

White Sturgeon Science Plan

State of California
California Natural Resources Agency



Department of Water Resources
Division of Integrated Science and Engineering | SWP Delta Fisheries Monitoring
and Technical Support Section
Fisheries and Infrastructure Operations Branch

July 2026

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Acronyms and Abbreviations

AMP	Adaptive Management Plan
CCF	Clifton Court Forebay
CDFW	California Department of Fish and Wildlife
CESA	California Endangered Species Act
COA	Condition of Approval
CVP	Central Valley Project
DWR	California Department of Water Resources
ESA	Endangered Species Act
FMWT	Fall Midwater Trawl
HABs	Harmful algal blooms
IEP	Interagency Ecological Program
ITP	Incidental Take Permit
LTO	Long-term operations

NMFS	National Marine Fisheries Service
PATH	UC Davis Pacific Aquatic Telemetry Hub
rkm	River kilometer
SFE	San Francisco Estuary
SLS	Smelt Larva Survey
SWP	State Water Project
USFWS	United States Fish and Wildlife Service
WOMT	Water Operations Management Team
WSMT	White Sturgeon Monitoring Team
WSTT	White Sturgeon Technical Team

1 Preface

The White Sturgeon Science Plan is a high-level document that outlines areas that are considered data poor for the species. The White Sturgeon Science Plan aims to inform management actions related to science priorities described in the Department of Water Resources' Incidental Take Permit (ITP) for Long-Term Operation of the State Water Project (SWP) in the Sacramento-San Joaquin Delta (ITP No. 2081-2023-054-00). The background on current monitoring activities and discussion of potential scientific approaches detailed in the Priority Science Area section provides context for further consideration of new science to improve the understanding of White Sturgeon ecology, stressors, and impacts as a result of SWP operations. While these descriptions include some specific examples, they are often framed in general terms with the understanding that additional work will be needed to clarify priorities and implementation schedules. The prioritization of science actions and schedule for implementation was developed through discussions between the Department of Water Resources (DWR) and the California Department of Fish & Wildlife (CDFW).

2 Status of White Sturgeon

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

White Sturgeon was petitioned for listing as threatened under both the Federal and California Endangered Species Acts (ESAs) in November 2023. The listing status is currently being reviewed and evaluated under both ESAs, and no official listing decision has been made. The California Fish and Game Commission designated White Sturgeon as a candidate species at its June 19, 2024, meeting, and candidate species are afforded full listing status protections under CESA until a listing decision is made. If the Commission lists the species as threatened or endangered, the White Sturgeon Science Plan will continue as outlined here. If the Commission determines listing is not warranted and the species is removed from candidacy, the White Sturgeon Science Plan will be voided as a DWR requirement of the ITP and transferred to the Interagency Ecological Program (IEP) Sturgeon Project Work Team as its steward.

3 Incidental Take Permit

On November 4, 2024, DWR received ITP No. 2081-2023-054-00 for the long-term operations (LTO) of the State Water Project (SWP) in the Sacramento-San Joaquin Delta. The ITP expires November 1, 2034.

3.1 ITP Condition of Approval 7.10.1 – White Sturgeon Science Plan

The White Sturgeon Science Program will include representatives from DWR and CDFW and allow for participation by United States Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), U.S. Bureau of Reclamation (Reclamation), and State Water Contractors. A major goal of this effort is to inform management of White Sturgeon and to identify potential additional management actions that could improve its status. As a major component of the White Sturgeon Science Program, this White Sturgeon Science Plan, prepared in collaboration with CDFW, describes new science needed to improve the understanding of White Sturgeon ecology, stressors, and potential impacts associated with SWP operations. The White Sturgeon Science Plan includes, but is not limited to, the following science priorities outlined in the ITP Condition of Approval (COA) 7.10.1:

- A schedule for implementation including deadlines for draft and final reports for each study required;
- A plan for development of a mathematical life cycle model for White Sturgeon, verified with field data collection, as a quantitative tool to characterize the effects of abiotic and biotic factors on White Sturgeon abundance and distribution, including major mortality events due to harmful algal blooms (HABs);
- New and ongoing monitoring that:
 - Characterizes the distribution and abundance of adult, sub-adult, juvenile, and larval life stages;
 - Collects necessary data to develop a future life cycle model including somatic growth as well as estimates of survival probabilities among life stages;
 - Characterizes changes in abundance and distribution of life stages across a range of hydrologic conditions, including varying ranges of X2 and water year types;
 - Considers revisions to existing IEP monitoring programs to expand the spatiotemporal distribution of sampling; and
 - Addresses factors that influence White Sturgeon catchability and gear efficiency;

- Improved understanding of White Sturgeon spawning, egg development, and rearing habitat distribution and use in the spawning rivers, Delta, and Suisun Marsh;
- An entrainment and residency program to quantify White Sturgeon entrainment and residency in Clifton Court Forebay (CCF) and to better understand factors that may contribute to White Sturgeon entrainment and residency in CCF;
- A White Sturgeon salvage prediction tool for generating a near-term forecast of the probability of future salvage designed to inform real-time operations; and
- Quantification of the lethal and sublethal impacts of HABs on White Sturgeon to support the White Sturgeon life cycle model development.

The White Sturgeon Science Plan may also include the following actions that were listed in the ITP:

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

The final White Sturgeon Science Plan may be periodically updated by DWR or CDFW to reflect updated science priorities or new information, and the updated plan will be submitted to CDFW for approval.

3.2 White Sturgeon Science Program Ties to Other ITP COAs

The following have been called out to integrate with or be complimentary to the White Sturgeon Science Plan:

3.2.1 ITP COA 7.9.6. - Georgiana Slough Salmonid Migratory Barrier Effectiveness Studies

Studies will be complimentary to, or integrated with, the White Sturgeon Science Plan (COA 7.10.1) to provide additional information regarding potential impacts to White Sturgeon migration.

3.2.2 ITP COA 7.10.2 - Larval White Sturgeon Salvage Monitoring and Reporting

DWR will implement larval White Sturgeon monitoring in salvage at the Skinner Fish Facility to identify the presence of White Sturgeon larvae > 20 mm. Larval White

Sturgeon salvage monitoring data will be provided to CDFW according to existing methods of salvage data transmission for all other Covered Species.

3.2.3 ITP COA 8.1.3 - White Sturgeon Monitoring Team

The purpose of the White Sturgeon Monitoring Team (WSMT) is to meet and review hydrologic, SWP and Central Valley Project (CVP) operational, fishery, and water quality data, and provide opportunities for engagement and discussion among biologists and operators on relevant information and issues associated with the Project and risk assessments. WSMT will include representatives from DWR and CDFW. DWR will make all raw data and modeling utilized as part of WSMT available to CDFW within ten days of a request.

3.2.4 ITP COA 8.4.7 - White Sturgeon Entrainment Protection Action

To minimize entrainment and salvage of White Sturgeon, Permittee shall convene WSMT the following business day if the following conditions are observed:

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

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

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

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

Within WSMT, Permittee and CDFW shall jointly develop the risk assessment and supporting documentation to inform discussions and considerations of operational actions by the Water Operations Management Team (WOMT). Input from all Permittee and CDFW WSMT members shall be included in the risk assessment, and any potential differences shall be noted and elevated as described in COAs 8.1.3, 8.1.4, 8.1.5, and 8.1.6.3. If a risk assessment conducted by the WSMT, or Permittee or CDFW WOMT representatives, determines that an action is needed to

minimize take of White Sturgeon, operational decisions shall be made following the process described in Condition of Approval 8.1.5. The WSMT shall convene as necessary throughout the water year.

3.2.5 ITP COA 8.4.8 - Evaluate and Develop Alternative White Sturgeon Entrainment Minimization During Real-time OMR Management

By 2027, DWR will, in coordination with CDFW, use best available science and information gained from the White Sturgeon Science Program (COA 7.10.1) to develop an alternative approach to minimizing White Sturgeon entrainment and salvage at the SWP and CVP export facilities that refines COA 8.4.7 based on new knowledge and understanding of White Sturgeon. This alternative approach will incorporate estimates of White Sturgeon loss in Clifton Court Forebay (CCF) as informed by the White Sturgeon Science Program (COA 7.10.1). DWR will consult with CDFW regarding the need for an amendment to the ITP (COA 5) to modify or replace COA 8.4.6 with White Sturgeon minimization actions that do not solely rely on salvage, based on findings from the White Sturgeon Science Program (COA 7.10.1) and the Adaptive Management Program (AMP) (ITP Attachment 4).

3.2.6 ITP COA 9.3 - Compensatory Mitigation for White Sturgeon

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

DWR will subsequently develop a plan for additional habitat restoration to offset the impacts of Project operations on White Sturgeon, in collaboration with CDFW. This plan will rely on the evaluation of habitat restoration projects required by COA 9.3, be informed by the White Sturgeon Life Cycle Model developed as a part of the White Sturgeon Science Program (COA 7.10.1) and include a budget and timeline for restoration implementation. DWR will submit a draft plan to CDFW for review by April 12, 2030. DWR will work with CDFW to incorporate comments on the draft plan and will submit a final plan to CDFW by October 12, 2030, for written approval by CDFW. Following CDFW approval, DWR will provide \$1,900,000 to implement the final plan. Unless otherwise approved in writing by CDFW, projects involving the

acquisition, restoration, and perpetual management of compensatory mitigation lands will be subject to the requirements of COA 9.5 of the ITP.

As a part of the process to develop and finalize a plan for additional habitat restoration to offset impacts of Project operations on White Sturgeon, DWR and CDFW will collaboratively use the White Sturgeon Life Cycle Model to re-evaluate SWP impacts on White Sturgeon as compared to the analyses used to support the ITP. DWR, in collaboration with CDFW, may propose adjustments to this funding obligation for White Sturgeon mitigation based on this updated evaluation of the magnitude and scope of impacts of SWP operations on the species, which adjustments may decrease or increase the obligation, with CDFW approval and determination that funding will provide sufficient restoration to continue to meet the full mitigation standard under CESA for White Sturgeon. The restoration plan required by COA 9.3, will ensure full mitigation for SWP impacts during the time when White Sturgeon is a Covered Species under the ITP, which includes the period it is a candidate species.

4 Purpose of the White Sturgeon Science Plan

The White Sturgeon Science Plan describes new science needed to improve the understanding of White Sturgeon ecology, stressors, and the influences of SWP operations on the population. A major goal of this effort is to inform the management of White Sturgeon under CESA protections and to identify potential additional management actions that could improve its status. The White Sturgeon Science Plan is a living document and may be periodically updated by DWR in consultation with CDFW to reflect updated science priorities or new information. Any updates to the White Sturgeon Science Plan must be approved by CDFW.

4.1 White Sturgeon Technical Team

The purpose of the White Sturgeon Technical Team (WSTT) is to provide a collaborative framework among federal, state, and water agencies to develop and coordinate scientific studies that inform one or more Priority Areas of the White Sturgeon Science Plan. The WSTT provides a regular forum for discussion, planning, and communication regarding the White Sturgeon Science Plan. Coordination is key for a collaborative and efficient process to ensure advancement in White Sturgeon scientific understanding over the term of the ITP or until a decision is made that White Sturgeon will not be listed. Refer to the WSTT Interagency Charter for more details on the roles and responsibilities of the members ([Appendix A Interagency Charter - White Sturgeon Technical Team](#)).

