PUBLIC POLICY INSTITUTE OF CALIFORNIA

Stress Relief

Prescriptions for a Healthier Delta Ecosystem

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SUMMARY

A century and a half of human uses of the Sacramento–San Joaquin Delta and its greater watershed have transformed the aquatic ecosystem, sharply reducing native fish populations. Efforts to reverse these declines have been largely unsuccessful, and the rising costs of regulation have fueled social conflicts. These conflicts have often played out in the courtroom, where scientific uncertainty has been used to undermine the legitimacy of Delta science.

The state is at a critical juncture on Delta policy. Implementation of the first "Delta Plan"—the foundational plan for meeting the "co-equal goals" of ecosystem health and water supply reliability called for in the Delta Reform Act of 2009—is to begin in 2013. Decisions are also expected on the Bay Delta Conservation Plan (BDCP), which is intended to improve conditions for native species while facilitating continued water exports from the Delta under the federal and state Endangered Species Acts. These and related efforts offer significant promise. But California still faces an uphill battle to incorporate science effectively in decisionmaking and make judicious management choices within a highly fragmented and adversarial institutional structure, involving dozens of federal, state, and local entities.

This report summarizes the results of a wide-ranging study examining steps California can take to improve the health of the Delta ecosystem through science-based, integrated management of the many sources of ecosystem stress. Our key findings:

1. "Reconciliation ecology" offers a realistic approach to managing the Delta's highly altered ecosystem and meeting the co-equal goals. Reconciliation seeks to improve ecosystem

processes to support desirable species while acknowledging that humans will continue to rely on the region's land and water resources. This approach would restore natural processes wherever possible (particularly favorable flows and habitat) and use infrastructure and technology (such as hatcheries) to support native species. Because some parts of the Delta are unlikely to support native species, area specialization is essential. Both the Delta Plan and BDCP contain elements of a reconciliation approach.

2. The reconciliation process needs to be guided by science and broadly supported by Californians. We surveyed the scientific community and engaged policymakers and stakeholders to gauge their current views. Scientists favor reconciliation strategies: strong majorities emphasized flow and habitat actions in and upstream of the Delta that would restore more natural processes. Stakeholders and policymakers generally agree with scientists on high-priority solutions. However, stakeholders were more likely to prioritize actions in areas unrelated to their own uses of the Delta and shy away from actions that would be costly for them.

3. A modest but powerful set of changes to existing institutional structures can help achieve better environmental outcomes while containing costs, which are likely to exceed several hundred million dollars annually:

   Consistent planning. Comprehensive reviews of the numerous related planning efforts to determine their compatibility with the state's overall Delta Plan.

   Integrated and accountable management. Proactive use of the new Delta Plan Interagency Implementation Committee to coordinate implementation of work plans, hold agencies accountable, and integrate adaptive management.

   More comprehensive and integrated regulation. Regulatory coverage of more stressors, reduced duplication, and expedited environmental permitting (currently a costly obstacle to ecosystem reconciliation).

   Common pool science. Creation of a Delta science joint powers authority involving regulators and regulated parties that would foster shared understanding, build knowledge, and inform adaptive management efforts.

With this game plan for a more environmentally effective, fiscally responsible approach, policymakers can make a stronger case to stakeholders and the broader public for the necessary financial support.

Please visit the report's publication page to find related resources:
www.ppic.org/main/publication.asp?i=1051

Introduction

> In times of stress, be bold and valiant.
> —Horace

The Problem

The most vexing area of California water policy is the Sacramento–San Joaquin Delta, a network of mostly manmade islands and channels at the confluence of the Sacramento and San Joaquin Rivers. Together with the San Francisco Bay, the Delta forms the largest estuary on the Pacific Coast of the Americas. It is the terminus of California's largest watershed and a major source of the state's water supply. It is also a valued ecological resource.

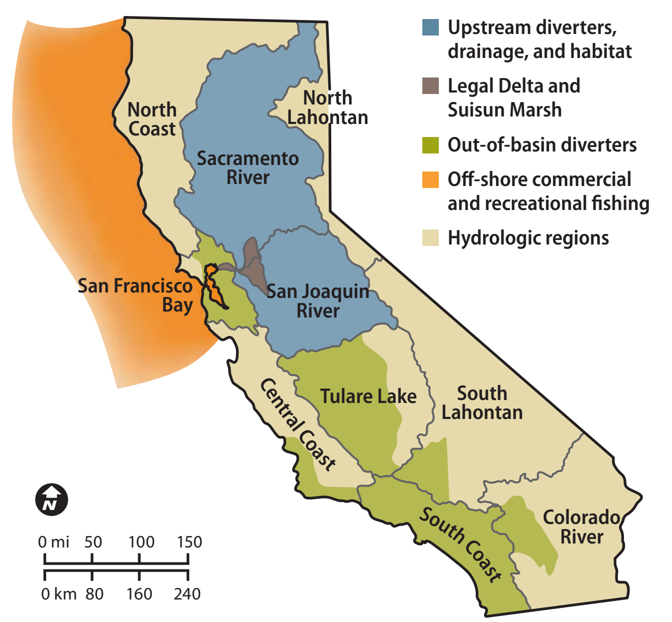
Human actions since the arrival of European settlers in the mid-1800s have severely disrupted conditions for native species, and especially fish, in the Delta itself and in upstream areas within the greater Sacramento and San Joaquin River watershed.

- More than 95 percent of the Delta's original 700,000 acres of tidal wetlands have been replaced by rock-rimmed agricultural islands, many of which lie well below sea level (Whipple et al. 2012).
- Water flows into and through the Delta have been profoundly altered from their natural, seasonally variable patterns by infrastructure built for water supply and flood control, including upstream dams and diversions and large export pumps in the south Delta. From 1995 to 2005, upstream diversions removed an average of 38 percent of annual runoff in the greater watershed (46.6 million acre-feet), and in-Delta and export diversions removed another 14 percent (Lund et al. 2007). Most of California's residents and irrigated farmland rely at least in part on water from this watershed (Figure 1).
- Wastewater and runoff from roughly 1.7 million households and 4 million acres of farmland within the Sacramento and San Joaquin River regions and the Delta itself have polluted the flows remaining in the system, degrading water quality.
- Upstream dams have cut off most natural salmon and steelhead spawning areas, and levees have shrunk the availability of riparian and seasonal floodplain habitat. Hatcheries, established to maintain salmon and steelhead fisheries after dams were built, have unintentionally harmed wild populations of these fish (Williams 2006; Lindley et al. 2009; Carlson and Satterthwaite 2011).
- Alien species have been introduced intentionally for fishing or through ship ballast water, aquarium releases, and ponds and nurseries, making the San Francisco Bay–Delta one of the most invaded estuaries in the world (Cohen and Carlton 1998). Some aliens thrive in this highly altered ecosystem, competing with natives for food, preying upon them, and degrading their habitat.

The causes of the Delta's aquatic ecosystem declines are many, and virtually all Californians bear some responsibility, as land and water users, consumers of local fish, and purchasers of imported goods that arrive in California by ship (Figure 1).

The past three decades have seen numerous rebalancing efforts to improve the health of the Delta's aquatic

Figure 1. Almost all Californians use Delta resources and share responsibility for its ecosystem woes



NOTES: Out-of-basin diverters include those receiving Delta exports as well as parts of the San Francisco Bay and Tulare Lake hydrologic regions receiving water from the Mokelumne, Tuolumne, and San Joaquin Rivers. Some water users in the San Joaquin River hydrologic region also receive Delta exports.

ecosystem and especially its imperiled native fish species, many of which are now listed under federal and state Endangered Species Acts (ESA). (See the text box for our definition of a "healthy ecosystem.") Scientific research has helped improve understanding of how the ecosystem works and what native species need to thrive. Mitigation actions have been launched to address many sources of ecosystem stress, including improvements in upstream habitat (e.g., removal of small dams, screening diversions, replacing gravel in spawning areas), changes in flow management (with particular focus on flow seasonality and export volumes), and new water quality regulations. And California has attempted to address the highly fragmented nature of resource management—which involves dozens of federal and state agencies and hundreds of local governments, water and wastewater utilities, and flood districts. Stakeholder involvement has been a hallmark of these efforts, with groups representing a wide range of interests participating in public processes (Lund et al. 2007; Layzer 2008).

Ecosystem health: subjective but meaningful

Ecologists are often uncomfortable with using the terms "healthy" or "unhealthy" to describe ecosystems. Health is defined according to human perceptions and values—the World Health Organization defines it as complete physical, mental, and social well-being of an individual or a group of individuals. This translates poorly to the food webs, species, and physical and chemical processes that make up ecosystems. Indeed, some argue that the Delta's ecosystem, which now resembles a lake in southern Arkansas, is perfectly healthy for today's mix of nonnative species. Yet, the term ecosystem health is widely used in policy discussions about the Delta. With apologies to ecologists, we define a healthy ecosystem as one with environmental and ecological conditions that sustain ecosystem functions or services valuable to society, including stable populations of desirable plants and animals (both native and nonnative), flood hazard reduction, and high-quality water for drinking, irrigation, and recreation. We focus on the objective of improving conditions for native fish—widely considered among the priority species society is seeking to maintain in this ecosystem.

The two most recent high-profile efforts at greater coordination are the Delta Plan and the Bay Delta Conservation Plan (BDCP). The Delta Plan is the state's foundational long-term (100-year) planning tool for meeting the "co-equal goals" of water supply reliability and ecosystem health established by the Delta Reform Act of 2009 (Cal. Water Code § 85054). It is scheduled to be adopted in the spring of 2013.[1] Responsibility for its development and implementation lies with the Delta Stewardship Council—a new state agency created by this same legislation. The BDCP has been under development since 2006 and is scheduled for public review in 2013. It would provide both broader environmental protection for the Delta's endangered species and a more reliable framework for water exports under the terms of both federal and state ESAs.[2] The BDCP is large—potentially involving multibillion-dollar investments in Delta habitat restoration and new water conveyance infrastructure—but more narrowly focused than the Delta Plan. If deemed sufficiently protective of native species, BDCP will be incorporated into the Delta Plan, as will other plans related to Delta management (e.g., water quality and flows, flood protection) and the conduct of science.[3]

These efforts offer significant promise but also face scientific, political, and institutional hurdles. The scientific and political hurdles are closely linked. Decisionmakers view science as the basis for policy changes, but science itself has become a major source of conflict. Although scientific understanding of the ecosystem has vastly improved, the Delta's complexity makes uncertainty inevitable. Also, as native fish populations have continued to decline, regulations intended to reverse these trends have become increasingly costly for the affected parties. Scientific uncertainty—and the inability of the scientific community to communicate effectively about what is and is not known—is frustrating, and decisionmakers often blame science as unreliable. Uncertainty has also become a rationale for resisting mitigation actions, both in regulatory forums and in the courtroom.[4] When parties engaged in coordinated planning processes are likely to meet as legal adversaries, science takes on a "combat" role—where legal defensibility, rather than improved understanding, becomes a driver, and all sides develop their own sources of expertise and make selective use of facts and analyses. These kinds of disagreements have been debilitating for policy discussions about the causes of native species declines and effective solutions (National Research Council 2012).

Another key hurdle is institutional fragmentation, which affects both Delta policy and science. Despite some important achievements in interagency coordination, fragmented approaches to planning, regulation, and management still threaten California's ability to manage the Delta ecosystem effectively (and *cost* effectively). "Stovepipes" and "silos" within and across agencies working on different aspects of a problem or on different stressors lead to piecemeal approaches. The consequences include inconsistent regulations, costly delays, missed opportunities, and, perhaps most important, an inability to make reasoned and balanced tradeoffs.

