Governing the Delta Science Enterprise: Results from a Stakeholder Survey

Mark Lubell, Tara Pozzi

Center for Environmental Policy & Behavior
Department of Environmental Science and Policy
University of California, Davis

Tanya Heikkila

Co-Director, Center for Policy and Democracy
School of Public Affairs
University of Colorado Denver

Andrea K. Gerlak

Director, Udall Center for Studies in Public Policy
University of Arizona

Final Report

Cite as: Lubell, Mark, Tara Pozzi, Tanya Heikkila, and Andrea Gerlak. 2022. "Governing the Delta Science Enterprise: Results from a Stakeholder Survey." *Center for Environmental Policy and Behavior, UC Davis.*

Table of Contents

List of Figures

List of Tables

Executive Summary

This report summarizes the results from a survey of California Bay-Delta science enterprise stakeholders conducted in 2021 by researchers from the University of California-Davis, University of Colorado-Denver, and University of Arizona. The goal of the survey is to analyze how science enterprise governance contributes to adaptive management and learning in the Delta. The survey was conducted in collaboration with the Delta Science Program, and the design was reviewed by Delta science experts. The Delta Science Program is the core organization of the Delta science enterprise: "the collection of science programs and activities that exist to serve managers and stakeholders in a regional system. The elements of an enterprise range from in-house programs within single agencies or other organizations to large-scale collaborative science programs funded by governments, to academic research that may operate independently of management and stakeholder entities" (Delta Stewardship Council, 2018).

The survey targeted 16 Delta science enterprise programs and received 180 useable responses. Most respondents participate in the Interagency Management Program (IEP) Work Team, followed by the California Water and Environmental Modelling Forum (CWEMF), Interagency Ecological Program (IEP) Management Team, and California Water Quality Monitoring Council (CAWQMC). The survey revealed the following initial findings, which this report details in more depth:

Science Enterprise Characteristics

- The Delta science enterprise involves individuals and organizations who spend a substantial amount of professional effort on Delta science and have a high degree of competence across multiple Delta issues.
- The Delta science enterprise is dominated by state and federal agencies that have responsibility for Delta management, as well as scientific experts from private consultants, science organizations, and universities.

Issues

- There is a mix of scientific agreement on Delta management issues, with the most agreement on invasive species, climate change, and floodplain management. Significant scientific disagreement exists for Delta issues that have traditionally been a source of conflict, such as water supply reliability, fisheries, and ecosystem restoration. Substantial disagreement also exists on social science topics that have historically received less scientific attention.
- Most stakeholders agree on the important role that science and government play in environmental management.

Science Forums

- Although there is limited data to compare individual science forums, there is some evidence of the functional specialties of particular forums such as the Interagency Ecological Program, which has developed a long history of monitoring Delta ecological conditions.

- Most stakeholders were satisfied with their science forum experience, with some dissatisfied with presence of financial resources, level of staffing, and engagement with Delta stakeholders.

Adaptive Management and Learning

- The Delta science enterprise is perceived as making substantial contributions to adaptive management, with the most progress on the "plan" and less progress on the "do" and "evaluate and respond" stages. However, science communication and data/analysis synthesis play a central role throughout the adaptive management cycle.
- The science enterprise has facilitated more learning about the environmental and social drivers of Delta management issues, but less learning about the science needs of stakeholders and how science governance links science to policy decisions. The Delta science enterprise has facilitated learning on five key topics: Delta smelt, aquatic invasive species, floodplain restoration/anadromous fish, nutrients/water quality, and Delta flows/water infrastructure.

Future Directions

- The top science need suggestions included a climate adaptation plan, effective science communication, fish community dynamics, and integration of social science.
- The top priority suggestions included a centralized management agency, increased science communication to diverse audiences, innovative and sustained funding structure, and a data hub.

A Central Recommendation: Science Enterprise Leadership Consortium

While the survey results may support or stimulate discussion of a wide range of potential recommendations, one central recommendation deserves attention: the development of a Science Enterprise Leadership Consortium (SELC). Stakeholders reported low levels of confidence in their knowledge of how the science enterprise is governed and links science to policy. Many people participate in multiple science forums with a focus on science communication and synthesis. Yet, our findings and experience in the Delta science enterprise point to a need for better integration of scientific workflows and models, the development of a "collaboratory", and more communication across the science enterprise. This is coupled with a desire for a more consistent funding stream and associated targets.

We recommend the development of a SELC to facilitate these goals and overcome some of the science enterprise challenges. The science enterprise is composed of multiple collaborative forums, and each collaborative forum has its own associated leadership. The leadership of the collaborative forums, and probably other important science agencies such as United States Geological Survey, can be convened as members of the SELC. They could meet quarterly to discuss the overall activities happening in the science enterprise, educate each other about the roles and capacities of their respective forums, and find opportunities for collaboration. The deliberations of SELC could also focus on more formal structural and funding changes in the science enterprise, such as the potential for a Joint Power Authority or better alignment of the various science enterprise products like the Science Needs Assessment, Delta Science Plan, Science Action Agenda, and State of Bay-Delta Science.

Introduction

This report summarizes the results of a survey of stakeholder participation in the Delta science enterprise and their perceptions of its effectiveness in supporting adaptive management. The goal of the survey is to analyze how science enterprise governance contributes to adaptive management and policy learning in the Delta. The California Delta is the largest estuary on the West Coast of the US that spans 1300 square miles with a watershed of 45,000 square miles including the Sacramento and San Joaquin River. The water supply from the Delta supports two thirds of the state's population with drinking water and three million acres of irrigated agriculture. The large demands are met with complex infrastructure systems for storage and conveyance of water. Concurrently, the Delta experiences multiple environmental problems that are magnified by climate change and urbanization.

The Delta Stewardship Council (DSC) was established in 2009 as the primary state agency tasked with managing this complex ecosystem. The DSC acts as a centralized governance institution to pursue "co-equal goals" of water supply reliability and ecological sustainability. One avenue for carrying out these goals is through the Delta Science Program (DSP). With the mission of "One Delta, One Science", the DSP works at the nexus of science, policy making, and management of the Delta. Its programming includes research funding and fellowships, independent scientific peer review, science synthesis, adaptive management, and science communication.

The Delta Science Program is at the core of the overall Delta science enterprise, which is a polycentric governance system that connects stakeholders (e.g., scientists, academics, practitioners, and policymakers) across agency and policy venues to collaborate on Delta management topics. This report focuses on individual perceptions about the Delta science enterprise and governance issues. The data contained in this report results from a survey on Delta science governance that was conducted in 2021. 180 individuals completed the survey questions presented here. Their affiliations include agencies at all levels of government, water districts, non-governmental organizations, and academics, among others.

Research Background

The science enterprise survey emerged from a history of collaborative research between the principal investigators and the Delta Science Program. The first research effort involved Co-PI Lubell collaborating with Delta Science Program staff to integrate social science into the Delta Science Plan (Delta Stewardship Council, 2019). Delta Science Fellow Matthew Robbins developed an initial network map (Figure 1) of the Delta Science Enterprise using key informant interviews to identify the science venues and online documents to identify participants in each venue. The results demonstrate the polycentric nature of the science enterprise, with diversity of stakeholders involved in multiple policy venues. The central actors are the state and federal agencies that fund and use science information in policy decisions, while the central venues are programs designed to coordinate multiple agencies, such as the Interagency Ecological Program (IEP) and Delta Plan Interagency Implementation Committee (DPIIC).

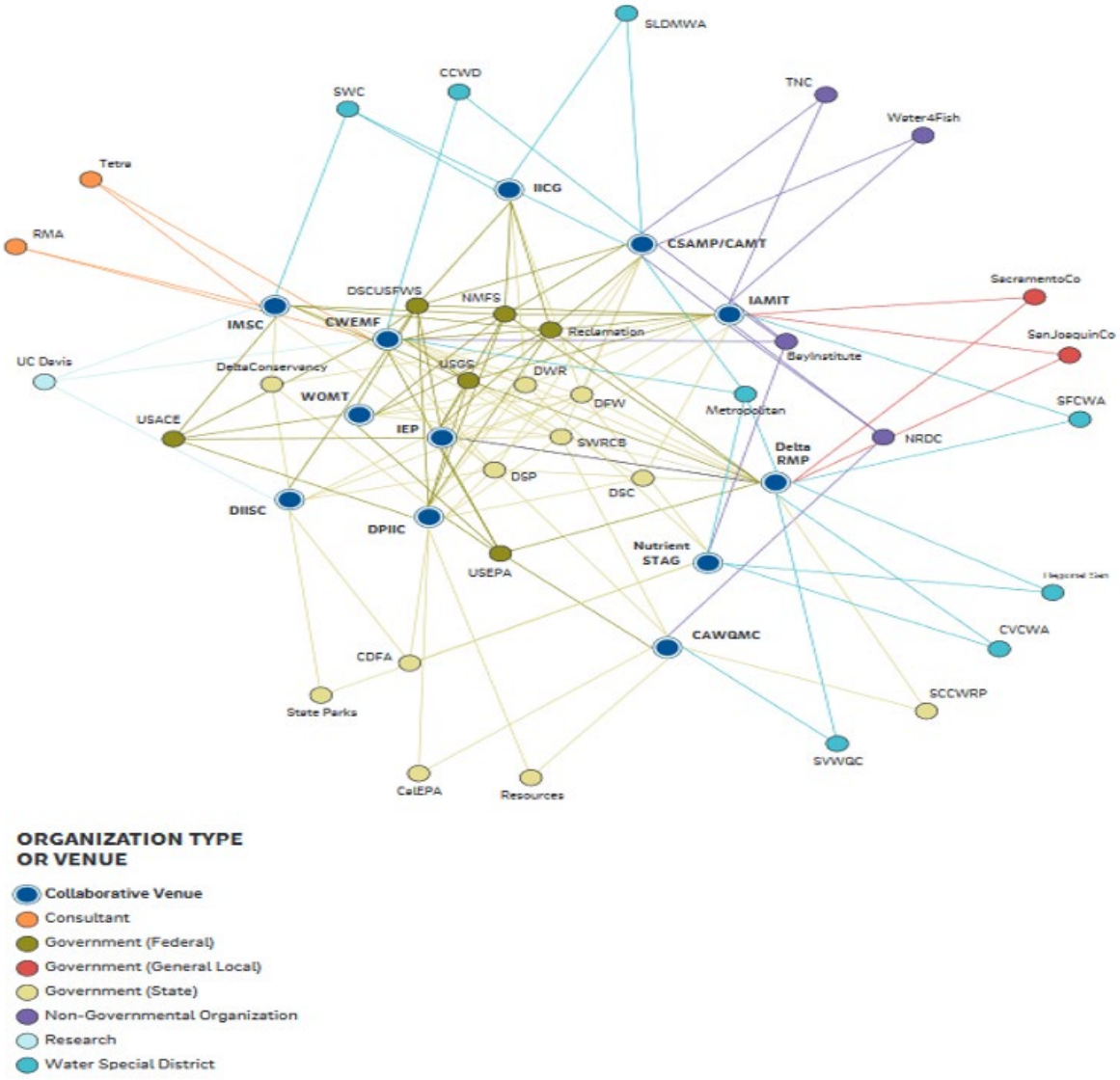

Figure 1: *Pilot Study Network Map of CA Delta Science Enterprise, from 2019 Delta Science Plan.*

The second research effort was a "Science Governance" workshop in January of 2020, with 20 stakeholders in the California Delta science enterprise, to explore catalysts and barriers to learning (Lubell and Heikkila, 2020). Workshop participants engaged in a guided discussion about the nature of the scientific enterprise and examples of learning in the Delta. Stakeholders identified several issue areas around which they observed learning, such as floodplain restoration and the role of human dimensions in ecosystem management. Stakeholders further identified elements of science governance that they believed supported learning, such as trusting relationships and ongoing dialogue across different science venues. Additionally, the workshop elicited examples of how the governance structure can impede learning, such as fragmentation of scientific efforts and limited resources. Workshop participants also described

notable differences between types of learning outcomes (e.g., technical learning versus political learning). The workshop helped us refine the design of the survey, and the key concepts it seeks to measure.

The third research effort was a Science Governance focus group that was conducted as part of the Delta Science Needs Assessment process in 2020. Participants answered a real-time "Mentimeter" survey in which they were asked to "Please define science governance". To construct the collective "mental model" of science governance, we coded the core concepts that appeared in the written answers and counted the number of times the concepts co-occurred. For example, if the concepts "workflow" and "structure" appeared together in one definition they are considered co-occurring.

- Structure/Process: Governance is an institutional structure that shapes the process of decision-making with respect to science. Policy scientists typically think about institutional structure as a set of rules, which means the devil is in the details about what exact rules there should be.
- Inform: Science should effectively inform policy and support decisions.
- Prioritization: Governance should prioritize the research questions and issues.
- Coordination: Governance should coordinate across groups of actors; a key process.
- Workflow: Governance should link various aspects of the scientific workflow (e.g., models and data integration). We pulled out workflow as a specific item because respondents often mentioned concrete aspects of science such as data.
- Representation: Governance defines the group of people or organizations who have the authority to shape decision-making.

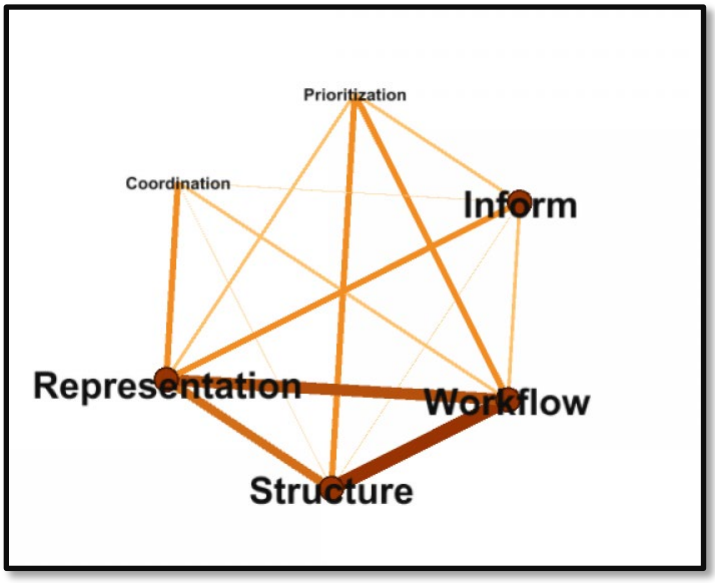

Figure 2: *The Mental Model of Science Governance.*

The results show that stakeholders are concerned about the relationship between governance structure and which actors are represented in the science enterprise, and how those actors will work together to integrate various aspects of the scientific workflow. The Mentimeter poll also asked stakeholders to identify potential solutions to science governance challenges, and the two main themes mentioned were leadership and trust, which are concepts that are measured in the survey.

Survey Methodology

The survey was launched on September 20th, 2021 and closed on November 24th, 2021. We disseminated the survey electronically through science forum leads. These forum leads then emailed the survey to their forum-specific electronic distribution list. This contact list included 16 different science forums in the Delta, along with the Delta Science Program listserv. We coordinated with forum leaders to distribute email invitations to their electronic distribution lists. The initial invitations were followed up with three reminders to encourage responses. (Responses per day are shown in Figure 3 below.) Although it would be preferable to manage a global list of individual respondents, most Delta science leaders were uncomfortable sharing their lists due to privacy concerns. As a result, we cannot calculate a formal response rate because we are unsure of how many individuals received the survey invitations. In the future, we believe this type of research will be more successful if we are given access to the full contact lists for all of the science forums.

