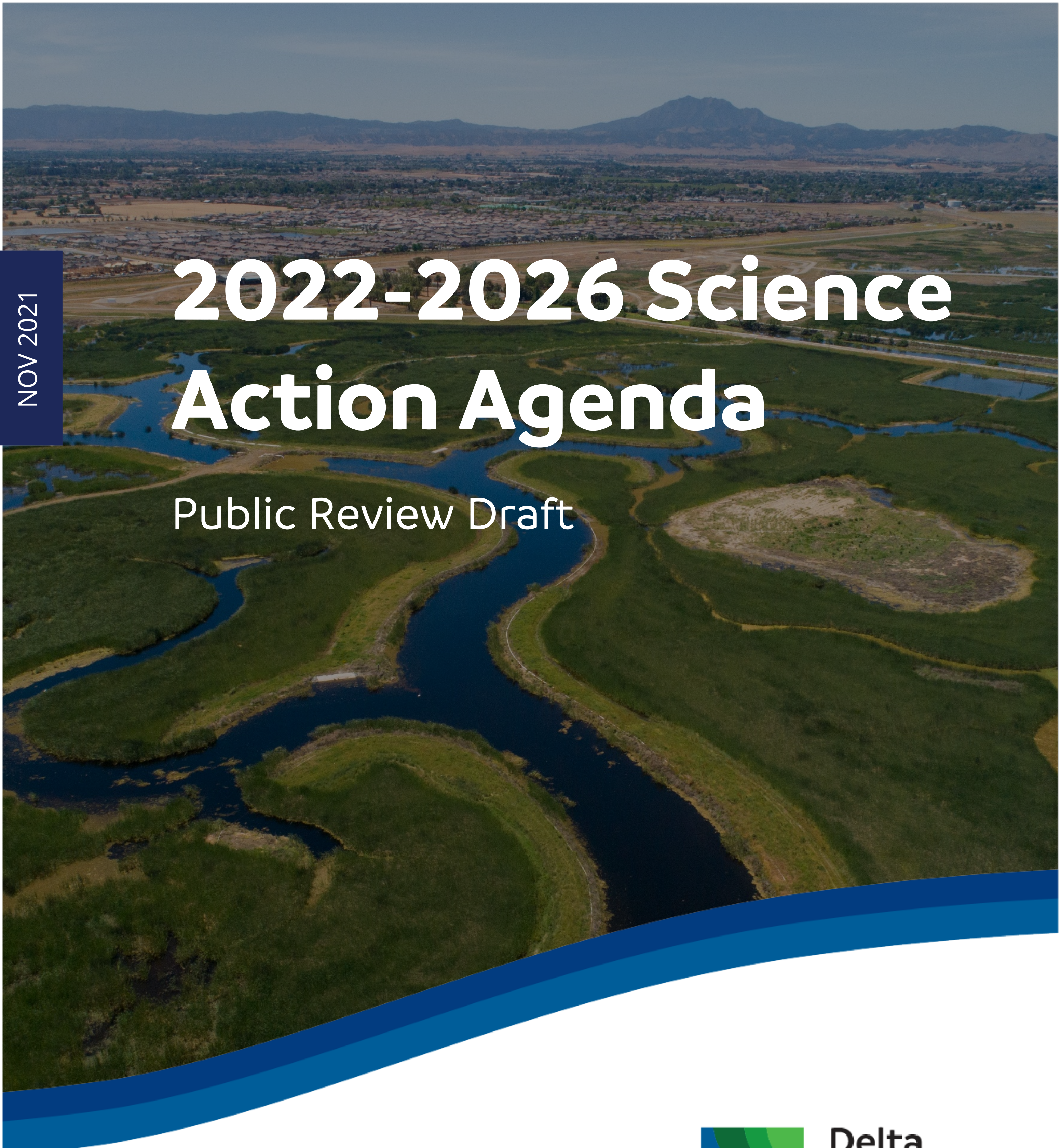
NOV 2021



2022-2026 Science Action Agenda

Public Review Draft

Delta Science Program

DELTA STEWARDSHIP COUNCIL

Table of Contents

2022-2026 Science Action Agenda 1
Draft SAA Review 2
Foreword 3
Overview 6
Introduction 10
Definitions 11
Co-production by the Numbers 13
Science Funding 14
Tracking Success 17
Management Needs, Management Questions, and Science Actions 18
Next Steps 33
References 34
Appendix A: SAA Development Process 36
Appendix B: 2017-2021 SAA Progress Summary 42
Appendix C: Developing and Applying Management Question and Science Action Criteria 45
Appendix D: List of Documents Used in Compiling Management Questions 50
Appendix E: Additional Management Questions and Science Actions 54
Appendix F: Compilation of Key Components of the 2022-2026 SAA 65

Draft SAA Review

Please provide your input on the draft SAA to the Delta Science Program by 5:00 PM on January 21, 2022, by email to SAA@deltacouncil.ca.gov or mail to 715 P Street, 15-300, Sacramento, CA 95814. The Delta Science Program will consider input from the review period when revising the final SAA, anticipated by Spring 2022. Visit the SAA webpage to learn more about the 2022-2026 SAA and its development.

Foreword

At the heart of some of the biggest challenges to management of the Sacramento-San Joaquin Delta (Delta) lie scientific uncertainties. For example, if a barrier is installed to combat salinity intrusion during drought, what is the likelihood that a harmful algal bloom would develop, and what would be the cost for human and nonhuman communities? What *are* the dominant factors contributing to a bloom at specific places and times, and how can management actions mitigate these risks? These scientific uncertainties typically span multiple disciplines and may transcend the jurisdiction of individual regulatory agencies. **The science and management community requires a clear organizational framework that defines and prioritizes actions to address scientific uncertainties underlying the most salient management needs**, ensuring that critical topics do not fall through the cracks between agency mandates. On the flip side, with 10 state and federal agencies that fund scientific investigations in the Delta, an organizational framework is also needed to avoid duplication of effort.

The Science Action Agenda (SAA) is a charter developed *by* the Delta science community, *for* the Delta science community, and it provides the necessary framework to address scientific uncertainties and avoid overlap. The 2022-2026 SAA joins a growing list of comprehensive action plans developed to support the governance of the nation's major estuaries and Great Lakes. These action plans vary in their topical or jurisdictional scope and time horizon but are widely recognized as essential mechanisms for deliberately identifying actionable management priorities, guiding decision-making, and ultimately helping to set goals, milestones, and metrics of success. **Here in the Delta, the SAA serves as a road map for where we need to collaborate and invest in science.**

Before I began as Delta Lead Scientist, I spent over a decade of my career working in the Everglades, which opened doors to further work in the Chesapeake Bay watershed and southern Louisiana, all with the aim of resolving scientific uncertainties associated with ecosystem restoration. Those experiences shaped my perspective, providing numerous lessons learned that can be applied to the Delta. Often, those systems serve as aspirational models for the Delta, providing insight on how to achieve estuary-scale integration of science and governance, and showing how collaborative development of goals, objectives, scenarios, and management strategies can help a region transition to effective, trusted, collaborative governance at the whole-system scale. With the process of co-production embraced in the development of the 2022-2026 SAA (see

Dr. Laurel Larsen touring the Delta near Bradford Island (Photo: Delta Science Program)

Co-production box on page 13), among other initiatives, the Delta is well on its way to a similar transformation.

