturgeon salvaged in a month as a function of mean Old and Middle River (OMR) flow with its 80 and 95% confidence intervals (CI). The vertical line corresponds to an effect size of 0, i.e. there is no effect of the variable. The effect size of seasons uses fall as a reference, which means the effect size of a given month is relative to fall.

When considering the trends of modeled probability from water years from 2003-2023, YOY White Sturgeon are generally more likely to be captured during wet years, especially following a peak of high mean OMR flows (Figure 27). This trend is not as clear when observing non-YOY White Sturgeon, in which the highest points of probability for capturing non-YOY White Sturgeon in salvage in a given month occur in years following a wet year and only in some cases (Figure 28). Furthermore, wet years are generally the years where the probability of catching White Sturgeon in salvage is higher for both YOY White Sturgeon (Figure 29) and non-YOY White Sturgeon (Figure 30).

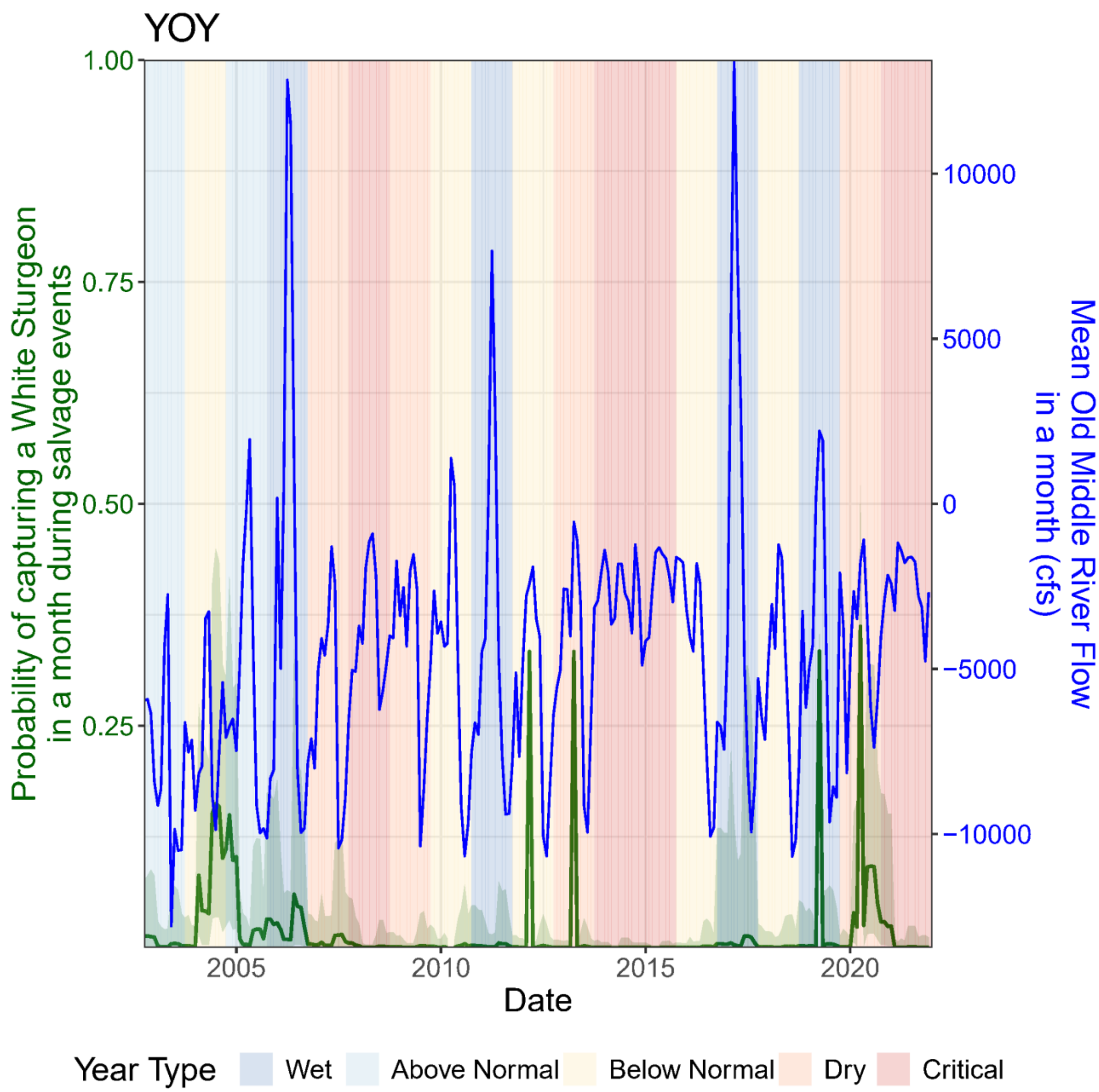

Figure 27. Green: Probability of capturing a young-of-year (YOY) White Sturgeon during salvage per month from water years 2003-2023 based on the model which uses the mean Old and Middle River (OMR) flow of each month as its hydrological covariate. Confidence intervals are at the 95%. Blue: Mean OMR flow for each month during water years 2003-2023. The background color of each water year corresponds to the water year type based on the Sacramento Valley Index.

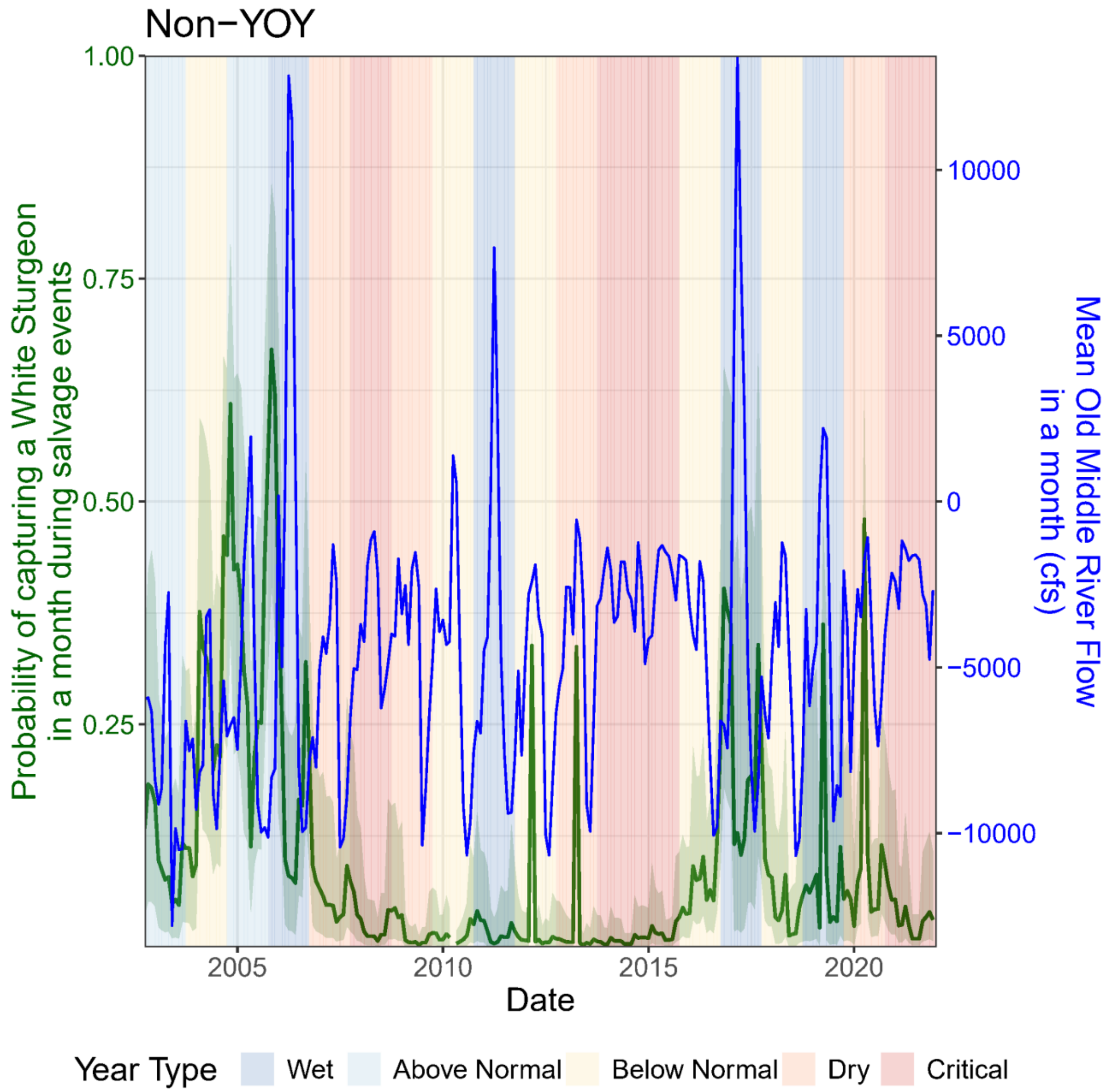

Figure 28. Green: Probability of capturing a non-young-of-year (YOY) White Sturgeon during salvage per month from water years 2003-2023 based on the model which uses the mean Old and Middle River (OMR) flow of each month as its hydrological covariate. Confidence intervals are at the 95%. Blue: Mean OMR for each month during water years 2003-2023. The background color of each water year corresponds to the water year type based on the Sacramento Valley Index.

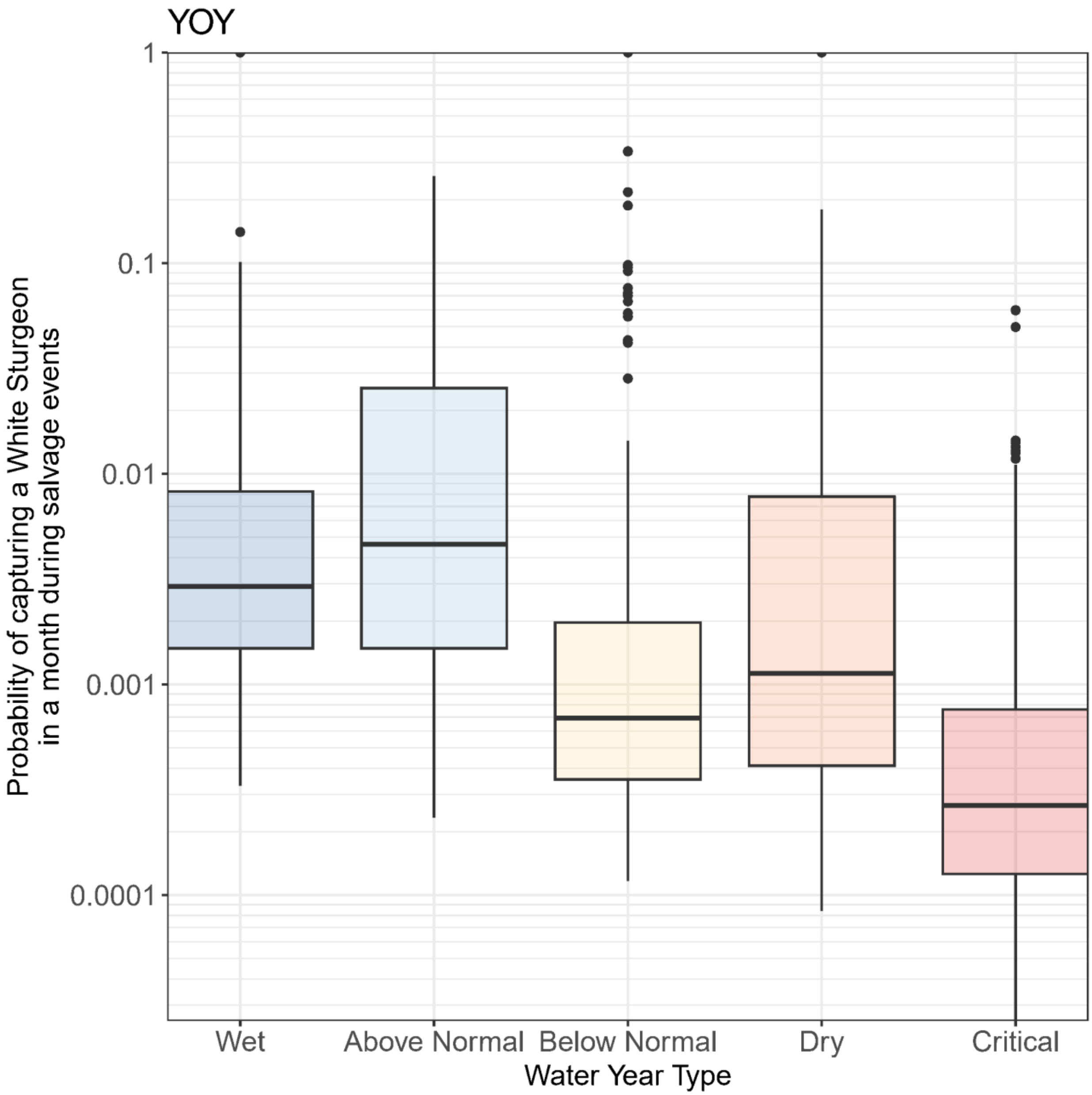

Figure 29. Boxplots of probabilities of capturing a young-of-year (YOY) White Sturgeon in salvage per month from water years 2003-2023 based on the model which uses the mean Old and Middle River (OMR) of each month as its hydrological covariate. Each data point is separated by water year type based on the Sacramento Valley Index.

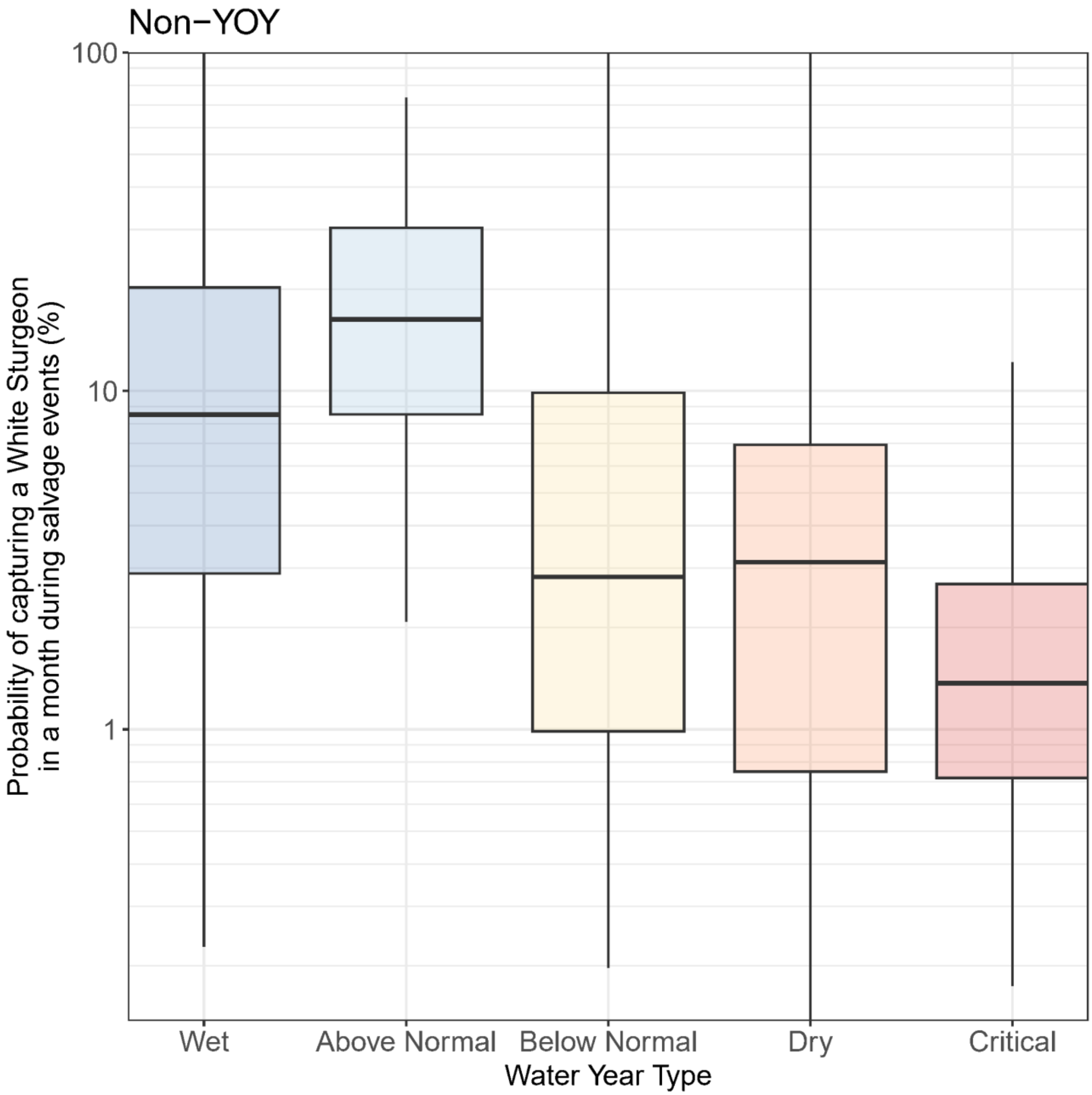

Figure 30. Boxplots of probabilities of capturing a non-young-of-year (YOY) White Sturgeon in salvage per month from water years 2003-2023 based on the model which uses the mean Old and Middle River (OMR) flow of each month as its hydrological covariate. Each data point is separated by water year type based on the Sacramento Valley Index.

Due to the higher probability of capturing a White Sturgeon in salvage during wet years, the trend of modeled probability through the range of historically observed Sacramento Valley Indices was explored. The model suggests that the probability of catching both YOY and non-YOY White Sturgeon in salvage increases exponentially as the Sacramento Valley Index increases (Figure 31). More specifically, the probability of salvage increases by 12-fold from its minimum value to maximum value for YOY White Sturgeon (Table 7) and by 3-fold from its minimum to maximum values for non-YOY White Sturgeon (Table 8). In addition, as suggested by the effect size of the model (Figure 25 and Figure 26), there is a weak increase in probability of catching non-YOY White Sturgeon in salvage for smaller mean OMR flows, and OMR does not affect the probability of catching YOY White Sturgeon.

When observing the probability of finding a non-YOY White Sturgeon in salvage in a month, as it varies through both Sacramento Valley Indices of 1 and 2 years ago, this probability changes in a similar way for both lags, and the changes in probabilities due to mean OMR are small (Figure 32).

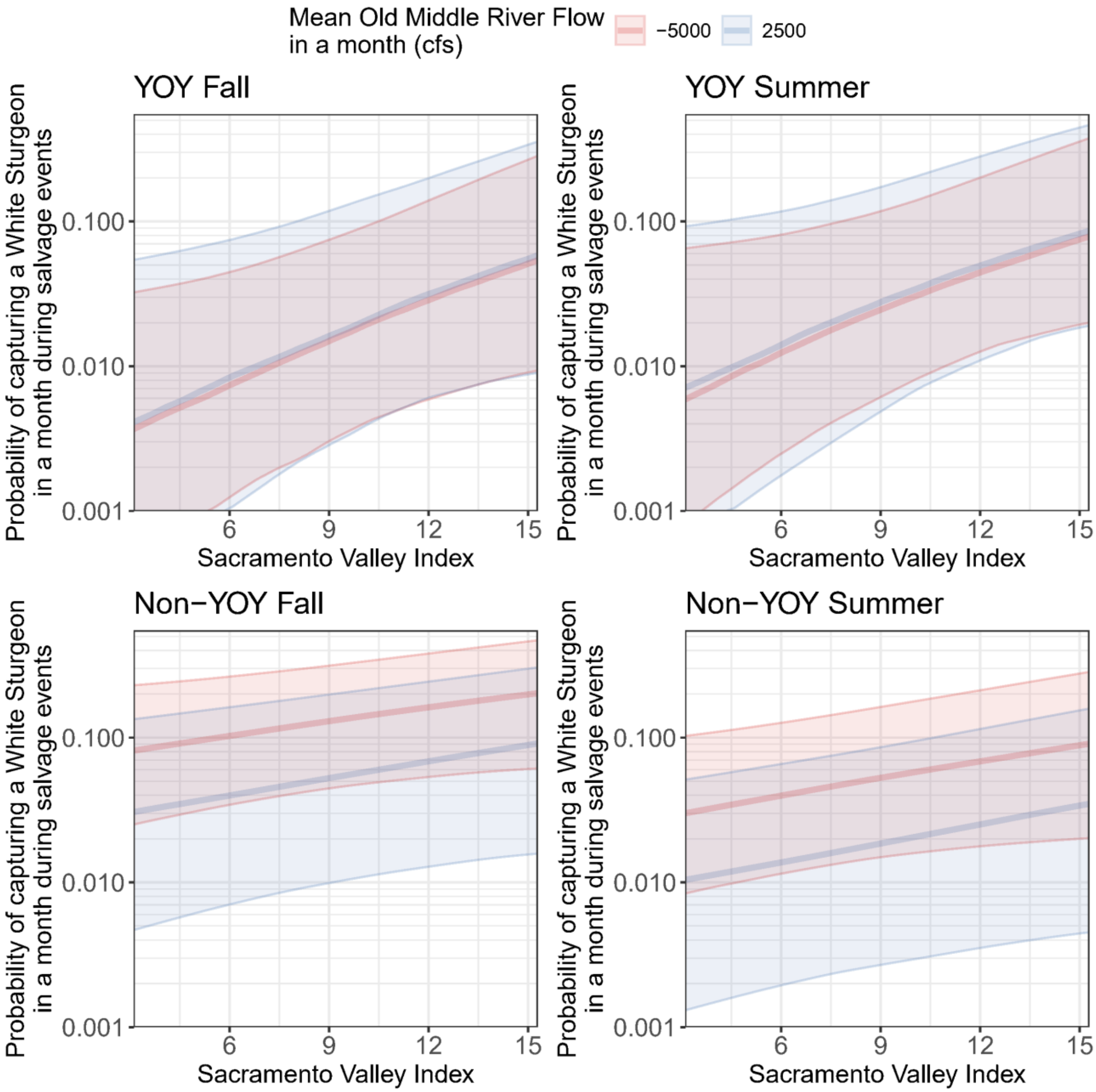

Figure 31. Probability of capturing either a young-of-year (YOY) White Sturgeon (top) or non-YOY White Sturgeon (bottom) White Sturgeon in a month during salvage events as a function of Sacramento Valley Index for a mean Old and Middle River (OMR) flow of -5,000 cfs and 2500 cfs during fall (left) and summer (right). Confidence intervals are at 95%.

Table 7. Minimum and maximum median probabilities of salvage of YOY White Sturgeon in a month separated by season estimated with the model that uses mean OMR and Sacramento Valley Index as its hydrological covariates.

Season	Minimum Probability of Salvage	Maximum Probability of Salvage
Summer	0.0075	0.079
Fall	0.0039	0.049

Table 8. Minimum and maximum median probabilities of salvage of non-YOY White Sturgeon in a month separated by season estimated with the model that uses mean OMR and Sacramento Valley Index as its hydrological covariates.

Season	Minimum Probability of Salvage	Maximum Probability of Salvage
Summer	0.026	0.077
Fall	0.067	0.17

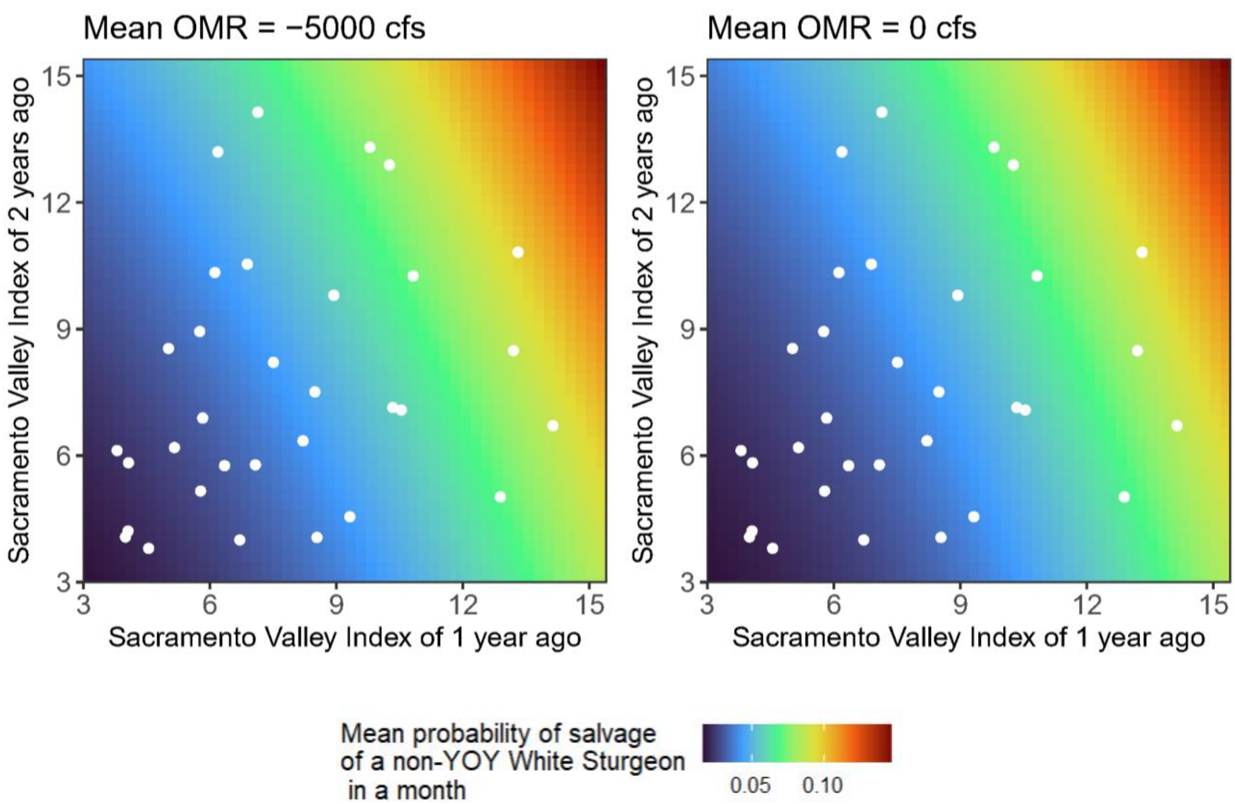

Figure 32. Mean probability of salvage of a non-young-of-year (YOY) White Sturgeon in a month as a function of both Sacramento Valley Index of 1 and 2 years ago for a mean monthly Old and

Middle River (OMR) flow of -5,000 (left) and 0 (right) cfs. White points represent observed lagged Sacramento Valley Indices during calendar years 1993-2024.

Utilizing the model with mean OMR as a hydrological covariate, the changes in expected number of White Sturgeon caught in salvage were evaluated under the different proposed Project operational scenarios. Scenario 9A_V2A shows a trend of increased expected number of YOY White Sturgeon caught in salvage relative to the baseline during above normal, below normal, and dry years (Figure 33), while scenario ITP_Spring shows a decreasing trend in expected number of YOY White Sturgeon caught in salvage relative to the baseline during above normal and below normal water years (Figure 34). A difference in the expected number of YOY White Sturgeon caught in each survey was not observed (Table 9). Both operational scenarios present a decreasing trend in the number of expected non-YOY White Sturgeon caught in salvage (Figure 35 and Figure 36) but no changes in the absolute number of expected non-YOY White Sturgeon caught in salvage (Table 10). Salvage may have a higher impact on White Sturgeon with a fork length smaller than 50 mm, which are not usually recorded. Recording the detections of these individuals in salvage may help in decreasing the uncertainty of this model and allow the use of a hydrological covariate with a higher temporal resolution available in these operational scenarios such as daily OMR.

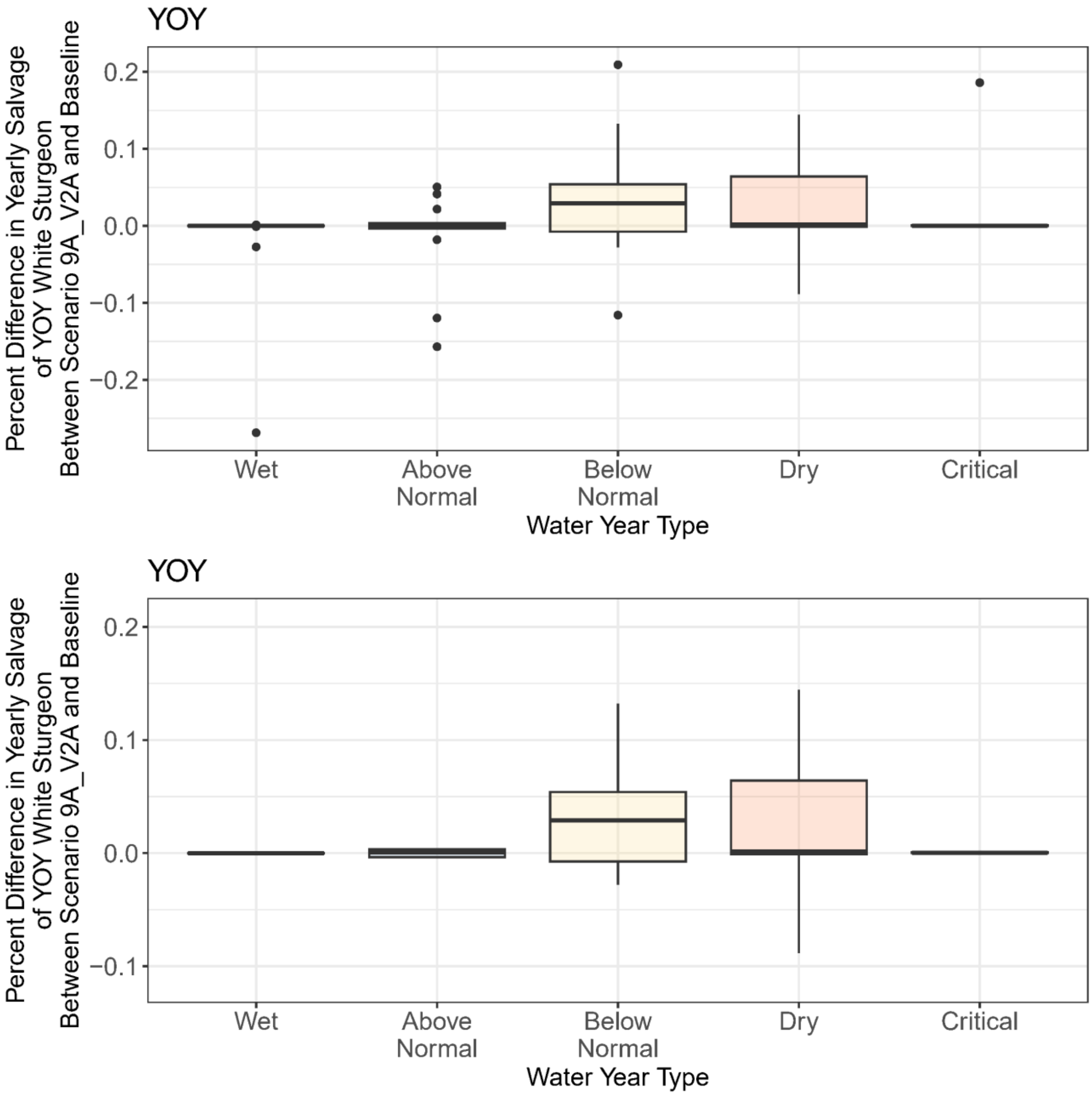

Figure 33. Percent difference in yearly number young-of-year (YOY) White Sturgeon caught in salvage between the Project operational scenario 9A_V2A and Baseline. Top panel represents the distribution of all water years. Bottom panel represents the distribution of water years within 1.5 times the interquartile range of all water years. Each data point is separated by water year type based on the Sacramento Valley Index.

