



Wings Landing, Suisun Marsh, Photo by P. Moyle

Making the Delta a Better Place for Native Fishes

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Forward

Why is Orange County Coastkeeper commissioning this paper that offers innovative recommendations to promote and expedite the restoration of native fish in the Sacramento-San Joaquin River Delta? What happens in the Delta impacts nearly all of California. Coastkeeper's involvement with Delta issues is common sense, because the future of the Delta is as important to Orange County as it is to the rest of the state.

This project began with conversations that the environmental community in Southern California has been essentially silent on Delta issues over the years. With important decisions pending that could determine the Delta's fate, we needed to gain a better understanding of the Delta. I proposed a trip to the Delta whereby southern and northern California environmental NGO leaders would tour the Delta by boat to experience and see first-hand the realities and serious problems that threaten its future.

In September of 2016, a group of environmental leaders took to three boats and toured major parts of the Delta. We were led by scientists who have committed their careers to generating valid science, both gaining an understanding of, and making recommendations on, how to restore or "reconcile" this vast resource. As Dr. Peter Moyle articulates, the historical Delta has been so modified that it is beyond restoration back to what is once was. The best we can hope for is a reconciliation of the Delta.

On the second day, we received presentations on the science of the Delta. It was important that this experience be based on the science of the Delta and not politics or policy. I stipulated there would not be an agenda item involving the California Fix, nor would it be discussed, unless a participant brought it up.

While on our tour, we banked the boats, climbed over a dike and down the other side only to stand in a pasture staring face to face at several cows. We were told the Department of Water Resources has owned this property since 1992. Almost in unison, we asked, "Why is this still a pasture? Why hasn't this been restored since the State has owned the property for 25 years?" To cut to the chase, our tour concluded with an agreement that we needed to expedite the restoration of native fish by learning about the impediments to meaningful and timely restoration projects. As we realized, it may already be too late to save the delta smelt; but maybe there is hope for the winter-run Chinook Salmon and other species.

When Dr. Moyle spoke to our group, it was obvious to me that we needed his expertise on fish

biology of the Delta in order to accomplish anything. Early in 2017, Coastkeeper asked Dr. Moyle to help us by sharing his vast knowledge and recommending what must be done to expedite, break down barriers and promote significant native fish restoration in the Delta. Thankfully, he graciously agreed and brought along two additional biologists, John Durand and Carson Jeffres, all affiliated with the Center of Watershed Sciences at the University of California, Davis.

Coastkeeper is proud to present their work with this paper, which offers solid recommendations to improve conditions for native fish restoration projects. It is our job to take these ideas and recommendations and turn them into actions that produce positive results.

I want to thank individuals and organizations that helped make this paper possible and ensured it was as impactful as possible. First, my dear friend, Sat Tamaribuchi, who has told me for years nothing will bring California to its knees faster than a major failure of the Delta. He is an elected Director of the Municipal Water District of Orange County (MWDOC). Sat enlisted Rob Hunter, MWDOC's very experienced and wise General Manager, then Rob enlisted Karl Seckel, Deputy General Manager of MWDOC, who redefines intelligence and getting things done. I brought in a friend, colleague and conservationist, Tom Rafitcan, Executive Director of the Sportfishing Conservancy. This small band of leaders became the steering committee that provided guidance. Many individuals reviewed and provided comments for seven drafts of this paper. The common thread between them was their passion to improve the Delta, though they have diverse views on how to achieve it. Another valuable voice from the beginning has been that of Curt Schmutte, a consulting expert on the Delta and he has the experience of successfully managing restoration projects there. Appreciation goes to the Metropolitan Water District for making the two-day tour for environmental NGO leaders possible. To all those involved in some way with this project, thank you!

-Garry Brown, Founder and President Orange County Coastkeeper

Prepared for: Orange County Coastkeeper

Making the Delta a Better Place for Native Fishes

Preface:

In the fall of 1972, I took my first sampling trip for fishes in the Delta, joining a Fish and Game crew for one day of the Fall Midwater Trawl Survey. I thought I was just out there to obtain a few fish for the fish biology class I was teaching. Instead, I caught a glimpse of the beauty of the Delta on a clear, windy fall day and experienced the diversity and abundance of its fishes. I saw catches of hundreds of small, iridescent smelt, silvery shad, and striped bass. Lots of interesting fish to study, I thought, and so I asked the biologists to save smelt for me. After the end of the trawling season, a CDFG truck pulled up at my laboratory, piled high with crates of bottles containing preserved smelt. Processing these fish made me one of the few experts on the biology of long-neglected delta and longfin smelt. It also started my long involvement with Delta and Suisun Marsh fishes and their conservation. In 1979, I started monthly sampling of fishes of Suisun Marsh, which in turn led to my laboratory documenting the decline of delta smelt and other native fishes of the entire Delta region.

I would like to say that conditions have improved for fish since then, but they haven't. As competition for water and loss of habitat have intensified, many native fishes have been placed on a trajectory towards extinction. Dams block access to most spawning and rearing habitat for salmon and steelhead. A vast majority of the wetlands and floodplains important to fish are farmed or urbanized. Rivers have diminished or highly regulated flows and are confined between levees. New aquatic habitats created by human actions are highly invaded by alien fishes, invertebrates, and plants that further change the ecosystems. In fact, most native fishes are minority members of novel ecosystems of made up of highly modified habitats dominated by alien species and manipulated by people. With the ever-increasing human population and demand for water in California, controversies over fish conservation swirl through the media, agencies, and courts.

The Delta and the rivers that feed it are central this controversy. The Delta is the heart of California's water delivery system. It also has the potential to become extraordinarily altered in every way imaginable, with an ecosystem that bears little resemblance to the enormously productive estuarine wetland system that once existed there. Continuing and rapid changes to the ecosystem have been largely harmful to native fishes and fisheries. And the changes are continuing, accelerated by climate change, with potentially drastic changes in the near future, as sea level rises and levees fail. In response, we Californians can shrug our shoulders and accept the changes, which we almost certainly will not like. Or we can engage in systematic efforts to direct change in ways that favor native and other desirable species, living in high-functioning ecosystems. We need to take charge, without delay, if we want delta smelt, Chinook salmon, and other fishes around as wild fish in our future.

This white paper focuses on the complex challenges of habitat restoration to favor native fishes, guided by a reconciliation ecology approach. It is aimed at informing representatives of

water agencies, environmental groups, and others who are not involved with Delta issues on a frequent basis but who are looking for ways to resolve conflicts over Delta water and endangered fishes. Our goal is to provide background information on the challenges of dealing the complex fish issues and then to provide some guidance for establishing and managing restoration projects that favor native fishes.

In this paper, we essentially provide a quick review of the problems to overcome and then insights into the factors that make a successful restoration program. As a start towards improving conditions for fishes, we recommend 17 actions, including some that can be implemented immediately, and some that will take longer. Some of these actions have been around in one form or another for over a decade—but the pace of implementation has not kept up with the pace of crisis. Restoration, and the status of native fishes, will continue to fall behind need if the 'standard operating procedures' don't change. There is a real need for leadership on the part of implementing agencies, such as California Department of Water Resources and California Department of Fish and Wildlife, to speed up the restoration process, by taking risks and treating each project as an experiment.

We need to break away from the attitude that we are in a holding pattern in the Delta, waiting to take action only if the ecosystem shifts once again to a new state or until an emergency is created by levee collapse or a fish kill. Instead, if we act with courage and deliberation, I can envision creating a Delta, or at least the north Delta, where every haul of a sampling trawl catches native fishes in water rich with plankton, while white pelicans soar overhead. This is not an impossible dream, but it will not happen without action NOW and without accelerated action in the future. The Delta is one of best studied habitats in the world: we know what to do. There is no reason why the native fishes of the Delta should not actually have a future there.

-Peter Moyle December 21, 2017

This white paper was originally suggested by Garry Brown of Orange County Coastkeeper, who provided many comments and suggestions and secured funding for it. Valuable insights into the Delta and its fishes were provided by Jim Hobbs, Jay Lund, and others the Center for Watershed Sciences. The opinions expressed in this document, however, are those of the authors who take responsibility for any errors of commission or omission.

Making the Delta a Better Place for Native Fishes

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SUMMARY

The Sacramento-San Joaquin Delta is the heart of California's water delivery system, connecting the precipitation-rich regions of the north with the dry farmlands and demanding urban areas of the south and coast, including the Bay Area. Scarce water resources create conflicts between people and fishes; as demand by people for water grows, less water is available for the environment. This white paper explores the ways to keep the native fishes, and the functional ecosystems they require, from disappearing. Our analysis is fish-oriented because salmon, smelt, and other declining fishes are major drivers of decisions on where to focus aquatic restoration efforts.

The goals of this white paper are to first provide a brief introduction to the Delta and then to describe why restoration of native fishes and natural processes is such a challenge in this system. We follow this with some general guidelines for restoration projects in the Delta and apply those guidelines with a project evaluation tool. We used this tool to evaluate 26 projects, mostly part of EcoRestore, to provide insights to help determine action items. We then present 17 action items, listed below, some of which can be accomplished fairly quickly, some that will take longer, and few that will have to be continuous. But taken together, our recommended actions could significantly improve the welfare of native fishes and help to create a novel aquatic ecosystem with many desirable features.

DELTA-WIDE ACTIONS

1. Four Easy Fixes
2. Expand Monitoring for Estuarine Health
3. Provide a Water Right for the Environment
4. Develop a Functional Flow Regime for the Delta
5. Expedite Permitting and Implementation of Habitat Restoration Projects REGIONAL

INITIATIVES

6. Expand EcoRestore and Learn from First 30,000 Acres
7. Expand Restoration Projects in the North Delta Habitat Arc
8. Establish Suisun Marsh as a Horizontal Levee
9. Eliminate Predation Problems at Clifton Court Forebay
10. Improve Delta Passage for Juvenile Salmon from the San Joaquin River and Tributaries.

REDUCING STRESSORS ON DELTA FISHES

11. Reversing Subsidence in the Delta

12. Accommodating Climate Change
13. Reducing Impacts of Invasive species
14. Reducing Impacts of Pesticides, Micro-contaminants, and Other Toxic Materials

PROBLEM-SOLVING RESEARCH

15. Experimenting with Island Flooding
16. Evaluating Restoration Projects
17. Developing a Stable Source of Innovative Research Funding

The alternative to taking these and other actions is to continue on our present path, which is leading to the extinction of native fishes and the loss of significant fisheries for Chinook salmon, steelhead, striped bass, and other fishes. It is important to remember that the Delta will always support a complex ecosystem. But whether that ecosystem is one that is desirable and consistent with our needs is up to us.

Making the Delta a Better Place for Native Fishes

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MAKING THE DELTA A BETTER PLACE FOR NATIVE FISHES

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I. GOALS

The Sacramento-San Joaquin Delta is a focal point of conflict between fish and people for water because roughly half the state's fresh water flowed through it historically; however, today much of that water is diverted before it reaches the Delta. Of the remainder, another half is diverted out of the Delta itself, mostly to the south Delta pumping plants of the State Water Project (SWP) and the federal Central Valley Project (CVP). The remaining water flows through the Delta to San Francisco Bay as outflow, which includes water designated for ecosystem purposes, water required to maintain Delta water quality, and water that is in excess of what can be captured (Mount et al. 2017).

As the need for water grows by the increasing population in California, less water is available for the environment. In the San Francisco Estuary (SFE) and its watersheds, people dominate the environment through control of water. While the agricultural, industrial and urban economies of the state are prosperous, the native fish fauna is in severe decline. Most native fishes are headed for extinction, with many listed under state and federal Endangered Species Acts (ESAs). The decline of native fishes reflects the rapid disappearance of habitats that they and other native plants and animals need to complete their life cycles. This includes the continuing loss of once-vast floodplain wetlands, riparian forests and free-flowing rivers. These habitats have been reduced to fragments imbedded in an agricultural landscape. They are increasingly unable to support the rich and abundant biota they once did. There is now a major opportunity to protect, restore, and even create habitats before the landscape becomes 'hardened' with alternate uses. See Appendix A for a more thorough treatment of the Delta and its fishes.

In writing this white paper, we operated under the following assumptions: (1) upstream diversions and Delta exports will continue to divert much of the water, just as they have been in the last 30 years. (2) EcoRestore and the Delta Conservation Framework (if adopted)¹ will be

¹The Delta Conservation Framework is being developed by the California Department of Fish and Wildlife (CDFW) in collaboration with the Natural Resources Agency, Delta Stewardship Council, Delta Conservancy, Department of Water Resources, and Delta Protection Commission. While still in draft form as of this writing (November 2017), the framework holds great promise as a vision for Delta overall. "The Delta Conservation Framework serves as a high-level guide for regional planning processes and ties together projects at the landscape scale through a common vision, guiding principles, and landscape-scale goals, strategies and objectives (p6)." <https://www.wildlife.ca.gov/conservation/watersheds/dcf>.

a driving force for habitat restoration, emphasizing adaptive management. (3) There will be large-scale changes to the Delta and its ecosystem as direct or indirect result of climate change, sea level rise, and levee failure. (4) The State Water Resources Control Board will eventually have to manage inflows to the Delta in a way that will improve conditions for native fishes, or at least not make them worse; this includes not letting environmental water be commandeered during severe droughts.

In the San Francisco Estuary (SFE) and its watersheds, people dominated the environment through control of water. While the agricultural, industrial and urban economies of the state are prosperous, the native fish fauna is in severe decline.

With these assumptions in mind, the goals of this white paper are to first provide a broad introduction to the Delta and then to describe why restoration of native fishes and natural processes is such a challenge in this system. We follow this with some general guidelines for habitat-oriented restoration projects in the Delta and apply those guidelines to develop a new project evaluation tool. We use this tool to evaluate 26 projects, mostly part of EcoRestore, in order to characterize successful restoration projects. We then use this information, in part, to develop 17 action items, some of which can be accomplished fairly quickly, some that will take longer, and few that will have to be continuous. They should all be acted on because of the growing urgency to provide habitat for a declining biota. Taken together, our recommended actions could significantly improve the welfare of native fishes and help to create a novel aquatic ecosystem with many desirable features. Our analysis is fish-oriented because salmon, smelt, and other declining fishes are major drivers of aquatic restoration efforts and regulatory actions. It is also the area in which the authors have the most collective expertise.