In other ways, the Delta can and does serve as a model for these other social-ecological systems. **Only the Delta has an action agenda focused specifically on priority science actions to resolve uncertainties critical to resource management.** By contrast, the action plans for other estuaries combine science actions with implementation actions, with a dominant focus on implementation. The relatively weak role of science in these strategic documents can have repercussions for governance, as recognized by the National Academy of Sciences in their 2021 biennial review of progress on restoration of the Everglades. In this review, the panel highlighted the need for a stronger organizational framework for the science underpinning decisions. Not only can an action agenda specific to science provide the foundation for a science framework that supports decision-making, but as I will argue, it can also go a long way to ensuring the robustness and independence of that framework.

How does the SAA support the independence of science? First, it identifies and sets research and action priorities that transcend the jurisdictions, mandates, and decisional time horizons of individual agencies and establishes them as community funding priorities. Second, it empowers truly independent scientists—those not affiliated with a regulatory agency—to develop the key science relevant to management. Absent an SAA, independent scientists often struggle to identify those questions or studies that would most benefit immediate management needs because they may not know where to find the information, or they lack the time to do so. (As an academic who has been there, I know the struggle.) Though a robust body of science is performed by regulatory agencies, engaging independent scientists to identify and resolve scientific uncertainties underpinning controversial and politicized decisions is critical for establishing trust in the scientific basis for decision-making.

Truly, the SAA is a pride-worthy cornerstone for the Delta science community. Despite the disproportionately small amount of federal dollars that the Delta has received compared to other estuaries, its science framework has arguably emerged as disproportionately strong. **The 2017-2021 SAA guided over $35 million in science investments (see box on page 14) that were directly relevant to priority management needs**.[1] For example, it resulted in tools for developing planning scenarios, estimates for how land-use change impacts primary productivity, and Chinook salmon abundance estimates, as well as new conceptual models and frameworks for assessing the effectiveness of restoration.[2] Further, the SAA was cited in Governor Newsom's Water Resilience Portfolio as a model for the entire state for how to engage with diverse stakeholders in order to prioritize scientific questions surrounding management of water supplies, water quality, and flood risk.[3] The SAA also establishes a precedent for a type of collaborative process that is increasingly used in non-scientific governance, such as regional budget planning.

Building on these successes, the SAA could become one means to elevate the Delta on a national stage, attracting additional investment for science and implementation. Doing so will require the demonstration and communication of the value of the science that it prioritizes for addressing urgent needs relevant to state and national interests. The iterative, collaborative process used to generate management questions, management needs, and science actions (see ‘How was the SAA developed?’ section on page 12) instills confidence that the science actions prioritize the most representative and urgent needs. Still, our community has a long way to go in “closing the loop” to connect science findings to directly informing management actions. The inaugural Progress Summary, which tracked progress on science actions in the 2017-2021 SAA (see page 17), is a step in the right direction. The Delta Science Tracker, currently under development, will provide another means of tracking and communicating progress on science priorities, and the Delta Science Program is committed to serving as a liaison between scientists and policymakers to spread awareness of the findings and value of the science originating with the SAA. But these initiatives require the commitment of the whole science community, who must foster or initiate those lines of communication and document research products in a trackable manner.

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, long-term usefulness of the SAA requires iteration, and the sustainability of the science framework that it supports requires effective communication of findings. Hence, the challenge that I leave you with is to commit to doing your part to clearly communicate your science to managers and decision-makers, as well as to your funding agency, who can often help with communications as well. After all, “available” is an inextricable component of the mandate to use “best available science” to support the attainment of the Delta Plan’s Coequal Goals.

With deepest respect,

Dr. Laurel Larsen, Delta Lead Scientist

---

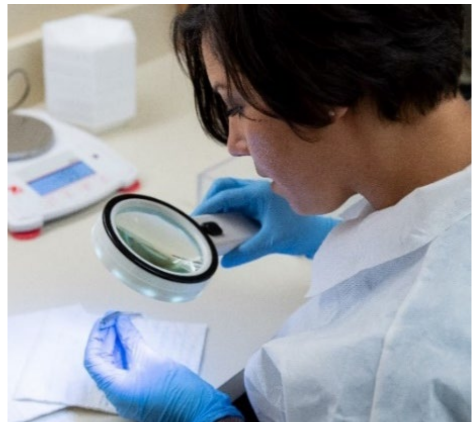
[1] Delta Stewardship Council, Delta Science Program. 2017. 2017-2021 Science Action Agenda.

[2] Delta Stewardship Council, Delta Science Program. 2021. 2017-2021 Science Action Agenda Progress Summary.

[3] 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.

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. It also establishes a foundation for funding critical science investigations. The 2022-2026 SAA is organized around the following six broad Management Needs, which collectively articulate major priorities for advancing science-based management in the Delta. The Management Needs are associated with Management Questions and 25 Top Science Actions, all collaboratively developed with input from the Delta science and management community:



Researcher examining Delta smelt (Photo: California Department of Water Resources)

Management Need 1: Improve coordination and integration of large-scale experiments, data collection, and evaluation across regions and institutions.

A. Establish publicly accessible repositories and interactive platforms 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 carry out large-scale experiments that can address uncertainties in the outcomes of management actions for water supply, ecosystem function, and socioeconomic conditions in the Delta.

Example: When major management actions occur, such as changes to nutrient loading, coordinated science across multiple groups advances a shared understanding of the impacts and saves time and resources.

Regional San's wastewater treatment plant upgrade aims to produce cleaner water for discharge to the Sacramento River (Photo: Regional San).

Management Need 2: Enhance monitoring and model interoperability, integration, and forecasting.

A. 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).

B. Enhance flood risk models through a co-production process with Delta communities to quantify and consider tradeoffs among flood risk management, water supply management, habitat restoration, and climate adaptation.
C. Evaluate and update monitoring programs to ensure their ability to track and inform management of climate change impacts, emerging stressors, and changes in species distributions.
D. Iteratively develop and update forecasts of climatological, hydrological, ecological, and water quality conditions at various spatial and temporal scales that consider climate change scenarios.

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

Drone view of algal bloom in San Luis Reservoir in 2021 (Photo: California Department of Water Resources).

Management Need 3: Expand multi-benefit approaches to managing the Delta as a social-ecological system.

A. Conduct studies to inform restoration approaches 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 benefit and burden human communities, with an emphasis on environmental justice.
D. Synthesize existing knowledge and conduct applied, interdisciplinary research to evaluate the costs and benefits of different strategies for minimizing introduction and spread of invasive species, and to inform early detection and rapid response strategies.
E. 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.

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

The Franks Tract (pictured) Futures project is exploring options for multi-benefit restoration approaches (Photo: California Department of Fish and Wildlife).

Management Need 4: Build and integrate knowledge on social process and behavior of Delta communities and residents to support effective and equitable management.

A. Collaboratively develop a long-term data collection and monitoring strategy for human communities in the Delta, with the goal of tracking and modeling metrics of resilience, equity, and well-being over time.
B. Measure and evaluate the effects of using co-production or community science approaches (in management and planning processes) on communities' perceptions of governance and decision-making processes.
C. Use multi-method approaches (e.g., surveys, interviews, oral histories, and/or observations) to develop an understanding of how stakeholder values, and cultural, recreational, natural resource, and agricultural uses vary geographically and across demographics.

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.

Fishing near Rio Vista Bridge (Photo: California Department of Water Resources).

Management Need 5: Acquire new knowledge and synthesize existing knowledge of interacting stressors to support species recovery and ecosystem health.

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 environmental thresholds relevant to managed fish species and location-specific survival probabilities to develop strategies that will support species recovery.
C. Identify the drivers and impacts of HABs severity and persistence.
D. Integrate existing models of hydrodynamics, nutrients, and other food web drivers to allow forecasting the effects of interacting stressors on primary production and listed species.
E. Quantify spatial and temporal "hotspots" of chemical contaminants and evaluate ecosystem effects through monitoring, modeling, and laboratory studies.