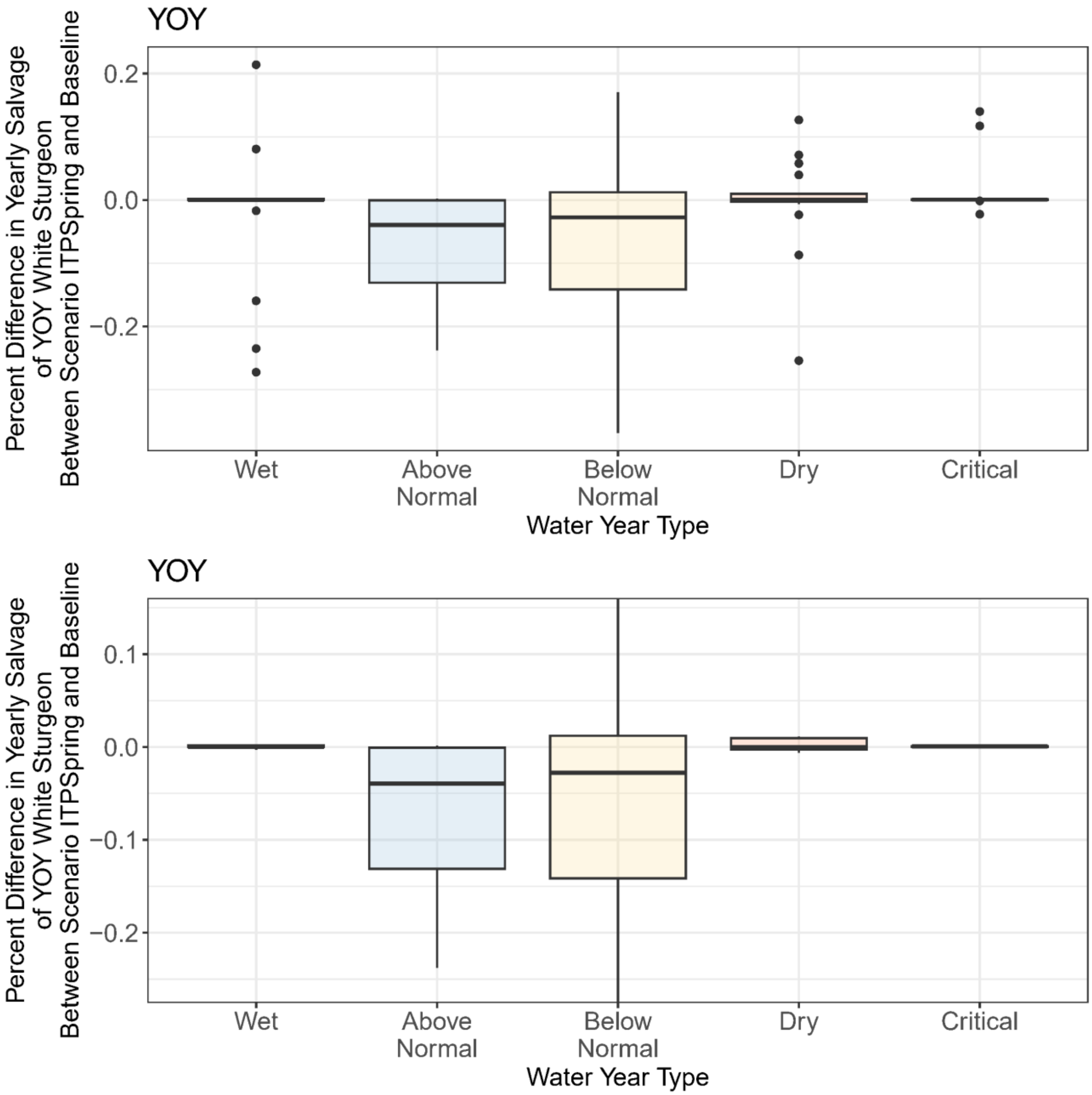

Figure 34. Percent difference in yearly number young-of-year (YOY) White Sturgeon caught in salvage between the Project operational scenario ITP_Spring and Baseline. Top panel represents the distribution of all water years. Bottom panel represents the distribution of water years within 1.5 times the interquartile range of all water years. Each data point is separated by water year type based on the Sacramento Valley Index.

Table 9. Total yearly expected number of young-of-year (YOY) White Sturgeon caught in salvage under different scenarios.

Water Year	Baseline	9A_V2A	ITP_Spring
1922	0	0	0
1923	1	1	1
1924	1	1	1
1925	1	1	1
1926	0	0	0
1927	1	1	1
1928	1	1	1
1929	1	1	1
1930	1	1	1
1931	0	0	0
1932	0	0	0
1933	0	0	0
1934	0	0	0
1935	0	0	0
1936	0	0	0
1937	0	0	0
1938	0	0	0
1939	1	1	1
1940	0	0	0
1941	0	0	0
1942	1	1	1
1943	0	0	0
1944	1	1	1
1945	1	1	1
1946	1	1	1
1947	0	0	0
1948	0	0	0
1949	0	0	0
1950	1	1	1
1951	0	0	0
1952	0	0	0
1953	0	0	0
1954	0	0	0

Water Year	Baseline	9A_V2A	ITP_Spring
1955	0	0	0
1956	0	0	0
1957	0	0	0
1958	0	0	0
1959	0	0	0
1960	1	1	1
1961	1	1	1
1962	0	0	0
1963	0	0	0
1964	1	1	1
1965	0	0	0
1966	0	0	0
1967	0	0	0
1968	0	0	0
1969	0	0	0
1970	0	0	0
1971	0	0	0
1972	1	1	1
1973	0	0	0
1974	0	0	0
1975	1	1	1
1976	1	1	1
1977	0	0	0
1978	0	0	0
1979	0	1	1
1980	0	0	0
1981	0	0	0
1982	0	0	0
1983	0	0	0
1984	0	0	0
1985	0	0	0
1986	0	0	0
1987	1	1	1
1988	1	1	1
1989	1	1	1

Water Year	Baseline	9A_V2A	ITP_Spring
1990	0	0	0
1991	1	1	1
1992	0	0	0
1993	1	1	1
1994	0	0	0
1995	9	9	9
1996	1	1	1
1997	0	0	0
1998	15	15	15
1999	0	0	0
2000	0	0	0
2001	0	0	0
2002	0	0	0
2003	0	0	0
2004	0	0	0
2005	0	0	0
2006	0	0	0
2007	0	0	0
2008	0	0	0
2009	0	0	0
2010	0	0	0
2011	16	16	16
2012	0	0	0
2013	0	0	0
2014	0	0	0
2015	0	0	0
2016	0	0	0
2017	2	2	2
2018	0	0	0
2019	0	0	0
2020	0	0	0
2021	0	0	0

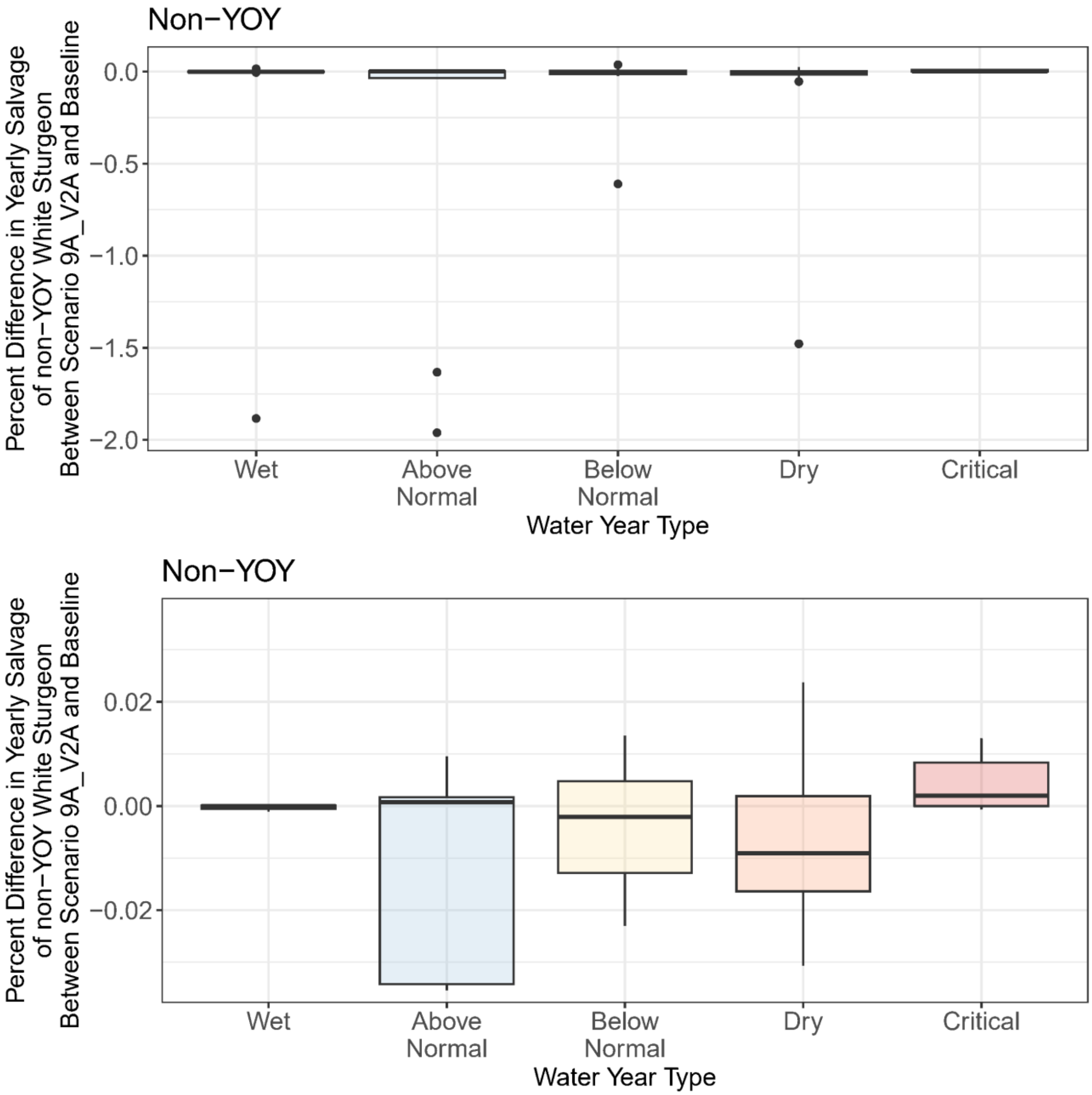

Figure 35. Percent difference in yearly number non-young-of-year (YOY) White Sturgeon caught in salvage between scenario 9A_V2A and Baseline. Top panel represents the distribution of all water years. Bottom panel represents the distribution of water years within 1.5 times the interquartile range of all water years. Each data point is separated by water year type based on the Sacramento Valley Index.

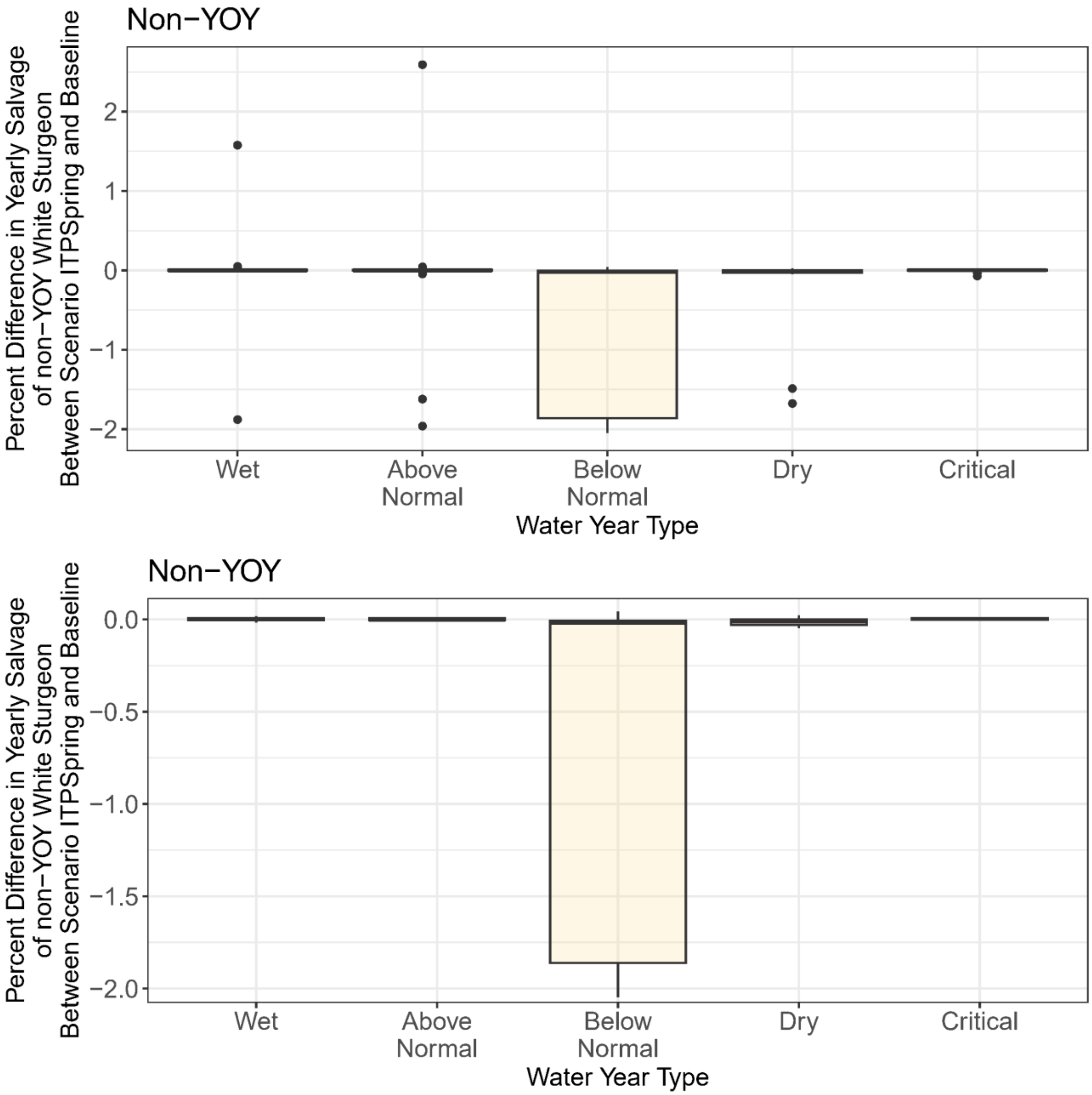

Figure 36. Percent difference in yearly number non-young-of-year (YOY) White Sturgeon caught in salvage between scenario ITP_Spring and Baseline. Top panel represents the distribution of all water years. Bottom panel represents the distribution of water years within 1.5 times the interquartile range of all water years. Each data point is separated by water year type based on the Sacramento Valley Index.

Table 10. Total yearly expected number of non-young-of-year White Sturgeon caught in salvage under different scenarios.

Water Year	Baseline	9A_V2A	ITP_Spring
1922	1	1	1

Water Year	Baseline	9A_V2A	ITP_Spring
1923	1	1	1
1924	1	1	1
1925	1	1	1
1926	1	1	1
1927	1	1	1
1928	1	1	1
1929	1	1	1
1930	1	1	1
1931	1	1	1
1932	1	1	1
1933	1	1	1
1934	1	1	1
1935	1	1	1
1936	1	1	1
1937	1	1	1
1938	1	1	1
1939	2	2	2
1940	1	1	1
1941	1	1	1
1942	2	2	2
1943	2	2	2
1944	2	2	2
1945	1	1	1
1946	1	1	1
1947	1	1	1
1948	1	1	1
1949	1	1	1
1950	1	1	1
1951	1	1	1
1952	1	1	1
1953	2	2	2
1954	2	2	2
1955	1	1	1
1956	1	1	1
1957	2	2	2

Water Year	Baseline	9A_V2A	ITP_Spring
1958	1	1	1
1959	2	2	2
1960	1	1	1
1961	1	1	1
1962	1	1	1
1963	1	1	1
1964	1	1	1
1965	1	1	1
1966	2	2	2
1967	1	1	1
1968	2	2	2
1969	1	1	1
1970	2	2	2
1971	2	2	2
1972	2	2	2
1973	1	1	1
1974	1	1	1
1975	2	2	2
1976	2	2	2
1977	1	1	1
1978	1	1	1
1979	1	1	1
1980	1	1	1
1981	1	1	1
1982	1	1	1
1983	2	2	2
1984	3	3	3
1985	2	2	2
1986	1	1	1
1987	2	2	2
1988	1	1	1
1989	1	1	1
1990	1	1	1
1991	1	1	1
1992	1	1	1

Water Year	Baseline	9A_V2A	ITP_Spring
1993	1	1	1
1994	1	1	1
1995	5	5	5
1996	16	16	16
1997	6	6	6
1998	2	2	2
1999	2	2	2
2000	1	1	1
2001	0	0	0
2002	0	0	0
2003	0	0	0
2004	0	0	0
2005	0	0	0
2006	1	1	1
2007	5	5	5
2008	3	3	3
2009	1	1	1
2010	1	1	1
2011	3	3	3
2012	4	4	4
2013	1	1	1
2014	1	1	1
2015	0	0	0
2016	1	1	1
2017	5	5	5
2018	10	10	10
2019	1	1	1
2020	1	1	1
2021	0	0	0

5.3.2. Modeling salvage as a function of water exports and Vernalis Gage Discharge

Water exports estimates ($EXPORTS$) were collected from Dayflow (DWR 2024) and Vernalis Gage Discharge ($Vernalis$) from USGS Station ID 11303500. Vernalis Gage Discharge was found to be highly correlated with the current year Sacramento Valley Index (Spearman correlation ~0.68) but loses this correlation when considering lags of the Sacramento Valley Index (Spearman correlation with SVI_{t-2} ~0.10). To preserve the model structure that analyzes both salvage of YOY White Sturgeon and non-YOY White Sturgeon and considering the high correlation between Vernalis Gage Discharge and current year Sacramento Valley Index, a model that uses Sacramento Valley Index and exports as hydrological covariates, with a similar structure to that of Equation 8, was built:

Equation 8

$$
\begin{aligned}
S_{YOY} &\sim Poisson(\lambda_{YOY}) \\
\log(\lambda_{YOY}) &\sim \beta_{YOY,0} + \beta_{YOY,EXPORTS} EXPORTS + \beta_{YOY,SVI} SVI + \beta_{YOY,season} + \\
&\quad z_{YOY,BY} + z_{YOY,Facility} + \log(T) \\
\text{logit}(\eta_{YOY}) &\sim \alpha_{YOY,0} + \alpha_{YOY,EXPORTS} EXPORTS + \alpha_{YOY,SVI} SVI + \alpha_{YOY,season} + \\
&\quad z_{YOY,BY} + z_{YOY,Facility} + \log(T) \\
S_{Non-YOY} &\sim Poisson(\lambda_{Non-YOY}) \\
\log(\lambda_{Non-YOY}) &\sim \beta_{Non-YOY,0} + \beta_{Non-YOY,EXPORTS} EXPORTS + \beta_{Non-YOY,SVI_{-1}} SVI_{-1} + \beta_{Non-YOY,SVI_{-2}} SVI_{-2} + \\
&\quad \beta_{Non-YOY,season} + z_{Non-YOY,BY} + z_{Non-YOY,Facility} + \log(T) \\
\text{logit}(\eta_{Non-YOY}) &\sim \alpha_{Non-YOY,0} + \alpha_{Non-YOY,EXPORTS} EXPORTS + \alpha_{Non-YOY,SVI_{-1}} SVI_{-1} + \alpha_{Non-YOY,SVI_{-2}} SVI_{-2} + \\
&\quad \alpha_{Non-YOY,season} + z_{Non-YOY,BY} + z_{Non-YOY,Facility} + \log(T) \\
z_{i,j} &\sim Normal(0, \sigma_{i,j})
\end{aligned}
$$

For $i = YOY, Non - YOY$ and $j = BY, Facility$.

Similar to the model using OMR as hydrological covariate, the models using either mean or max exports in a month perform relatively similar. However, the mean exports model's performance is slightly better than that of max exports, especially for predicting salvage of non-YOY White Sturgeon (Figure 37). In the mean exports model, the probability of catching YOYs in salvage was correlated with the Sacramento Valley Index and the mean exports in a month. Both this probability and the number of YOY White Sturgeon caught in salvage increases during the summer months (Figure 38). Similarly, the mean exports model suggests that non-YOY White Sturgeon are more likely to be caught in years after higher yearly Sacramento Valley Index, especially when exports are higher (Figure 39). However, while the number of non-YOY White Sturgeon caught in salvage is positively related to exports, the strength of this relationship is weaker (i.e., the 80% credible interval does not overlap with 0) than the probability of non-YOY White Sturgeon detection.

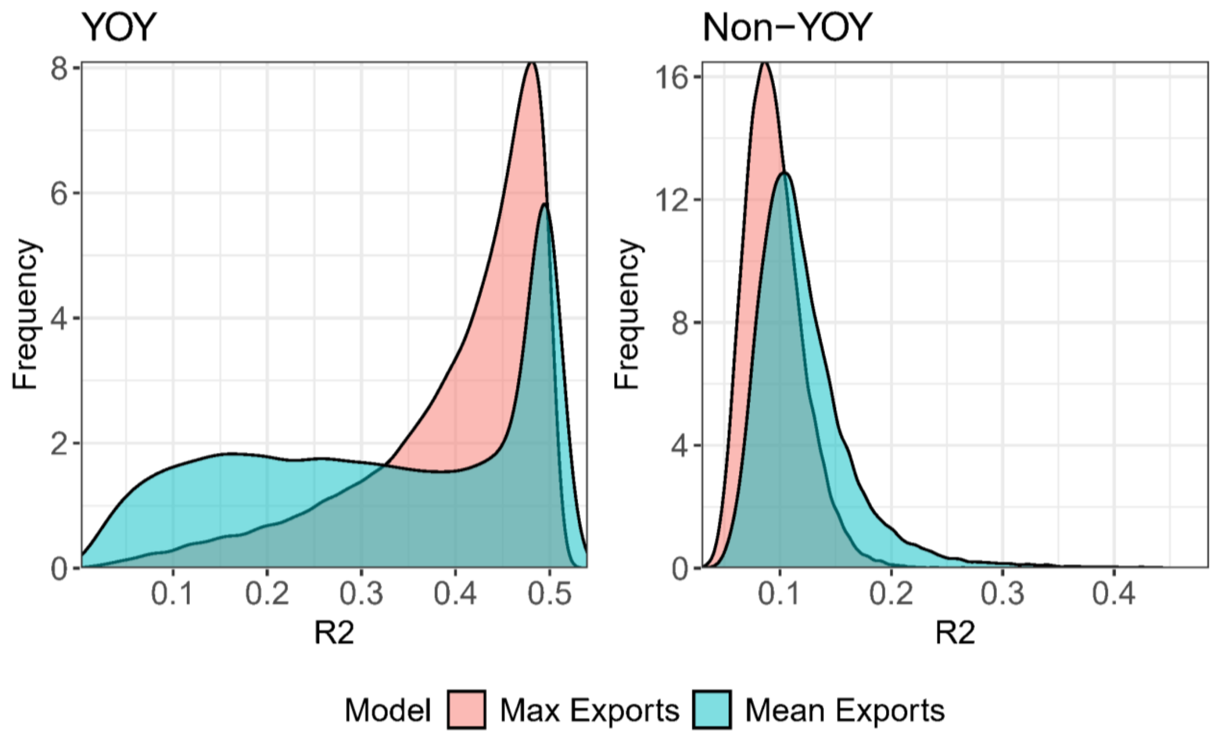

Figure 37. Distribution of Bayesian R2 values for models of number of salvage of young-of-year (YOY; left) and non-YOY (right) White Sturgeon using either max or mean exports as hydrological covariates.

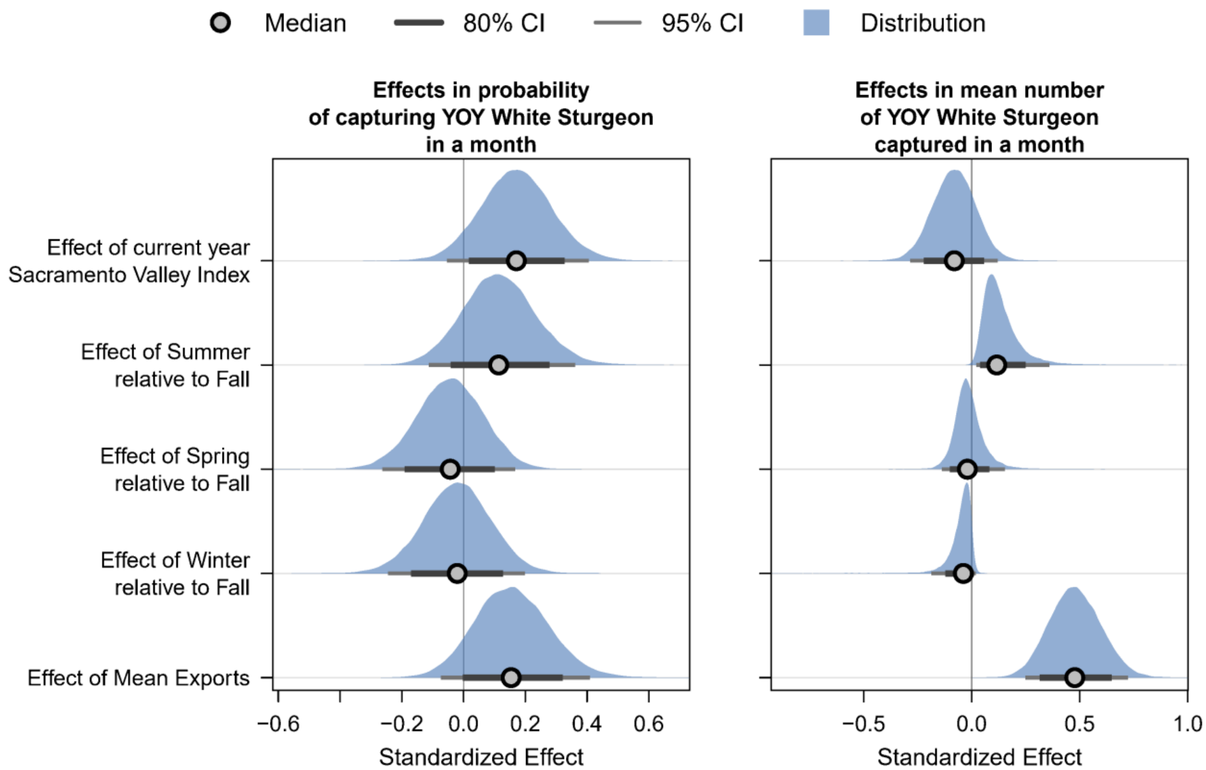

Figure 38. Effect size of the posterior distributions of the parameters of the model for the number of young-of-year (YOY) White Sturgeon salvaged in a month as a function of mean exports with 80% and 95% confidence intervals (CI). The vertical line corresponds to an effect size of zero, which indicates there is no effect of the variable. The effect size of seasons uses fall as a reference, which indicates the effect size of a given month is relative to fall.

