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Delta Science Program

DELTA STEWARDSHIP COUNCIL

2022–2026 Science Action Agenda

A Vision for Integrating Delta Science

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Acknowledgments The 2022–2026 SAA would not be possible without the tremendous engagement from scientists, managers, and those with a stake in the Delta. Special thanks to the participants of the 2020 and 2021 public workshops, survey respondents, and to the individuals and entities who provided input during the public review periods. Thank you to the Delta Science Program's Science Advisory Committee for their insights, to the Delta Science Program staff for their input, facilitation, and support throughout the process, and to the Delta Independent Science Board for their thorough and helpful review and comments. Unless otherwise noted, photographs are courtesy of the Department of Water Resources (DWR).

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The Science Action Agenda (SAA) is the way we come together to prioritize Science Actions to reduce uncertainties over the short-term (four- to five-year) time scale.

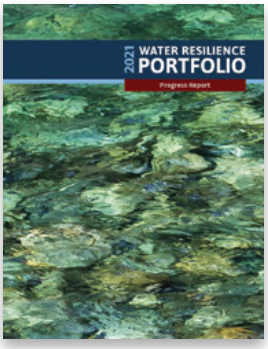
Foreword

At the heart of some of the biggest challenges to decision-making in the Sacramento-San Joaquin Delta (Delta) lies uncertainty. Uncertainty may be scientific in nature, relating to imperfect measurements (*measurement uncertainty*) or incomplete understanding of the mechanisms driving a phenomenon (*mechanistic uncertainty*). Uncertainty can also derive from the unknowable outcomes of random events (*stochastic uncertainty*) that make our ability to estimate future weather or climate, population patterns, economic drivers, natural disasters, or inputs to Delta waterways educated guesses at best. When making decisions about how best to manage natural resources in the Delta, these uncertainties compound, leading to complicated assessments of risk and difficulties in prioritizing across multiple goals, especially considering that action on one issue often involves tradeoffs for other issues (see Box 1).

The Delta Reform Act (Act) of 2009 provides guidance for moving forward under uncertainty while managing the Delta for multiple goals. It requires the Delta Stewardship Council (Council) to make use of the best available science and include a science-based, transparent, and formal adaptive management strategy for ongoing ecosystem restoration and water management decisions in the Delta Plan. It further specifies how to advance "best available" science in ways that reduce scientific uncertainty in the planning process (i.e., through funding new research). By mandating a science-based adaptive management strategy for the Delta, the Act implicitly acknowledges that decisions *must* be made under uncertainty, and that action presents an opportunity for learning, which then feeds into the next phase of planning and decision-making. The importance of coordination among the Delta Science Program, other Delta agencies, policymakers, and decision-makers is prominent in the Act. That coordination is *essential* to ensure that priorities for advancing the best available science are aligned with management priorities—in other words, that the scientific efforts that the Delta community invests in address those uncertainties whose resolution has the greatest potential to inform Delta decisions. The SAA is the way we come together to prioritize Science Actions to reduce such uncertainties over the short-term (four- to five-year) time scale. The 2022–2026 SAA was collaboratively produced by engaging scientists, managers, and decision-makers over a yearlong process to identify priority Management Questions and corresponding Science Actions.

Produced *by* and *for* the Delta science and management community, the SAA is truly a community-guiding document, with a reach extending well beyond the Delta Science Program. **The 2017–2021 SAA, for example, directed over $35 million in science investments by multiple agencies.** A few examples of the direct impacts of those investments on management include...[1]

- Tools for developing planning scenarios,
- Quantitative estimates for how wetland area impacts primary productivity (a relevant topic of discussion in the Voluntary Agreements for understanding the impact of restoration),
- New conceptual models and frameworks for assessing the effectiveness of restoration, and
- Increased investment in understanding the effects and sources of toxicity.



Further, **the 2017–2021 SAA was cited in Governor Newsom's Water Resilience Portfolio as a model for the entire state for how to engage with diverse stakeholders** to prioritize scientific questions surrounding management of water supplies, water quality, and flood risk.[2]

Box 1

Science Investments to Reduce Management Uncertainty: An Example from Salinity Control

An example of a management challenge that would benefit from scientific investment to resolve multiple types of uncertainty is that of managing Delta salinity under extended drought. Salinity barriers, such as the barrier deployed on the West False River in 2015 and 2021, have effectively limited salinity movement into the central and south Delta, but evaluating their integration into long-term strategies for salinity management requires understanding tradeoffs for ecosystems and human communities. One component of a tradeoff assessment is to address how long-term or repeated use of salinity barriers increases the risk of harmful algal blooms (HABs), and the impacts on human communities. Mechanistic uncertainties underlying this assessment include the dominant factors that produce a HAB at a particular place or time in the Delta, the health impacts of aerosolized toxins from HABs, and the economic costs of recreational impacts from the salinity barrier and potential HAB events. Currently, there are no instruments or sensors that can feasibly detect HABs in real-time, contributing to uncertainty. In projecting future impacts of salinity management strategies, there are also uncertainties related to climate projections and whether temperature, for example, may cause a HAB event that would not otherwise happen under slightly cooler conditions. Investment in the development of measurement and modeling tools can help resolve these uncertainties related to salinity management.

Looking ahead to the next four years, as climate-related extremes (e.g., droughts, floods) become increasingly frequent in California, the greatest management challenges require deep understanding of interlinked processes driving the Delta, such that a full spectrum of tradeoffs of management actions can be assessed and multi-agency solutions can be put into place. Thus, **the 2022–2026 SAA is built upon a vision of integration.**

"Integration" in this sense can mean many things:

1. the evaluation of many, simultaneous changes and responses that require multidisciplinary understanding (including social science knowledge, which has long been underutilized in Delta science and management),
2. the weaving together of different forms of knowledge (such as Traditional Knowledge, local community knowledge, and Western scientific approaches),
3. the combination and coupling of models formerly used independently,
4. the assimilation of data into models, and
5. collaborative planning and analysis that spans agencies and interest groups.

The 25 Science Actions in the 2022–2026 SAA work toward achieving an integrative understanding of the Delta at the landscape level and using that understanding to anticipate and plan for the future (see Box 2).

In advancing new basic understanding, setting the stage for synthesis, and producing new tools to evaluate tradeoffs and compare management choices, the Science Actions in the 2022–2026 SAA provide a foundation for achieving policy outcomes called for in the Delta Plan, collaborative interagency groups, and State and federal legislation. **Key policy objectives potentially advanced by the 2022–2026 SAA include improved invasive species management, climate-resilient wetland restoration, native species recovery, improved governance for human health and well-being, and management of HABs.** Further, the emphasis on social science integration and a more inclusive process for producing scientific understanding will serve statewide environmental justice initiatives and broaden the spectrum of the people who are included in Delta science.

Notably, potential science and policy outcomes of the 2022–2026 SAA are not restricted to the legal Delta. Part of "integration" is recognizing that challenges such as adapting to climate change in an equitable manner, managing contaminants and their impacts, anticipating and mitigating HABs, estimating sediment required for long-term survival of marshlands, and engaging a range of people and knowledge bases in the scientific process require coordination across the San Francisco

Bay and Delta (Bay-Delta) from the watershed's headwaters in the Sierra Nevada mountains to the lower portion of estuary in the San Francisco Bay. To that end, this update to the SAA was developed in communication with the 2022 update to the Estuary Blueprint and is synergistic with key actions in that document. **It is our hope and intention that the Science Actions will collectively prompt a greater degree of coordination at the whole-estuary and watershed scales over the next four to five years.**

Box 2

A Vision of Integration

The 25 Science Actions in the 2022–2026 SAA advance a vision of integration through a linked set of approaches that will help advance applied science and science governance that conceptualizes the Delta as a complete social-ecological system. This "systems" view of the Delta embraces the interdependency of processes that affect a range of spatial and temporal scales. The linked approaches detailed here will reduce different types of mechanistic, measurement, and stochastic uncertainty (see page 5), as well as quantify the combined uncertainty associated with management strategies, so that informed risk assessments can be developed to guide policy decisions.

1. **Advance basic understanding of social components of the Delta:** Understanding linked socio-ecological processes requires basic knowledge of the building blocks, both individually and in relation to other building blocks. Applied social science research in the Delta has lagged behind research on biological, physical, or other aspects of the system.

2. **Advance understanding of how different components of the Delta function as a system:** Interactions of multiple components of a system, such as temperature and water residence time, can produce effects different from those expected from studies of these components in isolation (e.g., in this case, stratification that leads to an algal bloom, which drives oxygen to low levels and inhibits fish hatching). Several actions address the need to identify interactive effects, threshold-type responses of some components of the system to small changes and drivers, and dominant drivers of phenomena amidst simultaneous changes in several variables.

3. **Provide accessible, relevant data for measuring the changing Delta:** Synthesis to understand interacting effects requires accessible, long-term data on multiple components of the Delta. The data must be available on time frames reasonable to inform future operations and should be relevant to emerging management concerns, such as HABs, new species invasions, and new contaminants.

4. **Implement adaptive management experiments:** Uncertainty will never be completely eliminated in project planning, necessitating the "action" phase of the adaptive management cycle. Implementation, accompanied by a rigorous program of monitoring, can rapidly reduce multiple types of uncertainty, advancing the next phase of planning and scaled-up implementation.

5. **Develop tools for integrative planning:** Key to assessing tradeoffs and comparing alternative management strategies and policies are modeling tools that enable forecasting and scenario-based projection. For scenarios to be sufficiently informed and for models to be trusted by the community, collaborative approaches to their development are increasingly called for. These tools are dependent on the availability of relevant data and mechanistic understanding of the system, and the approach to their development and use requires social science expertise, so these actions are strongly linked to other components of the vision of integration.

6. **Assess tradeoffs and multiple benefits of planned and ongoing management actions and policies:** Ultimately, all other types of actions in the SAA feed into this goal. Tradeoffs and multiple benefits may be estimated through predictive models or directly measured through observation and adaptive-management experimentation. These assessments will provide some of the strongest scientific bases for decision-making and policy.

The SAA is one component of a science vision for the Delta, that primarily emphasizes immediate science needs. It functions in tandem with the Delta Independent Science Board (Delta ISB) led Science Needs Assessment, which focuses on identifying longer-term science needs and addressing complex and changing problems.[3] With so many short-term science and management needs competing for limited attention and funding, it can be challenging to determine where longer-term, more abstract needs fall in a hierarchy of prioritization. However, by involving not just managers and agency or industry scientists but also academic scientists and the nonprofit sector in the identification of management needs and drafting of Science Actions, we were able to consider needs and gaps applicable to a range of timescales. Certain priority Science Actions in the SAA were directly inspired by the Science Needs Assessment, thereby laying the scientific groundwork for reducing the uncertainty underlying longer-term management needs.

I close this Foreword with a message of thanks and a challenge to the community. First, to all scientists, managers, and other interested parties who participated in any aspect of the intensive process for updating and documenting progress on the 2017–2021 SAA, *thank you!* Your patience with this process and faith in the product ensured that the 2022–2026 SAA is truly representative of diverse voices and the most current priorities. Second, the long-term usefulness of the SAA requires iteration, and the sustainability of the science framework that it supports requires effective communication of findings to the right audiences. Hence, the challenge that I leave you with is to commit to effective communication—of the relevant scientific findings (ideally made publicly available), and/or of the evolving need for science to inform management and policy.

It is a constant pleasure and source of inspiration to serve as a member of this community, which is so committed to finding creative and effective ways to manage the unique, beautiful, and complex landscape that is the Delta.

With deepest respect,

Dr. Laurel Larsen | *Delta Lead Scientist*

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1. Delta Stewardship Council, Delta Science Program. 2021. 2017–2021 Science Action Agenda Progress Summary.
2. California Natural Resources Agency, California Environmental Protection Agency, and California Department of Food and Agriculture. 2020. Water Resilience Portfolio—Governor's Executive Order N-10-19.
3. Delta ISB and DPIIC. 2021. DRAFT Science Needs Assessment: Building an Effective Delta Science Enterprise by Integrating Science for a Changing Delta.

Overview

The SAA is a four- to five-year focused science agenda for the Delta that prioritizes and aligns science actions to inform management decisions, identifies major gaps in knowledge, and promotes collaborative science. Part of a broader Delta Science Strategy (Figure 1), the SAA establishes a foundation for funding critical science investigations. A primary way that the SAA is implemented is by guiding competitive and non-competitive research and fellowship solicitations.

The 2022–2026 SAA is organized around the following six broad Management Needs and their associated Top 25 Science Actions (in no priority order), which collectively articulate major priorities for advancing science-based management in the Delta (List 1). All Management Needs and Science Actions were collaboratively developed with input from the Delta science and management community. Science Actions address areas of uncertainty for Delta management and range in their degree of development and funding.

List 1:

The top 25 Science Actions by associated Management Need. 'Building block' and 'New' symbols (right) distinguish between Science Actions that build on progress from the last SAA and new Science Actions, respectively. This categorization is meant to provide a quick, at-a-glance view of emerging and persisting science needs.

Builds on Past SAA

New Science Action






Management Need 1

Improve coordination and integration of large-scale experiments, data collection, and evaluation across regions and institutions

A. Establish publicly accessible repositories, interactive platforms, and protocols for sharing information, products, and tools associated with monitoring and modeling efforts, in support of forecast and scenario development, timely decision-making, and collaborative efforts

B. Evaluate the individual and institutional factors that enable or present barriers to coordination, learning, trusting, and using scientific information to inform decision-making and resource sharing within and among organizations

C. Identify and implement large-scale experiments that can address uncertainties in the outcomes of management actions for water supply, ecosystem function, and socioeconomic conditions in the Delta

Wastewater treatment plant upgrade to reduce ammonium discharge to the Sacramento River (Photo: Regional San)

Example: When major management actions occur, such as changes to nutrient loading, coordinated science across multiple groups can help to advance a shared understanding of management impacts and generate time and resource efficiencies.

Management Need 2

Enhance monitoring and model interoperability, integration, and forecasting

A. Evaluate and update monitoring programs to ensure their ability to track and inform the management of climate change impacts, emerging stressors, and changes in species distributions

B. Develop a framework for monitoring, modeling, and information dissemination in support of operational forecasting and near real-time visualization of the extent, toxicity, and health impacts of harmful algal blooms (HABs)

C. Enhance flood risk models through a co-production process with Delta communities to quantify and consider tradeoffs among flood risk management, water supply and water quality management, habitat restoration, and climate adaptation

D. Iteratively develop, update, and make widely available forecasts of climatological, hydrological, social-ecological, and water quality conditions at various spatial and temporal scales that consider climate change scenarios

Cyanobacterial HAB in Stockton (Photo: Keith Bouma-Gregson, USGS)

Example: Managing HABs, and the negative impacts they wreak on communities and ecosystems, depends on the availability of data, monitoring, and models that support forecasting.

Management Need 3

Expand multi-benefit approaches to managing the Delta as a social-ecological system

A. Conduct studies to inform restoration and approaches to protecting human communities that are resilient to interannual hydrologic variation and climate change impacts

B. Develop integrated frameworks, data visualization tools, and models of the Delta social-ecological system that evaluate the distribution of environmental benefits and burdens of management actions alongside anticipated climate change impacts

C. Identify how ecosystem restoration projects, in comparison to existing water management strategies, benefit and burden human communities, with an emphasis on environmental justice

D. Test and monitor the ability of tidal, nontidal, and managed wetlands and inundated floodplains to achieve multiple benefits over a range of spatial scales, including potential management costs, tradeoffs, and unintended consequences

E. Synthesize existing knowledge and conduct applied, interdisciplinary research to evaluate the costs and benefits of different strategies for minimizing the introduction and spread of invasive species, and to inform early detection and rapid response strategies

Flooded agricultural field near Lodi (Photo: DWR)

Example: Multi-benefit approaches to restoration can simultaneously provide for agriculture, carbon sequestration, fish and wildlife habitat, water quality, and recreation.

Management Need 4

Build and integrate knowledge on social process and behavior of Delta communities and residents to support effective and equitable management

A. Use multi-method approaches (e.g., surveys, interviews, oral histories, and/or observations) to develop an understanding of how human communities' values, and uses of cultural, recreational, agricultural, and natural resources vary across geography, demographics, and time

Fishing dock near Rio Vista Bridge (Photo: DWR)

B. Synthesize existing data and collaboratively develop additional long-term data collection and monitoring strategies to address knowledge gaps on human communities within the Delta and those reliant on the Delta, with the goal of tracking and modeling metrics of resilience, equity, and well-being over time

C. Measure and evaluate the effects of using co-production or community science approaches (in management and planning processes) on communities' perceptions of governance and on institutional outcomes, such as implementation or innovation

Example: A dearth of social data and research on how people live, work, and interact with the Delta limits effective and equitable management of the system.

Management Need 5

Acquire new knowledge and synthesize existing knowledge of interacting stressors to support species recovery and ecosystem health

Invasive water hyacinth in the Delta (Photo: DWR)

A. Identify and test innovative methods for effective control or management of invasive aquatic vegetation in tidal portions of the Delta under current and projected climate conditions

B. Identify thresholds in the survival and health of managed fish and wildlife species with respect to environmental variables (e.g., flow, temperature, dissolved oxygen) and location-specific survival probabilities to develop strategies that will support species recovery

C. Determine how environmental drivers (e.g., nutrients, temperatures, water residence time) interact to cause HABs in the Delta, identify impacts on human and ecosystem health and well-being, and test possible mitigation strategies

D. Integrate and expand on existing models of hydrodynamics, nutrients, and other food web drivers to allow for the forecasting of the effects of interacting stressors on primary production and listed species

E. Quantify spatial and temporal patterns and trends of chemical contaminants and evaluate ecosystem effects through monitoring, modeling, and laboratory studies

Example: A dearth of social data and research on how people live, work, and interact with the Delta limits effective and equitable management of the system.

Management Need 6

Assess and anticipate impacts of climate change and extreme events to support successful adaptation strategies

A. Evaluate how climate change, sea level rise, and more frequent extremes will impact habitats, water supply, water quality, sediment supply, long-term species persistence, primary productivity, and food webs

B. Evaluate individual and cumulative impacts and tradeoffs of drought management actions on ecological and human communities over multiple timescales

C. Evaluate the possible multi-benefits of management actions that promote groundwater recharge for ecological functions and water resilience under climate change (e.g., multiple dry year scenarios)

D. Identify how human communities connected to the Delta watershed are adapting to climate change, what opportunities and tradeoffs exist for climate adaptation approaches (i.e., agricultural practices, carbon sequestration, nature-based solutions/green infrastructure), and how behaviors vary with adaptive capacity

E. Predict and test how water allocation and supply decisions, and ecological flow scenarios should change under projected climate change to maintain habitat conditions, access of target species to critical habitat, and interactions among native and invasive species

Installation of a temporary emergency drought barrier in the Delta (Photo: DWR)

Example: With climate experts predicting more severe and frequent droughts due to climate change, evaluating and refining our drought management and adaptation toolbox is essential.

Introduction

The purpose of the SAA is to prioritize and align science actions to inform management decisions, identify critical knowledge gaps, build science infrastructure, and foster coordination to address current, persistent, and emerging challenges in the Delta. It also guides decisions about how to allocate funds for critical science investigations for a four- to five-year timeframe. Within this timeframe, the Delta Science Program facilitates the assessment and refocusing of priority Science Actions. Progress is measured on the Science Actions during this period, though they may require continued attention beyond the four- to five-year timeframe. This is particularly true for Science Actions that will provide a foundation from which to address longer-term science and management needs.

The SAA is collaboratively developed with a focus on clearly identifying both short- and long-term knowledge gaps that must be filled to advance management (Appendix A). One goal of the SAA is to highlight questions that reflect the priorities of interagency groups (e.g., Collaborative Science Adaptive Management Program, Delta Interagency Invasive Species Coordination Team), thereby benefitting multiple institutions' mandates and priorities. By their nature, the Needs, Questions, and Actions in the SAA require collective action.