4.2 Adaptive Management Program

COA 8.15 establishes the relationship between the AMP (ITP Attachment 4) and the 2024 SWP ITP. One goal of the AMP is to support existing and new monitoring and science to improve understanding of Covered Species ecology. Use of the AMP is required as part of COA 8.4.8. but not as part of COA 7.10.1. However, integration of science from the White Sturgeon Science Program and new approaches to minimization measures could occur through the AMP.

4.3 White Sturgeon Science Plan Timeline

- DWR will submit the draft White Sturgeon Science Plan to CDFW for review by July 12, 2025.
- The final White Sturgeon Science Plan will be submitted to CDFW within one year following submission of the draft plan for approval by CDFW.
- After the final plan is approved in writing by CDFW, DWR will fund and implement required monitoring and science according to the timelines specified in the final White Sturgeon Science Plan. DWR, in coordination with CDFW, will develop an annual funding plan for implementing science plan elements.

- At a minimum, DWR will convene the White Sturgeon Science Program through the WSTT quarterly every year following initiation of the final White Sturgeon Science Plan to:
 - Review data obtained from new and ongoing monitoring programs;
 - Review methods used to implement monitoring and recommend adjustments as they deem appropriate; and
 - Review draft results from new and ongoing science.
- All raw data and modeling acquired or developed as a part of the White Sturgeon Science Plan will be made available to members of the White Sturgeon Science Program on a mutually agreeable timeline.

The schedules for implementation of science areas outlined in Section 5 and Section 6 are provided in [Appendix B Timelines for Implementation](#). Deadlines for deliverables within individual science areas may be revised as necessary by DWR and in consultation with CDFW to accommodate changing scientific, logistical, or operational circumstances. Any adjustments to the deadlines must be approved by CDFW.

To ensure effective and transparent implementation of White Sturgeon Science Plan, timelines associated with individual science priority areas may be adjusted as needed in response to emerging data, regulatory considerations, resource availability, delays in interdependent tasks, or unforeseen field or environmental conditions. Any proposed timeline modifications will be evaluated based on their potential effects on overall project objectives and interdependent tasks. Any adjustments to the timelines for the science areas must be approved by CDFW.

4.4 Reporting

4.4.1 Science Plan Progress Reports

Updates and accomplishments related to the White Sturgeon COAs will be included in the Annual Status Report for the SWP ITP, due December 1 each year. Beginning in 2027, DWR will provide CDFW with a White Sturgeon Science Program Annual Report by November 1 that summarizes current progress in each science area and assesses the effectiveness of science plan implementation at improving understanding of White Sturgeon ecology, stressors, and impacts as a result of SWP operations.

4.4.2 Reporting for White Sturgeon Science Plan related Monitoring and Studies

The White Sturgeon Science Plan will be implemented continuously and consider relevant process cycles and timelines (e.g., grant solicitations, fiscal year,

contracting). After determining that a proposed project will effectively address a White Sturgeon Science Plan science need, DWR and CDFW will work collaboratively with the lead scientist(s) to develop and refine a study plan, with input from the WSTT. The study plans or annual monitoring plans for individual projects will include specific requirements and deadlines for reports and other deliverables. In addition to written reports, responsible parties for individual projects in the planning and execution stages are expected to provide verbal progress updates at quarterly WSTT meetings.

Reporting for studies and monitoring under the White Sturgeon Science Plan includes the following deliverables to be submitted to DWR and CDFW:

1. **Progress Reports** – These semi-annual written progress reports (1-4 pages) summarize the status of data collection, analyses, and funding, and discuss progress in relation to the project study or monitoring plan.
2. **Milestone Reports** – These reports document major analytical or other project milestones (e.g., data collected, QA/QCed, preliminary analyses) and include the data collected in support of White Sturgeon Science Plan science priorities. Milestone reports will generally be due within 30-90 days of a project milestone, but the schedule and content will vary by study. Specific deadlines and requirements will be determined during study development and included in the study plan.
3. **Draft and Final Reports** – Deadlines and content requirements for draft and final reports will be specified in project study plans or annual monitoring plans. Due dates will vary depending on an individual project's schedule; however, draft reports will be due a minimum of 6 months before the end of the appropriate phase (See [Appendix B Timelines for Implementation](#)). Final reports are due before the end of the phase, after incorporating comments received during review of draft reports. Any changes to the study plan, including adjusting deadlines, require approval from CDFW and DWR.

4.5 Funding

DWR's ITP Project Description proposed an annual budget of \$250,000 for the first two years, to develop and finalize the White Sturgeon Science Plan. After the White Sturgeon Science Plan is finalized, \$1 million a year (\$8 million total) is anticipated to support and implement portions of the White Sturgeon Science Plan. Annual funding allocations and expenditures will be reported each year within the annual funding plan and will reflect the timelines for implementing required monitoring and science established through this White Sturgeon Science Plan. DWR will have primary contracting responsibilities. The specific funding approach may vary

depending on the composition of the team responsible for each project (e.g. agency, university, consultant, public water agency).

It is anticipated that DWR will not fund every action contained within the White Sturgeon Science Plan. This White Sturgeon Science Plan is meant to be an overall look at White Sturgeon data needs and is intended to help many entities determine where their funding of studies or projects could help the species in general. However, some of the Priority Science Areas for White Sturgeon outlined below have clear implications and application to the SWP and, therefore, DWR would prioritize funding the following items in the White Sturgeon Science Plan:

- An entrainment and residency program to quantify White Sturgeon entrainment and residency in CCF and to better understand factors that may contribute to White Sturgeon entrainment and residency in CCF.
- A White Sturgeon salvage prediction tool for generating a near-term forecast of the probability of future salvage designed to inform real-time operations.
- White Sturgeon-specific studies of louver efficiency at the Skinner Fish Facility and loss within CCF.

5 Priority Science Areas for White Sturgeon

The following items have been identified as critical areas that need to be addressed in the White Sturgeon Science Plan. The schedule to implement each science area can be found in [Appendix B Timelines for Implementation](#).

5.1 Life Cycle Model

5.1.1 Introduction

One of the most important tools for the management of at-risk species is a suitable life cycle model to integrate the effects of multiple factors operating at different life stages, evaluate different management scenarios, and provide insight into overall population effects. COA 7.10.1 states:

- Develop a plan for development of a mathematical life cycle model for White Sturgeon, verified with field data collection, as a quantitative tool to characterize the effects of abiotic and biotic factors on White Sturgeon abundance and distribution, including major mortality events due to HABs.

Overall, a life cycle model is a tool for answering specific questions. Model form and function depend on what questions it is designed to answer, as well as what questions it can realistically answer based on the available information. The applications can require a suite of complementary modeling approaches to address each specific need rather than one grand model. For instance, model structure and function are different if we are using it to infer most-likely combinations of demographic population parameter values from retrospective monitoring information; project potential future status from prospective population simulations; estimate mechanistic effects of specific management actions; or examine the sensitivity to critical uncertainties. Spatial, temporal, aggregate/individual or deterministic/stochastic configurations of a model all depend on the intended purpose. Should a complete model or suite of models to address a particular priority management question not exist, a sub-model or partial model may be developed in the interim.

5.1.2 Key Background Information

There have been several approaches to model White Sturgeon life history across their range, with the first models originating in the early 1990's. Several conceptual models provide foundational information for the SFE population of White Sturgeon (Israel et al. 2009; Heublein et al. 2017a, 2017b). These qualitative conceptual models were a great first step, but this White Sturgeon Science Plan intends to further the development of the quantitative modeling of the White Sturgeon's life

cycle within the Sacramento-San Joaquin River basins, the Delta, and bays within the SFE. Although White Sturgeon can make marine migrations, it is less commonly quantified and is therefore considered as an Other Science Action in the White Sturgeon Science Plan (Other Science Actions). Rieman and Beamesderfer (1990) were the first to develop a quantitative life cycle model for populations on the lower Columbia River. Kohlhorst et al. (1991) followed shortly after with a model for the SFE.

Other examples include basic statistical models based on one or more drivers of recruitment (Stevens and Miller 1970; Kohlhorst et al. 1991; Fish 2010; SWRCB 2017). The most common is the relationship between young-of-year recruitment and Delta flow dating back to Stevens and Miller (1970). Higher Delta flow has repeatedly been shown to have a strong or significant relationship with recruitment (Stevens and Miller 1970; Kohlhorst et al. 1991; Fish 2010; SWRCB 2017; Blackburn et al. 2019). This approach was recently updated to evaluate finer resolution of flow dynamics that potentially influence this relationship (Arroyo-Esquivel et al. 2026).

The most comprehensive life cycle model currently being utilized to model population dynamics of White Sturgeon in the SFE was an age-structured model developed by (Blackburn et al. 2019) and utilizes numerous survival metrics across different age classes to model population dynamics under various management scenarios. Key aspects of this model include fecundity at age, probability of maturity at age, and age specific survival. An updated version of this model is currently in development that incorporates the effects of HABs and flow to recruitment dynamics to expand on the model's predictive ability (Arroyo-Esquivel et al., in-prep). Other sources of mortality that may be considered in a comprehensive life cycle model include harvest and non-harvest sources of mortality, which are listed under Other Science Actions (Other Science Actions) for this White Sturgeon Science Plan.

5.1.3 Primary Management Issues Addressed by a Life Cycle Model

The development of an updated and more comprehensive White Sturgeon life cycle model will help inform ITP management actions on White Sturgeon, as well as other planning activities (i.e. planning activities including but not limited to monitoring needs, entrainment risk, and salvage prediction tools). Potential management applications of a White Sturgeon life cycle model include the following:

- Understanding the effect of winter and spring flow on population trends.
- Determining how normal variation in watershed flow patterns might affect future population patterns through observed correlations with annual recruitment.
- Assessing the potential effects of habitat restoration on population trends.

- Estimating entrainment of individuals and the population level effects of entrainment.
- Determining the effects of new projects and processes on individuals and population trends.
- Understanding the effects of climate change on individuals and population trends.
- Understanding the effects of recreational harvest and poaching on population trends
- Providing valuable feedback for adaptive management processes.

5.1.4 Potential Scientific Approaches

A primary approach for updating and expanding a White Sturgeon life cycle model includes the refinement by Arroyo-Esquivel et al. (in-prep) of the previously established Blackburn et al. (2019) state-spaced model, as described in the Key Background Information section above (5.1.2). It is anticipated that refining an existing model will build on the previous White Sturgeon work described above. Arroyo-Esquivel et al., (in-prep), has produced useful products like more refined life-stage specific survival indices, habitat relationships with vital rates, and completion of population viability analyses. The ultimate choice of a modeling approach will be based on multiple factors including the breadth of management applications, development time, principal investigators qualifications, availability of input data (see Monitoring), and user-friendliness. Moreover, it is possible that other effective life cycle modeling approaches will be identified.

It is highly recommended that a formal characterization of uncertainty is included during the development of life cycle models. The process may include discussions about the sufficiency or deficiency of the data such as the quality, representativeness and resolution of the datasets, as well as any error associated with observation bias or detection probability. Additionally, the documentation of structural uncertainty and uncertainty attributed to model parameters would provide transparency and confidence in the application of the model(s).

