Common Response 3.1
Fish Protection

Introduction

Protecting the San Francisco Bay/Sacramento-San Joaquin Delta (Bay-Delta) watershed and its many beneficial uses of water is one of the State Water Resources Control Board's (State Water Board) primary responsibilities and top priorities. In response to declines of several native aquatic species since the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Watershed (Bay-Delta Plan or Plan) was last comprehensively updated, the State Water Board commenced a process to update the Bay-Delta Plan for the Sacramento River and its tributaries, Delta eastside tributaries (including the Calaveras, Cosumnes, and Mokelumne Rivers), and Delta for the reasonable protection of fish and wildlife beneficial uses, referred to as the Sacramento/Delta Update to the Bay-Delta Plan. The Bay-Delta Plan identifies beneficial uses of water to be protected in the Bay-Delta watershed, water quality objectives and program of implementation to achieve the reasonable protection of those beneficial uses, monitoring, evaluation, and special study provisions. The State Water Board's proposed action to update the Bay-Delta Plan is supported by a Staff Report/Substitute Environmental Document (Staff Report), which provides an evaluation of the environmental impacts and economic effects in support of consideration of different alternatives to update the Bay-Delta Plan to achieve reasonable protection of fish and wildlife beneficial uses in the Sacramento/Delta. The Staff Report is functionally equivalent to an Environmental Impact Report under the California Environmental Quality Act (CEQA) but also provides the additional analyses that support the State Water Board's consideration of the action under the Clean Water Act and Porter-Cologne Water Quality Control Act.

Development of the final Staff Report and final draft Bay-Delta Plan were informed by several opportunities for public comment over multiple years. This common response may address issues that were raised during any of those public comment periods. In September 2023, the State Water Board released the 2023 draft Staff Report evaluating different alternatives for the Sacramento/Delta Update to the Bay-Delta Plan for public review and comment. Following release of the 2023 draft Staff Report, the State Water Board released draft amendments to the Bay-Delta Plan in October 2024 (2024 draft Plan) for public review and comment that incorporated alternatives identified in the 2023 draft Staff Report with revisions based on public comments. The State Water Board released revised draft Plan updates in July 2025 (July 2025 revised draft Plan) but delayed public comment on that version of the Plan pending further updates, though some parties did submit public comments on the July 2025 draft that are part of the State Water Board's response to comments. In December 2025, the State Water Board released Chapter 13, *Revised Proposed Plan Amendments*, as a limited recirculation of the 2023 draft Staff Report (2025 partially recirculated draft Staff Report) together with the December 2025 revised draft Plan for public review and comment. These documents reflect the updated proposed project, referred to as the revised proposed Plan amendments, which brings together in the Bay-Delta Plan program of implementation a voluntary agreement (VA) pathway that incorporates commitments identified in the Healthy Rivers and Landscapes (HRL) proposal and would apply to specified HRL water rights, and a regulatory pathway based on the proposed Plan amendments that would apply to other water rights and to any HRL water rights no longer included under the VA pathway. In August 2026, the State Water Board released a final draft Bay-Delta Plan that included refinements to the revised proposed Plan amendments based on public comments received on the December 2025 revised draft Plan. At the same time, the State Water Board released this final Staff Report, including responses to comments previously received on the draft Staff Report. The final Staff Report informs the State Water Board's consideration of adoption of the Sacramento/Delta updates to the Bay-Delta Plan.

The State Water Board reviewed and considered all comments and developed common responses to address recurring comments and common themes. This common response addresses comments raised regarding the Staff Report's use of best available science, adequacy of modeling to support the benefits analyses, fish entrainment in the Delta, and other topics related to fish protection and aquatic ecosystem stressors that are discussed in Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations* and Chapter 4*, Other Aquatic Ecosystem Stressors*, and other chapters and sections of the 2023 draft Staff Report and in Chapter 13, *Revised Proposed Plan Amendments*, of the 2025 partially recirculated draft Staff Report. In particular, this common response addresses, but is not limited to, the following topics:

- The Staff Report's use of best available science; including:
    - Criteria for best available science
    - Process for updates to literature
    - Data sources
- Adequacy of the modeling to support the benefit analyses, including:
    - Flow and habitat benefit analyses
    - Temperature effects on salmonid fish
    - Flow effects on temperature
- Fish entrainment in the Delta, including:
    - Fish entrainment into the interior Delta
    - Fish losses at the south Delta export facilities
    - Old and Middle River flows and fish entrainment

This common response references related common responses as appropriate where recurring comments and common comment themes overlap with other subject matter areas. For responses to comments concerning temperature analysis and thresholds, cold water pool management, and upper watershed effects, see Common Response 7.6.2, *Aquatic Biological Resources and Cold Water Habitat*. For responses to comments related to general comments, please refer to Common Response 1.1, *General Comments.* For responses to comments related to the water quality control planning process, please refer to Common Response 1.2, *Water Quality Control Planning Process*. For more information on the revised proposed Plan amendments, see Common Response 1.3, *Revised Proposed Plan Amendments*.

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Staff Report Use of Best Available Science

Several commenters alleged that the best available science was not used in the Staff Report analysis. These included allegations that criteria for best available science were not followed, that the scientific basis reports were insufficient, that the references were outdated, or that the analyses relied on outdated or incorrect data sources.

Criteria for Best Available Science

Some commenters recommended that the use of science in the Staff Report follow criteria for best available science, such as those listed in the Delta Stewardship Council's Delta Plan. The Bay-Delta Monitoring and Evaluation Program (BDMEP) of the revised proposed Plan amendments includes a definition of best available science based on the criteria in Appendix 1A of the Delta Plan. Table CR 3.1-1 demonstrates how the process for incorporating science in the Staff Report followed these criteria for best available science.

Some commenters requested that State Water Board staff remove references from Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations,* of the Staff Report, in some cases because the references were not published in a peer-reviewed journal. While California Health and Safety Code section 57004 requires the State Water Board to submit for external peer review the scientific basis for, or scientific portion of, any rule proposed for adoption (as discussed in the following section of this common response titled *2017 Scientific Basis Report*), the State Water Board is not required to exclusively rely upon peer reviewed journal articles as references. In order to provide for the orderly and efficient administration of the water resources of the state—a duty assigned to the State Water Board by the legislature in California Water Code section 174—it is necessary that the State Water Board consider more sources of information than the contents of peer reviewed journal articles alone. Many other forms of information such as dissertations, pending research, Traditional Ecological Knowledge (TEK), and personal communications from those with local expertise can be incorporated into the Staff Report. The BDMEP definition of best available science lists sources of scientific information in order of priority as: independently peer-reviewed publications including scientific journal publications and books, other scientific reports and publications, and science expert opinion. In addition, when TEK is shared, it should be considered alongside non-indigenous forms of knowledge in informing decisions if permission for use is granted by the tribe. Scientific information was incorporated into the Staff Report in this order of priority. Common Response 11.1, *Tribal Engagement and Tribal Beneficial Uses*, includes a discussion of the consideration of TEK. In addition, much of the text in Chapters 2 through 4 of the Staff Report, including the references cited, was derived from the 2017 Scientific Basis Report that underwent external scientific peer review (see discussion below on the *2017 Scientific Basis Report)*.

Table CR 3.1-1. Application of best available science criteria from the Bay-Delta Monitoring and Evaluation Program of the revised proposed Plan amendments.

Criteria	Description	Application to Staff Report
Relevance	Scientific information used should be germane to the Bay-Delta watershed and/or biological and physical components (and/or process) affected by the proposed decisions. Analogous information from a different region but applicable to the Bay-Delta watershed and/or	Information from the Bay-Delta watershed was prioritized over information from other regions, when available. Information from other regions is clearly identified.

Criteria	Description	Application to Staff Report
	biological and physical components may be the most relevant when scientific information specific to the Bay-Delta watershed is nonexistent or insufficient. The quality and relevance of the data and information used shall be clearly addressed.	
Inclusiveness	Scientific information used should incorporate a thorough review of relevant information and analyses across relevant disciplines. Many analysis tools are available to the scientific community (e.g., search engines, citation indices).	A thorough literature review was conducted to ensure that the current understanding of the presented scientific topics is accurately presented.
Objectivity	Data collection and analyses considered should meet the standards of the scientific method and be void of nonscientific influences and considerations.	Objective research studies were prioritized for consideration over those with conflicts of interest that could result in nonscientific influences.
Transparency and Openness	The sources and methods used for analyzing the science (including scientific and engineering models) used should be clearly identified. The opportunity for public comment is recommended. Limitations of research used should be clearly identified and explained. If a range of uncertainty is associated with the data and information used, a mechanism for communicating uncertainty should be employed.	Methods were clearly described and the text has been subjected to public comment. The Scientific Basis Reports, which are the basis for the scientific information in the Staff Report, were subjected to multiple rounds of public comment and independent peer review. Uncertainty is communicated and limitations in the methods are clearly identified.
Timeliness	Timeliness has two main elements: (1) data collection should occur in a manner sufficient for adequate analyses before a management decision is needed, and (2) scientific information used should be applicable to current situations. Timeliness also means that results from scientific studies and monitoring may be brought forward before the study is complete to address management needs. In these instances, it is necessary that the uncertainties, limitations, and risks associated with preliminary results are clearly documented.	Scientific information was updated where more recent literature provides new or different information than previously presented in the Staff Report.
Peer Review	The quality of the science used will be measured by the extent and quality of the review process. Independent external scientific review of the science is most important because it ensures scientific objectivity and validity. The following criteria represent a desirable peer review process. Coordination of Peer Review. Independent peer review should be coordinated by entities and/or individuals that (1) are not a member of the independent external review team/panel and (2)	The Scientific Basis Reports were subjected to independent, external peer review.

Criteria	Description	Application to Staff Report
	have had no direct involvement in the particular actions under review. Coordination includes the vetting and selection of peer reviewers and all communication with peer reviewers until the review is complete. Independent External Reviewers. A qualified independent external reviewer embodies the following qualities: (1) has no conflict of interest with the outcome of the decision being made, (2) can perform the review free of persuasion by others, (3) has demonstrable competence in the subject as evidenced by formal training or experience, (4) is willing to utilize his or her scientific expertise to reach objective conclusions that may be incongruent with his or her personal biases, (5) is willing to identify the costs and benefits of ecological and social alternative decisions, and (6) is anonymous to and isolated from entities and individuals with direct involvement in the particular actions under review. When to Conduct Peer Review. Independent scientific peer review may be applied formally to proposed projects and initial draft plans, in writing after official draft plans or policies are released to the public, and/or to final released plans. Formal peer review may also be applied to outcomes and products of projects as appropriate.	

2017 Scientific Basis Report

Some commenters alleged that the 2017 Scientific Basis Report did not represent the best available science. In addition, several commenters stated that the information that was included in the 2023 draft Staff Report from the 2017 Scientific Basis Report is outdated and therefore cannot serve as the scientific basis for an amendment to the Bay-Delta Plan.

The peer-reviewed 2017 Scientific Basis Report provides the scientific basis for the regulatory pathway of the revised proposed Plan amendments and its prior versions, including the proposed Plan amendments, described in Chapter 5, *Proposed Changes to the Bay-Delta Plan for the Sacramento/Delta,* of the Staff Report. California Health and Safety Code section 57004 requires organizations within the California Environmental Protection Agency (CalEPA) to submit for external peer review the scientific basis for, or scientific portion of, any rule proposed for adoption. The State Water Board is subject to the peer review requirement because it is an agency within the CalEPA, and the proposed updates to the Bay-Delta Plan meet the definition for a “rule” under section 57004 (a)(1)(B), which includes policies adopted by the State Water Board pursuant to the Porter-Cologne Act that have the effect of a regulation. This process ensures that all proposed CalEPA rulemaking meets accepted standards and prevents influence on rulemakings stemming from irrelevant findings, unwarranted claims, unacceptable interpretations, and personal views.

In January 2017, the State Water Board submitted a request for the peer review of the final Scientific Basis Report in accordance with the established peer review guidelines (McAllister et al. 2017). Health and Safety Code section 57004 requires highly qualified external experts to perform impartial, independent peer reviews. The University of California, Berkeley selected five reviewers with substantial experience in hydrology, flow and non-flow needs of freshwater and estuarine fish, and establishment of environmental flows. The reviewers were asked to directly address eight scientific conclusions that form the basis of the rulemaking process. In addition, reviewers were asked to contemplate two overarching questions: 1) In reading the Scientific Report, are there any additional scientific conclusions that should be part of the scientific portion of the proposed rule (other than the current eight conclusions) 2) Taken as a whole, is the scientific portion of the draft water quality requirements based upon sound scientific knowledge, methods, and practices? All peer reviewers concluded that there was sound scientific support for the eight scientific conclusions. Peer reviewers also concluded that the scientific information, data and studies used in the report are based on sound scientific knowledge, methods, and practices. They did not recommend any additional scientific conclusions to formulate the proposed rule.

In preparing the Staff Report, Chapter 2, *Hydrology and Water Supply*, Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations,* and Chapter 4, *Other Aquatic Ecosystem Stressors*, were largely based on the corresponding chapters in the 2017 Scientific Basis Report. However, comments stating that no recent scientific references have been considered are unsupported. Before the release of the draft Staff Report in September 2023, scientific articles that were published after the release of the 2017 Scientific Basis Report were reviewed and added to the Staff Report as appropriate to update the science. In addition, more recent scientific references since the release of the 2023 draft Staff Report have been reviewed and added to the final Staff Report, as described below in *Process for Updates to Literature in Chapters 3 and 4 of the Staff Report*.

2026 Scientific Basis Report Supplement

Some commenters alleged that the Scientific Basis Report Supplement in Support of the Proposed Voluntary Agreements does not represent the best available science. The Scientific Basis Report Supplement serves as an addendum to the 2017 Scientific Basis Report by documenting the science supporting the anticipated environmental benefits of the proposed VAs, also referred to as the Healthy Rivers and Landscapes proposal. This report builds on the 2017 Scientific Basis Report with scientific information supporting specific flow and non-flow habitat restoration actions in the tributaries, flood bypasses, and Delta included in the VAs to provide the scientific basis for the VA pathway in the revised proposed Plan amendments. The Scientific Basis Report Supplement does not duplicate information in the 2017 Scientific Basis Report. Instead, it focuses on adding new scientific references, especially supporting recommendations on the Sacramento River, American River, Feather River, Yuba River, Bear River, Auburn Ravine, Putah Creek, Cache Creek, Friant system, Mokelumne River and the Delta. The draft Scientific Basis Report Supplement was released in January 2023 for public review and comment. The report was revised in response to public comment, and the final draft Scientific Basis Report Supplement was released as Appendix G2 of the draft Staff Report in September 2023. The final draft Scientific Basis Report Supplement was submitted for CalEPA External Scientific Peer Review in October 2023, following the same procedures as described above for the 2017 Scientific Basis Report. The University of California, Berkeley selected seven reviewers with substantial experience in environmental flows, aquatic ecology, salmonid ecology, riverine restoration ecology and habitat modeling, estuarine fish ecology, and wetland restoration ecology and habitat modeling. The reviewers were asked to evaluate six scientific conclusions that provide the basis for the Voluntary Agreements. All reviewers supported the six scientific conclusions. However, some reviewers had low confidence in their support for some conclusions, particularly in the quantitative and qualitative analyses used to evaluate the benefits of the VA commitments. The final draft was revised to address the reviewer's concerns and to respond to additional public comments, and the final Scientific Basis Report Supplement is being released with the final Staff Report as Appendix G2.

Process for Updates to Literature in Chapters 3 and 4 of the Staff Report

Several commenters provided specific references and attachments to their comment letters including, but not limited to, scientific articles, presentations, and technical reports. Some commenters suggested that the State Water Board should incorporate these suggested materials into the final Staff Report, in some cases with specific recommendations for how to incorporate them. Some commenters submitted large attachments of additional documents for consideration, with no context, and without stating specific conclusions that should be drawn from these resources. The State Water Board is not required to respond to attachments that the commenter did not directly relate to the Staff Report. Please see Common Response 1.1, *General Comments*, for further explanation on the approach to responding to comments.

All studies that commenters suggested should be specifically considered or cited for a specific conclusion were reviewed to note any new information that may potentially affect the discussion or conclusions in the Staff Report. Although not required, staff incorporated additional literature references into the final Staff Report as described below. Omission of individual scientific literature citations only affects the validity of the scientific analyses in the Staff Report if inclusion of the omitted literature would alter a conclusion. No conclusions in the Staff Report have been altered from the inclusion of additional literature citations suggested by commenters.

Recent research, reports, and special studies often serve to reinforce or complement the scientific knowledge found in the 2023 draft Staff Report, but do not significantly alter the findings or scientific basis on which the revised proposed Plan amendments or any alternatives are built. Newly incorporated information from added literature sources provides complementary or updated information to the scientific information in the 2023 draft Staff Report.

A consistent procedure was applied to update references in the Staff Report in response to comments suggesting incorporation of specific references for a clearly articulated purpose. As described further in Common Response 1.1, *General Comments*, submissions of literature lists without a specific connection of each reference to a specific change in the Staff Report were not considered. First, the findings of the suggested references were summarized. Then, the findings were compared to existing information in Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations*, and Chapter 4, *Other Aquatic Ecosystem Stressors*. New studies were included in the final Staff Report if they met the criteria described below. The most common additions to the Staff Report were more recent quantitative results from studies modeling flow and juvenile salmon outmigration survival and relationships between Delta smelt abundance and flow. These studies enhanced the descriptions of flow benefits at certain locations within the Delta without altering any conclusions or the underlying scientific basis for the flow scenarios analyzed in the Staff Report. In addition, information in Chapter 3 was updated with recent information on Endangered Species Act (ESA) and California Endangered Species Act (CESA) petitions and listings in response to comments.

In some instances, information in the Staff Report was updated to reflect evolving science. When updating Staff Report information to reflect evolving science, literature referenced by commenters was reviewed and additional literature review was conducted on these topics to include recent papers, studies, and reports that provide supplementary scientific content. For example, information related to harmful algal blooms (HABs) in Chapter 4, *Other Aquatic Ecosystem Stressors,* was updated to capture recently published studies of environmental conditions in the Delta that may affect HABs. Chapter 4 was also updated to reflect revisions made to the Scientific Basis Report Supplement. Specifically, information on shallow water habitat availability, food webs, and floodplain productivity was updated to align with the final draft Scientific Basis Report Supplement.

Scientific information from new studies was incorporated for either of the following two reasons:

1. A new study suggested by a commenter or discovered by literature review was cited and incorporated into Chapter 3 or 4 if it provided new or different scientific information from the scientific content already presented on the same topic in Chapters 3 or 4. However, incorporation of these new studies did not provide evidence to change the overall conclusions or broader concepts of Chapters 3 or 4 and generally reinforced the conclusions of those chapters. Inclusion of these citations similarly did not alter the conclusions of the environmental analysis in Chapters 7 and 9.
2. When commenters provided recent literature, the recent literature did not present new or different scientific information from the scientific content already presented on the same topic in Chapters 3 or 4, generally the most recently published study suggested by the commenter was cited. These revisions were intended to demonstrate that the most recent scientific literature was considered when updating the Staff Report.

2024 Biological Opinions

Multiple commenters questioned the use of outdated literature and models, including citations to the 2009 National Marine Fisheries Service (NMFS) Biological Opinion for the Long-Term Operations of the Central Valley Project and State Water Project describing Old and Middle River (OMR) flow requirements. While the specific OMR flow requirements described in Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations,* have changed since 2009, the science underlying them has not been contradicted (see the *Old and Middle River Flows and Fish Entrainment* section, below). References to the Biological Opinions were not updated throughout Chapter 3 because the underlying science has not changed, but a paragraph was added to final Staff Report Section 3.2.4, *Interior Delta Flows and Entrainment,* describing updated OMR flow requirements in the 2024 Biological Opinions and Incidental Take Permit.