How Does the Science Action Agenda Relate to Other Delta Science and Planning Efforts?

The Delta Science Program leads multiple efforts that support the use of science in the development and implementation of Delta policies and management, as required in the 2009 Delta Reform Act. The SAA is part of the Delta Science Program's overarching **Delta Science Strategy** (Figure 1), intended to guide and support the broad Delta science and management community through **planning, implementation, and reporting.** The three-part strategy establishes a foundation for achieving the vision of ***One Delta, One Science*—an open Delta science community that works together to build a common body of scientific knowledge to inform management.**

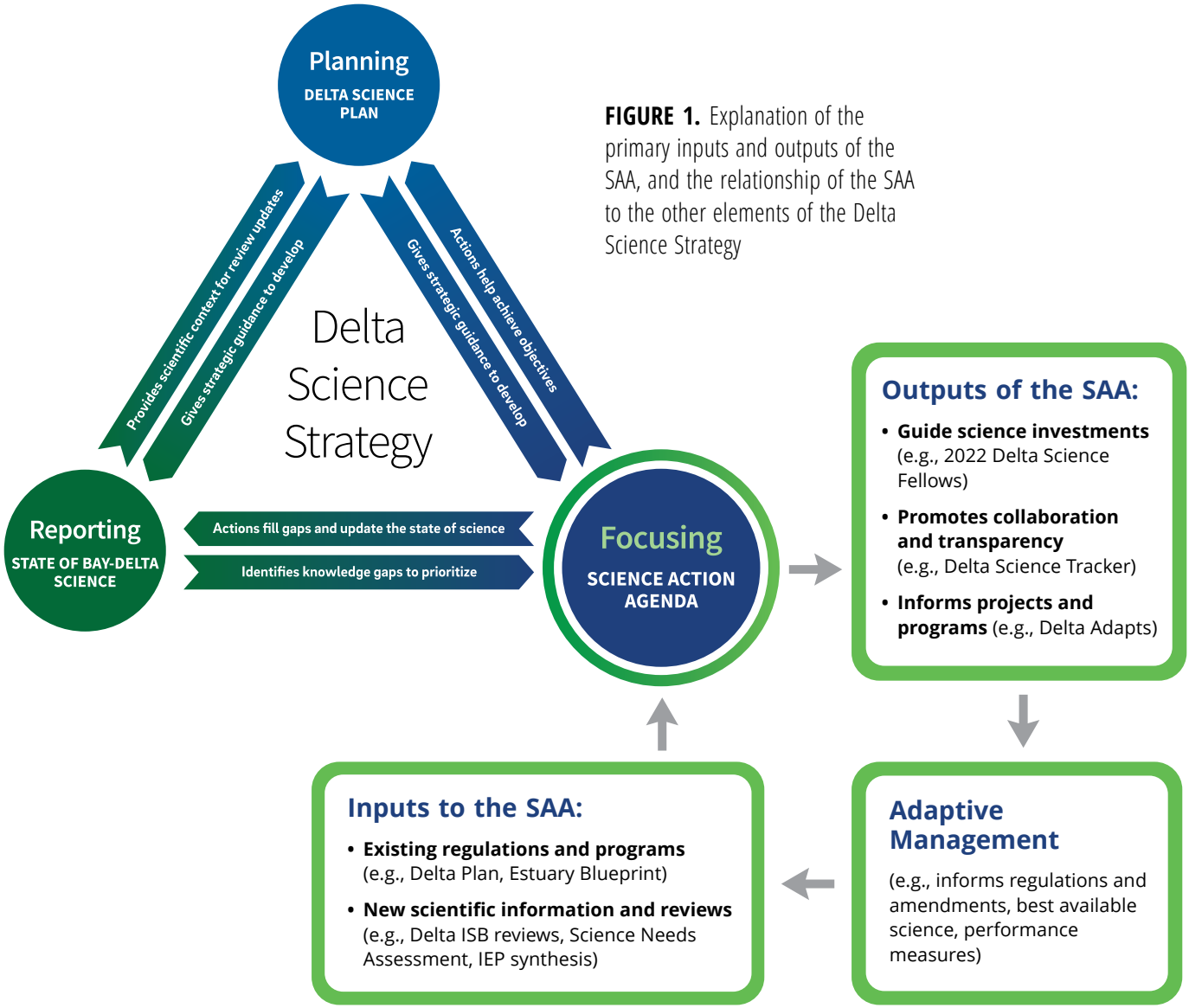
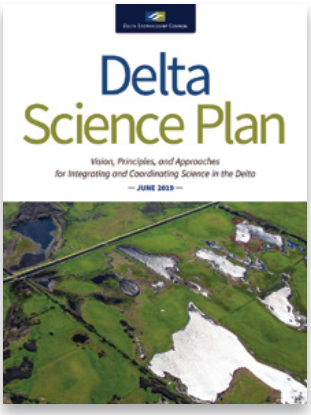


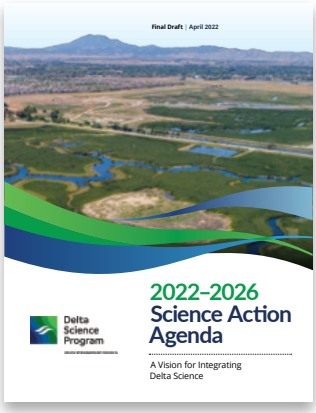
FIGURE 1. Explanation of the primary inputs and outputs of the SAA, and the relationship of the SAA to the other elements of the Delta Science Strategy

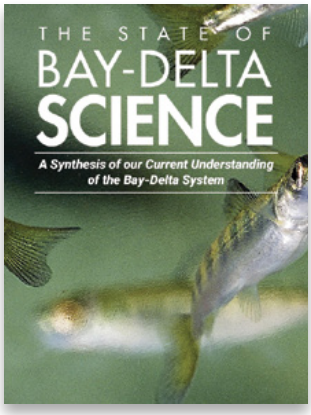
The Delta Science Strategy encompasses three key documents and processes: the **Delta Science Plan** (a strategic plan for advancing the science infrastructure of the Delta for enhanced coordination and collaboration), the **SAA** (to identify, prioritize, and catalyze critical management-relevant science), and the **State of Bay-Delta Science** (or SBDS, which synthesizes the latest understanding of major science themes that have seen significant scientific attention and progress).

These documents are updated every four to five years and inform one another. Examples of how these documents inform subsequent work include initiatives from the Council's Planning Division such as **Delta Adapts**[a] and the Delta Plan **Ecosystem Amendment**.[b]

The SAA is key to achieving the objectives of the Delta Science Plan and informing future iterations of the SBDS. The six objectives in the 2019 Delta Science Plan are to: (1) strengthen science-management interactions, (2) coordinate and integrate Delta science in a transparent manner, (3) enable and promote science synthesis, (4) manage and reduce scientific conflict, (5) support effective adaptive management,







and (6) maintain, communicate, and advance understanding of the Delta. The SBDS is a synthesis and communication effort intended to inform science and policy audiences about the "state of the science" for topics relevant to management of the Bay-Delta system. Science Actions in the SAA help advance the state of knowledge

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a. Delta Adapts: Creating a Climate Resilient Future is a two-phase initiative, encompassing a climate change vulnerability assessment and adaptation strategy, aimed at fostering a comprehensive, regional approach to climate resiliency in the Delta. (https://deltacouncil.ca.gov/delta-plan/climate-change)

b. The Delta Plan Ecosystem Amendment refers to proposed revisions to Chapter 4 of the Delta Plan which aim to achieve a dynamic and resilient restored landscape as envisioned in the Delta Reform Act of 2009. The Ecosystem Amendment portfolio includes protecting and restoring ecosystems and enhancing working or urban landscapes that provide habitat resources to species. (https://deltacouncil.ca.gov/delta-plan/amendments#:~:text=The%20Ecosystem%20Amendment%20portfolio%20includes,provide%20habitat%20resources%20to%20species.&text=The%20Ecosystem%20Amendment%20is%20the,and%20agency%20comments%20and%20coordination)

reflected in SBDS, and likewise the state of knowledge reported in SBDS informs the development of new Science Actions in SAA updates. Furthermore, the SAA builds on itself, as the 2022–2026 SAA incorporates progress made and outstanding gaps from the 2017–2021 SAA (see page 71, Appendix B).

The science catalyzed through the SAA is intended to inform regulations, legislative mandates, guide science investments and to promote collaboration and transparency (see "Outputs" in Figure 1). Further, the SAA is also driven by or contextualized within existing regulations and management plans and programs (see "Inputs" in Figure 1). For example, some actions in the Estuary Blueprint, a planning document to support a healthy and resilient San Francisco Estuary, support Science Actions in the SAA, and vice versa. The connections between Science Actions and relevant policies and management activities or programs are described in further detail in the "Context" column of Tables 1 through 6.

How Does the Science Action Agenda Inform Funding?

The 2017–2021 SAA guided over $35 million of science funding investments through competitive research award processes and targeted studies, with support from the Delta Science Program, the U.S. Bureau of Reclamation (USBR), the California Department of Fish and Wildlife (CDFW), and the State Water Contractors (SWC).

The SAA is especially critical to guiding science funding given that the scale of research needs in the Delta invariably outsizes the scale of science funding available. The SAA provides co-produced and publicly vetted priorities that, along with a rigorous independent review of science proposals, ensures that funding is distributed in a robust and strategic manner that is responsive to management gaps The SAA also helps promote collaboration and transparency by identifying critical topics or challenges that a multitude of researchers and agencies can coalesce around and make progress on together.

How was the Science Action Agenda Developed?

The SAA connects **Science Actions** with high priority **Management Needs.** Developing the 2022–2026 SAA began with crowdsourcing an unprioritized list of **Management Questions,** a new feature to this SAA (see Box 3). The addition of Management Questions was suggested by the Delta Plan Interagency Implementation Committee's (DPIIC)[c] 2019 Delta Science Funding and Governance Initiative, so that the SAA would enhance coordination across the Delta science enterprise and directly inform policy and management.[1] The approach to developing the 2022–2026 SAA leveraged co-production practices to involve managers and stakeholders throughout the entire process to ensure that Science Actions are responsive to Management Needs and Management Questions.

Science Actions respond to Management Needs and are informed by Management Questions (Figure 2). The definition of Science Actions is broad and encompasses activities (e.g., projects, funded research) that yield new information and improve the use of existing information (see Appendix C). Like in the 2017–2021 SAA, the Top 25 Science Actions identified in the 2022–2026 SAA focus on both: (1) generating new information or tools, and/or (2) improving or enhancing the use and reach of scientific information, tools, or knowledge.

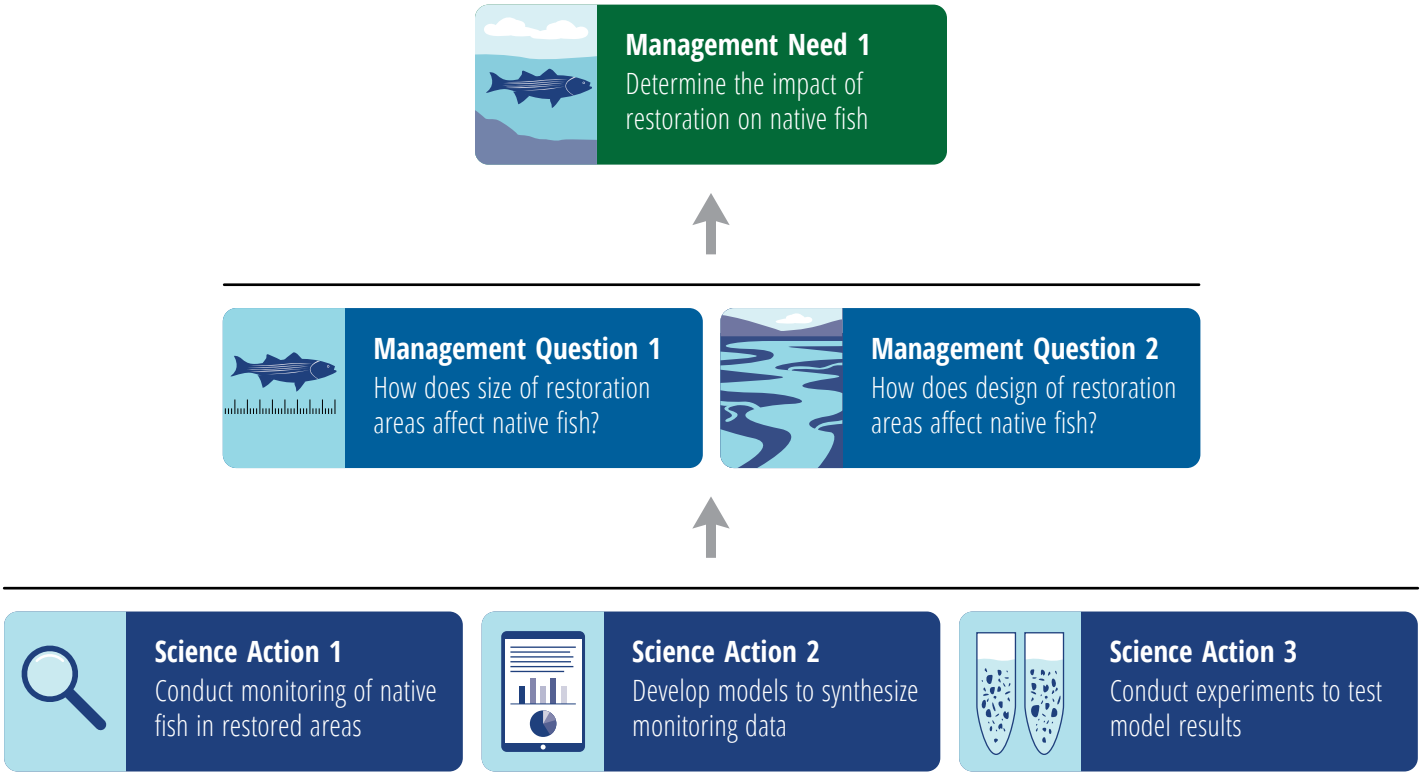
Box 3

Definitions

- **Management Needs** are broad and defined as information necessary to: (1) achieve policy or regulatory objectives, (2) assess the effects of a past or future management action, and/or (3) inform a decision among multiple scenarios.
- **Management Questions** target uncertainty around a given management topic, and often are specific to an entity's or set of entities' priorities. Management Questions generally have system-wide application, and, when answered, provide information that will inform Management Needs.
- **Science Actions** are scientific activities undertaken to generate information or create tools that advance the scientific capabilities to address physical, natural, and socio-economic challenges. Examples include field research, monitoring, modeling, data management, synthesis, adaptive management experiments, new methods, and more.

c. The DPIIC, a legislatively mandated committee of agencies responsible for implementing the Delta Plan, strives to facilitate Delta Plan implementation through collaboration in support of shared national, statewide, and local goals for the Delta.

FIGURE 2. Tiered pyramid diagram with example linking Management Needs, Management Questions, and Science Actions. This diagram is for illustrative purposes only and does not imply one-to-one connections between Science Actions, Management Questions, and Management Needs (Science Actions are responsive to the Management Needs and informed by the Management Questions).



Susan Tatayon

Former Chair of the Delta Stewardship Council

"The rate of change in the Delta watershed is accelerating, and the challenges we face in managing its resources are growing more and more complex. As we grapple with how to create sustainable policies that meet these challenges, relevant science is critical to successful policy decisions. The Science Action Agenda provides a framework for connecting science with policy decisions to shape a more resilient future for the Delta."

The Delta Science Program facilitated a multiple-phase, two-year process to develop the 2022–2026 SAA (see Figure 3, Appendix A). The update process embraced co-production with the Delta science and management community, including members of federal, State, and local agencies, academic institutions, non-profit organizations, and more. **Co-production in natural resource management is defined as the contributions of multiple, different knowledge sources and stakeholders with the goal of co-creating knowledge and information** and was operationalized in this process through extensive engagement and communication activities (see Box 4).[2, 3]

Box 4

Co-production by the Numbers

The 2022–2026 SAA was produced with extensive input and engagement from scientists, managers, and stakeholders throughout the Delta. Types and levels of engagement included...

- **25** online survey responses broadly informed the 2022–2026 SAA development process;
- **30** collaborative groups engaged in the process of identifying Management Questions;
- **1,279** Management Questions were proposed by stakeholders;
- **85+** workshop participants helped distill Management Questions to a top **65 list;**
- **30+** reviewers commented on the 2017–2021 SAA Progress Summary, in addition to **10+** external partners who contributed to the initial draft document;
- **Four** written comments were submitted on the draft Management Needs;
- **50+** Science Action workshop participants drafted **178** Science Actions; and
- **45** individuals responded to the survey on the proposed top **25** Science Actions.

In this context, co-production resulted in a comprehensive set of shared Management Needs, Management Questions, and Science Actions. It is worth noting the challenges and limitations of integrated, collaborative processes, including barriers to participation in the process (e.g., the COVID 19 pandemic may have affected participation) and influences on the discussions and outcomes of the process. Those who attended the virtual public workshops (Appendix A) had the opportunity to influence the outcomes of initial stages (e.g., Management Questions), which directed later stages (e.g., Science Actions). The Delta Science Program worked to provide numerous opportunities for multiple types of input at every stage of the process.

The process began in early 2020 with extensive outreach to members of the Delta science and management community. Delta Science Program staff canvassed networks, created an online survey, searched scientific literature, and engaged with

nearly 30 Delta-relevant collaborative venues to craft an initial set of Management Questions (Appendix D). A survey was circulated via the Council's listserv in the summer of 2020 to solicit general input on the SAA update process and collect proposed Management Questions. At various stages of the process, the Delta Science Program sought input from the Delta ISB[d] and Delta Science Program's Science Advisory Committee.[e]

Staff also coordinated with the Science Needs Assessment work group. This work group, led by the Delta ISB and DPIIC, calls for a long-term, forward-looking strategy to address rapid environmental changes in the Delta.[4, 5] Reviews conducted by the Delta ISB (e.g., on water quality, non-native species) were also a critical source of information on outstanding knowledge gaps.[6, 7]

An iterative, collaborative process was designed based on best practices for identifying science priorities, and included pre- and post-workshop surveying, establishing topic area subgroups, and fostering consensus-based discussion (Appendix A).[8, 9] An initial set of 1,279 Management Questions were refined at a public workshop in September 2020 to generate a final set of 65 Top Delta Management Questions, released in early 2021. The Delta Science Program used a modified content analysis approach,[10, 11] in which each question was coded with key themes that were then used to organize the 65 Top Management Questions into six Management Needs.

The Management Needs, together with the gaps identified in a collaboratively developed and publicly reviewed summary of progress on the 2017–2021 SAA (see page 28), were used to guide the creation of Science Actions, which were drafted, discussed, and refined at a July 2021 workshop (complete list available in Appendix E). Further prioritization and refinement of the over 100 drafted Science Actions were guided by criteria, and the goal of creating integrative Science Actions representative of the many Management Questions. The draft list of criteria was made available for feedback on the Council's website beginning in 2020 and reviewed by participants at the July 2021 Science Actions workshop (Appendix C). This led to the identification of the top 25 Science Actions. These Science Actions will guide funding priorities for the 2022–2026 period (see Box 5).

d. The Delta ISB is a board of nationally and internationally renowned scientists that provide oversight of the scientific research, monitoring, and assessment programs that support adaptive management of the Delta through periodic reviews of each of those programs.

e. The Science Advisory Committee is a volunteer-based, interdisciplinary group of scientists convened to provide expert input and advice to the Delta Science Program.