5.1.5 Additional Life Cycle Model Considerations

Unlike many of the other elements of the White Sturgeon 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 the following section on White Sturgeon monitoring needs (see Monitoring). For example, we cannot model how operational changes to winter and spring flows in a given water year will affect population trends until there is an independent assessment of how fine-scale flow patterns impact recruitment, which we currently lack. Some of the

associated data collection activities, if necessary, may need to be approved by permitting agencies.

These life cycle 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 SFE, some of these models are so complex and specialized that relatively few staff can run the models. For this reason, our goal is to generate a model (or models) that will be useable by a broader spectrum of scientists and staff. 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, graphical user interface, and documentation that is relatively user-friendly.

5.2 Monitoring

5.2.1 Introduction

White Sturgeon are sampled or detected in several of the current long-term fish monitoring surveys implemented within the SFE (see 5.2.2.1). However, most of the monitoring surveys do not target sturgeon and White Sturgeon are considered bycatch in these studies. For this reason, the ITP identified a need to assess ongoing studies and potentially modify them or develop new monitoring programs to target White Sturgeon. The review, modification, and/or development of monitoring programs will follow the framework outlined in Reynolds et al. (2016). The first step involves defining the problem or question, which will be informed by the gaps in knowledge identified during implementation of the Priority Science Areas including, but not limited to, the development of the life cycle model(s) (Life Cycle Model). In this Monitoring Priority Area, we describe the current suite of monitoring programs that collectively provide some data for White Sturgeon, their limitations, and potential approaches to filling key data gaps. Monitoring should include gaining information that is called out in the ITP that:

- Characterizes the distribution and abundance of adult, sub-adult, juvenile, and larval life stages.
- Collects necessary data to develop a future life cycle model including somatic growth as well as estimates of survival probabilities among life stages.
- Characterizes changes in abundance and spatiotemporal distribution of life stages across a range of hydrologic conditions, including varying ranges of X2 and water year types.
- Considers revisions to existing IEP monitoring programs to expand the spatiotemporal distribution of sampling.
- Addresses factors that influence White Sturgeon catchability and gear efficiency.

5.2.2 Key Background Information

Fifteen long-term fish monitoring surveys capture one or more White Sturgeon life stages annually and are listed below in order of targeted life stage, starting with those targeting eggs. Current fish-centric surveys vary in their temporal and geographic coverage of targeted life stages. For each survey, the sampling period and frequency are described as well as the sampling range, the target fish sizes, and original intent of the sampling. This list includes limitations that pertain to each survey's ability to comprehensively collect targeted life stages (size ranges) of White Sturgeon.

5.2.2.1 Current long-term fish monitoring surveys:

5.2.2.1.1 Egg and Larval Stage

- **Yuba River Spawning Surveys** (initiated 2017, not sampled in 2021): Samples mid-May through early September and uses egg mats and benthic d-nets.
 - **Target:** Eggs and early-stage larvae of Green (and White) Sturgeon
 - **Original intent:** Determine temporal, spatial, and habitat parameters for spawning in the Yuba River; determine recruitment to the early juvenile life stage.
 - **Limitations:** Misses White Sturgeon eggs and larvae from February through early mid-May. Some overlap of sturgeon species exists but current sampling mostly targets areas of higher green sturgeon abundance.
- **Bear River Spawning Surveys** (2017-2019, Intermittent): Samples February through June and uses egg mats and benthic d-nets.
 - **Target:** Eggs and early-stage larvae of White Sturgeon
 - **Original intent:** Determine temporal, spatial, and habitat parameters for spawning Bear River; determine recruitment to the early juvenile life stage.
 - **Limitations:** Lack of staffing and a competing need to conduct fish rescues within the Central Valley impact providing resources and time for this study on a regular basis.
- **Lower Feather River Green Sturgeon Spawning Survey** (initiated 2010): Samples twice weekly from April through August and use egg mats and benthic d-nets.
 - **Target:** Eggs and early-stage larvae of Green Sturgeon
 - **Original intent:** 1) Determine if spawning occurs in the lower Feather River; 2) identify spatial and temporal distribution; 3) characterize habitat preferences; and 4) determine if eggs are viable
 - **Limitations:** Misses White Sturgeon eggs and larvae from February through March. Surveys are only carried out when multiple sturgeon are confirmed in a potential spawning area. Some overlap of sturgeon species exists but current sampling mostly targets areas of higher green sturgeon abundance.

5.2.2.1.2 Larval and Juvenile Stage

- **Smelt Larva Survey** (SLS; initiated 2009): Samples every other week January- March and uses a single oblique tow per station. Range includes the Delta and downstream to eastern San Pablo Bay.
 - **Target:** 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 White Sturgeon larvae April through June that may have dispersed into habitat in San Pablo, Central and South San Francisco Bays, as well as those that may be in tributaries in those regions. Single tow per station doesn't allow for detection probability. The amount of time on or near the benthos is unknown, and therefore, efficiency of benthic sampling is unknown.
- **20-mm Survey** (initiated 1995): Samples biweekly late March – early July and uses three oblique tows per station. Range includes the Delta and downstream to eastern San Pablo Bay.
 - **Target:** 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 larvae hatching in February, and misses habitat in San Pablo, Central and South San Francisco Bays, as well as in tributaries in those regions. The amount of time on or near the benthos is unknown, and therefore, efficiency of benthic sampling is unknown.
- **Fish Salvage at the SWP and CVP** (initiated 1957 at CVP and 1968 at SWP): Currently samples 30 minutes of every 120 minutes of water export.
 - **Target:** All fish larger than 20 mm.
 - **Original intent:** Estimate the species, number, density, and size of fish collected at the salvage facilities in relation to water export rates to manage fish transport truck loading and scheduling and to estimate fish losses and mitigation.
 - **Limitations:** Misses larvae <20mm. The collection efficiency of the louvers is unknown for larvae and has not been comprehensively assessed for juveniles. Only samples when water is being exported.
- **Larval Entrainment Study** (LES; initiated 2022): Samples every week between January and April/May. The current sampling protocol involves a bongo frame with a 500 µm net and a 940 µm net deployed in the West Canal leading to CCF and at SLS stations 809, 812, 902, 915, and 918. The study also targets night-day differences in larval densities.
 - **Target:** Newly hatched larvae – small juveniles (5-10 mm best, up to 25 mm) and small- to medium-sized larvae; preserved in formalin and processed in the lab.
 - **Original intent:** Provide density information for larval and small juvenile Delta Smelt and Longfin Smelt in the zone of entrainment of the south Delta export pumps

- **Limitations:** Misses White Sturgeon larvae and juveniles in May and June. The amount of time on or near the benthos is unknown, and therefore, efficiency of benthic sampling is unknown.
- **Summer Townet Survey** (initiated 1959): Samples biweekly June—August and uses one to three oblique tows per station; range includes the Delta and downstream to eastern San Pablo Bay.
 - **Target:** small juveniles (20-50 mm); many <25 mm are preserved in formalin and processed in the lab; the rest are 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 habitat in San Pablo, Central and South San Francisco Bays, as well as in tributaries in those regions. The amount of time on or near the benthos is unknown, and therefore, efficiency of benthic sampling is unknown.
- **Fall Midwater Trawl Survey** (FMWT; initiated 1967): samples monthly September—December and uses a single 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;
 - **Target:** 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:** Omits habitat in Central and South San Francisco Bays. 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. The amount of time on or near the benthos is unknown, and therefore, efficiency of benthic sampling is unknown.
- **San Francisco Bay Study** (Bay Study; initiated 1980): Samples monthly year-round and uses one tow per station each with an otter trawl, which samples along the bottom, and a midwater trawl, which samples throughout the water column with a maximum depth of about 40 ft (DFG unpublished). Range includes lower rivers in western Delta throughout the SFE to southern South San Francisco Bay.
 - **Target:** Juveniles- small adult fishes (25-250 mm, varies by net) and invertebrates. Fish and crabs are mostly processed in the field and released; shrimps are 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:** Fewer stations per embayment compared to FMWT. Single tow

per station does not 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.

- **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.
 - **Target:** 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:** Larval net sampling is limited to only 3 months in spring so it missed larvae hatching January through March; Kodiak Trawl samples the top surface (~3.5 m) and White Sturgeon juveniles are more common toward the bottom, and the sampling effort does not cover habitat south of the San Joaquin River in the Delta, western San Pablo, South or Central San Francisco bays or their tributaries. It has been in operation for only a few years.
- **Chipps Island Trawl** (initiated 1976): samples 3-7 days per week, year-round, using a midwater trawl 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 Chipps Island only.
 - **Target:** 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 many benthic oriented White Sturgeon.
- **Suisun Marsh Survey** (initiated 1980): Samples monthly year-round, using a single otter trawl tow at each sampling location within sloughs in Suisun Marsh;
 - **Target:** 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 does not allow for detection probability.

5.2.2.1.3 Juvenile and Adult Stage

- **Adult Sturgeon Population Survey (1954-2022):** Sampled four times per week August through October using a trammel net
 - **Target:** Juvenile and adult White and Green Sturgeon in San Pablo and Suisun Bays
 - **Original intent:** Primarily focused on generating absolute abundance estimates from mark-recapture and mark-angler recapture estimation methods. It also provides relative abundance indices as catch-per-unit-effort from trammel netting, adult length metrics for tracking year classes, and generates fishery mortality rates from angler report cards.
 - **Limitations:** Targeted larger fish (≥ 42 cm); does not cover habitat in the Delta, South or Central San Francisco bays or their tributaries. The survey has since ended.
- **Long-term Monitoring of White Sturgeon Movement** (initiated 2011): Samples two to four times per week February through May using trammel and gill nets
 - **Target:** Sub-adult and adult White Sturgeon in Lower San Joaquin River between Manteca upstream to Sack Dam
 - **Original intent:** Assess migration and range of White Sturgeon in the San Joaquin River including determining pre-project fish passage for the Eastside Bypass Control Structure.
 - **Limitations:** Targets larger fish (> 42 cm) and does not cover habitat in the Delta, San Pablo, Suisun, South or Central San Francisco bays or their tributaries.
- **Population assessment of White Sturgeon in the California Central Valley using setline mark-recapture (Setline Survey)** (initiated 2024): Samples three times per week during April-May marking period and again August-September recapture period; Setlines;
 - **Target:** Juvenile, sub-adult and adult White Sturgeon in the lower Delta, San Pablo and Suisun Bays
 - **Original intent:** Estimate absolute abundance of White Sturgeon in SFE; monitor age structure, size structure of population; track spatial distribution in SFE; Target to acoustic tag ~ 200 fish annually for use in multiple projects.
 - **Limitations:** Targets larger fish (> 40 cm) and does not cover habitat in the Sacramento or San Joaquin rivers or their tributaries. Funding for this survey is uncertain and will need securing to continue for the long term.
- **Spawning assessment of White Sturgeon in the California Central Valley** (initiated 2025): March-April sampling period; side-scan SONAR, conventional video;
 - **Target:** Adult White Sturgeon in the Sacramento or San Joaquin rivers or

their tributaries

- **Original intent:** Identify locations of spawning aggregation and develop an index of White Sturgeon spawner abundance in Sacramento and San Joaquin rivers.
- **Limitations:** Targets spawning fish and does not cover habitat in the Delta, San Pablo, Suisun, South or Central San Francisco bays or their tributaries.
- **Georgiana Slough Salmonid Migratory Barrier Effectiveness Studies** (69 kHz acoustic telemetry initiated 2026): December-May evaluation period; 69 kHz acoustic telemetry.
 - **Target:** Adult and sub-adult White Sturgeon in the Sacramento River
 - **Original intent:** To determine whether or not the barrier impedes the movement of sturgeon at the Sacramento River-Georgiana Slough junction.
 - **Limitations:** No tagging effort; relies upon presence of sturgeon tagged by others.