Data Sources

The scientific information in Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations,* of the Staff Report relies on a variety of data sources, including both collected or measured environmental information and information resulting from modeling analyses.

Some commenters raised concerns with the data sources used in the presented information or analyses in Chapter 3. These concerns ranged from issues with the credibility of a particular data source to issues with how recently a data set was updated. In some cases, commenters suggested the use of a particular data set over another or asked for the analyses in Chapter 3 to be updated with data from more recent years. The following sections respond to comments on the data sources in Chapter 3.

Anadromous Fish Restoration Program and Constant Fractional Marking Program Data

Some commenters raised concerns with the use of Anadromous Fish Restoration Program (AFRP) data in the Staff Report, suggesting that figures from the AFRP are highly uncertain and flawed due to the assumptions around fish origin used for AFRP natural production estimates. Some commenters argued that the graphs and tables that use AFRP data throughout Section 3.4.3, *Life History, Distribution, and Abundance Trends over Time*, are therefore not indicative of natural production.

The AFRP was created through Title 34 of Public Law 102-575, also known as the Central Valley Project Improvement Act (CVPIA), enacted in 1992. The CVPIA federally mandated the creation of the AFRP, directing the Secretary of the Interior to "develop within three years of enactment and implement a program which makes all reasonable efforts to ensure that, by the year 2002, natural production of anadromous fish in Central Valley rivers and streams will be sustainable, on a long-term basis, at levels not less than twice the average levels attained during the period of 1967-1991." Similarly, the Salmon Protection Objective in the Bay-Delta Plan and State Water Board Water Right Decision 1641 states that "water quality conditions shall be maintained together with other measures in the watershed sufficient to achieve a doubling of natural production of Chinook salmon from average production of 1967-1991, consistent with the provisions of State and Federal law."

The purpose of the AFRP is to ensure sustainable natural production of anadromous fish, seeking to double natural production for each Chinook salmon run respective to the 1967-1991 time period. The Staff Report uses data from the Anadromous Fish Restoration Program (AFRP) to illustrate the recent (1992-2015) declines seen in natural production averages for all four Chinook salmon runs in the Sacramento and San Joaquin River watersheds.

The Staff Report acknowledges difficulties in determining natural production in Section 3.4.3.1, *Population Abundance Goals and Species Decline*. AFRP data indicate significant declines in natural production, despite population abundance goals, but the Staff Report recognizes the uncertainty associated with estimation methods (Cummins et al. 2008). The method used to produce the AFRP estimates has inherent limitations that create uncertainty in natural production estimates. Uncertainties in baseline population numbers, the presence of unmarked hatchery fish on spawning grounds, and a lack of data on the total percentage of hatchery fish present in the population all contribute to this uncertainty (Cummins et al. 2008; Newman and Hankin 2004).

While the Staff Report uses data from the AFRP to examine salmonid species abundance, some commenters suggested that data from the Constant Fractional Marking (CFM) Program should also be considered and accounted for in the survival and population analyses within the Staff Report.

The CFM Program began marking hatchery origin spawners in 2007 and can provide robust estimates of the present-day proportion of hatchery origin spawners on the tributaries. However, the lack of historical data from this program means that trends in the proportion of hatchery origin spawners cannot be observed prior to 2007, importantly missing the historic levels of native salmonids that are the target of restoration goals. AFRP numbers for fall run Chinook salmon can be dated back to 1952 and allow comparisons to historic salmonid run population numbers. Calculating long-term increases or averages for salmon requires many years of data and the AFRP is the only readily available dataset that satisfies this requirement. Although the CFM data are a valuable source of information, they are not a suitable substitute for the AFRP data because the time series is too short.

Although a commenter claimed the AFRP data are “known to be highly uncertain and flawed” and described how the AFRP data make assumptions about fish origin, they provided no supporting evidence for how these assumptions are flawed in ways relevant to how the data are used in the Staff Report, nor any documentation or quantification of the degree of uncertainty. Despite associated uncertainty, the AFRP natural production estimates and associated data are the numbers used by state and federal agencies to define the AFRP doubling goal and thus the Salmon Protection Objective outlined in the Bay-Delta Plan. For this reason, the AFRP estimates must be used to make accurate and consistent comparisons to measure progress toward these goals and, as described above, are the best available data for this purpose. In addition, natural production figures derived from AFRP data and used in the Staff Report were included in the peer-reviewed 2017 Scientific Basis Report. Please see earlier sections of this common response for a discussion on the peer review process of the 2017 Scientific Basis Report.

Fall Midwater Trawl

Throughout Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations*, the Staff Report uses data from the Fall Midwater Trawl (FMWT) to examine changes in species abundance over time and in relation to flow. Section 3.3.1, *Updated Quantitative Analysis,* describes how the FMWT abundance index is specifically used in the Staff Report analyses for abundance trends. Some commenters raised concerns with the use of FMWT data in the Staff Report, suggesting that FMWT data may not accurately reflect abundance for certain target species. Instead, the commenters recommended use of San Francisco Bay Study (Bay Study) data for longfin smelt or UC Davis Suisun Marsh Fish Study (Suisun Marsh Study) data for Sacramento splittail. The commenters stated that the FMWT does not sample longfin smelt in San Pablo Bay and San Francisco Bay. For Sacramento splittail, the commenter stated that the FMWT does not target bottom-oriented species and therefore does not illustrate the trends in relative splittail abundance seen in recent years from Suisun Marsh Study data.

The FMWT started data collection in 1967 and currently samples 122 stations ranging from San Pablo Bay to Stockton on the San Joaquin River, Hood on the Sacramento River, and the Sacramento Deep Water Ship Channel during the September to December period when fish move toward freshwater habitats for spawning. FMWT equipment and methods, such as the midwater trawl net, have remained consistent since the survey's inception, which allows annual abundance indices to be compared across time. The Bay Study began data collection in 1980 and currently samples 52 stations on a monthly basis, year-round. Sampling currently ranges from south of the Dumbarton Bridge in South San Francisco Bay, throughout San Pablo and Suisun bays, north to the confluence of Steamboat and Cache sloughs on the Sacramento River, and east to Old River Flats on the San Joaquin River. However, sampling was more limited in the first decade and was not conducted upstream of Sherman Lake near Antioch until 1991. The Bay Study samples with both an otter trawl and a midwater trawl at each open water station. The Suisun Marsh Study started standardized sampling in 1980, with 17 stations sampled consistently to the present. Sites are exclusive to the marsh surrounding Suisun Bay and are sampled on a monthly basis using beach seines and otter trawls.

Longfin smelt population abundance was analyzed in the Staff Report using the FMWT abundance index data rather than Bay Study data due to the longer history of the FMWT data set, allowing for changes in abundance to be documented over longer time scales, and because the FMWT population index has already been shown to be correlated with the Bay Study index (^Rosenfield and Baxter 2007; Nobriga and Rosenfield 2016). Additionally, longfin smelt move throughout the Delta during their growth and development, inhabiting both coastal ocean environments, such as San Francisco Bay, and tidally influenced freshwater habitats, including the habitats sampled by the FMWT. Juvenile and adult longfin smelt begin to move more into the interior and upper estuary during the fall, from September to December (Nobriga and Rosenfield 2016), which coincides with FMWT sampling of the upper estuary during the same September through December time period.

The FMWT index can be considered a time-bound quantification of longfin smelt population despite the spatial and temporal extent of their spawning migration that could vary depending on environmental conditions. The longfin smelt catch index estimated from the FMWT has been used in numerous scientific studies (Thomson et al. 2010; ^Kimmerer 2002b; ^Baxter et al. 2010; ^Rosenfield and Baxter 2007; ^Moyle 2002). Despite differences in geographic extent, timing, and sampling methods, the Bay Study and FMWT sampling programs detected the same general patterns in longfin smelt population dynamics and the two indices were well correlated (^Rosenfield and Baxter 2007; Nobriga and Rosenfield 2016). The U.S. Fish and Wildlife Service (USFWS) also uses FMWT data for longfin smelt Species Status Assessment reports (USFWS 2022; USFWS 2024b). They similarly conclude that the FMWT is highly correlated with the Bay Study for longfin smelt. In addition, the USFWS describes how the FMWT samples the low-salinity zone when Bay-Delta longfin smelt return to the upper estuary in the fall and early winter and conclude that the FMWT sampling in this region can be considered a reasonable index for population abundance since a large proportion of the longfin smelt population, including both young and old individuals, occupy this habitat prior to and during spawning (89 Fed. Reg. 61029, p. 59).

Similarly, the FMWT dataset was selected for Sacramento splittail abundance indices in the Staff Report rather than the Suisun Marsh Study data due to the longer sampling history of the FMWT and better coverage of the geographic extent of the species. Sacramento splittail can be found in various regions throughout the Delta depending on their life stage. As adults, splittail largely spend time in Suisun Bay, Suisun Marsh, and the western Delta during the summer and fall (Caywood 1974; ^Moyle et al. 2004). Mature splittail then migrate upstream for spawning in the winter-spring using the Yolo and Sutter bypasses when floodplains are sufficiently inundated (^Meng and Moyle 1995; ^Feyrer et al. 2006b; ^Sommer et al. 1997). The duration of floodplain inundation is strongly related to spawning success such that floodplain inundation of at least a month is needed for successful splittail spawning (^Sommer et al. 1997). This means that the mechanism for the benefits of flow to splittail populations is directly tied to inundation of the floodplain spawning areas. The FMWT covers significantly more area than the UC Davis Suisun Marsh Fish Study and, importantly, samples adjacent to the upstream floodplain spawning area for the species. Since the species-specific analyses in the Staff Report are focused on species related flow benefits, use of the FMWT data would be expected to more accurately capture the effects of flow on splittail abundance.

While the Suisun Marsh Study and Bay Study otter trawls are more effective at catching littoral species such as splittail than the FMWT (Huntsman et al. 2022), the FMWT is able to capture splittail effectively enough to produce a population index, the survey has a longer time series of data, and the survey more accurately covers the entire extent of their geographic range than the Bay Study or Suisun Marsh Study. Splittail catch data from the FMWT have also been used in prior scientific studies to illustrate species abundance (^Moyle et al. 2004; ^Kimmerer 2002b).

This discussion demonstrates that the use of FMWT data in Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations,* was appropriate. In addition, the applications of FMWT data in Chapter 3 were derived from the peer-reviewed 2017 Scientific Basis Report. Please see earlier sections of this common response for a discussion on the peer review process of the 2017 Scientific Basis Report.

Selection of Data Sources

Some commenters argued that the data sets used in the Staff Report are outdated and that more recent data should be incorporated to reflect the best available science. Additionally, commenters suggested that other data sets should be used or considered for analyses within the Staff Report.

The 2017 Scientific Basis Report forms the basis for the science and analyses provided in Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations*, of the 2023 draft Staff Report. Accordingly, much of the data used in the analyses are only current up to or near the release of the 2017 Scientific Basis Report. As addressed above, science and literature have been updated prior to release of the final Staff Report. The purpose of these updates is to provide new and relevant information, but these updates do not change the overall recommendations resulting from Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations,* or conclusions of the environmental analysis in Chapter 7, *Environmental Analysis*, Chapter 9, *Proposed Voluntary Agreements*, and Chapter 13, *Revised Proposed Plan Amendments*, of the Staff Report.

As discussed in more detail in Common Response 1.2, *Water Quality Control Planning Process*, a complex regulatory scheme under the federal Clean Water Act and California Porter-Cologne Act governs the quality of California's waters. Under this regulatory scheme, the State Water Board is required to "establish such water quality objectives in water quality control plans as in its judgment will ensure the reasonable protection of beneficial uses[.]" (Wat. Code, § 13241.) Water Code section 13241 also identifies certain factors that the State Water Board must evaluate when establishing water quality objectives, including the past, present, and probable future beneficial uses of water. Staff Report Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations,* presents and evaluates scientific information relevant to determining how to achieve the reasonable protection of fish and wildlife beneficial uses.[1] In satisfying its duties under the Porter-Cologne Act and the Clean Water Act, the State Water Board is not obligated to conduct an analysis using every data set available. While there may be debate regarding which dataset is best suited for an analysis, the data sets used in the Staff Report are all appropriate for the purposes for which they are used. Differing opinions on the best dataset for a purpose does not equate to inadequacy. A disagreement among experts does not make an environmental analysis inadequate. (Town of Atherton v. California High-Speed Rail Authority (2014, 228 Cal.App.4th 314.) The "relevant issue is only whether the studies are sufficiently credible to be considered as part of the total evidence that supports the agency's decision," not whether the studies "are irrefutable or whether they could have been better." (State Water Resources Control Board Cases (2006) 136 Cal.App.4th 674, 795.)

Additionally, the incorporation of more recent data would not change the resulting trends and conclusions drawn from the Staff Report analyses. In many instances, more recent data only reinforces the relationships observed in the 2017 Scientific Basis Report. As stated in State CEQA Guidelines, Section 15204, subdivision (a), lead agencies need only respond to significant

[1] For an explanation of other factors evaluated by the State Water Board pursuant to Water Code section 13241 and where those factors are discussed in the Staff Report, see section 13.6.2 of the Final Staff Report.

environmental issues and do not need to provide all information requested by reviewers as long as a good faith effort at full disclosure is made in the environmental document. (Cal. Code Regs., tit. 14, § 15204, subd. (a).) As more recent data has become available post release of the 2023 draft Staff Report, this new information is acknowledged but not included in the final Staff Report as it does not change the recommendations or conclusions which inform the basis of the State Water Board's CEQA analysis and its analysis pursuant to the Clean Water Act and Porter-Cologne Act.

Adequacy of Modeling to Support the Benefit Analyses

Several commenters critiqued the methods used to analyze benefits of the alternatives or suggested alternative analytical methods. The State Water Board is not obligated to conduct an exhaustive analysis using every approach, modeling tool, and data set available. While some commenters may prefer different modeling methods, the models used in the Staff Report are all appropriate for the purposes in which they are used. This subsection of this common response responds to comments on the modeling and scientific studies described in Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations,* and Chapter 4, *Other Aquatic Ecosystem Stressors*. Topics include modeled relationships between flow and species populations, habitat analyses, temperature, and entrainment of native fish species.

Flow Benefit Analyses

Some commenters expressed concerns with the flow benefit analyses and skepticism that increasing flow will result in increased abundance of native fish in the Bay-Delta. The scientific basis reports and Staff Report were informed by scientific studies on fish and wildlife responses to flow conditions throughout the Bay-Delta watershed. As described above, peer reviewers supported the conclusions of both Scientific Basis Reports. Methods for the analysis of the benefits of increased flow were primarily developed in the 2017 Scientific Basis Report. The 2026 Scientific Basis Report Supplement made minor modifications to the flow-abundance methods to incorporate model uncertainty and as described below, flow thresholds were updated in response to comments on the 2023 draft Staff Report.

The effects of flow on species were evaluated with a variety of analytical methods as described in the Staff Report in Section 3.3, *Species-Specific Analyses*. When possible, multiple methods were used and thus, in many cases, the conclusions were supported by multiple lines of evidence. These analyses included linear models of species abundance indices as a function of Delta outflow, estimation of median flows during a period of years when the population abundance of a species attained an abundance goal from the *"2010 Development of Flow Criteria for the Sacramento–San Joaquin Delta Ecosystem"* report, and logistic regressions of the probability of population growth as a function of Delta outflow. A regression analysis is a valid tool for estimating relationships of abundance with flow and follows the most common method used in other published Bay-Delta studies. In addition, these methods were peer reviewed as described above, and the limitations of these methods are acknowledged in the Staff Report, including in Sections 3.3.1, *Updated Quantitative Analysis*, and 3.14, *Evaluation of Bay-Delta Environmental Effects*.

Some commenters suggested that flow-abundance relationships could be spurious correlations or otherwise cast doubt on the benefits of flow for aquatic species in the watershed. The analyses and literature review in Chapter 3*, Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations,* affirm the positive effects of flow on aquatic species residing in and migrating through the Delta. While the slope of the flow-abundance relationship has changed for some species during the last half century of monitoring, it has always remained positive. Likewise, more Delta outflow in winter and spring consistently has been associated with a higher abundance of fish in fall. Chapter 3 also identifies mechanisms for the beneficial effects of flow (e.g., see Table 3.14-2). In addition, past studies have consistently demonstrated the importance of flow to species populations. Many of the scientific studies cited in Chapter 3 evaluated other environmental predictors in addition to flow, including temperature, turbidity, and off-channel rearing habitat availability and concluded that the best-fit models often included a combination of flow and another environmental predictors (e.g., Connor et al. 2003; Henderson et al. 2018, Hassrick et al. 2022). The preponderance of evidence in combination with the identification of mechanisms refutes suggestions that flow-abundance relationships could be spurious.

Some commenters claimed that recent data no longer support a positive relationship between flow and fish abundance, or that the linear regression analysis is inadequate, for example due to model uncertainty. Most of these comments did not provide details on specific uncertainties of concern or recommendations for alternative modeling methods. In addition, while some commenters agreed that increasing flow would boost native fish abundance, some expressed concerns that the abundance of non-native fish species would also increase. Results of recent studies using different modeling methods further affirm the relationships between flow and abundance described above and presented in Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations,* as well as the conclusion that a more natural flow regime benefits native over nonnative species. Colombano et al. (2022) used a multivariate autoregressive state-space (MARSS) model on long-term monitoring data from the Bay-Delta watershed. This study found a positive relationship between abundance and flow for anadromous and some estuarine dependent fish species, with geographical variability in the strength of the relationship (Colombano et al. 2022). Baruch et al. (2024) also used MARSS models to study the responses of the fish community to the restoration of a more natural flow regime in Putah Creek as a result of the Putah Creek Accord. They found that functional flow metrics, hydrologic variables that quantify the magnitude, timing, frequency, duration, and rates of change of the five functional flow components (fall pulse flow, wet season baseflow and peak flows, spring recession flow, and dry season baseflow; Yarnell et al. 2020),were significant predictors of fish abundance and that flow changes toward a more natural flow regime benefited native fish species and suppressed non-native fish species (Baruch et al. 2024). Jacinto et al. (2023) also reported that the richness of nonnative species decreased following the Putah Creek Accord, while the richness of native species increased or stayed constant, especially in the upper-most reaches of Putah Creek below the diversion dam.

Some commenters suggested that the positive correlations between flow and fish abundance should not be assumed to continue in the future or commenters otherwise expressed concern about uncertainty in the effects of flow. As described above, the Staff Report presents substantial evidence for the benefits of flow for fish, and other aquatic species, and recent studies further support those conclusions. However, uncertainty is inherent in any programmatic planning effort of this geographic and temporal scale. Climate change and the possibility for future unpredictable regime shifts add to this uncertainty. To address uncertainty, the revised proposed Plan amendments allow for adaptive management of flows, which could be used to incorporate new scientific understanding and respond to changing conditions. In addition, the science and monitoring conducted as part of the Bay-Delta Monitoring and Evaluation Program will evaluate the effectiveness of the flow and non-flow implementation actions and increase our understanding of the most effective management tools to improve conditions for fish and wildlife in the watershed. Science and monitoring information will be used to inform adaptive implementation, and annual and periodic reviews will offer an opportunity to regularly assess the Bay-Delta Plan and its implementation and adjust as needed. More information on the revised proposed Plan amendments can be found in Common Response 1.3, *Revised Proposed Plan Amendments*.