II. THE DELTA: FOCAL POINT OF CONFLICT

The Delta (Figure 1) forms the uppermost part of the SFE, the largest, most complex, and most altered estuary on the West Coast of North America. It is the heart of California's water delivery system, connecting precipitation-rich regions of the north with dry farmlands and urban areas of the south and coast, including the Bay Area. The Mediterranean climate that drives this system also drives estuarine processes, especially freshwater outflow. The seasonally arid climate makes the region around the estuary a highly desirable place for people to live and for endemic organisms to flourish.

The Delta region today bears only superficial resemblance to the historic Delta, which was a vast network of marshes, floodplains, and braided tidal river channels. It has undergone major changes since the 19th century, changes which are largely irreversible and ongoing (Moyle et

al. 2010, Whipple et al. 2012, Robinson et al. 2016). Historically, abundant water in the rivers flowing into the Delta created habitat for a highly endemic fish fauna, including four once-abundant runs of Chinook salmon.

The seasonal nature of these flows has resulted in dams on nearly every river to capture winter flows to store for use during the dry season and during droughts. To accommodate wet years, massive levees line the rivers to send the flood flows out to sea as quickly as possible. At the same time, massive changes in land use have taken place, turning wildlands into farms and cities that are highly dependent on developed water for consumption and removal of wastes. As a result, today's Delta is comprised of a network of tidal channels that are confined by levees to prevent flooding of deeply subsided adjacent farmed islands. Ongoing subsidence, levee failure, climate change, invasive species, new pollutants, and sea level rise, combined with growing demand by people for water, will transform the Delta yet again into a place quite different from the

Delta of today (Lund et al. 2010, Deverel et al. 2016). The actions we take today will determine what this Delta of the future will be like and whether or not it will favor native fishes.

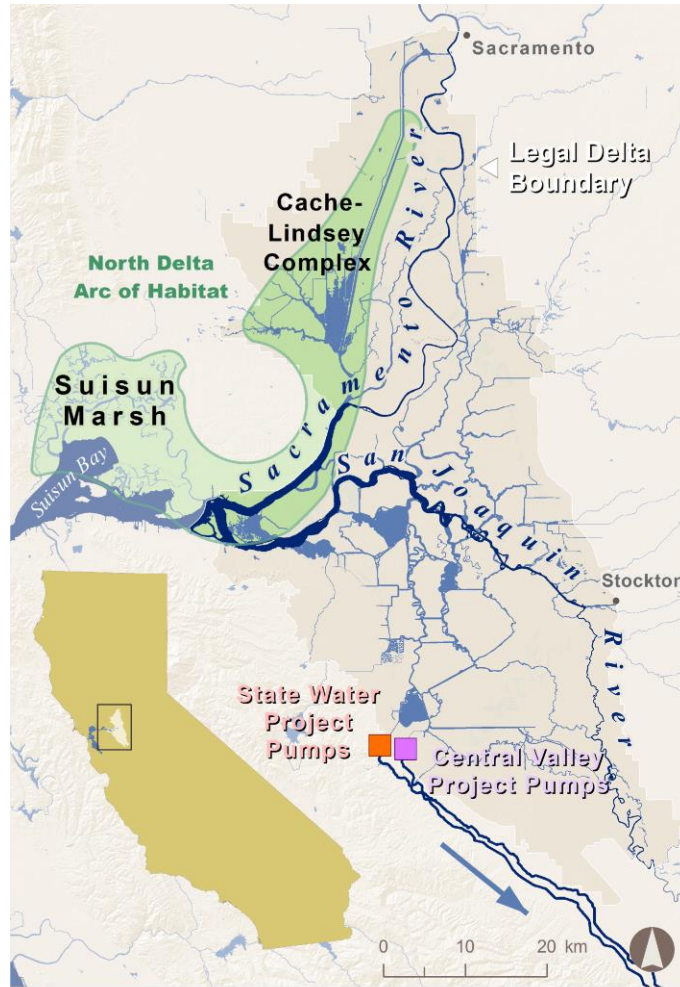


Figure 1. The Delta, showing the location of the North Delta Habitat Arc (green) in which most restoration projects are located. The Yolo Bypass at the upper end of the Arc extends beyond the legal Delta, but is closely connected with the Arc. Figure by Amber Manfree.

Since the 19th century, management actions have largely failed to protect and enhance native fishes, pushing an increasing number of species towards extinction. Under the state and federal endangered species acts, once an imperiled species is listed, measures—sometimes draconian—are initiated to promote recovery. These can generate endless controversy, as illustrated by political and legal sagas surrounding the endangered delta smelt and winter-run Chinook salmon². They also reduce interest in managing non-listed native species or doing

² While smelt and salmon get blamed for taking water from farmers in the southern Central Valley and urbanites in southern California and the Bay Area, most of their legal requirements are met with outflows to maintain water quality for both in-Delta farmers and the CVP and SWP pumps. In the past few years, during severe drought, exports have been reduced mostly for human health and safety, but these standards, indirectly benefitted native fishes. See Gartrell et al. (2017).

ecosystem-based management.

There is increasing recognition that this focus on single species management, even for endangered species, is ineffective. A more robust and integrative approach is needed to restore habitats from local to landscape scales. In California, the only major on-going effort to do management and restoration on a large scale is EcoRestore. This scale is fitting (and could be larger), given that investment in California's water infrastructure has been monumental. Without this investment, California would not be a world economic and social leader and the most populous state in the USA. However, unconstrained development has accrued an enormous environmental debt, which can only be mitigated by a concerted, major investment of local, state and federal resources. Even EcoRestore is a relatively modest proposal by this standard. It is scheduled to protect or restore 30,000 acres in the Delta and surrounding lands, including 9,000 acres of intertidal habitat, 3,500 acres of managed wetlands, 17,500 acres of floodplain habitat, and 1,000 acres of riparian habitat. Most EcoRestore projects require access to tidal and river flows to make them function well, which presumably means increased appropriations of water for environmental purposes. A great deal of trust in the implementing agencies by the general public is needed to make a project of this size work.

III. THE CHALLENGES OF DELTA RESTORATION

Overview.

The habitats of the Delta will be subject to significant changes in the coming decades. Many alien fishes, in contrast, will benefit from the changes (Quiñones and Moyle 2014, Moyle et al. 2015). These changes will make conditions for desirable species much worse and make restoration projects both more needed and more difficult. The biggest driver of large-scale change is global climate change because it is linked to sea level rise, greater variability in precipitation (bigger floods, longer droughts), and higher temperatures over longer, drier summers. Moyle et al. (2017) found that climate change is the factor most likely to deliver the final blow that drives many endemic salmon and trout species to extinction in California. Other major drivers include deteriorating water quality, invasions of new species, and catastrophic levee failures. Restoration projects will have to take these changes into account, which is why we recommend reconciliation ecology (Appendix B)³ as a guiding philosophy and adaptive management as essential approach.

³ Reconciliation ecology is the science of integrating self-sustaining populations of native plants and animals into highly altered ecosystems dominated by people and supporting many non-native species. Appendix B gives a more complete explanation.

This reconciliation ecology approach to management is compatible with the Delta Conservation Framework. Both measure success through such indicators as abundance of desirable fishes, water quality, and access of people to natural resources, as well as a healthy economy. The inevitability of change, however, means that Californians need to be actively involved in directing change toward creating processes and habitats that benefit both the environment and people, on as large a scale as possible.

The biggest driver of large-scale change is global climate change because it is linked to sea level rise, greater variability in precipitation (bigger floods, longer droughts), and higher temperatures over longer, drier summers.

But there will always be uncertainty as to the effectiveness of large projects like EcoRestore to improve conditions for native biota. Nevertheless, the SFE is one of the most studied estuaries in the world, so it is possible to make rough predictions of alternative future states resulting from broad management strategies (e.g., Lund et al. 2007, 2010, Moyle et al. 2014). Our scientific knowledge is certainly sufficient to develop an adaptive management program for the Delta, directed towards a desired future condition, as expressed in the draft Delta Conservation Framework. An incremental program of adaptive management would use management and restoration actions as experiments, complete with hypothesized outcomes, measured results, and recommendations for further actions. Each restoration action would then help inform and guide future actions. In such a program, there are no failures, just acceptance or rejection of hypothesized results. New actions and new results should provide management strategies that have increasing certainty about outcomes, supporting attempts to achieve broader system-wide consensus. The following sections deal with some of the major challenges to creating effective management strategies.

Effects of restoration.

Because habitats of the SFE are so fundamentally altered, restoration to a historic state is not possible. Restoration actions have to focus on processes, habitat functions, and species assemblages that incorporate as many desirable species as possible. Targeted restoration activities, such as subsidence reversal, will be important to creating long-term healthy Delta ecosystems, if they involve large acreage, intensive manipulation and/or improved flow regimes. However, many planned restoration projects are focused on creating more habitats that rely entirely on the natural tidal cycle for flooding and draining. The problem here is that tidal energy is a more or less fixed resource: the more area that is exposed to tidal action, the more the tidal energy has to be 'shared'. This means there will be less tidal energy to make each project work that depends on the rise and fall of the tides. Any project that creates new tidal habitat, such as flooding a large Delta island or creation of a new bit of tidal marsh, takes energy away from existing tidal areas. This is a small problem now but could become large if multiple Delta islands flood in response to high flow events, sea level rise, and/or earthquakes

(Enright 2014). If this happens, large tidal restoration projects, such as those recommended in this paper, could be in jeopardy. For an exhaustive treatment of possible effects tidal marsh restoration on fishes, see Sherman et al. (2017).

Targeted restoration activities, such as subsidence reversal, will be important to creating long-term healthy Delta ecosystems, if they involve large acreage, intensive manipulation and/or improved flow regimes.

It is increasingly important that Delta island managers be mindful of the need for subsidence reversal, through accumulation of organic matter produced by plants or through trapping of sediment by the plants. Done properly, it is possible that some of the effects of sea level rise can be countered by subsidence reversal. On a large scale, coordinated action by landowners in Suisun Marsh, which is not highly subsided, could grow vegetation in a way that would keep up with sea level rise, creating essentially a horizontal levee to protect Suisun City and Fairfield (Moyle et al. 2014). Subsidence reversal also has the advantage of sequestering carbon, helping to reverse the effects of climate change in a small way.

Inflows and outflows.

Flow is the most contentious issue in the Delta, especially given that all inflowing rivers are regulated by dams and most developed water is scheduled for human use. The continuing, increasing diversion of water from the Delta and upstream areas is a constant stress to the system because flow interacts with habitat and water quality, with non-native species, with contaminants, and with other factors associated with 'health' of the Delta ecosystem and decline of native fishes like delta smelt. Substantially increasing Delta outflows in most years is unlikely to happen (Appendix C). However, the State Water Resources Control Board is working on a process to define flow requirements across many competing needs, including the environment. The results of that process should have a big impact on the Delta ecosystem and on the effectiveness of restoration actions (https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/comp_review.shtml).

The proportion of river water devoted to environmental flows could be allocated in a more sophisticated manner, using the concept of functional flows, allocated by using an Environmental Water Budget (Mount et al. 2017; see Action #3, p. 21). The idea behind functional flows is to set up goals for the water available and then allocate it to achieve maximum benefit, including developing a flow regime that benefits fishes and the habitats they use, in which different species benefit in different years (Yarnell et al. 2015). This approach would have to be implemented in a flexible manner, using adaptive management.

The new classification of Delta flows of Gartrell et al. (2017) could make adopting functional flows easier or at least more transparent to water users. They recognize that environmental water actually has three components, ecosystem water, system water, and uncaptured water. Ecosystem water is the water specifically designated to benefit fish and wildlife, including that provided under biological opinions for endangered fishes in the Delta. System water is water that may have environmental benefits but is primarily managed to benefit cities and farms; a good example is the water used to keep the Delta fresh in summer, to keep salt water out of local and major diversions. Uncaptured water is water that is more than demand can handle so it flows out to sea; it is often counted as environmental water because of its benefits to the environment and people (Cloern et al. 2017). When water is classified in this manner, it shows that fish and wildlife demands have little impact on water supplies, because most environmental flows are actually derived from system water.

Flow is the most contentious issue in the Delta, especially given that all inflowing rivers are regulated by dams and most developed water is scheduled for human use.

However, because the Delta is so highly altered, a desirable environmental flow regime may be only effective if other aspects of the habitat are improved as well. For example, delta smelt need abundant plankton, cool temperatures, and moderate water clarity to survive; a flow regime that does not provide those factors will not benefit the smelt. Flows are most effective as a conservation tool if they interact with physical habitat (e.g., trees, floodplains, eroding banks) and create habitat gradients on a sufficiently large scale to produce the food and diverse habitat required by diverse fishes. A river-flow that mainly interacts with levees will not provide habitat for native fishes.

Sea level rise.

The Delta is particularly vulnerable to sea level rise because of the continued subsidence of farmed islands in the south and central Delta, many already well below sea level. Subsidence, combined with increased pressure on levees from sea level rise, floods, storm surges and earthquakes will ultimately result in levee collapse and flooding of subsided islands. While these projections may seem alarmist, studies predict large-scale change is going to happen.⁴ At some point, the south and central Delta may contain large expanses of salty water with reduced tidal influence, ending farming in the region. Fish and invertebrates will continue to be abundant but the assemblages are likely to be made up of salt-tolerant forms, both native and non-native, such as yellowfin goby, Mississippi silverside, Black Sea jellyfish, and overbite clam. Fighting this magnitude of change to keep the status quo will require large investment in barriers and levees, which will be increasingly difficult and expensive to repair.⁵ Taking sea

⁴ For more background, see Lund et al. (2007, 2010), Moyle (2008), and references therein.

