

LONGFIN SMELT SCIENCE PLAN

2024 – 2034



Developed Collaboratively by California Department of Water Resources, California Department of Fish and Wildlife, State Water Contractors, and the United States Fish and Wildlife Service

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EXECUTIVE SUMMARY

Longfin Smelt science has continued to progress since the species listing under the California Endangered Species Act (CESA) in 2009. However, there continue to be substantial gaps in our understanding of the biology of this species, including management activities needed to prevent further decline of Longfin Smelt in the San Francisco Estuary. In 2020, the California Department of Fish and Wildlife (CDFW) issued the California Department of Water Resources (DWR) an Incidental Take Permit (ITP) for the operation of the State Water Project (SWP). The 2020 ITP included a provision to develop a Longfin Smelt Science Program and implement science activities to further our understanding of the species. On November 4th, 2024, CDFW issued DWR a new ITP under CESA for the operations of the State Water Project. Within the 2024 ITP, Condition of Approval 7.8.1 requires DWR, in collaboration with the US Bureau of Reclamation (Reclamation), CDFW, the US Fish and Wildlife Service, and the State and Federal Water Contractors, to continue to support the Longfin Smelt Science Program through 2034. The first step in implementation under the 2024 ITP is to update the Longfin Smelt Science Plan to reflect scientific advances which have occurred since 2020 and to address remaining science and management priorities identified within the Longfin Smelt Science Plan.

This Longfin Smelt Science Plan, and the Longfin Smelt Science Program as a whole, is intended to serve multiple purposes: fulfill the requirement of the ITP described above, provide new science and information to federal agencies implementing the 2024 Record of Decision for long-term operations of the SWP and CVP, and provide a framework for Longfin Smelt scientific investments over the next 10 years. This program follows the same approach from the 2020 ITP which modeled the Longfin Smelt Science Program after the 2014 Longfin Smelt Settlement Agreement (CDFW 2014), but with a broader, open format, and is part of the Long-Term Operations of the State Water Project and the Central Valley Project Adaptive Management Program (LTO AMP). Our hope is that this format will encourage other partners to align their research with the Longfin Smelt Science Plan and the Longfin Smelt Science Program. Towards this goal, the Longfin Smelt Science Plan has identified six Priority Areas where scientific investments can produce valuable information for resource managers. These Priority Areas include:

1. Life Cycle Modeling
2. Factors Affecting Abundance, Growth, and Survival
3. Improved Distribution Monitoring
4. Longfin Smelt Culture
5. Fish Migration and Movements
6. Spawning and Rearing Habitats for Longfin Smelt

The six Priority Areas represent a suite of topics which cover uncertainties and assumptions identified in the development of the ITP, inform the science priorities in Condition of Approval 7.6.1, while also covering broader topic areas that are of management relevance. Specifically, the Longfin Smelt Science Plan describes how each study element provides: key background

information; management relevance; possible scientific approaches to informing that topic; additional considerations, such as coordinating with other processes (e.g. Interagency Ecological Program annual workplan) and any relevant science program accomplishments since 2020.

The Longfin Smelt Science Program will be implemented by the Longfin Smelt Technical Team, who will prioritize, develop, and execute studies that inform one or more identified priority areas. To do this, the technical team will review an updated team charter and finalize the updated Longfin Smelt Science Plan. The charter details the team's goals and objectives as well as the decision-making processes for selecting and prioritizing science investments.

Since one of the purposes of the Longfin Smelt Science Plan is to provide a framework for new scientific investments over the next 10 years, our hope is that this document will be informative to other partners (e.g. universities, consulting firms, public water agencies) who want to conduct management relevant science. The Longfin Smelt Technical Team will also serve as an adaptive management technical team for the LTO AMP, where findings and results stemming from the Longfin Smelt Science Program will help inform the adaptive management process.

In summary, the Longfin Smelt Science Plan outlines priorities for management relevant science during the 10-year duration of the 2024 ITP. The information produced from this process is expected to inform future permitting efforts as well as improve our general understanding of the species and its habitat needs.

STATUS OF LONGFIN SMELT

Longfin Smelt (*Spirinchus thaleichthys*) were once one of the most abundant species within the San Francisco Estuary (SFE) (Rosenfield and Baxter 2007). However, the long-term surveys have shown a precipitous decline in the abundance of the species over time and throughout the SFE (Rosenfield and Baxter 2007; Nobriga and Rosenfield 2016), with notable drops following the introduction of invasive clams in the late 1980s (Kimmerer 2002) and the Pelagic Organism Decline in the early 2000s (Thomson et al. 2010).

Based on concerns about the population status of the species, Longfin Smelt was listed as threatened under the California Endangered Species Act (CESA) in 2009 (CDFG 2009). The U.S. Fish and Wildlife Service (USFWS) has since found the San Francisco Bay-Delta Distinct Population Segment (DPS) of Longfin Smelt to warrant protection under the federal Endangered Species Act (ESA), but the listing was precluded at the time (USFWS 2012). In October of 2023, USFWS proposed the Bay-Delta DPS of Longfin Smelt for listing under the ESA. The proposal was finalized in August of 2024, and the Bay-Delta DPS of Longfin Smelt was officially listed under ESA with a status of endangered (ESA; 89 Fed. Reg. 61029; August 29, 2024).

However, after almost 15 years since the 2009 CESA listing, there is still a negative trend in Longfin Smelt detections, highlighting the need for continued management efforts and to establish a refuge population (Hobbs *et. al* 2017, Pollard and Flagg 2004, USFWS 2022). As the San Francisco Estuary population serves as the southernmost reproductive population for the species (Garwood 2017) and is genetically distinct from more northward populations (Saglam et al. 2021).

REGULATORY CONTEXT

Longfin Smelt Settlement Agreement

The California Department of Fish and Wildlife (CDFW), the California Department of Water Resources (DWR) and the State Water Contractors (SWC) entered into an agreement in 2014 to implement a multiyear Longfin Smelt Science Program. This earlier version of the Longfin Smelt Science Program was based on a 2009 challenge by the SWC's to DWR's Longfin Smelt incidental take permit for SWP operations issued by CDFW. Specifically, the Settlement Agreement represented a collaborative effort to resolve some of the major scientific issues raised in the SWC's legal challenge, improve management of Longfin Smelt, and ultimately

inform CDFW in development of future permitting needs related to Longfin Smelt. This effort lasted approximately five years, with an iterative approach where the direction of studies was adaptively managed based on results from previous years. Information resulting from the Settlement Agreement proved to be valuable (see Lewis et al. 2018, 2020), helping to inform future permitting. However, one of the more notable features of this effort was the function and efficiency of the technical team created as part of the process. This venue of Longfin Smelt experts within the representative agencies provided a forum to discuss important science topics related to the species. While the current version of the LFSSP will be broader in scope and occur for a longer duration than the Settlement Agreement did, it will maintain the same technical forum framework. Thus, while the Longfin Smelt Science Program will be a different approach to addressing Longfin Smelt science needs than the Settlement Agreement, it will continue to function at a similar technical level.

Questions examined in the Settlement Agreement included the following (see CDFW 2014):

Longfin Smelt distribution and regional contribution to overall abundance:

1. Quantify the relative abundance of early life stages and adult Longfin Smelt in Bay tributaries (e.g. Napa River, Sonoma Creek, Petaluma River, Alameda Creek and Coyote Creek) during the spawning and rearing seasons occurring during wet and dry years.
2. Determine if geochemical signatures of Bay tributaries vary to the extent that otolith geochemistry could be used to determine the relative contribution of Bay tributaries to recruited juvenile and adult fish collected in IEP-CDFW surveys in the San Francisco Bay.
3. Determine the extent to which initial rearing in different salinity zones and geographic areas contribute to the Longfin Smelt population and compare these contributions between wet and dry years.
4. Determine if geochemical signatures of the ocean environment can inform the extent to which Longfin Smelt use the near-shore ocean environment using otolith geochemical signatures.

Longfin Smelt vertical migration behavior

5. Determine the extent to which Longfin Smelt exhibit regular vertical movements within the water column during the day-night cycle, and whether these behaviors vary among different regions of the estuary or seasonally.

6. Determine the relationship between water transparency and the Longfin Smelt catch in the Bay Study midwater trawl and otter trawl sampling.
7. Determine whether changes may be needed in current Longfin Smelt survey index calculation methods, and whether the new information provides better insight into the proper formulation of quantitative population estimates

2020 Incidental Take Permit

On March 31, 2020 DWR and CDFW signed incidental take permit number 2081-2019-066-00 (ITP) for long-term operations of the State Water Project (SWP) in the Sacramento-San Joaquin Delta (Delta). This ITP authorized incidental take of Delta Smelt, Longfin Smelt, winter-and spring-run Chinook Salmon, and white sturgeon (amended into the ITP in 2024) as a result of operations of SWP facilities in the Delta and Suisun Marsh through March 31, 2030. The ITP included a Condition of Approval intended to improve understanding of SWP and CVP impacts on Longfin Smelt and build upon the current understanding of Longfin Smelt ecology. This Condition of Approval required DWR to establish the Longfin Smelt Science Program, develop a Longfin Smelt Science Plan (LFSSP) by December 1, 2020, and implement all elements of the plan during the term of the ITP.

Components of the Science Plan described in the ITP included (Condition of Approval 7.6.3 of the 2020 ITP):

- Develop a Longfin Smelt life cycle model. DWR, CDFW, and SWC will work collaboratively using the best available science to develop a mathematical life cycle model for Longfin Smelt, verified with field data collection, as a quantitative tool to characterize the effects of abiotic and biotic factors on Longfin Smelt populations.
- New and ongoing monitoring that:
 - Revises existing IEP monitoring programs to expand the spatial distribution of Longfin Smelt sampling to ensure equal sampling effort throughout the Delta, Suisun Bay, and San Francisco Bay regions.
 - Characterizes the distribution and abundance of adult, larvae, and juvenile life stages and changes in these estimates across a range of hydrologic conditions
 - Facilitates estimates of survival probabilities among life stages
 - Identifies factors that influence abundance growth, survival, and distribution

- Complete the Longfin Smelt life cycle in captivity at the Fish Conservation and Culture Laboratory (FCCL)
- Characterize Longfin Smelt spawning substrate and spawning microhabitat requirements
- Studies to improve the understanding of adult migration behavior and juvenile outmigration behavior including transport mechanisms for out-migrating larvae and juveniles

The Longfin Smelt Science Program included members from CDFW, DWR, USFWS and the State Water Contractors (SWC). Each of the participating agencies may suggest additional science priorities to be added to the Science Plan to expand on the requirements of the ITP.