The scientific information summarized in the Staff Report and used to inform the flow scenarios is consistent with the information used to support holistic methodologies for development of environmental flows. As described in Section 3.13.4, *Holistic Methods for Determining Environmental Flows*, holistic methodologies synthesize a vast assortment of hydrological information at the scale of the whole ecosystem, considering all ecosystem processes that may be influential in setting environmental flows. This information includes hydrologic data that reflects both developed and undeveloped conditions, regional or location-specific understanding of flow-ecosystem relationships, and more general ecological understanding of the aquatic system. The Staff Report reviews the hydrology of the Bay-Delta watershed in Chapter 2, *Hydrology and Water Supply*, and uses a 94-year hydrologic record of flow for modeling under current conditions and unimpaired conditions to illustrate the impacts of water development while still acknowledging that unimpaired flow does not represent the natural flow that would have occurred pre-development. Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations,* then reviews information on the relationship between flow and ecosystem structure and function, including species-specific responses to flow, to inform the assessment and development of environmental flows.

The following subsections address commenters' concerns about specific components of the flow benefit analyses, including a discussion on longfin smelt and Delta smelt as an example to address commenters' concerns about the analysis between flow and abundance, comments suggesting the use of life cycle models, comments suggesting specific frequencies of flow are needed, comments on tributary-specific flow recommendations or analyses, and updates to the flow threshold analysis in response to comments.

Longfin Smelt and Delta Smelt

Some commenters critiqued the flow-abundance analyses specifically for longfin smelt or Delta smelt and expressed skepticism that new management actions would produce population benefits for those species.

Commenters questioned the relationship between Delta smelt and spring, summer, or fall Delta outflow or X2[2] location. Other commenters supported these relationships and suggested additional evidence to provide further support. Staff Report Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations,* includes analyses of the relationship between Delta smelt abundance and Delta outflow for various seasons in Section 3.8.4, *Flow effects on Delta smelt*. The modeling showed a significant relationship between spring outflow and larval Delta smelt abundance (Figure 3.8-2). Modeling showed that Delta smelt were more likely to survive when summer outflow was higher. Most of the analyses of the seasonal relationships also demonstrated a time "lagged" effect, whereby conditions experienced by the prior year's cohort affects Delta smelt abundance in subsequent years. For example, examining historical data, the abundance of larval Delta smelt in spring has been positively correlated with the magnitude of Delta outflow during

[2] "X2 is the location in the Bay-Delta where the tidally averaged bottom salinity is 2 parts per thousand. It is expressed as the distance in kilometers from the Golden Gate Bridge."

previous winter-spring and fall periods. In addition, in years after 2002, if the magnitude of summer outflow was small (flows < 7,500 cubic feet per second [cfs]) between June and August, then abundance was lower during the fall of the same year (^CDFW 2016b). In the fall, more breeding adults combined with higher fall outflow resulted in greater larval abundance in the following spring (^Baxter et al. 2015). Outflow in the summer also increases the transport of food resources like zooplankton (^Hennessy and Burris 2017, Hassrick et al. 2023) that can contribute to increased survival of Delta smelt (^CDFW 2016b).

Some commenters recommended the consideration of additional studies that examine the relationship of outflow with Delta smelt abundance or population growth. Three recent studies modeled Delta smelt with stage-structured state-space models, using a variety of covariates including temperature, outflow (or X2), turbidity, food, and interior Delta flows (Smith et al. 2021; Polansky et al. 2021, 2024). The results of these studies support the summer and fall outflow relationships in the Staff Report. Polansky et al. (2021) found that Delta smelt recruitment in the spring was most influenced by temperature, X2 during the previous fall, and adult food, and that post-larval survival in the summer was most influenced by turbidity and summer outflow. Smith et al. (2021) was mainly focused on entrainment mortality but found that reduced summer outflow was associated with increased late post-larval mortality. Polansky et al. (2024) concluded that summer Delta outflow had the strongest effect of any covariates on survival and population growth rate and that population growth rate becomes positive when summer Delta outflow exceeds 10,208 cfs. This threshold has been incorporated into the flow threshold analysis in the Staff Report, as described further below.

Some comments suggested that the proposed fall X2 (increased Delta outflow in the fall) requirement would not have measurable effects on the Delta smelt population and cited the USFWS 2024 BiOp and Polansky et al (2024) as evidence. A recent report, "Summer-Fall Habitat Actions for Delta Smelt – Report on Effectiveness of Actions Taken Between 2011 and 2024 (DWR 2026)," summarizes the science supporting the Delta smelt summer-fall habitat action, including fall Delta outflow (X2) and the operation of Suisun Marsh Salinity Control Gates (SMSCG). This report concluded that that higher Delta outflow (lower X2) and SMSCG operation in summer and fall increased Delta smelt physical habitat availability and that higher Delta outflow (lower X2) and lower salinity in Suisun Bay and Suisun Marsh during summer showed stronger correlations to improved Delta smelt condition and survival than higher outflow and lower salinity during fall (DWR 2026).

In Polansky et al. (2024), summer Delta outflow was identified as the most influential hydrologic variable affecting Delta smelt population growth and fall turbidity (measured as Secchi depth) was identified as a stronger predictor of survival than fall Delta outflow. As described in Table 1 of Polansky et al. (2024), Delta outflow is mechanistically linked to turbidity because higher Delta outflow generally increases turbidity conditions that are beneficial to Delta smelt. The highest-performing models in the Polansky et al. (2024) study included both summer outflow and fall turbidity. Because Delta outflow influences the location and extent of low-salinity, turbid water, the effects of fall Delta outflow may be reflected in observed Secchi depth values. Consequently, models that include Secchi depth, including the highest-performing models in the study, may indirectly capture the effects of fall Delta outflow even when fall Delta outflow is not explicitly included as a covariate. Therefore, the absence of fall Delta outflow from the best performing models does not demonstrate an absence of effect or benefit to Delta smelt population. Rather, the importance of fall turbidity in the highest-performing models suggests that fall Delta outflow remains an important factor influencing Delta smelt population growth.

Recently the United States Geological Survey, published a report (Healy et al. 2025) continuing the discussion on the summer and fall flow effects on Delta smelt. They summarized their findings from a facilitated structured decision-making process. They evaluated the performance of various alternative management actions on different objectives that ranged from focusing on the best outcome for human health and water quality, to producing benefits to Delta smelt or salmonid populations. Within the analysis Healy et al. (2025) used an individual-based life cycle model to examine the change in distribution of Delta smelt, such as the one used in Rose et al. (2013). The analysis concluded that the two alternative management actions that would be most likely to maximize Delta smelt populations included increasing summer and fall outflow. These actions included either: 1) an evenly distributed outflow of 20,400 cfs from June to August, or 2) an average summer outflow of 20,400 cfs with peak outflow in June and receding amount in July and August. Both management actions included a 74 km X2 location from September to October. The authors predicted that both management actions would result in minimum abundance above the 400,000 needed to collect mature adult fish to maintain hatchery supplementation programs. For comparison, Polansky et al. (2024) incorporated average summer outflow as a predictor of population growth in their life cycle model, and the analysis resulted in thresholds of 10,200 cfs for a 50 percent probability of increase and 20,400 cfs for a 75 percent probability of increase. The alternative management actions for maximizing water supply exports for the State Water Project and the Central Valley Project did not estimate large Delta smelt populations.

For longfin smelt, commenters challenged the relationship between winter and spring outflow and abundance in the subsequent fall months. Some commenters also alleged that the effect of outflow on longfin smelt abundance has declined or disappeared in recent years and the benefits of increasing flow during the winter and spring for the population are uncertain. In addition, commenters disagreed with the use of the low salinity zone (X2 location) to define longfin smelt habitat.

The opposite point of view is also represented in the comments. Some commenters agreed that longfin smelt populations benefit from increased Delta outflow and that the positive relationship between longfin smelt and Delta outflow is well documented and durable through time and provided their own analysis through water year 2022. The Staff Report used the FMWT index for longfin smelt over the years 1967-2016 to illustrate the relationship between abundance and Delta outflows during the preceding January-June period (Figure 3.5-2). The analysis in the Staff Report found a significant relationship between January through June Delta outflow (or X2) and the subsequent FMWT index. In addition, the Staff Report analysis demonstrated that average daily outflows of 42,800 cfs in January to June are associated with a 50 percent probability of positive population growth. After the release of the 2023 draft Staff Report, commenters performed an analysis using a new period from 1988 to 2022 that showed that the FMWT abundance index change was positive when Delta outflow was 60,000 cfs or higher from January to June. The identified threshold is likely higher than the threshold identified in the Staff Report because a shorter and different time period was used (1988-2022 versus 1967-2016 in the Staff Report) and a different method of analysis was used. The commenters used a regression analysis that correlated longfin smelt *index change* with Delta outflow and the Staff Report used a logistic regression that evaluated *probability of population growth* at different outflow levels. Although both statistical approaches are valid, as described above, the State Water Board is not obligated to conduct an exhaustive analysis using every approach, modeling tool, and data set available. As is typical for statistical analysis, analyzing the same dataset different ways or analyzing different subsets of the same dataset (i.e., different time periods) would be expected to produce different results. In addition, the Staff Report methods for analyzing the relationships between flow and abundance were developed as part of the peer-reviewed 2017 Scientific Basis Report, and the peer-reviewers determined that the approach in the Staff Report is adequate for analyzing the effects of Delta outflow on the species.

Some commenters suggested that the analysis of longfin smelt should only consider Delta outflow outside the January through March period and cited Kimmerer and Gross (2022) for support. The same commenters did not reference new studies that would suggest an alternative threshold should be used from a different time period. The analysis from Kimmerer and Gross (2022) cannot be directly compared to the analysis in the Staff Report. Those authors used data sources that differ from those in the Staff Report analysis and used a shorter time period for the data analysis. Kimmerer and Gross (2022) estimated population size from data collected during the Smelt Larva Surveys from 2009 to 2020, an 11-year period, instead of using the Fall Midwater Trawl index data. The Staff Report includes a FMWT index analysis that encompasses data from almost 50 years, including 1967 to 2016. Moreover, Kimmerer and Gross (2022) compared data from observed and predicted catch per trawl, which led to underestimation of the population size, particularly during high flow years. Kimmerer and Gross (2022) did not find a significant statistical relationship between Delta outflow during the January-March period and larval longfin smelt abundance, but this finding does not mean there is no relationship between outflow and longfin smelt population size, as their analysis examined effects with data from only one life stage category: larvae. They suggest that "population size was not related to freshwater flow in the year of hatching [larval stage] but positively related to the subsequent juvenile abundance index." In the same study, Kimmerer and Gross (2022) ran a model including the year and spring X2 location as predictors of abundance, which were found to explain 81% of the deviance in the longfin smelt fall abundance index (Figure 2, Kimmerer and Gross 2022). Therefore, the spring outflow effects on abundance cannot be considered negligible based on their analysis. As described in the Staff Report, the specific flow estimated to correspond to a 50 percent probability of population growth is sensitive to the choice of months and years included in the analysis. Both the staff analysis and other analyses referenced in Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations*, indicate that longfin smelt population abundance indices respond positively to higher outflow conditions during January through to late spring. Moreover, the January through June period remains significant as it encompasses the peak spawning period for longfin smelt (^Emmett et al. 1991; ^CDFG 2009; ^Wang 1986, 2007) and longfin smelt are known to spawn in close proximity to the low salinity zone (^Baxter et al. 2009).

Some commenters observed that the FMWT longfin smelt indices in 2021 and 2022, both critically dry years, were higher than expected based on the flow abundance relationships in the Staff Report. These higher-than-expected catches could be attributed to possible changes in the location of suitable habitat where greater salinity intrusion during drought years could have shifted more fish into the geographic range of the FMWT survey. In addition, early season precipitation events prior to the FMWT sampling could have initiated longfin smelt migration into the estuary, temporarily increasing catch (Malinich et al. 2022). During the 2021 FMWT surveys, longfin smelt were only observed in the west Delta and San Pablo Bay regions, and catch was below average in September and October but began to increase until peaking in November (San Pablo Bay) and December (West Delta). In the subsequent wet year of 2023, the FMWT longfin smelt index (464) was close to or higher than index values for recent wet years. In the decision to list longfin smelt as federally endangered, USFWS responded to similar comments by explaining that the longfin smelt population is highly variable and the fluctuations in 2021 and 2022 are therefore not unexpected. They conclude that "Similar increases in abundance have occurred in 2000, 2006, 2011, 2013, and 2017;

however, all of these increases resulted in abundance estimates that are well below those prior to the declines experienced in the 1980s when population numbers were several orders of magnitude greater than those currently experienced by the DPS [distinct population segment]" (89 Fed. Reg. 61029 p. 61).

Some commenters noted that the Staff Report analysis of longfin smelt did not use data from the full geographic extent of the species' range and specifically did not include data from coastal marine waters. Currently no long-term monitoring data exist from all geographic regions where longfin smelt occurs. Thus, the best available data, covering the largest geographic extent and timeframe possible, were used to analyze the longfin smelt population in the Bay-Delta estuary. The discussion above on data sources provides more information on the data sources used for longfin smelt. In addition, Section 3.5.2, *Life History*, of the Staff Report acknowledges that longfin smelt spend time in San Francisco Bay and move outside of the Golden Gate to marine waters.

Since the release of the 2023 draft Staff Report, longfin smelt have been federally listed as endangered (89 Fed. Reg. 61029). The CDFW Smelt Larva Surveys demonstrate that catch of longfin smelt larvae has been consistently lower in the period from 2014-2019 than years prior (Eakin 2021). The USFWS identifies in the listing that the main cause of the population decline is "habitat loss, primarily due to long-term reductions and alterations to freshwater flow into the San Francisco Bay estuary." During the public rulemaking for longfin smelt, the USFWS received nearly identical comments as those received by the State Water Board, on the relationship between outflow and the low-salinity (X2) zone mechanism and longfin smelt. While the USFWS acknowledges "the decreasing explanatory power of the flow-abundance model" on longfin smelt (89 Fed. Reg. 61029 p. 37), "the SSA [species status assessment] reports illustrate the point that when declining spawning stock is considered in the outflow-abundance model, the explanatory power of the flow-abundance model did not degrade over time" (89 Fed. Reg. 61029 p. 38). Thus, the ability of the flow-abundance model to capture changes in longfin smelt populations has remained steady over time when accounting for declines in adult numbers, which are in turn caused by reduced outflow and other stressors. In addition, recent studies such as Colombano et al. (2022) and Kimmerer and Gross (2022), and Saffarinia et al. (2026) have reaffirmed the positive relationship of longfin smelt abundance with outflow.

It is not clear what mechanism is causing the apparent weakening of the relationship between longfin smelt and outflow observed in the last decade. Other ecosystem stressors, such as reduced turbidity (Nobriga and Rosenfield 2016), increasing salinity (Grimaldo et al. 2017) and predation (^Grossman 2016), influence survival in addition to outflow levels. The decline could also result from internal population dynamics, such as a stock-recruitment effect, whereby population size is affected by spawner abundance, or the Allee effect, in which population size decreases at low population densities as individuals struggle to find mates, food, or defend against predators. The USFWS conclusion that the flow-abundance model retains explanatory power after accounting for adult longfin smelt population numbers provides support for this hypothesis. In addition, given the hydrological variability in California and the high variability in species population numbers, a long time series is necessary to accurately characterize a flow-abundance relationship, so only looking at a "recent" subset of the timeseries (e.g., post-2017 years) is unlikely to yield a complete picture of the flow-abundance relationship. For example, White (2019) studied 822 populations of vertebrate species and found that 72% required at least 10 years of continuous monitoring to detect trends in abundance over time with high statistical power. Given the complexity inherent from the inter-annual variability in hydrological conditions, it should presumably require even more years of data to accurately estimate relationships between flow and abundance than to estimate trends over time.

To evaluate changes in the flow-abundance relationship and identify possible mechanisms, it would be beneficial to conduct further modeling of outflow and longfin smelt populations including stock-recruitment effects.

Life Cycle Models

The State Water Board received comments suggesting the use of life cycle models to improve understanding of the effects of flow and other environmental conditions on species population abundance. Commenters suggested a variety of models including the winter-run Chinook salmon life cycle model (Hendrix et al. 2019), *Oncorhynchus* Bayesian Analysis (OBAN), and the USFWS Delta smelt life cycle models. Some commenters suggested the use of life cycles models without providing any suggestions for a model that could be used. Life cycle models include effects of environmental conditions on different life stages of a species, such as egg, juvenile, and adult stages, and can be used to understand the possible effects of management decisions on population size.

The Staff Report already incorporates information from studies using life cycle models. The 2023 draft Staff Report cited life cycle modeling studies, and additional citations to more recent life cycle modeling studies have been added to the final Staff Report (e.g., Polansky et al. 2024), such as reference to the USFWS Delta Smelt modeling studies described in the prior section, *Longfin Smelt and Delta Smelt*. In the 2023 draft Staff Report, Rose et al. (2013) is an example of a life cycle model for Delta smelt which analyzed key life stages from eggs to age 3 adults and isolated the effects of factors associated with abundance. The Staff Report describes these results and those of other studies in Section 3.8.4, *Flow Effects on Delta Smelt*.

Life cycle models have some limitations. Existing life cycle models, such as the one used by the Central Valley Project Improvement Act Science Integration Team (CVPIA SIT, Peterson and Duarte 2020) for evaluating different management actions for achieving the salmon doubling goal, use parameter values for environmental conditions and life stage transitions estimated from literature or negotiated among interested parties, for species and geographic regions that differ from the Bay-Delta estuary, which may not accurately represent processes occurring for populations in the Bay-Delta watershed. Furthermore, life cycle models are not available for all species analyzed in the Staff Report and the models that are available, were often built and calibrated for specific management scenarios that differ from the flow scenarios evaluated in the Staff Report, and it is unclear whether these models could be modified to evaluate the flow scenarios, or how long that process would take, if feasible.

If life cycle models are further developed, they may be useful for implementation of the revised proposed Plan amendments, such as for development of Biological Goals, periodic reviews, and through the Bay-Delta Monitoring and Evaluation Program. More details on Biological Goals and the Bay-Delta Monitoring and Evaluation Program are provided in Common Response 1.3, *Revised Proposed Plan Amendments*.

Effects of Ocean Conditions

Some commenters suggested that the analyses in the Staff Report need to incorporate other factors such as ocean conditions in addition to freshwater flow effects. These commenters provided references to recent life cycle studies that analyzed salmon population responses to different environmental conditions during various life stages from early development (successful egg hatching), to outmigration, through to ocean residency. However, the results of these studies reinforce the conclusions in the Staff Report regarding the importance of freshwater flow for various life stages. Friedman et al. (2019) developed a life cycle model to evaluate variability in historic data for fall-run Chinook salmon returns. Analyzing different environmental conditions, they found that temperature-dependent egg mortality, freshwater flow and predation during early marine residence are the most influential factors on population numbers. Although they found that marine predation had the most significant effect on model performance, all of the environmental conditions are linked. Additional flow in the watershed directly impacts instream temperatures and produces carryover effects on marine survival. Michel (2019) is one of the few studies comparing survival rates for through-Delta outmigration to ocean life stages for overall cohort success (smolt to adult ratio) of Central Valley Chinook salmon. Michel (2019) concludes that outmigration survival and associated Delta conditions are the primary drivers of interannual variability in the smolt to adult ratio, and the role of marine conditions is limited. Freshwater flow during juvenile outmigration was a strong predictor for cohort success (Michel 2019). Only when marine conditions are abnormally poor, such as when productivity is at its lowest, do ocean conditions strongly impact cohort success. Ultimately, marine ecosystem conditions should continue to be studied, but do not discount the importance of flow on fish populations at various life stages.