⁵ Fixing the problem by reinforcing or increasing the height of levees is a program that is likely to fail, despite large on-

level rise into account must be part of any restoration efforts.

Levee failure.

As indicated, the probability of failure of multiple levees in the Delta in the foreseeable future is fairly high, if hard to predict with any exactitude (Deverel et al. 2016). Levee failure is the result of multiple interacting factors. First is the fact that most Delta levees are made mostly peat and other local materials, even if topped by rock. Peat soil islands subside every year they are farmed through oxidation or by being blown away by wind. Because water levels in channels around the islands are much higher than island elevation, water tends to seep under the levees, enhancing instability. These levees can overtop with floods, storm surges, and high tides, which can create breaks, especially if a levee has been weakened by burrowing rodents or other factors. Seismic risks to levees, resulting in collapse through liquefaction and breaching, are high (Deverel et al. 2016). Levee collapse from earthquakes seems certain, although when that will occur is very uncertain (it could happen tomorrow). While newly flooded islands may create some new habitat for fish, ecosystem benefits to native fishes are uncertain and unlikely (Moyle 2008, Deverel et al. 2016). Most flooded islands will be fairly deep, reducing tidal energy for the entire system, and likely to favor non-native species of invertebrates, aquatic plants, and fish. A Delta-wide strategy is needed to accommodate levee failure in relation to restoration.

Water quality problems.

Besides physical changes to the Delta, water quality is constantly changing, both seasonally and over the long term. With sea level rise, much of the Delta and Suisun Marsh are likely to become saltier. Climate change is predicted to make summer temperatures in most of the Delta too warm for cool-water species such as delta smelt, while favoring warm-water non-native species. Already much of the south and central Delta is too warm during much of the year (more than 25 degrees C). Additional, pervasive water quality problems include changes to suites of nutrients, microcontaminants, and pesticides released into the environment through waste-water treatment plants and from run-off from farms and cities. Even if such chemicals do not kill fish (and other organisms) directly, they can affect their health, making them more vulnerable to environmental change, predation, and other factors.

going investments. The current program consists of reinforcing levees with rock layers and creating rock piles in strategic places to deal with emergencies. Many current Delta levees may need replacement because they are largely made up of local materials, especially peat. Heavy rock layers on top of peat levees may compress the peat, lowering levee heights.

Alien species.

The aquatic realm of the Delta is dominated by non-native species, ranging from aggressive invaders to benign permanent residents. It is not possible to eradicate these species because most are naturalized to the system and comprise most of the biomass. Our studies in Suisun Marsh suggest that in some habitats relatively stable assemblages of native and non-native species have become established and have become integral parts of a novel ecosystem. Likewise, the present management of the south and central Delta has resulted in lake-like, warm, environment dominated by non-native aquatic plants; this environment favors largemouth bass, sunfish, and other non-native fishes and is largely unsuitable for most native fishes.

In much of the Delta, however, aliens require management; for example, herbicides are used to control large expanses of water hyacinth that otherwise interfere with boat passage. Invasive aliens can be a particular problem in restoration sites, potentially changing the trajectory of the restoration or requiring continuous control measures with unintended consequences. For example, South American water primrose, a long-time resident of the Delta, has become an emerging invasive, occupying niches opened up by management strategies to control other invasive plants like water hyacinth and Brazilian waterweed (Shruti Khanna, UCD, pers. comm. 2017).

IV. EVALUATING DELTA RESTORATION PROJECTS

The basic concept behind EcoRestore is that multiple, diverse restoration projects will cumulatively help to reverse the downward trends in native fishes like delta smelt and Chinook salmon. The long-term goal of this broad program of restoration is to provide sufficient habitat to maintain as much native biodiversity as possible for the indefinite future, focusing on floodplains, tidal marsh, and other wetlands. Reconciliation ecology (Appendix C) provides the template for the active management needed to achieve this goal, recognizing that, for better or worse, non-native species are irrevocable components of the ecosystem.

Here we provide some guidelines for habitat-oriented restoration projects. Our approach is largely consistent with the conceptual models and recommendations in the Fish Restoration Program Agreement: Implementation Strategy (Department of Water Resources, 2012) which includes a reconciliation approach as a possibility. Like Sherman et al. (2017), we recognize that wetland restoration projects must have a strong component of flows and physical processes that interact with the physical habitat.

Here we suggest general guidelines for habitat-oriented restoration projects and apply those guidelines to a proposed project evaluation tool. We then use this tool to evaluate 26 projects, mostly part of EcoRestore, to provide insights to help determine action items.

The long-term goal of this broad program of restoration is to provide sufficient habitat to maintain as much native biodiversity as possible for the indefinite future, focusing on floodplains, tidal marsh, and other wetlands.

Guidelines for restoration projects

Questions.

Each project must address well defined questions useful for adaptive management. For example, what fish species should it benefit? Will it produce phytoplankton and invertebrates for in situ use and/or export, to support pelagic food webs? Will it discourage alien invaders?

Monitoring.

Every project should have a monitoring program, to inform management if the basic questions are being addressed. In addition to determining operations, monitoring should provide data to inform new restoration actions as well as future modifications or restoration activities on established sites.

Active management.

Historically, tidal restoration projects often involved actions, such as breaching a levee, that were not subsequently evaluated, on the assumption the site would automatically go into a more natural, stable condition.⁶ In general, that turns out not to work well. Most restoration projects need active management, in which people take direct control of ecosystem processes. Particularly important is regulating residence time of the water in the project. If tidal flux or freshwater drainage is too rapid, production of zooplankton and benthic invertebrates (fish food) will be low. If residence of the water is too long, on the other hand, it can become warm, stagnant and hostile to juveniles of desirable fishes. An active management program should include actions to control invasive species, to engineer breeches or operate tidal gates for optimal water exchange, to reverse subsidence through enhanced growth of marsh plants, and to re-introduce native plants and animals. Good models for this kind of active management can be found in some duck hunting clubs in Suisun Marsh.

⁶ Restoration projects in the Delta would be better called reconciliation projects, but restoration is so deeply imbedded in the language of managers and the public, it would be confusing to switch titles. We use the term 'restoration' for habitat projects that are designed to benefit native or other desirable species and the food webs upon which they depend. Usually, restoration involves converting a piece of land from one use to another.

Non-native species.

Every restoration project will have non-native species. Each project needs to determine what species are benign and which will need long-term management, including control and eradication. Plans should also be in place for dealing with new invasive species.

Size.

In general, the bigger the project in terms of acreage and flows, including tidal flows, the better. A large, well-managed project is more likely to support more diverse species and habitats than aggregates of smaller ones. Small projects work best if they are located in strategic areas (e.g. along a migration corridor) or if they contain unusual habitats or species (e.g. a rare plant). It also helps if they are close to larger areas. These guidelines reflect some basic principles of reserve design in conservation biology.

Connectivity.

Another reserve design principle in conservation biology is that protected areas work best, especially for vertebrates, if they are connected to other protected areas nearby (the string of pearls concept). Nursery habitat must be linked to spawning and rearing habitat for older life stages. This connectivity also allows animals and plants to disperse to neighboring areas, enhancing genetic diversity and preventing local extinctions. For Delta channel networks to be effective, they must be supported by edge habitat of marsh or woodland to provide habitat, food and thermal refuge for migrating fish. These corridors can be important for birds and other biota.

Non-fishes.

While these guidelines focus on fishes, in many cases the greatest beneficiaries of a project may be other animals and plants, including migratory waterfowl. Restoration site design should always take a multiple species approach.

People.

Most restoration sites have a history of use by people. Users need to be involved in the project from inception, both to reduce adverse reactions and to take advantage of local knowledge.

Stakeholders.

Multiple stakeholder perspectives should be considered during the planning process, in order to optimize outcomes for maximum benefit, when possible. Unfortunately key stakeholder groups, including agencies such as the Department of Fish and Wildlife, and entities such as county governments, usually lack sufficient resources to hire professional personnel to work on each project. Thus, project proponents must either expect long delays or find ways to financially support stakeholder participation.

Evaluation procedure.

With the above guidelines in mind, we evaluated restoration sites using the following metrics (Appendix E):

- Size (acres)
- Connectivity to major water ways (e.g. Sacramento River)
- Number of desirable fish species likely to be supported by the project
 - Desirability of a species is rated in Appendix A.
- Number of ESA-listed fish species (out of 6) likely to benefit
- Ecosystem benefits to non-fish species
- Proximity to other natural or restoration sites
- Management approach
- Export of fish food production
- Invasive species problems

Using a scoring method devised for this process, we rated 26 projects from a field of about 100 potential projects (Appendix D). We chose projects based on availability of information and personal knowledge of them. Most were also EcoRestore Projects.

Insights.

The following are insights from our analysis of the projects:

1. The fish-focused evaluation tool we developed was easy to use, generated repeatable scores, and was consistent with our broader criteria.
2. EcoRestore appears to be a reasonably good collection of projects, largely concentrated in the North Delta arc of habitat. This location is appropriate because most of the habitat with the greatest potential for restoration is located in the region. Individual project location seems to have been based largely on acquiring sites in the region as they become available, regardless of size and suitability (Moyle, personal observation). Some marsh restoration projects in EcoRestore (e.g. Sherman Island Mayberry Ranch) are not tidal and do not contribute much to restoration of desirable fishes, so scored low, even though they benefit many other species.
3. The best tidal restoration projects were large in size (<1000 acres) with high connectivity to waterways that permit fish access to the projects or the invertebrate

food they produce.

4. Individual tidal restoration projects probably do not export phytoplankton or invertebrate food in sufficient abundance to sustain large numbers of fish; this fits with our understanding of the likely hydrodynamics of existing projects. The exceptions are projects that increase dynamic floodplains, including infrastructure projects; working floodplains are demonstrably good for juvenile salmonids and other native fishes and can export food and nutrients.
5. Projects that improve infrastructure that allows increased movement and survival of desirable fishes can have especially high conservation value, although few such projects were evaluated numerically. There seems to be a general consensus among fish biologists, for example, that improving Fremont Weir, Yolo Bypass channels and Clifton Court Forebay will have high benefits for survival of endangered fishes.
6. Collectively, projects in the North Delta Habitat Arc represent the best model for future projects because they consist of a portfolio of projects that are diverse in size, connectivity, and location; all are linked to the Sacramento River and its riparian zone. The river provides a corridor that connects projects and habitats by water and land, providing opportunities for a dynamic biota to exist, and to expand as restoration projects are added to the portfolio.

V. ACTIONS FOR FISHES.

The following is an annotated list of actions that are important to achieving a Delta vision that involves thriving native fishes. We emphasize that this is by no means a complete portfolio but consists of projects that we think are important from our personal experiences and knowledge and that encompass a wide array of actions. Our list starts with 'four easy fixes', projects with high value that can be accomplished fairly quickly (within 2 years) with focused action. We emphasize that the projects are easy at a conceptual level, but not necessarily politically simple. From there we go to 17 more action items in the categories of Delta-wide actions (4), Delta regional initiatives (6), actions reducing stressors (4), and problem solving research (3).

Most large-scale actions to improve conditions for fish in the Delta involve smaller actions that coalesce into bigger problems.

DELTA-WIDE ACTIONS

1. Four “Easy” Fixes

Most large-scale actions to improve conditions for fish in the Delta involve smaller actions that coalesce into bigger programs. The projects below are examples of these kinds of actions. Three are mostly underway and one is new. They were chosen because they are projects in which we are involved and for which we think progress is much slower than it should be. We see delays caused by slowness of the permitting process and by a reticence of state and federal agencies to take risks. We think it reasonable to see all these projects completed or well underway by early 2019. Presumably most EcoRestore projects in the North Delta Arc could have similar completion rates with proper encouragement.

- a. **Fremont Weir.** This project started out with the basic concept of ‘notching’ the weir at the upper end of the Yolo Bypass and has evolved into discussions of one or multiple gates, at various locations along the weir or along the levee on the east side of the bypass below the weir. Included in recent discussions have been channel improvements and re-establishment of a more natural channel through the Yolo Bypass. The idea is to permit annual flooding of at least part of the Yolo Bypass to benefit juvenile salmon and perhaps other native fishes. Stakeholders agree that this is a good project but progress has been slow because of disagreements on design of the project. An EIS with six options is due to be issued shortly. For the project to proceed, multiple agencies must make it a high priority. For full involvement of key stakeholders such as Yolo County, the Yolo Basin Foundation, etc., funding should be provided to pay for personnel to support analysis and approval. See #8 for further discussion of the Fremont Weir. Action items: Support the EIS option that provides the most benefits for fish while also providing flexibility for other uses of the Yolo Bypass, for flood management, farming, and waterfowl. Provide funding that insures full participation of key stakeholders in the process.
- b. **The McCormack-Williamson Tract (MWT)** is part of the northeast Delta. It includes the lowermost section of the Cosumnes River Preserve and is at an elevation gradient between the upland floodplain and the intertidal habitats. MWT is also immediately downstream of Stone Lakes National Wildlife Refuge. With the restoration of MWT, the Stone Lakes-Cosumnes River Preserve will be the largest contiguous restoration site in the Delta. Additionally, the restoration of MWT by itself will provide approximately 1400 acres of habitat (~ 1/3 subtidal, 1/3 intertidal, and 1/3 floodplain) into the Northeastern Delta. Action item: Restore MWT to tidal and floodplain habitat.
- c. **Delta smelt beaches.** This is a new project, inspired by the work of Dr. James Hobbs. He has noted that delta smelt most likely spawn on sandy beaches, as do other related smelt. The longest stretch of sandy beaches in the Delta is along the Sacramento River near Rio Vista; there is at least indirect evidence the beaches have been used for spawning (J. Hobbs, personal communication). These beaches require sand blowing/eroding in from the

Montezuma hills (ancient sand dunes) for renewal. Unfortunately, the beach areas, including those in Sandy Beach County Park, have been/are being invaded by giant reed, *Arundo donax*. *Arundo* stabilizes the sand and blocks access to beaches by smelt and other migratory fishes. Action items: (1) undertake an *Arundo* removal program along the Sacramento River in the Delta, followed by monitoring for smelt, (2) conduct a study to document use of beaches by smelt and other fishes, and (3) conduct a survey of beaches as potential spawning sites throughout the Delta, including others dominated by *Arundo*.