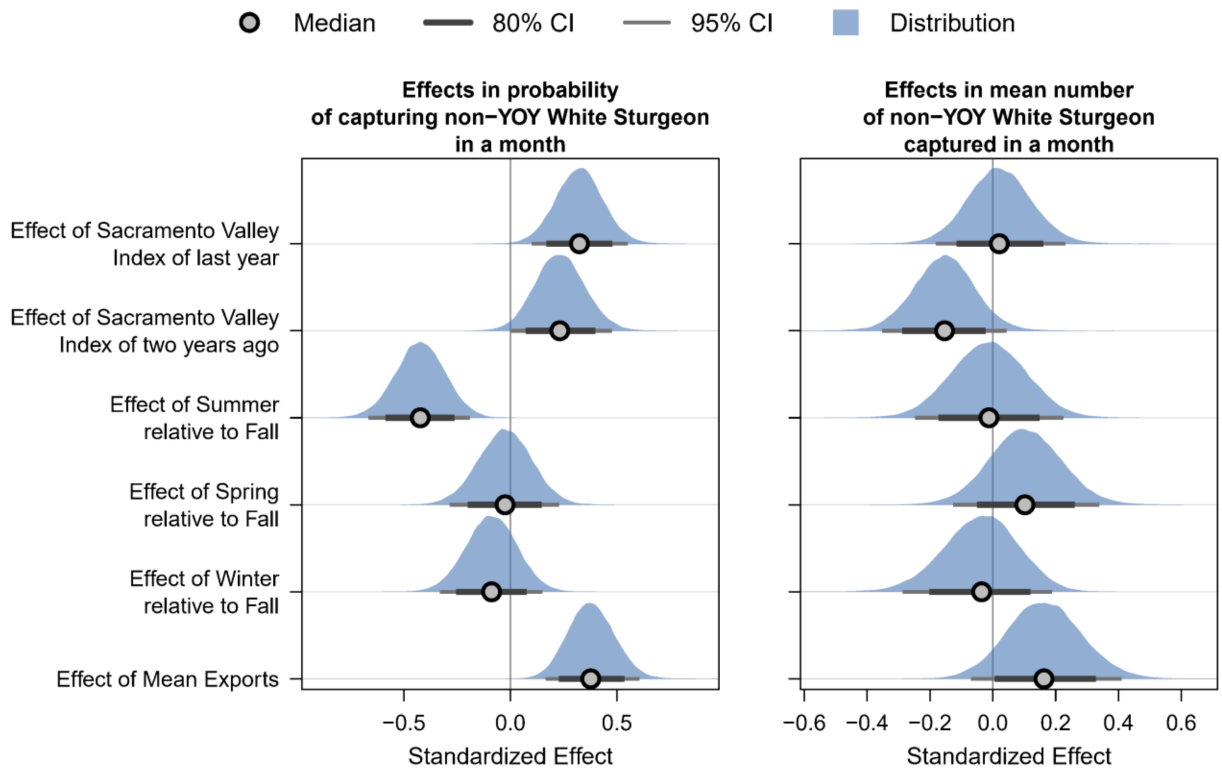

Figure 39. Effect size of the posterior distributions of the parameters of the model for the number of non-young-of-year (YOY) White Sturgeon salvaged in a month as a function of mean exports with 80% and 95% confidence intervals (CI). The vertical line corresponds to an effect size of zero, which indicates there is no effect of the variable. The effect size of seasons uses Fall as a reference, which indicates the effect size of a given month is relative to Fall.

When considering the trends of modeled probability from water years from 2003-2023, both YOY White Sturgeon and non-YOY White Sturgeon are generally more likely to be captured during wet years, especially during periods of high mean exports (Figure 40 and Figure 41). Furthermore, wet years are generally the years where the probability of catching White Sturgeon in salvage is higher for both YOYs (Figure 42) and non-YOYs (Figure 43).

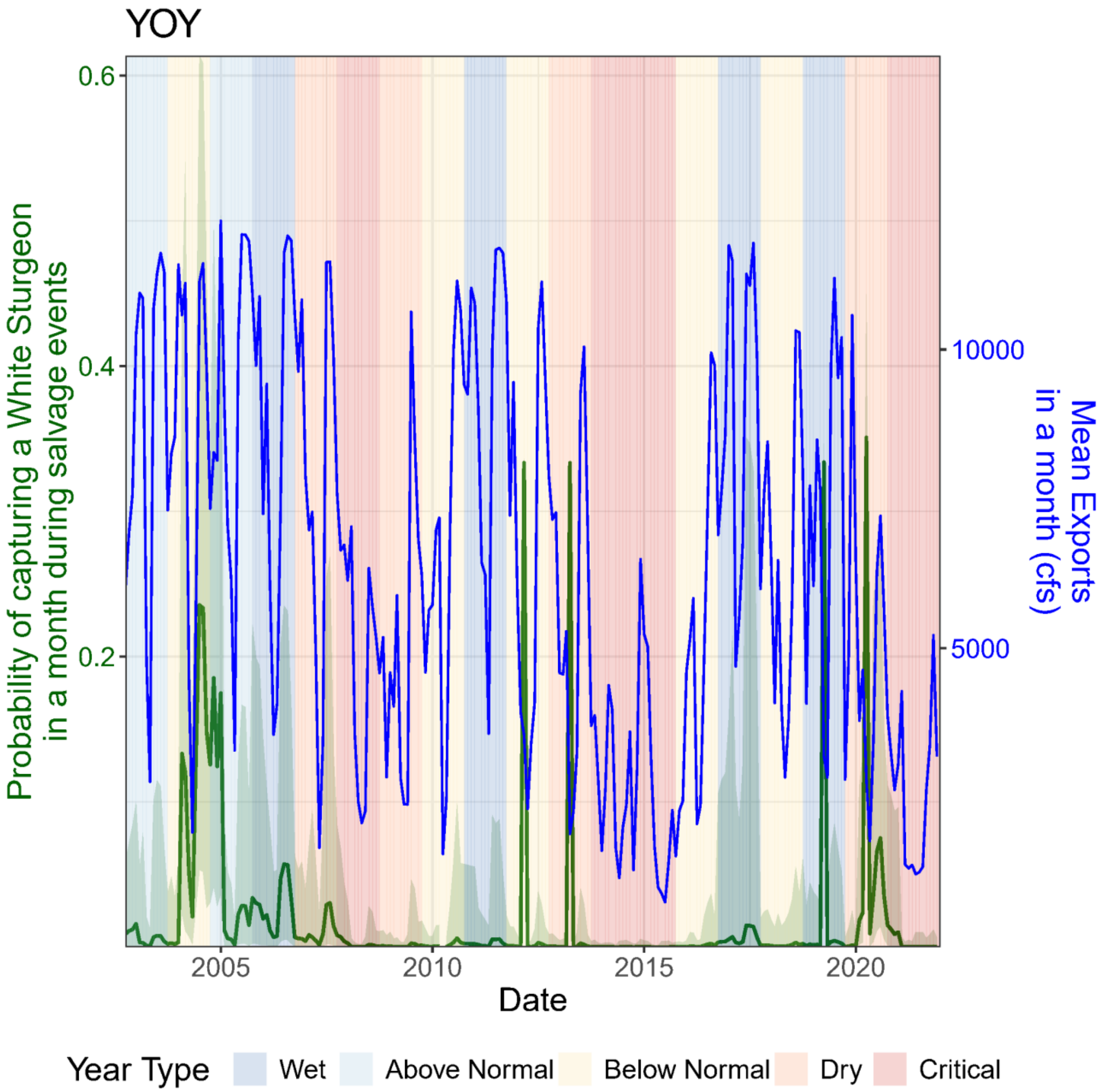

Figure 40. Green: Probability of capturing a young-of-year (YOY) White Sturgeon during salvage per month per from water years 2003-2023 based on the model which uses the mean exports of each month as its hydrological covariate. Confidence intervals are at the 95%. Blue: Mean exports for each month during water years 2003-2023. The background color of each water year corresponds to the water year type based on the Sacramento Valley Index.

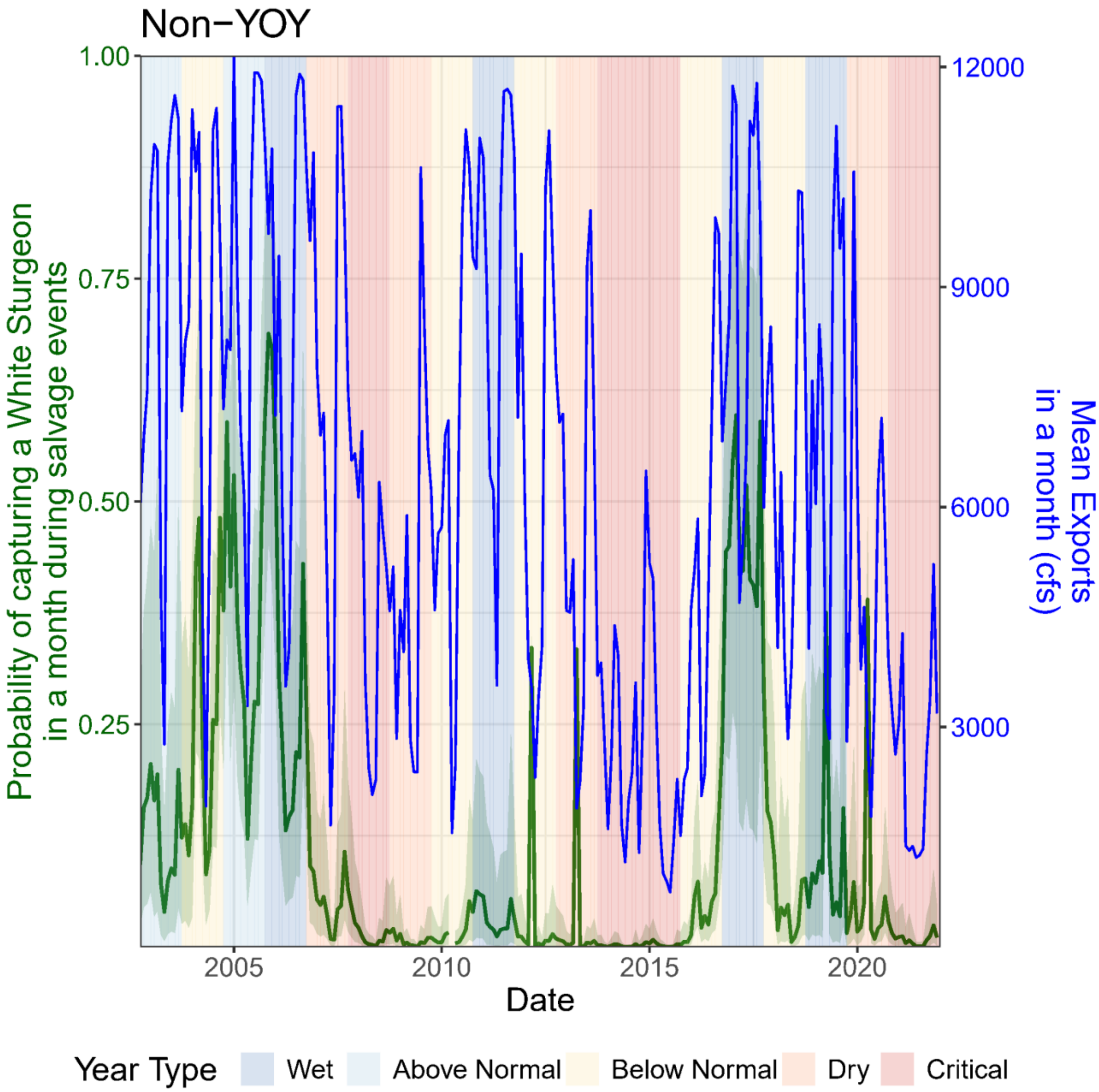

Figure 41. Green: Probability of capturing a non- young-of-year (YOY) White Sturgeon during salvage per month per from water years 2003-2023 based on the model which uses the mean exports of each month as its hydrological covariate. Confidence intervals are at the 95%. Blue: Mean exports for each month during water years 2003-2023. The background color of each water year corresponds to the water year type based on the Sacramento Valley Index.

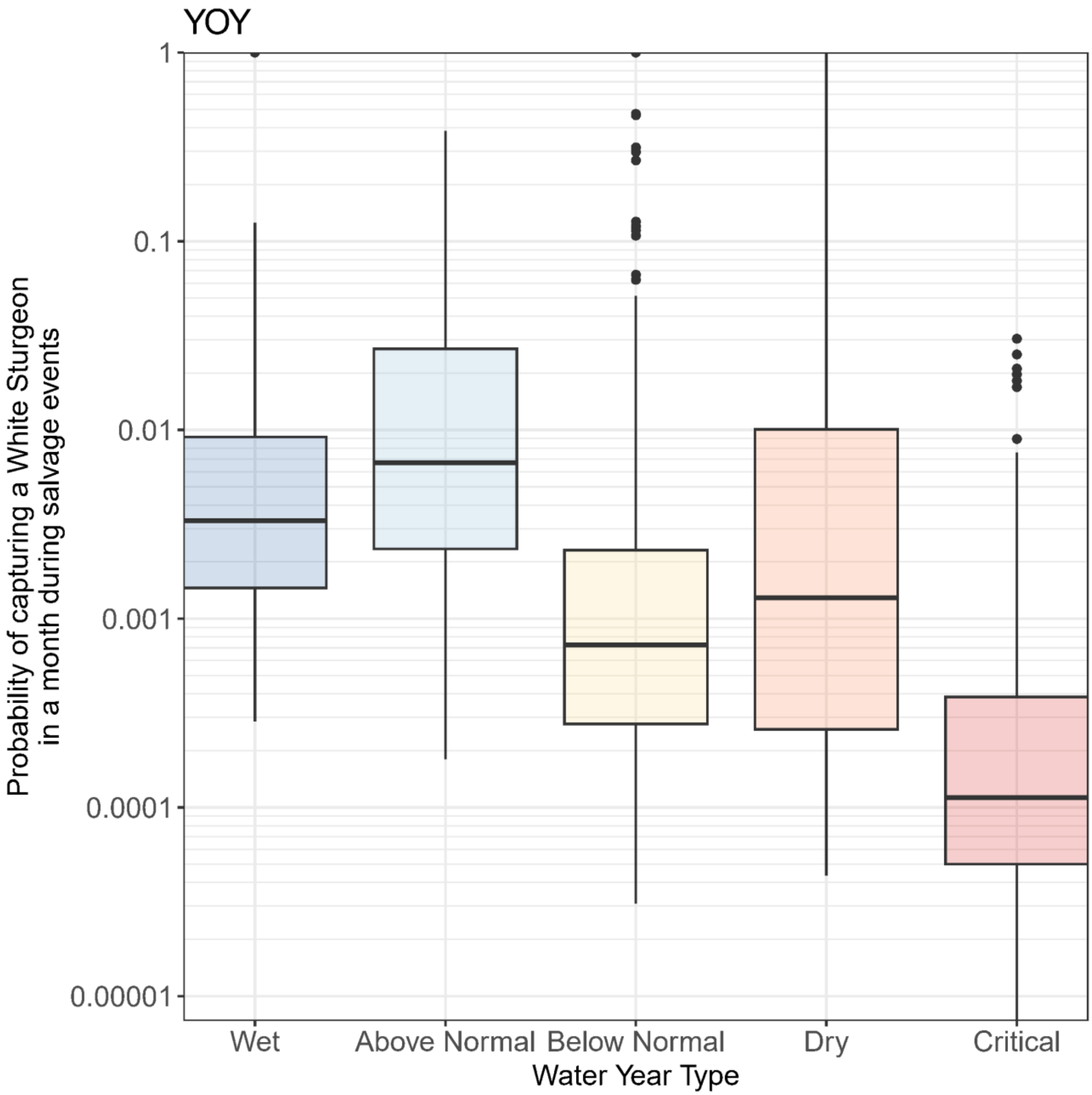

Figure 42. Boxplots of probabilities of capturing a young-of-year (YOY) White Sturgeon in salvage per month from water years 2003-2023 based on the model which uses the mean exports of each month as its hydrological covariate. Each data point is separated by water year type based on the Sacramento Valley Index.

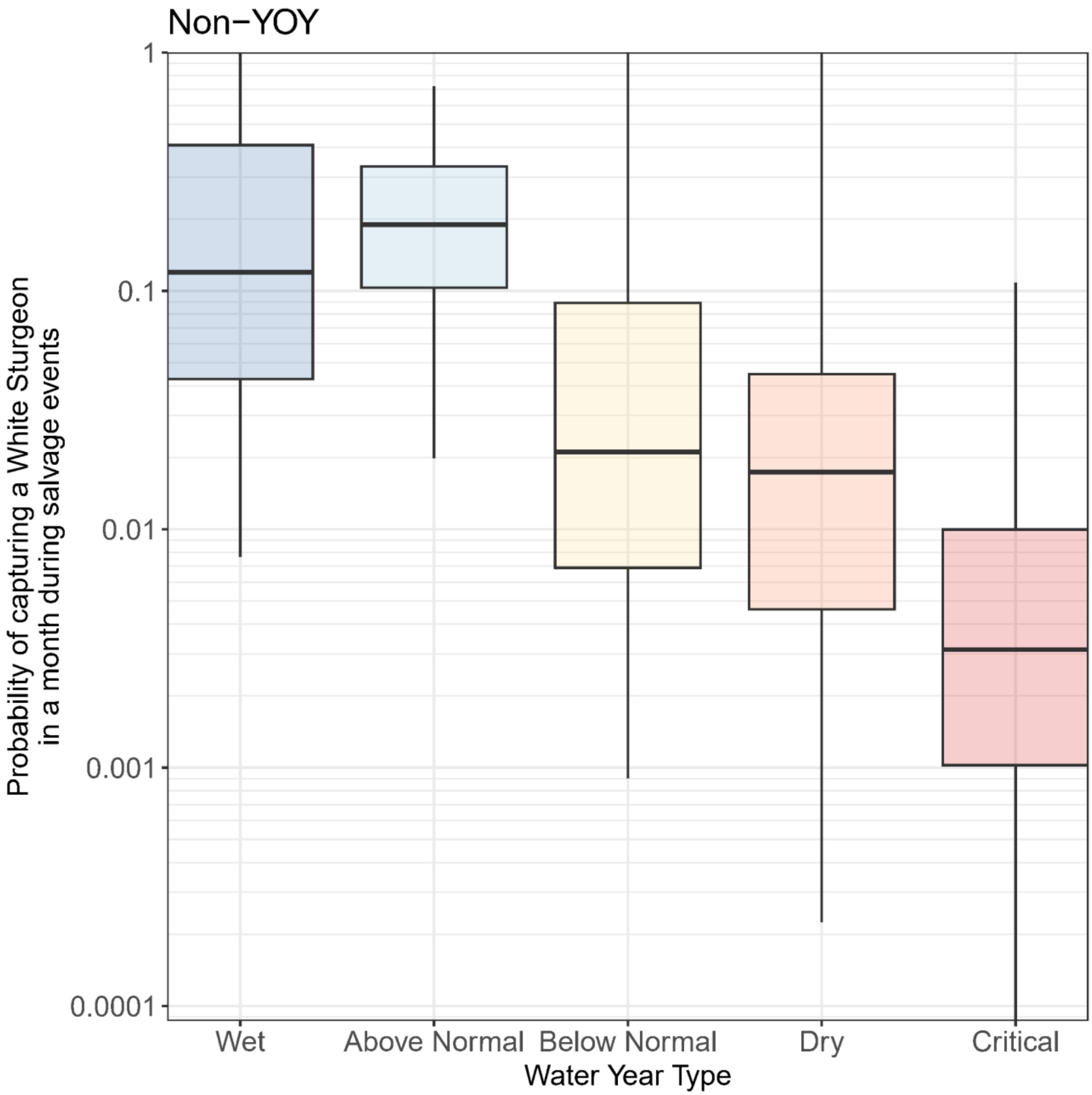

Figure 43. Boxplots of probabilities of capturing a non- young-of-year (YOY) White Sturgeon in salvage per month from water years 2003-2023 based on the model which uses the mean exports of each month as its hydrological covariate. Each data point is separated by water year type based on the Sacramento Valley Index.

Based on observed correlations between Sacramento Valley Index and exports (Figure 38 and Figure 39), a local sensitivity analysis was used to understand the extent to which the probability of salvage is affected by exports over the range of historically observed mean export values during both a critical year and a wet year, with their SVI value being the mean of observed SVI values during critical and wet years, respectively. During a critical year, the probability of salvaging a YOY White Sturgeon in a month with the highest amount of historically observed mean daily exports is similar to the probability of salvaging a YOY White Sturgeon in a month with the lowest amount of historically observed mean daily exports during a wet year (Figure 44). The difference is not as high for non-YOY White Sturgeon, but the probability of salvaging a non-YOY White Sturgeon in a wet year is approximately double the probability in a critical year during high export events (Figure 45). When looking at the minimum and maximum median probabilities of salvage in a month, the probability of salvaging a YOY White Sturgeon is an order of magnitude higher during a wet year than a critical year, and approximately doubles during the summer than in other seasons regardless of the type of water year (Table 11). For non-YOYs, the increase in probability of salvage between a critical and a wet year is approximately 2-fold, and the probability of catching a non-YOY in salvage during the summer months is about half of that probability during the other months (Table 12).

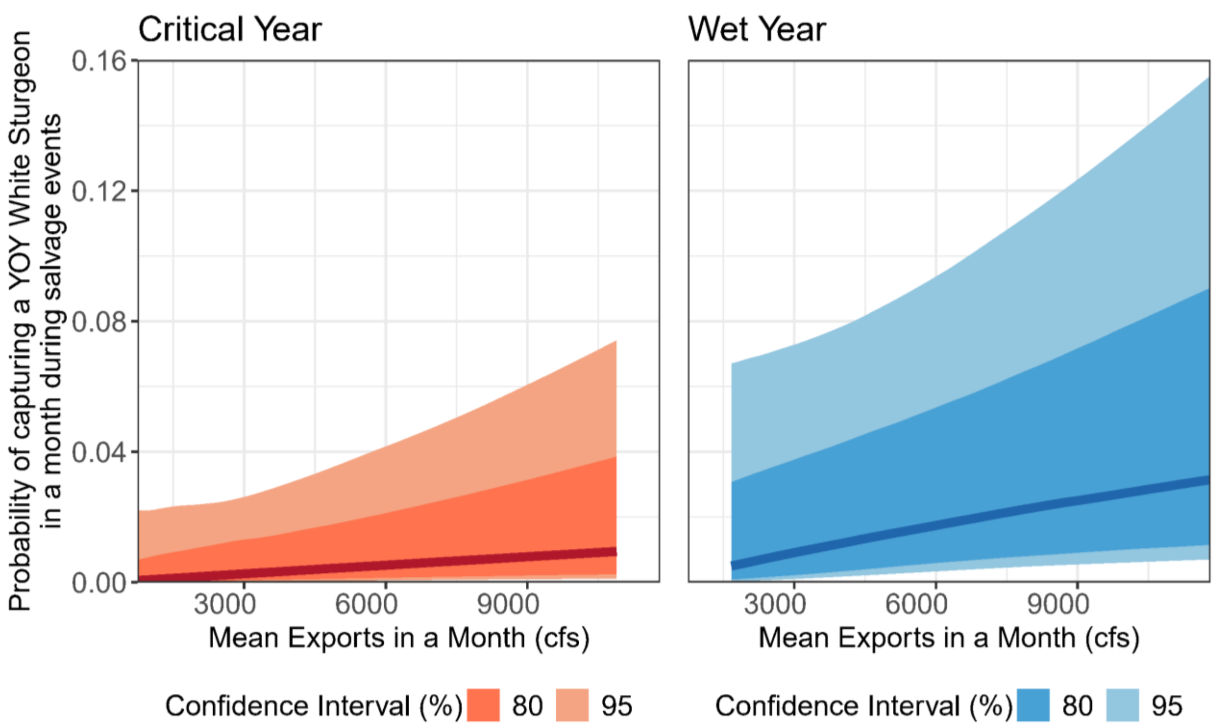

Figure 44. Probability of capturing a young-of-year (YOY) White Sturgeon in a month during salvage events as a function of mean exports during a critical year (left) and a wet year (right). Confidence intervals are at 80% and 95%.

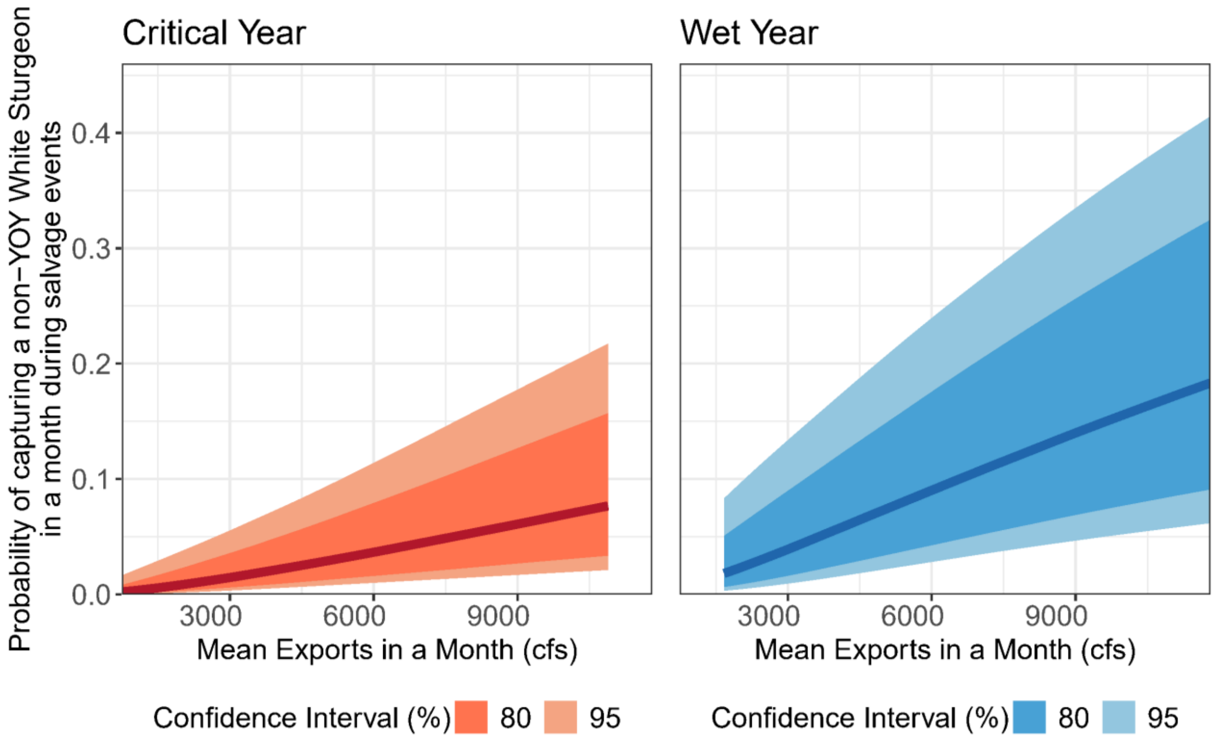

Figure 45. Probability of capturing a non- young-of-year (YOY) White Sturgeon in a month during salvage events as a function of mean exports during a critical year (left) and a wet year (right). Confidence intervals are at 80% and 95%.

Table 11. Minimum and maximum median probabilities of catching a young-of-year (YOY) White Sturgeon in salvage in a given month depending on the season and the water year type based on the Sacramento Valley Index.

Season	**Critical Year Minimum Probability**	**Critical Year Maximum Probability**	**Wet Year Minimum Probability**	**Wet Year Maximum Probability**
Fall	0.00043	0.0089	0.0019	0.030
Winter	0.00040	0.0079	0.0017	0.027
Spring	0.00032	0.0063	0.0013	0.024
Summer	0.00085	0.015	0.0036	0.048

Table 12. Minimum and maximum median probabilities of catching a non- young-of-year (YOY) White Sturgeon in salvage in a given month depending on the season and the water year type based on the Sacramento Valley Index.

Season	Critical Year Minimum Probability	Critical Year Maximum Probability	Wet Year Minimum Probability	Wet Year Maximum Probability
Fall	0.0030	0.111	0.0082	0.23
Winter	0.0024	0.093	0.0067	0.20
Spring	0.0027	0.101	0.0076	0.21
Summer	0.00089	0.038	0.0024	0.093

5.3.3. Modeling the relationship between salvage and year class strength

In addition to analyzing year class strength (catch per unit effort in IEP surveys, Section 5.2) and salvage as separate entities, the potential relation between catching YOY White Sturgeon in survey stations north of salvage facilities and catching YOY White Sturgeon in salvage facilities was analyzed. This relationship was suspected as a possible consequence of the hypothesis that individuals out-migrating from the Sacramento River move through the north and central Delta and may be detected in IEP surveys prior to detection at the salvage facilities in the south Delta.

This possible relationship was explored by analyzing the correlation between salvage events and the catch of YOY White Sturgeon in surveys north of salvage facilities at different lags and aggregations (i.e., hypothesizing that detections in the north and central Delta occur before salvage). All possible time lags from 7 to 105 days at daily increments and aggregation windows from 21 to 49 days at daily increments were evaluated. A mixed effects logistic model framework was used in which the probability of salvage was predicted as a function of 20-mm Survey or San Francisco Bay Study catch at the specific lag and given the specific aggregation window while accounting for water year as a random effect.

After identifying the lag that provides the highest correlation between catch in surveys and salvage of YOY White Sturgeon, the potential correlation between salvage, hydrological covariates, and detection of YOY White Sturgeon in surveys was explored. Total water exports ($EXPORTS$ in Dayflow) and Vernalis Gage Discharge ($Vernalis$, USGS Station ID 11303500) were used as hydrological covariates that are main contributors of the commonly used Old and Middle River Flow metric for salvage (Andrews et al, 2016).

To explore these correlations, a logistic regression was built to analyze the probability S of having a YOY White Sturgeon in salvage at any given day. Detection or lack of YOY White

Sturgeon in surveys was included as a logical factor, and both Vernalis Gage Discharge and total water exports as hydrological covariates. Both Vernalis and water exports were aggregated as a moving average of the past l days ($l = 30{,}60{,}90$) and a logistic regression model was built for each of these lags.

In equation form, the logistic regression is written as:

Equation 9

$$\text{logit}(S) \sim \beta_0 + \beta_{catch} + \beta_{Vernalis} Vernalis_l + \beta_{EXPORTS} EXPORTS_l$$

A trend was observed where generally more salvage events occurred after a YOY White Sturgeon was caught in the central or north Delta during the previous 90 days, after accounting for the hydrological conditions during which salvage events occurred (Table 13), than when zero YOY White Sturgeon were caught (Table 14). In addition to observing whether a YOY White Sturgeon was caught in the central Delta during the previous 90 days, the mean Vernalis flows and exports were separated during this 90-day period into low, moderate, and high categories. To determine these thresholds, a logistic regression was fit using a similar equation to Equation 3 without separating the data by detection or lack of detection of YOY White Sturgeon in central Delta survey stations during the previous 90 day period. This logistic regression calculates the probability of finding a YOY White Sturgeon in salvage, which can be used to assess risk of salvage. Thresholds for exports were determined by assessing the minimum exports required for any amount of Vernalis Gage Discharge associated with a 25 and 50 percentile risk of salvage determined by the logistic regression (0.05% and 0.17%). Thresholds for Vernalis Gage Discharge were determined using a similar process.