5.2.3 Primary Management Issues Addressed by Monitoring

Understanding the distributions of White Sturgeon at various life stages is key to understanding the habitat needs and movements of the species, and its vulnerability to entrainment under different conditions. Specifically, representative sampling of the distribution of each key life stage will improve the ability to calculate important population metrics and vital rates (e.g., abundance, survival, etc.) and improve their accuracy (e.g., a shift in distribution to outside the sampling frame will reduce accuracy of abundance calculations). Moreover, effective and geographically strategic sampling during the larval and early juvenile stages is important for successful investigation of the mechanisms underlying White Sturgeon recruitment. Similarly, knowledge of where important White Sturgeon habitat exists through different life stages and through varied environmental conditions (ex. flow, temperature, substrate) will be necessary to plan and execute effective restoration measures.

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 (see 5.4. Current annual larval fish sampling within the SFE by the SLS and 20-mm Survey provides information on hatch timing, proximity of larvae to the export pumps, the magnitude of flow through the lower Sacramento and San Joaquin rivers needed to help guide locally hatched larvae beyond the range of entrainment, and potentially the fraction of the larval population vulnerable to entrainment. Effective sampling of all White Sturgeon life stages can provide the data needed to improve life cycle models (see 5.1).

5.2.4 Potential Scientific Approaches

The potential scientific approaches to monitoring will depend on the knowledge gaps identified during the development of the life cycle model(s) and the problem framed in the first phase of the workflow by Reynolds et al. (2016). Once these needs are determined, the design of a monitoring program or the modifications to existing surveys can be developed. To illustrate, several of the existing surveys do not have sufficient geographic or temporal scale to cover the range of White Sturgeon. This is particularly true for the SLS and the 20-mm Survey, which, for example, would need to be expanded in time (to cover the periods when White Sturgeon larvae recruit to the gears) and geography (to cover the spatial range of these larvae as they develop into small juveniles).

Given the needs identified by the Science Program, additional sampling considerations may include the following examples:

- Consideration of whether and how to sample smaller tributaries (Sonoma Creek, Napa River, Petaluma River, Coyote Creek/Alviso Slough). It is currently unknown how many fish of different life stages occupy these habitats and if there are any number of fish that may attempt to reproduce there.
- Consideration of the need to expand the spatiotemporal sampling of early life stages equally across the SFE in all years. Some White Sturgeon begin their upstream spawning migration as early as December so it is possible to have larvae moving downstream in January. Currently the 20-mm Survey which detects the most larvae begins in mid-March and detects the most fish in the first 3 surveys. Beginning this survey earlier may help us better understand if spawning and larval recruitment occurs earlier from January to early March. Development of “sampling strata” for expanded sampling for all gear types. Such sampling strata will be needed to estimate water volume and calculate absolute abundance (i.e., strata volume and area are needed for strata density expansions).
- 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.
- Determination of whether to include replication of tows at each sampling location and include a dedicated benthic tow that targets White Sturgeon larvae.
- Assessment of whether the current Bay Study sampling effort per embayment should be increased.
- Utilization of acoustic tag data of various age groups, assessment of whether local coastal habitats are being utilized and at what frequencies.
- Development of a study plan to investigate the size of complete gear retention for White Sturgeon across different survey types.

- Evaluation and identification of potential capabilities or value of the various monitoring activities with respect to sturgeon.

5.2.5 Additional Monitoring Considerations

5.2.5.1 Collaboration

An important consideration for managers across different agencies is to maintain strong communication and collaboration with the Sturgeon Project Work Team, which is a group of individuals that encourages, facilitates, and coordinates sturgeon monitoring, research, and information dissemination and provides a technical forum for Central Valley sturgeon issues. This group regularly provides inventories of their research and monitoring ([Appendix C](#)). The data they collect may feed into several areas of needed knowledge.

5.2.5.2 Logistics

Expanded sampling efforts 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. 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 efforts, careful consideration may be given to reduce redundancy existing surveys that overlap temporally and spatially. 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. A broad evaluation of current survey efforts would be required to make sure that any increase in efficiency does not sacrifice components of a monitoring enterprise that are vital for the management needs of other species of management concern.

Decisions regarding the modification of current sampling programs may benefit from Value of Information (Bolam et al. 2019) and Value of Sample Information (Williams and Brown 2020) analyses to determine whether the changes are warranted. These tools aid natural resource managers in evaluating modifications to programs in the face of uncertainty.

5.2.5.3 Permits and Approvals

Any addition to survey sampling protocols will require assessment of the potential for take of species listed under the ESA or CESA and may require time for

development of new incidental take permitting. Moreover, substantial expansion of existing surveys may require review and approval by IEP, which has an annual approval cycle with specific deadlines.

5.3 Spawning, Development, and Rearing

5.3.1 Introduction

The spawning and rearing habitat of White Sturgeon is poorly understood due to a variety of reasons such as lack of sampling and difficulty of detections. There are no long-term surveys of White Sturgeon spawning areas at regular intervals, making it difficult to know the true extent of their distribution. Additionally, some sampling methods have limitations that make it difficult to impossible to distinguish between Green and White Sturgeon in areas where their distributions overlap. For these reasons, spawning habitat and spawning frequencies are identified as an area of scientific priority within the White Sturgeon Science Plan. Additionally, understanding core rearing areas is difficult due to lack of detection of larval and smaller juvenile White Sturgeon resulting from a patchwork of monitoring programs that are not dedicated to these age classes. Gaining a better idea of where early rearing might be taking place may aid in our understanding of what factors affect early survival.

Work conducted within this priority area is expected to inform the following priorities identified in COA 7.10.1 of the ITP:

- Improved understanding of White Sturgeon spawning, egg development, and rearing habitat distribution and use in the spawning rivers, Delta, and Suisun Marsh.

5.3.2 Key Background Information

5.3.2.1 Spawning Migration of Adults in the Sacramento and San Joaquin rivers

White Sturgeon in the SFE start maturation at approximately 10 years of age and close to 100% of the population reaches maturity by age 20 (Devore et al. 1995). Some mature White Sturgeon visit spawning sites in the Sacramento River every water year during the spawning season from December-June (Klimley et al. 2015). The spawning sites in the Sacramento River are located approximately between river kilometers (rkm) 239 and 317, mainly between Knights Landing and Colusa (Miller et al. 2020), as well as above the mouth of the Feather River (Kohlhorst 1976). Adults spend anywhere from three weeks to over two months in their spawning reach before returning downstream to the Delta (Miller et al. 2020). The telemetry data on the UC Davis Pacific Aquatic Telemetry Hub (PATH) dataset shows most detections near the town of Colusa (approximately rkm 280) occur between March and April (Table 5-1). The PATH dataset consists of 259 unique White Sturgeon which are observed a total of 12,528,265 times at different stations

located throughout the Sacramento River basin from calendar years 2010 to 2023. Adult and juvenile White Sturgeon have been detected upstream of this core spawning ground in some years, suggesting a larger spawning distribution, but lack of monitoring precludes confirmation of the frequency and density of fish in the upper sections of the Sacramento River.

Table 5-1. Percentage of overall detections of acoustically telemetered spawning White Sturgeon near Colusa on the Sacramento River between December – June

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

Adult White Sturgeon have been documented spawning in the San Joaquin River basin. Spawning on the mainstem San Joaquin River has been recorded between rkms 115–138 (Jackson et al. 2016). In the San Joaquin River basin, fertilized eggs were collected downstream of Grayson at rkm 138 (measured from the Sacramento River confluence) in late April 2011 and downstream of Vernalis between rkm 115 and 140 from late March through mid-May in 2012 (Jackson et al. 2016). In March and April of 2016, fertilized eggs were collected between rkm 115 and 140, however; collection of a single larvae approximately 1-day post-hatch at rkm 101 indicates that spawning occurs further downstream than previously known (Heublein et al. 2017b).

5.3.2.2 Egg and Fry Development

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

suitable substrate in SFE, especially in the San Joaquin River, may limit recruitment to the larval or juvenile life stages.

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

White Sturgeon yolk-sac larvae are 10-11 mm in total length at hatch. At temperatures between 14° C and 17° C, the yolk-sac is completely absorbed approximately 20-23 days post-fertilization (Wang et al. 1985). Under laboratory conditions, larvae reared at 11° C had a specific growth rate half of that observed for larvae reared at 18° C (Rodgers et al. 2019). Larvae are photonegative upon hatching, and swim near the bottom of rivers (Kynard and Parker 2005). In a laboratory study, the presence of physical cover in well-lit mesocosms decreased predation on White Sturgeon larvae that were < 17 mm in total length; however, larger individuals did not benefit from the presence of cover and other studies have observed that White Sturgeon leave cover at the size where exogenous feeding begins (Gadomski and Parsley 2005).

5.3.2.3 Rearing and Outmigrating Juveniles in the Sacramento River

Little is known about the timing of outmigration and rearing habitat of White Sturgeon larvae in the Sacramento River system between Glenn-Colusa Irrigation District and the City of Sacramento (Israel et al. 2009). However, juvenile White Sturgeon are believed to initiate a secondary dispersal (the primary dispersal occurring at the larval stage) in spring (March-May) by actively swimming

downstream at night (Kynard and Parker 2005). Dispersal duration is unknown, but observed swimming intensity and duration in laboratory studies indicate dispersal likely lasts several days and may span many kilometers (Kynard and Parker 2005). Small juvenile White Sturgeon are likely preyed upon by a variety of native and invasive piscivores (Hildebrand et al. 2016). Karp and Bridges (2015) conducted a mark-recapture study using hatchery juvenile White Sturgeon (approximately 200 mm fork length) to test the efficiency of louvers intended to prevent juvenile fish entrainment at the Tracy Fish Collection Facility. During this study, White Sturgeon were observed in the stomachs of Striped Bass collected at the facility.

