Delta Stewardship Council

Levee-Related Habitat Review

October 15, 2015

Public Review Draft

Submit comments by 5 p.m. Friday Nov. 13, 2015 to:
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Levee-Related Habitat Review

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Delta Stewardship Council

EXECUTIVE SUMMARY

The Delta Stewardship Council (Council) has undertaken the development of a Delta Levees Investment Strategy (DLIS) intended to guide State investments in flood risk reduction. While investing in levee improvements to reduce risk, the State has both an opportunity and an obligation to enhance habitats to provide a net benefit to both terrestrial and aquatic species, and to mitigate for the adverse environmental impacts of levee projects.

The extent and character of Delta habitats have been altered dramatically over the past 150 years, but remain essential to fulfill important ecological functions in the watershed. They form the basis for terrestrial and aquatic food webs, provide essential wildlife habitat and migratory corridors, filter nonpoint source pollution, and improve water quality.

The Council must ensure that the DLIS helps to implement the Delta Reform Act and the Delta Plan. The Delta Reform Act of 2009 established the Council and defined its mission: to achieve the coequal goals of water supply reliability for California and ecosystem restoration in the Delta, in a manner that protects and enhances the values of the Delta as an evolving place (Water Code section 85054). The Delta Reform Act required the Council to develop the Delta Plan and defined certain types of projects and programs as "covered actions" regulated by the Delta Plan. The Delta Plan includes 14 policies, including one that calls for levee projects to incorporate habitat benefits, where feasible, and another requiring the use of the best available science and adaptive management.

Restoration Mandates and Constraints

In addition to the Delta Reform Act, other previous legislative mandates require Delta levee projects to provide habitat improvements. Water Code section 12314(c) instructs the California Department of Fish and Wildlife (CDFW) to consider the value of riparian and fisheries habitat along riverine corridors. Water Code sections 12314(d) and 12987(d) require that state-funded Delta Levees Special Flood Control Projects, designed to improve project and non-project Delta levees, must be consistent with a net long-term habitat improvement program (aka enhancement) and have a net benefit for aquatic species in the Delta. However, implementation of levee-related habitat projects faces various regulatory and liability constraints, due in part to the need to balance flood risk reduction and habitat improvement.

Purpose and Approach

While the DLIS appropriately focuses on flood risk reduction as a primary purpose of state levee investments, this levee-related habitat review is intended to provide guidance in ensuring that levee investments will contribute to long-term improvement of river corridors with net benefit for fish and wildlife. Another goal of this review is to provide information about how much different habitat improvement options cost, specifically those habitat options that can be linked with flood risk reduction projects. The cost analysis focused principally on habitat enhancement projects conducted through the Delta Levees Special Flood Control Projects Program (Special Projects Program).

Through coordination with other agencies and stakeholders, we obtained descriptions of completed levee-related habitat improvement projects (hereafter, projects) and associated reports on monitoring that has been conducted within the Delta. Information about 15 levee-related projects was obtained from a query of 16 interviewees and 14 additional contacts provided by interviewees. Project effectiveness was evaluated in terms of: 1) the project stated objectives, performance measures, monitoring, and results; and 2) whether or not a project could be shown to benefit aquatic and/or terrestrial species.

For the purposes of this report, Council staff used the same habitat classifications and definitions as the California Department of Water Resources' (DWR's) FloodSAFE Environmental Stewardship and Statewide Resources Office (FESSRO). FESSRO identifies four different levee-related habitat types: freshwater marsh (tidal and non-tidal), shaded riverine aquatic (SRA), riparian forest and scrub shrub.

Analysis

Our review of habitat projects found that the majority of reports used vegetation monitoring as a means of measuring success. This finding was not unexpected because, prior to the adoption of the Delta Plan in 2013, adaptive management, including monitoring and assessment of project effectiveness for fish and wildlife, was not required or funded for every levee-related habitat project in the Delta. Vegetation coverage is an indicator of habitat, and is widely used as one of the ways to track progress in ecosystem restoration. However, the Delta is a highly altered ecosystem, and the relationships between vegetation coverage and benefits to target species are more complex than in systems that are closer to their historical ecological structure and function. Therefore, research and monitoring related to fish and wildlife response, as well as vegetation monitoring, is needed to determine whether projects are providing benefits to target species. Because fish and wildlife monitoring data were not available for most projects and existing data are inconsistent across projects, we were unable to compare the effectiveness of different types of habitat improvement projects. Instead, this report summarizes lessons learned from monitoring reports and through interviews with experts about which habitat designs may provide greater benefits to target native species.

Similarly, we experienced problems trying to accurately assess the costs of different habitat options associated with levee/habitat enhancement projects. Cost information for the habitat component of levee projects is rarely broken out from the risk reduction component (i.e., levee construction or habitat improvements), making it impossible to cleanly parse out and compare costs of different types of habitat improvements. As a result, our analysis presents the total costs of projects (i.e., the cost of not only the habitat component, but also the construction of the flood risk reduction component) broken down broadly into different habitat enhancement project types, such as setback levee projects versus projects involving riparian planting within levee riprap.

Project Design Considerations

Despite our inability to draw conclusions regarding the effectiveness of different habitat improvement designs, our review of project monitoring reports did result in some observations regarding effectiveness that can inform future projects. The review suggested a need for caution when applying lessons learned from other parts of the Central Valley to project design in the Delta, due to its unique estuarine and deltaic habitats and highly altered physical state. For example, the distance to setback levees for maximum environmental benefit for the Sacramento River is estimated to be between one and three times bank-full channel width (Larsen et al. 2012). In many parts of the Delta, a setback distance of three times bank-full width would equate to hundreds of feet (Diagram D1), which would be a challenge to achieve in places where the landward side of the levee is composed of deeply subsided peat soils. In such subsided areas, setback levees are often infeasible since it would require substantial import of fill material, which is cost-prohibitive. Additionally, there are many other challenges in doing a setback levee project that are not unique to the Delta. They include finding willing landowners to provide the land for the setback, which may result in seasonal or permanent loss of productive farmland; complications in protecting existing structures, easements, and utilities; and increased cost and time necessary for project design and permitting.

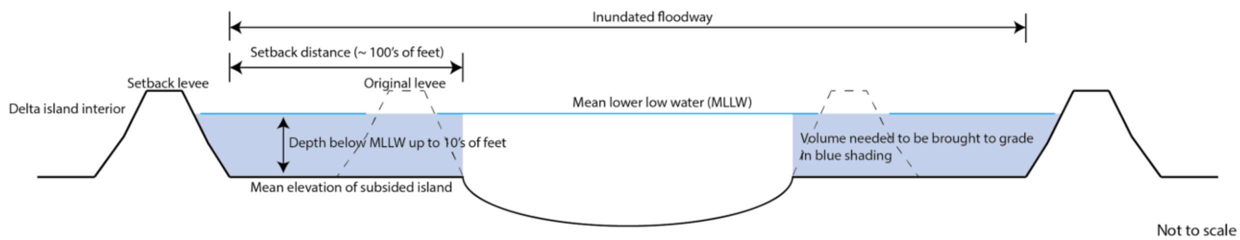

Diagram D1. Setback levee on deeply subsided Delta Island.

Given the high cost of setback levees where Delta islands are at subtidal elevations, modifying existing levees into “extra-wide” levees may be a more cost-effective option and may be more likely to be supported by landowners. Extra-wide levees allow the levee to be graded to create a waterside slope that ranges from subtidal to supratidal elevations where installation of riparian habitat, SRA, tidal marsh, and channel margin habitat can occur. In lieu of or in combination with a setback levee or extra-wide levee, a planting bench on the waterside levee slope may be installed to provide the appropriate depths and elevations for establishing channel margin habitat. These benches may be stabilized with riprap covered with soil and riprap mix that can support tidal marsh and/or riparian vegetation (Diagram D2). Planting on and near existing levees is generally inexpensive and conceptually would provide ecosystem benefits. Fish monitoring conducted along the Sacramento and American Rivers has shown increased occupancy of native species at sites with planting benches compared with adjacent riprapped banks lacking vegetation (Fishery Foundation of California 2006; FISHBIO 2015). In locations with especially high water velocity and steep bathymetric gradients at the waterside levee-slope, planting vegetation on the levee slope, with riprap as needed, may be a more feasible enhancement option than benches.

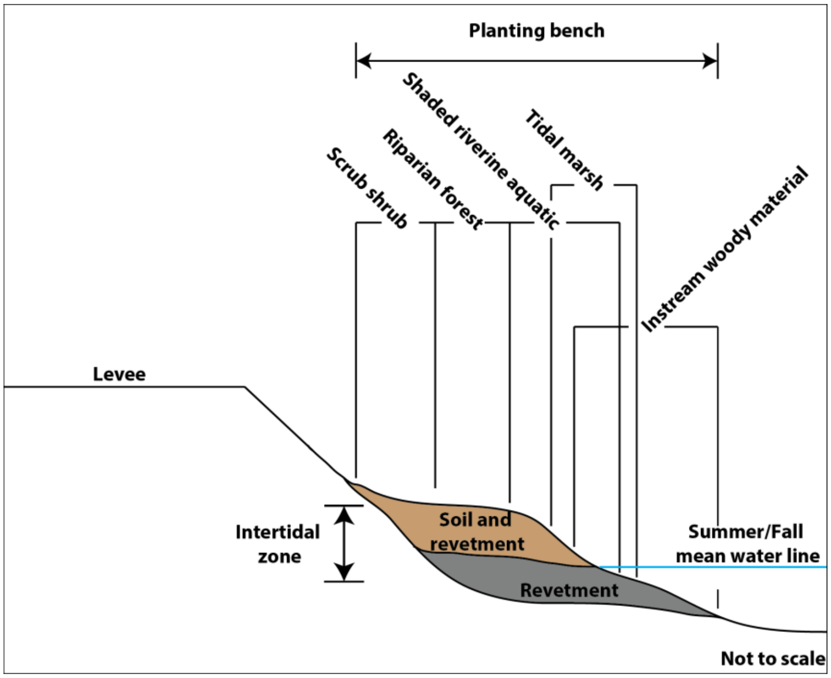

Diagram D2. Planting bench on waterside toe of levee.

Cost Analysis

We assessed cost ranges of multi-objective levee projects that included both risk reduction aspects and habitat improvements using data provided to us by DWR staff. In the past, Delta levee construction projects that incorporated habitat elements on-site generally involved planting of trees within riprap. The costs for these multi-objective projects ranged from approximately $1,400 to $5,200 per linear foot ($7 million to $26 million per linear mile). The true costs of restoring riparian habitat on levees is still uncertain, since improvement to the structural component of the levee for flood risk reduction purposes is usually the fundamental driver of these multi-objective projects, and the scale of construction work will be different depending on engineering design considerations.

In addition to assessing the costs of multi-objective levee projects, we also obtained information about the cost of off-site mitigation credits for levee projects. In 2012, DWR established the Bulk Credit Program, which provides off-site mitigation credits exclusively for reclamation districts (RDs) participating in the Delta Levees Program. These mitigation credits were negotiated for a lower price than retail and purchased from Westervelt's Cosumnes Floodplain Mitigation Bank (Table 1). Habitat credits include shaded riverine aquatic habitat, riparian forest, scrub-shrub, and freshwater marsh.

Table 1. DWR Bulk Credit Program Costs

Habitat Type	**Cost Information**	
Shaded Riverine Aquatic Habitat	$61	Per linear foot
Riparian Forest	$62,295	Per acre* *includes required buffer acreage that comprises the mitigation bank
Scrub-shrub	$62,295	
Freshwater Marsh	$120,000	

Source: DWR website (available at http://www.water.ca.gov/floodsafe/fessro/environmental/dee/dee_prog_mit.cfm)

Partially setback levees (i.e., “adjacent levees”, as defined in this report) have been constructed by DWR along portions of Sherman Island and Twitchell Island. The total costs of these setback levees projects in 2015 dollars were approximately $1,000 to $2,200 per linear foot ($5.5-11.4 million per linear mile). Future setback levees planned in the Delta are expected to be more expensive. The total cost of the proposed setback levee in West Sacramento (Southport Project) is predicted to cost an average of $12,700 per linear foot or $67 million per linear mile (USACE 2014), while preliminary cost estimates from DWR staff and RD 1601 (RD 1601, 2014) place the estimate for future construction of setback levees along the southern portion of Twitchell Island around approximately $2,700 to $3,700 per linear foot ($14.5 to $20 million per linear mile). The cost of the setback levee for the Southport Project is substantially higher than DWR’s past Delta setback levee projects because it includes the cost of land acquisition with urban entitlements in areas zoned and priced for housing and the newly constructed levees will be fully setback from the existing levees.

One major cost consideration unique to constructing setback levees in the Delta is that peat soils make for poor, unstable foundations for new levees. There are options to stabilize and prepare these peat soils to adequately support new setback levees, such as dynamic peat compaction or soil mixing. However, those options are quite expensive and may add many millions of dollars per mile of new setback levee. This is the reason for the higher cost estimated for the planned setback levee along the southern portion of Twitchell Island mentioned above.

Next Steps

Based on the findings of the review, we recommend taking the following steps to ensure that project effectiveness can be better evaluated in the future.

1. **Apply the Adaptive Management Framework to Future Projects.** Project proponents need to apply an adaptive management framework to future projects to facilitate scientific learning and reduce uncertainties, including evaluating how well the habitat-related aspects of levee improvements contributed to the establishment of ecosystem processes and the recovery of targeted species. This will require adequate funding for pre-project assessments (if feasible) as well as vegetation management and post-project monitoring for some years following construction.

2. **Develop Appropriate Monitoring and Performance Measures.** Levee investments and habitat improvements are complex issues in the Delta and they are closely linked to the coequal goals of providing a more reliable water supply for California and restoring the Delta ecosystem. Hundreds of millions of State dollars have been spent on levee improvements and maintenance, as well as habitat enhancement and associated monitoring in the Delta. However, based on the results of this review, we found that these projects often lack appropriate measures to assess effectiveness in providing benefits to target species. Without delineating quantifiable criteria at the outset of a project, it is difficult to measure success.

3. **Track the Incremental Cost of Habitat Improvements.** Better cost accounting of the habitat element of levee projects is necessary to better understand how funds have been invested to improve habitat in the Delta. For example, costs could be segregated by bidding construction and habitat components separately following the practice of the Sacramento Area Flood Control Agency (SAFCA). SAFCA does not bid/solicit levee improvements and habitat improvement projects in the same bid package, providing cost segregation and flexibility in selecting the

qualified and experienced contractors to implement the habitat improvement component of a multi-objective project.

4. **Carefully Consider the Tradeoffs Associated with Onsite and Offsite Mitigation.** While offsite mitigation for the environmental impacts of Delta levee projects often has practical advantages, it is important to ensure that mitigation takes into consideration life history requirements of native species. For example, degradation of channel margin habitat along migratory corridors for salmon should be mitigated on-site or at least elsewhere along the migratory corridor. Our review indicated there are opportunities to promote on-site habitat improvements for levee projects that can also protect and enhance flood risk reduction, including the use of planting benches and extra-wide levees, if willing landowners can be found.

5. **Use Landscape-scale Planning to Guide Project Siting and Design.** In general, larger and more complex habitats will serve to benefit a wider array of wildlife (Brown 2003, Herbold et al. 2014). Regardless of the size of an improvement site, projects should not be planned independently of one another, but viewed in a landscape context. For example, efforts should be made to link together fragmented patches of riparian forest to incrementally build towards large contiguous habitat corridors.

6. **Measure Fish and Wildlife Response through a Standardized Regional Monitoring Program.** By promoting a regional monitoring framework (e.g., the CDFW-led Interagency Ecological Program Tidal Wetlands Monitoring Project Work Team), instead of developing monitoring protocols on a project-by-project basis, it will become easier to compare results across projects and improve understanding of the effectiveness of different habitat improvement options. Regional monitoring also supports program-level adaptive management and a landscape-scale approach, as described above. Monitoring, research, and modeling should be linked and designed to close important knowledge gaps at relevant time and space scales (Delta ISB 2015). Additional and long-term funding is needed for this programmatic monitoring.

7. **Continue to use the Delta Levees and Habitat Advisory Committee (DLHAC) as a Venue to Discuss the Incorporation of Effective Habitat Improvement Components into Levee Projects.** The DLHAC convenes regular standing meetings of representatives of DWR, CDFW, Delta RDs, Delta engineers, and other Delta stakeholders. Since the group involves many Delta RDs and their engineers, it represents an opportunity for RDs to collaborate with state agencies to plan and adaptively implement and manage habitat projects under their jurisdiction.

Council staff looks forward to collaborating with agencies and stakeholders to further explore and jointly address the issues raised in this review.

I. INTRODUCTION

The Delta Stewardship Council (Council) has undertaken the development of Delta Levees Investment Strategy (DLIS), which will guide future State investments in flood risk reduction. While investing in levee improvements to reduce risk, the State has both an opportunity to increase floodplain and riparian habitats in the Delta, and an obligation to mitigate adverse environmental impacts of levee projects and provide a net benefit to terrestrial and aquatic species.

The Council must ensure that the DLIS helps to implement the Delta Reform Act and the Delta Plan. The Delta Reform Act of 2009 established the Council and defined its mission: to achieve the coequal goals. As stated in the California Water Code, "'Coequal goals' means the two goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. The coequal goals shall be achieved in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place." (Water Code section 85054). The Delta Reform Act required the Council to develop the Delta Plan and defined certain types of projects and programs to be "covered actions" regulated by the Delta Plan. The Delta Plan includes 14 policies, including one that calls for levee projects to incorporate habitat benefits, where feasible, and another requiring the use of the best available science and adaptive management.