2024 Incidental Take Permit and 2024 Biological Opinion

On November 4, 2024, CDFW issued ITP number 2081-2023-054-00 for long-term operations of the SWP to DWR, replacing the 2020 ITP. Shortly afterward on Dec. 20, 2024, Reclamation signed the Record of Decision regarding long-term operations of the Central Valley Project (CVP) and SWP under the federal Endangered Species Act. These regulatory documents both contain a description of a Longfin Smelt Science Program as part of science and monitoring requirements. This iteration of the Science Program is expected to be a continuation of the 2020 ITP Science Program, building on what has been learned over the previous four years and implementing science activities over the next 10 years (Nov. 4, 2024 – Nov. 4, 2034).

PURPOSE OF THE LONGFIN SMELT SCIENCE PLAN

There are two primary purposes of this document. The first is to create a pathway for DWR to fulfill their requirements as part of Condition of Approval 7.8.1 in the ITP (CDFW 2024), and the second is to create a framework which emphasizes topic areas for other Longfin Smelt science investments occurring through 2034.

The six Priority Areas described below were identified to address the priorities of the ITP but are also expected to inform broader management strategies within the SFE, such as those related to improved monitoring, restoration, and aquaculture. Because of this, the detailed sections for each element (below) include key background information about the topic, its relevance to management, potential approaches for research, and progress updates for topic areas where the Science Program has conducted work.

In implementation, this document serves as a framework for the Longfin Smelt Technical Team (LFSTT) to guide in the development and review of research proposed as part of the

ITP's Longfin Smelt Science Program. This is similar to the structure of the previous iterations of the Longfin Smelt Science Program as part of the Longfin Smelt Settlement Agreement and 2020 ITP. This plan does not pose explicit research questions, nor does it identify researchers to answer those questions. Instead, this process will occur through the LFSTT as part of LFSSP implementation. This is, in part, to prevent unnecessary challenges regarding the State of California's contracting process as part of DWR's requirement under the ITP, but to also promote science investments into broad topics that are important for advancing our knowledge of the species and allowing for iteration and learning over the next 10 years. Starting with the 2024 ITP and 2024 Biological Opinion (BiOp; USFWS 2024), the LFSSP will be managed as a living document. Updates to the plan will occur periodically throughout the term of the Science Program via request by the LFSTT, Adaptive Management Steering Committee (AMSC), or initiated by DWR and CDFW to remain responsive to the LTO AMP associated with the 2024 ITP and 2024 BiOp.

Our goal with this plan is to build a systematic and transparent approach to new and ongoing Longfin Smelt science between years 2024 and 2034 that will address and prioritize key uncertainties related to the 2024 ITP, 2024 BiOp and general species ecology, as well as report progress and findings. We also hope that other interested parties, such as universities, other agencies, and consultants can use this framework as a tool for prioritizing research needs for Longfin Smelt. We anticipate that work from other entities within these Priority Areas will substantially complement the work funded by DWR and Reclamation as part of the Longfin Smelt Science Program.

LONGFIN SMELT SCIENCE PROGRAM STRUCTURE

Implementation of the LFSSP is done through the Longfin Smelt Technical Team (LFSTT), and smaller sub teams, such as the Longfin Smelt Life Cycle Model Advisory Team.

Longfin Smelt Technical Team:

The role of the LFSTT is to facilitate the development of new or ongoing research efforts as they relate to Condition of Approval 7.8.1 of the ITP (CDFW 2024) and the Priority Areas of this plan. To do this, the LFSTT will develop or solicit research projects to fund as part of DWR's requirement within the ITP (CDFW 2024) and ensure that selected projects fit within the framework of this plan.

The LFSTT will also serve as the relevant technical team for Longfin Smelt in the LTO-AMP. The tasks, deadlines, and general purpose of the LFSTT within the AMP will be guided by the AMSC. The LFSTT will be a small group, composed of scientists from CDFW, SWC, FWC, DWR, USFWS, and Reclamation. The LFSTT may consult additional outside experts as needed.

Key roles and Responsibilities:

Team Cochairs: CDFW and DWR

Meeting Frequency: Quarterly

Funding of Elements identified in ITP: DWR

Funding of Additional Research: The LFSSP includes six broad priority areas of research, and it is possible that other partners may want to align their projects based on the LFSSP. The LFSTT is anticipated to work with these partners and funding groups to ensure these projects fit within the framework of the Plan as needed; however, these projects are not included as part of DWR's ITP requirement.

Technical Input: All group members.

Connection to LFSSP: The LFSTT is expected to develop or review and modify research proposals to ensure all work proposed in connection with the LFSSP will inform at least one or more Priority Areas.

Contract Management: DWR will be contract managers for projects selected by the LFSTT and funded by DWR, which is anticipated to be a large component of the work. However, some elements of this plan may be funded through other contract mechanisms (e.g. emergency drought funding) and may not be managed by DWR specifically.

Reporting: DWR and other contract managers will forward interim and final project reports to the full LFSTT promptly after receipt so that they may be discussed at a subsequent team meeting. DWR, with input from the LFSTT, will periodically synthesize the findings from all work related to the LFSSP. This can include work from interested parties, including other agencies, and academia, as well as work conducted as part of the DWR's ITP requirement; with the condition that this work contributes to one or more Priority Areas. These reports will be both made available online and submitted to the ITP's AMP on an as-needed basis.

Outreach: DWR will be the lead on outreach regarding plan milestones and development, however, it is expected that all team members will work to promote communication with the broader scientific and resource management community. For example, CDFW may take a major role in communication since they will co-chair the LFSTT.

Team Charter: The LFSTT will continue to regularly convene in through the entirety of the implementation of the Science Program. The team charter will establish the goals and objectives for the team, determine an appropriate decision-making process, as well as provide guidelines for membership and participation. The LFSTT charter is a living document and can be updated and modified as necessary to reflect participation and program direction.

COORDINATION

Suitable elements of the ITP's Longfin Smelt Science Program will be incorporated into the Interagency Ecological Program (IEP) Annual Work Plan, providing a venue for coordination on study plans, proposal review, and staff and equipment resources. The former Longfin Science Program has been a recurring element in IEP's Annual Work plan, and we anticipate that the 2024 ITP Longfin Smelt Science Program will continue in its place and that IEP will continue to provide a valuable coordination forum.

For each project there will be additional deadlines for deliverables. Our general goal is that each project would be expected to provide an annual progress update to the LFSTT. In addition, there would be draft and final reports, the exact deadlines of which would depend on the term of the contract. Peer-reviewed journal publications that result from LFSSP studies will also be shared with the LFSTT as they become available.

In addition to these coordination opportunities, there are other important ongoing efforts which will be informed by the LFSSP, such as the Healthy Rivers and Landscapes (HRL) Science Program. The HRL Science Program includes a commitment to evaluate how increases in Delta outflow as part of the HRL program would provide benefit to Longfin Smelt. The HRL Science Committee has drafted a [Science Plan](#) that includes specific hypotheses and identifies metrics of spawning and larval rearing habitat acres, distribution of larval and juvenile Longfin Smelt, as well as abundance estimates. The HRL Science Plan commits to coordination with the Longfin Smelt Science Plan in generating any new studies or monitoring plans to ensure there is no duplication and new work is complementary.

RELATIONSHIP TO ADAPTIVE MANAGEMENT PROGRAM

Adaptive management is a structured, iterative process for decision making when confronted with uncertainty associated with the 2024 ITP and 2024 BiOp. The LTO AMP Implementing Entities (CDFW, DWR, Reclamation, USFWS and the US National Marine Fisheries Service) will establish the Adaptive Management Steering Committee (AMSC) to oversee individual Adaptive Management Teams responsible for implementing each Adaptive Management Action, utilizing decision support tools such as structured decision making.

Appendix B of the LTO-AMP includes a list of Adaptive Management Actions details regarding the timeframe of evaluation of each action and the Adaptive Management Team responsible for implementing them. Specifically, Longfin Smelt Science Plan priorities are one of the actions listed and identifies the LFSTT as the Adaptive Management Technical Team for the AMP.

Essentially, using the LFSSP as a roadmap, the LFSTT will continue to develop and implement science actions that inform one or more Priority Areas of this plan. The expectation is that findings from the scientific activities conducted within the program will inform future permitting consultations. However, if new information pertinent to real-time operations for Longfin Smelt entrainment or if LFSTT provides other information relevant to more immediate management actions for Longfin Smelt during the term of the BiOp or ITP, Agency Directors may decide to re-initiate consultation or pursue an ITP amendment for the actions.

Currently, the AMP lists Longfin Smelt Science Actions as informing management decisions within the next ten years.

REPORTING

DWR is required to fund and implement required science and monitoring according to the Priority Areas included in this science plan. DWR is also required to convene the Longfin Smelt Technical Team at least quarterly each year throughout the duration of the permit to review progress implementing this science plan, share data and interim reports, discuss methods used to implement required monitoring, and review draft results from science required as part of this plan.

Data Availability and Management for elements of this science plan are expected to follow IEP's data management guidelines, with an emphasis on transparency and open data. Projects funded under the Science Program would be expected to prepare an annual report or provide progress updates to the LFSTT at least once a year. In addition, there would be final reports distributed to the LFSTT for review, the exact deadlines of which would be in the terms of each project's funding agreement.

FUNDING

DWR's 2023 ITP application proposed an annual budget of \$1 million a year to support the Longfin Smelt Science Plan. However, the exact level of support at any given time will vary substantially depending on which contracts are active, and the current priorities of the Longfin Smelt Technical Team. As noted above, DWR will have primary contracting responsibilities. The specific funding approach may also vary depending on the composition of the team for each project (e.g., agency, university, consultant, public water agency).

Additionally, the 2024 ITP includes Condition of Approval 9.1.5 which requires DWR to fund and maintain a Longfin Smelt Refugial Population and culture program. The funding for activities described in the LFSSP for Longfin Smelt culture is not included in the broader Science Program implementation.

OTHER SCIENCE PRIORITIES

The previous sections provide information about science priorities identified in the 2024 ITP and 2024 BiOp. However, the authors of this plan recognize that there are likely other high value science topics that are not included or described in this plan. Hence, we emphasize that the current Longfin Smelt Science Plan is not intended to deter researchers from pursuing other research topics. On the contrary, additional research is encouraged since it may be relevant to the science gaps identified within the Longfin Smelt Science Plan and could lead to new innovations in Longfin Smelt science and management. Moreover, it is likely that at least some of the science projects funded by the Longfin Smelt Science Program will include smaller elements that were not specifically identified above. For example, the Life Cycle Modeling effort may identify critical information gaps that can only be addressed with new monitoring or focused research.