No policy or management package is likely to reverse the declines in native species without a more organized, science-driven approach to Delta problem solving. This will require more integrated monitoring and scientific analysis, adequate and sustainable funding, and truly integrated management across agencies and interests that often operate at cross-purposes.

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Goals of This Report

This report summarizes the results of a study on how Californians can improve the health of the Delta's aquatic ecosystem through integrated management of the many sources of ecosystem stress. We focus on maintaining native biodiversity—an important social goal in its own right and a key to sustaining the many economic activities that rely on the water and land resources of the Delta's watershed. We draw together information from scientific, economic, institutional, and legal perspectives on the origins of the Delta ecosystem's problems, the efficacy of proposed solutions, and strategies for improved science and management. We reviewed relevant scientific, legal, and policy literature and benefitted from extensive input from scientists, policymakers, and stakeholders engaged in Delta science and policy.

We also conducted two confidential surveys in the summer of 2012. The first sought input from scientific experts—researchers who have authored peer-reviewed scientific journal articles on the Delta ecosystem—on the impact of ecosystem stressors on native fish species and the biological potential of a suite of management actions proposed to address these stressors. The second survey posed a subset of these questions to engaged stakeholders and policymakers—participants in the Delta Plan or BDCP process or senior officials of key state regulatory agencies.

We received responses from 122 scientists (41% of those contacted).[5] Slightly more than half of these scientists work for universities, roughly a third for federal and state agencies, and the remainder for advocacy organizations, local agencies, and consulting firms. We received responses from 240 stakeholders and policymakers (31%). We assign these respondents (often referred to below as "stakeholders") into six groups:[6]

Delta-based interests (38 respondents): representatives of local governments, water agencies, advocacy groups, and other engaged residents;

Environmental advocates (56 respondents): employees and members of environmental organizations;

Export interests (22 respondents): primarily representatives of water agencies outside the watershed that depend on Delta exports;

Fishing and other water-based recreation interests (14 respondents): principally representatives of recreational fishing within the watershed but also several representatives from the salmon and crab industries;

Upstream interests (39 respondents): representatives of agencies that divert water upstream of the Delta or discharge pollutants into the watershed; and

Federal and state officials (56 respondents): employees of regulatory and management agencies active in the Delta.

The survey of scientists helps synthesize the current scientific understanding of stressor impacts and mitigating actions, highlighting areas of higher and lower consensus. Seeking expert views is particularly valuable for the Delta, given the incomplete guidance from the scientific literature on forward-looking, ecosystem-based management (National Research Council 2012).[7] The stakeholder survey makes it possible to identify areas of agreement and divergence between scientific researchers and stakeholders and among different stakeholder groups. Our surveys aim to provide useful insights into the challenges and opportunities in Delta ecosystem planning and policymaking and to help inform the design of a Delta science effort that better supports the societal goal of ecosystem health.

In the following sections, we draw on this diverse set of analyses to answer the following questions:

How did we get here? How do scientists, government officials, and stakeholders view the causes of the current condition of the Delta's native fish species?

Where might we go? What is a realistic future for a more native-fish-friendly Delta ecosystem, given limitations imposed by the landscape, water availability, climate change, and the ecological needs of native species?

What are the most promising ways to get there? How do a wide range of ecosystem management actions compare in terms of likely biological effectiveness (as assessed by scientific experts) and other societal considerations (economic and financial costs and perceptions of various stakeholder groups)?

How can our institutions become more suited to the task? What are options for more integrated science, management, and regulatory oversight?

We conclude with some reflections on how to build public support for tackling this complex challenge.

This research has generated several reports:

Aquatic Ecosystem Stressors in the Sacramento–San Joaquin Delta (Mount et al. 2012) summarizes the science of Delta ecosystem stressors for a policymaking audience. Available at www.ppic.org/main/publication.asp?i=1024

Where the Wild Things Aren't: Making the Delta a Better Place for Native Species (Moyle et al. 2012) describes a realistic long-term vision for achieving a healthier ecosystem. Available at www.ppic.org/main/publication.asp?i=1025

Integrated Management of Delta Stressors: Institutional and Legal Options (Gray et al. 2013) lays out our proposals for institutional reform of science, management, and regulation. Available at www.ppic.org/main/publication.asp?i=1054

Scientist and Stakeholder Views on the Delta Ecosystem (Hanak et al. 2013) presents more results from our two surveys. Available at www.ppic.org/main/publication.asp?i=1053

Costs of Ecosystem Management Actions for the Sacramento–San Joaquin Delta (Medellín-Azuara et al. 2013) assesses costs of the management actions discussed here. Available at www.ppic.org/main/publication.asp?i=1052

The Role of Ecosystem Stressors

There is broad scientific agreement that undesirable changes to the Delta ecosystem are caused by a wide range of stressors (National Research Council 2012; Delta Independent Science Board 2011). We have grouped these stressors into five categories, all linked to human activity within the Delta and the greater watershed (Mount et al. 2012):

Discharges. Land and water use activities that directly alter water quality in the greater Delta watershed by discharging contaminants that pollute the water, degrade habitat, disrupt food webs, or cause direct harm to native species. This category includes point and nonpoint sources of conventional pollutants, nutrients (e.g., from fertilizers), "emerging contaminants," such as endocrine disruptors (e.g., from personal care products and pharmaceuticals), legacy pollutants from mining and waterfront activities, and other forms of water pollution.

Fish management. Policies and activities that can adversely affect populations of native species, such as commercial and sport harvest, poaching, and outdated hatchery practices.

Flow regime change. Alterations in flow characteristics from water management facilities and operations, including volume, timing, hydraulics, sediment load, and temperatures. This category includes upstream dams and diversions throughout the greater Delta watershed, in-Delta diversions, and exports.

Invasive species. Alien plants or animals that harm or displace native species by disrupting food webs, altering ecosystem functions, introducing disease, or increasing predation.

Physical habitat alteration. Land use activities that alter or eliminate physical habitat that supports native species, including upland, floodplain, riparian, open water/channel, and tidal marsh. This category includes levees, channelization, diking and draining of wetlands, dams, dredging for ship channels, and the narrowing or reduction of riparian zones, shallows, and tidal and fluvial marshes.

Two external sources of stress will interact with local stressors and influence the feasibility of management actions. Variability in ocean conditions directly affects native fishes that migrate through the Delta (salmon, steelhead, and sturgeon), as well as the regional climate and weather.[8] And climate change will affect the ecosystem through warmer temperatures, accelerated sea level rise, and changing runoff patterns.

Approaching complex stressors in a simplified way allows for a broad analysis of the causes of ecosystem stress and aids strategic thinking about mitigation strategies.

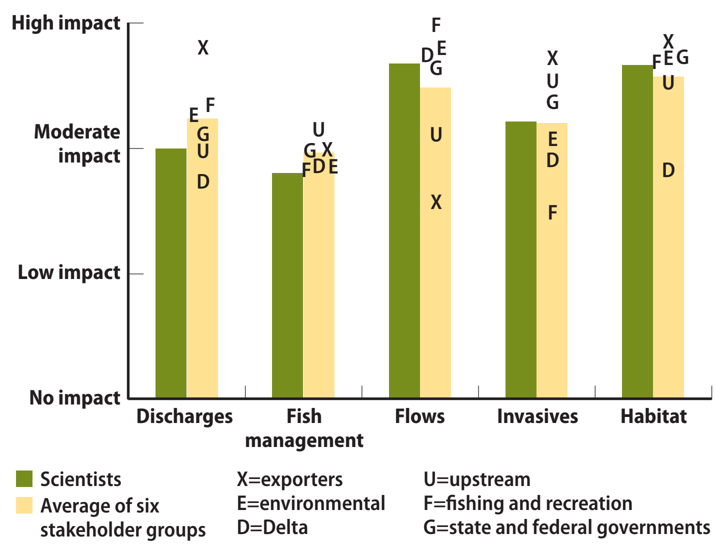
Which Stressors Are Most Important?

Few scientists are comfortable ranking stressors in order of their responsibility for the decline of the Delta's native species, given their significant and often complex interactions (National Resource Council 2012). For example, levees reduce seasonal floodplain habitat from high winter and spring flows, which reduces spawning and rearing areas for many native fish. Likewise, upstream water diversions can intensify effects from agricultural and urban discharges, altering food webs and ecosystems in ways that favor invasive species. Although the scientific community often emphasizes the complexity of the problem, recent public policy debates often oversimplify it—with various stakeholder groups focusing exclusively on one stressor or another.

Given this disconnect between scientific and public discourse, it is useful to see how various groups viewed ecosystem stressor roles in our confidential surveys. Figure 2 shows respondents' views of the importance of each of the five categories of stressors in the decline of native fish species. The pairs of bars compare the views of scientists (green) and the average view across all six stakeholder groups, with each group weighted equally (yellow); the average responses for each stakeholder group are indicated by one-letter abbreviations.

Despite often-heated public exchanges, both the scientists and representatives of stakeholder groups generally agree that all five stressor categories have contributed to the decline of the Delta's native fish. Most respondents believe that all stressor categories have had at least a moderately negative influence, and almost no one considers any category completely unimportant. This broad acceptance

Figure 2. Scientists and stakeholders tend to agree on stressor impacts



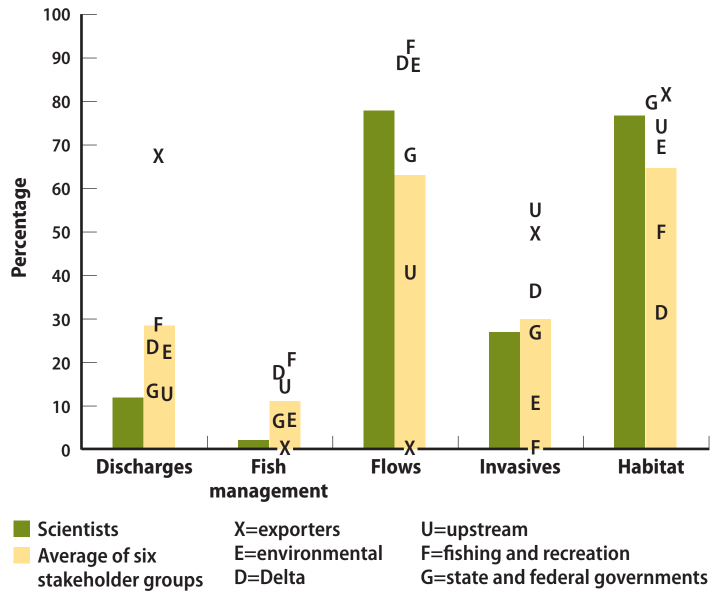
SOURCE: Hanak et al. (2013).

NOTES: The figure reports mean responses to the instruction: "Please indicate the level of impact you believe each stressor group has had on the historical decline of the Delta's native fishes." Categorical responses were coded as "no impact" (0), "low impact" (1), "moderate impact" (2), and "high impact" (3). For the scientists, this shows the average of responses to separate questions for three types of Delta fishes (pelagic, anadromous, and native resident). Among scientists, "don't know" rates were highest for discharges (15%) and direct fish management (12%), followed by invasive species (5%), habitat (2%), and flow regime (1%). For stakeholders, "don't know" rates were lower: fish management (9%), discharges (3%), invasives (3%), habitat (1%), and flows (0%).

suggests the potential for a more constructive public discourse on Delta policy.