Box 5

Science Funding

The SAA serves as the foundation for funding critical science investigations in the Delta. In 2021, the Delta Science Program, in collaboration with the USBR and the SWC, awarded $9.6 million for research in the Delta through a competitive proposal solicitation notice (PSN) that required addressing scientific gaps identified in the 2017–2021 SAA. The CDFW also used the SAA for their Watershed Restoration Grants Proposition 1 Program, which totaled roughly $7 million for Delta science. The SAA is used to identify research priorities for the Delta Science Fellows Program (Fellows) in partnership with California Sea Grant (CASG). Over the 2022–2026 timeframe, 20–30 early career science fellows will develop their work based on the SAA.

Year	2018	2019	2020	2021	2021
Award Type	Fellows	PSN	Fellows	PSN	PSN
Award	$1.5 Million	$17 Million	$1.5 Million	$9.6 Million	$7 Million
Funding Partners	Delta Science Program/SWC	Delta Science Program/ USBR/CDFW	Delta Science Program/SWC	Delta Science Program/ USBR/SWC	CDFW

How Should the Science Action Agenda be Used?

Given that the SAA represents shared science priorities of the Delta scientific community, it provides a valuable framework to guide science planning and funding by the Council and its partners.

Specific uses of the SAA include guiding competitive solicitations for science proposals, justifying agency priorities and budget change proposals, coordinating multi-agency efforts, and strategic planning efforts for individual science programs. The SAA also serves as a tool for communicating collaborative Delta science priorities within and outside of the system. The SAA can guide individual and collaborative science organizations to collectively advance scientific insights and ensure a robust science infrastructure for supporting management and policy decision-making.

Randy Fiorini

Former Chair of the Delta Stewardship Council

"The SAA is a tool that is very valuable in identifying science gaps that exist in the Delta that are necessary to be filled to inform management decisions. I want to encourage you to support and participate in the SAA development. It's a very important tool, worthy of your time, effort, and interest."

An additional 26 Management Questions and 75 Science Actions, listed in Appendices E were not prioritized for inclusion in the 2022–2026 SAA, based on the input received during the collaborative process. Appendix E is provided for archival purposes, highlighting other uncertainties and science needs of the Delta science and management community that were articulated during the SAA development process. Though not prioritized for funding for the 2022–2026 period, the Science Actions in Appendix E may inform future SAA updates.

When Will the Science Action Agenda be Updated Again?

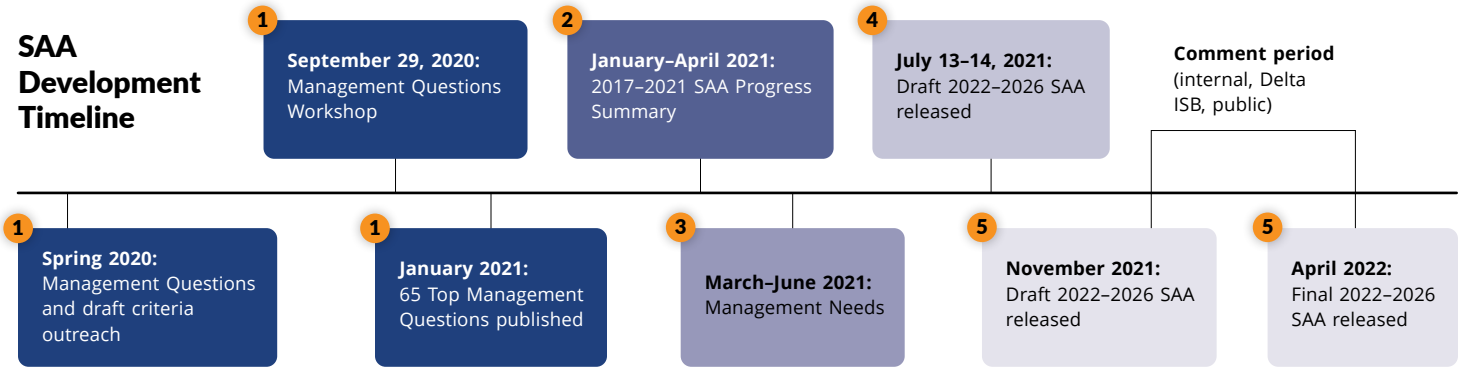
The SAA is updated every four to five years to regularly re-examine collective priorities and consider both persistent and emerging concerns. This edition of the SAA is anticipated to be reviewed and updated by the Delta Science Program beginning in 2025. As was the case with this iteration, the next SAA will be informed by progress made (see page 28) on the current Science Actions and will continue to adapt and respond to emerging needs.

When developing the next SAA, Delta Science Program staff will assess the various tradeoffs associated with the approach to updating the SAA, including the level of co-production, the time and capacity demands of the Delta Science Program and contributing partners, the need for flexibility in the document to account for emerging needs, and other approaches to further strengthen and streamline the SAA for the benefit of the Delta science and management community. The Delta Science Program will continue to adaptively manage the SAA and its associated process to ensure the document maintains its necessary relevance and utility.

2022–2026 Science Action Agenda Update Process

The SAA is a collaboratively developed document that prioritizes and aligns science actions to meet management needs for the Delta. There are three main components to the 2022–2026 SAA—Management Needs, Management Questions, and Science Actions—and the process of identifying each is detailed below. The 2022–2026 SAA also builds on progress made in advancing the 2017–2021 SAA. To learn more about the SAA update, visit https://scienceactionagenda.deltacouncil.ca.gov/ or email SAA@deltacouncil.ca.gov.

FIGURE 3. Infographic describing the process to develop the 2022–2026 SAA



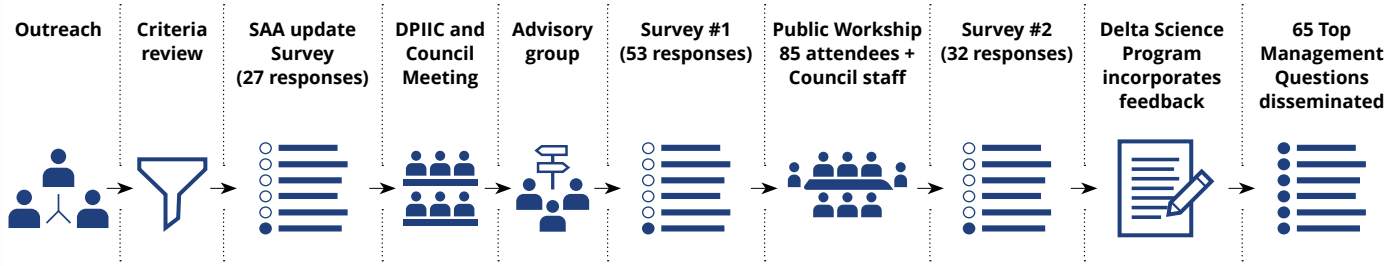
March 2020–January 2021

1

Management Questions

Management Questions target uncertainty around a given management topic, and often are specific to an entity's or set of entities' priorities. Management Questions generally have system-wide application, and, when answered, provide information that will inform Management Needs.

The 2022–2026 SAA update began with identifying priority questions focused on key uncertainties in Delta management that have enterprise-wide application. The questions are the foundation for Management Needs and, ultimately, priority Science Actions. To create the initial Management Questions list, the Delta Science Program engaged over 30 collaborative groups, circulated an online survey, and, in early 2020, reviewed relevant documents and reports. Through this, managers, scientists, and stakeholders submitted 1,279 questions, then pared down via surveys and a workshop to 65 Top Management Questions.



January–April 2021

2

Progress Summary

The Progress Summary provides three key benefits: 1) documents progress made on 2017–2021 SAA Science Actions and activities; 2) informs new actions in the 2022–2026 SAA; and 3) gauges the return on investment for SAA-guided funding efforts.

The Delta Science Program evaluated progress on the 2017–2021 SAA to further the SAA mission and inform the 2022–2026 SAA. In January 2021, the Delta Science Program 1) compiled relevant activities addressing the 25 2017–2021 SAA Science Actions; 2) assigned a progress status (below) to each Science Action; 3) received external input; and 4) identified remaining gaps and Science Actions to fill them for the 2022–2026 SAA.

Nine of the 25 2017–2021 SAA Science Actions saw significant progress, seven saw moderate progress, and nine saw early progress. Over **30 reviewers provided feedback** during the public review period for the draft Progress Summary.

Significant progress with management impact | **Significant progress** | **Moderate progress** | **Early progress**

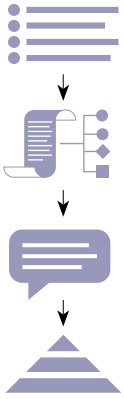
March–June 2021

3

Management Needs

Management Needs are broad and defined as information necessary to: 1) achieve policy or regulatory objectives; 2) assess the effects of a past or future management action; and/or 3) inform a decision between multiple scenarios.

The Delta Science Program staff developed the draft Management Needs based on the 65 Top Delta Management Questions following a modified content analysis approach. Management Needs were inductively developed through an iterative process of coding Management Questions by key management themes and combining similar key management themes to come up with cross-cutting Management Needs. Draft Management Needs were circulated for public review between late May to early June 2021.



65 Top Management Questions

Management Questions coded, sorted, and grouped to identify draft Management Needs

Four public comments received on draft Management Needs

Six Management Needs form foundation for Science Actions

June–September 2021

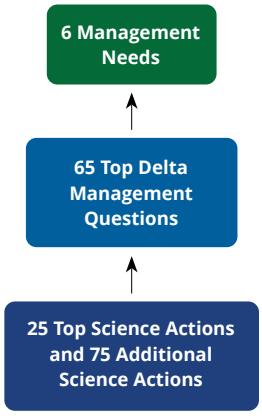
4

Science Actions

Science Actions are scientific activities taken to generate information or create tools that advance knowledge and address the physical, natural, and socio-economic challenges of the Delta. Examples include research, monitoring, modeling, data management, synthesis, adaptive management, new methods, and more.

The July 13 and 14, 2021, workshop focused on collaboratively identifying Science Actions responsive to the six Management Needs. **Over 50 scientists and managers participated in the workshop.**

Science Actions considered the 2017–2021 SAA Progress Summary, and each adhered to three basic criteria: a) yields new information on a science topic not fully addressed; b) has cross-agency or multi-group relevance; and c) is realistic. Following the workshop, the Delta Science Program merged and sorted 178 Science Actions and applied the Prioritization Criteria to identify the top 25 Science Actions to be included in the 2022–2026 SAA. The proposed 25 and additional 66 Science Actions were circulated for public review following the workshop in September 2021. A total of **45 responses** were received, which informed the final 25 Science Actions.



October 2021–April 2022

5

Finalizing the SAA

The Delta Science Program considered the feedback from fourteen individual comment letters, including from the Delta Independent Science Board, in developing the final SAA.

Tracking Success

Progress Summary

Taking stock of the progress made on addressing the 25 Science Actions in the 2017–2021 SAA was critical to informing the development of the 2022–2026 SAA (Figure 4). Progress was assessed through the 2017–2021 SAA Progress Summary (Summary). The Summary also served as a framework for synthesis of science activities in the Bay-Delta community, bringing to light how resources have been focused on each area over time and illustrating potential gaps. The complete Summary is discussed in greater detail in Appendix B. The key steps to developing the Summary were to…

- **compile** relevant activities (e.g., projects, funded research), funded by the Delta Science Program as well as other entities, addressing at least one of the 25 Science Actions during the timeframe of the SAA;
- **assign** a progress status to each Science Action, considering the relevance and status of the activities contributing to the Science Action; and
- **solicit** and receive input from the Delta science community.

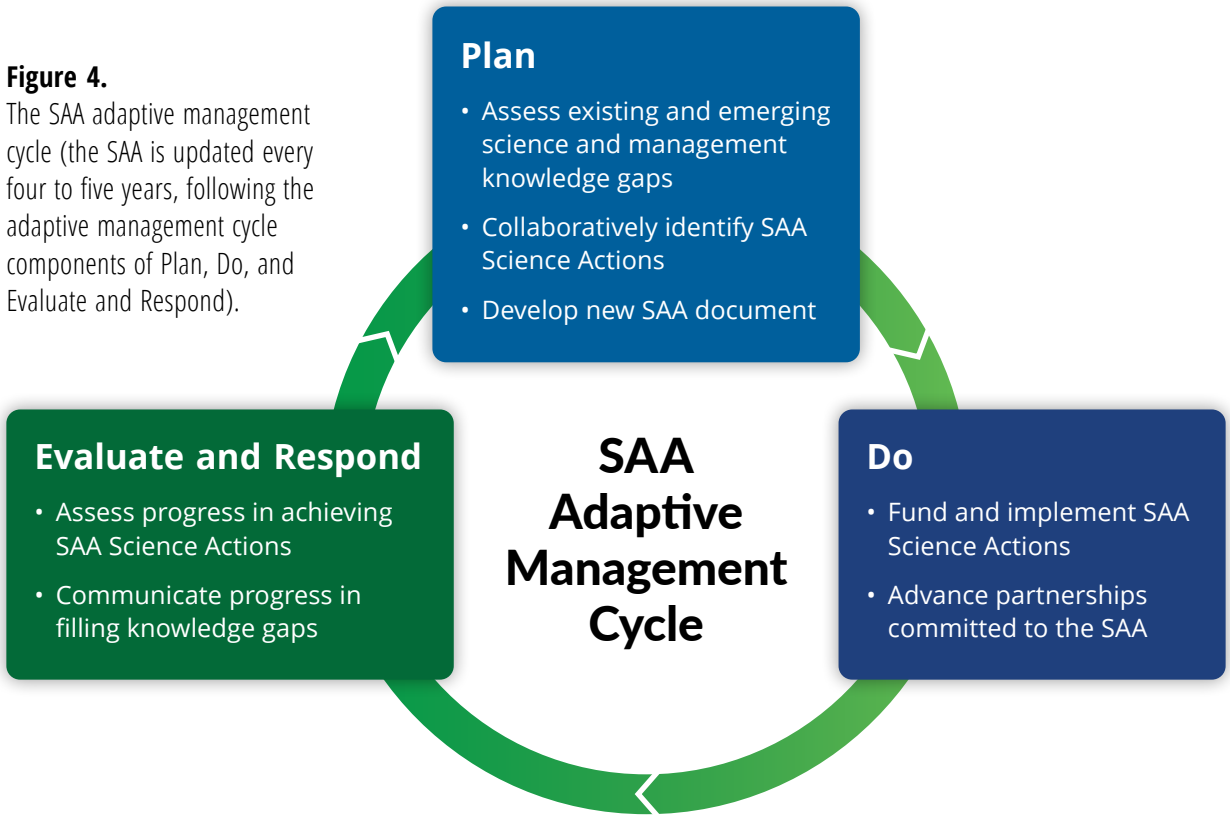


Figure 4.
The SAA adaptive management cycle (the SAA is updated every four to five years, following the adaptive management cycle components of Plan, Do, and Evaluate and Respond).

Among the 25 Science Actions in the 2017–2021 SAA, nine saw early progress, seven saw moderate progress, and nine saw significant progress. To best inform the development of Science Actions for the 2022–2026 SAA, the Delta Science Program identified outstanding gaps (Appendix B). Proposed Science Actions were drafted to address these gaps and provided to participants for consideration at the July 2021 workshop. This helped to ensure that the 2022–2026 Science Actions were informed by outstanding gaps in knowledge from the prior SAA, and all within the context of Management Needs and Management Questions (Appendices B and E).

The 2017–2021 SAA Science Actions called for both the generation of new tools/information (e.g., projects, funded research, modeling, monitoring) and the improvement or enhancement of the use and communication of scientific information, tools, or knowledge (e.g., communication, engagement, visuals). These two types of activities also compose the current list of identified activity types that contribute to the 2022–2026 SAA Science Actions.

Dr. Karsten Baumann provides instruction to graduate research assistants while installing a weather station for field data collection. This research is supported by the Delta Science Program (Photo: Hans W. Paerl).

Management Needs, Management Questions, and Science Actions

The six integrative Management Needs and 65 Top Delta Management Questions identified for the 2022–2026 SAA reflect the complexity of social and environmental challenges and knowledge gaps in the Delta.[f] Many of the Management Needs integrate social-ecological concepts, acknowledging the growing recognition of the importance of social science for understanding and managing the Delta as a social-ecological system.[12] In response to comments from the Delta ISB on the 2019 Delta Science Plan, the SAA explicitly considered Science Actions necessary to tackle climate change impacts.[13, 14, 15] For each Management Need, the relevant Management Questions, priority Science Actions, and relevant Context (e.g., specific knowledge gaps and needs to be addressed by the Science Action, or specific connections to management) are detailed in the sections below. The 26 Management Questions and 75 Science Actions not prioritized for inclusion in the 2022–2026 SAA are listed in Appendix E.

f. One additional Management Question ('How does invasive aquatic vegetation influence consumptive water use at the scale of the Delta?') was added to Management Need 3 in response to public comments, after the publication of the 65 Top Delta Management Questions.

Management Need 1

Improve coordination and integration of large-scale experiments, data collection, and evaluation across regions and institutions

Management Need 1 focuses on reducing uncertainty and building capacity for collaboration and coordination of large-scale experiments, completing the adaptive management cycle, and data collection. Although science in the Delta is coordinated on several fronts, Delta science could more directly inform management and advance more efficiently with increased coordination, communication, and deliberate action to dissolve barriers to collaboration. Effective management in the face of unavoidable uncertainties requires addressing barriers to integrating datasets, disciplines, institutions, and communication efforts throughout the Delta and its watershed.

The below Science Actions outline key steps toward supporting greater integration among agencies and interest groups within the legal Delta, as well as improved coordination between San Francisco Bay and Delta science activities, which has been identified as an important need for enhancing science and management in the Bay-Delta watershed (Table 1).[16]

Relevant Management Questions

- How can large-scale experiments (e.g., pulse flows, aquatic vegetation removal) be coordinated among stakeholders and implemented to test conceptual model assumptions and hypotheses and to inform future management?
- How can collaborative science efforts (e.g., Collaborative Adaptive Management Team, Interagency Ecological Program, Integrated Modeling Steering Committee) and decision-support tools be better supported, communicated, and integrated into management processes to inform science-based decisions?
- How can data availability, analysis, and communication be improved to minimize the effects of Central Valley Project (CVP) and State Water Project (SWP) water operations to Endangered Species Act (ESA)-listed species and improve water supply reliability?
- What key psychological, social, and structural barriers inhibit institutional learning, coordination across diverse stakeholders and agencies, and collaborative management in the Delta?

Table 1. Description of priority Science Actions for Management Need 1, including knowledge gaps and connections to management and the 2017–2021 SAA

#	Science Action	Context
1A	**Establish publicly accessible repositories, interactive platforms, and protocols for sharing information, products, and tools associated with monitoring and modeling efforts, in support of forecast and scenario development, timely decision-making, and collaborative efforts**	There is abundant monitoring data in the Delta, but limited ability or data sharing protocols to integrate across disparate monitoring efforts.[17] There is a need for the establishment of a virtual modeling collaboratory (for sharing models, cloud computing resources) as well as for resources and platforms for interoperable, open datasets and visualization tools for all data covering the Delta, as emphasized by Open and Transparent Water Data Act (AB 1755). In the interim, there is a need for frequent knowledge-sharing opportunities. Regional information repositories such as EcoAtlas and SediMatch could be expanded across the Delta and shared to inform scenario planning and decision-making at a regional scale. This builds on progress made to address Science Actions 2A, 2B, and 5A in the 2017–2021 SAA. Such resources are essential to support forecasting and resource management in a rapidly changing climate.
1B	**Evaluate the individual and institutional factors that enable or present barriers to coordination, learning, trusting, and using scientific information to inform decision-making and resource sharing within and among organizations**	The Delta is managed by many organizations operating at different scales, whose interests, objectives, and institutional structures are not always aligned, creating barriers to progress and coordination. These barriers are also created if the data being used to inform decision-making do not conform to the highest standards of quality. Data quality standards may include, for example, an established Data Management Plan, Quality Assurance Project Plan, appropriate training, and responsiveness to the intended use of the output. Understanding and adapting to institutional complexities that create barriers to progress and coordination will support a more effectively managed Delta and build on progress made to address Science Action 1B in the 2017–2021 SAA.