Image 2. Yolo Bypass and Sacramento. (Jeffres, C. January 2017)

- d. **Putah Creek restoration.** Putah Creek is a tributary to the Delta where it flows into the Yolo Bypass. Its flows originate today from Monticello Dam. The creek is already renowned for the success of 'natural' flow regime and diverse restoration projects in bringing back native fishes, including Chinook salmon. While funds for further restoration projects were awarded through Proposition 1, progress is currently stymied by permitting issues. Projects that need to go forward are channel improvements and re-establishment of a more natural channel through the Yolo Bypass. Action items: Support the process of the Solano Water Agency to do multiple channel restoration projects on Putah Creek, including working with politicians and others to convince permitting agencies (mainly ACE) to issue required permits.

2. Expand Monitoring for Estuarine Health

Monitoring is essential for determining how well the Delta ecosystem is functioning and for documenting change as the result of management actions. Long-term monitoring of the Delta was implemented to document changes to fish populations as a result of freshwater exports. Surveys were designed primarily to assess long-term trends in pelagic species such as striped

bass. The existing monitoring programs have successfully documented major shifts in the Delta fish populations-and ecosystem- over time and should be continued.⁷

In addition to biological monitoring, the existing network of physical and water quality monitors needs to be expanded and maintained in place. Traditionally, the array is expanded during periods of crisis, such as droughts, and then incrementally disassembled as memory of the drought fades. Without these stations it is impossible to determine biophysical changes occurring over long and short time scales. It is also much harder to determine the effects of EcoRestore on water quality conditions as restoration projects are implemented.

Monitoring is essential for determining how well the Delta ecosystem is functioning and for documenting change as the result of management actions.

The action items advocated here are aimed at developing a more ecosystem-based monitoring program. They are: (a) maintain existing multi-species surveys, but rely on striped bass and similar species as reference species for ecosystem health (b) develop new species-specific surveys if they do not come at the expense of existing long-term surveys, and (c) establish additional data collection at scale and time increments to capture bio/geo/chemical processes for monitoring of physical and water quality variables.

3. Provide an Ecosystem Water Budget

Whenever there is a water shortage crisis, environmental water is likely to be cut. This will continue to happen unless the environment is assigned an irrevocable share of the water. This will give representatives of the environment (e.g., through a special board or an environmental water czar) a place at the negotiating table during times of drought, for example. The details of this concept have been developed by the Public Policy Institute of California (Mount et al. 2017) as an Ecosystem Water Budget (EWB).

The EWB would work like an environmental water right but would rely on negotiated agreements, rather than rights assigned by the state. According to Mount et al. (2017), "The

⁷Because accurate estimates of population abundance of endangered fishes such as delta smelt are deemed necessary for management, there is interest in replacing long-term monitoring programs with new surveys. There are two main reasons for this. First, the Water Infrastructure Improvements for the Nation Act, Public Law 114-322 9 (December 16, 2016), mandates improved estimates of smelt distribution and abundance in order to allow more water to be diverted to the San Joaquin Valley farmers. The law makes the assumption that ecosystem water provided for smelt is a huge water cost (it is not, Gartrell et al. 2017).

The second reason is that the delta smelt population abundance has reached such low levels that long-term monitoring surveys rarely capture them, creating uncertainties for water exporters. Ironically, it's the long-term monitoring surveys that help managers establish "incidental take" (killing of endangered species) of delta smelt by water exports and diversions. With dwindling abundance comes reduced take, followed by reduced monitoring efforts to avoid take. This cycle reduces the ability to accurately assess population abundance. Implementing strict take numbers for monitoring surveys decreases their value because they can be halted when take is exceeded.

EWB would identify the volume and timing of water needed within each watershed to fulfill the purposes of the watershed ecosystem plans. The trustees ... would have the authority to store, purchase, or exchange water to augment that assigned to the EWB, to lease water to other parties during periods when the full allocation is not needed to achieve ecological objectives set forth in the plans (p 32).”

The EWB recommendations developed by Mount et al (2017) should be supported, in the context of the ‘co-equal’ water goals for the Delta. Action item: Adopt Environmental Water Budgets for the Delta and its inflowing rivers consistent with functional flow regimes discussed below.

4. Develop a Functional Flow Regime for the Delta

A functional flow regime allocates available water to achieve maximum benefit for multiple users (Yarnell et al. 2015; SFEI 2016). The flow regime must benefit desirable fishes if it is to be successful, especially from the Sacramento River, although different species will likely benefit in different years.

As an action item, functional flows should be developed and implemented so flows can be managed in wet, average, dry and drought periods in ways that will not further jeopardize native fishes. Ideally, this would be operated in the context of an Environmental Water Budget (Mount et al. 2017). There will still be water negotiations during times of drought, but there will be a better understanding of the needs of fishes if a functional flow regime is established at least in concept, assuring fish have a place at the negotiating table. The potential of implementing such a concept is apparently being examined by the SWRCB and water user groups.

The best thing that could happen to native fishes is to combine the necessary flows with habitat restoration projects that provide food and habitat when the fish need it most. The effectiveness of most restoration projects in or near the Delta for benefiting native estuarine and freshwater fishes depends on adequate fresh water flowing through or past them, especially to develop and provide the food necessary for healthy populations. The action item here is to work with SWRCB and other agencies to promote functional flows as an essential ingredient in restoring endemic fishes, with or without a designed Ecosystem Water Budget. EcoRestore projects are more likely to be successful if the projects can interact with an appropriate flow regime.

5. Expedite Permitting and Implementation of Habitat Restoration Projects

Projects typically suffer from slow progress including permitting and implementation hurdles. It is not uncommon for projects to take seven years or longer from inception to construction. This slow process not only hampers progress, but it slows the learning process and the development of recommendations that can be applied to future projects. A good example of how permitting and bureaucratic barriers can be overcome is the Wallace Weir project that

includes a \$15 million set of gates and other structures in the Yolo Bypass to capture stray Chinook salmon. From start to finish this major project has taken about two years, with private funding and expedited CDFW approval.

The most recent effort to help the process is Assembly Bill 2087 (Regional Conservation Investment Strategy), which went into effect in January 2017. The law encourages CDFW to engage in voluntary, non-regulatory approaches to conservation; such actions presumably will speed the eventual permitting process by getting stakeholders to work together. This can be done through regional conservation assessments, regional conservation investment strategies, and mitigation credit agreements (<https://www.wildlife.ca.gov/Conservation/Planning/Regional-Conservation>).

AB 2087 can be regarded one way to do the equivalent of an HCP/NCCP planning effort without getting mired in the formidable permitting and approval processes now required during the establishment phases. Action item: Encourage agencies and NGOs take advantage of the bill's provisions and put 'pressure' on CDFW to actively implement them.

Projects typically suffer from slow progress including permitting and implementation hurdles... This slow process not only hampers progress, but it slows the learning process and the development of recommendations that can be applied to future projects.

A more direct way of speeding up the permitting processes is for water agencies, foundations, and other organizations to provide permitting agencies, such as CDFW, with funds to hire an employee for several years who is dedicated to working on a particular project. Likewise, funding should be made available to crucial NGOs and other groups to hire a person that would allow them to fully participate in the process and be involved in outreach to members and the general public. The action item here is to develop a mechanism that would provide such funding of the permitting process.

REGIONAL INITIATIVES

The Delta has always had regions that differed from each other ecologically. Those differences have become exaggerated in the present Delta, with the north Delta having the greatest potential for contributing to the restoration of habitats for native fishes. While the Delta of today is still interconnected through its waterways, which must always be a consideration in management, it makes sense to treat the north Delta differently from the South and Central Delta from a reconciliation perspective.

6. Expand EcoRestore and Learn from First 30,000 Acres

The 30,000 acres proposed for restoration under EcoRestore should be regarded as a down

payment on an effort at least twice that size. EcoRestore is a rather modest proposal. It restores 30,000 acres in the Delta and surrounding lands of which 9,000 acres are intertidal habitat, 3,500 are acres managed wetlands, 17,500 are floodplains, and 1000 are riparian habitat.

For new projects, particular attention should be paid to large-scale projects that involve diverse participants, as is happening in the Yolo Bypass and to some extent in Suisun Marsh. As projects go forward, lessons learned from them will increase the likelihood of success of future projects. Funds for EcoRestore are mostly provided by the State and Federal Water Contractors in response to the biological opinions for delta smelt and winter-run Chinook salmon, in order to improve fish habitat. Action item: future state bond issues (such as the potential 2018 Bond Issue) and additional funding from the State and Federal water contractors (and other users) should be pursued to learn from and expand the efforts of EcoRestore (as in #7).

7. Expand Restoration Projects in the North Delta Habitat Arc

This is the arc of real and potential habitat restoration sites, the “string of pearls” connected by the Sacramento River. The Arc starts in the Yolo Bypass, swings through the Cache-Lindsay Slough region, goes down the Sacramento River, past Twitchell Island and Rio Vista, and ends in Suisun Marsh. The flows of the river are highly managed but provide basic connectivity. While the Arc already contains many EcoRestore sites, it needs to be recognized as an area in which natural and restoration sites are managed as an interconnected whole. This recognition already exists for the Yolo Bypass and the Fremont Weir.

The action item is to find and build even more projects in the Arc, especially those that improve connectivity. Every new or proposed project in the Arc should be evaluated for its connectivity to other sites and the Sacramento River, with priority given to sites that add the most value to the whole.



Image 3. Restored Marsh, Sherman Island. (Moyle, P. August 2015.)



Image 4. Suisun Marsh, showing the urban fringe. (Moyle, P.)

8. Establish Suisun Marsh as a Horizontal Levee

Recognize and start managing Suisun Marsh as a horizontal levee protecting Suisun City and Fairfield against sea level rise and storm surges. Because private and public lands in the marsh are minimally subsided, they have the potential to be managed in ways that accelerate the growth of marsh vegetation which will keep pace with sea level rise and reverse subsidence through deposition of organic matter. This would also improve habitat for fish and wildlife by preventing the marsh from becoming an expanse of open water (Moyle et al. 2014). There would also be benefits from carbon sequestration. SFEI (2016) has many recommendations for achieving such benefits throughout the Delta, while also discussing uncertainties. Suisun Marsh represents a major opportunity for applying reconciliation ecology to the entire marsh, maintaining habitat for water birds, improving habitat for fish and other native biota, sequestering carbon, and reducing sea level threat to cities. The action item here is to fund a process that would get the cities and marsh stakeholders to investigate the potential effects of accelerating sea level rise on the region and to develop plans to ameliorate problems. This action needs to start now because every day that passes allows land surfaces to fall further below the crucial inter-tidal zone thus reducing opportunities for rapid subsidence reversal.

9. Eliminate predation problems at Clifton Court Forebay

For decades, Clifton Court Forebay has been treated as a predator control problem, affecting juvenile salmon from the San Joaquin watershed. Ideally, to fix this problem, the SWP pumping plant should be redesigned with a different water intake system. One potential alternative is to maximize pumping through the CVP pumping plant to reduce SWP pumping, whenever salmon (or other species of concern) are present, because the CVP plant does not have a forebay. The two systems are more and more operated in tandem in any case, with interties between the canal delivery systems. The action item here is to find alternatives to forcing juvenile fish through the forebay death trap and implement the alternatives immediately. Just doing more studies should not be regarded as an acceptable alternative.

10. Improve Delta Passage for Juvenile Salmon from the San Joaquin River and Tributaries.

The region of the Delta where the flows enter from the San Joaquin, Merced, Tuolumne, and Stanislaus rivers is the most 'hardened' part of the Delta, with fewest opportunities for habitat restoration. However, the rivers still support spawning and rearing by Chinook salmon, a use that is supposed to increase with habitat and flow improvements on the four tributaries and large-scale restoration of flow and habitat in the San Joaquin River. A major obstacle for maintaining salmon populations is moving out-migrating salmon past the state and federal pumping plants, through the heavily leveed, urbanized, and polluted waterways of the South Delta. Ideally, a well-defined pathway, combining special barriers, improved habitat, and increased San Joaquin River inflows should be established for the salmon and other migratory fish (Salmonid Scoping Team 2017). Alternatively, if predation problems can be solved at Clifton Court Forebay, directing the juvenile salmon into the pumping plants to be salvaged could allow the fish to be trucked around the worst places in the Delta (see also #9). This would

allow most of the south and central Delta to be managed to support fisheries for non-native fishes, such as largemouth bass. The action item here is to identify the best way to move juvenile salmon past the pumps and into the lower Delta, and then out to sea. The selected route would be treated as an adaptive management experiment.

REDUCING STRESSORS ON DELTA FISHES

11. Reversing Subsidence in the Delta

Subsidence has caused many Delta islands to be 2-9 m below sea level, a process which continues as long as the islands are farmed. With sea level rise, king tides, earthquakes, and high flow events, levee collapse and island flooding is highly likely. It is unlikely that flooded islands will create open-water habitat suitable for native fishes unless special management strategies are developed (see # 12 for needed experiments). Thus reversing subsidence is highly desirable.