Frequency of Flows

Some commenters suggested that the flow thresholds identified in Staff Report Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations,* should include quantification of the necessary frequency of occurrence to provide reasonable protection of species or achieve population growth. Commenters also submitted suggestions for methods for defining the required frequency of occurrence of specific species' flow thresholds. For example, sturgeon require a relatively long time to sexually mature and spawn several times during their lifespan; as such, some commenters wished to see flow thresholds exceeded every year or at least 1 of 4 years to support the reproductive population.

In Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations,* frequency was considered when the ecological flow thresholds were identified to help shape and evaluate the proposed flow requirements. The ecological flow thresholds were chosen to represent flows (or X2 location) at which benefits to species were achieved, generally to support the needs of specific species. The flow thresholds provide an indication of the magnitude, duration, and seasonality of flow that may be required to support the native species. The thresholds correspond to periods within the species' life cycle when activities such as spawning or juvenile outmigration occur. The flow should not be taken to represent absolute flow needs (or a minimum value) that must be met at all times or in all years to support native species. Rather, they serve as indicators of conditions that favor native species and constitute a set of quantifiable metrics that can be used to assess the relative protection afforded by a range of flow alternatives. The Staff Report contains an analysis of how often each flow scenario and the flow commitments provided under the VA pathway would exceed these thresholds in Chapter 3 and Sections 9.6, *Beneficial Environmental Effects of Proposed VAs*, and, Section 13.5, *Beneficial Environmental Effects*, and Appendix H1c, *Beneficial Environmental Effects,* to quantify the environmental benefits. Although commenters asserted that the analysis should be supplemented with a discussion of how often these thresholds need to be met to provide reasonable protection, the State Water Board has broad authority and discretion to determine what levels of flow, in combination with other measures such as habitat restoration, provide "reasonable protection" to beneficial uses under Water Code section 13241. Please see Common Response 1.2, *Water Quality Control Planning Process,* for a discussion of the consideration of beneficial uses and factors under Water Code section 13241.

Updated Flow Thresholds

A few commenters requested that the Staff Report include information about new flow thresholds from additional scientific studies. The 2017 Scientific Basis Report includes quantitative evaluations of the frequency of exceeding ecological flow thresholds for native species under the flow scenarios. The background and rationale for each threshold is described in Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations*. Each flow threshold was chosen to represent flows at which benefits to species were achieved, generally to support the needs of specific species, but some represented key X2 thresholds known to be beneficial for native species. Studies suggested by commenters for updating flow thresholds were reviewed following the same process as described above in *Process for Updates to Literature in Chapters 3 and 4*. Additional flow thresholds were incorporated into the analysis based on consideration of the following: 1) whether new studies relied upon peer-reviewed robust scientific methods to evaluate flow benefits for native species in the Sacramento/Delta watershed; 2) whether the studies evaluated new statistical relationships from what was evaluated in the 2017 Scientific Basis Report; 3) whether the new studies quantified flow benefits for native fish species at locations not evaluated in the 2017 Scientific Basis Report; and 4) whether the new studies analyzed flow thresholds for species or salmon runs for which flow thresholds were not identified in the 2017 Scientific Basis Report. Five new thresholds that satisfy these criteria were added to the flow threshold analyses.

Two studies demonstrated a positive statistical relationship between flows in the interior Delta and survival of late fall-run and winter-run out-migrating Chinook salmon. These studies supplemented the analysis of the lower Sacramento River, in reaches that are tidally influenced. Perry et al. (2018) demonstrated that through the lower Sacramento River, Sutter and Steamboat Slough, and Georgiana Slough, late fall-run as surrogate for winter-run probability of outmigration survival increased with flows up to approximately 35,315 cubic feet per second (cfs) at Freeport from December through March. Hance et al. (2022) analyzed survival for winter-run Chinook salmon in the same reaches and found that survival probability increased with daily flows up to 35,315 cfs at Freeport from February to mid-May. Therefore, a new flow threshold is incorporated for 35,300 cfs at Freeport during December through May for the outmigration survival of winter-run Chinook salmon.

Michel et al. (2021) modeled outmigration survival for all runs (but predominantly fall-run) as a function of flows on the Sacramento River at Wilkins Slough. The flow-survival relationship was best depicted as a step function. During mid-March to mid-June survival increased markedly when daily mean flows exceeded 10,712 cfs. For the purposes of the ecological flow threshold benefits analysis, this conclusion was translated into a new threshold of 10,700 cfs at Wilkins Slough during March through June for the outmigration survival of Chinook salmon.

Munsch et al. (2020) modeled the effects of flow on the presence and catch (given presence) of fall, winter, and spring run Chinook salmon fry. Fry presence in the Sacramento River and Delta decreased considerably when the 30-day mean flow at Freeport was less than 17,657cfs. Fry catch, given presence, in the Sacramento River and Delta decreased considerably when flow was less than 26,486 cfs. Based on this information, new flow thresholds were incorporated for winter, spring, and fall run fry presence and abundance at Freeport flows of 17,700 and 26,500 cfs, respectively.

Polansky et al. (2024) used life cycle modeling to quantify the effects of habitat metrics (e.g., flow, food, temperature) on the population growth of Delta smelt. The authors found that Delta outflow during the summer affected survival and had the largest effect on population growth, and there was a 50 percent probability of positive population growth when mean daily outflow exceeded approximately 10,200 cfs during June through August. Therefore, a new flow threshold is incorporated for 10,200 cfs Delta outflow during June through August for the protection of Delta smelt.

Overall, these recent studies demonstrate that higher flows than those originally described in the 2023 draft Staff Report confer benefits for outmigration survival or population growth rates. The benefit analyses in Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations,* and Section 13.5, *Beneficial Environmental Effects*, have been updated with the new flow thresholds.

Tributary-Specific Analysis

A number of comments requested more information on individual tributaries and requested this information be used to produce tailored flow requirements for each tributary. Some commenters expressed that Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations,* did not contain enough specific tributary information on benefits or effects of flow to support the proposed unimpaired flow requirements. The scientific information on the tributaries in the Staff Report is sufficient for the purposes of the Staff Report. The required degree of specificity in an environmental document corresponds to the degree of specificity involved in the underlying activity being analyzed. (Cal. Code Regs., tit. 14, § 15146.) As acknowledged by the State CEQA Guidelines, an environmental document disclosing the impacts of a construction project will necessarily be more detailed than an environmental document evaluating a broad regulatory plan because the effects of a construction project can be predicted with much greater accuracy. (*Id.*, § 15146(a).) An environmental document need not be exhaustive; it need only be prepared with a sufficient degree of analysis to provide commenters with sufficient information to provide comments on the analysis and decision makers with sufficient information to make an intelligent, informed decision. (*Id.*, § 15151.) Due to the scope and complexity of Bay-Delta Plan, the environmental analyses of the Staff Report are necessarily broad.

Where possible, the Staff Report already includes information on the tributaries that informs the benefits of the revised proposed Plan amendments. For example, Section 3.4.5, *Flow Effects on Salmonids*, describes flow effects on salmonids in the tributaries (^Brandes and McLain 2001, CDFG 2010), including an analysis of the frequency of flow related stressors in the tributaries in Table 3.4-5. Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations,* also includes information on beneficial habitat restoration for salmonids on specific tributaries such as the American River (^Zeug et al. 2014, Wheaton et al. 2004a), Putah Creek (^Kiernan et al. 2012) and the Mokelumne River (Wheaton et al. 2004b). Chapter 4, *Other Aquatic Ecosystem Stressors*, contains scientific information about other aquatic ecosystem stressors that affect tributaries and the Delta such as habitat loss, water quality, nonnative species, fisheries management and climate change. The 2026 Scientific Basis Report Supplement includes additional information on stressors on the tributaries with flow and habitat restoration commitments that would be provided under the VA pathway.

As described above, the scientific basis for the revised proposed Plan amendments is contained in the scientific basis reports, which underwent independent scientific peer review and their contents were moved into Staff Report Chapters 2 through 4 and the evaluation of benefits in Section 9.6, *Beneficial Environmental Effects of Proposed VAs*, and Section 13.5, *Beneficial Environmental Effects*. Within the scientific basis reports, it is acknowledged that there is a lack of consistent monitoring on some of the tributaries. Tributaries often lack data, lack reliable data, or include large data gaps that make analyses difficult or impossible. For example, Appendix E to the final Scientific Basis Report Supplement describes the paucity of reliable tributary salmonid abundance data and other data sources (e.g., flow and habitat data) that prevented inclusion of stock recruitment modeling for the tributaries with commitments under the VA pathway within the report. Thus, as described above, the scientific information in the Staff Report represents the best available science necessary to evaluate the benefits of the flow requirements proposed in the revised proposed Plan amendments.

Some commenters proposed that lower levels of flow on certain tributaries would achieve similar benefits to the flow scenarios presented in the Staff Report. Additionally, some commenters argued that for tributaries with existing flow agreements, the currently provided flows are sufficient for the protection of native fish species. For example, commenters mentioned Putah Creek as a tributary where small amounts of flow have achieved benefits, suggesting that the "one size fits all" approach of the flow scenarios is inappropriate. The Putah Creek Accord identifies instream flows for lower Putah Creek below Putah Creek Diversion Dam to protect salmonid species. Small numbers of salmonids have returned to the creek since the implementation of the Accord (EDAW 2005). Under median hydrological conditions, the flows provided at Putah Creek for the Accord represent only roughly 15 percent of the total unimpaired flow for the stream (Chapter 2, *Hydrology and Water Supply*, Table 2.2-22). While the flows established by the Putah Creek Accord did increase the number of native fish species in stream, these benefits appear to be limited to the upstream portions of Putah Creek, and the Accord flows have been much less successful at increasing native fish abundance in the downstream reaches where nonnative species still dominate (^Kiernan et al. 2012; Jacinto et al. 2023). As described in Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendation*, at higher levels of unimpaired flow, such as those analyzed in the Staff Report, ecosystem conditions would be further enhanced, providing benefits for both native salmon species in the upstream and downstream reaches of Putah Creek and for estuarine species downstream in the Delta. Although species on certain tributaries, such as Putah Creek, may see some benefits at lower levels of flow, that does not negate the need for higher levels of flow to produce greater benefits or to improve conditions in lower reaches of the tributaries and in the estuary.

Some commenters requested that the State Water Board create unique flow recommendations for each tributary rather than the inflow requirements described in the Staff Report, which the commenters described as a one-size-fits all approach. One of the goals of the Sacramento/Delta update to the Bay-Delta Plan is to "provide an interconnected flow regime that provides for comprehensive protection for fish and wildlife from upstream natal Sacramento/Delta tributaries, through the Delta, and out to the ocean" (Section 7.1.3, *Purpose and Goals of the Sacramento/Delta Update to the Bay-Delta Plan*). As noted in Chapter 1, *Executive Summary*, of the Staff Report, though various state and federal agencies have adopted requirements to protect the Bay-Delta ecosystem, the best available science supports a more comprehensive strategy. The current Bay-Delta Plan objectives and implementation measures are minimal and focused on the Delta without considering instream flow needs within the tributaries and connecting those flows with the downstream watershed and Delta outflows. As discussed in Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations*, there are salmonid species in the Sacramento/Delta year-round as well as other aquatic species that require adequate flows from the tributaries for their protection. In accordance with the holistic instream flow approach discussed in Chapter 3, an unimpaired flow approach is proposed that would require a portion of the inflows to the tributaries to be left in the stream for environmental flow purposes, including inflow and Delta outflow purposes. Providing appropriate flow conditions throughout the watershed and throughout the year also would support genetic and life history diversity that allows native species to distribute the risks that disturbances from natural and anthropogenic stressors present to populations.

In addition, the revised proposed Plan amendments include adaptive implementation measures that would allow for implementation to be tailored to individual tributaries. Adaptive implementation includes the ability to manage the numeric flow requirements as a total volume of water on a water year basis to shape flows (e.g., providing pulse flows to cue migration) for the benefit of fish and wildlife and the ability to move within the required unimpaired flow range. Individual tributaries could submit local cooperative solutions that use those adaptive implementation measures to tailor implementation to their specific tributary, or the State Water Board could direct such tailored implementation. Furthermore, the revised proposed Plan amendments include water supply adjustments for existing water right holders at the outset of plan implementation to reduce water supply impacts and allow more water to be stored in reservoirs. Tributary-specific adjustments would apply to rainfall-dominated tributaries and tributaries that primarily supply municipalities, which would include Putah Creek and the Mokelumne and Calaveras Rivers. The revised proposed Plan amendments also provide for a VA pathway for an eight-year term with the possibility of extension that reduces the required flow contributions from tributaries with VA water rights. The VA pathway includes flow and non-flow habitat restoration commitments that the VA parties proposed as tailored to the needs of individual tributaries. After the VA pathway is implemented, the effectiveness of these measures will be evaluated, which will produce additional information on each tributary to inform consideration of tributary-specific implementation. Please see Common Response 1.3, *Revised Proposed Plan Amendments*, for more information on the regulatory and VA pathways, including adaptive implementation measures.

Habitat Benefit Analyses

Some commenters raised concerns related to the habitat benefits of the proposed Plan amendments or the VAs. Comments covered issues related to the potential benefits to habitat from increased flow, habitat availability within the Bay-Delta watershed, and overall floodplain benefits to fishes.

Some commenters highlighted that habitat is flow dependent and habitat that only functions in wet years will not provide benefits during dry years. The relationship between flow and habitat for the Bay-Delta watershed is described in the Staff Report in Section 3.2, *Flow and the Ecosystem*. This includes a discussion of the role of natural flow regimes in riverine systems as well as in estuarine resources and floodplains. Section 3.2.1, *Riverine Flows*, details ways in which the alteration of the natural flow regime has caused a loss of geomorphic processes that are important to a functioning ecosystem, including the loss of complexity and diversity of the channel and riparian and floodplain habitats (^Poff et al. 1997; Grant 1997). This section also describes how a more natural flow regime, which includes increases in overall Bay-Delta watershed flow, provides benefits that are in addition to increased habitat area, including increased connectivity and survival. More flow can increase longitudinal connectivity, create more beneficial migration transport, create less hostile rearing conditions, increase net downstream flow, and increase connectivity with the estuary and nearshore ocean during periods that are beneficial for aquatic organisms that have adapted to this system (Kondolf et al. 2006; ^Poff et al. 2007; TBI 2016).

The Staff Report further considers the effects of flow on habitat in Section 4.2, *Physical Habitat Loss or Alteration*. This section includes information on the current state of different habitat types in the Bay-Delta watershed and highlights the importance of flow for maintaining important ecosystem functions within these habitat types. Section 3.13.4, *Holistic Methods for Determining Environmental*

Flows, describes the importance of designing environmental flows to serve specific, well-understood functions of flow, such as large floods to maintain channel and bed morphology and flows that create and maintain floodplain connectivity that supports spawning, food production, and rearing.

Other commenters asserted that flow alone is not sufficient to recover species and that habitat restoration is also needed. The Staff Report acknowledges that ecosystem recovery depends on more than adequate flows, for example in Section 4.1*, Introduction*. Chapter 4, *Other Aquatic Ecosystem Stressors,* is dedicated to describing other aquatic ecosystem stressors including physical habitat loss or alteration. In addition, the revised proposed Plan amendments include comprehensive complementary measures including physical habitat restoration, fisheries management, control of waste discharges and invasive species, and other efforts by other agencies and parties in the watershed that are responsible for these actions. Many of the non-flow actions considered in the Staff Report, such as habitat restoration, address constraints to ecosystem function that flow measures alone cannot resolve but nevertheless depend on a more natural flow regime to be successful. For example, to address loss of floodplain habitat, increased flows can provide a higher level of spatial and temporal floodplain inundation, thereby increasing floodplain habitat availability. This benefit is complemented by floodplain restoration and riparian restoration projects that help provide the physical defining features for these habitat types. However, without sufficient flow to activate these physically restored floodplain and riparian habitats, the benefits of such projects are limited. Section 4.2.1, *Riparian Habitat and Open Channels*, discusses the importance of flow actions to promote riparian processes, including the establishment and maintenance of native riparian vegetation and other natural hydrologic and geomorphic processes through perennial and periodic storm flows that overtop channel banks, saturate soils, and encourage seed regeneration and other functions. Similarly, when activated by an appropriate flow regime, restored floodplains can recruit riparian vegetation and retain sediment during high flows, expanding floodplain habitat and riparian growth, which in turn can eventually provide a sustained source of woody debris, contributing to in-channel complexity as evidenced by recent floodplain restoration monitoring on the Cosumnes River (Clifton and Viers 2024).

Additionally, commenters pointed to the importance of tributary geomorphology when discussing the benefits of natural flow regimes since areas that are highly channelized by levees may not see increased habitat benefits from flows. The benefits of the alternatives considered in the Staff Report are evaluated in the context of the current configuration of the watershed, including existing stressors such as channelization. The monitoring data and studies on which the benefit analyses are based were conducted in the current configuration of the watershed and thus the benefits of the flow and non-flow actions presented in the Staff Report represent expected benefits despite existing stressors such as channelization. The impacts of human water development on available habitat and habitat quality are recognized throughout the Staff Report, including discussion of levee construction impacts on floodplain habitat in Section 3.14.2, *Salmonid Tributary Habitat Analyses*. A discussion on channelization, leveeing, and riprapping of river reaches is also included in Section 4.2.1, *Riparian Habitat and Open Channels*, noting that these practices have reduced habitat complexity, food availability, and protection from predators for native fish species (USACE and CDFG 2010). In addition, Section 2.1.1, *Natural and Unimpaired Flow*, defines and compares natural and unimpaired flow. While unimpaired flow represents an index of the total water available within a watershed under current physical conditions, natural flow represents flow that would have occurred absent human development of land and water supply. Section 2.1.1 acknowledges that in areas where greater land use changes have occurred, such as through the channelization of rivers or impoundment of water by dams, the difference between unimpaired flow and natural flow may be significant but the difference is not known with certainty. The flow scenarios are defined by unimpaired flow and thus the benefits of the flow scenarios are the expected benefits under current physical conditions.

With combined flow and non-flow actions such as habitat restoration, increased flow results in increased available habitat area for native estuarine fish species in the Bay-Delta system. However, benefits from increased flow are not strictly limited to increased habitat area. For example, Section 3.2, *Flow and the Ecosystem*, describes the ways in which flow regimes affect not only physical habitat, but also the survival of aquatic species that have evolved life history strategies based on natural flow regimes, upstream-downstream and lateral river connectivity that is essential to organism viability, and the invasion and success of nonnative species (^Bunn and Arthington 2002). Section 3.4.5, *Flow Effects on Salmonids*, discusses the importance of increased lateral connectivity of the main river channels to floodplains provided by increased floodplain flows for juvenile salmon. This connectivity improves access to higher quality rearing habitat than can be found in the mainstem river, potentially resulting in greater survival of floodplain juveniles that have access to this habitat (^Sommer et al. 2001a). Section 3.4.5 also contains information on the benefits of increased flow for juvenile salmonids as they migrate through the Delta, improving both abundance and survival as emigrants remain in the mainstem river channels and other higher survival routes rather than entering the interior Delta where survival is lower.