To help stimulate additional research, the Longfin Smelt Science Plan drafting team identified some important science topics that were not included in the Science Plan:

- Contaminant effects and risk assessments
- Invasive species effects
- The possible role of diseases in Longfin Smelt population dynamics
- Identifying the food web for Longfin Smelt
- Development of new tools (e.g., monitoring, health)
- Measurement of vital rates (e.g., growth, survival, reproduction)
- Climate change effects (e.g., hydrology, temperature)

This list is not intended to be comprehensive; rather, it is provided to show a continued interest in broader topics about Longfin Smelt science. Proposed additions to the science priorities identified in the plan should be brought to the Longfin Smelt Technical Team for review and inclusion. After unanimous approval by CDFW, DWR, Reclamation, USFWS, and State and Federal Water Contractors, such proposals would be incorporated as an addition to the Plan.

LONGFIN SMELT AREAS OF SCIENCE PRIORITY

LIFE CYCLE MODELING

Introduction

One of the most important tools for the management of at-risk species is a suitable life cycle model and Longfin Smelt is no exception. While field monitoring and research can be a useful approach to measure the responses of species to natural or managed changes in the environment, life cycle models can help to integrate the effects of multiple factors operating at different life stages, evaluate different management scenarios, and provide insight into overall population effects. For this reason, one of the highest priority science needs for Longfin Smelt identified in the ITP is the development of a life cycle model.

Key background information

There have been several approaches to model Longfin Smelt life history. One example includes basic statistical models based on one or more drivers of abundance. The simplest of these examples are relationships between Longfin Smelt abundance and outflow or X2 position (e.g., Jassby et al. 1995; Kimmerer 2002; Sommer et al. 2007). This approach was improved by incorporating a classical spawner-recruitment framework, allowing the authors to examine alternative conceptual models for drivers of abundance (Nobriga and Rosenfield 2016).

Maunder et al. (2015) used an innovative state-space approach to develop a demonstration life cycle model for Longfin Smelt. The model was designed to allow for hypothesis testing; for example, the effects of introduced clams, predators, and ammonia inputs. Two of the authors of the Longfin Smelt state-space model had previously used a similar framework for Delta Smelt (Maunder and Deriso 2011).

For fish and other species, one of the more sophisticated approaches to life cycle modeling is the development of individual based models (IBM). This approach is widely used for multiple species and has been successfully applied to Delta Smelt (Rose and Kimmerer 2013a,b; Kimmerer and Rose 2018), for evaluating different management actions. Due to its spatial and bioenergetic components the IBM allowed for an evaluation of the effects of changes to food supply and spatially explicit actions on the population. Currently, there is not yet a published IBM for Longfin Smelt; however, Loboschefskey (2013) used the general Delta Smelt framework to develop an IBM for Longfin Smelt as part of a PhD dissertation.

Primary Management Issues That This Area Will Address

It is expected that the development of a life cycle model will be a key tool to help understand the effects of ITP management actions on Longfin Smelt, as well as other related resources planning activities. Examples of some of the management applications of life cycle modeling for Longfin Smelt include the following:

- Estimating effects of entrainment relative to the population.
- Understanding the effect of winter and spring outflow on population abundance by life stage.
- Assessment of the potential effects of habitat restoration on population trends.
- Determine the effects of new projects (e.g. conveyance) and flow and habitat management (e.g., Healthy Rivers and Landscapes Program) on individuals and population trends.
- Understanding the effects of climate change (e.g., changes in precipitation or temperature patterns) on individuals and population trends.
- Informing adaptive management processes by enhancing the ability to evaluate management scenarios according to their objectives for Longfin Smelt.

Potential Scientific Approaches

Two primary approaches include additional refinement of an IBM and/or a state-spaced model, as illustrated by the review of progress above. It is anticipated that both approaches will build on previous work on Longfin Smelt and Delta Smelt, described above. An advantage of the IBM is that it can be coupled with hydrologic and hydrodynamic models, allowing the evaluation of focused water management changes and habitat projects. However, the state-spaced model also has significant attributes as illustrated by recent progress in the application of this approach to Delta Smelt (Polansky et al 2019; 2020). This work has produced useful products like more refined life-stage specific abundance indices, habitat relationships with vital rates, and completion of population viability analyses.

Note that the review above is not meant to constrain the choice of a particular modeling platform. The choice of a state-space modeling approach was based on multiple factors including the breadth of management applications, development time, PI qualifications, availability of input data, and user-friendliness (see below). Moreover, it is possible that other effective life cycle modeling approaches (not described above) will be identified for future application.

Progress to Date

In 2023, DWR executed an agreement with USFWS to develop a Longfin Smelt life cycle model as an element of the Longfin Smelt Science Program. Since then, a Lifecycle Modeling Team and a Lifecycle Advisory Team have been established. The modeling team began development on a state-space life cycle model focused on population growth rates. Life-stage specific conceptual models are being mapped out and refined in directed acyclic graphs (DAG). These DAG's can then be used to formulate models for ecological research purposes. The lifecycle model is intended to take outputs from other models, such as habitat suitability models, and use them as inputs to be adaptable to future developments. The modeling team is continuing to refine relationships between different environmental factors and population vital rates.

Additionally, in 2023, DWR executed an agreement with the US Geological Survey to produce a marine-habitat suitability index for Longfin Smelt. This dataset would allow for ocean conditions to be represented in the broader life cycle model, so their role in Longfin Smelt recruitment and population dynamics can be quantified.

Additional Considerations

Unlike many of the other elements of the Longfin Science Program, development of a life cycle model will not directly require new permits or take authorization. However, it is likely that the performance of the model will depend on the availability of high-quality input data, such as that described in a related section on Longfin Smelt monitoring needs. Some of the associated data collection activities, if necessary, may need to be approved by permitting agencies.

Another consideration is that these models will be most useful if they can be run by multiple staff within the resource agencies. While significant progress has been made in hydrodynamic and biological modeling in the San Francisco Estuary, some of these models are so complex and specialized that relatively few staff are capable of running the models. For this reason, our goal is to generate a model (or models) that will be publicly accessible and useable by a broader spectrum of scientists and staff in the region. To achieve this goal, there will have to be substantial coordination with potential users and experts during model development, and a commitment to a model structure and open documentation that is relatively user-friendly.

FACTORS THAT AFFECT LONGFIN ABUNDANCE, GROWTH, AND SURVIVAL

Introduction

Understanding the factors that affect abundance, growth and survival can be important in managing Longfin Smelt. Long term monitoring and targeted studies have provided key information on some of the important factors known to affect Longfin Smelt over time. However, there are likely other under-studied factors which influence growth, abundance, and survival and merit further exploration. Understanding these factors will not only improve management tools but will also increase our understanding of species' needs when it comes to life stage specific habitat suitability as well as increasing the accuracy and precision of predictive modeling tools. These factors represent a core component of Longfin Smelt ecology and therefore are identified as a Priority Area in the LFSSP for further research.

Key Background Information

Abundance

A number of analyses have documented the positive correlation between Longfin Smelt abundance in the fall and freshwater flows or position of X₂ in winter-spring (Stevens and Miller 1983, Jassby 1995). Kimmerer (2002) later detected a step decline in this relationship that corresponded with the establishment of the introduced clam *Potamocorbula amurensis* after 1987. Another step decline was attributed to the Pelagic Organism Decline after 2002 (Thomson et al 2010). Thomson et al. (2010) also found water clarity was an important covariate explaining Longfin Smelt abundance step changes in addition to the spring position of X₂. Mac Nally et al. (2010) included covariates of prey availability and predator abundances as well as abiotic factors from Thompson et al. (2010) and found strong support for the spring X₂ effect, but also identified a potential link between flow and prey abundance with Longfin Smelt abundance. An important prey item, *Eurytemora affinis* was found to be correlated with spring X₂ (Kimmerer 2002) suggesting the mechanism underlying the fall abundance to flow relationship may be driven, at least in part, by increased food and feeding, may promote rapid growth and survival in the early life stages. However, the effects of food may be complex as there is no simple relationship between flow and larval abundance, as measured by the 20 mm survey. An analysis by Maunder et al (2015) determined that ammonia, temperature, and Napa River Outflow were highly correlated with abundance suggesting alternative factors should be explored. Nobriga and Rosenfield (2016) tested several models that included the influence of adult stock and density dependence on Longfin Smelt population dynamics. All models indicated winter-spring flow was an important predictor of recruitment to age-0 but did not

find support for a relationship between flow and survival from age-1 to age-2. Furthermore, recruits-per-spawner had not declined over time, suggesting the food web changes from invasion of the overbite clam did not impact the flow to fall recruitment relationship, but a cyclic pattern in the residuals from this model implicated an ocean influence on recruitment. More recently, two papers have found continued support for the Longfin Smelt outflow relationship using more recent data, Taburello et al. (2019) and Kimmerer and Gross (2022).

While there remains continued evidence of a positive relationship between flow and abundance of Longfin Smelt, the specific mechanism(s) driving the relationship have yet to be identified. A number of hypothesized mechanisms have been identified to explain the flow-abundance relationship which include, (1) transport away from points of diversion to nursery habitat, (2) increased retention with flow in nursery habitat, (3) feeding in productive nursery habitats, (4) nursery habitat extent, (5) increased nursery habitat complexity that occurs in wetter years and (6) increased spawning and nursery habitat in bay-tributaries (Rosenfield and Baxter 2007, Grimaldo et al 2017, Lewis et al 2020).

Growth

Understanding the factors that affect individual growth can be important in managing Longfin Smelt. Growth during the early life-stage of fishes is a critical vital rate that can have large impacts on recruitment success. Larger fish are relatively less susceptible to stressors such as predation, thus fish exhibiting faster growth are more likely to survive the early life predation. Another key vital rate metric is size-at-maturity since larger individuals are more fecund, which in turn can improve population growth (Chigbu and Sibley 1994, CDFW 2009).

Longfin Smelt larval and small juvenile growth rates in the SFE have been assessed using apparent growth (changes in mean length over time, Baxter et al. 2005, CDFW 2009), growth rates from cultured larvae (Yanagitsuru et al. 2021), and otoliths (Dr. Levi Lewis *pers. comm*). Longfin Smelt growth in early life stages is generally slow (0.15mm/day- 0.22mm/day) and notably slower than Delta smelt (Baxter et al 2005, Gross et al. 2022).

There are several abiotic and biotic factors that may impact the growth of Longfin Smelt, which may in turn ultimately influence survival and abundance. For example, abiotic factors include temperature, salinity, turbidity, and contaminants. Biotic factors include prey type and abundance, toxic algae, and predation (Hobbs et al 2017). Greater prey densities have correlated with greater foraging success and larger larvae (Hobbs et al 2006, Barros et al.2021).