The groups diverged somewhat in their emphasis, however. A strong majority of scientists considered flows and habitat to be high-impact stressors, and most stakeholders agreed. The exceptions were groups benefiting most from actions causing ecosystem stress. Delta residents, who live and work in the highly altered landscape of today's Delta, were least likely to rank habitat alteration as a serious problem. Similarly, exporters and upstream interests, who benefit daily from water diversions, tended to view flows less negatively. Scientists generally ascribed a more moderate role to the three other stressor groups (discharges, fish management, invasives).[9] This was also the case with stakeholders on average, though here again the views of individual groups reflected their economic interests. Delta and upstream interests, who discharge pollutants into the watershed, gave discharges the lowest score, whereas exporters, located outside the watershed, scored them the highest. The divergence widened when respondents identified the top-two stressor categories (Figure 3). This illustrates the difficulties in using science to help guide policymaking for the Delta ecosystem.[10]

Figure 3. Views differed widely on which two stressors are most important



SOURCE: Hanak et al. (2013).

NOTES: The figure reports the share of each group that selected stressor categories in response to the question: "Considering interactions among different types of stressors, which two stressor groups have contributed most to the decline in the Delta ecosystem's overall ability to support native species?" "Don't know" response rates were as follows: state and federal officials (4%), scientists (2%), and no one in the other groups shown

A Realistic Vision for the Delta Ecosystem

Although assessments of the relative contributions of stressors may differ, it is hard to deny that the present-day Delta ecosystem bears only a superficial resemblance to the ecosystem of 25 years ago, not to mention the ecosystem of 50, 100, 150, and 250 years ago (Moyle and Bennett 2008; Whipple et al. 2012). Few of the changes to the ecosystem have been intentional. Rather, hundreds of actions over time to facilitate growth in California's human population and its economy have had unintended effects. Thanks to greater scientific understanding of ecological and human systems, Californians now know that social and economic choices lead to ecological change. In making such choices, policymakers and stakeholders must have ecological goals more firmly in mind. Otherwise, the Delta ecosystem will continue to change willy-nilly in ways that are bound to be progressively worse for its native species—and probably also for humans.

The Harsh Realities

Effective policies must be based on an acknowledgment that it is not possible to "undo" the damage caused by past actions:

The structure and functions of the Delta ecosystem have changed dramatically and will continue to change, regardless of future policy decisions. For instance, many deeply subsided Delta islands are bound to flood permanently at some point, creating habitat unlike anything existing there before. New invasive species will keep arriving, driving further changes.

Numerous human-caused and natural constraints limit management options. Human-caused constraints include widespread land subsidence, local urbanization, water scarcity, and invasive species. Sediment availability and tidal energy also limit management actions.

The current ecosystem is novel in its species composition and many of its physical features. The Delta is now home to a mix of native species and alien species from all over the world, and they interact in ways that are not always well understood. Some alien species (e.g., overbite clam, Brazilian waterweed, inland silverside fish) are clearly making the ecosystem less favorable for native species, whereas others have more positive effects (e.g., alien crayfish are now a major food for river otters).

Ecological improvement will require reducing physical and behavioral stresses on fish and other organisms, both within and upstream of the Delta. This will require tackling multiple sources of stress to better support ecological functions in the system.

Climate warming and sea level rise are steadily changing environmental conditions for individual species and entire biological communities. Managers can compensate for these changes to some extent (e.g., through better management of cold-water pools in reservoirs), but the effectiveness of most actions will reach a limit within 100 years without successful global efforts to slow the pace of climate change (Moyle, Quiñones, and Kiernan 2012).

These realities are sobering, but with sufficient political and institutional will, Californians can direct and adapt to inevitable ecological changes. To do this, Californians need a vision of what a desirable future Delta ecosystem should look like, what services they want it to provide, and what species it should support ("desirable" species). Otherwise, large sums of money are likely to be spent on measures that do little good for native fishes and the ecological functions that support them, such as massive levees to protect low-value land, additional and bigger dams, piecemeal mitigations for water diversions, and increased floodplain development.

A Hopeful Vision: Reconciliation Ecology

"Reconciliation ecology" offers a realistic but hopeful way to envision the future.[11] Reconciliation ecology recognizes that since humans are major players in all of the world's ecosystems, the conservation of biodiversity must occur within human-dominated systems. But reconciled ecosystems can have the look, feel, and function of natural systems—especially in terms of services provided—and these ecosystems can be managed to favor some organisms over others. The idea of a reconciled Delta ecosystem fits well with the co-equal goals of water supply reliability and ecosystem health established by the Delta Reform Act of 2009 and by federal law.[12] Reconciliation requires functional integration of the co-equal goals, accounting for interactions among stressors and the many beneficial uses that depend on the waters and lands that constitute the ecosystem. Likewise, reconciliation is compatible with state and federal ESAs, which are intended to prevent extinction and maintain populations of endangered species in their native range. Protection of endangered species can be a driver of a reconciled ecosystem, but climate and other irreversible changes may push even a reconciled ecosystem to a state where it cannot support some listed species.[13]

In *Where the Wild Things Aren't: Making the Delta a Better Place for Native Species* (Moyle et al. 2012), we present a vision of a reconciled Delta ecosystem that reflects our own evolving ideas of desirable possible futures. According to this thinking, a reconciled Delta should be guided by five concepts.

Natural processes should be restored wherever possible. In broad terms, this means allowing the Delta to function like the upper estuary it once was by providing for a strong, seasonally changing, upstream-downstream gradient in salinity, temperature, turbidity, and other factors related to inflow and outflow (Moyle et al. 2010). Locally, this will require breaching dikes to restore tidal marshes in parts of Suisun Marsh and the north Delta and managing parts of the Yolo Bypass as seasonal floodplain to benefit native fish and other wildlife.

Different parts of the Delta should be specialized for different functions. Although the Delta is often thought of as a single block of habitat, different regions functioned quite differently in the past (Whipple et al. 2012) and have different trajectories for the future. The region where the native ecosystem has the most ability to recover, given current land elevations and other ecosystem attributes, is the bayou-like Sacramento Delta: an arc of interconnected habitats (or potential habitats) for native species extending from the Yolo Bypass, through the northwest Delta (Cache-Lindsay Slough), past Sherman Island, and into Suisun Marsh. At the opposite extreme, a large block of subsided islands in the central Delta has a high probability of becoming permanently flooded, creating "lakes" with no historical equivalent that will mostly favor alien species. Many native species already prefer other areas (Figure 4a), and it seems realistic to promote area specialization in managing the ecosystem (Figure 4b).

Levees, channels, diversions, and gates should be reoperated, reconstructed, or removed to benefit desirable species. This will be needed partly to restore more natural processes, such as seasonal variation, habitat creation, and natural flow directions. In a reconciled Delta, this infrastructure would be redesigned and managed to meet the co-equal goals—a marked shift from when most of this infrastructure was built.

Near-term solutions will differ from long-term solutions. Today's ecosystem has been so heavily altered—physically and biologically—that it will take decades to bring about a more favorable state. In the near term, intensive management actions, such as conservation hatcheries, deliberately flooded islands, and managed floodplains, may be needed to prevent species from going extinct and to learn more about what works.

The Delta needs an effective, well-funded system of adaptive management. Adaptive management is a systematic, science-based approach to operating a dynamic system that encourages experimentation and does not punish managers for taking risks, as long as one can learn from failures. This approach should be built into the culture of organizations that do large-scale management of the Delta's natural resources. Experimental adaptation will be needed to deal with new invasions in the short run (e.g., quagga mussel) and with climate change in the longer run.

Elements of these guiding concepts are contained in available drafts of both the Delta Plan and the BDCP. At their core, both plans attempt to reconcile competing demands for use of the Delta's natural resources. Both acknowledge the need to restore ecological processes for native species, and neither envisions restoring the Delta to a historical condition. Both call for extensive habitat restoration in key areas where elevation, hydrology, and land use allow it, implicitly promoting the type of area specialization discussed above (and shown in Figure 4b).

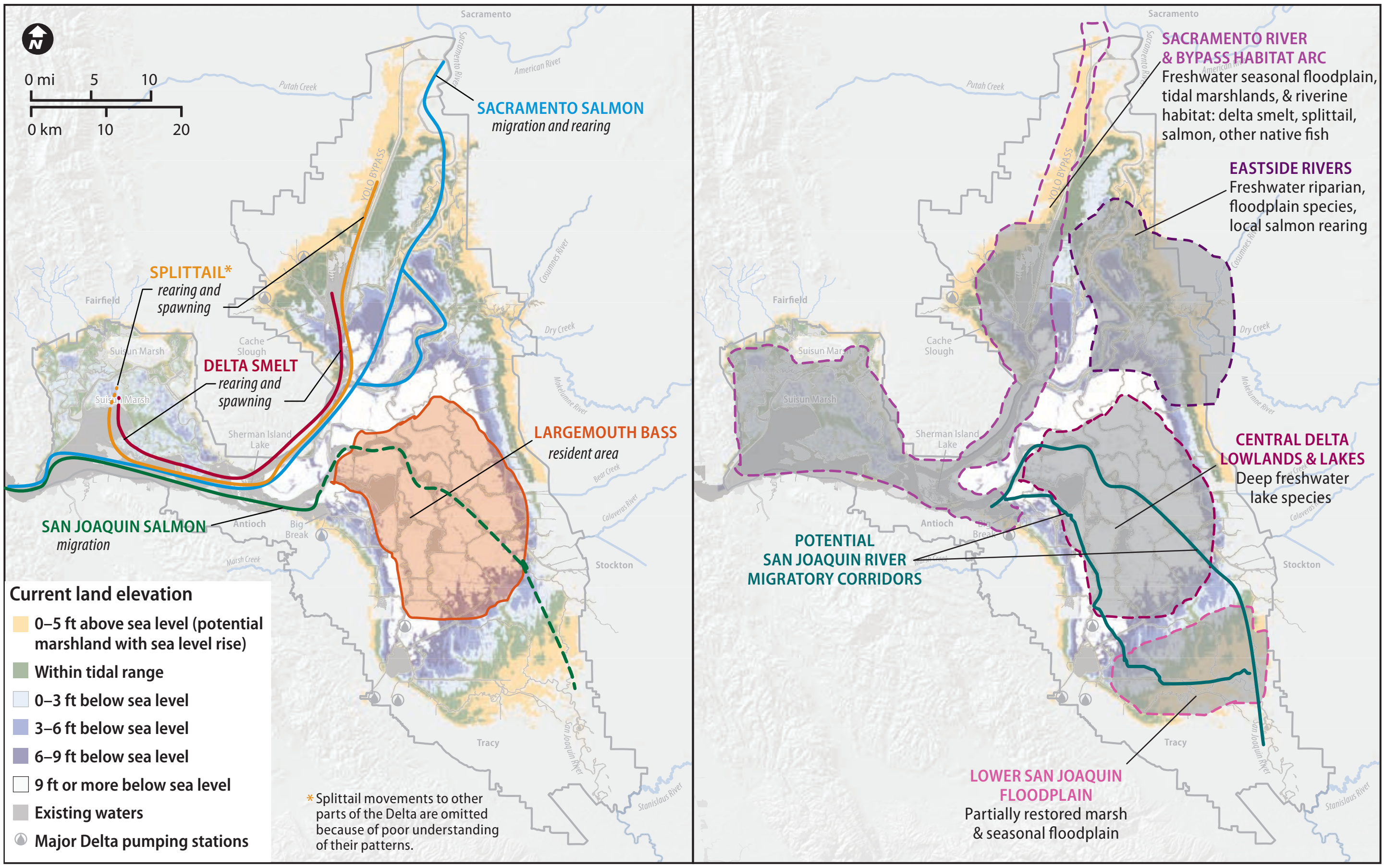
However, neither plan offers a comprehensive approach to ecosystem reconciliation. Neither fully regionalizes ecosystem management in the Delta—both plans tend to focus only on areas where native species are likely to persist, rather than also considering how other parts of the Delta might support alien species with some desirable properties, such as largemouth bass. And although both plans acknowledge that changes in climate, island flooding, land use, and invasive species will alter future ecosystems, they offer limited guidance on how to address these changes. Both plans envision a new conveyance system for Delta exports but otherwise tend to view flow management infrastructure in the Delta—particularly levees—as static for the indefinite future. This is highly unlikely to be the case (Lund et al. 2010). Finally, although both plans call for adaptive management and science-based decisionmaking, neither has yet offered a well-funded, well-designed adaptive management strategy supported by a robust and integrated science program.