5.3.2.4 Rearing and Outmigrating Juveniles in the San Joaquin River

Very little is known about the rearing and outmigration of juvenile White Sturgeon from the San Joaquin River, but evidence of spawning in the San Joaquin Basin has been documented. Confirmation of White Sturgeon spawning in the San Joaquin River occurred for the first time in 2011 and again in 2012 via egg mat studies (Jackson et al. 2016). In water year 2023, the 20-mm Survey, a survey conducted by CDFW to monitor post larval-juvenile Delta Smelt throughout the SFE, detected White Sturgeon larvae for the first time at the mouth of the Calaveras River. On March 11, 2024, the Larval Entrainment Study, a survey that samples the south Delta to better understand larval entrainment, found White Sturgeon larvae (12-13mm) north of Jersey Point and west of Oulton Point (Gilbert et al. 2025). In addition, recent monitoring efforts showed that adult White Sturgeon migrate as far up the San Joaquin River as the Tuolumne River, possibly for spawning (Diviney and Dahl 2024). Collectively, this evidence indicates that adult White Sturgeon migrate upstream into the San Joaquin River with reproduction apparent given the presence of eggs and small larvae.

5.3.2.5 Rearing and Outmigrating Juveniles in the Bay-Delta

White Sturgeon larvae begin appearing south of the city of Sacramento during the first 20-mm Survey of the year in March and, subsequently are recruited by the San Francisco Bay Study (Bay Study) gear mainly between the months of April and May (Table 5-2). During high flow years, White Sturgeon larvae can be observed as far downstream as Suisun Bay (Stevens and Miller 1970). Juvenile White Sturgeon can grow quickly given the right conditions, in laboratory studies with ample food at 20 and 25°C but growth was negatively affected by reductions in dissolved oxygen (DO) at all temperature treatments of 15°C, 20°C and 25°C (Cech et al. 1984). Juvenile White Sturgeon also increase their tolerance to salinity as they age, allowing White Sturgeon to occupy a wider range of habitats within the Bay-Delta as they become young adult sturgeon (Vaz et al. 2015). In laboratory studies, juvenile White Sturgeon can tolerate abrupt transfer from freshwater (0-ppt salinity) to 15-ppt-salinity water for up to five (5) days but experienced high mortality rates in abrupt transfers from freshwater to 25-ppt and 35-ppt-salinity water (Vaz et al. 2015). Miller et al. (2020) found that tagged juvenile White

Sturgeon (defined as having a total length between 50 cm and 90 cm) were most often detected in Suisun Bay and the Delta and infrequently observed as far west as San Pablo Bay. Subadult White Sturgeon (defined as having a total length between 90 cm and 140 cm) were most frequently detected in San Pablo Bay, Suisun Bay, San Francisco Bay, and the Delta, while a small number of individuals venture out into coastal waters for a short period of time (Miller et al. 2020).

Table 5-2. The first month of detection of larval White Sturgeon by the 20-mm Survey

Year	First Month of Detection
1993	May
1994	April
1995	April
1996	April
1997	April
1998	April
1999	May
2000	March
2001	N/A
2002	N/A
2003	March
2004	April
2005	July
2006	April
2007	N/A
2008	N/A
2009	N/A
2010	N/A
2011	March
2012	May
2013	May
2014	N/A
2015	N/A
2016	March
2017	March
2018	March
2019	March
2020	N/A
2021	N/A
2022	N/A
2023	March
2024	May

5.3.3 Primary Management Issues Addressed by Understanding Spawning and Rearing

Understanding White Sturgeon 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. Without a good understanding of the specific habitats that White Sturgeon spawn and rear in, it is difficult to identify beneficial actions. 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). Spawning and rearing habitat information also informs the development of life cycle and hydrodynamic models.

5.3.4 Potential Scientific Approaches

There are multiple approaches that could be used to increase our understanding of White Sturgeon spawning behavior and habitat choice with a focus on identifying causes or mechanisms that lead to recruitment failure. 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 White Sturgeon adult migration and spawning behavior could include:

- Increased acoustic tagging of juvenile, sub-adult, and adult White Sturgeon along with an increase in deployed acoustic receivers throughout the Sacramento and San Joaquin rivers, their tributaries, the Delta, and the bays of the SFE.
- Incorporation of real-time monitoring systems such as Juvenile Salmonid Acoustic Telemetry System and 69khz for juvenile, sub-adult, and adult sturgeon to help with real-time management needs as described in COA 8.4.7 and COA 8.4.8.
- Acoustic telemetry might provide insight into whether the Georgiana Slough Salmonid Migratory Barrier influences sturgeon migration and distribution.
- Sonar surveys of known and potential spawning areas to identify aggregations of spawning fish.

Approaches to characterize White Sturgeon spawning substrate could include:

- Laboratory-based research on spawning substrate preference and success rates of egg survival. Uncertainty exists about which substrate size is optimal for White Sturgeon in California due to issues with sedimentation and predation of eggs and larvae.
- Increased egg mat survey frequency and distributions to detect and quantify eggs. Eggs mats experience significant issues during high flow events and from

high sedimentation so developing new sampling protocols would also be beneficial.

- Perform systematic sampling with D-nets to capture drift larvae and locate spawning habitat in the adjacent upstream reaches. Utilizing particle tracking modeling with the hydrodynamic conditions that larvae were captured may improve estimates of which reaches larvae had emerged from spawning substrate.

Mapping of suitable spawning habitat can improve our understanding of potential spawning areas. Identifying White Sturgeon rearing habitat informs our understanding of where the species resides during this vulnerable life stage.

- Synthesis of historical data: Analysis of historical sampling data may provide insights into general habitat associations for larval and juvenile fish.
- Targeted field studies: Focused field studies in potential rearing habitats could help to identify characteristics and locations of the most suitable rearing areas.
- Microchemistry studies: Microchemistry studies are an important tool that can be used to understand some of the general rearing strategies with respect to age, geography and salinity (Sellheim et al. 2017).
- Laboratory studies: Studying White Sturgeon behaviors in a lab setting can be useful for understanding rearing behavior and preferences.

5.3.5 Additional Considerations

The new studies outlined in this Spawning, Development, and Rearing Science Priority will require assessment of potential for take of species listed under the ESA or CESA, and time for new take permitting. Since high numbers of White Sturgeon are needed for statistically robust mark-recapture and biotelemetry studies, substantial permitting hurdles may need to be cleared prior to the release of fish procured from either commercial hatcheries or from newly implemented White Sturgeon culturing programs. Consideration must be given to the types of tags and their compatibility with telemetry receivers that are currently installed or planned for salmonid telemetry studies developed through COA 7.9.1 and 7.9.5 and 7.9.6.

5.4 CCF Entrainment, Residency, and Contributing Factors

5.4.1 Introduction

The White Sturgeon Science Plan must include the development of an entrainment and residency program (2024 SWP ITP COA 7.10.1) to quantify White Sturgeon entrainment and residency in CCF and to better understand factors that may contribute to White Sturgeon entrainment and residency in CCF. Because entrainment of White Sturgeon is not currently quantified at the SWP salvage facilities, its importance as a factor affecting White Sturgeon abundance is uncertain. In this section, we describe the current process and anticipated goals for developing and testing different approaches to help determine the impact of the operations at the SWP south Delta export facilities on White Sturgeon.

5.4.2 Key Background Information

The information gained from this CCF Science Priority will be used to inform: 1) a model that generates a near-term forecast of the probability of future salvage (see White Sturgeon Salvage Prediction Tool), and 2) a model to estimate loss of White Sturgeon (see Louver Efficiency and Loss of White Sturgeon At CCF). As the first step in this process, a draft monitoring plan will be developed that will focus on four goals for the project:

- Improve estimates of young-of-year, juvenile, and adult White Sturgeon presence in the vicinity of the SWP to quantify the proportion of the population at risk for entrainment into CCF.
- Develop a quantitative estimate of White Sturgeon entrainment and residency in CCF to improve our understanding of potential loss in the SWP facility and CCF
- Further the understanding of environmental conditions and mechanisms leading to White Sturgeon entrainment events into CCF and the durations of residency in CCF.
- Achieve better resolution, in real time, of the magnitude and duration of White Sturgeon entrainment events into CCF.

Prior to the issuance of the ITP, larval fish sampling was conducted via a variety of long-term monitoring programs and targeted studies in the channels leading to the export facilities and within the facilities. Existing larval fish monitoring and studies consists of:

- CDFW's Smelt Larva Survey: Started in January of 2009 with the expressed goal of informing assessments of larval Longfin Smelt vulnerability to entrainment. Of the 10 White Sturgeon yolk-sac larvae observed in this survey, zero have been detected in the south Delta in the history of this monitoring program (Bashevkin

et al. 2024), which samples biweekly from the beginning of January to mid-March every year (see above; Chorazyczewski 2019). The geographic coverage of this survey's 44 stations extends from the lower Napa River and Carquinez to the freshwater portions of the Delta. At each station, a single oblique tow from the channel bottom to the surface is conducted with a sled mounted 500 µm net for 10 minutes, with samples preserved in 10% formalin for later analysis in CDFW's lab.

- CDFW's 20mm Survey: Started in 1995 with the goal of informing assessments of risk for larval Delta Smelt entrainment to the south Delta export facilities. Of the 422 White Sturgeon yolk-sac larvae captured in this study, a total of 13 were detected in the south Delta in the history of this program, which samples biweekly from March to June annually (see above; Mahardja et al. 2017; Tempel 2018). The 20mm survey samples 47 stations from Carquinez (and west to San Pablo Bay and the Napa River during high flow years) to the freshwater portions of the Delta. At each station, triplicate oblique tows from the channel bottom to the surface are conducted with a sled mounted 500 µm net for 10 minutes, with samples preserved in 10% formalin for later analysis in CDFW's lab.
- CDFW's Larval Entrainment Study: Began in 2022 with the goal of characterizing the abundance of Delta Smelt and Longfin Smelt in channels leading the south Delta export facilities using a variety of gear types and sampling methodologies. White Sturgeon larvae (12-13mm) were caught at a monitoring stations north of Jersey Point and west of Oulton Point (Gilbert et al. 2025).

From 2009 to 2025, staff at the Skinner Fish Facility and the Tracy Fish Collection Facility participated in the Qualitative Larval Fish Monitoring Program for the presence of larval (<20 mm) Longfin and Delta Smelt (Reclamation 2020). The program was terminated at both facilities in 2025. A total of 4 White Sturgeon yolk-sac larvae were detected in the history of this program, all of which were caught in the same sample in April 2023. This sampling varied in its start and end dates based upon recommendations from the Smelt Monitoring Team but typically occurs from February/March to early June. For each 30 min fish count the facility conducts, typically four per day, the standard fish screen (2.4 mm opening) is overlain with a larval screen (0.5 mm opening) and a sample was collected from the basin using a fine mesh dip net and preserved in 10% formalin.

5.4.3 Primary Management Issues Addressed

The CCF Science Priority will increase our understanding of juvenile White Sturgeon entrainment dynamics in the south Delta, particularly into CCF. Increased sensitivity and quantification of White Sturgeon presence in the south Delta is critical to informing the real-time operations of the SWP, minimizing the entrainment of White Sturgeon into CCF per Conditions of Approval 8.4.7 and 8.4.8, improving our ability to analyze patterns of entrainment and environmental

parameters that may correlate with entrainment events, and informing the creation of a robust White Sturgeon life cycle model.