The landlocked population of Longfin Smelt in Lake Washington was found to have alternating annual variation in growth, correlated with an odd/even pattern of corresponding high and low densities suggesting growth may be density dependent (Moulton 1974). In the same study by Moulton (1974), it was determined that males were larger than females suggesting males may grow faster than females. Although the odd/even year densities correlated with growth in the

Lake Washington study, no such consistent alternating pattern has been observed in the Longfin Smelt population within the SFE, and species densities were determined to be low enough to warrant listing (CDFW 2009, USFWS 2012). Some evidence of density dependence has been found for Longfin Smelt in the SFE (MacNally et al 2010, Maunder et al 2015, Nobriga and Rosenfield 2016, Lojkovic-Burris et al. 2022) suggesting that density dependence in growth rates should be evaluated in any lifecycle model that is developed as part of the LFSSP.

Survival

Several factors are expected to affect survival of Longfin Smelt. Those factors include direct effects such as entrainment and predation as well as indirect effects such as poor food availability or suboptimal water quality habitat (Hobbs et al 2017). Understanding the population level impacts of entrainment is one of the many questions regarding survival for Longfin Smelt. Recent estimates of larval LFS losses due to entrainment range between 0.8% - 1.5% of the annual larval population (Kimmerer and Gross 2022). Additionally, Gross et al (2022) arrived at similar estimates of entrainment losses for larval Longfin Smelt (0-2%). Low prey availability may be related to low survival of juveniles to adults (Nobriga and Rosenfield 2016) and survival from year 1 age class (Rosenfield and Baxter 2007). Predation studies in the SFE documented predation by Sacramento Pikeminnow (*Ptychocheilus grandis*) and Striped bass (*Morone saxatilis*) (Grossman 2016). A study of the California Current found that Longfin Smelt were also preyed upon by birds and mammals (Szoboszlai et al 2015). Another factor that influences the probability of Longfin Smelt survival is condition, such that poor condition due to increased stress or poor nutrition can reduce survival.

General list of factors affecting Abundance, Growth, and Survival

- Hydrology (e.g., Delta outflow, inflow, water year, bay tributary outflow)
- Water quality (e.g., temperature, salinity, turbidity, contaminants)
- Prey (e.g., copepods, mysids, other zooplankton)
- Harmful Algal blooms (e.g., dinoflagellates, toxic diatoms)
- Predation (e.g., fish, birds, and mammals)
- Competition/ invasive species (e.g., marine, estuarine, and freshwater competitors and/or invasives)
- Anthropogenic effects include Entrainment (e.g., urban and agricultural siphons, CVP and SWP operations), dredging, wetland habitat loss, water depletion, and in-water construction

Primary Management Issues This Topic Will Address

Understanding the drivers of abundance, growth and survival is a critical need to understand the effects of management actions including flow and habitat restoration on Longfin Smelt in

the SFE. Hence, these metrics are all critical for effectiveness-monitoring for ITP actions, and to develop new approaches for Longfin Smelt management. A related factor is that these measurements of vital rates are essential to inform population modeling, an essential tool for the management of imperiled species. Research into factors affecting growth and survival is also critical for a successful culture program. In turn, through the process of closing the lifecycle in captivity (see culture section below), much has been learned about how environmental conditions influence growth and survival for larval and juvenile LFS (Yanagitsuru et al. 2021 & 2022, Rahman et al 2023).

Increased research in these areas can lead to new management opportunities for the species, such as the use of habitat proxies (in addition to observed distribution data) for real-time operations management. Additionally, understanding these factors can also inform and improve new and ongoing monitoring programs to ensure that important factors are incorporated into sampling design and collected over the long term.

Potential Scientific Approaches

Laboratory studies

- Tolerance studies. Some initial studies have already been conducted (see Culture Section). Additional studies can be conducted where multiple factors are evaluated at the same time (see Jeffries et al 2016 and Pasparakis et al. 2024). The information can be used to develop habitat suitability indices, predictive mapping, and improve lifecycle modeling.
- Bioassays: Acute and Chronic toxicity studies. Studies on Delta Smelt and other SFE species can be used as a reference (see Foott and Stone 2007, Hobbs et al 2010, Jeffries et al 2016, Connon et al 2019, Hasenbein et al 2019). It may be necessary to conduct toxicity testing on Longfin Smelt instead of relying on surrogate studies as there may be species specific impacts (e.g., differences in temperature tolerance).
- Nutritional studies: Nutrient optimization, ration studies. These studies can improve culturing of the species which will provide a valuable resource of test subjects for further laboratory studies. These studies when combined with tolerance studies and bioassays can improve predictions of modeling for the effects of management actions on Longfin Smelt vital rates.
- Behavioral studies: Swimming Behavior (Swanson et al 2000), Predation studies, Prey selection. Behavioral studies have been useful for evaluating the interactions of multiple stressors. The studies can inform actions like habitat restoration and fish screen design.

Field Monitoring and Investigations

- Surveys: Trawls, eDNA, telemetry, acoustics, bioassays (see Dryfoos 1965, Gold et al 2011, Connon et al 2019). These would include both ambient monitoring, which would be good for trend analyses and relative effects, and special studies monitoring, which would be short-term surveys designed to evaluate a short-term management action.
- Targeted field experiments: BACI, Cage studies, Comparative/Reference studies such as those conducted by the Tidal Wetland Monitoring group. Targeted studies would be appropriate for addressing specific questions and uncertainties of a management action. The regular surveys may not be appropriate to use therefore a targeted field experiment would be better.
- Condition and health studies: combining otolith age and growth information with somatic condition indices, diets and isotope markers can be used to further understand abiotic and biotic drivers of health, growth and survival.

Modeling

- Multivariate analysis (see Mahardja et al 2020, Kimmerer et al 2018) for initial exploration of simple relationships and hypothesis testing. Results can guide future syntheses and lifecycle model development.
- Lifecycle modeling as mandated by the ITP
 - Utilization or improve the current lifecycle model, Maunder et al (2015, see Hanson 2014) and/or develop a new model (See Lifecycle Model Section)
- Synthesis analysis:
 - Review of prior multivariate and univariate analyses to identify and prioritize gaps in knowledge to inform management of the species.
 - Risk Assessment using toxicology studies on Delta Smelt and other fish from the SFE as surrogates
- Update previous synthesis efforts using current data (see Tamburello et al 2019). This will check for any changes in relationships or further validate relationships to reduce potential for relying on spurious or outdated relationships.

Progress to Date

In 2023 a project proposal to investigate the mechanisms underlying the Longfin Smelt abundance-outflow relationship was presented to the LFSTT. Funding was jointly provided by DWR and SWCs to conduct field sampling and a paired modeling exercise to test the hypothesis that the mechanism behind the abundance-outflow relationship is transport of larvae to nursery areas or increased retention in downstream nursery areas due to gravitational circulation. Preliminary results have been presented in several venues including the Bay Delta Science Conference (2024) and the IEP Workshop (2025). Preliminary findings from the

particle tracking models showed increased retention within the upper estuary when the particles display a sinking behavior, particularly when outflow is high. The authors hypothesize that increased outflow enhances stratification and gravitational circulation as the salinity field moves seaward into the deeper waters of Carquinez Strait and increases the retention of larval and juvenile LFS within high quality nursery habitat.

Additional Considerations

As for all other elements of this study plan, there are other factors to consider when addressing what is needed to generate more information on Longfin Smelt growth, abundance, and survival for management. Survey limitations, permitting, and culture limitations may be factors. In addition, there are larger scale issues that may require being more adaptive to changing conditions such as water year, the status of restoration sites, and climate change.

Increasingly, long-term survey data is being used beyond the original purpose of the surveys. However, long term survey datasets are a wealth of information and should be utilized as appropriate (Stompe et al 2020). Biases are present in all types of monitoring and should be identified and accounted for where possible and practical (Latour 2016). Moreover, long-term surveys are often not sufficient for evaluating the effects of a specific management action or questions to inform management actions. In such cases, modification or special studies will need to be considered, which will require new permits and impose logistical limitations that will need to be addressed. If permits are not available, alternative monitoring techniques or methodologies will need to be considered, such as monitoring of fish related factors including food density, composition, and availability or using no or low take methods such as fish cameras, bioacoustics, and eDNA. In addition, there may be some significant resource limitations such as staff, equipment, and the availability of cultured fish. As has been noted by the IEP Fleet Resiliency Strategy, there are a limited number of boats and crews available for use. Alternative sources of boats and crews may need to be developed or identified from existing programs using outside staff (e.g., partner agencies, consulting biologists).

IMPROVED DISTRIBUTION MONITORING

Introduction

Longfin Smelt are sampled in many of the monitoring programs implemented within the SFE. However, these monitoring programs are often limited in their ability to match the temporal and geographic distribution of Longfin Smelt. For this reason, the development or modification of monitoring programs for Longfin Smelt have been a focus of this science plan. In this Priority Area, we describe the current suite of monitoring programs which collectively provide the long-term datasets for Longfin Smelt, their limitations, and potential approaches to filling key data gaps.

Key background information

Eight long-term fish monitoring surveys effectively capture one or more Longfin Smelt life stages annually and are listed below. An additional pilot monitoring program was initiated in 2022 to investigate the entrainment of larval fishes including LFS. Except for eggs, all Longfin Smelt life stages are collected by one or more of the current agency fish-monitoring surveys described below and in Honey et al. (2004). Longfin Smelt produce demersal, adhesive eggs, which have not been collected in the SFE and no sampling study exists to address this gap (*see section on spawning and rearing habitats*).

Current fish-centric surveys vary in their temporal and geographic coverage of targeted life stages. For each survey listed below, the sampling period and frequency are described as well as the sampling range, the target fish sizes and original intent of the sampling. The list below also includes limitations that pertain to survey's ability to comprehensively collect targeted life stages (size ranges) of Longfin Smelt. The Spring Kodiak Trawl collects some juvenile and adult Longfin Smelt, but not enough to warrant inclusion. Similarly, neither the historical CDFG Resident Fishes shoreline electrofishing survey nor the current USFWS beach seine survey sampling (Honey et al. 2004) capture sufficient numbers of Longfin Smelt to warrant inclusion in this discussion either.

1. **Smelt Larva Survey** (initiated 2009): Samples biweekly December- March, single oblique tow per station; range includes the Delta and downstream to San Pablo Bay;
 - **LFS catch life stage and size range:** Newly hatched larvae – small juveniles (5-10 mm best, up to 25 mm); preserved in formalin and processed in the lab.
 - **Original intent:** Provide density and proximity information for larval Longfin Smelt in relation to south Delta export pumps and density information within low-outflow range of larval Longfin Smelt.