#	Science Action	Context
1C	**Identify and implement large-scale experiments that can address uncertainties in the outcomes of management actions for water supply, ecosystem function, and socioeconomic conditions in the Delta**	Implementation is often cited as a gap in adaptive management of Delta resources.[18, 19] There is a need for large- and pilot-scale physical experiments that utilize the principles of adaptive management (e.g., summer operation of the Suisun Marsh salinity control gates) and leverage risk analyses and strategic contingency planning, in order to progressively segue to larger scale experimentation and adaptation. Flexibility and efficiency in permitting is also needed (such as through the Cutting the Green Tape Initiative) to enable large-scale experimentation.

Modeling Collaboratory

The need for a virtual collaboratory was highlighted at the Delta ISB's Science Needs Assessment Workshop during the fall of 2020 and identified in priority Science Action 5A in the 2017–2021 SAA.[16] A longstanding idea, this collaboratory would be a virtual platform that could support the collaborative development of interoperable models, enhance the transparency and accessibility of the modeling process, and facilitate data assimilation, synthesis, and visualization. The Delta Science Program and the Integrated Modeling Steering Committee are prioritizing advancement of the virtual collaboratory idea during the timeframe of the 2022–2026 SAA.

Management Need 2

Enhance monitoring and model interoperability, integration, and forecasting

Management Need 2 focuses on advancing modeling, monitoring, and tools to forecast, detect, and respond to changes in the system. In the context of modeling, interoperability and integration refer to coupling different types of models (e.g., of climate, flow, water quality, habitat, or fish). "Integration" refers to the outputs of one model (e.g., flow) being foundational inputs to another model (e.g., water quality). "Interoperability" refers to active communication between models while they run (e.g., a flow model driving changes in submersed aquatic vegetation, which drives further changes in flow). Integration and interoperability can also refer to

the assimilation of monitoring data into models. Forecasting with models relies on historical data and assumptions as inputs to models that predict future conditions and trends to inform management.

Advancements in monitoring and model interoperability, integration, and forecasting should be accomplished in a manner such that the resulting tools are made publicly available and effectively and regularly inform management of the Delta as a social-ecological system (Table 2). Integrated models, for example, can be used to help identify the sensitivity of a management outcome to changes in multiple variables and to facilitate prioritization of the most critical data needs for improved risk assessments. These types of evaluations are particularly relevant as climate change and policy implementation accelerate ecological and social changes in the Delta and its watershed. In this vein, the Delta ISB and DPIIC Science Needs Assessment determined that an integrated forecasting system—such as for anticipating HABs—is a critical need for the Delta.[20] The Science Actions below are highly relevant to work and missions of multiple entities and programs within the Delta, including the Central Valley Regional Water Quality Control Board Delta Nutrient Research Plan and the Delta Regional Monitoring Program.

Relevant Management Questions

- How can monitoring efforts be better designed, facilitated, integrated, and standardized to achieve status-and-trend monitoring objectives (e.g., for aquatic and terrestrial species), and to fit the scale of management actions, timing of ecosystem processes, and climate change challenges?
- How can the Delta science enterprise integrate new tools and real-time forecasting and observations into decision-making for water and ecosystem management?
- How can models and tools necessary to integrate water supply, groundwater, and flood management be supported and developed to evaluate scenarios for Sustainable Groundwater Management Act (SGMA) implementation, climate change adaptation, and management of the Delta for the coequal goals?
- What water quality data (e.g., contaminant bioavailability and toxicity, nutrients, water temperature) should be prioritized to add to Delta ecosystem models to evaluate future ecosystem and management changes?

Table 2. Description of priority Science Actions for Management Need Two, including knowledge gaps and connections to management and the 2017–2021 SAA

#	Science Action	Context
2A	**Evaluate and update monitoring programs to ensure their ability to track and inform the management of climate change impacts, emerging stressors, and changes in species distributions**	Long-term monitoring at appropriate spatial and temporal scales is a critical asset of Bay-Delta science and is pivotal to informing adaptive management via regulatory management requirements.[21] However, monitoring programs and associated regulatory requirements must adapt and continue to incorporate new tools, while still evaluating long-term trends. Building on the progress made to address Science Action 5B in the 2017–2021 SAA, this action stems from collaborative science groups and the Delta ISB who have repeatedly identified this need. Some of these program evaluations are underway through the Interagency Ecological Program (IEP), Collaborative Adaptive Management Team (CAMT), and the Six-agency Redesign process.
2B	**Develop a framework for monitoring, modeling, and information dissemination in support of operational forecasting and near real-time visualization of the extent, toxicity, and health impacts of harmful algal blooms (HABs)**	There is a need for Delta-specific tools to manage HABs that depict current and near future conditions, inform water intake operations, issue public health advisories, and communicate impacts and warnings of HABs.[16] These tools may build on or leverage an existing statewide HABs monitoring framework and incident reporting portal, as well as Delta-specific community-based science.
2C	**Enhance flood risk models through a co-production process with Delta communities to quantify and consider tradeoffs among flood risk management, water supply and water quality management, habitat restoration, and climate adaptation**	Flood risk models have traditionally been limited to assessing hydrologic and physical changes, but these efforts need to be expanded to assess the full suite of flood risk impacts (e.g., on ecosystems and Delta communities, including the distributions of those impacts on underserved communities) and tradeoffs. This action emphasizes the engaged process needed to build buy-in to different management approaches. This action builds on the Council's Delta Adapts initiative and progress made to address Science Action A1C in the 2017–2021 SAA.

Builds on Past SAA | New Science Action

#	Science Action	Context
2D	**Iteratively develop, update, and make widely available forecasts of climatological, hydrological, social-ecological, and water quality and supply conditions at various spatial and temporal scales that consider climate change scenarios**	Although various statewide forecasting tools (e.g., DWR Bulletin 120 hydrologic forecasts, SCHISM, Flood-Managed Aquifer Recharge (Flood-MAR), forecast-informed reservoir operations) already exist, there are gaps (e.g., soil moisture, "thirsty air," soil salinity, ability to meet water allocations, economic revenue) in the availability of products relevant to priority Delta issues and often a need to update the underlying models after putting them to the test against real data. The full potential of many tools will be realized only when used in combination.[22] For example, drought management may be improved by connecting forecasts of invasive aquatic plants and their consumptive water use, flow, salinity, and water quality.

Management Need 3

Expand multi-benefit approaches to managing the Delta as a social-ecological system

Management Need 3 focuses on how the Delta could be managed more comprehensively as a social-ecological system, in a way that is cognizant of interactions among its human, nonhuman, and physical components across spatial and temporal scales. There is a need for more multi-benefit solutions that protect and restore species biodiversity, maintain working lands, and support economic opportunities, especially considering climate change. Such integrated, comprehensive management is called for in Governor Newsom's 2020 Executive Order N-82-20 and is particularly essential when managing large systems with

limited resources. The following Science Actions propose ways to assess tradeoffs, motivate coordination and collaboration across many actors, respond to rapidly changing environmental conditions, and optimize management approaches for multi-benefit objectives (Table 3).

Relevant Management Questions

- How can we achieve floodplain inundation for species recovery, improved ecological processes, and flood control while balancing needs for agriculture, recreation, and other human uses?
- In what ways do different management actions (e.g., restoration, water operations, levee maintenance) affect the risk of species invasions or spread, and what best management practices can minimize that risk?
- How are ecosystem benefits and burdens distributed across the Delta, and what are the drivers of this distribution?
- In non-wet years, what management actions can provide similar ecological benefits to wet year flows, including flow and non-flow actions (e.g., salinity barriers, spring/summer flows, habitation restoration), individually and in combination?
- What are the tradeoffs among native species, nonnative and/or invasive species, and ecosystem function from management actions intending to address the impacts of increased temperatures?
- How do management actions (e.g., source control practices or managed flows) and habitat types influence nutrients, carbon, contaminants, and sediment fluxes in the Delta?
- How do we monitor and evaluate ecosystem restoration outcomes (e.g., for species recovery and ecosystem services), including benefits, detriments, and landscape-scale effects?
- What are the interactions between flow and aquatic and tidal habitat, and how do other stressors influence those interactions (e.g., contaminants, other water quality changes, climate change issues or impacts)?
- What land management actions maximize benefits for sequestering carbon, reducing or reversing subsidence, and reducing flood risk?
- How does invasive aquatic vegetation influence consumptive water use at the scale of the Delta?

Table 3. Description of priority Science Actions for Management Need Three, including knowledge gaps and connections to management and the 2017–2021 SAA

#	Science Action	Context
3A	**Conduct studies to inform restoration and approaches to protecting human communities that are resilient to interannual hydrologic variation and climate change impacts**	This action calls for field, laboratory, and modeling studies that address uncertainties about how sea-level rise, increasing temperatures and hydrologic variability, and changing sediment supply interact with wetland restoration approaches and efforts to protect vulnerable human communities. These studies should consider how outcomes are affected over short and long timescales, and be informed by findings of the Council's Delta Adapts initiative.
3B	**Develop integrated frameworks, data visualization tools, and models of the Delta social-ecological system that evaluate the distribution of environmental benefits and burdens of management actions alongside anticipated climate change impacts**	This action is responsive to calls for conceptual and quantitative models for understanding the coupled human-natural dimensions of the Delta, with a focus on understanding distributive environmental justice and economic impacts.[12] Integrative tools, such as the Central Valley Water and Land Use Futures tool developed by the U.S. Geological Survey (USGS) and Point Blue Conservation Science, can be used to evaluate and assess the likely outcomes (e.g., economic) under different management actions. This action builds on progress made to address Science Action A3B in the 2017–2021 SAA.
3C	**Identify how ecosystem restoration projects, in comparison to existing water management strategies, benefit and burden human communities, with an emphasis on environmental justice**	As a nature-based solution for potentially promoting climate and ecosystem resiliency, habitat restoration needs to be evaluated for its impacts on the Delta's most vulnerable human communities. If burdens to human communities are identified, subsequent research could focus on means to mitigate or lessen those impacts. This action builds on the Delta Adapts initiative, the 2019 review of the Delta Plan that calls for more focus on environmental justice impacts, and on the progress made to address Science Action A3B in the 2017–2021 SAA.

#	Science Action	Context
3D	**Test and monitor the ability of tidal, nontidal, and managed wetlands and inundated floodplains to achieve multiple benefits over a range of spatial scales, including potential management costs, tradeoffs, and unintended consequences**	There is a need to better understand the impacts of restoration projects at different elevations, particularly the cumulative benefits and impacts of restoration on ecosystems at multiple spatial scales. This action calls for additional studies to assess the breadth of possible impacts of restoration and builds on the early progress made to address Science Action 3B in the 2017–2021 SAA.
3E	**Synthesize existing knowledge and conduct applied, interdisciplinary research to evaluate the costs and benefits of different strategies for minimizing the introduction and spread of invasive species, and to inform early detection and rapid response strategies**	It is widely understood that the Delta is host to multiple invasive species and that a proactive approach to control is needed.[7] This action calls for reviewing available science on managing invasive species spread, including a rigorous look at how alternative control strategies might perform, possible non-target effects of different strategies on ecosystems and human uses alike, and how control strategies might be informed by early detection of new invaders.

Management Need 4

Build and integrate knowledge on social processes and behavior of Delta communities and residents to support effective and equitable management

Management Need 4 focuses on improving understandings of social processes and human behavior in the Delta that are crucial to effective and equitable management. It also calls for actions that work to build trust and engage communities, including communities in the Delta, reliant on the Delta, and those with historical ties to the Delta, with a particular focus on historically marginalized or underserved communities. Increased engagement with Tribal governments,

inter-Tribal organizations, and Indigenous community organizations is also a key priority both for relationship-building and to understand the needs and interests of Indigenous peoples with ancestral ties to the Delta. The social sciences provide tools for investigating how people living, working, and recreating in and around the Delta view and interact with the system, how the Delta impacts their health and well-being, and how their behaviors influence environmental issues. Improved understanding of the human dimensions of the Delta are critical to informing more holistic management approaches that incorporate the interactions between human and non-human parts of the system and to optimizing both ecological and human well-being. The following Science Actions encourage use of social science to inform and strengthen management processes and policy decisions (Table 4).

Relevant Management Questions

- How can management activities and policy decision-making in the Delta be informed by environmental justice principles, the values of Delta communities and communities reliant on the Delta, and Local and Traditional Knowledge?
- How are costs and benefits of economic development and ecosystem management distributed across Delta communities?
- How and why do risk perceptions related to climate and environmental changes vary across the Delta's diverse human communities?
- What aspects of the Delta are integral to the values, beliefs, and practices of different human communities, and how have those values, beliefs, and practices changed over time?
- What factors drive the extent to which different Delta communities trust scientists, management agencies, and others who have a stake in the Delta, and what are the most effective approaches for earning and/or building trust?
- What factors explain how information is communicated and used in Delta decision-making processes, and what are effective approaches for enhancing these processes?

Table 4. Description of priority Science Actions for Management Need Four, including knowledge gaps and connections to management and the 2017–2021 SAA

#	Science Action	Context
4A	**Use multi-method approaches (e.g., surveys, interviews, oral histories, and/or observations) to develop an understanding of how human communities' values, and uses of cultural, recreational, agricultural, and natural resources vary across geography, demographics, and time**	There is a need to better understand how human communities, including tribal communities, communities in the Delta, and communities reliant on the Delta use and value different aspects of the Delta, and how uses and values vary in response to environmental and social changes, to inform management, planning, and policy. This action builds on the progress made to address Science Action A1B in the 2017–2021 SAA.
4B	**Synthesize existing data and collaboratively develop additional long-term data collection and monitoring strategies to address knowledge gaps on human communities within the Delta and those reliant on the Delta, with the goal of tracking and modeling metrics of resilience, equity, and well-being over time**	While environmental monitoring in the Delta has been a practice for over 50 years, and despite the long history of human uses and inhabitance of the Delta (e.g., indigenous peoples' presence in the region), assessing the livelihoods, well-being, economy, and recreation of past and present-day human communities in and reliant on the Delta has been lacking. This action calls for establishment of a consistent monitoring and reporting program that tracks and assesses how the Delta's communities are changing over time and is responsive to calls for this work from multiple groups.[12, 17, 22]
4C	**Measure and evaluate the effects of using co-production or community science approaches (in management and planning processes) on communities' perceptions of governance and on institutional outcomes, such as implementation or innovation**	Retrospective assessments of the outcomes of co-production or community science to improve management in the Delta have been limited. This action calls for studies that measure and evaluate the effect of utilizing co-production or community engaged science approaches on outcomes of interest, such as building public trust in government and science, increasing scientific literacy, encouraging civic engagement, improving program implementation, or spurring learning and innovation.[23, 24, 25]

Management Need 5

Acquire new knowledge and synthesize existing knowledge of interacting stressors to support species recovery and ecosystem health

Management Need 5 seeks to reduce uncertainty in approaches to fostering ecosystem health and native species recovery, including identification of dominant stressors and their interactions. Here, "stressor" is defined as any factor that affects the behavior, health, or fitness of a target species. Examples of stressors include both flow (e.g., drought and unintended consequences of flow management actions) and non-flow related factors (e.g., predation, competing species, contaminants,

and limited supplies of food or nutrients). Stressors often co-occur and can have synergistic effects on species populations, but the nature and magnitude of these impacts are not well understood. For example, high variability in hydrologic conditions, driven by climate change, can impact contaminant loading, presenting a need to understand areas of the Delta that are vulnerable to amplified contaminant exposure during extreme events (e.g., droughts, floods). This Management Need recognizes that for some topic areas (e.g., fisheries, water quality), there are long-standing datasets and published work that, when integrated and synthesized, can serve to enhance the knowledge base. In these cases, needed Science Actions may entail data science and synthesis activities to leverage these existing resources. The following Science Actions outline key steps for better understanding the ingredients to species recovery and ecosystem health (Table 5).

Relevant Management Questions

- What are the impacts of existing and changing environmental factors (abiotic and biotic), in combination with other stressors, on the overall viability of all life stages of native species?
- Where, and under what conditions (e.g., habitat, water temperature, trophic interactions, flow, including at known hotspots), do we find increased predation pressure on native aquatic species in the Delta, and can those conditions be altered to reduce this pressure?
- What are the sources, exposure pathways, and impacts of contaminant mixtures on all life stages of native fish species and their food sources in the Delta?
- What levels and types of control for invasive/non-native populations produce the highest cost-effectiveness (e.g., in terms of boating access, fish habitat, food production), with the least ancillary harm?
- How does restoration in key tributaries and the Delta (e.g., wetland habitat) affect food web dynamics and at-risk species recovery, diversity, distribution, and trends?
- How do invasive/non-native species (e.g., plants, invertebrates) influence tidal marsh ecosystem functions critical to ESA-listed species recovery?
- What are successful frameworks for early detection and rapid response (including integrated control strategies) to new invaders and what are the opportunities for improving prevention, monitoring, reporting, and control within the Delta?

- How do microbial communities (e.g., bacteria, picoplankton, and microzooplankton) contribute to trophic interactions in the San Francisco Bay-Delta, and what monitoring efforts are needed to understand their role in the estuarine food web?
- How do growth and survival of wild juvenile Chinook salmon and steelhead vary across the Delta watershed's multiple habitat types?
- How and why do zooplankton communities and primary productivity change with environmental factors, flow actions, and over space and time?

Table 5. Description of priority Science Actions for Management Need Five, including knowledge gaps and connections to management and the 2017–2021 SAA

#	Science Action	Context
5A	**Identify and test innovative methods for effective control or management of invasive aquatic vegetation in tidal portions of the Delta under current and projected climate conditions**	Invasive aquatic vegetation control strategies pioneered and tested in lacustrine (i.e., lake) environments may not work as expected in lotic (i.e., river) and tidal environments, creating a need for new strategies or innovative uses of existing strategies (e.g., physical controls, greater integration of chemical, biological, and mechanical approaches). This action is responsive to a broad need in California to deter invasive species from waterways by improving management.[26] Notably, development of new tools involves evaluation of non-target impacts, particularly on the food web, where recent work suggests complex interactions between chemical controls and plankton.[27] This action builds on the progress made to address Science Action A4B in the 2017–2021 SAA.

#	Science Action	Context
5B	**Identify thresholds in the survival and health of managed fish and wildlife species with respect to environmental variables (e.g., flow, temperature, dissolved oxygen) and location-specific survival probabilities to develop strategies that will support species recovery**	Thresholds are defined as points of rapid change in a response variable (e.g., survival or physiological indicators of health) in response to small changes in environmental drivers (e.g., flow, temperature, dissolved oxygen). Improved species recovery strategies require understanding of these functional changepoints, as well spatial changepoints (i.e., "hotspots"), where factors such as barriers to migration may cause highly localized anomalies in survival probabilities. This action builds on the progress made to address Science Action A4A and A5A in the 2017–2021 SAA.
5C	**Determine how environmental drivers (e.g., nutrients, temperatures, water residence time) interact to cause HABs in the Delta, identify impacts on human and ecosystem health and well-being, and test possible mitigation strategies**	In the Delta, most HABs of concern are formed by cyanobacteria; however, the environmental drivers, human and ecosystem health effects, and well-being impacts are still in need of investigation. This action focuses on clarifying how nutrients, temperature, flows, and water residence time interact to produce blooms at specific locations and times, as well as the impacts of those blooms on human health, well-being, and livelihoods (e.g., impacts to recreation, human health via aerosolized toxins, agricultural water use, subsistence fishing, or other human uses) and ecosystem function. Additionally, effective management of HABs and associated toxins is an area in need of science support. HAB mitigation approaches must be innovative and evaluate the interaction of the approach with other ecosystem features (i.e., aquatic vegetation, nutrient dynamics). This action builds on the progress made to address Science Action 4D in the 2017–2021 SAA.