Example: With globalization and climate change, new tools are needed to manage and predict invasive aquatic vegetation and the associated environmental stress it inflicts.

Invasive water hyacinth in the Delta (Photo: Delta Science Program).

Management Need 6: Assess and anticipate climate change impacts to support successful adaptation strategies.

A. Evaluate how climate change, sea level rise, and more frequent extremes will impact habitats, water quality and sediment supply changes, the long-term persistence of native and non-native species, productivity, and food web support.
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 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, and how behaviors vary with adaptive capacity.
E. Test and predict how water allocation and ecological flow scenarios under projected climate change will influence habitat conditions, target species' access to critical habitat, and interactions among native and invasive species.

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.

Low water levels in Shasta Lake, photographed on October 28, 2021 (Photo: California Department of Water Resources).

Introduction

Why do we need a science action agenda?

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 in a four- to five-year timeframe.

The SAA is collaboratively developed with a focus on clearly identifying knowledge gaps that must be filled to advance management and the associated science actions that will help to fill those gaps (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), thereby benefitting multiple institutions' mandates and priorities. By its nature, the needs, questions, and actions in the SAA require collective action.

The SAA is part of the overarching Delta Science Strategy (Figure 1), intended to guide and support the broad Delta science 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. The Delta Science Strategy includes, but is not solely comprised of, the Delta Science Plan (strategic plan), the SAA (actionable approach), and the State of Bay-Delta Science (reporting on progress). The SAA is key to achieving the objectives of the Delta Science Plan and informing future iterations of the State of Bay-Delta Science. The 2022-2026 SAA builds on progress made on the 2017-2021 SAA (Appendix B).

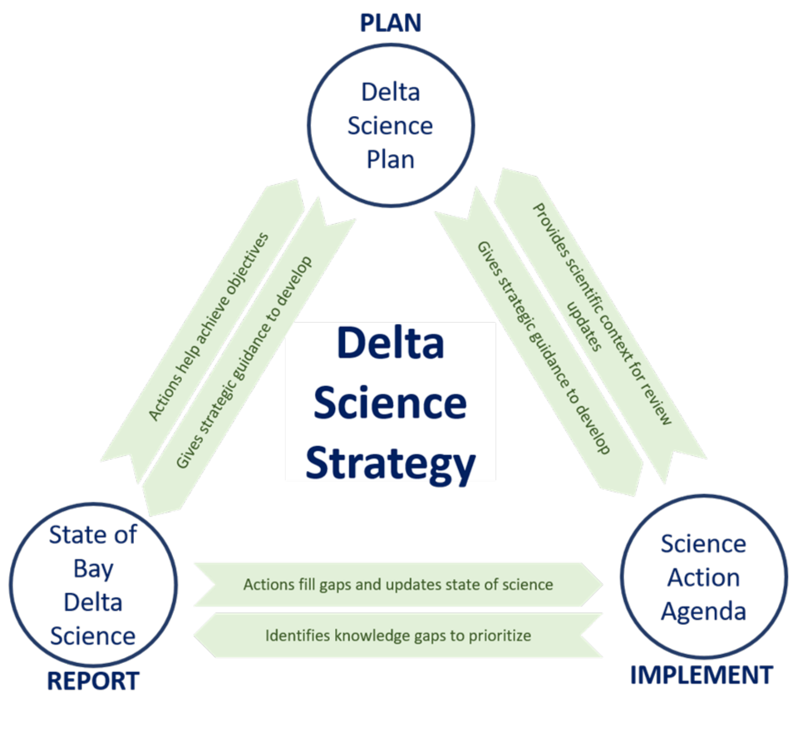


Figure 1. Relationship of the three elements of the Delta Science Strategy

How does the SAA inform funding?

The 2017-2021 SAA guided science funding investments for over $35 million 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 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.

What are the components of the 2022-2026 SAA?

The SAA connects **Science Actions** with high priority **Management Needs**. Developing the 2022-2026 SAA began with the crowdsourcing of an unprioritized list of **Management Questions**, a feature new to this version of the SAA. This addition was suggested by the Delta Plan Interagency Implementation Committee's (DPIIC)[a] 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.[4] 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

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 between multiple scenarios.
- **Management Questions** target uncertainty around a given management topic, often are specific to a single agency or a set of agencies' or organizations' priorities (but do, 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 utility of knowledge to address the physical, natural, and social-economic challenges of the Delta. Examples include research, monitoring, modeling, data management, synthesis, adaptive management, new methods, and more.

[a] The DPIIC, a 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.

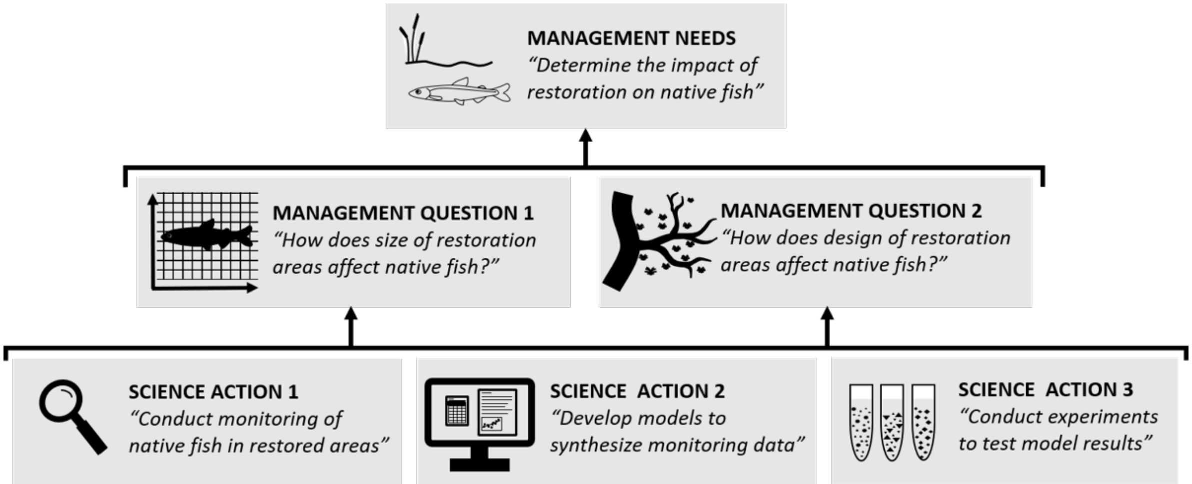


Figure 2. Tiered pyramid diagram linking Management Needs, Management Questions, and Science Actions. This diagram is for illustrative purposes only and does not imply one-to-one connections between Science Actions, Management Questions, and Management Needs.

broad and encompasses activities (e.g., projects, funded research) that yield new information and improve the use of existing information (see Science Actions Screening criteria 1a and 1c, Appendix C). The Top 25 Science Actions identified in the 2022-2026 SAA focus on: (1) generating new information or tools, and/or (2) improving or enhancing the use and reach of scientific information, tools, or knowledge.

"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.

– Susan Tatayon, Delta Stewardship Council Chair

How was the SAA developed?