Using the categorical hydrological covariates, the results show a trend where salvage of YOY White Sturgeon occurs during events of higher exports (Table 13 and Table 14). Although the number of salvage events occurring during high exports with high Vernalis Gage Discharge events is smaller than that of low Vernalis Gage Discharges, there are approximately 17 times more days with moderate Vernalis Gage Discharges than days with high Vernalis Gage Discharge events. This implies that proportionally more days with high Vernalis Gage Discharge had salvage of YOY White Sturgeon than days with low Vernalis Gage Discharge. Furthermore, mean salvage of YOY White Sturgeon through the 30 days following a high Vernalis Gage Discharge increases as Vernalis Gage Discharge and exports increase, especially when YOY White Sturgeon were caught in the central Delta during the preceding 90 days (Figure 46) compared to when no YOY White Sturgeon were caught (Figure 47).

Table 13. The percentage of all salvage events from January 1, 1993, to May 14, 2024, during periods with high (>8,500 cfs), moderate <8,500 and >5,500 cfs), and low (< 5,500 cfs) levels of

mean water exports and high (>17,500 cfs), moderate (<17,500 and > 11,500 cfs), and low (< 11,500 cfs) Vernalis Gage Discharge were met in the last 90 days, and a young-of-year (YOY) White Sturgeon was caught in the central Delta in the last 90 days, determined by a simple logistic regression.

YOY White Sturgeon Caught	**Low Vernalis**	**Moderate Vernalis**	**High Vernalis**
High Exports	12.50%	12.50%	11.40%
Moderate Exports	6.82%	13.60%	33.00%
Low Exports	0.00%	0.00%	1.14%

Table 14. Percentage of all salvage events from January 1, 1993, to May 14, 2024 , during periods with high (>8,500 cfs), moderate <8,500 and >5,500 cfs), and low (< 5,500 cfs) levels of mean water exports and high (>17,500 cfs), moderate (<17,500 and > 11,500 cfs), and low (< 11,500 cfs) Vernalis Gage Discharge were met in the last 90 days, and a young-of-year (YOY) White Sturgeon was not caught in the central Delta in the last 90 days., determined by a simple logistic regression.

YOY White Sturgeon Not Caught	**Low Vernalis**	**Moderate Vernalis**	**High Vernalis**
High Exports	5.68%	0.00%	0.00%
Moderate Exports	2.27%	0.00%	0.00%
Low Exports	1.14%	0.00%	0.00%

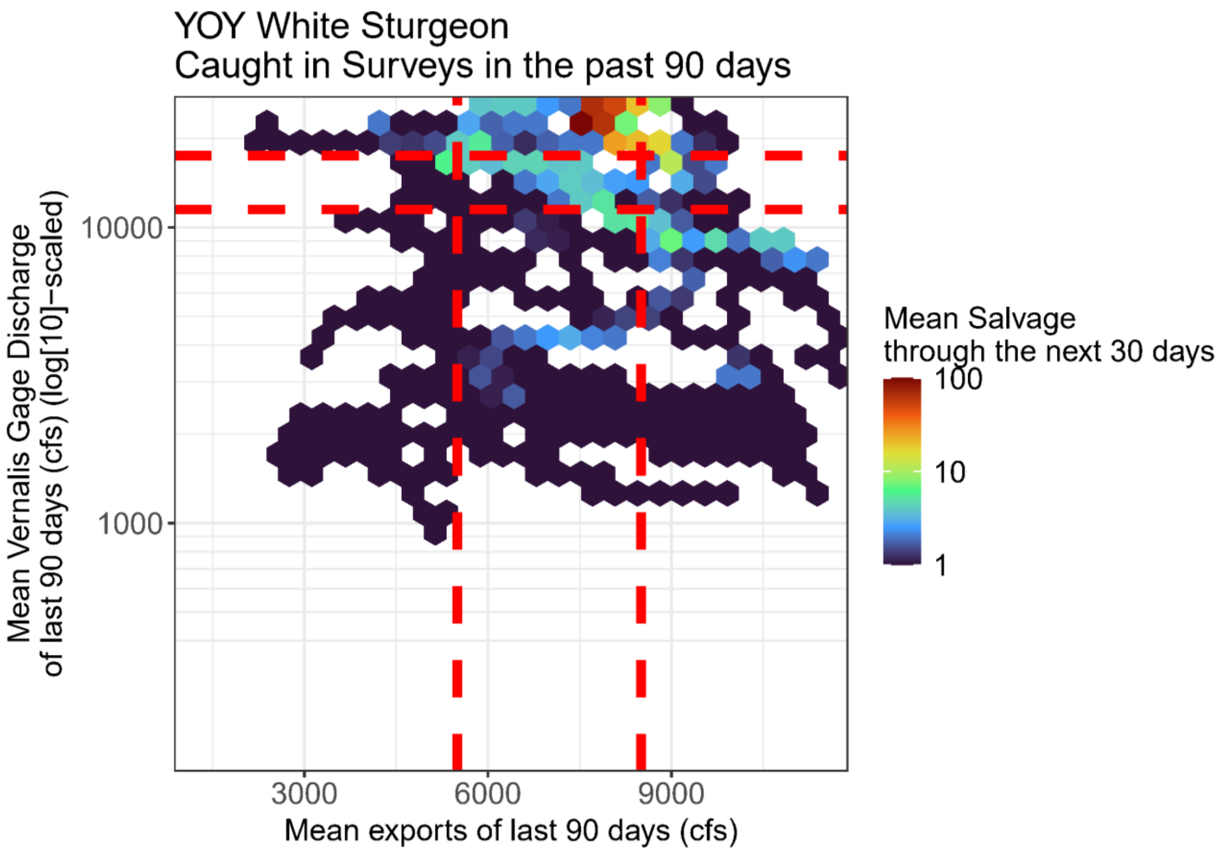

Figure 46. Mean salvage of young-of-year (YOY) White Sturgeon during the 30 days after a salvage event occurred and a YOY White Sturgeon was caught in the past 90 days at different observed hydrological conditions. The red dashed lines represent the thresholds to separate Vernalis Gage Discharge and exports in low, moderate, and high categories.

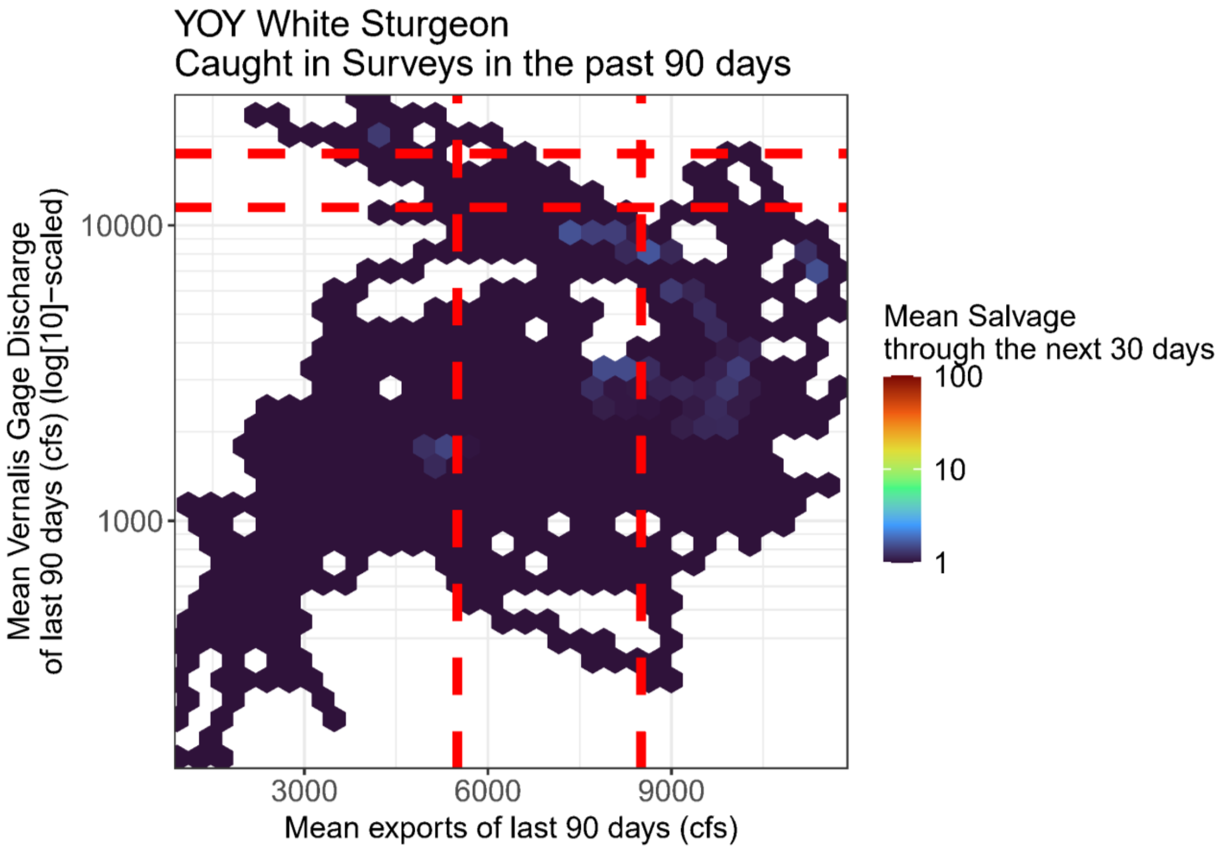

Figure 47. Mean salvage of young-of-year (YOY) White Sturgeon during the 30 days after a salvage event occurred and a YOY White Sturgeon was not caught in the past 90 days at different observed hydrological conditions. The red dashed lines represent the thresholds to separate Vernalis Gage Discharge and exports in low, moderate, and high categories.

Expected log-likelihood indicated that a 90-day lag produced the best model to identify a lag for the moving average of Vernalis Gage Discharge and exports (Table 15). Unlike other models shown in the previous sections, the differences between a 90-day lag and other lags are large, especially relative to standard error. This provides strong evidence for the 90-day lag model being a significantly better model than either the 60-day or 30-day lagged models.

Table 15. Expected log-likelihood of models of probability of having a salvage event given there was a catch of young-of-year (YOY) White Sturgeon in the central Delta in the last 90 days,

dependent on different lags of mean exports and Vernalis Gage Discharge estimated using the Leave-One-Out cross validation method. The expected difference of log-likelihoods between a given model and the model with the highest log-likelihood, as well as its standard error (SE).

Lag	**Expected Log-Likelihood**	**Expected difference with highest likelihood model**	**SE of difference**
90 days	-358.77	N/A	N/A
60 days	-374.88	16.11	4.08
30 days	-393.26	34.48	7.11

The effect size plot of the 90-day lag model shows that all our covariates have a strong influence on the probability of having a salvage event of YOY White Sturgeon (Figure 48). That is, the probability of salvage is strongly related to exports, Vernalis flow, and detection of White Sturgeon in surveys in the last 90 days.

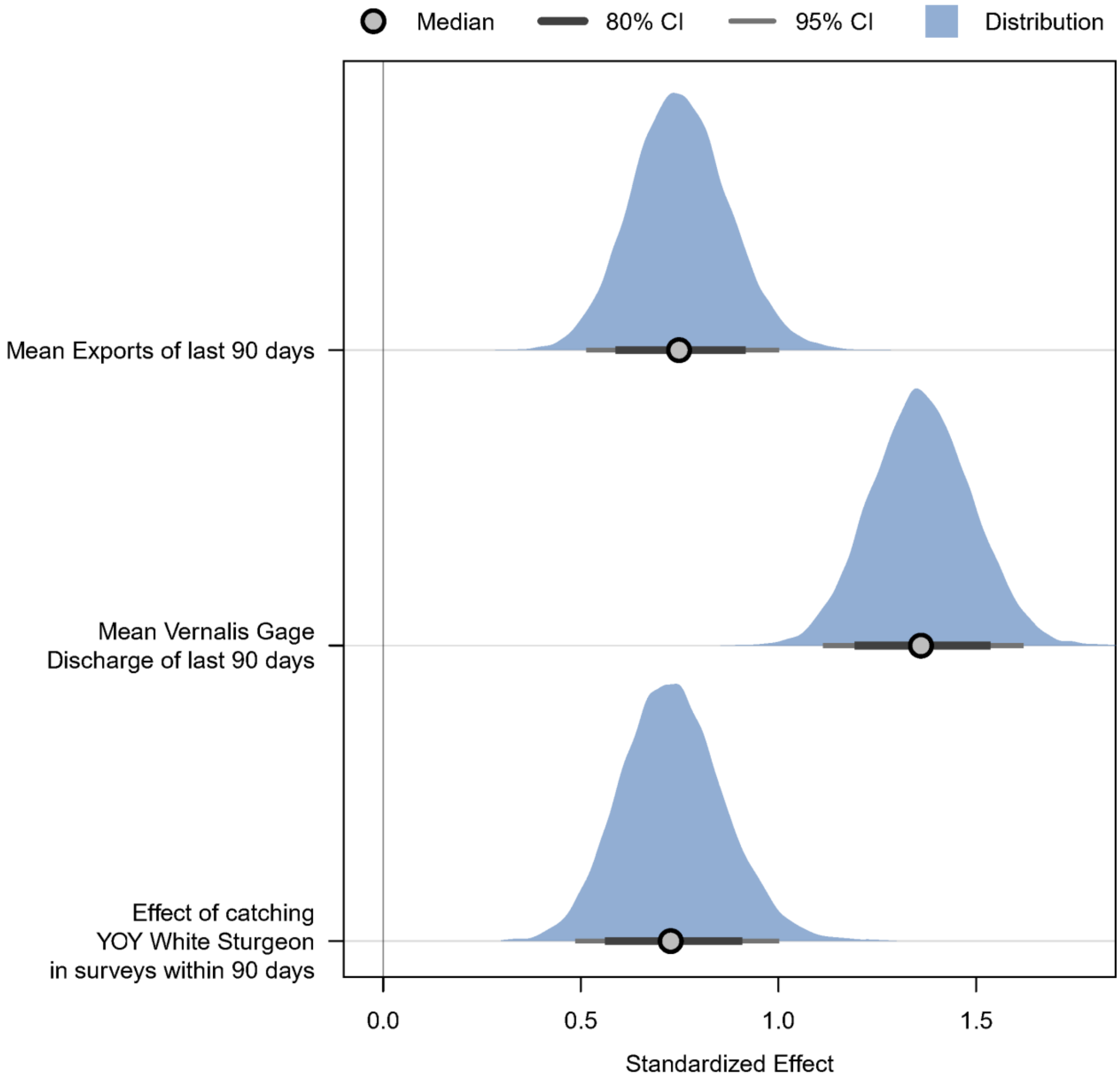

Figure 48. Effect size of the posterior distributions of the parameters of the best model for the probability of observing a salvage event of young-of-year (YOY) White Sturgeon on a given day with its 80 and 95% confidence intervals (CI). The vertical line corresponds to an effect size of 0, i.e. there is no effect of the variable.

When simulating across a range of observed 90-day mean Vernalis Gage Discharge and export values, the probability of observing a salvage event of YOY White Sturgeon increases more than an order of magnitude when a YOY White Sturgeon was caught by surveys in the central and north Delta during the preceding 90 days (Figure 49 and Figure 50).

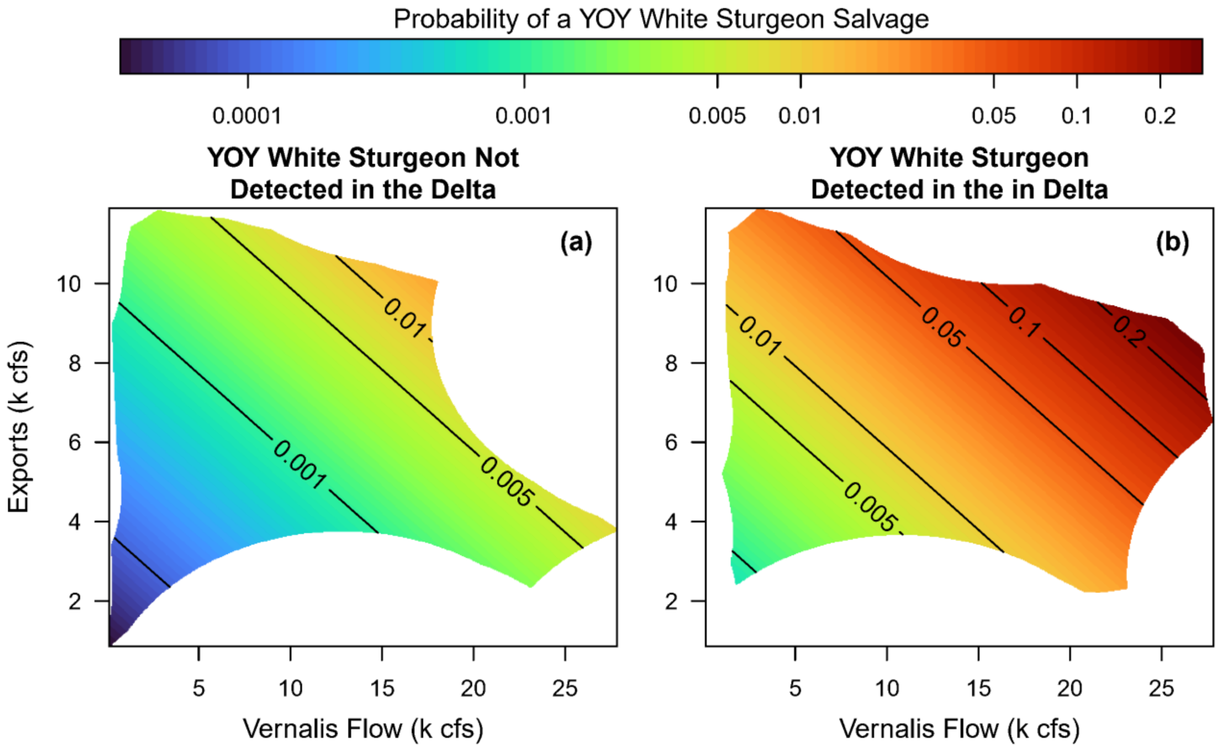

Figure 49 Heatmap of probability of a salvage event of YOY White Sturgeon in a given day given a YOY White Sturgeon was caught in central Delta within the last 90 days (left) or not (right).

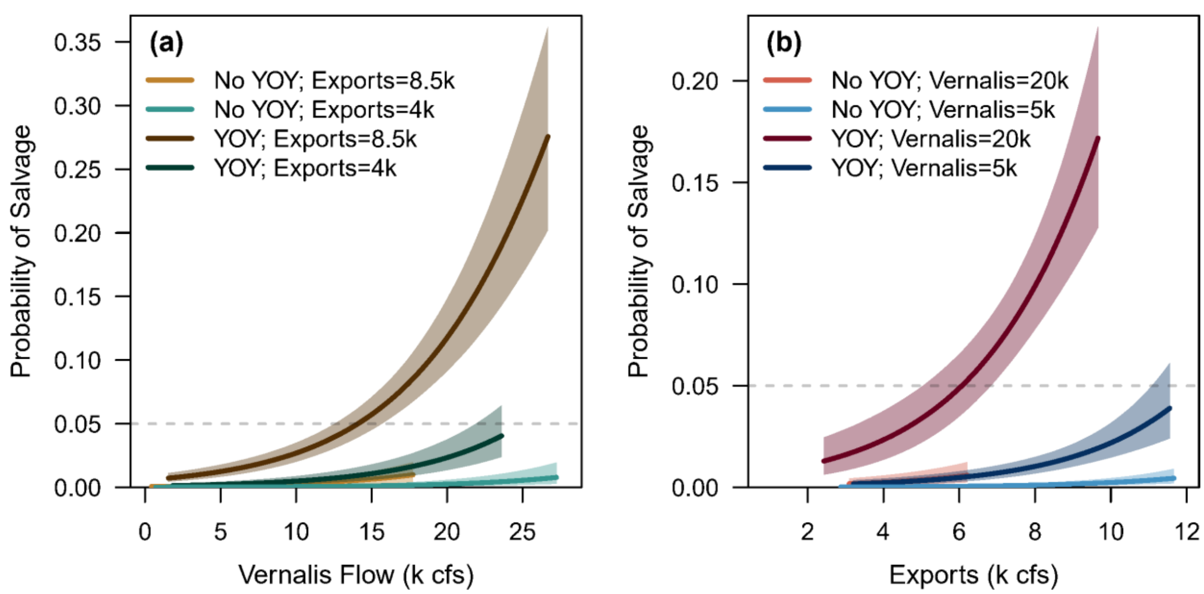

Figure 50. Probability of salvage of young-of-year (YOY) White Sturgeon (a) across Vernalis flow given high and low exports as well as (b) across exports given high and low Vernalis flow shown with recent detections in surveys (YOY) and without recent detections in surveys (No YOY) in the central Delta. Polygons represent 95% credible intervals.

5.4. Effects of South Delta Export Operations on Potential Mortality of White Sturgeon Driven by Harmful Algal Blooms

As described in Section 4.2.1, mortality of White Sturgeon caused by intense HAB events has a strong impact on White Sturgeon's population growth rate. The changes in hydrology produced by water exports have the potential to exacerbate this impact by increasing the incidence of HAB events. To explore this potential, a model that correlates hydrological covariates with incidence of algal blooms in the Delta was developed. Data for water quality parameters collected in different stations within the Delta were used (Battey and Perry 2023). This dataset consists of measurements of several water quality parameters, including but not limited to chlorophyll a, dissolved ammonia, dissolved silica, surface water temperature, surface water pH, and incidence of *Microcystis aeruginosa* from calendar years 1975 to 2022 and covers the presence/absence of HABs throughout the Delta. Incidence of *M. aeruginosa* was consistently collected starting on calendar year 2015. This incidence is measured on a scale of 1 to 5, where 1 represents no *M. aeruginosa* detected, and 5 represents a very high amount of *M. aeruginosa* detected. Hydrological data from Dayflow (DWR 2024) was also compiled, more specifically X2 and total outflow.

The potential relationship between hydrological covariates and the incidence of HABs was explored using a logistic regression model (Lane et al. 2009). In this model, a HAB event was defined as those events in the water quality dataset where the incidence of *M. aeruginosa* is higher than 3 (i.e., higher than a medium observation of *M. aeruginosa*). The water quality parameters of dissolved ammonia, dissolved silica, surface water temperature, and surface water pH were incorporated as covariates, in addition to a hydrological covariate, either $X2$ or total outflow (OUT). In addition, a random effect $z_{station}$ of the station where the water quality was measured was incorporated.

In equation form, the model for the probability of a HAB event p_{HAB} using X2 as the hydrological covariate is given by:

Equation 10

$$\begin{aligned} \text{logit}(p_{HAB}) &= \beta_0 + \beta_{Ammonia} Ammonia + \beta_{Silica} Silica + \beta_{pH} pH \\ &\quad + \beta_{Temperature} Temperature + \beta_{X2} X2 + z_{station} \\ z_{station} &\sim Normal(0, \sigma_{station}) \end{aligned}$$

and a similar equation for the model using total outflow as the hydrological covariate:

Equation 11

$$\begin{aligned}\text{logit}(p_{HAB}) =& \beta_0 + \beta_{Ammonia}Ammonia + \beta_{Silica}Silica + \beta_{pH}pH \\ &+ \beta_{Temperature}Temperature + \beta_{OUT}OUT + z_{station} \\ z_{station} \sim& Normal(0, \sigma_{station})\end{aligned}$$

The models presented in this section were fit using Bayesian regression with the brms package in R (Burkner et al. 2017). The best model was determined using LOO (Vehtari et al. 2016). Consistent with other models developed in this document (Sections 5.1, 5.2, and 5.3.3), the best Bayesian model was determined utilizing LOO methodology.

Based on the log-likelihoods presented in Table 16, the model developed to assess the probability of a HAB event with the highest log-likelihood is the model that includes X2 as the hydrological covariate. However, a small, expected difference in log-likelihood, as well as the high standard error relative to the mean difference suggests that the model using total outflow as a hydrological covariate does not perform significantly different than the model using X2.

Table 16. Expected log-likelihood of models of probability of having an intense harmful algal bloom dependent on different hydrological covariates estimated using the Leave-One-Out cross validation. The expected difference of log-likelihoods between a given model and the model with the highest log-likelihood, as well as its standard error (SE).

Hydrological Covariate	**Expected Log-Likelihood**	**Expected difference with highest likelihood model**	**SE of difference**
X2	-94.07	N/A	N/A
Total Outflow	-95.14	-1.06	0.81

When analyzing the model of the probability of HAB events as a function of X2, the effect size plot of the model shows a weak correlation between X2 and the probability of HAB events as the tail of the posterior distribution crosses the vertical line of zero (Figure 51). Besides X2, only a correlation between the probability of having a HAB event and the surface water temperature was found.

By exploring the probability of HAB events through the range of historically observed values of surface water temperature and X2, the probability of having HAB events in the summer increases as water temperature increases and as X2 increases for warmer water temperatures (Figure 52). Furthermore, most of the HAB events in the data were observed during periods of extremely high X2 values and high surface water temperatures.

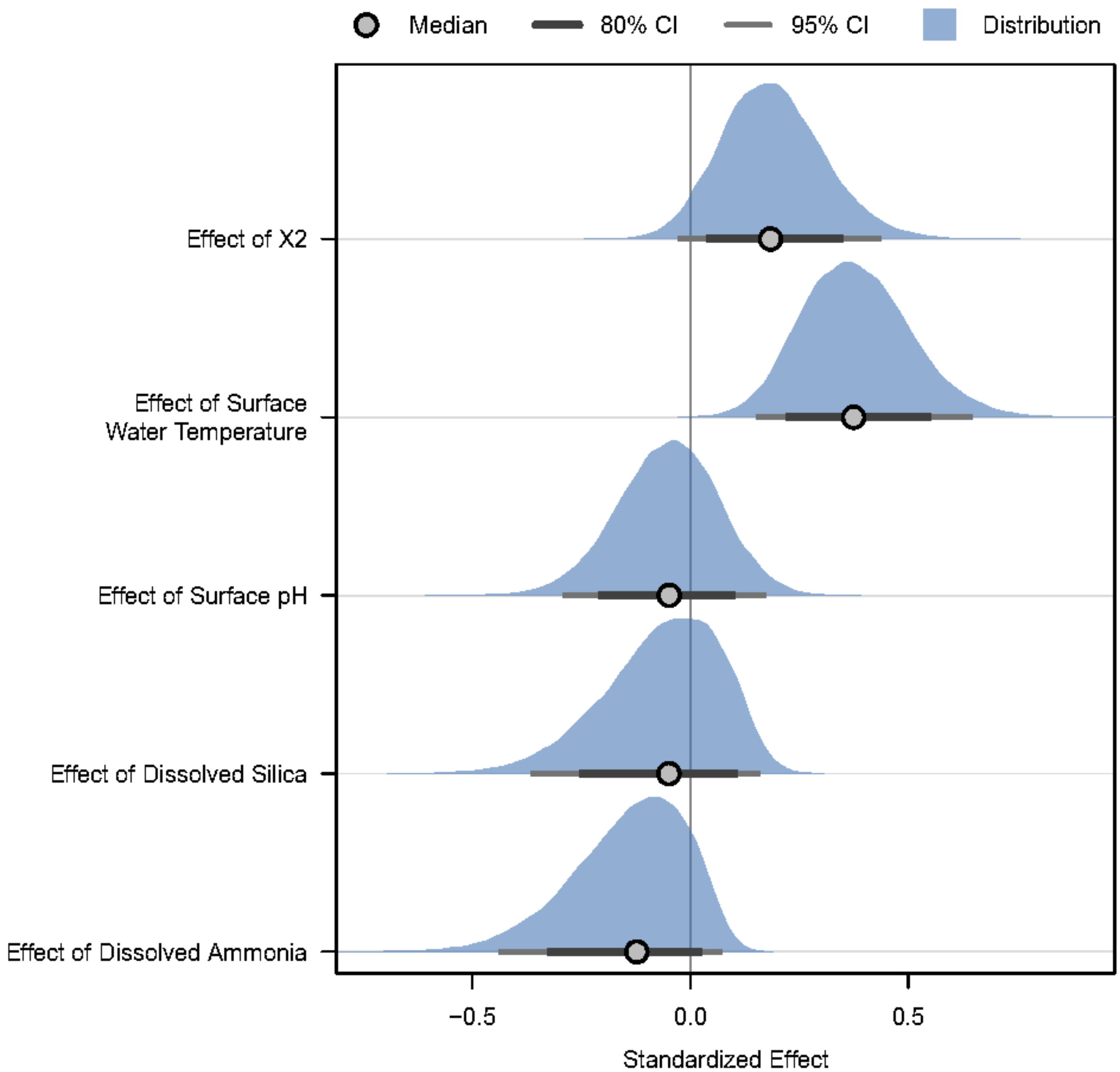

Figure 51. Effect size of the posterior distributions of the parameters of the model of the probability of a harmful algal bloom event as a function of X2 with its 80 and 95% confidence intervals (CI). The vertical line corresponds to an effect size of zero, i.e. there is no effect of the variable.