The primary goal of this report is to support the DLIS by suggesting steps needed to improve the effectiveness of habitat improvements related to levee projects in the Delta. Levee-related habitat improvement projects in this report are defined as habitat restoration, enhancement, and/or mitigation projects that were implemented in association with levee projects in the Delta region (i.e., legal Delta, Suisun Marsh, and lower Sacramento and San Joaquin Rivers). The suggested next steps are based upon: 1) a review of levee-related habitat improvement projects conducted in the Delta region, 2) interviews with staff from regional, state and federal agencies, universities, nongovernmental organizations, and consulting firms, 3) review of relevant literature, and 4) principles of best available science and adaptive management.

Our review of habitat projects found that the majority of reports used vegetation monitoring as a means of measuring success. Of the 15 projects for which monitoring reports were available, 12 had data on vegetation, six had fish data, and three had bird data. (See table in Appendix 5.) This finding was not unexpected because, prior to the adoption of the Delta Plan in 2013, adaptive management, including monitoring and assessment of project effectiveness for fish and wildlife, was not required or funded for every levee-related habitat project in the Delta. Vegetation coverage is an indicator of habitat, and is widely used as one of the ways to track progress in ecosystem restoration. However, the Delta is a highly altered ecosystem and the relationships between vegetation coverage and benefits to target species are more complex than in systems that are closer to their historical ecological structure and function. Therefore, research and monitoring related to fish and wildlife response, as well as vegetation monitoring, is needed to determine whether projects are providing benefits to target species.

While projects associated with levee program mitigation and enhancement may only be able to provide a small part of the habitat restoration needed to fulfill the coequal goals, State agencies should strive to make the most of opportunities to obtain multiple benefits from their investments. Our hope is that this review will be helpful in identifying data gaps, clarifying future needs, and providing recommendations for enhancing the adaptive management process for habitat improvements undertaken within the context of flood risk reduction.

II. BACKGROUND

Recommendations for future levee-related habitat improvements should be guided in part by an analysis of how historical habitats functioned (Robinson et al 2015); therefore we provide a summary of the historical habitats of the Delta and subsequent habitat loss and species impacts since Euro-American settlement in the mid-19th century.

Historical Habitats of the Delta

Located in central California, the San Francisco Estuary is the largest estuary on the west coast of North America, receiving runoff and snowmelt from 40 percent of California's landmass (Brown & Michniuk 2007). The Delta is the inland, freshwater portion of the estuary where two major watersheds, the Sacramento River in the north and the San Joaquin River in the south, converge on their way to the sea. Early visitors to the Sacramento Valley described riparian forests ranging from narrow bands to stands several miles wide (Thompson 1961). Large sediment loads allowed for the formation of natural levees up to 20 feet above the floodplain and created suitable conditions for the establishment and successional development of structurally diverse riparian communities.

Large, continuous corridors of riparian vegetation (approximately 324,000 hectares) were present along major and minor rivers throughout the Central Valley (Katibah 1984). Valley foothill riparian, a historically critical habitat, naturally occurred above tidal influence and had a mixed canopy of large, mature trees (e.g., willows, cottonwoods, sycamores, oaks) with a dense understory (Whipple et al 2012). Riparian areas have been identified as the most critical habitat type in all of California for land birds (passerines and near-passerines) (Manley & Davidson 1993; DeSante & George 1994) and indeed, it is one of the most productive habitats for all forms of wildlife (Faber 2003). Mature stands of trees provide nesting habitat for desirable species such as Swainson's hawks and white-tailed kites (Dixon et al. 1957), and are utilized by great blue herons and double-crested cormorants for interspecies, communal nesting colonies. Additionally, they support a diversity of neotropical migrant songbirds (e.g., grosbeaks, orioles, flycatchers, warblers, vireos) by providing foraging areas where the birds can glean or catch insects on the wing.

The mosaic of varied habitats within the flood basins of the north Delta, tidal islands of the central Delta, and distributary rivers of the south Delta once supported an immense diversity of fish and wildlife. Through complex seasonal fluctuations in water temperature, droughts, and floods the Delta provided refuge for vast populations of salmon, Delta smelt (*Hypomesus transpacificus*), and millions of birds migrating along the Pacific Flyway. Historical landscapes in the Delta included tidal and non-tidal freshwater emergent wetland, willow thickets, willow riparian scrub or shrub, valley foothill riparian, grassland, and many more unique habitat complexes (Whipple et al 2012).

Habitat Loss and Species Impacts

Since the mid-19th century the Delta landscape has been altered dramatically. During the Gold Rush, hydraulic mining activities drastically impacted watersheds, choking off tributaries and river channels with sediment. The tidal islands of the central Delta were "reclaimed" in the latter part of the century by draining the wetlands and dredging material from natural sloughs to build up levee-protected islands for agriculture.

The Delta supplies water for agricultural, urban, and wildlife uses throughout the state, through the Central Valley Project (CVP) and the State Water Project (SWP). The CVP and SWP are the nation's largest water storage and conveyance systems (DWR 2015b), composed of a complex system of dams, reservoirs, and water diversions that alter hydrologic regimes in the Delta. At present, 83 percent of California's native freshwater fish populations are imperiled or extinct, largely due to the impacts of invasive species, agricultural impacts, and dams (Moyle et al. 2011).

The central Delta is a patchwork of heritage communities and agricultural islands protected by engineered levees and crisscrossed with a network of sloughs and channels. Along major river reaches in the Lower Sacramento River Conservation Planning Area designated in the *Draft Central Valley Flood System Conservation Strategy*, which includes the northwestern portion of the Delta, DWR estimates that revetment exists on 60 percent of riverbank, covering a stretch of 130 miles (DWR 2015c). The leveed channels lack the bathymetric complexity of natural riverine systems and were essentially designed to flush sediment, convey water, and provide flood protection for the adjacent islands (Burau 2007). The altered ecosystems of the Delta, with reduced flow and turbidity, higher temperatures, high contaminant loads, and invasive aquatic vegetation (IAV) provide conditions that support an undesirable, nonnative fish assemblage (Nobriga et al. 2005; Brown & May 2006; Brown & Michniuk 2007, Grimaldo et al. 2012).

Many of the levees are heavily riprapped on the water side and devoid of significant vegetation with the exception of some invasive annual grasses and weeds. Where vegetation is permitted to grow, naturally established riparian vegetation or tule beds exist in discontinuous, narrow bands. Over 95 percent of the riparian habitat along the Sacramento River has been lost, greatly reducing the river's ability to support wildlife populations that will continue to be viable in the long-term (Katibah 1984). Habitat loss and fragmentation have negatively impacted many avian species in the Delta. In the absence of high marsh vegetation for cover, many species are more vulnerable to predators. Riprapping along levees also adversely impacts native aquatic species by providing habitat that benefits invasive piscivorous fish more than native Chinook salmon (FISHBIO, 2015).

The extent and character of Delta habitats have been altered dramatically over the past 150 years, but remain essential to important ecological functions in the watershed. They form the basis for terrestrial and aquatic food webs, provide essential wildlife habitat and migratory corridors, shade and cool water, filter nonpoint source pollution, and improve water quality. The fragmented remnants of habitat types that once dominated the historical Delta continue to support a variety of threatened and endangered species. As the importance of these habitats in supporting fish and wildlife species has become more widely recognized, support has grown for restoring riparian corridors and recovering some of the functions that have been lost or degraded.

Restoration Mandates in the Delta

Legislation passed in 1988 significantly increased funding for Delta levees, mandating no net loss of fish or wildlife habitat in the Delta and providing funds to mitigate past losses. Water Code sections 12314(d) and 12987(d) require that the expenditures of the state-funded Delta Levees Special Flood Control Projects Program “are consistent with a net long-term habitat improvement program.” The Special Projects Program must also provide a net benefit for aquatic species in the Delta, as determined by California Department of Fish and Wildlife (CDFW). These programs, which have been in place for over 20 years, have resulted in many habitat improvement projects.

Delta levees and ecosystem restoration received additional funding and attention in the CALFED era. The CALFED Record of Decision was finalized in 2000, committing state and federal agencies to work together to achieve four interrelated objectives: water supply reliability, water quality, ecosystem restoration, and levee system integrity. The levee objective promoted an integrated approach, stating, “Improve Bay-Delta levees to provide flood protection, ecosystem benefits and protection of water supplies needed for the environment, agriculture and urban uses.”

When the Delta Reform Act of 2009 replaced CALFED with the Delta Stewardship Council and the Delta Plan, the commitment to interagency cooperation to achieve multiple objectives, including flood risk reduction and ecosystem restoration, in the Delta was retained. As mentioned above, the Delta Reform Act established the coequal goals, as well as several objectives regarding habitat in the Delta, including the following:

- “*Restore large areas of interconnected habitats within the Delta and its watershed by 2100*”

- "*Establish migratory corridors for fish, birds, and other animals along selected Delta river channels*; and
- "*Restore habitat necessary to avoid a net loss of migratory bird habitat and, where feasible, increase migratory bird habitat to promote viable populations of migratory birds*."

In 2013, the Council approved the Delta Plan, which includes 14 policies with regulatory authority. One of those policies, ER P4, promotes the expansion of riparian habitat in levee projects. The policy also requires the evaluation of the feasibility of setback levees in several specific geographic locations within the Delta, including along the Sacramento River between Freeport and Walnut Grove, the San Joaquin River from the Delta boundary to Mossdale, the north and south forks of the Mokelumne River, Paradise Cut, Steamboat Slough, and Sutter Slough, as well as urban levee improvement projects in the cities of West Sacramento and Sacramento.

The Delta Reform Act established a self-certification process for demonstrating consistency with the Delta Plan. This means that state and local agencies proposing to undertake a qualifying action, called a "covered action" in the Act, must submit to the Council a written certification of consistency with detailed findings as to whether the covered action is consistent with the Delta Plan. Generally speaking, the lead CEQA agency determines whether that plan, program, or project is a covered action and certifies consistency, but a funding or approving agency may also determine whether a project is a covered action and certify consistency.

Mitigation Requirements

Mitigation for impacts to riparian habitat is a legal process overseen by multiple regulatory agencies. Senate Bill 34 mandated that the Delta Levees Program, which includes Subventions and Special Projects, results in no net long-term loss of riparian, fisheries, and wildlife habitat (Water Code sections 12341(c) and 12987(c)). In 1992, the California Resources Agency, DWR, the California Central Valley Flood Protection Board (CVFPB), and the California Department of Fish and Game (now Department of Fish and Wildlife, CDFW) entered into a memorandum of understanding (MOU) to direct the implementation of the no net long-term loss of habitat policy established by SB 34 (DWR 1992). This agreement provided CDFW with the authority and responsibility to approve mitigation plans for each levee project under the Subventions and Special Projects Programs. The MOU also calls for mitigation of unavoidable habitat impacts to mitigate on-site, with off-site measures explored if on-site measures are deemed impractical. This MOU was later amended in response to the Legislature enacting AB 360 in 1996, which called for "net long-term habitat improvement" (as defined in Water Code Section 12310), instead of merely avoiding habitat loss.

The revised MOU called for each levee project under the Subventions or Special Projects Program to include a habitat improvement program component developed in coordination with CDFW. For mitigation of habitat loss, the mitigation requirements could be achieved by constructing new habitat and protecting it with a conservation easement, or by using habitat credits from an existing habitat area or mitigation bank. Often it is difficult to impossible to obtain a conservation easement for habitat placed within the levee prism, because of concerns that such habitat could very easily be destroyed if there is a need for emergency levee repairs. As a result, mitigation for impacts to riparian vegetation on levees is often mitigated offsite (e.g., interior of the island).

Compared to habitat mitigation, habitat enhancement projects funded by DWR's Special Projects Program have more flexibility in where habitat improvements can be sited, because there is no requirement that these sites be protected with conservation easements. In essence, this key difference allows enhancement projects to include planting riparian vegetation along levee slopes. For habitat enhancement projects conducted under the Special Projects Program, the revised MOU calls for the achievement of the following objectives:

- *"Improve and increase aquatic habitats so that they can support the sustainable production and survival of native and other desirable estuarine and anadromous fish in the estuary"*
- *"Improve and increase important wetland habitats so they can support the sustainable production and survival of wildlife species"*
- *"Increase population health and population size of Delta species to levels that ensure sustained survival."*

The United States Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) are responsible for implementation of the federal Endangered Species Act (ESA), which is intended to prevent and avoid impact, or "take", to threatened and endangered species. Under ESA, "take" of protected species can include impacts to their habitat, so USFWS and NMFS have the authority to mandate mitigation for impacts to loss of that habitat (e.g., riparian forest, which represents habitat for numerous threatened and endangered bird species). Similarly, CDFW has authority to mandate mitigation of riparian habitat if impacts to that habitat will result in "take" of California Endangered Species Act (CESA) protected species.

CDFW also administers the Streambed Alteration Agreements Program under Sections 1601 to 1606 of the California Fish and Game Code. CDFW has jurisdiction of the bed and channel, and to the top of the bank of all streams, extending laterally to the upland edge of adjacent riparian vegetation, and may require mitigation for impacts to riparian habitat through the Streambed Alteration Agreement Program.

Other agencies have mandates to protect riparian habitats on the basis of protecting beneficial uses of water. The United States Army Corps of Engineers (USACE) has regulatory authority over riparian areas if they occur within jurisdictional wetlands under the federal Clean Water Act. The USACE is mandated with enforcing a Federal "no net wetland loss" policy, so the USACE can mandate mitigation for impacts to riparian habitats that are also jurisdictional wetlands. The State Water Resources Control Board (SWRCB) is currently developing the Wetland and Riparian Protection Policy, as directed by the State Water Board's Resolution 2008-0026. A key purpose of the Wetland Riparian Protection Policy is to ensure "no net loss" of these two habitat types, because of their recognized value to protect beneficial uses of waters of the State. The language of this resolution calls for the SWRCB to develop a statewide policy to protect riparian areas through a watershed-based approach.

The California Environmental Quality Act (CEQA) review process requires projects to disclose impacts from their construction and operation. The CEQA process requires assessments of the effects of a project on a wide variety of resources including forestlands, essential fish habitat, and habitats that are considered rare natural communities by CDFW (e.g., certain types of riparian forest). Avoidance, minimization, and mitigation measures are often included in CEQA documents, if the review process reveals that a project may have significant impacts on these or other key resources.

For projects that are covered actions under the Delta Plan, Delta Plan Policy G P1 requires that those projects include mitigation measures equivalent to or exceeding those listed in Delta Plan Program EIR. This EIR contains several mitigation measures particularly germane to mitigation related to levee construction impacts on riparian and aquatic habitat. For example, Biological Resources Mitigation Measure 4-3 states that "where substantial loss of habitat for fish and wildlife species is unavoidable, compensate for impacts by preserving in-kind habitat", while Biological Resources Mitigation Measure 4-4 states "protect, restore and enhance connectivity of habitats, including but not limited to wetland and riparian habitats that function as migration corridors for wildlife species."

Generally, the mitigation ratio required by these agencies for construction-related impacts to riparian habitat is variable, with no set standard or policy for established mitigation ratios. Mitigation requirements and ratios are often determined by the regulatory agencies or project proponent on a per-project basis. For the Delta Levees Program though, CDFW follows set standard mitigation ratios for riparian forest, scrub shrub, freshwater marsh, and shaded riverine aquatic habitat, whether the mitigation occurs on-site or off-site.

Constraints to Implementing Levee-Related Habitat Projects

Implementation of levee-related habitat projects faces various regulatory and liability-related constraints, due in part to the need to balance flood risk reduction and habitat improvement. As part of the 2017 Central Valley Flood Protection Plan (CVFPP) Update, DWR has drafted a Central Valley Flood System Conservation Strategy (DWR 2015c), including a Levee Vegetation Management Strategy, which explains the need for vegetation management:

> *"Levee vegetation management is particularly important because levee vegetation can impede visibility and accessibility for inspections and flood fighting, and in some limited cases, it may pose an unacceptable threat to levee integrity. In channel areas in between State Plan of Flood Control (SPFC) levees, the floodplain and channel may provide opportunities for important riparian and wetland habitat, as well as agricultural operations. However, land uses in these areas also need to be managed to maintain the channel's ability to convey high flows during flood events. Finally, invasive plants can adversely affect operations and maintenance (O&M) of the SPFC and are a documented stressor on the species, habitats, and ecosystem processes targeted by this Conservation Strategy. Management of invasive species, and eradication of them where feasible, reduces O&M needs by increasing channel capacity and provides important ecosystem benefits."*

Although levee vegetation management is widely acknowledged to be important, there is considerable controversy regarding the current nationwide policy of the USACE to require removal of trees and most shrubs from a "vegetation-free zone" on and around levees under their jurisdiction, and also to prevent planting of most vegetation other than grasses within this zone. Federal legislation (Public Law 113-121, the Water Resources Reform and Development Act of 2014) was recently passed that requires reevaluation of this policy by November 2015. This effort may result in an update to the USACE Engineering Technical Letter (ETL) 1110-2-583, *Guidelines for Landscape Planting and Vegetation Management at Levees, Floodwalls, Embankment Dams and Appurtenant Structures* (2014), which states that vegetation on the levee and within 15 feet of the levee toe does not meet USACE engineering standards, but the reevaluation process has not yet been funded. In the meantime, the USACE allows local sponsors to apply for a variance. Local sponsors responsible for USACE levees face a liability risk if they do not meet USACE engineering standards, i.e., they may not be eligible for rehabilitation assistance if their levee fails. In 2011, USACE adopted the System-Wide Improvement Framework Policy (SWIF), which was intended to enable USACE to work collaboratively with resource agencies and levee sponsors to transition existing levees to Corps standards while maintaining rehabilitation assistance and adhering to the ESA and other federal environmental laws. However, the procedures for obtaining a variance from the ETL remain burdensome.

