REVIEW OF THE MONITORING ENTERPRISE IN THE SACRAMENTO-SAN JOAQUIN DELTA

Delta Independent Science Board

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Executive Summary

In the Sacramento-San Joaquin Delta and Suisun Marsh (the Delta; Figure 1), there are numerous examples of how monitoring has helped with decision-making on water operations, water conveyance, water quality, flood protection, habitat restoration, or habitat alterations. However, the need to assess long-term monitoring in the Delta to ensure it is responsive to management has been identified through various venues and in initiatives endorsed by the Delta Plan Interagency Implementation Committee. To help address this need, the Delta Independent Science Board (Delta ISB) undertook a review of the monitoring enterprise, which covers the suite of monitoring activities or programs that are collected in the region, to assess whether the information collected from monitoring is meeting the needs of the management agencies, whether coordination could be improved, and how monitoring data can support the implementation of adaptive management. This review helps to implement Delta Science Plan Action 3.3 ("Routinely evaluate monitoring programs in the Delta to identify gaps, redundancies and management relevance"; see DSC-DSP 2019).

This review was broken out into two components. Component 1 was the development of an inventory of monitoring activities in the Delta that spans the physical, biological, chemical, geological, and social sciences, prepared by ESSA Technologies Ltd, CBEC eco engineering, and PAX Environmental Inc. in collaboration with and under the direction of the Delta ISB. It resulted in three reports:

(1) a lessons and methodology report (Nelitz et al. 2019), which consisted of a literature review of lessons learned within the Delta along with five other systems (Chesapeake Bay, Great Lakes, Puget Sound, Great Lakes, Coastal Louisiana in the United States, and Queensland, Australia).
(2) a summary report of monitoring activities in the inventory (Nelitz et al. 2020a); and
(3) a comprehensive synthesis report (Nelitz et al. 2020b), which assesses the relevance of monitoring activities in serving the needs of decision makers and identifies opportunities to improve monitoring based on the initial analysis of the inventory.

Component 2 resulted in this fourth and final report, which is the Delta ISB's evaluation and recommendations of monitoring informed by a variety of sources. These sources are the three Component 1 reports and inventory, an extensive literature review, professional experiences of Delta ISB members, perceptions on monitoring shared in public comments, results of a questionnaire that was sent out to the Delta community that received 34 responses, and 11 interviews with monitoring practitioners in the Delta.

As part of this review 157 unique monitoring activities were catalogued into an inventory. Of the 157 monitoring activities, 62% (97) are influenced by a management driver, such as a biological opinion or incidental take permit, and 44% (69) meet fundamental attributes that represent high data quality, such as publicly accessible data, data collection guided by a monitoring design or sampling protocol, and reliable QA/QC procedures.

Although a majority of monitoring activities in the inventory are influenced or required by a management driver, and a substantial number of monitoring activities meet several attributes that represent high quality data, 70% (16) of the 23 questionnaire respondents disagreed that the information collected from monitoring serves the needs of decision-makers. Several commenters from the questionnaire and interviews cited a monitoring-management disconnect. Most monitoring programs are not designed to sufficiently answer management questions and have not been designed and/or implemented with the intent of explicitly supporting adaptive management in the Delta.

As part of the review, the Delta ISB identified potential monitoring gaps, such as chemical contaminants, dredging, and non-native species, and opportunities to improve coordination, efficiencies, data quality, and accessibility to better support the needs of management. Although the Delta Plan provides useful guidance on decision-making needs, there are no agreed upon management questions in which monitoring should address to support adaptive management that spans the management areas of water supply, water quality, flood protection, species, habitat, and land use to achieve the coequal goals. This has resulted in some fragmentation with how monitoring is conducted and coordinated in the Delta.

To help improve coordination, adaptive management, and how monitoring could better meet the needs of management, the Delta ISB developed five best practices that should be formally adopted into individual monitoring programs, and three overarching recommendations that are directed at the monitoring enterprise as a whole.

Best Practices for Individual Monitoring Programs

Overall, the Delta ISB advises that every monitoring program develop a monitoring plan or road map using the adaptive management framework of a well-designed monitoring program developed for this review. This would involve six steps that should be part of any monitoring effort (Figure 3), to develop (1) the purpose of the monitoring program, (2) the problem statement, (3) the monitoring design, (4) how the program will be implemented, (5) how information collected will be used to facilitate learning, and (6) how the monitoring program will be revised. The **monitoring program should be underlain by five best practices** to help address some of the challenges and issues with monitoring identified in the review:

1. Monitoring should be closely tied to the goals, objectives, and specific questions of interest to managers and decision makers.
2. Monitoring should be informed by stakeholder engagement and participation if appropriate, including use of alternative forms of data and knowledge such as Traditional Ecological Knowledge and qualitative observations.
3. Monitoring plans should have enough flexibility to take advantage of new information and opportunities to adapt to issues as new techniques and technologies become available.
4. Monitoring programs must include adequate data management, analysis and synthesis, and should strive to improve statistical validity.
5. Monitoring programs should ensure the data are accessible and shared with the public and other agencies.

Recommendations for the Monitoring Enterprise

Consideration of the best practices or the development of a monitoring plan by an individual monitoring program would help address some of the findings related to the disconnect between monitoring and management, communication, and data quality and accessibility. However, more transformative changes are needed to fully address these findings. Therefore, the Delta ISB makes **three recommendations (or “big moves”) that could better link monitoring to management**, and begin to address the gaps and opportunities to improve efficiencies identified in this report. These recommendations are:

1. Developing priority science and management needs and questions for the monitoring enterprise, and synthesizing information around these questions in biannual reports or at a summit.
2. Reimagining monitoring designs for priority monitoring needs that is guided by a system-wide conceptual model.
3. Strengthening the organizational structure and integration to support monitoring and adaptive management.

The implementation of the three recommendations are interlinked and should be guided by the six-step adaptive management framework for monitoring developed for this review, which could ultimately lead to a comprehensive monitoring plan for the enterprise. These recommended changes will be difficult to implement, but the complexity, urgency, and long-standing nature of many challenges facing the Delta dictate the need to do things differently. As no single agency could implement all the recommendations alone, the decision on how to proceed with recommendations lies with the enterprise as a whole. Through the questionnaire, the Delta ISB sought feedback on these preliminary recommendations, and found there was strong support for them. To move forward, the Delta ISB suggests the Delta Stewardship Council - Delta Science Program form the workgroup, described in Delta Science Plan Action 3.4 (DSC-DSP 2019), that will facilitate monitoring program coordination and integration to discuss the findings and recommendations of this review, and how to move forward with the recommendations.

The inventory of monitoring activities that was developed for this review will be a useful tool for implementing the three “big move” recommendations by providing information on what is being done in the Delta and helping with integration and coordination of monitoring. The data and information from the inventory will be incorporated and made public with the launch of the Delta Science Tracker in 2022, which will provide a comprehensive tool to track, visualize, and summarize science activities in the Sacramento-San Joaquin Delta region. Metadata within the inventory (and consequently the Delta Science Tracker) can quickly become out of date, so we encourage the community to maintain updated metadata and explore how the Delta Science Tracker could be fully utilized.

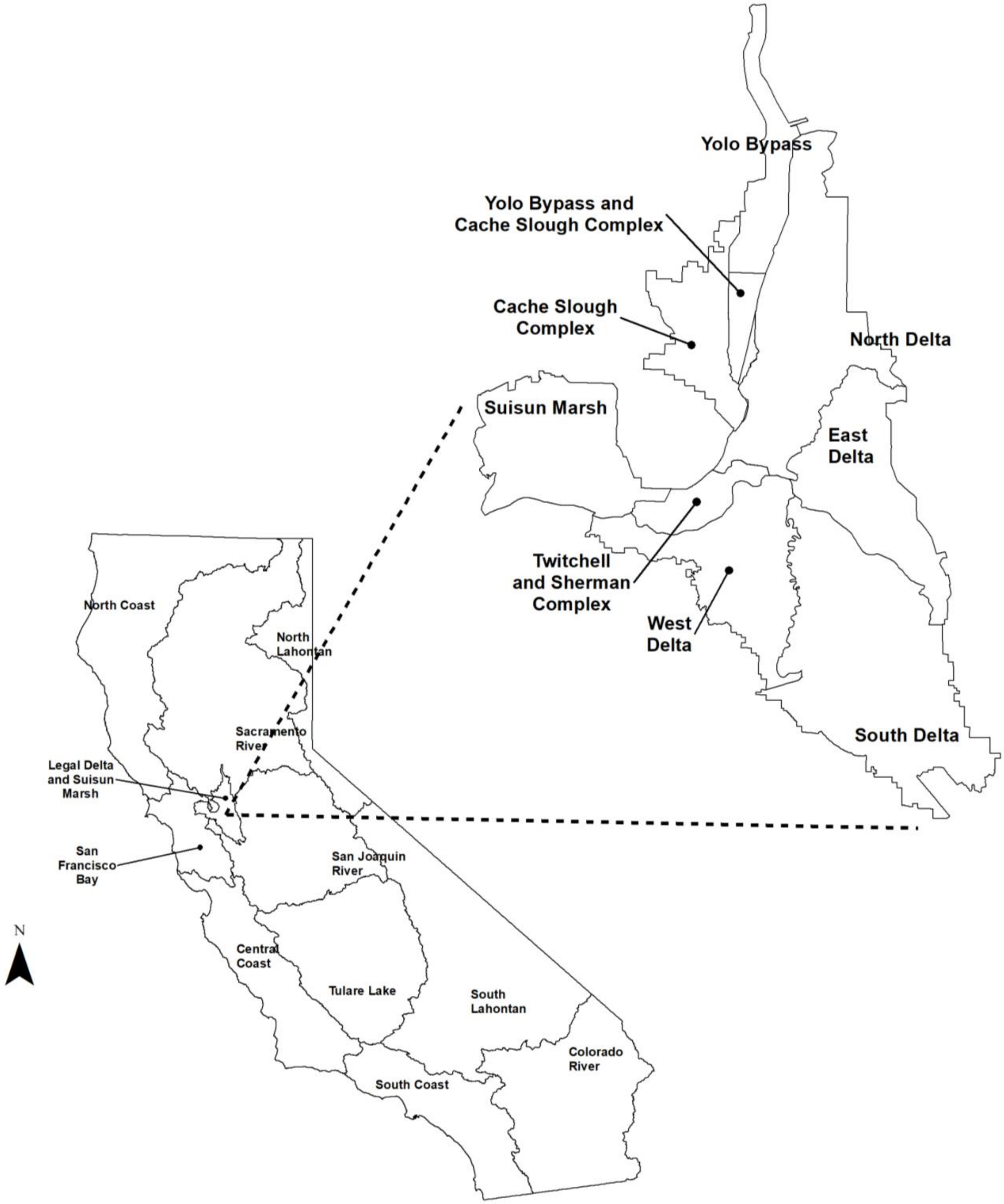

Figure 1. Geographic overview of the Sacramento-San Joaquin Delta regions, along with the California Basins.

Mon·i·tor

To watch and check a situation carefully for a period of time in order to discover something about it[1]

The systematic process of collecting, analyzing and using information to track a programme's progress toward reaching its objectives and to guide management decisions[2]

1. Introduction

1.1. Delta ISB Mandate and Scope of this Review

By legislative mandate, the Delta Independent Science Board (Delta ISB) reviews the adequacy of the science in support of adaptive management for the Sacramento-San Joaquin Delta (see Figure 1). The Delta Reform Act states that "The Delta Independent Science Board shall 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 that shall be scheduled to ensure that all Delta scientific research**, monitoring**, and assessment programs are reviewed … (WC 85280 (a)(3)). Thus, a review of monitoring in the Delta is a fundamental charge to the Delta ISB. Previous reviews by the Delta ISB covered habitat restoration, water quality, fish and flows, Delta as place, levees, adaptive management, non-native species and the Interagency Ecological Program (IEP).

Monitoring is central to all of the topics considered in the previous and current Delta ISB reviews, and a key component of the Delta Plan's adaptive management cycle (Wiens et al. 2017; see Figure 2). However, the need to assess long-term monitoring programs in the Sacramento-San Joaquin Delta to ensure they are responsive to management has been identified through various venues and in initiatives endorsed by the Delta Plan Interagency Implementation Committee (DSC and USGS 2017, DSC 2018). Consequently, the Delta ISB undertook a review of the monitoring enterprise, which covers the suite of monitoring activities or programs that are collected throughout

[1] Taken from the Cambridge Dictionary: https://dictionary.cambridge.org/us/dictionary/english/monitoring
[2] Taken from UN Women: https://www.endvawnow.org/en/articles/330-what-is-monitoring-and-evaluation-.html

the Sacramento-San Joaquin Delta and Suisun Marsh (the Delta; Figure 1). For this review, a monitoring activity collects data for a specific purpose and related to a specific question, while a monitoring program is a higher order aggregation or network of monitoring activities that are coordinated to serve a common purpose for data collection. For example, the California Department of Fish and Wildlife's Fall Midwater Trawl and the United States Fish and Wildlife Service's Delta Juvenile Fish Monitoring Program are individual monitoring activities, but they are coordinated through IEP, which is considered a monitoring program.

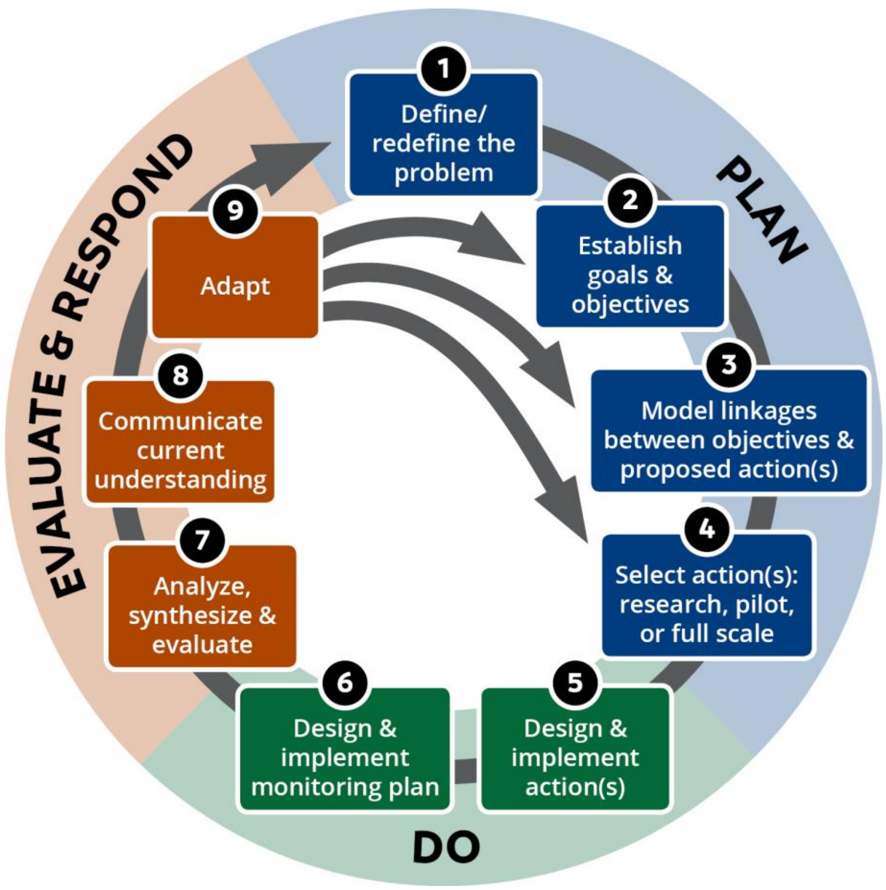

Figure 2. The nine-step adaptive management framework. Taken from the Delta Plan (2013) and Wiens et al. (2017), modified for accessibility.

The overall objectives of the monitoring enterprise review are to review the state of monitoring in the Delta and to offer recommendations that may improve how (1) current and future monitoring programs meet informational needs of management and policy; (2) monitoring programs can be better coordinated; and (3) monitoring data can support implementation of adaptive management and assessments of performance measures that spans the biological, geological, physical, chemical, and social sciences. This review is the largest review undertaken by the Delta ISB.

In this review, we examined the broad array, networking, and coordination of monitoring programs in the Delta and assess whether they provide the information needed to respond to the many challenges and problems in the Delta. We also examine how monitoring data are being used by managers and agencies to provide accurate and current information to policy-makers. The intended audience for this review spans the Delta Stewardship Council, adaptive management practitioners, decision-makers, and entities that use monitoring information from the Delta to plan, conduct, and regulate management in the Delta, including policy making. In particular, various collaborative initiatives have expressed interest in the findings and recommendations from this review, including:

- The Delta Science Funding and Governance Initiative, which builds of discussions from the 2016 Science Enterprise Workshop and is assessing whether the current levels of funding and the governance structure can efficiently meet current and future science needs (see DSC 2019; Recommendation 2.3: Develop protocols and coordinate independent, regular reviews to evaluate the effectiveness of monitoring, following the completion of the Delta ISB reviews); and

- The Water Resilience Portfolio, which contains a suite of actions to prepare California from water supply challenges, such as extreme drought and floods, and rising temperatures (see CNRA et al. 2020; Action 23.2: Improve Delta monitoring efforts based upon Delta Independent Science Board recommendations).

- The 2019 Delta Science Plan, which provides a framework for coordinating and communicating science activities (see DSC-DSP 2019; Action 3.3: Routinely evaluate monitoring programs in the Delta to identify gaps, redundancies and management relevance);

This report complements our review of the IEP, which is a major coordinator of monitoring and scientific activities in the Delta. That review takes a broader overview of Delta ecological science, while also giving more attention to IEP as a program with its own organizational structure. In contrast, the monitoring enterprise review looks into the monitoring activities that are coordinated by the IEP along with those that are not.

1.2 What is Monitoring and Why Review?

As described in the definitions at the beginning of this review, monitoring entails measuring something to grasp what is happening. But scientific monitoring is more than that; it is a systematic process that is conducted with certain objectives and outcomes in mind. There are a number of formal and informal definitions of monitoring. We adopt an adaptive management framework of a well-designed monitoring program that is guided by six steps that should be part of any monitoring effort (Figure 3).

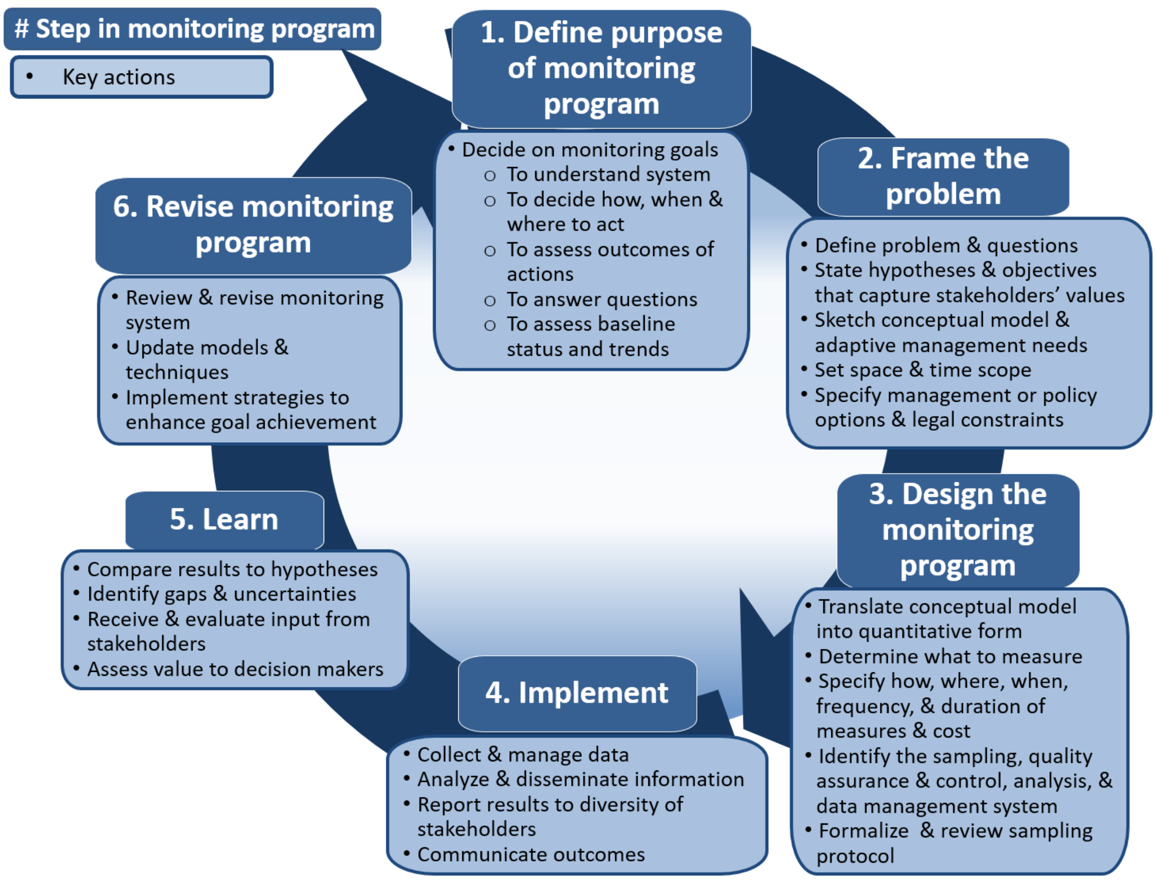

Figure 3. Framework for monitoring is based on the road map in Reynolds et al. (2016) as well as concepts inherent to adaptive management.

Each of the six steps of the monitoring program requires actions and decisions as shown in the framework (Figure 3) and detailed in the following sections. Because the objectives, sampling technology, and scientific understanding can change as the monitoring proceeds and new information becomes available, the program is depicted as a cycle. While some steps can be initiated simultaneously, finalization of later steps depends on completion of the prior steps. Hence, iterations within and among the steps can occur as a step is influenced by new information. And the entire circuit may be reinitiated if the monitoring objectives are adjusted in view of changing conditions, priorities, or available information.

Step 1. Defining the purpose of the monitoring program requires clarity about the plans and goals for the activity. The intent might be to understand the system; to decide how, when, and where to take actions; to assess the outcomes of actions; to answer questions; or to assess baseline status and trends.

Step 2. Framing the problem includes several components. First, the management problem should be clearly defined and key questions set forth. As part of the adaptive management process, hypotheses and objectives should be specified that reflect the diverse values of stakeholders. Sketching out a conceptual model requires a graphical representation of the key components that includes interactions within the system and depicts how adaptive management needs might be addressed. Setting the temporal and spatial boundaries for monitoring requires that the extent and duration as well as the frequency and density of monitoring be specified. Identifying boundaries can be challenging, particularly if the products or wastes are exported outside the system. The final part is to identify management or policy options as well as any legal constraints.

Step 3. Designing the monitoring program must be based on science and take into account the purpose of the monitoring program (step 1) and how the problem is specific (step 2). The design step requires that the conceptual model be translated into a quantitative form. The monitoring design includes the metrics (what will be measured), the methods (how will the measurements be taken) and the sampling design (where, when, and the frequency & duration of measures). The cost of the monitoring program should be part of this process and often the cost of monitoring restricts what can be implemented. The design also includes the sampling regime, quality assurance and control, analysis, and the system for data management. A final component is formalization of the sampling protocol. When possible, this scheme will benefit from a scientific and statistical review before implementation.

Step 4. Implementation of the monitoring program is straightforward if the prior steps have been followed. The implementation step includes the collection and management of data according to the established protocol as well as analysis and disseminate of information. Results should be reported to diverse stakeholders in a manner that best suits their experience, knowledge, and modes of communication. Communication of outcomes from the monitoring program should highlight effects and potential consequences of current activities in the system and anticipated changes.

Step 5. Learning from the monitoring program is a key part of adaptive management. First, the results should be compared to hypotheses so that the initial theories can be accepted, rejected, or (as is frequently the case) modified based on the new information. Gaps in knowledge and uncertainties should also be identified. The information learned can then be conveyed to stakeholders for their evaluation. The learning should be communicated to decision makers with a request to assess it value.

Step 6. Revising and updating the monitoring program is the final step. Information about the knowledge gained, gaps, uncertainties, and value of the monitoring program to decision makers should guide the revision. Furthermore, models and techniques may need to be updated based on the learnings from the monitoring program, new information, new pressures to the system, anticipated changes, or advances in sampling procedures. These revisions may improve strategies to enhance goal achievement.

The monitoring program cycle is used as the basis and guide for developing recommendations in this review. Fundamentally, monitoring provides data that serve as a foundation for a 'supply chain' of scientific knowledge that flows from knowledge producers to knowledge consumers (e.g., see Lemos et al. 2012). Long-term monitoring or studies provide insight on how the ecosystem changes over time and help differentiate between short-term and long-term variability (e.g., Wolfe et al. 1987; Bograd et al. 2003; Lindenmayer et al. 2012; Hughes et al. 2017). Information obtained from long-term monitoring has the potential to help anticipate problems before they occur. This process occurs as data are collected, quality controlled, stored, distilled, and synthesized into different knowledge products that add value at different points in the chain to serve the varied needs of different audiences (e.g., Wiens et al. 2017).

Many in California have noted the imperative and need for improving monitoring and decision making in the Delta. Policy makers, managers, scientists, and resource users working in the region are faced with a complexity of interrelated issues that will only become more difficult to address in the future (Hanak et al. 2012; Luoma et al. 2015; Healey et al 2016; DSC 2018a; 2018b).

The monitoring enterprise in the Delta spans across many disciplines in the physical, chemical, geological and biological sciences and extends into social science as well. Successful programs provide critical information needed for management decisions in the Delta. In addition, monitoring is essential in the "plan, do, adjust" cycle of adaptive management. For example, monitoring data could be used to inform both the design of an engineering project (e.g., a fish ladder) and be used to test the functionality of the project.

"Monitoring" covers a wide range of activities and objectives. At the broadest level, monitoring activities in the Delta can be categorized as *compliance* monitoring and *environmental* monitoring, although these categories form a continuum reflective of the monitoring purpose. Compliance monitoring is required explicitly or implicitly by law and is intended to assess whether activities meet the specific requirements of regulations, permits, or licenses. Compliance monitoring is designed to deliver inputs, outputs, and sometimes outcomes regarding the consequences of actions that are prescribed. Compliance monitoring may have varying degrees of legal flexibility and specificity.

Environmental monitoring is directed toward obtaining the data necessary to evaluate the condition of or changes in environmental factors of interest: pollutant levels in water, abundances of endangered species, presence of non-native invasive species, soil condition, and so on. Roni et al. (2013) recognized several functional purposes for monitoring environmental variables: baseline, status and trends, implementation, effectiveness, and validation.

In fact, attempts to pigeonhole monitoring efforts into one or another category are likely to obscure some of the ways in which monitoring varies. First, the *level of specificity* of what is needed in a monitoring program is highly variable and depends on the audience (Nelitz et al. 2019). For example, a recovery plan developed through a broad engagement process may articulate a goal to restore tidal wetland habitats. A modeler may articulate a need to assess the impacts of wetland restoration on Delta flows, water levels, water quality, ecosystems, and Delta fish communities. A program manager may be interested in monitoring the acreage of existing or restored habitat types as a measure of program success, whereas a scientist may be interested in understanding how tidal wetland restoration leads to sustained changes in vegetation architecture and plant species composition. Each of these cases relates to a common need for decision-making (e.g., tidal wetland restoration) but describes the need in a different way requiring a different level of specificity. In the Delta, Jones (2014) highlighted such differences in terms of communication needs, as have those involved in reporting data as part of routine natural resource management (Fancy et al. 2009) and water quality monitoring and reporting in the Bay-Delta (CWQMC 2008).

Second, the *specific questions of relevance to decision makers and scientists are different* (Nelitz et al. 2019). Nichols and Williams (2006) differentiated between “monitoring for active conservation” (i.e., monitoring with a focus on discriminating among competing hypotheses about effective conservation actions) and “monitoring for science” (i.e., monitoring with a focus on studying specific attributes, relationships, or hypotheses to improve predictions and understanding of the system). Questions or hypotheses that reflect uncertainties about the system, and hence serve as a motivation for monitoring, can be distinguished into “scientific uncertainties” and “management uncertainties.” In adaptive management programs elsewhere (e.g., Missouri River, Fischenich et al. 2018), such a distinction enables decision makers to focus on those uncertainties that are most relevant to them and scientists to focus on priority research efforts.

More broadly, the “Delta enterprise,” of which the monitoring enterprise is a major part, involves two major components: a *management enterprise* and a *science enterprise* (Nelitz et al. 2020a). The science enterprise includes a spectrum of knowledge products ranging from targeted research and field studies, monitoring activities, quantitative models, analyses, data portals, knowledge syntheses, science planning tools, and monitoring and assessment frameworks. Monitoring activities have linkages and provide fundamental value to most of these products within the science enterprise, but not all of these knowledge products represent monitoring. In addition, space-time resolutions involved in monitoring differ from case to case.

The management enterprise includes many interrelated goals; legislated, regulatory, and operational authorities; management actions; and policy issues or questions that set the management context for the Delta and dictate the need for knowledge products from the science enterprise, including monitoring.

Monitoring data are foundational to the process of adaptive management, which has been highlighted by the Delta Reform Act of 2009 as an essential component of management in the Delta. In combination, monitoring and adaptive management strengthen the "line of sight" through critical knowledge gaps, the actions over which decision makers have some control, and the ability of scientists to learn about the system that managers are trying to influence. Adaptive management provides a systematic structure for focusing on critical uncertainties of decision makers, implementing management actions to help resolve those unknowns (ideally using principles of experimental design), and then using rigorous science (including monitoring) to evaluate and learn about the effectiveness of those interventions (Meyer 2013; Waylen and Blackstock 2017; Wiens et al. 2017).

2. Review Methods

Although there are useful inventories of monitoring activities in the Delta, such as the Bay-Delta Live or the California Data Exchange Center, there was not a comprehensive inventory of all monitoring activities that span the physical, chemical, biological, and social sciences in the Sacramento-San Joaquin Delta and Suisun Marsh (the Delta) in which to assess the monitoring enterprise. As a result, there was a need to develop a comprehensive inventory of monitoring activities for the Delta, and this Delta ISB review was broken out into two components. ***Component 1*** (2018 to 2020) focused on the development of a monitoring inventory and developing initial insights surrounding monitoring in the Delta, which was prepared by ESSA Technologies Ltd., CBEC eco engineering, and PAX Environmental Inc (the Project Consulting Team) under the direction and collaboration with the Delta ISB. The Project Consulting Team was selected after two Request for Proposals from the Delta Stewardship Council, where Delta ISB members were involved in the scoring of proposals.

Component 2 is the Delta ISB's evaluation and recommendations of monitoring activities informed by an analysis of results obtained in Component 1, questionnaires and interviews with monitoring practitioners in the Delta, literature reviews, and the professional experiences of Delta members with monitoring in the Delta and elsewhere.

Prior to the onset of the review, the Delta ISB also organized three "Brown Bag Seminars" and five panel discussions from 2017 to 2018 to learn about the state and scope of monitoring in the Delta, and the current challenges with monitoring (see Appendix A). The topics covered included tidal wetlands, water quality, invasive weeds, IEP, and regional programs. These seminars and panel discussions provided useful information to identify monitoring activities for the inventory and helped identify some initial best practices that monitoring activities could consider to improve its effectiveness that was further analyzed during the review.

In addition, a monitoring workshop was held on April 30, 2019, in Sacramento, California that was attended by 60 representatives from various organizations to explore their hopes and concerns they had for the monitoring enterprise review and to help inform the development of an inventory (see ESSA et al. 2019). Based off the feedback received from this workshop, the review focused on the following questions to help assess how current monitoring programs meet management needs and how they might be coordinated or modified to improve their responsiveness to management.

1. Are there <u>potential gaps or redundancies</u> in serving the relevant needs of decision makers?

2. What is the <u>level of coordination</u> of data collection across different organizations?

3. Are there <u>other opportunities to increase efficiencies</u> in monitoring?

4. Is the <u>data quality</u> of monitoring appropriate to address purposes and needs for information?

5. Are <u>data accessible</u> to the public, decision makers, other scientists, and all stakeholders?

6. What <u>resources</u> are being dedicated to monitoring?

2.1 Component 1: Monitoring Inventory and Analysis

Based on the above questions, the Project Consulting Team with direction and in collaboration with the Delta ISB completed the first component of this review, which involved undertaking a comprehensive inventory of the physical, chemical, biological, geological, and socio-economic drivers of monitoring activities across the Delta and summarizing how these activities are addressing the needs of decision makers. It resulted in three reports that make up the overall Monitoring Enterprise Review, along with this report:

1. a lessons and methodology report (Nelitz et al. 2019),
2. the development of the monitoring inventory database and a subsequent summary report of monitoring activities in the inventory (Nelitz et al. 2020a), and
3. a comprehensive synthesis report (Nelitz et al. 2020b), which assesses the relevance of monitoring activities in serving the needs of decision makers and identifies opportunities to improve monitoring based on the initial analysis of the inventory.

Although the full methodology and results can be found in these three reports, we briefly summarize the methodology and results in this report to provide context for the Delta ISB's findings and recommendations.

2.1.1. Previous Reviews of Monitoring and Literature Reviews

To help inform the review methods and the recommendations, a literature review using a Results Hierarchy (or logic model framework) as the structure for categorizing the information (Gates Foundation, no date) was done to gather insights learned from other systems, as well as the Delta itself. The selection of case studies was focused on including, to the extent possible, large-scale monitoring programs in complex, highly managed delta ecosystems primarily within North America that have also applied adaptive management to varying degrees. The final selection of case studies was guided by the Delta ISB. These five case studies included: (1) Chesapeake Bay, (2) Great Lakes, (3) Coastal Louisiana, and (4) Puget Sound in the United States, as well as (5) Queensland, Australia.

Results from this literature review are summarized in Nelitz et al. 2019.

2.1.2. Inventory Development

Undertaking an inventory of the monitoring enterprise required clarifying the scope of monitoring activities, which involved developing a structure for organizing metadata about monitoring activities. Based on the literature review (see Section 2.1.1.) and feedback from the Monitoring Enterprise Workshop (ESSA et al. 2019), an organizational framework was developed to represent the monitoring parameters that were within scope of this review. The intent in developing this framework was not to represent the full complexity of cause-effect linkages among all components in the Delta.