The Delta Science Program facilitated a multiple-phase, nearly 18-month process to develop the 2022-2026 SAA (Figure 3, and Appendix A). The update process embraced co-production with the Delta science community, which includes 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.[5, 6]

Co-production by the Numbers

The 2022-2026 SAA was produced with extensive input and engagement from scientists, managers, and stakeholders throughout the Delta. Engagement numbers include:

- **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**
- **30+** reviewers commented on the 2017-2021 SAA Progress Summary, in addition to **10+** external partners who contributed to the initial draft document
- **4** written comments were submitted on the draft Management Needs
- **50+** Science Action workshop participants drafted **178** Science Actions
- **45** individuals responded to the survey on the proposed top **25** Science Actions

In this context, co-production resulted in a more comprehensive and relevant set of management gaps and science needs that are shared among many in the broader Delta science community. It is worth noting the challenges and limitations of integrated, collaborative processes, including barriers to participation in the process and influences on the discussions and outcomes of the process. Those who attended 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 Delta Stewardship Council's (Council) 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 Independent Science Board (Delta ISB)[b] and Delta Science Program's Science Advisory Committee[c].

---

[b] 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

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

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.[7, 8] Reviews conducted by the Delta ISB (e.g., on water quality, non-native species)[9, 10] were also a critical source of information on outstanding knowledge gaps.

An iterative, collaborative process was designed based on best practices for identifying science priorities, and included pre- and post-workshop surveying, topic area subgroups, and consensus-based discussion (Appendix A).[11, 12] 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,[13, 14] in which each question was coded with key themes that were then used to organize the 65 Top Delta Management Questions into six Management Needs.

The Management Needs, together with the gaps identified in a collaboratively developed and publicly reviewed assessment of the progress on the 2017-2021 SAA (see Tracking Success), 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 Prioritization criteria. The draft list of criteria was made available for feedback on the

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 SWC, awarded $10 million for research in the Delta through a competitive proposal solicitation notice (PSN) that required addressing scientific gaps identified in the 2017-2021 SAA. CDFW also used the SAA for their Watershed Restoration Grants Proposition 1 Program, which totaled roughly $7 million for Delta science.

The SAA also guides review and funding decisions for applications to the Delta Science Fellows Program in partnership with California Sea Grant. Over the 2022-2026 timeframe, 20-30 early career science fellows will develop their work based on the SAA.

Year	Award Type	Award (in $)	Funding Partners
2018	Fellows	1.5 million	Delta Science Program/SWC
2019	PSN	17 million	Delta Science Program/USBR/CDFW
2020	Fellows	1.5 million	Delta Science Program/SWC
2021	PSN	9 million	Delta Science Program/USBR
2021	PSN	7 million	CDFW

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 guide priorities for funding for the 2022-2026 period.

How should the SAA be used?

Because 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, agency budget change proposals, coordinated multi-agency efforts (e.g., 2020 California Water Resilience Portfolio), 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 existing individual and collaborative science organizations to collectively advance scientific insights and ensure a robust science infrastructure for supporting management and policy decision-making.

The 26 Management Questions and 75 Science Actions listed in Appendix E and F were not prioritized for inclusion in the 2022-2026 SAA based on the input received during the collaborative process. Appendix E are provided for archival purposes, highlighting other questions and science needs of the Delta science and management community that were articulated during the SAA update process. Though not prioritized for funding for the 2022-2026 period, the Actions in Appendix E may inform future SAA updates.

"The SAA is a tool that is very valuable in identifying science gaps that exist in the Delta that are necessary to fill 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."

– Randy Fiorini, Former Chair of the Delta Stewardship Council

---

When will the SAA be updated again?

The SAA is updated every four to five years in order 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 with this iteration, the next SAA will be informed by progress made (see Tracking Success) on the current Science Actions and will continue to adapt and respond to emerging needs.

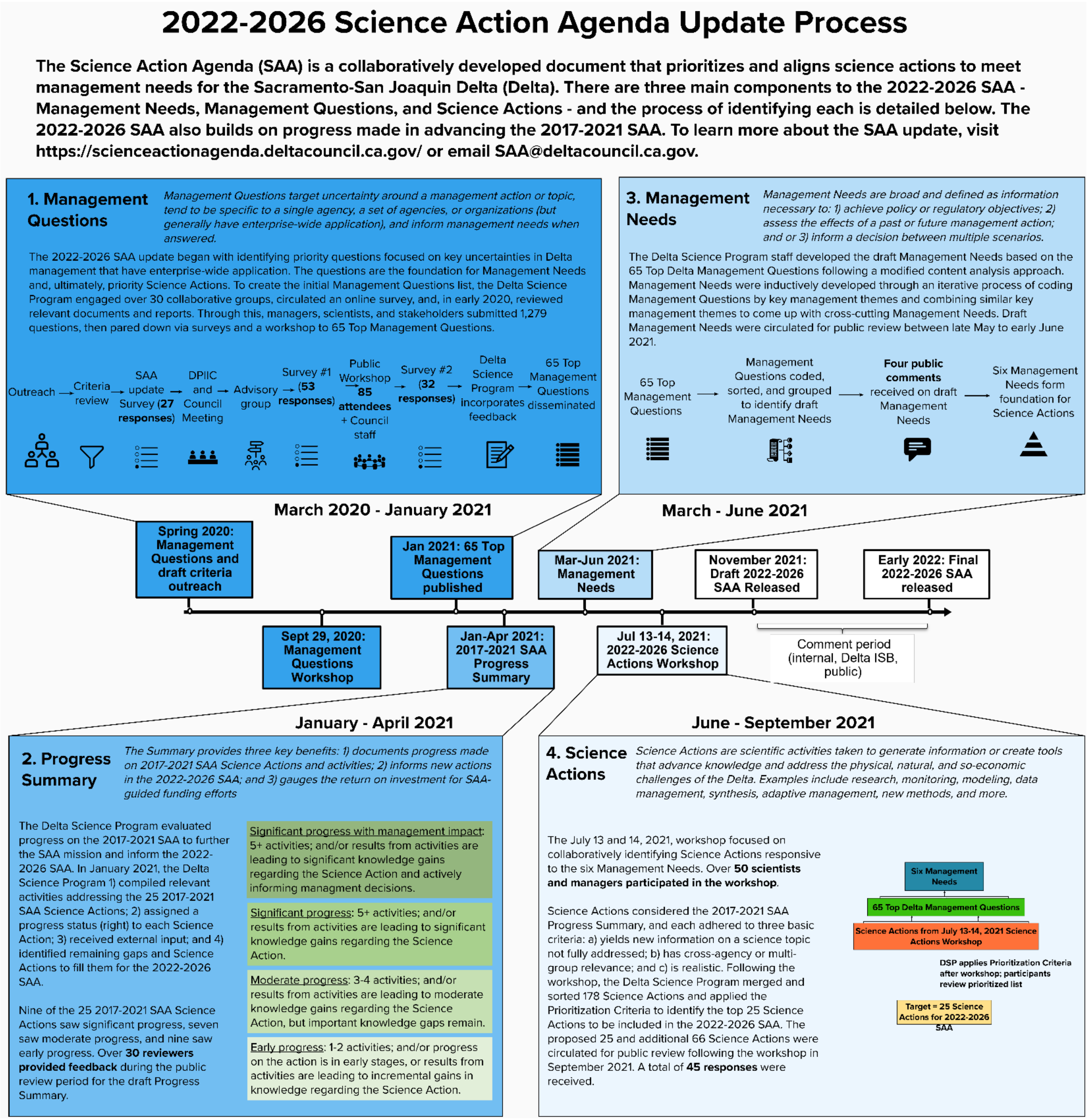


Figure 3. Draft infographic describing the process to develop the 2022-2026 SAA.

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.