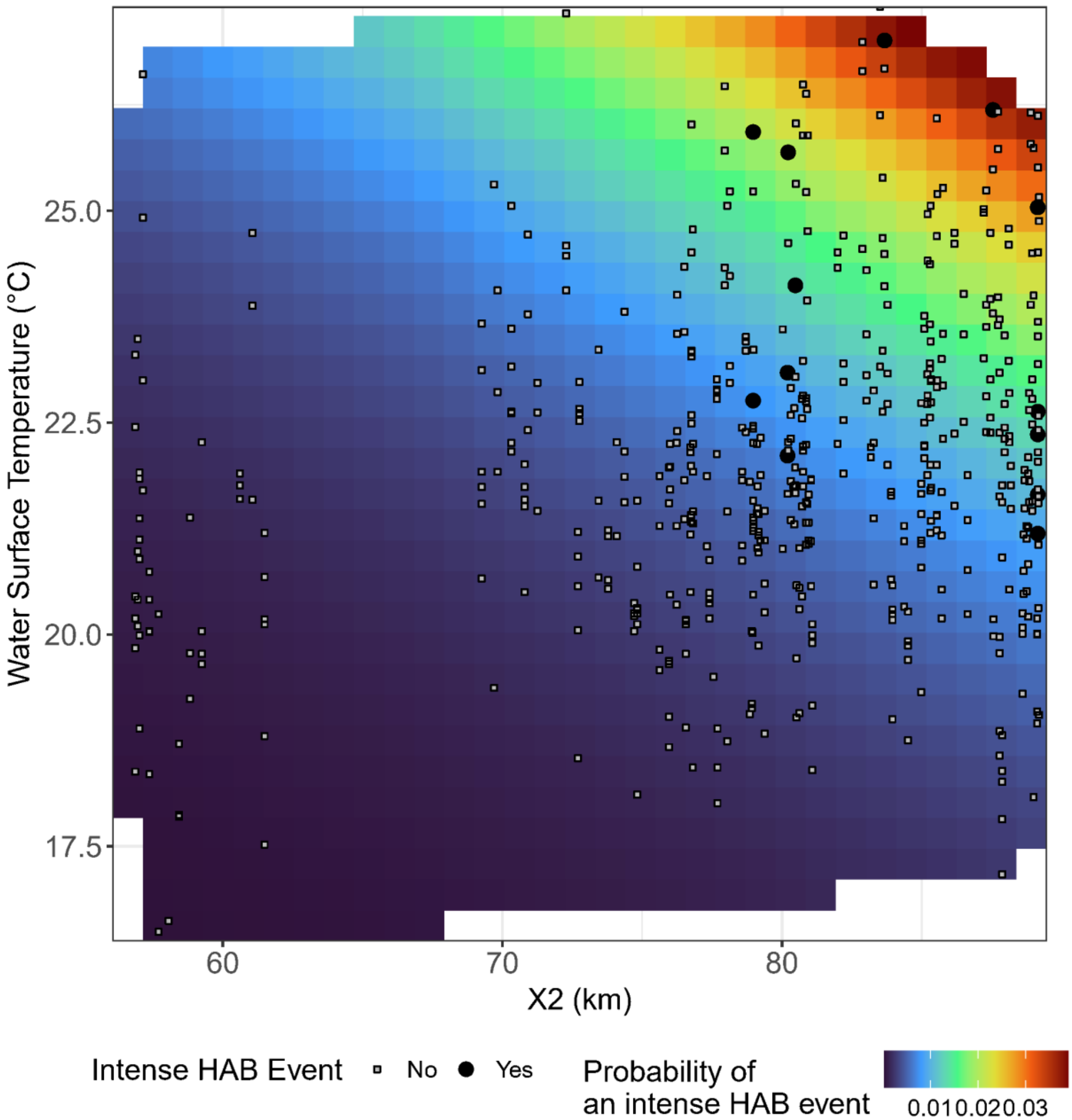

Figure 52. Heatmap of probability of a harmful algal bloom (HAB) event in a given day as a function of historically observed combinations of X2 and water surface temperature in the summer, while keeping dissolved ammonia, dissolved silica, and surface water pH equal to their mean. Black dots represent hydrological conditions during HAB events in the summer.

5.5. Effects of Georgiana Slough Salmonid Migratory Barrier on Routing and Survival

The Georgiana Slough Salmonid Migratory Barrier Project, which is comprised of a Bio Acoustic Fish Fence (BAFF) system spanning the majority of Georgiana Slough, provides an important deterrent at the Sacramento River-Georgiana Slough junction and is expected to provide a higher probability of juvenile survival to Chipps Island for emigrating CHNWR and CHNSR. While the barrier serves as a minimization measure for long-term operations of the SWP, the barrier could have additional impacts on White Sturgeon that are currently not well studied. Sturgeon are known to avoid turbulent flow conditions such as those produced by the BAFF system (USBR 2019). Both the Sacramento and San Joaquin rivers are part of White Sturgeon rearing habitat, and Georgiana Slough may be a route sturgeon use to move between rivers. While the predation risks along different routes are unknown, an increased predation risk in alternative movement routes as well as increased predatory risk adjacent to the in-water barrier components cannot be discarded, as that increased predatory risk has been observed for salmon (DWR and Reclamation 2012; DWR 2015). It is unknown if the BAFF attracts a greater number of predators to the site, though it is possible that the barrier also acts as a deterrent to predators (DWR and Reclamation 2012). In pilot studies, the BAFF was found to deter predators when operating and there was no indication that the structure provided holding habitat for predatory fishes. However, certain species of predatory fishes may become conditioned to the barrier over time (DWR 2015). It is also possible that take of White Sturgeon due to the Georgiana Slough Salmonid Migratory Barrier may occur if there is an increased risk of vessel strikes associated with an increased time in the Sacramento River.

DWR documentation for the BAFF notes that the design for the barrier may allow for the passage of larger sensitive species, like adult Chinook Salmon, with a clearance of at least 1.5-2 ft between the barrier frame and the stream channel bottom (DWR 2015). However, this clearance does not satisfy the fish passage criteria for sturgeon, for which a clearance of 3-5 ft between the barrier and the stream channel bottom is recommended (USBR 2019). By increasing the depth clearance of the BAFF system to 3 ft for the passage of White Sturgeon, impacts associated with the Georgiana Slough Salmonid Migratory Barrier may be minimized.

5.6. Effects of Summer and Fall Habitat Actions on White Sturgeon

The purpose of the Summer and Fall Habitat Action is to reduce salinity in the major channels that supply Suisun Marsh and Grizzly Bay through the operation of the Suisun Marsh Salinity Control Gates (SMSCG) and adjusting operations to achieve a monthly average X2 of 80 km in September and October of above normal and wet years. Adult and juvenile White Sturgeon are present in these habitats during this time of year and may be impacted by operations of the SMSCG; however, the number of individuals that could encounter the SMSCG is not well understood due to lack of data. Boat lock passage is available when the gates are closed to limit the impediment window for individual White Sturgeon moving through the area. Increased acoustic tagging of adult and juvenile White Sturgeon will help to inform how many White

Sturgeon interact with the SMSCG facility and if their movements are impeded as a result of the operations.

Operation of the SMSCG from September through May to meet salinity standards set by the SWRCB and Suisun Marsh Preservation Agreement coincides with the winter and spring upstream migration period of adult White Sturgeon, as well as with the general occurrence of adult and juvenile White Sturgeon in the SFE (Miller et al. 2020). The degree to which operations of the SMSCG impact White Sturgeon is unknown, however, SMSCG operational criteria remain constant for both the Proposed Project and Baseline Conditions and SMSCG operations for Delta Smelt Summer and Fall Habitat Actions are distinct from operations to meet salinity standards.

5.7. Effects of Skinner Fish Protection Facility Improvements on White Sturgeon

DWR periodically conducts maintenance and improvement projects at the Skinner Fish Facility that may impact the salvage of White Sturgeon. When these operations take place, there is a window of time that salvage operations are disrupted, leading to a potential increased loss due to entrainment. Due to the seasonal variability in the probability of sturgeon salvage, the timing of these maintenance and improvement projects determines their impact on White Sturgeon (see Section 5.3). The one-week spring maintenance and inspection window at the end of April through mid-May may potentially lead to increased entrainment of upstream migrating adults and downstream migrating larval and juvenile White Sturgeon if salvage operations are disrupted (See Section 5.3). The one-week summer herbicide and algicide treatment window at the end of June though the first week in July may lead to increased impacts and take of all life stages of White Sturgeon that are present in CCF (See Section 5.12). The one-week fall herbicide and algicide treatment window in October may lead to increased impacts and take on all life stages of White Sturgeon that are present in CCF (See Section 5.12). Periodically, DWR establishes new release site improvements for salvaged fish to reduce predation-related losses. These improvements would be most beneficial to smaller-sized individuals due to their increased predation vulnerability.

5.8. Effects of Smelt Habitat Restoration on White Sturgeon

DWR Is required to complete 8,000 acres of tidal habitat restoration, 209.49 acres of mesohaline habitat restoration and an additional 396.3 acres of tidal wetland habitat restoration to benefit DS and LFS. White Sturgeon have been documented to use all estuarine habitat types throughout their range; however, the extent to which they occupy shallow tidal wetlands in the SFE remains uncertain. Patton et al. (2020) found that sturgeon rarely use the shallow tidal wetlands at Rye Island in the Delta. However, sturgeon have been documented using shallow tidal creeks and wetlands more frequently in San Pablo and San Francisco bays (Moyle 2002; Leidy 2007).

5.9. Effects of Water Transfers on White Sturgeon

The July through November water transfer window established through the 2020 SWP ITP (CDFW 2020) will remain unchanged for both Baseline and Proposed Project operational scenarios. Salvage of White Sturgeon does occur at the SWP facility during the transfer window and continued take is expected to be consistent with previous operational scenarios (Figure 33-Figure 36).

5.10. Effects of South Delta Temporary Barriers Project on White Sturgeon

Operation of the south Delta temporary barriers may begin as early as May 1st and extend through November 30. This time period partially overlaps with the adult winter and spring upstream spawning migration period for White Sturgeon through the Delta (See Section 4.1.4), creating a possible impediment to spawning on the San Joaquin River and its tributaries. This operational timing also overlaps with larval and juvenile downstream migration and affects non-migrating juvenile adult White Sturgeon in the Delta that may encounter the barriers and have movement blocked, potentially slowing travel time or increasing residency time leading to take from predation. However, the implementation of agricultural barriers in the south Delta would not change between the Baseline Conditions and alternative Proposed Project operational scenarios.

5.11. Effects of Baker Slough Pumping Plant on White Sturgeon

Operations of the Baker Slough Pumping Plant (BSPP) would be expected to have minimal effects on White Sturgeon because BSPP fish screens are designed using NMFS fish screen criteria for salmonids to prevent entrainment and minimize impingement of juvenile fishes larger than 25 mm (NMFS 2023). These criteria include a low approach velocity that is generally below recommended water flow velocity to protect White Sturgeon juvenile and adult life stages present in the area (Verhille et al. 2014). As described in Section 4.1.5 & 4.1.8, White Sturgeon larvae may occur in the bays and Delta during spring, especially in higher outflow years, making them susceptible to entrainment through the fish screens given that no recommended approach velocity has been estimated for larval White Sturgeon (Verhille et al. 2014).

5.12. Effects of Clifton Court Forebay Weed Management on White Sturgeon

The number of White Sturgeon that enter the CCF, how long they reside, and whether they exit via the radial gates is currently unknown. White Sturgeon may be exposed to herbicide treatments, but the effects of copper or Aquathol K (endothall-based) treatments in the form of direct harm or mortality is unknown. However, NMFS presumes that these treatments have a similar effect on sturgeon as they do on Rainbow Trout and outmigrating Chinook Salmon (Rea 2015; 2017 as referenced in the ITP Application).

Mechanical removal of aquatic weeds in CCF occurs on an as-needed basis; therefore, could coincide with the occurrence of White Sturgeon. Occurrence near mechanical removal activities is more likely if both fish and weeds are concentrated into areas by prevailing water movement in CCF. Any potential adverse effects on individual White Sturgeon from mechanical removal of water hyacinth or other aquatic weeds, such as injury from contact with cutting blades, could result in take of White Sturgeon.

5.13. Effects of OMR Management on White Sturgeon

Old and Middle River (OMR) flow provide a surrogate indicator for how export pumping at Banks and Jones pumping plants influence hydrodynamics in the south Delta. The management of OMR flow, in combination with other environmental variables, can minimize entrainment of fish into the south Delta, the Banks Pumping Plant, and the Skinner Fish Facility. DWR manages OMR flow by changing exports at the Banks Pumping Plant in response to real-time operating criteria. Condition of Approval 8.3 requires DWR to reduce exports to achieve a 14-day average OMR index no more negative than -5,000 cfs during the duration of the OMR Management season (January through June). OMR Management can begin any time after December 1 if a First Flush Action (Condition of Approval 8.3.1) or Adult Longfin Smelt Entrainment Protection Action (Condition of Approval 8.3.3) occur, or any time after December 20 if an Adult Delta Smelt Entrainment Protection Action (Condition of Approval 8.3.2) occurs. Condition of Approval 8.6 allows OMR Management for DS, LFS, CHNWR, and CHNSR to end before June 30 if specific water temperature threshold exceedances occur earlier. Specifically, Permitee may conclude OMR Management for CHNWR and CHNSR on June 30, or when the following conditions have been observed, whichever occurs first:

- Daily average water temperature at Mossdale (MSD) exceeds 22.2°C for seven days (does not have to be consecutive) in June, and
- Daily average water temperature at Prisoner's Point (PPT) exceeds 22.2°C for seven days (does not have to be consecutive) in June.

DWR may conclude OMR Management for DS and LFS on June 30, or when the Daily mean water temperature at CCF (CDEC station CLC) is 25°C or higher for three consecutive days.

White Sturgeon benefit from extending the OMR Management season into June by reducing the number of entrained YOY White Sturgeon during the early months of summer, as observed by an increased salvage of YOY White Sturgeon during summer months (Figure 25).

6. Minimization of Take and Impacts of the Taking on White Sturgeon

The following sections describe how Conditions of Approval included in the 2024 SWP ITP will minimize take of White Sturgeon and impacts of the taking by Project infrastructure and operations.

6.1. Condition of Approval 7.10.1 White Sturgeon Science Program

This Condition of Approval requires the DWR to continue the White Sturgeon Science Program (WSSP). The WSSP shall include representatives from DWR and CDFW and allow for participation by USFWS, NMFS, Reclamation, and SWP Contractors. The primary goal of this effort is to inform management of White Sturgeon and to identify potential additional management actions to improve the population. DWR shall prepare a draft White Sturgeon Science Plan, in collaboration with CDFW, that describes new science needed to further the understanding of White Sturgeon ecology, stressors, and impacts, as a result of SWP operations, by July 12, 2025. The Plan shall include, but is not limited to, the following science priorities:

- A science plan for the development of a mathematical life cycle model for White Sturgeon, verified with field data collection, as a quantitative tool to characterize the effects of abiotic and biotic factors on White Sturgeon abundance and distribution, including major mortality events due to HABs;
- New and ongoing monitoring that:
  - Characterizes the distribution and abundance of adult, sub-adult, juvenile, and larval life stages;
  - Quantifies White Sturgeon entrainment into CCF to better understand factors that may contribute to White Sturgeon entrainment and residency in CCF;
  - Surveys CCF to inform presence and holding locations of White Sturgeon in CCF;
  - Monitors the entrance of CCF to better document the timing of White Sturgeon entrainment into CCF;
  - Collects necessary data to develop a future life cycle model including somatic growth as well as estimates of survival probabilities among life stages;
  - Characterizes changes in abundance and distribution of life stages across a range of hydrologic conditions, including varying ranges of X2 and water year types;
  - Considers revisions to existing IEP monitoring programs to expand the spatiotemporal distribution of sampling; and
  - Addresses factors that influence White Sturgeon catchability and gear efficiency;
- Improved understanding of White Sturgeon spawning, egg development, rearing habitat distribution and use in the spawning rivers, Delta, and Suisun Marsh;

- A White Sturgeon salvage prediction tool for generating a near-term forecast of the probability of future salvage designed to inform real-time operations; and
- Quantification of the lethal and sublethal impacts of HABs on White Sturgeon to support the White Sturgeon life cycle model development.

The White Sturgeon Science Program may also include the following actions:

- Development of a genetic management plan to support the use of cultured White Sturgeon for research purposes;
- Provide input to inform implementation of Condition of Approval 8.4.7;
- Improved understanding of the genetic diversity within California White Sturgeon; and
- White Sturgeon-specific studies of fish screen efficiency at Skinner Fish Facility and loss within CCF.

Under this Condition of Approval, DWR shall work collaboratively with the WSSP to consider edits and comments on the draft White Sturgeon Science Plan while preparing the final Plan. The final White Sturgeon Science Plan shall be submitted to CDFW within one year following submission of the draft plan, for approval by CDFW. After the final Plan is approved in writing by CDFW, DWR shall fund and implement required monitoring and science according to the timelines specified in the final White Sturgeon Science Plan. At a minimum, DWR shall convene the WSSP quarterly every year following initiation of the final White Sturgeon Science Plan to:

- Review data obtained from new and ongoing monitoring programs;
- Review methods used to implement monitoring and recommend adjustments as they deem appropriate; and
- Review draft results from new and ongoing science.

Condition of Approval 7.10.1 White Sturgeon Science Program requires the creation of a WSSP to prepare a White Sturgeon Science Plan to inform a systematic and transparent approach to new and ongoing science to address and prioritize key uncertainties related to White Sturgeon ecology, stressors, and Project impacts. Given the uncertainties regarding White Sturgeon stressors, distribution, and population status, this is a necessary measure to allow for the refinement of existing measures and development of appropriate and effective future actions to minimize Project impacts by: improving our general understanding of the species ecology through monitoring, modeling, and general data assessment; helping to identify the drivers of the potential impacts of the taking by life stage and or seasonality; allowing for the quantification of impacts with appreciation for inherent uncertainty; and informing meaningful ways to minimize those impacts relative to Project operations and future actions. This Condition of Approval will minimize effects of Project operations on White Sturgeon by facilitating ongoing science and monitoring needed to inform real-time operations and refinement of Conditions of Approval in the ITP.

6.2. Condition of Approval 7.10.2 Larval White Sturgeon Salvage Monitoring and Reporting

Condition of Approval 7.10.2 requires DWR to implement larval White Sturgeon salvage monitoring and reporting at the Skinner Fish Facility to identify the presence of White Sturgeon larvae ≥20 mm. Larval White Sturgeon salvage monitoring, and salvage data, will be provided to CDFW according to existing methods of salvage data transmission for all other Covered Species.

Condition of Approval 7.10.2 will minimize take of White Sturgeon by improving our understanding of salvage within the south Delta export facilities and allowing for real-time assessment of sturgeon entrainment and salvage data associated with Project operations. This data will also inform the collaborative discussion which will take place if the White Sturgeon Monitoring Team (Condition of Approval 8.1.3) is convened per Condition of Approval 8.4.7.

6.2.1 Condition of Approval 7.5.2 Skinner Delta Fish Protective Facility Improvement Process, Condition of Approval 7.10.2 Larval White Sturgeon Salvage Monitoring and Reporting, and Condition of Approval 8.13 Skinner Fish Protective Facility CDFW Staff

The Skinner Fish Facility minimizes losses resulting from fish entrainment at Banks Pumping Plant by relocating salvaged fish and producing data to inform risk assessments of fish entrainment. DWR operates the facility to capture fish entrained by Banks Pumping Plant into CCF. Salvage of fish occurs at the Skinner Fish Facility whenever Banks Pumping Plant is actively pumping. Fish are salvaged in the Skinner Fish Facility every 120 minutes and monitored during a 30-minute fish count. Salvaged fish are transported by truck to release sites near the confluence of the Sacramento and San Joaquin rivers.

Condition of Approval 7.5.2 requires DWR to continue to refine and improve Skinner Fish Facility fish sampling procedures and infrastructure to improve accuracy and reliability of data and fish survival. Specifically, Condition of Approval 7.5.2 requires DWR to minimize impacts from excessive debris, such as reduced counts resulting from required maintenance activities, through continued implementation of fall herbicide application to CCF and completion of a

Debris Management Effectiveness Study to analyze the effectiveness of CCF herbicide application on debris management procedures. If the results of the Debris Management Effectiveness Study identify feasible additional improvements that require further development and/or prioritization, an SDM process may be utilized to develop improvement requirements including design criteria and/or procedures to implement the study recommendations (e.g. alternative methods of managing fish counts during periods of heavy debris and/or large numbers of fish).

Within one year from issuance of the ITP, DWR will submit a draft Debris Management Effectiveness Study Plan to CDFW for approval. The Debris Management Effectiveness Study Plan will include a timeline for study completion, and an SDM process for alternatives development, and design criteria development with participation from DWR, CDFW, NMFS and USFWS. At the conclusion of the SDM process, DWR will submit the SDM recommendations to CDFW for approval and will implement recommendations within two years. These improvements should help estimates of White Sturgeon caught in salvage be more accurate, thus minimizing the Project's effects on White Sturgeon.

Historical salvage records of White Sturgeon include a single larval White Sturgeon individual (<30 mm, Figure 23). Improvements in sampling procedures and infrastructure at the Skinner Fish Facility will also adhere to Condition of Approval 7.10.2, which states that larval White Sturgeon greater than, or equal to, 20 mm shall be monitored and salvaged at the Skinner Fish Facility. These data must be provided to CDFW according to existing methods of data transmission as per all other species.

Under Condition of Approval 7.5.1, DWR will provide Reclamation, CDFW, USFWS, and NMFS notice of salvage disruptions due to planned facility maintenance (planned outages) in an annual maintenance plan. For unplanned facility maintenance, notice will be provided as soon as practicable. In the event of an unplanned outage (e.g., power disruption) extending beyond one hour, DWR will stop pumping, but may continue to operate the CCF radial gates.

Under Condition of Approval 8.13, DWR will fund two full-time Environmental Scientist and one Senior Environmental Scientist, Specialist positions in CDFW's Fish Facility and Entrainment Unit to work collaboratively with DWR's Skinner Fish Facility staff. Duties of the CDFW's Fish Facility and Entrainment Unit staff include, but are not limited to: receiving daily salvage data from the Tracy Fish Collection Facility and Skinner Fish Facility, conducting QA/QC on salvage data and on the salvage database, training DWR's Skinner Fish Facility staff, overseeing salvage facility operations, working with DWR annually to review and revise the Skinner Delta Fish Facility Operations Manual, reviewing annual salvage reports, receiving notifications regarding inspections or maintenance of fish protective equipment, engaging in real-time decision making to determine whether reduced fish count times (reduced counts) at the Skinner Fish Protective Facility are appropriate, and participating in the Alternative Loss Estimation Pilot Study and the Debris Management Effectiveness Study.

The salvage process at the Skinner Fish Facility generates valuable data sources characterizing entrainment and take of White Sturgeon with a high amount of sampling effort. The duties performed by CDFW's Fish Facility and Entrainment Unit staff will ensure proper identification of White Sturgeon at the Skinner Fish Facility, which allows for an accurate calculation of salvage used to assess threshold exceedances for OMR Management. These staff members will also maintain consistency in operating to the established protocols to ensure continued generation of a robust dataset that has undergone QA/QC.

DWR, in collaboration with CDFW's Fish Facilities and Entrainment Unit, will develop and implement a revised written training curriculum for implementation in water year 2025 as identified in Section IV: Fish Identification of the 2021 DWR/CDFW Interagency Agreement for Fish Facilities Operation (DWR and CDFW 2021). Skinner Fish Facility will have access to a staff biologist from CDFW's Fish Facilities and Entrainment Unit for consultation to support Skinner Fish Facility staff, research studies, and special handling of tagged fish.

Conditions of Approval 7.5.4, 7.5.1, 7.10.2, and 8.13 will minimize take of Covered Species including White Sturgeon by improving accuracy of species identification and data collection during the salvage process, improving salvage database management to provide a robust and reliable dataset for informing management decisions, and improving fish survival through updated Skinner Fish Protective Facility operations.

6.3. Condition of Approval 8.1.3 White Sturgeon Monitoring Team

Condition of Approval 8.1.3 requires DWR to convene the WSMT with the core membership from DWR and CDFW. The WSMT will meet as needed throughout the year on the following business day if the thresholds in Condition of Approval 8.4.7 are met. This allows for joint participation to review hydrologic, SWP and CVP operational, fishery, and water quality data, and provide opportunities for engagement and discussion among biologists and operators on relevant information and issues associated with the Project and risk assessment. Any potential differences in opinion among DWR and CDFW WSMT members shall be noted and elevated to WOMT as described in Condition of Approval 8.1.4, and operational decisions shall be made following the process described in Condition of Approval 8.1.5 (Collaborative Approach to Real-time Risk Assessment). The WSMT will continue to convene as necessary throughout the year. This Condition of Approval will minimize impacts to White Sturgeon by facilitating implementation of the real-time operating Condition of Approval (8.4.7) focused on White Sturgeon.

6.3.1 Condition of Approval 8.1.4 Water Operations Management Team and Condition of Approval 8.1.5 Collaborative Approach to Real-time Decision Making

Condition of Approval 8.1.4 requires DWR to convene the WOMT, composed of manager-level representatives from DWR, CDFW, NMFS, Reclamation, USFWS, and SWRCB each week during the OMR flow management season (October through June), and otherwise as needed. WOMT considers expert advice provided by the WSMT, Salmon Monitoring Team (SaMT), and Smelt Monitoring Team (SMT) to make final determinations for Covered Species minimization needs and Delta water operations. The WOMT has the authority to request operational changes at the CVP and SWP export facilities to manage OMR flows to an average daily OMR index less negative than the current daily OMR index. Condition of Approval 8.1.5 (Collaborative Approach to Real-time Decision Making) describes the process by which all available biological, abiotic, and operational information to inform operational recommendations will be transmitted from the Monitoring Teams to the WOMT, and to the Directors of CDFW and DWR if resolution is not achieved in WOMT. If the Directors of CDFW and DWR do not agree, the Director of CDFW may require DWR to implement an operational recommendation provided by CDFW. Reduced exports typically associated with increased OMR flows in response to risk assessments and operational advice will reduce entrainment of juvenile White Sturgeon into the export facilities (Section 5.3 - Effects of South Delta Export Operations on Salvage of White Sturgeon). Additionally, these Conditions of Approval will minimize impacts to White Sturgeon by facilitating implementation of the real-time operating Condition of Approval (8.4.7) focused on White Sturgeon.

6.4. Condition of Approval 8.3 Onset of OMR Management

Condition of Approval 8.3 requires DWR to adjust exports to achieve a 14-day average OMR index no more negative than -5,000 cfs throughout the duration of OMR Management. OMR Management is intended to minimize take of Covered Species emigrating through the Delta, by creating less negative net OMR flows during the time that Covered Species are expected to be present in the Delta and at risk of entrainment into the interior and south Delta. Less negative net OMR flows are accomplished through CVP and SWP export reductions and help reduce entrainment of Covered Species into the interior Delta and the CVP and SWP export facilities in the south Delta. For junctions on both the Sacramento River and San Joaquin River, a -5,000 cfs OMR reverse flow limit provides protection compared to more negative OMR reverse flow levels that would exert a larger influence on flow routing at distributary junctions and, thus, on juvenile routing and survival (SST 2017).

OMR Management can begin any time after December 1 if a First Flush Action (see Section 6.7; Condition of Approval 8.3.1) or Adult Longfin Smelt Entrainment Protection Action (see Section 6.7; Condition of Approval 8.3.3) occurs, or any time after December 20 if an Adult Delta Smelt Entrainment Protection Action (see Section 6.7; Condition of Approval 8.3.2) occurs. DWR will reduce exports to achieve a new OMR index within three days of an action that requires changes to OMR flows (Condition of Approval 8.1.7). If none of these actions occur in December, OMR Management begins automatically on January 1 and can extend through the end of June (see Section 6.2.11 – End of OMR Management; Condition of Approval 8.6). Juvenile White Sturgeon are present in the Delta during all months of the year, so any reduction in exports typically associated with a more positive OMR flow benefits them through reduced risk of entrainment (Section 5.3 - Effects of South Delta Export Operations on Salvage of White Sturgeon).

6.5. Condition of Approval 8.4.7 White Sturgeon Entrainment Protection Action

Condition of Approval 8.4.7 aims to minimize the entrainment and subsequent take of White Sturgeon through the development of a risk assessment and coordinated actions. If the following conditions are met, DWR will convene the White Sturgeon Monitoring Team (WSMT – Condition of Approval 8.1.3) the following business day:

- Young of year (YOY) White Sturgeon have been detected in at least one of the following north or central Delta survey stations in the last 90 days: 20mm Survey stations 705, 707, 711, 716 or Bay Study Survey stations 751, 760, 761, and
- The mean total exports of the last 90 days are greater than, or equal to, the exports defined by the following equation:

$$Exports_{90-day\ average} = 14{,}296.76\ +\ -0.41 Vernalis\ Flow_{90-day\ average}$$

Upon convening, WSMT will review all available information to develop an assessment of further entrainment and salvage of WS including:

- Data from new and ongoing science and monitoring;
- Biological modeling and data analysis;
- Hydrologic data, SWP and CVP exports and operations, and hydrologic model output; and
- Available information to estimate residence time in CCF

Condition of Approval 8.4.7 will minimize take of White Sturgeon by establishing a real-time operations measure, through which the WSMT will convene to discuss data, salvage, and other pertinent biotic and abiotic factors pertaining to White Sturgeon, if YOY White Sturgeon are detected in specified north or central Delta survey stations and mean total exports exceed Vernalis Discharge Gage-specific threshold, based on historical salvage data and trends. Condition of Approval 8.4.7 requires WSMT CDFW and DWR representatives to develop a risk assessment and supporting documentation to inform discussions and considerations of operational actions in WOMT. Because data shows that salvage of White Sturgeon has occurred year-round, this measure could apply at any time, if triggered. CDFW staff also considered salvage at CVP to be an indicator of risk of take at the SWP, because of the projects' proximity to each other and the SWP's influence on hydrodynamics, and consequently risk to White Sturgeon.

OMR Management in response to loss of Covered Species and their surrogates at the south Delta export facilities will help minimize take of White Sturgeon emigrating through the Delta. Management of OMR flows is recognized to help reduce negative effects on White Sturgeon via the reduction of exports at the facilities (See Section 5.3 – Effects of South Delta Export Operations on Salvage of White Sturgeon). OMR Management was designed to reduce negative net OMR flows when real-time OMR restrictions are triggered by loss of Covered Species at the CVP and SWP export facilities. A less negative net OMR flow is typically accomplished by export reductions at the CVP and SWP export facilities. OMR restrictions and potential export reductions can provide protection for White Sturgeon by reducing further entrainment into the interior Delta and the CVP and SWP export facilities. As presented in Section 5.3 - Effects of South Delta Export Operations on Salvage of White Sturgeon, higher numbers of juvenile White Sturgeon are salvaged during times when exports are higher. Reduced exports typically associated with more positive OMR flows will reduce the entrainment of juvenile White Sturgeon into the export facilities. Regulating OMR flows and exports will prevent or reduce the number of fish entrained into the interior Delta and the CVP and SWP export facilities, where they would experience high mortality rates. An OMR flow index (OMR index) will be calculated using an equation published by Hutton (2008) and used to determine CVP and SWP export limitations described in the sections below.