Rather, it depicts broad linkages between management actions and environmental drivers / conditions, habitats, and species of interest to decision makers, scientists, and stakeholders in the Delta, as well as the direct socio-economic drivers of ecosystem change.

Regarding the temporal horizon of monitoring activities, the intent of this review was focused on inventorying ongoing / active monitoring activities rather than historic, now defunct monitoring. The intent will be to focus on monitoring activities for which data have most recently been collected within the previous 5 years (i.e., at least once since beginning of 2014) and for which it is anticipated to occur again within the next 5 years (i.e., before end of 2024).

This research included monitoring activities that relate to all monitoring themes and parameters in Figure 4 with a focus on monitoring activities within the legal boundaries of the Delta and Suisun Marsh (Figure 1). However, it is widely known that the Delta is strongly influenced by upstream and downstream influences. As such, upstream and downstream linkages were considered where appropriate for many of the parameters identified above. In many cases, however, statewide or national scale monitoring activities included sampling locations within and outside the Delta. To represent the spatial coverage of such activities, the hydrologic unit code (HUC) boundaries for the state were used to assign sub-basins where sampling locations were located for an activity (see Figure 1).

The monitoring inventory was designed to collect metadata about monitoring activities within scope of this review (see Appendix B, Table B-1 for the metadata collected in the inventory). Monitoring activities that were within scope of the review were identified through the literature reviews, the Monitoring Enterprise Workshop (ESSA et al. 2019), the brown bag panels/panel discussions, and additional searches on the Internet. Metadata for the inventory was collected through Internet searches, and when information was missing, monitoring programs were contacted by email or a phone call to help address the questions. Quality assurance and control of the metadata were ongoing throughout the review process, but most of the information collected was last updated in March 2020.

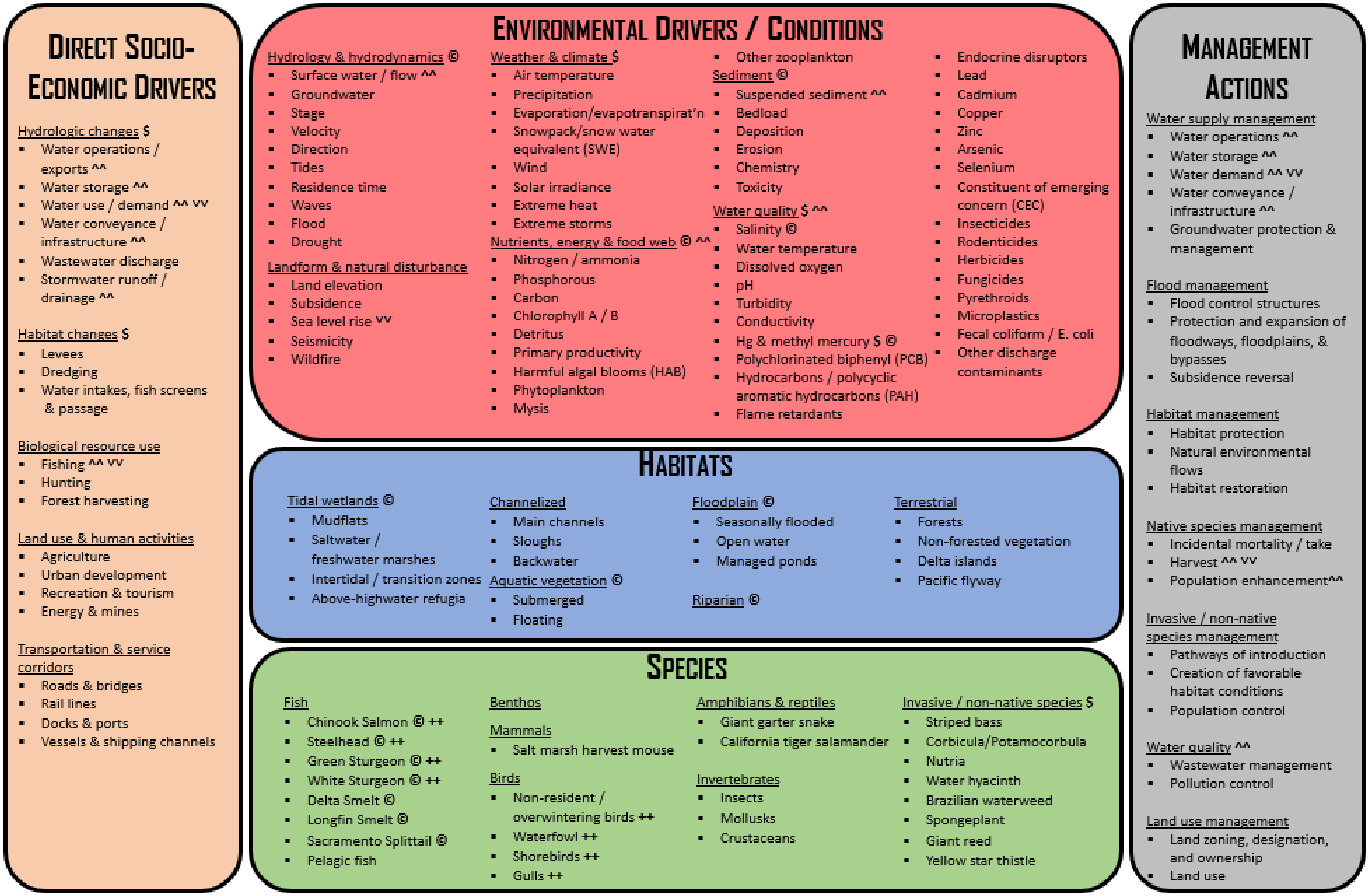

Figure 4. Organizational framework representing the biological, physical, chemical, geological and socio-economic components of relevance and within scope of this review. Note the use of the following abbreviations: $ denotes primary stressors on the Delta, © denotes components with detailed conceptual models, ^^ (double caret) denote components with upstream drivers / stressors that influence the Delta, vv (double circumflex) denote components with downstream drivers / stressors that influence the Delta, and ++ denote non-resident species that use the Delta for a portion of life cycle. See Appendix B for the organizational framework in list format.

2.1.3. Inventory Analysis

Methods for answering the six broad review questions are described in the subsections below and are described in more depth in Nelitz et al. 2019.

Are there potential gaps or redundancies in serving the relevant needs of decision makers?

For the purposes of this review, gaps are monitoring parameters where there is not sufficient temporal and/or spatial coverage to address specific questions, while redundancies are potential areas of overlap in temporal and/or spatial coverage to answer specific questions. Determining gaps and redundancies in monitoring requires understanding the science or management questions in which information collected from monitoring should address, and the specific monitoring parameter, as the temporal and spatial coverage varies depending on the parameter.

Overall, the desired outcome for the Delta is based on achieving coequal goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem, which needs to be achieved in a manner that protects and enhances the Delta as an evolving place (CA Water Code Section 85054). However, there is not a consolidated description of the management context , decision-making needs or specific questions for adaptive management in the Delta.

Understanding the management context is necessary to help assess whether monitoring is serving the needs of decision makers. To address this gap, the Delta Plan (DSC 2013), Delta Science Plan (DSC-DSP 2019), and Science Action Agenda (DSC-DSP 2017) were used as the basis for identifying common management themes and actions, since these documents guide science and decision making in the context of the Delta's coequal goals. Through this process, seven management areas were identified to help inform the review.

- **Water Supply Management** – Decisions that influence how water resources affect the Delta and its users. Such actions include water operations, water storage, water demand, water conveyance / infrastructure, and groundwater protection and management.
- **Flood Management –** Decisions that influence how flood waters are managed affecting ecosystems, people, and property in the Delta. Such actions include construction and operation of flood-control

structures; protection and expansion of floodways, floodplains, and bypasses; and subsidence reversal.

- **Habitat Management –**Decisions that influence how terrestrial, riparian, and aquatic habitats are managed within the Delta. Such actions include restoration, protection, and the use of flows and habitat to improve ecosystem conditions.
- **Native Species Management –** Decisions affecting the abundance of native aquatic or terrestrial-animal or plant species relevant to the Delta. Such actions influence incidental take or mortality (e.g., at fish screens and water intakes), harvest (e.g., recreational harvesting of fish and wildlife), and population enhancement (e.g., through hatcheries).
- **Invasive Species/ Non-native Species Management –** Decisions affecting the population abundance and habitats of invasive / non-native species in the Delta. Such management actions include preventing introductions, avoiding creation of favorable habitat conditions, and control populations (e.g., harvest, culling, biocontrol).
- **Water Quality Management –** Decisions affecting surface and groundwater quality within the Delta. Such actions include wastewater management (e.g., effluent recapture, recycling, and treatment of wastewater), pollution discharge controls (e.g., pyrethroids, methylmercury, CECs, pesticides, nutrients), and their adverse events on aspects of water quality in the Delta (such as dissolved oxygen, turbidity, salinity, and harmful algal blooms or HABs).
- **Land Use Management (Delta as an Evolving Place) –** Decisions affecting terrestrial land designation, use, and cover within the Delta (e.g., urban, agricultural, and natural / protected areas). Such management actions include land zoning, designation, conversion, and ownership, as well as land use.

The management context provides some insight on decision-making needs and helping to determine monitoring gaps and redundancies. However, we did not attempt to develop an agreed upon list of questions that information from monitoring should address.

To help understand the spatial and temporal coverage, “monitoring needs profiles” were developed for each of the seven management themes identified above (Nelitz et al. 2020b). A list of monitoring parameters within each management theme were identified based on a review of important drivers of management within the Delta, including key plans, strategies, biological opinions, and related legislation (see Appendix B for a list of management drivers). Afterwards, the monitoring inventory was queried to produce summary plots for each monitoring parameter within each management theme, which included the total number of sampling activities, the relative distribution of those activities across Delta regions (e.g., south Delta, north Delta; see Figure 1), sampling frequency classes (e.g., 15-minute intervals, hourly, daily, weekly), and across sampling program durations. These metrics help to provide an overview of the general spatial and temporal coverage of monitoring parameters important for decision-making across a range of management contexts and lend themselves to high-level interpretations of possible patterns in gaps and redundancies. However, the coarse resolution of this analysis did not lend itself to drawing detailed inferences about whether monitoring is occurring at exactly the right times or places to meet management needs. Instead, the results of this assessment were a starting point to identify potential gaps and redundancies. Additional analysis of gaps and redundancies was assessed in Component 2.

What is the <u>level of coordination</u> of data collection across different organizations?

Network analyses were used to provide insights on the level of coordination. A network analysis is a quantitative approach and visualization method that can reveal and analyze patterns of relationships across different components of a system, including individuals, organizations, ecosystem components, and management objectives for conservation and monitoring (see Nelitz et al. 2020). Organization names, roles, and monitoring themes were extracted from the monitoring inventory and used to develop network diagrams, calculate network and node metrics, and ultimately explore the level of coordination across monitoring activities in the monitoring enterprise.

However, these analyses do not provide an indication about what type of network may be most desired or ideal for the monitoring enterprise since that determination is based on a value judgement. Additional engagement, which occurred during Component 2, was used to identify specific opportunities for positively influencing coordination among organizations involved in monitoring.

Are there <u>other opportunities to increase efficiencies</u> in monitoring?

The inventory was used to calculate the number of monitoring activities collecting data for each monitoring parameter. The metadata information in the inventory was reviewed for monitoring parameters that had the most monitoring activities, such as water quality, fish, waterfowl, and habitat, to qualitatively identify potential opportunities to improve efficiency and reducing redundancies, with a focus on considering improvements to data management, sampling methods/approaches, and monitoring design.

Is the <u>data quality</u> of monitoring appropriate to address purposes and needs for information? Are <u>data accessible</u> to the public, decision makers, other scientists, and all stakeholders?

Based on an extensive literature review, the following data attributes were common approaches for assessing both data quality and accessibility (US EPA 2006; Kahn et al. 2012; DAMA UK 2013; Pickard et al. 2015):

- <u>Purpose</u>: Do the data and monitoring meet the intended goals and criteria of the study in which it was collected?
- <u>Monitoring guidance</u>: Were the methods used to obtain data well-described and represent best practices (e.g., following established sampling protocols or monitoring design)?
- <u>QA/QC</u>: Have the data been reviewed to ensure they are correct, reliable, and free of error (e.g., independently reviewed, inter-compared, published, QA/QC'ed)?
- <u>Timeliness</u>: Do the data represent reality at the required point in time (e.g., real-time, weekly, annually updated)?
- <u>Public accessibility</u>: Are the data readily accessible (e.g., open source)?
- <u>Machine readable</u>: Are the data provided in a machine readable format ready for analyses?
- <u>Uncertainty</u>: Does the data include quantitative estimates of variability (e.g., 95% confidence intervals)?

To assess the data quality of monitoring activities in the inventory, each monitoring activity was queried on whether it followed monitoring guidance (yes/no/unknown), had QA/QC protocols (yes/no/unknown), reported uncertainty (yes/no/unknown), and whether reporting was timely (reported in >1 year, < 1 year, or unknown). This provides information of what is the data quality, but not whether if it is appropriate to address information needs, which was evaluated in Component 2. To assess data accessibility, each monitoring activity in the inventory was queried on whether it was accessible to the public (yes/no/unknown), machine readable (yes/no/unknown) and whether reporting was timely (reported in >1 year, < 1 year, or unknown).

What resources are being dedicated to monitoring?

Insights about the resources being dedicated to monitoring were developed by summarizing the information about cost (i.e., start up and annual costs) and effort (i.e., number of sample sites within the Delta) for each monitoring activity in the inventory.

2.2 Component 2: Delta ISB's Analysis

Component 1 provided important insights about potential gaps and redundancies (scope, parameters, spatial and temporal coverage), the level of coordination, and opportunities for improving efficiencies (see Nelitz et al. 2020b). However, additional analysis was needed to understand the management context in which to make recommendations, understand the constraints and challenges for making recommendations, and understand perceptions of monitoring and how it aligned with the inventory analysis. Analyses for Component 2 were based off information obtained from Component 1, questionnaires, interviews, literature reviews, and the Delta ISB member's experiences with monitoring.

2.2.1. Questionnaire Analysis

The Delta ISB released a questionnaire to the Delta community to seek feedback on Component 1 findings and recommendations, which were based on an initial analysis of the Delta monitoring inventory.[3] The purpose of the questionnaire was to help refine the findings and recommendations from the Component 1 analysis and to help identify areas for further analysis. Respondents were presented with 19 statements that were based on findings or recommendations from Component 1 (see Nelitz et al. 2020b). Respondents were asked to indicate the extent to which they disagreed or agreed with each statement on scale ranging from 1 (strongly disagree) to 5 (strongly agree). They were also given the option to select "I do not know."

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[3] A copy of the online questionnaire can be found at: https://docs.google.com/forms/d/e/1FAIpQLSdWkTAHwh0-dIGYsZ1Z0UJSYq1AKvQUW9WTh7ej6KsioOkxzQ/viewform. Detailed results from the questionnaire can be found in Appendix B.

Each statement had a write-in text option where respondents could explain or elaborate upon their numerical response.

The questionnaire, which was available from May 21, 2020, to June 5, 2020, was distributed to 60 participants from the 2019 Monitoring Enterprise Review Workshop (ESSA et al. 2019), which helped inform the scope of the inventory and analysis. The survey was also distributed to the IEP mailing list (215 recipients) and the Delta Stewardship Council listserv (2,862 recipients). We cannot precisely quantify the number of individuals who had an opportunity to take the questionnaire because there was some cross posting among emailing lists, and the survey was also available on other platforms, including the Delta Stewardship Council's website and Maven's Notebook.

A total of 34 individuals responded to the questionnaire. While insights provided by this sample are interesting and informative, they cannot necessarily be generalized to represent the views of any larger Delta population due to the small sample size and non-random survey distribution methods. Results of our data analysis are provided in Appendix C.

In results below, we provide summary statistics (counts and percentages) associated with each statement. In all cases, responses of agree and strongly agree (4 or 5) were combined into "agree;" and responses of strongly disagree or agree (1 or 2) were grouped into "disagree." A numerical response of 3, the midpoint of the scale, was interpreted as neutral and omitted for purposes of analysis. For this reason, the total number of responses varies from statement to statement.

Write-in responses were analyzed qualitatively to identify and distill key takeaways and major themes.

2.2.2. Interviews

The Delta ISB conducted 11 semi-structured interviews with scientists and managers who either have knowledge of and experience with monitoring in the Delta; and/or whose agency has management responsibilities that could be informed by monitoring. Interviewees included representatives from State (n=4), Federal (n=2) and local agencies (n=2), as well as a consulting firm (n=1) and a non-governmental organization (n=1). They were selected to cover interests aligned with the range of management themes that were identified for the review (see Section 2.1.3).

Questions were sent to interviewees in advance (see Appendix D for the questions), with follow-up and clarifying questions incorporated as needed. All interviews were recorded and transcribed for purposes of analysis.

Interview data were analyzed using the methods of qualitative content analysis (Cho and Lee 2014). An analytical framework was developed to organize and categorize interview content pertaining to the following thematic areas: current and future management needs; monitoring gaps, including barriers to and suggestions for addressing gaps; ideas about improving monitoring for adaptive management; and monitoring coordination needs, including to barriers to and suggestions for addressing these needs (See Appendix D).

For some of these thematic areas, we employed a deductive coding approach in which interview text was sorted into a discrete set of potential ideas or responses – coding categories - which were pre-defined and assigned alphanumeric labels in the analytical framework (Cho and Lee 2014; see Appendix D). Coding categories were derived from findings in Component 1. Recognizing that interviewees were not restricted to comment only on material covered in Component 1, for each thematic area "other" categories were also created to capture responses or ideas not explicitly identified in the analytical framework. For each interview, text that fit into any given coding category was tagged with the corresponding alpha-numeric label (i.e., in the margin). After each transcript was coded, results were tabulated in an Excel spreadsheet by assigning 1 to each coding category that was present (i.e., mentioned at least once in the interview), and assigning 0 to all other categories. If a coding category could not confidently be labelled present in or absent from an interview, a numeric value of 97 was assigned, as a flag for more detailed analysis (see below)

For the other thematic areas there was no reasonable way to anticipate potential responses and pre-define discrete coding categories. Therefore, text relevant to these areas was highlighted and moved to a separate document. Subsequently, an inductive coding approach was used to identify themes and patterns that emerged directly from the interview data (Cho and Lee 2014).

Given limitations in time and capacity, coding responsibilities were shared by two analysts. Each analyst was assigned a subset of thematic areas and coded interview transcripts independently. After all interviews were coded, the analysts held a series of meetings to review and resolve coding categories assigned 97 for each interview. Final coding decisions reflect consensus among both analysts.

Coding results were quantitatively summarized and qualitatively synthesized. These results provided context on barriers, constraints, and challenges pertaining to efforts to improve the monitoring enterprise. They also provided additional management context to help inform the Delta ISB in formulating its recommendations.

Lastly, interviewees were asked to complete an optional survey to provide feedback on the initial best practices (see Appendix A). Feedback was used to refine best practices into the final versions presented in this report.

3. Synthesis Findings

The monitoring inventory (Component 1 of this review) included 157 unique monitoring activities, with 170 sampling activities at over 4,000 sampling locations representing 128 unique monitoring parameters (all of the monitoring activities in the inventory are found in Nelitz et al. 2020a and Appendix B). Of the 157 monitoring activities, 97 (62%) are influenced by a management driver. The top five most referenced drivers are the Clean Water Act: Section 303(d), California Fish and Game Code, Water Right Decision 1641/Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary, Federal Endangered Species Act, and the biological opinion on the long-term operations of the State Water Project and Central Valley Project from the United States Fish and Wildlife Service.[4]

There are many examples of how long-term monitoring programs in the Delta has informed management In the Delta, long-term monitoring has provided important information on the status of trends of various species, which has been used to support the listing of a species under the federal or State Endangered Species Act (e.g., longfin smelt; see CDFG 2009) or the

[4] Note that the development of the inventory was undertaken when the 2008 and 2009 biological opinions were in effect for the long-term operations of the State Water Project and Central Valley Project, along with the 2009 incidental take permit for the State Water Project. Results were generally cross checked with the new biological opinions and incidental take permit.

delisting of a species (e.g., splittail; see USFWS 2003; Sommer et al. 2003), and to track the overall health of the Delta based on the Delta Plan Performance Measures. It can also help with the detection of new non-native or invasive species that enter the Bay-Delta system, such as the overbite clam in 1986 (e.g., see Carlton et al. 1990).

Outside of status and trends, long-term monitoring data can be analyzed through statistical methods to create or inform policy. For example, Jassby et al. (1995) analyzed long-term flow and ecological data to introduce the X2 concept, where salinity in the estuary that measures 2 parts per thousand has a positive statistical relationship to various estuarine resources (e.g., phytoplankton, larval fish survival). The concept was adopted as a regulatory standard under Water Right Decision 1641, where flows in the Delta are managed to meet X2 requirements at various times of the year (SWRCB 2000).

Although more than a majority of monitoring activities in the inventory are influenced or required by a management driver (e.g., a biological opinion) and there are many examples of how long-term monitoring informs Delta management, questionnaire results indicate that 70% disagreed that the *"Overall, current information collected from monitoring serves the needs of decision makers and stakeholders across the Delta"* (see Figure 5; 26% agreed, 4% don't know; N=23). Additionally, when asked if "*data are analyzed and synthesized in a way that enables management decisions*," 61% of questionnaire respondents disagreed (22% agreed,17% disagreed; N=23; see Figure 5). Respondents indicated that synthesis is not well-connected to management decisions or communicated in an accessible or timely manner to those who need the information. Data analysis needs improvement to adequately address management needs.

Several commenters from the questionnaire cited a monitoring-management disconnect, so that even in cases where a great deal of resources are dedicated to monitoring species of concern, including Chinook salmon and Delta smelt, most monitoring programs are not designed to sufficiently answer management questions and do not collect essential detailed information such as habitat use and life stage information. The monitoring enterprise was also critiqued for not being nimble enough to respond to rapidly changing management needs, and for emphasizing long-term studies at the expense of more direct special studies.

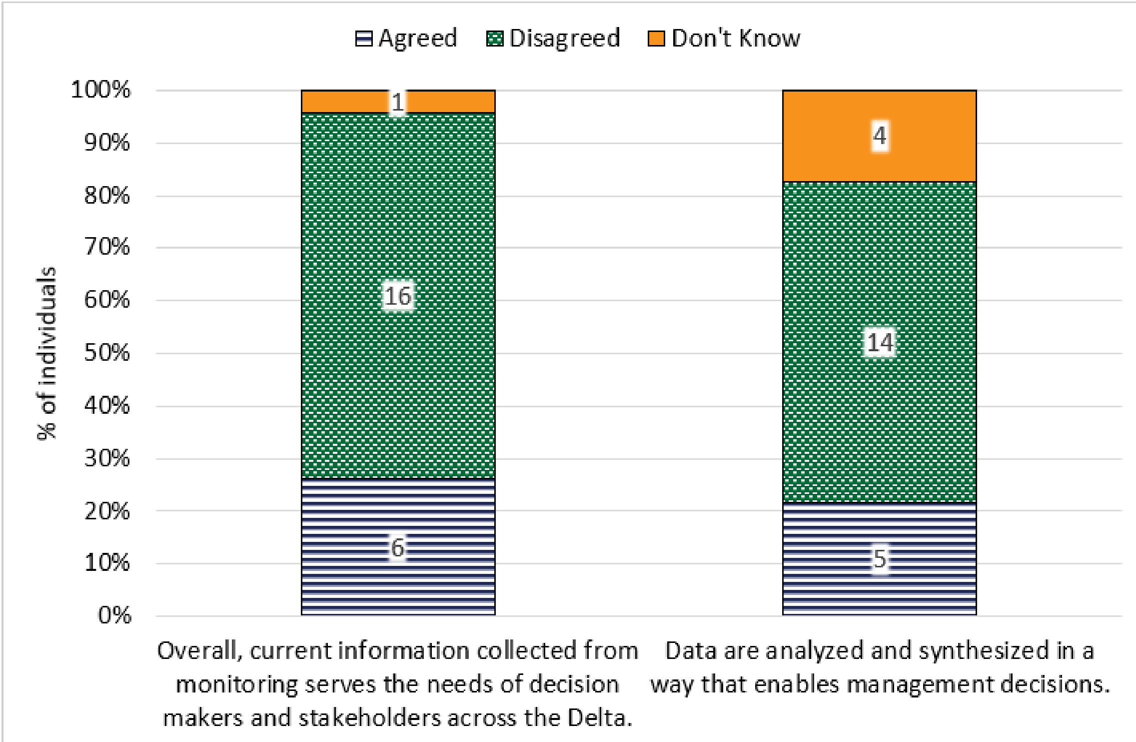

Figure 5. Questionnaire responses on whether information collected, analyzed and synthesized from monitoring serves the needs of decision-makers. Labels within a bar graph indicate the total number of responses. See Appendix C for more information.

To help inform recommendations that could improve monitoring and understand how management could be better linked to management needs, key findings from the brown bag seminars and panel discussions (Appendix A), literature review (Nelitz et al. 2019), the inventory analysis (Nelitz et al. 2020b), questionnaire analysis (Appendix C), and interview analysis (Appendix D) are summarized and synthesized below by each review question.

Question 1. Are there potential gaps or redundancies in serving the relevant needs of decision makers?

Identifying gaps and redundancies

Figure 3 provides a detailed framework for designing, implementing, and adapting an effective monitoring program based off Reynolds et al. (2016). It suggests that this process begins with a robust problem definition, which can be developed through cross-disciplinary workshops, and conceptual model or framework development as critical foundations of an effective monitoring program. These steps are also essential in the analysis and adaptation phase of monitoring to refer back to when identifying gaps and redundancies that may be impeding optimization of a monitoring program by identifying exact attributes that need to be monitored to address specific management needs. A clear and specific foundation not only supports the creation of a robust monitoring program, but also allows for efficient analysis of the effectiveness of a program. Reynolds et al. (2016) also underscored the importance of prioritizing data documentation, management, and analysis for an effective monitoring program. Timely analysis and summarization of new information and timely communication of information to decision makers will allow for detection of issues, gaps, and redundancies so that they may be addressed in a timely manner.

Although there are Delta specific conceptual models for various topical areas, such as the effects of tidal wetland restoration on fish (Sherman et al, 2017), the biology of Delta smelt (Baxter et al. 2015) and the scientific understanding of important aspects of the Delta ecosystem for the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP; e.g., see Durand 2008 for aquatic food web, Werner et al. 2008 for chemical contaminants, etc.), there is not a comprehensive conceptual model that links existing conceptual models and spans the management areas to achieve the coequal goals. As management questions and needs in support of adaptive management have not been clearly defined for the enterprise, we did not attempt to create an agreed-upon conceptual model, but created an organizational framework (Figure 4) for identifying monitoring that is within the scope of the review to help with the assessment of gaps and redundancies.

"Monitoring Needs Profiles" for each of the seven management themes relevant to the Delta were developed to understand potential gaps or redundancies based on the inventory analysis, which can be found in Nelitz et al. 2020b. Although useful, the coarse resolution and breadth of this analysis for 128 parameters across the entire monitoring enterprise did not lend itself to drawing definitive inferences about whether monitoring is occurring at exactly the right times or places to meet all management needs. As a result, additional feedback was received via the brown bag seminars/panel discussions, interviews and from questionnaire responses. We did not focus our work on redundancies in monitoring based on feedback received from the Monitoring Enterprise Review Workshop (ESSA et al. 2019), which was not an area where participants felt the Delta ISB should focus our review. Instead, workshop participants were interested in potential gaps. However, we note that identifying and reducing redundancies will make available funds and resources to address monitoring gaps. Illustrations of gaps that were identified through our review methods are below.

Environmental Drivers/Conditions

Based on the inventory analysis, chemical contaminants - with the potential exception of mercury/methylmercury -- was a potential gap, and 67% of questionnaire respondents agreed that this is a gap (see Figure 6, 15% disagreed, 19% don't know, N=27). Many of the respondents who disagreed with the statement in the questionnaire did not necessarily disagree that there may be gaps with the monitoring of chemical contaminants, but that there was extensive monitoring of mercury/methylmercury. Gaps associated with chemical contaminants was also mentioned during the brown bag seminars and interviews.

Overall, contaminants are known to have a range of effects on both human and ecosystem health. High levels of mercury/methylmercury has long been a concern for fish health and human consumption of fish (Scheuhammer et al. 2007). However, additional contaminants are a concern for both humans, by threatening the quality of drinking water, and the health of the ecosystem. Herbicide and pesticide runoff is a serious concern and was mentioned as a likely driver of decreased chlorophyll-a, with larger food-web consequences as phytoplankton and zooplankton are likely affected by such contaminants. Several interview and questionnaire respondents expressed concern about the lack of knowledge about contaminants of emerging concern, potential synergistic interactions, sublevel effects, and ecosystem reactions to the range of contaminants that enter the Delta. One interviewee expressed this concern:

> *"We know contaminants are having an effect on species. We don't know the magnitude, we don't know the spatial extent, we don't even know necessarily what all the contaminants are. So, if folks are doing monitoring of their discharge to be in compliance with their waste discharge requirements, that doesn't tell us what's happening in the ecosystem. And there's mixtures of chemicals and then there's other things that we don't even know that we should be monitoring for."*

That is, there are unknown unknowns. These findings are consistent with the recommendations made in our water quality review, where we recommended that the Delta Regional Monitoring Program expand the contaminants it monitors, and increase the temporal and spatial coverage of its measurements.

Although not identified by the inventory analysis as a gap, harmful algal blooms (HABs) were mentioned from interviewees and questionnaire participants, as a potential gap. This is also consistent with our review on water quality science, where we indicated that a more structured and exhaustive monitoring for cyanoHABs and toxins is needed to effectively forecast bloom inception and mitigate HAB events (Delta ISB 2018).

HAB's have been a concern for drinking water quality for decades, and can cause cyanobacterial toxin poisoning in people, fish, shellfish, mammals, and birds in addition to other potential ecological effects such as hypoxia and overshading of large swaths of habitat. Microcystis can impair and harm species that consume it, including Sacramento splittail and Delta smelt, as well as zooplankton. HAB events have been increasing in California, likely driven by drought and hotter temperatures, but still remain inadequately understood. As one interviewee explained:

> "*The risk of harmful algal blooms through the system, the occurrence and the conditions that lead to their development and their associated toxins within the watershed and also macrophytes, the type that are growing under the water and floating on top of the water and really what effect they're having on nutrients through the system is greatly unknown.*"

Other environmental drivers/conditions mentioned during the course of the review, although not as frequently mentioned include:

- Sub-surface Salinity
- Sediment Toxicity
- Nitrogen
- Zooplankton
- Tidal flows on water quality

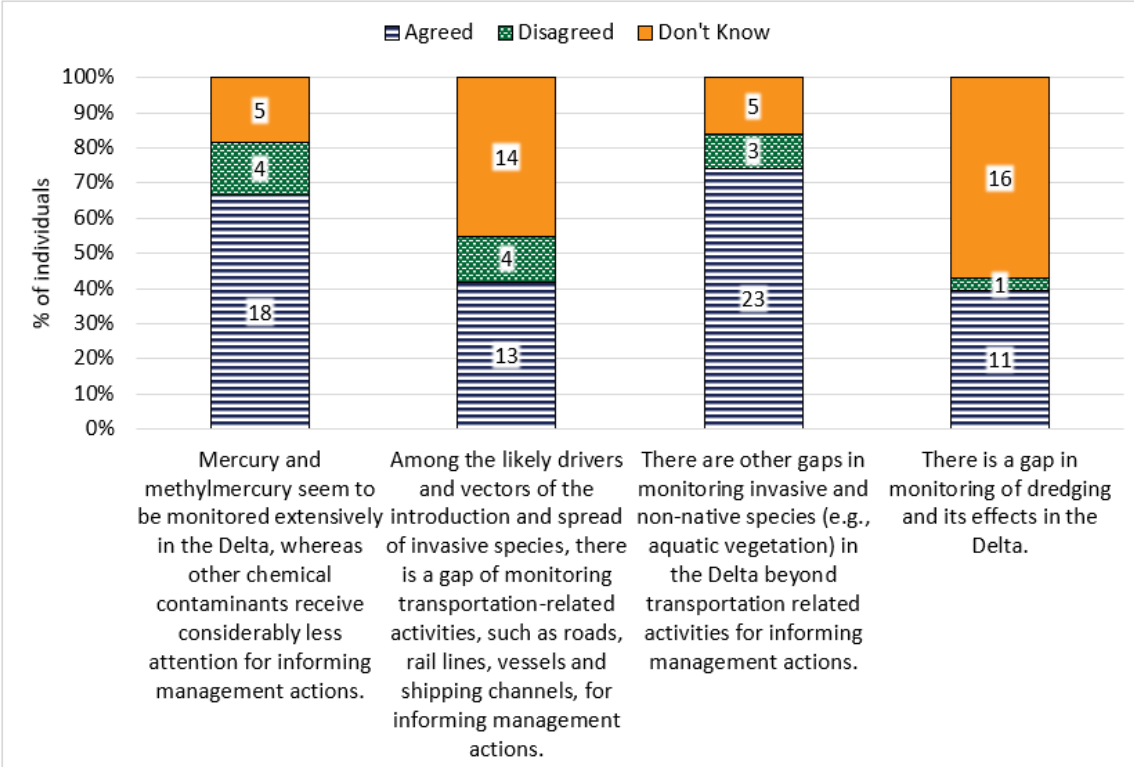

Figure 6. Questionnaire responses on whether participants agreed or disagreed with the gaps identified from the inventory analysis. See Appendix C for more information.