DWR and others engaged in levee repairs have been relying upon *California's Central Valley Flood System Improvement Framework* (Framework), signed in 2009 by participants in the California Levees Roundtable, a group of high-level representatives of federal, state and local flood management and resource agencies, to guide their project design. The State's levee vegetation management strategy described in the 2012 CVFPP and Conservation Framework is built on concepts in the California Levees Roundtable's Framework. DWR's draft Levee Vegetation Management Strategy for the 2017 CVFPP Update supports removing high risk trees near the top of the levee while retaining lower waterside vegetation to reduce risk while avoiding widespread loss of habitat that would be difficult if not impossible to mitigate. For new levees, the draft Levee Vegetation Management Strategy suggests alternative approaches to providing shaded riverine aquatic habitat, such as construction of planting berms located beyond the regulated levee prism, described in further detail below.

In addition to regulatory constraints and liability concerns, levee habitat projects are constrained in some cases by lack of interest or capacity on the part of local reclamation districts. According to Delta flood management experts, many RDs do not want habitat on their levees given the increased risk associated with biological hazards (e.g., burrowing beavers) and uncertainties regarding ongoing cost of maintenance of the habitat. One way to address these concerns would be for landowners to donate or sell easements to state agencies if those agencies agree to construct and maintain habitat on their land. Projects would need to be designed to reduce the risk of burrowing by animals (e.g., by placing riprap at the toe of the levee beneath the soil used to create planting berms).

III. PURPOSE AND APPROACH

While the DLIS appropriately focuses on flood risk reduction as a primary purpose of state levee investments, this levee-related habitat review is intended to provide guidance in ensuring that levee investments will contribute to long-term improvement of river corridors with net benefit for fish and wildlife. Another goal of the review is to provide information about how much different habitat improvement options cost, specifically those habitat options that can be linked with flood risk reduction projects.

Definition of Levee-Related Habitat Types

In order to conduct the review of levee-related habitat projects, Council staff needed to determine which habitat types to include and how they would be defined. We reviewed the typology developed by the California Department of Water Resources’ (DWR’s) FloodSAFE Environmental Stewardship and Statewide Resources Office (FESSRO) for the Delta Levees Program. FESSRO identifies five different levee-related habitat types (Fig. 1) and they provide descriptions of each of these habitat types. They include: channel-margin habitat (aka Delta Levees Program-specific Fish Friendly Levee Habitat), freshwater marsh (tidal and non-tidal), shaded riverine aquatic (SRA), and riparian habitat, including riparian forest and scrub shrub. For the purposes of this report, we use the same habitat classifications and definitions as FESSRO.

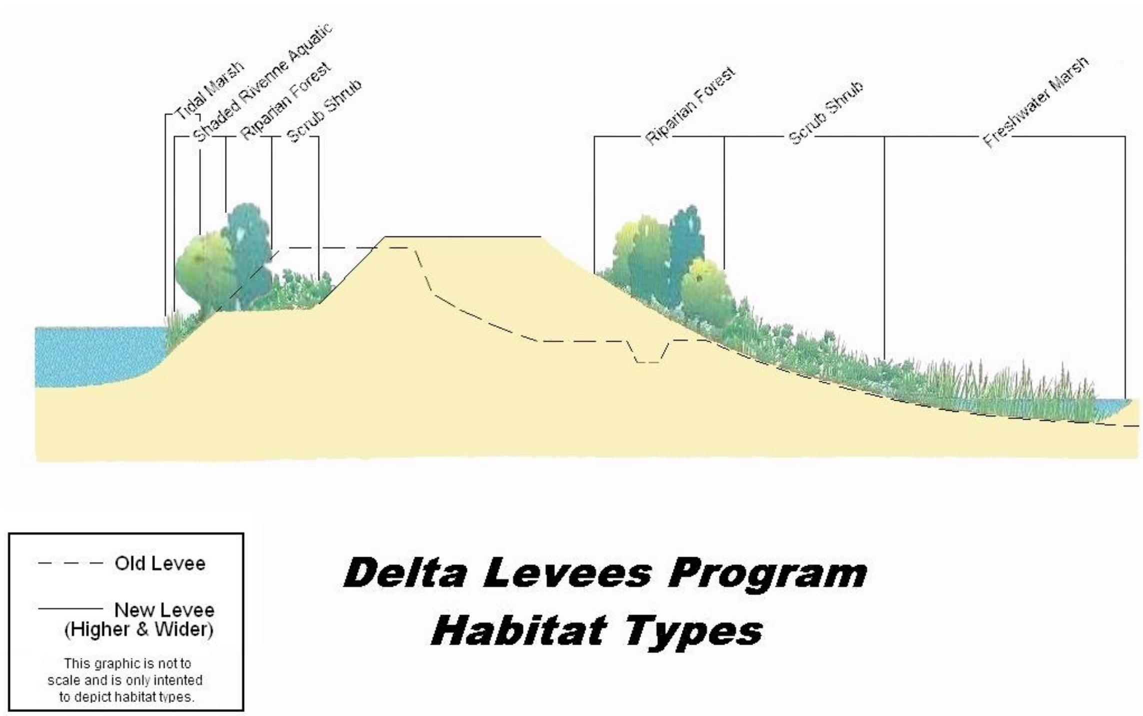

Figure 1. Cross-section of a levee and related habitats on a subsided island as defined by FESSRO.

Note: for purpose of this review, scrub shrub and riparian forest are categorized as riparian habitats.

Source: DWR 2015a.

Riparian forest refers to the vegetation and plant communities growing along rivers and streams. Riparian forest habitat comprises large trees and woody plants over 20 feet tall and can have a dense understory of shrubs and herbaceous plants. The scrub shrub habitat type includes woody trees, shrubs, and vines generally under 20 feet tall and can include, but is not limited to willow, alder, rose, box elder, and blackberry. SRA habitat is the near-shore aquatic area occurring at the interface of a river and adjacent woody riparian habitat. SRA is characterized by a bank composed of natural, eroding substrates supporting riparian vegetation that overhangs or protrudes into the water, providing nearshore shade. Another important component of SRA habitat is the presences of live or dead instream woody material (IWM) that can serve as a velocity break, providing refuge for smaller native fishes, but also potentially for non-native predators. Freshwater marsh habitat describes both tidal and non-tidal areas. Tidal marsh may occur along the levees of slower moving water from 30 cm below mean lower low water (MLLW) up to mean higher high water (MHHW) where emergent vegetation such as cattails and tules grow (Atwater & Hedel 1976).

Information Gathering

Information about 15 levee-related habitat improvement projects (mapped in Figure 2) was obtained through a query of 16 interviewees and 14 additional contacts provided by interviewees. The interviews covered a variety of topics, including project components, pre- and post-construction monitoring to evaluate project effectiveness, the cost of incorporating habitat improvement into projects, the use of adaptive management in making post-construction decisions, and lessons learned that can inform other similar efforts in the Delta. (See Appendix 4 for details.)

Project Effectiveness Review

Through coordination with other agencies and stakeholders we obtained descriptions of completed levee-related habitat improvement projects and associated monitoring reports conducted within the Delta to evaluate project effectiveness. Note that the majority of the projects evaluated were planned prior to the adaptive management framework put forth in the Delta Plan (2013); therefore, we do not assess whether or not the project followed an adaptive management framework. Rather, project effectiveness is considered in terms of 1) the project stated objectives, performance measures, monitoring, and results and 2) whether or not a project could be shown to benefit aquatic and/or terrestrial species.

Cost Analysis Review

The Delta Stewardship Council requested and compiled cost data information for habitat improvement projects associated with levee projects from various sources, including DWR, USACE, USFWS, consultants, and nongovernmental organizations. We looked at habitat enhancement projects, where habitat improvements were incorporated along where the levee construction work occurred, as well as habitat mitigation projects that occurred off-site. The main objective of the analysis was to determine the incremental cost of incorporating habitat improvement components into levee construction projects, either through the creation of habitat features on-site (e.g., creation of a habitat bench) or through acquisition of habitat credits from a mitigation bank.

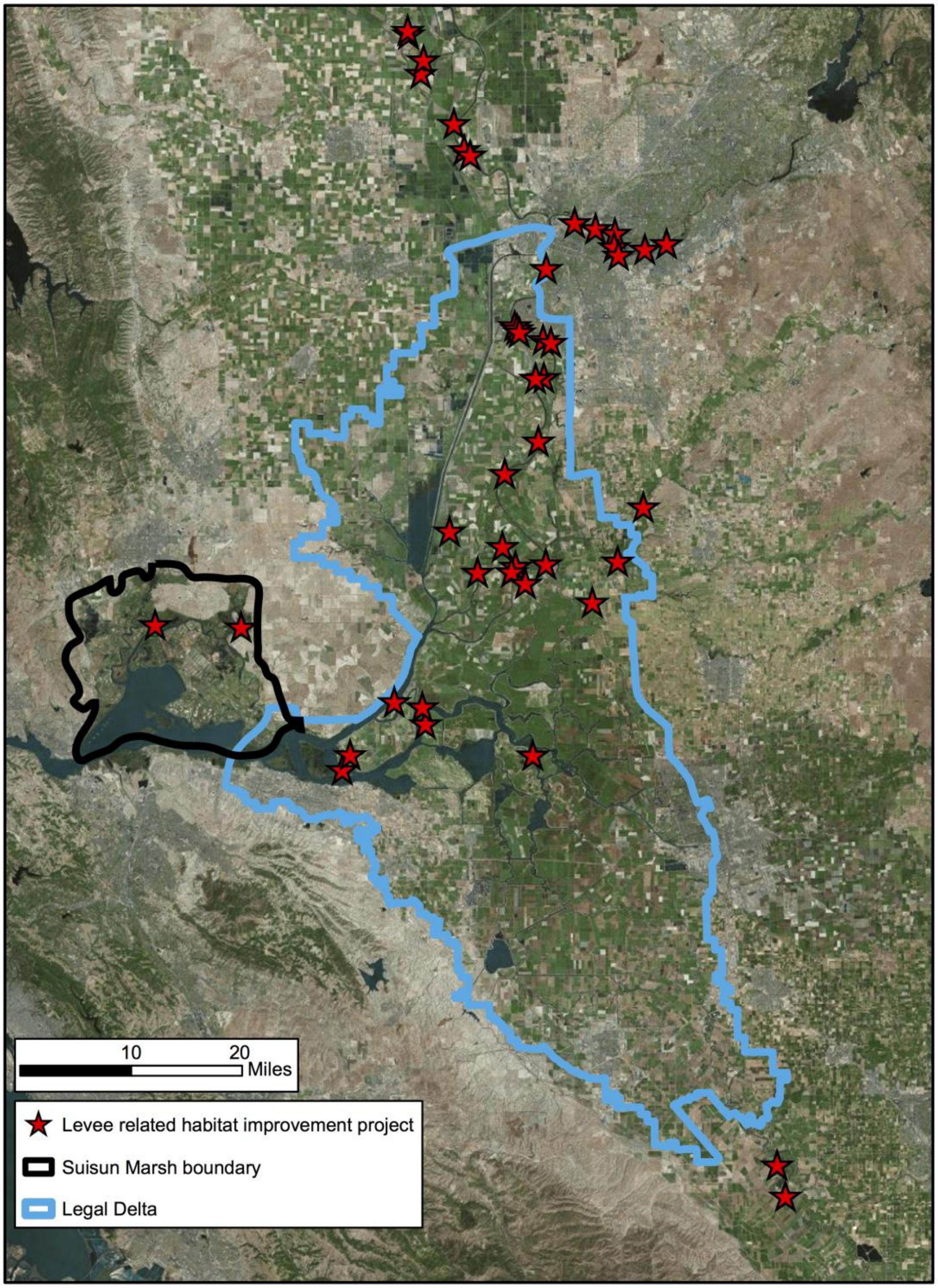

Figure 2. Levee-related habitat improvement projects. *Note: Projects lacking monitoring reports are not shown. See Appendix 5 for a complete list of projects reviewed for this report.*

IV. ANALYSIS

Project Effectiveness

The Council's review could not compare the effectiveness of different types of habitat improvement projects due to the inconsistent or insufficient level of appropriate fish and wildlife monitoring data across projects to evaluate the effects of a habitat project on target species. Determining net benefit to species would require, in the near term, evidence of increased occupancy of restored habitat by the target species, and, over the long term, evidence of a relationship between increased availability of habitat and population growth of the target species. The general lack of this type of monitoring data from levee related habitat projects in the Delta is due in part to a lack of available funds to pay for species response monitoring for projects undertaken by the Delta Levees Program.

Through our interview process, we were informed that monitoring of wildlife response is rarely required (see exception for Natomas Basin Conservancy), and that post-construction monitoring is largely limited to regulatory compliance monitoring. This compliance monitoring typically takes place over a three-to-five year period and documents the successful initial establishment of planted vegetation and spread of invasive weeds at the site (if sites fail to achieve the target for survival of planted vegetation, or if sites exceed a defined threshold of cover by invasive weeds, these issues must be remediated in order for the mitigation site to be considered in compliance).

Despite our inability to draw conclusions regarding the effectiveness of different habitat improvement designs, our review of project monitoring reports resulted in some observations regarding effectiveness that can inform future projects. (For details, see Appendix 1, Lessons Learned). Later in this report, we summarize our observations and provide guidance for future monitoring and research projects to reduce some of the key uncertainties associated with these levee-related habitat projects.

Cost Analysis

We were unable in our costs analysis review to achieve our primary objective specifically isolating the costs of habitat improvements for multi-objective projects. Cost information for the habitat component of these projects is rarely broken out from the risk reduction component (i.e., levee construction or rehabilitation), making it impossible to isolate costs of the habitat improvements. We did break out average total costs of different habitat improvement project types (e.g., riparian enhancement projects versus setback levees mitigation banks); however, since these cost figures include total project costs (which may include the costs of construction for general levee improvements), there is a large amount of variance in cost estimates for different types of habitat improvements. All costs for these projects were standardized to 2015 dollars, with the inflation correction factor based upon the United States Bureau of Labor Statistics' Consumer Price Index (CPI).

Considerations to Guide Future Projects

Habitat improvement projects should be viewed as an opportunity to conduct studies that serve to fill crucial information gaps (Brown 2003, Herbold et al. 2014). Although vegetation performance measures are an important component of baseline monitoring, more response variables are needed to confirm benefits to wildlife, especially aquatic species. Wildlife response monitoring is generally limited to presence or absence data for a species. Presence or abundance of a species within a habitat is generally assumed to reflect a net benefit to individuals or populations; however, further studies are needed to confirm this assumption and determine the extent to which habitat plays a role in survival especially across the life stages of migratory fishes (e.g., Rosenfeld 2003).

Scale and location are two additional limitations with regards to habitat improvement in the Delta. Fundamental questions such as, what scale of habitat areas is needed to outweigh adverse edge effects within each target habitat, remain undefined. For tidal marsh restoration, no quantitative guidelines exist that relate restoration extent to functional contributions for target species at the population scale (Herbold et al. 2014). Fundamental scale questions must be considered for effective restoration, including the effective tidal marsh width and area needed to enhance ecological value such as food web benefits, predator refuge for aquatic and terrestrial wildlife, and bird habitat. The same could be asked for SRA—will SRA habitat in the Delta provide significant water temperature benefits to fish? The Delta has wide, deep channels with abundant flow from tidal exchange; it is unknown whether relatively narrow widths of shade within those wide channels can provide appreciable cooling to benefits to fish (Greenberg et al. 2012).

Native Fish Requirements

The monitoring reports we received pertaining to the effects of channel margin improvements focused almost exclusively on salmonid response. As such, we limited the focus of the following discussion regarding native fish requirements to these species. Past habitat enhancement projects have likely benefited other native fish species too (e.g., splittail, tule perch, delta smelt, longfin smelt, Sacramento pikeminnow, sturgeon), so we encourage future levee-related habitat projects to consider monitoring a broader suite of fish species beyond salmonids.

1. **Importance of channel margin habitat with shallow water, gently sloping banks, and fine substrate.** Shallow water with gently sloping channel banks and fine substrate (indicative of decreased velocities) can increase habitat occupancy by native salmonids while decreasing occupancy by predatory fish (FISHBIO, 2015; Appendix 1). However, recent acoustic fish telemetry surveys indicate that migrating salmonids may not effectively utilize established or restored habitat along the channel banks due to flow patterns of the waterway ([Interviewee, permission to cite pending] pers. comm.). Hydrodynamic modeling is needed to determine the optimal length and position of in-water habitat enhancements such as planting benches that will allow fish access.

Planting benches have been shown to benefit aquatic species along the Sacramento and American River (Fishery Foundation of California 2006; FISHBIO 2015); however, one possible negative side effect of planting benches is that, due to construction requirements, planting benches inherently replace shallow and intertidal habitats. Currently, their benefit to native aquatic wildlife is not well understood. One may expect that riparian installation on planting benches may not provide net positive benefits to aquatic wildlife if the waterside bathymetry of the planting bench does not contain intertidal depths at which channel margin wetlands (i.e. fringing tidal marsh) may develop.