6.6. Condition of Approval 8.4.8 Evaluate and Develop Alternative White Sturgeon Entrainment Minimization During Real-time OMR Management

Condition of Approval 8.4.8 requires DWR, in coordination with CDFW, to use the best available science and information made available from the WSSP (Condition of Approval 7.10.1) to develop an alternative approach to minimizing White Sturgeon entrainment and salvage at the SWP and CVP export facilities by 2027. This alternative approach will refine Condition of Approval 8.4.7 based on new knowledge and understanding White Sturgeon, and estimates of White Sturgeon loss in CCF. Potential minimization approaches may include, but are not limited to, the following science priorities:

- The development of a loss equation to estimate juvenile White Sturgeon loss at the CVP and SWP export facilities.
    - There is currently no loss equation available to estimate loss of White Sturgeon at the CVP and SWP export facilities. The development of a loss equation should be comprised of four main components, each associated with mortality: pre-screen loss, screening (louver) efficiency, salvage, and handling and trucking loss (CDFW 2018).
- The development of additional larval and juvenile White Sturgeon entrainment monitoring and protection actions.
    - Currently, there are no White Sturgeon specific long-term monitoring actions established with the aim of improving the understanding of the presence and movement of larval and juvenile White Sturgeon in the immediate vicinity of CCF and the south Delta export facilities. Ongoing larval surveys in the SFE use gear that focuses on pelagic fish larvae and are conducted during the day for safety reasons. However, larval White Sturgeon are known to feed and disperse primarily during the night which makes it difficult for these surveys to detect them (Kynard and Parker 2005). Amendments to current monitoring programs as well as the developments of new ones, should focus on specific aspects of White Sturgeon life-histories to help improve detection rates.

6.7. Conditions of Approval 8.11.1 Operation of Georgiana Slough Salmonid Migratory Barrier and 7.9.6 Georgiana Slough Salmonid Migratory Barrier Effectiveness Studies

Condition of Approval 8.11.1 requires DWR to continue to annually install and operate the Georgiana Slough Salmonid Migratory Barrier Project through the duration of the 2024 SWP ITP to deter outmigrating juvenile CHNWR and CHNSR from entering the interior Delta, consistent with the Adaptive Management Program for the 2024 SWP ITP (see Attachment 4 to the 2024 SWP ITP). This ongoing effort was initiated in 2021 under the 2020 SWP ITP Condition of Approval 8.9.1 (CDFW 2020) and DWR will adhere to the existing Georgiana Slough Salmonid Migratory Barrier operations and monitoring plans, and any updates to these plans, developed jointly by DWR, CDFW, NMFS, and USFWS (see Section 4.1.6 – Rearing and Outmigrating Juveniles in the Bay-Delta; CDFW 2020, DWR 2022b, DWR 2022a). DWR (2022b) identified the BAFF as the preferred barrier technology to be installed at the junction of the Sacramento River and Georgiana Slough. The BAFF consists of acoustic transmitters, a bubble curtain to capture the sound, and a light array to illuminate the bubble curtain and simulate a physical barrier. DWR will operate the barrier annually no later than November 16 through April 30, and potentially into May, based on availability of power resources (DWR 2022b).

The operations period overlaps with White Sturgeon adult upstream and downstream spawning migrations along with downstream larval and juvenile migration. DWR installed and began full operation of a BAFF on November 29, 2023 (DWR 2023). The installation of the BAFF requires it be anchored to the streambed of the Sacramento River, which potentially creates a physical barrier to movement underneath the structure. To allow for passage of benthically oriented adult White Sturgeon, a recommendation of three (3) foot depth and ten (10) foot width minimum passage has been established by DWR and Reclamation (2012). This indicates that the framing that attaches to the pilings along with any cables, hoses, and other structures need to be attached in a way that allows for a minimum of 3 ft from the bottom to allow for passage.

6.8. Condition of Approval 8.12 Spring Delta Outflow

Condition of Approval 8.12 requires DWR to protect Delta outflow during the months of March, April, and May to minimize take of Covered Species, including White Sturgeon, by reducing entrainment into the interior Delta and south Delta CVP and SWP export facilities, as well as providing greater quantity and quality of rearing habitat in the Delta from increased water availability. These benefits of spring Delta outflow are anticipated to increase survival of downstream dispersing larval and juvenile White Sturgeon. Spring Delta outflow will be achieved initially through export curtailments as described in ITP Condition of Approval 8.12.1. During years when the Healthy Rivers and Landscapes Program (HRL) is implemented DWR shall implement Condition of Approval 8.12.2 to provide 50 TAF of Delta inflow that is dedicated to Delta outflow in March of dry, below normal, and above normal water years. DWR may provide flows in April or May, if approved by CDFW. As required by Condition of Approval 8.12.2 DWR shall also provide 92.5 TAF of SWP south Delta foregone exports in April and May of dry and below normal years and 117.5 TAF in above normal water years. DWR conducted a comparison of the water volumes in Table 5 of the ITP to the outflows that would be expected, on average, in above normal, below normal, and dry water year types if Condition of Approval 8.12.1 was implemented and concluded that they are equivalent (DWR 2024c).

The two Spring Delta Outflow options are represented in CalSim 3 modeling as two different Proposed Project scenarios. The ITP_Spring modeling scenario incorporates all proposed SWP operations associated with Condition of Approval 8.12.1. The 9A_V2A modeling scenario incorporates all proposed SWP operations and DWR's contribution to HRL as required by Condition of Approval 8.12.2. See Section 5.2 – Effects of South Delta Export Operations on Year Class Strength of White Sturgeon and Appendix C – CalSim Modeling Results for additional details on CalSim 3 modeling of the Proposed Project.

8.9. Condition of Approval 8.15 Relationship Between the Adaptive Management Program and the 2024 SWP ITP

Condition of Approval 8.15 establishes the relationship between the Adaptive Management Program (ITP Attachment 4) and the 2024 SWP ITP. A goal of the Adaptive Management Program is to support existing and new monitoring and science to improve understanding of Covered Species ecology. The following actions described in Condition of Approval 7.10.1 of the ITP will serve to fill information gaps identified in this Effects Analysis and could be integrated into the Adaptive Management Program:

- Acoustic telemetry studies and analysis to better estimate White Sturgeon occupancy and migrations through the Delta and loss due to CVP and SWP operations.
- Development and finalization of the White Sturgeon Loss Equation to provide a more accurate estimate of sturgeon loss and loss parameters at the CVP and SWP export facilities.
- Potential impacts of the Georgiana Slough Salmonid Migratory Barrier annual operation on White Sturgeon (Condition of Approval 7.9.6); and

- Protection of Delta outflow during spring months (March – May) through SWP and CVP actions, and, potentially, SWP contributions towards the HRL, which would benefit recruitment of larval and juvenile white sturgeon (SWP share provided by Condition of Approval 8.12.2).

These additional monitoring, science, and management actions will elucidate impacts of the Project and facilitate the development of new measures to minimize take or impacts of the taking to White Sturgeon associated with Project impacts as required by Condition of Approval 8.4.8. Integration of science from the White Sturgeon Science Program and new approaches to minimization measures could occur through the Adaptive Management Program. In the Adaptive Management Program each action will have a dedicated Adaptive Management Technical Team comprised of technical staff representing DWR, CDFW, Reclamation, USFWS, and NMFS. The Adaptive Management Steering Committee will be responsible for support, coordination, and implementation of the Adaptive Management Program, and will be comprised of manager-level representatives from DWR, CDFW, Reclamation, USFWS, and NMFS. Condition of Approval 5 (Consultation Regarding Amendment) requires DWR to consult with CDFW regarding the need for an amendment to the ITP in response to changes recommended through the Adaptive Management Program or changes in response to an independent review panel.

6.10. Minimization of Effects of Maintenance at Clifton Court Forebay

DWR will conduct maintenance activities in CCF as described in Conditions of Approval 7.5.1, 8.14.2 and 8.14.3 (see Section 5.12 – Clifton Court Forebay Weed Management). DWR will employ specific practices to minimize impacts of CCF maintenance activities on Covered Species, including White Sturgeon.

Aquatic algae treatments are anticipated to occur on an as-needed basis to control aquatic weeds and algal blooms in CCF. DWR may apply herbicide and algaecide treatments to CCF consisting of peroxide-based aquatic algaecides year-round and Aquathol K and copper-based aquatic compounds from June 28 through October 31. Peroxide-based aquatic algaecides are considered non-toxic and will be applied up to 10.2 parts per million (ppm) hydrogen peroxide. Aquathol K, which has low toxicity to fish, will be applied up to 3 ppm, and Copper-based compounds, which are considered acutely toxic to fish, will be applied at a maximum concentration of 1 ppm to minimize impacts on Covered Species.

DWR will aim to avoid application of herbicide and algaecide treatments during times when Covered Species are present in CCF. Aquathol K and copper-based aquatic compounds may be applied, if necessary, prior to June 28 or after October 31 if the average daily water temperature within the CCF is greater than or equal to 25°C, and if Covered Species are not at additional risk. Before applying Aquathol K or copper-based aquatic compounds outside of the June 28 to October 31 time frame, DWR shall notify and confer with CDFW, NMFS and USFWS to determine whether ESA- or CESA-listed fish species are present and at risk from the proposed treatment. Following herbicide and algicide application using Aquathol K and copper-based aquatic compounds, CCF radial gates will remain closed for a minimum of 12 hours and up to 72 hours after treatment.

Mechanical boat-mounted aquatic weed harvesters will be utilized on an as-needed basis year-round. Environmental awareness training will be conducted for all personnel involved (Condition of Approval 6.4 – Education Program).

6.11. Minimization of Effects of South Delta Temporary Barriers Project

DWR will operate the South Delta Temporary Barriers Project as described in Condition of Approval 7.7 and Section 3.9 of the ITP Project Description (see Section 5.10 – Agricultural Barriers). Timing of barrier construction and removal, as well as barrier flap gate operations, will minimize take of White Sturgeon. Upstream migration of spawning adult White Sturgeon begins as early as December and ends around June (see Section 4.1.4– Spawning Migration of Adult White Sturgeon), partially overlapping the construction of the South Delta Temporary Barriers Project which starts annually at the beginning of May. Additionally, downstream dispersal of larval and juvenile White Sturgeon occurs during this period and into the summer months as well (see Section 4.1.5, 4.1.6, 4.1.7) and may be impeded by operations of the barrier. White Sturgeon have a greater risk of exposure to the barriers, during construction and operation, due to their timing and positions in migratory corridors and rearing habitats. Historically, YOY White Sturgeon salvage increases during the summer when they disperse downstream and rear in the Delta. At this same time, they would also be exposed to intermediate and full culvert operations.

To minimize impacts to Covered Species, DWR will keep all barrier flap gates tied open during barrier construction and will keep the Grant Line Canal Barrier flashboard structure open to allow for volitional fish passage. DWR (2018) evaluated the effects of the barriers and determined that juvenile salmonid survival improved during intermediate culvert operations (i.e., barriers installed with flap gates tied open) and declined during full operations. To allow for passage of benthically oriented adult White Sturgeon, a three (3) foot depth and ten (10) foot width minimum passage has been established by the Reclamation and DWR (DWR and Reclamation 2012). Following construction and approval from CDFW, NMFS, and USFWS, DWR may begin intermediate culvert operations after May 15 when all but one flap gate is untied at each barrier. The untied flap gates are set to operate tidally, allowing passage for White Sturgeon and other Covered Species during flap gate openings. Passage, however, is limited at the Grant Line Canal Barrier during intermediate culvert operation because the flashboard structure is closed. On June 1, or when the average daily water temperature measured at the Mossdale (MSD) station has reached 71.6°F (22°C), full operation with all flap gates operating tidally may begin.

Condition of Approval 7.7 requires DWR to seek written approval from CDFW prior to full operations of the barriers, and without approval DWR must continue intermediate operations. Condition of Approval 7.7 also requires DWR to seek written approval before raising the weir elevation of the barriers by one (1) ft on or after June 15.

By September 15, DWR must remove a section of the Old River at Tracy and the Middle River barriers (i.e., notch the weir) and remove the flashboard structure at the Grant Line Canal Barrier to provide passage for up-migrating adult salmonids and minimize the negative effects of delayed White Sturgeon migration timing. This requirement will minimize impacts to White Sturgeon present in the area and exposed to barrier operations.

6.12. Additional Minimization

Additional minimization measures are those Conditions of Approval included in the 2024 SWP ITP which are intended to minimize take and impacts of the taking to a Covered Species other than White Sturgeon but may provide ancillary protections to White Sturgeon when implemented. The following section briefly summarizes these additional Conditions of Approval and explains how they provide additional minimization for White Sturgeon.

Condition of Approval 8.2.1 - Natural-origin Winter-run Chinook Salmon Early Season Weekly Loss Thresholds

This Condition of Approval will limit exports to achieve a 7-day average OMR index of no more negative than -5,000 cfs for seven consecutive days when weekly loss of genetically verified CHNWR or CHNSR exceeds weekly loss thresholds. This Condition of Approval will be active from November 1 through December 31.

If Condition of Approval 8.2.1 thresholds are exceeded and exports are limited, it may reduce the take of White Sturgeon that are migrating through or residing in the Delta by reducing the magnitude of negative OMR flow via reduced exports typically associated with increased OMR flows, given exports are negatively correlated with entrainment of White Sturgeon (See Section 5.3 – Effects of South Delta Export Operations on Salvage of White Sturgeon).

Condition of Approval 8.3.1 – First Flush

This Condition of Approval will limit exports to maintain a 14-day average OMR index no more negative than -2,000 cfs for 14 consecutive days after the date when the first flush conditions are met. This Condition of Approval will be active between December 1 and the last day of February.

If Condition of Approval 8.3.1 initiates in any given water year, it may reduce the take of White Sturgeon that are migrating through the Delta via reduced exports typically associated with increased OMR flows, given exports are negatively correlated with entrainment of White Sturgeon (See Section 5.3 – Effects of South Delta Export Operations on Salvage of White Sturgeon).

Condition of Approval 8.3.2 – Adult Delta Smelt Entrainment Protection

Condition of Approval 8.3.2 limits south Delta exports to maintain a 5-day average OMR index no more negative than -3,500 cfs when the turbidity at OBI is 12 (FNU) or higher. This Condition of Approval will be active after the First Flush Action (Condition of Approval 8.3.1) or December 20, whichever comes first, and end when the three-day continuous average water temperatures at Jersey Point or Rio Vista reach 12 °C (typically in February or March).

If Condition of Approval 8.3.2 initiates in any given water year, it may reduce the take of White Sturgeon that are migrating through the Delta via reduced exports typically associated with increased OMR flows, given exports are negatively correlated with entrainment of White Sturgeon (See Section 5.3 – Effects of South Delta Export Operations on Salvage of White Sturgeon).

Condition of Approval 8.3.3 – Adult Longfin Smelt Entrainment Protection

Condition of Approval 8.3.3 limits south Delta exports for seven consecutive days between December 1 and the start of OMR Management to achieve a 7-day average OMR index no more negative than -5,000 cfs within three days of when cumulative water year salvage of LFS exceeds the salvage threshold defined in Condition of Approval 8.3.3. This Condition of Approval will also limit south Delta exports for seven consecutive days between the start of OMR Management to the end of February to achieve a 7-day average OMR index no more negative than -3,500 cfs after cumulative water year salvage of LFS exceeds the salvage threshold defined in the 2024 SWP ITP.

If Condition of Approval 8.3.3 initiates in any given water year, it may reduce the take of White Sturgeon that are migrating through or residing in the Delta via reduced exports typically associated with increased OMR flows, given exports are negatively correlated with entrainment of White Sturgeon (See Section 5.3 – Effects of South Delta Export Operations on Salvage of White Sturgeon).

Condition of Approval 8.4.1 – Larval and Juvenile Delta Smelt Entrainment Protection

Condition of Approval 8.4.1 limits south Delta exports to maintain a 7-day average OMR index no more negative than -3,500 cfs when the average Secchi depth in the central and south Delta is 1m or less across 12 stations in the 20-mm and SLS surveys (809, 812, 815, 901, 902, 906, 910, 912, 914, 915, 918, 919). This COA will be implementable as soon as the three-day continuous average water temperatures at Jersey Point or Rio Vista reach 12 °C (typically in February or March) through the end of OMR Management.

If Condition of Approval 8.4.1 initiates in any given water year, it may reduce the take of White Sturgeon that are migrating through or residing in the Delta via reduced exports typically associated with increased OMR flows, given exports are negatively correlated with entrainment of White Sturgeon (See Section 5.3 – Effects of South Delta Export Operations on Salvage of White Sturgeon).

Conditions of Approval 8.4.2 – Larval and Juvenile Longfin Smelt Entrainment Protection

Condition of Approval 8.4.2 will limit exports to maintain a 7-day average OMR index of no more negative than -3,500 cfs for seven days when larval and juvenile LFS catch at stations 809 and 812 by SLS or 20-mm Survey exceed the threshold. This Condition of Approval will also limit exports to maintain a 7-day average OMR index of no more negative than -3,500 or -2,500 cfs for 14 days when the cumulative juvenile LFS salvage at CVP and SWP facilities exceed 50% or 75% of the annual salvage from 2009 through the water year preceding the current water year respectively.

If the thresholds are exceeded at any time during the water year, it may reduce the take of White Sturgeon that are migrating through or residing in the Delta via reduced exports typically associated with increased OMR flows, given exports are negatively correlated with entrainment of White Sturgeon (See Section 5.3 – Effects of South Delta Export Operations on Salvage of White Sturgeon).

Condition of Approval 8.4.3 – Winter-run Chinook Salmon Annual Loss Threshold

This Condition of Approval will limit exports to maintain a 7-day average OMR index of no more negative than -3,500 or -2,500 cfs for seven consecutive days when annual loss of natural or hatchery CHNWR exceeds 50% or 75% of their respective calculated annual loss threshold. This Condition of Approval will apply to cumulative loss of CHNWR each year beginning on July 1.

If Condition of Approval 8.4.3 is triggered any time during the CHNWR salvage season, it may reduce the take of White Sturgeon that are migrating through or residing in the Delta by reducing the magnitude of negative OMR flow via reduced exports typically associated with increased OMR flows, given exports are negatively correlated with entrainment of White Sturgeon (See Section 5.3 – Effects of South Delta Export Operations on Salvage of White Sturgeon).

Condition of Approval 8.4.4 –Winter-run Chinook Salmon Weekly Distributed Loss Threshold

This Condition of Approval will limit exports to maintain a 7-day average OMR index of no more negative than -3,500 for seven consecutive days when the weekly loss of CHNWR exceeds the loss threshold. This Condition of Approval may be triggered anytime between January 1 and the end of OMR Management.

If the thresholds in Condition of Approval. 8.4.4 are exceeded at any time between January 1 and the end of OMR Management, it may reduce the take of White Sturgeon that are migrating through or residing in the Delta via reduced exports typically associated with increased OMR flows, given exports are negatively correlated with entrainment of White Sturgeon (See Section 5.3 – Effects of South Delta Export Operations on Salvage of White Sturgeon).

Conditions of Approval 8.4.5 - Spring-Run Chinook Salmon and Surrogate Annual Loss Thresholds

This Condition of Approval will limit exports to maintain a 7-day average OMR index of no more negative than -5,000 (in November or December) or -3,500 cfs (on or after January 1) for seven consecutive days when the cumulative loss threshold for each CHNSR surrogate groups is exceeded. This Condition of Approval will be active between November 1 through the end of OMR Management.

If the thresholds are exceeded at any time between November and the end of OMR Management, it may reduce the take of White Sturgeon that are migrating through the Delta via reduced exports typically associated with increased OMR flows, given exports are negatively correlated with entrainment of White Sturgeon (See Section 5.3 – Effects of South Delta Export Operations on Salvage of White Sturgeon).

Condition of Approval 8.10.1 Barker Slough Pumping Plant Larval Delta Smelt Protection and Condition of Approval 8.10.2 Barker Slough Pumping Plant Larval Longfin Smelt Protection

Conditions of Approval 8.10.1 and 8.10.2 require DWR to reduce BSPP diversions during spring months to protect larval DS and LFS during dry and critical water year types. Condition of Approval 8.10.1 requires DWR to reduce the maximum 7-day average diversion rate at the BSPP to less than 100 cfs between May 1 and June 30 of dry and critical water years if catch of larval DS in 20-mm survey at station 716 exceeds 5% of the total catch of larval DS across the north Delta. DWR will further reduce the 7-day average diversion rate at the BSPP to less than 60 cfs between March 1 and April 30 of dry and critical water years if catch of larval DS in 20-mm survey at station 716 exceeds 14% of the total catch of larval DS across the north Delta. Condition of Approval 8.10.2 requires DWR to reduce the maximum 7-day average diversion rate at the BSPP to less than 100 cfs between January 1 and March 31 of dry and critical water years to minimize entrainment of larval LFS.

Reducing the BSPP diversions during the spring months will reduce the potential entrainment of larval and juvenile White Sturgeon into the BSPP forebay and will have a beneficial impact on food web dynamics in the greater Yolo Bypass region by reducing the amount of prey items removed from the system through exports (see Smelt Effects Analysis, ITP Attachment 5, Sections 6.4.2 and 9.4.2).

7. Mitigation for Take and Impacts of the Taking on White Sturgeon

7.1. Condition of Approval 9.3 Mitigation for White Sturgeon

Under Condition of Approval 9.3 (Compensatory Mitigation for White Sturgeon) DWR will, in collaboration with CDFW, continue to convene and fund $150,000 to support the evaluation of potential habitat restoration project(s) within the Sacramento and San Joaquin rivers for White Sturgeon. The evaluation shall include but not be limited to scoping of potential restoration projects within the Sacramento and San Joaquin rivers. DWR will submit a draft report documenting the results of the scoping process, including associated restoration project recommendations to CDFW by April 12, 2025. DWR will submit a final report to CDFW within one year of April 12, 2025 for written approval by CDFW.

After approval by CDFW, and no later than April 12, 2030, DWR will develop a plan for additional habitat restoration to offset impacts of Project operations on White Sturgeon, in collaboration with CDFW. The plan will rely on the report prepared in 2025 and be informed by the White

Sturgeon Life Cycle Model developed as a part of the WSSP (Condition of Approval 7.10.1). Following CDFW approval, Permittee will provide $1,900,000 to implement the final plan. The funding allocated for the final plan may be adjusted based on an updated evaluation of the magnitude and scope of impacts of Project operations on the species, which adjustments may decrease or increase the obligation, with CDFW approval and determination that funding will provide sufficient restoration to continue to meet the full mitigation standard under CESA for this White Sturgeon. This Condition of Approval will benefit White Sturgeon by supporting the implementation of a project or projects that are selected based on the White Sturgeon Life Cycle Model to offset impacts of the Project.

7.2. Condition of Approval 9.2.2 Mitigation for Impacts Associated with Project Operations

Condition of Approval 9.2.2 requires DWR to fund $19.9 million in CHNWR and CHNSR compensatory mitigation. This funding is carried forward from the compensatory mitigation obligation originally established the 2020 SWP ITP Condition of Approval 9.2.1, which required DWR to fund $20 million over the term of the 2020 SWP ITP towards enhancement and restoration projects to benefit CHNWR and CHNSR in the Sacramento River watershed upstream of the Delta. Mitigation provided under the 2020 SWP ITP Condition of Approval 9.2.1 required DWR to fund habitat restoration that would benefit all life stages of CHNWR and CHNSR in upstream tributaries of the Delta where spawning, egg incubation, rearing, and emigration occurs (CDFW 2020). To date, DWR has funded $100,000 towards the 2020 SWP ITP Condition of Approval 9.2.1 in the form of a draft feasibility study for a Willow Bend habitat restoration project intended to improve habitat conditions for juvenile and adult CHNWR and CHNSR in the reach of the Sacramento River near Moulton Weir in Colusa County. The Willow Bend feasibility study was not finalized or approved by CDFW and there are currently no next steps for the restoration project identified (CDFW 2021). If pursued later, habitat restoration actions in the Willow Bend area would most likely benefit spawning adults along with rearing larval and juvenile White Sturgeon.

Under Condition of Approval 9.2.2, DWR is committed to funding $1 million by June 2025 towards the Sunset Weir and Pumps Project on the lower Feather River. The Sunset Weir and Pumps Project is identified as Alternative 3 in DWR's funded Alternatives Evaluation Study for the project. Alternative 3 includes the removal of the Sunset Pumps Diversion Dam, a boulder weir owned and operated by Sutter Extension Water District (SEWD), located on the lower Feather River near Live Oak in Sutter County. The project also includes modification of existing Sunset Pumps to operate at a lower water surface elevation and installation of fish screens on twelve diversions upstream of the existing weir with the intention of not adversely affecting water delivery capabilities (ESA 2023). Currently the Sunset Pumps Diversion Dam functions as a boulder weir to maintain water surface elevation at the pump intakes; however, hydraulic modeling has confirmed that the boulder weir is a fish passage barrier under most flow conditions (ESA 2023, Appendix A). Additionally, acoustic tag data has shown that higher predation near Sunset Pumps leads to a decrease in the survival of out-migrating juvenile Chinook Salmon and steelhead (ESA 2023). The same predation pressures would be applicable for White Sturgeon as well.

The objective of the Sunset Weir and Pumps Project is to improve fish passage by removing the existing boulder weir, a known migratory barrier to CHNFR, CHNSR, Central Valley steelhead, the Southern Distinct Population Segment (DPS) of North American Green Sturgeon (*Acipenser medirostris*), and White Sturgeon, and installing CDFW approved fish-protective screens for the Sunset Pumps diversion and upstream neighboring private diversions using NMFS fish screen criteria. Removing the boulder weir will restore 8 miles of the Feather River to a more natural riverine condition making it more suitable for salmonid spawning and rearing (ESA 2023). Upgrades to the pump station will allow it to function without the increased river stage provided by the boulder weir by lowering pump intakes by 11 ft (ESA 2023). Additionally, installing fish-protective screens on each diversion will reduce out-migrating juvenile salmonid and White Sturgeon mortality caused by entrainment into the currently unscreened diversions.

Funding for the Sunset Weir and Pumps Project provided by Condition of Approval 9.2.2 will improve upstream adult passage and spawning habitat and allow access to habitat that was formerly limited due to either structural or flow impediments. Increasing access to upstream habitat allows for spatial diversity in spawning that may increase juvenile production, life history diversity, and genetic diversity. Improving fish passage throughout the Sacramento River Basin would reduce migratory delays, open up more available spawning habitat, and could enhance ecosystem function through improved habitat connectivity.

7.3. Condition of Approval 9.2.1 Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project

Condition of Approval 9.2.1 requires DWR to complete the implementation of the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project (YBSHRFP Project) also known as “The Big Notch Project” by 2026 to enhance floodplain rearing habitat and fish passage in the Yolo Bypass, which will benefit a variety of species including White Sturgeon, CHNWR and CHNSR, Central Valley steelhead, and the Southern DPS of North American Green Sturgeon. The Big

Notch Project will allow increased flow from the Sacramento River to enter the Yolo Bypass through a gated notch on the east side of the Fremont Weir. From November to March 15, Sacramento River water can passively flow through the notch during periods when Sacramento River elevations are greater than 14 ft NAVD88. After March 15, Big Notch Project flows will be limited to prevent additional inundation through Fremont Weir (DWR 2020). The Big Notch Project will connect the new, gated notch to Tule Pond with a channel that parallels the existing east levee of the Yolo Bypass. It would allow flows up to approximately 6,000 cfs, depending on Sacramento River elevation, through the gated notch to provide flow for adult fish passage, juvenile emigration, and floodplain inundation for juvenile rearing habitat (DWR 2020). The Big Notch Project also includes a supplemental fish passage facility on the west side of the Fremont Weir and improvements to allow fish to pass through Agricultural Road Crossing 1 and the channel north of Agricultural Road Crossing 1. Objectives of the Big Notch Project include increased access to and acreage of seasonal floodplain rearing habitat for juvenile fish, reduction in fish stranding, increased aquatic biotic production to provide food through an ecosystem approach, and a reduction in migratory delays and loss of fish at Fremont Weir and other structures in the Yolo Bypass (DWR 2020).

CDFW will continue to operate the Wallace Weir Fish Collection Facility to capture and relocate adult salmonids and sturgeon. Monitoring efforts will record the number of salmonids and sturgeon caught at the fish collection facility during operations. Reclamation, DWR, and CDFW staff will visually inspect the Fremont Weir stilling basin, the deep pond, Tule Pond, and all channels incorporated into the Big Notch Project for stranded fish following operations. Additionally, CDFW periodically inspects the deep pond and Oxbow Pond for sturgeon presence following an overtopping event using Dual-frequency Identification Sonar (DIDSON) cameras and gill nets. Acoustic telemetry monitoring will occur during the first five years of operation of the Big Notch Project. Upstream-migrating adult CHNFR and White Sturgeon will be captured in the lower Yolo Bypass and affixed with acoustic transmitters. Receivers will be located downstream of the fish passage structure and upstream of the structure in the Sacramento River to provide information on fish passage success. Adaptive Resolution Imagining Sonar (ARIS) cameras will be used to confirm successful and unsuccessful sturgeon passage attempts at the structure entrance (DWR 2020). Monitoring juvenile fish entrainment and growth on the floodplain as well as adult passage will be imperative to assessing the goals of the Big Notch Project and ensuring benefits to species.

References

5 United States Code § 553(e). Rule Making.

16 United States Code § 1533(b). Determination of endangered species and threatened species.

50 Code of Federal Regulation § 424.14. Petitions for listing endangered and threatened species and designating critical habitat.

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Appendix A.

Data Sources and Limitations

CDFW conducted analyses for this Effects Analysis using the most comprehensive datasets available and attempted to use data from water years 2003 through 2023 whenever possible to best represent recent historical conditions. However, there were limitations of data from multiple datasets used in analyses that are of note. Limitations of source data stemmed from inconsistent funding for monitoring, incomplete QA/QC processes, and inconsistencies of data collection and reporting methodologies between and within monitoring programs that could not be resolved at the time this Effects Analysis was written. Additionally, salvage and loss values in the Effects Analysis (CDFW 2020b) for the 2020 SWP ITP (CDFW 2020a) may not harmonize completely with values found in this Effects Analysis due to methodology changes and updates to data sources that have occurred since completion of the previous Effects Analysis. Data used in this document are the best available and are newer versions of datasets that were used in the Effects Analysis for the 2020 SWP ITP.

The CDFW Bay-Delta Region salvage database (Affentoulis et al. 2024) contains salvage data for all White Sturgeon captured in salvage at both the CVP and SWP export facilities from January 1, 1993 to May 14, 2024.