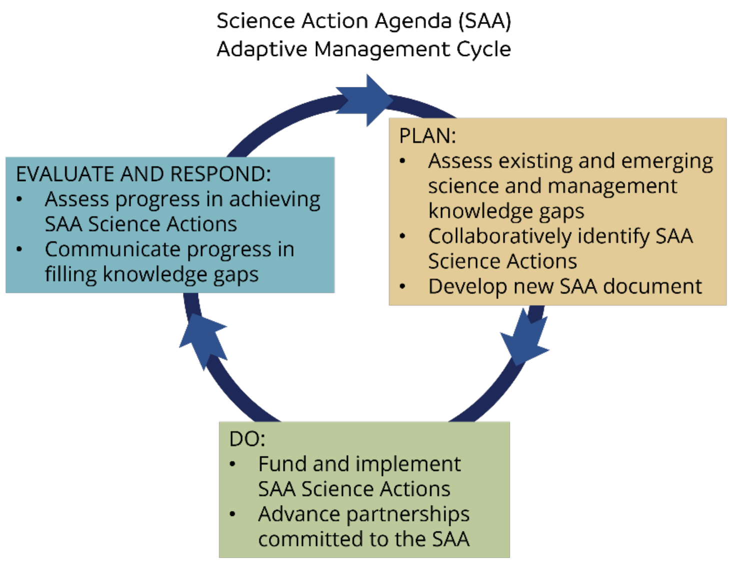


Figure 4. The SAA adaptive management cycle. The SAA is updated every four to five years, following the adaptive management cycle components of plan, do, and evaluate and respond.

The key steps to developing the Summary were to:

- Compile relevant activities (e.g., projects, funded research) 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;
- Solicit and receive input from the Delta science community.

Among the 25 2017-2021 Science Actions, 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 remaining gaps. Science Actions were drafted to address these gaps and submitted with additional proposed Science Actions for participants to consider at the July 2021 workshop. In this way, draft 2022-2026 Science Actions were informed by outstanding gaps in knowledge from the prior SAA, under the framework of newly identified Management Needs and Management Questions.

The 2017-2021 SAA Science Actions called for both the generation of new tools/information (e.g., projects, funded research, modeling, monitoring) and 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 may contribute to the 2022-2026 SAA Science Actions. The list may be expanded to include additional activities as needed.

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. Many of the Management Needs incorporate social-ecological concepts, acknowledging the growing recognition of the importance of social science for understanding and managing the Delta as a social-ecological system.[15] In response to comments from the Delta ISB on the 2019 Delta Science Plan,[16] the SAA explicitly considered Science Actions necessary to tackle climate change impacts.[17, 18] The Management Questions, Science Actions, and existing gaps (e.g., specific knowledge gaps and needs to be addressed by the Science Action) are detailed in the sections below.

Installation of the emergency salinity drought barrier in the West False River (Photo: California Department of Water Resources)

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 for large-scale experiments, completing the adaptive management cycle, and data collection. Although science in the Delta is coordinated on a number of fronts, Delta science could more directly inform management and could advance more efficiently with increased coordination and deliberate action to dissolve current barriers to collaboration. Effective management requires resolving barriers to connecting datasets, disciplines, institutions, and communication efforts throughout the Delta. 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).[19]

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?

Modeling Collaboratory

The need for a virtual "collaboratory" was highlighted at the Delta ISB's Science Needs Assessment Workshop in Fall 2020.[19] 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.

Table 1. Description of priority Science Actions for Management Need One, including existing gaps and connections to the 2017-2021 SAA.

#	Science Action	Existing Gaps
1A	Establish publicly accessible repositories and interactive platforms 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 to integrate across disparate monitoring efforts.[20] There is a need for the establishment of a virtual modeling "collaboratory" (for sharing models, cloud computing resources, and more) as well as for resources and platforms for interoperable, open datasets and visualization tools for all data covering the Delta. 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 a number of organizations operating at different scales, whose interests, objectives, and institutional structures are not always aligned, creating barriers to progress and coordination. Understanding and adapting to such institutional complexities will support a more effectively managed Delta and build on progress made to address Science Action 1B in the 2017-2021 SAA.
1C	Identify and carry out 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.[21, 22] There is a need for pilot-scale physical experiments that test the assumptions and principles of adaptive management, to progressively segue to larger scale experimentation and adaptation.

Management Need 2: Enhance monitoring and model interoperability, integration, and forecasting.

Management Need 2 focuses on advancing existing modeling, monitoring, and tools to forecast, detect, and respond to changes in the system. These advancements should be accomplished in a manner such that modeling, monitoring, and tools effectively and regularly inform management of the Delta as a complex social-ecological system (Table 2). This is particularly relevant as climate change accelerates ecological and social changes in the Delta. There is a critical need for models and assumptions to be updated to better predict future conditions to inform management.[8] 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.[24]

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 existing gaps and connections to the 2017-2021 SAA.

#	Science Action	Existing Gaps
2A	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 tools to manage HABs[19] that depict current and near future conditions, inform water intake operations, issue public health advisories, and communicate impacts and warnings of HABs.

#	Science Action	Existing Gaps
2B	Enhance flood risk models through a co-production process with Delta communities to quantify and consider tradeoffs among flood risk management, water supply 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 effects and tradeoffs (e.g., on ecosystems and Delta communities). This action emphasizes the engaged process needed to build buy-in to different management approaches. This action builds on the Council's Delta Adapts project and progress made to address Science Action A1C in the 2017-2021 SAA.
2C	Evaluate and update monitoring programs to ensure their ability to track and inform management of climate change impacts, emerging stressors, and changes in species distributions.	Long-term monitoring is a critical asset of Bay-Delta science.[23] However, monitoring programs 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.
2D	Iteratively develop and update forecasts of climatological, hydrological, ecological, and water quality conditions at various spatial and temporal scales that consider climate change scenarios.	Various distinct forecasting tools (e.g., DWR Bulletin 120 hydrologic forecasts) already exist, but their full potential will only be realized by connecting disparate components to tell a full story.[24] For example, forecasts of temperatures, habitats, and fish conditions could be combined for a better forecast of fish populations. In another example, drought management can be improved by connecting forecasts of invasive aquatic plants, Delta 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 holistically 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, holistic 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).

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 services and disservices 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 to native species and ecosystems 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?

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

#	Science Action	Existing Gaps
3A	Conduct studies to inform restoration approaches 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 to affect outcomes over short and long timescales.
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 human dimensions of the Delta, with a focus on understanding distributive environmental justice and climate impacts.[15] Integrative tools can be used to evaluate and assess the likely outcomes 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 benefit and burden human communities, with an emphasis on environmental justice.	As a nature-based solution for potentially promoting climate resiliency and ecosystem, habitat restoration needs to be evaluated for its impacts on the Delta's most environmentally-vulnerable communities. This action builds on the Delta Adapts project, the 2019 review of the Delta Plan that calls for more focus on environmental justice impacts, and progress made to address Science Action A3B in the 2017-2021 SAA.
3D	Synthesize existing knowledge and conduct applied, interdisciplinary research to evaluate the costs and benefits of different strategies for minimizing 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.[10] 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.
3E	Test and monitor the ability of tidal, nontidal, and managed wetlands and	There is a need to better understand the impacts of restoration projects at different elevations, particularly the cumulative benefits and impacts of

#	Science Action	Existing Gaps
	inundated floodplains to achieve multiple benefits over a range of spatial scales, including potential management costs, tradeoffs, and unintended consequences.	restoration on ecosystems at multiple spatial scales. This action calls for additional studies to assess the breadth of possible impacts and builds on the early progress made to address Science Action 3B in the 2017-2021 SAA.

Environmental scientists collect water samples on the Research Vessel Sentinel (Photo: California Department of Water Resources)

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 with current and historical ties to the Delta, with a particular focus on marginalized or disadvantaged communities. According to Dr. Jessica Rudnick, "the social sciences can help us understand 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".[25] The following Science Actions encourage use of social science to inform and strengthen management processes and policy decisions (Table 4).