Channel margin wetlands may benefit aquatic species by serving as an important refugia and rearing habitat for fish and was likely a key component to the historical food-web development (Herbold et al. 2014). The creation of additional intertidal areas will affect the both site-specific and Delta-wide hydrodynamics and thereby water levels and water conveyance. Integrated hydrodynamic modeling coupled with landscape-scale restoration considering future scenarios of changes in sea level, sediment supply, tidal stages, infrastructure, and habitat restoration is needed to ensure the long-term efficacy and sustainability of habitat restoration efforts (Stralberg et al. 2011, Swanson et al. 2015). Future enhancement efforts of the Delta's channel margin wetlands must consider and address uncertainties regarding optimum area, elevations, residence time, nutrient transport, the extent of edge and channels, and the nature and connectivity with adjacent habitats (Herbold et al. 2014).

2. Importance of providing the appropriate density of in-stream submerged vegetation or woody material. IWM has been shown to benefit aquatic species in numerous locations (Roni et al. 2015) and larger IWM (> 10.2 cm diameter to create velocity breaks) can provide daytime cover for Chinook salmon smolts from avian and introduced fish predators (Zanjanc 2013). For sites along the Sacramento River with IWM in low and medium densities Chinook Salmon fry occupation increased by two- and three-fold, respectively (FISHBIO 2015). However, IWM in "high density" has increased occupation of invasive predatory fish by 20-fold while decreasing occupation of Chinook Salmon fry by about 75 percent compared to similar sites that lacked high-density IWM (FISHBIO 2015). Further study of how IWM density, size, and location affects invasive predatory fish and native aquatic species along river corridors and tidally-influenced Delta channels must be conducted before we assume IWM will invariably provide net benefit to aquatic species.

4. Importance of shaded riverine aquatic habitat in providing benefits to rearing fish along channel margin habitat. Overhanging riparian vegetation can provide an important source of food from the terrestrial environment to the aquatic system as insects enter the water by falling off riparian vegetation overhanging the river (Murphy and Meehan 1991; Smokorowski and Pratt 2006). Organic inputs from vegetation debris entering the stream (e.g., falling leaves, woody debris) can also contribute to the aquatic foodweb. Nearshore, vegetated shallow waters are often preferentially utilized by juvenile salmon, since they provide refuges of calmer waters, higher food productivity, and protective cover from avian and fish predation.

SRA also provides water temperature cooling benefits along narrow channels of the Delta; many native fish like salmon and smelt can be temperature impaired during the late spring and summer months and the beneficial microclimates that SRA may provide may be increasingly important with climate change. A recent study indicates that if all trees were removed from levees Delta waters would increase by 0.2°F delta-wide and up to 7°F within narrower channels (Greenberg et al. 2012). Along deeper and wider channels, however, the cooling benefits decrease (Greenberg et al. 2012); this observation highlights the importance of considering the ratio between channel volume and shaded area provided by vegetation. Modeling should be conducted to determine what height of trees and width of shaded area is needed to provide appreciable water temperature cooling benefits to aquatic species across the Delta to inform habitat restoration implementation and feasibility.

The placement of riprap within channel margin habitat has been linked to degradation in habitat suitability for juvenile salmon in the Delta. The placement of riprap provides cover for non-native fish predators who hold in the gaps of the riprap material and ambush smaller fish as they move to and from the nearshore habitat (McLain and Castillo 2009). As a result, areas of the Delta that have been riprapped are associated with lower salmon counts during fish surveys than areas with sandy or muddy substrates, either because salmon are volitionally avoiding riprapped habitat or because they are suffering high predation loss (Schmetterling et al. 2001, Garland et al. 2002, McLain and Castillo 2009).

<u>Bird Requirements</u>

1. Importance of managed croplands for hunting and foraging areas. Species such as the Swainson's hawk (*Buteo swainsoni*) and the greater Sandhill crane (*Grus canadensis tabida*) can benefit from appropriately managed livestock pastures and agricultural land. In lieu of native grasslands, grain or alfalfa fields can provide Swainson's hawks with suitable hunting grounds especially if they are bordered by sufficient riparian groves that provide trees for roosting and nesting. Post-harvest mulching and flooding of corn fields, like those on the conservation farmlands of Staten Island in the central Delta, provide excellent foraging and roosting habitat for overwintering Greater Sandhill cranes during migration. The conversion of agricultural lands to almond production and vineyards has inflated the value of cropland in California and drought has reduced the acreage of rice fields which serve as surrogate wetlands for waterfowl. Given the loss of native habitats like oak grasslands for Swainson's hawks and wetlands along the Pacific flyway for Sandhill cranes, carefully managed agriculture in the Central Valley can provide necessary habitat for these threatened species.

2. Importance of riparian habitat width. Larger riparian or marsh areas with connectivity between habitats will benefit avian species by providing protection, food resources, and nesting areas. Riparian length by width class is one metric used to evaluate life history support status for riparian wildlife, typically passerine birds (Whipple et al 2012). The width of riparian habitat along the river channels of the Delta has decreased dramatically in most areas from miles to feet. In general, riparian corridors that are a minimum of 100 m wide are needed to provide foraging and nesting opportunities for neotropical migrant birds (Golet et al. 2013). While limited opportunities for riparian restoration at that scale exist within the Delta, smaller projects that build incrementally towards establishing continuous corridors of riparian forest may be possible on an island-by-island basis through habitat projects conducted by individual RDs.

3. Importance of connectivity and minimization of edge effects to reduce predation. Aside from protecting large areas of continuous habitat for the benefit of avian species, management and enhancement projects should aim to provide connectivity between habitats and lower perimeter-to-area ratios to reduce negative edge effects such as increased nest predation. The density of three Song Sparrow subspecies found in the San Francisco Bay estuary, including the Suisun Song Sparrow, were greater in larger marshes that were not isolated from each other and not adjacent to urban areas (PRBO 2002). Additionally, Suisun Song Sparrow nests were the least successful and experienced the highest levels of predation in isolated marsh habitats with higher perimeter-to-area ratios. Although habitat improvement projects tend to be completed in small sections over time as funding becomes available, landscape-level features should be considered whenever possible in conservation planning.

Refining Project Goals and Design in Light of Delta-Specific Constraints

We advise caution when applying lessons learned from other parts of the Central Valley to the Delta, due to its highly altered physical state. The role of flood bypasses, such as the Yolo Bypass, and intertidal and supratidal elevations on the outer edges of the Delta in providing floodplain and intertidal habitat is more significant in the Delta because of the constraints to natural overbank flooding along subsided Delta islands.

When considering tidal marsh and riparian habitat restoration options for the Delta, setback levees have been commonly proposed. Setback levees can enable reestablishment of natural riverine processes necessary for establishing sustainable riparian habitats, and can provide broad areas of floodplain habitat that benefit aquatic and terrestrial target species (Stromberg et al. 2007; Shafroth et al. 2010; Golet et al, 2013).

The draft Central Valley Flood System Conservation Strategy (DWR 2015) lists several factors that should be considered when determining if a setback levee is appropriate for a given location. One of those factors, "Elevations within the floodway that provide for frequent inundation and support riparian and wetland habitats and species," is particularly important when considering using a setback levee as a habitat improvement option in the Delta. Therefore, the following points should be addressed for setback levees in the Delta, though Delta geography often makes it difficult for them to be properly addressed:

- Is the setback distance great enough to allow the channel to reinitiate riverine geomorphic processes (e.g. channel-migration, sedimentation, and cut-offs)?
- Is the inundated floodway created by the setback at intertidal to supratidal elevations?
- What are the timing, duration, and frequency of flood flows (Williams et al. 2009)?

These elements may be utilized to create a spatially explicit framework to determine where setback levees are an appropriate habitat restoration option. The setback distance to establish riverine geomorphic processes for the Sacramento River was estimated to be between one and three times bank-full channel width (Larsen et al. 2012). This is a considerable obstacle when the setback distance needed to restore riverine geomorphic processes for many Delta channels is on the scale of hundreds of meters and many Delta landowners do not readily support levee projects that would cause loss of arable land. The second consideration critically important for the Delta is that most Delta islands lie at subtidal elevations. Levees along deeply subsided islands at subtidal elevations are not suitable locations to implement setback levees as a habitat improvement option unless the inundated floodway lying at intertidal and supratidal elevations can be brought to grade at considerable expense. Another consideration is that unlike upstream areas of the Sacramento and San Joaquin Rivers, soils in much of the Delta are comprised of peat soils which make for poor, unstable foundations for new levees. Options are available to stabilize and prepare these peat soils to adequately support new setback levees, such as dynamic peat compaction or soil mixing, but those options are quite expensive and may add many millions of dollars per mile of new setback levee. Finally, there are numerous other challenges to implementing setback levee projects that are not necessarily unique to the Delta but are still problematic including, but not limited to: finding willing landowners to provide the land, which often results in loss of agricultural land; complications in protecting existing structures and utilities; and maintaining access for mineral rights holders.

Adjacent levees (see Diagram D3 for definition) on average cost more than typical levee improvement projects because they require a substantial amount of fill, and like setback levees, also require stabilization of soil foundations. However, while setback levees have been shown to benefit ecosystems in other regions (DWR 2015c), adjacent setback levees: 1) do not follow the conceptual model of how setback levees provide ecosystem benefits and 2) have not been monitored properly to indicate whether or not there are positive benefits to native wildlife in the Delta.

Although there is a lack of monitoring data to definitively show if adjacent levees provide benefits to native Delta species, construction of an adjacent levee can make sense in situations where continuing to maintain an existing levee is more expensive in the long-term than shifting the prism of the levee landward. An example of such a situation occurred with levees on Twitchell Island along the San Joaquin River. The waterside slopes of these levees required armoring from riprap because of the highly erosive forces (i.e., boat wakes from large shipping vessels and waves resulting from long wind fetch) along this stretch of the San Joaquin River; however, the rock riprap needed to be constantly replaced as the riverbank is naturally very steep and the rocks would eventually slide off the levee to the bottom of the river bed ([Interviewee, permission to cite pending] pers. comm. 2015). During the mid-2000's, the Delta Levees Program helped fund construction of an adjacent levee along a short stretch of the existing levee on Twitchell Island as a more cost-effective measure in the long run from a flood risk reduction standpoint. In addition, DWR staff helped incorporate habitat enhancement aspects into this project with the intended goal of creating riparian habitat and providing channel margin habitat for Delta fishes. Although the levees along the San Joaquin River on Twitchell Island are not identified by the Delta Plan (i.e., Delta Plan Policy ER P4) as areas where setback levees should be considered to benefit Delta habitat, in similar future circumstances, where adjacent or setback levees are determined to be the most effective option for providing flood risk reduction, we recommend that such projects integrate habitat enhancement features to the maximum extent possible. Since we still have considerable knowledge gaps regarding the potential benefits that adjacent levees have on the Delta's native species, conducting species level monitoring of these projects is crucial.

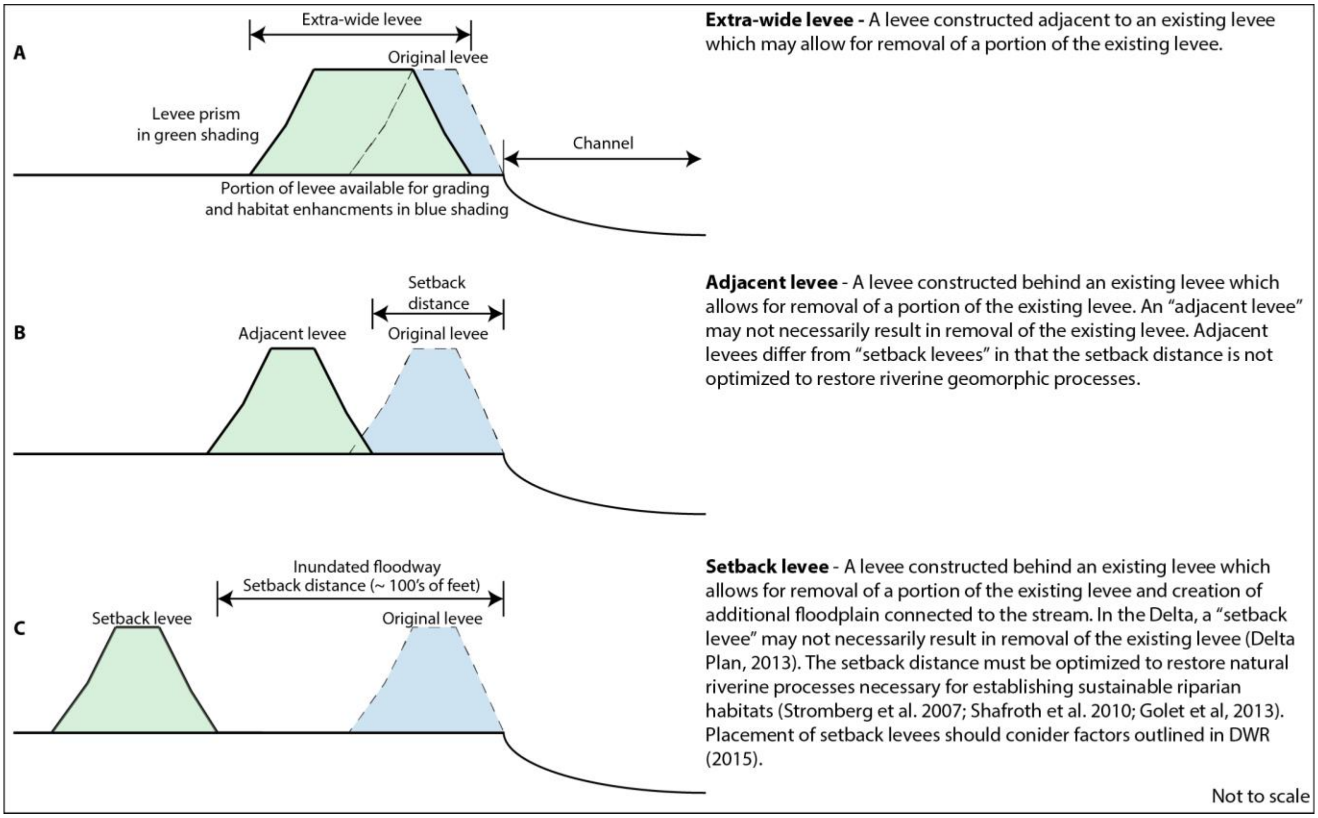

Diagram D3. Illustration and definitions of extra-wide levee, adjacent levee, and setback levee.

<u>Design Considerations for Extra-wide Levees</u>

Given the high cost of setback levees where Delta islands are at subtidal elevations, extra-wide levees may be a more cost effective option and be supported by landowners. The extra-wide levee concept essentially strengthens and widens an existing levee. The regulated levee prism shifts landward allowing the waterside slope to be considered for a range of habitat improvement possibly including graded benches that range from subtidal to supratidal elevations. This design would allow riparian habitat, SRA, and channel margin wetland restoration to occur on the waterside slope of the levee. A slope with multiple elevation ranges is critical for providing habitat benefits to native wildlife along channels in years with low river stage (Diagram D4; Fishery Foundation of California 2006).

Extra-wide levees may provide more habitat benefits than adjacent levees since the riparian habitat, SRA, tidal marsh, and channel margin habitat are interconnected along a single slope that ideally gently grades into the channel (Diagram D4; FISHBIO 2015). However, extra-wide levees may also require substantial conversion of land, and the loss of farmland may only be acceptable to local landowners on larger Delta Islands.

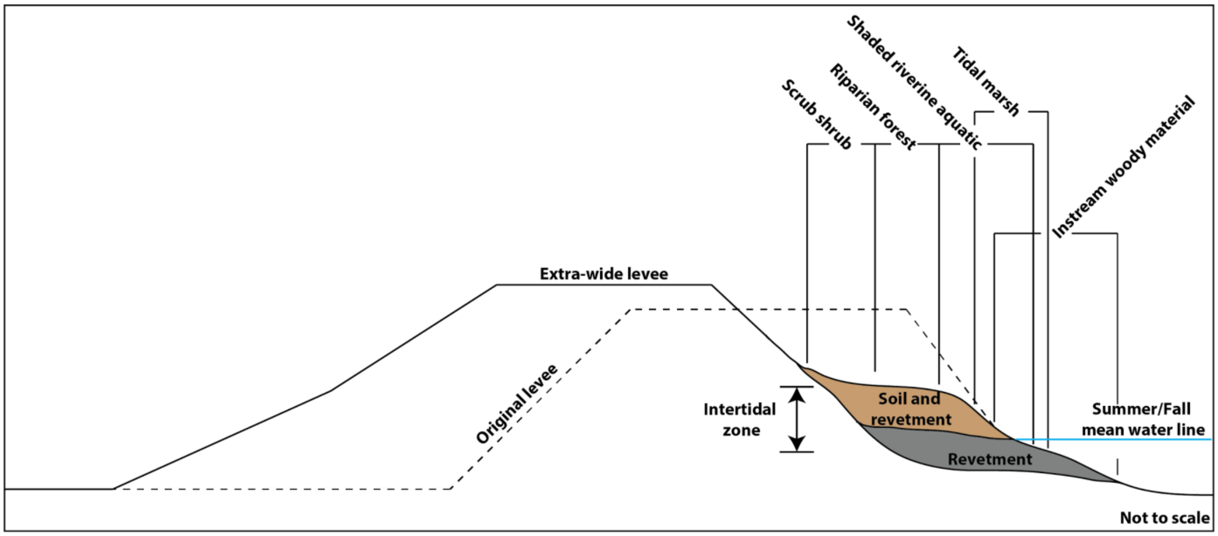

Diagram D4. Extra-wide levee with water-side slope of levee graded into planting bench.