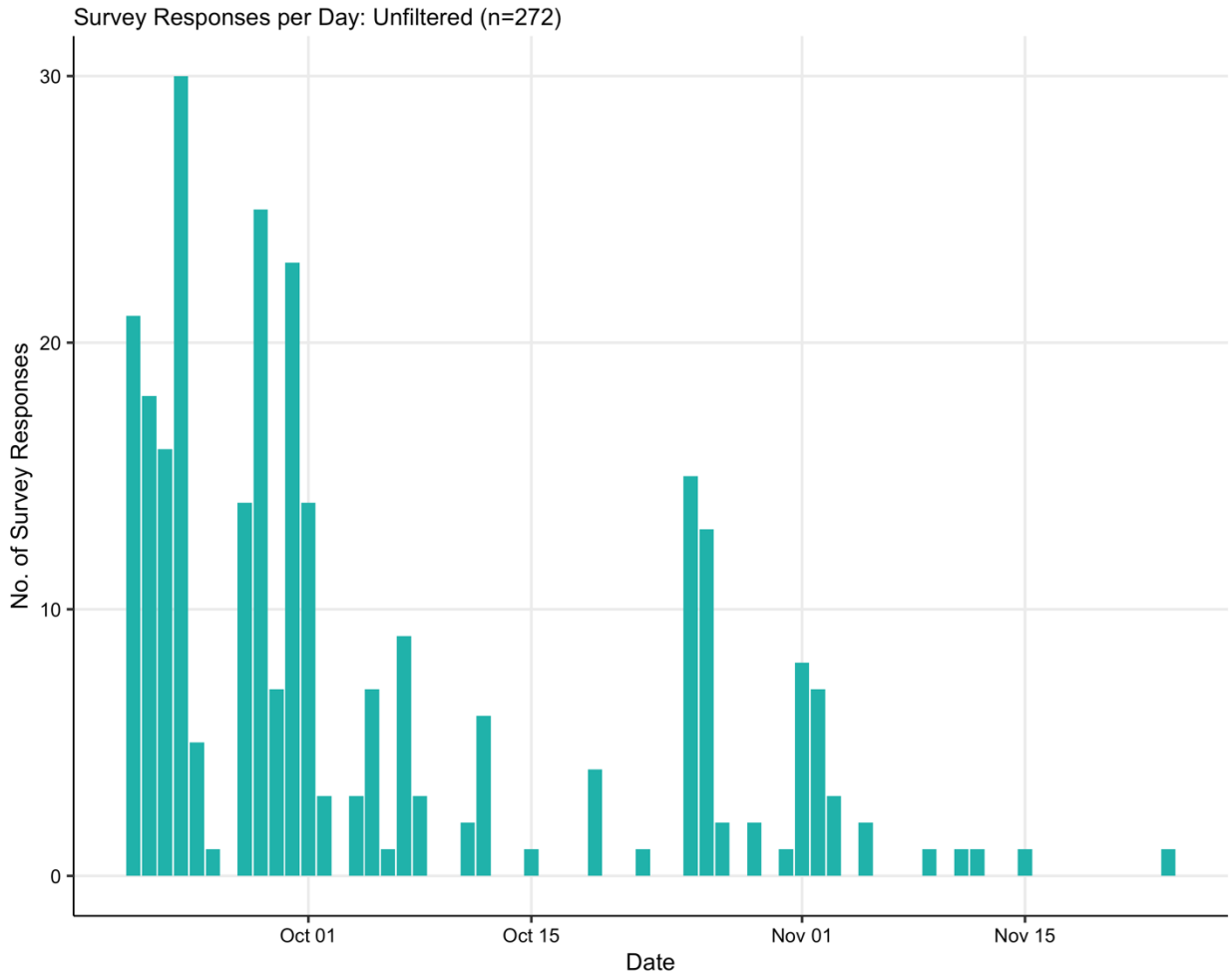

Figure 3: *Number of responses per day survey was open.*

As shown in Figure 4, we received responses from 13 Delta science enterprise forums, which was collected by tracking the survey responses attributed to the specific link assigned to each forum. We obtained 272 responses, of which 222 were responses that met the survey's screening question of being a Delta stakeholder; however, only 180 of those responses completed the survey. Based on this, most respondents are from Interagency Management Program (IEP) Work Team, the California Water and Environmental Modelling Forum (CWEMF), the Interagency Ecological Program (IEP) Management Team, and California Water Quality Monitoring Council (CAWQMC). The size of the science venues varies substantially—some are large like the IEP while others, like the ISB, have very few members. A potentially confusing aspect of the response tracking is that we cannot always differentiate between forum and sub-forums, such as CSAMP and CAMT. However, questions later in the survey allow the respondents to indicate all the different forums in which they have participated, as well as the primary forum they spend the most time. Overall, the number of respondents appears roughly proportional to forum size and the sample is broadly representative of the Delta science enterprise actors involved with addressing the Delta's issues.

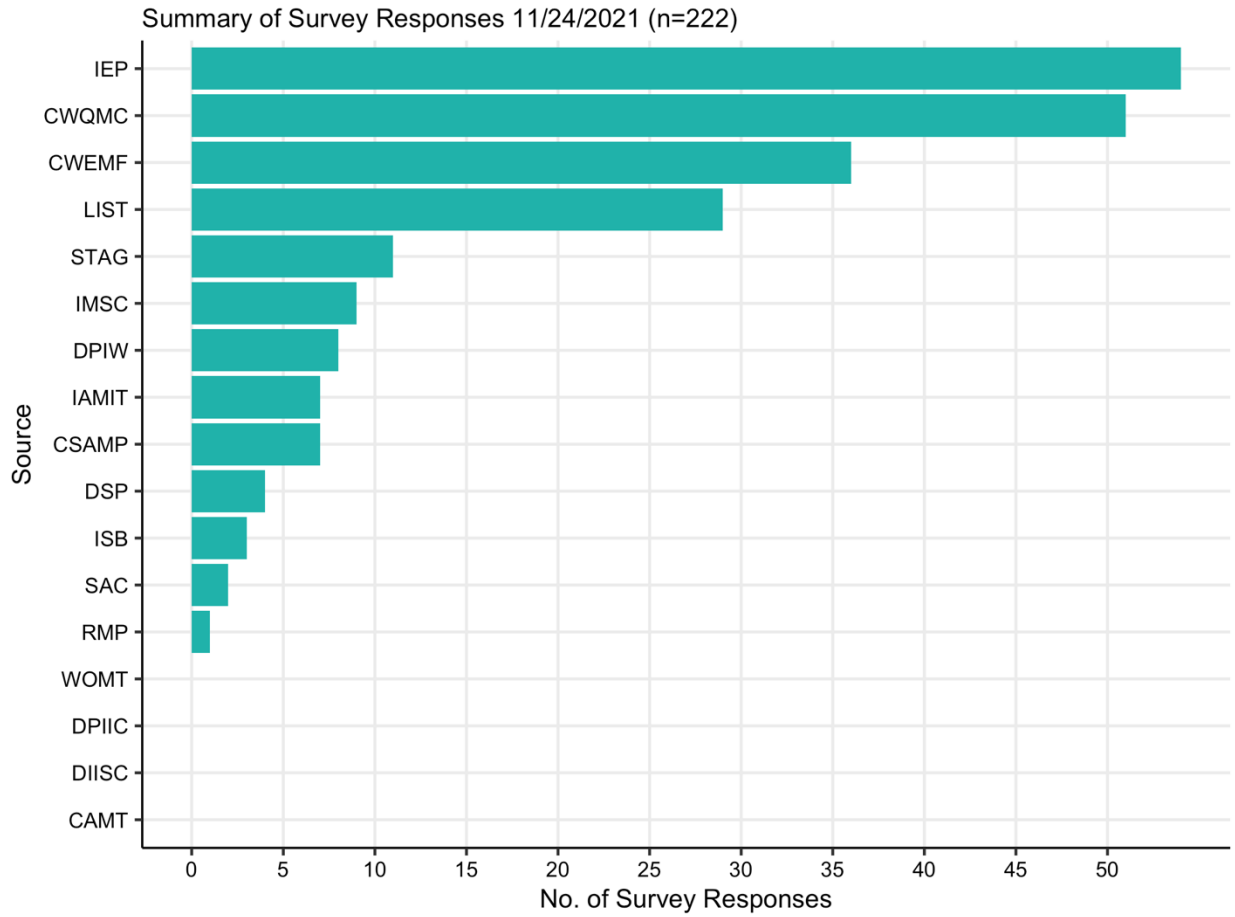

Figure 4: *Number of survey respondents by science forum.*

Respondent Characteristics

To better understand the individuals who took the survey, one question asked respondents about their level of involvement in the Delta science enterprise and another question asked about the primary organization they represent or work for. Almost 44% of respondents said that the Delta science enterprise is a major part of their work, which provides confidence that the opinions expressed in the survey represent a significant amount of experience (Figure 5).

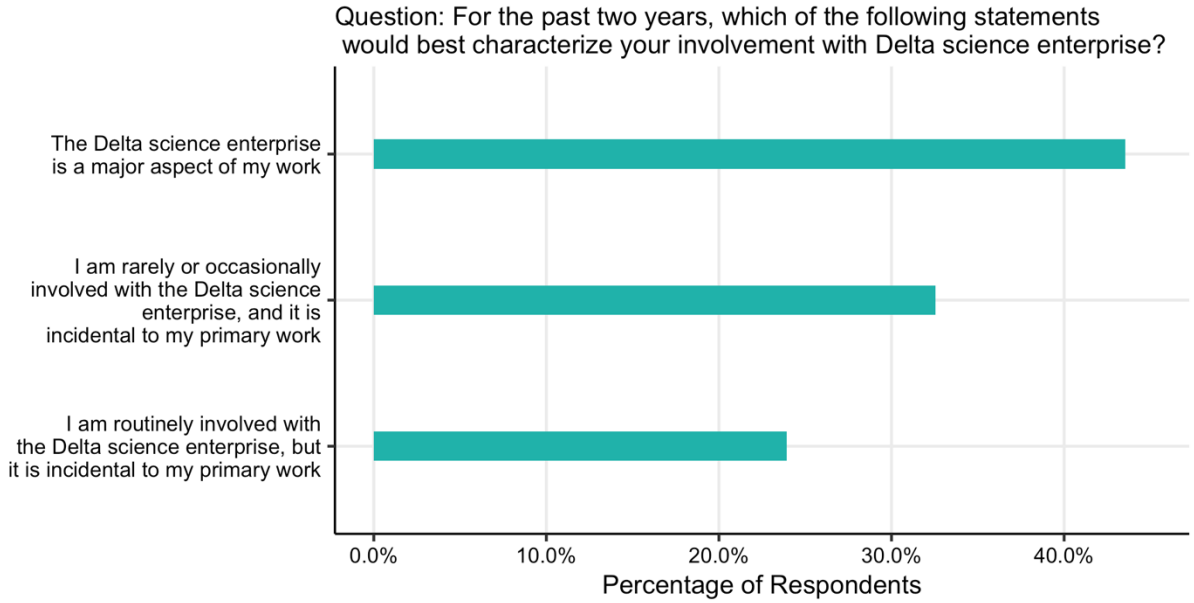

Figure 5: *Respondents' level of involvement with the Delta science enterprise.*

The respondents represent a broad diversity of types of organizations, as shown in Figure 6. The largest number of respondents represent state government. Consulting and research organizations are the second highest category of respondents, followed by academia, the federal government, and water special districts. The dominance of state government respondents reflects the high capacity of California environmental policy and the central role of the Delta Stewardship Council and Delta Science Program. Unlike a survey that would focus on Delta resource management, the Delta science enterprise has a high number of consultants and academic researchers—the knowledge workers who produce and disseminate science in the Delta. While there is a lot of overlap between organizations involved in the science enterprise, and organizations that are involved with Delta management including elected officials, the two communities are not exactly the same.

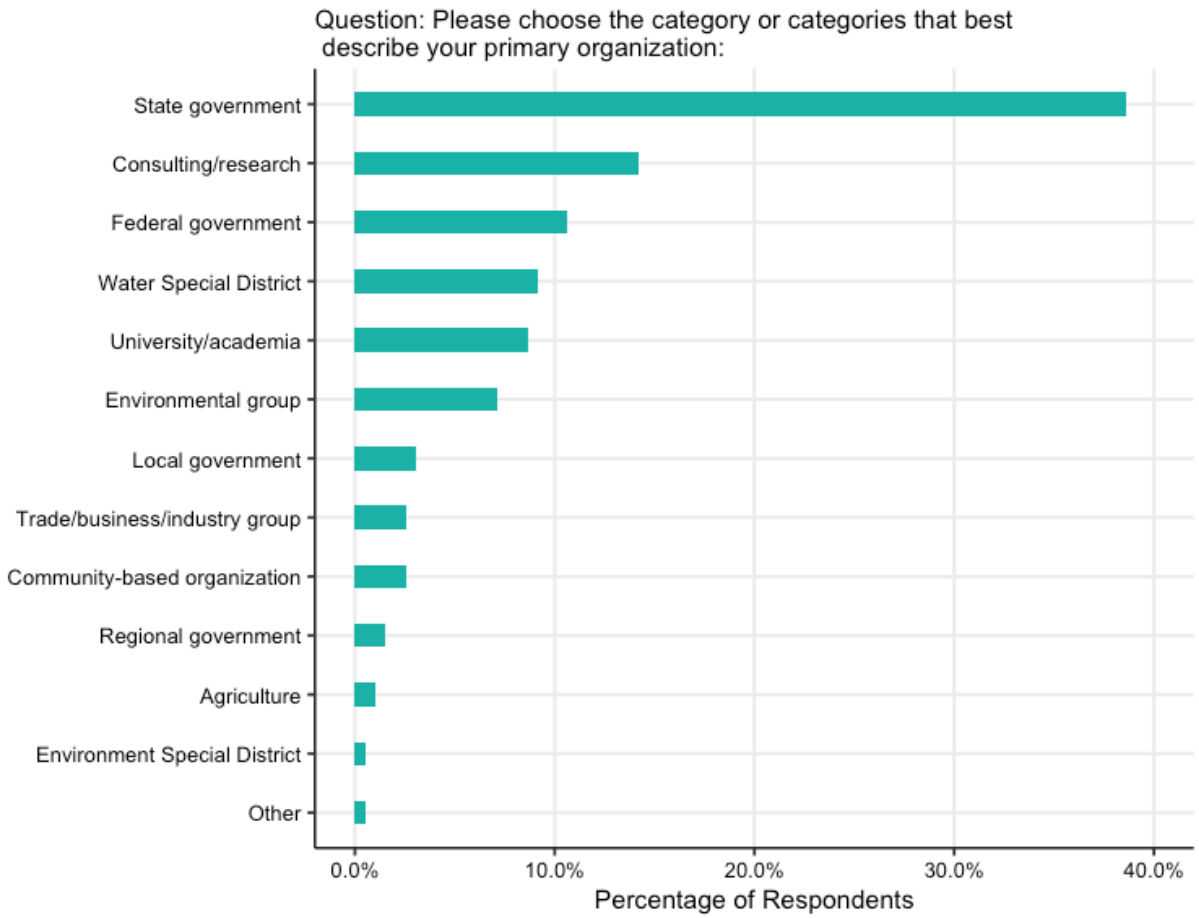

Figure 6: *Respondents' primary organization.*

Figure 7 reports a breakdown of the count of our survey respondents by Delta science and management issues. Respondents reported working on an average of four different issues. The largest number of respondents (n = 112) work on water quality and/or contaminants. Climate change, ecosystem restoration, and fisheries are the next most common issues that people work on. Economic development was reported as having the least number of respondents (n = 23) working on the issue. Social science issues receive much less emphasis overall than environmental issues, although environmental justice is the most frequent social science issue.

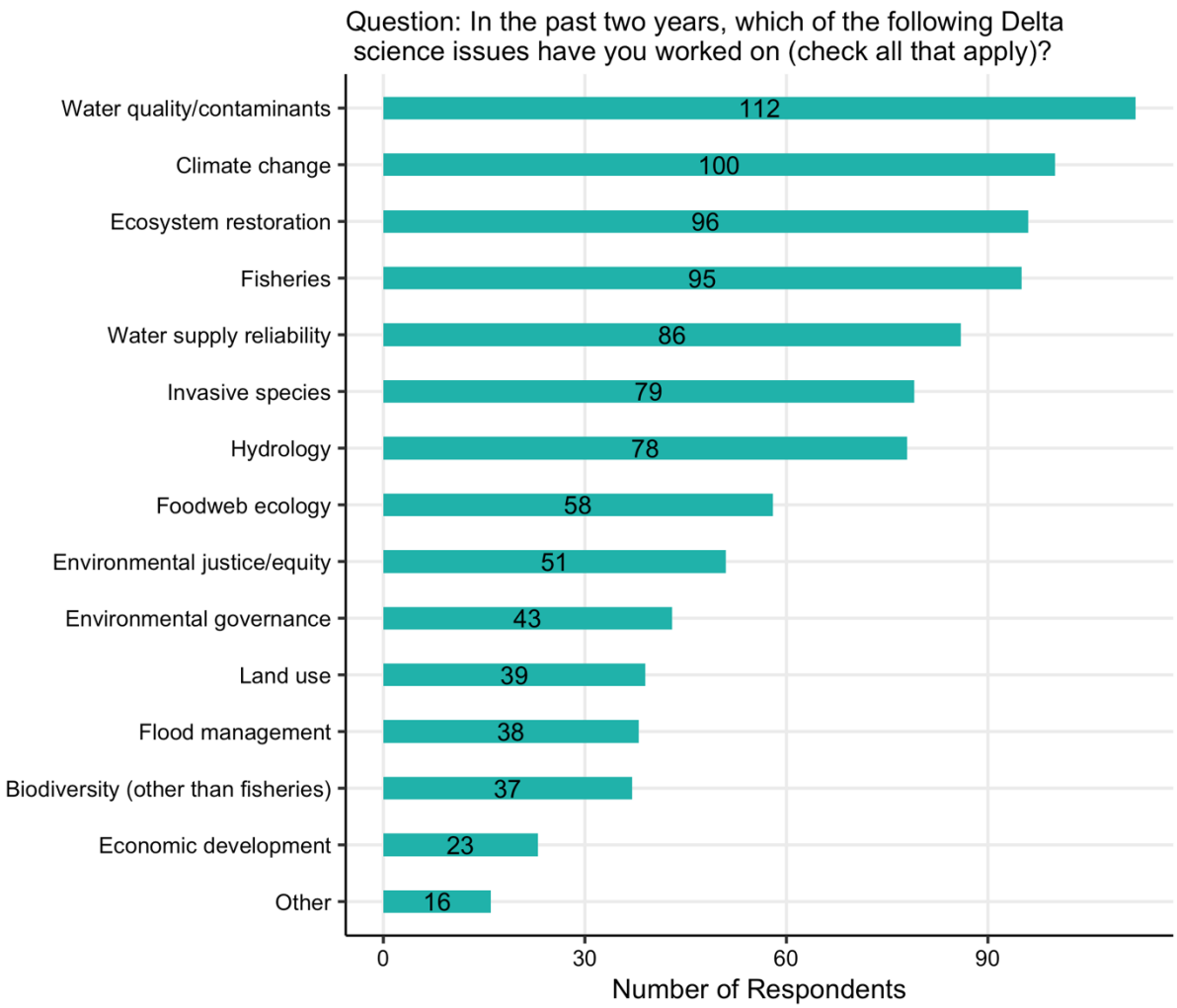

Figure 7: *Delta science issues respondent's work on.*

On average, respondents have worked on Delta science issues for 9 years. The majority of respondents hold a doctoral degree (46%) and are male (57%). Although we did not collect information about race or ethnicity, they should be considered in the future as indicators of diversity.