Management Questions

- How can environmental justice principles, values of Delta communities, and traditional ecological knowledge be incorporated into the Delta science enterprise to support management activities and policy decision-making in the Delta?
- 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 existing gaps and connections to the 2017-2021 SAA.

#	Science Action	Existing Gaps
4A	Collaboratively develop a long-term data collection and monitoring strategy for human communities in 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 Delta's long human history, assessing the livelihoods, well-being, economy, and recreation of the Delta's human communities 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.[26, 15, 20]
4B	Measure and evaluate the effects of using co-production or community science approaches (in management and planning processes) on communities' perceptions of governance and decision-making processes.	Retrospective assessments of co-production or community science 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, and encouraging civic engagement.
4C	Use multi-method approaches (e.g., surveys, interviews, oral histories, and/or observations) to develop an understanding of how stakeholder values, and cultural, recreational, natural resource, and agricultural uses vary geographically and across demographics.	There is a need to better understand how human communities use and value different aspects of the Delta, and how these vary across different sub-populations, to inform management, planning, and policy. This action builds on the progress made to address Science Action A1B in the 2017-2021 SAA.

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 predation, competing species, contaminants, and food or nutrient availability. 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. The following Science Actions outline key steps for better understanding key ingredients to species recovery and ecosystem health (Table 5).

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 degree of control keeps invasive/non-native populations at a level that allows for desired and cost-effective management outcomes (e.g., boating access, fish habitat, food production)?
- 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 existing gaps and connections to the 2017-2021 SAA.

#	Science Action	Existing Gap
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 environments often do not work in lotic, tidal environments, creating a need for new strategies or innovative use of existing strategies. This action builds on the progress made to address Science Action A4B in the 2017-2021 SAA.
5B	Identify environmental thresholds relevant to managed fish species and location-specific survival probabilities to develop strategies that will support species recovery.	Potential environmental thresholds include water quality impacts to fish physiology (e.g., flow, temperature, and dissolved oxygen requirements), as well as structural and habitat requirements, such as barriers to migration and predator hotspots. This action builds on the progress made to address Science Action A4A and A5A in the 2017-2021 SAA.
5C	Identify the drivers and impacts of HABs severity and persistence.	In the Delta, most HABs of concern are formed by cyanobacteria; however, the causes, health impacts, and effective management of HABs and their toxins remains elusive. This action builds on the progress made to address Science Action 4D in the 2017-2021 SAA, and focuses on clarifying how nutrients, temperature, flows, and residence time interact to produce blooms at specific locations and times, as well as the impacts of those blooms on human health and ecosystem function.
5D	Integrate existing models of hydrodynamics, nutrients, and other food web drivers to allow forecasting 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. This action builds on the progress made to address Science Action 4C and A5A in the 2017-2021 SAA.

#	Science Action	Existing Gap
5E	Quantify spatial and temporal "hotspots" of chemical contaminants and evaluate ecosystem effects through monitoring, modeling, and laboratory studies.	While contaminant monitoring and special studies are ongoing, they tend to be disparate and in need of synthesis to improve the understanding of spatial and temporal variability,[9] and of how contaminant impacts scale to the population level. This action builds on the progress made to address Science Action 4D in the 2017-2021 SAA.

Environmental scientists at the John E. Skinner Delta Fish Protective Facility (Photo: California Department of Water Resources)

Management Need 6: Assess and anticipate climate change impacts 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 our methods of adapting to the rapidly changing climate. It calls for new studies and updates to existing scientific paradigms to adequately track rapidly changing 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 this Management Need is to rigorously compare and evaluate effective approaches for responding to changing conditions to maintain water supply and ecosystem function. The following Science Actions target uncertainties concerning individual and cumulative climate change impacts while considering different adaptation strategies and approaches (Table 6).

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 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 existing gaps and connections to the 2017-2021 SAA.

#	Science Action	Existing Gap
6A	Evaluate how climate change, sea level rise, and more frequent extremes will	This action calls for studies that improve our ability to understand and anticipate the changes to the Delta ecosystem that are underway or likely to occur

#	Science Action	Existing Gap
	impact habitats, water quality and sediment supply changes, the long-term persistence of native and non-native species, productivity, and food web support.	under future climate conditions. These studies can ensure that monitoring and research address and track change and emerging uncertainties, in order to inform management. This action builds on the progress made to address Science Action 3B, 4B, and 4C in the 2017-2021 SAA.
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 Delta communities, 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.
6C	Evaluate the possible multi-benefits of management actions that promote groundwater recharge for ecological functions and water resilience under 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 region-specific studies to understand multiple impacts of groundwater recharge projects and is responsive to SGMA implementation and the 2020 Water Resilience Portfolio. Evaluations can inform future drought response and planning efforts.
6D	Identify how human communities connected to the Delta watershed are adapting to climate change, what opportunities and tradeoffs exist for climate adaptation approaches, 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.

#	Science Action	Existing Gap
6E	Test and predict how water allocation and ecological flow scenarios under projected climate change will influence habitat conditions, target species' access 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.

Next Steps

From 2022 to 2026, the SAA will be used to guide competitive and non-competitive science funding for the Council and its partners, as well as to shape program priorities and foster science coordination and transparency. The Delta Science Program will track progress made on implementing the Science Actions in the 2022-2026 SAA. This may include improving the way that funded projects are tracked and progress metrics are reported. Progress on the Science Actions will play a critical role in implementing and informing the next Delta Science Plan, anticipated for release in 2024.

The Delta Science Tracker (Tracker) being developed by the Delta Science Program will provide an online portal for tracking science efforts in the Delta, and its launch is anticipated in early 2022. 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 SAA management areas and needs.