#	Science Action	Context
5D	**Integrate and expand on existing models of hydrodynamics, nutrients, and other food web drivers to allow for the forecasting of the effects of interacting stressors on primary production and listed species**	Understanding impacts of interacting drivers of food webs (e.g., flow, nutrients, temperature, habitat) on multiple trophic levels requires integrated models, particularly those that focus on processes affecting the base of food webs, at spatial scales appropriate to the species of interest. Additionally, multiple planned management actions aim to enhance food web processes to benefit listed species (e.g., Summer-Fall Flow Actions to benefit Delta Smelt, tidal wetland restoration); integrated models with predictive capacity will help evaluate and compare management scenarios. This action builds on the progress made to address Science Action 4C and A5A in the 2017–2021 SAA.
5E	**Quantify spatial and temporal patterns and trends of chemical contaminants and evaluate ecosystem effects through monitoring, modeling, and laboratory studies**	While contaminant monitoring and targeted studies are ongoing, they tend to be disparate and in need of synthesis to improve the understanding of spatial and temporal variability, the interaction of contaminants with other environmental factors (e.g., flow levels, water temperature), and how contaminant impacts scale to the population level.[6] This action builds on the progress made to address Science Action 4D in the 2017–2021 SAA.

Management Need 6

Assess and anticipate impacts of climate change and extreme events to support successful adaptation strategies

Management Need 6 focuses on uncertainties around climate change impacts in the Delta (e.g., invasive species prevalence and spread, public health and safety, native species management, and water operations) and the need to evaluate methods for adapting to the rapidly changing climate. It calls for new studies and updates to existing scientific paradigms to adequately track rapidly changing and increasingly extreme climate conditions (e.g., frequent droughts and floods) that affect all aspects of the Delta system, including both ecological and human communities.

In addition to tracking rapid change, another focus of Management Need Six is to rigorously compare and evaluate effective approaches to responding to changing conditions while maintaining water supply and ecosystem functioning. The following Science Actions target uncertainties concerning individual and cumulative climate change impacts while considering different adaptation strategies and approaches (Table 6).

Relevant Management Questions

- How will projected environmental changes in the Delta impact human communities, and how can these impacts be communicated and incorporated into proactive, effective, and equitable Delta management decisions?
- How will land use changes, sea level rise, and climate change impact the long-term resilience of critical Delta ecosystem services and native species?
- How can ecological conditions and processes that support self-sustaining natural communities and benefits to public health, safety, and recreation be enhanced to support resilience to climate change?
- What are the effects of extreme climatic conditions (e.g., drought, atmospheric rivers) on food web dynamics and aquatic and terrestrial species habitat, survival, and migration patterns?
- How and why are different human communities in the Delta and reliant on the Delta currently adapting or not adapting to climate change, and what are the barriers communities face to adaptation?
- How will invasive species management approaches need to adapt to climate change?

Table 6. Description of priority Science Actions for Management Need Six, including knowledge gaps and connections to management and the 2017–2021 SAA

#	Science Action	Context
6A	**Evaluate how climate change, sea level rise, and more frequent extremes will impact habitats, water supply, water quality, sediment supply, long-term species persistence, primary productivity, and food webs**	This action calls for additional studies that improve our ability to understand and anticipate the changes to the Delta ecosystem that are underway or likely to occur under future climate conditions and extreme events (e.g., droughts, floods). These studies would help to ensure that monitoring and research address and track change and emerging uncertainties, to inform management. This action builds on the progress made to address Science Action 3B, 4B, and 4C in the 2017–2021 SAA. These studies should be informed by findings of the Council's Delta Adapts initiative.
6B	**Evaluate individual and cumulative impacts and tradeoffs of drought management actions on ecological and human communities over multiple timescales**	Current knowledge gaps include understanding how drought management actions impact habitat, species, and the economics, livelihoods, and wellbeing of human communities in and reliant upon the Delta, as well as how these management actions influence the interactions and feedbacks between human and ecological components of the system. This action calls for studies that assess the synergies and tradeoffs of different drought management actions, especially with alternate sequencing of wet and dry years.

#	Science Action	Context
6C	**Evaluate the possible multi-benefits of management actions that promote groundwater recharge for ecological functions and water resilience under climate change (e.g., multiple dry year scenarios)**	Some studies of the benefits of groundwater recharge for ecological and economic benefit have occurred, but how groundwater recharge can be managed to maximize synergies between the two, and in different types of water years, remains a gap. This action calls for more specific studies to understand the multiple benefits and impacts of groundwater recharge projects both within and between regions, consistent with existing mandates responsive to SGMA implementation and the 2020 Water Resilience Portfolio. Evaluations can inform future drought response and planning efforts (e.g., Flood-MAR).
6D	**Identify how human communities connected to the Delta watershed are adapting to climate change, what opportunities and tradeoffs exist for climate adaptation approaches (i.e., agricultural practices, carbon sequestration, nature-based solutions/green infrastructure), and how behaviors vary with adaptive capacity**	There is a need to understand how people are adapting to climate change impacts, both within the Delta and in communities that are dependent on or connected to the Delta. A large gap in knowledge includes understanding what people are currently doing to adapt, what opportunities exist for adaptation, and how different communities are or will adapt differently based on their financial, social, and technical capital. This action builds on the progress made to address Science Action A1A in the 2017–2021 SAA.
6E	**Predict and test how water allocation and supply decisions, and ecological flow scenarios should change under projected climate change to maintain habitat conditions, access of target species to critical habitat, and interactions among native and invasive species**	Understanding how climate change will compound and complicate challenges related to water allocation and ecological flow, and in turn how associated water allocation and ecological flow decisions will affect species and habitat, remains a major knowledge gap. This action seeks studies that analyze these interactions and builds on the progress made to address Science Action 4C in the 2017–2021 SAA, as well as on the Computational Assessments of Scenarios of Change for the Delta Ecosystem.

Next Steps

From 2022 to 2026, the SAA will be used to guide competitive science funding (e.g., biennial CASG Science Fellows and proposal solicitations) and non-competitive science funding (e.g., Directed Actions) by the Council and other funding agencies (e.g., USBR, CDFW, SWC). The SAA will also help to shape program priorities across Bay-Delta agencies and foster science coordination and transparency. The Delta Science Program will track progress made on implementing the Science Actions in the 2022–2026 SAA, including through the use of the Delta Science Tracker, a web-based tracking tool released in 2022. Progress on the Science Actions will play a critical role in implementing and informing the next Delta Science Plan, anticipated for release in 2024.

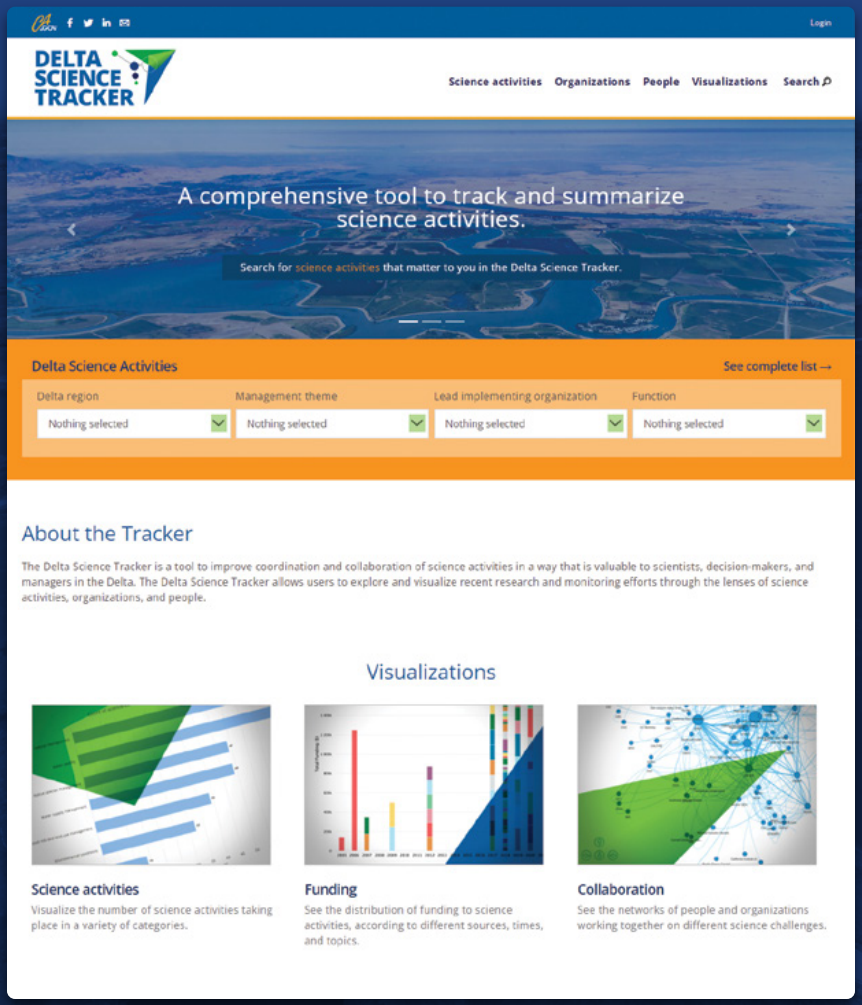
Some efforts and collaborative discussions that are responsive to the SAA are already underway. For example, interagency teams are planning independent science workshops to advance a shared understanding of HABs, to identify next steps for developing a platform for integrated modeling, and to evaluate salinity management scenarios during drought. Additionally, ongoing research to support species recovery that is aligned with the SAA is being conducted in response to the Biological Opinions (e.g., experimental releases of cultured Delta Smelt, and development of adaptive management plans to evaluate flow actions). This collaborative work, in addition to newly funded science activities over the term of this new SAA, will inform the Delta Science Program's work to track implementation progress across the many agencies and groups that are involved. As with this SAA, the tracking and communication of progress will inform the development of the next SAA as a centralized and continuing framework for current and cross-cutting science priorities for the Delta.

Tracking SAA Implementation with the Delta Science Tracker

Communication and collaboration are critical to fostering science that informs management. But this is easier said than done given the multiple agencies and individuals who do science or are responsible for management in the Delta. The Delta Science Tracker (Tracker), deployed in Spring 2022 by the Delta Science Program, seeks to address barriers to communication and collaboration by providing an online portal for tracking science efforts in the Delta, including how activities are responsive to the SAA.

Identified in the DPIIC Science Funding and Governance Initiative and the 2019 Delta Science Plan, the publicly searchable Tracker enables rapid information gathering about different types of funded activities and the products generated through those activities.[4] The Tracker allows scientists to learn about who else is conducting related work and to identify collaborators, while managers and project proponents can access recent, best available science on various topics of interest, and visualize funding streams.

Projects uploaded to the Tracker can be sorted by relevant Action Areas from the previous 2017–2021 SAA and Management Needs from the 2022–2026 SAA. Contributions of projects to the Tracker by the Delta science and management community will facilitate the assessment of progress made on 2022–2026 SAA.



Guide to Acronyms

AB	Assembly Bill
CalEPA	California Environmental Protection Agency
CAMT	Collaborative Adaptive Management Team
CASG	California Sea Grant
CDFW	California Department of Fish and Wildlife
CNRA	California Natural Resources Agency
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
Delta ISB	Delta Independent Science Board
DPIIC	Delta Plan Interagency Implementation Committee
DSP	Delta Science Program
DWR	California Department of Water Resources
ESA	Endangered Species Act
Flood-MAR	Flood-Managed Aquifer Recharge
HABs	harmful algal blooms
IAMIT	Interagency Adaptive Management Integration Team
IEP	Interagency Ecological Program
MAST	Management, Analysis, and Synthesis Team
PSN	Proposal Solicitation Notice
RMP	Regional Monitoring Program
SAA	Science Action Agenda
SAIL	Salmon and Sturgeon Assessment, Indicators, Life Stages
SBDS	State of Bay Delta Science
SFEI	San Francisco Estuary Institute
SGMA	Sustainable Groundwater Management Act
SWC	State Water Contractors
SWP	State Water Project
USBR	U.S. Bureau of Reclamation
USGS	U.S. Geological Survey

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Hyperlinks

- Delta Reform Act (Act), https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=200920107AB12 (page 5)
- Water Resilience Portfolio, https://resources.ca.gov/Initiatives/Building-Water-Resilience/portfolio (page 6)
- Estuary Blueprint, https://www.sfestuary.org/estuary-blueprint/ (page 8)
- Delta Science Strategy, https://deltacouncil.ca.gov/delta-science-program/delta-science-strategy (page 17)
- 65 Top Delta Management Questions, https://scienceactionagenda.deltacouncil.ca.gov/pdf/2021-1-13-mqs-tops-questions-list.pdf (page 23)
- 2017–2021 SAA Progress Summary, https://scienceactionagenda.deltacouncil.ca.gov/pdf/SAA-Progress-Summary.pdf (page 28)
- Open and Transparent Water Data Act (AB 1755), https://water.ca.gov/ab1755 (page 32)
- EcoAtlas, https://www.ecoatlas.org/regions/ecoregion/bay-delta (page 32)
- SediMatch, https://www.sfei.org/projects/sedimatch-web-tool (page 32)
- Suisun Marsh salinity control gates, https://water.ca.gov/News/Blog/2020/Nov-2020/Salinity-Gates (page 33)
- Cutting the Green Tape Initiative, https://resources.ca.gov/Initiatives/Cutting-Green-Tape (page 33)
- Delta Nutrient Research Plan, https://www.waterboards.ca.gov/centralvalley/water_issues/delta_water_quality/delta_nutrient_research_plan/ (page 35)
- Delta Regional Monitoring Program, https://deltarmp.org/ (page 35)
- Monitoring framework, https://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/1141_FHABStrategy_FullReport.pdf (page 36)
- Incident reporting portal, https://mywaterquality.ca.gov/habs/index.html (page 36)
- DWR Bulletin 120, https://cdec.water.ca.gov/snow/bulletin120/ (page 37)
- SCHISM, https://water.ca.gov/Library/Modeling-and-Analysis/Bay-Delta-Region-models-and-tools/SCHISM (page 37)
- Flood-Managed Aquifer Recharge (Flood-MAR), https://water.ca.gov/programs/all-programs/flood-mar (page 37)
- Executive Order N-82-20, https://www.gov.ca.gov/wp-content/uploads/2020/10/10.07.2020-EO-N-82-20-.pdf (page 38)
- Central Valley Water and Land Use Futures tool, https://wim.usgs.gov/geonarrative/centralvalleyfutures/ (page 40)
- Computational Assessments of Scenarios of Change for the Delta Ecosystem, https://www.usgs.gov/mission-areas/water-resources/science/cascade-computational-assessments-scenarios-change-delta (page 53)

Dr. Oikawa and her team install equipment used to produce the first ever, multi-year data set of the complete carbon budget of a Bay-Delta tidal marsh. This research is supported by the Delta Science Program (Photo: Patty Oikawa).


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Appendix A: SAA Development Process

Background

To date, the 2017–2021 SAA has successfully guided over $35 million of science investments in the Delta. Pursuant to the 2019 Delta Science Plan's Action 2.2 calling for "inclusive development and continued implementation of the SAA," the 2022–2026 SAA seeks to capture and spotlight new, persistent, and emerging knowledge gaps. The primary entities responsible for updating the SAA include the Delta Science Program, the Delta Agency Science Workgroup (a body of scientists from DPIIC agencies), and action participants including the wider Delta science community. Building on the success of the 2017–2021 SAA, this update strove to raise the bar further still with the level of co-production carried out throughout the process, by including broad agency and stakeholder input. The steps below outline the approach led by the Delta Science Program to update the SAA between early 2020 and early 2022.

Outreach and Engagement

The process for updating the SAA was designed to be collaborative, transparent, and robust. Informed by input from public workshops, surveys, presentations, and meetings, this shared research agenda captures a wide range of perspectives. Early outreach meetings consisted of presentations and discussions with over 30 collaborative venues in the Delta (e.g., Collaborative Adaptive Management Team, Interagency Adaptive Management Integration Team). These discussions covered the background, scope, and timeline of the SAA. The Delta Science Program solicited individuals and groups for early input on the proposed screening and prioritization criteria and possible sources of management questions (e.g., recent reports and publications). In addition, nearly 30 documents were reviewed for potential management questions (Appendix D).

In summer 2020, Delta Science Program staff presented the updated approach to the Council and DPIIC. DPIIC members were surveyed for potential Management Questions and were asked how they use the SAA. A public survey was circulated via the Council's listserv to solicit input on the SAA more broadly and to gather proposed Management Questions. Respondents were asked how their organization

used the 2017–2021 SAA, how well the SAA is meeting its goal of organizing and catalyzing scientific actions in the Delta, and how many top Management Questions should be considered as part of the process. A total of 27 survey responses were received. Most respondents were very or somewhat familiar with the SAA, and 67% agreed or strongly agreed that the SAA is meeting its objective of organizing and catalyzing scientific actions to address priority management needs in the Delta. When asked how organizations use the 2017–2021 SAA, the top answers were: (1) to create partnerships/collaborations (52%), (2) to inform research and monitoring design (33%), and (3) to prioritize funding (33%).

Identifying Management Questions (March 2020–January 2021)

To create the initial list of Management Questions, the Delta Science Program reviewed background literature on best practices for collaboratively identifying research priorities,[1, 2] engaged over 30 collaborative groups, circulated an online survey to the Delta community, and reviewed relevant documents and reports. Through this effort, 1,279 Management Questions were initially compiled.

Table 1. Management Questions distillation process

Management Questions Count	Delta Science Program Method	Outcome
1,279	Staff solicited and compiled management questions from meetings, documents, and surveys.	Submitted questions sorted into Management Need, Management Question, Science Action; 12 Science Actions removed
1,267	Staff in teams of two scored questions based on publicly-vetted screening criteria.	Removed 14 Management Questions that did not pass screening criteria
1,253	Staff in teams of two assigned screened Management Questions to draft themes; consulted full group when necessary; finalized themes.	Management Questions organized into themes (placed into two themes, if relevant to both)
1,335	Staff assigned "merger" and "reviewer" to each management theme; after merger proposed merging of questions, reviewer accepted, declined, or clarified the suggestions.	Merged similar Management Questions to reduce redundancies; 154 Management Questions removed
1,181	Staff sorted draft list of Management Questions into nine management themes rated in pre-workshop survey for consideration at September 2020 workshop.	87 workshop participants weighed in on Management Questions
110	Staff incorporated workshop feedback to shorten list; 110 Management Questions were sent via post-workshop survey to participants for final review.	Received 53 survey responses
65	Staff incorporated post-workshop survey feedback and disseminated list.	Management Questions sorted by number of themes and weighted average from survey

The Delta Science Program hosted a workshop with over 85 participants from federal, State, and local agencies, academia, non-governmental organizations, and water entities on September 29, 2020, to discuss, edit, and prioritize the list of 1,181 Questions (Table 1). Participants from the 2019 DPIIC Science Funding and Governance Initiative helped guide workshop planning. Members included Kate Spear (National Oceanic and Atmospheric Administration), Darcy Austen (SWC), Sheila Green (Westlands Water District, WWD), Terry Mitchell (Regional San), Michael Roberts (DWR), Scott Petersen (San Luis Delta Mendota Water Authority), Shelley Ostrowski (WWD), and Amanda Bohl (Council). Over the course of two meetings, committee members weighed in on (1) the themes for sorting Management Questions for the September 2020 workshop, (2) the workshop agenda, and (3) the organization of Management Questions in the pre-workshop survey. The breakdown of workshop participants by affiliation is listed in Table 2 and does not include 19 staff from the Council's Planning & Performance and Science Divisions who facilitated the workshop's nine concurrent breakout sessions.