- **Limitations:** Misses larvae hatching in April (rarely May) and habitat in Central San Francisco Bay and southern South San Francisco Bays, as well as in tributaries to San Pablo and San Francisco bays. Single tow per station doesn't allow for detection probability.

- 2. **20-mm Survey** (initiated 1995): Samples biweekly late March – early July, three oblique tows per station; range includes the Delta and downstream to San Pablo Bay;
 - **LFS catch life stage and size range:** Medium-sized larvae – small juveniles (10-30 mm); preserved in formalin and processed in the lab.
 - **Original intent:** Provide density and proximity information for larval and small juvenile Delta Smelt in relation to south Delta export pumps.
 - **Limitations:** Misses recruitment to gear beginning in February and misses habitat in Central and South San Francisco Bays, as well as in tributaries to San Pablo and San Francisco bays.

- 3. **Summer Towntnet Survey** (initiated 1959): Samples biweekly June-August, 1-3 oblique tows per station; range includes the Delta and downstream to eastern San Pablo Bay;
 - **LFS catch life stage and size range:** small juveniles (20-50 mm); many <25 preserved in formalin and processed in the lab; others processed in the field and released.
 - **Original intent:** Produce an abundance index for Striped Bass at 38 mm mean size for use in survival estimation.
 - **Limitations:** Misses recruitment to gear beginning in April and misses habitat in San Pablo, Central and South San Francisco Bays, as well as in tributaries in those regions, though tributary use is likely temperature limited at some point between April and June. Oblique tows are limited in the ability to sample the benthic environment.

- 4. **Fall Midwater Trawl Survey** (initiated 1967): samples monthly September—December, 1 oblique tow per station, which samples throughout the water column, but a maximum depth of about 40 ft (DFG unpublished); range includes the Delta and downstream to western San Pablo Bay;
 - **LFS catch life stage and size range:** Juveniles- small-sized adults (50-150 mm) processed in the field and released.
 - **Original intent:** Produce an abundance index for age-0 Striped Bass in fall.
 - **Limitations:** Juveniles don't fully recruit to gear until 60-70 mm (Longfin Smelt are slimmer than Delta Smelt of the same length and Delta Smelt recruit at 60 mm, Mitchell et al. 2017) and omits habitat in Central and South San Francisco Bays (tributary use is delayed until temperatures drop in late November or December). Single tow per station does not allow for detection probability, but stations are in

close proximity thus spatial binning could be conducted to assess detection. Midwater trawls do not sample benthic environments.

5. **Bay Study Survey** (initiated 1980): Samples monthly year-round, 1 tow per station each with an otter trawl (OT) which samples along the bottom, and a midwater trawl (MWT) which samples throughout the water column with a maximum depth of about 40 ft (DFG unpublished); range includes lower Sacramento and San Joaquin rivers in western Delta throughout the SFE to southern South San Francisco Bay;
 - **LFS catch life stage and size range:** Juveniles- small adult fishes (40-250 mm, varies by net) and invertebrates. Fish and crabs mostly processed in the field and released; shrimps preserved in formalin and processed in the lab.
 - **Original intent:** Provide data to monitor the distribution and abundance trends for a suite of invertebrate and fish species.
 - **Limitations:** Juveniles don't fully recruit to OT gear until about 40-50 mm and MWT-gear until 60-70 mm and covers open water habitat only. Fewer stations per embayment compared to FMWT. Single tow per station doesn't allow for detection probability estimation. Does not sample tributary marsh habitats to San Pablo Bay and South San Francisco Bay and has limited sample stations in the Central, South, and North Delta.

6. **Enhanced Delta Smelt Monitoring** (initiated 2016): Samples weekly to biweekly year-round, with up to 2 surface larval-net tows or 4 surface Kodiak trawl tows per randomly selected sampling location (high catches of Delta Smelt will reduce tow number); range sampled includes the Delta and downstream through the eastern half of San Pablo Bay.
 - **LFS catch life stage and size range:** 20-mm trawl (larval net) used April – June to target medium-sized Delta Smelt larvae – small juveniles (10-30 mm) preserved in the field and processed in the lab, and a Kodiak Trawl used July- March to target Delta Smelt juveniles-adults (40-150 mm) processed in the field and released;
 - **Original intent:** Sample in a probabilistic fashion to estimate absolute abundance of Delta Smelt late-stage larvae in spring and older life stages through remaining seasons.
 - **Limitations:** 20-mm sampling is limited to only 3 months in spring, sampling distribution doesn't cover recruitment region in wet years; Kodiak Trawl samples the top surface (~3.5 m) and Longfin Smelt juveniles and adults while are more common at mid-depths and toward the bottom, and the sampling effort does not cover Longfin Smelt habitat south of the San Joaquin River in the Delta, western San Pablo, South or Central San Francisco bays or their tributaries. Has been in operation only a few years. Gear types used are limited or unable to sample the benthic environment.

7. **Chippis Island Trawl** (initiated 1976): samples 3-7 days per week, year-round, using a MWT fished near the surface to conduct ten 20-min tows per sampling day; range sampled – three trawl lanes (north, middle and south) in channel adjacent to Chippis Island only.
 - **LFS catch life stage and size range:** Juveniles – small adult fishes (40-150 mm) most processed in the field and released; tagged fish processed in the lab;
 - **Original intent:** Estimate percent passage or survival of emigrating juvenile Chinook Salmon and Steelhead.
 - **Limitations:** Samples only a single location, gear samples near surface only and likely misses some benthic oriented individuals, fraction of the population reaching and passing Chippis Island between late fall and late spring likely varies with outflow: maximum passage likely occurs when X_2 is > 81 and drops as X_2 moves downstream. Nonetheless, sampling during the winter-spring spawning period appears sufficient to detect the presence of Longfin Smelt migrating into the Delta, a precursor to entrainment in the south Delta export pumps. Gear types used are limited or unable to sample the benthic environment.

8. **Suisun Marsh Survey** (initiated 1980): Samples monthly year-round, using a single OT tow at each sampling location within sloughs in Suisun Marsh;
 - **LFS catch life stage and size range:** Juvenile and small adult fish and invertebrates (25-250 mm) processed in the field and released.
 - **Original intent:** Track trends in distribution and abundance of invertebrate and fish communities in Suisun Marsh.
 - **Limitations:** Samples fish and inverts only within Suisun Marsh. Single tow per station doesn't allow for detection probability.

Limitation of all surveys: None of the listed surveys sample the local coastal waters believed to provide habitat July -September for Longfin Smelt in their second year of life (Rosenfield and Baxter 2007), if not longer (CDFG 2009). This information gap is therefore a substantial limitation in our understanding and management of Longfin Smelt. A second limitation is that uncertainty exists on the ability of the current suite of monitoring programs to detect changes in distribution as environmental conditions change, such as outflow. That is, the effect size and statistical power of the current sampling regime have yet to be quantitatively evaluated.

Primary Management Issues This Topic Will Address

Understanding the distributions of Longfin Smelt at various life stages is key to understanding the habitat needs and movements of the species, their response to key environmental factors

such as flows, and the species' vulnerability to entrainment under different conditions. Specifically, effectively sampling the entire distribution of each key life stage will improve the ability to calculate abundance indices, potentially estimating population size, and the populations center of distribution (e.g., abundance, survival, etc.) and improve the accuracy of these metrics (e.g., a shift in distribution to outside the sampling frame will reduce accuracy of abundance calculations). Moreover, effective and geographically comprehensive sampling during the larval and early juvenile stages is important to successful investigation of the mechanisms underlying the Longfin Smelt outflow-abundance relationship. Similarly, knowledge of where important Longfin Smelt habitat exists through different life stages and through varied environmental conditions (e.g., outflow, temperature) will be necessary to plan and execute effective habitat restoration.

Understanding the impact of loss to the population from entrainment into the south Delta and CVP/SWP facilities and other diversions is important for establishing management strategies to minimize entrainment. Current annual larva sampling within the Delta, Suisun Bay, and San Pablo Bay by the SLS provides information on hatch timing, proximity of larvae to the export pumps, the magnitude of flow through the lower San Joaquin River needed to help guide locally hatched larvae beyond the range of entrainment, and potentially the fraction of the larval population vulnerable to entrainment. Production of young-of-year-fish from areas not effectively sampled by long-term monitoring (e.g., SF Bay and tributaries) is therefore important for understanding the proportion of young life-stages vulnerable to entrainment.

Effective sampling of all Longfin Smelt life stages can provide the data needed to populate a life cycle model (see *Life Cycle Modeling* section). As noted previously, life cycle models are essential tools for the management of special status fishes in the Bay-Delta.

Potential Scientific Approaches

As noted previously, several of the existing surveys do not have sufficient geographic or temporal scale to cover the range of Longfin Smelt. This is particularly true for the SLS and 20-mm Survey, which could still be expanded in time and geography to cover the periods larvae recruit to the gears and the range of these larvae through small juveniles. The same may also apply for the Summer Towntnet Survey, but that program is less useful for entrainment management given its timing. It is conducted at a time of year when south Delta temperatures typically exceed maximum tolerance for juvenile Longfin Smelt (June or July).

Additional sampling considerations and decisions to be made include:

- Consideration of whether and how to sample smaller tributaries (Sonoma Creek, Petaluma River, Coyote Creek/Alviso Slough). The number of larvae originating from these tributaries are limited by the small geographical area of these habitats, but

surviving larvae may provide disproportionately important contributions to subsequent life stages.

- Consideration of the need to expand the spatial sampling of early life stages equally across the SFE in all years. The bay tributary sampling conducted during the Longfin Smelt Settlement Agreement found very few larvae in bay tributaries in dry years, while in wet years, most larvae were found in San Pablo Bay and downstream.
- Consideration of whether expanded sampling should continue to use fixed sampling locations, employ an assumption of random sampling and design-based estimation (e.g., Newman 2008), or attempt to randomize sample site selection.
- Determine whether individual surveys should include replication of tows at each sampling location.
- Evaluate the value of adding zooplankton sampling to expanded survey sampling and to surveys that do not currently collect zooplankton.
- Assess whether current SF Bay Study sampling effort per embayment should be increased.
- Assess whether local coastal distribution should be monitored at some frequency annually or investigated at some frequency annually for several years -- to estimate the proportion of the population that uses this habitat and during what seasons – and then stop, either permanently or for some period of time prior to repeating the process to see if use has changed.
- Develop a study plan to investigate size of complete gear retention for Longfin Smelt; some data for retention exists for SLS and 20-mm Survey.
- Develop a study plan to investigate the depth distribution of Longfin Smelt and the factors that affect what strata of the water column is used.
- Evaluate the use of genetic monitoring techniques to be incorporated into existing or expanded surveys to understand distribution and potentially population size. These techniques could include environmental DNA (eDNA) or using genotypes of the adult population and offspring as a way to estimate abundance (close kin mark recapture approach, as in Bravington et al. 2016 and Prystupa et al. 2021)

Progress to Date

To address limitations in larval and juvenile LFS monitoring, SLS and 20-mm expanded their geographic sampling coverage into Carquinez Strait and parts of San Pablo Bay in 2023 with similar levels of effort used in other regions of the Delta. The expanded geographic sampling allows for a more complete assessment of the larval and juvenile LFS distribution within the upper estuary under high flow conditions. In 2020, SLS was expanded temporally to include two surveys in December. Larval LFS have been detected in all surveys performed in December

since 2020, albeit in small numbers, suggesting that spawning can regularly occur as early November.