References

[4] Delta Stewardship Council. 2019. Delta Science Funding and Governance Initiative Implementation Report
[5] Lemos, M.C. and Morehouse, B.J. 2005. The co-production of science and policy in integrated climate assessments. Glob Environ Change 15(1):57–68.
[6] Djenontin, I.N.S., and Meadow, A.M. 2018. The art of co-production of knowledge in environmental sciences and management: lessons from international practice. Environmental Management 61, 885–903 (2018). https://doi.org/10.1007/s00267-018-1028-3.
[7] Delta ISB. 2020a. Building an Effective Delta Science Enterprise.
[8] Norgaard, R. B, Wiens, J. A, Brandt, S. B, Canuel, E. A, Collier, T. K, Dale, V. H, et al. 2021. Preparing Scientists, Policy-Makers, and Managers for a Fast-Forward Future. San Francisco Estuary and Watershed Science, 19(2). http://dx.doi.org/10.15447/sfews.2021v19iss2art2. Retrieved from https://escholarship.org/uc/item/40x3z74k.
[9] Delta ISB. 2018. Water Quality Science in the Sacramento-San Joaquin Delta. Chemical Contaminants and Nutrients. Sacramento, CA.
[10] Delta ISB. 2021. The Science of Non-native Species in a Dynamic Delta. Sacramento, CA.
[11] Sutherland, W.J., E. Fleishman, M.B. Mascia, J. Pretty, M.A. Rudd. 2011. Methods for collaboratively identifying research priorities and emerging issues in science and policy. Methods in Ecology and Evolution 2011, 2, 238–247. doi: 10.1111/j.2041-210X.2010.00083.x.
[12] Fleishman, E., D.E. Blockstein, J.A. Hall, M.B. Mascia, M.A. Rudd, J.M. Scott, W.J. Sutherland, A.M. Bartuska, A.G. Brown, C.A. Christen, J.P. Clement, D. Dellasala, C.S. Duke, M. Eaton, S.J. Fiske, H.Gosnell, J.C. Haney, M. Hutchins, M.L. Klein, J. Marqusee, B.R. Noon, J.R. Nordgren, P.M. Orbuch, J. Powell, S.P. Quarles, K.A. Saterson, C.C. Savitt, B.A. Stein, M.S. Webster, A. Vedder. 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
[13] Elo S. and Kynga S. H. 2008. The qualitative content analysis process. Journal of Advanced Nursing 62(1), 107–115. doi: 10.1111/j.1365-2648.2007.04569.x
[14] Burla, L, Knierim, B, Barth, J, Liewald, K, Duetz, M, and Abel T. 2008. From text to codings: intercoder reliability assessment in qualitative content analysis. Nurs Res. 2008 Mar-Apr;57(2):113-7. doi: 10.1097/01.NNR.0000313482.33917.7d. PMID: 18347483.
[15] Biedenweg, K., J. Sanchirico, H. Doremus, R. Johnston, J. Medellín-Azuara, and C.M. Weible. 2020. A Social Science Strategy for the Sacramento-San Joaquin Delta. Report delivered to the Delta Stewardship Council.
[16] Delta Stewardship Council, Delta Science Program. 2019. Delta Science Plan: Vision, principles, and approaches for integrating and coordinating science in the Delta.
[17] Delta ISB. 2018. Review of the Updated Delta Science Plan
[18] Delta ISB. 2020. Memorandum: Preparing for Accelerating and Uncertain Environmental Change.
[19] Delta ISB and DPIIC. 2021. DRAFT Science Needs Assessment: Building an Effective Delta Science Enterprise by Integrating Science for a Changing Delta.
[20] Delta ISB. 2021. Review of the Monitoring Enterprise in the Sacramento-San Joaquin Delta. Available from: https://deltacouncil.ca.gov/pdf/isb/meeting-materials/2021-10-12-draft-isb-mer-report.pdf.
[21] Delta Independent Science Board (Delta ISB). 2016. https://www.deltacouncil.ca.gov/pdf/isb/products/2016-02-19-adaptive-management-report.pdf.

[22] Wiens, J.A., J.B. Zedler, V.H. Resh, T.K. Collier, S. Brandt, R.B. Norgaard, J.R. Lund, B. Atwater, E. Canuel, and H.J. Fernando. 2017. Facilitating Adaptive Management in California's Sacramento–San Joaquin Delta. San Francisco Estuary and Watershed Science, 15(2). https://doi.org/10.15447/sfews.2017v15iss2art3.
[23] Delta ISB. 2019. A Review of the Interagency Ecological Program's Ability to Provide Science Supporting Management of the Delta. Available from: https://deltacouncil.ca.gov/pdf/isb/products/2019-11-13-final-isb-iep-review.pdf.
[24] Delta ISB and DPIIC. 2021. Science Needs Assessment Integrating Science for a Rapidly-Changing Delta - Principal Science Recommendation - Interagency Forecasting. Available at: https://deltacouncil.ca.gov/pdf/dpiic/meeting-materials/2021-03-08-item-4-science-needs-assessment-draft-recommendations.pdf.
[25] Rudnick, J. 2021. Understanding People in the Face of Rapid Environmental Change. Delta Stewardship Council Blog August 26, 2021.
[26] Delta ISB. 2017. Review of Research on the Sacramento-San Joaquin Delta as an Evolving Place. Available from: https://deltacouncil.ca.gov/pdf/isb/products/2017-05-18-isb-delta-as-a-place.pdf.

Appendix A: SAA Development Process

Background

To date, the 2017-2021 SAA has successfully guided over 35 million dollars 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 responsibility for updating the SAA is with the Delta Science Program and Delta Agency Science Workgroup (a body of scientists representing 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 common 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 targeted individuals and groups to provide early input on the proposed screening and prioritization criteria and 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 Delta Stewardship Council (Council) and DPIIC. DPIIC members were surveyed for potential Management Questions and 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 would be ideal. 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 with over 30 collaborative groups, circulated an online survey to the Delta community, and reviewed relevant documents and reports. Through this effort, 1,279 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	85 workshop participants weighed in on Management Questions
110	Staff incorporated workshop feedback to shorten list; 110 Management Questions	Received 53 survey responses

Management Questions count	Delta Science Program Method	Outcome
	were sent via post-workshop survey to participants for final review	
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). An advisory committee of participants from the 2019 DPIIC Science Funding and Governance Initiative was formed to help guide workshop planning. 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.

Table 2. 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
Grand Total	87	54

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.

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 targeted input from subject matter experts was used to inform the Science Actions Workshop in July 2021. See additional details in Appendix B.

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 the category label appropriately encompassed all Management Questions included. The draft Management Needs were circulated for public review in late May and early June 2021.[5] Only minor changes occurred to the Management Need 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.

As noted in Table 3, workshop participants developed 178 Science Actions responsive to the six Management Needs. 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 on the priority and wording of the top 25 Science Actions. Participants could also propose reconsidering any of the 66 extra Science Actions for 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.

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
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	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; 66 Extra Science Actions were included in Appendix E

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.

Methods used to prioritize these science actions are explained in Appendix C.

[1] Sutherland, W.J., E. Fleishman, M.B. Mascia, J. Pretty, M.A. Rudd. 2011. Methods for collaboratively identifying research priorities and emerging issues in science and policy. Methods in Ecology and Evolution 2011, 2, 238–247. doi: 10.1111/j.2041-210X.2010.00083.x.
[2] Fleishman, E., D.E. Blockstein, J.A. Hall, M.B. Mascia, M.A. Rudd, J.M. Scott, W.J. Sutherland, A.M. Bartuska, A.G. Brown, C.A. Christen, J.P. Clement, D. Dellasala, C.S. Duke, M. Eaton, S.J. Fiske, H.Gosnell, J.C. Haney, M. Hutchins, M.L. Klein, J. Marqusee, B.R. Noon, J.R. Nordgren, P.M. Orbuch, J. Powell, S.P. Quarles, K.A. Saterson, C.C. Savitt, B.A. Stein, M.S. Webster, A. Vedder. 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, Abel T. From text to codings: intercoder reliability assessment in qualitative content analysis. Nurs Res. 2008 Mar-Apr;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.

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 and 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 in 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 was the first attempt to formally track progress in addressing the Science Actions outlined in the SAA, providing a foundation to build from for future summaries.

2017-2021 SAA

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

- **Action Area 1:** Invest in assessing the human dimensions of natural resource management decisions.
- **Action Area 2:** Capitalize on existing data through increasing science synthesis.
- **Action Area 3:** Develop tools and methods to support and evaluate habitat restoration.
- **Action Area 4:** Improve understanding of interactions between stressors and managed species and their communities.
- **Action Area 5:** Modernize monitoring, data management, and modeling.

Summary approach

Information needed to assess progress

Progress was assessed based on the relevant activities addressing the Science Actions and the status of those activities that were initiated, ongoing, or completed between 2016-2021. The Delta Science Program gathered information on relevant science activities through collaborative science venues, its own staff involvement and work on relevant activities, and by tracking science funding programs. Types of activities included funded research (e.g., through Delta Science Program Proposal Solicitation, California Department of Fish and Wildlife's Prop 1 Restoration Grant Program), monitoring (e.g., efforts collecting needed information), modeling and synthesis (e.g., integrated models), 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., Delta ISB), publications, and outreach (e.g., symposia). What part(s) of the Science Action the activity was addressing, the timeline for completion, status of the activity, and the primary entity performing the work were also collected.