Design Considerations for Planting Benches and Planting Vegetation on Levees

In lieu of or in combination with a setback, adjacent, or extra-wide levee, a planting bench on a waterside levee slope (see Diagram D2) may be installed to provide appropriate depths and elevations for establishing channel margin habitat (FISHBIO 2015; Fishery Foundation of California 2006). Planting benches create a physical boundary within the channel and may provide heterogeneity in the channel velocity profile; however, planting benches in channels with high velocity may be subject to frequent erosion and require maintenance.

When designing planting benches and vegetation planting on levee slopes and intertidal margins, multiple elevations should be considered to provide habitat benefits in years with different river stages. A survey of the Lower American River found that out-migrating juvenile salmonids utilized riprap reaches with riparian habitat and channel margin enhancement (e.g., in-stream woody material) nearly as much as "natural" (i.e., non-riprapped) levee slopes (Fishery Foundation 2006). However, in years with very low flow, river stage fell to an elevation below the channel-margin enhancement projects and out-migrating juvenile salmonids use of these areas fell by about 83% while out-migrating juvenile salmonids use of natural levee slopes fell by only 20%. Years with very high river stages may also prove problematic for channel-margin enhancement projects conducted at a limited range of elevations; when river stages are high the enhancement site could occur at depths too great for native aquatic and/or terrestrial species to utilize the habitats (Fishery Foundation of California 2006).

In locations with especially high water velocity and steep bathymetric gradients at the waterside levee-slope, planting vegetation on the levee slope and within the intertidal zone may be a more feasible habitat enhancement option than planting benches. This method has been effectively applied in at least three locations within the Delta (Grand Island, King Island, and Canal Ranch). Ballast buckets developed by Jeff Hart have been successfully utilized to establish tule marsh at Grand Island and alders have been successfully planted in levee riprap at Canal Ranch. Planting on and near existing levees is generally inexpensive; however, no wildlife related monitoring to date has been conducted at these sites to determine habitat benefits to terrestrial and/or aquatic wildlife.

Cost Analysis

<u>Onsite Riparian Habitat Improvement</u>

DWR provided cost information for Delta levee construction projects that incorporated habitat elements on-site. Generally these projects involved enhancement of riparian habitat on the levees through planting of trees within bank erosion control materials (e.g., riprap), with an average of approximately 600 trees planted per linear mile, while mitigation requirements for habitat impacts during these levee projects were satisfied through purchases of mitigation credits. The total costs for these projects (i.e., the sum of both the flood risk reduction and habitat enhancement elements of the project) vary widely, from approximately $1,400 to $5,200 per linear foot ($7 million to $26 million per linear mile).

DWR also provided cost estimates for two pilot-scale demonstration projects that were intended to utilize riparian plantings and biotechnical solutions (e.g., brush boxes) to stabilize levee slopes and provide erosion control. The scope of these projects involved much less construction related activities compared to the general levee improvement projects and hence cost substantially less with costs of approximately $80 to $200 per linear foot ($400,000 to $1.1 million per linear mile).

We observed with these multi-objective levee projects that there was a negative correlation between size of the project and the average cost per linear foot (i.e., larger projects were generally cheaper, on a cost per foot basis, than smaller projects). This result indicates that based on cost-effectiveness, it is preferable to restore large amounts of habitat at once in fewer projects instead of many smaller projects (refer to Figure 3).

One major limitation in evaluating the costs of restoring habitat based on these multi-objective projects is that it is very difficult to differentiate the costs of restoring the riparian habitat versus the costs associated with design engineering and construction of the levee improvement work. As a result, although the scale and approach for replanting riparian vegetation was similar across the multi-objective levee projects that DWR provided, the total costs of the projects varied by several factors. As improvement to the structural component of the levee for flood risk reduction purposes is often the fundamental driver of these projects, and the scale of construction work will vary depending on site-specific considerations (e.g., how badly degraded the levee is, or how far the levee is deviating from PL 84-99 standards); therefore, the true costs of restoring riparian habitat on levees is still uncertain.

Table 3. Costs of Multi-Objective Levee Improvement Projects with On-Site Habitat Improvement (Adjusted to 2015 Dollars)

	Project Location	**Linear Feet of Project**	**Cost Per Linear Foot**
Multi-Objective Levee Improvement Projects	Lower Jones Tract	2,550	$2,300
	Orwood and Palm Tract	1,000	$3,200
	Orwood and Palm Tract	2,000	$2,800
	Lower Roberts Tract	1,400	$2,200
	Lower Roberts Tract	2,800	$1,400
	Upper Jones	1,600	$2,200
	Upper Jones	3,100	$1,400
	Woodward Island	1,000	$5,200
	Woodward Island	1,000	$5,100
		Average of above	$2,900
Habitat Demonstration Projects	Tyler Island	2,000	$80
	Grand Island	1,000	$200
		Average of above	$140

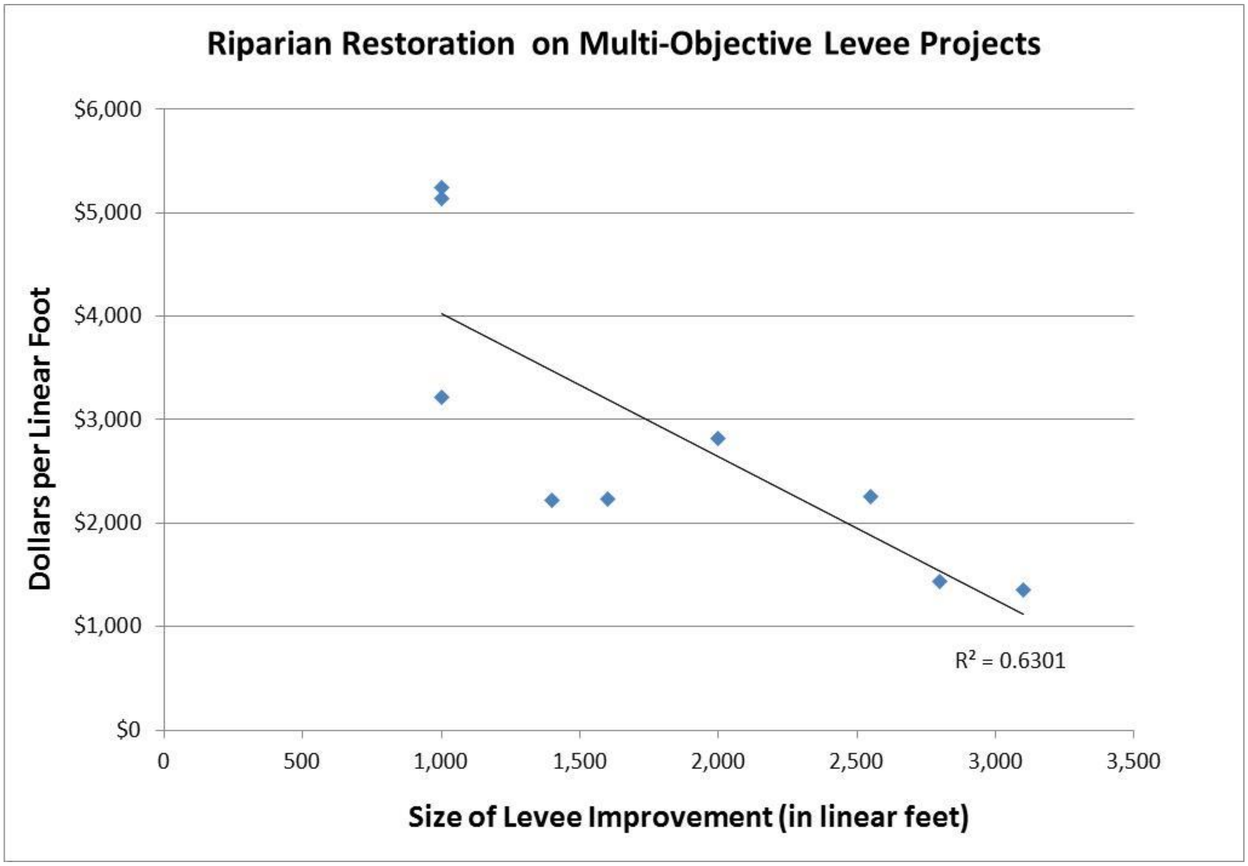

Figure 3. Relationship between size of multiple-objective levee improvement projects which include on-site habitat improvements and total cost of project.

<u>Offsite Mitigation Banks</u>

In 2012, DWR established the Bulk Credit Program which provides off-site mitigation credits for RDs participating in the Delta Levees Program. DWR purchased a large quantity of these mitigation credits through Westervelt Ecological Services' Cosumnes Flood Mitigation Bank, located near the confluence of the Cosumnes and Mokelumne Rivers. These mitigation credits include shaded riverine aquatic habitat, riparian forest, scrub-shrub, and freshwater marsh. The Delta Levees Program received a bulk discount from Westervelt when it purchased the mitigation credits and in turn those credits are available to the RDs at the same discounted rate (see Table 4 below). If engineering constraints limits the potential to restore habitat on-site along a levee, then purchasing these credits may be more cost effective than radically altering a levee construction design so it can accommodate riparian vegetation and other habitats. The Delta Levees Program has also funded offsite mitigation and enhancement projects to create riparian and freshwater wetland habitats. These habitat improvement efforts occurred in the interiors of Delta islands and not on top of levees. The average per acre costs of these projects is in a similar range as the costs of the Bulk Credit Program (see Table 5).

Table 4. DWR Bulk Credit Program Costs

Habitat Type	**Cost Information**	
Shaded Riverine Aquatic Habitat	$61	Per linear foot
Riparian Forest	$62,295	Per acre* *includes required buffer acreage that comprises the mitigation bank
Scrub-shrub	$62,295	
Freshwater Marsh	$120,000	

Source: DWR website (available at *http://www.water.ca.gov/floodsafe/fessro/environmental/dee/dee_prog_mit.cfm*

Table 5. DWR Off-Channel Habitat Mitigation and Enhancement Projects (Adjusted to 2015 Dollars)

Project Location	Acreage	Created habitat types	Total Cost (in millions)	Price per acre (in thousands)
Bradford Island	50	• Freshwater marsh (3 ac) • Scrub shrub (22 ac) • Riparian forest (25 ac)	$2.2	$45.0
Sherman Island (Parcel 11)	5.67	• Riparian forest • Freshwater marsh • Shrub scrub	$0.77	$135.6
Decker Island	26	• Tidal Freshwater marsh and riparian	$14.7	$563.8

Source: DWR staff

Setback Levees

In the mid 2000's, DWR constructed setback levees along the southern portions of Sherman Island and Twitchell Island at an average cost of approximately $1,000 to $2,200 per linear foot or $5.5-11.4 million per linear mile (in 2015 dollars). Some costs typically associated with setting back levees though were not included in this cost assessment, because of unique circumstances. First, the land where these particular setback levees were established was owned by DWR, so the cost of purchasing the land is not incorporated. Second, berms were placed on the landward toe of the levee many years prior to the construction of the setback levee, which helped stabilize the normally unstable peat soil. The cost of constructing these berms are unknown and were not included as costs for the setback levee project. Third, these setback levees were constructed adjacent to the existing levee decreasing the volume of fill and contributing to major savings in materials costs.

Future planned setback levees in the Delta are expected to be significantly more expensive. The total cost of the proposed setback levee in West Sacramento (Southport Project) is predicted to cost an average of $12,700 per linear foot or $67 million per linear mile (USACE 2014), while preliminary cost estimates from DWR staff and RD 1601 (RD 1601, 2014) place the estimate for future construction of setback levees along the southern portion of Twitchell Island around approximately $2,700 to $3,700 per linear foot ($14.5 to $20 million per linear mile). The cost of the setback levee for the Southport Project is substantially larger than DWR's past Delta setback levee projects because it includes the cost of land acquisition and the newly constructed levees will be fully setback from the existing levees.

Table 6. Cost of Setback Levees in the Delta, with costs adjusted to 2015 dollars

Setback Levee	Status	Linear Feet	Total Cost (in $ million)	Cost per linear foot
Sherman Island	Implemented	6,000	$12.9	$2,200
Twitchell Island	Implemented	2,400	$2.5	$1,000
Southport (West Sacramento)	Planned	29,300	$373.7	$12,700

Twitchell Island	Planned	23,000	63.1	$2,700

Of all the habitat improvement options considered, setback levees generally are one of the most expensive options if all cost considerations are taken into account. Site-specific considerations may make setback levee projects economically prudent. For example, USACE determined that the cost of constructing the setback levee for the Southport Project would be cheaper than retrofitting the existing levee (e.g., installation of slurry cutoffs, seepage walls, and stability berms), in part because the total length of the new setback levee would be shorter than the existing levee. Also, the original setback levee project at Twitchell Island constructed during the early 2000's was determined to be cheaper than continuing to maintain the existing levee, because the cost of regularly placing riprap to protect the levee from boat wake erosion became prohibitive.

V. NEXT STEPS

Based on the findings of the review, we suggest taking the following steps to improve the design of future restoration, enhancement, and mitigation projects and ensure that effectiveness can be better evaluated in the future. We note that long-term steady sources of funding and dedicated staff resources for monitoring and adaptive management will be necessary to assess and improve the performance of habitat projects over time.

1. Apply the Adaptive Management Framework to Future Projects.

An adaptive management framework building on past successes and experiences in the Delta is an integral part of resource management planning. For successful outcomes, future multi-objective projects should be planned, designed and executed based on the adaptive management framework, which incorporates the best available science into the decision making process. As defined in the Delta Reform Act, adaptive management is "a framework and flexible decision making process for ongoing knowledge acquisition, monitoring, and evaluation leading to continuous improvements in management planning and implementation of a project to achieve specified objectives" (Water Code section 85052). Delta Plan Policy G P1 calls for habitat restoration projects to use best available science and to develop an adaptive management plan with documented resources to implement that plan. (The definitions for "best available science" and "adaptive management" are documented in the Delta Plan's Appendix 1A and 1B, respectively).

Additionally, future habitat improvement projects must be strategically located and planned considering the best available predictive and conceptual models (e.g., SAM, MAST, SAIL) of target species (native and invasive) and future scenarios of changes in sea level, sediment supply, and infrastructure that will determine the long-term efficacy and sustainability of habitat management (Stralberg et al. 2011, Swanson et al. 2015).

2. Develop Appropriate Monitoring and Performance Measures.

Levee investments and habitat improvements are complex issues in the Delta and they are closely linked to the coequal goals of providing a more reliable water supply for California and restoring the Delta ecosystem. Hundreds of millions of State dollars have been spent on levee improvements and maintenance, as well as habitat enhancement and associated monitoring in the Delta. However, based on the results of this review, we found that these projects often lack appropriate measures to assess effectiveness in providing benefits to target species. Without delineating quantifiable criteria at the outset of a project, it is difficult to measure success.

3. Track the Incremental Cost of Habitat Improvements.

Better cost accounting of the habitat element of levee projects is necessary to better understand how funds have been invested to improve habitat in the Delta. Costs could be segregated by bidding construction and habitat components separately following the practice of the Sacramento Area Flood Control Agency (SAFCA). SAFCA does not bid/solicit levee improvements and habitat improvement projects in the same bid package providing cost segregation and flexibility in selecting the qualified and experienced contractors to implement the habitat improvement component of a multi-objective project.

DWR has recognized the importance of breaking down these costs into habitat and flood risk reduction components in order to make more informed decisions in how to disburse state funds for the Delta Levees Program. In the future, DWR intends to make such a cost breakdown a requirement for receiving grant funding. We support this proposed requirement of the Delta Levees Program, because it will enable DWR to better assign how state investments in Delta levees are being disbursed and if restoration objectives are being realized.

4. Carefully Consider the Tradeoffs Associated with Onsite and Offsite Mitigation.

During our review, we observed that onsite mitigation and enhancement of channel margin habitat for Delta levee projects is challenging. RDs, whose chief responsibility is protecting their island from flooding, have to be willing to not only allow vegetation to be established along or adjacent to their levees, but also committed for the long-term to maintain it. Multiple regulatory hurdles (e.g., Section 408 permits for alteration of USACE levee and Section 404 permits needed for wetland fill when constructing shallow water benches) can make incorporating habitat components into levee rehabilitation projects challenging, costly, and time-consuming. Conservation easements are not typically issued for habitat located within the levee prism based on concern that such habitat could very easily be destroyed if there is a need for emergency levee repairs; as a result, habitat mitigation typically cannot occur on levees because of requirements that such mitigation projects be protected into perpetuity through an easement. Additionally, design of habitat components on levees is constrained because ultimately it cannot compromise water conveyance by changing the performance or reliability of the channel to safely carry flood flows or by impairing levee structure.

Offsite mitigation was often used for projects in the Delta Levee Program, such as creation of marsh and riparian forest in the interior portions of islands, when habitat impacts were large during levee repair. When habitat impacts were relatively small, the RDs have satisfied their mitigation obligation through the purchase of bank credits (e.g., DWR's Bulk Credit Program). Generally, regulatory agencies prefer that mitigation occurs on-site with in-kind functions. However, if constraints or other considerations prevent the establishment of habitat mitigation on-site, then off-site mitigation may be the best option to mitigate for habitat impacts during levee repairs and rehabilitation.

Assessing whether the mitigation projects are effectively mitigating the impacts of lost habitat is challenging. In order to address that question fully, obtaining baseline monitoring data prior to removal of habitat and additional monitoring of mitigated habitat is needed. Questions of scale and location must be considered when implementing habitat mitigation. Area is not necessarily the best measure for habitat quality. For example, removal of a large contiguous (e.g., 200 ac) tidal marsh habitat cannot be adequately mitigated by many smaller mitigation sites (e.g., twenty 10 ac sites), because of the increased impact of edge effects and the loss of ecological functions that may only occur in larger-sized habitat patches.