By 2027, in coordination with CDFW, DWR will use best available science and information gained from the White Sturgeon Science Program (COA 7.10.1) to develop an alternative approach to minimizing White Sturgeon entrainment and salvage at the SWP and CVP export facilities that refines COA 8.4.7 based on new knowledge and understanding of White Sturgeon. This alternative approach will incorporate estimates of White Sturgeon relative loss in CCF as informed by the White Sturgeon Science Plan (COA 7.10.1). The CCF Science Priority specifically addresses the parameterization of entrainment and residency in CCF that may be included in a model to estimate loss of White Sturgeon (see Recommended Science Priority for Louver Efficiency & Loss).

5.4.4 Potential Scientific Approaches

The entrainment and residency program will include an evaluation of the existing direct and indirect larval fish sampling methods identified in 5.4.2 Background Information. Expanding and modifying the existing larval fish surveys may improve our understanding of the likelihood of larval White Sturgeon presence in the south Delta and entrainment into CCF. Modifications to the active larval fish surveys include sampling for longer periods of time near the bottom of channels in the south Delta. Indirect sampling using environmental DNA will also be evaluated as a method for detecting White Sturgeon presence (Brandl et al. 2015; Baerwald et al. 2020).

The Setline Survey (5.2 Monitoring) inserts passive integrated transponder tags to fish caught in the study's footprint (Suisun Bay and San Pablo Bay). It is unlikely that these tagged fish will generate robust results to understand juvenile White Sturgeon presence in the south Delta. We propose either expanding the Setline Survey into the south Delta or conducting a separate study utilizing setlines in the south Delta. Captured juvenile White Sturgeon would have acoustic tags inserted for mark-recapture and biotelemetry studies to quantify entrainment of White Sturgeon into CCF and the duration of residency. The receiver network will include receivers that are currently installed or planned for salmonid telemetry studies developed through COA 7.9.1 and 7.9.5.

These methods also include potential applications both in south Delta channels and within the infrastructure of the CCF and Skinner Fish Facility. All the methods will be evaluated in an iterative process, with an initial red flag review to remove methods that are prohibitive in some sense, then a second round of evaluation will occur to examine how each method could assist in meeting the project goals. These evaluations will include the scientific merit of the method (gear selectivity, sensitivity, utility, etc.), the feasibility and logistics of carrying out the sampling (effort required, reliability of method, etc.), and the management relevance of the

data produced (sample processing time [data available in near-real-time for entrainment management decisions], data utility for modelling, benefits for monitoring other species, etc.).

Once candidate methods are chosen, a draft monitoring plan will be created, and a pilot evaluation study will be conducted to further refine the methods. Based on the results of the pilot study, a final monitoring plan will be created and implemented to codify the new monitoring. The specific elements chosen for the final monitoring plan will be selected by the White Sturgeon Science Program, in consultation with the White Sturgeon Monitoring Team, and with final approval by CDFW.

5.4.5 Additional Considerations

All methods being evaluated would increase the resource needs of the agencies undertaking the sampling. The review, modification, and/or development of monitoring programs will follow the framework outlined in Reynolds et al. (2016). Depending on the methods included in the pilot and final monitoring plans, there may be a need for new permits authorizing additional take of listed species. The use of setlines for sampling White Sturgeon may result in bycatch of other species as well as the mortality of fish caught on hooks due to predation. Since high numbers of White Sturgeon are needed for statistically robust mark-recapture and biotelemetry studies, substantial permitting hurdles may need to be cleared prior to the release of fish procured from either commercial hatcheries or from newly implemented White Sturgeon culturing programs. Consideration must be given to the types of tags and their compatibility with telemetry receivers that are currently installed or planned for salmonid telemetry studies developed through COA 7.9.1 and 7.9.5 and 7.9.6.

This priority is closely related to the recommended science priority on Louver Efficiency & Loss as it will involve biotelemetry studies. The development and implementation of biotelemetry studies for both priorities are best performed in tandem to reduce costs and effort.

In-water activities in CCF require close coordination with SWP Operations and Management and study designs must adhere to the safety and logistical measures set forth by them. All in-water activities in CCF will require work to be done during the hours when the radial gates are shut. Any passive gear-types used in CCF that remain unattended in the water, such as setlines, must be appropriately secured to avoid drifting and fouling of SWP facility equipment.

As with the expansion of any science program, there will be considerable logistical hurdles, from staffing and vessel needs, to increasing capacity of the sample processing pipeline, to creating a robust data management and quality assurance program. It is anticipated that these new or expanded monitoring elements will

undergo periodic review, synthesis, and adaptive management to ensure that they continue to produce valuable and actionable information well into the future.

5.5 White Sturgeon Salvage Prediction Tool

Develop a White Sturgeon salvage prediction tool for generating a near-term forecast of the probability of future salvage designed to inform real-time operations. This Prediction Tool Science Priority is directly applicable to the SWP and further consideration by the WSTT and resource managers is needed to determine how the salvage prediction tool is applied in real-time operations.

5.5.1 Introduction

The White Sturgeon Science Plan must include the development of a forecasting tool to predict near-term probability of future salvage of White Sturgeon (2024 SWP ITP COA 7.10.1). Because little is known of White Sturgeon entrainment, residency, and loss at the SWP facilities and CCF, substantial effort is needed to develop the White Sturgeon prediction tool. In this section, we describe the current process and anticipated goals for developing and testing different approaches.

5.5.2 Key Background Information

Development of a tool to forecast White Sturgeon salvage is a means to minimize loss during operations of the SWP. The implementation of this Prediction Tool Science Priority is dependent on the information gained from the CCF Science Priority since the low numbers of White Sturgeon recorded in and around the Skinner and Tracy Fish Facilities from the available datasets present an obstacle for any modeling effort. Salvage prediction tools that exist for Skinner and Tracy Fish Facilities rely on robust timeseries datasets from targeted monitoring programs for Chinook salmon (Tillotson et al. 2022, Gaeta et al. *in prep*).

5.5.3 Primary Management Issues That This Area Will Address

The development of a forecasting tool to predict near-term probability of future salvage of White Sturgeon is critical to informing the real-time operations of the SWP, minimizing the entrainment of White Sturgeon into CCF per COAs 8.4.7 and 8.4.8 and improving our ability to analyze patterns of entrainment and environmental parameters that may correlate with entrainment events. Ultimately, this information will allow scientists and managers to adaptively manage south Delta operations to minimize impacts to White Sturgeon populations while maximizing water export capacity.

5.5.4 Potential Scientific Approaches

Near-term forecasting of the probability of future salvage of White Sturgeon must be predicated on the best available science and the outcomes from earlier elements

of this White Sturgeon Science Plan. The development of a White Sturgeon salvage prediction tool may follow the modes taken for juvenile salmonid entrainment prediction tools (e.g., Tillotson et al. 2022, Gaeta et al. *in prep*) that use machine learning models to determine key environmental and biological cues that correlate with trends in salvage. Additionally, an entrainment model trained with robust biotelemetry data from studies in the south Delta can be applied in tandem with other models to predict the risk of future salvage.

5.5.5 Additional Considerations

All models being evaluated would increase the resource needs of the agencies undertaking the development of the White Sturgeon salvage prediction tool. This effort will proceed using a consensus-driven process to select the most appropriate modeling technique based on the best available science and data. An independent review panel or publication into the peer-reviewed literature will be essential to solidify the confidence behind the salvage prediction tool by resource managers prior to implementation.

5.6 Harmful Algal Blooms

5.6.1 Introduction

The White Sturgeon Science Plan is required to include quantification of the lethal and sublethal impacts of HABs on White Sturgeon to support the White Sturgeon life cycle model development (2024 LTO ITP COA 7.10.1). These events have caused large reductions in the SFE White Sturgeon populations and have been named as a primary reason for the petition to list and subsequent candidacy status.

5.6.2 Key Background Information

Currently, cyanobacterial HABs in the Delta are typically dominated by the genus *Microcystis*, though mixed assemblages that include *Planktothrix*, *Aphanizomenon*, *Dolichospermum* and other genera are increasingly observed (Lehman et al. 2005, 2008, 2017, 2022; Spier et al. 2013; Perry et al. 2025). These blooms tend to occur in low salinity and their cyanotoxins can travel downstream. In 2022 and 2023, HABs dominated by the raphidophyte, *Heterosigma akashiwo*, resulted in mass fish kills in the higher-salinity lower SFE (Senn 2023). Overall, phytoplankton, of which there are many bloom forming types in the SFE, are complex organisms that have species-specific growth requirements. Research is still ongoing related to the *H. akashiwo* HAB strain occurring in the lower SFE. White Sturgeon mortalities have been observed to correspond with the timing of the *H. akashiwo* blooms and are considered a factor in listing White Sturgeon as a threatened species under CESA (San Francisco Baykeeper et al. 2023). A strain from the Pacific Northwest was shown to live at a wide range of salinities (10-32 ppt) but the organisms may be deadlier to fish in lower salinities (10-20 ppt) or when in competition with another alga (Ikeda et al. 2016).

5.6.3 Primary Management Issues That This Area Will Address

The development of a tool to quantify the lethal and sublethal impacts of HABs on White Sturgeon and its subsequent incorporation into the life cycle model would allow for a more accurate understanding of White Sturgeon population dynamics and risk due to HAB events.

5.6.4 Potential Scientific Approaches

Modeling efforts have begun as part of the White Sturgeon Effects Analysis (2024 LTO ITP) and have aimed to better predict the frequency of HABs in the SFE. However, predicting the frequency of HAB events and its intensity is inherently difficult and proves challenging with previous approaches. Developing new approaches will allow us to improve the predictive ability of the life-cycle models.

Additionally, quantifying how many fish are lost during a HAB event has been challenging since most sturgeon carcasses sink. The current assumption is that observed floating to sinking carcasses follow a ratio of 1:8 (CDFW 2023), which could imply that hundreds to thousands of sturgeon mortalities are uncounted during these events.

5.6.5 Additional Considerations

The need to develop a new approach to predict the frequency of HAB events in the SFE is two-fold. First is being able to develop a model that more accurately predicts the frequency of HAB events. Efforts to monitor and predict the probability of bloom formation are currently underway. Second, once a HAB event occurs, quantifying the mortality rate would require an increase in the resources needed by agencies undertaking monitoring.

6 Other Science Actions

6.1 Actions Identified in ITP COA 7.10.1

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

6.1.1 Development of a Genetic Management Plan to Support the Use of Cultured White Sturgeon Fish for Research Purposes

A genetic management plan would be important if significant numbers of hatchery sturgeon were planned to be released for supplementation or experimental purposes. The White Sturgeon Science Plan only considers hatchery supplementation for the potential use of hatchery fish as test subjects for entrainment and residency, Skinner Fish Facility louver efficiency and CCF loss. This recommended Genetic Management Science Priority will be considered further by the WSTT for inclusion in the final White Sturgeon Science Plan. A potential schedule for implementing the Genetic Management Science Priority is provided in [Appendix B Timelines for Implementation](#).

6.1.2 Improved Understanding of Genetic Diversity Within California White Sturgeon

Improving our understanding of genetic diversity of White Sturgeon in California may be used to inform population status assessments. This recommended Population Genetics Science Priority and any associated conservation and management applications will be considered further by the WSTT for inclusion in the final White Sturgeon Science Plan.