CDFW has developed methods for defining the sampling frame and volumes across different CDFW monitoring programs. The defined sampling strata allow for an estimation of water volume and ultimately a calculation of absolute abundance for each region with associated confidence intervals (Slater et al. 2023). Using these standardized sampling frames, it is now possible to compare the estimated abundances of species across multiple CDFW monitoring programs (Polansky et al. 2019).

In 2022, CDFW and DWR initiated a Larval Entrainment Monitoring Study (LES) to fulfill Condition of Approval 7.6.2 of the 2020 ITP. The new monitoring study had three main objectives to help inform water management decisions; develop a quantitative estimate of larval smelt entrainment, enhance our understanding of how environmental factors and physical conditions lead to large larval entrainment events, and increase the ability, in real time, to identify the magnitude and duration of Delta Smelt and Longfin Smelt larval entrainment events. LES has completed 4 field seasons (2022-2025) and results are in review as of August 2024. In 2022-2023 LES sampled within West Canal, outside of Clifton Court Forebay during which they detected more LFS in 2022 (a dry year) and detected fewer LFS in 2023 (a wet year). LES experienced several challenges to sampling in West Canal including large accumulations of floating and submerged vegetations, obstructions and snags that fouled sampling equipment, and inability to consistently access the sampling locations due to high channel flows. In 2024-2025 the LES adjusted sampling to concentrate effort in the Lower San Joaquin River, upriver of the Confluence with the Sacramento River. During these years, samples were also taken as a transect along the Old and Middle River Corridor. This adjustment in geographic focus was intended to provide better estimates of detection probability and improved understanding of spatial variability among sample locations. In addition to regular sampling, special studies were conducted to examine catch efficiency across different net types and net mesh sizes, temporal variability (night vs day), and water column distribution (surface vs bottom presence). Finally, in 2025 LES samples were collected in parallel with eDNA collections, by DWR, for additional comparison on detectability. Preliminary results of regular sampling and special studies have been presented at the IEP workshop (2023-2025), the Bay Delta Science Conference (2024) and published within the IEP Newsletter.

Additional Considerations

Logistics

Further expansions in sampling as described above will require additional resources including boat(s), personnel, and sampling gear to account for added locations. Expansion of sampling into new regions will also add several days of field work to each sample period and additional sample intervals will need to be added for many surveys. Continued expansion of SLS and 20-mm Survey will require additional laboratory staff and space (Stockton CDFW lab space will be surpassed), or an alternate sample processing pipeline (e.g., using genetic tools) to process samples in a timely manner.

In contrast to expanding the sampling, survey evaluation with the idea of reducing redundancy could be considered. Several of the surveys overlap temporally and spatially and reducing redundancy can provide additional flexibility in resources to address other needs such as reducing detection bias or expanding to under-sampled regions or life-stages. This of course would require a broad evaluation to make sure that any increase in efficiency does not sacrifice components of a monitoring enterprise that are vital for management needs for other species of management concern.

Adding other factors like additional zooplankton sampling or water quality measurements like contaminants will come with additional resource needs regarding additional materials, storage capacity, and staff. For example, lab space limitations will be exacerbated if zooplankton sampling is added to expanded surveys. Current vessel resources are sufficient for existing sampling but will likely need to be expanded to take on additional sampling (i.e., added sampling will put more hours on vessels and require more maintenance/repair and more back up vessels).

Permits and Approvals

Any addition to survey sampling panels will require assessment of potential for take of species listed under the ESA or CESA, and time for new take permitting. Moreover, substantial expansion of existing surveys may require review and approval by IEP, which has an annual approval cycle with specific deadlines.

LONGFIN SMELT CULTURE

Introduction

The effort to establish Longfin Smelt in culture started in early 2010 and has been steadily progressing since, with the lifecycle being completed in captivity for the first time in the spring of 2023 (Hung et al., 2024). The importance of establishing a managed, captive population of Longfin Smelt is twofold: 1) to buffer against extinction and 2) to increase the availability of fish for research. Due to the importance of this captive propagation program, CDFW identified the establishment of a Longfin Smelt refugial population as a mitigation requirement in DWR's 2024 ITP (section 9.1.5). To begin the process of meeting this mitigation requirement, DWR partnered with UC Davis in 2024 to establish the Longfin Smelt Conservation and Culture Program (LFSCCP).

As the Longfin Smelt culture activities are now an ITP mitigation item, they are no longer explicitly identified as part of the Longfin Smelt Science Program. However, in recognition of the importance of continued close coordination between the LFSCCP and the Longfin Smelt Science Program, Longfin Smelt Culture will remain a priority item in the Longfin Smelt Science Plan. The Longfin Smelt Technical Team will provide input and guidance for the LFSCCP as needed and receive regular updates on the status of the captive population. Examples of this input and guidance could include:

- Assistance with coordinating wild broodstock collection from long-term monitoring programs.
- Input on laboratory experiments to improve the culture process, especially as it pertains to experiments that would also fill knowledge gaps relevant to improving the LFS lifecycle model.
- Other input and assistance to the LFSCCP as needed to assist in meeting program goals.

Key Background Information

LFSCCP Program Goals and Progress to Date

In June 2024, the LFSCCP completed the first draft of the Longfin Smelt Culture Manual (Bell et al. 2024), critical documentation of the culture program's progress to date and for highlighting the program's goals through 2028. These goals include:

- 1) Continue to evaluate and improve wild broodstock collection, including equipment and protocols, to ensure long-term success and maximize survival and production per spawner.
- 2) Develop flow-through and recirculating systems for adult fish at the Bodega Marine Laboratory (BML) and maintain facilities for rearing all life stages (embryos, larvae, juvenile, and adults) at the Putah Creek Facility (PCF) on the UC Davis campus.
- 3) Evaluate and improve specific feed, salinity ranges, turbidities, and temperatures required throughout the life cycle of Longfin Smelt and develop methods to reliably bring lab-raised fish into spawning condition.
- 4) Consistently close the life cycle in captivity, with a goal to produce at least 500-1000 genetically managed broodstock fish per year.
- 5) Develop tools and methods for the incorporation of a formal genetic management plan (GMP) into the program.
- 6) Establish a refugial population for Longfin Smelt, informed by a GMP, that reasonably captures the wild genetic diversity of the SFE and can serve as a backup to the wild population.
- 7) Maintain all relevant Federal and State permits to operate the program and comply with all permitting rules and regulations.
- 8) Develop a strategy for the production of fish for research and establish a fish request mechanism to make this resource available to other researchers.
- 9) Evaluate program components to enable future potential increases in production.
- 10) Develop staffing for long-term programmatic support.

Primary Management Issues This Area Will Address

As noted previously, Longfin Smelt are listed as threatened under CESA and endangered under ESA, and there is a management need for a refuge population to allow for the possibility of supplementing the wild population to prevent extinction, as well as supplying fish for research to reduce the need for collecting individuals from the wild. Unlike Delta Smelt and salmonids, the San Francisco Bay-Delta Distinct Population Segment (DPS) of Longfin Smelt lack a captive refugial population to buffer against further population declines as a result of the stressors that the species continues to face. In addition to potential future supplementation, successfully culturing Longfin Smelt will provide a more thorough understanding of the species' life history, thereby improving its management. Significant progress has recently

been made on understanding the species embryonic and larval needs by exploring salinity (Yanagitsuru et al., 2022; Rahman et al., 2023) and temperature (Yanagitsuru et al., 2021; 2024) requirements. Cultured fish could also provide further information on reproduction, growth, feed preferences (Mulvaney et al., 2022), and response to stressors such as suboptimal water quality. This type of information is a critical need for the development of life cycle models and to identify habitat requirements that could be addressed through management actions (e.g., flow, restoration, etc.)

Longfin Smelt captive propagation will also allow for further field and lab studies to support management. One of the bottlenecks in evaluating the effects of management actions on Longfin Smelt is that their numbers are low and take authorization could limit the implementation of additional field sampling. Cultured fish therefore allow us to use laboratory and field approaches (e.g., enclosures) to understand how the species' physiology, ecology, and genetics respond to different environmental variables and management actions.

Potential Scientific Approaches

With the recent progress on culturing Longfin Smelt, research should be focused on improving the efficiency and scalability of culture practices throughout its entire lifecycle. Further investigating the salinity and temperature requirements for all life stages of Longfin Smelt will continue to be important, especially as the role of rearing in full strength sea water becomes more integral to the program's culture practices (Bell et al. 2024). Similarly, research to improve the efficiency of transitioning fish from live feed to commercial feed is underway (Mulvaney et al., 2022) and will continue to enable the program to improve the survival and scalability of rearing early life stages. As both Longfin and Delta Smelt are known to prefer more turbid environments (Mahardja et al. 2017, Moyle et al. 2016), more research is needed to understand the effects of turbidity on Longfin Smelt, including the effects of turbidity on growth, survival, feeding, and predation.

Genetic tools are currently under development for assessing relatedness among potential broodstock when making spawning crosses (S. Kieran, pers. comm.). As the LFSCCP progresses towards establishing a formal refugial population of Longfin Smelt, these tools will be critical for ensuring related individuals are not spawned, as well as for tracking domestication in the captive population.

In summary, continuing to improve the processes around reliably culturing Longfin Smelt in captivity will require intense focus on the favorable conditions for the species at every life stage to maintain survivorship. Many of these parameters have been identified at the FCCL for Delta Smelt, another Osmerid native to the SFE (Maunder and Deriso 2011, Moyle 2002, Moyle et. al 2016). Given that Longfin Smelt are anadromous, with a lifecycle of up to 3 years (Merz

et al. 2013, Moyle 2002, Rosenfield and Baxter 2007), a more adaptive scientific approach will be used to discover the requirements at every life stage.