Planning of habitat improvement sites should consider life history requirements of native species. For example, the mainstem Sacramento River, Sutter Slough, and Steamboat Slough are key migratory corridors for millions of Sacramento Valley-based Chinook salmon. As described in the Central Valley Salmon and Steelhead Recovery Plan, the first principle in salmonid conservation is to promote functioning, diverse, and interconnected habitats necessary for the viability of those species (NMFS 2014). Given the extensive loss of upriver spawning grounds and extreme modification of Delta habitats, care is needed to minimize the impacts of future levee projects and focus channel margin enhancement to protect and restore key migratory corridors. Degradation of channel margin habitat (e.g., removal of shaded riverine aquatic habitat and emergent vegetation by placement of bank erosion control riprap) along these migratory corridors for salmon should be mitigated onsite or at least elsewhere along the migratory corridor. If shaded riverine aquatic habitat is created in areas of the Delta that are not along major salmon migratory corridors, such as Middle River, then the mitigation would not be expected to provide the same ecological benefits to salmon.

Our review also indicated there have been successful examples where onsite habitat improvements have been incorporated into flood risk reduction projects, including the use of planting benches, made possible by the cooperation of willing landowners. Planting benches allow the use of biotechnical options and natural materials such as brush bundles and tule plantings to protect the waterside slopes of levees from wind wave erosion. Such approaches help minimize the need for frequent maintenance of riprap, soften the shoreline to benefit aquatic species, and provide structural protection for levees.

Shallow benches, fine substrate, gently sloping banks, and IWM increases occupation of native aquatic species and decreases occupation of invasive piscivorous fish (Fishery Foundation of California 2006; Gewant & Bollens 2012; Zanjanc 2013; FISHBIO 2015). In comparison riprapped substrates decrease native aquatic species and increase invasive piscivorous fish (Fishery Foundation of California 2006; MacLain & Castillo 2009; Zanjanc 2013; FISHBIO 2015). Hydrodynamic analyses to identify areas where riprap is necessary to protect levee slopes and where riprap may be removed and/or augmented with biotechnical treatments should be conducted in consultation with conceptual models of target aquatic species to maximize benefits (Golet et al. 2013).

5. Use Landscape-scale Planning to Guide Project Location and Design.

Correct spatial structure and patterns are critical prerequisites for restoring and maintaining desired ecosystem processes and functions, and for providing appropriate habitat for native species. Available opportunities and resources are often limited for habitat improvements and although habitat improvement actions at smaller scales produce benefits, planning for ecosystem restoration should always consider the larger spatial scales and landscape. In general, larger and more complex habitats will serve to benefit a wider array of wildlife (Brown 2003, Herbold et al. 2014). Furthermore, studies have shown that fragmented habitats provide considerably lower benefits than large contiguous habitat patches, since small areas of habitat are more prone to edge effects (e.g., increased predation risk or pollution from adjacent parcel). Although planning and implementation of restoration at a landscape scale can present formidable challenges, it also presents great opportunities to improve the overall health of Delta ecosystems.

The Delta Plan calls for the development of landscape-scale conceptual models, led by the Delta Science Program in collaboration with other agencies, academic institutions, and stakeholders. The current regulatory framework and constraints on project funding often places short-term benefits, such as a need to mitigate for an individual project, before long-term benefits of connectivity and appropriateness of scale. Landscape ecology provides a set of tools for assessing and prioritizing limited habitat improvement opportunities. Regardless of the size of a restoration site, projects should not be undertaken independently of one another, but viewed in a landscape context.

6. Measure Fish and Wildlife Response through a Standardized Regional Monitoring Program.

Much of the project monitoring we evaluated focused on parameters such as survival rate of planted trees or other parameters that can be measured quickly and inexpensively. While vegetation coverage is an indicator of habitat, and is widely used as one of the ways to track progress in ecosystem restoration, the Delta is a highly altered ecosystem and the relationships between vegetation coverage and benefits to target species are more complex than in systems that are closer to their historical ecological structure and function. Therefore, research and monitoring related to fish and wildlife response, as well as vegetation monitoring, is needed to determine whether projects are providing benefits to target species.

One of the challenges in promoting effective monitoring programs in levee-related habitat projects is that the amount of funding allotted for monitoring efforts is typically low. Monitoring is often short term (e.g., three years or less) which may not capture the response of the site to a range of environmental conditions (e.g., drought or flood). Additionally, benefits to fish and wildlife may be difficult to measure on a per-project basis. For instance, many species display marked variation in abundance and distribution influenced by distant riverine disturbances or intermittent large-scale processes (flooding, etc.) that cannot be captured without cumulative, long-term monitoring (Golet et al. 2008).

The Interagency Ecological Program's (IEP) notable long-term regional monitoring efforts throughout the Delta and San Francisco Bay have measured the variability in water quality, food webs, and fish assemblages over time. Additionally, the IEP Tidal Wetlands Monitoring Project Work Team is developing a system-wide generalized monitoring plan with a focus on the effectiveness of tidal marsh restoration projects on fish and the aquatic environment. A similar approach should target restoration sites beyond the required post-project monitoring period as interannual and seasonal variability of wildlife response may exceed the variability between different habitats being measured. To respond to these challenges, we recommend monitoring of levee-related habitat projects be replaced by a regional monitoring program that uses standardized sampling methodologies to assess native fish and wildlife responses to habitat projects.

Establishing Delta-wide monitoring protocols would allow us to better understand what has been learned from these projects and determine how they can be better designed in the future. Appropriate indicators to obtain performance data should be determined prior to groundbreaking, preferably during the infancy of a project. Additional data may be necessary for a complete analysis, but without baseline performance measures there is no standard by which to judge progress. Furthermore, the use of a standardized suite of ecological indicators makes a retrospective evaluation of habitat improvement project success a feasible option (Golet et al. 2013). In addition to Delta-wide monitoring protocols, a standard framework for reporting would allow for the development of a centralized database, making it easier to compare results across projects and improve understanding of the effectiveness of different habitat improvement options.

Standardized Fish Monitoring

Benefits for native fish and to channel margin habitat is often ostensibly a main driver in the design of mitigation and restoration projects in the Delta. However, monitoring of threatened and endangered native fish can be particularly challenging because it often requires obtaining incidental take permits (ITPs) from CDFW, as well as Section 7 permits from the federal wildlife agencies (United States Fish and Wildlife Service and the National Marine Fisheries Service). The permitting process is time-intensive and may play a role in preventing necessary monitoring from being conducted to assess the effects of levee projects. In response, we recommend that a State-supported regional monitoring program, supplied with the necessary listed fish species ITPs, conduct the monitoring of fish response to levee-related habitat projects. Such a monitoring program is being developed by the IEP Tidal Wetland Monitoring Work Group to assess future tidal marsh projects, especially the response of fish species to marsh restoration. Concurrently, DWR is building upon the work of the Tidal Wetland Monitoring Work Group, and through the working group, will seek to implement a similar monitoring program for assessing levee-related habitat projects. The key benefit of a regional monitoring program is that species-based or more advanced physical habitat monitoring could be funded and implemented by experienced agency scientists and/or consultants to collect long-term monitoring data.

Standardized Bird Monitoring

An objective of the Delta Reform Act is to increase habitat to support viable populations of migratory birds. In order to determine progress towards this objective, wide-scale monitoring of bird responses to habitat projects is needed. As such, we recommend that bird surveys use a peer reviewed standardized methodology across multiple projects. One example of such a program is the multi-tiered, integrated monitoring program implemented in 1995 by the Point Reyes Bird Observatory (PRBO, now Point Blue Conservation Science) and The Nature Conservancy (TNC). That program evaluated the efficacy of restoration activities at the Cosumnes River Preserve (CRP), an important area supporting a wide diversity of avifauna that was once abundant in the Central Valley (Gaines 1974). Information was collected on habitat usage (in both restored and adjacent riparian habitat), species richness, diversity, and demographic parameters to assess the health of the songbird community. Detailed, long-term monitoring efforts such as this are needed to assess linkages between population trends, riparian restoration, and localized flood regimes.

7. Use the Delta Levees and Habitat Advisory Committee (DLHAC) to discuss incorporation of effective habitat improvement components into levee projects.

The DLHAC is a regular standing meeting between DWR, CDFW, Delta RDs, and other Delta stakeholders. The DLHAC, or a subcommittee thereof, could provide a venue for agencies and RDs to collaborate on the design, adaptive management, and performance of levee-related habitat projects. We envision that the Delta Science Program can become involved with the DLHAC to advise on project design and support the RDs integrating adaptive management into levee project planning and maintenance.

Final Remarks

None of the recommendations we have made in this report are novel; in one form or another, they have been previously suggested by other agencies and/or Delta stakeholders. Implementing them, however, will take leadership, persistence, and adequate long-term funding. Aside from calling for tracking of the cost of habitat improvements in levee projects (as mentioned previously, FESSRO staff have committed to doing so in the future), the recommendations in this report either are related to promoting best available science, or adaptively managing projects (see Appendix 2 for more details).

Recently, some progress has occurred that would help implement the next steps identified in this review. This includes the following:

- Delta Science Program provides adaptive management and science liaisons who will work with agencies and project proponents to base habitat improvement project designs based on best available science and adaptive management at an individual project scale.
- Delta Conservancy and Delta Science Program are leading an effort to develop landscape-scale conceptual models for different regions of the Delta and Suisun Marsh. These conceptual models will help guide future restoration designs and will be vetted through a process that solicits input from both the regulatory and wildlife agencies as well local stakeholders.
- The Delta Independent Science Board is currently drafting a report on how adaptive management in the Delta can be improved.
- CDFW is leading an effort to develop a framework for regional monitoring of restored tidal wetlands in the Delta and Suisun Marsh; it is expected to be completed in 2016. DWR experts are closely involved in this effort and once it is completed, they plan on building upon the foundation of this framework and adapting it as necessary to assess levee-related habitat projects that affect channel margin habitat (e.g., setback levee projects). The eventual goal is to implement a regional monitoring program guided by the monitoring framework to look back at past levee projects as well as provide monitoring support for future levee-related habitat projects. The major benefit of monitoring the status of projects implemented in years or decades past would that it would provide insights into how these habitat improvement projects function once they are fully mature.

Overall, a long-term commitment to and funding for adaptive management is needed to address the issues identified in this report. As the DLIS guides State investments in Delta levees to achieve flood risk reduction, there will be a concurrent effort to undertake habitat improvements to address the impacts of levee construction on wildlife habitats and native species. We look forward to working collaboratively with other agencies and stakeholders to ensure that the State makes wise investments in Delta levees and associated habitats and makes progress toward achieving the coequal goal of ecosystem restoration in the Delta.

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APPENDIX 1. LESSONS LEARNED FROM PAST PROJECTS

Although we could not assess project effectiveness for several of the projects reviewed, many general lessons were gleaned from these efforts. Lessons learned derived from project reviews and the interview process are summarized below by habitat type.

Lessons Learned – Channel Margin Habitat and SRA

Of the 15 projects reviewed, 12 of them improved or restored riparian habitat and seven of them improved or restored SRA (see Appendix 5). All of the projects that implemented riparian habitat or SRA improvement objectives had performance measures related to vegetation success measured by percent survival, percent cover, and/or growth. Four projects also measured fish occupancy and two projects measured fish and bird occupancy. All riparian habitat enhancement projects met vegetation related performance targets.

We reviewed both small and large-scale levee improvement projects, ranging from projects that affected just 700 linear feet to those that were over two linear miles in size. Although many of these projects include revetments (e.g., riprap), establishment of waterside planting benches can enhance the value and increase the occupancy of channel margin habitats by Chinook salmon juveniles and fry (FISHBIO 2014). Analysis of gastric contents suggest that a high proportion of juvenile salmonids actively use levee repair sites along the Sacramento and Bear Rivers and Steamboat, Sutter, and Cache Sloughs not only as a migratory corridor, but also for rearing and foraging (FISHBIO 2014).

In applying the Standardized Assessment Methodology (SAM) to USACE's Sacramento River Bank Protection Project (SRBPP) emergency repair sites with and without bank revetment, modeling outcomes indicated a net loss of habitat that required mitigation measures such as the installation of IWM and riparian cover to provide SRA for salmonids. These recent projects, informed by a robust, site-specific model highlight the value of modeling links between project objectives and design and implementation actions. Many habitat restoration projects could benefit from this type of predictive model when used in the planning phase.

Habitat features of levee repair sites along the Sacramento and Bear Rivers and Steamboat, Sutter, and Cache Sloughs were evaluated to determine which features promote salmonid use and should be incorporated into future levee projects to maximize habitat value. Habitat utilization by fish species of interest (e.g., Chinook salmon, steelhead) were compared between mitigated and unmitigated levee repair sites and naturalized sites that had not been riprapped and were dominated by naturally established native riparian and emergent vegetation. Mitigated sites were post-2006 emergency levee repair sites that incorporated habitat mitigation features and unmitigated sites represented typical levee repairs that consisted of rock revetment without additional habitat enhancement. Boat electrofishing surveys showed no differences in the fish community composition between mitigated sites and naturalized sites. However, habitat occupancy of Chinook salmon fry was significantly higher at naturalized sites than at unmitigated sites with riprap only.

Similarly, riprapped banks without instream or overhead cover along the Lower American River showed the lowest occupancy by Chinook salmon juveniles during their critical rearing period and outmigration in the spring (Fishery Foundation of California 2006). Where monitoring data exist, it appears that the use of habitat by juvenile salmon significantly related to the amount of instream and overhead cover (size, type, and quantity) available (Fishery Foundation of California 2006). Snorkel surveys of channel margin enhancement sites along the Lower American River found that riprapped sampling units with high cover had similar juvenile Chinook salmon densities to un-rocked units with similar cover values during high river stages (Fishery Foundation of California 2006). After a few years of vegetative growth, enhanced channel margins with large IWM and a scalloping of the rocked edge show relatively high utilization by young salmon (Fishery Foundation of California 2006). It is important to point out that river stage plays a crucial role in determining the habitat usage of these enhancement sites. The amount of cover available in enhanced rocked (riprapped) sites and non-rocked sites decreased greatly when river flows and stage fell below 2000 cfs and 18 ft, respectively (Fishery Foundation of California 2006). On the rocked mitigation sites, waterside planting benches were exposed during low flows making the habitat unavailable and resulting in a significant decrease in fish densities (Fishery Foundation of California 2006). This result suggests that more attention needs be given to create multiple depths of near-shore bathymetry during the design phase of channel margin enhancement projects.

Juvenile Chinook salmon were found in greater numbers over sand/silt substrate rather than substrate composed predominantly of large rock. Conversely, one of the most abundant introduced predatory species, smallmouth bass (> 150 mm FL), were found to be 10 times more prevalent over rocky substrate compared to areas with sand/silt substrate and more prevalent along shores with steeply sloping banks. Chinook fry and steelhead prefer gently sloping banks compared to steep bank slopes, highlighting the value of readily inundated shallow water habitat with sand/silt substrate (FISHBIO 2014).

In addition to shallow water, gently sloping banks, and fine substrate, habitat features such as low- or medium-density submerged vegetation or instream woody material (IWM) encourage habitat use by Chinook salmon fry and juveniles. Nearshore habitat use by Chinook fry increased by two- and three-fold with the presence of IWM in low and medium densities, respectively. The presence of high density IWM did not significantly influence occupancy probability of juvenile Chinook salmon; however, it negatively affected the use of habitat by fry by about 75 percent compared to similar sites that lacked high-density IWM. This may be related to the finding that habitat use of the piscivorous smallmouth bass (> 150 mm FL) increases by 20-fold with increasing density of IWM in nearshore habitats compared to locations lacking IWM (FISHBIO 2014). While the presence of woody material increases habitat use by Chinook salmon (juvenile and fry) and smallmouth bass; the density of the woody material is the factor associated with whether habitat use by smallmouth bass and juvenile Chinook salmon will increase (“low- and medium-density”), or smallmouth bass (> 150 mm FL) occupancy will increase (“high-density”). In this study area, naturalized sites have the largest amount of high-density woody material, but other habitat characteristics (e.g., substrate, depth, current velocity) at these sites substantially reduce occupancy by smallmouth bass (> 150 mm FL) (FISHBIO 2014).

Depending on how readily native vegetation will establish naturally on a site, plantings could be spaced to allow for natural colonization. However, in many cases monitoring required on waterside planting benches must meet USACE section 404 permitting requirements or stated SRA habitat project goals. Typically, this means that more plantings must be made during the contracted maintenance period to achieve stated SRA goals and compensate for tree mortality. Tree loss to beaver damage is fairly common in Delta levee enhancement projects. Frequently, every planted tree needs a large cage constructed of strong materials to protect it from beavers.

The ideal size of a habitat patch to be restored is dependent on the patch size requirements for target species. The construction of habitat using dredged materials showed that the creation of one large (Venice Cut) versus several smaller (eight on Donlon Island) dredged material islands (DMI) had lower construction cost and supported a greater variety and abundance of vegetation and avian species (England et al. 1990). Further, it was suggested that the constructing one large DMI with low slopes and irregular edges could support the same shallow water fish community as several smaller islands (England et al. 1990).