Choosing the Most Promising Actions

In choosing a portfolio of actions to support a reconciled Delta ecosystem, two considerations are key: the biological potential to support desirable species and the cost to those using the Delta's lands and waters. Ideally, the highest potential for biological payoff would come at the lowest cost. In practice, high-potential actions may have high costs, which means that negotiating tradeoffs is a major challenge for Delta policymaking.

Figure 4. Fish habitats today and in a reconciled Delta

a. Current habitat **b. Future habitat (ecosystem areas)**



NOTES: The northwest corridor provides the most favorable habitat for native fish species. Salmon, delta smelt, and splittail are native fish species, and largemouth bass is an alien species valued for recreational fishing that does well in the more altered central Delta. Colored lines indicate principal migratory routes through the Delta of each species. Dashed line indicates San Joaquin salmon migration (poor conditions). Topography of major urban areas excluded.

NOTES: Ecosystem areas would support different functions. These areas would continue to support most urban and agricultural land uses as well as transportation functions. Islands within the central Delta whose economic value (including for such strategic uses as roads and rail lines) justifies the expense would continue to be protected. The Sacramento River and Bypass Habitat Arc includes a migratory corridor for Sacramento River salmon and steelhead. San Joaquin River salmon would need migratory corridors through the inhospitable central Delta. Topography of major urban areas excluded.

SOURCES: Moyle et al. (2012); the base elevation map is adapted from Stuart Siegel, *Wetlands and Water Resources* (2009). LiDAR elevation sources: Suisun Marsh (2005); Delta (2007).

Here, we examine the biological potential and likely costs of some promising actions for supporting the Delta's native fish species. For views on biological potential, we draw on our survey of scientists, who assessed the ability of 32 actions to improve conditions for the Delta's native fish species and picked the five actions they considered most promising as a package. Although scientific understanding of what will work in this ecosystem is still uncertain and subject to change, ecosystem management will need to be informed by science on an ongoing basis. The survey gauges the current views of the scientific community about the success and relative importance of a broad suite of actions.

We also examine the potential costs of actions and the views of policymakers and stakeholders on ecosystem priorities. Our study *Costs of Ecosystem Management Actions for the Sacramento–San Joaquin Delta* (Medellín-Azuara et al. 2013) is a first attempt at sorting a large suite of potential actions by their economic and financial costs. Our survey of stakeholders and policymakers allows a comparison with scientist views on priority ecosystem actions. Although ecosystem policy must be informed by science, policy is ultimately made by society.

When stakeholder views diverge from those of scientists, strategies are needed to develop a common understanding.

What Do Scientists Consider Most Promising?

Table 1 presents the actions we asked scientists to evaluate for their potential to improve the Delta ecosystem's ability to support native fishes. The list includes interventions addressing each stressor area, sorted by level of implementation experience within the Delta watershed and likely costs. Over half of these actions (denoted as "under way") are already employed to some extent within the Delta watershed, with additional implementation planned or being considered.[14] The other measures have not yet been tried here. Two actions—tidal marsh restoration (#29) and farm fertilizer discharge control (#5)—are planned for near-term implementation ("planned"). Several others are being considered based on modeling or experience outside the basin ("considered"). For example, BDCP negotiators are studying a canal or tunnel to divert exports around or under the Delta (#21). Finally, some actions are still at the conceptual stage ("conceptual") and not yet sufficiently developed for active consideration—for example, ideas about controlling invasive clams, which compete with native species for food (#24), and increasing sediment available to the Delta, which could help support tidal marsh restoration (#32).

Gauging Potential Impact

We asked scientists to consider the potential impact of each action relative to current conditions. Table 2 summarizes their responses along several dimensions: the columns group the actions into three groups according to the mean impact score, and the rows group them according to the level of consensus on these scores, as measured by the standard deviation of responses. Asterisks designate actions about which a high share of respondents (10% or more) answered "don't know"—another measure of uncertainty. And the actions are grouped by annual cost (lower cost is under $100 million per year and higher cost is over this amount).

Scientists were most likely to rank habitat- and flow-related actions as having a strong potential for positive impact.[15] Consensus was highest (Table 2, top left corner) regarding two flow actions (introducing more variable flows and reducing exports), two Delta habitat actions (expanding seasonal floodplains and tidal marshes), and two actions addressing habitat upstream of the Delta (improving upstream spawning and rearing habitat and removing selected dams). "Don't know" response rates were also low for these actions.

The scientific consensus on the strong potential of seasonal floodplain expansion is not surprising; field experience shows that several native fish species benefit from spawning and rearing in floodplain environments (Sommer et al. 2001; Moyle et al. 2004; Jeffres, Opperman, and Moyle 2008). The consensus over tidal marsh restoration is more surprising, because some public discussions have tended to highlight perceived difficulties in regenerating the type of tidal marsh habitat that was once abundant in the Delta.[16]

The top two flow management options are quite distinct. Reducing exports is a familiar option that can simultaneously freshen water outflow (helping to get fish to the productive "mixing" zone in the west Delta near Suisun Marsh) and reduce entrainment of fish and larvae in the export pumps in the south Delta. Reducing exports is also a "knob" that can be turned quickly to affect Delta ecosystem conditions. In contrast, patterning flow variability to better support native fish species has been much discussed in recent years but is not yet well defined, and its potential consequences have yet to be fully explored.[17]

In the middle of the pack—with medium impact scores and high-to-medium levels of consensus—are actions designed to reduce discharges (#1–#5) and control invasive species directly and through salinity variation (#22, #25), as well as efforts to support wild salmon populations by reducing their harvest and changing hatchery management policies (#14). Most of these actions are already employed within the Delta watershed. The idea of separating hatchery and wild populations of salmon is new for California but has been successful in the Pacific Northwest (Fraser 2008).[18]

Average impact scores were lowest for most direct fish management actions and two engineering solutions to alter flows—adding new gates to improve fish passage (#15) and diverting exports through a new canal or tunnel (#21).

Table 1. Many actions might help improve conditions for the Delta's native fishes

	Action	Implementation stage [a]	Annualized costs [b]
Discharges	1. Reduce urban nonpoint discharges (e.g., stormwater, landscaping runoff)	Under way	$–$$
	2. Reduce farm pesticide discharges	Under way	$$–$$$
	3. Reduce toxic substance discharges (e.g., emerging contaminants)	Under way	$$–$$$
	4. Reduce urban point discharges (e.g., wastewater treatment plants, industry)	Under way	$$–$$$
	5. Reduce farm fertilizer discharges	Planned	$$$
	6. Dilute pollutant loads with increased freshwater flows	Considered	$$–$$$
Direct fish management	7. Truck juvenile salmonids around the Delta	Under way	$
	8. Increase enforcement to prevent poaching	Under way	$
	9. Increase screening of water diversions	Under way	$–$$
	10. Develop new conservation hatcheries to support native fish (e.g., delta smelt hatchery)	Under way	$$
	11. Reduce harvest of anadromous fish (salmon, steelhead, sturgeon)	Under way	$$
	12. Trap and truck fish around dams	Considered	$
	13. Allow unrestricted fishing on nonnative predatory fish (e.g., striped bass, largemouth bass)	Considered	$$
	14. Manage hatcheries to separate hatchery fish from wild populations (e.g., change hatchery locations, mark hatchery fish)	Considered	$$
Flow regime	15. Add gated structures within the Delta to improve fish passage	Under way	$–$$
	16. Reduce entrainment at export pumps	Under way	$$
	17. Reduce Delta exports	Under way	$$–$$$
	18. Increase net Delta outflows	Under way	$$–$$$
	19. Improve flow regime upstream of the Delta	Under way	$$–$$$
	20. Pattern Delta flow variability to support native species	Considered	$$–$$$
	21. Divert Delta exports through a canal or tunnel	Considered	$$$
Invasive species	22. Directly control invasive aquatic vegetation	Under way	$–$$
	23. Increase actions to prevent new invasions (e.g., ballast water, trailered boats, aquarium trade)	Under way	$$
	24. Directly control invasive clams	Conceptual	$–$$
	25. Increase salinity variability in the Delta	Conceptual	$$$
Physical habitat	26. Expand seasonal floodplains	Under way	$–$$
	27. Improve or increase upstream spawning and rearing habitat	Under way	$$
	28. Remove selected dams	Under way	$$–$$$
	29. Restore tidal marsh and shallow water habitat (e.g., Liberty Island, Suisun Marsh)	Planned	$$
	30. Improve in-Delta channel margin habitat (e.g., setback levees)	Considered	$$
	31. Increase deep-water habitat (e.g., Franks Tract, Mildred Island)	Conceptual	$$
	32. Increase sediment loads flowing into Delta	Conceptual	?

[a] "Under way" denotes actions that are currently being implemented in the Delta watershed to some extent; "planned" denotes actions not yet implemented but planned for near-term implementation; "considered" denotes actions being considered based on modeling or experience outside the basin; "conceptual" denotes actions still at the conceptual stage, not likely to be implemented in the near term.

[b] $, < $10 million; $$, $10 million to $99 million; $$$, $100 million to $700 million. Investment costs are annualized at 5 percent for perpetuity (so, a $1 billion investment costs $50 million per year). Cost estimates do not include economic spillover (multiplier) effects—e.g., additional revenue losses in other sectors from reductions in crop output or increased revenues from new investments (Medellín-Azuara et al. 2013).

Table 2. Scientists agree more about the potential impact of some actions than others

	High potential impact	Medium potential impact	Low potential impact
High scientific consensus	**Lower-cost actions** #26 Expand seasonal floodplains (U) #27 Improve upstream habitat (U) #29 Restore tidal marsh (IP) **Higher-cost actions** #28 Remove selected dams (U) #20 Introduce more variable flows (IC) #17 Reduce exports (U)	**Lower-cost actions** #2 Reduce farm pesticides (U) #3 Reduce toxic discharges (U) #1 Reduce urban nonpoint discharges (U) #22 Control invasive vegetation (U)* **Higher-cost actions** #4 Reduce urban point discharges (U)	**Lower-cost actions** #9 Screen more diversions (U) #8 Prevent poaching (U)*
Medium scientific consensus	**Lower-cost actions** #29 Improve channel habitat (IC)* #23 Prevent new invasions (U) **Higher-cost actions** #18 Increase net outflow (U) #19 Improve upstream flows (U)	**Lower-cost actions** #16 Reduce entrainment (U) #14 Separate hatchery/wild fish (IC)** #11 Reduce salmon harvest (U) **Higher-cost actions** #25 Increase salinity variability (CO)* #5 Reduce fertilizer discharges (IP)	
Low scientific consensus		**Lower-cost actions** #24 Control invasive clams (CO)* **Higher-cost actions** #6 Dilute pollutant loads (IC)*	**Lower-cost actions** #32 Increase sediment loads (CO)** #15 Add gates for fish passage (U)** #13 More fishing of predators (IC)* #10 Conservation hatcheries (U)* #12 Truck fish around dams (U)* #31 Increase deep-water habitat (CO) #7 Truck salmon around Delta (U)* **Higher-cost actions** #21 Divert exports via tunnel (IC)**

SOURCE: Hanak et al. (2013).