Benefits from tributary flows that contribute to overall Delta outflow are also crucial for the success of salmon and estuarine species in the Bay-Delta system. Section 3.2.2, *Freshwater Flow and Estuarine Resources*, details the importance of tributary flow for pushing the salt field down the estuary in spring during snowmelt events as temperatures warm, a benefit that cannot be achieved through habitat restoration. Section 3.14.1, *Summary of Flow Thresholds for Species Protection*, describes how salmonids rely on sufficient tributary flows to provide the necessary olfactory cues and passage conditions for successful migration to holding and spawning areas in their natal stream, a benefit that also relies solely on flow rather than habitat restoration. Larger and more variable tributary outflows also benefit salmon by increasing the connectivity between the mainstem and tributaries and improving conditions for adult spawning, as discussed in Section 3.4.5.1, *Adult Migration, Spawning and Incubation*. Additional discussion on species level benefits from flow can be found in the *Flow Benefit Analyses* section of this common response that describes and defends the flow abundance relationships utilized in the Staff Report that evidence the need for increased Delta outflow. Similarly, the *Tributary-Specific Analysis* section of this common response provides further justification and explanation of the need for increased tributary flow in increasing Delta outflow for the protection of salmon and native estuarine species. While habitat restoration combined with sufficient levels of flow can increase the amount of available habitat for species, increased flow from tributaries contributing to overall increased Delta outflow is necessary for achieving certain species benefits that cannot be achieved through habitat restoration alone.

Is Habitat Limiting?

Some commenters asserted that the area of habitat within the Bay-Delta watershed is not currently a limiting factor for native anadromous and estuarine fish populations including Chinook salmon and Delta and longfin smelt, and that increasing the amount of habitat would not benefit native fishes without increasing flows. Other commenters asserted the reverse, that habitat restoration would benefit native fish populations. While there is uncertainty about whether habitat area is limiting fish populations, evidence suggests it could provide benefits.

Salmonid spawning is limited by the availability of suitable habitat because a finite number of redds can be constructed in a given area. The development of additional spawning habitat, through constructed habitat and habitat restoration, should provide more opportunities for spawning (Merz and Setka 2004; Roni et al. 2008; McManamay et al. 2010) and consequently an increase in the number of juveniles. Juvenile salmon and steelhead require access to suitable rearing habitat and suitable food resources during rearing. Habitat loss exacerbates the effects of other stressors, especially in ecosystems with low freshwater flows (^Mount et al. 2012). Increased habitat complexity and hydrologic connectivity is needed to maximize the effectiveness of increased flows in supporting native fish (^Mount et al. 2012).

The benefits of increased habitat may depend on the type of habitat restored. Some commenters expressed that many of the assumed benefits of floodplains (e.g., food export, rearing habitat outcomes) require further investigation and that actualization of these benefits is also linked to flow. The Scientific Basis Report Supplement, Section 2.2.1, acknowledges the uncertainty surrounding current habitat availability and whether the current composition of floodplain habitat types is a limiting factor for juvenile salmon at present inundation regimes. As flow, connectivity, and fish access are all inextricably linked, it is questionable whether physical rearing habitat (as opposed to inundating flows) within the floodplain bypasses is a limiting factor, as flow creates both access and habitat (DWR and Reclamation 2012). Additionally, the Staff Report recognizes that the beneficial rearing outcomes from higher growth rates seen in floodplains, such as enhanced survival benefits during outmigration and in the ocean, require further investigation and remain to be proven (Sommer et al. 2001; Takata et al. 2017).

While uncertainties exist regarding the benefits of additional floodplain habitat, the loss of complex physical habitats, including riverine channels and floodplains, is recognized as a major contributor to historical declines of salmonids and other native fishes, and is a key stressor that currently limits the recovery of these species (^NMFS 2014a). Numerous studies of the habitat preferences and distribution patterns of juvenile salmon clearly demonstrate the importance of shallow, low-velocity nearshore, floodplain, and off-channel habitat for successful rearing (Garland et al. 2002; Beechie et al. 2005; Tiffan et al. 2006; FISHBIO 2015a, 2015b). Successful rearing of juvenile Chinook salmon is associated with the magnitude, timing, and duration of natural peak winter and spring flows, which expand seasonally available rearing habitat and provide access to productive riparian, floodplain, and wetland habitat (Mesick et al. 2007; Opperman 2006; ^Sommer et al. 2001a; Williams 2006; ^USDOI 2010; Munsch et al. 2019). For juvenile salmon, the benefits of such habitat derive not only from potential increases in food availability, but reduced predation risk and energy expenditures associated with access to shallow, low velocity areas and cover. Although these benefits are most important for smaller rearing juveniles, good quality channel margin habitat is also considered important for migrating smolts because it provides protective cover from predators and velocity refuge during downstream migration (Williams 2006; Burau et al. 2007; Zajanc et al. 2012). With higher, more frequent flows expected under the flow scenarios, potential growth and survival benefits are expected to extend throughout the rearing and migration corridor for juvenile salmon, including tributary reaches where the active floodplain is narrow and such habitat is limited to narrow strips of riparian vegetation along the channel margins. Where low-lying floodplain and off-channel areas occur naturally or where floodplain restoration has been implemented, these benefits would be further enhanced. While opportunities for potential benefits from floodplain restoration may exist, these benefits are still not fully understood, including the ways in which these benefits may be mediated by factors such as flow or fisheries management. For example, the efficacy of restoration efforts for juvenile salmon in the Bay-Delta depends on both flow and spawner abundance (Munsch et al. 2020), and for late fall-run Chinook salmon on the mainstem Sacramento River, habitat availability may not be not a significant predictor of migration success, but flow is a strong predictor (Henderson et al. 2018). In addition, connectivity between rivers and floodplains may be more important than the amount of habitat in determining successful use of floodplain habitat (^Feyrer et al. 2006a; DWR and Reclamation 2012; Reclamation and DWR 2019; Opperman et al. 2010). Restoration of these shallow water habitats can be beneficial if connectivity issues are addressed in restoration designs.

Recent studies have shown that inundated floodplain habitats, such as those seen in the agricultural fields of the Yolo Bypass, provide high levels of food productivity (Corline et al. 2017; Jeffres et al. 2020) and enhance the growth of hatchery fish released into those fields. However, agricultural drainage has been shown to increase pesticide concentrations in water and prey resources (i.e., zooplankton) in the Yolo Bypass (Orlando et al. 2020; Orlando et al. 2025) and juvenile Chinook salmon in the Yolo Bypass have been shown to have higher concentrations of current-use pesticides than salmon rearing in the Sacramento River (Anzalone et al. 2022; Anzalone et al. 2024). Bypass floodplains are also associated with higher bioaccumulation of methylmercury in fish (Davis et al. 2025). For fish occupying these habitats, water quality monitoring is needed to ensure fish are not exposed to additional stressors such as pesticides and methylmercury. While additional work is still needed to further quantify and assess the significance of floodplain bypass benefits, juvenile Chinook salmon rearing in the Yolo Bypass supports increased life history diversity, enhancing the resilience of Central Valley Chinook salmon populations towards increasingly uncertain environmental conditions (Takata et al. 2017, Goertler et al. 2018).

Riparian habitat, which provides juveniles salmon with shallow and protected areas for foraging, has also degraded both in quality and quantity, negatively affecting juvenile salmon survival (^NMFS 2014a). On the Sacramento River, roughly 99% of riparian vegetation was lost between the years 1848 and 1972 (Sands and Howe 1977). Similarly, tidal marsh habitat used by juvenile salmonids during rearing has decreased significantly over the past 150 years, with the Delta now supporting less than 10,000 acres of small, fragmented tidal wetland (^USFWS 2008 BiOp).

Some commenters argued that habitat is not limiting Delta smelt or longfin smelt and that evidence is uncertain that restoration of additional tidal wetland habitat would benefit them. With regard to Delta smelt, the Staff Report considers that there are a number of factors, including reduced habitat, which may be responsible for declines in abundance. Staff Report Section 3.8.4, *Flow Effects on Delta Smelt*, lists exports, food, summer water temperature, predators, and declining Delta outflow as conditions that could be implicated in the decline of Delta smelt abundance. The importance of sufficient food supplies for Delta smelt is discussed in further detail in Section 3.8.2, *Life History*. Similarly, for longfin smelt, Section 3.5.4, *Flow Effects on Longfin Smelt,* discusses the effects of Delta outflow and exports on longfin smelt. In addition, Chapter 4, *Other Aquatic Ecosystem Stressors,* describes non-flow stressors such as physical habitat loss that affect native species. Although some commenters suggested that habitat restoration could increase food availability to benefit species such as Delta and longfin smelt, Section 4.2.3, *Floodplain and Wetland Habitat*, describes uncertainty in the food web benefits of wetland and floodplain benefits since available research has not conclusively supported food benefits, especially for tributary and estuarine tidal wetland restoration. However, as described in the introduction to Chapter 4, it is difficult to determine how much each stressor affects native species in isolation because stressors interact and may act in conjunction with each other and thus it is possible that habitat restoration could provide benefits for Delta and longfin smelt.

Further information on instream spawning and rearing habitat, floodplains, estuarine habitat, and potential benefits to fish can be found in the 2026 Scientific Basis Report Supplement. To assess possible benefits related to habitat and floodplain inundation associated with the flow scenarios described in the Staff Report, analyses of habitat available for salmonids and estuarine species are included in Sections 3.14, *Evaluation of Bay-Delta Environmental Flow Effects*, Section 9.6, *Beneficial Environmental Effects of Proposed VAs*, and Section 13.5, *Beneficial Environmental Effects*. In addition, the Bay-Delta Monitoring and Evaluation Program and the supplemental science and monitoring for the VA pathway would provide an opportunity to evaluate hypothesized benefits of habitat restoration for native fishes.

Interpreting the Quantitative Habitat Benefit Analyses

Some commenters referenced results from the salmonid tributary habitat analysis and the estuary habitat analysis to compare the benefits of the VAs to the various flow scenarios. These commenters generally suggested that the VAs provide more benefits than the 55 scenario due to the increased habitat provided by the VAs and because of this, the VAs provide more benefits with less negative impacts than the flow scenarios. As described in more detail in Common Response 1.3, *Revised Proposed Plan Amendments*, the revised proposed Plan amendments include both a regulatory pathway based on the flow scenarios and a VA pathway. This section provides information on the limitations and interpretation of the quantitative benefit analyses.

The salmonid tributary habitat analysis and the estuary habitat analysis are informative for quantifying expected changes in habitat area, but the results do not fully represent the extent of benefits that would be provided by increased flows. As described in Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations,* of the Staff Report, scientific evidence indicates that alterations to natural flow regimes and the overall reduction of flow in the Bay-Delta ecosystem have negatively affected fish, particularly estuarine species. The ecological significance of flow and different flow alterations can be found in Section 3.2, *Flow and the Ecosystem*. Within this section, the Staff Report describes the significance of naturally variable flow conditions to supporting biological and ecosystem processes necessary to support and protect fish and wildlife beneficial uses. Section 3.2.1, *Riverine Flows*, provides evidence for the importance of natural flow regimes in supporting native species that have adapted to natural regimes, preserving genetic and life-history diversity of natural stock, maintaining habitat connectivity across river and delta systems, and sustaining suitable water temperatures throughout the seasons. In Section 3.2.2, *Freshwater Flow and Estuarine Resources*, the Staff Report includes information on Delta outflow and outlines the importance of natural flows from upstream tributaries in providing ecological cues for native fish species, creating estuarine habitat through movement of the salt field, inundating floodplains, increasing turbidity, and increasing survival of migratory anadromous fishes. In consideration of these benefits, the Staff Report explains in Section 3.13.5, *Justification for Environmental Flows*, how additional inflows are needed both to provide tributary flows for native species including salmonids and to contribute to Delta outflows for the critical functions that outflow provides for estuarine species. The flow scenarios analyzed in the Staff Report were developed in large part based on outflow needs for the estuary to protect estuarine species. Further details on the need for Delta outflow can be found in Section 5.4.4.2, *Basis for New and Revised Delta Outflow Objectives*.

The benefit analyses in Chapters 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendation,* 9, *Proposed Voluntary Agreements*, and 13, *Revised Proposed Plan Amendments*, of the Staff Report were based on analyses in the peer reviewed 2017 Scientific Basis Report and the Scientific Basis Report Supplement. Benefits of the alternatives were analyzed using the same methods. These analyses quantified the benefits of additional flow and non-flow habitat restoration in the Delta and individual tributaries in terms of available habitat, the frequency of achieving protective flow thresholds, and potential changes in population indices of estuarine fishes.

The purpose of this update to the Bay-Delta Plan is to reasonably protect fish and wildlife beneficial uses in the Sacramento/Delta. The degree to which the various benefit analyses are directly connected to this purpose depends on the resulting metric from the analysis. Metrics more strongly connected to a species' persistence and population levels, would be more strongly connected to the protection of that species. Thus, the benefits metric most directly connected to the purpose of this project is the potential change in population indices of estuarine fishes. The flow thresholds are also closely connected to the project purpose since they were selected as flows associated with reasonable protection of fish and wildlife, as justified for each threshold in Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendation*. The tributary and estuarine habitat results are informative for understanding the possible benefits of the alternatives but they are not sufficient on their own as a quantification of benefits because: 1) they do not have a quantitative connection to population numbers or viability, 2) habitat will only benefit the population if habitat is limiting, which is unknown, and 3) actions such as increased flow have other benefits for fish populations including improved connectivity and survival that cannot be quantified as habitat acres and thus are not represented in the habitat results. For these reasons, the benefits of the various alternatives should not be compared solely based on the habitat analysis results.

Temperature Effects on Salmonid Fish

Some commenters raised concerns about the appropriateness of using the U.S. Environmental Protection Agency's (USEPA) 2003 recommended temperature criteria for protection of salmonids as a benchmark for evaluating temperature-related impacts and benefits of the proposed updates to the Bay-Delta Plan. The commenters were primarily concerned with the use of the USEPA (^2003) temperature criteria because they were developed by USEPA Region 10 (Oregon, Idaho, Washington, and Alaska) for use in the Pacific Northwest, and commenters suggest that the temperature criteria are not applicable in California, which is located in USEPA Region 9 (California, Nevada, and Arizona). Commenters also cited evidence from laboratory studies or the existence of salmon in habitats during periods of higher temperatures as evidence that the USEPA Region 10 criteria were not appropriate. In the water quality control plan planning process and other planning and regulatory processes (e.g., Federal Energy Regulatory Commission (FERC) relicensing), the State Water Board has maintained that any supporting studies and impact evaluations for these actions should follow the 2003 USEPA guidance. Many of the temperature index values used to analyze temperature-related impacts of the proposed updates to the Bay-Delta Plan came from the 2003 USEPA temperature criteria, but temperature index values from other sources were also used for the analysis as indicated in Appendix H1b, *Water Temperature Modeling and Fish Assessment for the Sacramento, Feather, American, and Yuba Rivers*, in the fish assessment methods section.

The thermal requirements of freshwater fishes may be species-specific and genetically fixed among populations of the same species (Elliott and Elliott 2010). Though the temperature tolerance of a fish is a function of its genetics and thermal history or acclimation, there is strong evidence for a genetic basis for the different upper temperature tolerances in salmonid species (Carline and Machung 2001). The basic parameter used to define the thermal requirement for a fish species is the critical thermal maximum for survival because it is often correlated with other critical temperatures such as the optimum temperature for growth and the upper limits for feeding and growth (Elliott and Elliott 2010). During egg incubation or embryo development of salmonid species, water temperature affects the rate of embryo and alevin development, the amount of dissolved oxygen in the water, and the survival of early fry (McCullough et al. 2001).

For salmonid species, the embryonic (i.e., egg) stage requires the lowest water temperature. Additionally, thermal windows for salmonid fish are narrowest for embryos and spawners, and widest during the juvenile life stage as absolute thermal tolerance increases as salmon age from embryos to fry (Mayer et al. 2024).

USEPA Guidance on Water Temperature Criteria for Salmonid Fish

USEPA (^2003) recommended the upper temperature criteria as the 7-day average of the daily maximum water temperature (7DADM) for various life stages of salmonid species, including for spawning and incubation, juvenile rearing, adult migration, and smoltification. The temperature criteria guidance was established to define the biological requirements of native salmonid species for their survival and recovery pursuant to the Endangered Species Act. USEPA (^2003) considered elevated temperatures as an important factor in the decline of salmonids and restoring suitable temperature regimes was a critical element in protecting salmonid populations.

For the protection of salmon during spawning, egg incubation, and fry emergence, USEPA (^2003) recommends 55 °F (13 °C) 7DADM from the average date spawning begins to the average date egg incubation ends. The temperature criterion for the egg and embryo incubation in USEPA (^2003) was informed by McCullough et al. (2001). The literature review by McCollough et al. (2001) included studies conducted on Chinook salmon in the Central Valley (e.g., Healey 1979). For the water temperature effects on developing eggs, McCullough et al. (2001) stated that water temperatures from 4 °C to 12 °C (39.2 °F to 53.6 °F) resulted in relatively high survival to hatching and emergence, and constant temperatures of 6 °C to 10°C (42.8 °F to 50 °F) would be considered as optimum for most salmonid species based on laboratory studies. Further, McCullough et al. (2001) concluded that constant temperatures above 9-10 °C (48.2-55 °F), equivalent to natural fluctuating stream temperatures with daily maximums of 11-12 °C (51.8-53.6 °F), would reduce the survival of Chinook salmon embryos and alevins. McCullough et al. (2001) noted that Healey (1979), which was conducted in the Central Valley, found the highest survival (97%) of Chinook salmon embryos occurred in creek water where the daily maximum reached 55°F (12.8°C) only a few times during the first two-week period of development and very good (90%-94%) survival where the temperatures at the onset of egg incubation were between 55 and 57. 5°F (12.8 and 14.2°C). Based on the review, McCullough et al. (2001) recommended that that daily maximum temperatures should not exceed 13.5-14.5 °C (56.3-58.1 °F).

This can be compared to the upper critical temperature of 12 °C for Chinook salmon egg incubation, as suggested for Chinook salmon in Alaska (Scannell 1991). Murray and McPhail (1988) found a rapid decline in survival from fertilization to emergence at water temperatures above 11 °C for Chinook salmon collected from a river in British Columbia. After hatch, salmon alevins reared at higher temperatures (e.g., 12 °C) absorbed yolk more rapidly than those reared at lower temperatures (6-10 °C) as they required more energy than available in the remaining yolk (Murray and McPhail 1988).

Richter and Kolmes (^2005) provided upper optimal temperature criteria to protect different life stages of salmonid fish as 7DADM and corresponding weekly mean temperatures. For the protection of spawning and egg incubation, they recommended a 7DADM of 13 °C (55 °F) or a weekly mean temperature of 10 °C (50 °F) (^Richter and Kolmes 2005). For juvenile rearing, they recommended a 7DADM of 16 °C (61 °F) or a weekly mean temperature of 15 °C (59 °F) (^Richter and Kolmes 2005). While some life stage events, including spawning, may occur under a wide range of water temperatures, suitable temperature regimes for incubating embryos are more restrictive (reviewed by ^Richter and Kolmes 2005). Additionally, higher water temperatures would have indirect effects on the salmonid populations, as temperature affects adult migration, spatial extent and distribution, water quality through effects to dissolved oxygen, and the prevalence and virulence of diseases at different life stages (^Richter and Kolmes 2005).