6.1.3 Louver Efficiency and Loss of White Sturgeon At CCF

White Sturgeon-specific studies of fish louver efficiency at Skinner Fish Facility and loss within CCF. This recommended Louver Efficiency and Loss Science Priority will be considered further by the WSTT for inclusion in the White Sturgeon Science Plan.

If adopted as a Science Priority in the White Sturgeon Science Plan, the Louver Efficiency and Loss element would involve conducting studies like those used in developing loss calculations for juvenile Chinook Salmon. These include estimates of louver efficiency, pre-screen loss (predation and mortality), and entrainment rates into CCF; the last of which dovetails with Science Priority CCF Entrainment, Residency, and Contributing Factors.

To meet these needs, robust mark-recapture and biotelemetry studies may be used to generate estimates of louver efficiency when applied using an experimental approach like those for juvenile Chinook Salmon (Clark et al. 2009; Zeug et al. 2025). Given the alignment in procedures between these studies and those described in Science Priority CCF Entrainment, Residency, and Contributing Factors, it is recommended that the development and implementation of biotelemetry studies for both elements are performed in tandem to reduce costs and effort involved in permitting and field work. It should also be noted that the availability of cultured fish and their approval for release into the wild to obtain suitable sample sizes are also a potential constraint for studies in this element.

6.2 Actions Not Identified in ITP COA 7.10.1

The previous sections provide information about science priorities that were specifically identified in the ITP. However, there are likely other high value science topics not identified in this White Sturgeon Science Plan and should not deter researchers from pursuing other research topics. Additional research is encouraged since it may be relevant to the science gaps identified within the White Sturgeon Science Plan and could lead to new innovations in White Sturgeon science and management. Moreover, it is likely that some of the science projects funded by the White Sturgeon Science Program will include smaller elements that are 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 White Sturgeon Science Plan drafting team identified some important science topics that were not included in the ITP:

- Contaminant effects
- Invasive species effects
- Effect of screened and unscreened diversions beyond the State Facility
- Identifying the food web for White Sturgeon
- Development of new tools (e.g. monitoring, health, mortality-based datasets)
- Climate change effects (e.g. hydrology, temperature)
- Quantifying harvest and non-harvest sources of adult mortality (e.g., boat strikes, poaching, disease)
- San Francisco Bay and the Pacific Ocean migration

This list is not intended to be comprehensive; rather, it is provided to show a continued interest in broader topics about White Sturgeon science. Proposed additions to the science priorities identified in the plan should be brought to the White Sturgeon Technical Team for review.

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Appendix A.
Interagency Charter - White Sturgeon
Technical Team

A. Interagency Charter – White Sturgeon Technical Team

A.1 Background

White Sturgeon (*Acipenser transmontanus*) was petitioned for listing to both the Federal and California Endangered Species Acts (ESAs) in November 2023. The listing status is currently being reviewed and evaluated by both ESAs and no official threatened designation has been made. However, the Fish and Game Commission voted to designate White Sturgeon as a candidate species at its June 19, 2024, meeting. Since state candidate species are afforded protections of full listing status, DWR requested to add White Sturgeon as an additional Covered Species to the take authorization provided by the ITP for the long-term operations (LTO) of the State Water Project (SWP) in the Sacramento-San Joaquin Delta (ITP No. 2081-2019-066-00) issued March 31, 2020. The ITP was amended on July 12, 2024, to include Condition of Approval (COA) 7.9.1- White Sturgeon Science Program. DWR received a new ITP for the LTO of the SWP in the Sacramento-San Joaquin Delta (ITP No. 2081-2023-054-00) issued November 11, 2024, which rescinded and replaced ITP No. 2081-2019-066-00. The White Sturgeon Science Program was carried over into the new ITP and is now referred to as COA 7.10.1.

A.2 Introduction

DWR is required to implement a White Sturgeon Science Program (Science Program) and develop a White Sturgeon Science Plan (WSSP) for the term of the ITP if White Sturgeon obtain threatened status; otherwise, if listing White Sturgeon as threatened is not warranted then the requirement is voided. Any Work Plan that may come from this endeavor will be transferred to the Sturgeon PWT if the Science Program should be dissolved due to non-listing.

A.2.1 Objectives

COA 7.9.1 identifies two overarching objectives for the Science Program that the WSSP activities are designed to achieve.

1. Implement science needed to improve the understanding of White Sturgeon ecology.
2. Implement science needed to improve the understanding of impacts to White Sturgeon associated with the operations of the SWP.

The WSSP will address the following priority areas within COA 7.10.1:

1. Life Cycle Modeling

2. Improved Abundance and Distribution Monitoring
3. Factors Affecting Abundance, Growth, and Survival
4. Spawning and Rearing
5. Salvage Prediction Tool Development
6. Harmful Algal Blooms

A.3 White Sturgeon Technical Team Charge

This charter establishes a collaborative scientific technical team, the White Sturgeon Technical Team (WSTT), to implement the WSSP as part of the Science Program mandated by COA 7.9.1. Coordination is key for a collaborative and efficient process to ensure advancement in White Sturgeon scientific understanding over the term of the ITP or until a decision is made that White Sturgeon will not be listed. Therefore, this charter describes the establishment and activities of the WSTT to coordinate implementation of the WSSP.

A.3.1 Purpose

The purpose of the WSTT is to provide a collaborative forum among federal, state, and water agencies to develop and coordinate scientific studies that inform one or more Priority Areas of the WSSP. The WSTT provides a regular forum for discussion, planning, and communication regarding the WSSP.

A.3.2 Roles and Responsibilities

The WSTT will be co-chaired by CDFW and DWR. The chairs are expected to lead discussions and work closely with WSTT members to successfully implement the WSSP. The WSTT will be composed of two subteams, the Core and the Working Group. The WSTT Core will be comprised of DWR and CDFW members only. The WSTT Working Group membership will be open to representatives from DWR, CDFW, USFWS, SWC, Reclamation, NOAA Fisheries, USACE and the Interagency Ecological Program (IEP). Membership is limited to no more than three representatives from each non-core entity. The WSTT will generally make consensus-driven recommendations to DWR for WSSP implementation. However, the WSTT Working Group will recognize that sometimes there is a diversity of scientific opinions and in those cases where a consensus does not emerge, the WSTT Core will make the final decision.

The WSTT will review data obtained from new and ongoing monitoring programs.

The WSTT will review methods used to implement monitoring and recommend adjustments as they deem appropriate. This includes the development of research objectives, methods, and other project recommendations.

The WSTT will review draft results from new and ongoing science as it pertains to the WSSP.

A.3.3 Example Activities

- Develop scopes of work and guide implementation of scientific studies to address one or more of the priority areas identified in the WSSP.
- Develop monitoring plans to guide implementation of new monitoring identified in the ITP and WSSP.
- In regular coordination meetings, evaluate progress on scientific studies and monitoring initiated by the WSTT, receive study updates, and provide guidance to researchers and monitoring team leads as needed.
- Update agency Directors or designees serving on the Adaptive Management Team on activities related to the Science Program and implementation of the WSSP.
- Technical Coordination: provide updates on coordination efforts with study-specific technical experts.
- Stakeholder Coordination: provide updates to stakeholder groups.

A.3.4 Communication and Outreach

The WSTT will communicate plans and activities to relevant stakeholders (e.g., IEP Stakeholder Group and the Sturgeon PWT), management teams (e.g., CAMT, IEP Coordinator Team), and the local scientific community. Communication with stakeholders should be bidirectional, both in sharing planning documents, products, and deliverables, as well as soliciting feedback.

A.3.5 Meeting Frequency

The WSTT will meet as frequently as necessary, considering available staff resources, to make reasonable progress on implementation of the WSSP, with minimum quarterly meetings as required by COA 7.9.1 of the ITP.

A.3.6 Developing Recommendations

The WSTT will work collaboratively to develop recommended scopes of work, science plans, and monitoring plans as needed to implement science and monitoring required by the ITP and identified in the priority areas of the WSSP. The WSTT will recommend approaches for the logistics of planning and developing projects for each Priority Area. The WSTT will strive for unanimous consensus on recommendations.

Although this document sets forth a cooperative and consensus-driven process, all agencies recognize that they each have statutory responsibilities that cannot be

delegated, and that this document does not and is not intended to abrogate any of their statutory responsibilities.

Any member of the WSTT may recommend scientific studies that address the Priority Areas of the WSSP. Recommendations may also be developed collaboratively within the WSTT. Recommendations will be discussed and then approved or rejected by the WSTT through general consensus. If there is disagreement on a recommendation developed within the WSTT then the issue will be elevated to DWR and CDFW management for resolution.

A.3.7 Membership

Individual members of the WSTT may be identified by member entities of the WSTT and will be appointed by the WSTT co-chairs. While membership to the WSTT is not bound to any term or period of service, members are expected to participate and contribute in constructive and effective ways for as long as they are members of the WSTT.

The WSTT will evaluate and be a central forum for emerging White Sturgeon science. To facilitate cooperative and consensus-driven investments into White Sturgeon science, the WSTT will receive occasional input from technical experts outside of the WSTT for guidance on methods and approaches for elements of the WSSP. The WSTT will request input, review, or additional feedback from the Sturgeon PWT. An independent working group will work in parallel on Larval Entrainment Monitoring, which is a separate Condition of Approval (7.9.2). This group is expected to coordinate with the WSTT for implementation of the WSSP, however it is subject to specific deadlines and requirements described within Condition of Approval 7.9.2.

A.4 Members

Core and Working Group members:

- CDFW: Travis Apgar (Co-Chair), John Kelly, Dylan Stompe, Erica Meyers, Kristal Davis-Fadtke, Brooke Jacobs, Ryan McKim, Dan Kratville, New CDFW-WB EPM, Steve Slater, Marc Beccio, Nick Bauer
- DWR: Daniel Cox (Co-Chair), Alicia Seesholtz, Brian Schreier, Curtis Yip, Javier Miranda, Daphne Gille, Katie Osborn, Chris Wilkinson, Lenny Grimaldo, Trishelle Tempel, Louise Conrad

Working Group members:

- USFWS: Joe Miller, Will Smith, Josh Gruber, Philip Street
- SWC: Shawn Acuña, Darcy Austin, Ray Beamsderfer
- Reclamation: Josh Israel (placeholder)

- NMFS: Peter Dudley, Nick Demetras
- USACE: Mike Thomas

Appendix B.

Timelines for Implementation

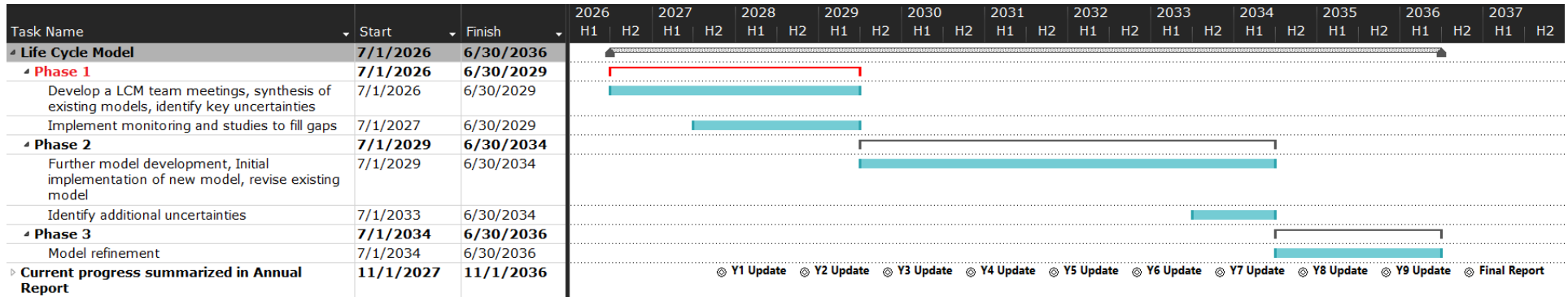
B. Timelines for Implementation of the White Sturgeon Science Plan

The timelines listed herein depict the general schedules for the implementation of the *Priority Science Areas* and *Other Science Actions* identified in the White Sturgeon Science Plan.