Additional Considerations

Longfin Smelt have a complex life history, inhabiting a wide range of conditions throughout their life cycle. Therefore, a successful captive propagation program requires experienced personnel and a broad range of equipment and facilities capable of obtaining and discharging fresh, brackish, and saltwater. The creation of rearing facilities at Bodega Marine Laboratory provides access to full strength seawater for certain life stages. The rearing environment may cause artificial selection and altered migratory behavior if ever released into the wild for supplementation, as has been observed for hatchery-reared salmonids (Brenner et al. 2012, Jonsson et al. 1991, Knudsen et al. 2006, Pascual and Quinn 1994). As excessive discharge of saline water is not permitted at the Putah Creek Facility, recirculation systems have been installed at those rearing facilities to accommodate a wide range of tank salinities.

Since Longfin Smelt are listed as threatened under CESA and endangered under FESA, appropriate permits are required whenever collecting wild broodstock. Culturing will require ample adult numbers, so it will likely be necessary to attain adults from sources in addition to the existing collections from Chipps Island Trawl and South Bay. To facilitate this, the culture program is investing in a new vessel, as well as expanding relationships with long-term monitoring programs that regularly collect Longfin Smelt adults. As Longfin Smelt catch numbers from field surveys have substantially decreased over time, balancing sufficient collection numbers while preventing over-harvesting of the fish will be a challenge to assess and manage.

Longfin Smelt in the SFE range across a wide area, and with the culture program having its primary rearing facilities at Putah Creek in Davis, CA, and secondary rearing facilities at Bodega Marine Laboratory and the FCCL, the need for transporting Longfin Smelt across long distances at multiple life stages is a critical component of the culture program. The development of reliable, efficient, and flexible transportation methods will therefore be of continuing importance and will also pay dividends in the event that supplementation of the wild population is considered.

The LFSCCP is not intended to directly support a full supplementation program, which would open up a substantial range of other issues. For example, supplementation programs for anadromous fish species have resulted in reduced genetic adaptation due to founder effects, domestication selection, inbreeding depression, and overall decreased long-term fitness on wild populations (Araki and Schmid 2010, Attard et al. 2016, Christie et al. 2016, Janowitz-Koch et al. 2019, Waples 1991). Even if the proposed effort remains focused on the maintenance of a

refugial population and producing fish for research, effective genetic management of the captive population will be a critical component of the program.

The genetic makeup of Longfin Smelt in the SFE has recently been analyzed (Saglam et al., submitted), and genetic tools for managing a Longfin Smelt refugial population are currently in development. Better understanding Longfin Smelt population genetics will assist in managing both the captive and wild populations. For example, the geochemical and genetic makeup of Longfin Smelt from multiple regions (e.g., South Bay, Suisun Bay, etc.) should be analyzed for distinction and continuity. Field surveys and geochemical analysis of Longfin Smelt otoliths suggest that the SFE population may be expressing multiple life history strategies (Lewis et al. 2020), and it remains unclear if crossing adults from various regions with different life histories would result in genetic drift or reduced long-term fitness. Sufficient funding and personnel for comprehensive genetic and geochemical analysis will be necessary to compare captive reared Longfin Smelt to wild broodstock and conserve the SFE population gene pool in a captive refugial population.

FISH MIGRATION AND MOVEMENTS

Introduction

Longfin Smelt are a small fish species within the SFE that are assumed to move considerable distances for spawning and rearing, however research into the species' migration behavior has been limited, see Rosenfield and Baxter (2007). By enhancing our understanding of movement and migration strategies for Longfin Smelt, we can improve our understanding of entrainment risk and develop new tools for managing the species. Because of this, migration behavior was identified as an important science priority for Longfin Smelt within the LFSSP. In this Priority Area, we hope to research a broad category of topics, such as larval swimming behavior and egg drift, in addition to the priorities identified in the ITP.

Key Background Information

Longfin Smelt are known to be anadromous and therefore have at least two major population scale movements within the SFE each year; upstream migration of maturing adults from more saline habitat to low salinity and freshwater habitats for spawning, and downstream emigration of juveniles for rearing (Rosenfield and Baxter 2007). However, it is unclear how Longfin are able to navigate through the SFE, where they contend with tidal forces and changes in salinity during migrations which can span from the ocean to fresh water reaches of the Sacramento and San Joaquin rivers. Observations from Lake Washington, where distinct migration behaviors have been documented (Brocksmith and Sibley 1995, Dryfoos 1965, Martz et al. 1996, Moulton 1974), provide some insight into migration behaviors used by Longfin within the SFE.

In the absence of SFE specific information, and knowing that all ages of Longfin Smelt are absent from the Delta and south San Francisco Bay from mid-summer to late fall (Baxter 1999, CDFG 2009), the effects analysis for the ITP developed a conceptual model to provide insight into how adult Longfin Smelt may interact with water exports when spawning (Eakin et al. 2020). This conceptual model had two prevailing assumptions regarding migration behavior. First, it was assumed that Longfin move rapidly upstream once detected in the Chipps Island Trawl. This assumption is based on observations from Lake Washington, where both active spawning and the movement of ripe and spent fish were only observed from the late evening through early morning (Martz et al. 1996, Moulton 1974). These observations also lead to the second assumption for migration behavior in this conceptual model, in that spawning occurs relatively soon after upstream migration. This is in contrast to Delta Smelt (*Hypomesus transpacificus*), which often migrate upstream and "hold" for some time before they spawn

(Sommer et al. 2011).

The ability of adult Longfin Smelt to move upstream against substantial flow is another area of uncertainty. In the Delta, tidal surfing is a strategy that Delta Smelt use to work their way upstream by using the power of the flood tide to “surf” their way to spawning grounds (Bennet and Burau 2014). It is not known if Longfin use a similar strategy, as they were observed in Kodiak surface tows on the flood and ebb tides but, unlike Delta Smelt, were absent from shoreline sampling. More recent investigations in Suisun Bay found that juvenile and adult LFS typically have a benthic distribution independent of tide (Young et al. 2024). In Lake Washington, adult Longfin Smelt were observed in the low velocity habitat along channel margins while continuously moving upstream (Martz et al. 1996, Moulton 1974). Martz et al. (1996) also observed fish actively swimming upstream throughout the channel in Cedar River, where flows averaged 400 cfs in the winter, suggesting that Longfin can swim against higher velocity waters to an extent. This may be an important component of swimming strategies in the smaller bay tributaries, where flows are relatively low compared to the Delta.

Swimming behaviors of larval Longfin are another topic of interest within the SFE. Two-dimensional particle tracking models, such as the Delta Simulation Model 2 (DSM2), have been used to analyze how hydrodynamics influence larval Longfin distribution (CDFG 2009, Gross et al. 2022, CDFW 2024). However, the ability of these models to accurately represent larval fish movements is somewhat dependent on how the particles are expected to behave. For example, in the absence of known information, particles are often treated as “neutrally buoyant” and will behave more passively in the water column than particles with swimming behaviors. This results in more downstream dispersal than we observe in the monitoring data (Gross et al. 2022, Kimmer and Gross 2022), suggesting that larval LFS have behavioral mechanisms that result in retention within the Delta.

Fortunately, there is some information regarding larval Longfin swimming behaviors within the SFE. First, Longfin are able to implement vertical migration strategies after developing an air bladder (~10-12 mm) (Bennet et al. 2002). This strategy may explain findings from Baxter (1999) and Dege and Brown (2004) where distribution of larvae was influenced by Delta outflows. In culture, larval Longfin, like other fish species of the Delta, appear to be attracted to light sources (Yanagitsuru pers. comm.) indicating some ability to move around in the water column after hatching. This is further supported by Brocksmith and Sibley (1995) where larvae were hatched in a lab setting and immediately swam to the surface before dying several days later. Additionally, Quinn et al. (2012) documented strong diel vertical migrations in both the spring and fall seasons for Longfin Smelt in Lake Washington, indicating that larval Longfin Smelt within the SFE may also reposition themselves in the water column based on time of day.

Lastly, the role of egg drift in the downstream dispersion of pre-hatch fish is unknown. Eggs are an under-sampled part of the Longfin life history within the SFE (see monitoring section) and thus it is unknown if egg drift occurs. In Lake Washington, egg collection by passive drift nets accounted for approximately 8% of eggs sampled in the Cedar River (Martz et al. 1996). This same study also documented the highest catch of “eyed up” eggs at the mouth of the Cedar River in May, following peak storm events in April. This anecdotal information suggests that it is possible some larvae are hatching in locations that are different from where their eggs are deposited.

Primary Management Issues That This Area Will Address

Effective management of an imperiled species is improved each time important knowledge gaps are filled. Understanding Longfin Smelt migration and movement strategies presents an opportunity to develop more focused and effective management strategies for the species at multiple life-history stages. For example, information on this topic can lead to the development of:

- *Improved real-time monitoring:* By understanding movement behaviors, more effective and targeted monitoring can be developed to inform water operations of fish movements or hatching in the southern Delta.
- *Effective entrainment triggers:* By increasing our knowledge of migration and movement behaviors, managers can develop more reliable and effective triggers for export reductions based on real-time information.
- *Improvements to modeling tools:* Models are used as tools for managing at-risk species and can be improved by incorporating fish movements. Examples of such models include particle tracking and life-cycle models.

In addition to effective entrainment management, this topic can also provide important insight into the ecology of Longfin Smelt and its relationship to other habitat conditions including temperature and flows. By developing a better understanding of transport mechanisms for young larvae and eggs, managers may be able to develop new ways of minimizing and mitigating losses to the water export facilities through manipulation of hydrologic processes.

Potential Scientific Approaches

There are multiple approaches that could be used to increase our understanding of Longfin Smelt migration and movement behaviors, below are a list of some of the more applicable approaches to filling this data gap.

- *Targeted field studies:* If Longfin Smelt are moving at night, and staying near shore, then daytime, mid-channel trawling techniques are likely missing fish. Targeted studies likely using specialized gear could therefore help to better understand adult movements.
- *Otolith studies:* Otoliths are an important tool that can be used to understand some of the general migration strategies with respect to age, geography, and salinity (Hobbs et al. 2010).
- *Laboratory studies:* Because the establishment of Longfin Smelt in culture is still in development, the opportunity to study these behaviors in a lab setting has only recently become available. These efforts can be useful for understanding behaviors of several life stages.
- *Telemetry methods for adults:* Telemetry technology has been improving over time and may be at a point where its applicable for use on Longfin Smelt adults. This approach can provide greater resolution in movement patterns up and down the SFE by older fish and perhaps hatchery surrogates, once available via improved culture methods.
- *Modeling studies:* Use of 3D particle tracking models to test different swimming behaviors for young fish, and comparisons with observed fish distributions.