Non-native species/Invasive Species

Invasive or non-native species can impact every aspect of ecosystem services and sustainability, including food-webs and habitat structure (Delta ISB 2021), and have contributed to an estimated 25% of all plant extinctions and 33% of animal extinctions globally (Pyšek et al. 2020). From the inventory analysis, there is a gap with monitoring of non-native or invasive species. Among the likely drivers and vectors of introduction and spread, there is very little monitoring of transportation-related vectors, such as roads, rail lines, vessels and shipping channels, though it is unclear whether the comprehensiveness of these monitoring activities may be sufficient to address the needs for this information. We sought clarity on this uncertainty through the questionnaire. Overall, a large portion of the participants did not know if there were gaps in monitoring of transportation-related activities for invasive/non-native species (45% did not know, but 42% agreed; N=31, see Figure 6). As one participant noted,

> *"There are multiagency staff and programs (CDFW's Marine Invasive Species Program and United States Fish and Wildlife Service's Aquatic Invasive Species) that monitoring and work on invasive species. These staff and program are not effectively part of the Bay-Delta monitoring enterprise, because of the institutional barriers enterprise leaders reinforce to emphasize the management themes they desire it to focus on."*

When asked if there were gaps in monitoring in general for invasive or non-native species beyond transportation-related activities, 74% agreed (see Figure 6, 10% disagreed, 16% don't know, N=31). Some of the respondents who agreed indicated that there is not a specific monitoring network to quickly identify new invasive species early in the invasion or a comprehensive invasive species monitoring program in the Delta for some of the most widespread and established invasive plant and animal species. There were comments on the impact of budget cuts in creating these gaps. For example, UC Davis conducted annual measurements of the Delta with hyperspectral imagery to map invasive aquatic weeds from 2004 to 2008 for the then Department of Boating and Waterways. It stopped during the recession and then starting again in 2014 for California Department of Fish Wildlife and later the California Department of Water Resources.

As noted during our panel discussion on invasive weeds monitoring, the California Department of Food and Agriculture once had the Noxious Weed Eradication Program, which had dedicated biologists surveying the whole state at regular intervals and taking care of high priority invasive and noxious weeds, and the Weed Management Area Program, which were local stakeholder collaborations, focused on control of invasive plants. Each weed management area had their top 10 weeds that they were monitoring and looking out for. Both programs were terminated due to funding issues despite being defined in State code.

Direct Socio-Economic Drivers

Related to monitoring of direct socio-economic drivers, there are many monitoring activities associated with important drivers of land use change (agriculture and urban development) based on the inventory analysis, though there is a possible gap in monitoring of dredging, despite its potential impacts on fish habitat and water quality, and its importance to a number of management themes (see Nelitz et al. 2020b). Dredging in the Delta is important for flood control, levee stability and recreation, and can range from marina dredging projects to major channel deepening (ACOE 2007). When asked if there is a potential monitoring gap with dredging, 39% of the questionnaire respondents agreed that this was a gap, but 57% did not know (see Figure 6, N=28). Like with the monitoring of transportation-related activities to manage non-native or invasive species, there is potential that existing monitoring is sufficient, but not well integrated with the rest of the monitoring enterprise. As one questionnaire participant indicated,

> *"The ACOE (Army Corps of Engineers) does quite a bit of monitoring on its dredging activities. The ACOE management themes of flood management, habitat management, land use management, etc. are not effectively part of the Bay-Delta monitoring enterprise. Independently, they have developed a parallel enterprise related to this activity because leaders in the monitoring enterprise are not focused on this."*

Other socio-economic drivers mentioned during the course of the review, but not as frequently mentioned include:

- Water use/demand
- Levees
- Recreation and tourism
- Agriculture
- Socio-economic data gaps generally
- The effectiveness of management actions (including flow, restoration, etc.)
- Perceptions of the Delta as a place (unique Delta values, recreation, cultural and natural resources)
- The need for more detailed information on structure of disadvantaged communities, including access to green space

Species

Monitoring related focal species of most relevance to decision makers, such as Chinook salmon, steelhead, Delta smelt, and green sturgeon, tend to be relatively well represented in the inventory (see Nelitz et al. 2020b). Status and trends monitoring of fish listed under the State or federal Endangered Species Act are used to inform the water operations of the State Water Project and Central Valley Project (Tempel et al. 2021), and many restoration projects in the Delta are planned to provide habitat for listed fish, like Delta smelt and longfin smelt (DWR and DFG 2012). Despite the wealth of monitoring, gaps in monitoring were mentioned for listed species with a particular focus on Chinook salmon and Delta smelt during the interviews, brown bag seminars/panel discussions, and public comments.

Fish

For winter-run Chinook salmon, Johnson et al. (2017) assessed the current monitoring network with existing conceptual models and found that there is limited information on condition, genetic identity, life stage and abundance once Chinook salmon leave the upper Sacramento River. Some of the gaps associated with Chinook salmon monitoring mentioned in questionnaire responses were consistent with the findings from this article.

Although Delta smelt was noted as having too much focus during the interviews and in questionnaire responses, others also mentioned specific Delta smelt gaps, primarily as to how Delta smelt are sampled. Some of the long-term monitoring programs that are used to monitor Delta smelt were noted as being ineffective, such as the Fall Mid-Water Trawl, which was described during the IEP brown-bag seminar: *"[It] does not sample well in the shallows (where delta smelt are) and many critics say it is not a useful sampling device*." However, the newer Enhanced Delta Smelt Monitoring Program was recognized by several participants as a great improvement (USFWS 2019). During the tidal wetland restoration brown bag seminar and panel discussion, speakers spoke to the difficulty of monitoring a critically endangered species that spends a lot of its life in difficult to sample, shallow habitats. "*To monitor how restoration is helping, you might kill some Delta smelt. It is real balancing act…"* These constraints have led to incomplete ecological and life cycle data, which can make their preservation and restoration particularly difficult (Polansky et al. 2018). In addition, concerns have been brought up that it is difficult to receive an incidental take permit to start up new studies or monitoring activities to understand the impact that management actions have on Delta smelt. Instead, food-web resources are monitored, as is the case for monitoring the effects tidal restoration have on this species. The regulatory agencies have to balance the need to understand the impact management actions have on Delta smelt, while reducing harm to the species by allowing incidental take.

Birds

Monitoring of birds was mentioned a few times in the questionnaire responses, as a potential gap, while benthic invertebrates were mentioned in the questionnaire responses and by an interviewee. The Delta region provides important habitat for a diversity of birds and may serve as a promising opportunity for bird conservation. Waterfowl, shorebirds, ducks, and birds of prey, including many listed and at-risk species, use and rely on Delta habitats, including managed wetlands, shallow-flooded habitats, grasslands, oak savannahs, and riparian forests, and rely on the Delta as an essential migration and overwintering location (Dybala et al. 2020). However, multiple questionnaire respondents noted a serious lack of bird monitoring in the Delta: "*There are few if any long-term datasets to inform management on birds in the Delta*" and stating that "*Monitoring of avian species in the Delta has never been well done, coordinated, or a priority*." Dybala et al. (2020) recommends that large amounts of habitat restoration will be required to maintain healthy bird populations, and without adequate monitoring, bird populations will remain inadequately understood and protected.

Invertebrates

Invertebrates, particularly benthic invertebrates, were also noted as being poorly understood due to a lack of spatial and temporal coverage, but likely play numerous influential roles in the ecosystem. One questionnaire participant stated, "*There are very few programs monitoring life in the benthos, which can be important in understanding nutrient cycling, phytoplankton biomass, food web interactions, and alternate sources for Delta fish. Current monitoring programs lack the spatial and temporal coverage necessary to understand the role and impact of this factor on the Delta ecosystem*." Benthic invertebrates can play an important role in food-web support, but also include non-native species of concern, including Asian clams and *Corbicula*, which was explained by one interviewee. "*There's the DWR program through IEP looking at [the benthics], but otherwise we don't have many monitoring programs to understand what the role of benthic organisms are…We need to understand the community composition before effective regulations can start being enacted*."

Habitats

Monitoring of aquatic and terrestrial habitats tend to be relatively well represented in the inventory (see Nelitz et al. 2020b). However, a lack of monitoring in the shallows, which was not tracked in the inventory, was frequently mentioned during the brown bag seminars and the interviews. Shallow habitat accounts for a large portion of the habitat in the Delta, and likely plays an important role in providing habitat for fish (including Delta smelt, as mentioned by questionnaire and brown-bag seminar participants), invertebrates, and phytoplankton. Slow moving, shallow habitats historically supported native fish populations including Sacramento perch, Sacramento splittail, hitch, and others (SFEI-ASC 2014). As good habitat for phytoplankton and invertebrates, these productive areas are likely a significant source of food for fish and essential support for the food-web (Odum 1980; Lucas et al. 2002). However, they are difficult to sample, but must be sampled to understand their significance in the ecosystem and to adequately restore them. Three interviewees commented on the importance of shallow habitats, with one mentioning potential species interactions that may be affecting their ecological role "*It's in the shallows where people want to have phytoplankton growing, which is also where they can really get going is the shallows, but not if the clams are there, they'll graze them right down*." Not all shallow habitat is the same, however. The high residence time of shallow habitats can support beneficial phytoplankton populations but can also facilitate invasion of non-native submerged aquatic vegetation, including *Egeria* (SFEI-ASC 2014), underscoring the importance of monitoring and understanding shallow habitats across the Delta.

Question 2. What is the <u>level of coordination</u> of data collection across different organizations?

Monitoring activities across the monitoring enterprise are implemented, funded, and / or supported by 132 organizations. The 9 most common and influential were the organizations that have historically coordinated under the IEP:

1) California Department of Fish and Wildlife
2) California Department of Water Resources
3) California State Water Resources Control Board
4) National Oceanic and Atmospheric Administration
5) U.S. Army Corps of Engineers
6) U.S. Bureau of Reclamation
7) U.S. Environmental Protection Agency
8) U.S. Fish and Wildlife Service
9) U.S. Geological Survey

The examination of the network analyses, found in ESSA et al. 2020b, highlighted that there are differences in the number of organizations involved in monitoring networks for various topical areas (e.g., fish monitoring), and the density of these networks depends on the issue or topic. For instance, water quality monitoring appears to have a denser monitoring network than bird monitoring (see Figure 7). This suggests that the structures for coordinating and sharing monitoring information should be assessed not just across the entire monitoring enterprise, but within specific issue areas. Although the information from the network analysis cannot be used to prescribe improvements to monitoring networks, they do provide useful diagnostic information for understanding their structure and exploring ways of strengthening support and coordination among organizations with common information needs.

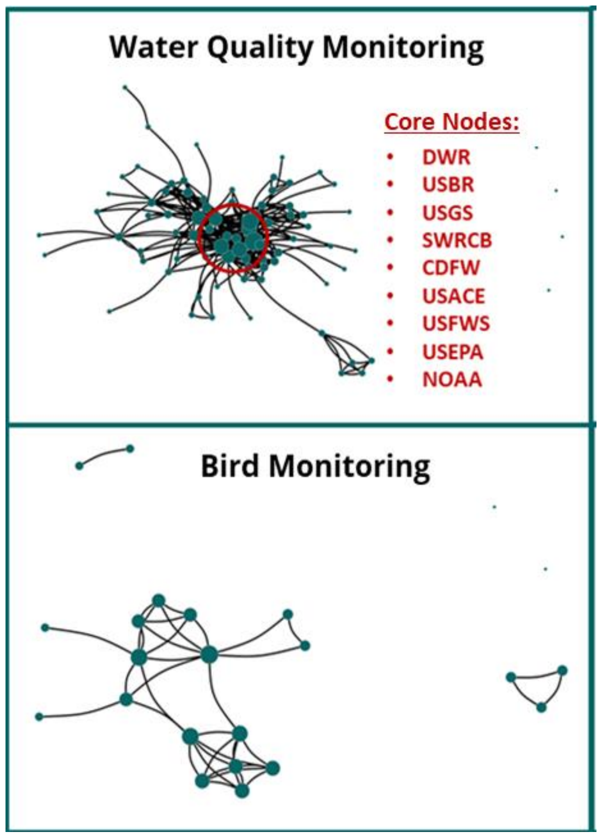

Figure 7. Illustration of monitoring networks found in Nelitz et al. 2020b.

Component 2 analyses further explored aspects of the Delta monitoring enterprise where coordination can be improved. Currently, the California Department of Water Resources is working to establish The Rio Vista Estuarine Research Station, which would bring together State and federal agencies conducting monitoring under the IEP into a single location. Moreover, coordination is occurring at some level through project work teams of workgroups for some topical areas, such as the California Water Quality

Monitoring Council workgroups, the Delta Interagency Invasive Species Coordination Team, IEP's Tidal Wetland Restoration Monitoring Project Work Team and IEP's Juvenile Monitoring Project Work Team.

Even so, interviewees pointed to specific issues, such as nutrients, species, flows, food webs, chemicals/contaminants that would benefit from greater monitoring coordination. More generally, interviewees highlighted the need for coordinating monitoring across ecosystem components, such as between water quality and agricultural land use; habitat restoration and land use; human health and environmental conditions; and flood control and water quality. As described by one interviewee: "*the floodplain people aren't talking to water quality people downstream…the notion of flood control is traditionally divorced from the notion of water quality. When in fact it should be considered to be a component of water quality, right*?" Questionnaire respondents also generally agreed that changes are needed to support better coordination monitoring and adaptive management. For example, one questionnaire respondent noted: "*It is not clear there is any integration of monitoring in adaptive management. No biological models being used for adaptive management are being informed by the survey data*."

Several interviewees indicated that each of the organizations they represent, as well as other key stakeholders, should play a role in coordinating monitoring. These roles may vary - whether by providing the scientific expertise, the regulatory structure, the organizational venue, or the resources for coordination (e.g., tools, data, communication). Additionally, some interviewees recommended that monitoring plans should take local interests and local knowledge into consideration, so they produce information local people can use.

Monitoring that is better coordinated, and potentially more integrated, across topical areas as well as spatial and temporal scales can foster a more holistic understanding of monitoring needs and uncover new ways to solve problems. As one interviewee suggested: "the more we work together, I think the better it gets for everybody." These benefits are widely supported by literature on ecosystem management and monitoring. In any ecosystem, coordination of monitoring data is critical for diagnosing and understanding the drivers of complex ecosystem problems, for assessing how policy solutions or management actions affect the system as a whole, and creating capacity to respond to ecosystem-wide changes (Burton et al., 2014; Schultz et al., 2015; Kupschus et al., 2016; Sparrow et al., 2020). Despite transaction costs and communication costs that occur with greater coordination, there are also opportunities to improve efficiencies in the monitoring enterprise. When coordination is lacking, siloed thinking is reinforced which can impair creative problem solving.

There is often a keen interest in the economics of monitoring, but not a lot of data to support this. For example, there is an interest via the Delta Science Funding and Governance Initiative to conduct an assessment of science funding and the efficiency on the use of those funds (DSC 2019). Coordinating across programs and looking at when there are synergies and when things do not align can help with the socio-economics of monitoring.

Question 3. Are there other opportunities to increase efficiencies in monitoring?

Concurrent with the Delta ISB's review, there have been efforts to review monitoring or make improvements to monitoring, including efforts to develop a steelhead monitoring plan for Sacramento-San Joaquin basin (see DSC and USBR 2021); a completed review by IEP on the effectiveness of three IEP monitoring surveys (Fall Midwater Trawl, Bay-Study, and Suisun Marsh Study); and a 5-agency effort to review IEP monitoring surveys to meet the evolving needs for management of delta smelt and longfin smelt (Summer Townet Survey, Fall Mid Water Trawl, Spring Kodiak Trawl, Smelt Larval Survey, and 20mm Survey). We hope that these efforts and our review of the monitoring enterprise review can be melded to educe opportunities for more efficient and useful monitoring where collaborations between monitoring agencies are well coordinated.

Through the inventory analysis, the following opportunities for efficiencies were identified:

- Related to monitoring of environmental drivers / conditions, most emphasis of monitoring is on water quality, specifically water temperature, turbidity, salinity, conductivity, and dissolved oxygen. For these parameters, there may be opportunities for increasing comparability of data by standardizing use and calibration of equipment, employing consistent sampling protocols, and centralizing data management. Based on the questionnaire results, 70% agreed with this finding, while 10% disagreed and 20% did not know (see Figure 8; N=30). Respondents in questionnaire indicated that the California Department of Water Resources and the United State Geological Survey are working on standardizing their protocols for their individual organizations, so there may be opportunities to build off these efforts.

- Related to habitat monitoring, channelized and tidal wetland habitats are commonly represented across the monitoring enterprise. There may be opportunities for greater coordination of monitoring of habitat and species components since habitat monitoring tends to be driven by species needs. This coordination could be further improved if guided by standardized habitat classification schemes. Based on the questionnaire results, 71% agreed with this finding, while 14% disagreed and 24% did not know (see Figure 8; N=28). The State Water Resources Control Board is currently using a standard classification system developed by the science consortium of Southern California Coastal Water Research Project, Moss Landing Marine Lab, and San Francisco Estuary Institute; however, it is not commonly used in the Delta. A common obstacle would be to get the monitoring enterprise to agree to a classification scheme.
- Related to species monitoring, the most recurrent species in the monitoring inventory are Chinook salmon, steelhead, and green sturgeon. Based on the network analysis of monitoring activities, fish monitoring appears to be relatively well coordinated, though efficiencies may exist for improving telemetry data collection. Based on the questionnaire results, 40% agreed that fish monitoring is well coordinated, while 26% disagreed and 20% did not know (see Figure 8; N=30). During the course of this review, the Interagency Telemetry Advisory Team was formed, which has helped improve the data collection of telemetry.

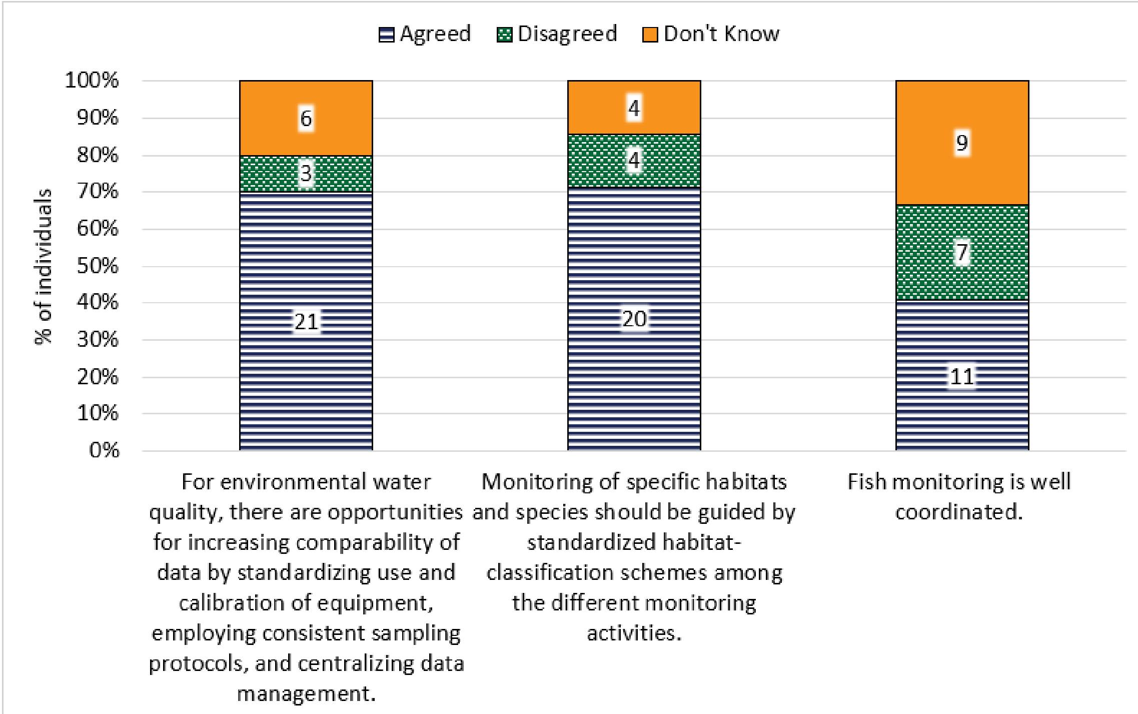

Figure 8. Questionnaire responses on whether participants agreed or disagreed with the opportunities to improve efficiencies identified from the inventory analysis. Labels within a bar graph indicate the total number of responses. See Appendix C for more information.

Based on the panel discussion with regional and national monitoring programs, national monitoring programs should include sites in the Delta and coordinate with Delta programs. There is an opportunity to join the Environmental Protection Agency's monitoring effort, the National Wetland Condition Assessment (see Appendix A), which is underway by Environmental Protection Agency to compare randomly selected sampling points across the U.S. Field sampling includes assessment of non-native species, which we identified as a potential gap, and a suite of indicators of disturbance to aquatic ecosystems. This effort occurs at 5-year intervals and already includes sampling in the Delta. Sampling can be expanded to allow comparisons of wetland conditions between the northern and southern Delta, as well as with the broader nation-wide array of monitoring sites. Furthermore, the Delta Plan Interagency Implementation Committee (DPIIC) agencies should also consider participating in the National Rivers and Streams Assessment, scheduled for 2023 to 24, which assesses the ecological conditions of rivers and streams and the key stressors that affect them throughout the United States. Macroinvertebrates and fish are used to indicate condition, as part of the National Rivers and Streams Assessment.

In addition, the Delta monitoring enterprise may consider incorporating new techniques, technologies, analyses and database management procedures, which, when integrated is also commonly known as 'smart monitoring' solutions. Rapid innovations in sensory material and advent of new fabrication paradigms of electronic, computer and bio molecular technologies have resulted in advanced sensors, with vast functionalities at micro, nano- and molecular scales. Modern sensors are miniature, more accurate, fast, rugged, stable, and low power, and at times possess self-calibrating and multifunctional capabilities. Their data rates are extremely high, because of which a variety of data storage systems (or 'key-value stores') have emerged with focus on scalability. These sensors typically transmit monitoring data wirelessly, allowing the streamlining of data acquisition and data processing using Artificial-Intelligence (AI) and machine learning techniques encapsulated in Internet of Things (IoT). Integration of disparate sensors with extremely large volumes of data (i.e., Big Data Paradigm) via wireless networks into a single database, for example on a cloud-based system, is enabled by IoT. AI may perform QA/QC and analyses, data fusion, identification of causalities, thus transforming of Big Data into actionable insights with minimum human intervention. This, in turn, resulting in lower latency and timely information for management and policy decisions. For example, the NSF-funded Array of Things (AoT) and its successor Software-Defined Sensor Networks (SAGE) for City of Chicago is of this ilk, and may provide useful pointers for development of IoT networks (Licaurte 2021).

A new technique that is rapidly becoming a standard tool is the environmental DNA (or eDNA), where DNA is extracted from an environmental sample, for example, soil, sediment, water or snow that contain excretions from live and dead organisms. The rapid space-time diffusion of DNA from its source(s) causes its presence somewhere in the waterbody known during sampling. The method involves the collection of water samples, eDNA extraction and a rapid PCR step to amplify the DNA of the target species. eDNA sequencing can be used to detect rare, transient and domain obscure species, including non-native/invasive species and their biomass distributions, or to map high-resolution space-time variation of ecosystem change and biodiversity patterns (Darling and Mahon 2011; Chave 2013; Shade et al. 2018). Modern sequencing methods allow identification of entire faunas and rapid ecosystem assessments. eDNA techniques are environmentally benign, multi-species, non-invasive, efficient, easy to standardize and more accurate than other field sampling methods, although workflow involving eDNA remains specialized (Rees et al. 2014). With ever advancing DNA sequencing technology, the adaptation of eDNA is rapidly growing. As eDNA is a non-invasive technique, it could provide a useful way to sample for Delta smelt to understand the impact of restoration on this fish given concerns we have heard about the inability to sample for Delta smelt since projects are not able to acquire incidental take.

Another technique with growing applications for environmental monitoring is the Unmanned Autonomous Systems carrying myriad of sensor systems for spatial/temporal monitoring and analysis, a review of which can be found in Manfreda et al. (2020). Implementation of such systems for Delta monitoring enterprise is afoot (Bloch 2020), and appears to offer great potential, especially for detecting non-native/invasive species, which was identified as a potential gap in our review.

Question 4. Is the data quality of monitoring appropriate to address purposes and needs for information?

There are a variety of desired data attributes that serve as a useful guide for ensuring data (and related monitoring) are of high quality and provide credible information for decision makers (e.g., US EPA 2006). Based on the inventory analysis, a substantial number of monitoring activities (44% or 69 of 157 monitoring activities) meet several fundamental attributes that represent high data quality to address the purposes and needs of that data, such as publicly accessible data, data collection guided by a monitoring design or sampling protocol, and reliable QA/QC procedures (see Nelitz et al. 2020b; Figure 9). From the inventory analysis, roughly 60% of the monitoring activities had QA/QC procedures in place. However, 39% of questionnaire respondents disagreed that "The procedures for quality assurance and control for the sampling methods …are adequate" (see Figure 10; 32% agreed, 29% did not know, N=31). Several commenters from questionnaire respondents noted a general lack of data (particularly for bird, plant, and invertebrate monitoring) that inherently causes insufficient data quality assurance due to a lack of data. In response to this question, one participant noted: "*The methods are suitable for the program's goals but are not well-documented (especially meta-data), tracked and updated…The Delta science community has placed a disproportionate amount of value on peer-reviewed* *science publications, rather on documentation and QA/QC, and QA/QC related* studies."

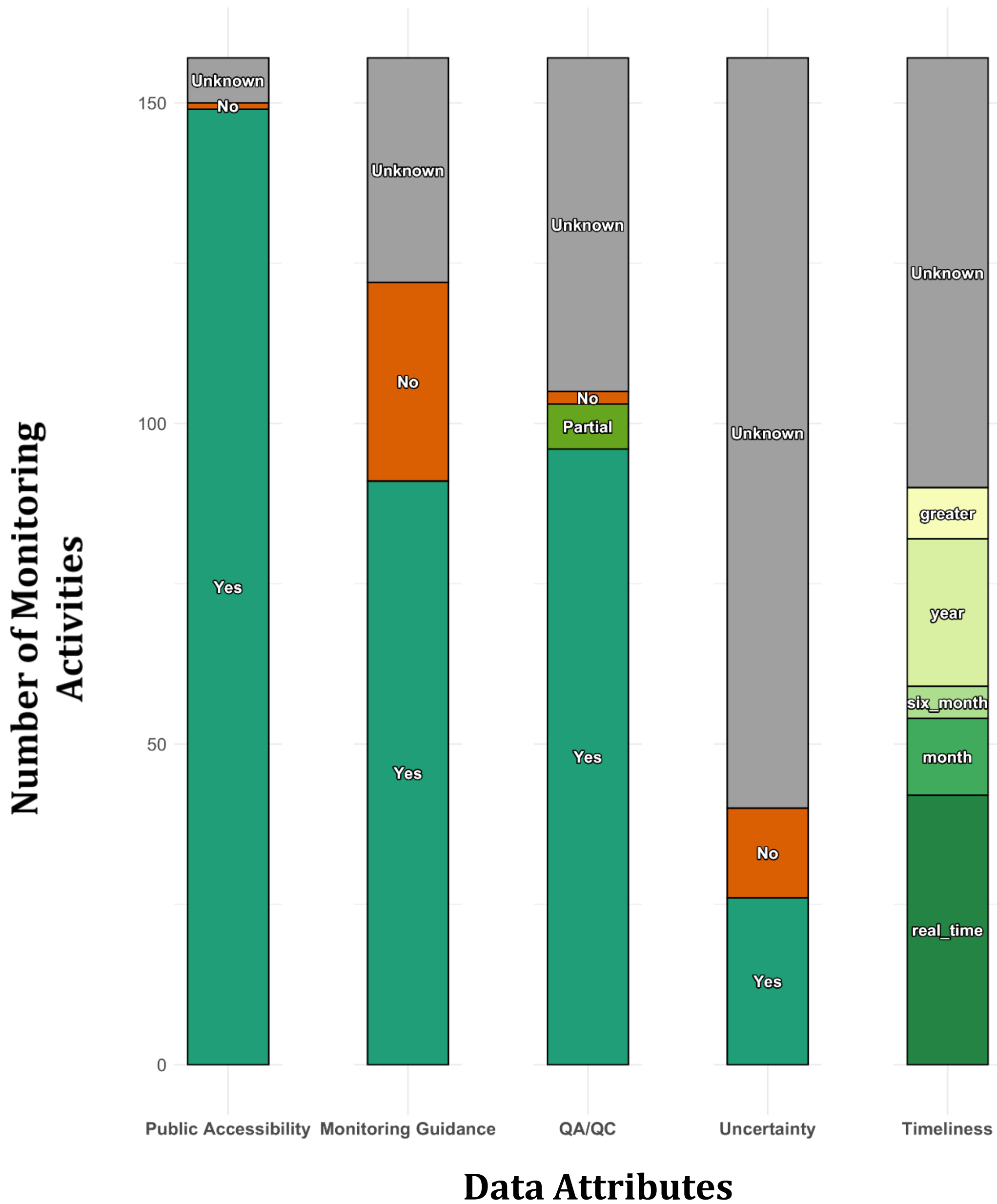

Figure 9. Stacked bar graph representing groupings and counts of monitoring activities from the inventory analysis according to five attributes of data quality (public accessibility, monitoring guidance, QA/QC, timeliness, and uncertainty estimate)

Given the scope and breadth of this review, it was neither possible nor intended to conduct a detailed evaluation of the scientific rigor of all monitoring activities in the monitoring inventory since that would require intimate knowledge of the detailed design and purpose of each monitoring activity. Understanding data quality, can provide some insights on scientific rigor. To help provide additional insights, we sought feedback from the Delta community in Component 2. Based on the brown bag seminar and panel discussions on tidal wetland restoration, monitoring in the Delta needs to pay attention to the statistical criticisms that can be raised against it. One of the problems of monitoring in an aquatic system arises from the linear array of boat-based sampling. The samples are not randomized and there's a potential for spatial autocorrelation among those samples. You can test for spatial autocorrelation to determine the degree to which the samples are in fact independent of one another or the degree to which they are compromised by autocorrelation.

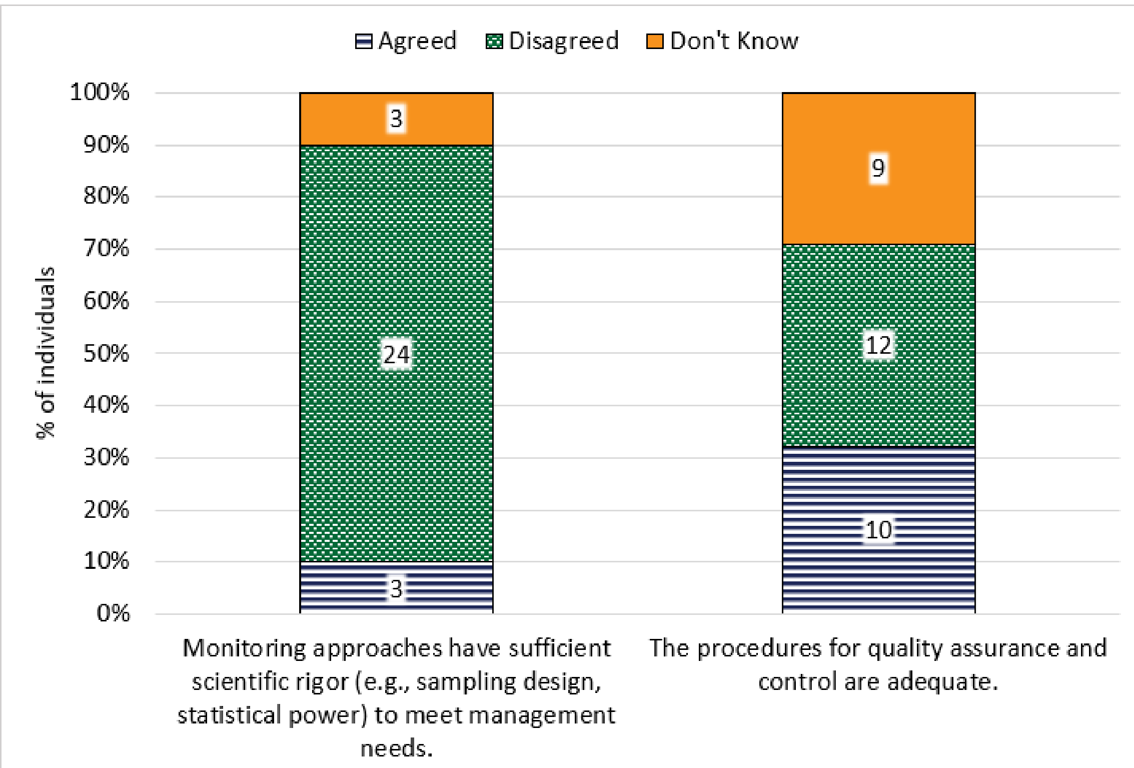

Figure 10. Questionnaire responses on whether participants agreed or disagreed with the statements related to data quality. Labels within a bar graph indicate the total number of responses. See Appendix C for more information.

Questionnaire participants were asked to identify the top two major monitoring parameters that they believed the Delta ISB should consider in greater detail and were then asked if the monitoring and QA/QC procedures for these parameters are sufficiently rigorous. The results indicate that 80%

disagreed that there was enough scientific rigor for the two monitoring parameters they selected (see Figure 10 ;10% agreed, 10% did not know; N=30). Several respondents suggested that the scientific rigor of monitoring in the Delta broadly is inadequate since programs are infrequently, if ever, reviewed for their scientific rigor or how well they address management needs. Others mentioned sampling design flaws and constraints (small sample sizes, fish size bias, inappropriate or inadequate sampling techniques, inadequate and/or inconsistent spatial and temporal monitoring) and topical, temporal, and geographical gaps (birds, plants, invertebrates, shallow habitats, tidal wetlands, night sampling) that result in inadequate scientific rigor.

Question 5. Are data accessible to the public, decision makers, other scientists, and all stakeholders?

From the inventory analysis, 95% of the monitoring activities are publicly accessible (149 of 157 monitoring activities), 63% are machine readable (99 of 157), and 52% are available within a 1 year or less timeframe (82 of 157). Overall, 34% of all monitoring activities (53 of 157) meet all of these conditions: are publicly accessible, machine readable, and available within a 1 year or less timeframe (see Figure 11). Although data appears to be accessible, 60% of questionnaire respondents (N=20) disagreed with the statement: "Data availability and sharing among agencies and groups doing monitoring are sufficient" (20% agreed and 20% did not know; See Appendix C). Regardless of whether a questionnaire respondent agreed or disagreed, there was general acknowledgement that improvements have been made in recent years, especially with the passage and current implementation of The Open Data and Transparent Water Act (Assembly Bill 1755), which requires the California Department of Water Resources in consultation with other State agencies to develop and operate an integrated platform for sharing data and for developing protocols for data documentation, data sharing, public access, and quality assurance/control.