Use of 2003 U.S. Environmental Protection Agency – Recommended Temperature Criteria

The 2003 USEPA temperature guidance (^USEPA 2003) is the product of a collaborative process between states, tribes, and federal agencies to: (1) meet the biological requirements of native salmonid species for survival and recovery pursuant to the ESA; (2) provide for the protection and propagation of salmonids under the Clean Water Act, and (3) meet the salmonid rebuilding needs of federal trust responsibilities with treaty tribes (^USEPA 2003). The 2003 USEPA guidance is based on a comprehensive review and synthesis of a large body of peer-reviewed studies and published papers, including temperature studies completed on Central Valley salmonids, and subsequent review by both an independent scientific panel and the public. The summary of scientific literature for the 2003 USEPA guidance is presented in McCullough et al. (2001).

Evidence from a number of studies within California support the use of the USEPA water 7DADM temperature criteria as a benchmark for evaluating and establishing protective standards for anadromous salmonids (Welsh et al. 2001; Hines and Ambrose 2000; Deas et al. 2004; Sacramento River Temperature Task Group 2016; USEPA 2011; North Coast Regional Water Board 2005). The 7DADM is recommended because it describes the maximum temperatures that fish are exposed to over weekly periods while protecting against acute effects, such as migration blockage, and harmful or chronic effects, such as temperature effects on growth, disease, smoltification, and competition (^USEPA 2003). For example, the Sacramento River Temperature Task Group (2016) reported that USEPA's 2003 temperature maximum of 55°F (12.8°C) (7DADM) "captures conditions that winter-run eggs and fry are exposed to on a daily basis while reducing the potential that one extremely high daily maximum temperature would result in exceeding the temperature criterion".

In 2011, USEPA transmitted the final list of waterbodies that were added to California's 2008–2010 list of water quality limited segments still requiring total maximum daily loads (TMDLs) pursuant to Clean Water Act, section 303(d), and 40 CFR 130.7(d)(2). Within this letter, USEPA stated the following.

> EPA believes that EPA's Temperature Guidance values are appropriate for use in the Central Valley. The criteria have been used by California in their 303(d) list recommendations as well as selected as targets in Total Maximum Daily Loads (TMDLs) in the North Coast Region of California (Carter 2008). They have also been used by National Marine Fisheries Service ("NMFS") to analyze the effects of the long-term operations of the Central Valley Project and State Water Project, and to develop the reasonable and prudent alternative actions to address temperature-related issues in the Stanislaus River (^NMFS 2009 BiOp). Reviews of appropriate temperature criteria for use in the Stanislaus have yielded findings consistent with the EPA Temperature Guidance values (Deas et al. (2004) and Marston (2003)).

In that letter, USEPA also notes that a letter dated November 15, 2010, from Maria Rea (NMFS) to Alexis Strauss also supports the use of the Temperature Guidance values.

The use of the US EPA 2003 criteria for listing water temperature impaired water bodies in the San Joaquin River basin is scientifically justified. It has been recognized that salmonid stocks do not tend to vary much in their life history thermal needs, regardless of their geographic location. There is not enough significant genetic variation among stocks or among species of salmonids to warrant geographically specific water temperature standards (US EPA 2001). Based upon reviewing a large volume of thermal tolerance literature, McCullough (1999) concluded that there appears to be little justification for assuming large genetic adaptation on a regional basis to temperature regimes. Prior to adoption of the revised water temperature standards for Oregon streams in 1996, there were separate water temperature standards assigned to salmon habitat in the western vs. the eastern portions of the state. Salmon-bearing streams in the western Cascades and Coast Range were assigned a standard of 14.4°C [57.9°F], but salmon-bearing streams in northeastern Oregon had a standard of 20.0°C [68.0°F], largely on the assumption that they would be adapted to the warmer air temperature regimes of the region. The large (5.6°C [10.1°F]) difference in adaptation that would be required, however, is not supportable by any known literature (McCullough 1999).

Varying climatic conditions could potentially have led to evolutionary adaptations, resulting in development of subspecies differences in thermal tolerance. However, the literature on genetic variation in thermal effects indicates occasionally significant but very small differences among stocks and increasing differences among subspecies, species, and families of fishes. Many differences that had been attributed in the literature to stock differences are now considered to be statistical problems in analysis, fish behavioral responses under test conditions, or allowing insufficient time for fish to shift from field conditions to test conditions (US EPA 2001).

Although many of the published studies on the responses of Chinook salmon and steelhead to water temperature have been conducted on fish from stocks in Oregon, Washington, and British Columbia, a number of studies were reported for the Central Valley salmonids. ^Myrick and Cech (2001, 2004) performed a literature review on the temperature effects on Chinook salmon and steelhead, with a focus on Central Valley populations…

It is evident that the difference in thermal response is minimal in terms of egg incubation, growth, and upper thermal limit. Healey (1979 as cited in ^Myrick and Cech 2004) concluded that Sacramento River fall-run Chinook salmon eggs did not appear to be any more tolerant of elevated water temperature than eggs from more northern races. ^Myrick and Cech (2001) concluded that it appears unlikely that there is much variation among races with regard to egg thermal tolerance because data from studies on northern Chinook salmon races generally agree with those from California. They further concluded that fall-run Central Valley and northern Chinook growth rates are similarly affected by water temperature.

California Central Valley Salmonid Temperature Studies

The USEPA Region 10 guidance (^USEPA 2003) was designed as a guidance tool for streamlining the establishment of temperature criteria in Oregon, Washington, Idaho, and Alaska. The Region 10 guidelines (^USEPA 2003) have been used by NMFS in their implementation of Biological Opinions for the Long-term Operations of the Central Valley Project (CVP) (^NMFS 2009 BiOp, ^NMFS 2019 BiOp, NMFS 2024), including implementation of the Sacramento River Temperature Management Plan, as also required by State Water Board Water Rights Order 90-5. The USEPA (^2003) included temperature-related survival and tolerance studies conducted on the Central Valley salmonid fish. California represents the southern-most range extent for nearly all the native salmonid species and the historic and current environmental conditions in the Central Valley are considerably different than those in the Pacific Northwest USEPA Region 10 area. It has been hypothesized that California salmonid species may have developed traits and behaviors adapted to the local environmental conditions, specifically temperature regimes (Zillig et al. 2018). However, as the following literature review on temperature-related studies demonstrates, temperature thresholds for the survival of the Central Valley salmonids are consistent with those presented in the USEPA (^2003).

The embryonic stage, or egg development, is the most thermally sensitive stage of the salmonid life cycle that requires colder temperatures than any other life stages (Martin et al. 2020). Maintaining water temperatures sufficiently cold from spawning through egg incubation periods of Chinook salmon to support high survival rates has been the primary management objective in the Sacramento River below the Shasta and Keswick Reservoirs.

In the Central Valley, winter- and spring-run Chinook salmon populations are most at risk of high temperatures as they typically spawn earlier and therefore are exposed to warmer conditions (Zillig et al. 2018). ^Myrick and Cech (2001) provides the most comprehensive review on the water temperature effects on different life stages of salmonid species in the Central Valley. They concluded that Chinook salmon eggs can survive temperatures between 1.7 °C (35.1°F) and 16.7 °C (62.1 °F), with the highest survival rates between 4 °C (39.2 °F) and 12°C (53.6° F) (^Myrick and Cech 2001). Additionally, ^Myrick and Cech (2001) concluded that Central Valley steelhead would require slightly colder water temperatures during the egg incubation period as they can survive temperatures between 2 °C (35.6 °F) and 15 °C (59 °F), with the highest survival rates between 7 °C (44.6 °F) and 10°C (50 °F).

^Myrick and Cech (2001) summarized that water temperatures higher than 13.3 °C (56 °F) would result in increased egg mortality of fall-run and winter-run Chinook salmon; below this temperature egg mortality is minimal. Further they concluded that Chinook salmon eggs from the Sacramento-San Joaquin River are not more tolerant of high temperatures than more northern races (^Myrick and Cech 2001). Additionally, temperature indirectly affects anadromous salmonids through its effects on pathogen infectivity and virulence, as elevated water temperatures are associated with higher rates of infection and increased mortality for both juvenile Chinook salmon and steelhead (^Myrick and Cech 2001; ^Richter and Kolmes 2005). Cooler temperatures reduce the risk of predation and disease for juvenile salmon (^Richter and Kolmes 2005; Michel et al. 2020; Nobriga et al. 2021).

Experimental studies (Healey 1979; USFWS 1999) and synthesis efforts (Boles 1988; ^Myrick and Cech 2001; Zillig et al. 2018) have been conducted to understand temperature effects on different life stages of Central Valley salmonid species. Healey (1979) conducted laboratory incubation experiments with Chinook salmon eggs and fry and reported that abnormally high salmon egg and fry losses could occur when river temperatures exceed 14.2° C (57.5 °F). Further, Healey (1979) concluded that Sacramento River Chinook salmon were no more tolerant of high temperatures than other strains. Boles (1988) conducted a literature review on the water temperature requirements for different life stages of Chinook salmon primarily focused on the Sacramento River. Boles (1988) reported that Chinook salmon eggs incubated at temperatures ranging from 11.7 °C (53 °F) to 14.1 °C (57.5 °F) resulted in the highest survival, and eggs incubated at water temperatures greater than 15.5°C (60°F) or less than 3.3°C (38°F) suffered high mortality. Further, Boles (1988) explained that the adverse effects of high temperatures during the pre-spawn adult holding period or egg incubation would not become apparent until fry stage. USFWS (1999) conducted a comprehensive laboratory study of temperature effects on incubating winter-run and fall-run Chinook eggs and concluded that incubation temperatures above 13.3°C (56°F) resulted in significantly higher alevin mortality than under lower temperatures. USFWS (1999) further recommended that water temperatures between the Bend Bridge and Keswick Dam in the Sacramento River should not exceed 13.3 °C (56 °F) during the incubation period to prevent excessive egg mortality of winter-run Chinook salmon.

Recent studies by Martin et al. (2017, 2020) suggested that laboratory studies may have overestimated the upper temperature limit for winter-run Chinook salmon eggs by almost 3 ºC. Their conclusion was based on biophysical modeling and experimental studies on oxygen delivery to the embryos along with field-observed egg-to-fry survival rates in the upper Sacramento River. Martin et al. (2017, 2020) concluded that river water temperature of 12.0 °C (53.6 °F) in the field would result in egg mortality comparable to the lab temperature of 15.4 °C (59.7 °F) due to the oxygen consumption and slow water velocities in the hyporheic zone. They suggested that the slower flowing water in the river would not supply sufficient oxygen needed for eggs incubating in the interstitial spaces, and the field-observed egg-to-fry survival rates under the slower river flow equated to about a 3 ºC difference in the temperature tolerance of eggs when compared to the laboratory-derived temperature-survival relationships (Martin et al. 2017, 2020).

Del Rio et al. (2019) further demonstrated the importance of dissolved oxygen conditions in addition to temperature during egg incubation through a series of laboratory experiments. They found that hatching rates of Chinook salmon eggs reared under normoxia (dissolved oxygen close to the saturation) were significantly higher than those reared under hypoxia (dissolved oxygen close to 50% saturation) regardless of water temperatures (10.0 and 14 °C or 50 and 57.2 °F) (Del Rio et al. 2019). Hatching success rates were 40.5% (10 °C-normoxia), 19.8% (10 °C-hypoxia), 35.1% (14 °C-normoxia), and 9.9% (14 °C-hypoxia). Though temperature did not have a significant effect on hatching success of salmon eggs based on the statistical analysis (P=0.06), they found the lowest survival rate in the hypoxia (dissolved oxygen 50%) and high temperature (14 °C or 57.2 °F) treatment. Del Rio et al. (2019) suggested that the management target temperature of 56 °F (13.3 °C) used to promote embryo survival in the Sacrament River below Keswick Dam may be too high in some cases since salmon embryo mortality could occur at lower temperatures in hypoxia, complementing the findings of Martin et al. (2017, 2020).

One commenter argued that the 13 °C (55.4 °F) temperature criterion for spawning is overly restrictive because successful spawning occurs in the lower American River even when temperatures exceed the threshold. In addition to the evidence presented above, fall-run Chinook salmon specifically prefer egg incubation temperatures at or below 56°F (Reclamation 2014). Preferred stream temperatures are defined as those most frequently inhabited by fish when given a choice along a thermal gradient, reflecting conditions that support optimal feeding, physiological function, and normal behavior (McCollough 1999). Therefore, the American River Group, a multi-agency and stakeholder technical team, utilizes 56°F (13°C) as a critical temperature threshold at Hazel Avenue in November during steelhead and fall-run Chinook salmon spawning (NMFS 2024). It is also important to note that survival during early life stages is only one measure of temperature effects on salmonids. Elevated temperatures can induce stress, leading to reduced growth and developmental rates, higher susceptibility to disease, and increased vulnerability to predators (Bratovich et al. 2005; McCollough 1999). Even sub-lethal temperatures can impact critical processes including migration, reproduction, and smoltification (McCollough 1999). Water temperature in the lower American River is of particular concern for salmonids, often reaching and exceeding levels that are stressful to juvenile rearing salmonids, particularly during the summer and early fall (^NMFS 2014a). Maintaining lower water temperatures directly below the Nimbus Dam helps reduce temperatures throughout the lower American River, improving both the quality and quantity of habitat available during periods of adult holding and juvenile outmigration.

Conclusion: Temperature Effects on Salmonid Fish

The 2003 USEPA temperature criteria guidance is based on an expert-reviewed synthesis of a large body of peer-reviewed studies and published papers in the region including those from the Central Valley streams. USEPA compiled multiple lines of evidence for the development of scientifically justified temperature guidance based on major physical and biological metrics, including thermal effects on salmonid physiology, behavior, and distribution; interactions between multiple stressors (thermal and other); and spatial and temporal variation in patterns of stream temperature (McCullough et al. 2001). Further, USEPA acknowledged in the guidance document that numeric criteria should be based on both laboratory experiments and studies determining where fish perform best in their natural environment considering food availability, competition, predation, and fluctuating temperatures (^USEPA 2003).

Based on the review of existing literature on temperature effects on Chinook salmon, the temperature guidance provided in the USEPA (^2003) are applicable to the Central Valley streams and rivers and would confer protection of Chinook salmon populations. Thus, the Staff Report continues to use the USEPA (^2003) temperature criteria for salmonid fish.

Flow Effects on Temperature

Sacramento River and Tributaries

This section addresses commenters' concerns regarding water temperatures along the Sacramento River, from below Keswick Dam to the Delta, and how flow management may influence those temperatures. Commenters also expressed concerns about fish mortality resulting from high water temperatures in other Sacramento River tributaries. Several commenters recommended that the State Water Board consider the effects of flow on water temperature throughout the system to support all native fish species. Some comments expressed concern about elevated river temperatures and their impact on Chinook salmon, including effects on egg incubation, juvenile rearing and survival, and spawning success throughout the Sacramento River system. Additionally, concerns were raised about whether flow management would significantly affect water temperatures. Some commenters emphasized that adequate flows and appropriate water temperatures are necessary to support native fish populations and facilitate effective habitat use. Below is a brief summary of temperature conditions in the Sacramento River and a description of flow effects on temperature, as well as sections in the Staff Report where the effects of flow management on temperature are evaluated.

While there are regulatory requirements to keep the water temperature at the upper reaches (about 11 miles) of the Sacramento River cold (<11.9 °C or 53.5 °F) during the Chinook salmon egg incubation season, no current efforts exist to manage water temperatures in the remaining lower 220 miles of non-tidal segment of the river. Water temperatures along the Sacramento River are a function of water temperature at the Keswick discharge, river discharge, travel time, and ambient temperature. Generally, water temperatures in the Upper Sacramento River approximately 30 miles downstream from Keswick Dam are reflective of reservoir tailwater with temperatures suitable for juvenile salmon rearing year-round. Water temperatures in the Lower Sacramento River fluctuate dramatically, ranging from a median monthly temperature of 10°C in the winter months to higher than 20°C in the summer months (Michel et al. 2023). The migratory corridor for juvenile Chinook salmon is likely disconnected when daily mean water temperatures are higher than 20°C (68°F), as their survival is near zero under these conditions (Michel et al. 2020; Nobriga et al. 2021).

In a study of the Sacramento River, Daniels and Danner (2020) found that the primary controlling factor for river temperatures varied along the length of the river. In the most upstream reaches, dam discharge temperature was the primary controlling factor. In the most downstream reaches, air temperature was the primary controlling factor, although dam discharge and discharge temperature still affected downstream river temperature. Based on these findings, Michel et al. (2023) further evaluated the ability of discharge-mediated temperature management in the Sacramento River from Keswick Dam to Knights Landing (just downstream of Wilkins Slough) throughout the entire year using the River Assessment for Forecasting Temperature model. To account for net daily differences in flow along the length of the river, the river was divided into three sections based on the existing gauge locations at Keswick, Vina, Butte City, and Wilkins Slough. The study evaluated whether achieving the water temperature target of 20 °C (68°F) for Chinook salmon juvenile and adult migration was possible with discharge levels that the authors considered reasonable. They demonstrated that discharge-mediated temperature management could regulate downstream water temperatures in the Sacramento River at the Wilkins location (RM 118), approximately 184 miles downstream from Keswick Dam (RM 302). Michel et al. (2023) indicated that manipulating the timing and magnitude of discharge of approximately 10,000 cfs can be a valuable management tool to target cool temperatures (<20°C or 68°F) for salmonid migration and other temperature-sensitive native fauna, especially during the late spring and early fall periods.

Zarri et al. (2019) evaluated the impact of river temperature and discharge management on winter-run Chinook salmon (egg-to-fry survival) and green sturgeon (larval body condition) along the Sacramento River. Green sturgeon occur downstream of the winter-run Chinook salmon spawning locations, and their optimum for egg development and larval growth occurs in a temperature range between 14-17°C. By modeling the optimized monthly temperature and discharge with a selective withdrawal from the temperature control device (TCD) gate to the optimal temperature target, Zarri et al. (2019) identified an optimal Keswick release schedule of 150 cubic meters per second (cms) (5,300 cfs) discharge with 11.5 °C temperature that would benefit both Chinook salmon egg incubation and green sturgeon larval growth during June through early July.

These studies suggest that scientifically informed management of reservoir releases and flows could effectively manage water temperatures along the Sacramento River to benefit native fish species. In addition, the Staff Report evaluates the effects of the proposed instream flow requirements on water temperatures for native fish species in the Sacramento/Delta and tributaries. Staff Report Section 7.6.2, *Aquatic Biological Resources*, and Appendix A6, *Water Temperature Modeling and Fish Assessment for the Sacramento, Feather, and American Rivers*, provide water temperature model results for the 35 – 75 flow scenarios, evaluating the effects of the flow scenarios on water temperatures and different life stages of native fish species in the Sacramento, Feather, and American Rivers. Chapter 13, *Revised Proposed Plan Amendments*, and Appendix H1b, *Water Temperature Modeling and Fish Assessment for the Sacramento, Feather, American, and Yuba Rivers*, include updated temperature modeling for the revised proposed Plan amendments for the Sacramento, Feather, American, and Yuba Rivers. See also Common Response 7.6.2, *Aquatic Biological Resources and Cold Water Habitat,* for a discussion of the water temperature evaluation in the Staff Report.

The Sacramento River has over 20 major salmon-bearing tributaries. Maintaining the diversity of sub-populations of salmonids on the major Bay-Delta tributaries has been identified as an important factor for achieving population viability (Carlson and Satterthwaite 2011; ^NMFS 2014a). The proposed new cold water habitat objective described in Staff Report, Sections 5.4.3, and 13.3.3.3, each titled *Cold Water Habitat*, would address tributary-specific temperature needs by requiring that cold water flows from reservoirs be maintained and timed to provide for downstream temperatures to protect salmon and other native fish species at critical times of year or that alternative protection measures are implemented to ensure that fish below dams are kept in good condition (consistent with Fish and Game Code section 5937). Refer to Common Response 1.3, *Revised Proposed Plan Amendments*, for a discussion of implementation of the cold water habitat objective.