Figure 8 summarizes the variety of experiences that respondents have interacting with science in the Delta. The responses indicate that people fill multiple roles in the science enterprise; all respondents reported having at least one of these experiences, whereas others reported up to nine (n = 3). Respondents reported an average of three different experiences. The largest number of respondents (15%) reported facilitating science communication. Use of science to support management decisions and synthesis of science for use by others were the second (14.7%) and third (14.2%) most reported experiences. Conducting original research and using science for advocacy are infrequently selected, with the least number of respondents (8%) assessing the state of research in the Delta. Overall, the main functional activities of the science enterprise are facilitating the spread of knowledge and linking science to policy rather than directly conducting research.

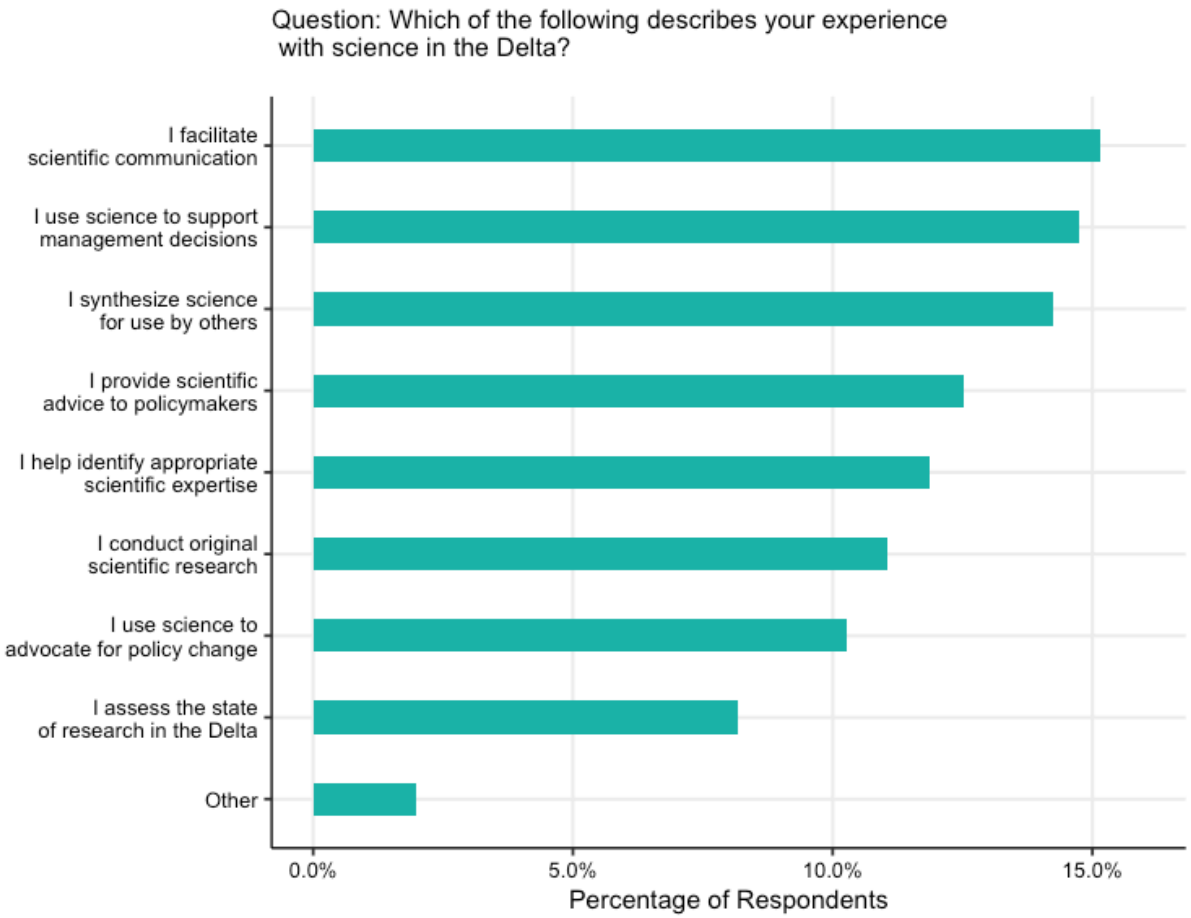

Figure 8: *Respondents' experience with science in the Delta.*

Respondents indicate a high level of self-reported competence across all Delta issues. In a question asking them to rate their competence, most respondents indicated expert or high competence for the issues they work on (Figure 9). The highest number of respondents reported "expert" competence in climate change (n=32), followed by fisheries (n=24), ecosystem restoration (n=23), and hydrology (n=22). Whereas the highest number of respondents reported "high" competence in water quality/contaminants (n=57), ecosystem restoration (n=49), and fisheries (n=46). There was the lowest number of "expert" competence in economic development (n=4) and land use (n=4) and lowest number of "high" competence in economic development (n=11) and flood management (n=17).

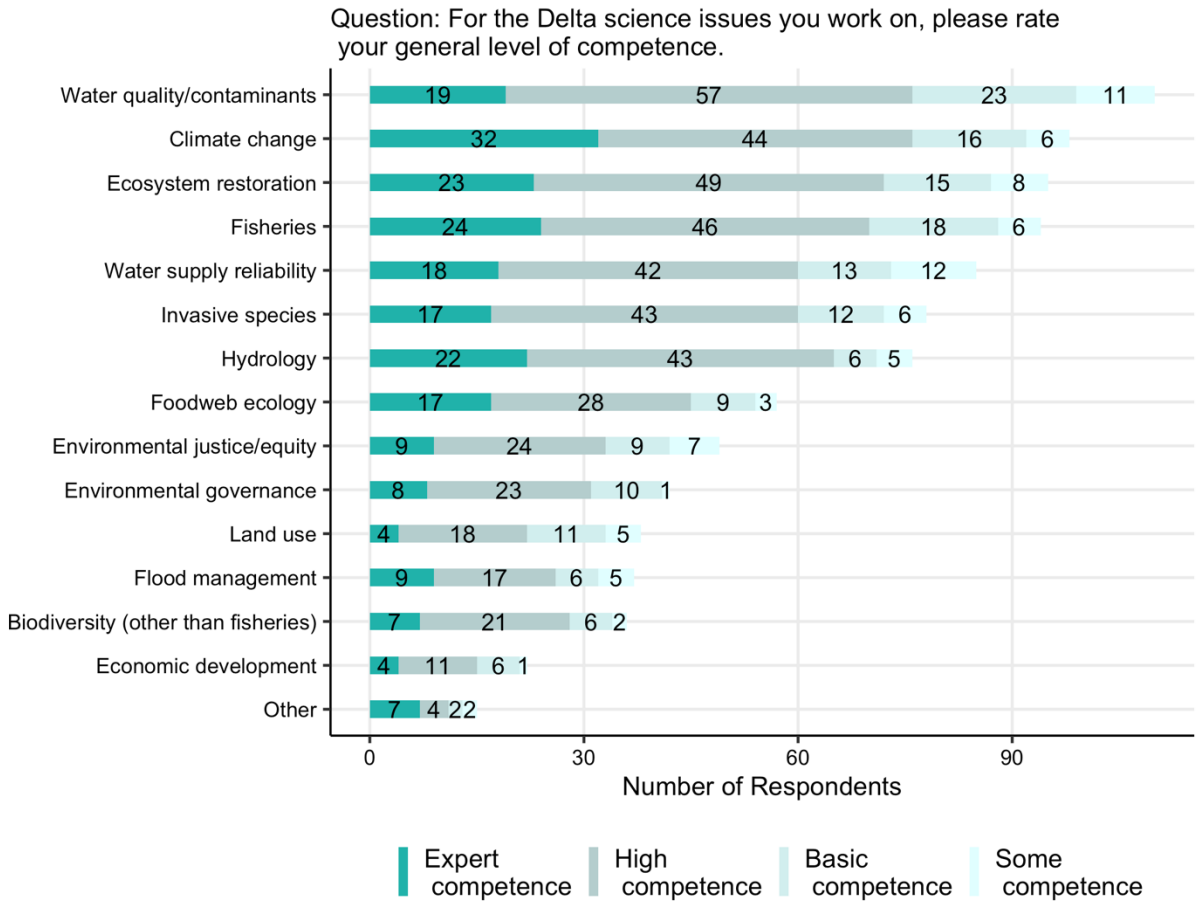

Figure 9: *Respondents' level of competence in Delta science issues.*

Science Enterprise Collaboration and Learning

The science enterprise brings together actors from disparate organizations to collaborate and learn from each other. Given the interdisciplinary and multi-organizational nature of Delta issues, the survey asked a question about the level of agreement regarding the main areas of work in the Delta. Such agreement can potentially indicate where collective learning in the system has occurred. The sliding response scale ranged from 0-100, with 0=Significant Disagreement and 100=Significant Agreement. As highlighted in Figure 10, the only three issues where respondents report more agreement than disagreement are invasive species, climate change, and flood management. In contrast, there is significant disagreement on ecosystem restoration, fisheries, land use, environmental justice/equity, environmental governance, and water supply reliability. Water supply reliability, ecosystem restoration, and fisheries are traditionally the heart of the policy conflict in the Delta. The social science issues have not received as much scientific attention as other issues. Connecting land-use and water management is also a challenging issue, which is often the target of integrated watershed management.

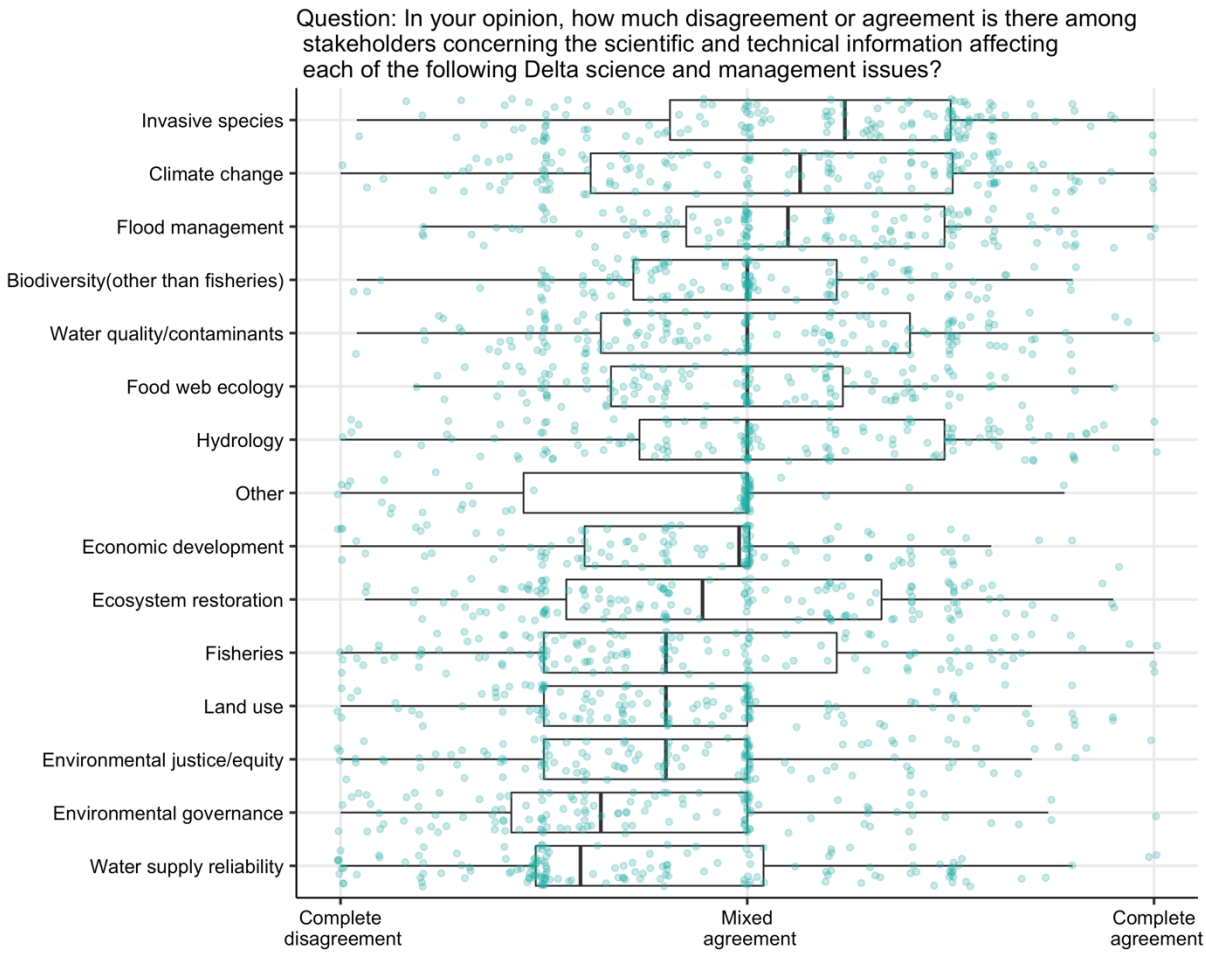

Figure 10: *Perceived level of stakeholder agreement around scientific and technical information affecting Delta science and management issues.*

How stakeholders perceive the appropriate role and legitimacy of the relationship between science and policy influences how they participate in the science enterprise and their perceptions of its performance. Figure 11 reports the results of several questions about respondents' views about science and policy. Overall, a majority agree that science and government are important components of environmental management. Almost unanimously, respondents report that policy decisions ought to involve input from the affected stakeholders. However, they agree less on the idea that scientists should express their opinions about management implications. This reflects the argument that science should only analyze the causes and effects of policies rather than engage in value debates. The least amount of agreement was reported for scientists integrating social equity into their research process, but 67% still agreed.

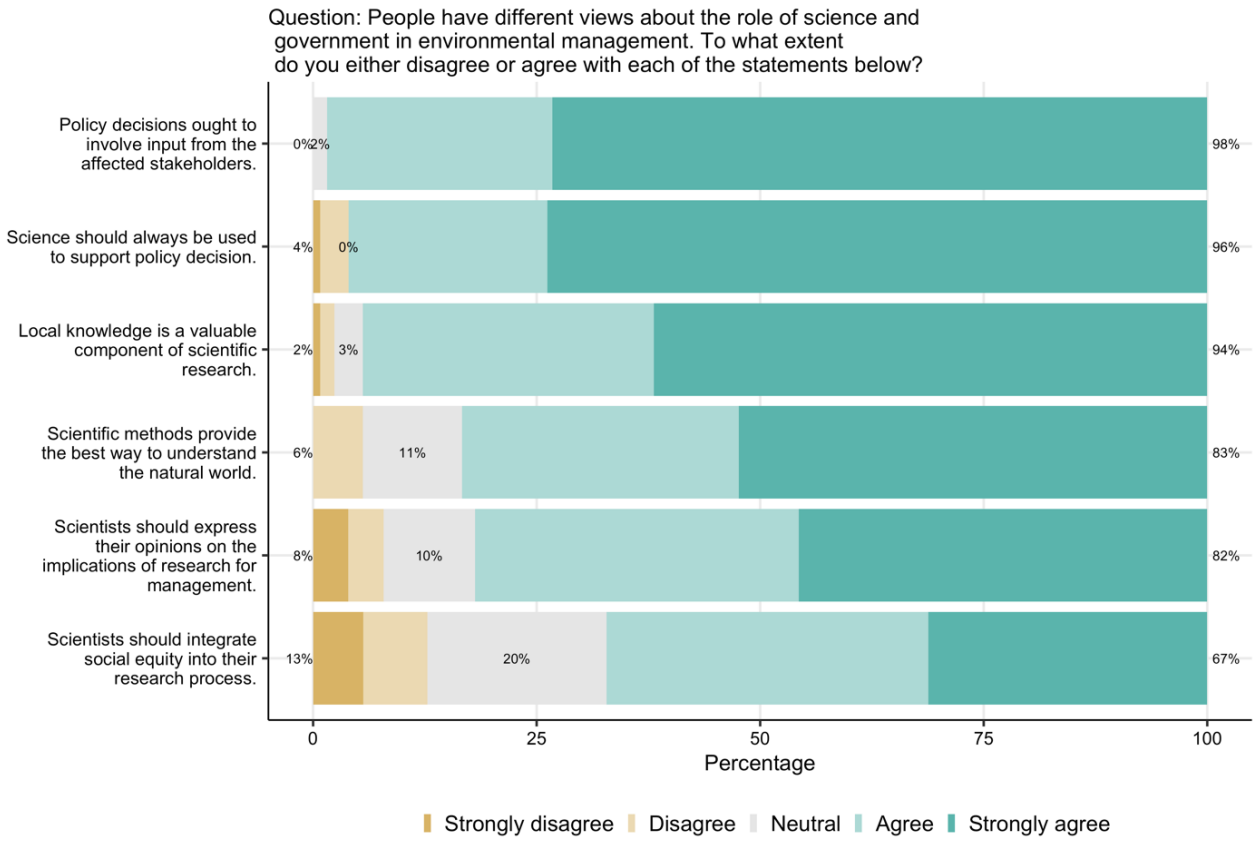

Figure 11: *Respondents' views regarding the role of science and government in environmental management.*

The overall goal of the science enterprise is to enable collective learning and enhance the capacity for adaptive management. Learning for adaptive management includes understanding the biophysical and social aspects of the system, and how science links to policy. One survey question asked respondents to report which areas they have gained a better understanding of Delta science issues. As indicated in Figure 12, respondents reported the highest levels of agreement (87%) for gaining a better understanding of the drivers or effects of Delta issues. Respondents also substantially agreed that they were exposed to multiple scientific disciplines and learned about how human behaviors affected the Delta. In contrast, there were lower levels of agreement for understanding how the science enterprise functions and links to policy decisions. These findings suggest that science enterprise stakeholders need to be educated about the overall concept of the science enterprise, and the conditions under which science does or does not link to policy.