Lessons Learned – Riparian Habitat

Restoration and habitat enhancement needs to continue if we wish increase the chances of survival for target species at the population level, but where should our efforts be focused and how much is needed? State agencies need to continue to convene workshops to elicit advice from wildlife experts, consultants, and restoration practitioners to determine priority sites within the management area that will benefit most from habitat improvement efforts. From an ecological standpoint, any diverse natural habitat should be preserved. Legacy and existing habitat is more developed and structurally complex than most enhancement projects would be able to achieve; therefore, it is usually cheaper to preserve this habitat, if feasible, considering the construction, planting, and maintenance costs of enhancement projects. The current riparian forest habitat in the Delta is highly fragmented and only a small fraction of what used to exist in the historical Delta remains (Whipple et al 2012). If populations of native species that depend on riparian habitat are to recover, both protection of existing habitat and creation of new riparian habitat are necessary. Habitat projects that increase connectivity along important migratory corridors are expected to provide greater benefits for native terrestrial and aquatic species than creating habitat that is isolated from other patches of like habitat.

In California, riparian forests provide the most critical habitats for foraging and nesting landbirds. In general, for avian species, species richness (i.e., number of different species present) will increase proportionally with habitat availability as the extent and complexity of vegetative cover develops. Despite the lack of design criteria to create dredged material islands (DMI) in flooded Venice Cut and Donlon Island, considerable habitat development occurred during the three to five years following the deposition of dredged material from the widening and deepening of the Stockton Deep

Water Ship Channel (England et al. 1990). Tule marsh and riparian vegetation established through natural colonization, providing 81 acres of shallow water, wetland, and upland (riparian) habitat, and continued to develop over a three-year monitoring program (England et al. 1990). Subsequent surveys found that a wide diversity of birds (122 species) begun to utilize the habitats, with abundances increasing as acreage and quality of vegetative cover developed (England et al. 1990).

The bird monitoring we reviewed was conducted a few years after project completion, with data for a one-to-three year period. For riparian restoration projects, species numbers and richness tends to increase as succession continues on a site and mature canopies develop (Golet et al. 2008). Therefore, long-term wildlife monitoring efforts (e.g., birds, fishes, insects, mammals) that can provide additional insights on the inter-annual variation in wildlife community compositions and habitat use is needed.

Many restoration sites, although varying in trajectory in vegetation characteristics as they mature, show a similar sigmoidal bird response representing an initial rapid increase in bird abundance or diversity followed by a plateau (Nur et al. 2006). Because it is likely that young riparian restoration sites have different wildlife use patterns than mature restoration sites or remnant forests, it would be beneficial to conduct comparison studies in naturally recruited riparian forests to see if restoration sites can provide the same ecological functions (Golet et al. 2008). Studies investigating bird habitat relationships in riparian areas of the Central Valley and along the Sacramento River verify the importance of an understory composed of diverse vegetation that contributes to the overall structural complexity of a forest. The abundance of several species of landbirds were highly correlated to cover of blackberry (*Rubus* spp.), mugwort (*Artemesia douglasiana*), and herbs (Nur et al. 2004). Findings such as these should help direct restoration planting design to include a diverse understory.

Nesting activities are dependent on the successional stage of the riparian habitat and the maturation of preferred woody shrubs or trees. Newly restored areas can provide ideal nesting sites for species that favor early to mid-successional riparian habitats, such as least Bell's vireos (Golet et al. 2011). After sites have had time to mature (10 or more years) they more closely mimic the complexity found in legacy forest patches (Golet et al. 2008) preferred by raptors, herons, and neotropical migrant songbirds. Canopy closure is another factor that contributes to the complexity of a habitat, but until detailed studies of microhabitat use are undertaken, habitat enhancement will continue to focus on dominant tree species (Laymon & Halterman 1989).

In designing any restoration site, the nature of adjacent habitats and connectivity between the areas needs to be taken into consideration. A study comparing restoration sites of different ages, as well as agricultural and remnant riparian sites along the middle Sacramento River stretch from Red Bluff to Colusa confirm benefits for special-status species (Golet et al. 2008). Increases in avian abundance were not only seen at restoration sites, but also in adjacent remnant forest patches, suggesting that positive spill-over effects may be occurring (Golet et al. 2008). To support a river's natural cooling, riparian corridors should connect with larger tracts of riparian habitat (> 20 ha) which allow convection currents of air to flow from the cool forests over the water (CALFED 2000 from Golet et al. 2011). A long-term monitoring study in the Cosumnes River Preserve (CRP) demonstrated linkages between population trends of riparian songbirds and flooding events on the adjacent floodplain that were dependent on species and site (restored vs. mature sites) (Nur et al. 2006).

The northern tip of Decker Island in the western Delta was restored in 2000 (14 acres) and 2004 (12 acres) in an attempt to "recreate" historical river habitat. The levee on Horseshoe Bend was breached to allow tidal flow into the island and the slough-like channels that were constructed. Native trees, shrubs and grasses were planted to provide freshwater emergent wetland and riparian habitat for wildlife. Bird surveys conducted years after the project completion (2007-2008) found higher bird densities (number of birds detected per hectare) for almost all species at the restoration site than the reference site that characterized pre-project conditions. The reference site was an adjacent, non-restored area on the island consisting of upland pasture and valley foothill riparian habitats while the restoration site contained freshwater emergent wetland and newly planted riparian habitat. Concurrent surveys were also conducted in a remnant mature, late successional valley foothill riparian habitat on Elk Slough in the northern Delta. Over time, with the establishment and maturation of tree plantings species richness at the restoration site has been increasing but is still lower than that of Elk Slough, which is expected as the newly established riparian vegetation in the restored area will take time to mature and achieve similar ecological functions as an area of late successional forest. The increase in species richness at the restoration site is attributed to the arrival of cavity nesting birds now able to utilize maturing trees. In general, riparian habitat benefits to target species scale with both riparian habitat corridor size and age (Golet et al. 2002; 2013; England et. al. 1990). A study comparing restoration sites of different ages, as well as agricultural and remnant riparian sites, along the middle Sacramento River stretch from Red Bluff to Colusa, showed a similar pattern of species richness of landbirds increasing as restoration sites matured (Golet et al. 2008).

Riparian tree species naturally established on DMIs in elevation zones of 0.0 to +3-3.5 ft MWL that were inundated daily but also exposed for more than half the time (England et al. 1990). Willow (*Salix* spp.) development was rapid, tending to occur at higher elevations and growing most readily on or near peat soils (England et al. 1990). One report on the survival of riparian enhancement plantings in the Delta from a survey of 1463 trees distributed along approximately 7.7 km of Georgiana Slough, found: 1074 boxelder, 1 buckeye, 91 alders, 213 ash, 8 sycamore, 65 valley oak, 4 black willow, 3 red willow, and 4 arroyo willow (Hart, 2006). The report does not provide information on the number of species originally planted; therefore, we cannot assess which species had the greatest survival.

One habitat mitigation project report documents the establishment of a mosaic of riparian plantings by considering the following criteria: topography, soil types, depth to groundwater, location, and extent of native and non-native plant species (Stillwater Sciences 2011). Riparian habitat plantings in the San Joaquin River NWR were similarly planned based upon field elevations, observed depth to water table, and habitat needs of the target species. San Joaquin River NWR riparian restoration project had a measurable benefit to at least one target species, the endangered riparian brush rabbit (*Sylvilagus bachmani riparius*) (River Partners 2003; 2014; ESRP 2012). Riparian plantings were successful relative to vegetation-related performance measures and are expected to be sustainable after maintenance and irrigation has ended (River Partners 2014). The lesson learned from these reports shows that a mosaic of riparian habitat plantings can be established and maintained when multiple physical (e.g., topography, soil types, depth to groundwater, location) and biological factors (e.g., extent of native and non-native plant species, plant specific needs) are considered (Griggs 2009).

Lessons Learned – Tidal Marsh

Four of the 15 projects reviewed herein implemented tidal marsh restoration and/or enhancement (Stockton DMI, Donlon Island, Sherman Island, and Twitchell Island) with one report presenting a study of tule species (*Scirpus acutus*, *S. americanus*, and *S. californicus*) survival as a function of elevation (Hart, 2006). Two tidal marshes were restored using dredged material at flooded Donlon Island and Venice Cut (Stockton DMI) while a tidal marsh at Decker Island was restored by constructing shallow intertidal channels. The tidal marsh enhancement sites at the two setback levee sites were located in the intertidal swale between the setback levee and abandoned levee. The Donlon Island site was the only project with a five-year post-construction fish-monitoring program. Grimaldo et al. (2012) studied fish assemblages for two years at Venice Cut 12 years after project completion.

Juvenile Chinook salmon were caught in the subtidal channels and shores of the habitat development project on Decker Island in the western Delta in the months of March, April and May. However, the restoration site created a more ideal spawning and rearing area for invasive largemouth bass (*Micropterus salmoides*) and invasive aquatic vegetation (IAV) than for juvenile salmon. Less than two years after the completion of the first phase of the project, over 90 percent of the tidal channels were completely clogged with invasive Brazilian waterweed (*Egeria densa*) and water hyacinth (*Eichhornia crassipes*). Before fish monitoring could take place on the Decker Island enhancement site, IAV needed to be cleared from the dead-end channels. The removal of IAV may benefit native species, but will not prevent centrarchids from occupying the area or spawning (Rockriver 2008).

As thousands of young-of-the-year (YOY) largemouth bass were caught in one of the channels on Decker Island before it was overgrown with water hyacinth and Brazilian waterweed, it is clear that shallow backwater conditions will be exploited by non-native plants and fishes. “As with problematic non-native plants, certain animal populations may need to be curtailed via control measures (Golet et al. 2008).” Suggested actions to remedy the problem included creating rocky bottoms, very soft muddy bottoms, or some type of artificial substrate to make the channels less suitable for largemouth bass spawning (Rockriver 2008). Construction during Phase II of Decker Island restoration included mudflats and tule habitats that were designed to dewater and decrease centrarchid reproductive success by causing egg desiccation and encouraging avian predation on the eggs. Site visits indicate that tidal marsh restoration may be benefiting several terrestrial species with Pacific Pond Turtle, river otters, various snake species, raptors, and many species of passerine birds being noted by DWR staff. Future restoration efforts that aim to create shallow water habitat to benefit native fishes should emphasize intertidal habitats that can become inundated and dewater on lower tides.

Similarly, Grimaldo et al. (2012) found that non-native fishes in association with submerged aquatic vegetation (SAV) dominated reference and restored (e.g., Venice Cut) tidal marshes. Without monitoring data for the setback levee sites, we cannot determine if tidal marsh enhancement at these sites are dominated by native or non-native fishes. Given the high correlation between IAV and non-native fishes, tidal marsh restoration sites should be appropriately designed to drain at low tides and/or be located in portions of the Delta with lower colonization rates by invasive plants (Grimaldo et al. 2012).

Historic freshwater tidal marshes in the Delta, dominated by tule species, formed between mean higher high water and 0.3 m below mean lower low water (Atwater & Hedel 1976). The tidal elevations of DMIs in the flooded islands of Venice Cut and Donlon were an excellent predictor of what would grow. Natural colonization of tules (*S. californicus*), cattails (*Typha* spp.), and flatsedge (*Cyperus eragrostis*) proceeded rapidly after construction of DMIs and occurred primarily between -2.0 and +1.0 ft MWL (mean water level) (England et al. 1990). In a bank stabilization and habitat enhancement project on a slough off of the south fork of the Mokelumne River, tules colonized some of the planting benches intended for upland riparian plants, an indication that the site elevation was more suitable for freshwater emergent vegetation.

Plantings of the tule species *S. acutus, S. americanus*, and *S. californicus* (50 plantings each) show that after one year with no subsequent maintenance, only one planting of *S. americanus* had survived, and that plantings of *S. californicus* exhibited greater survival and colonization than *S. acutus* at all elevations from -2 ft to +1 ft elevation (no reference to local water levels given; Hart, 2006). Survival and colonization was greatest at higher elevations (Hart, 2006). Ongoing sea-level rise, tidal marsh restoration, and changes levee configuration will affect the tidal prism and associated water-level variations in the Delta making tidal marsh sustainability highly elevation dependent. Future tidal marsh restoration should be strategically implemented to maximize long-term sustainability, considering future changes in the intertidal zone and sediment supply, and should be placed in the larger context of landscape-scale restoration (Herbold et al. 2014; Swanson et al. 2015).

Tidal marsh restoration design must consider site-specific, location, and species-specific design considerations to benefit target species (Herbold et al. 2014). For example, recent work shows that food-web benefits from tidal marsh are spatially limited (Herbold et al. 2014); therefore, tidal marsh restoration designed to benefit target species (e.g., Delta smelt, Chinook salmon) must be located in the range of target species. Furthermore, abundant IAV in the central and south Delta may reduce tidal marsh restoration benefits to native aquatic species; therefore, some have suggested that tidal marsh restoration should be concentrated in regions where IAV colonization is less likely and target species, such as Delta smelt and Chinook Salmon, are more prevalent (e.g., the north Delta; Grimaldo et al. 2012). In the case of wetland restoration, water and shorebirds will respond to resource availability provided by the benthic and fish communities. Decreasing the edge effects in marsh habitats would lessen the impact of nest robbing and increase the reproductive success of marsh birds.

APPENDIX 2. RECOMMENDATIONS REGARDING THE USE OF ADAPTIVE MANAGEMENT

Recommendations given in this section follow “A Nine Step Adaptive Management Framework” in Appendix C of the Delta Plan (Appendix of Figure C-1). It is worthwhile to note that while it may be inappropriate to require an adaptive management plan for every situation, larger-scale or programmatic restoration efforts should employ adaptive management so that we can learn from these efforts and improve the scientific basis of management practices. Adaptive management liaisons in the Delta Science Program can guide practitioners through the steps of the adaptive management cycle that are appropriate for specific projects.

Step 1 – Define/Redefine the Problem

Defining a problem clearly sets the foundation for effective adaptive management. This step needs to be addressed at the outset of a project and all parties involved should come to consensus about what the problem is. Having a clear definition of the problem early on will give managers and practitioners a better idea of the types and level of collaboration necessary to address the problem effectively.

Step 2 – Establish Goals and Objectives

After the problem has been carefully articulated, the goals and objectives of the project need to be established. In order to determine whether your project is having the intended effects, it is important to set objectives that can be assessed by measurable outcomes. Goals may be site-specific, but should take into account ecological and species targets for prioritizing actions. Gillilan et al. 2015 have proposed using specific terminology for channel alteration projects based on resulting ecosystem function and geomorphic variability (Figure 4). Restoration, enhancement, and erosion control and containment are a subset of terms applicable to stream and river bank improvement efforts.

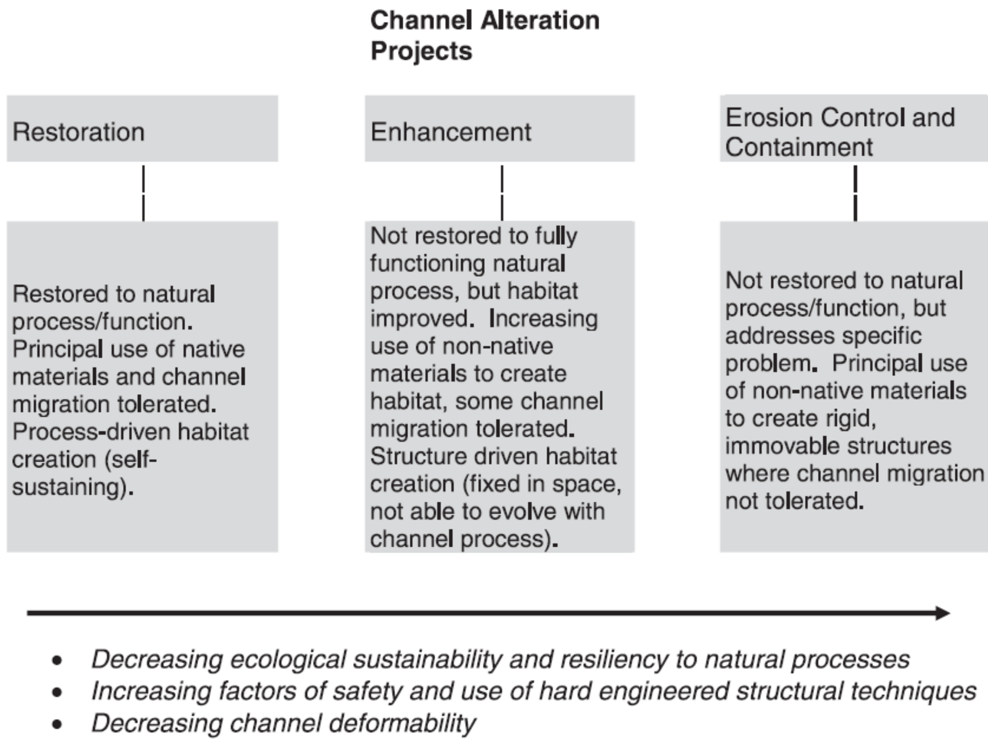

Figure 4. Geomorphic restoration project type continuum from Gillilan et al. 2015

Step 3 – Model Linkages between Objectives and Proposed Actions

Conceptual, quantitative, computer, and simulation/predictive models can help establish the mechanisms behind causal relationships, identify key uncertainties, and view potential outcomes of various options. Conceptual models can explain why an action will achieve an objective based on best available science. The application of models alone should not determine proposed actions, but rather provide additional support when used in conjunction with practitioner expertise, field experience, and scientific research. Project scope and budgetary concerns along with the availability and sophistication of appropriate models will determine which models will be used.

Determining habitat quality indices for species of interest is necessary to quantitatively rank potential sites based on the benefits they offer. Conservation efforts and site prioritization should be informed by habitat distribution models for species of concern. Conceptual models can provide insight into the benefits for target species at different life stages and times of year. Based on the needs of target species from their conceptual model, we can develop the actions to create the appropriate habitat to support them. The implementation of a project should generate scientific questions and test hypotheses to help improve the conceptual models and reduce uncertainty.