Following the workshop and nearly 10 months of collaborative and transparent work, a list of 110 Management Questions was produced and circulated to participants for public input. The Delta Science Program considered the feedback from 53 respondents, applied selection criteria to consider which Management Questions were most pressing for the SAA and released the list of 65 Top Delta Management Questions. Details on the selection criteria and methods used to prioritize these Science Actions are explained in Appendix C.

Table 2. Number of public workshop participants by affiliation

Affiliation Type	September 2020 Management Questions Workshop	July 2021 Science Actions Workshop
Academia	4	11
Federal agency	12	10
NGO/Consulting/ Other	7	9
State agency	51	16
Water/local agency	13	8
Total	**87**	**54**

After releasing the 65 Top Delta Management Questions, the Delta Science Program began the process of organizing the Management Questions into broader Management Needs.

Assessing Progress on the 2017–2021 SAA (March–June 2021)

The Delta Science Program assessed progress toward completing the Science Actions identified in the 2017–2021 SAA to inform the 2022–2026 SAA. The Progress Summary (Summary) compiled relevant activities contributing to the 25 Science Actions in the 2017–2021 SAA and included a high-level description of progress made and a status for each Science Action. The Delta Science Program circulated a draft Summary for public review in late April through early May 2021. The public comments received via an online survey and from targeted outreach to subject matter experts was used to inform the Science Actions Workshop in July 2021. See additional details in Appendices B and E.

Developing Management Needs (April–June 2021)

Management Needs were developed through an iterative process of coding Management Questions by keywords and management themes and combining similar key management themes to come up with cross-cutting Management Needs.[3, 4] Four Delta Science Program scientists then independently sorted Management Questions into draft Management Needs. Discrepancies in how Management Questions were categorized were discussed until consensus on categorization was reached and then further reviewed by five members of the Delta Science Program leadership team. Finally, wording for the draft Management Needs was reviewed to ensure each appropriately encompassed all associated Management Questions. The draft Management Needs were circulated for public review in late May and early June 2021.[5] Only minor changes were made to the Management Needs' phrasing following feedback received at the Science Actions workshop and via the public comment period, which generated four written comments.

Identifying and Refining Science Actions (July–September 2021)

On July 13 and 14, 2021, the Delta Science Program hosted the Science Actions Workshop. The goal of the workshop was to identify Science Actions that were responsive to the six Management Needs that stemmed from the 65 Top Delta Management Questions developed in 2020.

Workshop participants, including scientists and managers from multiple affiliations (Table 2) and engaged with nearly 30 collaborative venues in the Bay-Delta (e.g., Delta Regional Monitoring Program [RMP], California Water Quality Monitoring Council, CAMT), developed 178 Science Actions responsive to the six Management Needs (Table 3). Delta Science Program staff then merged, refined, and scored the Science Actions based on publicly vetted prioritization criteria (Scientific Relevance, Impact, Timeliness, Ability to Create Collaboration/Change, and Risk/Opportunity Cost). A total of 91 Science Actions, 25 of which were proposed for the 2022–2026 SAA based on their high scores, were circulated via an online survey for feedback.

The purpose of the survey was to receive final input from workshop participants on the priority and wording of the top 25 Science Actions. Participants could also propose elevating any of the 66 extra Science Actions to the top 25 list. This feedback was incorporated by the Delta Science Program in developing the final list of Science Actions for the SAA. This included reviewing the list of 13 Science Actions that received low scores based on the prioritization criteria to determine which were relevant for inclusion in Appendix E of this document. Methods used to prioritize these Science Actions are explained in Appendix C.

Table 3. Science Actions distillation process

Science Actions count	Delta Science Program Method	Outcome
150	Staff circulated a pre-workshop survey for registrants to propose Science Actions responsive to the six Management Needs.	>150 submitted Science Actions were sorted by Management Need and made available to workshop attendees.
178	Staff hosted concurrent breakout sessions by Management Need for Science Actions to be developed by participants at July 2021 workshop.	Participants proposed nearly 300 Science Actions on day one and refined them to 178 by day two.
104	Staff merged (to reduce redundancies), edited, and sorted the set of Science Actions, then applied the prioritization criteria.	A total of 13 Science Actions received low enough scores to not be circulated to participants for review.

Science Actions count	Delta Science Program Method	Outcome
91	Staff disseminated a post-workshop survey with the Science Actions that passed the prioritization criteria to workshop participants; the survey was structured to focus input on the proposed top 25 Science Actions.	Staff received 45 survey responses.
66	The 66 Extra Science Actions (not proposed for the Top 25) were circulated to workshop participants for reconsideration.	Four Science Actions were moved from the Extra to Top 25 Science Actions list.
25	Staff incorporated feedback from survey respondents and refined the list of Top 25 Science Actions.	Top 25 Science Actions were included in SAA.
75	Extra Science Actions provided in Appendix E include the 66 Science Actions provided to survey respondents and nine that scored low during the prioritization process.	Upon additional review, four Science Actions that scored low during the prioritization process were removed entirely.

The breakdown of workshop participants by affiliation is listed in Table 2 and does not include 19 staff from the Council's Planning and Science Divisions who facilitated the workshop's nine concurrent breakout sessions.

Public Comment on the Draft SAA (November 2021–January 2022)

The draft 2022–2026 SAA was released for public review on November 18, 2021, and made available for comment through January 21, 2022. The announcement was shared via the Council's listserv and website, via targeted emails to collaborative venues, and the draft was presented at public (DPIIC, Council) and other collaborative group meetings during the fall of 2021. Thirteen individual comments were submitted during the public review period for the draft SAA. The comments generally highlighted the need to better connect the prioritized Science Actions to relevant legislation, regulations, and existing programs, suggested minor revisions to the Science Actions, and supported the co-production process and integration of social science throughout the priorities. Comments can be viewed at: https://deltacouncil.box.com/s/l4jvjec7g5j4mtwr87q5p2i27p43usna.

Delta Independent Science Board Comments on Draft SAA (January 2022)

The Delta ISB conducted a review of the draft 2022–2026 SAA and submitted comments to the Delta Science Program on January 28, 2021. The review addressed three parts: science agenda, process and documentation, and suggestions for future approaches. Major comments included the need to strengthen the connection of the SAA to the vision and goals of other established science and management efforts (e.g., Delta Plan, Delta Science Plan), clarification on the temporal scope and scale of the Science Actions, more emphasis on water supply, synthesis, integrative modeling, and drought, and expansion on how the progress made on the 2017–2021 SAA directly influenced the selection of priority Science Actions for the 2022–2026 SAA. In response to these comments, the wording of some Science Actions and one Management Need was modified, and multiple revisions were made to clarify the Foreword, Introduction, and body of the report. Specifically, integration was highlighted in the Foreword as a major guiding principle used for developing the SAA and priority Science Actions, and information on "outstanding gaps" related to progress on Science Actions from the 2017–2021 SAA was added to Appendix B.

Modifying the SAA Based on Comments (January–March 2022)

Significant revisions that were made to the report in response to comments from the public review period include: text revisions to Science Actions and the addition of clarifying language to the Context for each Science Action; expansion of linkages between the SAA and existing or planned regulations, mandates, and programs; and language to further promote human dimension aspects in the Science Actions. Text revisions were made to some Management Questions and one Management Question ('How does invasive aquatic vegetation influence consumptive water use at the scale of the Delta?') was added to Management Need 3.

Delta Stewardship Council "Acceptance" (March–April 2022)

Delta Science Program staff presented the draft 2022–2026 SAA to the Council at the December 2021 meeting and invited comment from Council members and the public. Following the public review period and final editorial process, the Delta Science Program asked the Council to "receive and accept" the final 2022–2026 SAA at the April 2022 Council meeting. The final SAA was also scheduled to be presented to the Collaborative Science and Adaptive Management Program and DPIIC in spring/summer 2022.

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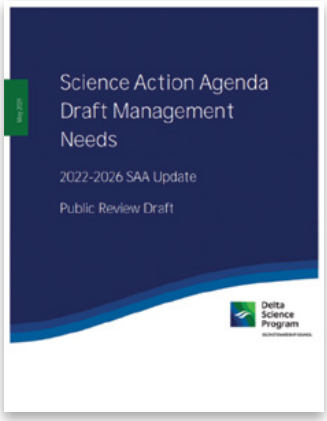
1. Sutherland, W.J., Fleishman, E., Mascia, M.B., Pretty, J., and Rudd, M.A. 2011. Methods for collaboratively identifying research priorities and emerging issues in science and policy. Methods in Ecology and Evolution 2: 238–247. doi: 10.1111/j.2041-210X.2010.00083.x.
2. Fleishman, E., Blockstein, D.E., Hall, J.A., Mascia, M.B., Rudd, M.A., Scott, J.M., Sutherland, W.J., Bartuska, A.M., Brown, A.G., Christen, C.A., Clement, J.P., Dellasala, D., Duke, C.S., Eaton, M., Fiske, S.J., Gosnell, H., Haney, J.C., Hutchins, M., Klein, M.L., Marqusee, J., Noon, B.R., Nordgren, J.R., Orbuch, P.M., Powell, J., Quarles, S.P., Saterson, K.A., Savitt, C.C., Stein, B.A., Webster, M.S., and Vedder, A. 2011. Top 40 Priorities for Science to Inform US Conservation and Management Policy. BioScience 61: 290–300. doi: 10.1525/bio.2011.61.4.9
3. Elo S., and Kyngas, H. 2008. The qualitative content analysis process. Journal of Advanced Nursing 62(1): 107–115. doi: 10.1111/j.1365-2648.2007.04569.x
4. Burla L., Knierim, B., Barth, J., Liewald, K., Duetz, M., and Abel, T. From text to codings: intercoder reliability assessment in qualitative content analysis. Nursing Research 57(2): 113-7. doi: 10.1097/01.NNR.0000313482.33917.7d. PMID: 18347483.
5. Delta Stewardship Council, Delta Science Program. 2021. Science Action Agenda Draft Management Needs Public Review Draft.

Hyperlink: Draft Management Needs, https://scienceactionagenda.deltacouncil.ca.gov/pdf/2021-05-26-saa-draft-management-needs.pdf (page 66)

Appendix B: 2017–2021 SAA Progress Summary



The overarching goal of the Progress Summary (Summary) was to determine what progress was made to address the 25 Science Actions identified in the 2017–2021 SAA. The Summary provided three key benefits: (1) it served to document progress made on 2017–2021 SAA Science Actions by inventorying relevant activities—part of the "evaluation" phase in the adaptive management cycle; (2) the progress documented helped to inform the "response" phase of identifying new actions for the 2022–2026 SAA; and (3) it piloted an approach to understanding the return on investment from the Delta Science Program and its partners' funding efforts, which are guided by the SAA. This Summary was the Delta Science Program's first attempt to formally track progress toward addressing Science Actions outlined in the SAA, providing a foundation to build upon for future summaries. The Delta Science Program will work to implement a more forward-looking approach to track the inputs to new projects (e.g., funding), and well as outputs (e.g., publications), and outcomes (e.g., science-informed policy and management), of those projects as they begin to address priorities in the 2022–2026 SAA.

2017–2021 SAA

The 2017–2021 SAA was developed collaboratively in 2016 and includes 25 Science Actions grouped into the following five Action Areas:

1. invest in assessing the human dimensions of natural resource management decisions;
2. capitalize on existing data through increasing science synthesis;
3. develop tools and methods to support and evaluate habitat restoration;
4. improve understanding of interactions between stressors and managed species and their communities; and
5. modernize monitoring, data management, and modeling.

Summary Approach

Information Needed to Assess Progress

Progress was assessed based on the relevant activities that addressed Science Actions and the status of those activities (initiated, ongoing, or completed) between 2016 and 2021. The Delta Science Program gathered information on relevant science activities (supported by the Delta Science Program or other entities) by soliciting collaborative science venues, input from Delta Science Program staff involved in various activities throughout the Delta, and by tracking science funding programs.

The different types of activities included **funded research** (e.g., through the Delta Science Program's competitive solicitations, the California Department of Fish and Wildlife's Proposition 1 Restoration Grants Program), **monitoring** (e.g., continuous data collection efforts across the Delta), **modeling and synthesis** (e.g., integrated modeling efforts), **programs** (e.g., new or existing programs specifically or indirectly informing an action, such as the Wetlands Regional Monitoring Program), **projects** (e.g., Delta Adapts), **reviews** (e.g., by the ISB), **publications,** and **outreach** (e.g., the 2020 spring-run chinook salmon symposium hosted by the Delta Science Program).

For each activity, the Delta Science Program collected information on the part(s) of the Science Action that the activity addressed, the timeline for completion, the status of the activity, and the primary entity performing the work.

Status of Progress Made

The 25 Science Actions were assigned to one of four general status categories. Recognizing that scientific progress is not linear or categorical, for the purposes of this summary, progress was binned according to the rubric below to distill observations from the inventory of completed and ongoing activities.

- **Significant progress with management impact:** 5+ activities; and/or results from activities are leading to significant gains in knowledge regarding the Science Action and actively informing management decisions.
- **Significant progress:** 5+ activities; and/or results from activities are leading to significant gains in knowledge regarding the Science Action.
- **Moderate progress:** 3–4 activities; and/or results from activities are leading to moderate gains in knowledge regarding the Science Action, but important knowledge gaps remain.

- **Early progress:** 1–2 activities; and/or progress on the action is in early stages, or results from activities are leading to incremental gains in knowledge regarding the Science Action.

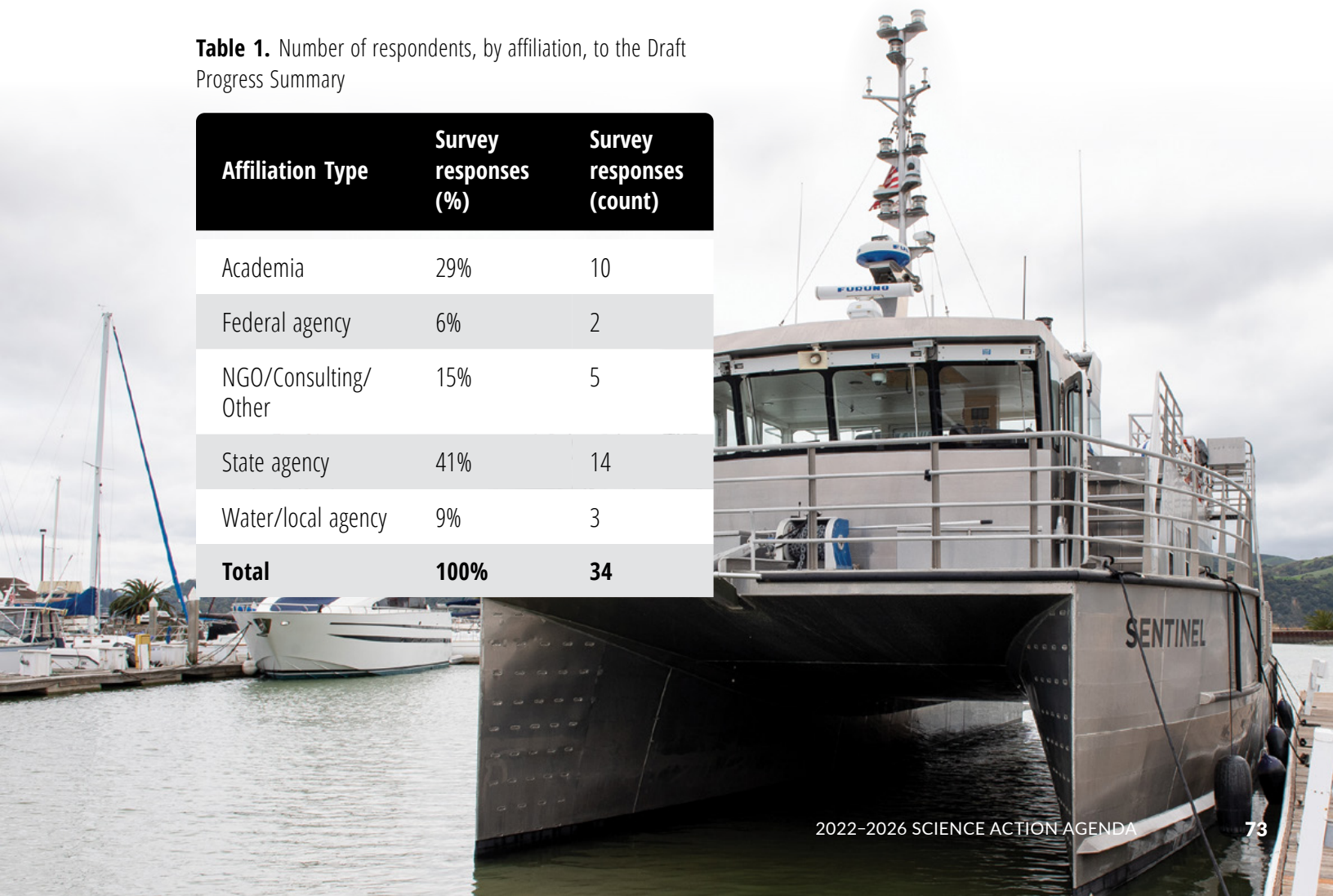
After tallying the activities by activity type and considering their contributions to the Science Actions, a progress status was assigned to each of the 25 Science Actions. The general progress for each of the five major Action Areas was then evaluated.

Outreach

The Delta Science Program drafted an initial Summary in early 2021, which included the list of activities contributing to the Science Actions and relevant details. The draft list of activities was circulated for targeted input from relevant entities and program leads throughout the Bay-Delta (e.g., from the IEP), and this step added substantially to the list of completed and ongoing activities. The Delta Science Program then synthesized the feedback to generate a draft Summary for broader public review. A draft Progress Summary was circulated for public review in late Spring 2021. Over 30 comments received via an online survey from a variety of respondents were incorporated into the final Summary available on the Council's website (Table 1).[1]

Table 1. Number of respondents, by affiliation, to the Draft Progress Summary

Affiliation Type	Survey responses (%)	Survey responses (count)
Academia	29%	10
Federal agency	6%	2
NGO/Consulting/ Other	15%	5
State agency	41%	14
Water/local agency	9%	3
Total	**100%**	**34**



Using the Progress Summary to Inform the 2022–2026 SAA

Outstanding gaps in progress for the Science Actions of the 2017–2021 SAA informed the development of Science Actions for the 2022–2026 SAA at the July 2021 Science Actions workshop (Table 2). Some of these specific gaps directly influenced the Top 25 Science Actions for the 2022–2026 SAA.