NOTES: For a more detailed list of actions, see Table 1. Actions are split into thirds based on two survey scores. "Impact" measures the sample average impact score, in answer to the question: "In your opinion, what is the potential impact of each of the following actions on the Delta ecosystem's ability to support native fishes?" with "strongly positive" = 3, "moderately positive" = 2, "weakly positive" = 1, "neutral" = 0, and "negative" = – 2. "Consensus" is measured as the standard deviation of these impact scores, where a low standard deviation indicates high consensus. Actions within each section are ranked by impact scores (highest to lowest). Implementation stage: "U" = already under way to some extent, "IP" = implementation planned in the near-term, "IC" = implementation under consideration, and "CO" = conceptual only. Costs: Lower-cost actions are likely to cost under $100 million per year, and higher-cost actions are likely to cost more than this amount.

*10 percent to 16 percent of respondents answered "don't know." **21 percent to 25 percent responded "don't know."

Scientists agreed that neither screening of diversions (#9) nor greater enforcement of antipoaching laws (#8) is likely to offer significant ecosystem benefits (Table 2, top-right corner).[19] For other actions, the low impact scores reflect wide divergences in views (Table 2, bottom-right corner). This group of actions also had the highest shares of "don't know" responses; nearly a quarter of those surveyed stated that they could not assess the potential of the two flow-engineering actions.

The lack of consensus and high share of nonresponses on the canal or tunnel—which has been under active consideration in BDCP negotiations and much discussed within the scientific community—reflect uncertainty regarding the project's size and operation. Whereas most other actions focus primarily on ecosystem enhancement, this project has been conceived to both improve water export reliability and reduce the harmful effects of south Delta pumping on native fish. If managed for conservation objectives, a tunnel could facilitate more variable flow patterns (#20) and reduce entrainment (#16)—two actions scientists consider quite promising. At the time of the survey (and as of this writing in February 2013), information about operations was not sufficient to allow most scientists to weigh in on this issue with confidence.

Choosing Priority Packages

Because actions to mitigate Delta stressors are likely to work best in combination, we also sought scientists' views on the five actions that together would most benefit the Delta's native fish species. To isolate the priorities from a biological perspective, scientists were instructed to consider only impacts on native fish, not the economic costs of the actions. This question elicits *top* priorities only; respondents might consider actions not chosen to be worthwhile. (Indeed, some scientists noted that they would have liked to choose more than five.)

To better see the patterns, we grouped actions with similar functions or focus into nine areas. Table 3 reports the share of scientists who picked at least one action in each of these nine areas, along with the share that picked each individual action.

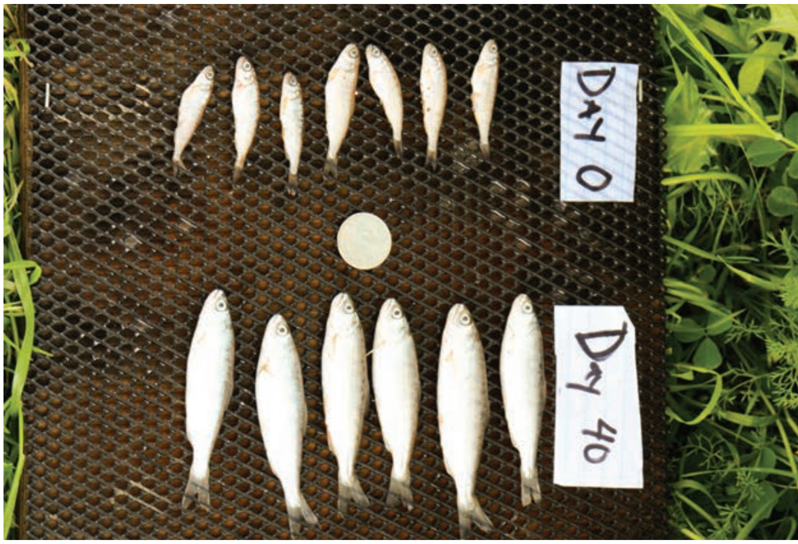
For scientific experts on the Delta ecosystem, the most promising ways to improve conditions for native fish combine habitat and flow management, both within the Delta and upstream. More than 60 percent of all scientists surveyed picked Delta habitat (82%), Delta flow variability (65%), reduced diversions (62%), and upstream management (61%). There is tremendous agreement on these choices: 63 percent of those surveyed picked actions in at least three of these areas; 93 percent chose at least two; and only one scientist selected none. These choices reflect the prevalence of high-impact actions in all four areas (Table 2, second column), particularly expanding seasonal floodplains (chosen by 61%) and the more experimental tools of patterning flow variability to support native species (59%) and restoring tidal marsh (48%).[20]

Although most scientists also picked at least one action outside these four areas, there were no strong patterns in the other combinations selected.[21] Some familiar actions, such as reducing discharges, had moderate support, as did some more experimental actions, such as separating hatchery and wild populations of salmon and steelhead. Few scientists chose other experimental actions, such as expanding conservation hatcheries and using gated structures to improve fish passage. And few selected harvest management actions, even though some of these—most notably, increased harvesting of predators—are often promoted in public debates.[22]

Overall, the scientists' priorities are consistent with the broad vision of a reconciled Delta outlined above—most notably, the emphasis on co-managing habitat and flows to restore more natural ecosystem functions in support of native species. However, they steered away from some actions that might be useful for attaining these objectives—including diversion engineering with a tunnel (#21), fish screens (#9), or gates (#15) and creating conservation hatcheries to maintain genetic diversity in native fish populations in the near term (#10). The lower priority levels for these actions reflect higher uncertainty about their potential impacts (Table 2, bottom-right corner).

What Do Stakeholders Prioritize?

On average, stakeholder groups and scientists had broadly similar rankings of priority areas (compare the green and



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Scientists have found that young salmon grow faster in seasonal floodplains.

yellow bars in Figure 5). They agreed on four out of five top areas—all but upstream management (which ranked sixth for stakeholder groups) and diversion engineering (which ranked seventh for scientists). However, as with the stressor rankings, there were some significant differences

Table 3. Scientists' top priorities include better management of habitat and flows

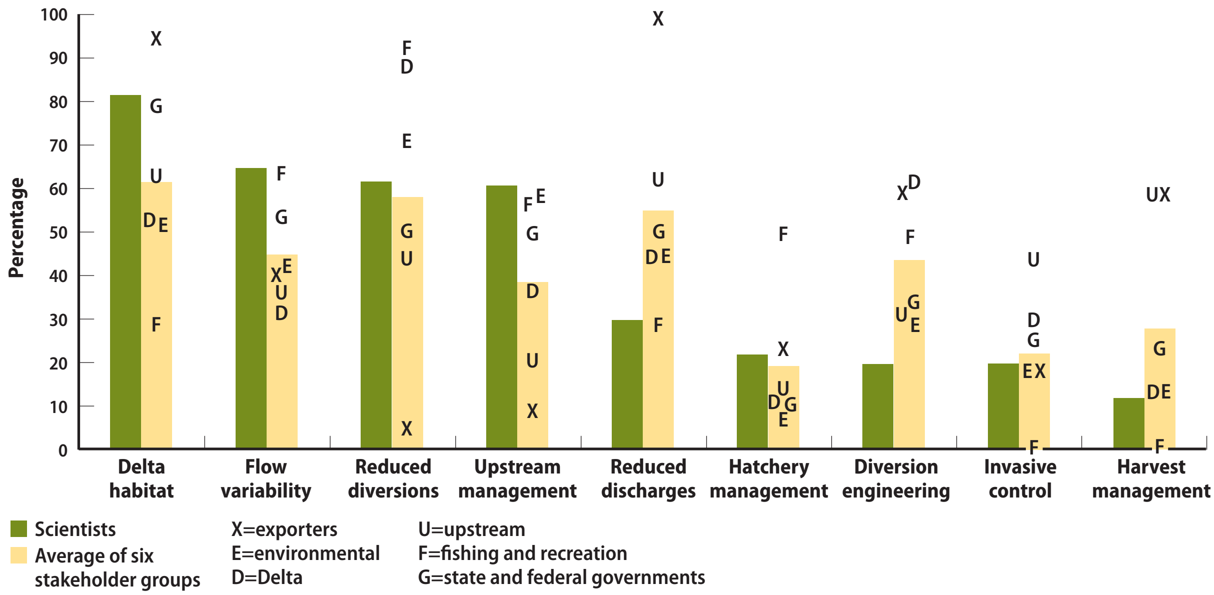
Action area	Individual actions
Delta habitat (82%)	**Habitat actions within the Delta** #26 expanding seasonal floodplain (61%) #29 restoring tidal marsh (48%) #30 improving channel-margin habitat (15%) #32 increasing sediment loads (8%) #31 increasing deep-water habitat (3%)
Delta flow variability (65%)	**Flow manipulations focusing on variability (not average water diversions)** #20 patterning Delta flow variability to support native species (59%) #25 increasing salinity variability to control invasive species (24%)
Reduced diversions (62%)	**Increasing the volume of instream flows** #17 reducing exports (39%) #18 increasing net Delta outflows (35%) #6 diluting pollutant loads with increased freshwater flows (4%)
Upstream management (61%)	**Habitat and flow actions upstream of the Delta** #19 improving upstream flow regime (30%) #27 increasing upstream spawning and rearing habitat (25%) #28 removing selected dams (21%)
Reduced discharges (30%)	**Reducing discharges directly (rather than by dilution)** #4 urban point sources (13%) #3 toxic substances (11%) #2 farm pesticides (7%) #5 farm fertilizers (6%) #1 urban nonpoint sources (4%)
Hatchery management (22%)	**Improving the role of hatcheries** #14 separating hatchery and wild fish (16%) #10 developing conservation hatcheries for native fish (5%) #12 trapping and trucking fish around dams (1%) #7 trucking juvenile salmon around the Delta (1%)
Diversion engineering (20%)[a]	**Using technology to make diversions less harmful for native fish** #16 reducing entrainment at the export pumps (11%) #21 building a canal or tunnel for exports (7%) #9 increasing screening of diversions (2%) #15 adding gated structures to improve fish passage (0%)
Invasive species control (20%)	**Managing invasive species directly (rather than with flows)** #23 preventing new invasions (11%) #22 directly controlling existing invasive plants (7%) #24 directly controlling existing invasive clams (5%)
Harvest management (12%)	**Directly managing recreational and commercial fishing** #11 reducing harvest of anadromous fish (7%) #13 allowing unrestricted fishing of nonnative predatory fish (6%) #8 preventing poaching (1%)

SOURCE: Hanak et al. (2013).