Nevertheless, improvements should continue to be made, as datasets are hard to find, lack sufficient documentation or are not available in a timely manner to conduct analysis, as mentioned by the questionnaire respondents. This is consistent with the inventory analysis, where nearly 95% of the data from monitoring activities are publicly accessible, but this percentage drops to 34% when considering whether the data are accessible in a timely manner and also machine readable (Figure 11). Although there were many comments that improvements have been made in recent years in regards to data accessibility, there was a comment from the interviews that it appeared there has been a reduction in transparency and data sharing in recent years: *"We've noticed a significant reduction in transparency, you know, from both the State and federal agencies in recent years, and that is really counterproductive to informing and engaging the public and some of these needs."* However, this depends on the datasets. As part of our review, we found that United States Bureau of Reclamation has improved its efforts in recent years by providing an integrated platform of sharing its monitoring data that it funds related to the in-season management of Chinook salmon via the SacPAS website (Central Valley Predication and Assessment of Salmon).

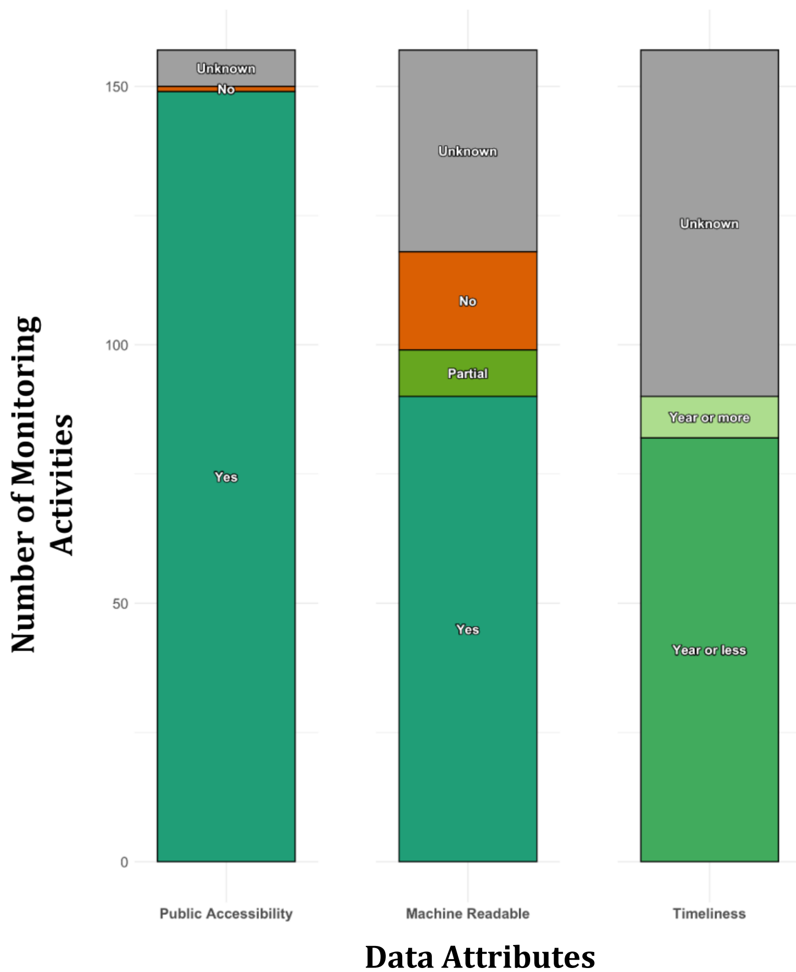

Figure 11. Stacked bar graph representing groupings of monitoring activities according to three attributes of data accessibility (public accessibility, machine readable, and timeliness). Queried from monitoring inventory analysis.

Question 6. What <u>resources</u> are being dedicated to monitoring?

Although not the case for every organization that works within the Delta, obtaining funding for long-term monitoring has been difficult because of ever changing funding priorities and mechanisms or funding carries restrictions. For example, bond funding may provide money to do things, but may not follow up and determine the outcomes (i.e., lacks accountability). Dedicated and sustainable sources of long-term funding and greater flexibility in how that funding may be spent are needed to support effective and cost-efficient monitoring programs (State of California 2015; Delta ISB 2016; EcoRestore 2017). As a start, there is a need to quantify the amount of funding spent on monitoring in the Delta.

However, monitoring costs could not be generated for most monitoring activities in the inventory, as the information was not available or could not be disaggregated between monitoring activities (e.g., funding is aggregated by an agency for multiple monitoring activities in the inventory) or within a monitoring activity for different regions (e.g., a monitoring activity has stations in the Bay and Delta). There was annual cost information available for 25% of monitoring activities (39 of 157 monitoring activities). Although costs of monitoring cannot be determined for all 157 monitoring activities, Delta Plan Interagency Implementation Committee is now releasing an annual Delta crosscut budget of science and monitoring expenditures that spans State, federal, and local agencies and are working to address the issues identified from the inventory analysis with estimating cost.

The first report was released in July 2020 for science related expenditures from July 1, 2018, to June 30, 2019 (DSC 2020) and a second report was released in July 2021 for science related expenditures from July 1, 2019 to June 30, 2020 (see DSC 2021). Information across both years cannot be compared, as more organizations reported in year 1 than in year 2, and there was some other inconsistencies with reporting between years (see DSC 2021). Even so, it provides information on the level of funding available for the Delta. From July 1, 2018 to June 30, 2019, a total of $47.1M was expended on monitoring during this time period, which makes up 53% of all science expenditures, including research and synthesis, for that fiscal year. Many of the issues identified from this review are present in these figures from Delta Plan Interagency Implementation Committee (e.g., it does not disaggregate funding between the Bay-Delta for a single monitoring activity), but the effort is a great start to help improve the understanding on the financial resources devoted to monitoring.

4. Barriers and Opportunities

From our findings, there is a need for more integration and collaboration, and ultimately, coordination, across monitoring activities focused on different thematic areas and geographic regions to help identify and fill gaps, and improve efficiencies, data quality and accessibility. This will help foster a more holistic understanding of Bay Delta status, trends, and responses to management.

Despite recognition of the need for, and benefits of, greater coordination, and addressing monitoring gaps, a number of barriers can impede coordination and the ability to address monitoring gaps (as highlighted in Figure 12). These include the siloed nature of organizational structures, perceived risks associated with changing monitoring programs, the time and effort required when monitoring staff have other priorities, the regulatory and legal constraints, funding, lack of leadership, a disconnect with management needs, and poor communication, among others.

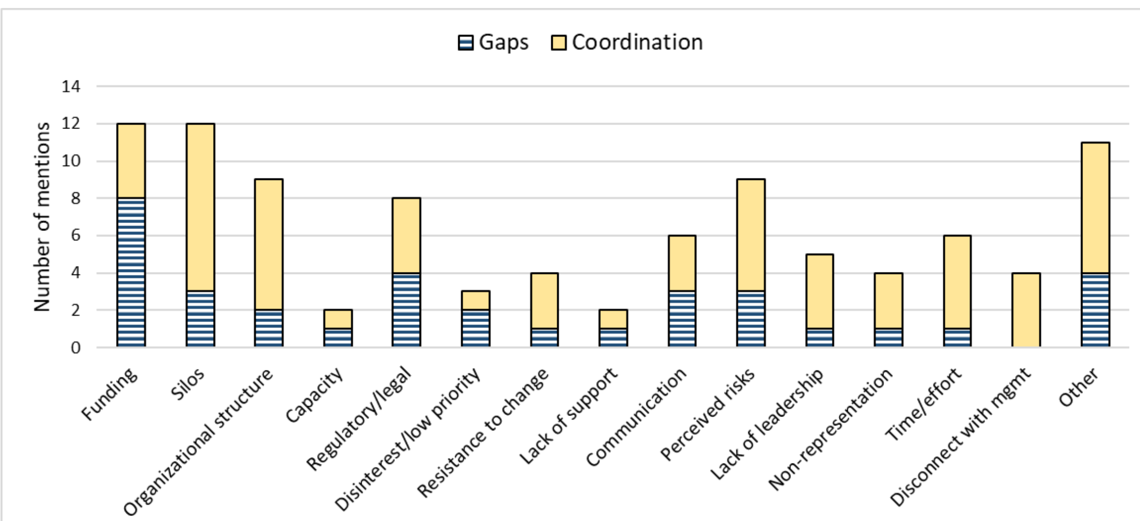

Figure 12. Barriers to addressing gaps and achieving greater coordination. Note: multiple mentions within interviews were counted as a single mention.

At the same time, Component 2 analyses illuminated diverse types of opportunities and mechanisms for overcoming barriers to coordination and filling monitoring gaps in the Delta monitoring enterprise. We found that when participants were asked how to address monitoring gaps, they often offered recommendations for coordination or reorganization, since this is itself a strategy for addressing gaps. These opportunities for overcoming barriers to achieve greater coordination and to fill monitoring gaps can be categorized into four overarching types of change or investments: 1) financial; 2) organizational/human-resources/structural; 3) regulatory and legal; and 4) cultural/social.

1) ***From a financial perspective***, one interviewee noted: "*the strongest tool that's available to make people work/coordinate with each other is the money*". Others acknowledged that funds are currently allocated primarily by the California Department of Water Resources and the United States Bureau of Reclamation– and thus there is a need for funding sources that are not tied to the water projects (e.g., the state general fund). Other options may include the potential for co-funding by multiple organizations, such as through a joint-powers authority, or through end-users of Delta water resources. However, one interviewee provided a different perspective, noting that it is not funding shortages, but the inability to sample listed fish due to take limitations, that is responsible for monitoring gaps. This suggests that, for some key monitoring parameters, increased funding from more diversified sources may have limited impact.
2) ***From an organizational/human-resources/structural perspective***, a number of interviewees, as well as questionnaire respondents, indicated a need for adapting existing, or creating new, organizational mechanisms that allow different monitoring authorities and agencies to work together on monitoring. While some recommended a new entity, or a new a federal-state partnership, others identified existing organizations, such as the Delta Science Program, which could take the lead in coordinating monitoring. Others focused on improving coordination between regulators and regulated entities. As one questionnaire respondent stated: "*If we want better coordination, it should broaden leadership between regulatory and regulated entities so power is shared*." Another interviewee suggested that voluntary agreements between agencies (e.g., similar to the National Estuary

Program), can also create the organizational infrastructure need to establish effective coordination.

3) ***From a regulatory/legal perspective***, the interviews highlighted the importance of regulatory tools that are linked to funding streams (e.g., Clean Water Act Section 401 Water Quality Certifications and 404 permits). Relatedly, permits with more specific guidance on how to achieve compliance could incentivize coordination, or agencies with regulatory requirements, such as the State Water Resources Control Board, California Department of Fish and Wildlife, and United States Fisheries Service and National Marine Fisheries Service could potentially mandate coordination. Other suggestions related to the regulatory sphere included outcome-based regulatory options to encourage trying new tools, ideas, and approaches to monitoring, updating the Bay-Delta Water Quality Control Plan, a new set of biological opinions, and a new incidental take permit. One interviewee emphasized the need to understand how various tools complement one another, and how they can be used to coordinate monitoring without imposing excessive burden on regulatory or regulated communities. Further, hesitancy to reorganize monitoring programs for fear of losing long-term datasets was a recurring theme in interviews. To alleviate these concerns, several interviewees emphasized the importance of retaining long-term datasets. In addition to regulatory/legal mechanisms, one interviewee emphasized the potential for either legislation or executive order to mandate monitoring coordination, and provide associated funding streams.
4) ***From a cultural/social perspective***, several options for overcoming barriers related to miscommunication, distrust, and risk hesitancy were identified in the interviews. These include: spending time building shared vocabularies to avoid miscommunication, as well as building more shared understanding of the state of the system, and convening multi-stakeholder groups to ask management questions, form research programs, and discuss findings. Collaborative groups can also conduct more economical experiments (example of multiple agencies comparing and calibrating chlorophyll-a measurements), and bring partners closer to collecting comparable data. This can help address the hesitancy to reorganize monitoring programs for fear of losing long-term datasets, which was a recurring theme in interviews.

> To alleviate these concerns, several interviewees emphasized the importance of retaining long-term datasets. One interviewee further noted the importance of having initial champions get the momentum going on these types of effort.

5. Best Practices and Recommendations

There are greater efforts to integrate across geographic regions today than in the past, where monitoring programs in the Bay and Delta were even more segregated, although continued efforts toward geographic integration are still needed (Nelitz et al. 2019; Nelitz et al. 2020b). In our findings, we identified potential gaps, opportunities to improve efficiencies, and areas for improving coordination, data quality and accessibility. To help improve coordination, adaptive management, and how monitoring could better meet the needs of management, we provide best practices that that we recommend to be formally adopted into **individual** monitoring programs, and three overarching recommendations that are directed at the monitoring enterprise as a whole, which take into consideration the barriers and opportunities described above.

Best Practices for Individual Monitoring Programs

Overall, we advise that every monitoring program or activity develop a monitoring plan or road map using the six-step framework in Figure 3, which includes describing (1) the purpose of the monitoring program, (2) the problem, (3) the monitoring design, (4) how the program will be implemented, (5) how information collected will be used to facilitate learning, and (6) how the monitoring program will be revised, which also consider periodic independent peer review.

The monitoring program should be underlain by five best practices to help address some of the challenges and issues with monitoring identified in the review (Figure 13): (1) formally tie monitoring to goals, objectives, and questions; (2) be informed by stakeholders needs and capability and include alternative forms of data and knowledge; (3) adapt as new information and technology become available; (4) include data management, analysis, and synthesis; and (5) ensure data are accessible (Figure 13). Each practice should be a part of each step in the monitoring program.

The five best practices identified for this review are meant to be actions that most monitoring programs could implement immediately in an effort to improve monitoring. Although they are strongly recommended, it is recognized that each best practice may not be appropriate or applicable for all monitoring programs or in all situations. It should not be seen as a go-to-source for designing a monitoring program. There are other resources that could be used instead (e.g., Reynolds et al. 2016).

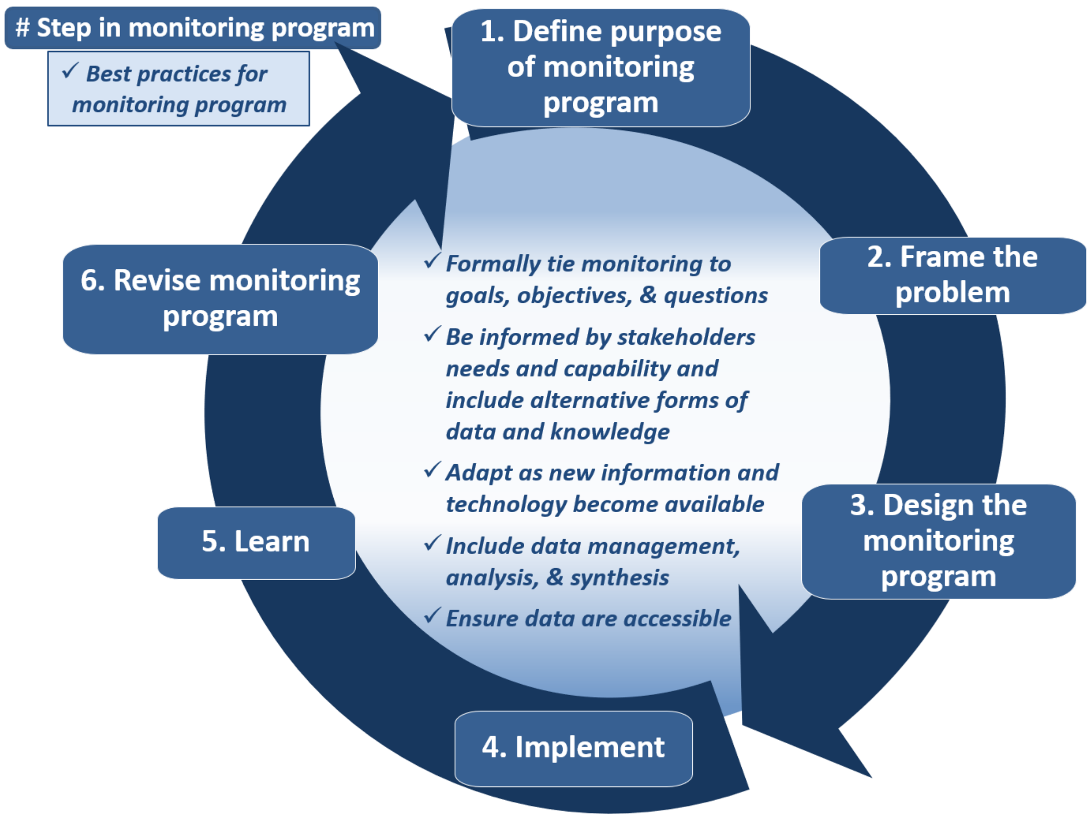

Figure 13. Best practices should be a part of each step in the monitoring program.

1. **Monitoring should be closely tied to the goals, objectives, and specific questions of interest to managers and decision makers.**

Specific management and scientific goals, objectives, and questions must be defined to focus monitoring system design on the collection of data that will be most relevant to decision-making, especially when resources are limited. Linking monitoring with the design of management actions will also help to ensure that the monitoring is targeted, informative, and cost-effective rather than broad-based and unfocused (IEP-SAG 1999; CAMT 2017).

Several commenters from the seminar and interviews identified a disconnect between management needs and monitoring as a barrier to improving coordination and addressing monitoring gaps. As indicated in the questionnaire results, 70% disagreed that monitoring was serving the needs of decision makers (see Figure 5). Using monitoring to address management needs that was not explicitly designed to address was noted during our panel discussion on tidal wetland restoration monitoring as a common practice that can result in ineffective management. More relevant and directed monitoring, designed through communication between managers and scientists would help "to bridge the gulf between articulated need and usability," as described during one of our interviews. However, many interviewees warned that this improvement should not come at a cost to current long-term monitoring programs that serve an essential role of monitoring long-term trends and ecosystem drivers, but that both types of monitoring must be prioritized in the monitoring enterprise. Additionally, this best practice can be difficult to implement in cases where questions and priorities change rapidly and cannot always be addressed.

Monitoring needs and questions should be made clear to staff designing and conducting monitoring, and staff should be aware of the goals and objectives of the monitoring program. Communication at all levels is essential for a successful monitoring enterprise. A need for "coordinating the coordination" through improved communication between scientists and managers was discussed as a way to improve the efficacy of the monitoring enterprise during our brown bag seminar and panel discussion with the Fish Restoration Program. Staff should be aware of program goals to ensure data quality and proper decision making.

2. **Monitoring should be informed by stakeholder engagement and participation if appropriate, including use of alternative forms of data and knowledge such as Traditional Ecological Knowledge and qualitative observations.**

Stakeholders are recognized as a key component to the monitoring enterprise, but they are often neglected. Some interviewees identified the issue of some entities not having a seat at the table as a major barrier to coordination and reorganization of the monitoring enterprise. The definition of a successful monitoring program can differ between stakeholder groups, therefore early stakeholder involvement can be important for context framing and identification of constraints. Without stakeholder support, programs will likely face difficulties launching and integrating into the monitoring enterprise. Although stakeholder engagement can be overall beneficial for monitoring programs, several commenters noted that relying on stakeholders to guide the direction of the monitoring enterprise is “not likely to result in a robust program that is representative of broad interests,” and should be used when appropriate, but not overly relied upon. Additionally, stakeholder groups can vary between projects and should be carefully considered. However, providing opportunities for stakeholder engagement can help provide alternative forms of information, such as qualitative or anecdotal observations, and traditional ecological knowledge (Zedler and Stevens 2018).

Best practices for stakeholder engagement include situational awareness of the place and problem, creation of a suitable culture for engagement, focus on power-sharing in the engagement process, co-ownership, co-generation of knowledge and outcomes, the technical process of integration, the processes of reflective and reflexive experiences, and regular and transparent communication (Kliskey et al. 2021). Situational awareness requires knowledge of the diverse worldviews and cultural experiences of the stakeholders and communities being engaged. Appropriate cultures for engagement are based on empowerment, trust, and equity (Reed 2008). Power sharing requires initiating stakeholder engagement early, creating repeated engagement opportunities, and sustaining the engagement process. Co-ownership requires attention to the power dynamics among stakeholders so as to allow all contributions to be valued, for federal, state, and local actors often have unique insights into the dynamics of the system. Co-generated knowledge involves stakeholders at all stages in the monitoring program. Technical process of stakeholder engagement requires explicit integration of stakeholder knowledge and science using approaches that are both conventional (e.g., computational model) and non-conventional (e.g., Indigenous knowledge; traditional ecological knowledge). Reflective and reflexive approaches to stakeholder engagement include the sharing of experiences and discussion of uncertainties, risks, and shortcomings that arise in the engagement process (Khodyakov, et al. 2018, Thizy et al. 2019). Regular and transparent communication among stakeholders and scientists fosters successful stakeholder engagement and co-generation of knowledge.

Capacity limitations can be a significant barrier to cross-agency and cross-jurisdictional collaboration on monitoring and management at broader ecological scales, particularly in a system driven by the frequent emergence of crises that divert attention from long-term efforts. Only when individual agencies and programs are capable of fulfilling their basic mandates will they be able to consider and support broader, overarching, and cross-jurisdictional issues (Hoenicke and Hoshovsky 2002; Delta ISB 2016; DSC-DSP 2017). During our interviews, funding, capacity, and staff time were identified as key barriers to improving coordination of monitoring or addressing key gaps (Figure 12). When internal capacity is limited, citizen-science monitoring programs carry great potential to expand regional monitoring capacity, provided that sufficient training, support, and oversight can be provided (USEPA-SFEP 1994; Grossinger et al. 1996; SFEP 2007, Skinder and Hoover 2009; Kraus-Polk and Milligan 2019).

Citizen science can be most effective when there is an objective approach, such as photography or identifying a distinct event (e.g., a levee break, or presence of an easily identifiable invasive species, which were gaps identified during this review). One commenter during our panel discussion with national and regional monitoring programs noted that there is clearly a role for community involvement in monitoring, noting NOAA's cooperative data collection program that has been using climate data collected for free by people with gauges in their backyard for decades. This panelist further acknowledged that although citizen science can provide some useful data, a fair amount of effort is needed to make these program rigorous enough so that the monitoring information can be interpreted and put it to good use. Citizen science information can be useful as an addition to professionally collected data but can be unreliable and incorporation must be carefully designed and evaluated.

3. **Monitoring plans should have enough flexibility to take advantage of new information and opportunities to adapt to issues as new techniques and technologies become available.**

Several commenters from the seminars and interviews noted inflexibility, either in funding or in permits, as a barrier to rapid responses to management needs. It was noted that a large share of IEP monitoring is compliance monitoring or a result of a regulatory mandate, resulting in programs that are difficult to adjust. Flexibility, where possible and appropriate, could help to address monitoring and management gaps more quickly. A monitoring plan in the adaptive management context should be seen as a living document, where changes could be made to meet evolving needs. Essential long-term information should always be collected, but additional monitoring information may be subject to modification as needed based upon critical evaluation. However, one interviewee warned that "flexibility and adaptation within a regulatory framework can deprive the regulated communities of their rights", and therefore should be very cautiously used in regulatory requirements.

Investment of time and resources into exploring the potential of new monitoring techniques and technologies (e.g., remote sensing, real-time monitoring systems) can increase program capacity to collect data more efficiently across broader spatial and temporal scales or answer new monitoring and management questions than previously possible using traditional methods (Cloern et al. 2002; Hestir et al. 2008; IEP-SAG 2013; Fichot et al. 2015; Healey et al. 2016; Schiff et al. 2016; Bergamaschi et al. 2017). Some of the modern techniques highlighted during the questionnaires and interviews include remote sensing, eDNA, and large sample statistical techniques ("Big Data"). When considering new technologies or techniques, especially for long-term monitoring programs, there must be mechanisms in place that guide how to and whether to incorporate new technologies or techniques.

Utilizing modern techniques for data collection and analysis will improve programs by reducing incidental take, increasing accuracy and precision, and improving data synthesis and communication. Some of these techniques can come at a high cost and are not appropriate for all programs but can greatly improve others and should be considered, where feasible. Although it has notable limitations, eDNA was suggested as a promising strategy during our brown bag seminar and panel discussion with national and regional monitoring programs for detection of rare species and could be used to limit mortality of sampling for listed species, especially Delta smelt. Big Data approaches are useful for discovering the "hidden needle in a haystack of data." This is especially valuable for any kind of high frequency monitoring especially one that generates volumes of data.

Monitoring programs should set up a formal independent scientific review conducted at regular time intervals to reassess the effectiveness of the program with recommendations for improvement, and whether information is collected at the right time and space scales. There should be mechanisms in place on how to transition a monitoring design to a different temporal and spatial scales when warranted. There is often resistance to changing a monitoring measurement scheme, and having a mechanism in place on how to make changes to a program would be important.

4. **Monitoring programs must include adequate data management, analysis and synthesis, and should strive to improve statistical validity.**

Data in specific subject areas have often been collected faster than they can be analyzed using sophisticated statistical procedures or simple numerical models (Hoenicke and Hoshovsky 2002). Data analysis, interpretation, and reporting out to policy makers, managers, and the public should have equal priority with data collection and be resourced accordingly to support evidence-based decision-making (Luoma et al. 2011; CAMT 2017). As we learned during the water quality brown bag seminar and panel discussion, lack of data analysis and communication causes data siloes, which have resulted in separate and compartmentalized science that has impeded the ability to make informed management decisions.

Many commenters noted that, although data analysis, synthesis, and communication has been improving over time, it is still inadequate and must continue to be improved and prioritized alongside data collection. Adequate data analysis and synthesize was identified as a key strategy for addressing gaps in the monitoring enterprise, and that without it, programs will not be effectively updated. Several commenters noted that this is not an easy task enterprise-wide, can be costly, and may require additional training, support, and guidance to be done properly. As observed from the questionnaire, many respondents did not feel that data are analyzed or synthesized in a way that enables management decisions. Synthesis is not well-connected to management decisions or communicated in an accessible or timely manner to those who need the information.

To improve statistical validity, monitoring designs should be developed with the assistance of an environmental statistician to produce sampling designs that are: representative of variability in conditions, account for confounding factors and shifting baselines, and make efficient use of limited resources to produce robust results that can be used to draw predictive inferences about unmonitored sites in order to answer specific monitoring questions (CAMT 2017; Raimondi et al. 2016).

Several comments during the brown bag seminars were made on the issue of statistical reliability in many monitoring programs and suggested integrating hypothesis testing and quantitative approaches whenever appropriate to improve statistical validity. However, interviewee comments additionally acknowledged that it is not always feasible to collect statistically rigorous data in the field, due to the scale of the monitoring enterprise, limited resources, and the unpredictability of collecting biological data.

5. **Monitoring programs should ensure the data are accessible and shared with the public and other agencies.**

Data accessibility, usability, versatility, and interoperability across databases and models are critical to serve a wide variety of different user needs and to promote the use of monitoring data in decision-making across multiple thematic, spatial, and temporal scales (NSF 2016). Although our inventory analysis indicated the majority of the data from the monitoring activities in the inventory were accessible, several interviewees noted data inaccessibility, both intentional and unintentional, as a major barrier to addressing monitoring gaps and reorganizing the monitoring enterprise. Similar to the effort to improve the statistical validity of monitoring programs, proper data accessibility takes time and resources and may require training, support, and guidance. Although the seminars and interviews made it clear that data accessibility and communication have improved in recent years, a more intentional and concerted effort by monitoring programs to improve data accessibility would greatly benefit the monitoring enterprise and encourage trust building between decision makers, scientists, and the public. These efforts should be done in coordination and build off the efforts of the California Department of Water Resources to implement The Open and Transparent Water Data Act (Assembly Bill 1755).

Recommendations

Consideration of the best practices or the development of a monitoring plan by an individual monitoring activity or program would help address some of our findings related to the disconnect between monitoring and management, communication, and data quality and accessibility. However, more transformative changes may be needed to help ensure monitoring is responsive to the needs of management at the enterprise level, as there are not agreed upon adaptive management questions that monitoring should inform that span the management areas of water supply, water quality, flood, species, habitat, and land use to achieve the coequal goals. Without the management questions, we cannot fully assess how monitoring is addressing the informational needs of the management agencies. Therefore, we make three recommendations (or "big moves") that could better link monitoring to management and begin to address the gaps and opportunities to improve efficiencies described in the previous section of the report. The implementation of the three recommendations is interlinked and should be guided by an adaptive management framework for monitoring, as presented in Figures 3 and 13, which could ultimately lead to a monitoring plan for the entire science enterprise. These recommended changes will be difficult to implement, but the complexity, urgency, and long-standing nature of many challenges facing the Delta dictate the need to do things differently.

Recommendation (Big Move) #1:
Develop priority science and management needs and questions for the monitoring enterprise, and synthesize information around these questions in biannual reports or at a summit.

Most monitoring guidance emphasizes the need for a clear purpose at an early stage of monitoring design (e.g., US EPA 2006; McDonald-Madden et al. 2010; Roni et al. 2013; Reynolds et al. 2016), which is reflected in in step 1 of our framework for monitoring (see Figure 3 and 13). Having a clear and appropriate purpose is important since not all problems are well suited for adaptive management (Murray et al. 2015; Wiens et al. 2007; Delta ISB 2016). Adaptive management represents one, but not the only, learning strategy available to scientists and decision makers. This review of the monitoring enterprise revealed that there are a multitude of management themes around which adaptive decision making could focus and many monitoring activities collecting data each with their own dedicated purpose. There are, however, few long-term monitoring activities focused on resolving the fundamental management uncertainties that underpin the reason for applying adaptive management. This recommendation promotes a shift towards providing a clearer synthesis of the state of knowledge including fundamental management uncertainties of relevance to the Delta, more standardization in the way the Delta and its management uncertainties are described and referenced, as well as more focus around the priority science and management needs for monitoring and adaptive management.

More work is also required to provide greater specificity about the management questions to guide monitoring and adaptive management. For instance, workshop participants revealed a long list of over 150 questions of relevance to monitoring and adaptive management yet had little agreement around the fundamental questions (or hypotheses) of most importance (ESSA et al. 2019). Moreover, 79% of questionnaire respondents disagreed that *"there is a common understanding of the priorities required to meet science and management needs"* (see Appendix C; 10% agreed, 10% did not know; N=29).

Written responses from the questionnaire indicated that it was not necessarily a disadvantage or surprising that organizations would have their own priorities and needs, and that "*Science and management is not one monolith - there are many needs and it doesn't seem useful to force "science" into one box."* However, one of the biggest barriers to filling gaps or to improve coordination based off the interviews was related to organizations working in silos (Figure 12). Organizations contributing to monitoring have their own interests and priorities – with monitoring programs designed, accordingly, to collect data differently. Synthesizing, standardizing, and developing priority science and management needs and questions would be an important first step to start addressing this barrier.

The development of priority management questions should be guided by step 1 (Define the purpose of monitoring) and step 2 (Framing the problem) of the monitoring framework (Figure 3 and 13).To help implement this recommendation, a variety of existing resources are available to provide guidance (e.g., US EPA 2006; Reynolds et al. 2016), and there are current efforts via the Science Action Agenda update, which are identifying and prioritizing management questions and science actions to address research gaps, could be used as a framework for developing management questions and needs for monitoring.

With the development of priority management needs and questions, the Delta Science Program could facilitate the development of biannual reports that synthesizes monitoring information to answer these questions, and evaluate if any changes need to be made. These monitoring reports could be facilitated by monitoring summits to help synthesize information. The development of these reports should be guided by steps 4 to 6 of the monitoring framework.

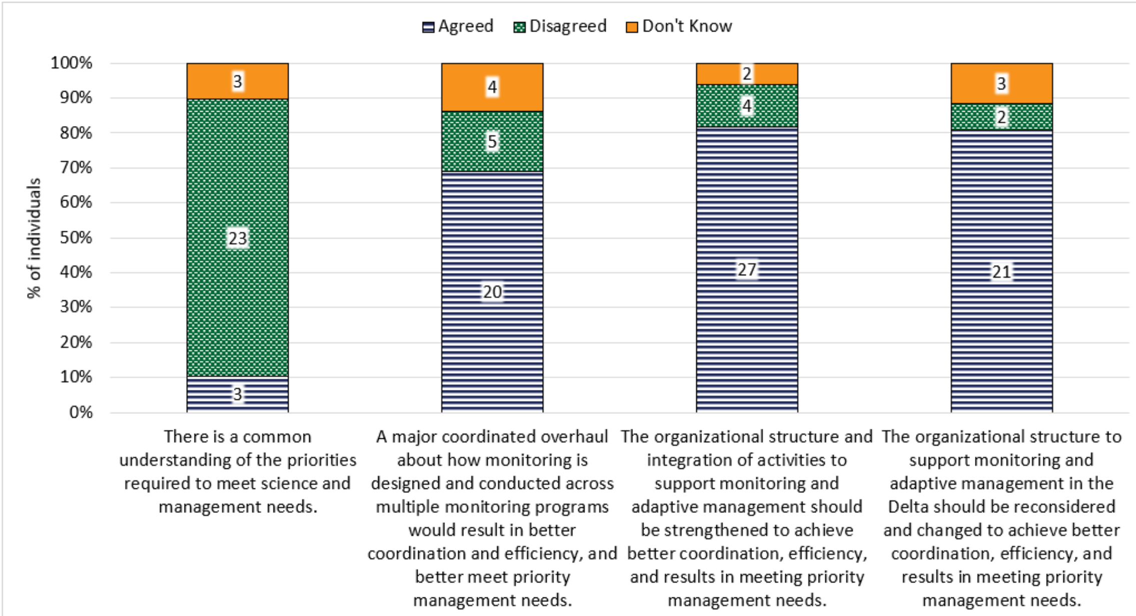

Figure 14. Questionnaire responses on whether participants agreed or disagreed with changes needed in the Delta Monitoring Enterprise. Labels within a bar graph indicate the total number of responses. See Appendix C for more information.