Appendix A References

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Appendix B. CalSim Modeling Results

Appendix C includes CalSim 3 modeling results of Baseline Conditions and two Proposed Project scenarios (9A_V2A and ITP_Spring). Table B-1 through Table B-12 present CalSim 3 modeling results for mean Sacramento River flow at Freeport grouped by ater year type. Table B-13 through Table B-24 and Figure B-1 through Figure B-4 present CalSim 3 modeling results for mean monthly SWP south Delta exports grouped by water year type. Figure B-5 through Figure B-8 present mean monthly OMR flows grouped by water year type. CalSim 3 modeling results presented below are based on information CDFW obtained from DWR's November 2023 ITP Application (DWR 2023) and subsequent coordination with DWR.

B.1. Modeling Assumptions

CalSim 3 modeling conducted for DWR's ITP Application produced monthly water supply values for water years 1922 through 2021. Modeled Baseline Conditions assume existing CVP operations (under the implementation of the 2019 NMFS Biological Opinions (BO; NMFS 2019), the 2019 USFWS BO (USFWS 2019), and the water year 2022 and 2023 Interim Operations Plans – Export Curtailments for Spring Outflow (Pacific Coast Federation of Fishermen's Associations v. Raimondo, 2022 and 2023) and existing SWP operations (under the implementation of the 2019 NMFS BO, the 2019 USFWS BO, and the 2020 SWP ITP (CDFW 2020)). The water year 2022 and 2023 Interim Operations Plans – Export Curtailments for Spring Outflow (Pacific Coast Federation of Fishermen's Associations v. Raimondo, 2022 and 2023) applied to existing CVP operations assumed CVP contribution in April and May of critical, dry, and below normal water year types to the 2020 SWP ITP Condition of Approval 8.17 – Export Curtailments for Spring Outflow (see below for more details). CVP contribution in critical, dry, and below normal water years assumed CVP export as the maximum of 900 cfs or up to 60% of the total permittable export under Condition of Approval 8.17. The two modeled Proposed Project scenarios (9A_V2A and ITP_Spring) assumed existing CVP operations and proposed SWP operations (under the implementation of the 2024 SWP ITP).

The ITP_Spring CalSim 3 modeling scenario includes proposed SWP operations as well as SWP implementation of the 2020 SWP ITP Condition of Approval 8.17 – Export Curtailments for Spring Outflow. Condition of Approval 8.17 includes export curtailments for all water year types, determined by the 75% exceedance forecast for the San Joaquin Valley Index, by requiring DWR to manage exports to achieve a specific inflow to export (I:E) ratio for each water year type using San Joaquin River flow at Vernalis and combined CVP and SWP exports from April 1 through May 31. The 9A_V2A scenario includes proposed SWP operations as well as DWR's contribution to HRL, which includes a Delta inflow block of water and SWP export curtailments. The increase in Delta inflow equates to a 50 thousand acre-feet (TAF) inflow block of water in

March of dry, below normal, and above normal water year types. The SWP export curtailment equates to a 92.5 TAF Delta outflow block of water in April through May of dry and below normal water year types and a 117.5 TAF Delta outflow block of water April through May of above normal water year types. No Delta inflow block or export curtailments are proposed for critical or wet water year types.

Baseline Conditions, 9A_V2A, and ITP_Spring scenarios all include CVP operations adhering to the 2020 SWP ITP Condition of Approval 8.17 per the water year 2022 and 2023 Interim Operations Plans (Pacific Coast Federation of Fishermen's Associations v. Raimondo, 2022 and 2023). Including the CVP contribution towards Condition of Approval 8.17 in Baseline Conditions is appropriate considering the timing of the ITP Application, whereby CVP operations were controlled by the water year 2023 Interim Operations Plan. However, given ongoing consultation for the re-initiation of long-term operations of the CVP and SWP, inclusion of the CVP contribution towards Condition of Approval 8.17 in the Proposed Project scenarios does not reflect future CVP operations presented in Reclamation's 2023 Biological Assessment for their Proposed Action (USBR 2023). Reclamation's Biological Assessment states that CVP will not continue to contribute to Condition of Approval 8.17. Instead, Reclamation is proposing CVP export reductions will occur for two years through early implementation of HRL in March through May, with further implementation dependent on the SWRCB adoption of the HRL into the updated Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary, which was last updated in 2018 (SWRCB 2018). DWR's hydrodynamic and biological modeling based off CalSim 3 modeling, which includes CVP continued contribution towards Condition of Approval 8.17, likely underestimate impacts on CHNWR and CHNSR compared to expected future operational scenarios whereby CVP will only curtail exports for two years to support spring Delta outflow unless HRL is approved by the SWRCB.

The ITP Application indicates that historical 50% exceedance forecast of the Sacramento River index was used to determine water year type in CalSim 3 (DWR 2023, Appendix E), which can change monthly between January and June until the final water year type determination is made. DWR modeled OMR Management minimization measures in CalSim 3 by estimating the historical percentage of each month during OMR Management, January through June, that would have historically been subject to OMR action responses beyond operating to -5,000 cfs (referred to as "historical percentage of month"). The historical percentage of month method used the percentage of each month that an OMR minimization measure would historically be triggered under Baseline Conditions and Proposed Project scenarios based on historical data from water years 2010 to 2022. Historical percentages of each month under OMR action responses were averaged by water year type and input into CalSim 3 as the average OMR percentage by water year type and month applied to water years 1922 through 2021 for OMR managed at -3,500 cfs (see DWR 2023, Appendix E). Between water years 2010 and 2022, there were zero above normal water year types for March through June; therefore, DWR applied the average of below normal and wet water year types for March through June to above normal water year types for water years 1922 through 2021.

DWR did not model in CalSim 3 all OMR minimization measures or all components of OMR minimization measures as presented in the 2024 SWP ITP for implementation. For example, under Baseline Conditions, CHNWR daily loss thresholds (2020 SWP ITP Conditions of Approval 8.6.2 and 8.6.3) were not modeled in CalSim 3. Therefore, any OMR action responses resulting from a daily threshold exceedance would not be accounted for in the Baseline Conditions. For both Proposed Project scenarios, although the Winter-run Chinook Salmon Weekly Distributed Loss Thresholds were modeled in CalSim 3, rolling 7-day sums of loss each day were not used to determine threshold exceedances (see Section 6.2.7; Condition of Approval 8.4.4). Instead, threshold exceedances contributed to OMR restrictions when the total loss for each 7-day week, beginning with week 1 as January 1 through January 7, exceeded the weekly threshold. This approach to modeling did not allow for threshold exceedances to occur more than once per week, which may underestimate the percentage of each month under an OMR action response for CalSim 3 modeling. Other real-time management actions from the ITP Application, including the Winter-run Chinook Salmon Early Season Migration (Section 6.2.5; Condition of Approval 8.2.1) and Spring-run Chinook Salmon and Surrogate Thresholds (Section 6.2.8; Condition of Approval 8.4.5), were not modeled because historical exceedances either never occurred between water years 2010 through 2022 or only occurred in low numbers that did not generate patterns for modeling assumptions. OMR measures for steelhead were incorporated in CalSim 3 modeling of Baseline Conditions and Proposed Project scenarios; however, DWR did not request take coverage for steelhead in their ITP Application. Although OMR restrictions were coarsely modeled in CalSim 3, there is still uncertainty in future OMR restrictions between January and June, and the historical percentage of month method is merely a coarse representation of what would have occurred historically under different OMR Management.

It should be noted that, although the intent of the ITP Application was to isolate impacts of the Proposed Project on Covered Species from those of CVP, due to limitations of CalSim 3 and the simulation of joint SWP and CVP operations for managing OMR flows, all OMR Management measures were modeled with both the Proposed Project and Reclamation's Proposed Action rather than CVP operations under the 2019 NMFS and USFWS BOs. All elements of CVP other than OMR Management measures were modeled as operations under the 2019 NMFS and USFWS BOs. To aid in identifying SWP contribution to changes in OMR flow modeled in CalSim 3, DWR included Table E-7-1 in their ITP Application that shows the estimated SWP proportion of an effect that may be a result of joint operations of the SWP and CVP. The SWP proportion of an effect is the proportion of the change in OMR flow between Baseline Conditions and the Proposed Project that is attributable to SWP. Table E-7-1 can be used in conjunction with biological modeling results to better understand how SWP operations may contribute to changes in Covered Species impacts in the Delta resulting from CVP and the Project.

B.2. Mean Sacramento River Flow at Freeport by Month and Water Year Type

Table B-1. Mean October Sacramento River Flow at Freeport (cfs) under Proposed Project and Baseline Conditions CalSim 3 modeling scenarios grouped by water year type based on the Sacramento Valley Index. Percent differences between the Proposed Project scenarios (9A_V2A and ITP_Spring) and Baseline Conditions are in parentheses.

Water Year Type	Baseline Conditions	9A_V2A	ITP_Spring
Wet	14,238	14,301 (0%)	14,279 (0%)
Above Normal	10,754	10,735 (0%)	10,792 (0%)
Below Normal	12,008	12,074 (1%)	12,124 (1%)
Dry	11,242	11,228 (0%)	11,298 (1%)
Critical	8,193	8,241 (1%)	8,092 (-1%)

Table B-2. Mean November Sacramento River Flow at Freeport (cfs) under Proposed Project and Baseline Conditions CalSim 3 modeling scenarios grouped by water year type based on the Sacramento Valley Index. Percent differences between the Proposed Project scenarios (9A_V2A and ITP_Spring) and Baseline Conditions are in parentheses.

Water Year Type	Baseline Conditions	9A_V2A	ITP_Spring
Wet	19,275	19,300 (0%)	19,315 (0%)
Above Normal	12,798	12,816 (0%)	12,793 (0%)
Below Normal	13,863	13,716 (-1%)	13,658 (-1%)
Dry	12,156	12,238 (1%)	12,242 (1%)
Critical	8,304	8,501 (2%)	8,347 (1%)

Table B-3. Mean December Sacramento River Flow at Freeport (cfs) under Proposed Project and Baseline Conditions CalSim 3 modeling scenarios grouped by water year type based on the Sacramento Valley Index. Percent differences between the Proposed Project scenarios (9A_V2Aand ITP_Spring) and Baseline Conditions are in parentheses.

Water Year Type	Baseline Conditions	9A_V2A	ITP_Spring
Wet	38,326	38,311 (0%)	38,312 (0%)
Above Normal	19,238	19,226 (0%)	19,256 (0%)
Below Normal	16,409	16,594 (1%)	16,446 (0%)
Dry	16,120	15,913 (-1%)	15,940 (-1%)
Critical	12,175	12,291 (1%)	12,224 (0%)

Table B-4. Mean January Sacramento River Flow at Freeport (cfs) under Proposed Project and Baseline Conditions CalSim 3 modeling scenarios grouped by water year type based on the Sacramento Valley Index. Percent differences between the Proposed Project scenarios (9A_V2A and ITP_Spring) and Baseline Conditions are in parentheses.

Water Year Type	Baseline Conditions	9A_V2A	ITP_Spring
Wet	49,611	49,609 (0%)	49,619 (0%)
Above Normal	40,840	40,853 (0%)	40,824 (0%)
Below Normal	22,233	22,292 (0%)	22,275 (0%)
Dry	16,110	15,967 (-1%)	15,954 (-1%)
Critical	13,504	13,564 (0%)	13,534 (0%)

Table B-5. Mean February Sacramento River Flow at Freeport (cfs) under Proposed Project and Baseline Conditions CalSim 3 modeling scenarios grouped by water year type based on the Sacramento Valley Index. Percent differences between the Proposed Project scenarios (9A_V2A and ITP_Spring) and Baseline Conditions are in parentheses.

Water Year Type	Baseline Conditions	9A_V2A	ITP_Spring
Wet	58,955	58,948 (0%)	58,887 (0%)
Above Normal	44,381	44,362 (0%)	44,333 (0%)
Below Normal	28,831	28,645 (-1%)	28,662 (-1%)
Dry	21,943	22,122 (1%)	22,123 (1%)
Critical	15,633	15,972 (2%)	15,953 (2%)

Table B-6. Mean March Sacramento River Flow at Freeport (cfs) under Proposed Project and Baseline Conditions CalSim 3 modeling scenarios grouped by water year type based on the Sacramento Valley Index. Percent differences between the Proposed Project scenarios (9A_V2A and ITP_Spring) and Baseline Conditions are in parentheses.

Water Year Type	Baseline Conditions	9A_V2A	ITP_Spring
Wet	51,700	51,864 (0%)	51,664 (0%)
Above Normal	44,719	45,232 (1%)	44,505 (0%)
Below Normal	26,880	27,591 (3%)	26,838 (0%)
Dry	20,280	21,094 (4%)	20,301 (0%)
Critical	13,458	13,633 (1%)	13,372 (-1%)

Table B-7. Mean April Sacramento River Flow at Freeport (cfs) under Proposed Project and Baseline Conditions CalSim 3 modeling scenarios grouped by water year type based on the Sacramento Valley Index. Percent differences between the Proposed Project scenarios (9A_V2A and ITP_Spring) and Baseline Conditions are in parentheses.

Water Year Type	Baseline Conditions	9A_V2A	ITP_Spring
Wet	41,478	41,477 (0%)	41,470 (0%)

Water Year Type	Baseline Conditions	9A_V2A	ITP_Spring
Above Normal	25,970	26,035 (0%)	25,973 (0%)
Below Normal	17,525	17,489 (0%)	17,542 (0%)
Dry	12,680	12,530 (-1%)	12,666 (0%)
Critical	9,842	9,787 (-1%)	9,836 (0%)

Table B-8. Mean May Sacramento River Flow at Freeport (cfs) under Proposed Project and Baseline Conditions CalSim 3 modeling scenarios grouped by water year type based on the Sacramento Valley Index. Percent differences between the Proposed Project scenarios (9A_V2A and ITP_Spring) and Baseline Conditions are in parentheses.

Water Year Type	Baseline Conditions	9A_V2A	ITP_Spring
Wet	34,789	34,788 (0%)	34,787 (0%)
Above Normal	23,271	23,303 (0%)	23,297 (0%)
Below Normal	17,000	16,721 (-2%)	16,724 (-2%)
Dry	11,993	12,072 (1%)	12,044 (0%)
Critical	8,603	8,652 (1%)	8,642 (0%)

Table B-9. Mean June Sacramento River Flow at Freeport (cfs) under Proposed Project and Baseline Conditions CalSim 3 modeling scenarios grouped by water year type based on the Sacramento Valley Index. Percent differences between the Proposed Project scenarios (9A_V2A and ITP_Spring) and Baseline Conditions are in parentheses.

Water Year Type	Baseline Conditions	9A_V2A	ITP_Spring
Wet	25,726	25,757 (0%)	25,675 (0%)
Above Normal	18,576	18,544 (0%)	18,370 (-1%)
Below Normal	13,942	13,889 (0%)	13,787 (-1%)
Dry	13,111	12,611 (-4%)	12,552 (-4%)
Critical	9,802	9,623 (-2%)	9,712 (-1%)

Table B-10. Mean July Sacramento River Flow at Freeport (cfs) under Proposed Project and Baseline Conditions CalSim 3 modeling scenarios grouped by water year type based on the Sacramento Valley Index. Percent differences between the Proposed Project scenarios (9A_V2A and ITP_Spring) and Baseline Conditions are in parentheses.

Water Year Type	Baseline Conditions	9A_V2A	ITP_Spring
Wet	19,747	19,701 (0%)	19,728 (0%)
Above Normal	21,240	21,074 (-1%)	21,060 (-1%)
Below Normal	21,195	21,001 (-1%)	20,952 (-1%)
Dry	18,418	18,421 (0%)	18,410 (0%)
Critical	10,616	10,534 (-1%)	10,585 (0%)

Table B-11. Mean August Sacramento River Flow at Freeport (cfs) under Proposed Project and

Baseline Conditions CalSim 3 modeling scenarios grouped by water year type based on the Sacramento Valley Index. Percent differences between the Proposed Project scenarios (9A_V2A and ITP_Spring) and Baseline Conditions are in parentheses.

Water Year Type	Baseline Conditions	Study 9A_V2A	Study7_ITP_Spring
Wet	17,661	17,621 (0%)	17,669 (0%)
Above Normal	18,936	18,405 (-3%)	18,362 (-3%)
Below Normal	17,505	17,312 (-1%)	17,377 (-1%)
Dry	13,073	12,837 (-2%)	12,769 (-2%)
Critical	8,518	8,326 (-2%)	8,348 (-2%)

Table B-12. Mean September Sacramento River Flow at Freeport (cfs) under Proposed Project and Baseline Conditions CalSim 3 modeling scenarios grouped by water year type based on the Sacramento Valley Index. Percent differences between the Proposed Project scenarios (9A_V2A and ITP_Spring) and Baseline Conditions are in parentheses.

Water Year Type	Baseline Conditions	9A_V2A	ITP_Spring
Wet	19,574	20,568 (5%)	20,757 (6%)
Above Normal	18,945	20,695 (9%)	21,500 (13%)
Below Normal	14,947	14,925 (0%)	15,189 (2%)
Dry	10,808	10,851 (0%)	10,828 (0%)
Critical	8,516	8,518 (0%)	8,519 (0%)

B.3. Mean SWP South Delta Exports by Month and Water Year Type

Table B-13. Mean October State Water Project (SWP) south Delta exports (cfs) under the Proposed Project and Baseline Conditions CalSim 3 modeling scenarios grouped by water year type based on the Sacramento Valley Index. Percent differences between the Proposed Project scenarios (9A_V2A and ITP_Spring) and Baseline Conditions are in parentheses.

Water Year Type	Baseline Conditions	9A_V2A	ITP_Spring
Wet	4,167	4,079 (-2%)	4,072 (-2%)
Above Normal	2,485	2,382 (-4%)	2,429 (-2%)
Below Normal	3,250	3,177 (-2%)	3,179 (-2%)
Dry	2,719	2,738 (1%)	2,744 (1%)
Critical	1,667	1,670 (0%)	1,522 (-9%)

Table B-14. Mean November State Water Project (SWP) south Delta exports (cfs) under the Proposed Project and Baseline Conditions CalSim 3 modeling scenarios grouped by water year type based on the Sacramento Valley Index. Percent differences between the Proposed Project scenarios (9A_V2A and ITP_Spring) and Baseline Conditions are in parentheses.

Water Year Type	Baseline Conditions	9A_V2A	ITP_Spring
Wet	5,565	5,582 (0%)	5,602 (1%)
Above Normal	4,389	4,302 (-2%)	4,321 (-2%)
Below Normal	4,374	4,387 (0%)	4,393 (0%)
Dry	3,846	3,852 (0%)	3,853 (0%)
Critical	1,565	1,571 (0%)	1,567 (0%)

Table B-15. Mean December State Water Project (SWP) south Delta exports (cfs) under the Proposed Project and Baseline Conditions CalSim 3 modeling scenarios grouped by water year type based on the Sacramento Valley Index. Percent differences between the Proposed Project scenarios (9A_V2A and ITP_Spring) and Baseline Conditions are in parentheses.

Water Year Type	Baseline Conditions	9A_V2A	ITP_Spring
Wet	4,519	4,452 (-1%)	4,475 (-1%)
Above Normal	4,212	4,222 (0%)	4,230 (0%)
Below Normal	3,926	4,038 (3%)	3,906 (-1%)
Dry	3,716	3,529 (-5%)	3,542 (-5%)
Critical	2,472	2,467 (0%)	2,480 (0%)

Table B-16. Mean January State Water Project (SWP) south Delta exports (cfs) under the Proposed Project and Baseline Conditions CalSim 3 modeling scenarios grouped by water year type based on the Sacramento Valley Index. Percent differences between the Proposed Project scenarios (9A_V2A and ITP_Spring) and Baseline Conditions are in parentheses.

Water Year Type	Baseline Conditions	9A_V2A	ITP_Spring
Wet	4,262	4,175 (-2%)	4,172 (-2%)
Above Normal	2,965	2,900 (-2%)	2,900 (-2%)
Below Normal	2,861	2,756 (-4%)	2,767 (-3%)
Dry	2,572	2,547 (-1%)	2,525 (-2%)
Critical	2,685	2,346 (-13%)	2,333 (-13%)

Table B-17. Mean February State Water Project (SWP) south Delta exports (cfs) under the Proposed Project and Baseline Conditions CalSim 3 modeling scenarios grouped by water year type based on the Sacramento Valley Index. Percent differences between the Proposed Project scenarios (9A_V2A and ITP_Spring) and Baseline Conditions are in parentheses.

Water Year Type	Baseline Conditions	9A_V2A	ITP_Spring
Wet	5,917	5,975 (1%)	5,963 (1%)
Above Normal	3,873	3,591 (-7%)	3,833 (-1%)
Below Normal	3,219	3,052 (-5%)	3,054 (-5%)
Dry	2,464	2,211 (-10%)	2,176 (-12%)
Critical	2,585	2,454 (-5%)	2,466 (-5%)

Table B-18. Mean March State Water Project (SWP) south Delta exports (cfs) under the Proposed Project and Baseline Conditions CalSim 3 modeling scenarios grouped by water year type based on the Sacramento Valley Index. Percent differences between the Proposed Project scenarios (9A_V2A and ITP_Spring) and Baseline Conditions are in parentheses.

Water Year Type	Baseline Conditions	9A_V2A	ITP_Spring
Wet	5,124	5,233 (2%)	5,312 (4%)
Above Normal	3,251	3,335 (3%)	3,334 (3%)
Below Normal	2,988	2,910 (-3%)	2,913 (-2%)
Dry	2,160	2,123 (-2%)	2,123 (-2%)
Critical	1,626	1,624 (0%)	1,624 (0%)

Table B-19. Mean April State Water Project (SWP) south Delta exports (cfs) under the Proposed Project and Baseline Conditions CalSim 3 modeling scenarios grouped by water year type based on the Sacramento Valley Index. Percent differences between the Proposed Project scenarios (9A_V2A and ITP_Spring) and Baseline Conditions are in parentheses.

Water Year Type	Baseline Conditions	9A_V2A	ITP_Spring
Wet	3,567	3,633 (2%)	3,622 (2%)
Above Normal	788	1,072 (36%)	786 (0%)
Below Normal	801	992 (24%)	809 (1%)
Dry	797	838 (5%)	796 (0%)
Critical	720	872 (21%)	718 (0%)

Table B-20. Mean May State Water Project (SWP) south Delta exports (cfs) under the Proposed Project and Baseline Conditions CalSim 3 modeling scenarios grouped by water year type based on the Sacramento Valley Index. Percent differences between the Proposed Project scenarios (9A_V2A and ITP_Spring) and Baseline Conditions are in parentheses.

Water Year Type	Baseline Conditions	9A_V2A	ITP_Spring
Wet	2,588	3,823 (48%)	2,821 (9%)
Above Normal	1,209	1,981 (64%)	1,272 (5%)
Below Normal	906	1,694 (87%)	977 (8%)
Dry	683	884 (29%)	682 (0%)
Critical	609	861 (41%)	629 (3%)

Table B-21. Mean June State Water Project (SWP) south Delta exports (cfs) under the Proposed Project and Baseline Conditions CalSim 3 modeling scenarios grouped by water year type based on the Sacramento Valley Index. Percent differences between the Proposed Project scenarios (9A_V2A and ITP_Spring) and Baseline Conditions are in parentheses.

Water Year Type	Baseline Conditions	9A_V2A	ITP_Spring
Wet	4,067	3,960 (-3%)	3,962 (-3%)
Above Normal	2,583	2,367 (-8%)	2,337 (-10%)
Below Normal	2,074	1,930 (-7%)	1,891 (-9%)
Dry	1,780	1,605 (-10%)	1,591 (-11%)
Critical	784	714 (-9%)	749 (-4%)

Table B-22. Mean July State Water Project (SWP) south Delta exports (cfs) under the Proposed Project and Baseline Conditions CalSim 3 modeling scenarios grouped by water year type based on the Sacramento Valley Index. Percent differences between the Proposed Project scenarios (9A_V2A and ITP_Spring) and Baseline Conditions are in parentheses.

Water Year Type	Baseline Conditions	9A_V2A	ITP_Spring
Wet	7,038	7,051 (0%)	7,068 (0%)
Above Normal	6,999	7,150 (2%)	7,150 (2%)
Below Normal	7,013	6,953 (-1%)	6,969 (-1%)
Dry	5,323	5,499 (3%)	5,475 (3%)

Critical	531	490 (-8%)	500 (-6%)

Table B-23. Mean August State Water Project (SWP) south Delta exports (cfs) under the Proposed Project and Baseline Conditions CalSim 3 modeling scenarios grouped by water year type based on the Sacramento Valley Index. Percent differences between the Proposed Project scenarios (9A_V2A and ITP_Spring) and Baseline Conditions are in parentheses.

Water Year Type	**Baseline Conditions**	**9A_V2A**	**ITP_Spring**
Wet	6,803	7,129 (5%)	7,177 (5%)
Above Normal	6,949	7,153 (3%)	7,180 (3%)
Below Normal	6,376	6,347 (0%)	6,459 (1%)
Dry	1,706	1,664 (-2%)	1,651 (-3%)
Critical	329	351 (7%)	332 (1%)

Table B-24. Mean September State Water Project (SWP) south Delta exports (cfs) under the Proposed Project and Baseline Conditions CalSim 3 modeling scenarios grouped by water year type based on the Sacramento Valley Index. Percent differences between the Proposed Project scenarios (9A_V2A and ITP_Spring) and Baseline Conditions are in parentheses.

Water Year Type	**Baseline Conditions**	**9A_V2A**	**ITP_Spring**
Wet	5,438	6,553 (21%)	6,775 (25%)
Above Normal	4,144	5,204 (26%)	5,980 (44%)
Below Normal	4,446	4,316 (-3%)	4,559 (3%)
Dry	1,659	1,592 (-4%)	1,591 (-4%)
Critical	525	520 (-1%)	518 (-1%)

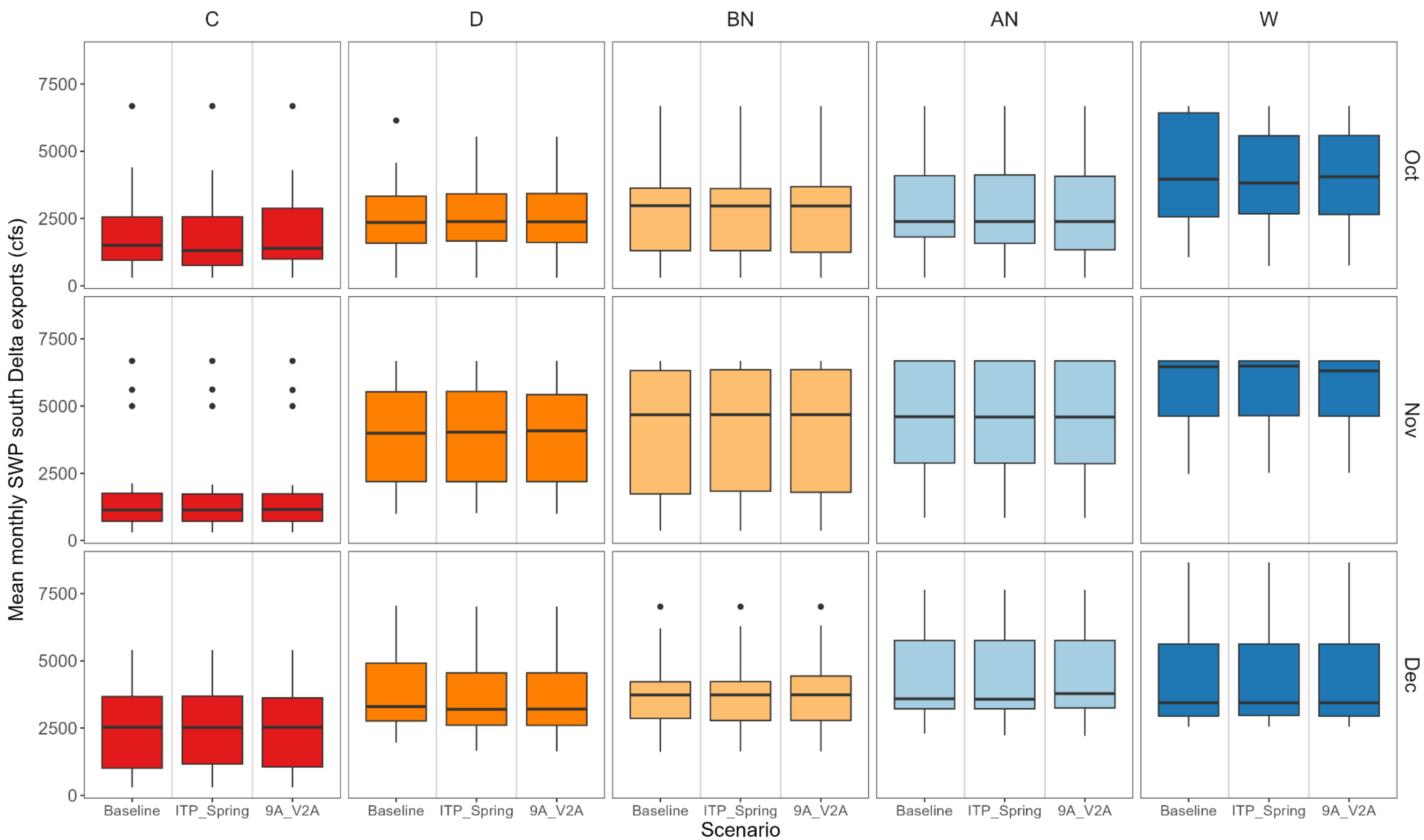

Figure B-1. Mean State Water Project (SWP) south Delta exports (cfs) under the Proposed Project (9A_V2A and ITP_Spring) and Baseline Conditions CalSim 3 modeling scenarios by month and water year type; October through December. Water year types were classified using the Sacramento Valley Index and noted as Critical (C), Dry (D), Below Normal (BN), Above Normal (AN), and Wet (W).

The black line through each box represents the median and the box encompasses the range of the first and third quartiles. The ends of the whiskers represent the minimum and maximum values. Outliers [1.5 x (Quartile 3 - Quartile 1)] are represented as points.