Temperature Effects in the Delta

Some commenters expressed concern that the effect of flow on water temperature was not analyzed in the Delta. A qualitative analysis of the possible effects of the flow scenarios on water temperatures in the Delta was included in Section 7.6.2, *Aquatic Biological Resources*, of the 2023 draft Staff Report. The analysis was qualitative because there is no readily available methodology for translating water temperature effects in the Sacramento/Delta tributaries through the Delta. A brief summary of the effects of flow on temperature in the Delta is provided below.

The effect of Delta inflow on water temperatures in the Delta is limited because water generally has warmed considerably by the time it reaches the Delta, approaching maximum values dictated by meteorological driven equilibrium values. As a result, substantial changes in flow would be needed to alter Delta inflow temperatures. In one study of Delta water temperatures, flow was not needed to produce accurate estimates of water temperature with statistical modeling, although the study noted that particularly high flows such as occurred during the winter of 1997–1998 could affect model accuracy (^Wagner et al. 2011). Other studies indicate that water temperatures within the Delta may reach equilibrium values farther inland under low flow conditions as a result of increased atmospheric forcing (i.e., longer residence time allows more time for meteorological conditions to affect water temperature) (^Vroom et al. 2017; ^Gleichauf 2015) and that Delta water temperatures tend to be lower under average or high inflow conditions as compared to low inflow conditions (^Jeffries et al. 2016; ^Gleichauf 2015). Effects of flow on Delta water temperature are complex; while lower flow may allow water temperatures to reach equilibrium farther inland, lower flow also may allow the cold ocean water to reach within the Delta (^Gleichauf 2015).

Bashevkin and Mahardja (^2022) found that Delta water temperature is positively or negatively correlated with Delta inflow depending on time of year and location within the Delta. These relationships are mediated by meteorology (^Vroom et al. 2017; ^Bashevkin and Mahardja 2022) and snowmelt (^Knowles and Cayan 2002). The summer period, when local precipitation is minimal, appears to be most influenced by upstream factors, whereas local precipitation and other meteorological conditions may influence much of the winter patterns (^Bashevkin and Mahardja 2022).

Overall, it is important to note that water temperature-related effects on aquatic species associated with changes in Delta inflow are expected to be minor because water from upstream reservoirs approaches equilibrium with atmospheric conditions by the time it reaches the Delta. Furthermore, the extent of the causal influence of inflow on water temperatures is an area of active uncertainty (^Bashevkin and Mahardja 2022).

Fish Entrainment in the Delta

This section responds to comments received about the evaluation of flow and water management effects on entrainment, and the effects of entrainment on native fish species in the Delta.

Entrainment is a physical process whereby groups of aquatic organisms are spatially redistributed through the action of moving water, resulting in geographic isolation of the entrained portion of the population (Smith et al. 2020). In the Sacramento-San Joaquin Delta, such "entrainment" of fish occurs at the river-distributary junctions and at the water diversion and export facilities located primarily in the south Delta. In the south Delta, larval and juvenile fish such as Delta smelt and longfin smelt could be considered entrained and potentially lost from the population once they enter Old and Middle Rivers (USFWS 2024a). Processes of fish entrainment and overall impacts on the fish populations at these locations in the Delta vary depending on time of year, channel morphology, hydrologic conditions, facility operational conditions, and the hydraulic influences that fish experience. The effects of water project operations and some other water management actions on entrainment, and entrainment effects on native fish species in the Delta, are described in Staff Report Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations* and in the 2017 Scientific Basis Report.

The information regarding entrainment that is contained in the 2023 draft Staff Report has been summarized below and updated with new literature in response to comments. In addition, the final Staff Report is updated with more recent relevant scientific literature to support the relationship between increased flows at Sacramento River locations and through-Delta survival of juvenile salmonids, and the effects of Delta Cross Channel (DCC) gate operations, south Delta exports, and OMR reverse flows on entrainment and survival of fish in the interior Delta.

Entrainment into the Interior Delta and Export Operations (via Delta Cross Channel and Georgiana Slough)

Some commenters claimed that the 2023 draft Staff Report overstated the effects of water exports in the south Delta on juvenile salmon migratory route selection and entrainment into the interior Delta at the DCC and Georgiana Slough and also claimed that the 2023 draft Staff Report relied on outdated science and conceptual models of the impacts of CVP and State Water Project (SWP) export operations. Commenters suggested providing additional description and analysis of how DCC gate operations and flows into Georgiana Slough influence the hydrodynamic conditions and juvenile salmonid routing at the Sacramento River and distributary junctions. Commenters further suggested additional evaluation of the effects of mitigation actions intended to reduce juvenile salmonid entrainment into the interior Delta such as the Georgiana Slough Salmonid Migratory Barrier.

The Delta is a complex network of natural and man-made channels that juvenile salmon must navigate on their journey to the ocean. Fish routing into different channels is driven by the relative quantities of discharge entering each channel, the horizontal distribution of fish in the water column as they pass a channel junction, and by tidal cycles that alter flow patterns at river junctions. Once fish enter a given channel, they are subject to channel-specific processes that affect their rate of migration, vulnerability to predation, feeding success, growth rates, and ultimately, survival (^Perry et al. 2013). Movement of juvenile salmon among migration pathways in the Delta is further influenced by water management actions that route water from the Sacramento and San Joaquin Rivers into the area of influence of the Project pumping facilities in the south Delta. In the Delta, Sacramento River flows, tidal flows, channel modifications (e.g., DCC), proportional split of flow into distributary channels, and water export operations (including DCC gate operations and export pumping in the southern Delta) influence the routing of migrating juvenile salmon from the Sacramento River to the interior Delta, where their survival rate is low (Perry et al. 2010).

Juvenile salmonids originating from the Sacramento River basin and migrating through the Delta could be entrained (i.e., routed) into the interior Delta via Georgiana Slough and the DCC. This discussion primarily addresses the flow routing and fish entrainment in the Sacramento River at distributary junctions including Sutter and Steamboat Sloughs, DCC (when gates are open), and Georgiana Slough. As described in Chapter 3, *Scientific Knowledge to Support Fish and Wildlife Flow Recommendations*, water management actions, including opening the DCC gates and operating the export pumps, increases Sacramento River flow into interior Delta channels and away from the mainstem Sacramento River and western Delta, thereby increasing fish entrainment into the interior Delta. Once entrained into the interior Delta, juvenile salmon experience longer travel times and are exposed to adverse environmental conditions (e.g., predation, lower water quality, slow flows) compared to those remaining in the mainstem Sacramento River. Sutter and Steamboat Sloughs diverge westward from the Sacramento River upstream of the entrance to the interior Delta via the DCC and Georgiana Slough, and juvenile salmon that enter Sutter and Steamboat Sloughs avoid routing into the interior Delta where their survival rates are lower. Thus, management actions could increase overall through-Delta survival by increasing the proportion of fish entering Sutter and Steamboat Sloughs and reducing the proportion of fish that enter the interior Delta via the DCC and Georgiana Slough.

The rate of fish entrainment into these distributaries is proportional to the rate of river flow routing into these distributary channels (Perry et al. 2010, Cavallo et al. 2015). Thus, estimating the proportion of flow entering a Delta junction can be strongly predictive of the proportion of migrating salmonids that may move from the Sacramento River mainstem channel into a distributary via that junction. However, actual fish entrainment is more complicated and is affected by river flow, tidal flows, development of secondary circulation in the Sacramento River, and other factors (^Perry et al. 2015, Perry et al. 2018; Ramón et al. 2018; Hance et al. 2020; Singer et al. 2020).

Many studies have shown that increasing Sacramento River flows are related to enhanced survival of juvenile salmonids migrating through the Delta as discussed in Staff Report Section 3.4.5, *Flow Effects on Salmonids*. The increased migration survival of juvenile salmonids under higher flow conditions in the Sacramento River is the outcome of a variety of factors affecting their travel and mortality, both directly and indirectly. Higher river flow and velocity through the main migration corridor (Sacramento River route) decrease the proportion of flow diverted and fish entrained into the interior Delta channels (via Georgiana Slough and Delta Cross Channel), where salmonid migration time is longer, and reduce direct entrainment-related mortality at the CVP and SWP export facilities in the south Delta. Generally, when more flow is routed into interior Delta channels to support export pumping operations, flow through the Sacramento River mainstem is reduced. Thus, export operations result in more fish routing into the interior Delta where survival is lower than in the mainstem Sacramento River.

Commenters suggested providing additional description and analysis of how DCC gate operations influence Sacramento River hydrodynamics and affect juvenile salmonid routing at the Georgiana Slough junction. Various measures have been evaluated and recommended to reduce juvenile salmon entrainment into the interior Delta through the DCC and Georgiana Slough that would ultimately enhance overall through-Delta survival of juvenile salmonid populations originating from the Sacramento River basin. Operations of the DCC gates during October and November are based on monitoring of salmonids migrating through the Sacramento River corridor as a part of the Long-term Operations of the Central Valley Project and State Water Project that could reduce the potential impacts of gate operations on juvenile salmon entrainment (NMFS 2024). Operations of the DCC gates assume that fish entrainment into the DCC is directly proportional to the mean fraction of river inflow that is diverted to the interior Delta (^Low et al. 2006).

Entrainment of juvenile Chinook salmon from the Sacramento River into the interior Delta at the DCC and Georgiana Slough can be substantial and is influenced by channel configuration, DCC gate operations, and hydrodynamic conditions at these distributary junctions. Perry et al. (2010) estimated that up to 35% of juvenile Chinook salmon migrating from the Sacramento River basin could be entrained into the interior Delta through the DCC and Georgiana Slough. This represents up to 50% of the juvenile salmon remaining in the mainstem Sacramento River after passing the Sutter and Steamboat Slough junctions that could subsequently enter the interior Delta at these two junctions. Perry et al. (2010) further showed that the probability of entrainment through Georgiana Slough alone remained relatively consistent at approximately 10%. However, when the DCC gates were open, the combined probability of juvenile salmon entering the interior Delta through Georgiana Slough and DCC was up to 25 percentage points higher than the probability of entering Georgiana Slough alone (Perry et al. 2010). Singer et al. (2020) reported that the proportion of juvenile salmon entering Georgiana Slough ranged from 6.8 to 26.7% when the DCC gates were closed. Perry et al. (^2015) found that the probability of fish entering Georgiana Slough increased considerably during flood tides and identified reverse flows as the primary mechanism that caused the inverse relationship between daily entrainment and net river flow.

Perry et al. (2018) found that the proportion of fish using each migration route depended on river flow as well as DCC Gate operations. As Sacramento River flow (measured at Freeport) increased, the probability of fish entering Sutter and Steamboat Sloughs where survival is higher increased, and the probability of fish entering Georgiana Slough where survival is lower decreased. Opening the DCC gates decreased the probability of entering Georgiana Slough but resulted in an overall increase in the proportion of fish entering the interior Delta through either the DCC or Georgiana Slough. Route-specific survival rates of juvenile salmon migrating from Freeport on the Sacramento River to Chipps Island increased with increasing Sacramento River flows at Freeport, but approached an asymptote, leveling off at about 0.75 for the Sacramento River and Sutter and Steamboat sloughs, and at about 0.35 for fish entered Georgiana Slough as the Sacramento River flows increased to greater than 30,000 cfs. The asymptotic relationships between the Sacramento River flows and route-specific survival rates were driven by survival in the most downstream reaches with strong tidal influence, since survival for all other reaches approached 1 as flow increased but remained constant with flow for the strongly tidal reaches. Overall, higher flow on the Sacramento River measured at Freeport increases the probability fish remain in the mainstem Sacramento River or enter Sutter and Steamboat sloughs, while also increasing reach-specific survival in the Sacramento River and interior Delta channels. However, survival is inherently lower in interior Delta channels for the fish routed through Georgiana Slough and DCC than for fish that remain in the Sacramento River mainstem or enter Sutter and Steamboat Sloughs, even under higher flow conditions. Therefore, water management actions that increase the proportion of Sacramento River flow routed into the interior Delta channels, and consequently increase the routing of juvenile salmon into the interior Delta channels, are expected to reduce overall juvenile salmon survival.

The Staff Report summarizes the best available science describing the factors affecting routing and migration pathways of juvenile salmon at the distributary junctions in the Delta. As described above and in Section 3.4.5.3 *Juvenile Through-Delta Emigration*, the migration pathway of Sacramento River-origin juvenile salmon is influenced by multiple factors affecting hydrodynamics in the region, including Sacramento River inflows, tidal flows, channel modifications (e.g., DCC), proportional flow split into distributary channels, and export operations. The 2023 draft Staff Report accurately describes the effects of export operations, including DCC Gate operations and south Delta export pumping on whether juvenile salmon remain in the mainstem Sacramento River or are routed into the interior Delta via the DCC and Georgiana Slough. The DCC facilitates the diversion of water from the Sacramento River into the interior Delta to the CVP and SWP export pumps (Reclamation 2023). DCC gate operations have a substantial effect on the water routing and juvenile salmon entrainment into the interior Delta, as described in the Staff Report and in the sections above. Because juvenile salmon are routed proportionally with the flow, conditions that increase the movement of Sacramento River water through the DCC and Georgiana Slough into the interior Delta also increase the likelihood that fish follow those migration pathways. South Delta export pumping further influences these hydrodynamic conditions and the movement of water through the interior Delta. The influence of water exports on routing juvenile salmon into the interior Delta is more pronounced at the San Joaquin River junction, where higher export rates increased the proportion of fish entering the interior Delta by up to 7% at the Head of Old River in the south Delta (Cavallo et al. 2015).

The Staff Report does not state, as some comments claim, that routing of flow and juvenile salmon at Sacramento River distributary junctions is strongly controlled by SWP and CVP export rates. In particular, the claim that a Salmon Scoping Team (SST) report suggesting that the rate of SWP and CVP exports has little effect on route selection at key locations (SST 2017), but does not acknowledge that the Salmon Scoping Team (SST 2017) also reports that increased south Delta exports increase the proportion of flow directed toward the interior Delta at key channel junctions, including Georgiana Slough. As sated above, salmon are routed proportionally with flow. When increased exports increase the proportion of flow directed toward the interior Delta at key channel junctions, salmon routing into the interior Delta and salmon mortality is also increased. Further, the SST report (SST 2017) reiterated the uncertainty related to the issue by stating, "Incomplete multi-year analysis of existing Chinook salmon and steelhead AT data (analysis is ongoing); however, conclusions will remain uncertain due to limited observations at high export levels and correlation between exports and inflow, and possibly other variables (e.g., water temperature)."

Contrary to commenters' claims that the 2023 draft Staff Report overstated the effects of exports on migration routing for juvenile salmon, the available scientific evidence summarized above and in the Staff Report demonstrates that CVP and SWP export operations, together with DCC gate operations and other hydrodynamic factors, strongly influence the probability that Sacramento River-origin juvenile salmon enter the interior Delta where survival is lower and fish are subjected to an increased risk of entrainment at the Project export facilities.

Commenters further recommended additional evaluation of the effects of mitigation actions intended to reduce juvenile salmonid entrainment into the interior Delta such as the Georgiana Slough Salmonid Migratory Barrier. Installation and operation of a non-physical barrier (e.g., bio-acoustic fish fence [BAFF]) (Perry et al. 2012) and a physical barrier (floating boom fish guidance structure) (Romine et al. 2017) at the entrance of Georgiana Slough showed that their effectiveness in reducing juvenile salmon entrainment into the interior Delta could vary depending on the time of day and hydrologic conditions. Seasonal installation and operation of a BAFF has been evaluated to estimate its effectiveness at reducing juvenile salmon entrainment into Georgiana Slough from the Sacramento River. Operation of the BAFF along the entrance of Georgiana Slough has been marginally effective, reducing juvenile salmon entrainment into Georgiana Slough from 22.3% when the BAFF was not operating to 7.7% when the BAFF was operating under a range of flow conditions in the year 2011 (Perry et al. 2012). A separate analysis by DWR showed similar effectiveness of the BAFF operations reducing the juvenile salmon entrainment in 2011 (from 22.1% BAFF off to 7.4% BAFF on) and 2012 (from 24.4% BAFF off to 11.8% BAFF on) (DWR 2015). Perry et al. (2012) concluded that effectiveness of the BAFF declined with increasing river discharge, likely because increased water velocities swept fish across the BAFF into Georgiana Slough. Further, other hydraulic factors such as cross-stream distribution of fish could influence the performance of the non-physical barrier. Hance et al. (2020) further supported the BAFF operations reduced entrainment probability of juvenile Chinook salmon into Georgiana slough.

A physical barrier using the floating fish-guidance structure (FFGS) designed to reduce juvenile Chinook salmon entrainment was deployed in the main-stem Sacramento River just upstream of the Georgiana Slough divergence (Romine et al. 2017). Although the FFGS was somewhat effective in reducing fish entrainment into Georgiana Slough under low (<7,000 cfs) and intermediate Sacramento River discharges (7,000-14,000 cfs), it increased fish entrainment into Georgiana Slough under river flows greater than 15,000 cfs (Romine et al. 2017). However, overall fish entrainment rates were much greater during low flow conditions compared to intermediate and high flow conditions. Because fish entrainment into the interior Delta is affected by complex hydrodynamics at the location of the physical barrier, dynamic deployment of the FFGS should be considered to reduce fish entrainment into the interior Delta via Georgiana Slough (Romine et al. 2017).

Swyers et al. (2024) evaluated the potential benefits of dynamic operation of a BAFF at Georgiana Slough and FFGS at Steamboat Slough on the through-Delta survival of juvenile winter-run Chinook salmon (from Verona to Chipps Island). They estimated that optimized operations of the BAFF at Georgiana Slough during November 1 through March 15 each year could improve overall through-Delta survival of juvenile winter-run Chinook salmon by 6.3% over baseline without the fish guidance structures in place.

The Staff Report considered and incorporated the most recent peer-reviewed studies and agency reports on routing, entrainment, and survival of fish species in the Delta. These studies showed that (1) river flow and hydrodynamic conditions, including the south Delta exports, strongly influence juvenile salmon routing; (2) entrainment into the interior Delta decreases salmon survival, with survival through the interior Delta routes, including the Georgiana Slough route, roughly half that of mainstem routes; and (3) higher Sacramento River flows reduce entrainment-related mortality by decreasing the proportion of fish entering the interior Delta and thereby decreasing exposure to south Delta hydrodynamics.

Studies have evaluated a range of operational and structural measures at the DCC and Georgiana Slough, including seasonal DCC gate operations, non-physical barriers such as the bio-acoustic fish fence, and physical fish guidance structures. Recent evaluations indicate that dynamically operated, seasonally optimized mitigation measures can reduce juvenile salmon entrainment and modestly improve overall through-Delta survival of juvenile salmonids (e.g., Swyers et al. 2024). The final Staff Report has been updated based on this information.

Fish Losses at the South Delta Export Facilities

Water export operations at the SWP and CVP facilities result in fish entrainment through the incidental removal of aquatic species in the water diverted by the facilities. In the south Delta, a more spatially expansive definition of entrainment includes transport of fish through the Old and Middle Rivers corridor, where entrained fish are exposed to adverse environmental conditions and elevated predation risks before arriving near the SWP and CVP facilities (Smith 2019). Fish initially entrained into the southern portion of Delta are then transported to the SWP and CVP export facilities through a combination of volitional movement and hydrodynamics (^Kimmerer 2008).