NOTES: This table reports the shares of scientists that picked each individual action (right-hand column) and at least one action in each of the nine action areas (left-hand column), in answer to the question: "Considering interactions, what are the five actions that would result in the most beneficial impact on the Delta's native fish species?" Table 1 lists individual actions.

[a] We included reducing entrainment (action #16) in diversion engineering even though one way to achieve this is to reduce export diversions. Other options involve technological methods, such as changing the timing of diversions and using barriers and fish screens.

Figure 5. Some stakeholders diverged from scientists on top-priority actions



SOURCE: Hanak et al. (2013).

NOTE: See Table 3 for a mapping of individual actions into action groups.

between scientists and individual stakeholder groups.[23] Scientists were more likely to prioritize Delta habitat than all groups except exporters and government officials. Scientists were also more likely than most to prioritize Delta flow variability and upstream management, and they were in the middle regarding reduced diversions—higher than exporters (almost none of whom chose this alternative)—and lower than Delta and fishing interests (almost all of whom did). They were less likely than many other groups to prioritize reduced discharges, diversion engineering, and harvest management.

State and federal officials overlapped most with the scientists on management priorities, just as they did on the relative importance of different stressor categories.[24] Environmental advocates' views were also fairly similar to those of the scientists, though environmental respondents were more likely to concentrate on flow-related actions and less on habitat or other complementary actions.[25]

Although all survey respondents were instructed to focus only on the biological potential of actions (not costs), groups with economic interests tended to steer away from actions likely to impose additional costs or other social or economic disruptions on themselves. Instead, each group tended to choose actions more likely to shift financial burdens to someone else. Thus, exporters avoided measures that would reduce their diversions (either directly or through changes in upstream management), while prioritizing "nonflow" stressors—such as discharges, Delta habitat, and harvest management—for which costs would likely be borne by other stakeholder groups or taxpayers. (Exporters have pledged to pay for the construction of a canal or tunnel, the diversion-engineering tool many of them favor, but negotiations to date have assumed that this new facility would pay for itself by improving their water supply reliability and quality.) Likewise, fishery interests did not support harvest management—a direct hit on their livelihood—but strongly endorsed reducing diversions and improving upstream management to benefit fish populations. Upstream interests did not support upstream management measures, which could cost them land and water, and they supported reducing diversions only if those came at the expense of exporters, not themselves (41 percent of upstream stakeholders selected reducing Delta exports as a priority action, versus only 3 percent who chose increasing net Delta outflows—a more general action that could reduce upstream diversions). Delta interests were more enthusiastic about reducing other water users' diversions and less enthusiastic about measures to develop more Delta habitat, which might harm the local economy, even if landowners are compensated for converted lands.[26]

Stakeholders can find support for these disparate views in the information they consult on the Delta. Most stakeholders responding to the survey are actively engaged in Delta issues, consulting media on this topic daily and government and scientific materials at least weekly. In recent years some groups—notably exporter interests—have expanded their own scientific efforts on multiple stressor topics. Some of this research has supported the idea that discharges (and consequent reduced food supplies), rather than diversions, are the key culprit (and hence key solution) to native fish declines (Glibert 2010; Miller et al. 2012). In contrast, environmental advocates and fishery interests are most likely to rely on advocacy group publications, which often emphasize the importance of reducing diversions.[27]

Given these differences, it is heartening that stakeholders often seem willing to consider actions that might be costly to them but beneficial to native species. For instance, more than half of Delta-based respondents chose at least one Delta habitat action, and more than 60 percent of upstream interests and nearly half of Delta-based interests selected at least one discharge-related action. Over 40 percent of exporters chose flow variability actions, which could reduce diversions. And many more environmental advocates picked nonflow actions than might have been expected, given the public positions taken by many environmental groups.

Costs of Reconciliation

The patterns of stakeholder priorities highlight an important social consideration in ecosystem management for the Delta: many individual management actions will be costly. Our cost estimates suggest that any comprehensive reconciliation package will cost at least several hundred million dollars per year on an ongoing basis. Some highly ranked flow- and discharge-related actions are likely to be particularly expensive (more than $100 million per year each), and the combined costs of habitat improvements could easily exceed this amount as well. In many cases, there has been an expectation that individual groups would bear the costs directly (especially for discharges and flows). Even in areas that are expected to receive some taxpayer support (e.g., habitat, proposed to be covered at least in part by state bond funds), fiscal and social realities will require implementing ecosystem management cost effectively.

Institutions for a Reconciled Delta

Reconciliation ecology offers promise for meeting the co-equal goals of improving ecosystem health while supporting the economic activities that depend on Delta land and water. But for this to happen, management institutions must become more effective. And science must become a more reliable and relied-upon basis for shared understanding of the Delta's problems by reducing uncertainties surrounding potential management strategies in an ongoing and interactive way.

Despite some recent progress, institutional fragmentation is a major obstacle to achieving ecosystem management goals (National Research Council 2012). Here we propose some modest, yet powerful, changes to better integrate planning and management, regulatory oversight, and science and adaptive management. Further details are in *Integrated Management of Delta Stressors: Institutional and Legal Options* (Gray et al. 2013).

The Fragmentation Challenge

A list of key regulatory and management entities highlights the barriers to coherent ecosystem management (Table 4). For each stressor, numerous agencies at different levels of government provide regulatory oversight, and many other agencies and individuals manage the related resources. This fragmentation makes it hard to address individual

Table 4. The alphabet soup of Delta ecosystem stressor management

Stressor	Regulatory agencies	Management entities
Discharges	**State**: State Water Resources Control Board (SWRCB) and Regional Water Quality Control Boards (RWQCBs), Department of Toxic Substances Control (DTSC), Department of Pesticide Regulation (DPR), county agricultural offices **Federal**: U.S. Environmental Protection Agency (USEPA), U.S. Army Corps of Engineers (USACE)	Local urban and agricultural dischargers
Fish management	**State**: Department of Fish and Wildlife (DFW), Fish and Game Commission (FGC) **Federal**: U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), Pacific Fisheries Management Council (PFMC)	**Hatcheries**: USFWS, DFW **Fish screens**: urban and agricultural diverters **Harvest**: commercial and recreational fishery
Flows	**State**: SWRCB, DFW, Central Valley Flood Protection Board (CVFPB) **Federal**: USACE, USFWS, NMFS, Federal Energy Regulatory Commission (FERC)	**State Water Project (SWP)**: Department of Water Resources (DWR) **Central Valley Project (CVP)**: U.S. Bureau of Reclamation (USBR) **Local projects**: local urban and agricultural water agencies
Delta habitat	**State**: RWQCB/SWRCB, DFW, CVFPB, Delta Stewardship Council (DSC), Delta Protection Commission (DPC) **Federal**: USACE, USFWS, NMFS **Local**: cities and counties	**Flood control**: USACE, DWR, and local reclamation districts **Land use**: land owners **Restoration**: Delta Conservancy (DC)
Upstream habitat	**State**: DFW, RWQCB/SWRCB **Federal**: USACE, FERC, USFWS, NMFS **Local**: cities and counties	**Water diverters**: DWR, USBR, and local agricultural and urban water agencies **Flood control**: USACE, USBR, DWR, CVFPB, and local dam owners, operators, and reclamation districts **Land development**: land owners
Invasive species	**State**: DFW, RWQCB/SWRCB, DPR, Department of Boating and Waterways (DBW), Department of Food and Agriculture (DFA) **Federal**: USEPA, U.S. Coast Guard (USCG), U.S. Department of Agriculture (USDA)	**Invasive weed treatment**: DBW, local landowners

SOURCE: For more details, see Gray et al. (2013).

NOTES: This list is not exhaustive. Local governments (cities and counties) must approve any actions that involve land use or construction. Permission of additional state and federal agencies may also be required for some actions (e.g., for historical preservation).

stressors effectively and nearly impossible to develop integrated approaches that consider interactions among stressors at appropriate geographic scales. The consequences of this fragmentation include:

Missed opportunities for watershed-based approaches. The federal and state ESAs are governed by two federal agencies (USFWS for most aquatic and terrestrial species and NMFS for ocean-going fish including salmon, steelhead, and sturgeon) and one state agency (DFW). "Incidental take authority" and "take permits" (which authorize project managers to kill or harm listed species up to specified numeric limits) are typically issued for individual species on a project-by-project basis. These agencies have made progress in coordinating guidance, and habitat conservation plans (such as the BDCP) now encourage multispecies approaches. But even with a BDCP permit for water exports, ESA compliance within the watershed will remain fragmented, with many smaller projects by other regulated entities (land users, flood control, water and wastewater utilities) running separate mitigation programs.

Oversight gaps. Numerous entities at the federal and state levels have some hand in invasive species prevention and control, but no entity is charged with coordinating these efforts. The lack of comprehensive regulation of some

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Water hyacinth has invaded many Delta channels. Many agencies—and none—are responsible for preventing new invasive species.

stressors also raises concerns of fairness in regulatory burdens across different segments of society.

Conflicting mandates. The USACE proposes to remove vegetation on levees in the interests of flood control, whereas the fisheries agencies promote this vegetation to provide shaded habitat along river edges.

Costly delays. Many permits and approvals are required to demonstrate that projects are not causing environmental harm. Even projects whose primary intent is to help the environment are encountering obstacles. To restore habitat on a small island in the north Delta—a project on which there is broad agreement—the managers may need to obtain ten permits, consult on ten statutes, and ensure consistency with eight programs, with 18 state, federal, and local agencies.[28] Each approval requires a separate process, which raises costs and increases the odds that agencies will require inconsistent terms for approval. These kinds of roadblocks will be multiplied many times over in the restoration of large acreages of physical habitat in the Delta—a top priority for BDCP and for more than 80 percent of scientists in our survey.

Less reliable science. Most of the entities listed in Table 4—and many others—are involved in largely separate scientific activities related to the ecosystem. Although some coordination occurs under the Interagency Ecological Program (IEP), which unites nine federal and state agencies for monitoring and evaluation related to the take permits for the export projects, integrated approaches to key activities such as large-scale modeling have proven elusive. In its review of multiple stressors, the National Research Council (2012) cited the lack of an integrated approach to science in the Delta as a primary reason for the failure to understand and manage stressors effectively. Lack of a common basis for hypothesis testing has also encouraged the development of parallel efforts by regulated parties.

Finally, fragmentation has not only hindered the ability to deal with tradeoffs in ecosystem management (such as those in the levee vegetation example above), it has also made it hard to provide regulatory incentives to manage stressors jointly. Yet joint stressor management is likely to yield sizable environmental benefits and should also reduce overall costs.

Building on existing governance structures and management models, we propose four types of institutional change.

Consistent planning. More comprehensive use of consistency reviews by the Delta Stewardship Council to determine whether planning efforts relevant for addressing Delta ecosystem stressors are consistent with the state's overall Delta Plan.

Integrated and accountable management. Proactive use of the new Delta Plan Interagency Implementation Committee (DPIIC) to coordinate implementation of agency plans and to integrate multiagency adaptive management.

More comprehensive and integrated regulatory oversight. Additional stressor regulation, reduced duplication, new incentives for joint stressor management, and coordinated and expedited permit review through a new office: the Delta Ecosystem Regulatory Coordinator (DERC).

Integrated science and adaptive management. Creation of a Delta science joint powers authority (JPA), involving regulators and regulated parties and the Delta Science Program (DSP). Formation of an adaptive management alliance within the DPIIC to link science and management.