Recommendation (Big Move) #2

Reimagine monitoring designs for priority monitoring needs that is guided by a system-wide conceptual model.

The reality is that many monitoring activities across the monitoring enterprise have not been designed and/or implemented with the intent of explicitly supporting adaptive management in the Delta. For instance, there is limited effectiveness monitoring, which only makes up 3% of monitoring activities in the inventory, and some potential gaps in the availability of monitoring to provide data for monitoring parameters of relevance to all management issues. As a result, it is somewhat unrealistic to expect that the broad collection of monitoring activities will adequately meet the diversity of management needs. Others also acknowledge that deficiencies in monitoring can be difficult to address after a monitoring design has been implemented (e.g., Downes et al. 2002).

For these reasons, achieving improvements in coordination of monitoring among different organizations, ensuring sufficiency of coverage, and identifying other opportunities for efficiency gains may likely best be served by reimagining the monitoring designs for priority monitoring needs, as opposed to finding piecemeal ways of adjusting existing monitoring activities that were never designed to work together. Hence, the intent with this recommendation is to encourage investments in a reimagined monitoring design for priority needs that are of fundamental importance to decision-makers and adaptive management across the Delta. Such investments may become increasingly necessary as a way of understanding and responding to the rapid changes facing the region (Norgaard et al. 2021). There are also opportunities to discuss how monitoring stations for different parameters like fish and water quality can be co-located, as recommended in our water quality review (Delta ISB 2018) and the Delta Science Plan. Furthermore, when reimagining a monitoring design, it will be possible to better employ principles of monitoring design – randomization, stratification, and replication (Cochran 1977; Green 1979; Sit and Taylor 1998; McDonald 2002; US EPA 2006; Montgomery 2012).

From our questionnaire respondents, 69% agreed that “a major coordinated overhaul about how monitoring is designed and conducted across multiple monitoring programs would result in better coordination and efficiency, and better meet priority management needs” (see Figure 15 and Appendix C; 17% disagreed; 14% did not know; N=29). From our interviews, there is an interest to make monitoring more programmatic rather driven by compliance or specific management drivers (e.g., Water Right Decision 1641), and better integrating modeling and monitoring with key management needs. However, we understand that many of the monitoring activities are part of “compliance monitoring,” where key decisions are based off a particular monitoring station (e.g., water quality compliance under Water Right Decision 1641). As a result, there is some limitations of what can be changed without revising permits. Even so, permits often do not go into the level of specificity in terms of how monitoring is designed.

One of the concerns with a reimagined monitoring design is the risk of losing long-term datasets or losing the quality of a dataset if changes are made. However, there are methods in the literature on how to cross-calibrate data between different methodologies. For example, there are different gear types and trawling methods used across monitoring activities to sample zooplankton in the Delta. Methods exist for comparing zooplankton data collected using different methods; although there are limitations (Ohman and Smith 1995; Clark et al. 2001; John et al. 2001).

It is also important to note that many of the long-term monitoring programs have undergone changes to sampling, including the Delta Juvenile Fish

Monitoring Program (USFWS 2019) and fish salvage at the John E. Skinner Fish Protective Facility (Morinaka 2013). Many individual monitoring programs or activities have undergone periodic peer review, such as the California Department of Water Resources' Environmental Monitoring Program and have incorporated programmatic changes from these reviews (see Mueller-Solger and Hymanson 2003 on how the Environmental Monitoring Program addressed recommendations from a technical review by the IEP Science Advisory Group that involved stakeholder engagement).

Having the guidance and clarity resulting from an improved understanding of priority needs from ***Recommendation #1*** will ensure that a reimagined monitoring design is guided by a clear purpose. Implementation of ***Recommendation #2*** should be guided by step 3 of our monitoring framework (Design the monitoring program; see Figure 3 and 13). To help with a reimagined monitoring design, it may be useful to develop a comprehensive conceptual model that looks at the system holistically, which currently does not exist for the Delta. Developing this model will be possible once you know what the management questions or needs are. This could help identify major uncertainties and gaps with addressing the management questions. A conceptual model of how the system works provides a mechanism for an entity to justify why they are sampling some parameters and not others. Many conceptual models for various topical areas currently exist, which could help with developing a comprehensive conceptual model.[5]

Recommendation (Big Move) #3:
Strengthen organizational structure and integration to support monitoring and adaptive management.

Studies and reviews of programs have found that coordination and integration are among the important functions being provided by an effective organizational structure (Green et al. 2015) and several others have noted that these functions could be strengthened for the Delta (e.g., Herrgesell et al. 1993; Bernstein et al. 1997; Cloern et al. 2002; CWQMC 2008; 2010; Noon et al. 2017). Many components of an organizational structure

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[5] The Interagency Adaptive Management Integration Team has compiled a list of conceptual models that are applicable to the Delta ISB, which is available on the Interagency Adaptive Management Integration Team website: https://deltacouncil.ca.gov/delta-science-program/interagency-adaptive-management-coordination.

already exist in the Delta for monitoring or coordinating data, such as the California Water Quality Monitoring Council workgroups, the Collaborative Science and Adaptive Management Program, and the IEP. However, this structure may not lend itself to implement the recommendations described above.

An overall organizational framework is lacking for the Delta monitoring enterprise that links the range of management drivers in the Delta (e.g., Water Right Decision 1641 and State Water Project Incidental Take Permit) across monitoring programs, such as the IEP and the Delta Regional Monitoring Program, and implementing adaptive management at a system wide-scale, despite many management drivers calling for an adaptive management approach. This has resulted in some fragmentation with how monitoring is conducted or how adaptive management is implemented, despite the Delta Plan providing broad guidance and authority for aligning adaptive management around a common need.

As noted in the case studies from this review (Nelitz et al. 2019), and in a review of adaptive management programs by others (Greig et al. 2013), such fragmentation could addressed by a more integrated organizational structure. For this reason, we recommend strengthening the organizational structure and integration to support monitoring and adaptive management that enables the implementation of the recommendations in this review. This could come in the form of a new authority or council to govern monitoring in the Delta region or an existing entity could take on these responsibilities, such as the Delta Science Program, or the California Water Quality Monitoring Council.

In our questionnaire, we asked respondents two separate questions related to organization. We first asked if the organizational structure and integration of activities to support monitoring and adaptive management should be ***strengthened*** to achieve better coordination, efficiency, and results in meeting priority management needs. Afterwards, we asked if it should be ***re-considered***. Both questions generated similar results (see Appendix C; Figure 14). In terms of whether the organization structure should be ***strengthened***, 82% agreed, while 12% disagreed and 6% did not know (N=33). In comparison, 81% agreed when asked whether the organization structure should ***re-considered***, while 8% disagreed, and 12% did not know, N= 26).

Organizational changes could help address some of the barriers, such as agencies working in silos, lack of leadership, and funding, to fill gaps or improve coordination to better meet the needs of management. Some of the insights from the interviews noted how a strengthened or different organization structure could:

- Reduce the amount of work done in silos and any work the appears redundant if an umbrella organization or State-Federal program with an overarching mandate relating monitoring and the coequal goals overall, was formed.
- Broaden the set of partners, which could provide a broader set of funding, to fill gaps. Current funding structures also contribute to silos – decisions are made by directors according to their own objectives/requirements.
- Increase efficiencies with addressing gaps by provide a venue for collaboration.

The review of five case studies from other systems (Chesapeake Bay, Great Lakes, Puget Sound, Great Lakes, Coastal Louisiana in the United States, and Queensland, Australia) identified several attributes that could contribute to successful monitoring and adaptive management in the Delta (see Nelitz et al. 2019) that could be considered when discussing re-organization: [6]

- *Leadership and executive direction*: Effective communication with and a strong commitment from leadership facilitate success, backed up by the decision authority and legislative driver(s) to support adaptive management.

- *Organizational structure*: A structure to make and implement decisions, involve others, and respond to unexpected events or the availability of new information over time. An organizational structure needs to include at least five components to effectively support complex adaptive management programs: (1) scientists, (2) implementation staff, (3) leadership and managers, (4) independent science reviewers and (5) stakeholders.

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[6] It should be emphasized that similar needs were identified in the Delta ISB's review of the IEP's ability to provide science and support adaptive management. In that report, recommendations 6-8 dealt with the above issues.

- *Problem definition and practice of adaptive management*: Agreement and focus on the correct problem to address in a way that is durable and captures the larger context. A rigorous science process that adopts a mindset focused on learning about uncertainties affecting decisions should also help to address the problem.
- *Communication*: Clear, accurate, multi-way communication to engage audiences within and outside the organizational structure governing adaptive management.
- *Funding*: Sufficient financial resources to implement monitoring and adaptive management, which can be an indicator of the presence or lack of leadership support.

Although no case study was without its challenges and no case study except for Coastal Louisiana met all five attributes, they provided useful insight for the Delta monitoring enterprise. A detailed summary of key insights from each case study is found in Nelitz et al. 2019. In addition, lessons can also be learned from other programs that we did not review, such as the Rhode Island Environmental Monitoring Collaborative, Everglades, and the Platte River Project. In addition, there is value with looking at other programs within California, including the San Francisco Bay Regional Monitoring Program, the San Francisco Estuary Project, the Southern California Coastal Water Research Project, and Southern California Wetland Regional Monitoring Program.

Among the features of the case studies from other systems that is particularly critical for the Delta monitoring enterprise is enhanced communication. Several interviewees noted the importance of more sustained communication between scientists, managers, and policy makers to support adaptive management. This may require expanding or creating new venues for stakeholders in the monitoring enterprise to interact regularly across different scales of decision-making and across issue or topical areas. Such regularized and structured communication is necessary for building shared understanding and overcoming organizational and regulatory path dependencies, differences in organizational cultures, and perceived risks to modifying monitoring systems, which several of our interviewees highlighted.

Next Steps

As no single agency could implement all the recommendations alone, the decision on how to proceed with recommendations lie with the enterprise as a whole, where work is coordinated through collaborative venues like the Delta Plan Interagency Implementation Committee, the IEP, or the Collaborative Science and Adaptive Management Program. However, we provide a few suggestions on how to move forward. As this review helps address Action 3.3 in the 2019 Delta Science Plan ("Routinely evaluate monitoring programs in the Delta to identify gaps, redundancies, and management relevance"), we suggest that the Delta Stewardship Council - Delta Science Program form the workgroup, described in Delta Science Plan Action 3.4 (DSC-DSP 2019), that will facilitate monitoring program coordination and integration to discuss the findings and recommendations of this review, and whether to move forward with any of the recommendations.

This workgroup could also be the basis to implement recommendations from other venues that have expressed interest in making improvements to monitoring based off the findings and recommendations from this review, including the Delta Science Funding and Governance Initiative (see DSC 2019) and The Water Resilience Portfolio (see CNRA et al. 2020). Over the course of this review, we have also learned of many other activities to review monitoring (e.g., 5-agency review of IEP fish surveys) and have received invitations to present findings and recommendations of this review from the Delta Regional Monitoring Program, the Collaborative Adaptive Management Team's Salmon Committee and the Collaborative Science and Adaptive Management Program. Although there is overlap of individuals or agencies in these venues, it will be useful to discuss the findings and recommendations of this review "collectively" along with other efforts to improve monitoring to avoid creating "silos" of discussion.

As part of implementation, the workgroup should consider the geographic context for implementing the recommendations. Although this review is focused on the Delta, it may be useful to consider the entire Bay-Delta or Central Valley Watershed, depending on who will lead the effort. According to the monitoring activity inventory compiled for Component 1 of this review, most monitoring activities of relevance to the Delta occurs at the state scale (31%), followed by the Delta regional (29%), local (19%), and national scales (18%).

One of the potential barriers to implementing the three recommendations is the perceived risks associated with change, including (1) good programs currently in place will be scrapped, or that there will be a loss of quality/consistency, (2) fear of losing authority/influence, and (3) increased cost. One of the potential ways to overcome this barrier is openly discussing the risks of change, as an enterprise, which could help overcome this barrier. By examining the likelihood that various risks will actualize, and exploring opportunities to address or minimize risk, it may be possible to reduce generalized aversion to change and increase willingness to try new approaches. The workgroup suggested above could be a venue for these discussions.

The Delta Science Plan (DSC-DSP 2019) lists who should lead the effort to implement Action 3.4. It describes this effort being led by the IEP, the California Water Quality Monitoring Council and its workgroups, and the Delta Regional Monitoring Program. In our interviews, we sought feedback on who should lead efforts to re-organize and improve the coordination of monitoring. Interestingly, these organizations were not brought up during the interviews when we asked interviewees who should lead efforts to improve the coordination and organization of monitoring. Potential leaders that were mentioned include:

- Delta Stewardship Council- Delta Science Program in collaboration with United States Environmental Protection Agency if covering the Bay, as well as the Delta
- Delta Independent Science Board
- California Natural Resources Agency
- California Department of Water Resources
- California Department of Fish and Wildlife
- Waters users and contractors

However, collaborative leadership was mentioned by several interviewees. One individual described collaboration among regulatory and regulated agencies and other community members, while another individual described a state/federal partnership. As an initial start, the Delta Science Program could help facilitate the formation of the workgroup and discuss leadership with workgroup participants. Regardless of who leads the workgroup or how the workgroup is formed, there needs to be opportunities for public participation and stakeholder engagement, which could help address some of the concerns that we heard over the course of the review of some organizations not "having a seat at the table" and is a best practice identified in this review.

6. Conclusion

Although there was strong support for these recommendations from those who completed the questionnaire and those we interviewed, this was not the first time the Delta ISB has made a recommendation on re-organizing or improving the integration of science and monitoring to address certain management needs. The Delta ISB made calls to IEP to re-consider its organization to ensure it continues to meet the needs of its partners and stakeholders (see Delta ISB 2019a), and the science enterprise as a whole to prepare for rapid environmental changes that will occur (see Delta ISB 2019b). Although these recommendations have been considered for implementation, changes have not been made; although a proposal is being developed on re-organizing the science enterprise, as part of the Science Needs Assessment. We understand that the major recommendations in this report are not easy to implement and require substantial collaboration and resources.

The Delta is a complex, coupled social-ecological system that involves many interconnected components within which it is difficult to clearly understand cause-effect linkages. Applying adaptive management to large, complex ecosystems is hard, and many scientific uncertainties remain despite the large investment to science and monitoring in the region. These difficulties are not surprising given the geographic extent over which the Delta is influenced, from the upstream headwaters of the Sacramento and San Joaquin basins to the downstream coastal communities that rely on the Delta's water supplies. Such difficulties are shared by other large systems, such as the Great Lakes and are illustrated by the following quote from a recent review of information coordination and flow in the Great Lakes basin:

"Results from the analyses conducted on the program inventory and at the workshop showed that we [scientists] dedicate most time and resources to the collection, management, and analysis of data and much less attention to delivery of information to decision makers. In fact, we were unable to find a single example of a regional or basinwide decision maker who had access to the necessary information for assessing programs and progress to accomplish GLWQA objectives and making well-informed allocation decisions" (Great Lakes Science Advisory Board 2018).

As part of this review, we developed an inventory of monitoring activities, which will be a useful tool for implementing the three recommendations by providing information on what is being done in the Delta and helping with integration and coordination of monitoring. The data and information from the inventory will be incorporated and made public with the launch of the Delta Science Tracker in 2022, which will provide a comprehensive tool to track, visualize, and summarize science activities in the Delta region. Metadata within the inventory (and consequently the Delta Science Tracker) can quickly become out of date, so we encourage the community to maintain the tool and explore how the Delta Science Tracker could be fully utilized. We see great potential of how this tool can provide opportunities to increase collaboration, communication, coordination, and integration of both science and monitoring activities to help inform management decisions in the region, especially in light of rapid environmental change.

Appendix A. Brown Bag Seminars and Panel Discussions Summaries

December 2018

From November 2017 to July 2018, the Delta Independent Science Board (Delta ISB) hosted three brown bag seminars and five panel discussions to help understand the state of monitoring in the Delta, as seen from a wide range of perspectives to help inform its review on the monitoring enterprise. Information obtained from these seminars both helped inform Component 1 of the review, which was the development of the monitoring inventory, and Component 2, which was the development of Delta ISB recommendations. These brown bag seminars and panel discussions helped introduce the following programs/activities that either collect or coordinate monitoring data in the Sacramento-San Joaquin Delta to the Delta ISB.

- **California Water Quality Monitoring Council** was created to coordinate water quality monitoring efforts across the state and has 13 workgroups, networks, and web portals to integrate and coordinate water quality and related ecosystem monitoring, assessment, and reporting. These workgroups cover topics including bioaccumulation, harmful algal blooms, environmental flows, estuary monitoring, wetland monitoring, molecular methods, trash monitoring, water quality monitoring, data innovation and utilization, and safe drinking water.
- **California-Nevada River Forecast Center (CNRFC)**: The CNRFC aggregates flow data into a local database to provide two types of forecasts: deterministic river guidance and ensemble streamflow. They coordinate with federal, state, and local agencies to collect critical data and make these data available in an interactive site.
- **Interagency Ecological Program**: The Interagency Ecological Program (IEP) is a consortium of state and federal agencies that conduct broad ecological monitoring, research, modeling, and data syntheses to provide and integrate information for the management of the San Francisco Bay-Delta ecosystem. The IEP performs both long-term and focused monitoring of a wide variety of organisms and habitats, including fish, invertebrates, and vegetation, as well as water quality. Some of the key programs conducted by IEP include:

  - ***The San Francisco Bay Study***, focused on monitoring listed species under the Endangered Species Act and detecting new invasive species;
  - ***The Fall Midwater Trawl (FMWT)***, focused on monitoring the abundance and distribution of striped bass and is used to determine the incidental take limit at the pumping facilities for Delta smelt; and
  - ***Enhanced Delta Smelt Monitoring (EDSM*)**,** which increases the frequency of the sampling collection to support life-cycle model data needs and acts to supplement long-term IEP monitoring programs.
- **Fish Restoration Program:** The Fish Restoration Program (FRP) is a joint effort between the Department of Water Resources and the California Department of Fish and Wildlife that, in coordination with IEP, monitors how sensitive fish populations respond to tidal habitat restoration projects in Suisun Marsh and the Sacramento-San Joaquin Delta ecosystems. The main goals of the program are to restore 8,000 acres of intertidal habitat to enhance food web production and transport for native fishes and to increase the amount and quality of salmonid rearing habitat and increase salmonid survival in the Delta. The FRP monitoring team monitors fish and zooplankton abundances before, during, and after restoration projects and provides guidance to promote consistency in monitoring methods across the Delta.
- **Delta Regional Monitoring Program:** The Delta Regional Monitoring Program, initiated by the Central Valley Regional Water Quality Control Board, conducts, coordinates, and synthesizes water quality monitoring in the Delta focusing on mercury, nutrients, pesticides and toxicity, and pathogens. This program aims to provide baseline information of Delta water quality and provide data to assess potential linkages between water contaminants and ecosystem response to inform water usage decisions in the Delta.
- **Monitoring Avian Productivity and Survival (MAPS):** MAPS is an international monitoring program of the Institute for Bird Populations (IBP) that consists of over 1,200 stations in the United States and Canada and aims to provide demographic information of bird populations through banding, which is done by members of public agencies, non-governmental groups, and individuals. MAPS provides information to assist with avian management, such as tracking and estimating vital rates (productivity, survivorship, recruitment), key habitat locations, and population response to acute and large-scale habitat and climate changes.

- **Monitoring Neotropical Migrants in Winter (MoSi):** MoSi, the sister program of MAPS, also uses banding efforts by public agencies, non-governmental groups, and individuals across 22 countries to monitor and provide vital rates of birds, focusing on Neotropical migrant land birds that breed in the United States and Canada, to address similar management questions as MAPS.
- **National Water Quality Assessment (NAWQA):** NAWQA monitors the status and trends in water quality of important watersheds throughout the United States, including some sites in the Delta, to examine the effectiveness of the nation's environmental laws on water and to support science-based policies and management strategies to improve and protect water resources used for drinking water, recreation, irrigation, energy development, and ecosystem needs. NAWQA has long term monitoring programs of surface water and groundwater.
- **San Francisco Bay National Estuarine Research Reserve (NERR):** The San Francisco Bay NERR is one of 29 National Estuarine Research Reserves established across the United States that monitor estuary ecosystems to track environmental change and address the needs of decision makers and support science-based management. NERR programs also prioritize education and outreach, stewardship, and training to promote communication and collaboration within and between agencies, stakeholders, and the broader community. The San Francisco Bay NERR has two sites in the San Francisco Bay-Delta Ecosystem: China Camp State Park in San Pablo Bay and Rush Ranch in Suisun Marsh, where they monitor aquatic and terrestrial plant and animal populations, including birds, mammals, fish, reptiles, and amphibians.
- **National Wetland Condition Assessment (NWCA):** The NWCA is a national monitoring program that is part of the larger National Aquatic Resources Surveys (NARS) program of the US Environmental Protection Agency (EPA). The NWCA surveys, conducted every five years, use standardized sampling practices of all wetlands, tidal and nontidal, in the conterminous United States to characterize biological, chemical, and physical features of each site, including vegetation, soil, hydrology, water chemistry, algae, and buffer characteristics. These data are used to answer basic questions about the extent to which the nation's wetlands support healthy ecological conditions and the prevalence of key stressors at the national and regional scale.

This appendix describes how the information obtained from the seminar was used to inform the Delta ISB's review. An overview of the panelists/speakers, topics, and questions are summarized below.

Topic (with video recording)	Date	Seminar Speaker/Panelists	Seminar/Panelist Questions
Tidal wetland restoration monitoring	11/17/17 Part 1	***Seminar Speaker:*** Stacy Sherman (California Department of Fish and Wildlife) Seminar Presentation: Fish Restoration Program: Monitoring the Effectiveness of Tidal Wetland Restoration for the Benefit of Native Fish Species ***Panelists:*** • Rosemary Hartman (California Department of Fish and Wildlife) • Erik Loboschefsky (California Department of Water Resources) • Ramona Swenson (ESA Associates) • Heather Swinney (United States Fish and Wildlife Service)	• What are some of the key issues with monitoring in the Delta? • How can the Delta ISB's review help inform your work? • Are current monitoring programs meeting informational needs of management agencies? • Can individual and larger-scale monitoring programs be better coordinated? • Does monitoring data support implementation of adaptive management and assessments of performance measures? • Can you identify gaps in monitoring? • In your opinion, is an appropriate level of scientific rigor being used in current programs to meet the needs of management and policy decisions? • Can you recommend how/if the monitoring enterprise can be improved, consolidated, coordinated, and streamlined?

Topic (with video recording)	Date	Seminar Speaker/Panelists	Seminar/Panelist Questions
Water Quality Monitoring and the California Water Quality Monitoring Council	1/5/18 Part 3	***Seminar Speaker:*** Karen Larsen (State Water Resources Control Board) Seminar Presentation: California Water Quality Monitoring Council – Increasing Efficiency and Effectiveness Through Collaboration ***Panelists:*** • Greg Gearheart (State Water Resources Control Board) • Kris Jones (California Department of Water Resources) • Lori Webber (State Water Resources Control Board) • Adam Laputz (Central Valley Regional Water Quality Control Board) • Laura Valoppi (State and Federal Water Contractors Agency) • Val Connor (Retired)	Same as above
"Invasive" weed monitoring	5/3/18 Part 4	***Seminar Speaker:*** None ***Panelists:*** • Gina Darin (California Department of Water Resources)	Same as above

Topic (with video recording)	Date	Seminar Speaker/Panelists	Seminar/Panelist Questions
		• Eddie Hard (California Department of Parks and Recreation) • Shruti Khanna (California Department of Fish and Wildlife) • Susan Ustin (University of California, Davis) • Jeff Wingfield (Port of Stockton)	
Monitoring conducted by the Interagency Ecological Program (IEP)	1/4/18 Part 2	***Seminar Speaker:*** Steve Culberson (Interagency Ecological Program) Seminar Presentation: IEP Management Science: Theory, Practice, Future ***Panelists:*** • Kaylee Allen (United State Fish and Wildlife Service) • Larry Brown (United States Geological Survey) • Gregg Erickson (California Department of Fish and Wildlife) • Wim Kimmerer (San Francisco State University) • Ted Sommer (California Department of Fish and Wildlife)	• How effective is coordination among IEP agencies and between IEP and other agencies/programs with producing and using science? • How effective is the IEP science-governance structure in providing credible and relevant scientific information in support of managing the water-export facilities in a way that can minimize harm to key ecosystem components, while also providing a reliable water supply? • How effective are the current institutional arrangements that support the interagency investment in IEP for producing and using science? Are these current institutional arrangements applicable in the future? • Does IEP have the ability to use ecosystem forecasting mechanisms to anticipate

Topic (with video recording)	Date	Seminar Speaker/Panelists	Seminar/Panelist Questions
			environmental changes? What is IEP's ability to communicate this information to other agencies? • What is the role of IEP as a synthesizer of information about the Delta and its environment and as the nexus for the creation of "science narratives" about the needs of the Delta that go beyond what is in technical reports? • How well are the various components of IEP working to produce and use science? Are there organizational suggestions that could improve IEP efficiencies

Regional and national monitoring that includes the Bay-Delta	7/12/18 Part 5	***Panelists:***
		• Steve Albert (Institute for Bird Populations)
		• Joseph Domagalski (United States Geological Survey)
		• Matt Ferner (San Francisco State University)
		• Robert Hartman (National Weather Service, Retired)
		• Mary Kentula (United States Environmental Protection Agency)
			• Please briefly describe the monitoring program:
			    ○ What are the purposes and goals of your program?
			    ○ What is the geographic scale?
			    ○ What is the temporal scale?
			• What are some of the products of the monitoring data (decisions, publications, syntheses)?
			• Who are the major users of your data?
			• How are the data from your program being used in the Delta region (if applicable)?

Topic (with video recording)	Date	Seminar Speaker/Panelists	Seminar/Panelist Questions
			• How does your program coordinate its monitoring, both internally within the program, and externally with other entities? Is this effective?

Component 1 Findings

These brown bag seminars and panel discussions helped identify key resources that were used to help inform the development of the monitoring inventory.

- IEP Tidal Wetland Restoration Monitoring Framework: This document assessed system-wide tidal wetland sampling efforts to identify potential needs and opportunities for improvement and developed a framework founded on hypothesis-based monitoring to assess the effectiveness of tidal wetland restoration projects in the Delta and Suisun Marsh. The document provides suggestions for cost-effective monitoring strategies and recommendations for data management, analysis, quality assurance, and reporting protocols. This report documents much of the existing monitoring in the Delta that could inform monitoring of the effectiveness of tidal wetland restoration monitoring, and recommends methods, considerations, and constraints for many monitoring topics also discussed in the Monitoring Enterprise Review.
- IEP Framework for Aquatic Vegetation Monitoring in the Delta: This document described potential frameworks for monitoring the aquatic vegetation community and distribution in the Delta and Suisun Marsh to inform resource management needs. They defined three objectives of monitoring programs focused on aquatic vegetation and presented three possible scenarios (“best case scenario”, the “moderate-funding scenario”, and the “bare bones scenario”) and how they could best address these three objectives. The report also evaluated various kinds of remote sensing tools available to monitor in the Delta and Suisun Marsh,

summarized existing data and data presently being collected over parts of the Delta-Suisun region, and examined aquatic vegetation monitoring methods in other regions similar to the Delta.

- Independent Review of the Delta Regional Monitoring Program (RMP): This review identified features of an effective monitoring program, provided an assessment of the ability for the Monitoring Design of the Regional Monitoring Program to address management needs and answer assessment questions, and provided recommendations of scientific criteria for distributing limited resources towards monitoring. The review provides general recommendations for statistical analyses involved in sampling design and consideration of tidal and other temporal factors when determining sample schedules, while also providing specific suggestions for each of the detailed monitoring designs addressing the four priority constituents (pesticides and toxicity, mercury, pathogens, and nutrients). Many of the recommendations and topic areas also apply to the Delta Monitoring Enterprise.
- Past External Reviews of IEP: The IEP Science Advisory Group (SAG) is a standing panel of independent external experts that was established in the 1990s. IEP regularly calls on the SAG to review IEP elements and provide advice on scientific issues. IEP programs undergo review, and these reports were used for ESSA's literature review (Nelitz et al. 2019).

Component 2 Findings

The seminar speakers and panelists provided a wealth of information about current monitoring programs, including challenges and needs. Perspectives from the seminar presenters and panelists led to some key insights surrounding the broad review questions for the monitoring enterprise review, which were further investigated once the inventory was developed. These findings, organized below by question and management topic, were used to develop initial best practices for improving the monitoring enterprise in the Delta and helped with the development of the recommendations. Specific initial best practices and recommendations are listed under the questions that informed their development.

Question 1. Are there potential gaps and redundancies in serving the relevant needs of decision makers?
Answers to this question were used to develop initial best practices 4 and 5.

Tidal wetlands

During the seminar and panel on tidal wetland restoration monitoring, we learned the following:

1. Most of the effectiveness monitoring that occurs under the Fish Restoration Program at restored tidal wetlands focuses on food resources for listed fish species, as restoration was undertaken to address requirements from biological opinions or the incidental take permit on the long-term operations of the Central Valley Project and State Water Project. There is not a dedicated source of funding to monitor non-listed fish species, including mammals, birds, and microbes, which could be a potential gap.
2. Although the Fish Restoration Program is evaluating the effectiveness of restored sites for listed fish under the Endangered Species Act, perhaps the biggest issue for monitoring is listed species take (especially for Delta smelt). Due to concerns with sampling an endangered species, it is difficult to receive take for Delta smelt for monitoring. If you cannot sample your targeted species, you hamper the ability to learn.
    a. ***See Initial Best Practices 4 and 5***
3. There is an emphasis on surface open-water habitat monitoring, but semi-shallow water habitats as well as deep open-water habitats are underrepresented.

Water quality

During the seminar and panel discussion on water quality monitoring, we learned the following:

1. The Delta RMP review recommended that tidal phase and variation in flow need to be taken into account in sampling plans. If the tidal phase/flow is not taken into consideration, then one might be concluding the source is upstream when in reality it is downstream, or vice versa, depending on whether the sample was taken on a flood, ebb, or slack tide. This is especially important in water-quality monitoring, but the principle is applicable to chemical, physical, or biological components being sampled in the water column of a tidal system.

2. For pesticide monitoring, the review panel emphasized using aquatic and sediment toxicity testing more widely to identify where and when toxicity is occurring in the Delta, then use further testing and chemical analysis (especially broad or non-target chemical analysis) to further identify sources of the toxicity.
3. The Delta RMP review also identified the need for thresholds, trigger points, and estimates of reliability.
4. One easy gap to identify is contaminants of emerging concern, which the Delta RMP is working to address.

<u>Invasive Weeds</u>

1. There are both gaps in monitoring, but also overlap. Monitoring needs to occur at the correct timing and the correct quality. The IEP Aquatic Vegetation Project Work Team is trying to bring together a dataset of existing monitoring of the Delta that has been conducted over the past several decades, what has been done with it, and what key findings those studies provided.
2. The California Department of Food and Agriculture once had the Noxious Weed Eradication Program, which had dedicated biologists surveying the whole state at regular intervals and taking care of high priority invasive and noxious weeds, and the Weed Management Area Program, which were local stakeholder collaborations focused on control on invasive plants. Each weed management area had their top 10 weeds that they're monitoring for and are on the lookout for. Both programs were cut due to funding issues despite being defined in State code.

Question 2. What is the level of coordination of data collection across different organizations?
Answers to this question were used to develop initial recommendation 1 and 2 and initial best practices 3 and 7.

<u>General issues</u>

1. There is a need for improved communication between scientists and managers (i.e., coordinating the coordination).
    a. ***See Initial Best Practice 3***
2. There is a lot of coordination, but it isn't complete. In many cases, collaboration is the means for any level of success. Some programs don't collect any data but are dependent on observations from thousands of sites.

Relationships with other agencies that you're dependent on for those data are critical. A structure and framework that helps people work together is needed, like the California Data Exchange Center that facilitates sharing of water quality data.

a. ***See Initial Recommendation 2***

<u>IEP</u>

1. Monitoring that falls under IEP appears to be very well coordinated through the Science Management Team, the work plan process, project work teams, the annual meeting, etc. Participants generally know what each other are doing and are helping each other out. IEP staff do not always do a good job at reporting back within their own agency. When a program is up and running, there is less need for oversight.
2. The number of potential forces that can blow everything apart in IEP in any given year is astounding. The fact that IEP has been able to get things going for over 40+ years speaks to IEP's ability. There are a lot of different parts in how IEP does coordination. IEP Coordinators and IEP Science Management Team Members are very active in going to different non-IEP management forums, such as the Collaborative Adaptive Management Team and the Collaborative Science and Adaptive Management Program. The coordination at times actually is excessive. With respect to funding and doing other projects, IEP works as much as possible with other funding entities to discuss shared priorities and coordinate shared needs. All of this comes with a price, since the number of issues that IEP is responsible for is staggering. It is way more complicated and at times not feasible to cover everything that people want IEP to do. A solution to coordination is resources. IEP has high turnover and is burning though staff pretty quickly since expectations are high, especially at the management level. There is a constant re-training within individual agencies.
3. However, programs not within IEP (e.g., Delta RMP) sometimes get forgotten and are not talking to one another. There are similar issues with special studies from university researchers. This is especially true of special studies where there's not a good understanding of what everyone's doing and why. This is especially unfortunate because all are working in a system with limited resources, including limited take of Delta smelt.