Experiments on subsidence reversal are promising and application of the knowledge to more large-scale projects, such as on Twitchell Island, is needed. A particularly promising region to implement subsidence reversal on a large scale is Suisun Marsh, which has minimal subsidence in most areas. The use of rice growing for subsidence reversal and carbon sequestration in the Delta is also a promising development that should be encouraged. For the long-term, subsidence reversal should begin even on highly subsided islands, which could be combined with a levee stabilization program. Because seepage under subsided island levees is a growing problem, increasing likelihood of levee failure, deliberately flooding to shallow depths to promote marsh vegetation could reverse subsidence and reduce stress on levees. Growing rice may have similar benefits. Achieving subsidence reversal in the face of sea-level rise is a difficult and long (100+ years) process. Subsidence reversal in the long run can provide more habitat and food for fish and help to stabilize the physical structure of the Delta. The action needed is to expand/increase subsidence reversal projects NOW, treating each project as an adaptive management experiment. The goal is to make subsidence reversal successful in as many locations as possible and to achieve significant carbon sequestration.

12. Accommodating Climate Change

Climate change is predicted to make summer temperatures in most of the Delta too warm for cool-water species such as smelt, while favoring warm-water nonnative species such as largemouth bass, common carp, and Mississippi silverside. The 2012-16 drought provided a good demonstration of this effect, with much of the Delta being too warm in summer for smelt and salmon. Longer droughts with reduced inflows will encourage spread of alien plants, invertebrates, and fish. All restoration actions should have dealing with climate change effects built into their design. It is important that the responses to climate change be planned for and to be flexible (adaptive/active management).

Action items: First, maintain and expand monitoring programs for water quality variables (especially flows and temperature), as well as for key aquatic species, to be able to detect change and respond to it. Second, fund a strong modeling group that can use these data; this is essential to develop predictions to enable early responses. Such models could also be used to develop a 'triage' system to determine the most effective use of restoration funds. Unfortunately, an underlying problem here is that unless climate change gets under control globally, some native species, especially those that cannot tolerate warmer temperatures in the Delta, will not survive as wild fish. Third, establish a policy that concentrates climate-change related native fish actions in the North Delta Arc as being most likely to pay off for native fishes, in the short run (<50 years).

All restoration actions should have dealing with climate change effects built into their design. It is important that the responses to climate change be planned for and to be flexible (adaptive/active management).

13. Reducing Impacts of Invasive species

The Delta supports an extraordinary diversity of non-native species and they dominate most habitats. However, only a relatively small number of them would be classified as harmful invaders that have likely significantly changed the ecosystem in recent years: water hyacinth, Brazilian waterweed, overbite clam, and Mississippi silverside. These are species whose control or eradication would presumably improve the ecosystem for more desirable species. Large control programs already exist for hyacinth and waterweed but they are largely ineffective in that they have to be repeated annually. Most other species are thoroughly integrated into the present ecosystem, adapted to the highly altered conditions, so present no threats. As an action item, a centralized, well-funded program, should be established that deals with:

- Prevention of new invasions, such as zebra and quagga mussels
- Development of control programs to manage existing harmful invaders, including invasive clam species, ideally using biological control.
- Evaluation of the positive and negative attributes of non-native species to determine which ones are in fact harmful and which ones deserve management as beneficial species (e.g., sport fishes such as largemouth bass).
- The Delta as a novel ecosystem, in which most non-native species are thoroughly integrated. Use this concept to develop management strategies that create habitats that favor declining native species, and reduce the impact of invasive nonnative species.

14. Reducing Impacts of Pesticides, Micro-contaminants, and Other Toxic Materials

The Clean Water Act and the Porter-Cologne Act cleaned up most of the macropollutants, such as sewage, going into the Delta. However, potentially harmful compounds such as those associated with human hormones, sunscreen, and pyrethroid pesticides, continue to enter the system at very low concentrations. Such chemicals can affect health of fish, reducing reproductive potential or making them more vulnerable to predation or disease. The problem is both huge and diffuse, with potential ramifications for human health as well. Actions to reduce effects also have to be huge and diffuse involving (a) education of the public, to use less, (b) banning the most toxic classes of compounds, (c) improving waste-water treatment, (d) continuous monitoring of the presence of micro-contaminants in Delta waterways and (e) an effective program of science to determine emerging and extant toxic threats. Industry should be held as a stakeholder in the process, and responsible for developing and funding a program in conjunction with government. It is important to find out if natural and restored marshes significantly detoxify the water and if so, find ways to make the process work better.

PROBLEM-SOLVING RESEARCH

15. Experimenting with Island Flooding

We accept as a given that multiple islands will flood in the south and central Delta as the result of some combination of earthquakes, sea level rise, and large storms, although how soon this will happen is not known. While over \$700 million dollars has already been spent on strengthening levees, failures will happen and decisions will need to be made as to whether or not to engage in repair (Deverel et al. 2016). The action item is to let at least one island flood deliberately, but install tidal gates on the breach to allow some tidal action. While levees on a flooded island would presumably be maintained, essentially creating a lake, levee stress would come mainly from wave action, rather than unequal head pressure and seepage. A deliberately flooded island would provide a powerful opportunity for studying the new ecosystem, as well as the general impact on the rest of the Delta. Such islands could be manipulated to provide food exports to adjacent habitats. A good candidate for this adaptive management experiment is Webb Tract, just acquired by Metropolitan Water District of Southern California. Mildred Island and Franks Tract, long submerged, could be studied as comparisons.

16. Evaluating Restoration Projects

To understand what makes a successful restoration project, use a tool like the one presented in this paper (Appendix E) to evaluate all projects, including those that were 'inadvertent' restoration projects such as Big Break. The scoring system could then be used as a first cut for evaluating proposed projects that benefit fishes. The information could be mandated to (a) quickly identify new projects to expand EcoRestore and (b) develop new and better management strategies for projects (e.g., tidal gates). Robinson et al. (2016) provide many

recommendations for making restoration work. The action item is to develop and adopt an easy-to-use tool to systematically rate the success of restoration projects and to use it in an adaptive framework.

17. Developing a Stable Source of Innovative Research Funding

Funding for research largely comes from agencies through a variety of sources, but especially propositions that get approved by voters. Much of this research is coordinated by the Interagency Ecological Program. This method of funding has made the San Francisco Estuary one of the best studied in the world. Action item: develop a special program that funds innovative research on an annual basis. The program should emphasize high priority directed actions and original proposals for innovative studies that will better guide restoration and management of an ever-changing ecosystem.

VI. CONCLUSIONS

If coordinated restoration actions are not undertaken soon, there will be increasingly irreversible and costly social and environmental consequences. Making this happen will take considerable 'pressure' from stakeholders. Key agencies include the Delta Stewardship Council, the State Water Resources Control Board, the California Department of Water Resources, the California Department of Fish and Wildlife, the U.S. Bureau of Reclamation, the US Fish and Wildlife Service, and the National Marine Fisheries Service but actions also require approval of local governments, water boards, reclamation districts, NGOs, and stakeholders. Involvement by diverse agencies and stakeholders is highly desirable, but will also result in increasing delays from risk-averse bureaucracies. We are not sure of the best way to resolve this dilemma but we do want to avoid the situation where major actions are more likely to take place in response to disasters such as earthquakes, droughts and floods than as the result of rational long-term decision-making.

As mentioned, a good place to start is to develop a consensus on a realistic vision of the future Delta as fish habitat. The San Francisco Estuary Institute has developed a reasonable picture of what the Delta was like in the past and what it is like today, and what actions could create a better future for the Delta (Whipple et al. 2012, Robinson et al. 2016). In particular, Robinson et al. (2016) provide "a blueprint for creating new, reconciled landscapes that integrate natural and cultural processes, and maximize resilience to climate change, invasive species, and other challenges." SFEI's objectives are to develop process-based prescriptions for the entire Delta and its native biota, creating a reality-based, sustainable ecosystem, which encompasses most of the present use by people. In this report we are focused more narrowly on what is good for desirable fishes and that (mostly) can be implemented fairly quickly. We therefore strongly recommend that Robinson et al. (2016) be used as place to start in developing a unified vision

of the future Delta. Actions such as the ones we recommend should fit into this vision but they should fit well into any vision that sees native and desirable non-native fishes as important for conservation action.

We emphasize that the problems of fish conservation are increasingly severe and need to be addressed now. By taking the 17 actions listed above, and others, we can start to direct the future of the Delta in a more positive direction, to provide conditions under which native fishes will thrive. The Delta Stewardship Council would seem to be well placed to lead this effort.

If coordinated restoration actions are not undertaken soon, there will be increasingly irreversible and costal social and environmental consequences.

The alternative to taking these actions is to continue on our present path, which is leading to the extinction (real and effective, see Baumsteiger and Moyle 2017) of native fishes and the loss of significant fisheries for Chinook salmon, steelhead, striped bass, American shad, and other estuarine-dependent species. It is important to remember that the Delta will always support a complex ecosystem. But whether the ecosystem is one we want to live with or not, is up to us. If we don't take concerted action "We will fail into a solution" which will probably be a solution we Californians will not like. Optimistically, we think that a reconciled ecosystem that both supports abundant native fish and wildlife and provides valuable water, fisheries, and other services to people is possible. But need for action is immediate if we are to realize that vision.

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Appendices

Appendix A. The Delta and its Fishes

Appendix B. Reconciliation Ecology: A Novel Approach for a Novel Ecosystem

Appendix C. Delta Conveyance and Fish

Appendix D. Restoration Project Evaluation for Fishes.

Appendix E. A Scoring System for Restoration Projects



Cache Slough Sunrise. Photo by Peter Moyle

Appendix A

The Tidal Delta and its Fishes

We assume that most readers of this white paper will have some familiarity with the Delta and its fishes. This appendix is designed to provide a common understanding with those whose knowledge is limited. The first part is a basic introduction to the geography of Delta, related to its importance to fishes. The second part is an introduction to the fish fauna, followed by a list of Delta fishes. The list includes scientific names of all fishes and of important macroinvertebrates and plants. We identify these fishes and invertebrates as native or non-native (alien), note their relative abundance in today's Delta, decide the official status of native species, and then score their importance to restoration projects.

Geographic scope: the tidal Delta

This paper focuses on the tidal Delta but includes Suisun Marsh and Bay, and the Yolo Bypass and other floodplains (e.g., Cosumnes, Sutter Bypass). We recognize the importance of upstream areas as sources of water, nutrients, and food resources and as spawning and rearing habitat for migratory fishes that pass through the Delta. However, stream restoration projects are outside the scope of this document. Discussion of Sacramento River levee, flow, and flood management projects can be found in Opperman et al. (2017) and references therein. The San Joaquin River is the focus of a major restoration program from Friant Dam down to the mouth of the Merced River (<http://www.restoresjr.net/>).

We follow Whipple et al. (2012) in dividing the Delta proper into three distinct ecological areas, based in part on historic landscape patterns: the north Delta, the central Delta, and the south Delta. We include the Yolo Bypass-Sacramento River corridor as part of the northern Delta, however, and link this region to Suisun Marsh and Bay. The three areas have different restoration challenges.

The south Delta is extremely altered physically by subsidence, levees, invasive aquatic vegetation, and urban development. Its hydrodynamics are dominated by the CVP and SWP pumping plants and water from the regulated Stanislaus, Tuolumne, and Merced Rivers. The most obvious fish problems for the southern Delta are keeping native fishes from being entrained (including keeping them out of Clifton Court Forebay) and finding ways to allow juvenile salmon coming from the inflowing rivers to make their way past (or through) the pumping stations, through the Delta and out to sea. The habitat is increasingly unsuitable for native fishes, especially as water quality deteriorates in summer.

The Central Delta consists of leveed islands of farmland, mostly devoted to annual crops and pasture, some of which are subsided more than 12 feet below sea level. The levees, made largely of native materials (mostly peat) are highly prone to failure (Deverel et al. 2016). The channels between the islands are

generally poor places for native fishes, with relatively poor water quality in summer and heavy infestations of invasive aquatic weeds. The Central Delta includes Franks and Mildred's Tracts, large 'flooded' islands that are now open water; they are seasonally important for striped bass and some other desirable fishes, and support year-around fisheries for largemouth bass, catfish, and sunfish.

The North Delta is the focus of most restoration projects because the Yolo Bypass, Cache-Lindsey Complex, and Suisun Marsh are all connected by the Sacramento River, forming the North Delta Habitat Arc (Figure 1 in main document, Moyle et al. 2010). The dominance of the relatively functional Sacramento River means that slough and floodplain habitat is diverse and abundant and that water quality is higher than in other parts of the Delta. This is the main river corridor used by spawning salmon and other anadromous fishes, delta smelt, longfin smelt, and Sacramento splittail. The numerous connected sloughs in Suisun Marsh and the north Delta region, bordered by mostly non-subsided grasslands and wetlands, provide many habitat restoration opportunities, with successful projects already in place. We regard the Cosumnes-Mokelumne River + McCormick-Williamson Tract corridor as connected to the North Delta Habitat Arc but also as being transitional habitat that has connections to the Central Delta.

These regions will be subject to significant changes in the coming decades. Restoration actions have to take into account these changes. These changes are likely to make conditions for desirable species much worse. Many alien fishes, in contrast, will benefit from the changes (Quiñones and Moyle 2014, Moyle et al. 2015). The biggest driver of large-scale change is global warming because it is linked to sea level rise, greater variability in precipitation (bigger floods, longer droughts), and higher temperatures over longer, drier summers. Other drivers include deteriorating water quality, invasions of new species and changes in behavior of previous invaders, although these are climate change related as well. Moyle et al. (2017) found that climate change is the factor most likely to deliver the final blow that drives native salmon and trout species to extinction in California, because it also drives habitat change.

Delta Fishes

The scope of this paper is narrowed somewhat by its focus on native estuarine dependent fishes, both listed and non-listed species, along with non-native striped bass and American shad. Below, we present a list of all species and some macroinvertebrates, with scientific names. We have rated each species as to its desirability as an indicator of restoration effectiveness, based on our expert opinions.

- The most highly rated species are those listed under state and federal ESAs, as mandated by the acts; they are often drivers of restoration projects. Other highly rated species are non-listed natives but also

include striped bass (see below) and American shad as focal species because they have habitat requirements similar to native species and are abundant enough to be easy to monitor; they have been adapting to the rapidly changing environment for nearly 140 years and are thoroughly integrated into the ecosystem.