Progress to date

Cultured LFS have been used in foundational research needed to advance the potential of using acoustic telemetry to study the movements and migration of adult LFS. Initial research projects have focused on tag retention and survival post implantation of dummy acoustic tags. Next steps will include refinement of surgical procedures to increase survival, rates of tag shedding, effect of post-tagging transportation, and studies on sublethal impacts of tagging (i.e., swimming ability), as well as comparisons of surgical implantation response differences between wild-caught and cultured Longfin Smelt (S. Gonzales, pers comm).

Additional Considerations

Many of the methods described above would require permitting for collection and sampling of wild fish. The number of permits required may depend on the location of sampling. If sampling

were to occur in the Delta, then permits for take would be needed under both ESA and CESA due to geographic overlap with Delta smelt and other federally listed fish species.

Laboratory studies are currently limited because Longfin Smelt culture is in early stages of development and wild broodstock is limited. However, it is expected that Longfin Smelt culture practices will continue to improve over time and minimize this limitation in the future.

SPAWNING AND REARING HABITATS FOR LONGFIN SMELT

Introduction

Like Delta Smelt, spawning and rearing habitats for Longfin Smelt remain poorly understood. Identification of these core habitats will improve habitat restoration actions aimed at benefiting the species. Characterizing and mapping spawning and rearing habitat throughout the Delta are also important for understanding potential impacts as a result of operations of the SWP.

Key Background Information

Longfin Smelt have been described as semelparous, spawning primarily during the second year of life from November through June with most spawning occurring from Late December through February (CDFW 2024). However, a small proportion of young-of-year Longfin Smelt have been observed to reach maturity in their first year (CDFW 2024). Longfin Smelt have generally been thought to spawn in the tidal reaches of the upper SFE (CDFG 2009, Moyle 2002, Wang 1986), though more recent studies have observed spawning in tributaries of San Francisco Bay (Grimaldo et al 2017, Lewis et al 2020). The precise locations and substrates used in the SFE have not been identified. Recent investigations have found that fertilization success is higher in freshwater (0.4ppt) when compared to low salinity waters (5ppt), suggesting that successful spawning is limited to areas where there is enough freshwater inflow to provide a suitable salinity gradient (Rahman et al. 2013)

Longfin Smelt spawn negatively buoyant (demersal), adhesive eggs that are about 1-mm in diameter (Dryfoos 1965, Chigbu and Sibley 1994, Wang 2007), similar to other stream spawning members of family Osmeridae (Hay and McCarter 2000, Martin 2015). While eggs have not been observed in the SFE, observations of yolk-sac staged larvae suggest spawning habitat extends from the tidal reaches of the Sacramento and San Joaquin Rivers to Suisun Bay and Suisun Marsh (Grimaldo et al. 2017, CDFW 2009, Meng and Matern 2001, Wang 1986). However, adult and larval Longfin Smelt have also been found in the Napa-Sonoma Marsh, Petaluma River and the Alviso Marsh in Lower South San Francisco Bay as well as in shallow water habitat in Suisun Bay and San Pablo Bay, indicating the spawning habitats of this species may be distributed over a much broader geographic range than previously known (Grimaldo et al. 2017, Lewis et al. 2019).

The Cedar River is the largest tributary entering Lake Washington (45 mi in length) with average discharge of 659 cubic-feet-per-second (cfs) and peak-flows up to 10,000-cfs. The stretch of river where Longfin Smelt were found to spawn consisted of a mixture of large

gravel and cobbles to smaller gravel and sands near the mouth. Longfin Smelt eggs have been collected from the river mouth to 1.2-km upstream, with the majority of eggs found from the mouth to approximately 300m upstream (Harza Co. 1994, Brocksmitth and Sibley 1995, Martz 1996). Eggs were deposited from the river margin to 3.3-m depth with relatively low velocities from 0.7 – 2.7 fps. Most eggs were found on sand-gravel substrates ranging from 0.063 to 32mm in diameter. Martz et al. (1996) combined the data from these studies and found negative correlations between grain size, water velocity and distance from the river mouth with egg abundance. Artificial stream spawning experiments were also conducted in a lab setting and the authors concluded that Longfin Smelt preferred spawning on sand substrates (Martz et al. 1996 Brocksmitth and Sibley 1995). The sand grains function to weigh-down the embryos, keeping them on the bottom of the riverbed. However, the embryos are subject to drift if flows are high. In the Cedar River, Martz et al. (1996) collected eggs using drift nets suggesting that some proportion are dislodged by movement of bottom material with high flows.

Longfin Smelt use habitat differently by life stage; larvae have generally been found from the tributaries of San Francisco Bay to the South Delta near the CVP and SWP and the Cache Slough Complex in the North Delta (Merz et al. 2013, Baxter 1999, Lewis et al. 2019). Larvae can be found from very shallow waters in tidal marsh (Grimaldo et al. 2017, Meng and Matern 2001) to near-bottom of deep channels (Bennett et al. 2002). While larvae can be found over a wide geographic distribution (Merz et al. 2013) their rearing habitat has been identified to include shallow low salinity marsh habitat (Grimaldo et al 2017). Hieb and Baxter (1993) and Baxter (1999) showed that downstream dispersal of larvae appeared to be a function of outflow during the larval period extending from Suisun Bay into San Pablo and central San Francisco bays during high outflow years. Dege and Brown (2004) analyzed 20-mm Survey data and found the geographic center of distribution of small larvae (< 20 mm FL) was located at or just upstream of X2 during low and below average outflow conditions. They also show that the center of distribution tended to start above and end downstream of X2 through the sampling season in high outflow years.

Suitable rearing habitat is also largely governed by the distribution of low-salinity habitat. Grimaldo et al. (2017) used a Generalized Additive Model to describe larval Longfin Smelt distribution with respect to salinity, Secchi depth, temperature, and depth. Temperature and year were the strongest driver of larval Longfin Smelt explaining 57.5% of the deviance. Salinity was also found to be significant driver at 18.7% of the deviance. Larval densities were found to peak between 3 and 4-psu with an upper threshold of 18-psu for occurrence. Larval densities were negatively related to Secchi depth, peaking at 50-cm and when temperatures were between 8 and 12 °C. Using a similar analytical technique Lewis et al. (2019, Fig 18 for post-larvae to juveniles up to 32-mm FL) found a similar relationship between larva to juvenile life stages (up to 32-mm FL) and salinity and Secchi depths. Although fish were found in higher temperature (12-17 °C) this was likely due to later sampling and older fish occurring when

seasonal temperatures were warmer. Using otolith chemistry, Hobbs et al. (2010) examined the natal portion of adult otoliths and found that fish hatched into habitats ranging from freshwater to salinity >4-6-PSU, however, the majority hatched into habitats with salinities from 1 to 3-PSU. Rahman et al. (2023) found similar hatching and rearing success for larvae in 0.4ppt and 5.0 ppt conditions in culture, but egg fertilization success was significantly higher in 0.4 ppt compared to 5.0 ppt suggesting that freshwater may play an important role in egg fertilization.

Primary Management Issues That This Area Will Address

Understanding spawning and rearing habitats is critical for the design and maintenance of habitat restoration projects and could be used to inform entrainment risk assessments. Moreover, this information is important to help understand the effects of local habitat alterations such as pesticide inputs, dredging, water diversions, and aquatic weeds. Unless we have a good understanding of the specific habitats that Longfin Smelt occupy, it is difficult to identify protective measures. Good information on spawning habitats can also help inform overall management of the species, relative to other management issues (e.g., flow, food web, predators). Towards this goal, spawning and rearing habitat information would inform the development of life cycle and hydrodynamic models that could be used as a tool to evaluate the effects of spawning habitat restoration versus other potential management actions.

Potential Scientific Approaches

There are multiple approaches that could be used to increase our understanding of Longfin Smelt spawning behavior and habitat choice. Here we list approaches for filling this data gap, however this list is not intended to encompass all possible approaches.

Approaches to improve understanding of Longfin Smelt adult migration and spawning behavior:

- Targeted field studies to identify spawning habitat (see *Fish Migrations and Movements*). Longfin Smelt spawn on river, bay, slough bottoms most likely at night requiring target field studies refined to document spawning locations and substrates. Histopathology of gonad and biomarkers to determine spawn timing and refractory period.

Approaches to characterize Longfin Smelt spawning substrate:

- Conduct laboratory-based spawning substrate preference studies.
- Develop methods to detect and quantify eggs (egg drift nets, sieves to find buried eggs.)
- Deploy mats or other artificial substrates in areas likely to have spawning, for example sandy beaches from Rio Vista to the confluence, Lower San Joaquin to Antioch, Roe-Ryer Island sloughs, and other small sloughs around Suisun Bay. Depth variation should also be considered as some evidence suggests hatching can occur in deep water as well.

Mapping of sandy habitat can improve our understanding of potential spawning areas.

Characterize Longfin Smelt rearing habitats

- *Synthesis of historical data:* Analysis of historical sampling data may provide insights into general habitat associations for young fish (e.g., Grimaldo et al. 2017).
- *Targeted field studies:* Focused field studies in potential rearing habitats could help to identify characteristics and locations of the most suitable rearing areas.
- *Otolith studies:* Otoliths are an important tool that can be used to understand some of the general rearing strategies with respect to age, geography and salinity (Hobbs et al. 2010).
- *Laboratory studies:* Because the establishment of Longfin Smelt in culture is still in development, the opportunity to study these behaviors in a lab setting has only recently become available. These efforts can be useful for understanding rearing behavior and preferences.

Progress to Date

No studies on spawning or rearing habitat for LFS have been conducted as part of the LFSSP as of the 2025 Longfin Smelt Science Plan update.

Additional Considerations

Longfin Smelt spawning runs can be rapid, occur overnight during the winter with inclement weather in habitats that are difficult to access. As a result, there are considerable logistical challenges associated with identifying exact spawning locations. Additionally, methods to identify eggs may need to be developed.

Some of the methods described above would require permitting for collection and sampling of wild fish. The number of permits required may depend on the location of sampling. If sampling were to occur in the Delta, permits for take would be need for both the state and federal endangered species acts due to overlap and potential take of Delta smelt or other federally

listed fish species. This sampling would need to be coordinated through IEP to ensure proper permit and take coverage.

Laboratory studies are currently limited because Longfin Smelt culture is in early stages of development and wild brood stock is limited. However, it is expected that Longfin Smelt culture practices will continue to improve over time and minimize this limitation in the future.

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