<u>California Water Quality Monitoring Council</u>

1. The CMQMC coordinates data management initiatives. There is a strong need for agency scientists to have guidance and support on how to effectively manage their data in a coordinated way. This recently came up in the review of the sustainability of water and environmental management in the Bay-Delta by the National Research Council. In their review, they noted how silos of data have resulted in separate and compartmentalized science that has impeded the ability to make informed management decisions *(Kris Jones, Water Quality Monitoring and the California Water Quality Monitoring Council)*.
    a. ***See Initial Best Practice 7***

<u>Water quality</u>

1. Better integration of water quality with the other monitoring types is needed, as is a unified discussion and communication on coordination and collaboration *(Val Connor, Water Quality Monitoring and the California Water Quality Monitoring Council)*.
    a. ***See Initial Recommendation 1***
2. There could be better integration across programs, such that water quality and toxicity testing is an integrated part of monitoring that is being conducted for biological components. The current Directed Outflow Program integrates toxicity testing and chemical analysis into a fish and food-web monitoring program to evaluate outflow augmentation. Such an integrated approach of evaluating fish presence, food-web components, and toxicity testing is an important addition to the traditional approach of monitoring just fish and food-webs *(Laura Valoppi, Water Quality Monitoring and the California Water Quality Monitoring Council)*.
    a. ***See Initial Recommendation 1***

Question 3. Are there other opportunities to increase efficiencies in monitoring?
Answers to this question were used to develop initial recommendation 1 and initial best practices 1, 5, 6, and 7.

<u>General issues</u>

1. As discussed during the water quality seminar and panel, barriers to improve monitoring really are institutional/organizational and human nature. They have a lot to do with training. The SWRCB has an incredible training academy that was developed by Office of Information Management Analysis (OIMA). Training helps with infrastructure and deals with the “people” part of monitoring. It’s the social part that needs to be addressed, and this requires expertise in organizational behavior and management and people skills. In terms of that expertise in organizational behavior and management, biological scientists don’t have a lot of expertise in that.
    a. ***See Initial Recommendation 1***
2. Most agency scientists are not data-management professionals, although they may try to do due diligence to effectively manage their data, as we learned during the water quality seminar and panel. There are inherent challenges with bringing data together from siloed programs, such as different QA/QC procedures, data standards, and protocols. These are challenges that a lot of agency scientists don't really have the training to deal with.
    a. ***See Initial Best Practice 7***
3. There really is a need for support and guidance to help scientists on how to effectively manage data. Data management is often an afterthought. Data management should be discussed at the onset of projects, and agency scientists should have the support and guidance that they need to be able to effectively manage data in a coordinated way *(Kris Jones, Water Quality Monitoring and the California Water Quality Monitoring Council)*.
    a. ***See Initial Best Practice 7***
4. As discussed during panel discussion on tidal wetland restoration monitoring, there are times when there are opportunities to sample due to the hydrological conditions, but you cannot go out and sample because it is not in your study plan and you do not have the necessary incidental-take permits
    a. ***See Initial Best Practice 5***

5. There is a need for flexible work plans to address issues of take for targeted species*, as discussed during our brown bag seminar and panel discussion on tidal wetland restoration monitoring.*
    a. ***See Initial Best Practice 5***
6. Remote sensing could be more widely used, acknowledging its strengths and limitations*, as discussed during our panel on invasive weed monitoring.*
    a. ***See Initial Best Practice 6***
7. As discussed during our panel on invasive weed monitoring and regional programs, having more systematic monitoring is important. Often a monitoring program is structured with reference to particular needs, questions, and hypotheses and is tuned to those kinds of purposes. This is an advantage because it's a tailor fit, but there are also disadvantage because then the data are constrained by the questions that are being asked. This becomes particularly important in two respects: one is how can you tailor a data-collection system and the data themselves to address future questions that haven't even been thought of? New questions related to climate change and to a variety of other changing conditions may be outside the framework of what has been previously experienced. Agencies want to be able to use long-term datasets to address some of the potential consequences of these changes, but the long-term datasets may have been designed with reference to different kinds of questions, so part of the question is how do you make that transition? Is the data collection, the very basis of the monitoring program, something that constrains future options in terms of dealing with it and using it? That relates also to the parallel question of, if you start these things using state of the art methodology at that time that's no longer state of the art at a later time, that's forgotten art. New methods of data collection come along: how do you design a monitoring program that can absorb the new methodologies without creating incompatibilities in the dataset, or do you stick with the old methods even though you can no longer get the results published because they're no longer state of the art methodologies?
8. As discussed during the panel with national and regional monitoring programs, the NERRs have debated about the intention of a monitoring program and whether or not you have a hypothesis you're testing, or a specific question you're trying to address with your monitoring program, which is often the case. The NERRs

have had a lot of internal debate about this because that program was not set up that way, other than the general question of trying to understand short-term variability and long-term trends in environmental drivers, which was the primary motivation for setting up the monitoring programs. Whether you have a research question-driven monitoring program or a more general "let's monitor things to see how they change" kind of program, you can extract general and specific information from each of those, which may need to be supplemented or augmented over time as new factors come into play. For example, a lot of bench chemistry that was done in the lab or the sensors used were the earliest versions of automated data loggers. As new sensors have come out, maintaining the same parameter types and same basic frequencies of monitoring should be the aim. Coming to a consensus about upgrading and pulling everyone up to the next level is important, but the old methods and data collected should still be compatible. That is at least the intention.

   a. ***See Initial Best Practice 1***

9. In the case of the NARS Assessments, techniques become obsolete and new questions arise, as discussed during the panel with national and regional monitoring programs. Core indicators stand the test of time and are the ones used to assess the basic condition of aquatic resources. At the same time, we always have a number of indicators that are being tested to anticipate the future or that might be a better way to do something that is core.
   a. ***See Initial Best Practice 5***

Question 4. Is the data quality of monitoring appropriate to address purposes and needs for information?
Most of the answers to this question came from the seminar and panel discussion on tidal wetland restoration monitoring, and were used to develop initial best practices 1 and 7.

1. Some of the key issues with monitoring in tidal marshes and for restoration are data-management challenges, limited resources, and just the scale over which we need to monitor . Moreover, tidal-marsh monitoring is not often done at a level for doing really rigorous hypothesis testing, which is where we'd really like to be to test the designs of these projects.

   a. ***See Initial Best Practices 1 and 7***

2. Sooner or later scientists will question the adequacy and statistical reliability of the monitoring data on which decisions are being made. Monitoring in general and in the Delta in particular needs to pay attention to the statistical criticisms that can be raised against it. One of the problems of monitoring in an aquatic system arises from the linear array of boat-based sampling. The samples are not randomized and there's a potential for spatial autocorrelation among those samples. You can test for spatial autocorrelation to determine the degree to which the samples are in fact independent of one another or the degree to which they are compromised by autocorrelation.
3. However, it's difficult to begin with a robust statistical design and expect to follow it, so often one must start with the realities of the field situation and one's objectives and then adjust the sampling accordingly. Furthermore, agency staff may not have the time to actually analyze their data or the resources to learn how to analyze their data properly. However, some agencies reportedly have some new programs to help increase scientific training, including statistical training.
   a. ***See Initial Best Practice 7***
4. The usual approach in the Delta of collecting data, then figuring out what statistical and data analysis will be performed on the data after the fact, is inefficient and should be greatly improved by applying key monitoring principles and designing monitoring using a quantitative approach.
   a. ***See Initial Best Practice 1***

Question 5. Are data accessible to the public, decision makers, other scientists and all stakeholders?

As discussed during the panel on tidal wetland restoration monitoring, there is a lot of monitoring that goes on, but academic researchers, monitoring groups and other stakeholders have a lack of understanding on how to access other program's data, a lack of data standards, and a lack of knowledge of how data should be stored and managed. The IEP's Data Utilization Work Group is working toward improving this and there is a movement to comply with Assembly Bill 1755, which requires water-related data to be made publicly available. Data accessibility is improving quickly but could still be better. This finding was used to inform ***Initial Best Practice 7***.

Question 6. What resources are being dedicated to monitoring?
This question was not asked directly of the panelists. During the seminar and panel on tidal wetland restoration monitoring, a panelist indicated that the size of laboratory staff across agencies is too low. There are plans to have a field station at Rio Vista that will co-locate some of the major agency monitoring groups, which will be a valuable addition.

Initial Best Practices and Recommendations

Based on insights that emerged from the brown bag panel and seminars, initial best practices and recommendations were developed early on to help address how current and future monitoring programs meet informational management needs of agencies, can be better coordinated, and can help with the implementation of adaptive management and performance measures. Additional analysis through the inventory tool, questionnaire results, and interview results helped with finalizing the best practices for the review, which are found in the main report.

Initial Recommendations

Recommendation 1. An overall organizational framework needs to be considered for the overall MER.

An overall monitoring framework is lacking for the Delta, but it is being considered in some quarters. For example, the SWRCB uses the monitoring framework proposed by the EPA. In any event, there is a need to define questions better, need for a technically defensible design, development of core indicators, and continuation of quality assurance, data management assessment, external peer review, and infrastructure planning (see Delta RMP report for details).

Recommendation 2. Many of the monitoring programs in the Bay and Delta have similar goals and are affected by similar stressors. Rather than having separate programs, they should be combined when appropriate. Tidal wetlands offer the best opportunity for this change in monitoring.

Both the Bay and Delta are being affected by climate change at increasing rates. Both have well developed scientific capabilities for monitoring, and the regions have similar structures for program governance and administration. These programs should be linked. The Wetlands Regional Monitoring Program being developed for the San Francisco Bay can readily be adapted to the Delta.

Recommendation 3. National monitoring programs should include sites in the Delta and coordination with Delta programs. The Delta Science Program, with the assistance and cooperation of the IEP, should serve as clearinghouse to coordinate with national monitoring programs.

Initial Best Practices

Initial Best Practice 1. *Monitoring should be closely tied to the goals, objectives, and specific questions of interest to managers and decision makers.*

Several participants from the panel discussion on tidal wetland restoration monitoring seminar and interviews identified a disconnect between management needs and monitoring as a barrier to improving coordination and addressing monitoring gaps. Participants noted the common practice of using monitoring to address management needs that it was not explicitly designed to address, which can result in ineffective management.

Initial Best Practice 2. *Stakeholders need to be more involved when monitoring programs in the Delta are started, stopped, or changed.*

Stakeholders are a key component to the MER but are often neglected. It is important to involve stakeholders early on to discuss how to integrate new and changing programs. These relationships and discussions are key for launching subsequent phases of monitoring programs. Some organizations have consistent stakeholder involvement, such as the California Water Quality Monitoring Council; however, more outreach to stakeholders, such as non-governmental organizations environmental justice advocates is needed.

Initial Best Practice 3. Management needs and questions must be made clear to staff designing and conducting monitoring. However, the conversations must be two-way, with the monitoring staff also understanding the important questions that confront management. A need for “coordinating the coordination” through improved communication between scientists and managers was discussed as a way to improve the efficacy of the monitoring enterprise during our brown bag seminar and panel discussion on the Fish Restoration Program.

Initial Best Practice 4. New ways need to be established for setting Delta smelt take. Agencies should consider ways of monitoring Delta smelt that minimize take (e.g., eDNA, cameras). Incidental take from pulling a net through water for collecting zooplankton for food-web monitoring is inevitable; permitting incidental take in these situations should continue.

There is the potential through adaptive management to add in the fish monitoring component if the Delta smelt population improves over time using adult equivalents, which may be less impactful to the population. Minimizing the time of year that collecting and monitoring are done to avoid the season when Delta smelt are primarily present in larger numbers may help by implementing minimization measures when the monitoring is being done to help reduce the take. eDNA has been used successfully in many stream systems to find cryptic species. eDNA is in the realm of special studies, but not currently long-term monitoring. We believe that this approach will be a useful to detect rare species. It could also be very useful in detecting new invasive species before they are present in high enough abundances to generally capture them. Plus, the eDNA filters can be archived.

Initial Best Practice 5. Monitoring in the Delta is not flexible enough to be proactive as new issues arise. This needs to be corrected through actions such as routine assessment of permitting requirements to look for opportunities to streamline or eliminate them.

A very large share of IEP monitoring is compliance monitoring or the result of a regulatory mandate, which is often perceived as not being very flexible. Flexibility currently may lie somewhere between the "shalls" and the "shoulds." However, monitoring requirements in a biological opinion or a water rights decision are often not very explicit and some adjustments to the "should" can be made. These adjustments require more coordination and often lie outside the IEP jurisdiction. Because the agencies that require the monitoring must agree to changes, this can make things challenging.

Initial Best Practice 6. *The use of remote sensing in monitoring should be expanded.*

Satellite imagery is collected every few weeks and has many uses, but is subject to cloud-free atmosphere and is coarse in spatial resolution, for example, limiting the capability to detect cover of plant species on waterways. Hyperspectral imagery from piloted aircraft is expensive and not easily processed in a timely manner. It also is less expensive in flying costs and far quicker to process. This may include real-time imaging by remotely piloted small drones, in which case, the cost could come down to even more affordable levels. Boat-mount extension-arm digital mega-pixel RGB photos sent back in real-time may be the most practical, lowest-cost solution for monitoring and management of Delta aquatic vegetation.

Initial Best Practice 7. *More data analysis and synthesis are needed; "Big Data" techniques and approaches can help*.

When everyone thinks about monitoring, the focus is mostly on data collection, data-management issues, and synthesis and analysis. Studies have demonstrated that data management, syntheses, and analyses require more time than the field effort (Domagalski, 2019). One estimate is that 25-30% of the overall budget is spent on the quality assurance part alone.

Monitoring programs often generate huge quantities of data. Huge quantities of data are the subject of current Big Data approaches being developed in California institutes and universities. Big Data approaches are useful for discovering the “hidden needle in a haystack of data”. The difficulty, however, is in knowing what characterizes the “needle” that is valuable in the “haystack” of data collected. NERR’s perspective that is emerging is focused around an analysis package in R (swampr) that is set up to analyze data, look at different stations and years, and plot it in different ways to look for different relationships and patterns and allow people who are good at data manipulation to adjust and play with the scripts. This is especially valuable for any kind of high frequency monitoring especially one that generates volumes of data.

Initial Best Practice 8. Qualitative or anecdotal observations gathered along with quantitative monitoring data can be of critical importance and must be reported and archived in a fashion that can preserved, analyzed, and used.

Photographic records are often used by USGS and stored with field observations in a database. They are then used in training for citizen science and teaching programs for school children. There are various approaches to make this information accessible. For example, when it is directly related to data that are being archived, the information can be included as a metadata note in the associated file. This information should be accessible beyond the agency gathering the information.

While monitoring, personnel are often observing novel events and changes. Ways of tagging unique observations must be maintained. Probability sampling may result in more of these types of encounters because just a map is used and there is no judgment about whether a site is easy to sample or convenient. This approach forces monitoring crews to go into places they’ve never been before rather than traditionally taking the water sample where, for example, the road crosses the bridge. Reportedly, a group of academic researchers rethought their wetland classification they developed for an area because they were seeing types of wetlands they had never seen before with probability sampling.

Initial Best Practice 9. Community and citizen science should be more involved in Delta monitoring programs, both to offer opportunities for expanded monitoring activities as well as to increase public awareness of environmental issues.

The Delta Stewardship Council and the Delta Science Program have made public participation a priority in their various activities. NERR has tried many different citizen science initiatives around the NERRs, and there are a variety of perspectives and opinions about their success. Approaches to make sure the data are collected consistently, that people are recording what they are supposed to record, and not omitting records are questionable in some cases. However, an approach that has worked well is photo monitoring. Any time that there is an objective component of citizen monitoring, those types of approaches have been shown to be highly effective. Another approach that works to some extent is with educational units, such as high school science classes and clubs. Likewise, community and citizen monitoring has a role in emergency services with spotter networks that are able to observe when negative events are happening. For example, a levee break, water getting into someplace unexpected, a potential dam break, monitoring for the presence of invasive species such as nutria are all possible examples. There is clearly a role for people to observe events and to be able to get that information to the appropriate agencies. For example, the cooperative data collection program that NOAA supports is the backbone of their climate network, and these data are all collected for free by people with gauges in their backyards, and they have been doing that for over 100 years. It has to be acknowledged though that for some advantages that community and citizen monitoring provide, a fair amount of effort is needed to make the program rigorous enough so that the monitoring information can be interpreted and put it to good use.

Appendix B. Monitoring Inventory (Component 1)

The monitoring inventory, developed for this review provides a useful database structure for bringing together disparate information sources into a common platform, and an online portal for making this information accessible to others. The metadata attributes found in the inventory can be found in Table B-1 and the 157 monitoring activities in the inventory can be found Table B-2. A full overview of the inventory can be found in Netliz et al. 2020b.

The inventory is currently available upon request and the metadata collected will be launched through the Delta Science Tracker web portal, which is currently being developed by the Delta Stewardship Council-Delta Science Program that will cover both monitoring and research in the Delta.

Table B-1. Metadata attributes and descriptions in the monitoring inventory.

Metadata Category	Metadata Attributes
Overview	• Name • Monitoring program • Description • Purpose • Information sources • Name & role of organization (Implementing, Funding, Supporting) • Known challenges • Cost and year of start-up • Annual cost • Cost comment • Management themes / actions • Management drivers • Management comment
Data Quality	• Data QA/QC • Data management • Data reporting • Timeliness • Uncertainty • Machine readable

Metadata Category	Metadata Attributes
Sampling Activity	• Monitoring themes / parameters (Direct socio-economic drivers, Environmental drivers / conditions, Habitats, Species) • Monitoring metrics • Type of monitoring • Sampling years • Sampling frequency • Sampling timing • Sampling location(s) (California sub-basins, Delta regions, Delta islands, Delta channels) • Spatial scale • Spatial extent • Number of locations (Entire geographic extent, Within California, Within Delta) • Sampling comment • Sampling equipment • Monitoring design • Sampling protocol

Table B-2. Summary of management drivers and their alignment with management themes of relevance.

Note the use of the following abbreviations to denote management themes to which these drivers apply: WSM = Water Supply Management, FLD = Flood Management, WQL = Water Quality, HAB = Habitat Management, SPP = Native Species Management, ISM = Invasive / Non-Native Species Management, and LUM = Land Use Management. Y=Yes or N=No.

Name of management driver	Start Year	WSM	FLD	WQL	HAB	SPP	ISM	LUM
A Central Valley Project Improvement Act Implementation Plan for Fish Programs / Fish Restoration Plan	2015	Y	Y	N	Y	Y	N	N
California WaterFix	2016	Y	N	Y	Y	Y	N	N
California Code of Regulations: Title 23: Waters	1941	N	N	N	N	N	N	N
California EcoRestore	2015	N	Y	N	Y	N	N	N

Name of management driver	Start Year	WSM	FLD	WQL	HAB	SPP	ISM	LUM
California Environmental Quality Act (CEQA) Compliance - Mitigation Monitoring and Reporting Program (MMRP)	1969	N	N	N	N	N	N	N
California Guidelines for Cyanobacteria in Recreational Inland Waters	2008	N	N	Y	N	N	N	N
California Hatchery Review Project	2012	N	N	N	N	Y	N	N
California State Endangered Species Act (SESA or CESA) - Incidental Take Permit (ITP) - 2081(b)	1997	N	N	N	N	N	N	N
California State Lands Commission (CLSC) - Article 5: Marine Terminals Inspection and Monitoring	1938	N	N	N	N	N	N	N
Central Valley Flood Protection Plan (CVFPP)	2012	Y	Y	N	N	N	N	N
Central Valley Flood Protection Plan (CVFPP) - Conservation Strategy	2016	N	Y	N	Y	N	N	N
Central Valley Joint Venture (CVJV) Implementation Plan	1990	Y	N	N	Y	N	N	Y
CDFW SWP Incidental Take Permit	2009	N	N	N	N	N	N	N
CEQA: AB 52, Consultation with Native American Tribes	2015	N	N	N	N	N	N	N
Clean Water Act: Sections 401, 402, 404(b)(1)	1970	N	N	N	N	N	N	N
Cosumnes Preserve's North Delta Program	2018	N	Y	N	Y	N	Y	N
Delta Conservation Framework 2018-2050	2018	N	Y	Y	Y	Y	Y	Y
Delta Levees Maintenance Subventions Program	1973	Y	Y	N	Y	N	N	N
Delta Levees Special Flood Control Projects	1988	Y	Y	N	Y	N	N	N
Delta Levees Investment Strategy	2013	Y	Y	N	Y	N	N	N
Delta Plan / Delta Reform Act of 2009	2013	Y	Y	Y	Y	Y	Y	Y
Delta Smelt Resiliency Strategy	2016	N	N	Y	Y	Y	Y	N
Dutch Slough Tidal Restoration Project	2016	N	N	N	Y	N	N	N
East Contra Costa County Habitat Conservation Plan and Natural Community Conservation Plan	2007	N	N	N	Y	Y	N	Y

Name of management driver	Start Year	WSM	FLD	WQL	HAB	SPP	ISM	LUM
Endangered Species Act: Section 4 "Post-Delisting Monitoring"	1973	N	N	N	N	N	N	N
Endangered Species Act: Section 7 "Interagency Consultation"	1973	N	N	N	N	N	N	N
Fish Restoration Program Agreement (FRPA)	2010	N	N	N	Y	N	N	N
National Historic Preservation Act (NHPA) - Section 106 (State Historic Preservation Officer)	1966	N	N	N	N	N	N	N
Porter Cologne Water Quality Control Act (California Water Code)	1969	N	N	N	N	N	N	N
Proposition 1 Restoration Grant Program	2014	Y	N	Y	Y	N	N	N
Recovery Plan for Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the Distinct Population Segment of California Central Valley Steelhead	2014	Y	N	N	Y	Y	N	N
Recovery Plan for the Central California Distinct Population Segment of the California Tiger Salamander (Ambystoma californiense)	2017	N	N	N	Y	Y	Y	N
Recovery Plan for the Giant Garter Snake	2017	N	N	N	Y	N	N	N
Recovery Plan for the Southern Distinct Population Segment of N. Am. Green Sturgeon	2018	Y	N	Y	Y	Y	N	N
Recovery Plan for Three Endangered Species Endemic to Antioch Dunes, California	1984	N	N	N	Y	N	Y	N
Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California	2013	N	N	N	Y	N	N	N
Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon	2005	N	N	N	Y	N	N	N
Sacramento San Joaquin Delta Diazinon and Chlorpyrifos TMDL	2007	N	N	Y	N	N	N	N
Sacramento Valley Salmon Resiliency Strategy	2017	N	Y	N	Y	Y	N	N

Name of management driver	Start Year	WSM	FLD	WQL	HAB	SPP	ISM	LUM
Sacramento-San Joaquin Delta Methylmercury TMDL	2010	N	N	Y	N	N	N	N
San Joaquin County Multi-Species Habitat Conservation and Open Space Plan	2000	N	N	N	Y	Y	N	Y
Solano Multispecies Habitat Conservation Plan	2012	N	N	N	Y	Y	N	Y
South Sacramento Habitat Conservation Plan	2018	N	N	N	Y	Y	N	Y
Suisun Marsh Habitat Management, Preservation, and Restoration Plan	2013	N	Y	Y	Y	Y	Y	Y
SWP-CVP NMFS Operations Biological Opinion (BiOp) / Re-initiation	2009	Y	Y	Y	Y	Y	Y	Y
SWP-CVP USFWS Operations Biological Opinion (BiOp) / Re-initiation	2008	Y	Y	Y	Y	Y	Y	Y
Water Right Decision 1641 / Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary- Update	2018	Y	N	Y	N	N	N	Y
Water Quality Control Plan Voluntary Agreements	No Data	Y	N	N	Y	N	N	N
The Water Infrastructure Improvements for the Nation (WIIN) Act	2016	Y	N	Y	N	N	N	N
Yolo Bypass Salmonid Habitat Restoration and Fish Passage Implementation Plan	2012	N	N	N	Y	Y	N	N
Yolo Habitat Conservation Plan / Natural Community Conservation Plan	2018	N	N	N	Y	Y	N	Y

Table B-3. Summary of monitoring activities in the inventory

If unknown start and end year, noted as “UNK” in table.

Activ ID	Monitoring Activity Name	Implementing Organization(s)	Start Year	Latest Year
7	Statewide Crop Mapping	California Department of Water Resources (DWR), Land IQ	2014	2019
8	National Wetlands Inventory	US Geological Survey (USGS), US Fish and Wildlife Service (USFWS)	1975	2019

Activ ID	Monitoring Activity Name	Implementing Organization(s)	Start Year	Latest Year
10	Continuous Water Quality Monitoring Stations	California Department of Water Resources (DWR)	1968	2019
12	20-mm Survey (Delta Smelt distribution monitoring)	California Department of Fish and Wildlife (CDFW)	1995	2019
13	Benthic Organism Study	California Department of Water Resources (DWR), US Bureau of Reclamation (USBR)	1975	2019
14	Fall Midwater Trawl Survey (FMWT)	California Department of Fish and Wildlife (CDFW)	1967	2019
15	San Francisco Estuary Invasive Spartina Project	California State Coastal Conservancy	2000	2019
16	Bioaccumulation Monitoring Program	Moss Landing Marine Laboratories, California Department of Fish and Wildlife (CDFW), San Francisco Estuary Institute (SFEI)	2011	2019
17	Classification and Assessment with Landsat of Visible Ecological Groupings (CALVEG)	US Department of Agriculture (USDA) - Forest Service Region 5	1978	2018
19	Bioassessment Program	California Department of Fish and Wildlife (CDFW)	2000	2019
21	Juvenile Salmonid Monitoring - Red Bluff Diversion Dam	US Fish and Wildlife Service (USFWS)	1994	2019
22	Central Valley Chinook Adult Escapement Monitoring Project	Western Ecosystems Technology Inc., Pacific States Marine Fisheries Commission, California Department of Fish and Wildlife (CDFW)	2007	2018
23	San Francisco Bay Study	California Department of Fish and Wildlife (CDFW)	1980	2019
24	Soil Survey Geographic Database (SSURGO)	US National Park Service (NPS), US Department of Defense (DoD), US Bureau of Land Management (BLM), US Bureau of Indian Affairs (BIA), US Department of Agriculture (USDA) - National Cooperative Soil Survey	UNK	2019

Activ ID	Monitoring Activity Name	Implementing Organization(s)	Start Year	Latest Year
25	Groundwater Ambient Monitoring and Assessment Program (GAMA)	California Department of Pesticide Regulation (DPR), California Department of Water Resources (DWR), California State Water Resources Control Board (SWRCB), US Geological Survey (USGS)	2000	UNK
26	Fisheries Branch Anadromous Assessment	Yuba River Management Team, US Fish and Wildlife Service (USFWS), The Fishery Foundation of California, US Bureau of Reclamation (USBR), East Bay Municipal Utilities District, California Department of Fish and Wildlife (CDFW), California Department of Water Resources (DWR)	1952	2019
27	Anadromous Fish Abundance and Trends	California Department of Fish and Wildlife (CDFW), Pacific States Marine Fisheries Commission	1998	2019
28	Anadromous Fish Distribution	National Oceanic and Atmospheric Administration (NOAA), Pacific States Marine Fisheries Commission, California Department of Fish and Wildlife (CDFW)	2002	2019
29	Freshwater CyanoHABs Program (Blue-Green Algae Harmful Algal Blooms)	US Environmental Protection Agency (US EPA), California State Water Resources Control Board (SWRCB)	2005	2019
30	Stream Pollution Trends Monitoring Program (SPOT)	California State Water Resources Control Board (SWRCB)	2008	2019
31	Environmental Monitoring Program (EMP): Discrete Water Quality Monitoring	California Department of Water Resources (DWR)	1975	2019
32	Smelt Larva Survey	California Department of Fish and Wildlife (CDFW), California Department of Water Resources (DWR), California State Water Resources Control Board (SWRCB)	2009	2019

Activ ID	Monitoring Activity Name	Implementing Organization(s)	Start Year	Latest Year
33	Spring Kodiak Trawl Survey	California Department of Fish and Wildlife (CDFW)	2002	2019
34	Striped Bass Study	California Department of Fish and Wildlife (CDFW)	1969	2019
35	Sturgeon Study	California Department of Water Resources (DWR)	UNK	2019
36	Summer Townet Survey	California Department of Fish and Wildlife (CDFW)	1959	2019
37	Zooplankton Study	California Department of Water Resources (DWR)	1972	2019
38	Delta Juvenile Fish Monitoring Program (DJFMP)	University of California - Davis (UC Davis), US Fish and Wildlife Service (USFWS)	1976	2019
39	Suisun Marsh Fish Study	University of California - Davis (UC Davis)	1979	2019
40	Fire and Resource Assessment Program (FRAP) Fire Perimeters	US National Park Service (NPS), US Bureau of Land Management (BLM), US Department of Agriculture (USDA) - Forest Service Region 5, California Department of Forestry and Fire Protection (CALFIRE)	1996	2019
41	California Aquatic Resource Inventory (CARI)	California Wetlands Monitoring Workgroup (CWMW), San Francisco Estuary Institute (SFEI)	2008	2016
44	Breeding Waterfowl Surveys	California Waterfowl Association (CWA), California Department of Fish and Wildlife (CDFW), Pacific Flyway Council	1948	2019
45	Multibeam Delta Bathymetry Surveys	California Department of Water Resources (DWR)	2011	2019
46	Fish Salvage and Genetic Analysis	California Department of Fish and Wildlife (CDFW), California Department of Water Resources (DWR), US Bureau of Reclamation (USBR)	1957	2019
47	Feather River Hatchery/ Oroville Facility Fishery Studies	California Department of Fish and Wildlife (CDFW), California Department of Water Resources (DWR)	1961	2019

Activ ID	Monitoring Activity Name	Implementing Organization(s)	Start Year	Latest Year
48	Recreational Freshwater Fishing Licenses	California Department of Fish and Wildlife (CDFW)	UNK	2019
49	Hunting Licenses (waterfowl)	California Department of Fish and Wildlife (CDFW)	UNK	2019
50	State Park System Statistics Monitoring	California Department of Parks and Recreation	1961	2019
51	Yolo Bypass Fish Monitoring	California Department of Water Resources (DWR)	1998	2019
52	California Boat Registration	California Department of Parks and Recreation	1960	2019
53	Periodic Groundwater Level Measurements	California Department of Water Resources (DWR)	2009	2019
54	Municipal Water Quality Investigation Program (MWQI)	California Department of Water Resources (DWR)	1982	2019
55	Enhanced Delta Smelt Monitoring (EDSM) Program	US Fish and Wildlife Service (USFWS)	2016	2019
56	Quality Assurance & Quality Control (QA/QC) Program	California Department of Water Resources (DWR)	1992	2019
57	Vegetation Classification and Mapping Program (VegCAMP)	California Department of Fish and Wildlife (CDFW)	2007	2019
58	Sacramento District Water Control Data System (WCDS)	US Army Corps of Engineers (USACE)	1990	2019
59	California Irrigation Management Information System (CIMIS)	University of California - Davis (UC Davis), California Department of Water Resources (DWR)	1982	2019
60	Delta Region Areawide Aquatic Weed Project (DRAAWP)	California Department of Water Resources (DWR), National Aeronautics and Space Administration (NASA) - Ames Research Center, Sacramento-San Joaquin Delta Conservancy, California Department of Food and Agriculture	UNK	UNK

Activ ID	Monitoring Activity Name	Implementing Organization(s)	Start Year	Latest Year
		(CDFA), US Department of Agriculture (USDA) - Agricultural Research Service, University of California - Davis (UC Davis), California Department of Parks and Recreation		
61	Invasive Species Program	California Department of Fish and Wildlife (CDFW)	UNK	UNK
62	Water Tracker	Point Blue Conservation Science	UNK	UNK
63	Continuous Monitoring of Water Quality & Suspended-Sediment Transport (Bay-Delta)	US Geological Survey (USGS)	1988	2019
64	Water Quality of San Francisco Bay	US Geological Survey (USGS)	1968	2019
65	Suisun Marsh Monitoring Program	California Department of Water Resources (DWR)	1998	2019
66	Western Regional Climate Center (WRCC) - Weather Monitoring	Desert Research Institute (DRI), National Oceanic and Atmospheric Administration (NOAA)	1986	2019
67	Surface Water Protection Program	US Environmental Protection Agency (US EPA), California State Water Resources Control Board (SWRCB), US Geological Survey (USGS), California Department of Pesticide Regulation (DPR)	1925	2018
68	Plate Boundary Observatory (PBO)	UNAVCO	2003	2019
69	Farmland Mapping & Monitoring Program (FMMP)	California Department of Conservation (DOC), US Department of Agriculture (USDA)	1982	2019
70	National Pipeline Mapping System	US Department of Transportation (DoT)	2002	2019
73	Well Completion Monitoring	California Department of Water Resources (DWR)	1969	2019
74	Water Conservation and Production Reports	California State Water Resources Control Board (SWRCB)	2014	2019

Activ ID	Monitoring Activity Name	Implementing Organization(s)	Start Year	Latest Year
75	National Water Use Science Project (NWUSP)	US Geological Survey (USGS)	1950	2015
76	Berkeley Seismology Lab Geophysical Networks	University of California - Berkeley, US Geological Survey (USGS)	1993	2019
78	Stormwater Multiple Application and Report Tracking System (SMARTS)	California State Water Resources Control Board (SWRCB)	UNK	2018
79	California Strong Motion Instrumentation Program (CSMIP)	California Department of Conservation (DOC)	1972	2019
80	Regional Monitoring Program for Water Quality in San Francisco Bay	San Francisco Estuary Institute (SFEI) - Regional Monitoring Program (RMP), US Geological Survey (USGS)	1993	2019
81	Fish Restoration Program Monitoring	California Department of Fish and Wildlife (CDFW)	2015	2019
82	Regional Geologic Mapping Program (RGMP)	California Geologic Survey (CGS), California Department of Conservation (DOC)	1981	2019
83	Seismic Hazards Program	California Department of Conservation (DOC)	1992	2019
84	Energy Almanac	California Energy Commission (CEC)	1981	2019
85	Mineral Resources Program	California Department of Conservation (DOC)	1978	2019
86	National Strong Motion Project (NSMP)	US Geological Survey (USGS)	1932	2019
88	Atmospheric River Reconnaissance	National Oceanic and Atmospheric Administration (NOAA), National Center for Atmospheric Research (NCAR), University of California - San Diego - Scripps Institute of Oceanography	2014	2019
89	Advanced Hydrologic Prediction Service - Precipitation Monitoring	National Oceanic and Atmospheric Administration (NOAA)	1961	2019