- Some alien species are rated as undesirable because they are likely harmful to natives (e.g., Mississippi silverside, wakasagi)
- Some alien species get mixed reviews (ranked as 0?) because they are characteristic of habitats that are indicative of non-estuarine conditions (e.g., largemouth bass, bluegill sunfish in aquatic macrophytes beds) but are more a symptom of a problem than the cause. They also have some desirability because they support recreational fisheries.
- Finally, there is a large group of alien fishes that appear to be neutral or nearly so in their desirability; usually they are only moderately abundant and appear to be integrated into the local novel fish assemblages; species include white crappie, golden shiner, and bigscale logperch.

The striped bass, introduced into the Delta in 1879, is much vilified as a predator on salmon and smelt, a reputation which is largely undeserved (Grossman 2016). Most sampling programs for fishes in the Delta were originally set up for striped bass, because of its value for as an indicator species, for which they still have value. For a review of the problem, see <https://californiawaterblog.com/2011/01/31/striped-bass-control-the-cure-worse-than-the-disease/>

Desirability of Delta fishes and macroinvertebrates

Desirability of a species to people is a value judgment. But such judgments drive decision-making and generate controversy. Thus the largemouth bass may be one group's highly desirable game fish and another group's undesirable invasive predator. Restoration projects in the Delta generally focus on native species, especially those listed under the endangered species acts (ESAs), so the latter species have become highly desirable from a management perspective, in part because of the strict legal requirements of the ESAs. Similarly species, native or non-native, that are good indicators of ecosystem health (e.g., of a functioning estuary), such as striped bass and delta smelt, are regarded as more desirable than those that are not. Here we present a list of common Delta fishes with a method for scoring their desirability, for those who accept the basic value judgments mentioned above. The desirability score is a measure of how desirable it would be to have the species benefit from a restoration project. It is calculated as outlined below.

Desirability scoring. Here is how we scored desirability for fishes and selected non-fishes of the Delta region, including Suisun Marsh, based on expert opinion and Moyle (2002). Fishes rarely captured in sampling programs are omitted. Non-fishes are mostly organisms thought to play important roles in the Delta

ecosystem. The scoring is based on the assumption that native fishes are generally more desirable as objects of conservation than non-native species. Species listed as threatened or endangered always have highest desirability, as mandated by the state and federal endangered species acts.

Desirability score: desirability of the species as an objective of restoration projects, to increase or stabilize numbers.

+3 Very highly desirable, species listed under state and federal ESAs or potentially listable. Examples: delta smelt, green sturgeon, splittail

+2 highly desirable. Native Fish Species of Special Concern and species (native or non-native) that are good indicators of a 'healthy' estuary. Examples: Sacramento hitch, striped bass, white sturgeon,

+1 desirable. Native fishes not covered in 2 & 3, non-native species important in foodwebs supporting native species and not harmful in other ways. Examples: pikeminnow, Sacramento sucker, crayfish species.

0 neutral - non-native species with no known negative effects on native fishes or the Delta foodwebs/ecosystem. Examples: bigscale logperch, warmouth, .

0? Probably not neutral in effects but support fisheries. This includes non-native species that are abundant mainly because they thrive in highly altered, warm-water habitats, but do not demonstrably to harm at the population level to native species. If studies show harm, they could be given negative ranks. Examples: largemouth bass, bluegill, redear sunfish, white catfish.

-1 undesirable. Non-native species with some potential for harm to natives but not documented or unlikely because only locally or sporadically abundant. Examples: rainwater killifish, white crappie.

-2 highly undesirable. Non-native species that likely suppress native species directly through competition or predation or through their effects on habitat. Examples: common carp, threadfin shad, Asian clam,

-3 very highly undesirable. Species with known, (or highly likely) on-going negative impacts on native fishes or on functioning of ecosystems that support native species. Examples: Mississippi silversides, overbite clam.

In the tables below we present our desirability scores for all fishes that make significant use of the Delta (Table 1) as well as scores for aquatic plants and macroinvertebrates of special interest (Table 2).

Table A1. Fishes of the Delta. Abundance ratings are judgments based on multiple sampling programs of the authors. For Status: TE = listed as threatened or endangered under state and federal ESAs. SSC =state species of special concern (Moyle et al. 2015).

Common Name	Scientific Name	Abundance, Delta	Status	Desirability score
Pacific lamprey	<i>Lampetra tridentata</i>	common	SSC	+2
green sturgeon	<i>Acipenser medirostris</i>	uncommon	TE	+3
white sturgeon	<i>A. transmontanus</i>	common	SSC	+2
American shad	<i>Alosa sapidissima</i>	common	alien	+2
threadfin shad	<i>Dorosoma petenense</i>	abundant	alien	-2
common carp	<i>Cyprinus carpio</i>	abundant	alien	-2
red shiner	<i>Notropis lutrensis</i>	uncommon	alien	-1
golden shiner	<i>Notemigonus crysoleucas</i>	common	alien	-1
goldfish	<i>Carassius auratus</i>	common	alien	0
hitch	<i>Lavinia exilicauda</i>	common	SSC	+2
Sacramento blackfish	<i>Orthodon macrolepidotus</i>	common	native	+1
Sacramento pikeminnow	<i>Ptychocheilus grandis</i>	common	native	+1
splittail	<i>Pogonichthys macrolepidotus</i>	common	SSC	+3
Sacramento sucker	<i>Catostomus occidentalis</i>	abundant	native	+1
black bullhead	<i>Ameiurus melas</i>	common	alien	-1
channel catfish	<i>Ictalurus punctatus</i>	common	alien	-2
white catfish	<i>Ameiurus catus</i>	abundant	alien	-1
Delta smelt	<i>Hypomesus transpacificus</i>	rare	TE	+3
longfin smelt	<i>Spirinchus thaleichthys</i>	rare	TE	+3
Chinook salmon	<i>Oncorhynchus tshawytscha</i>	common	TE	+3
Steelhead	<i>O. mykiss</i>	uncommon	TE	+3
Mississippi silverside	<i>Menidia audens</i>	abundant	alien	-3
rainwater killifish	<i>Lucania parva</i>	uncommon	alien	-1
western mosquitofish	<i>Gambusia affinis</i>	abundant	alien	-2
threespine stickleback	<i>Gasterosteus aculeatus</i>	common	native	+2
prickly sculpin	<i>Cottus asper</i>	abundant	native	+1
staghorn sculpin	<i>Leptocottus armatus</i>	uncommon	native	+1
striped bass	<i>Morone saxatilis</i>	abundant	alien	+2
black crappie	<i>Pomoxis nigromaculatus</i>	abundant	alien	-2
white crappie	<i>P. annularis</i>	uncommon	alien	-1
bluegill	<i>Lepomis macrochirus</i>	abundant	alien	0?
redeer sunfish	<i>L. microlophus</i>	abundant	alien	0?
green sunfish	<i>L. cyanellus</i>	uncommon	alien	-1
warmouth	<i>L. gulosus</i>	uncommon	alien	0
largemouth bass	<i>Micropterus salmoides</i>	abundant	alien	0?
spotted bass	<i>Micropterus punctulatus</i>	common	alien	-1

bigscale logperch	<i>Percina macrolepida</i>	abundant	alien	0
tule perch	<i>Hysterocarpus traski</i>	common	native	+2
shimofuri goby	<i>Tridentiger bifasciatus</i>	common	alien	0
shokihaze goby	<i>Tridentiger barbatus</i>	rare	alien	0
yellowfin goby	<i>Acanthogobius flavimanus</i>	uncommon	alien	-1
starry flounder	<i>Platichthys stellatus</i>	rare	native	+1

Table A2. Desirability scores for invertebrates and aquatic plants likely to be important for native fishes in the Delta. Alien/native indicates multiple species that are both native and alien.

Common Name	Scientific Name	Abundance, Delta	Status	Desirability score
Asian clam	<i>Corbicula fluminea</i>	abundant	alien	-2
Overbite clam	<i>Potamocorbula amurensis</i>	abundant	alien	-3
Siberian prawn	<i>Exopalaemon modestus</i>	abundant	alien	-1?
Oriental grass shrimp	<i>Palaemon macrodactylus</i>	common	alien	0
Red swamp crayfish	<i>Procambarus clarkii</i>	abundant	alien	-2
Mysid shrimp	3+ species	common	alien/native	+3
Water fleas	<i>Daphnia magna</i> , <i>pulex</i>	abundant	native	+3
copepods	Calenoidea	abundant	alien/native	+3
Gammarid amphipods	Multiple species	abundant	alien/native	+3
Corophiid amphipods	Multiple species	abundant	alien/native	+3
Brazilian waterweed	<i>Egeria densa</i>	abundant	alien	-3
Water hyacinth	<i>Eichoria crassipes</i>	abundant	alien	-3
Creeping water primrose	<i>Ludwigia peploides</i>	abundant	alien	-3
Sago pondweed	<i>Stuckenia pectinata</i>	abundant	native	+1

Appendix B.

Reconciliation Ecology: A Novel Approach for a Novel Ecosystem¹

One and a half centuries of intensive land and water use within the greater Delta watershed have transformed the Delta's ecosystem from a natural landscape to one that is part of a largely domesticated environment—an ecosystem dominated by people in which other species also live, native and non-native. In such a novel ecosystem, traditional approaches to environmental management - including conservation, preservation, and restoration—are unlikely to significantly improve conditions for native species. For example, dedicated nature reserves greatly restrict human uses and, in principle, exclude alien species. Yet pervasive human alterations of the Delta make such traditional approaches politically unviable as well as physically and biologically infeasible

In contrast to the more traditional approaches, reconciliation ecology focuses on sustaining biodiversity and ecological services in ecosystems that have been substantially altered by human actions and in which humans continue to maintain an important presence. Instead of simply setting aside selected habitat for preservation, a reconciliation approach seeks ways for people and other species to share habitats, although this may require intensive management for particular species. It assumes that alien species and highly altered landscapes can be part of sustainable ecosystems, even if the ecosystems will have novel patterns and processes. It also assumes that most native species will be managed to have populations large enough allow adaptation to environmental change, in part through evolutionary mechanisms.

The management toolbox for reconciliation ecology combines traditional preservation and restoration strategies with civil and ecological engineering. Reconciliation also requires an open, comprehensive assessment of each ecological system, with clear goals for management and open dialogue among stakeholders, in an adaptive management framework. Conservation of most remaining native species should be a primary goal, along with maintaining ecosystem processes most similar to past patterns. For example, Putah Creek (a regulated tributary to the Delta via the Yolo Bypass) has a flow regime patterned after natural flows, but with much less water, in an incised channel. It stream is a leveed ribbon of restored habitat in an agricultural landscape and now supports a diverse group of native and non-native fishes. The reconciliation ecology approach is demonstrably compatible with EcoRestore projects that have active, continuous management

¹ *This essay is derived from material in Moyle et al. (2012), which should be consulted for more details and references. A good read on reconciliation ecology is Rosenzweig, M. 2003. Win-win Ecology: How the Earth's Species Can Survive in the Midst of Human Enterprise. Oxford: Oxford University Press.*

Appendix C.

Delta Water Conveyance Alternatives. What's Good for Fish?

The biggest controversies in the Delta involve how to manage the water that flows in and through it. One of the questions that generates the most steam is “How do we convey water across the Delta, to the pumps, while satisfying the needs of fisheries, endangered fishes, Delta farmers, and water exporters?” Native fishes need the water to flow downstream and mix with tidal water, mimicking the dynamics of a functioning estuary. In-Delta users need water to flow downstream to create a hydraulic barrier to prevent salinity incursion. Water exporters need downstream flow and north to south flows across the Delta so water can be diverted for delivery to water contractors in the Bay Area, the San Joaquin Valley and southern California. The current system does not balance these needs very well, as indicated by the continuing contention over water, symbolized the status of the endemic delta smelt.

The delta smelt is on a trajectory towards extinction in the wild, a trend coinciding with increased diversion of water from the Delta². The spawning adult population is at an all-time low, despite the wet winter of 2017-2018. Given the trajectory of the population and climate predictions for California, maintaining delta smelt –and most other desirable species- in the Delta for the next 20-30 years is not likely to happen without significant improvements to their habitat. This improvement will only come only if the water conveyance problem is solved.

While conveyance issues have always been controversial, the biggest controversy of the past was over the Peripheral Canal, which was defeated by voters in 1982. While defeat of the Canal resulted in less water being exported south than might otherwise have been, exports still crept upwards through the 1980s and 1990s, with water moved through complex pathways in the general direction of the pumps (Lund et al. 2007). This resulted in 30 years of increased entrainment of smelt and other endangered fishes in the pumps or the water moving them to unfavorable habitats in the Central and South Delta.

While scientists developed models explaining mechanisms behind the degradation in Delta conditions, alternative conveyance was not seriously discussed until Lund et al. (2007) examined a series of potential outcomes to the growing problems developing in the Delta. By this time, the problems had expanded beyond exponential declines in native species to include new invasive

² For recent justification for this statement see Hobbs et al. (2017), Moyle et al. (2016) and Baumsteiger and Moyle (2017). Also, Hobbs, J and P. Moyle 2018. Will delta smelt have a happy new year? California WaterBlog. January 14, 2018. <https://californiawaterblog.com/2018/01/14/will-delta-smelt-have-a-happy-new-year/>

species, poor water quality, subsidence of Delta islands, harmful algal blooms, nutrient loading, low food web productivity, climate warming, sea level rise, and high contaminant loads. Adding to the sense that the magnitude of the problems was outstripping our willingness to address them (Luoma et al. 2015) was the developing understanding that the entire system could change rapidly if an earthquake or flood struck, crumbling levees and flooding islands.