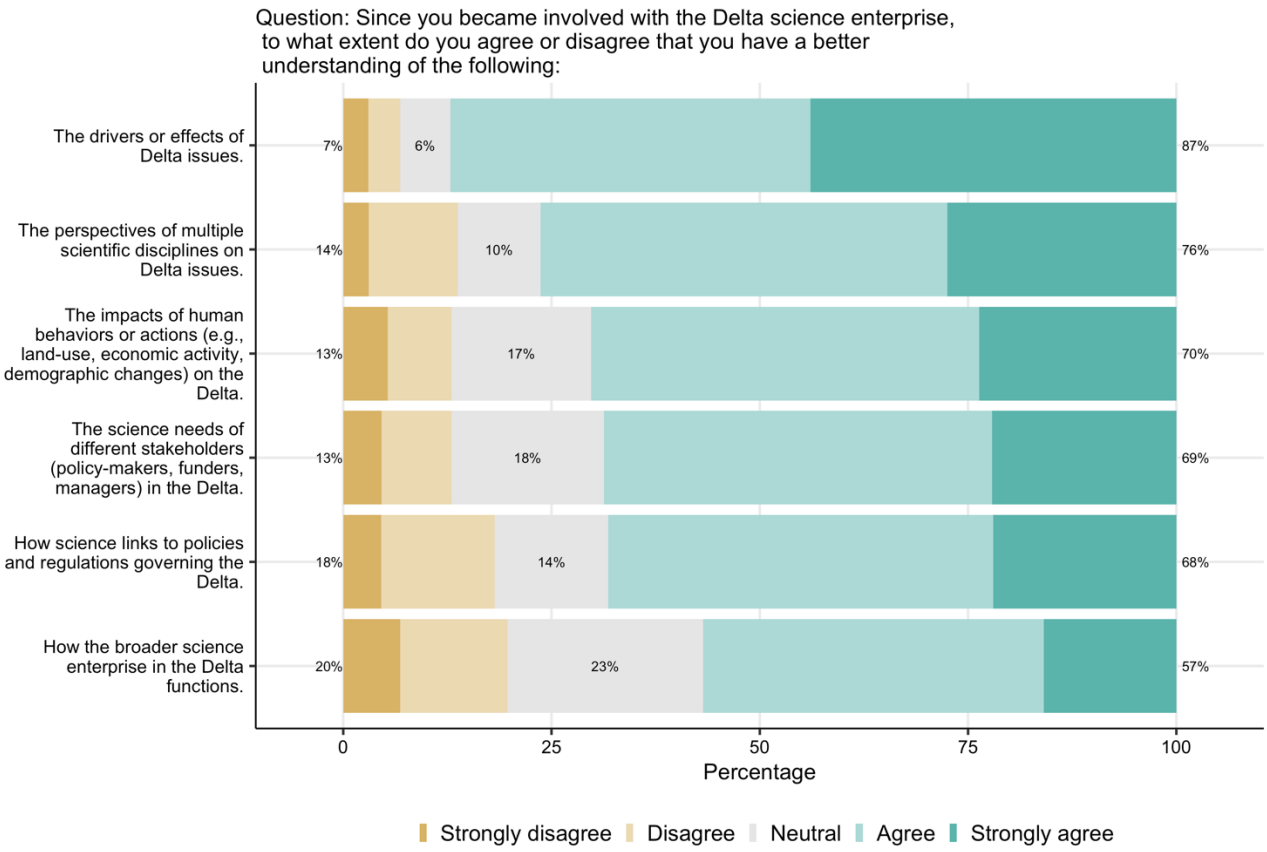

Figure 12: *Respondents' understanding of the Delta science enterprise.*

One question on the survey asked respondents to report how well the Delta science enterprise has achieved various goals of the program (see Figure 13). Respondents reported the highest levels of satisfaction in the enterprise's ability to integrate different types of science to improve understanding of the Delta ecosystem (54% satisfied or strongly satisfied), as well as the enterprise's ability to address conflictual issues (51%). The lowest levels of satisfaction were reported regarding making sufficient progress on identifying solutions to problems in the Delta (59% somewhat dissatisfied or very dissatisfied), in monitoring policy implementation (56% somewhat dissatisfied or very dissatisfied) and interpreting the management or policy implications from science in the Delta (50% somewhat dissatisfied or very dissatisfied). These findings suggest that respondents feel that the Delta science enterprise is most useful for developing knowledge about the Delta, but less useful for connecting to policy and predicting future problems.

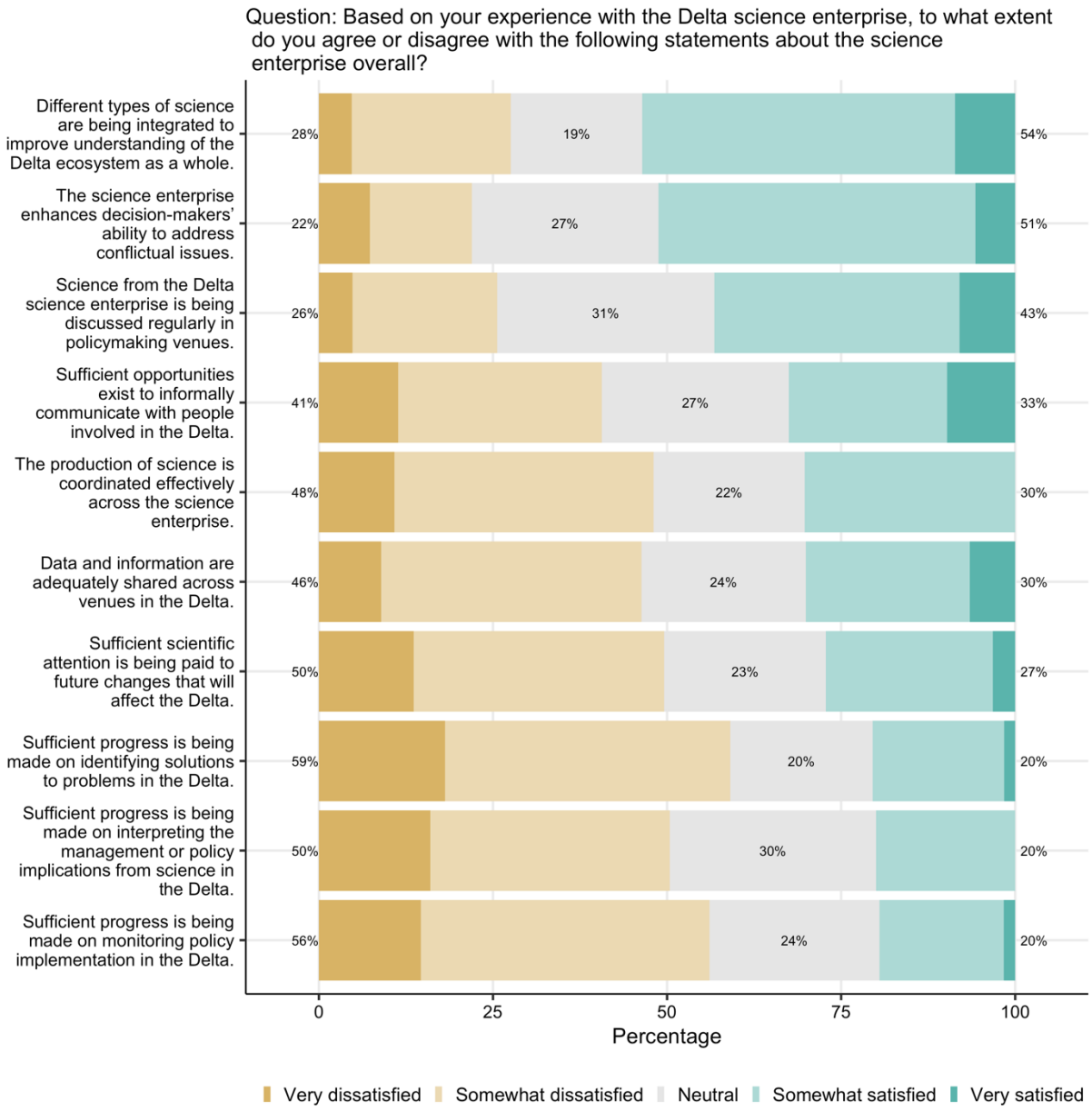

Figure 13: *Respondents' perspectives on the science enterprise overall.*

Science Enterprise Forum Participation

In the Delta science enterprise, the science forums are the social spaces where scientists and stakeholders interact to engage in the scientific process and link the scientific process to policy. Each science forum operates independently and therefore may narrowly address one issue or tackle multiple issues. To understand the performance of the individual forums, the survey asked each respondent to indicate whether they participated in the range of available forums, and then for their main forum, to evaluate their experience with respect to the goals of adaptive management.

Figure 14 reports the patterns of participation across the forums among those who responded to the survey; percentages were calculated based on the total number of responses per forum which varied from 151 to 158 responses. On average, respondents reported participating in three forums and majority participating in those forums intermittently. All respondents reported participating at least intermittently in one of the forums, whereas only two respondents reported participating in over nine forums (both at an intermittent participation level). Respondents reported the highest levels of participation in the Interagency Ecological Program (IEP) Work Team with 38 respondents participating regularly and 49 respondents participating intermittently. Respondents reported the lowest levels of participation in the Delta Interagency Invasive Species Coordination Team (DIISC) with 5 respondents participating regularly and 13 respondents participating intermittently. These patterns of participation reflect the number of survey respondents who came from each forum. There 29 respondents who reported participating at least intermittently in an "Other" forum.

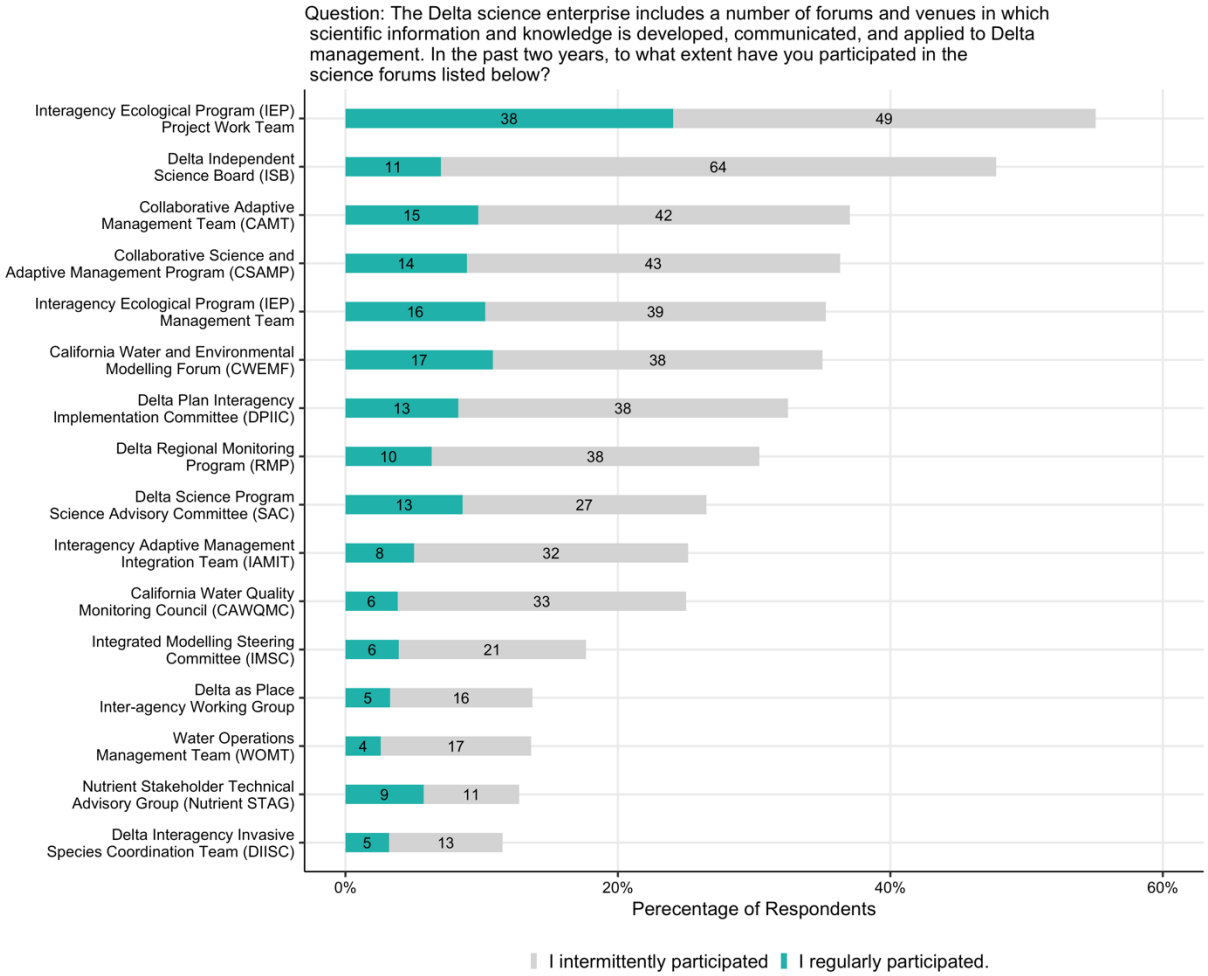

Figure 14: *Respondents' participation in Delta science enterprise.*

The survey also asked the respondents to indicate which is their "primary forum" where they spend the most time, with the goal of asking them to report on their experience in their primary

forum (Figure 15). While many respondents participated in multiple forums, the constraints of survey response effort made it infeasible to ask them about their experience in every forum. Most respondents (18%) selected "other" for their primary forum because their forum was not listed as one of the options (e.g., Sacramento River Science Partnership, Delta Levee Investment Strategy, State Water Contractors). Of the forums listed in the survey question, the greatest number of respondents listed the Interagency Ecological Program Work Team (13%) as their primary forum. This was followed by the California Water and Environmental Modelling Forum (9%), the Interagency Ecological Program Management Team (8%), and California Water Quality Monitoring Council (8%). The IEP responses reflect the fact that IEP is divided into multiple workgroups.

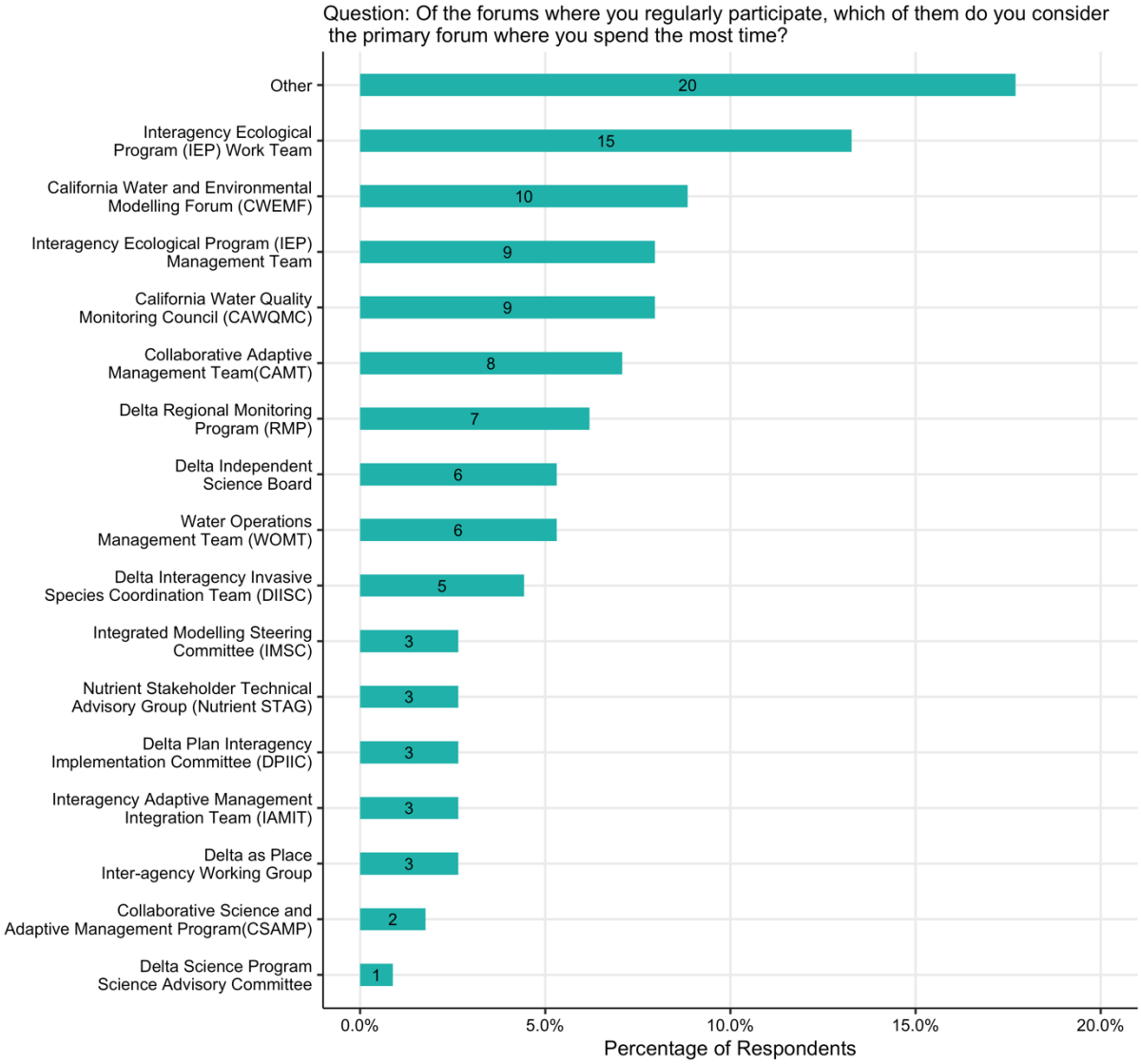

Figure 15: *Respondents' primary forum.*

Capacity for Adaptive Management

One of the goals of this survey was to understand how governance enables the capacity for adaptive management. The Delta Plan relies on a nine-step Adaptive Management framework

(Figure 16). There are three main stages of the cycle: plan, do, and evaluate/respond. To measure the extent to which individual forums contributed to adaptive management capacity, the respondents evaluated their primary forum with a series of survey questions linked to the adaptive management cycle. Unfortunately, about half the respondents skipped or answered a select few of the set of questions asking them to characterize their experience with their primary forum. Thus, we can only really provide an initial assessment of forum performance, which is most reliable for the most popular forums.