Most of these changes can be accomplished without new legislation, but they will require new commitments by and interactions among various state, federal, and local agencies, including some pooling of resources.

Consistent Planning

The Delta Plan is the foundational long-term vision for meeting the state's co-equal goals for the Delta. The first Delta Plan[29] comprehensively examines the Delta ecosystem's problems and establishes policies to guide the Delta Stewardship Council and the actions of other agencies and individuals. The DSC's authority to regulate plan implementation is limited: when petitioned to review proposed local actions and state nonregulatory actions within the statutory Delta and Suisun Marsh, the DSC must determine whether these actions are consistent with the Delta Plan ("consistency determinations"). It can deny certification of consistency even if the proposed actions are permitted under other state, federal, or local laws, thereby potentially blocking those actions from being carried out until amended.[30] For all other relevant actions—including state regulatory actions within the Delta, federal actions, and all actions outside the statutory Delta—the DSC can provide comments and recommendations but has no regulatory authority.

The limits on the DSC's regulatory authority reflect multiple parties' resistance to additional oversight of their actions. (Indeed, the DSC's authority within the Delta is causing consternation among local governments there, who object to its oversight of their land-use decisions.) However, there is great value in an expert agency's assessment of whether actions are consistent with the state's comprehensive planning tool for the Delta ecosystem. The DSC should use its advisory role to provide nonbinding "consistency opinions" for plans outside its regulatory purview. Assessments could be initiated by the DSC or requested by outside parties, including planning agencies themselves (who may wish to demonstrate that their intended actions are consistent with the overall Delta Plan). These DSC opinions would provide guidance to the agencies themselves, and they would establish an evidentiary record for judicial review of the agencies' actions.[31]

Integrated and Accountable Management

An underappreciated component of new Delta governance is the Delta Plan Interagency Implementation Committee, also called for under the Delta Reform Act of 2009. Convened by the DSC, this committee is charged with coordinating implementation of all relevant actions pursuant to the Delta Plan. The DPIIC will consist of the principal state, federal, and local planning and regulatory agencies. It will provide a forum for harmonizing the many planning processes relating to the Delta and the greater watershed and for devising common implementation strategies.

To boost the effectiveness of this forum, the DSC should require that agencies present their near- and long-term plans to help implement the Delta Plan. This will increase the potential for consistent actions and heighten public awareness of the many decisions that affect the Delta ecosystem. This will also make it easier to hold agencies accountable for actions and inaction. As discussed below, the DPIIC is also the appropriate forum for coordinating adaptive management.

Comprehensive and Integrated Regulatory Oversight

Regulatory oversight of Delta ecosystem stressors is better today than it was 20 or even 10 years ago.[32] However, there are still significant gaps in the regulation of stressors. Most regulatory efforts focus on Delta exports, point sources of pollution, and commercial fishery harvests. Far less attention has been paid to upstream and in-Delta water diversions, agricultural and urban runoff, invasive species, and physical habitat disturbance, even though legal authority generally exists to address these stressors. Effective and fair ecosystem management requires comprehensive regulatory approaches.

Going forward, regulatory bodies must also continue to reduce regulatory duplication and inconsistencies. The DPIIC public coordination process provides opportunities to identify and address these problems. To help inform decisionmakers about the need for action, the DPIIC should issue regular reports about gaps and conflicts in regulatory approaches.

Two recent proposals have suggested frameworks for one area particularly worth exploring: the use of regulatory incentives to jointly manage stressors. The BDCP is considering increasing the volume of water exports authorized in response to improvements in physical habitat. And the SWRCB, in its draft water quality control plan for the San Joaquin River, has proposed adjusting the volume of instream flows that upstream water diverters will be required to maintain in response to changing conditions.[33] This would provide incentives for water diverters to work with landowners on creating more favorable conditions for aquatic and riparian species.[34]

Another priority is to encourage more integrated environmental permitting. Environmental review and permitting processes were instituted to prevent construction and development from causing environmental harm or putting public safety at risk. But the current, fragmented system is often costly and time-consuming and does little to ensure that mitigation actions truly benefit the environment. We propose the creation of a new office—the Delta Ecosystem Regulatory Coordinator (DERC)—to coordinate and expedite permitting. The DERC, which could be located within the Office of the Governor or the DSC, would convene the various agencies whose approval is needed for any given action that affects the resources of the Delta ecosystem. Actual permitting decisions would remain vested in the individual agencies, but the DERC would ensure that agencies share information, collaborate, establish record submission and hearing schedules that encourage applicants to present integrated analyses and minimize duplication, and make timely decisions.

Common Pool Science and Adaptive Management

Delta science must push the frontiers of knowledge on effective ecosystem management in ways that enhance its legitimacy in the eyes of the many interests who have a stake in the outcome. Scientific knowledge should inform, not prescribe, policies and decisionmaking—the use of the Delta's resources will ultimately be decided through political and legal processes. Instead of serving these needs, Delta science has been used in some of the Delta's most vigorous disputes and contentious litigation. Low opinions of scientific reliability are unlikely to be changed by funding increases, new programs, and prescriptions for more coordination alone. Although scientific research will never be completely removed from the courtroom, "combat science" needs to be sidelined in favor of new ways of advancing knowledge and guiding management.

Shared Purposes, Resources, and Results: Delta Science JPA

Lessons from two successful collaborative science models in Southern and Northern California (see the box) lead us to recommend that science for multiple stressors in the

Joint powers authorities: A new model for Delta science

Two successful and respected programs working on multiple stressors in California—the Southern California Coastal Water Research Program (SCCWRP) and the San Francisco Estuary Institute (SFEI)—may serve as models for integrated research that garners broad support. The success of these programs stems from their high-quality research and transparency and their involvement of a mix of regulators, regulated parties, and other stakeholders to build consensus on research plans and results. Both programs use JPAs among regulating and regulated agencies that allow for efficient oversight and funding of research.

SCCWRP was created in 1969 through a JPA between water dischargers and state regulators to conduct research and monitoring focused on the coastal waters and ecosystems of Southern California. SCCWRP monitors wastewater and storm discharge, guides the development of new standards, identifies and tests new technology, and develops new approaches to water and ecosystem management. Fourteen commission members represent regulatory and regulated agencies that oversee and fund the program. Stakeholder groups are regularly involved in monitoring and research activities.

SFEI was established in 1986 as the Aquatic Habitat Institute; it expanded to become SFEI in 1993. This nonprofit conducts monitoring and research on the waters of the San Francisco Bay–Delta and the Central Valley. Although it originally focused on storm and wastewater monitoring and management, SFEI has expanded its efforts to a broad range of multiple stressors and ecosystem restoration. In 2007, SFEI began administering the Aquatic Science Center, a JPA involving the SWRCB and wastewater agencies in the Bay Area. SFEI is overseen by an 11-member board of directors made up of water managers, regulators, stakeholders, and academics.

Delta ecosystem be overseen by a new organization that pools resources, plans jointly, shares data, and fosters consensus understanding of scientific results and their implications for management. A joint powers authority (JPA) or similar instrument could bind the primary regulators with the regulated entities.[35] To ensure a broad consensus on scientific results, it may be appropriate to include other key groups in this JPA.

The many disparate science and monitoring initiatives—including the IEP—should be overseen by the JPA. The JPA would fund much of the relevant research by outside parties, such as the U.S. Geological Survey, nonprofits, and universities, through contracts and grants. The JPA would not terminate participating agencies' own scientific studies or their legal obligation to base policy decisions on sound science. Rather, it would tackle the larger, most complex and controversial issues. It would also foster the development of common science plans, system models of operations, hydrodynamics, water quality, ecosystems, and biological life cycles, and facilitate common data standards, storage, and access. And it would become a major source of information for adaptive management programs in the Delta (discussed below).

All parties to the Delta JPA must invest in the outcome by contributing funds and/or staff. This creates an incentive for parties to resolve differences within the JPA and achieve consensus on means and ends, reducing the likelihood of litigation.

Under this proposal, the Delta Science Program (DSP) would oversee Delta science for the JPA. Although the Delta Plan prescribes that the DSP serve as the coordinator of science in the Delta, this program does not currently have the mandate, authority, or budget to take on integration.[36]

Adaptive Management: Using Science in Management

A framework is also needed to organize ecosystem management efforts and ensure that they both inform and are informed by evolving scientific understanding. This is the essence of the adaptive management idea advanced in so many recent Delta planning processes. Adaptive management seeks to bring scientific work into the center of management decisions for complex problems that involve uncertainty. The original concept envisioned a central scientific group responsible for synthesizing and regularly suggesting promising actions to a management group, which could modify operations accordingly (Hollings 1978). Suggestions would be developed through computer models, pilot studies, and empirical results from field data. Results from each management cycle would improve understanding of the system. In essence, all adaptive management efforts should be hypotheses to be tested, refined, or rejected.

Adaptive management is essential to improve the health of the Delta ecosystem, given the changing conditions in the ecosystem and the many uncertainties about how effective various management actions may be. (Recall the many experimental actions ranked as high priorities by scientists in our survey and the many "low consensus" actions that still need fleshing out.) But it cannot be carried out effectively by dozens of agencies operating independently (Walters 2007). To integrate the necessary expertise, resources, and authorities, we suggest that the major parties pool their efforts through the DPIIC. Many field-level actions should be coordinated at the subregional level, following the area specialization needed for successful ecosystem reconciliation (Figure 4b).

> "Combat science" needs to be sidelined in favor of new ways of advancing knowledge and guiding management.

Getting There

The proposals outlined here are not radical, but they will be a stretch for many agencies—perhaps most notably for parties to the BDCP, who have proposed parallel science and adaptive management structures tailored to implement a project that is ambitious, but not sufficiently comprehensive, to address the many sources of ecosystem stress. A common pool approach to science—which requires that

California needs a statewide conversation about the value of a reconciled Delta— not just a source of water and land to support our economy, but also a place of natural heritage for current and future generations to appreciate.

each entity give up some control to make it more useful, reliable, and relied upon—may be a worthwhile and necessary tradeoff.

Secure and stable resources will be required for the DSC to serve as a coordinating agency, the new DERC to coordinate and expedite permits, and the DSP to manage the new science JPA. More generally, strong institutions will require strong leaders at the helm. Integration will be elusive in some areas. But existing institutions can be managed and adapted to become more ecologically successful and cost effective.

Building Public Support

More integrated and effective enforcement of environmental laws can contribute to a healthier Delta ecosystem, but achieving this goal will also require broad public support. The costs of reconciliation efforts could be several hundred million dollars per year. This amount pales in comparison with the state's $1.9 trillion economy, or even the $30-plus billion that Californians spend annually on water services and management (Hanak et al. 2012). But many of these costs would be borne by specific stakeholders (both businesses and households), and recent Delta conflicts have been fueled by their cost concerns.

As our survey shows, stakeholders are more likely to prioritize actions unrelated to their own uses of Delta resources and to shy away from actions that would be costly for them. However, there is more common ground than is usually assumed. All parties agree that multiple sources of stress—including those related to their own actions—have contributed to the decline in the Delta's native fish populations, and many prioritize at least some actions that might directly increase their water, wastewater, stormwater, or flood control fees.