Lund et al. (2007) suggested that some version of the Peripheral Canal might be a desirable way to balance fish and water conflicts. Most water diversions around the world are in-river extraction rather than estuarine extractions, where salinity and tides create complications with water management and species needs. The surface canal idea morphed into the concept of one or two tunnels to carry water under the Delta rather than around it. This ultimately became California WaterFix.

The “Fix” would move Sacramento River water directly to the CVP and SWP export pumps in the South Delta, while presumably reducing reverse flows across the central and south Delta that are perceived as harmful to fish. The Fix is still being negotiated. A more recent variation on the proposal would build one large tunnel, with less total capacity. But whether California WaterFix is built or not, the need for an improved water conveyance system to the South Delta pumps remains for the following reasons:

(1) The status quo is not sustainable; it will result in the likely collapse of many remaining stocks of desirable fishes even with large investment in restoration projects. Optimizing freshwater exports for agricultural and urban use while minimizing effects of ecosystem change and fish entrainment in diversions has not created effective policy for either water users or for fishes

(2) Delta infrastructure (mostly levees) is old and vulnerable to catastrophic failure (Lund et al. 2010). Large-scale collapse of Delta levees can result in intrusion of salt water into Delta, creating interruptions in water supply for Delta agriculture and for municipal water users, which could affect millions of people. Emergency responses will not involve careful long-term strategies. An emergency freshwater transfer system across the upper Delta, for example, will likely make conditions worse than the status quo, from an ecosystem and native fish perspective.

In the following parts of this essay we first discuss California WaterFix because it is the ‘big gorilla in the room’ even if its exact nature is in flux. It is also the only effort to develop a comprehensive plan for managing Delta water and fish. No other plans have been seriously developed. We then discuss other options, using WaterFix as the foil.

California WaterFix.

Advantages from a fish perspective. California WaterFix in its various manifestations has the follow positive aspects for fishes:

- Entrainment of delta smelt into the export pumps in the south Delta would be reduced because intakes would be upstream of current smelt habitat and would be screened. Other fishes will be also be largely screened out of the tunnels.
- Flows presumably can be better managed to reduce North-South cross-Delta movement of water to create a more East-West estuarine-like gradient of habitat, especially in the north Delta.
- Large investments will be made in habitat restoration projects (adding to EcoRestore) to benefit native fishes, including the various runs of salmon³.

Uncertainties. There are huge uncertainties associated with WaterFix, in terms of effects on fishes. It is a giant experiment that may or may not work as promised, no matter what the models and experts say. The giant fish screens needed for WaterFix to work, for example, will be pushing screening technology to the limit, and have to protect weak swimmers like smelt and juvenile sturgeon as well as juvenile salmon.

WaterFix is supposed to operate using an adaptive management framework, to deal with uncertainty. This means management activities can change operations proceed, as conditions change, and as new information becomes available.

‘True’ adaptive management treats each management action as an experiment with testable hypotheses and continuous monitoring that allows success or failure –and the reasons for it- to be determined. Large-scale experimentation with projects of this magnitude is difficult, even with adequate monitoring. In short, adaptive management is a good idea but making it work at this scale will be extremely difficult.

The ability of EcoRestore and other restoration efforts to compensate for negative effects of California WaterFix has many uncertainties as well. Although restoration of tidal marshes should benefit salmon, water birds, and many other species, the potential for restored tidal wetlands to support delta smelt and other pelagic fishes is only weakly supported with current scientific data. Large-

³ EcoRestore has its biggest focus on restoring tidal marsh/slough habitats but includes, or can include, projects more specifically aimed at salmon and pelagic fishes, such as improving floodplain habitat on the Yolo Bypass. <http://resources.ca.gov/ecorestore/california-ecorestore-projects/>

scale experimentation with restoration projects will be challenging and will likely require 20+ years of data to make reasonable assessments

Trust issues. There are also trust issues with WaterFix. For it to work as promised, we have to accept that:

- Water will continue to be exported at roughly the same rates as it has been, with no or little net increase in exports.
- It will be operated without significant increases in water being diverted upstream of the Delta.
- Full implementation of EcoRestore will occur and alleviate many of the endangered species issues.
- Water for the environment will not be sacrificed every time there is a water emergency (the co-equal goals promise).

Trusting that operation of the project will be fish-friendly is a problem because under emergency conditions, such as another severe drought, environmental water could be re-allocated for other uses (e.g., through Temporary Urgency Change Petitions to the State Water Resources Control Board). A major worry is the current administration in Washington DC, which shows little concern for environmental issues and endangered species. It is already trying to change the water allocation system and weaken the Endangered Species Act. For example, the WIIN legislation passed by Congress in 2016 is likely to shake up the way water is managed for endangered fish in the Delta.

Alternatives

We see four general alternatives to WaterFix:

1. Status quo alternative. This means continuing to rely on ad hoc responses to droughts and floods as well as delaying large-scale infrastructure improvements necessary to accommodate sea level rise, big storm surges, extended drought, and earthquakes. Under this scenario, invasive species will become even more dominant and native species, such as delta smelt, will disappear. There is room here, of course, for innovative programs that reverse island subsidence, control invasive species, and help reverse declining trends in native fishes through large-scale habitat restoration and managed flow releases from dams. This will take a visionary effort, led by the Delta Stewardship Council, and coordination of the actions of many agencies, a difficult task (See Lund and Moyle 2013 for suggestions on how to do this). The tasks set forth in the main White Paper can make this option more favorable, although conveyance will continue to be a problem that undermines restoration effectiveness. One way to assure flows would favor fishes more would be assign the environment a flexible Ecosystem Water Budget (Mount et al. 2017), roughly equivalent to a water right.

2. Build one tunnel alternative. This seems to be the current favored plan. The idea, as presented by Lund (2017), is to build a single tunnel with just enough capacity to supply urban water needs and to function as an emergency conveyance system during levee failures or severe drought. This could protect California's urban water supply from catastrophic failure, but from a delta smelt's perspective, this is just a step above the status quo, because it lacks flexibility. Ultimately the pumps in the South Delta will continue to supply most water exports, mostly for agriculture (i.e., dual conveyance). Cross-Delta movement of water will continue, as will entrainment mortality of native fishes. Presumably, EcoRestore would be fully implemented, providing some relief for native fishes.
3. Increased outflows alternative. Roll back water delivery volumes to pre-1980 or earlier levels. The goal would be increased flows down the Sacramento and San Joaquin Rivers through the Delta and estuary. This should have many positive effects (Cloern et al. 2017) and would be especially beneficial to native fishes, such as delta smelt, that require estuarine gradients of temperature, salinity, and water clarity. It would also allow for pulse flows to carry juvenile salmon out to sea and to flood parts of the Yolo Bypass for fish rearing on an annual basis. Higher flows would also enhance the benefits of restoration projects under EcoRestore. A conveyance method would continue to be needed to maintain estuarine function while delivering reduced water for export. How this could be accomplished in the face of increased agricultural and urban water demands is uncertain, especially in times of drought.
4. Delta cross-channel alternative. Construct a North-South cross-Delta channel with reinforced levees, tidal gates, weirs, and barriers that would deliver Sacramento River water to the South Delta under most situations (see Lund et al. 2010). This would anticipate the need an emergency conveyance system should levees fail as the result of sea level rise, flooding, land subsidence, and earthquakes, or all four. However, this option would ignore most estuarine ecosystem needs of the Delta, especially if it was operated with little consideration for environmental water during drought conditions. It could be partially mitigated through EcoRestore, provided the restoration efforts were tied to sufficient flows down the Sacramento River and through the Delta, at key times. One way to assure such flows would be to have the environment assigned a flexible Ecosystem Water Budget (Mount et al. 2017), roughly equivalent to a water right.

All options face common challenges: they have to deal with major changes to the Delta wrought by sea level rise, subsidence of farmed islands in the south and central Delta, increased frequency of large storms/floods, and earthquakes. While these projections, most featuring levee collapse, may seem alarmist,

studies predict large-scale change is going to happen; it's mostly a question of when⁴. Thus, at some point, the south and central Delta will likely contain large expanses of brackish water with reduced tidal influence, ending farming in this region. This new Delta will be a much more difficult place through which to move fresh water to the south Delta pumping plants. Fish and invertebrates will continue to be abundant but the assemblages are likely to be made up of salt-tolerant forms, such as yellowfin goby, Mississippi silverside, starry flounder, striped bass, northern anchovy, Black Sea jellyfish, and overbite clam. Lake-like regions will continue to support largemouth bass and other warm-water fishes. Fighting this magnitude of change to keep the status quo will require large investment in levees and barriers, as well as in EcoRestore, making the Delta even more artificial and highly managed than it is today.

So what happens to delta smelt and other native fishes under these options? *Assuming* successful supplementation from a conservation hatchery and *assuming* EcoRestore and additional measures improve native fish habitat and food supply before it is too late, the extinction of species may be prevented. Even if the tunnels (or tunnel) were authorized and survive lawsuits and political opposition, their operation would be at least 10-20 years in the future. Thus, native fish recovery will have to be well on its way for the tunnels to have a detectable effect. Meanwhile, the longer we delay, the more likely drastic large-scale emergency measures will need to be put in place, with minimal consideration for environmental or recreational needs.

So, the best option for smelt, and other native fishes, especially salmon, is presumably #3 or something like it, because it should result in a large increase in freshwater flows through smelt habitat (Moyle et al. 2012). This conclusion is essentially the same as that of the much-ignored Recovery Plan for the Sacramento/San Joaquin Delta Native Fishes (USFWS 1996). The realities of California water politics, however, dictate that one of the other options is much more likely to happen. In addition, flows by themselves will not result in substantial improvement of fish populations without other factors operating as well, such as habitat restoration, invasive species control, and other actions. Of these options, the original California WaterFix option seems to deal best with future changes to the Delta and seems most likely to keep delta smelt, salmon, and other desirable fishes as part of the Delta ecosystem, especially if in association with expansion of EcoRestore. However, even if approved, WaterFix will take a long time to build, so actions like those suggested in the main White Paper here are still badly needed. In fact, they are needed regardless of WaterFix. We are past the point where passive management and ad hoc responses to emergencies will keep delta smelt and most other desirable fishes as participants in the Delta's ecosystem. Large-scale changes require

⁴ For more background, see Lund et al. (2007, 2010), Moyle (2008), and references therein.

large-scale, active management solutions, preferably associated with an inviolable Ecosystem Water Budget (Mount et al. 2017).

On a final note, we emphasize that this analysis is based on what is good for native fishes. It does not take into account socioeconomic problems, urban and agricultural water demands, social welfare of Delta peoples, or other non-biological factors. However, a Delta that supports desirable fishes will likely also support a wide array of ecosystem services, such as fisheries and high water quality, which also benefit people.



Frank's Tract, May 22, 2009. Large expanses of open water are likely to increase in the Delta, one of the justifications for WaterFix. Photo by Peter Moyle

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Appendix D. Restoration Project Evaluation for Delta Fishes

Introduction. In this section we present a tool that allows for a quick evaluation of the benefits of restoration projects to desirable fishes, whether proposed, in progress, or completed. As a test of the tool, we evaluated a selected sample of existing projects (26 out of about 100 possible projects), most of them part of EcoRestore. We chose projects for which information was readily available or with which we were personally familiar. This is a preliminary sample but our ultimate goal is to provide a tool to evaluate all projects for which sufficient information is available. The comparison of evaluations using by this tool or something similar should provide insights into the characteristics of successful (and unsuccessful) projects to help guide future projects, including 'fixing' existing projects that are not working as well as they could. Most of the projects we evaluated are focused on increasing tidal or floodplain habitat.

Conceptual model. Our evaluation method is based on a basic conceptual model that includes the following 'rules':

- a. The focus of management is on desirable fish species, with highest priority for declining, especially ESA-listed, native species. The more desirable species a project benefits, the better.
- b. Benefit to other native species (e.g. waterbirds) is a positive attribute.
- c. Non-native species are players in the ecosystem but invasive species are not dominant.
- d. Bigger is better in terms of area, to achieve large populations of desirable species and to increase habitat diversity.
- e. Connectivity to a major distribution system for fish and fish food, such as the Sacramento River, is essential.
- f. Adjacency to other similar restoration projects or natural areas is better than isolation.
- g. The ability of a project to export nutrients, plankton, and other fish food to the larger system is a positive attribute; the more, the better. Residence time of the water in a project should be managed closely to achieve this.
- h. Intensive management, including monitoring, is essential for long-term project success.

Methods. We used a standard format to score projects on a 0-100 scale. Projects with scores on the upper end of the scale are highly desirable in terms of benefits to native and other desirable fishes and those on the lower end least desirable. *The scoring method is presented in detail in Appendix E;* it basically consists of rating each project on 8 metrics, based on literature and expert opinion/knowledge:

- Size (acres)
- Connectivity to major water ways (e.g. Sacramento River)

- Number of desirable fish species likely to be supported by the project
 - Desirability of a species is rated in Appendix A
- Number of listed fish species (out of 6) likely to benefit
- Ecosystem benefits to non-fish species
- Proximity to other natural or restoration sites
- Management approach
- Export of fish food production
- Invasive species problems

When readily available information was missing or not clear, we used our best judgment based on personal knowledge of the projects or similar projects.

We developed a list of around 100 potential projects and evaluated 25 projects, which were chosen on the basis of *one or more* of the following criteria: (a) stated value to desirable fishes, (b) availability of information, (c) familiarity to the authors, and (d) listed as an EcoRestore project in:

http://resources.ca.gov/docs/ecorestore/ECO_FS_Overview.pdf .

The scores shown here should be regarded as preliminary because they were created by the authors while developing the tool and represent an incomplete example of restoration projects. For a more systematic evaluation projects should be scored by at least three people working independently, and the scores averaged. This study is meant to be more an example of possibilities rather than a finished product.