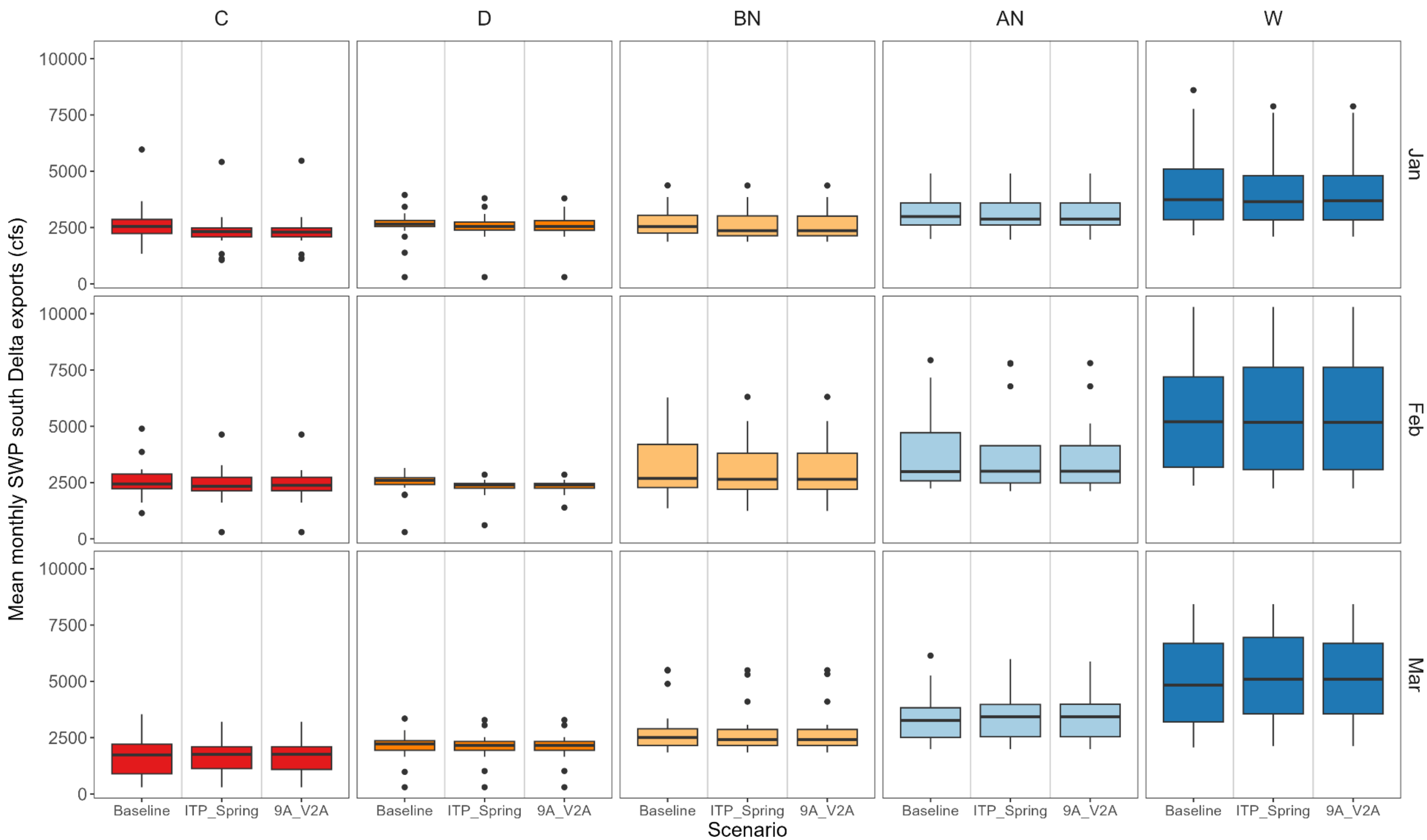

Figure B-2. Mean State Water Project (SWP) south Delta exports (cfs) under the Proposed Project (9A_V2A and ITP_Spring) and Baseline Conditions CalSim 3 modeling scenarios by month and water year type; January through March. Water year types were classified using the Sacramento Valley Index and noted as Critical (C), Dry (D), Below Normal (BN), Above Normal (AN), and Wet (W). The black line through each box represents the median and the box encompasses the range of the first and third quartiles. The ends of the whiskers represent the minimum and maximum values. Outliers [1.5 x (Quartile 3 - Quartile 1)] are represented as points.

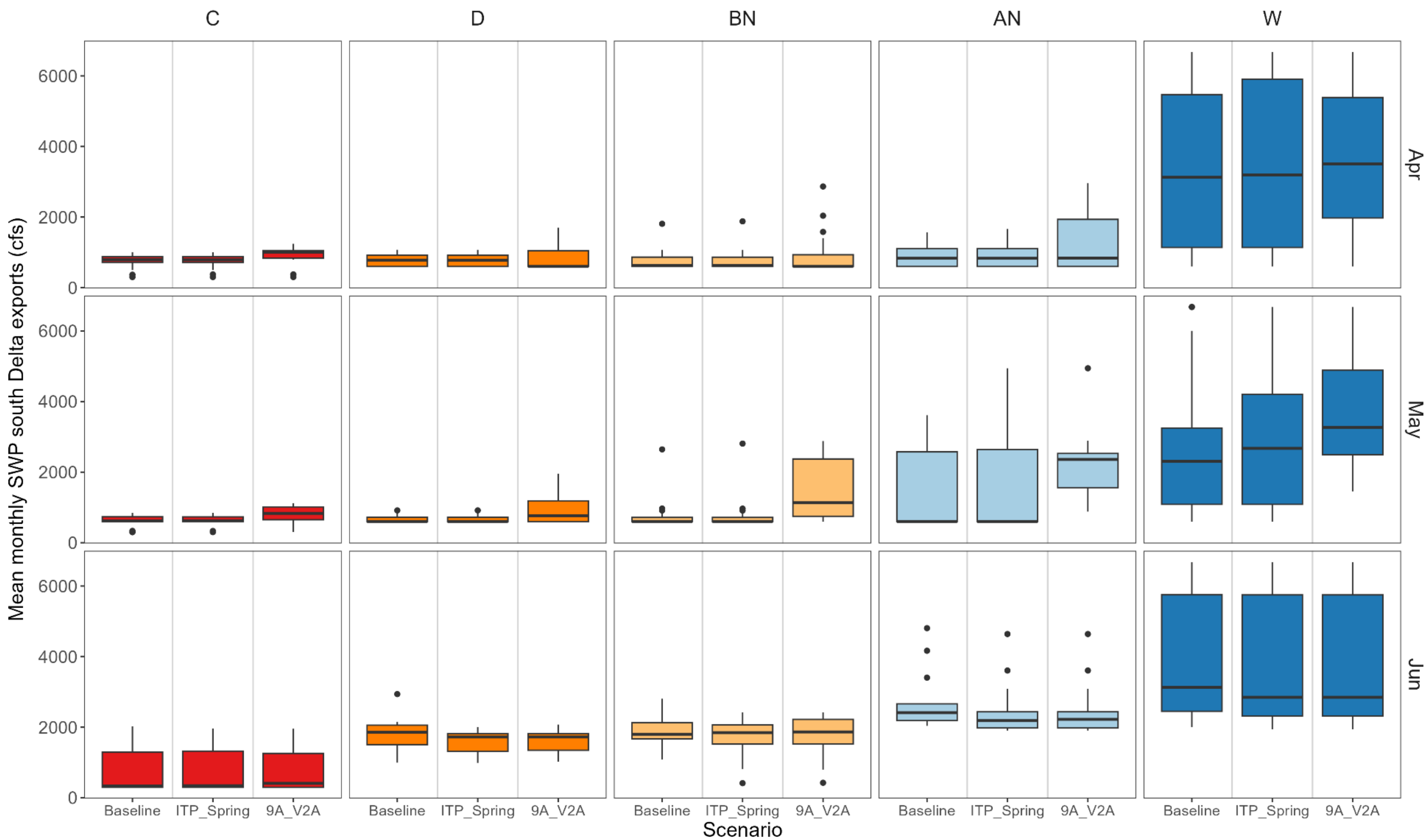

Figure B-3. Mean State Water Project (SWP) south Delta exports (cfs) under the Proposed Project (9A_V2A and ITP_Spring) and Baseline Conditions CalSim 3 modeling scenarios by month and water year type; April through June. Water year types were classified using the Sacramento Valley Index and noted as Critical (C), Dry (D), Below Normal (BN), Above Normal (AN), and Wet (W). The black line through each box represents the median and the box encompasses the range of the first and third quartiles. The ends of the whiskers represent the minimum and maximum values. Outliers [1.5 x (Quartile 3 - Quartile 1)] are represented as points.

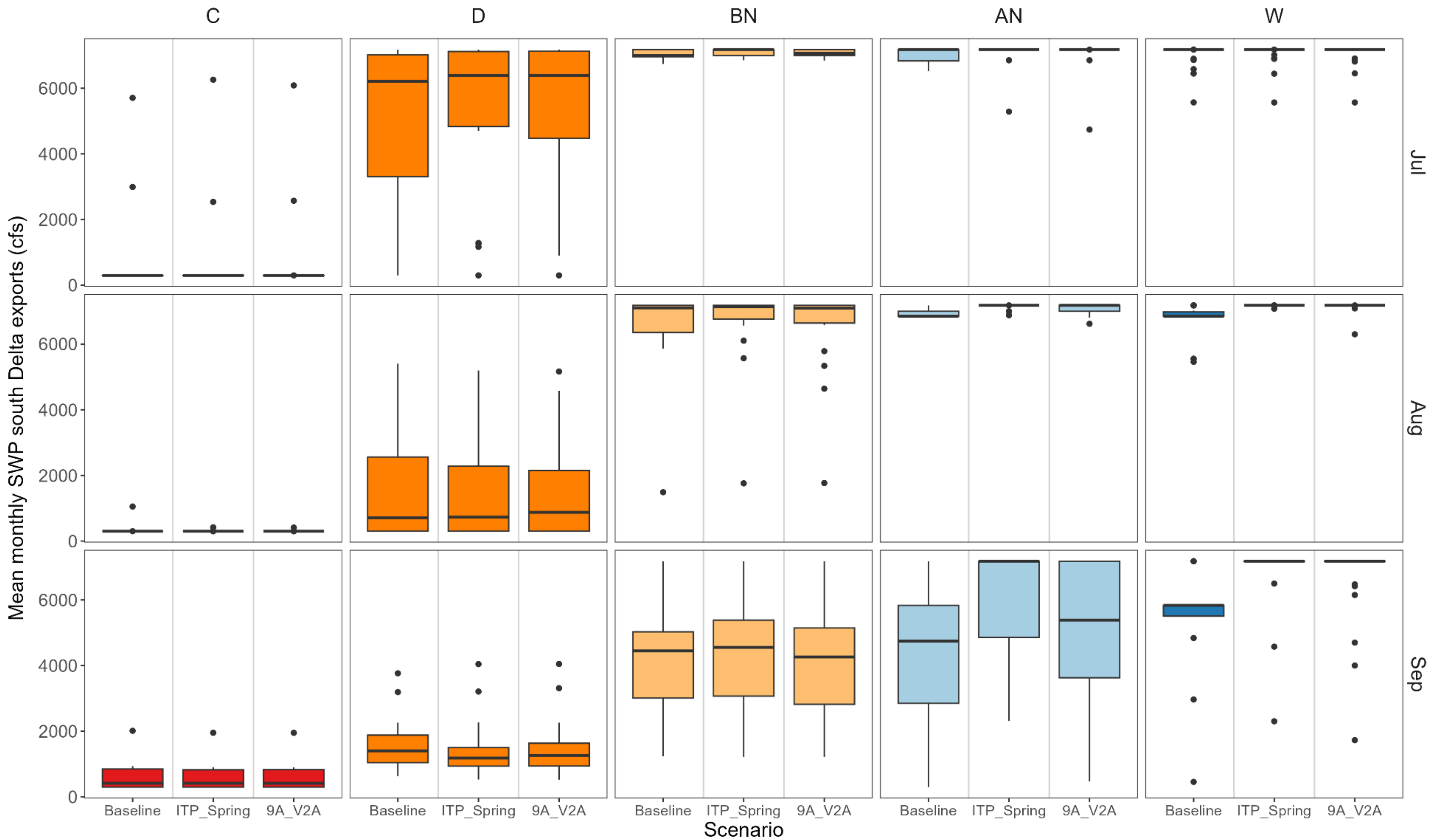

Figure B-4. Mean State Water Project (SWP) south Delta exports (cfs) under the Proposed Project (9A_V2A and ITP_Spring) and Baseline Conditions CalSim 3 modeling scenarios by month and water year type; July through September. Water year types were classified using the Sacramento Valley Index and noted as Critical (C), Dry (D), Below Normal (BN), Above Normal (AN), and Wet (W). The black line through each box represents the median and the box encompasses the range of the first and third quartiles. The ends of the whiskers represent the minimum and maximum values. Outliers [1.5 x (Quartile 3 - Quartile 1)] are represented as points.

B.4. Mean OMR Flows by Month and Water Year Type

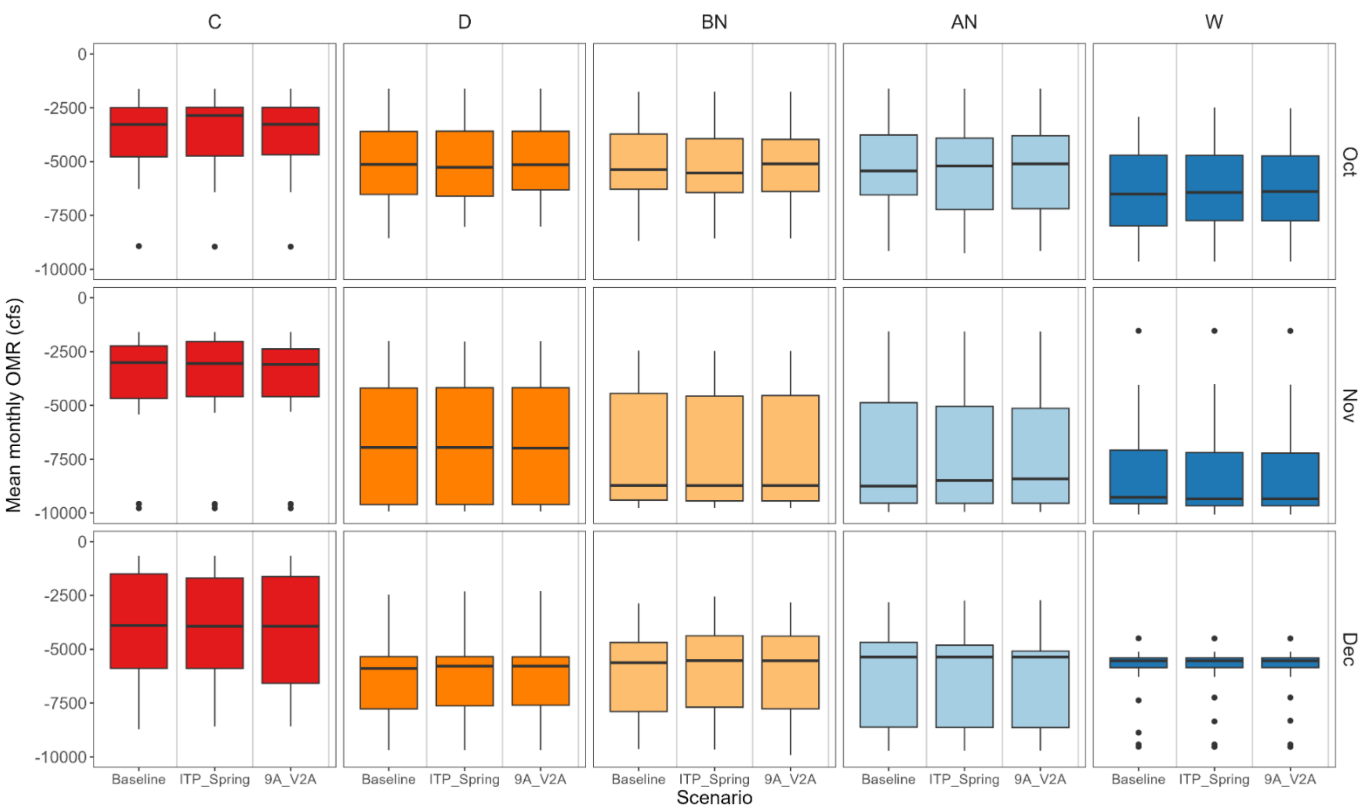

Figure B-5. Mean Old and Middle River (OMR) flows (cfs) under the Proposed Project (9A_V2A and ITP_Spring) and Baseline Conditions CalSim 3 modeling scenarios by month and water year type; October through December. Water year types were classified using the Sacramento Valley Index and noted as Critical (C), Dry (D), Below Normal (BN), Above Normal (AN), and Wet (W). The black line through each box represents the median and the box encompasses the range of the first and third quartiles. The ends of the whiskers represent the minimum and maximum values. Outliers [1.5 x (Quartile 3 - Quartile 1)] are represented as points. Graphics were magnified to focus on the interquartile range and median, so some outliers may not be shown.

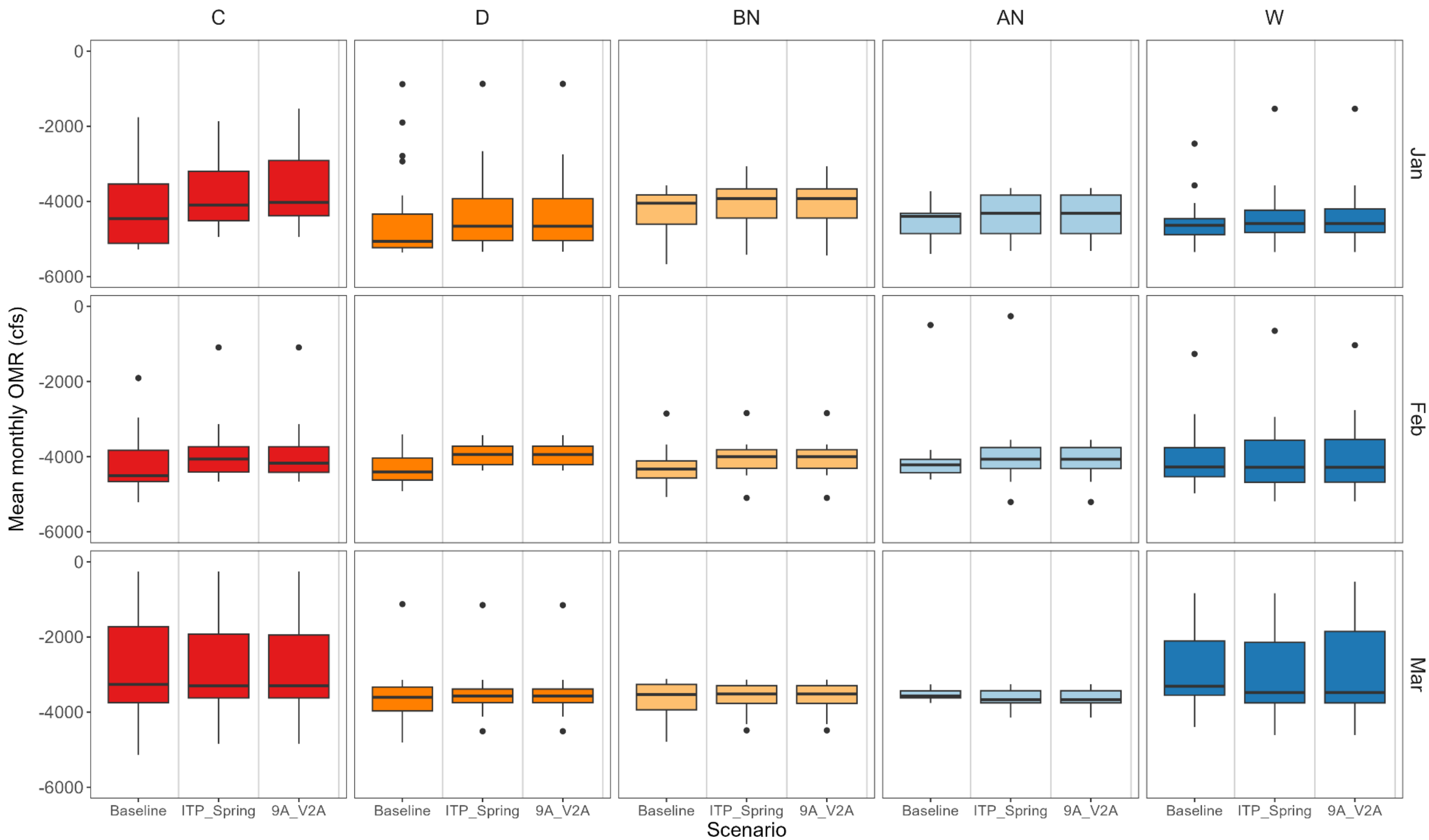

Figure B-6. Mean Old and Middle River (OMR) flows (cfs) under the Proposed Project (9A_V2A and ITP_Spring) and Baseline Conditions CalSim 3 modeling scenarios by month and water year type; January through March. Water year types were classified using the Sacramento Valley Index and noted as Critical (C), Dry (D), Below Normal (BN), Above Normal (AN), and Wet (W). The black line through each box represents the median and the box encompasses the range of the first and third quartiles. The ends of the whiskers represent the minimum and maximum values. Outliers [1.5 x (Quartile 3 - Quartile 1)] are represented as points. Graphics were magnified to focus on the interquartile range and median, so some outliers may not be shown.

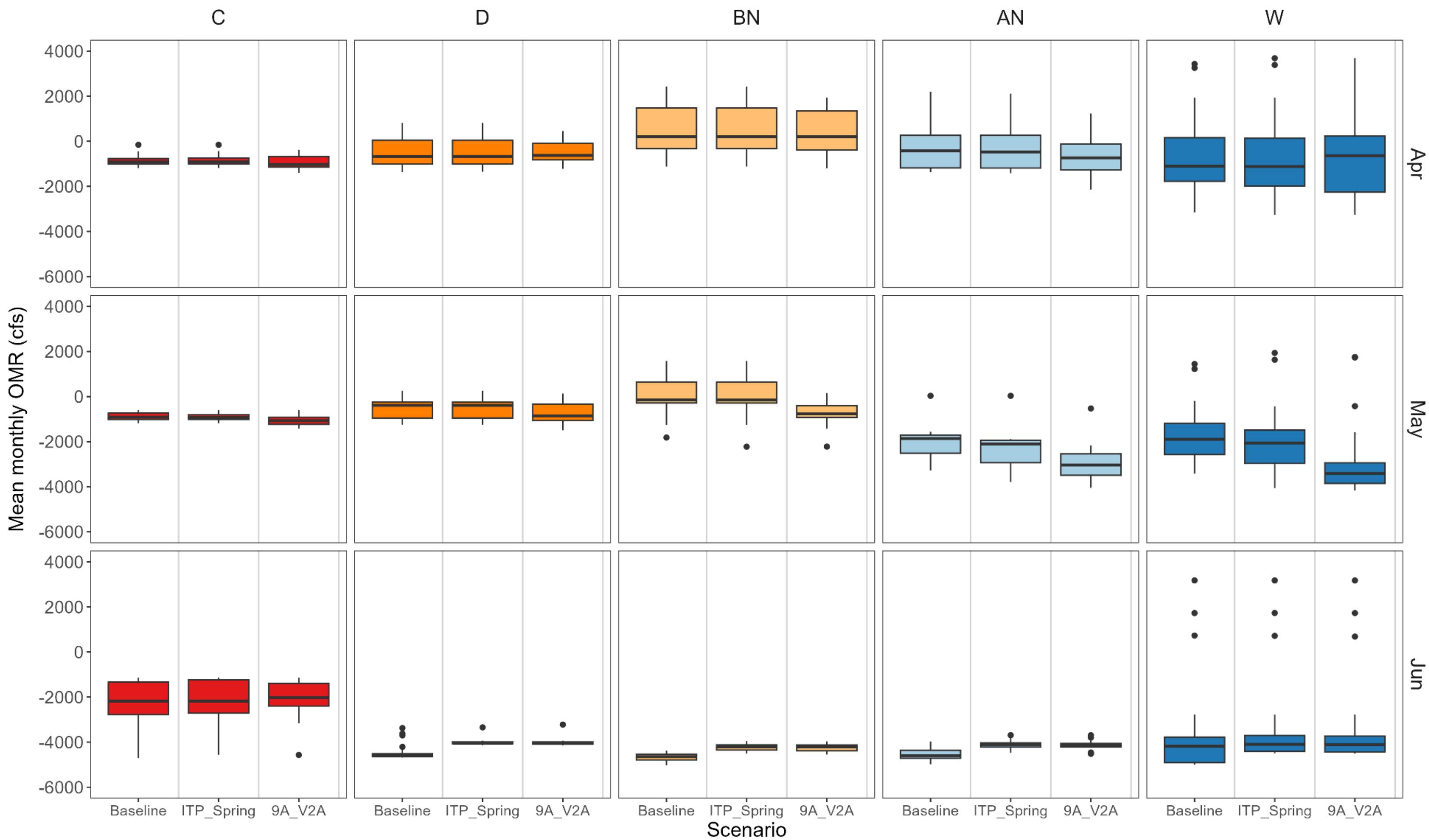

Figure B-7. Mean Old and Middle River (OMR) flows (cfs) under the Proposed Project (9A_V2A and ITP_Spring) and Baseline Conditions CalSim 3 modeling scenarios by month and water year type; April through June. Water year types were classified using the Sacramento Valley Index and noted as Critical (C), Dry (D), Below Normal (BN), Above Normal (AN), and Wet (W). The black line through each box represents the median and the box encompasses the range of the first and third quartiles. The ends of the whiskers represent the minimum and maximum values. Outliers [1.5 x (Quartile 3 - Quartile 1)] are represented as points. Graphics were magnified to focus on the interquartile range and median, so some outliers may not be shown.

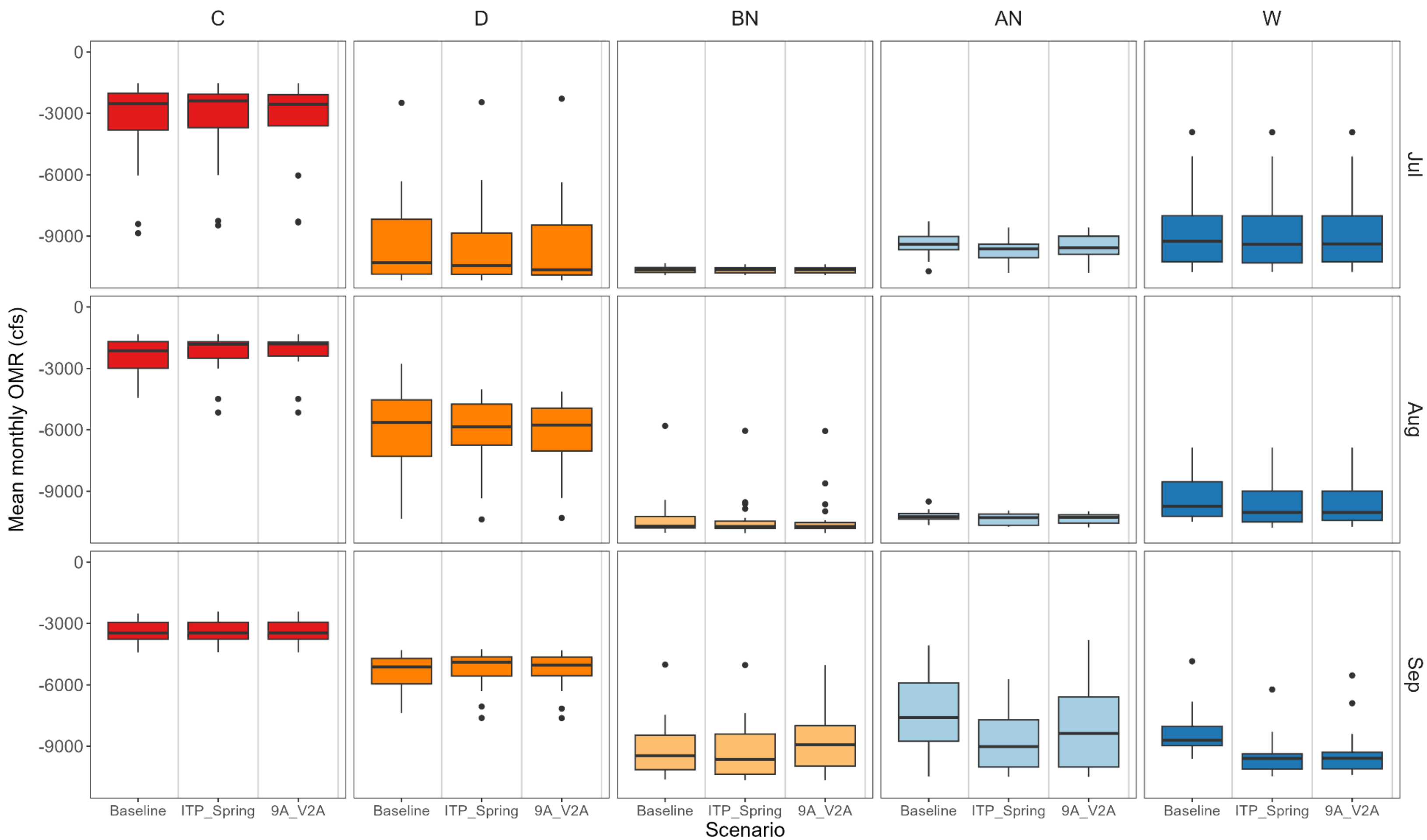

Figure B-8. Mean Old and Middle River (OMR) flows (cfs) under the Proposed Project (9A_V2A and ITP_Spring) and Baseline Conditions CalSim 3 modeling scenarios by month and water year type; July through September. Water year types were classified using the Sacramento Valley Index and noted as Critical (C), Dry (D), Below Normal (BN), Above Normal (AN), and Wet (W). The black line through each box represents the median and the box encompasses the range of the first and third quartiles. The ends of the whiskers represent the minimum and maximum values. Outliers [1.5 x (Quartile 3 - Quartile 1)] are represented as points. Graphics were magnified to focus on the interquartile range and median, so some outliers may not be shown.

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