For example…

- **Science Action A1A in the 2017–2021 SAA,** *"Implement studies to understand social-economic adaptations to climate change (e.g., human behavioral response in the agriculture sector to changes in water prices),"* **only saw early progress.** The Progress Summary found that few studies overall have informed adaptations to climate change, particularly regarding human behavior.
- **Science Action 6D in the 2022–2026 SAA,** *"Identify how human communities connected to the Delta watershed are adapting to climate change, what opportunities and tradeoffs exist for climate adaptation approaches (i.e., agricultural practices, carbon sequestration, nature-based solutions/green infrastructure), and how behaviors vary with adaptive capacity,"* **builds directly on the gap identified for Science Action A1A in the Progress Summary.**

Table 2. Outstanding gaps for the 2017–2021 SAA Science Actions

Science Action	Status	Outstanding Gaps
1A: Investigate the most cost-effective methods to improve species habitat on working lands	Moderate Progress	Activities that directly consider and analyze monetary and non-monetary costs and/or benefits from management actions to improve species habitat on working lands
1B: Develop tools to assist adaptive management in the Delta	Significant Progress	Processes to identify the best tools to support adaptive management, models of adaptive pathways to inform adaptation decision-making, and ideas for refining governance structures
1C: Initiate a research program on the Delta as an evolving place that integrates the physical and natural sciences with the social sciences	Early Progress	Initiation of a research program to support the social sciences and understand the Delta as an evolving place and integrate social and natural sciences

Science Action	Status	Outstanding Gaps
A1A: Implement studies to understand socio-economic adaptations to climate change (e.g., human behavioral response in the agriculture sector to changes in water prices)	Early Progress	Social scientific studies identifying socio-economic barriers to climate change adaptation in the Delta; social scientific studies of human behavior and behavior change in response to specific climate change impacts in the Delta (e.g., drought, flooding)
A1B: Develop methodology for assessing the long-term costs and benefits of managed wetlands and ponds	Moderate Progress	Greater progress in developing a methodology to assess costs and benefits in the context of existing agricultural activities, results of landscape-scale planning processes to determine large-scale feasibility
A1C: Initiate Delta levee risk assessment studies that address individualized levee fragility curves, identify levee sections most subject to earthquake-induced liquefaction, clarify attenuation of ground motions from Bay Area earthquakes, monitor land-level changes adjacent to levees post-earthquakes, hydrodynamic studies to project magnitude of levee breaches, duration, and severity of disruption	Early Progress	More research on perceptions of risk, acceptable levels of risk, tradeoffs, and valuation factors combining both physical and social sciences
2A: Strategically build the capacity to do collaborative science synthesis by implementing the science synthesis mechanisms outlined in the Delta Science Plan	Significant Progress	More staff time, staff training, and resources to conduct synthesis and communicate its findings to appropriate audiences, including Delta managers
2B: Identify and prioritize important data sources that should be interconnected to promote collaboration and provide the technology necessary to easily access this information	Significant Progress	Continued dataset integration with strengthened workforce expertise, prioritized data for integration, and improved access and discoverability of data resources
A2A: Develop improved sturgeon abundance estimates through modeling and synthesizing data from cohort abundances studies, surveys, and report cards	Early Progress	Abundance estimates are lacking
A2B: Produce a system-wide analysis of existing telemetry results to provide an understanding of fish movement and predation	Early Progress	Studies focused explicitly on predation and consistent diagnosis of predation in telemetered fish analyses

Science Action	Status	Outstanding Gaps
3A: Develop methods for evaluating long-term benefits of habitat restoration based on current understanding of how species use restored areas and how use changes over time as habitats evolve	Significant Progress	Assessment and possible adjustment of methods as uses and long-term benefits of habitat restoration become more well known, data processing and synthesis from implemented restoration projects
3B: Estimate and assess the system-wide effects of location and sequence of tidal marsh habitat restoration projects in regions where sea level is rising and climate is changing	Early Progress	Systemwide synthesis of early data collection, long-term data sets for assessment and evaluation, and studies directly focusing on a system-wide evaluation using scenario planning tools
A3A: Review effort to examine effectiveness of habitat restoration	Early Progress	Long-term data sets for assessment and evaluation
A3B: Collect environmental, social, and economic baseline data and develop a database of pre-project habitat conditions at the landscape scale (e.g., native species presence/condition, water quality, current food and predator densities, condition in adjacent channels, and socio-economic valuations of management practices and environmental stewardship)	Moderate Progress	Social and economic baseline data compiled and synthesized with spatial environmental data in a data repository, synthesis of pre-project restoration conditions
4A: Implement studies to better understand the ecosystem response before, during, and after major changes in the amount and type of effluent from large point sources in the Delta including water treatment facilities	Significant Progress	Analysis and publication/availability of data from before and during the Regional San Wastewater Treatment Plant upgrade
A4B: Identify effective mechanical and biological control strategies for established non-native clams and potential invasive mussels, including developing effective prevention measures for potential invaders	Early Progress	Identification of effective control strategies; development of effective prevention and early detection measures
5A: Advance integrated modeling through efforts such as an open Delta collaboratory (physical or virtual) that promotes the use of models in guiding policy	Moderate Progress	Establishment of a collaboratory and centralization of integrated modeling efforts

Science Action	Status	Outstanding Gaps
5B: Explore innovative technologies and cost-effective methods for scientific monitoring and analysis of flow, water quality, and ecosystem characteristics (e.g., improved tools for fish monitoring, LiDAR, high-resolution bathymetry technology, new measurements for Delta levee hazards, and citizen scientist monitoring programs)	Significant Progress	Improved infrastructure and more activities focused on innovative technologies and methods related to analysis; more citizen science efforts; monitoring program funding for testing new technologies in the field alongside existing practices; increased Bay-Delta integration of data collection and processing
A5A: Build on existing models to integrate fish and water quality monitoring data to report, simulate, and forecast distribution of salmon runs in time and space. These actions should be coordinated with tagging studies and other monitoring data to provide accurate and consistent interpretation of information to support decision-makers (e.g., coupling 3-D hydrodynamic modeling of the Delta with juvenile salmon behavior and survival)	Moderate Progress	Greater forecasting and open-source, documented 3D hydrodynamic models
A5B: Conduct baseline surveys throughout spawning habitat, map egg collection and larval rearing habitat, and quantify availability using various characteristics identified through egg sampling (water temperature, depth, velocity, substrate, etc.)	Early Progress	Public availability of existing baseline data
A5C: Develop and implement a Bay Area and Delta regional wetland monitoring program	Moderate Progress	Greater organization of information from existing monitoring programs; formalizing synthesis links between Bay and Delta monitoring programs

1. Delta Stewardship Council, Delta Science Program. 2021. 2017–2021 Science Action Agenda Progress Summary.

Hyperlink: Progress Summary, https://scienceactionagenda.deltacouncil.ca.gov/pdf/SAA-Progress-Summary.pdf (page 71)

Appendix C: Developing and Applying Criteria to Management Questions and Science Actions

This section outlines the process to develop and utilize screening, selection, and prioritization criteria for the SAA's Management Questions and Science Actions. Prioritization is a complicated and challenging task; however, with limited resources and given the focused scope of the SAA, it is critical. The approach outlined here is a hybrid of the criteria used for the 2017–2021 SAA and feedback from public input.

Outreach and Input on Draft Criteria (April–June 2020; June–July 2021)

Two types of criteria were developed to inform the components of the SAA: (1) **Management Questions screening** and **selection criteria,** which were applied to screen and sort the list of Management Questions, and (2) **Science Action screening** and **prioritization criteria,** which were used to inform the drafting and prioritizing of the list of Science Actions. These criteria were developed by updating the 2017–2021 SAA criteria, crafting Management Question criteria for this new component to the SAA, and seeking external input. The draft criteria were available on the Council's website for public review from April 2020 to June 2021. The draft Science Actions prioritization criteria were again made available for review at the Science Actions Workshop in July 2021. Participants weighed in via a survey, which was used to finalize the language and application of the Science Actions prioritization criteria.

To apply the below sets of criteria, Delta Science Program staff reviewed all Management Questions and Science Actions and determined if they met the criteria. Staff discussed and came to consensus applying a score of 1 (yes, meets the criteria), 0.5 (partially meets the criteria), or 0 (does not meet the criteria). All sub-criteria were scored individually.

Screening and Selection Criteria—Management Questions

Screening Criteria

The purpose of the screening criteria was to ensure that proposed Management Questions fall within the scope of the near-term needs of the Delta's science-management landscape. Screening criteria were applied to refine the initial list of Management Questions in advance of the September 2020 public workshop.

1. **Management Question Not Fully Addressed**
    a. Currently there is no, or only partial information (existing data, monitoring activities, research, tools, or infrastructure) to help address this question.
2. **Applicable to Delta-relevant Federal, State, and Local Initiatives**
    a. If answered, the Management Question would increase the effectiveness of policies regarding the management of species, ecosystems, socio-economic needs, and ecological processes in the face of climate change and other stressors throughout the San Francisco Bay-Delta watershed.
3. **Feasible**
    a. The Management Question must be addressed by one or more Science Actions.
    b. Scored based on, but not screened: The Management Question can be addressed through means that are possible given fiscal, legal, and institutional considerations.

Selection Criteria for Inclusion in the SAA

The purpose of the selection criteria was to identify the Management Questions that best align with the scope of the SAA (address key uncertainties and institutional gaps, while promoting collaboration among agencies and organizations), as identified by the following criteria:

1. **High Impact**
    a. The Management Question has been identified by one or more key agencies.
    b. The opportunity for progress addressing the Management Question is high.

c. Addressing the Management Question will have a high potential to address and resolve areas of uncertainty.

2. **Timeliness**

   a. The Management Question needs to be addressed within a four-year time frame.

   b. Efforts to begin addressing the Management Questions need to happen within the next four years.

   c. The Management Question is linked to forthcoming decisions or actions that require information to evaluate among best alternatives.

3. **Risk Assessment**

   a. Evaluation of the opportunity cost—is the cost of not immediately addressing the Management Question high?

Screening and Prioritization Criteria—Science Actions

Screening Criteria

After the 65 Top Delta Management Questions were organized into Management Needs, Science Actions were identified to address those Management Needs and uncertainties expressed in the Management Questions. The following screening criteria were used by workshop participants and Delta Science Program staff to guide the development of Science Actions for the 2022–2026 SAA (adapted from Appendix C of 2017–2021 SAA):

1. **Science Topic Not Fully Addressed**

   As written, will the Science Action yield new information or tools to inform unaddressed or partially addressed management needs?

   a. The Science Action will provide information to evaluate best alternatives and/or associated uncertainty in forthcoming management decisions.

   b. The Science Action is only being partially funded or addressed by an agency or group, but requires cross-agency support, or is currently not being addressed by any group.

   c. The Science Action enhances relevance and accessibility of existing scientific information.

2. **Cross-agency or Multi-group Priority**

   As written, will the Science Action yield information that is relevant to cross-agency and interdisciplinary science, management, and policy priorities?

   a. The Science Action is relevant to multiple agencies, stakeholders, and entities, is not site-specific, and is applicable to the research, monitoring, and science goals of the larger Delta science community.

   b. The Science Action is linked to a high-priority policy or regulatory issues that have cross-agency implications such as the California Water Resilience Portfolio, Incidental Take Permits/Biological Opinions, EcoRestore, the Delta Plan, or a new Governor's initiative.

   c. The execution and outputs of the Science Action will inform policy or management in support of achieving the coequal goals in the Delta Plan.

3. **Realistic/Feasible**

   As written, will the Science Action be addressed given legal, fiscal, and institutional constraints and considerations, or could this Action foreseeably promote change in constraints that could allow it to proceed?

   a. The Science Action can likely proceed given legal, fiscal, and institutional constraints, requirements, and considerations.

   b. The capacity to carry out the research successfully is well established and described.

Prioritization Criteria

The following set of criteria was used by the Delta Science Program following the 2021 Science Actions workshop to prioritize Science Actions within each Management Need for the 2022–2026 SAA (adapted from Appendix C of 2017–2021 SAA):

1. **Scientific Relevance**

   As described, is the Science Action based on sound rationale and recommended by science and management leadership in the Delta?

   a. The Science Action is based on a sound rationale (e.g., has a high degree of support from relevant science communities or local and Traditional Knowledge and has a high potential to advance knowledge).

b. The Science Action is recommended by the Delta lead scientist, IEP lead scientist, Delta ISB, or an independent peer review or advisory panel, or other science leaders (e.g., other federal, State, and local science leads and collaborative groups).

2. **Impact**

   As described, does the Science Action have a high potential to address existing, emerging, or anticipated gaps in knowledge and will it support priority themes within the Delta science community (e.g., promotes diversity, equity, and inclusion and advances predictive tools and capacity)?

   a. The Science Action will provide actionable information within the existing management framework of the Delta such that it can be used by one or more key agencies within a four-year time frame and may also lay a foundation for anticipating and/or addressing longer-term change within the Delta.

   b. The Science Action identifies and addresses current, emerging, or anticipated gaps in knowledge relevant to multiple agencies or policy/management bodies (e.g., DPIIC, CSAMP, Council).

   c. Implementing the Science Action supports synthesis activities and involves integrating existing data from individual agencies spanning various geographical locations.

   d. The Science Action supports the broader Delta scientific community by providing tools, facilities, or professional development for scientists.

   e. Outcomes of the Science Action have a high potential to address and resolve areas of scientific conflict.

3. **Timeliness**

   As described, is there opportunity for near-term progress to be made on the Science Action?

   a. The Science Action is ripe for further development and the opportunity for progress is high.

   b. The project has partial resource support and commitments that can be greatly enriched by focused short-term attention.

4. **Collaboration and Change**

   As described, will the Science Action encourage or require multi-agency or entity collaboration?

   a. The Science Action is synergistic with existing efforts and will support (or require) multi-agency collaboration.

   b. Utilizes collaborative efforts and opportunities to change constraints or remove barriers to action.

5. **Risk/Opportunity Cost**

   As described, is there a high cost of not acting on this Science Action?

   a. Not taking this action today would pose a severe risk to core scientific, technical, and organizational capabilities to address management needs today and in the future.

   b. Addressing this scientific topic is an immediate opportunity for innovation and scientific advancements with high potential for critical new knowledge of the Delta.

Applying the Criteria to Identify the Draft List of Priority Management Questions and Science Actions (August–December 2020; June–August 2021)

Management Questions

The Management Questions screening criteria were applied to all Management Questions in advance of the September 2020 workshop. Only 14 Management Questions were removed from the initial list of 1,279 based on the screening criteria. Following the September 2020 workshop, the selection criteria were used to inform the list of 65 Top Delta Management Questions. Management Questions from the September 2020 workshop were scored based on the selection criteria, but none were removed based on their scores. All Management Questions from the list of 65 were included in the final list.

Science Actions

The Science Actions screening criteria were used to guide the development of Science Actions at the July 2021 workshop. Specifically, Science Actions had to: (1) be responsive to an individual management need, considering the associated Management Questions; and (2) consider the 2017–2021 SAA "Progress Summary" (i.e., should aspects of the last SAA be carried over to the next one or was enough progress made?). Science Actions should also adhere to the three basic screening criteria listed above.

Prioritization criteria were presented to participants of the July 2021 Science Actions workshop for feedback via a survey. A total of 12 comments were received, which largely emphasized the importance of the "Scientific Relevance," "Impact," and "Risk/Opportunity Cost" criteria. These three criteria held the highest weight in scoring Science Actions (9 out of 13 possible points). After the 178 Science Actions drafted at the July 2021 workshop were merged to reduce redundancy and refined by the Delta Science Program, a total of 104 Science Actions were assessed based on the prioritization criteria, scoring between 7 and 13. A total of 13 Science Actions that scored below 11.5 during the prioritization process were not included in the survey. A set of 91 Science Actions (25 proposed as top priority; 66 extra) were circulated via a post-workshop survey for feedback. Upon review by the Delta Science Program, four Science Actions that scored low during the prioritization process were removed, resulting in the 100 Science Actions included in Appendix E.

Appendix D: List of Documents Used in Compiling Management Questions

The following collaborative groups were contacted, and relevant documents produced by these groups were reviewed, to inform the SAA update (Table 1). Many organizations submitted proposed Management Questions, participated in the multiple public workshops, or provided survey responses.

- Bay Regional Monitoring Program
- California Water Quality Monitoring Council—Wetlands Workgroup
- Collaborative and Adaptive Management Team
- Collaborative and Adaptive Management Team—Delta Smelt Scoping Team
- Collaborative and Adaptive Management Team—Salmon
- Contaminants Project Work Team
- CVPIA Science Integration Team
- Delta Adapts Project Team
- Delta as a Place Interagency Working Group
- Delta Conservancy Board meeting
- Delta Interagency Invasive Species Coordination Team
- Delta Nutrient Stakeholder and Technical Advisory Group
- Delta Plan Interagency Implementation Committee/Delta Agency Science Workgroup
- Delta Regional Monitoring Program—Steering Committee and Technical Advisory Group
- Delta Tributaries Mercury Council
- IEP Coordinator's Team
- IEP Science Manager's Team
- IEP Stakeholder Group

- Interagency Telemetry Advisory Group
- Sacramento River Science Partnership
- San Francisco Bay Nutrients Project Stakeholder Advisory Group/Nutrient Technical Workgroup and/or Steering Committee
- Science Advisory Committee
- State Water Contractors Science Program
- Suisun Marsh Habitat Management, Preservation and Restoration Plan Principals/Adaptive Management Advisory Team
- Voluntary Agreements participants
- Water Operations Management Team

Table 1. List of documents (by associated organization) reviewed for developing the list of Management Questions

Title of Document	Associated Organization
Central Valley Improvement Plan 2017 Work plan Attachment 1: Memo on CVPIA Core Team Priorities (2016)	Central Valley Project Improvement Act (CVPIA)
Central Valley Improvement Plan 2017 Work plan	CVPIA
State of Bay Delta Science (SBDS) Chapter—Perspectives on Bay-Delta Science Policy (2016)	Delta Science Program
Basin Plan Amendments for Salt and Nitrate	Central Valley Regional Water Quality Control Board
Workshop report—Earthquakes and High Water as Levee Hazards in the Sacramento-San Joaquin Delta (2016)	Delta ISB
SBDS Chapter—Factors and Processes Affecting Delta Levee System Vulnerability	Delta Science Program
SBDS Chapter—Nutrient Dynamics in the Delta: Effects on Primary Producers (2016)	Delta Science Program
Factors Affecting the Growth of Cyanobacteria with Special Emphasis on the Sacramento-San Joaquin Delta	Nutrient Research Strategy Science Work Group

Title of Document	Associated Organization
Recommendations for a Modeling Framework to Answer Nutrient Management Questions in the Sacramento-San Joaquin Delta (2016)	Nutrient Research Strategy Science Work Group
Primary Production in the Sacramento-San Joaquin Delta (2016; Revised 2019)	San Francisco Estuary Institute (SFEI)/Delta Science Program
Changing nitrogen inputs to the northern San Francisco Estuary: potential ecosystem responses and opportunities for investigation (2020)	SFEI/many authors
San Francisco Bay Nutrient Management Strategy Science Plan (2016)	SFEI
SBDS Chapter—Contaminant Effects on California Bay-Delta Species and Human Health (2016)	Delta Science Program
Delta Nutrient Research Plan (2018)	Central Valley Water Quality Control Board
Wetlands Regional Monitoring Program Plan	Wetlands RMP
SBDS Chapter—Delta Smelt: Life History and Decline of a Once-Abundant Species in the San Francisco Estuary (2016)	Delta Science Program
An updated conceptual model of Delta Smelt biology: Our evolving understanding of an estuarine fish (2015)	IEP Management, Analysis, and Synthesis Team (MAST)
Diagnosis of a drought syndrome in the San Francisco Estuary (submitted, 2016)	MAST
Factors Controlling Submersed and Floating Macrophytes in the Sacramento-San Joaquin Delta (2016)	Nutrient Research Strategy Science Work Group
IEP Science Strategy 2020–2024	IEP
Interagency Adaptive Management Integration Team (IAMIT) draft uncertainties	IAMIT
Adaptive Management Framework for the California Water Fix and Current Biological Opinions on the coordinated operations of the Central Valley and State Water Projects (2016)	CDFW

Title of Document	Associated Organization
California Water Action Plan (2016)	California Natural Resources Agency (CNRA)
SBDS Chapter—Climate Change and the Delta (2016)	Delta Science Program
Regional Monitoring Program for Water Quality in San Francisco Bay (2020)	Bay RMP
Increasing efficiency and effectiveness through collaboration: First triennial audit of implementing a comprehensive monitoring program strategy for California 2011–2014 (2014)	California Water Quality Monitoring Council
Delta Tributaries Mercury Council Strategic Plan	Delta Tributaries Mercury Council
Delta Regional Monitoring Program Quality Assurance Project Plan for Fiscal Year 2019–2020 Monitoring	Delta RMP
Review of Research on the Sacramento-San Joaquin Delta as an Evolving Place (2017)	Delta ISB
Interim Science Action Agenda (2014)	Delta Science Program
High Impact Science Actions (2015)	Delta Science Program
Comprehensive Conservation and Management Plan (2016)	SFEI
Water Resilience Portfolio	CNRA; California Environmental Protection Agency (CalEPA); California Department of Food and Agriculture
Framework of Voluntary Agreements	CalEPA; CNRA
Monitoring Enterprise Review	Delta ISB
Suisun Marsh Plan	Adaptive Management
Delta ISB's Water Quality Science in the Sacramento-San Joaquin Delta. Chemical Contaminants and Nutrients	Delta ISB
Effects of Water Project Operations on Juvenile Salmonid Migration and Survival in the South Delta (2017)	CAMT Salmonid Scoping Team

Title of Document	Associated Organization
SBDS Chapter—Predation on Fishes in the Sacramento—San Joaquin Delta: Current Knowledge and Future Directions (2016)	Delta Science Program
Increasing the management value of life stage monitoring networks for three imperiled fishes in California's regulated rivers: case study Sacramento Winter-run Chinook salmon (2016)	IEP Salmon and Sturgeon Assessment, Indicators, Life Stages (SAIL)
Increasing the management value of life stage monitoring networks for three imperiled fishes in California's regulated rivers: case studies Southern Distinct Population Segment 2 of the North American Green Sturgeon and Sacramento-San Joaquin River White Sturgeon (2016)	IEP SAIL
Near-term Restoration Strategy for the Central Valley Project Improvement Act Fish Program	USBR

Appendix E: Additional Management Questions and Science Actions

A total of six Management Needs, 66 Management Questions, and 100 Science Actions were identified during the development of the 2022–2026 SAA, only a subset of which are prioritized for funding in the SAA. One Management Question was added to Management Need Three in response to feedback received during the draft SAA public comment period, after the initial list of 65 Top Delta Management Questions was published in 2021. The 26 Management Questions listed below were not directly relevant to the Top 25 Science Actions for the 2022–2026 SAA but do express other sources of uncertainty shared by the Delta science and management community. The 75 Science Actions listed below were not identified as priorities for funding via the SAA. Nevertheless, these Management Questions and Science Actions are a valuable distillation of activities needed to address other management uncertainties in the Delta. They are included here for archival purposes and for reference, noting that currently deprioritized actions may become elevated in importance beyond the time horizon of the 2022–2026 SAA.