Results. Our Habitat Restoration Evaluation Tool appears to be a reasonable way to provide a ‘first cut’ evaluation of restoration projects that allows them to be compared with other projects, *in terms of value to fishes*. As a test, we evaluated 26 marsh projects based on information available and location (Figure D-2, Table D-1). Scores ranged from 19 to 70. Most projects considered to be part of EcoRestore scored as having moderate to high desirability (>50) from a fish perspective. Those with low scores were not fish-oriented, but were intended to restore non-tidal wetlands or upland habitat. Projects with the highest scores were tidal restoration projects that were large in size, had connections to a main waterway (e.g., Sacramento River) and had monitoring and significant management programs in place or planned.

Large size and connectivity were closely tied to one another because large projects typically had broad connections to main channels and both strongly tidal and influenced by high outflows during winter-spring months. Large projects were also the only projects that were likely to have significant export of nutrients, phytoplankton or zooplankton to open channels, where they might benefit delta smelt and other fishes. They tended to have high scores also because of benefits to multiple fish species.

Table D-1. Projects evaluated, showing average and percentage scores based on score sheet (Appendix E).

Project Name	Average Score	Percent Score
Big Break	24.3	49%
Blacklock Island	20.5	41%
Bradmoor Island	24.0	48%
Browns Island Regional Shoreline	28.0	56%
Cache Slough Shaded Riverine Aquatic Habitat Enhancement	20.0	40%
Chipps Island	33.0	66%
Cosumnes River Preserve	37.0	74%
Decker Island Tidal Habitat Restoration	26.0	52%
Delta Meadows	18.5	37%
Dutch Slough Tidal Marsh Restoration	29.0	58%
Fremont Weir Adult Fish Passage Modification	18.0	36%
Goat Island, Suisun	29.5	59%
Grizzly Slough Floodplain Project	29.0	58%
Hill Slough Tidal Restoration	28.5	57%
Lindsey Slough	29.3	59%
Lisbon Weir	24.0	48%
Lower Putah Creek Realignment	31.7	63%
Lower Yolo Ranch Tidal Restoration	32.0	64%
McCormack Williamson Tract Project	31.7	63%
Prospect Island Tidal Habitat Restoration	30.3	61%
Sherman Island – Belly Wetland Restoration	20.7	41%
Sherman Island – Future projects	18.0	36%
Sherman Island – Mayberry Farms Wetlands	18.7	37%
Sherman Island – Whale’s Mouth Wetland	15.0	30%
Sherman Island Setback Levee-Mayberry Slough	25.7	51%
Southport Setback Levee	26.0	52%
Tule Red Restoration	32.7	65%
Twitchell Island – East End Wetland	18.7	37%
Twitchell Island – SJ River Setback Levee	24.7	49%
Twitchell Island – West End Wetland	13.0	26%
Wings Landing Suisun Marsh	31.0	62%
Winter Island Tidal Habitat Restoration	32.0	64%

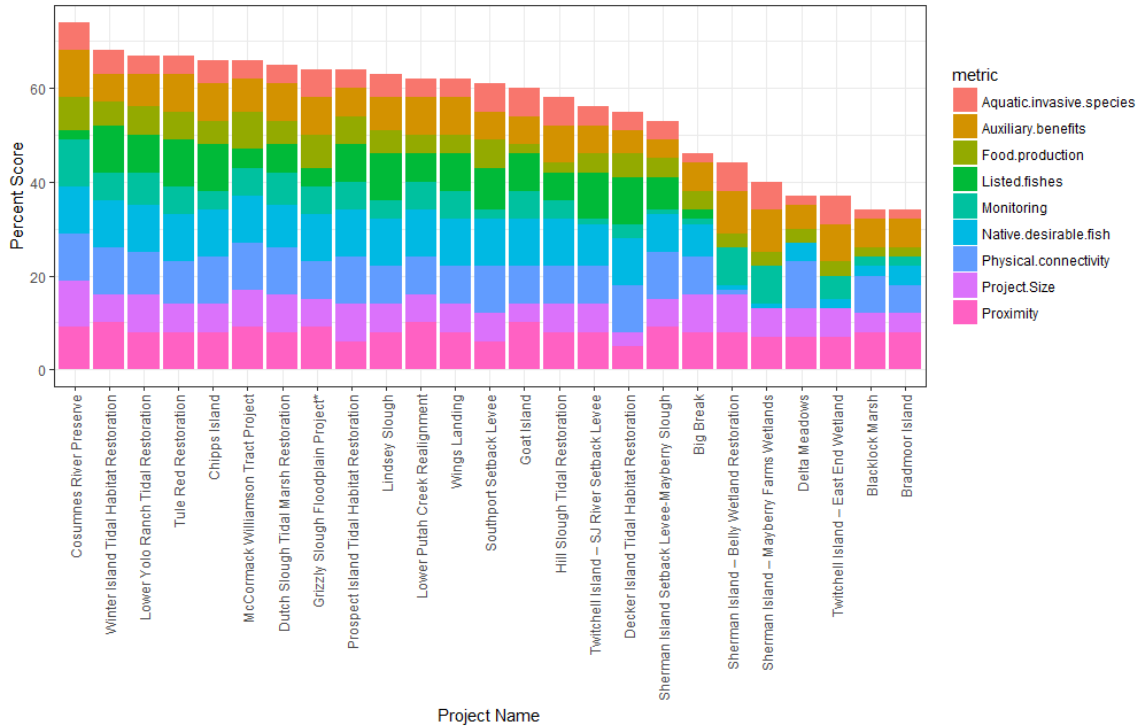


Figure D-2. Scores for 26 marsh restoration projects. Different colors reflect different metrics that were scored.

The importance of monitoring and active management was also reflected in the higher scores. The need for active management is suggested by low scores for Blacklock Tidal Restoration (26) and Big Break (43). Blacklock Island is a small (70 acres) tidal restoration project in Suisun Marsh in which levees were breached and no further action taken. Today it has low value to desirable fishes because it is filling in with native tules and invasive giant reed (*Phragmites*) with the remaining shallow water dominated by invasive Mississippi silversides. A proposed expansion of the project with better monitoring and management can raise the score significantly, by increasing size, connectivity, and tidal influence (Durand, unpublished information). The low success of Blacklock is useful in showing how to increase restoration success for a nearby project. Bradmoor Island is as restoration project (50 acres) for which current plans involve breaching levees without much further action; taking a more active approach (use of tidal gates, invasive plant control, etc.) would likely make this project more fish friendly.

Big Break, in Contra Costa County, was created by a levee failure in 1928 and 1500 acres flooded were left as shallow water habitat. While fairly large in size, adjacent to the main river, and subject to large tides, Big Break is warm, shallow, clogged with invasive aquatic plants (mainly Brazilian waterweed) and mainly supports an assemblage of warmwater non-native fishes such as

largemouth bass and bluegill sunfish. It is an example of how lack of management has a negative effect on projects with other positive attributes, such as size (Moyle, unpublished observations).

Discussion. While our analysis emphasizes the need for large projects because they provide the greatest diversity of habitat for fishes, this should not take away from the value of smaller projects, especially if they are close to one another and connected to a river corridor. Goat Island Restoration Project, for example, is located in Suisun Marsh on Rush Ranch, Solano Open Space. It is a small (80 acres) project but is adjacent to the Mallard Slough complex, which is the most 'natural' tidal habitat in Suisun Marsh and a major nursery area for native fishes and striped bass (D. Colombano, UCD, pers. comm. 2017).

A distinct advantage of smaller projects, which does not appear in our scoring system, is that they are easier to manipulate to achieve desired results. For example, small projects that have tidal gates can have the residence time of the water controlled, increasing production of zooplankton that is likely to support native fishes (which could be deliberately introduced). With gates, managers can also dry up the site to get rid of invasive species, including eradicating invasive plants. Unfortunately, many small projects, such as Blacklock Island, are 'walk away' projects with no management, so they can quickly be dominated by invasive species, something less likely to happen on large projects.

Pure infrastructure projects included in EcoRestore were difficult to evaluate using our criteria, so are not included in the evaluations. However, most affect large areas and many fishes so are considered to be important even if not scored. Projects that fit in this category include Wallace Weir Fish Rescue Facility and Clifton Court Forebay Reconstruction for predation reduction.

Most of restoration projects in the Delta are located in the North Delta Habitat Arc, a region that starts in the Yolo Bypass, extends through the Lindsey-Cache Slough region, down the Sacramento River with its edge and island areas, and into Suisun Marsh, a brackish water tidal system dominated by desirable fishes. The reason for this is the presence of existing high-quality habitat and connectivity. Most of the habitat has considerable potential for being improved to support listed fishes and other biota. The Sacramento River is the great connector of the diverse habitats of the region. The more habitat restoration projects in the region connect with one another, the greater their collective ecological benefits, especially to fishes. In contrast, there are few projects in the South and Central Delta, largely because the region has few opportunities for restoration of habitat that favors native and other desirable fishes. Some interesting new opportunities, however, may lie in return of a number of large Delta islands in the region to tidal habitat

Appendix E. A Scoring System for Restoration Projects.

This appendix includes a score sheet and an explanation of how to use it for rating a restoration project.

Project Name: name useful for internet searches

Region: general area where project located

Status: what stage is the project in, from wild idea to fully operational

Tidal restoration: Is creation of tidal habitat a major focus of project?

Multibenefits: Other benefits than for fish are as or more important (e.g., flood management).

Size: acres of total project. Scored by increments X 10, on assumption bigger is better for most restoration projects, a basic rule of conservation biology.

Physical connectivity: Projects with tidal or direct connectivity to major waterways have more value to fish than those with low or no connectivity.

Proximity to other restoration projects or natural areas. The assumption here is that there is likely to be a synergy between projects that are close to one another. Isolated projects therefore scored much lower than those with close association with other nearby projects.

Native/desirable fishes supported by project. Desirability scores are in Appendix C.

Listed fishes likely to benefit: winter and spring run Chinook salmon, CV steelhead, delta smelt, longfin smelt, green sturgeon

Auxiliary ecosystem benefits: While a relatively low score (1-5) is assigned to this metric, it indicates how much the project is ecosystem based by its value to species besides fishes.

Monitoring plus active management Active management (defined in text), based on a regular monitoring program, is more likely to result in a project that works as expected.

Food production for fish: The idea that tidal and other projects can produce 'excess' algae and invertebrates that then benefit fishes in main waterways is frequently cited as a reason for restoration projects.

Aquatic invasive species: All projects in the Delta region will contain non-native species, some which are invasive and must be controlled to meet project goals. They are a major limiting factor to restoration success and most projects will have an invasive species problem to some degree.

Scores: while the scores have been made categorical for easy understanding, they are actually on a continuum. Thus this difference between a score of 49 and a score of 50, which place the species in different categories is not meaningful.

Score Sheet, Habitat Restoration Projects (Value to Delta Fishes)

Project Name _____

EcoRestore? Y N Agency in charge: _____

Region: Suisun, Sac River, N Delta, Yolo BP, S/C Delta

Status: Finished/in progress/approved/proposed/wild idea.

Tidal: Y N, Partial. Multibenefit? Y N Fish a major goal? Y N ?

A. Size: ACRES _____

1. <10 acres
2. 10-99
3. 100-1000 acres
4. 1000-10,000 acres
5. 10,000+ acres

B. Physical connectivity via water/flow to major waterway (e.g. Sac River)

0. None to waterways
1. Occasional connection, small, unpredictable (e.g. drainage ditch)
2. Seasonal connection, regular but short term
3. Regular tidal and/or seasonal connection (or potential), narrow channel(s) (<10 m wide)
4. Permanent connection to tributary to major waterway including sloughs and floodways.
5. Permanent tidal or seasonal connection to major waterway, including sloughs floodways.

C. Proximity to other restoration or natural areas

1. Isolated, an island of habitat, no similar natural areas within 10 km
2. Semi-isolated, nearest similar natural areas within 1-10 km
3. Other natural areas close by (within 1 km) but not adjacent
4. Adjacent to another natural area
5. Adjacent to at least two other natural areas

D. Native/desirable fish species likely supported by project, directly or indirectly (See Table 1)

0. 0
1. 1-2
2. 3-4
3. 5- 6
4. 7-8
5. 9+

E. Listed fishes that will benefit or potentially benefit from project? (6 species total)

WRCS, SRCS, CVSH, DS, LFS GST

0. None
1. 1
2. 2
3. 3
4. 4
5. 5-6

- F. Auxiliary ecosystem benefits (benefits to native plants and animals other than fishes)
 - 1. Little or none
 - 2. Comparatively low diversity, mostly seasonal use
 - 3. Moderate diversity, year around and seasonal use
 - 4. High diversity, year around and seasonal use
 - 5. Biodiversity hotspot, with endemic species and high concentrations of migratory birds
- G. Monitoring plus active management for desirable species
 - 0. Not a project feature (no or minimal) monitoring
 - 1. Monitoring (actual or planned) present so reactive management possible
 - 2. Project features allow for partial active management (e.g. weed control, internal gates)
 - 3. Small-scale active management projects planned or in place (e..g a tidal gate) or none needed
 - 4. Large-scale active management program present on paper and partly instituted or none needed
 - 5. Large-scale active management in place and working, with more planned or possible, or none needed.
- H. Food production for fish
 - 1. Local production only, interior ponds/marsh
 - 2. Interior production with low export to outer channels
 - 3. Moderate seasonal export of internal production
 - 4. High seasonal export of invertebrates, nutrients taking place or likely to
 - 5. Year around high export of invertebrates, nutrients etc. taking place or likely to.
- I. Aquatic invasive species issues, real or projected
 - 0. Area contains 100% undesirable alien species; invasive (weedy) species dominate aquatic ecosystem
 - 1. Some native species present in low numbers; weedy species most abundant
 - 2. Roughly even mixture of native and alien species; weedy species abundant
 - 3. Invasive species not a problem or easily controlled; some natives abundant
 - 4. Native species dominate (more than 75% of individuals of major taxa)
 - 5. Invasive species largely absent or with active prevention program

Total score % score (x/45)

Scores (%)

75-100 Highly desirable project

50-74 Moderate desirability

25-49 Low desirability

<25 Not desirable