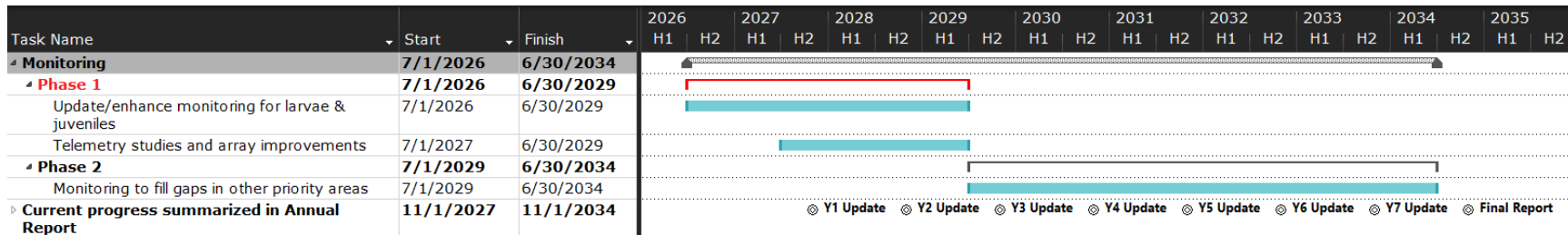
Deadlines for deliverables within individual science areas may be revised as necessary by DWR and in consultation with CDFW to accommodate changing scientific, logistical, or operational circumstances. Any adjustments to the deadlines must be approved by CDFW.

To ensure effective and transparent implementation of White Sturgeon Science Plan, timelines associated with individual science priority areas may be adjusted as needed in response to emerging data, regulatory considerations, resource availability, delays in interdependent tasks, or unforeseen field or environmental conditions. Any proposed timeline modifications will be evaluated based on their potential effects on overall project objectives and interdependent tasks. Any adjustments to the timelines for the science areas must be approved by CDFW.

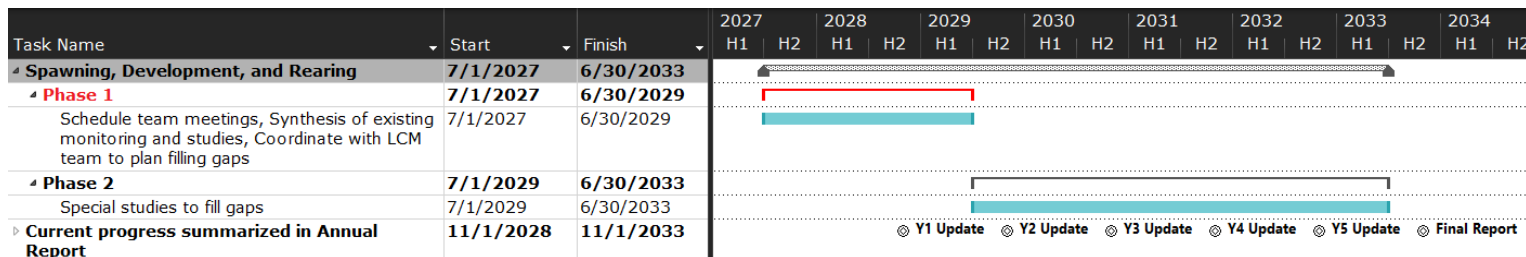
B.1 Life Cycle Model



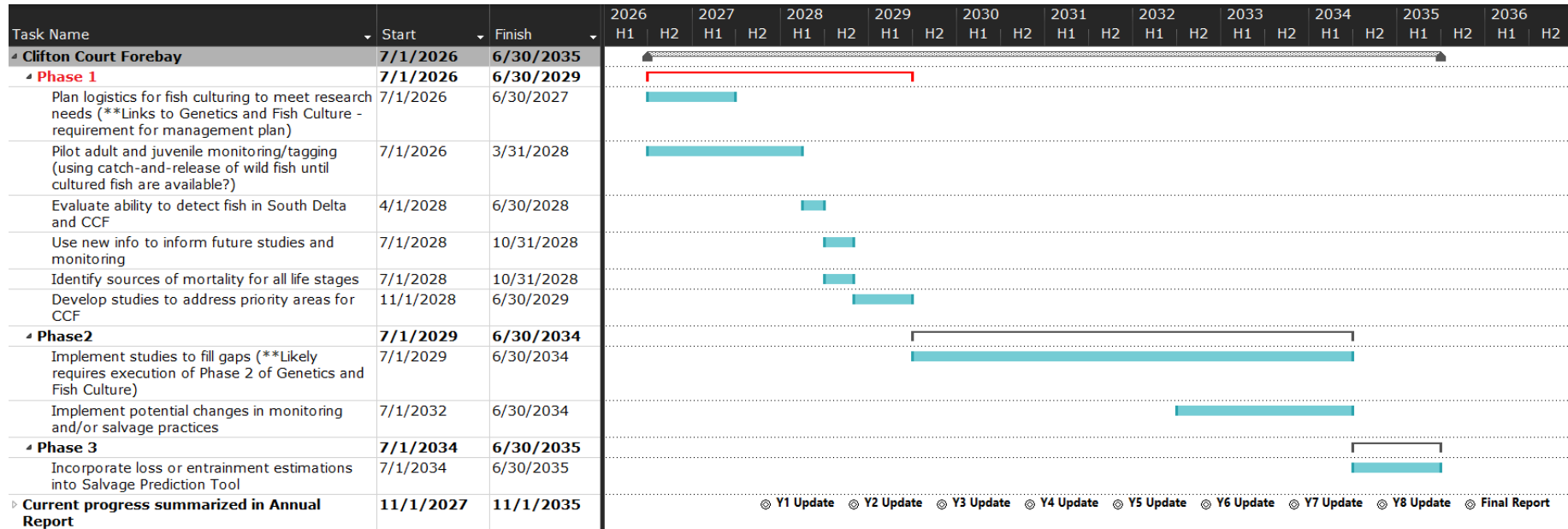
B.2 Monitoring



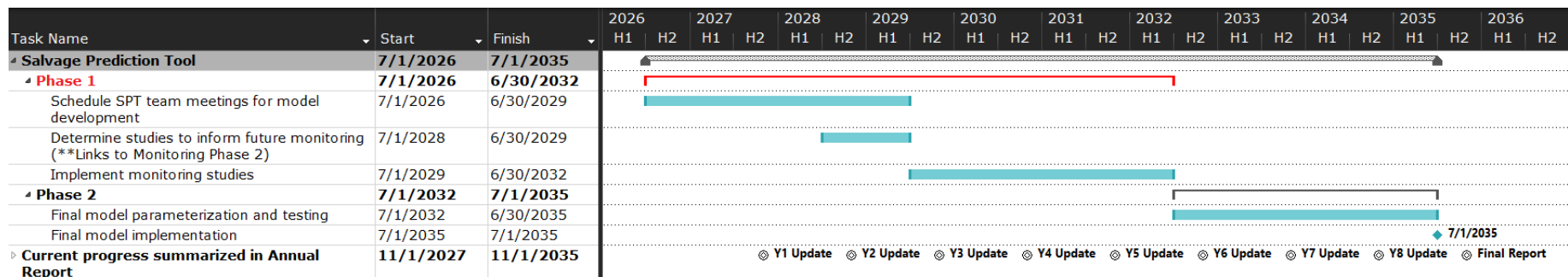
B.3 Spawning, Development, and Rearing



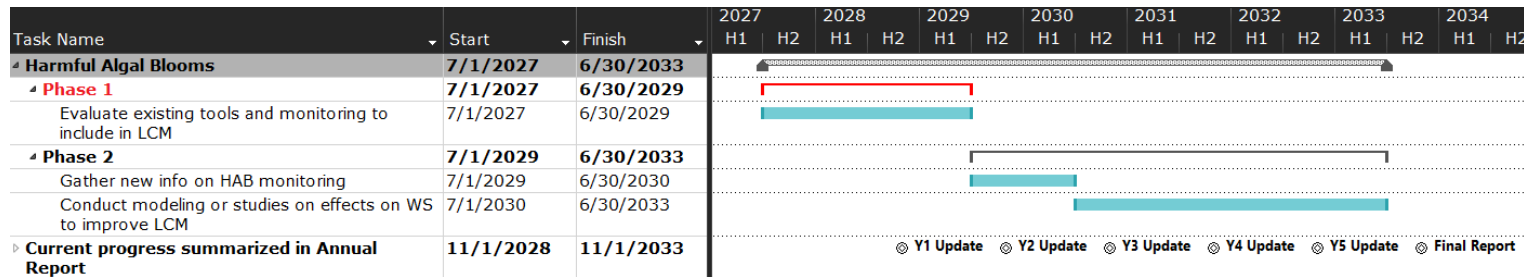
B.4 Clifton Court Forebay



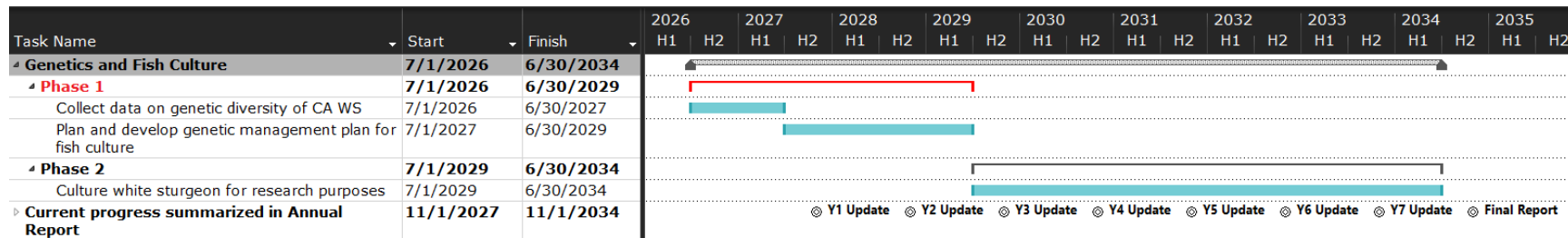
B.5 Salvage Prediction Tool



B.6 Harmful Algal Blooms



B.7 Genetics and Fish Culture



Appendix C.

Inventory of Studies

C. Inventory of White Sturgeon Studies

The attached document contains an inventory of White Sturgeon studies prepared by the White Sturgeon Project Work Team and was last updated in 2025.



Appendix C-2025
Inventory of Studies