Status of progress made

The 25 Science Actions were assigned to one of four general status categories. While (in reality) there is a gradient of progress, not discrete categories, the progress bins here provide an approach 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 and proportional breakdown by activity type and considering their contributions to the Science Actions, a progress status was assigned for 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 project details. The draft list of activities was circulated for targeted input from relevant entities and program leads throughout the Bay-Delta (e.g., Interagency Ecological Program), 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 were incorporated into the final Summary available on the Council's website.[1]

Table 1. Draft Progress Summary reviewers by affiliation.

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
Grand 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. Some of these specific gaps directly informed 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, to "Identify how human communities connected to the Delta watershed are adapting to climate change, what opportunities and tradeoffs exist for climate adaptation approaches, and how behaviors vary with adaptive capacity," builds directly on this gap identified in the Progress Summary.

---

[1] Delta Stewardship Council, Delta Science Program. 2021. 2017-2021 Science Action Agenda Progress Summary.

Appendix C: Developing and Applying Management Question and Science Action Criteria

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 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 comments.

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 the new SAA component, and seeking external input. The draft criteria were available on the Council's website for public review between 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 or 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. Applicability to Delta-relevant Federal, State, and local initiatives
    a. If answered, the Management Question would increase the effectiveness of policy 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 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 associated with 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, not site-specific, and 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 ecological knowledge and has 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 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, it was asked that Science Actions 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 there enough progress made?). Science Actions should also adhere to 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 great importance of Scientific Relevance, Impact, and Opportunity Cost. 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 Top; 66 extra) were circulated via a post-workshop survey for feedback.

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
- 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 / AMAT
- 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
SBDS Chapter—Perspectives on Bay-Delta Science Policy (2016)	Delta Science Program
Basin Plan Amendments for Salt and Nitrate (2019, approved by OLS Jan. 2020)	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 Growth of Cyanobacteria With Special Emphasis on the Sacramento-San Joaquin Delta (2015)	Nutrient Research Strategy Science Work Group
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 Regional Monitoring Program

Title of Document	Associated Organization
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)	Interagency Ecological Program (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)	California Department of Fish and Wildlife
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 Regional Monitoring Program (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 Regional Monitoring Program
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)	San Francisco Estuary Partnership

Title of Document	Associated Organization
Water Resilience Portfolio	CNRA; Cal EPA; California Department of Food and Agriculture
Framework of Voluntary Agreements	Cal EPA; 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)	Collaborative Adaptive Management Team Salmonid Scoping Team
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	US Bureau of Reclamation (USBR)

Appendix E: Additional Management Questions and Science Actions

A total of six Management Needs, 65 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. 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 questions the Delta science and management community have. 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. The organization of all Management Needs, Management Questions, and Science Actions is shown in Appendix F.

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
2: Enhance monitoring	Four/ One	Four/ Thirteen	• #1 Strengthen	• #2 Capitalize on existing

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
and model interoperability, integration, and forecasting			science-management interactions	data through increasing science synthesis
3: Expand multi-benefit approaches to managing the Delta as a social-ecological system	Nine/ 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	• #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
			understandin g of the Delta	
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 climate change impacts to support successful adaptation strategies	Six/ One	Five/ Sixteen	• #1 Strengthen science-management interactions • #6 Maintain, communicate, and advance understandin g 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 directly downloading 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 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 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.
- Perform observational, laboratory, and synthesis studies to resolve independent and synergistic effects of factors on phytoplankton communities and higher trophic levels based on historical and contemporary responses to changes in nutrient

loading, hydrologic inputs, and temperature, and use that understanding to develop mechanistic models that can be used to evaluate alternate management scenarios.
- 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.

Appendix F: Compilation of Key Components of the 2022-2026 SAA

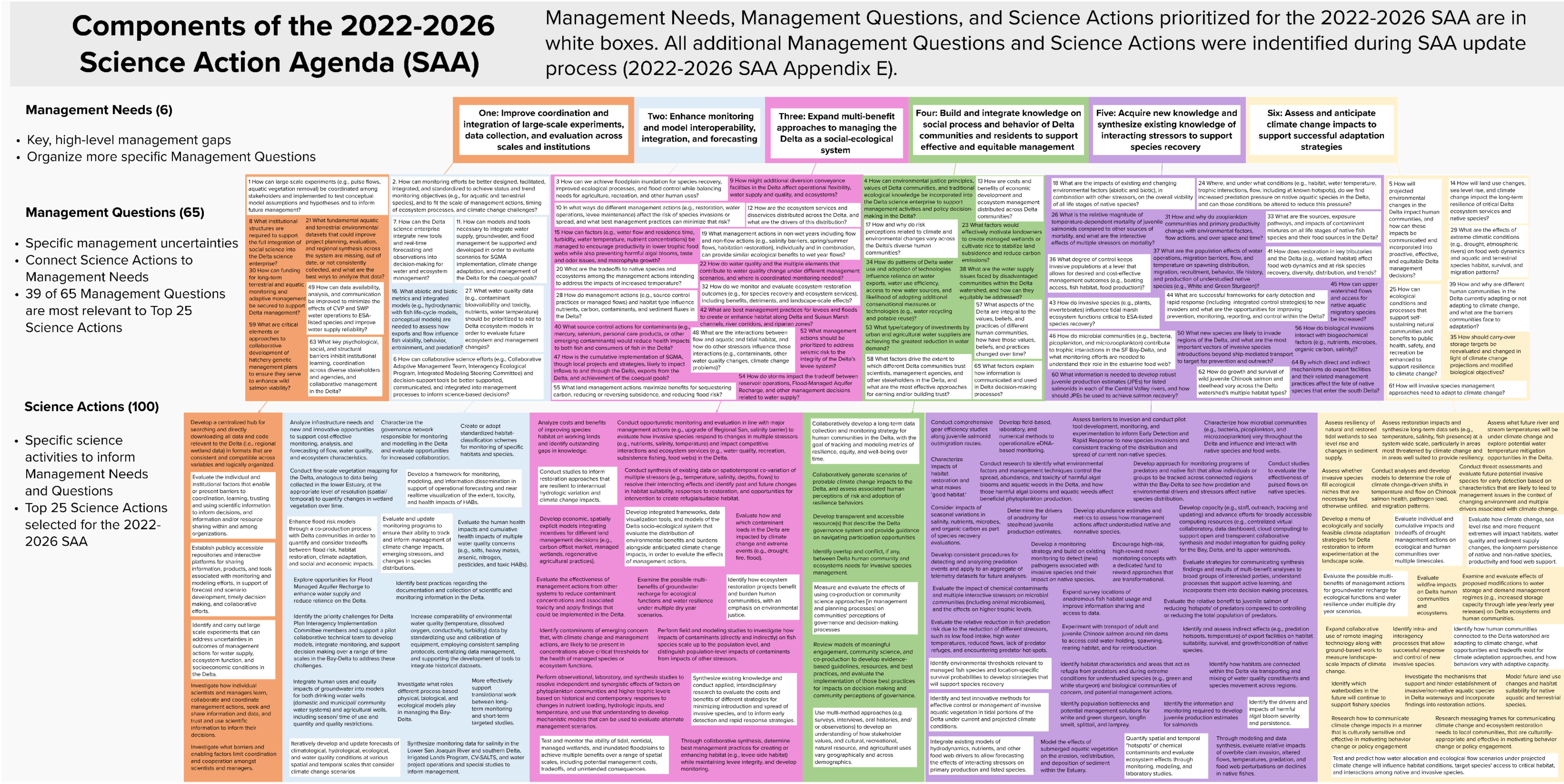


Figure 1. Draft schematic of all six Management Needs, 65 Management Questions, and 100 Science Actions identified during the 2022-2026 SAA update process. Only those in white are prioritized for funding through the SAA.