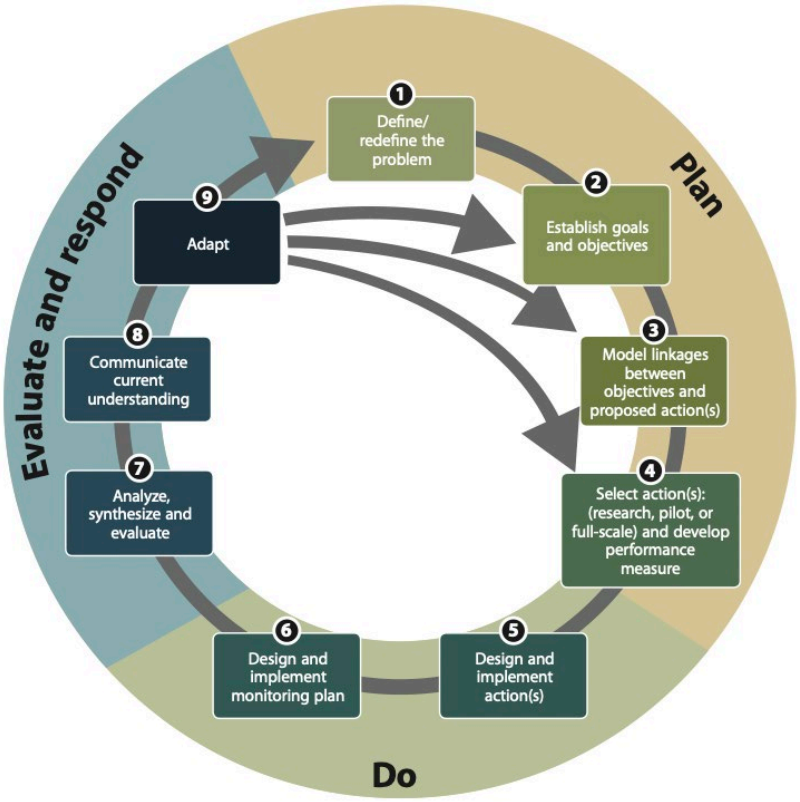

Figure 16: *Delta Plan's nine-step Adaptative Management Framework.*

Figure 17 displays the average effectiveness of the forums across each step of the adaptive management cycle. The figure does not distinguish between forums, but rather just combines all answers associated with each respondent's primary forum. The question had a sliding response scale ranging from 0 to 100, where 0 represented "not effective" and 100 represented "very effective." The results somewhat support the adaptive management cycle, with the earlier steps of the "plan" stage receiving the highest effectiveness ratings: identify and assess (median = 74), establish goals (median = 66.5), analyze causal linkages (median = 60), and selecting management actions (median = 55). The "do" stage, which involves designing, implementing, and monitoring actions (median = 54) is rated about the same effectiveness as the selecting management actions (median = 55.5). Interestingly, parts of the "evaluate and respond" stage are rated as more effective than the "do" stage, especially communicating science (median = 64) and synthesizing science (median = 62). Influencing management (median = 55) and adapting decision-making

(median = 59) are rated about the same as earlier stages. These results suggest that while the science enterprise is best at planning, adaptive management is not a linear, temporally-ordered cycle that progresses from one stage to the next. Rather, science communication and data analysis are central activities of the science enterprise that inform the entire data management cycle with more continuous interaction between the science enterprise and other aspects of Delta management.

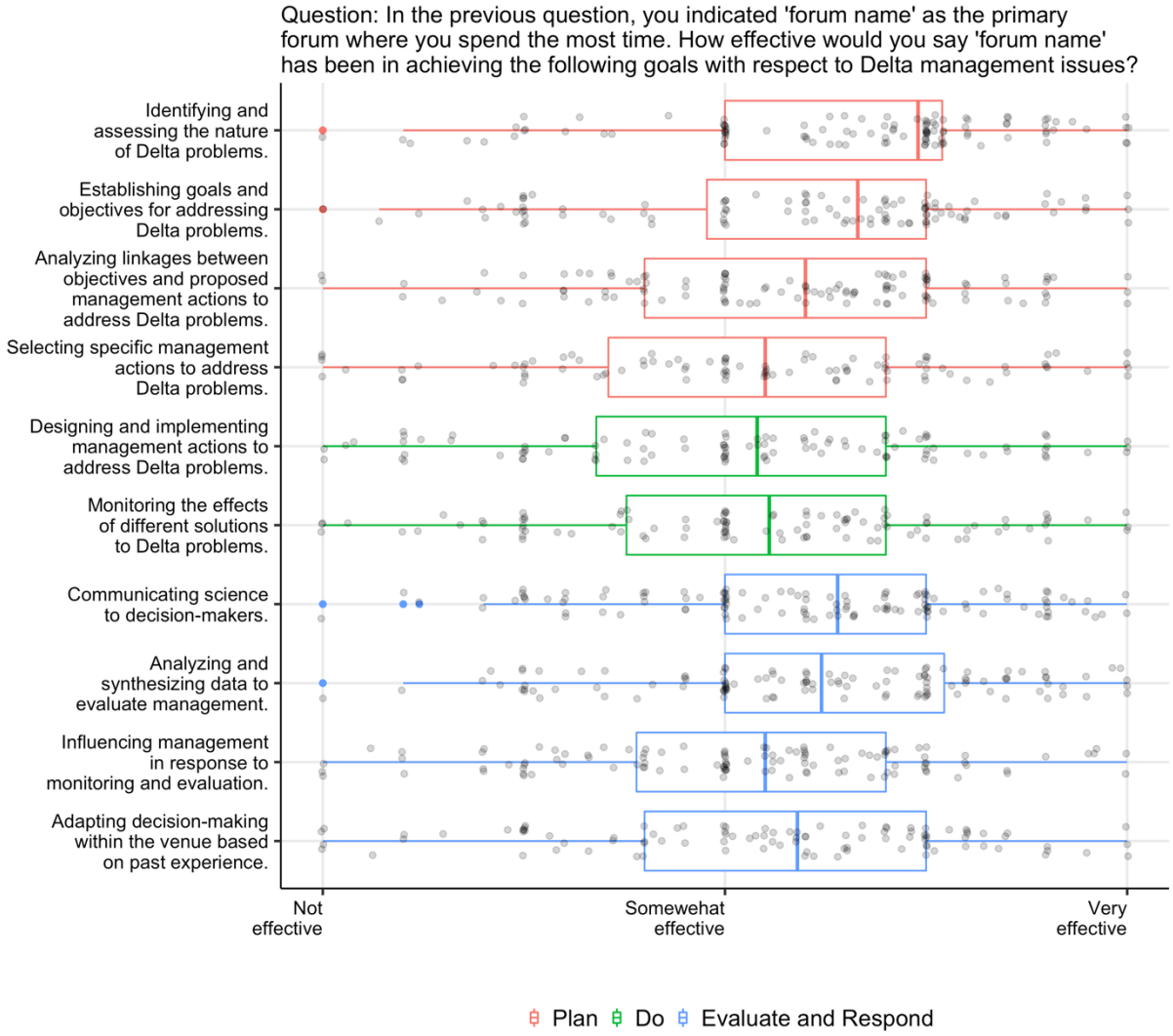

Figure 17: *Overall forum contributions to the adaptive management cycle. The boxplot shows the distribution of responses for each step of the adaptive management cycle, where the center line represents the median, the box representers the inter-quartile range between 25% and 75% of responses, and the horizontal lines represent the full extent of data points.*

Overall, there was almost a full range of responses from not effective to very effective at each step of the adaptive management cycle. This variance in responses suggests respondents disagree on the effectiveness of Delta science enterprise to develop adaptive management

capacity. This variance may be due to individual differences, forum-level variables such as funding and leadership, and system-level variables such as interconnectedness among forums.

In addition to the overall adaptive management cycle, Table 1 displays the median effectiveness of each stage of the adaptive cycle for all forums that data was provided. For reference, the table also includes the overall effectiveness for all forums so that forums above the overall score are "overperforming" while forums below are "underperforming". However, some forums received very few responses which reduces the validity of any overall rating.

Table 1: Individual forum contributions to the adaptive management cycle. The median effectiveness score was calculated for each stage of the adaptive management cycle, where 0 means not effective and 100 means very effective. The number of responses column reflects the number of respondents who specified that specific forum as their "primary forum".

Forum Name	Plan	Do	Evaluate and Respond	Number of Respondents*
Delta as Place Inter-agency Working Group	75.0	70.0	75.0	3
Delta Interagency Invasive Species Coordination Team (DIISC)	75.0	76.0	47.0	5
Nutrient Stakeholder Technical Advisory Group (Nutrient STAG)	70.5	38.0	39.0	3
Water Operations Management Team (WOMT)	70.5	67.0	74.5	6
Interagency Management Program (IEP) Work Team	70.0	61.0	60.0	15
Other	70.0	55.0	60.0	20
Delta Independent Science Board	66.0	46.5	57.5	6
Interagency Ecological Program (IEP) Management Team	65.0	56.0	62.0	9
California Water and Environmental Modelling Forum (CWEMF)	64.0	63.0	65.0	10
Overall Forum Performance	**64.0**	**54.5**	**60.0**	121**
Delta Science Program Science Advisory Committee (SAC)	62.5	NA***	57.5	1
California Water Quality Monitoring Council (CAWQMC)	62.0	55.0	55.5	9
Collaborative Adaptive Management Team (CAMT)	60.0	40.0	60.0	8
Interagency Adaptive Management Integration Team (IAMIT)	60.0	35.0	45.0	3
Collaborative Science and Adaptive Management Program(CSAMP)	55.0	55.0	57.5	2

Delta Plan Interagency Implementation Committee (DPIIC)	54.0	45.5	65.0	3
Integrated Modelling Steering Committee (IMSC)	51.5	12.0	79.0	3
Delta Regional Monitoring Program (RMP)	51.0	50.0	50.0	7

*These numbers represent the total number of respondents who answered any part of this question; therefore, some of the stages reflect a smaller sample size than listed in this column.

**Some respondents answered this forum performance question that did not select a primary forum, therefore the total number of respondents for overall forum performance is higher than the sum total of primary forum respondents.

***No data received for the "do" stage of the Delta Science Program Science Advisory Committee.

To get a better sense of how different forums contribute to the adaptive management cycle, Figure 18 displays the results for the three forums with the most responses: a) IEP Work Team, b) CWEMF, and c) IEP Management Team. In the "plan" stage, all three forums reported similar trends of effectiveness except for selecting specific management actions to address Delta issues; IEP Management Team reported the least amount of effectiveness at this step. The "do" stage also reported diverging results with designing and implementing management actions to address Delta problems with IEP Management Team reporting the least effectiveness and CWEMF reporting the highest. Conversely, IEP Management Team reported monitoring the effects of different solutions in the Delta as one their most effective steps in the adaptive management cycle. The "evaluate and respond" stage followed similar trends across forums for the most part, again with a central role for science communication and data analysis/synthesis. IEP Work Team reported the least amount of effectiveness for influencing management in response to monitoring and evaluation, where IEP Management Team reported the least effectiveness for adapting decision-making within the venue based on experience. While these forum-level results do align closely with the overall trends reported in Figure 17, they also reflect some specific forum-level functions such as IEP's long history of monitoring.

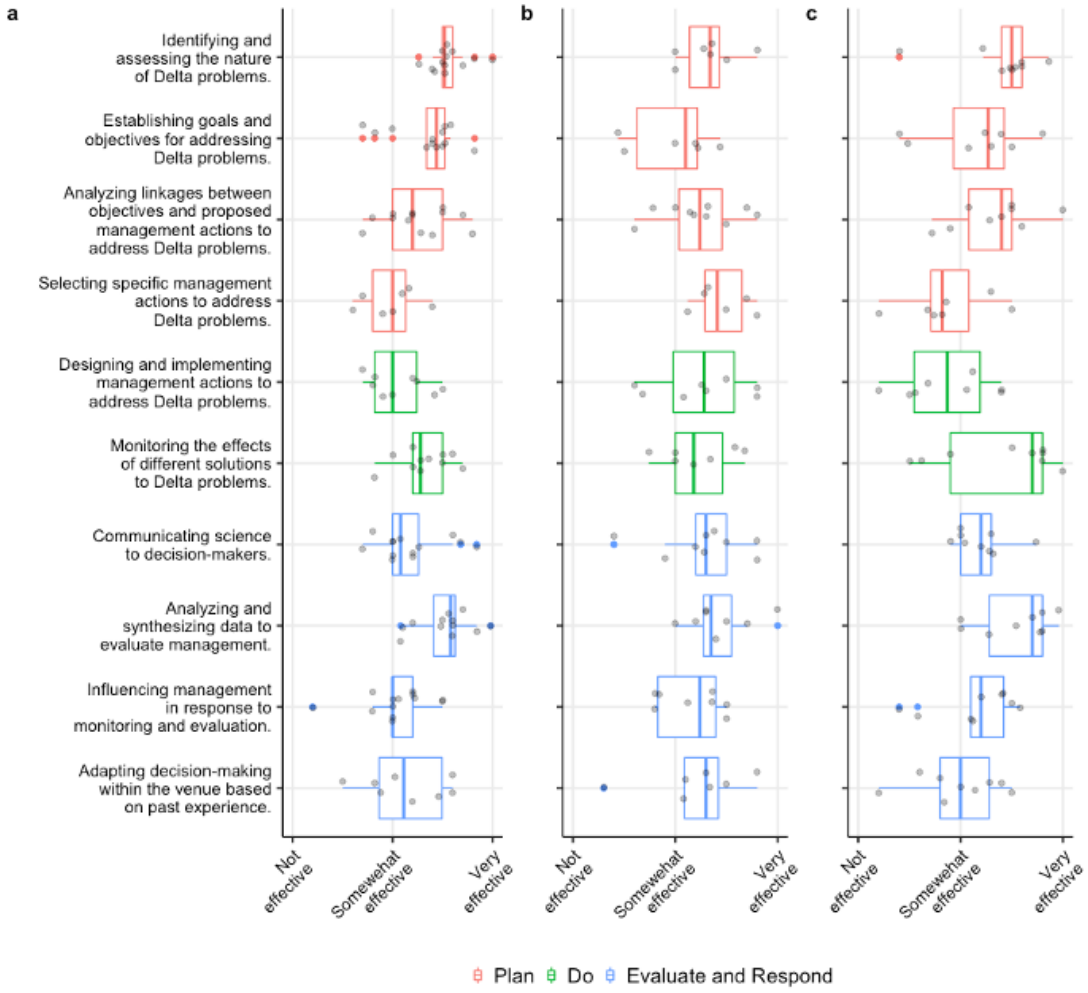

Figure 18: *Summary of three forums contributions to the adaptive management cycle: a) IEP Work Team (n=15), b) CWEMF (n=10), and c) IEP Management Team (n=9).*

Figure 19 reports overall forum satisfaction. Respondents reported high levels of satisfaction, including both somewhat satisfied and very satisfied, with their primary forum's amount of participant interaction (66%), presence of effective leadership (62%), and transparency of information sharing outside forum (60%). Respondents reported the highest levels of dissatisfaction, including both somewhat dissatisfied and very dissatisfied, with presence of financial resources (49%), level of staffing (38%), and engagement with Delta stakeholders (38%).