Activ ID	Monitoring Activity Name	Implementing Organization(s)	Start Year	Latest Year
90	Local Climatological Data	National Oceanic and Atmospheric Administration (NOAA)	1931	2019
92	Streamflow Monitoring	US Geological Survey (USGS)	1850	2019
93	National Geospatial Agriculture Monitoring	US Department of Agriculture (USDA), National Agricultural Statistics Service (NASS)	1997	2019
95	California Cooperative Snow Surveys (CCSS) program	California Department of Water Resources (DWR)	1929	2019
96	Precipitation Monitoring	California Department of Water Resources (DWR)	1956	2019
97	Physical Oceanographic Real-Time System (PORTS)	National Oceanic and Atmospheric Administration (NOAA)	1991	2019
98	Mid-Winter Waterfowl Survey (MWS)	US Fish and Wildlife Service (USFWS)	1935	2019
99	Central Valley Joint Venture (CVJV)	US Fish and Wildlife Service (USFWS)	1988	2019
100	San Francisco Bay Joint Venture	US Fish and Wildlife Service (USFWS)	1988	2019
101	Delta Regional Monitoring Program	University of California - Davis (UC Davis) - Aquatic Health Program Laboratory, Moss Landing Marine Laboratories, California Department of Water Resources (DWR), US Geological Survey (USGS), San Francisco Estuary Institute (SFEI) - Aquatic Science Center	2015	2019
102	Pacific Flyway Shorebird Survey	Point Blue Conservation Science	UNK	2019
103	The Heron and Egret Project	San Francisco Bay Bird Observatory, Audubon Canyon Ranch	2011	2019
105	Audubon Christmas Bird Count (CBC)	National Audubon Society	1900	2019
106	California Partners In Flight (CalPIF)	Point Blue Conservation Science	1992	
107	Central Valley Enhanced Acoustic Tagging Project	University of California - Santa Cruz, National Oceanic and Atmospheric Administration (NOAA)	2017	2019

Activ ID	Monitoring Activity Name	Implementing Organization(s)	Start Year	Latest Year
110	North American Breeding Bird Survey (BBS)	Mexican National Commission for the Knowledge and Use of Biodiversity (CONABIO), Environment and Climate Change Canada (ECCC), US Geological Survey (USGS)	1966	2019
111	Marine Invasive Species Program (MISP)	Smithsonian Institute - Smithsonian Environmental Research Center, California Department of Fish and Wildlife (CDFW)	2000	2019
112	Monitoring Avian Productivity and Survivorship	The Institute for Bird Populations	1989	2019
113	Central Valley Project - Reservoir Monitoring	US Bureau of Reclamation (USBR)	1938	2019
114	State Water Project - Reservoir Monitoring	California Department of Water Resources (DWR)	1960	2019
115	Water Quality Data for California	US Geological Survey (USGS)	1915	2019
116	eBird	Cornell Lab of Ornithology	UNK	UNK
117	Discrete dissolved oxygen monitoring in the Stockton Deep Water Ship Channel	California Department of Fish and Wildlife (CDFW), US Geological Survey (USGS), California Department of Water Resources (DWR)	1968	2019
119	Surface Water Quality Monitoring	California State Water Resources Control Board (SWRCB)	1999	2019
120	Drinking Water Well Monitoring	California State Water Resources Control Board (SWRCB)	2019	2019
121	Surface Water Monitoring	California Department of Water Resources (DWR)	UNK	UNK
122	Phytoplankton and Chlorophyll-a Monitoring	California Department of Water Resources (DWR)	1975	2019
123	Delta-Mendota Canal Water Quality Monitoring	US Bureau of Reclamation (USBR)	2002	2019
124	Aquatic Invasive Species Programs	California Department of State Parks, Division of Boating and Waterways	1983	2019
125	National Pollution Discharge Elimination	US Environmental Protection Agency (US EPA)	1972	2019

Activ ID	Monitoring Activity Name	Implementing Organization(s)	Start Year	Latest Year
	System (NPDES) Self-Monitoring Program			
126	Contra Costa Water District Source Water Monitoring	Contra Costa Water District (CCWD)	1940	2019
128	Grasslands Bypass Project Monitoring	US Bureau of Reclamation (USBR)	1998	2019
129	Central Valley Project	US Army Corps of Engineers (USACE), US Bureau of Reclamation (USBR)	1933	2019
130	State Water Project	California Department of Water Resources (DWR)	1960	2019
131	Endangered Species Project	California Department of Pesticide Regulation (DPR)	1988	2019
132	Pesticide Use Reporting	California Department of Pesticide Regulation (DPR)	1989	2019
133	San Francisco Bay Bathymetry	National Oceanic and Atmospheric Administration (NOAA) - National Ocean Service (NOS), National Oceanic and Atmospheric Administration (NOAA), US Geological Survey (USGS)	1867	UNK
134	Freeport Regional Water Project	East Bay Municipal Utilities District	2007	2019
135	Highway Performance Monitoring System (HPMS)	California Department of Transportation (Caltrans)	1978	2019
136	AIS Marine Vessel Traffic Monitoring	Marine Traffic	2013	2019
137	California Recreational Fisheries Survey (CRFS)	California Department of Fish and Wildlife (CDFW)	2004	2019
138	National Water Level Observation Network (NWLON)	National Oceanic and Atmospheric Administration (NOAA) - National Ocean Service (NOS)	UNK	UNK
139	DOGGR Oil and Gas Well Monitoring	California Department of Conservation (DOC)	1900	UNK
140	Waterborne Commerce of the United States (WCUS) Monitoring	US Army Corps of Engineers (USACE)	1922	2018

Activ ID	Monitoring Activity Name	Implementing Organization(s)	Start Year	Latest Year
141	Port of Stockton Monitoring	Port of Stockton Board of Commissioners	2000	2019
142	Lower Sacramento River Green Sturgeon Telemetry Monitoring	California Department of Fish and Wildlife (CDFW)	2015	2019
143	California Fish Passage Assessment Database (PAD)	Pacific States Marine Fisheries Commission	2002	2019
144	Local Maintaining Agency Annual Reporting	California Department of Water Resources (DWR)	2007	2018
145	Levee Inspections	California Department of Water Resources (DWR)	2003	2018
146	Levee Waterside Erosion Surveys	California Department of Water Resources (DWR), US Army Corps of Engineers (USACE)	1998	2018
147	Water Quality Exchange (WQX)	US Environmental Protection Agency (US EPA)	1963	2019
148	California Natural Diversity Database (CNDDB)	Department of Fish and Game (DFG), NatureServe, California Department of Fish and Wildlife (CDFW)	1979	2019
149	Drought Stressor Monitoring	California Department of Fish and Wildlife (CDFW)	2014	2017
150	San Francisco Bay National Estuarine Research Reserve	National Oceanic and Atmospheric Administration (NOAA) - National Ocean Service (NOS)	1995	2019
151	Middle Sacramento River Salmon and Steelhead Rotary Screw Trap Monitoring	California Department of Fish and Wildlife (CDFW)	1966	2016
152	Coleman and Livingston Stone Hatchery Releases	US Fish and Wildlife Service (USFWS)	1942	2016
153	Electronic Water Rights Information Management System (eWRIMS)	California State Water Resources Control Board (SWRCB)	2007	2019
154	AmeriFlux Network	US Department of Energy - Office of Biological and Environmental Research (DOE-BER)	1996	2019

Activ ID	Monitoring Activity Name	Implementing Organization(s)	Start Year	Latest Year
155	Telemetered Stream Gauge Stations (Surface Water Monitoring)	California Department of Water Resources (DWR), Department of Fish and Game (DFG), National Marine Fisheries Service (NMFS) (NOAA-Fisheries), US Fish and Wildlife Service (USFWS), US Bureau of Reclamation (USBR)	UNK	UNK
156	Groundwater Monitoring	California Department of Water Resources (DWR), Department of Fish and Game (DFG), National Marine Fisheries Service (NMFS) (NOAA-Fisheries), US Fish and Wildlife Service (USFWS), US Bureau of Reclamation (USBR)	UNK	UNK
157	Water Quality Monitoring	California Department of Water Resources (DWR), Department of Fish and Game (DFG), National Marine Fisheries Service (NMFS) (NOAA-Fisheries), US Fish and Wildlife Service (USFWS), US Bureau of Reclamation (USBR)	UNK	UNK
158	Nutria Eradication Program	California Department of Fish and Wildlife (CDFW)	2018	2019
159	Perennial Streams Survey	US Forestry Service (USFS), US Environmental Protection Agency (US EPA), California State Water Resources Control Board (SWRCB), Southern California Stormwater Monitoring Coalition (SMC)	2000	2019
160	Aquatic Invasive Species (AIS) Program	US Fish and Wildlife Service (USFWS)	1991	2019
161	Central Valley Angler Survey	California Department of Fish and Wildlife (CDFW)	1995	2019
162	Mokelumne River Fish Hatchery	East Bay Municipal Utilities District	1964	2019
163	Mokelumne River Rotary Screw Trap Monitoring	East Bay Municipal Utilities District	1992	2019
164	Beneficial Use Assessment	California Water Board, Central Valley Region	2007	2019

Activ ID	Monitoring Activity Name	Implementing Organization(s)	Start Year	Latest Year
165	Aquatic Invasive Species Program (CDFW)	California Department of Food and Agriculture (CDFA), California Department of State Parks, Division of Boating and Waterways, California Department of Parks and Recreation, California Department of Fish and Wildlife (CDFW), California Department of Pesticide Regulation (DPR), California Department of Water Resources (DWR)	UNK	2019
166	Water Quality in the Nation's Stream and Rivers	US Geological Survey (USGS)	1991	2017
167	Groundwater Quality Trends Monitoring	US Geological Survey (USGS)	1988	2012
168	SJCDWQC Surface Water Monitoring	San Joaquin County Resource Conservation District, San Joaquin County & Delta Water Quality Coalition (SJCDWQC)	2003	2019
169	SJCDWQC Groundwater Quality Trend Monitoring	San Joaquin County Resource Conservation District, San Joaquin County & Delta Water Quality Coalition (SJCDWQC)	2003	2019
170	Nitrogen Monitoring (Self-Reporting)	Westside San Joaquin River Watershed Coalition	2014	2019
171	National Wetland Condition Assessment (NWCA)	US Environmental Protection Agency (US EPA)	2011	2016
172	Sacramento Watershed Coordinated Monitoring Program (SWCMP)	California Department of Water Resources (DWR), California State Water Resources Control Board (SWRCB), Central Valley Regional Water Quality Control Board (Central Valley RWQCB)	2008	2019
173	California Rice Commission (CRC) Surface Water Monitoring	California Rice Commission	2004	2019
174	California Rice Commission (CA Rice)	California Rice Commission	1997	2019

Activ ID	Monitoring Activity Name	Implementing Organization(s)	Start Year	Latest Year
	Groundwater Monitoring			
175	Moderate resolution imaging spectro radiometer MODIS	National Aeronautics and Space Administration (NASA)	UNK	2019
176	Ecosystem Spaceborne Thermal Radiometer Experiment on International Space Station (ECOSTRESS)	National Aeronautics and Space Administration (NASA)	UNK	2019
177	Landsat Science Program	Goddard Space Flight Center	UNK	2019
178	Sentinel Satellite	European Space Agency	UNK	2019
179	Sacramento River Water Quality Monitoring	Woodland-Davis Clean Water Agency	2009	2019
180	WorldView-3	DigitalGlobe	2014	2019

Appendix C. Questionnaire Analysis

Overview

A total of 34 individuals responded to the questionnaire that sought feedback on the initial findings and recommendations from the initial analysis of the Delta monitoring inventory and to help identify areas for further analysis. Detailed methods are described in Section 2.2.1 of the report. To start off the questionnaire, participants began by providing background on their role in the monitoring enterprise (e.g., Program Manager, Data Collector, etc.), their years of experience working in the Delta, and the management context in which they were providing their response based off the themes identified for the review (e.g., water supply, flood and land use).

Overall, the majority of participants had 10 or more years working in the Delta monitoring enterprise. When asked to indicate their role in Delta monitoring, most respondents self-identified as a data user/analyst/synthesizer of monitoring data. Data collectors and program managers were the second and third most common roles with which respondents self-identified (Figure C-1). When asked to indicate management areas in which they work, most respondents selected habitat management, while there was very little representation on flood and land use management (Figure C-1).

Afterwards, participants had the opportunity to rate on a scale of 1 to 5 on whether they disagreed or agreed to 19 statements that were based off the findings and recommendations from the initial analysis. Results can be found in Table C-1 and Figure C-2 below. Afterwards, participants had the opportunity to state why they agreed or disagreed to a statement. A general summary of what participants agreed or disagreed to a statement is included in this appendix.

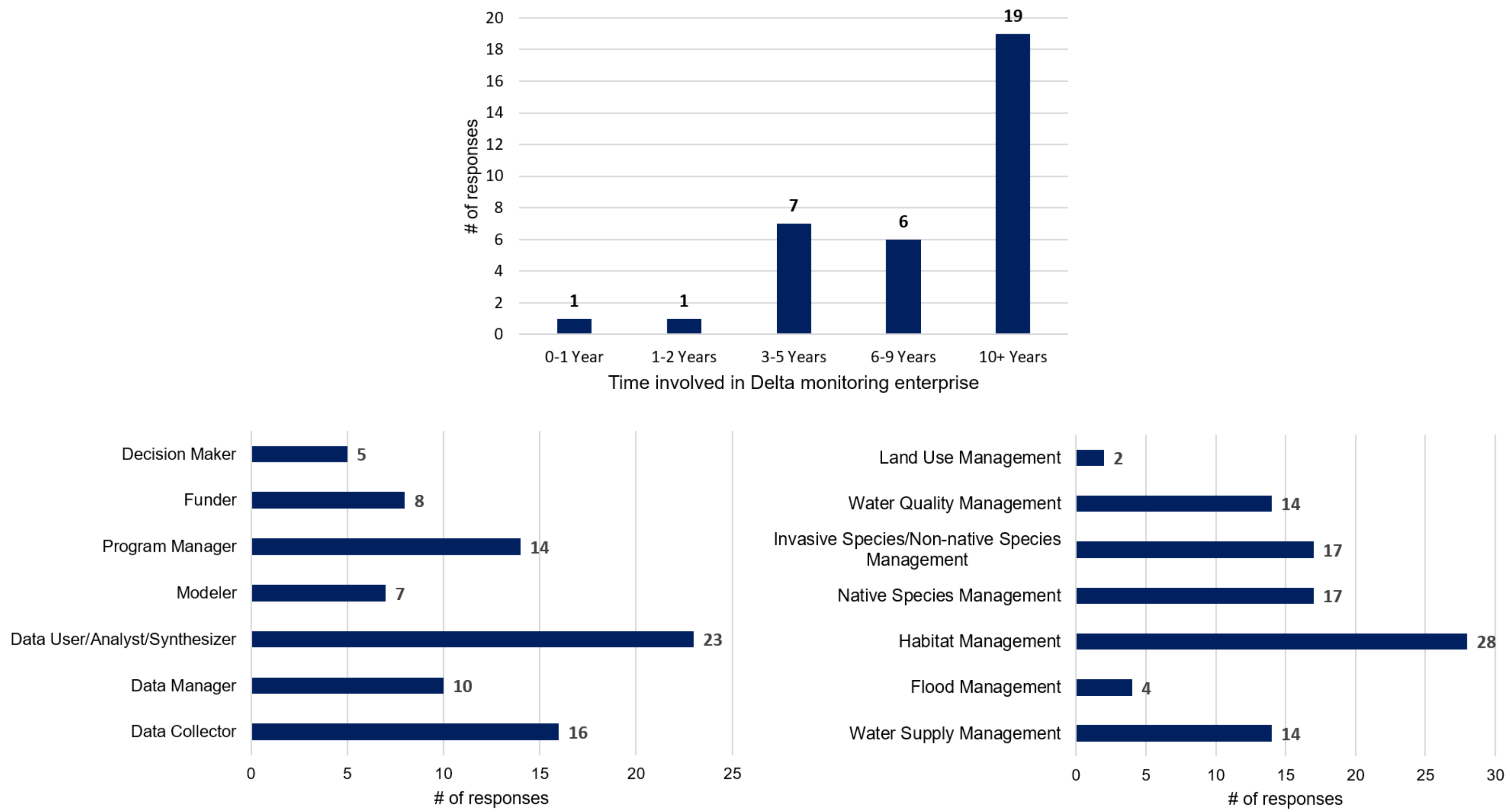

***Figure C-1. Demographics of questionnaire respondents. Top graph: Participant's self-identified length of involvement with the Delta monitoring enterprise (N=34). Bottom left graph: Participant's self-identified role within the Delta monitoring enterprise. Participants had the option of choosing multiple categories if they serve multiple roles (N=34). Bottom right graph: Participant's selection of management areas in which they based their response. Participants had the option of choosing multiple management areas (N=34*).**

Table C-1: All Questionnaire results of the percent of individuals who agreed, disagreed or did not know to a questionnaire statement.

Statement	Percent Agree	Percent Disagree	Percent Don't Know	N (Sample Size)
5. Overall, current information collected from monitoring serves the needs of decision makers and stakeholders across the Delta.	26%	70%	4%	23
6. The frequency and timing at which the monitoring of the top two parameters you identified in question 4 are conducted is sufficient for informing management decisions.	23%	74%	3%	31
7. The spatial coverage of monitoring of the top two parameters you identified in question 4 is sufficient for informing management decisions.	17%	77%	7%	30
8. Monitoring approaches have sufficient scientific rigor (e.g. sampling design, statistical power) to meet management needs.	10%	80%	10%	30
9. The procedures for quality assurance and control are adequate.	32%	39%	29%	31
10. Mercury and methylmercury seem to be monitored extensively in the Delta, whereas other chemical contaminants receive considerably less attention for informing management actions.	67%	15%	19%	27
11. Among the likely drivers and vectors of the introduction and spread of invasive species, there is a gap of monitoring transportation-related activities, such as roads, rail lines, vessels, and shipping channels, for informing management actions.	42%	13%	45%	31
12. There are other gaps in monitoring invasive and non0natve species (e.g. aquatic vegetation) in the Delta and beyond transportation related activities for informing management actions.	74%	10%	16%	31
13. There is a gap in monitoring of dredging and its effects in the Delta.	39%	4%	57%	28

Statement	Percent Agree	Percent Disagree	Percent Don't Know	N (Sample Size)
14. The quality, quantity, and capabilities of sampling equipment (e.g., boats, sensors and sensor networks, nets) are sufficient for conducting effective monitoring in the Delta.	14%	57%	29%	28
15. For environmental water quality, there are opportunities for increasing comparability of data by standardizing use and calibration of equipment, employing consistent sampling protocols, and centralizing data management.	70%	10%	20%	30
16. Monitoring of specific habitats and species should be guided by standardized habitat-classification schemes among the different monitoring activities.	71%	14%	14%	28
17. Fish monitoring is well coordinated.	41%	26%	33%	27
18. Data availability and sharing among agencies and groups doing monitoring are sufficient.	20%	60%	20%	20
19. Data are analyzed and synthesized in a way that enables management decisions.	22%	61%	17%	23
20. There is a common understanding of the priorities required to meet science and management needs.	10%	79%	10%	29
21. The organizational structure and integration of activities to support monitoring and adaptive management should be strengthened to achieve better coordination, efficiency, and results in meeting priority management needs.	82%	12%	6%	33
22. The organizational structure to support monitoring and adaptive management in the Delta should be reconsidered and changed to achieve better coordination, efficiency, and results in meeting priority management needs.	81%	8%	12%	26
23. A major coordinated overhaul about how monitoring is designed and conducted across multiple monitoring programs would result in better coordination and efficiency, and better meet priority management needs.	69%	17%	14%	29

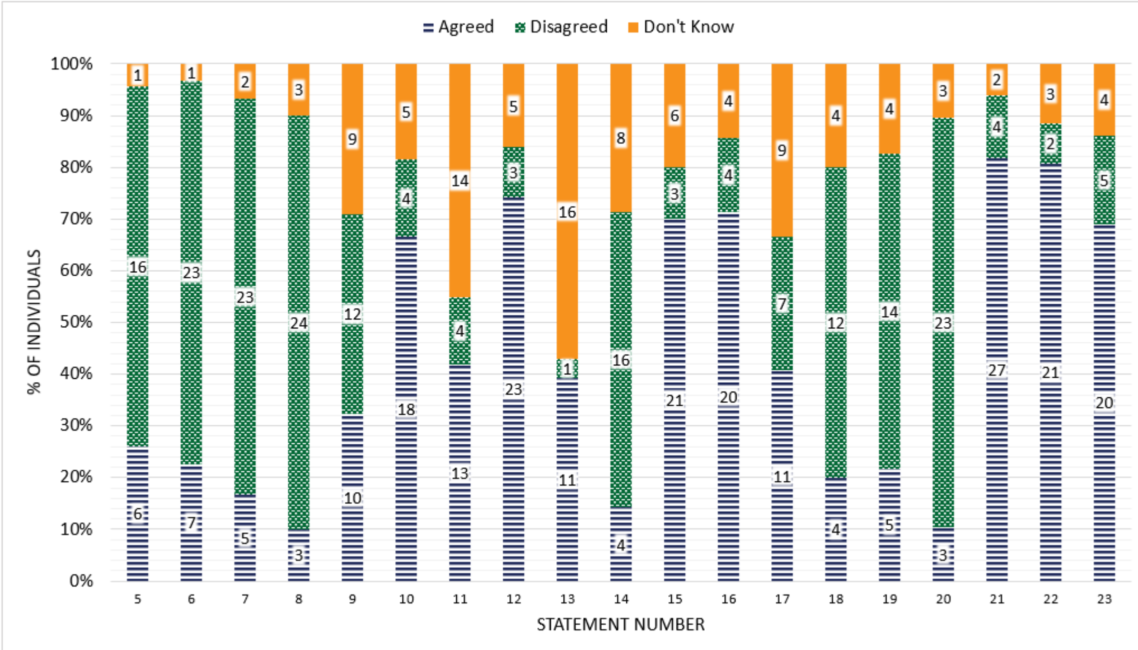

Figure C-2. The percent of individuals who responded that they agreed, disagreed or did not know to a questionnaire statement.

General Perceptions

Prior to completing the inventory analysis, ESSA, on behalf of the Delta ISB, hosted a workshop in April 2019 to gather input from Delta scientists, practitioners, program managers, and decision makers for their review. They asked the participants "How well does monitoring currently serve the needs of decision makers and stakeholders across the Delta." A majority (60%) of respondents indicated "Moderately", 17% indicated "Very", 13% indicated "Slightly", and 10% indicated that they did not know.

In their questionnaire, the Delta ISB asked a similar question to get a sense of opinions on the overall effectiveness of the monitoring enterprise. They asked participants to rate on a scale of 1 to 5 their level of agreement or disagreement on the following statement:

Question 5: Overall, current information collected from monitoring serves the needs of decision makers and stakeholders across the Delta.

Overall, 26% of the participants agreed that current monitoring serves the needs of decision makers and stakeholders across the Delta, while 70% disagreed. One participant who agreed with the statement praised the Delta monitoring enterprise: "*Fisheries and ecosystem monitoring in the Delta are* *also some of the most long running and robust in our Nation. An extensive amount of monitoring is currently conducted in the Delta to inform management and operations of water conveyance programs, plan habitat restorations, protect sensitive species, regulate pesticide use, advance scientific knowledge, and protect the multiple beneficial uses of water*."

However, the majority of respondents disagreed, noting gaps, both general and specific, and disconnects between monitoring and management needs. Specific insufficiencies included harmful algal bloom monitoring, terrestrial species (especially birds) and habitat (riparian and near aquatic habitat) monitoring, and the need for more specific information on species that are currently extensively monitored, including salmon and longfin smelt. These participants noted that, although a lot of resources are dedicated to monitoring these species, there are still major knowledge gaps when it comes to specifics such as habitat use and life stage information, largely larval stages. When discussing salmonid monitoring in the Delta, one participant explained that monitoring efforts are not designed to answer management questions by stating "*If we started with questions that need to be addressed, we'd likely end up with juvenile salmonid monitoring in the Delta that is quite different from what we've been doing."* Monitoring-management disconnect was a common observation of those that disagreed, noting that, in some cases, monitoring is designed well to answer management questions, but in other case ("*Trawls such as the Fall midwater, spring kodiak, summer tow net, and 20mm larval, and bay studies*") it is not. One barrier related to this issue was that monitoring is not nimble enough to respond to rapidly changing management needs, and that "*the needs of decision makers change more quickly than the science does*." Other respondents noted that there is an emphasis on long-term studies in the Delta, but not enough special studies to address imminent management needs. General gaps mentioned a need for greater "*spatial and temporal resolution"* in many monitoring efforts, and a need for improved synthesis, analysis, and communication for monitoring to be useful to decision makers.

Additionally, 11 participants indicated a neutral stance on this statement. These responses fell into three categories: first, that monitoring has been improving, although it still needs to continue to improve to be adequate; second, it is difficult to determine whether or not monitoring is sufficiently addressing management needs, either due to a lack of communication or that the linkage to structured decision-making has yet to be formalized; or third, that monitoring is sufficient, but there are other limitations to addressing management needs, namely modeling capabilities and data accessibility.

Monitoring and Sampling Design

Temporal and Spatial Gaps

In their initial review, ESSA was able to identify topical gaps, but could not adequately describe temporal and spatial gaps due to the course resolution of the analysis. Two questions below were designed to help clarify this. Participants were first asked to select the top two major monitoring parameters that they believed the Delta ISB should consider in greater detail (Figure C-3). They were then asked four follow up questions regarding the two monitoring parameters that they selected, two of which were:

> Question 6: The frequency and timing at which the monitoring of the top two parameters you identified in question 4 are conducted is sufficient for informing management decisions.
>
> Question 7: The spatial coverage of monitoring of the top two parameters you identified in question 4 is sufficient for informing management decisions.

The majority of respondents stated that the frequency and timing (74%) and spatial coverage (77%) of monitoring was insufficient to inform management decisions, while 23% and 17%, respectively, stated that it was sufficient. Those that disagreed mentioned a need for greater temporal and spatial resolution broadly as well as deficiencies for specific species and habitats. A common issue mentioned for both questions, was that the monitoring being done is not strategic to properly sample species or habitats of interest.

One participant who agreed that the frequency and timing of monitoring was sufficient suggested that fish monitoring may be excessive to the point that is detrimental for fish populations and "*may be having a larger impact on the species than the value of the information and some of the stressors it is purported to inform decisions about*," and that fish take should be more strategic. However, other respondents disagreed with the statement and noted specific deficiencies in fish monitoring. Multiple respondents mentioned a need for more frequent and/or more targeted sampling of salmon to clarify how they use the Delta and their response to changes in habitat, including restoration, channelization, and other anthropogenic habitat modification. A need for improved monitoring of restoration projects in general was mentioned, including how fish and wildlife respond to restoration. Additional topical deficiencies mentioned by those that disagreed included harmful algal blooms (HAB's), terrestrial animals (particularly birds) and plants, and sediment and benthic invertebrates. While discussing benthic macroinvertebrates, one participant stated, "*Current monitoring programs lack the spatial and temporal coverage necessary to understand the role and impact of this factor on the Delta ecosystem*."

Other respondents more broadly reported that the frequency of monitoring is insufficient, and that more real-time and year-round monitoring is necessary for effective management, stating "*Fine time-scale monitoring is required for ecological understanding*" and that the monitoring enterprise needs to "*implement more real-time methods and new technology to make decisions quicker."* More specific temporal deficiencies included a need for higher resolution of invasive species and HAB's. One participant who disagreed stated the difficulty of effectively monitoring for HAB's: "*HAB's can develop or decline on a daily basis and therefore require very frequent sampling to identify conditions regulating their size and occurrence."*

Those that disagreed with the statement that spatial resolution was sufficient mentioned a need for greater monitoring in habitats including wetlands, shallow and benthic habitats, upland habitats, and more specific targeting of fish habitat in general.

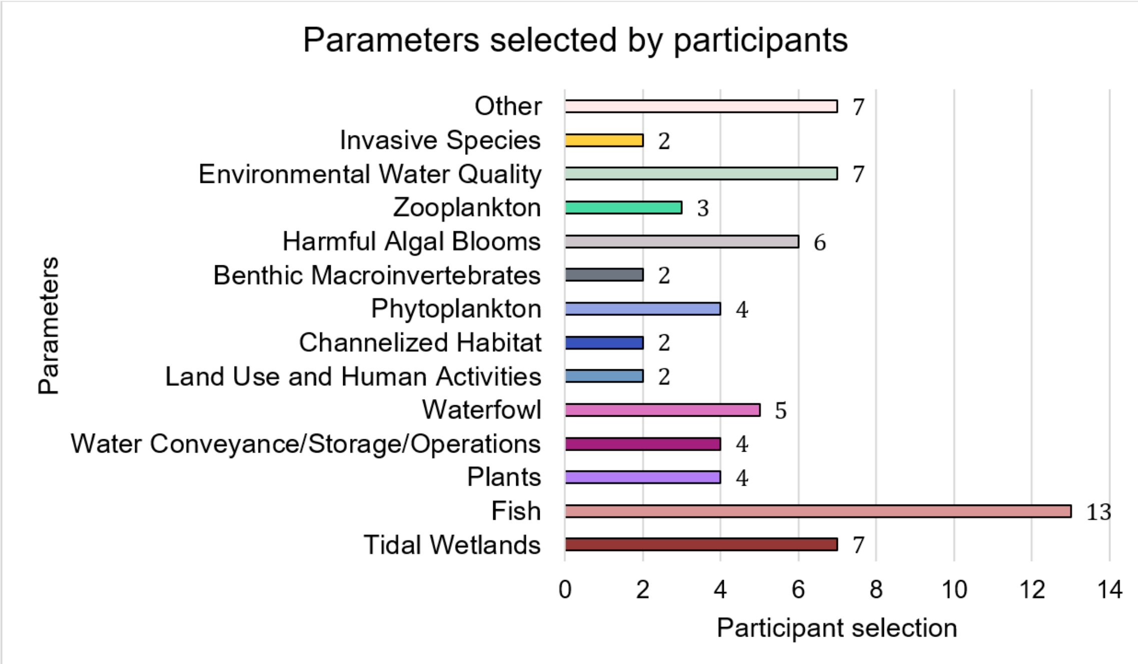

Figure C-3. Parameters selected by participants in which they based their responses for Question 5 to 8.

Scientific Rigor

As part of the inventory review, ESSA attempted to characterize the level of data quality of the monitoring enterprise by asking the question "**What is the data quality of monitoring to address purposes and needs for data?**" Five attributes of data quality were used to analyze monitoring activities: public accessibility, monitoring guidance, QA/QC, timeliness (lag between collection and reporting), and uncertainty estimate. They grouped various monitoring activities into groups that met varying aspects of data quality and found that a substantial number of monitoring activities (44%) met several fundamental attributes that represent high data quality, including 17% of monitoring activities that provide uncertainty estimates and 52% of monitoring activities that collect data that are reported within a 1 year or less timeframe. Although this analysis gave insight to aspects of data quality of the monitoring enterprise overall, it was impossible to conduct detailed evaluations of the scientific rigor of all monitoring activities in the Delta given the scope and breadth of the review. Therefore, in an effort to understand perceptions of scientific rigor, the Delta ISB asked the following two questions:

Question 8: Monitoring approaches for the top two parameters you identified in question 4 have sufficient scientific rigor (e.g., sampling design, statistical power) to meet management needs.

Question 9: The procedures for quality assurance and control for the sampling methods of the top two parameters you identified in question 4 are adequate.

A substantial majority of respondents (80%) indicated that they did not think that the monitoring approaches for their top two parameters have sufficient scientific rigor to meet management needs. Only 10% agreed that there was sufficient scientific rigor, and 10% indicated that they did not know. However, the perceptions of quality assurance and control were more evenly split, with 32% agreement, 39% disagreement, and 29% indicating that they do not know if the procedures for quality assurance and control for the sampling methods of their top two parameters are adequate.

Scientific rigor

Several commenters suggested that the scientific rigor of monitoring in the Delta is not adequate since programs are infrequently, if ever, reviewed for their scientific rigor or how well they address management needs. As explained by one participant, "There is inadequate survey and method review to determine if much of the fish monitoring actually meets management needs. Phytoplankton monitoring is even less well understood than fish." Other commenters mentioned this pattern for specific efforts including EMP phytoplankton monitoring, Delta juvenile salmonid monitoring (include SAIL, although another commenter suggested SAIL as an example of a well-designed program), and IEP monitoring broadly. Another respondent commented that although "*there is enough scientific rigor to meet the EMP program's goals…there is not enough sampling/rigor to meet the broader science communities needs of more invert/ sediment sampling*" suggesting a mismatch between monitoring and management needs.

Inadequate scientific rigor was also mentioned as a result of topical and geographical gaps including plant and bird monitoring, fish and zooplankton use of restored areas, HAB's, shallow habitats and tidal wetlands (particularly as they pertain to zooplankton production for food web support), sampling at night, and insufficient coverage of habitat ranges of species of concern (Longfin Smelt). Respondents also spoke to other sampling design flaws that result in inadequate scientific rigor. Some commented that broadly sample sizes are too small and therefore result in a lack of power for scientific testing. Additional sample design concerns included issues with temporal consistency, adequate spatial coverage, detection probability (given presence), fish size bias, and inappropriate or inadequate sampling techniques, including optical tools that do not sufficiently sample microcystis. One respondent suggested that it would not be unfeasible to update programs to improve their scientific rigor, but that many programs are inadequate "*because most existing sampling programs were instituted before development and wide accessibility (to computing power) of bayesian modeling techniques, and of novel sampling methods (such as eDNA and isotope/otolith analyses). Now it seems many of these programs are not updated because of the notion of required continuity*", recognizing a barrier to improvement that was brought up during multiple aspects of this review.

Quality assurance and control

There was much less agreement on whether there is sufficient quality assurance and control of sampling methods. Several commenters noted that QA/QC procedures have improved considerably and are well developed, noting that this aspect of sampling has become a higher priority in recent years. However, other disagreed, for example stating, "*The methods are suitable for the program's goals but are not well-documented (especially meta-data), tracked and updated…The Delta science community has placed a disproportionate amount of value on peer-reviewed science publications, rather on documentation and QA/QC, and QA/QC related studies.*" Again, several commenters emphasize the lack of data on topical areas such as birds, plants, and invertebrates in the Delta, and therefore a lack of quality assurance due to that lack of data. One participant also commented on discrepancies between lab based sampling and noisier, less accurate field sampling. There was also a large amount of respondents (29%) that indicated they did not know the answer to this question, which may speak to a lack of transparency on the level of quality assurance across programs.