Table 1. Number of Management Questions and Science Actions developed through the SAA update process relevant to each Management Need

Management Need	Number of Management Questions (in the Top 25/additional in Appendix)	Number of Science Actions (in Top 25/additional in Appendix)	Associated 2019 Delta Science Plan Objectives	Builds on Action Areas of the 2017–2021 SAA
1: Improve coordination and integration of large-scale experiments, data collection, and evaluation across regions and institutions	Four/Four	Three/Three	#2 Coordinate and integrate Delta science in a transparent manner #4 Manage and reduce scientific conflict #5 Support effective adaptive management	#2 Coordinate and integrate Delta science in a transparent manner #4 Improve understanding of interactions between stressors and managed species and their communities

Management Need	Number of Management Questions (in the Top 25/additional in Appendix)	Number of Science Actions (in Top 25/additional in Appendix)	Associated 2019 Delta Science Plan Objectives	Builds on Action Areas of the 2017–2021 SAA
2: Enhance monitoring and model interoperability, integration, and forecasting	Four/One	Four/Thirteen	#1 Strengthen science-management interactions	#2 Capitalize on existing data through increasing science synthesis
3: Expand multi-benefit approaches to managing the Delta as a social-ecological system	Ten/Eight	Five/Eleven	#2 Coordinate and integrate Delta science in a transparent manner #5 Support effective adaptive management #6 Maintain, communicate, and advance understanding of the Delta	#1 Invest in assessing the human dimensions of natural resource management decisions #3 Develop tools and methods to support and evaluate habitat restoration
4: Build and integrate knowledge on social process and behavior of Delta communities and residents to support effective and equitable management	Six/Five	Three/Four	#2 Coordinate and integrate Delta science in a transparent manner #5 Support effective adaptive management #6 Maintain, communicate, and advance understanding of the Delta	#1 Invest in assessing the human dimensions of natural resource management decisions

Management Need	Number of Management Questions (in the Top 25/additional in Appendix)	Number of Science Actions (in Top 25/additional in Appendix)	Associated 2019 Delta Science Plan Objectives	Builds on Action Areas of the 2017–2021 SAA
5: Acquire new knowledge and synthesize existing knowledge of interacting stressors to support species recovery	Ten/Seven	Five/Twenty-eight	#3 Enable and promote science synthesis #4 Manage and reduce scientific conflict	#2 Capitalize on existing data through increasing science synthesis #4 Improve understanding of interactions between stressors and managed species and their communities
6: Assess and anticipate impacts of climate change and extreme events to support successful adaptation strategies	Six/One	Five/Sixteen	#1 Strengthen science-management interactions #6 Maintain, communicate, and advance understanding of the Delta	#1 Invest in assessing the human dimensions of natural resource management decisions

Management Need One: Improve coordination and integration of large-scale experiments, data collection, and evaluation across scales and institutions

Additional Management Questions

- What institutional structures are required to support the full integration of social science into the Delta science enterprise?
- What fundamental aquatic and terrestrial environmental datasets that could improve project planning, evaluation, and regional synthesis across the system are missing, out of date, or not consistently collected, and what are the best ways to analyze that data?
- How can funding for long-term terrestrial and aquatic monitoring and adaptive management be secured to support Delta management?
- What are critical elements or approaches to collaborative development of hatchery genetic management plans to ensure they serve to enhance wild salmon viability?

Additional Science Actions

- Develop a centralized hub for searching and accessing all data and code relevant to the Delta (i.e., regional wetland data) in formats that are consistent and compatible across variables and logically organized
- Investigate how individual scientists and managers learn, collaborate and coordinate management actions, seek and share information and data, and trust and use scientific information to inform their decisions
- Investigate what barriers and enabling factors limit coordination and cooperation amongst scientists and managers

Management Need Two: Enhance monitoring and model interoperability, integration, and forecasting

Additional Management Questions

- What abiotic and biotic metrics and integrated models (e.g., hydrodynamic with fish life-cycle models, conceptual models) are needed to assess how exports and flow influence fish viability, behavior, entrainment, and predation?

Additional Science Actions

- Analyze infrastructure needs and new and innovative opportunities to support cost-effective monitoring, analysis, and forecasting of flow, water quality, and ecosystem characteristics
- Characterize the governance network responsible for monitoring and modelling in the Delta and evaluate opportunities for increased collaboration
- Conduct fine-scale vegetation mapping for the Delta, analogous to data being collected in the lower Estuary, at the appropriate level of resolution (spatial/temporal) to quantify changes in wetland vegetation over time
- Create or adopt standardized habitat-classification schemes for monitoring of specific habitats and species
- Evaluate the human health impacts and cumulative health impacts of multiple water quality concerns (e.g., salts, heavy metals, arsenic, nitrogen, pesticides, and toxic HABs)
- Explore opportunities for Flood Managed Aquifer Recharge to enhance water supply and reduce reliance on the Delta
- Identify best practices regarding the documentation and collection of scientific and monitoring information in the Delta
- Identify the priority challenges for Delta Plan Interagency Implementation Committee members and support a pilot collaborative technical team to develop models, integrate monitoring, and support decision- making over a range of time scales in the Bay-Delta to address these challenges
- Increase comparability of environmental water quality (temperature, dissolved oxygen, conductivity, turbidity) data by standardizing use and calibration of equipment, employing consistent sampling protocols, centralizing data management, and supporting the development of tools to integrate historical datasets
- Integrate human uses and equity impacts of groundwater management into models for both drinking water wells (domestic and municipal/community water systems) and agricultural wells, including season/time of use and quantity and quality restrictions
- Investigate what roles different process-based physical, biological, and ecological models play in managing the Bay-Delta

- More effectively support translational work between long-term monitoring and short-term targeted studies
- Synthesize monitoring data for salinity in the Lower San Joaquin River and southern Delta, Irrigated Lands Program, CV-SALTS, and water project operations and special studies to inform management

Management Need Three: Expand multi-benefit approaches to managing the Delta as a social-ecological system

Additional Management Questions

- How might additional diversion conveyance facilities in the Delta affect operational flexibility, water supply and quality, and ecosystems?
- How can factors (e.g., water flow and residence time, turbidity, water temperature, nutrient concentrations) be managed to encourage productivity in lower trophic food webs while also preventing harmful algal blooms, taste and odor issues, and macrophyte growth?
- How do water quality and the multiple elements that contribute to water quality change under different management scenarios, and where is coordinated monitoring needed?
- What source control actions for contaminants (e.g., mercury, selenium, personal care products, or other emerging contaminants) would reduce health impacts to both fish and consumers of fish in the Delta?
- What are best management practices for levees and floods to create or enhance habitat along Delta and Suisun Marsh channels, river corridors, and riparian zones?
- How is the cumulative implementation of SGMA, though local projects and strategies, likely to impact inflows to and through the Delta, exports from the Delta, and achievement of the coequal goals?
- What management actions should be prioritized to address seismic risk to the integrity of the Delta's levee system?
- How do storms impact the tradeoff between reservoir operations, Flood-Managed Aquifer Recharge, and other management decisions related to water supply?

Additional Science Actions

- Analyze costs and benefits of improving species habitat on working lands and identify outstanding gaps in knowledge
- Conduct opportunistic monitoring and evaluation in line with major management actions (e.g., upgrade of Regional San, salinity barrier) to evaluate how invasive species respond to changes in multiple stressors (e.g., nutrients, salinity, temperature) and impact competitive interactions and ecosystem services (e.g., water quality, recreation, subsistence fishing, food webs) in the Delta
- Conduct synthesis of existing data on spatiotemporal co-variation of multiple stressors (e.g., temperature, salinity, depths, flows) to resolve their interacting effects and identify past and future changes in habitat suitability, responses to restoration, and opportunities for intervention to create refugia/suitable habitat
- Develop economic, spatially explicit models integrating incentives for different land management decisions (e.g., carbon offset market, managed wetlands, regenerative agricultural practices)
- Evaluate how and which contaminant loads in the Delta are impacted by climate change and extreme events (e.g., drought, fire, flood)
- Evaluate the effectiveness of management actions from other systems to reduce contaminant concentrations and associated toxicity and apply findings that could be implemented in the Delta
- Examine the possible multi-benefits of groundwater recharge for ecological functions and water resilience under multiple dry year scenarios
- Identify contaminants of emerging concern that, with climate change and management actions, are likely to be present in concentrations above critical thresholds for the health of managed species or ecosystem functions
- Perform field, laboratory, and modeling studies to investigate how impacts of contaminants (directly and indirectly) on fish species scale up to the population level and distinguish population-level impacts of contaminants from impacts of other stressors
- Improve understanding of interactive factors including nutrients, hydrology, and temperature, affecting phytoplankton communities and higher trophic levels, utilizing new studies, data synthesis, or mechanistic models

- Through collaborative synthesis, determine best management practices for creating or enhancing habitat (e.g., levee-side habitat) while maintaining levee integrity, and develop monitoring

Management Need Four: Build and integrate knowledge on social process and behavior of Delta communities and residents to support effective and equitable management

Additional Management Questions

- What factors would effectively motivate landowners to create managed wetlands or cultivate rice to stabilize land subsidence and reduce carbon emissions?
- How do patterns of Delta water use and adoption of technologies influence reliance on water exports, water use efficiency, access to new water sources, and likelihood of adopting additional conservational measures or technologies (e.g., water recycling and potable reuse)?
- What are the water supply issues faced by disadvantaged communities within the Delta watershed, and how can they equitably be addressed?
- What social, cultural, and political factors must be understood to design and implement effective invasive species management plans?
- What type/category of investments by urban and agricultural water suppliers are achieving the greatest reduction in water demand?

Additional Science Actions

- Collaboratively generate scenarios of probable climate change impacts to the Delta, and assess associated human perceptions of risk and adoption of resilience behaviors
- Develop transparent and accessible resource(s) that describe the Delta governance system and provide guidance on navigating participation opportunities
- Identify overlap and conflict, if any, between Delta human community and ecosystems needs for invasive species management

- Review models of meaningful engagement, community science, and co-production to develop evidence-based guidelines, resources, and best practices, and evaluate the implementation of those best practices for impacts on decision-making and community perceptions of governance

Management Need Five: Acquire new knowledge and synthesize existing knowledge of interacting stressors to support species recovery

Additional Management Questions

- What is the relative magnitude of temperature-dependent mortality of juvenile salmonids compared to other sources of mortality, and what are the interactive effects of multiple stressors on mortality?
- What are the population effects of water operations, migration barriers, flow, and temperature on spawning distribution, migration, recruitment, behavior, life history, and production of understudied native species (e.g., White and Green Sturgeon)?
- How can upper watershed flows and access for native aquatic migratory species be increased?
- What new species are likely to invade regions of the Delta, and what are the most important vectors of invasive species introductions beyond ship-mediated transport to target for prevention and outreach?
- How do biological invasions interact with biogeochemical factors (e.g., nutrients, microbes, organic carbon, salinity)?
- What information is needed to develop robust juvenile production estimates (JPEs) for listed salmonids in each of the Central Valley rivers, and how should JPEs be used to achieve salmon recovery?
- By which direct and indirect mechanisms do export facilities and their related management practices affect the fate of native species that enter the south Delta?

Additional Science Actions

- Assess barriers to invasion and conduct pilot tool development, monitoring, and experimentation to inform Early Detection and Rapid Response to new species invasions and consistent tracking of the distribution and spread of current non-native species
- Characterize how microbial communities (e.g., bacteria, picoplankton, and microzooplankton) vary throughout the Delta and influence and interact with native species and food webs
- Characterize impacts of habitat restoration and what makes 'good habitat'
- Conduct comprehensive gear efficiency studies along juvenile salmonid outmigration routes
- Conduct research to identify what environmental factors and management techniques control the spread, abundance, and toxicity of harmful algal blooms and aquatic weeds in the Delta, and how those harmful algal blooms and aquatic weeds affect beneficial phytoplankton production
- Conduct studies to evaluate the effectiveness of pulsed flows on native species
- Consider impacts of seasonal variations in salinity, nutrients, microbes, and organic carbon as part of species recovery evaluations
- Determine the drivers of anadromy for steelhead juvenile production estimates
- Develop a monitoring strategy and build on existing monitoring to detect (new) pathogens associated with invasive species and their impact on native species
- Develop abundance estimates and metrics to assess how management actions affect understudied native and nonnative species
- Develop approach for monitoring programs of predators and native fish that allow individuals or groups to be tracked across connected regions within the Bay-Delta to see how predation and environmental drivers and stressors affect native species distribution
- Develop capacity (e.g., staff, outreach, tracking and updating) and advance efforts for broadly accessible computing resources (e.g., centralized virtual collaboratory, data dashboard, cloud computing) to support open and transparent collaborative synthesis and model integration for guiding policy for the Bay, Delta, and its upper watersheds

- Develop consistent procedures for detecting and analyzing predation events and apply to an aggregate of telemetry datasets for future analyses
- Develop field-based, laboratory, and numerical methods to operationalize eDNA-based monitoring
- Encourage high-risk, high-reward novel monitoring concepts with a dedicated fund to reward approaches that are transformational
- Evaluate strategies for communicating synthesis findings and results of multi-benefit analyses to broad groups of interested parties, understand processes that support active learning, and incorporate them into decision-making processes
- Evaluate the impact of chemical contaminants and multiple interactive stressors on microbial communities (including animal microbiomes), and the effects on higher trophic levels
- Evaluate the relative benefit to juvenile salmon of reducing 'hotspots' of predators compared to controlling or reducing the total population of predators
- Evaluate the relative reduction in fish predation risk due to the reduction of different stressors, such as low food intake, high water temperatures, reduced flows, lack of predator refuges, and encountering predator hot-spots
- Expand survey locations of anadromous fish habitat usage and improve information sharing and access to data
- Experiment with transport of adult and juvenile Chinook salmon around rim dams to access cold-water holding, spawning, rearing habitat, and for reintroduction
- Identify and assess indirect effects (e.g., predation hotspots, temperature) of export facilities on habitat suitability, survival, and growth/condition of native species
- Identify habitat characteristics and areas that act as refugia from predators and during extreme conditions for understudied species (e.g., green and white sturgeon) and biological communities of concern, and potential management actions
- Identify how habitats are connected within the Delta via transporting and mixing of water quality constituents and species movement across regions
- Identify population bottlenecks and potential management solutions for white and green sturgeon, longfin smelt, splittail, and lamprey

- Identify the information and monitoring required to develop juvenile production estimates for salmonids
- Model the effects of submerged aquatic vegetation on the erosion, redistribution, and deposition of sediment within the Estuary
- Through modeling and data synthesis, evaluate relative impacts of overbite clam invasion, altered flows, temperatures, predation, and food web perturbations on declines in native fishes

Management Need Six: Assess and anticipate climate change impacts to support successful adaptation strategies

Additional Management Questions

- How should carry-over storage targets be reevaluated and changed in light of climate change projections and modified biological objectives?

Additional Science Actions

- Assess resiliency of natural and restored tidal wetlands to sea level rise and changes in sediment supply
- Assess restoration impacts and synthesize long-term data sets (e.g., temperature, salinity, fish presence) at a system-wide scale, particularly in areas most threatened by climate change and in areas well suited to provide resiliency
- Assess what future river and stream temperatures will be under climate change and explore potential water temperature mitigation opportunities in the Delta
- Assess whether invasive species fill ecological niches that are necessary but otherwise unfilled
- Conduct analyses and develop models to determine the role of climate change-driven shifts in temperature and flow on Chinook salmon health, pathogen load, and migration patterns
- Conduct threat assessments and evaluate future potential invasive species for early detection based on characteristics that are likely to lead to management issues in the context of changing environment and multiple drivers associated with climate change

- Develop a menu of ecologically and socially feasible climate adaptation strategies for Delta restoration to inform experimentation at the landscape scale
- Evaluate wildfire impacts on Delta human communities and ecosystems
- Examine and evaluate effects of proposed modifications to water storage and demand management regimes (e.g., increased storage capacity through late year/early year releases) on Delta ecosystems and human communities
- Expand collaborative use of remote imaging technology along with ground-based work to measure landscape-scale impacts of climate change
- Identify which waterbodies in the future will continue to support fishery species
- Identify intra- and interagency processes that allow successful response and control of new invasive species
- Investigate the mechanisms that support and hinder establishment of invasive/non-native aquatic species in Delta waterways and incorporate findings into restoration actions
- Model future land use changes and habitat suitability for native aquatic and terrestrial species
- Research how to communicate climate change impacts in a manner that is culturally sensitive and effective in motivating behavior change or policy engagement
- Research messaging frames for communicating climate change and ecosystem restoration needs to local communities, that are culturally appropriate and effective in motivating behavior change or policy engagement

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"As climate change and its impacts on the Delta intensify, the greatest management challenges require a deep understanding of the interlinked processes driving the Delta, such that a full spectrum of the tradeoffs of management actions can be assessed and multi-agency solutions can be put into place. Thus, the 2022–2026 SAA is built upon a vision of integration."

Dr. Laurel Larsen | *Delta Lead Scientist*