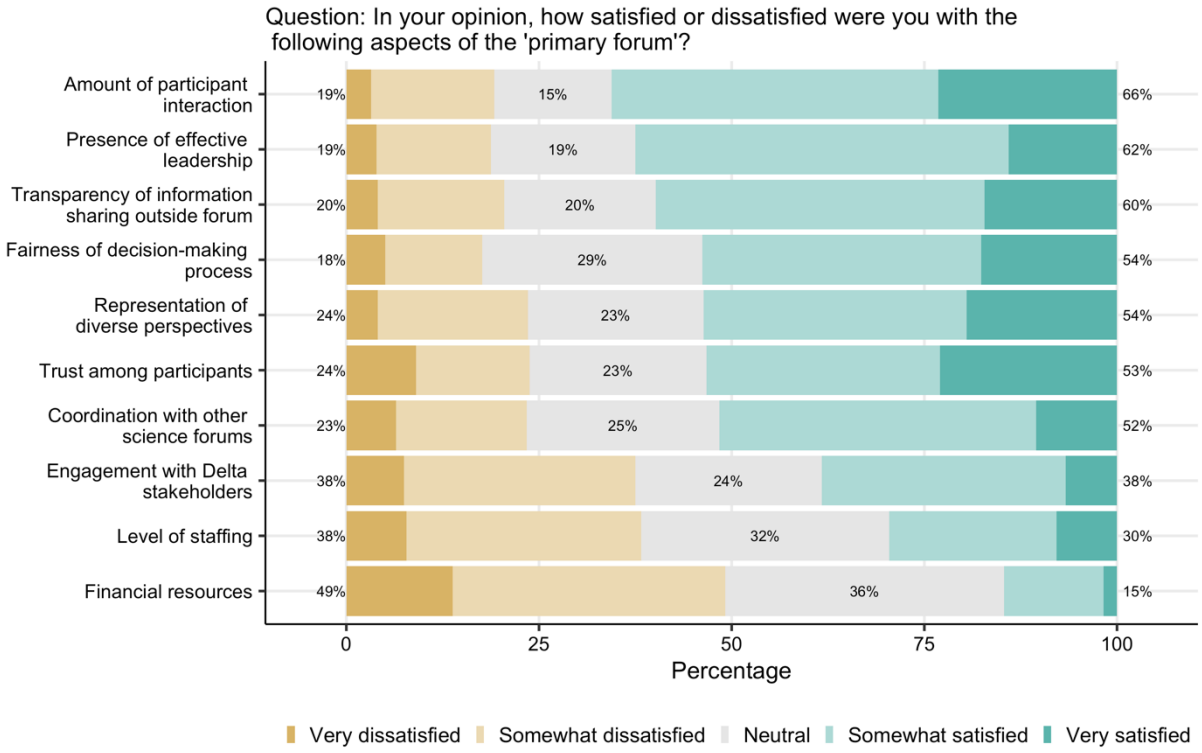

Figure 19: *Overall Delta science enterprise forum satisfaction.*

To analyze how different aspects of forum structure and process are associated with forum performance, Figure 20 reports the correlation between each of the questions in Figure 19 with the "plan, do, evaluate" measures of forum performance. For example, the correlation between perceptions of effective leadership and "plan" is about 0.49, 0.45 for "do", and 0.55 for "evaluate". Overall, the presence of effective leadership had the highest, average correlation (calculated by average the size of the correlations represented by the three bars) between forum satisfaction and adaptive management capacity (.50), followed by trust among participants (.50), and transparency of information sharing outside forum (.45). These findings align with sentiments shared during the Science Governance focus group in 2020 where participants expressed leadership and trust as two key themes for providing solutions to Delta issues. Interestingly, the lowest, average correlation of satisfaction and adaptive management capacity was for level of staffing (.27) and financial resources (.17). Our results showed the lowest relation between financial resources and a forum's contributions to the adaptive management cycle, especially in the "plan" part of the cycle. This finding suggests that adaptive management capacity is less related to administrative resources than expected, and much more strongly related to social processes within the forum.

There are also some interesting differences across the stages of adaptive management. The correlations between forum structure and process and the "do" stage are lower in all cases except staffing and financial resources. This suggest that the "do" stage is constrained by institutional challenges outside of the science enterprise, at the intersection between science and policy. The relationship between administrative resources and adaptive management is

strongest at the evaluation stage, which is often perceived as a set of activities with high resource demand. For example, in the literature on watershed partnerships and project evaluation, there is evidence that the planning stages of setting up partnerships receive more attention and effectiveness, while monitoring is expensive and less effective.

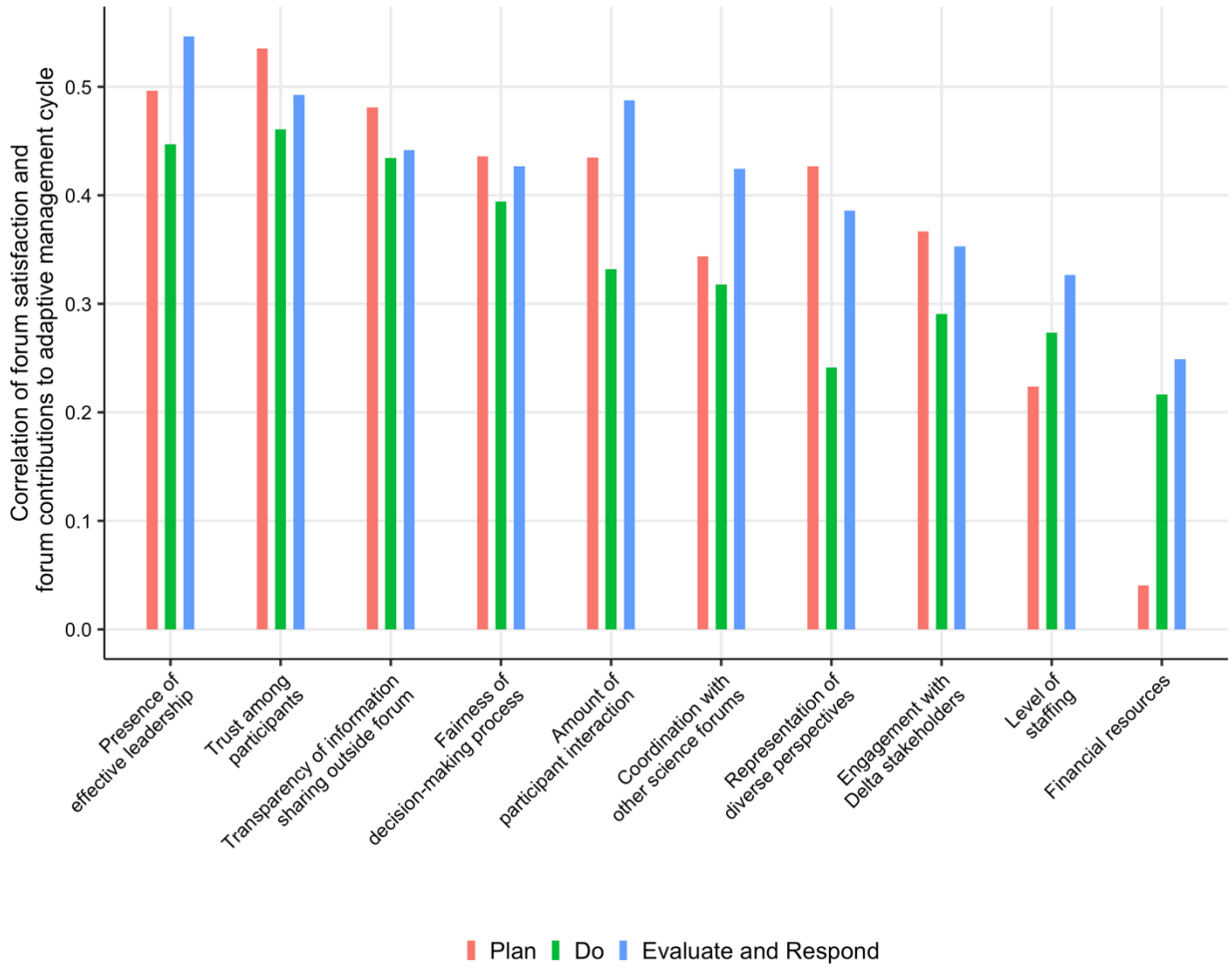

Figure 20: *Overall correlative relationship between respondents' primary forum contributions to the adaptive management cycle and their perceptions of forum structure and process.*

Summary of Qualitative Answers

The Delta science enterprise led several important changes in Delta policies and/or management over the last decade. One question on the survey asked respondents to report up to three examples of these changes. Appendix A highlights the free response answers from the survey. Several topics were covered, some include:

- Delta smelt drivers, solutions
- Invasive species, especially aquatic plants

- Water quality and nutrients
- Floodplain restoration and anadromous species
- Delta flows and water management infrastructure
- Protection of endangered species
- Integration of social science

As we move forward in improving the effectiveness of the science enterprise, it is important to understand what Delta stakeholders view as the top science needs and priority changes to make progress in achieving the Delta Science Plan's goals. Respondents had an open response opportunity to provide what they believe to be the top science need that is not currently being addressed in the Delta science enterprise. Several individuals reported a need for clear designation of climate change impacts and linked management strategies to address Delta issues. Several responses also discussed improving science communication that explains why and how science activities are prioritized and follows science-informed policy through its life cycle, as well as transparency with decision-making to ensure equitable and just research practices. There were several responses regarding the integration of social science across research efforts and broadening the spatial scale of the Delta to incorporate broader watershed needs. Some respondents also reported fish community dynamics and food web ecology as a top science need for the Delta. These needs align closely with the more comprehensive forthcoming Science Needs Assessment. Appendix B includes the free response answers from the survey.

In addition to continuing to pursue a robust science enterprise, it is critical that the program is effective in its endeavors. Respondents shared the highest priority changes they would recommend for increasing the effectiveness of the Delta science enterprise. Many respondents reported that an inter-agency entity that facilitates collaboration across organizations is greatly needed. Furthermore, science communication for diverse audiences with additional funding to support science communication efforts. Several respondents also reported prioritizing infrastructure to support science funding (e.g., rapid fund availability, transparency of funding, sustained funding programs). Respondents also requested support for data integration to reduce efforts across agencies by increasing data accessibility, potential through a data hub. Appendix C includes the free response answers from the survey.

Conclusions

This report presented the key results of the Delta science enterprise survey focused on measuring the adaptive management capacity of science forums in the Delta. We invited a diverse range of stakeholders in Fall 2021 from 16 different science forums to complete the survey. We received 180 useable responses from a broad sample of stakeholders, comprised mostly of state government officials as well as professionals in non-governmental sectors and academics. Most of our respondents work on water quality/contaminants, climate change, ecosystem restoration, and fisheries. Additionally, most respondents have a diverse set of experiences and activities within the science enterprise, with the most common experiences including science communication, management decisions, and science synthesis.

The survey asked about respondents' perceptions and experience with collaboration and learning in the science enterprise, which is a governance structure focused on developing both individual and collective learning to bolster effective adaptive management. Only a minority, three out of 14 issues, did respondents report more agreement than disagreement (invasive species, climate change, and flood management). This result highlights there are still barriers to collaboration among many of the Delta issues. Conversely, there is a high level of agreement on the role of science and government in environmental management. These two findings suggest a need for continued effort in developing the Delta science enterprise as a mechanism for collaboration, especially on Delta issues that see high levels of disagreement (e.g., water system reliability, environmental governance, environmental justice/equity, land use, and fisheries).

Respondents expressed that they felt the Delta science enterprise increased their understanding of the drivers or effects of Delta issues, the perspectives and science needs of different scientific disciplines stakeholders and impacts of human behaviors on the Delta. However, we found that science enterprise stakeholders feel like they do not understand the overall concept of the science enterprise, and the conditions under which science does or does not link to policy. Especially, since respondents feel that the science enterprise is a useful mechanism for integrating different types of science and facilitating cooperation; however, it is not accomplishing management outcomes in a desired timeline.

Almost all respondents reported they participate in at least one science forum, with a majority participating, at least intermittently, in four forums. The largest number of respondents took part in the Interagency Ecological Program (IEP) Work Team, followed by the Delta Independent Science Board (ISB), and Collaborative Adaptive Management Team (CAMT). When asked to report on their primary forum, the greatest number of respondents answered Interagency Ecological Program (IEP) Work team, the California Water and Environmental Modelling Forum, and the Interagency Ecological Program (IEP) Management Team. The large number of responses from IEP is likely due to the well-established program that is divided into multiple workgroups. Additionally, respondents reported many other science forums in addition to our original list which exemplifies the diversity of forums and agencies involved with the polycentric governance arrangements of the science enterprise.

One of the main goals of the survey was to understand how the polycentric governance framework of the Delta science enterprise effects the capacity for adaptive management in the Delta. Based on the nine-step Adaptive Management framework, the cycle of adaptive management is broken into three main stages: plan, do, and evaluate/respond. Overall, forums experienced the lowest capacity for the "do" portion which is focused on designing and implementing action and monitoring plans. Interestingly, parts of the evaluate/respond stage showed similar levels of capacity to the plan stage which suggests that adaptive management is not a linear, temporally-ordered cycle like was previously thought. Rather, science communication and data analysis are central activities of the science enterprise that informs the entire data management cycle with more continuous interaction between the science enterprise and other aspects of Delta management.

Looking forward, respondents provided a rich body of qualitative answers for how the Delta science enterprise has led to important changes over the last decade, what science needs it should focus on, and the top priority changes to make it a more effective entity in solving Delta issues. The latter section of information touches on some key areas of focus including an inter-agency entity to facilitate collaboration, increasing science communication, improving infrastructure for science funding, and facilitating data integration and accessibility.

Literature Cited

Delta Stewardship Council (2018). *A More Reliable Water Supply for California (as amended April 26, 2018).* https://deltacouncil.ca.gov/pdf/delta-plan/2018-04-26-amended-chapter-3.pdf

Lubell, M., & Heikkila, T. (2020). *A Summary Report of Delta Science Enterprise Governance Workshop.* Department of Environmental Science and Policy at the University of California Davis and School of Public Affairs at the University of Colorado Denver (pdf).

Appendix A

Free response answers to survey question: Please describe up to three examples of where science has led to important changes in Delta policies or management.

Example 1	Example 2	Example 3
State/Federal ESA	Annual fisheries surveys in the SFE	
2020 Record of Decision on the Long-Term Operation of the Central Valley Project and State Water Project	Habitat Restoration under EcoRestore	
Development of notch for Yolo Bypass to improve fish access to floodplain	Implementation of Suisun Marsh Salinity Control Gate action for Delta Smelt	OMR management for salmon and smelt
splittail status	delta smelt captive rearing	Formation of independent science board
fisheries decline monitoring has led to increased outflow		
Discovery of relationships between the abundance of many key species with X2 led to establishment of X2 standards.	Documented decline of Delta smelt led to federal and state listing and resulting regulations	Documentation of the ecosystem services of tidal wetlands led to large effort to restore wetlands in the Delta
Floodplain research on benefits to the food web and fish has led to an emphasis on floodplain restoration projects	The importance between flow and endangered fishes has resulted in management of water that must take both human and ecosystem needs into account.	
Mercury cycle studies has freed up delta restoration projects	Effects of exotics has lead to better fisheries management.	Subsidence studies have lead to ground water management.
Reduction of entrainment	Impact of habitat reduction on survival	Role of limited productivity on ecosystem function and resilience
writing of new Biological Opinions in 2019 and the display of the inadequacy of new Biological opinions in court 2020	description of climate change impacts on water supply and aquatic life in the Delta	Importance of wetland restoration and floodplain management in species protection
Low counts of Delta Smelt have led to Delta Smelt supplementation planning (and implementation in the future)	Increase in aquatic vegetation (which can be harmful for endangered, native fish	Low fish food supply has led to North Delta Food Subsidy study, designed to increase food production

	species) has led to more control of aquatic vegetation	
Sommer 2001 and associated studies have led to floodplain restoration as major management action for salmon.	Importance of location of low salinity zone (LSZ) for smelt species has led to major changes in water release (outflow) volumes and schedules.	Discovery of trophic subsidy plumes coming out of Yolo Bypass into lower Sacramento River in some years has led to coordinated draining of rice fields to purposefully create plumes.
Risk assessment of water primrose and alligator weed as harmful invasives led to their inclusion in the Aquatic Invasive Species Integrated management plan which is executed by the Division of Boating and Waterways.		
Understanding use of Delta habitat by different life stages or life history strategies can support different management actions that preserve/support those different life history strategies.		
The delta tunnels have been successfully slowed due to delta science around water supply and species loss.	Harmful algal bloom proliferation in the Delta has been recognized and via the work of the CCHAB Network has led to legislation establishing a freshwater harmful algal bloom program as part of SWAMP.	
rice/wetlands/flyway	water quality	stream flows
salt water intrusion barriers	using bubble curtains to help direct fish movement through the Delta.	
YBFMP monitoring program brought to light the value of the Yolo Bypass for fish	Monitoring adult salmon strays in the bypass led to projects to improve fish passage	modeling and evaluating climate change impacts impacts policy considerations for the future
Limiting withdrawals		
Death of the “Two-gates” project	More quickly moving to Delta drought salinity barrier	

Turbidity and delta smelt	Pumping and clear water barrier	Wastewater nutrient treatment and reductions
Issuance of new effluent license to Regional San	designation of protected species of fish	water regulation for salmon
Telemetry studies and analysis of data generated by them have shifted some focus from the direct effects of water exports to other factors potentially under management control such as the abundance of predators and altered habitat conditions within the delta that contribute to high predation.		
The integration of adaptive management into the covered action process to improve restoration success.	The Science Action Agenda is a link between managment needs on the ground and science action that has funding and policy implications.	The listing of endangered species under both the state and Federal Enangered Species Act has impacted Delta policy for decades and many of these listings have been championed by scientists.
The incorporation of climate change science stalled/hopefully improved the large water transport infrastructure project planned for the Delta.	Science about salmon migration in the Delta (Russ Perry et al.) directly informed new Biological Opinions for operation of the CVP/SWP.	Science about non-flow actions (e.g. habitat restoration) has informed the update to and implementation of the SWRCB's Bay-Delta Plan. This has implications for both new policies and water/habitat management.
The Delta ISB Delta as an Evolving Place thematic review in part led to the Social Science Task Force which wrote the Delta Social Science Strategy which is now being implemented by the Delta Stewardship Council and others. There is currently a much higher emphasis being placed on social science in general in the Delta.	The Delta ISB Rapid Change letter to DPIIC has informed DPIIC efforts on science funding and governance including the Science Needs Assessment. There is now increased emphasis on the importance of planning for rapid change in terms of the science enterprise and science governance.	The body of work on Delta food webs has shown how important the relationship food webs are as a driver of native species viability.