In addition to the direct costs of more environmentally protective water and land management, a Delta solution will likely require that California voters approve state general obligation bond funds. As part of the 2009 water reform package, the legislature approved a large ($11 billion) water bond for the November 2010 ballot. The bond includes roughly $2 billion for Delta ecosystem investments—a large share of the habitat improvement planned under the BDCP. Weak polling caused the vote to be delayed twice, and the legislature seems likely to revamp (and shrink) the proposal before it goes to voters in late 2014. Without a bond financed with general tax dollars, a comprehensive Delta ecosystem solution will require additional fees on those benefiting from the Delta's water and land resources.[37]

Garnering public support for either new fees or new bonds will require clear messages about the benefits. In a recent PPIC opinion poll, a strong majority of Californians (61%) said that they supported more state spending to improve conditions for the state's native fish species, but support fell to less than half (39%) when the funding source was identified as higher water bills.[38] The case for more funding will be easier to make if policymakers and managers can demonstrate that the money will be spent in an integrated, cost-effective manner to promote the co-equal goals of ecosystem protection and reliable water supply. California also needs a statewide conversation about the value of a reconciled Delta that meets these goals—not just a source of water and land to support our economy, but also a place of natural heritage for current and future generations to appreciate. ●

Notes

[1] When discussing this plan, we refer to the final draft, issued in November 2012 (Delta Stewardship Council 2012).

[2] When discussing this program, we refer to materials that were made public in 2012 (Bay Delta Conservation Plan 2012).

[3] Technically, BDCP must meet the conservation standards of the state's Natural Communities Conservation Planning Act, which provide for recovery of listed species, and it must otherwise be deemed consistent with the Delta Plan (Gray et al. 2013). For an overview of other related planning processes, see Mount (2011) and Water Education Foundation (2012).

[4] See Kahan (2012) for a discussion of this phenomenon as it relates to climate change policy.

[5] To check for potential bias, we ran statistical tests to determine whether responses to key survey questions differed along the dimensions on which respondents differed from nonrespondents. In general, we found relatively few statistically significant differences; these are noted in endnotes where relevant (see Hanak et al. 2013, Technical Appendix A, for details).

[6] A seventh "other" category (15 respondents) includes a mix of groups too small to analyze separately; those responses are reported along with detailed survey results in Hanak et al. (2013).

[7] The use of expert elicitation is expanding in many fields to address gaps in the scientific literature, particularly where there is uncertainty about priorities for decisionmaking (see Hanak et al. 2013, Technical Appendix A).

[8] Ocean-related sources of climate variability include the El Niño–Southern Oscillation and the Pacific Decadal Oscillation, among others.

[9] Scientists considered fish management to be more serious for anadromous fish—the focus of many management actions—than for pelagic or resident native fish (Hanak et al. 2013).

[10] Similar patterns appeared when respondents were asked to consider how stressors would affect native fishes in the future if management continued as it is today. Upstream and Delta interests were the most optimistic regarding the future impacts of both discharges and habitat alterations, areas where they bear primary responsibility. Similarly, exporters and upstream interests expressed the most optimistic view regarding flows. For all three stressors, scientists do not share this optimism (Hanak et al. 2013).

[11] The term was coined in 2003 by Mark Rosenzweig, a University of Arizona ecologist, after assessing worldwide declines in biodiversity.

[12] The U.S. Congress has also adopted these co-equal goals (Energy and Water Development Appropriations Act of 2012 § 205). The concept of co-equality also appears prominently in the Draft Principles and Regulations for federal water resource projects (Council on Environmental Quality 2009).

[13] For example, climate change models suggest that Delta temperatures will become increasingly inhospitable to delta smelt if present trends continue (Brown et al. 2013). Several environmental laws currently constrain the range of responses to such threats, including the ability to make conservation investment tradeoffs or triage between species for whom extinction in the wild is highly likely and others in less advanced stages of decline (Hanak et al. 2011).

[14] For instance, the Sacramento Regional County Sanitation District—the Delta's main urban point source of ammonium—has been ordered to upgrade its treatment facilities by 2022. Efforts also are under way to reduce farm pesticide discharges, to improve flow regimes upstream of the Delta, and to expand seasonal floodplain habitat in the Yolo Bypass. The National Marine Fisheries Service (NMFS) has proposed removing two dams on the Yuba River to improve salmon access to upstream habitat. (Some smaller dams have already been removed in upstream tributaries, such as Butte Creek, Battle Creek, and Clear Creek.)

[15] There were few distinguishing characteristics of scientists choosing actions with high versus low average impact scores. Leading scientists (those named by their peers as having exceptional understanding of the Delta's aquatic ecosystem), those with broader publishing experience across stressor groups, and those with past or present affiliation with the Moyle fish laboratory at the University of California, Davis, tended to rank most actions as having lower potential (Hanak et al. 2013). However, these characteristics were not generally associated with choices of priority actions, as described below.

[16] Much of the Delta is so deeply subsided that re-creation of tidal marsh is impossible in many areas. However, restoration opportunities exist in parts of the Sacramento River and Bypass Habitat Arc shown in Figure 4b. This includes areas within the north Delta, centered on the Cache-Lindsey Slough region, and perhaps in a few other areas, such as the McCormack-Williamson

Tract, and within Suisun Marsh, now managed as a nontidal freshwater or brackish marsh. This marsh is likely to become increasingly saline as sea level rises, so it will bear only superficial resemblance to former Delta marshes, which were principally freshwater (Moyle, Manfree, and Feidler in press).

[17] This action would likely include increased seasonal flood flows and perhaps reduced flows in the fall to more closely mimic seasonal flow variability that existed before human development of the Delta. However, the alteration of habitat and increasing pressures on the system from a warming climate could also make some "unnatural" flow patterns desirable (Moyle et al. 2012). The cost in terms of reduced water diversions for human uses would depend on the specific timing and the ability to recapture these flows after they serve environmental purposes (Medellín-Azuara et al. 2013).

[18] This would involve such measures as marking all hatchery fish and changing hatchery locations to reduce commingling of hatchery fish and wild populations during spawning. This strategy might be less successful in California, given the challenges of siting replacement hatcheries.

[19] Poaching is regarded worldwide as a major problem for sturgeon conservation (Pires and Moreto 2011), and reducing poaching on green and white sturgeon within the Delta could be effective because these fish are slow to reach maturity, live a long time, and have high fecundity. The low impact score for this action likely reflects the view that poaching is not a major issue for other native Delta fishes such as salmon and steelhead.

[20] More generally, the correlation between mean impact scores and the share of scientists who picked each action in their top five priorities was very high (0.73).

[21] Clustering exercises in which action choices were weighted by their ranks produced one very large cluster favoring the habitat-flow combinations described above (102 scientists) and four very small clusters, generally emphasizing one or more of the less popular areas. No systematic differences appeared in the characteristics of these scientists relative to those in the larger group. In addition, there were few significant differences in the characteristics of scientists choosing the nine action areas: Leading scientists (see note 5) were less likely to choose diversion engineering options and more likely to choose flow variability, Moyle lab affiliates were less likely to choose upstream management actions, those with publications on invasive species were more likely to choose actions in that area, and those with publications on fish management were more likely to favor hatchery management actions (Hanak et al. 2013, Table C7a).

[22] In 2008, a group of exporter interests sued the state Department of Fish and Game (DFG) (now the Department of Fish and Wildlife), arguing that predation by nonnative striped bass was a major contributor to the decline in salmon populations. In a 2012 settlement, DFG agreed to reduce restrictions on striped bass fishing, but this action was not approved by the state Fish and Game Commission, which regulates hunting and fishing licenses. Most scientists consider that the heavy predation of juvenile salmon moving through the Delta is a symptom of other problems and that increased fishing of predators is unlikely to be very effective in restoring salmon populations (Moyle 2011).

[23] The differences reported here are statistically significant at the 90 percent level or higher in two-tailed tests following logit regressions in which action areas are dependent variables, and independent variables are stakeholder group affiliations (Hanak et al. 2013).

[24] The correlation coefficient between action choices of the scientists and the state-federal government group is highest—between 0.88 and 0.92, depending on how the actions are measured (Hanak et al. 2013).

[25] Exporters had the most diverse portfolio of priority action areas (with 73% picking actions in four or five areas, out of a potential of five), and environmental advocates had the least diverse (with only 43% picking four or five action areas).

[26] Delta interests' high score for diversion engineering reflected a preference for reducing entrainment at the export pumps (32%) and screening diversions (18%), not for building a canal or tunnel (5%) (see Hanak et al. 2013, Table B19).

[27] Examples of environmental advocacy publications emphasizing reduced diversions include Natural Resources Defense Council (2008) and Friends of The River (n.d.). Examples of fishing industry positions include Grader (2013) (salmon industry) and Jennings (2011) (sports fishing more generally).

[28] For details, see Gray et al. (2013), Table 1.

[29] The plan is to be adopted by the DSC in the spring of 2013 and updated every five years.

[30] As discussed in Gray et al. (2013), there is some ambiguity in the current statute regarding whether state and local agencies can pursue actions deemed inconsistent with the Delta Plan. The legislature should clarify the DSC's existing certification authority for these actions. It could explicitly provide that agencies cannot take actions that the DSC has found to be inconsistent with the Delta Plan. Alternatively, it could provide

that all actions must be consistent with the plan but leave it up to the courts to make the ultimate determination. Under this approach, agencies could proceed with actions not certified as consistent, and parties could sue to block such actions as violating the Delta Reform Act. Both approaches are found in other statutory schemes.

[31] Because the courts are likely to give significant deference to the council's expert opinions, agencies may have an incentive to seek the DSC's opinion on the consistency of their proposed actions with the Delta Plan, even though they would be neither legally obligated to do so nor bound to follow the council's recommendations. A DSC consistency opinion would help to affirm the agency's decision. In contrast, an opinion by the council that an action would be inconsistent with the Delta Plan would undermine the agency's defense of the action in court.

[32] The state and regional water boards have begun coordinating the regulation of water quality and flows. The three state and federal fisheries agencies now work jointly on many recommendations. USACE and DWR collaborated closely on the latest Central Valley flood plan. FERC is doing more holistic watershed analysis before permitting hydropower dams. And state and federal pesticide regulators are getting better at providing coherent oversight of different laws related to the use of these products.

[33] See State Water Resources Control Board (2012), Appendix K.

[34] From an equity standpoint, this is an imperfect solution, because the burden of compliance falls on water diverters, who will have to encourage land users to participate in habitat restoration (even though land users are benefiting from earlier destruction of physical habitat). But it is preferable to simply regulating flows as though other stressors do not exist.

[35] Key regulators would include USFWS, NMFS, DFW, USEPA, SWRCB, the Central Valley and San Francisco RWQCBs, USACE, and the DSC. Regulated entity members would include USBR, DWR, CVP and SWP contractors, upstream and in-Delta diverters, representatives of dischargers, and others. Legally, only two entities need to form the JPA; all other members, including federal agencies, can join without being formal signatories to the agreement creating the JPA.

[36] Moreover, the DSP answers only to the DSC, limiting its relationship to other science programs.

[37] Various funding mechanisms could be used, ranging from Delta-specific diversion, discharge, and use fees to statewide water and environmental fees (Hanak et al. 2011).

[38] Results are from Baldassare et al. (2012). In regression analyses controlling for various factors at once, willingness to pay for additional native fish protection with higher residential water bills increased with education and income and was higher for whites and Latinos than for Asians or African Americans, and higher for renters than owners (who are more likely to directly pay for their water bills). It was also higher for those who consider themselves more liberal and more supportive of the idea of paying higher taxes for more government services. Although willingness to pay was not associated with people's views about whether water supply is a problem in their region, it was lower among residents of two major regions relying on Delta exports—Southern California and especially the San Joaquin Valley.

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