Multiple commenters questioned the adequacy of the 2023 draft Staff Report's analysis regarding entrainment of Delta smelt, longfin smelt, juvenile salmon, and other fish species at the water export facilities in the south Delta. Concerns included the use of outdated literature and models, and lack of demonstrated population-level benefits from further entrainment reductions. Commenters further stated that fish entrainment at the south Delta export facilities is being effectively managed, and additional reductions in entrainment would be unlikely to produce population-level benefits for estuarine fish species such as Delta smelt, and longfin smelt.

Entrainment of Juvenile Salmonids

Some commenters claimed that juvenile salmon entrainment at the SWP and CVP export facilities has been low and is managed in real time by multi-agency teams pursuant to the BiOp and ITP.

The fish facilities for the SWP (John E. Skinner Delta Fish Protective Facility) and CVP (Tracy Fish Collection Facility) collect a fraction of the entrained fish, which are referred to as salvage. A percentage of the fish entrained into the vicinity of the facilities is lost to predation or other sources of mortality (near field pre-screen loss) and unable to reach the screens of the fish facilities to be salvaged. The 2019 and 2024 NMFS BiOps (^NMFS 2019 BiOp, NMFS 2024) provided thorough reviews on salmonid entrainment at the water export facilities. The prescreen loss rate at the CVP's Tracy Fish Collection Facility is estimated to be around 15% (NMFS 2024) while it was about 77% for salmonids at the SWP's Skinner Fish Protective Facility (NMFS 2024). However, these prescreen loss rates vary greatly depending on the export rates and hydrodynamic conditions in the surrounding areas of the Delta.

Juvenile salmon directly entrained into the CVP and SWP export facilities (including the SWP Clifton Court Forebay) experience high mortality rates and only a small proportion survive the salvage and relocation process. Gingras (1997) reported 63-99% prescreen loss rates of juvenile Chinook salmon at the SWP's Skinner Fish Facility, from the radial gates of the Clifton Court Forebay to the trash booms that deflect large debris away from the fish facility. Clark et al. (2009) reported greater than 74% pre-screen loss for juvenile steelhead from the Clifton Court Forebay to the fish screens at the SWP facility, which was within the range of prescreen loss rate estimated by Gingras (1997) for juvenile salmon. Jahn and Kier (2020) estimated that the overall survival rate of juvenile salmon entrained into Clifton Court Forebay would be less than 10% under average conditions at the SWP facilities. They further estimated that fish survival at the CVP facility would be less than 50%, from the trash boom to salvage (Jahn and Kier 2020). Juvenile salmon have higher survival rates at the CVP facility than at the SWP facility, because the CVP does not have a forebay comparable to Clifton Court Forebay, where conditions contribute to reduced fish survival (Jahn and Kier 2020).

Tillotson et al. (2022) evaluated how water management actions were related to entrainment risk of juvenile salmonids during the January-June period to inform how the water diversions in the south

Delta export facilities could be adjusted based on real-time predictions. They concluded that entrainment risk of juvenile salmon at the south Delta export facilities increased with higher export rates and more negative OMR flows. In addition, Tillotson et al. (2022) reported that the proportion of juvenile salmon entrained at export pumps increased substantially when total exports increased above 6,000 cfs to 7,000 cfs, supporting the conclusion by Kimmerer (^2008).

Multiple studies demonstrate that prescreen mortality of juvenile salmon at the south Delta export facilities is high, often exceeding 70% at the SWP and 50% at the CVP facilities, and that entrainment risk increases sharply when the combined south Delta export rates exceed approximately 6,000–7,000 cfs. These findings contradict the comments asserting that entrainment at the south Delta water export facilities is negligible or being effectively managed and mitigated.

Entrainment of Delta Smelt

Castillo et al. (2012) reported very high pre-screen loss rates of Delta smelt (94.3% to 99.9%) at the SWP facilities, from the Clifton Court Forebay entrance to the Skinner Fish Facility with slightly lower loss rates for adult Delta smelt (94.3% and 99.1%) compared to the rate observed for juveniles (99.9%). Further, they concluded that pre-screen loss at the SWP facilities was the largest source of mortality for Delta smelt and the salvage of Delta smelt at the SWP was not a consistent index of entrainment as the smaller Delta smelt juveniles could be under-sampled at the CVP's Tracy Fish Facility and SWP's Skinner Fish Protective Facility (Castillo et al. 2012).

USFWS (2024a) concluded that the proposed operations of the CVP and SWP, based on OMR flow management, would not eliminate entrainment of subadult, adult, larval, and juvenile Delta smelt. However, entrainment would be maintained at levels similar to those observed since 2009. Based on the life cycle model-entrainment, USFWS (2024a) estimated that monthly entrainment-related mortality would be approximately 9 to 16 percent of the population for subadult and adult Delta smelt (December-March) and 8 to 10 percent for post-larval Delta smelt (April-May).

Subadult and Adult Life Stages (December – March)

The tidal and net flow of water toward the south Delta export facilities are frequently indexed using OMR flows, which influence the vulnerability of Delta smelt to entrainment at the export facilities. OMR flow is a good indicator of Delta smelt entrainment risk (^Grimaldo et al. 2009; Kimmerer 2011; Smith et al. 2020; USFWS 2024a). As adult Delta smelt disperse, their advection into the south Delta can be affected by OMR flows, mediated by turbidity.

The USFWS 2024 BiOp (USFWS 2024a) provided a thorough review including the most recent scientific literature on the impacts of the south Delta water export facilities on entrainment of Delta smelt. Further USFWS (2024a) explains how the CVP and SWP water exports affect the Delta smelt population in the south Delta as well as the effectiveness of the salvage process for the fish entrained into the export facilities.

A large proportion of Delta smelt entrained into the water export facilities, e.g., Clifton Court Forebay in the SWP and the intake channel in the CVP, would go unobserved (Castillo et al. 2012; Smith 2019). For example, Smith (2019) estimated that 53 to 142,488 adult Delta smelt were "entrained" per year from 1994 to 2016; however, the numbers of subadult and adult Delta smelt actually observed at the fish facilities ranged from 0 to 1,708 fish. Additionally, most entrained Delta smelt never reach the fish facilities because they are presumably eaten by predators in the channels of the south Delta or in front of the facilities (Castillo et al. 2012; USFWS 2024a).

Based on the combination of the hydrodynamic influence of the projects, high predation rates, and the limited efficacy of salvage at the fish facilities, USFWS (2024a) concluded that most fish reaching Old and Middle Rivers would be lost (^Kimmerer and Nobriga 2008; Korman et al. 2021). Smith et al. (2021) suggested that entrainment was a major source of subadult and adult Delta smelt mortality during the December-March period of 1995-2015, frequently accounting for more than 30 percent of mortality (Smith et al. 2021). Polansky et al. (2021), using a state-space model, reported that the survival of subadult Delta smelt was related to turbidity in the south Delta, OMR flows, and the presence of predatory fish. Further, Polansky et al. (2024) stated that population-level survival of Delta smelt during winter (subadult to adult) may be reduced due to entrainment at the export facilities.

Smith et al. (2021) further concluded that management of Old and Middle River flows had helped lower the fraction of total mortality caused by entrainment in recent years. USFWS (2024a) estimated that monthly entrainment losses of subadult and adult Delta smelt in the December-March period would be about 9 to 16 percent of the population, and they could range from 4 percent to 31 percent, when accounting for uncertainty in the estimates. Information from these studies suggests that OMR management is an effective manner to minimize the entrainment of subadult and adult Delta smelt into Old and Middle Rivers and other parts of the south Delta (USFWS 2024a).

Larval and Juvenile Life Stages (April – June)

Entrainment losses of age-0 Delta smelt (larval, post-larval, and juvenile fish) at the south Delta channels and water export facilities are difficult to estimate due to multiple factors. Collection of Delta smelt at the water export facilities via salvage could provide potentially the most accurate representation of fish loss via entrainment. However, salvage of age-0 Delta smelt is even less efficient than for subadult and adult Delta smelt and a large majority of age-0 Delta smelt entrainment goes unobserved (^Kimmerer 2008; Castillo et al. 2012; Smith et al. 2020). USFWS (2024a) estimated that most of larval and juvenile Delta smelt reaching Old and Middle Rivers would be lost due to the persistent hydrodynamic influence of the water export operations on these channels.

Since age-0 Delta smelt tend to drift during their early life history to move from the Delta to downstream habitats, particle tracking models have been used to estimate the influence of net flows in the south Delta on entrainment risk. Smith et al. (2021) estimated the proportional losses of early (April-May) post-larval Delta smelt due to entrainment as less than 20 percent and almost zero for late (June) post-larval fish since 2004. Since the implementation of OMR management, the proportional entrainment of post-larval Delta smelt has been under 10 percent of the population (Smith et al. 2021). USFWS (2024a) estimated that entrainment losses of post-larval Delta smelt in the April-May period would be about 8 to 10 percent of the population (or 4 to 18 percent after accounting for uncertainty) and during June it would be about 1 percent of the population.

Entrainment of Longfin Smelt

Entrainment of adult and pre-spawning juvenile longfin smelt at the water export facilities appears to be a minor source of loss. This is primarily because the average location of longfin smelt is more seaward (west) than Delta smelt during the period when they are exposed to the effects of south Delta water exports (USFWS 2024a).

Larval longfin smelt could be vulnerable to entrainment in the water export facilities if spawned in the south Delta or transported there by a combination of tidal and net river flow current (USFWS

2024a). Though collection of fish at the salvage facilities would represent the most accurate estimate of fish loss through entrainment, salvage of age-0 longfin smelt (post-larvae and juveniles) is less efficient than it is for subadults and adults as the louvers at the export facilities are only designed to redirect fish larger than 20 mm in length, which is larger than age-0 longfin smelt (USFWS 2024a). Thus, entrainment of most of the age-0 longfin smelt would go unobserved, especially during January-March when many fish are too small to be salvaged. Further, recent declines of the longfin smelt population as described in Section 3.5.3*, Population Abundance Trends over Time*, could have lowered the probability of detection.

Kimmerer and Gross (2022) estimated that entrainment losses could reach about 0.5 percent of the larval longfin smelt population per day under very low flow conditions while it would be close to 0 percent under high Delta outflow conditions. Based on these calculations, Kimmerer and Gross (2022) estimated that up to 2.9 percent of the larval longfin smelt population would be lost through entrainment per year during the study period of 2009-2020. Gross et al. (2022), using a 3-D particle tracking model, estimated similar entrainment losses of larval longfin smelt in a dry year (2013) and a wet year (2017), concluding that up to 3 percent of the population was entrained in 2013 and no more than 0.15 percent in 2017. USFWS (2024a) clarified that these estimates of larval longfin smelt entrainment should be considered a minimum as they do not include post-larvae and young juveniles that are visible in samples of salvaged fish and because of the assumption that mortality rates in the South Delta are the same as other parts of the ecosystem.

The Staff Report reviewed and incorporated the most recent and comprehensive analyses that showed ongoing entrainment risks for Delta smelt, longfin smelt, and juvenile salmonids. The claim in public comments that entrainment is "effectively managed" or that further reduction of fish entrainment cannot provide population-level benefits is not supported by the best available science. USFWS (2024a) explicitly concludes that current entrainment losses remain significant and that reducing entrainment mortality is necessary to improve population growth rates, especially for Delta smelt. The Staff Report reflects these findings and describes updated flow-related protections consistent with federal biological opinions and current scientific understanding.

Old and Middle River Flows and Fish Entrainment

Several comments cited scientific literature linking reverse OMR flows caused by high water exports to entrainment mortality of Delta smelt, describing these flows as one of the most powerful predictors of sub-adult survival. Commenters argued that entrainment losses (including salvage and prescreen mortality) have been underestimated and threaten the population viability of Delta smelt. Commenters suggested Staff Report should identify and revise flow targets to better protect Delta smelt during spring, summer, and fall, and reduce the impacts of the reverse OMR flows. Further, commenters recommended that reducing entrainment mortality could enhance the probability of Delta smelt population growth.

As described below and in Staff Report Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations,* scientific studies support the management of OMR flows and water quality parameters in the south Delta to reduce Delta smelt entrainment to the water export facilities. The Staff Report identifies that OMR flows should be maintained between -1,250 cfs and -5,000 cfs depending on the presence of Delta smelt and other environmental factors including turbidity that influence entrainment (Section 3.8.4.4, *Interior Delta Flow*).

As described in final Staff Report Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations,* the 2008 USFWS BiOp provided that (1) entrainment risk of Delta smelt depended on the location of fish relative to the export facilities; (2) Delta smelt salvage at the export facilities began to increase with OMR flows more negative than -1,250 cfs; and (3) salvage rate increased exponentially with increasingly negative OMR flows (i.e., more negative than -5,000 cfs). The USFWS BiOps issued in 2019 and 2024 (USFWS ^2019 BiOp, 2024a) reiterated the influence of tidal and net flows in Old and Middle Rivers on the vulnerability of Delta smelt larvae, juveniles, and adults to entrainment at the water export facilities and concluded that OMR flow was a good indicator of larval Delta smelt entrainment risk. The most recent BiOp (USFWS 2024a) summarized the level of entrainment impacts on the Delta smelt population with the most recent scientific literature and also concluded that OMR management, while incorporating effects of turbidity in the south Delta, is an effective way to minimize the entrainment of subadult and adult Delta smelt into Old and Middle Rivers and other parts of the south Delta.

The USFWS BiOp (USFWS 2024a) explains the mechanism of sub-adult and adult Delta smelt entrainment at the water export facilities and its relationship to negative OMR flows. As OMR flows become more negative, typically under higher south Delta export conditions, more Sacramento River water backfills into the south Delta to replace water being exported and this process occurs at a faster rate. If the Sacramento River water is turbid and being moved across the Delta quickly, then that turbidity can also be transported into the south Delta. This "turbidity bridge" from the Sacramento River to the south Delta provides a habitat corridor and facilitates the movement of adult Delta smelt in the net flow direction of Old and Middle Rivers, as they use flood tides to move further inland. Higher salvage of subadult and adult Delta smelt has been observed under more turbid conditions in the south Delta (^Grimaldo et al. 2009; Grimaldo et al. 2021). This salvage pattern may have resulted from Delta smelt preferring higher turbidity and flow or from reduced predation risk under more turbid conditions (Korman et al. 2021).

Recent studies that investigated the effects of spatial, environmental, and hydrologic parameters on through-Delta survival of juvenile salmonids migrating through the lower San Joaquin River corridor and south Delta have generally found similar conclusions about the effects of OMR flows.

Buchanan and Skalski (2020) reported that the migration survival of juvenile fall-run Chinook salmon through the San Joaquin River corridor (from the head of Old River to Chipps Island) was negatively associated with net Middle River flow and net combined Old and Middle River flow, i.e., higher survival under more negative OMR flows, during a 5-year study (2010-2014). However, the authors provided several important limitations of the study: (1) a small range of net OMR flows were observed during most years since the data were collected when the OMR restrictions were in place; and (2) approximately half of the juvenile salmon detected at Chipps Island were those that went through CVP salvage and were trucked to the Delta exit. In addition to the limited range of OMR flow conditions observed, through-Delta survival rates of fall-run Chinook salmon were consistently low (less than 0.05 during the years 2011 through 2014), making it difficult to confirm any statistical trends. Based on these limitations, authors suggested that as migration survival through the San Joaquin River route improves, the relationship between interior Delta flow and survival may change. Additionally, the data from one wet year (2011) accounted for the majority (52%) of the available data for the 5-year analysis (2010-2014) used in Buchanan and Skalski (2020). A subsequent study with more expanded data (years: 2009–2014, 2016–2017) of fall-run Chinook salmon migration survival through the lower San Joaquin River and south Delta found that the significant negative relationship between the net OMR flows and salmon survival from Buchanan and Skalski (2020) was not supported (Buchanan and Whitlock 2022). In addition, Buchanan et al.

(^2021) reported that through-Delta (from the head of Old River to Chipps Island) survival of juvenile steelhead was positively correlated with net OMR flows, i.e., higher survival under more positive OMR flows, during a 6-year study (2011-2016).

Polansky et al. (2021), using a state-space model (SSM), further demonstrated the aggregated influence of turbidity and OMR flows on the sub-adult Delta smelt survival. Smith et al. (2021) concluded that entrainment mortality of all life stages of Delta smelt was greater at low water clarity and low OMR flows. Grimaldo et al. (2021) further considered the factors related to adult Delta smelt entrainment losses (i.e., salvage) at the CVP and SWP facilities during the "first flush" and "seasonal" entrainment windows. They found that the best predictor of salvage at both CVP and SWP facilities were subadult abundance, SWP exports, OMR flow, and south Delta turbidity concurring with the previous studies (Grimaldo et al. 2021).

Tillotson and Brandon (2023) and Smith et al. (2021) suggested that entrainment mortality under the current regulations since 2007 have not increased population growth rates of Delta smelt. Although they found that even zero net OMR flows would not result in a high probability of population growth under current environmental conditions, that does not equate to no benefit of OMR flow management. Thus, OMR flow management remains a valid option for reducing entrainment mortality, as survival has been linked to a range of OMR flows across all life stages of Delta smelt (Smith et al. 2021). Smith et al. (2021) suggested that juvenile Delta smelt mortality may be limited by maintaining sufficient outflow to keep the low salinity zone westward of the confluence of the Sacramento and San Joaquin Rivers where turbidity is often higher and water temperatures are cooler. Management actions that reduce mortality, including entrainment losses, and enhance seasonal ecosystem conditions would be necessary to improve the odds of Delta smelt population recovery (Smith et al. 2021).

Some commenters questioned whether fish entrainment at the south Delta export facilities is "effectively managed" for the Delta smelt population and whether further reduction in entrainment would have a population-level effect. However, a "population-level effect" of a fish species could only be realized when the cumulative effects of various other environmental and biological factors affecting different life stages have been accounted for. USFWS (2024a) concluded that the proposed operations of the CVP and SWP, based on OMR flow management, would not eliminate entrainment of subadult, adult, larval, and juvenile Delta smelt, but entrainment would be maintained at levels similar to those observed since 2009. Based on the life cycle model-entrainment, USFWS (2024a) estimated that monthly entrainment-related mortality would be approximately 9 to 16 percent of the population for subadult and adult Delta smelt (December-March) and 8 to 10 percent for post-larval Delta smelt (April-May). Higher flows resulting from the revised proposed Plan amendments would enhance various habitat conditions for Delta smelt, including hydrology (e.g., Delta outflow and OMR flows), turbidity, and water temperature conditions, and result in potentially higher population growth rates than current conditions.

The Staff Report acknowledges-and is consistent with-the substantial body of scientific literature demonstrating that reverse (negative) OMR flows strongly influence entrainment mortality of Delta smelt, particularly during the subadult and adult life stages (December–March). Other studies showed that turbidity, hydrodynamics, and OMR interact to influence Delta smelt vulnerability to entrainment. Scientific evidence further indicates that higher Delta outflow and less negative OMR flow conditions create more favorable habitat and reduce entrainment mortality, thereby increasing the likelihood of population stabilization or growth.

Conclusion: Fish Entrainment in the Delta

The Staff Report considered and incorporated the most recent peer-reviewed studies and agency reports on routing, entrainment, and survival of fish species in the Delta. These new studies have improved understanding of how hydrodynamics, river flow, and export operations influence juvenile salmon routing and survival. The Staff Report evaluates the need for flow targets and OMR management consistent with these findings. The updated flow recommendations are supported by the most recent peer-reviewed studies and reports documenting entrainment as a continuing population-level threat to Delta smelt.

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