Operation of flows through the Yolo and Sutter Bypass as influenced by research demonstrating food web benefits	Experimental operation of Suisun Marsh salinity control gates to benefit smelt	The impetus behind the upgrade of the Regional San WWTP
The identification of the "fish-X2" relationships leading to the X2 standards	Identification of declines leading to listing and protective measures delta and longfin smelt	Identification of water quality problems and possible effects on nuisance and other algal blooms leading to upgrade of the Sacramento wastewater treatment plant
Using published research on previous efforts in the Delta we were able to justify improved engagement with community based organizations on environmental justice issues.	Work on the lack of robust social science on the effects of restoration in the Delta informed a policy change in the Delta Plan to require a disclosure of social benefits related to restoration.	Landscape modeling of subsidence informed the development of a Delta Plan performance measure that recommends subsidence reversal as a strategy for future process based wetland restoration.
minimum Delta outflow	limits on exports	water pollution control
Integration of AM across multiple agencies	Consideration of multi-stressor scenarios	
SWRCB Bay-Delta Water Quality Control Plan (Phase 1) evaluation metrics	Salmon and Smelt Biological Opinions	Targeting of Riparian /Floodplain Restoration design
Nutrient research informing Regional San Upgrade	Delta Adapts informing DSC covered action policies	Research and monitoring at one site informing restoration planning at the next
Export restrictions to protect delta smelt and other species	Flood management infrastructure	Salinity control reservoir releases and infrastructure
Identification of mercury contamination of fish eaten by subsistence fishers has led to a start in programs to reduce mercury exposure.	Nutrient studies that lead to discharge limitations for SRCSD	
Fish monitoring reveals Delta smelt decline to near extinction; affect policy on water allocations to agriculture vs environment.	Research in 1990s-early 2000s reveals pelagic organism decline; leads in part to Delta Reform Act in 2009 and new focus on coordinating science and management.	Research on aquatic weeds and their control reveals link to aquatic habitat quality for listed fish. Leads to new funding and ineragency projects on restoration through aquatic weed control.

monitoring and research on ESA species regional abundance	fish toxicity studies leading to safer fish consumption guidelines/warnings	Georgiana Slough bubble curtain - aiding survival of salmon outmigration
SFEI's Historical Ecology report provided a solid foundation for science studies in the Delta	SFEI's Delta Renewed report provided a framework for ecological policy options and decisions in the Delta.	
Contaminants are no longer just another stressor. It has been long recognized in other watersheds to be a mitigating factor. The proliferation of research and advocacy of scientists have finally increased the awareness and incorporation of contaminants in management and policy. There is still a long way to go as there are still misinformation being cited regarding contaminants	Aquatic Weeds like contaminants were just another stressor but now that we recognize that they have long been impacting the system there has been a greater focus and inclusion into synthesis and management actions. Much of the work by the DRAAWP and its members has led to this.	Habitat Restoration is the action that has long been stagnated. There is a lot of uncertainty in the face of little information and climate change but there has been a greater recognition of their need and more progress on implementation that has been improved from work like the publication by Whipple et al 2012 and Cut the Green Tape Initiative.
The use of the Low Salinity Zone to manage for delta smelt in the 2008 USFWS Biological Opinion	Zooplankton monitoring to inform yolo bypass and food subsidy projects for Suisun marsh	
Documentation of the pelagic organism decline.		
Coordinated tributary flows to meet salinity goals	Fish screening methods and timing to prevent entrainment	Curtailment
Eradication of Nutria	establishing temperature measuring points based on water year type and other factors versus a fixed point	more interactions between agencies in conducting Endangered Species Consultations
Nutrient studies leading to more stringent wastewater treatment plant discharge permit requirements in the Delta.	Studies on salmon migration and survival patterns informing drought emergency regulations.	Research on food web benefits of flooded habitats and pulse flows leading to management actions to improve food resources for Delta smelt.
Bay-Delta Plan Phase 1 Update 2018 (State Water Board)	Implementation of advanced filtration and nitrification-denitrification processes by municipal wastewater treatment plants discharge in	Pesticides and contaminants of emerging concern monitoring in the Delta funded by the Delta Regional Monitoring Program

	or near the Delta, as a result of NPDES permit requirements.	
Improved understanding of Delta smelt biology has led to flow and non-flow actions designed to be protective of Delta smelt habitat (actions described in the 2016 California Natural Resources Agency Delta Smelt Resiliency Strategy). State Water Project and Central Valley Project pumping operations are also informed by scientists' understanding of conditions that could lead to Smelt (both Delta Smelt and Longfin Smelt) establishing spawning populations near the pumps.	Improved understanding of the value of floodplains for salmon life history has led to mandates for floodplain restoration and the potential for managed floodplains (which are distinct from non-managed floodplains) to be part of the management profile for Central Valley salmonids.	Evaluations of the 2015 False River Barrier installed to protect water quality in the interior Delta revealed that the Barrier was effective in achieving water quality goals. Investigations of ecosystem effects showed that invasive aquatic vegetation increased but many other potential ecosystem effects were minimal. Because of these results, the Barrier is being used again in the current drought, and there is increased discussion/thought now being put into management of the invasive vegetation.
2018 Bay-Delta Plan amendments to flow objectives	2018 DSC rejection of California Water Fix	
Salinity management	Selenium management	Mercury modeling
data stories from monitoring efforts		
Fish guidance studies that lead to better guidance structure operations		
Science on nutrient dynamics led to requirements for Regional San to upgrade its treatment plant processes.	Science on food limitations in fish and changes in community composition at the lower trophic levels has led to implementation of actions to restore productivity such as tidal wetland restoration and N Delta food actions	Science on native fish utilization of floodplains has led to actions to restore floodplains.
Climate science has been consistently considered in any Delta related studies		
Contaminants are being considered in the development of actions and evaluating the effect of those actions. Current structured decision making efforts have incorporated	Invasive Aquatic Weeds actions are being developed and implemented to further control the ecosystem engineers. Outreach across multiple stakeholders have	Habitat Restoration has been progressing very slowly with few if any actions occurring until recently. There is greater recognition of the necessity of restoration and with that

contaminants in their decisions matrices.	allowed the biological opinion for the control the weeds to be amended to include the use of innovative control methods.	increase in recognition and the Green Tape initiative to help facilitate implementation there may be significant increases in restoration projects.
Ammonium Inhibition Hypothesis contributed to mandated ~2 billion dollar WWTP upgrade	Hypothesis that the North Delta Flow Action improved downstream conditions (i.e., increased phytoplankton abundance).	Drivers behind Pelagic Organism Decline has lead to restoration efforts across the Delta
North Delta Flow Action	Suisun Marsh Salinity Control Gates action	Delta Smelt supplementation
research from the Yolo Bypass fish monitoring program influence floodplain/bypass restoration efforts and the Fremont weir notch	Feather River salmon disease research and experimentation with pulse flows has influenced permit agencies in allowing adaptive management (still progress to be made here, though)	the evaluation of aquatic weed treatment and its shortcomings has emphasized the importance of evaluating success when attempting to restore Delta habitats.
Importance of flows	Collapse of species	Over diversion of water from the Delta
It has failed to address heavy juvenile salmon losses at the State Water Project	It has failed to address significant juvenile salmon losses pump discharge systems	
relatively rapid response to nutria impacts based on awareness of the potential impacts of invasive species	better management of Yolo Bypass and similar areas where there are food web benefits for fish	
Better scientific understanding of the relationship between temperature and winter run egg survival led to more effective reservoir operations in the Sacramento River	Better understanding of the factors influencing delta smelt entrainment led to more effective management of project export pumping and reduced salvage	Research on food limitation of delta smelt and other pelagic organisms led to development of food web enhancement actions
Franks Tract Futures project matched fisheries, hydrological, ecological science with cultural, economic and recreation data to devise/develop/test options to reach project goals with foundational input from stakeholders.	Delta Conveyance Authority Stakeholders Engagement Committee presented project science to stakeholders for local, specialized input on design and features of the conveyance project. This resulted in significant project design adjustments based on local expertise.	Dutch Slough restoration project used science and heavy community input to guide design and implementation. Conventional wisdom has pointed to great restoration values in the “north Delta Arc”, though approaching policy decisions with science opened the possibility of adding to

		Dutch Slough values by restoring Franks Tract and potentially sections of Big Break along the southern reaches of the central and west Delta.
Knowledge of Delta hydrodynamics has influenced how water operations in the Delta are undertaken.	Knowledge of fish migrations and food web assemblages has led to more sustainable management of water resources upstream of the Delta	Knowledge of keystone species habitat has allowed targeted restoration actions to occur.
Planned responses to anticipated sea level rise.	Changing operation of Delta pumps in response to scientific information about entrainment.	Changes in operation of Delta Cross Channel gates in response to information about migratory fish behavior.
age-0 herring trawl data for prediction of herring spawning stock biomass for fishery mgmt	age 0-1 halibut trawl data for understanding climate effects on stock and potentially on recruitment to the fishery (still in progress)	
Turbidity management for migrating Delta Smelt.	Tracking the invasion and ecological effects of Potamocorbula amurensis	Determining the importance of floodplain inundation for Sacramento splittail spawning.
Drought forecasting to inform water management and operations, but more is needed (e.g. increased policy changes, discussions on trade-offs, and implementation of proposed actions).	Climate change analysis informing water management and operations to develop new, long-range solutions to impacts.	Identification of new issues and challenges to the Delta (e.g. harmful algal bloom, pharmaceutical pollutants, etc.) to inform water management and operations of new concerns that can affect water quality and supply.
Water Flow	Contaminants	Invasive Species
The science of river flows effecting salmon populations.	Increasing river flows to enhance salmon populations. These increased flows dramatically affect other populations living in the river.	
Identification of harmful algal blooms in the Delta leading to the realization and (hopefully soon) implementation of regular HAB monitoring there.	Understanding of the role of invasive species (i.e., benthic clams) in driving ecosystem-level changes in the Delta.	Recognition of the importance of floodplains in driving lower-trophic productivity and the resultant drive behind restoration efforts.
Delta salinity barrier	Co-equal goals	Levee setbacks

Research has highlighted the need of co-equal goals for water supply and ecosystems. Other goals added to the mix as well. That has been the basis for various years now in planning management, policy.	Consultation processes and academic reviews have found that socioeconomic factors. New requests for proposal underscore the need of social scientist and covering human systems as well.	Levee risk assessment tools have been conducted periodically in the Delta have contributed to improvements in management and prioritization of flood protection.
drought synthesis for this year's drought barrier.	salmon/smelt science feeding into regulations (ITP, BiOp).	
Invasion of nutria - science supported control/eradication from other systems was an important tool in communicating the need to respond rapidly in CA; led to multiple state funding sources and possible Federal funding	Science or lack thereof led to the social science task force and recent efforts to support more social science integration in Delta management	
Improving fisheries to some extent through changing water-flow patterns	Dealing w/peat as the basement of the levy system to reduce loss of levies during flood events.	Better control of business & recreation use so it doesn't erode the ecosystem and water quality and general pollution.

Appendix B

Free response answers to survey question: What do you perceive is the top science need that is not currently being addressed in the Delta science enterprise?

Top Science Needs
Political obstacles that hinder effective management implementation
Representations of physical and biological process for food web and competition/predation dynamics
Limited sediment supply to counter sea level rise. Reduced reservoir capacity due to accumulation of sediment above dams.
interactions among climate change, sea level rise, earthquakes, major floods, invasive species that will accelerate change in the Delta as an ecosystem
Adjacent terrestrial species (fresh and brackish marsh) that are negatively impacted from tidal restoration
Existing managed wetlands have an important function in the ecosystem which is not being studied
Food web processes, composition, and drivers. Far too much focus on fish, much less on what the fish need to survive.
Non-native predator management
Methods to minimize and alternative developments, to delta water diversions.
The limits of ecological prediction given signal-to-noise issues – we expect ecology to be more like physics. It's not.
What are the best management options after we lose important levees in the Delta, and how do we adapt to climate change to minimize those impacts when they happen
Not sure, but likely something related to rising temperatures and lack of water, and how to manage for increasing volatility of climate
Institutional inertia or interests that block the use of science-derived understanding by multi-stakeholder groups to identify and trial creative actions to address hypothesized key drivers of key problems. Example: solutions being tried to address effect of warming climate and reduced water supply on salmon in rivers are currently limited mainly to varying how we release water from dams, rather than trialing more creative solutions like passage around dams.
Active monitoring of aquatic invasive plants and their impacts on the ecosystem.
There is not enough feedback on whether or not implemented policies reach their intended outcomes
1) Use of existing monitoring infrastructure (e.g., acoustic tagging) or augmenting it and linking it to efforts to develop juvenile production estimates for salmonids. 2) Developing robust and reliable monitoring to inform real-time management and linking that to the adaptive management circle to develop further "experiments" for subsequent years. 3) Evaluations of both the economic and ecosystem costs *and* benefits of potential infrastructure improvements (e.g., Delta Cross Channel gates, Tracy Fish Facility louvers),

since infrastructure is something that we *can* control and, given this system and the status of Delta aquatic species, it should be state of the art.
The Delta science enterprise focuses on something that doesn't really exist anymore. I'd say a benefit would be to consider what can replace the Delta that is self-sustaining, at equalibrium, optimal given the actual environmental characteristic present.
Drinking water issues
Lidar and microseismicity monitoring NOW, in construction > operations and GIS model for causes and effects.
Full and open transparency regarding monitoring and data. Including access to the data in a machine readable well documented form across stakeholder groups doing monitoring in the delta.
Psychology and social science so that UC Davis and friends will understand why the best science in the world will not fix what's broken in the Delta unless / until it's paired with an analysis of justice, equity, inclusion, power imbalances, etc.
Toxicity due to mixtures of endocrine disruptors, pharmaceuticals, and pesticides which are not well removed during sewage treatment nor are they known due to the limitations of the CWA in regulating individual chemicals. Multiple stressors impacts.
I am the inventor of the new system of the cross-country pipelines for importing seawater or other fluids, having the "in-line pump" as segments of the pipeline for uphill routes, and having the "in-line-generator" as segments of the pipeline for downhill routes. I am also the inventor of the new system for using the pipeline as a foundation for solar panels which eliminates expenses for purchasing or leasing huge sections of land, which is an expensive requirement for conventional solar facilities on an industrial scale.
The science data needs to be run through an economics "digester" and then feed to politicians and voters.
How many larval fish (<20mm) are entrained at the water facilities and what impact that is having on the ecological community.
Use of quantitative modeling tools across disciplines.
Science agencies need internal science and technical plans and coordination of science and technical plans across agencies.
Quantitative understanding of the energetic pathways supplying the lower food web(s).
Integrated understanding of flow and nutrients as driver of the ecosystem
We need to move from thinking of the delta as an ecosystem unto itself to thinking of it as an interface between ecosystems (ocean and riverine).
synergies in environmental processes to support regulatory permitting effectiveness
Planning, and implementing plans, for sea-level rise and other effects of climate change.
A comprehensive ecosystem restoration vision that interages multiple benefits, especially adaptation to climate change for both built and natural systems.
Climate change across the board.
Looking at the human dimension in shaping perceptions that lead to various Delta decisions at multiple levels and across numerous stakeholder groups.
Social-science understanding of decisionmaking processes and institutional politics within the Delta

Determining achievable reductions in contaminant concentrations, such as for mercury.
Exclusive focus on the Delta and its needs should be broadened to include a balance with system-wide operations and implications.
Effect of the reduction in nutrient loading with the upgrade of the Sacramento WWTP. We have known this was coming a decode ago but no opportunity arose for a coordinated effort to understand the changes, and only a few piecemeal projects were proposed and funded.
Externalities impacting fisheries and thinking more flow can compensate for them. Climate impacts reducing feasibility of any actions to address fishery and habitat issues.
How would “Sacramento Bay” function in the future (with sea level rise) and what changes in land use, habitat, and infrastructure could be made during the next 100 yrs to improve that future function
environmental justice
Flow and water quality monitoring and modeling
climate change effects; temperature effects on fish behavior, contaminant effects with increased temperature, shift in foodweb etc.
The value of fisheries to stakeholder groups is not given enough weight. Lots of resources are dedicated to Delta smelt and relatively little are given for other species.
A clear and public understanding of the ecological impart of the next 20 million people in the watershed.
Effects of contaminant mixtures on organism through community levels
Effects of climate change on Delta ecosystems and how to relate that to management
Effect of chronic drought on invasive species
Limits of ecosystem sustainability within changed climate regimes
Effectively communicating the ecological policy options to key decision makers
Identifying strategies to manage sea level rise increases through integrated floodplain management, including taking land out of production and reducing diversions that alter natural environmental flows
social scientific understanding of Delta human communities - perceptions, attitudes, values, desired future conditions, etc.
Synthesis and communication
Design and construction of juvenile salmon migratory pathways considering real flow regimes not pipe dreams.
Identifying contaminant sources that may be reducing salmon and Delta smelt populations such as leachate from tire disposal sites, etc.
How to improve habitat conditions and the food web to support native fish species and provide more resilience to address climate change.
Harmful cyanobacteria drivers and short- and long-term management measures that can be feasibly and legally implemented for the Delta
Long-term salinity management in the face of drought and sea level rise, and the cascading effects of those potential management actions on the ecosystem.
Multi-layering of data, analysis, and synthesis to cater to a broad range of stakeholders from more detail to high level understanding, i.e., from technical specialists to resource managers to policy makers/executive to the general public.