Potential Gaps from Inventory Analysis

In the initial inventory analysis, chemical contaminants (with the potential exception of mercury/methylmercury), invasive/non-native species and dredging had the fewest monitoring activities in relation to other parameters that are of key interest to various management drivers (e.g., Clean Water Act, Delta Plan, etc.), which represents a potential gap. However, there is a possibility that these monitoring parameters can be effectively monitored by fewer monitoring activities. Whether this is an actual gap must be determined by the user community. To investigate this, participants rated on a scale of 1 to 5 on the following potential gaps identified by the inventory analysis:

> Question 10. Mercury and methylmercury seem to be monitored extensively in the Delta, whereas other chemical contaminants receive considerably less attention for informing management actions.
>
> Question 11. Among the likely drivers and vectors of the introduction and spread of invasive species, there is a gap of monitoring transportation-related activities, such as roads, rail lines, vessels and shipping channels, for informing management actions.
>
> Question 12. There are other gaps in monitoring invasive and non-native species in the Delta beyond transportation related activities for informing management actions. Question 13. There is a gap in monitoring of dredging and its effects in the Delta.

Overall, the majority of participants agreed that there were gaps associated with the monitoring of contaminants (67% agreed) and invasive/non-native species beyond transportation-related activities (74% agreed; see Figure C-2). However, a large portion of the participants did not know if there were gaps in monitoring of transportation-related activities for invasive/non-native species (45% did not know), or dredging (57% did not know). A reoccurring response of one participant indicated that there may be gaps to some of these monitoring activities, but they did not see how this will inform management actions. Furthermore, another participant indicated that they were not sure if they would necessarily prioritize these monitoring gaps even if they agreed that there was a gap.

Contaminants

Overall, participants indicated the need to improve and expand monitoring for contaminants. However, one participant indicated "*Numerous other contaminants are monitored by agricultural, wastewater, and stormwater agencies, with management programs established to help reduce the impacts of chemicals exceeding established TMDL concentrations. Selenium, pesticides, nutrients, and heavy metals all receive a fair amount of* *monitoring in regulated water discharges."* This indicates that there could be missing monitoring activities in the inventory related to the monitoring of regulated discharged. In addition, another participant who disagreed felt there was quite a bit of pesticide and herbicide monitoring, but less so for contaminants of emerging concern. Other participants who agreed with the finding acknowledged that although there is monitoring of contaminants, there is not enough information to identify sources, fates and effects on the Delta ecosystem.

Some of the respondents who disagreed with the finding did not necessarily disagree that there were gaps with monitoring of contaminants, but disagreed that there appeared to be extensive mercury and methylmercury monitoring, or that there should be less focus on mercury and methylmercury monitoring (which was not the Delta ISB's intent). Based on the responses, there could be a potential gap in monitoring mercury/methylmercury concentrations on levees (as most monitoring occurs in channels) and animal, such as fish and birds. As one participant noted, "*Sampling mercury in water is not an appropriate surrogate for directly sampling methylmercury in animals, such as fish and birds. Water and sediment mercury concentrations are not correlated with fish and wildlife methylmercury concentrations."*

Invasive Species

About 45% of the respondents indicated that they did not know if there was a gap of monitoring transportation-related activities, such as roads, rail lines, vessels and shipping channels, for managing invasive or non-native species. Many of the respondents were aware of the entities that have responsibilities with managing invasive or non-native species, but did not know the extent of their monitoring activities. As one respondent noted, "*California Department of Fish and Wildlife, State Lands Commission, Food and Agriculture, Parks and Recreation, and Coastal Conservancy all have funded programs to manage invasive species. The U.S. Coast Guard, U.S. Environmental Protection Agency (EPA), U.S. Fish and Wildlife Service (FWS), U.S. Army Corps of Engineers, and National Oceanic and Atmospheric Administration (NOAA) also play a role in regulating ballast water spread of invasive species. We do not know what the current level of engagement for these organizations is in monitoring transportation-related activities for potential invasive species introductions in the Delta region."* Another respondent acknowledged that they are aware of data being collected, but have never seen any data published: *I know that the State Lands Commission and CDFW collect data on invasive species associated with shipping and recreational vessels but I have never seen anything published about it. Data that sit in someone's computer or on a website in raw form are as good as useless for decision-makers."*

Although many respondents did not know if monitoring transportation-related activities was a gap, there were still a large percentage of respondents who agreed that this was a gap (42%) compared to the respondents who disagreed (19%). There is potential that existing monitoring is sufficient, but not well integrated with the rest of the monitoring enterprise. As one respondent indicated, "*There are multiagency staff and programs (CDFW's Marine Invasive Species Program and United States Fish and Wildlife Service's Aquatic Invasive Species) that monitor and work on invasive species. These staff and program are not effectively part of the Bay-Delta monitoring enterprise, because of the institutional barriers enterprise leaders reinforce to emphasize the management themes they desire it to focus on."*

When asked if there were gaps with monitoring invasive species beyond transportation relative activities, 74% agreed that there were gaps, 10% disagreed, and 16% did not know. Some of the respondents who agreed indicated that there is not a specific monitoring network to quickly identify new invasive species early in the invasion or a comprehensive invasive species monitoring program in the Delta for some of the most widespread and established invasive plant and animal species. As noted by one respondent, "*Absolutely a gap in invasive species monitoring. Good examples are Aquatic Vegetation and Nutria. Existing staff and programs are expected to monitor/ track and communicate these invasions without any additional resources (and at times reduced resources). The expansion of Aquatic Vegetation in the Delta is well known anecdotally, but there is no comprehensive monitoring program for it and its potential massive impacts on the ecosystem."* Other respondents focused on the need to improve communication and public awareness on the spread and prevention of invasive/non-native species.

Many of the comments on gaps related to invasive/non-native species focused on how the monitoring of aquatic vegetation is limited and not adequate to understand extent of the problem and to understand the effectiveness of management actions. There were a few comments related to remote sensing; one respondent indicated there was a gap since these efforts were cut from 2009 to 2012 due to the budget crisis in the State of California, while another commenter indicated that remote sensing programs are not time-intensive enough to provide adequate monitoring for understanding or control non-native/invasive species.

Dredging

Of all the potential gaps identified, most of the respondents were not familiar with the monitoring of dredging. However, two participants indicated that the United States Army Corps of Engineer (ACOE) does quite a bit of monitoring of dredging in the Bay-Delta, which was not reflected in the inventory. As one participant indicated, "*The ACOE does quite a bit of monitoring on its dredging activities. The ACOE management themes of flood management, habitat management, land use management, etc. are not effectively part of the Bay-Delta monitoring enterprise. Independently, they have developed a parallel enterprise related to this activity because leaders in the monitoring enterprise are not focused on this."* Like with the monitoring of transportation-related activities to manage non-native or invasive species, there is potential that existing monitoring is sufficient, but not well integrated with the rest of the monitoring enterprise. Other commenters indicate that there is monitoring of dredging (e.g., chemical composition), but there is lack of research and understanding the about effects of dredging on aquatic ecosystems in the Delta.

Opportunities for Increasing Efficiency

In their review, ESSA identified new opportunities for increased efficiency for the most common monitoring parameters within four broad monitoring categories (direct socio-economic drivers, environmental drivers/conditions, habitats, and species). The Delta ISB included two questions below (Question 15 and 16) to get a sense of the level of support for some of ESSA's suggestions for increased efficiency. They also included two additional opportunities for improved efficiency (Questions 14 and 17) to evaluate perceptions of the role of limited equipment on improving efficiency and perceptions of the level of coordination of fish monitoring as a whole. Although ESSA found fish coordination well-coordinated, the Delta ISB included Question 17 to assess perceptions of that finding and to identify potential opportunities for improvement.

Question 14. The quality, quantity and capabilities of sampling equipment (e.g., boats, sensors and sensor networks, nets) are sufficient for conducting effective monitoring in the Delta.

Question 15. For environmental water quality (temperature, dissolved oxygen, conductivity, turbidity), there are opportunities for increasing comparability of data by standardizing use and calibration of equipment, employing consistent sampling protocols, and centralizing data management.

Question 16. Monitoring of specific habitats and species should be guided by standardized habitat-classification schemes among the different monitoring activities.

Question 17. Fish monitoring is well coordinated.

Sampling equipment

A few participants agreed that the quality, quantity, and capabilities of sampling equipment is sufficient (14%), recognizing that although there is always room for improvement, sampling methods are in good shape overall and continue to improve. However, the majority of respondents (57%) disagreed, and 29% indicated that they did not know. The most commonly reported issue was an aging boat fleet, with one respondent expressing serious concern over the severity of the issue, stating "*it takes a tremendous amount of time, resources, and technical expertise for agencies to procure a new boat. This is a looming crisis for the Delta monitoring community*." A general lack of sufficient funding and resources was identified by multiple participants as the cause of inefficiencies. Lack of funds results in limited and/or underpaid field crews and a lack of equipment redundancy that results in lost data when equipment malfunctions. Additionally, whether due to funding limitations or poor sampling design, multiple participants explained that the gear used for sampling is not ideal for their sampling targets: "Current trawling gear targets mainly large older juvenile salmon (mainly hatchery release sizes), and not the pre-smolt age classes we are providing habitat for. Beach seines don't work very well in the muddy Bay-Delta" and "People also need to recognize the limitations of boat type and not expect one boat (or other piece of equipment) to be able to do everything." Others mentioned issues of efficiency in juvenile salmon monitoring and littoral habitats generally, and a need for greater standardization across sampling techniques. Several participants also mentioned data collection networks, including water quality and telemetry networks, as strategies for improving efficiency of monitoring.

One respondent, who indicated a neutral opinion on this statement, suggested that sampling gear is not the limitation for addressing inefficiencies, but rather how the monitoring enterprise was designed. *"The quality, quantity, and capabilities have led to a world-class network monitoring the Delta. However…most of the monitoring has been focused on a small sector of management themes by its leaders, which have reduced its ability to be nimble and capable to detect changes and effects of the broader set of management themes occurring in the Bay-Delta.*"

Environmental water quality, habitat, and species monitoring

The majority of respondents agreed with ESSA suggestions of standardization to improve efficiency for environmental water quality monitoring (70%) and species and habitat monitoring (71%), however, many who agreed qualified their responses. For both environmental water quality and habitat and species monitoring, participants emphasized that, although standardization would be beneficial in many cases, maintaining flexibility is also essential for addressing management questions. "*Some studies might require full depth profiles conducted from a boat, while others may only need a quick grab sample from the shoreline. Different instruments may be preferred for long-term and continuous deployment vs. a quick field sample. Differing levels of precision and accuracy are required based on the research and management question being addressed*." Many commenters emphasized the importance of prioritizing management needs over standardization, independent of whether they agreed or disagreed with the statement. Some participants that disagreed suggested that standardization can even be prohibitive in a programs ability to address management needs. "*Monitoring programs need to be adaptive and change their techniques over time as new knowledge of the system is gained and the management questions change. Providing guidelines and recommendations for sampling and analysis techniques can be useful but forcing researchers to use one standardized habitat-classification scheme would greatly impair the ability of researchers to refine their monitoring programs to address their specific study objectives and limit the discovery of new scientific insight*."

Several commenters spoke to the difficult task of standardization, and the necessity of collaboration to achieve appropriate levels of standardization and improved efficiencies in monitoring. "*Centralizing data management is helpful, but this might be a challenge due to the large diversity of water quality monitoring equipment and the large number of research monitoring activities that collect this data over short periods of time to inform other scientific analysis. It can be helpful if one or more entities take the lead in field and laboratory inter-calibration studies.*" In addition to collaboration, another respondent suggested expanded data networks, such as through community science, as a way to improve efficiencies in monitoring.

Fish monitoring

Perceptions of the coordination of fish monitoring were more evenly split between respondents, with 41% agreeing that fish monitoring is well coordinated, 26% disagreeing, and 33% that did not know. Several participants that agreed recognized the role of IEP in improving coordination of fish monitoring in the Delta. "*To keep these surveys running takes a small army and the different programs should be commended for being able to conduct these surveys under varying levels of adversity*." Others that agreed qualified their agreement stating that, although fish monitoring is generally well coordinated, some efforts could still be better integrated, such as the telemetry efforts among agency and academic institutions, and standardized. One participant agreed that fish monitoring is well coordinated with regular meetings and communication, but despite this there is still a mismatch between monitoring efforts and management needs. "*Increasingly, decision makers are emphasizing they would like monitoring information to inform them about population-level characteristics from the surveys not just presence/absence or relative indices*."

About a quarter of respondents (26%) responded that fish monitoring is not well coordinated, primarily due to siloed programs with varying specific goals and/or sampling methods that are not coordinated with each other or with other aspects of monitoring such as environmental drivers or conceptual and quantitative models. One respondent noted some overlap in fish monitoring efforts that may reduce efficiency, but also recognized the benefit of a level of redundancy in monitoring.

Appendix D. Interview Questions and Coding Framework

This appendix includes the interview questions along with the prompt that was provided to each interviewee before the start of the interview. In addition, interviewees were asked to provide feedback on the draft best practices (see Appendix A) via a survey.[7] Interviewees were provided a copy of interview questions, the prospectus, and the summary of work completed to date prior to the interview. After interviews were completed, responses were analyzed using a coding framework, which is included near the end of this appendix (see Section 2.2.2 of report for methods).

Interviewees from various organizations were invited and represented the wide range of management themes identified from this review. However, when asked in the interview how monitoring could help address current or future management needs, no interviewees mentioned needs related to flood or non-native species management (see Figure D-1). Management needs mentioned in interviews most frequently related to water supply management, native species management, and water quality management, along with a host of "other" management needs that were not defined in our analytical framework (see Table D-1). Interviewees representing regulatory agencies indicated that they have monitoring needs centered around determining regulatory protections for beneficial uses. Other interviewees expressed that their organizations don't have management needs per se, as they work to fulfill monitoring requirements for compliance.

[7] A copy of the best practices survey is available at https://docs.google.com/forms/d/e/1FAIpQLSf3tApQGq8A676kxjadujdIEwgqEjDZeLRyCmRFA_LAiciMbw/viewform

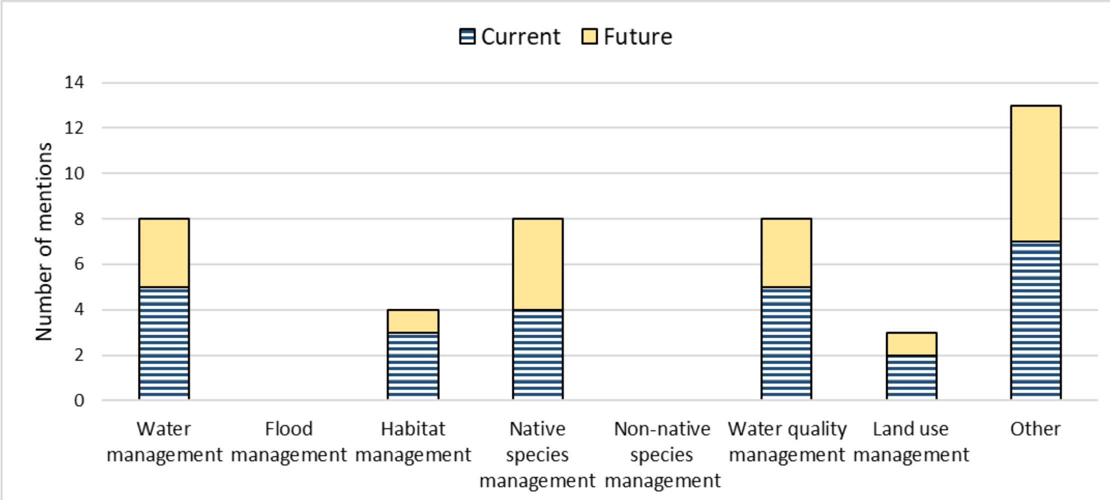

Figure D-1. Current and future management needs addressed by monitoring. Note: multiple mentions within interviews were counted as a single mention. See Table D-1 for other management needs.

Table D-1. Other current management and future management needs identified by participants that could be addressed by monitoring.

Current Management Needs	*Future Management Needs*
• Need to understand the Delta socio-economic system, including recreation, agriculture, and natural resources • Need for performance measures to assess issues governed under the Delta Plan and the achievement of the coequal goals • Needs for legacy monitoring • Need to understand the biological and physical drivers of the ecosystem (especially in order to inform water operations) • Need to understand biological species/wildlife generally (did not specify native or non-native)	• Needs related to understanding the Delta as an evolving place and environmental justice • Management for long-term environmental and climatic change, including drought • Monitoring to inform multi-benefit projects • The need to integrate management of the upper and lower estuaries • Monitoring at high frequencies in order to remove tidal influences

Prompt Read at the Start of Interview

Thank you for agreeing to participate in this interview. I'm ________ and I work as staff for the Delta ISB. For this interview, we are joined by ___________ of the Delta ISB and ________ who also works as staff for Delta ISB. Today, we'll be asking you questions to help inform the Monitoring Enterprise Review, which is assessing how current monitoring programs meet management needs and how they might be coordinated or modified to improve their responsiveness to management. Information collected from these interviews will be aggregated and analyzed using qualitative methods.

The goal of this interview is to learn about your organization's perspective on monitoring. You are also welcome to share your individual perspective at any time, but we would appreciate if you would clearly state when you do so. Otherwise, we will assume you are representing the organizational perspective. Do you have any questions about that?

Participating in this interview is completely voluntary, and if you prefer not to participate you are free to decline. You are also free to skip any questions or discontinue the interview at any time once it is in progress. To help with analysis, we would like to record this interview, which will be transcribed for purposes of analysis. Personally identifiable information will not be included in any publicly available reports, but please be aware that the interview recording and transcript (including our staff notes) are subject to retrieval under the Public Records Act. Are you okay if we record this interview?

By proceeding with the interview, you indicate your consent to participate and to be recorded.

Questions

1. The Monitoring Enterprise refers to the full suite of monitoring programs and activities that collectively provide data about the physical, chemical, biological, and socio-economic (i.e., social-ecological) components of the Delta system. For this review, monitoring covers sampling design and sampling, data management, analysis and synthesis, and communication. Please briefly describe your role and experience in relation to the Monitoring Enterprise in the Delta.

2. What current management needs does your organization have that are addressed or could be addressed by monitoring? Please be as specific as possible.
    a. Do you anticipate future management needs, either in or outside your organization, which are or could be addressed by monitoring? If so, please describe them.
3. Would you say there are major gaps in monitoring in topical, temporal and geographical areas? By gaps, I mean monitoring that is important to address current or future management needs, but is not currently done or planned. If so, please describe these gaps that are relevant to your organization's management needs. And for this question, you are again welcome to reflect on gaps that affect the broader enterprise as well, including those of other organizations.
    a. What would you say are the barriers to addressing these gaps?
    b. Do you have any ideas about how to begin addressing these gaps? Please be as specific as possible.
4. From our initial analysis, most of the long-term monitoring has not been designed and/or implemented with the intent of explicitly supporting adaptive management; although, many datasets are used in decision-making. Do you have ideas for improving how monitoring informs or is used in adaptive management, or how monitoring can be designed to support adaptive management?
5. From our initial review, there has not been an overall organizational framework for monitoring in the Delta that cuts across the management areas of water supply, flood, water quality, land use, habitat, and species to achieve the coequal goals. In a questionnaire completed by 34 stakeholders, most agreed there is a need to achieve better efficiency and coordination in monitoring to meet management needs, which could result in major changes with how monitoring is designed and organized. We'd like to hear your ideas about how this could be achieved. I have a set of questions on this topic, which I will ask one by one.
    a. What management areas need better coordination? What are the barriers to improve coordination? If the current organization and level of coordination meets your needs, feel free to state so.
    b. Do you have any ideas on how monitoring should be coordinated that cuts across all areas of management to achieve the coequal goals?

c. What role do you see for your organization in efforts to re-organize and strengthen the coordination of monitoring?
    i. What other organizations would need to be a part of efforts to re-organize monitoring, and what role do you see them playing?
    ii. Who should take the lead in these efforts?
d. What financial or regulatory mechanisms could be used to drive changes in the organization of monitoring?
    i. Can you think of other mechanisms or processes that could facilitate change in the organization of monitoring? If so, please describe them.
e. What challenges are associated with efforts to re-organize monitoring in the Delta?
f. As part of our review, we have looked into the organization of monitoring of Chesapeake Bay, Great Lakes, Coastal Louisiana, and Puget Sound in the US, and Queensland, Australia to help gain insights that could be applied to the Delta. Are you aware of any other watershed/systems where monitoring is done effectively that we should consider?
g. Do you have anything else to add about how Delta monitoring could be re-organized to improve efficiency and coordination?

6. Is there anything else we should consider in our review of the Delta Monitoring-Enterprise?

7. Do you have any questions for us about this review, or any of our initial findings that we provided in a summary prior to the interview?

Coding Framework

Below is the coding framework used to analyze interview transcripts described above in section **2.2.2 Interviews**.

Section A Current and future management needs

A1 Current management needs of organization

NOTE: management needs are issues we need monitoring data for. They are not particular monitoring metrics, parameters, or activities. Gaps are particular monitoring metrics, parameters, or activities that are not being measured/done.

Start by coding child-codes (e.g., A1.1a) as follows: 0 absent, 1 present, 97 unclear. Annotate text to mark where theme appears (if present) and keep notes in the spreadsheet to highlight important details. After child codes are complete, assign a code to parent code (e.g., A1.1) as follows: 0 absent, 1 at least one child code present.

- A1.1 Water management
  - A1.1a Water management general
  - A1.1b Water operations
  - A1.1c Water storage
  - A1.1d Water demand
  - A1.1e Water conveyance or infrastructure
  - A1.1f Groundwater protection and management
  - A1.1g Water management other (specify)
- A1.2 Flood management
  - A1.2a Flood management general
  - A1.2b Flood control structures
  - A1.2c Protection and expansion of floodways, floodplains, and bypasses
  - A1.2d Subsidence reversal
  - A1.2e Flood management other (specify)
- A1.3 Habitat management
  - A1.3a Habitat management general
  - A1.3b Habitat protection
  - A1.3c Natural environmental flows
  - A1.3d Habitat restoration
  - A1.3e Habitat management other (specify)
- A1.4 Native species management
  - A1.4a Native species management general
  - A1.4b Incidental mortality/take
  - A1.4c Harvest
  - A1.4d Population enhancement
  - A1.4e Management of specific native species (specify)
  - A1.4f Native species other (specify)
- A1.5 Introduced species
  - A1.5a Introduced species general
  - A1.5b Pathways of introduction
  - A1.5c Creation of favorable habitat conditions
  - A1.5d Population control
  - A1.5e Management of specific introduced species (specify)

  - A1.5f Introduced species other (specify)
- A1.6 Water quality
  - A1.6a Water quality general (including chemicals/contaminants)
  - A1.6b Wastewater management
  - A1.6c Pollution control (emphasis on control/reduction of contaminants)
  - A1.6d Water quality other (specify)
- A1.7 Land use management
  - A1.7a Land use management general
  - A1.7b Land zoning, designation, and ownership
  - A1.7c Specific land use (specify which land use)
  - A1.7d Land use management other (specify)
- A1.8 Other current management need (NOTE: include references to wildlife or general ecosystem goals in this category)
  - *0 Absent*
  - *1 Present (specify)*
  - *97 Unclear*

A2 Future management needs of organization

- A2.1 Water management
  - A2.1a Water management general
  - A2.1b Water operations
  - A2.1c Water storage
  - A2.1d Water demand
  - A2.1e Water conveyance or infrastructure
  - A2.1f Groundwater protection and management
  - A2.1g Water management other
- A2.2 Flood management
  - A2.2a Flood management general
  - A2.2b Flood control structures
  - A2.2c Protection and expansion of floodways, floodplains, and bypasses
  - A2.2d Subsidence reversal
  - A2.2e Flood management other
- A2.3 Habitat management
  - A2.3a Habitat management general
  - A2.3b Habitat protection
  - A2.3c Natural environmental flows
  - A2.3d Habitat restoration

  - A2.3e Habitat management other
- A2.4 Native species management
  - A2.4a Native species management general
  - A2.4b Incidental mortality/take
  - A2.4c Harvest
  - A2.4d Population enhancement
  - A2.4e Management of specific native species (specify)
  - A2.4f Native species other
- A2.5 Introduced species
  - A2.5a Introduced species general
  - A2.5b Pathways of introduction
  - A2.5c Creation of favorable habitat conditions
  - A2.5d Population control
  - A2.5e Management of specific introduced species (specify)
  - A2.5f Introduction species other
- A2.6 Water quality
  - A2.6a Water quality general (includes contaminants/chemicals)
  - A2.6b Wastewater management
  - A2.6c Pollution control (emphasis on control/reduction of contaminants)
  - A2.6d Water quality other
- A2.7 Land use management
  - A2.7a Land use management general
  - A2.7b Land zoning, designation, and ownership
  - A2.7c Specific land use (specify which land use)
  - A2.7d Land use management other
- A2.8 Other future management need (NOTE: include references to wildlife or general ecosystem goals in this category)
  - *0 Absent*
  - *1 Present (specify)*
  - *97 unclear*

Section B Monitoring gaps

B1 Topical gaps

Start by coding child-codes (e.g., B1.1a) as follows: 0 absent, 1 present, 97 unclear. Annotate text to mark where theme appears (if present) and keep notes in the spreadsheet to highlight important details. After child codes are *complete, assign a code to parent code (e.g., B1.1) as follows: 0 absent, 1 at least one child code present.*

- B1.1 Direct socio-economic drivers
    - B1.1a Water operations/exports
    - B1.1b Water storage
    - B1.1c Water use/demand
    - B1.1d Water conveyance/infrastructure
    - B1.1e Stormwater runoff/drainage
    - B1.1f Levees
    - B1.1g Dredging
    - B1.1h Recreation and tourism
    - B1.1i Water intakes, fish screens, and passage
    - B1.1j Agriculture
    - B1.1k Urban development
    - B1.1l Roads or bridges
    - B1.1m Rail lines
    - B1.1n Docks or ports
    - B1.1o Vessels or shipping channels
    - B1.1p Wastewater discharge
    - B1.1q Energy or mines
    - B1.1r Forest harvesting
    - B1.1s Socio-economic general
    - B1.1t Socio-economic other
- B1.2 Environmental drivers/conditions
    - B1.2a Surface water/flow
    - B1.2b Water temperature
    - B1.2c Salinity
    - B1.2d Conductivity
    - B1.2e Turbidity
    - B1.2f Water quality general
    - B1.2g Groundwater
    - B1.2h Subsidence
    - B1.2i Stage
    - B1.2j Sea level rise
    - B1.2k Snowpack
    - B1.2l Velocity
    - B1.2m Nutrients, energy, or food web (include zooplankton)
    - B1.2n Sediment- toxicity
    - B1.2o Nitrogen/ammonia

  - B1.2p Phosphorous
  - B1.2q Carbon
  - B1.2r HABs
  - B1.2s Suspended sediment
  - B1.2t Dissolved oxygen
  - B1.2u pH
  - B1.2v Contaminants
  - B1.2w Sediment – erosion
  - B1.2x Environmental general
  - B1.2y Environmental other
- B1.3 Habitats
  - B1.3a Floodplain
  - B1.3b Mudflats
  - B1.3c Saltwater/freshwater marshes
  - B1.3d Intertidal/transition zones
  - B1.3e Above highwater refugia
  - B1.3f Channelized habitat
  - B1.3g Riparian habitat
  - B1.3h Non-forested vegetation
  - B1.3i Tidal wetlands
  - B1.3j Terrestrial
  - B1.3k Shallows general
  - B1.3l Habitat general
  - B1.3m Habitat other
- B1.4 Species
  - B1.4a Communities or ecosystem perspective (general)
  - B1.4b Fish general
  - B1.4c Chinook salmon and steelhead
  - B1.4d Delta smelt
  - B1.4e Longfin smelt
  - B1.4f Green sturgeon
  - B1.4g Birds
  - B1.4h Invasive/non-native species
  - B1.4i Invasive fish
  - B1.4j Invasive plants
  - B1.4j Benthic invertebrates (include shrimp, unless clearly talking about zooplankton)
  - B1.4k Species general
  - B1.4l Species other

- B1.5 Other

B2 Temporal gaps

- *0 Absent*
- *1 Present (characterize in notes)*
- *97 Unclear*

B3 Geographical gaps

- *0 Absent*
- *1 Present (characterize in notes)*
- *97 Unclear*

B4 Technical gaps

This includes sampling design, analysis methods, and instrumentation, etc.

- *0 Absent*
- *1 Present (characterize in notes)*
- *97 Unclear*

Section C Barriers to addressing gaps

Code each category (e.g., C1) as follows: 0 absent, 1 present, 97 unclear. Annotate text to mark where theme appears (if present) and keep notes in the spreadsheet to highlight important details.

- C1 Funding (includes financial limitations, funding structure)
- C2 Siloed perspectives (e.g., individuals or organizations representing single or specific interests; specific motivations for monitoring)
- C3 Organizational structure/coordination
- C4 Staff capacity/expertise
- C5 Regulatory/legal (permits, monitoring to fulfill regulatory requirements)
- C6 Disinterest/low priority (individual or organizational)
- C7 Cultural resistance to change
- C8 Lack of political will (e.g., support from public, internal leadership, elected officials)
- C9 Communication
- C10 Perceived risks (e.g., of higher regulations; of losing current programs)
- C11 Lack of leadership

- C12 Certain entities not having a seat at the table
- C13 Time/effort required
- C14 Disconnect between monitoring and management needs (monitoring driven by scientific interest, rather than management needs; or generally not monitoring what we need for management)
- C15 Other (make note)

Section D Suggestions to address gaps

Annotate relevant text with code D and compile in separate document. After compiling all relevant text, cluster as appropriate. Create additional spreadsheet if necessary.

Section E Suggestions on monitoring for adaptive management

Annotate relevant text with code E and compile in separate document. After compiling all relevant text categorize into these bins. Create additional spreadsheet if necessary.

Section F Monitoring coordination and reorganization

F1 Management areas needing more coordination

Code each category (e.g., F1.1) as follows: 0 absent, 1 present, 97 unclear. Code all management areas discussed, even if they are mentioned in the same instance (e.g., if person discusses need to coordinate habitat management with native species management, assign 1 to F1.4 and F1.5). Annotate text to mark where theme appears (if present) and keep notes in the spreadsheet to characterize the coordination needs.

- F1.1 General need for coordination
- F1.2 Water supply management
- F1.3 Flood management
- F1.4 Habitat management
- F1.5 Native species management
- F1.6 Introduced species management
- F1.7 Water quality management
- F1.8 Land use management
- F1.9 Other coordination needs

F2 Barriers to coordination and/or challenges of re-organization

Code each category (e.g., F2.1) as follows: 0 absent, 1 present, 97 unclear. Annotate text to mark where theme appears (if present) and keep notes in the spreadsheet to highlight important details.

- F2.1 Funding (includes financial limitations, funding structure)
- F2.2 Silos (e.g., individuals or organizations representing single or specific interests; specific motivations for monitoring)
- F2.3 Organizational structure/coordination
- F2.4 Staff capacity/expertise
- F2.5 Regulatory/legal (permits, monitoring to fulfill regulatory requirements)
- F2.6 Disinterest/low priority (individual or organizational)
- F2.7 Cultural resistance to change
- F2.8 Lack of political will (e.g., support from public, internal leadership, elected officials)
- F2.9 Communication
- F2.10 Perceived risks (e.g., of higher regulations; of losing current programs)
- F2.11 Lack of leadership
- F2.12 Certain entities not having a seat at the table
- F2.13 Time/effort required (includes challenges of building relationships/trust)
- F2.14 Disconnect between monitoring and management needs (monitoring driven by scientific interest, rather than management needs; or generally not monitoring what we need for management)
- F2.15 Other

F3 Suggestions for coordination

Annotate relevant text with code F3 and compile in separate document. After compiling all relevant text, cluster as appropriate. Create additional spreadsheet if necessary.

F4 Role of current organization in improving coordination/reorganization

Code F4 as follows: 0 no role, 1 some role(s), 97 unclear.

For child codes (e.g., F4.1), code as follows: 0 absent, 1 present, 97 unclear, 99 N/A (F4 coded 0). Annotate text to mark where theme appears (if present) and keep notes in the spreadsheet to highlight important details.

- F4.1 General
- F4.2 Leadership role
- F4.3 Supporting role as participant
- F4.4 Facilitator role (helping others convene/coordinate)
- F4.5 Advocate for coordination
- F4.6 Other role (specify)

F5 Other organizations involved in improving coordination/reorganization

Code F5 as follows: 0 no other organizations named, 1 some organization(s) named, 97 unclear.

For child codes (e.g., F5.1), code as follows: 0 absent, 1 present, 97 unclear, 99 N/A (F4 coded 0). Annotate text to mark where theme appears (if present) and keep notes in the spreadsheet to track which organizations were named, and other relevant details.

- F5.1 General
- F5.2 Leadership role
- F5.3 Supporting role as participant
- F5.4 Facilitator role (helping others convene/coordinate)
- F5.5 Advocate for coordination
- F5.6 Other role (specify)

F6 Mechanisms of reorganization

Code each category (e.g., F6.1) as follows: 0 absent, 1 present, 97 unclear. Annotate text to mark where theme appears (if present) and keep notes in the spreadsheet to highlight important details.

- F6.1 Financial
- F6.2 Regulatory
- F6.3 Other (specify)

F7 Examples from other systems of improved coordination/re-organization

- *0 No*
- *1 Yes (specify)*

- *97 Unclear*

Section G Other important content both

Annotate relevant text with code G only if it does not belong in any of the coding categories above but is important not to lose. After coding is complete, compile all text marked G in a separate document and cluster/code as appropriate. Create a separate spreadsheet if necessary.

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