data integrity
Reducing reliance on water from the Delta
Increasing delta water flows
I think the top unaddressed science need is a better understanding of limiting factors for delta and longfin smelt
Risk to implement innovative science in planning and management practices
The foodweb ecology of the estuary. Much is not known about what affects the dynamics in the foodweb and much is not studied, such as the detrital foodweb. The detrital foodweb represents the bulk of the carbon budget of every estuary yet there is almost nothing done to evaluate it.
Data Access and Integration - data is not being sufficiently used because it is not easily queried
Delta fish community dynamics, particularly rare/cryptic native fishes
transparency about decision making
Simply that science be a greater driver of decisionmaking, rather than politics
How to fill in data gaps in the Delta…the need to open the “black box” and how that impacts project operations of the CVP/SWP.
Much strong advocacy for use of science in decision-making & practice, not politics
Study the current entrainment losses at the CVP and the SWP pumps and develop solutions
relative importance and connection of flow and non-flow related effects on food webs and other ecosystem services
Actually caring about the environmental disaster of the Delta Tunnel. It is all about power and greed.
Long-term viability of continued water exports
Potentially catastrophic impacts of rapid and accelerating climate change.
Impact of water quality from Tributaries to the Delta. i.e. much of the Delta Science is governed by the Legal Delta. The whole watershed needs to be considered. Thus impacts of wildfires, land use, contaminants, pathogens, habitat modification, etc, needs to be integrated/addressed
Presenting WHY the science is being proposed/done. This must go beyond “improving water quality”, “saving endangered species”, or "reversing subsidence to why water quality worsened, species declined, and islands subsided. Interpreting what brought on the issue being studied and what were the drivers- social, economic, political, historical - that allowed it to happen.
Development of experimental designs and methods to test the effects of management changes (e.g., changes to water flow management, nutrient loading (point and non-point source), reservoir and water temperature management. This also depends upon political will and risk appetite to test the management changes.
Continued funding for long-term monitoring (e.g., Bay Trawls; or rather, reinstated funding after recent years when data gaps have caused huge problems)
We cannot assess climate effects without long-term datasets and we cannot predict fisheries recruitment/biomass without long-term datasets.

More experiments should be conducted in the Delta to test the outcomes of differing environmental management options.
Climate change impacts to the Delta and identification of adaptation strategies to implement
Water Source and regularity for feeding tunnel
Measuring public values and “integrated” steps to protect and conserve them.
Climate change effects on historical fisheries. Planning for and directing the desired biodiversity existing on southern delta rivers.
Public awareness
The impact of climate change on the Delta ecosystem and California water enterprise
Collaborative modeling. Allow some degree of openness in the tools developed or employed in research to allow a broader audience better inform their decisions.
There is an over-emphasis on Delta Smelt and salmonids, and listed species in general, and a lack of a holistic approach to the greater ecosystem.
Social science studies that highlight where the biggest failures in government/management/co-production are (e.g., is it lack of political will?)
Analysis of the social and ecological benefits of functional ecosystem flows
Anticipatory planning for future Delta science needs. Who is the end user for individual research projects and how does it fit into the greater plan for Delta science.

Appendix C

Free response answers to survey question: What are the highest priority changes you would recommend to increase the effectiveness of the Delta science enterprise?

Top Priority Changes
Pursuing environmental justice/political actions that'll supplement effective management practices.
Redesign the governance to avoid a myopic focus on the water projects and level the playing field to reduce the potential for individual bias and achieve a more federated decision making process that diversifies science activities to areas outside of regulatory agency silos.
More integration of science and information between Delta and upstream habitat. Multi-agency science enterprise managed by an independent contractor or organization rather than a state agency such as that seen in IEP/CDFW.
More integrative science
Improve communication to partners that are not fishcentric, but an important part of the ecosystem, adjacent marshes.
Listed species are being disregarded/dismissed during fish restoration planning.
More coordination, less conflict. Stop paying lawyers and economists to wade into scientific issues in which they have no expertise. Don't throw money at a problem to hire consultants to give you the answers you want to hear instead of trusting agency staff to do the job right. Hire more statisticians and data scientists in the State Workforce, which may require changes to personnel classifications since no classifications currently exist for those jobs, making it difficult to compete with other sectors in which they could be paid more.
Research focused on policy decisions rather than academic needs.
Establish a coordinated body of all science enterprise participants that include the entire estuary (Bay+Delta) similar to those in the Chesapeake Bay Program or the Puget Sound.
Better syntheses of information to the general public and popular press
Increase participation of policy makers in meaningful discussions about what technical issues need their input. Making policy maker input continual rather than occasional and disjointed.
Centralized governance for environmental decision making
Multi-stakeholder structured decision making to generate and implement creative actions to solve wicked problems. A good example is the current endeavor being lead by non-agency stakeholders (water users and environmental advocacy groups) to quantitatively re-identify what salmon recovery would look like, and to brainstorm actions to make it happen outside of the narrower considerations of governmental regulatory processes.
Increase opportunities for competitive funding awards to achieve cutting-edge research that addresses priority science areas and information gaps in the region.
Most scientific studies implemented are short-term, limited by funding. There is a need for long-term, broad-scale studies to understand the whole impacts of changes to the Delta ecology
More cohesion and centralization.
Have a digest detailing which scientific outcomes altered/updated which Delta policies.

Articulate a mechanism (bridge) between science and policy. Currently there is no path for using science to update policy. The major policies influencing the Delta are codified in ancient agreements.
Communicating science to policy makers and the public is shockingly poor. Technical folks are trained to communicate in specific ways, and these ways do not translate well to more general audiences.
More online meeting and central webpage with schedules/access to meeting, and summaries/minutes of meetings with podcasts.
More coordination among stakeholders/agencies with scientists outside their organizations; a clearer pipeline for science to reach policymakers
Better communication across groups working in the Delta. Possibly combining the efforts of some of the groups listed.
Scientists should spend more time telling decision-makers what will happen if they continue ignoring the best available science. Universities should stop perpetuating the myth that science “informs” policy and that better science is the key to better policy.
Empower scientists so that their work is actually used to make policy and management decisions. Ensure that expertise is used in decision making.
Reach the voters and politicians as well as agricultural interests with a broad array of digestible science showing the implications over time of policy changes made today.
I believe significant reductions in the program will drive efficiencies and innovation. The program should be oriented to the focus of high priorities not just keep expanding.
Large scale habitat restoration. 98% of marsh habitat has been lost from the region. Studies show that fringe marshes do not provide the ecosystem functions of a complex marsh habitat. Large land areas designed with dendritic channels are needed to restore productivity and natural ecosystem functions to the region.
For my purposes, and for general public awareness, a high level report that looks at the top 10 priority management questions and reports on how science is making progress on informing decision makers on the priorities.
Direct efforts towards making existing data and models discoverable, with documented QA/QC. Encourage the science and management community to think big rather than nibbling at the big issues.
A common water accounting framework across state agencies
1) Improved communication within the science community, 2) Improved data access and integration, 3) Increased opportunities for (a) communication of management needs to the science community, and (b) communication of science to management.
Streamlining governance.
Increased regulatory permitting effectiveness and flexibility
Centralized data portal, extensive stakeholder engagement (co-creation) to drive implementation
Re-imagine an effective governance for the Delta science enterprise.
Finding a way to incentivize, launch, and support broader collaboration across players in the Delta science enterprise.

Develop resources to promote structured decision making and co-Production at large scales, by more agencies
Facilitate data and model sharing and access
On-the-ground testing of proposed management actions (i.e., actually doing adaptive management), including experimental flows, multi-benefit floodplain actions, and nature-based solutions for climate resilience and salinity management
Provide a funding pool that allocates based on consistency with a set of science guidelines on transparency, comparability, and inter-program communication/coordination.
Large problems require large, coordinated scientific efforts, analogous to those used in climate studies and involving University and other non-agency scientists in the design and development of programs. We have collectively missed the boat several times in failing to undertake the large programs needed to solve the problems: 1) A push by scientists involved in the “fish-X2” workshops to develop a coordinated program to understand the underpinning of those relationships in the mid-90s, which was rejected because the standard was settled and the information was allegedly not needed; 2) The failure to understand the effect of the Sacramento plant upgrade referred to above; 3) The failure so far to develop a comprehensive view of the effects of the patchwork of restoration projects in the upper estuary; and 4) The failure to consider the estuary as a whole ecosystem and instead to focus on the Delta. This last was exacerbated by the Pelagic Organism Decline, in which a key organism is longfin smelt which doesn’t really live in the Delta.
Better integration and providing policy makers with realistic options with humility as to what is actually achievable.
The funding needs to be much more independent. As long as all the science is funded by water contractors, DWR, and settlements dependent on the continued status quo of water supply operations we’ll never see scientist ask the real questions. Even independent funding programs like the DSP’s rely on a process whereby you ask actors whose jobs and work and expertise are tied up in a totally failing status quo what they consider most important. So our “independent” funding programs are largely captured. We’re basically dealing with systemwide scientific and regulatory capture and getting predictable results from it, but no one is willing to say it.
Give independent science a louder voice that can be heard over well-funded water agency junk science
Institutional clearinghouse to integrate various science programs and make science more available, and communication. Better leadership! at many levels and endorsement for high-priority findings and framing policy objectives regardless of whose feelings get hurt. Independence from political grandstanding and insulation from fluctuations in state executive policy
Increased data sharing and quicker dissemination of the results of projects, maybe through a digital hub where Delta publications, data and models can be accessed? We have these now, but many separate ones, which are unknown to people outside that particular group. Also, as unpopular as this is, resources are not infinte. Climate change progression will be expensive (fires, infrastructure rebuilds/relocation etc.) and much of our funds for the ecosystem comes

from the same pot of money. What do we want to spend it on? We may have to not spend all of our funds on species that are not likely to make it past 2050 (like Delta Smelt) and focus on creating habitats/refuge for species that will withstand the changes in temperature (and salinity for aquatic organisms) shortened seasons (with trophic mismatch), and more frequent drought. We are not there yet, and projects are now often considering multiple benefits, but that conversation will have to be had in the not distant future.
Do more work around environmental justice. Vulnerable communities are being left behind.
Take more novel approaches to Delta management. Utilize duck clubs as food production machines, inject turbidity, inject nutrients to seed blooms, etc.
Most of the science deals with technical detail rather than the major policy drivers — many more people coming over the rest of this century, a much larger human footprint, and changing demographics in California toward a classic southern European view of natural resources (in contrast to the classic northern European view).
Better coordination of efforts, and more funding for studying effects of contaminants on ecosystem.
Increased flexibility and coordination among agencies to speed implementation of actions on climate change and invasive species. Many actions have been recommended; few have been implemented on the ground.
Establish permanent funding source for basic Delta science.
Acknowledge the scope and breadth of the Delta Science Enterprise and base priorities on which areas bring the most change for the better of the life in the Delta (land, water, air, etc.) and then give more weight to those that aren't already receiving support from other enterprises (reducing redundant efforts/funding source competition). Attract qualified scientists to continue management of DSE.
Increase the budget for communicating the highly scientific and technical finding in a manner that is accessible to non-science policy decision makers.
Science gets a lot of attention but does not, on its own, tell anyone what to do. I think there needs to be more explicit and transparent interface between science and policy so that the values/politics that are guiding the flow of science to management and policy can be better understood and are accessible to stakeholders. basically, better communication about and perhaps dedicated venues to highlight interactions between science and values/politics
Conveying findings effectively to policy makers and to advocate for more comprehensive management decisions when it's felt that they are insufficient given the science.
More synthesis, communication, collaboration, less bureaucracy.
Programs that take action on the following fronts: predator barriers, predator removal, enhancement of juvenile migration corridors, point and non-point pollution
Work toward moving issues more quickly through the process to reach final goals
Science synthesis and communication to bring a shared understanding of the science activities underway and what we are learning. Individual agencies and organizations will continue to have science programs. We need mechanisms in place to increase the information sharing and learning between the organizations.

Involve agencies whose mission it is to manage Delta resources (e.g., water quality regulation) in decisions of what research to fund through State bond and Delta Science Program funding initiatives.
Require that data collected with State or federal funding or through IEP be placed in some publicly accessible database in a reasonable timeframe.
1) All science programs need to invest in proactive and effective science communication programs that develop customized products for the diverse audiences that need to understand Delta science; 2) Establish an inter-agency science leadership team for the Delta that provides guidance to agency directors and policy-makers on the "long-game:" how to prepare the Delta and its science and water infrastructure for climate change impacts. This team needs to have authority (unlike the ISB) and the structure needs to be set up so that policy-makers are engaged and listening. The team needs to be willing to talk with decision-makers about how different management decisions might play out, given the latest understanding of the science. This could possibly a science-arm of DPIIC, but with more authority. 3) A science funding infrastructure is needed that is actually nimble. This needs to be out of the hands of State or federal contracting structures; current structures are beleaguered by restrictions and a myriad of rules and contracting takes a very long time. Science leaders need to be able to infuse money rapidly into projects when the need presents itself.
Effective Communication! Communication! Communication!
Continued effort at communication. Not that this is not being done, but more could be done.
Using accredited laboratories for scientific decisions
Better communications with decision-makers from Southern CA regarding desalination options.
Take money and politics out of the decisions
Improve the connection between management needs for information and the information being collected. We currently spend a lot of resources collecting status and trends data that is of limited utility to understanding what actions we need to take to restore important ecosystem functions and beleaguered fish populations or to understand how effective our management actions are at achieving their intended/desired outcomes.
Build a centralized place to share the latest relevant science advances in a single place
Facilitators with training in Adaptive management and Structured Decision Making
Provide additional support for data integration, harmonization and access efforts, recognizing that redundant efforts across different agencies are acceptable. As technology improves and evolves this will naturally sort itself out. Continue to and expand funding to support collaboration and communication. Recognize the value of having experts that focus their scientific careers on the Delta and thus gain in-depth knowledge and experience.
Greater communal support and assessment of science initiatives, e.g. having more funding solicitations or interagency study design and prioritization as opposed to single agency directed initiatives.
Streamline the permitting and funding processes
More explicit management recommendations from scientists

Regular synthesis of datasets, increased frequency of recommendations on whether monitoring enterprise provides sufficient data to analyze the effectiveness of management actions, increased communications regarding studies that reinforce/contradict existing management actions.
Much strong advocacy for use of science in decision-making & practice, not politics
Relative to salmon, focus on the largest loss points in the Delta and develop solutions. Cross Channel Gates, Indirect Losses, CVP and SWP losses and Salvage losses.
Greater participation and coordination with academic institutions; better coordination among agencies; regular science updates for decision makers
Funding the scientists, and then listening to, and acting on, their hard truths.
We have a bewildering array of agencies and people involved, all with different motivations and goals. It feels very disorganized. Not sure how to fix this, though.
Habitat restoration, thermal refuges in particular.
Connecting it to people. By unwinding and interpreting the social complexities that lead to situations requiring scientific study. To go beyond allowing/providing a forum for differing opinions by interpreting those opinions vis a vis science.
Make funding processes open and transparent, and allow bold ideas to thrive rather than kill off any creativity. Currently, science is incremental and is done by only a previlaged few people and agencies, and innovative solutions and transformational science is not happening.
Develop mechanisms to link managers with scientific researchers, iteratively, throughout the development, conduct, and assessment of the results and implications of scientific research, so that scientific research stays focused on management-relevant outcomes.
Inter-agency/inter-organizational communication/collaboration (outside the Delta science enterprise) - e.g., one branch of CDFW not aware of work of another, nor communication with NOAA, etc.
There should be more open scientific coproduction studies conducted in the Delta, which bring together diverse stakeholder representatives to define research questions, help design the experimental methods, and interpret study findings.
Development adaptation strategies to address climate change impacts to the Delta as well as development of policies and governance to implement those adaptation strategies.
More integration via a single web site.
Give more attention to sources and and management strategies for engaging both institutional and physical uncertainties.
Planning for the future of our rivers with a warming climate.
Increase opportunities for scientists to converse directly with policymakers.
Diverse teams that include stakeholders, scientists, decision makers and communications specialists during all stages of studies and projects.
Coordination and Communication. It is hard to organize, archive, and document science in the Delta. There is no one-stop place for a new scientist to train themselves covering most disciplines.
Fund more long-term studies of populations other than the salmon runs.
Seek to better align mandates/missions of agencies. have officials take bold/science-based decisions.

More transparency, coordination, and collaboration in science funding decisions, as well as more funding for management-relevant science.
Communication between scientists and non-scientists needs to be greater. Research conducted needs to have the end user in mind and broader- mayors, local governments, local NGOs- these type of groups need greater facilitation into the Delta science facilitation and planning. Also, regular evaluation to identify nexuses between monitoring and other efforts should be increased. Long term monitoring efforts provide valuable data, however they could be restructured to answer more pressing and modern questions than those that they were developed to answer.
Education Education Education!!!