If a goal of the project is to create or enhance habitat for Delta smelt, Chinook salmon, steelhead, or sturgeon, the IEP conceptual models (i.e., Management, Analysis, and Synthesis Team [MAST] or Salmonid/Steelhead/Sturgeon Assessment Indicators by Life Stages [SAIL]) should be consulted to model linkages between objectives and proposed actions. Levee construction and repair mitigation measures to offset environmental impacts along the Sacramento River can be evaluated on a per-species basis using the Standardized Assessment Methodology (SAM). The SAM is a predictive model developed by Stillwater Sciences for the Corps of Engineers' Sacramento River Bank Protection Project (SRBPP) emergency repair sites (some of which are included in this review). The model identifies and quantifies the response of threatened and endangered fish species at each life stage to a variety of bank protection measures. By ranking the quality and quantity of habitat variables (e.g., bank slope, floodplain availability, bank substrate size, instream structure, aquatic vegetation, and overhanging shade), the SAM can assess species response for each season, target year, and life stage. In this way, agency staff and consultants can determine what design components to employ to best avoid, minimize, or compensate for project impacts. The SAM can be used to predict the impacts of many bank protection measures including setback levees, planted benches, installed wood, vertical extent of bank armor, rock sizes, rock clusters, fish groins, launchable riprap, and various biotechnical treatments (Stillwater Sciences 2015).

Step 4 – Select Action(s) (research, pilot, or full-scale) and Develop Performance Measures

There are three levels of action to consider carefully when planning a restoration project: research, pilot, and full-scale. Even if the intended action is a full-scale restoration, what you know about the cause-and-effect relationships in the system should determine what type of action is appropriate. If not much is known about the system and there is high uncertainty that taking a specific action or set of actions will result in the expected outcome, more research should be done. If there are informed hypotheses regarding the potential outcome despite large knowledge gaps, a pilot study could be conducted to test those assertions. Additionally, if project costs are high or may produce irreversible effects, it would be wise and appropriate to conduct a pilot-study prior to undertaking full-scale implementation. If there is a high degree of certainty that taking an action will result in a desired outcome that addresses the problem, a full-scale restoration project could be implemented. Planning should be well-documented throughout the entire process.

Determining the effectiveness of a project is very difficult if adequate performance measures are not put into place. Performance measures should consist of a set of metrics to objectively evaluate whether restoration practitioners have achieved their project objectives and target goals. The absence of agreed-upon indicators and an overall framework for evaluation make it difficult to assess performance (Kleinschmidt et al. 2003). Appropriate indicators should be developed and an effective monitoring program to obtain those data should be determined prior to groundbreaking, preferably at the beginning of a project. In retrospect, additional data may be necessary for a complete analysis, but without baseline performance measures, there is no yardstick to judge progress. In an effort to better understand what has been learned from these projects and determine how they can be better designed in the future, Delta-wide monitoring protocols should be established. Furthermore, the use of a standardized suite of ecological indicators makes a retrospective evaluation of restoration success a feasible option (Golet et al. 2008).

Step 5 – Design & Implement Actions

The design of project actions should be planned alongside the development of monitoring plans to be effective. Establishing monitoring plans during the evolution of project design will result in more focused monitoring and informative data collection. An assessment of habitat quality is essential if in-kind mitigation is to occur. Existing habitat should be assessed using standardized vegetation mapping techniques to assess its quality and extent.

Choosing a restoration site and determining the scale of a project should target locations with ecologically meaningful characteristics, rather than being based on river mile or ownership boundaries (Seavey et al. 2012). For every restoration or enhancement project there are site-specific considerations that will determine what type of project is possible and how it should be designed. If restoration efforts are to result in the desired communities of plants and animals, many factors must be taken into account including, but not limited to: elevation, land use history, soil types, moisture content, wave wash, flood regime, residence time, nutrient and detritus supplies, water depth, groundwater supply, hydrograph, predators, and non-native invasives. Considering that the origin of materials used to construct most Delta levees is unknown, pre-construction evaluation of the soil conditions onsite is important. Similarly, as levees are subject to many hydrological forces including river flow/stage, tides, boat wakes, and wind fetch, an evaluation of hydrological and erosional factors should be made.

Techniques from projects that have shown increased usage by target species in the past should inform future project design.

Step 6 – Design and Implement Monitoring Plan

Despite widespread agreement in the scientific community regarding the importance of monitoring to evaluating restoration success, most projects have little or no monitoring (Golet et al. 2008). When projects are designed to meet permit or regulatory requirements, compliance monitoring is usually conducted for three-to-five years to ensure that the habitats created achieve success criteria through survival and vigor of planted species and ensure that non-native invasive weeds are kept below established thresholds. Based on compliance monitoring alone, it is difficult to determine how levee projects with habitat enhancement components are impacting wildlife, yet funding for monitoring of wildlife response is often unavailable, particularly for small-scale projects.

From the figures we have been provided for this review, it appears that the considerable bulk of project funds go to construction costs while only a small percentage (< 2 percent in some cases) go to post-project activities such as monitoring and assessment. In a previous review of 44 river restoration projects in California, interviewees who served as project managers stated that lack of funding (48 percent of respondents) and lack of staff or time (32 percent of respondents) were the main constraints for monitoring (Kondolf et al. 2007). If we are to effectively learn from these projects, additional funds are needed to invest in post-project monitoring, especially over the long term.

Step 7 – Analyze, Synthesize, and Evaluate

Timely analysis of monitoring data is necessary to evaluate the effectiveness of actions as they progress and adaptive management is still possible. Too often the analysis, synthesis, and evaluation of monitoring data is not conducted or is done a very short time after the construction of a project. Analysis of management actions typically compares responses between treatments over time and against controls (if any). It follows that determining whether these success criteria have been met requires the development of an assessment protocol and suitable indicators (Step 4). In and of themselves, the development of such metrics could be a costly objective (Gillilan et al. 2005; Palmer et al. 2005), but would emerge as a matter of course if there were a concerted effort to design restoration projects as experiments.

Adaptive management experiments are generally implemented at a larger scale than those used for traditional scientific experiments (Morghan et al. 2006). Management sites often comprise heterogeneous units with varied land-use histories, making it difficult to partition equivalent experimental units into a statistically significant set of replicates (Walters 1986). Resource and personnel limitations, time constraints, and lack of funding can make it difficult to conduct adaptive management experiments at the management scale, but this is what is necessary to determine effectiveness. The opportunistic development of smaller experimental plots within a restoration site can make experimental adaptive management a viable option for most projects.

Despite heavy investment in restoration projects, including $500 million funded by CALFED Bay-Delta Ecosystem Restoration Program (ERP) alone from 1996 to 2005, the effectiveness of these projects remains largely unevaluated (Kondolf et al. 2007). Even with a clear lack of measurable objectives, over half of interviewed restoration managers stated that their projects were completely successful (52 percent) and many claimed that their projects were partially successful (36 percent) (Kondolf et al. 2007). The success of restoration efforts is difficult to measure as they tend to be judged using a mixture of financial indices and generalized, subjective measures including cost-effectiveness, stakeholder satisfaction, visual aesthetics, infrastructure protection, risk-reduction, increased recreational opportunities, community outreach, and contribution to the advancement of restoration science (learning success) (Palmer et al. 2005). Most restoration practitioners emphasize the need for standardized metrics to evaluate success.

Step 8 – Communicate Current Understanding

The design of habitat restoration and enhancement projects can benefit greatly through consultation with researchers. Agency managers and scientists with years of expertise in different systems need to come together to determine the best strategies for projects in the Delta. Sophisticated hydrodynamic, elevation, and species-specific models should inform management practices and determine the most suitable sites for improvement. Improving science communication is essential if we are to distill the importance of scientific findings for resource managers and decision-makers.

Coordinated efforts and forums like the IEP, the Delta Restoration Network (DRN), and the Delta Plan Interagency Implementation Committee (DPIIC) are good examples of agencies working collaboratively to facilitate the exchange of information and identify critical science actions needed to benefit the Delta. Given the extent of restoration projects that have been undertaken in and around the Delta, a database of restoration projects would be helpful for restoration practitioners and agency managers alike.

California is one of the forerunners of river restoration in terms of number of projects and overall investments, yet the state lacks a comprehensive catalog documenting the design, implementation, monitoring, and evaluation of restoration efforts (Kondolf et al. 2007). Even following a positive evaluation of their projects, restoration practitioners often only disseminate information in internal agency reports or report summaries for funders (Kondolf et al. 2007). In order to inform investments and improve future projects, we need a web-based catalog that would be easy to access for the broader scientific community, state agencies, NGOs, and stakeholders. Many efforts to understand the extent of California restoration projects by compiling summary databases or interviewing restoration practitioners have faced substantial difficulties in their data gathering phases (Kondolf et al. 2007). The National River Restoration Science Synthesis (NRRSS) effort compiled a large database (4,023 stream restoration projects) by mining existing databases and requesting agency records. Data fields populated included project year, location, basin size, project size, intent(s), responsible agency and contact information, planning and construction dates, project activities, monitoring component, and record source (Kondolf et al. 2007).

Step 9 – Adapt

When project results are beneficial, design techniques and lessons learned through implementation can be applied elsewhere (taking into account site-specific considerations). If appropriate performance measures (Step 4) and monitoring plans (Step 6) were developed and project actions do not achieve the intended results, this provides the opportunity to adapt and re-evaluate.

Experience and best judgment will dictate whether to continue down the established path, redefine the problem and set new goals and objectives, or modify management actions to achieve the original goals.

APPENDIX 3. HABITAT ENHANCEMENT CONSIDERATIONS FOR NATIVE SPECIES

Habitat Enhancement Considerations for Salmonids

Habitat mitigation measures were not required for channel and riverbank modifications until the listing of several Sacramento River species under state and federal Endangered Species Acts in the early 1990s, namely winter-run and spring-run Chinook salmon, steelhead, and Delta smelt (FISHBIO 2015). Other native fishes which are currently listed as threatened are the longfin smelt (*Spirinchus thaleichthys*), Sacramento splittail (*Pogonichthys macrolepidotus*), and green sturgeon (*Acipenser medirostris*). Habitat improvements can include the creation of on-site riparian habitat, shaded riverine aquatic habitat (SRA), or offsite mitigation. Riparian enhancement can improve the habitat value of channel margins by improving water temperature conditions for native aquatic species (shading; Greenberg et al. 2012), increasing insect drop-off, and creating a buffer zone between the water and urban and agricultural lands. Features of enhanced channel margin habitat can include shallow or overhanging banks, scalloped bank edges with riparian or marsh vegetation, and the installation of appropriately sized instream woody material (IWM). Enhancement of channel margin habitat can serve to benefit native fishes by providing cover from predators, creating areas of reduced water velocities, and contributing to the aquatic food web.

Shallow nearshore environments along levee channels have been shown to be utilized by Chinook salmon fry in the northwestern Sacramento-San Joaquin Delta, where higher densities of Chinook salmon fry were observed near shallow beaches than in riprapped nearshore zones (MacLain & Castillo 2009). Juvenile Chinook salmon will preferentially occupy areas with small substrate, gently sloping banks, and low current velocity (FISHBIO 2014). Additionally, areas with these habitat characteristics significantly reduce occupancy by predatory smallmouth bass (*Micropterus dolomieu*) greater than 150 mm fork length (FL) (FISHBIO 2014). Levee improvements that include a channel shelf planted with emergent vegetation could provide refuge from predators, decrease localized instream currents, and increase the prey availability for small fishes and smolts (e.g., phytoplankton, zooplankton, macroinvertebrates, insects). In general, restorations that provide more habitat complexity will be more successful; this would include incorporating variability in channel edges (scalloping), emergent bench surfaces (depth and slope), and native vegetation.

Nearshore habitat enhancement on the waterside of levees can provide forage benefits for emigrating juvenile Chinook salmon, improve survival of young-of-the-year salmonids, and affect holding time for Chinook and Central Valley steelhead smolts (Zanjanc 2013). Stomach content analysis of juvenile Chinook salmon along the Sacramento and Bear Rivers and Steamboat, Sutter, and Cache Sloughs suggest that channel margin habitat along the levees not only improve migration corridors, but are used as rearing habitat as well. Dietary analysis suggested that terrestrial food sources may be locally important for rearing salmonids (FISHBIO 2015). In addition to providing foraging benefits for small fishes, vegetated channels play an important role in predator avoidance (Gewant & Bollens 2012).

A recent acoustic study on emigrating Chinook salmon and steelhead smolts in the Sacramento River found the movement pattern of salmon smolts to be more influenced by habitat variables than they were for steelhead smolts (Zanjanc 2013). Steelhead smolts interacted less with nearshore habitat features and may be responding to large-scale environmental cues and channel bottom features. For salmon smolts, the probability of holding (remaining at a site for ≥ 1h) increased as fine substrates increased (indicative of decreased velocities) and holding time increased with greater IWM size and density (Zanjanc 2013). However, spatial and temporal factors (e.g., release location, flow, day/night) had a considerably greater influence on holding behaviors than habitat variables. Levee improvement efforts should consider nearshore vegetation and habitat features that provide overhead shade and larger IWM (> 10.2 cm diameter to create velocity breaks) which can provide daytime cover for Chinook salmon smolts from avian and introduced fish predators.

Seasonal floodplains can also provide improved spawning and larval rearing habitat for the threatened Sacramento splittail (*Pogonichthys macrolepidotus*) which is an obligate floodplain spawner (Moyle 2002). Other native fishes such as the Sacramento blackfish (*Orthodon microlepidotus*) are opportunistic floodplain spawners, while the prickly sculpin (*Cottus asper*) and Sacramento sucker (*Catostomus occidentalis*) are river spawners whose larvae wash out onto the floodplain (Crain et al. 2004). Recaptured juvenile Chinook salmon that reared in the floodplain habitat of Yolo Bypass were found to have higher growth rates than their counterparts that were released into the adjacent river channel concurrently (Sommer et al. 2001). Increased growth rates are thought to have resulted from higher prey availability (benthic invertebrates) and would contribute to higher survival rates during outmigration to the ocean. After spending several weeks on a flooded rice field in 2013, juvenile

Chinook salmon experienced a five-fold weight gain and were seven times more likely to be successful during outmigration than juvenile salmon that remained in the river channel and navigated the perilous Delta. As much upstream habitat has been blocked by dams and native fishes have evolved with seasonal inundation of floodplains in the early spring, this habitat is more important than ever, especially to salmonids and Sacramento splittail. Recommendations for a flood pulse emphasize an early inundation (February – April) followed by fairly rapid draining to allow juvenile native fish to benefit on the rearing grounds before warmer temperatures and lower flows begin to favor alien species (Sommer 2001, Crain et al. 2004).

Tidal marsh restoration was thought to be the best strategy to benefit native fishes in the Delta. The downward trend of native fish abundance in the Delta coincides with the proliferation of invasive aquatic vegetation like water hyacinth and Brazilian waterweed (Brown 2000, Brown & Michniuk 2007, Brown & May 2006) that now covers much of the Delta's waterways (CDBW 2001) and provides an abundance of habitat for non-native centrarchids (members of the sunfish family including invasive black bass species). In a recent study looking at the fish assemblages of reference and restored tidal marshes in the central Delta, invasive waterweed and Eurasian water milfoil (*Myriophyllum spicatum*) were the dominant SAV (Grimaldo et al. 2012). Assemblage differences were most pronounced between areas of open-water shoals and high density mats of SAV and there was little variation between newly restored (flooded islands) and intact reference sites (Grimaldo et al. 2012). This indicates that tidal marsh restoration should be focused in areas where elevation and salinity conditions do not promote the colonization of SAV and native fishes are most abundant, such as the north Delta (Nobriga et al. 2005; Brown & Michniuk 2007; Grimaldo et al. 2009). Additionally, seasonally restored wetlands which are only inundated during the winter and spring may benefit native species while limiting the recruitment and exploitation of the area by alien fishes (ref?).

When it comes to ecosystem restoration, the decisions of natural resource managers are based on many considerations and ultimately constrained by funding. Managers must decide what type of habitat to restore, consider mixed use benefits (e.g., agricultural land seasonally inundated for fish rearing), and plan and evaluate the outcomes using adaptive management practices. As habitat preference varies significantly from species to species, it is imperative to understand the life-history requirements of target species when determining the size, location, and design configuration of the restoration project (Herbold et al. 2014). Measuring the expected benefit of habitat restoration projects comes with its own unique set of challenges as well. Ultimately, for conservation measures to be effective, it will be essential to better understand whether species abundance and distributions accurately reflect patterns of survival and reproductive success that ultimately determine population persistence (Vickery et al. 1992, Battin 2004).

Habitat Enhancement Considerations for Avian Species in the Delta

Larger riparian or marsh areas with connectivity between habitats will benefit avian species by providing protection, food resources, and nesting areas. Riparian length by width class is one type of metric used to determine life history support status for riparian wildlife (Robinson et al. 2014). The width of riparian forests along the river channels of the Delta has decreased dramatically in most areas from kilometers to a few meters. For example, stretches of riparian forest that represent "optimal" habitat (> 500m) for the endangered yellow-billed cuckoo have decreased by 91 percent (Robinson et al. 2014). A "suitable" habitat patch for the yellow-billed cuckoo has been defined as 41-80 hectares (ha) of willow-cottonwood (riparian) forest 200 m wide or greater, with at least 1 ha of dense nesting habitat per pair (Laymon & Halterman 1989). The majority of riparian habitat existing today is of "unsuitable" width (0-100 m) to support the yellow-billed cuckoo (Laymon & Halterman 1989). In general, riparian corridors a minimum of 100 m wide are needed to provide foraging and nesting opportunities for neotropical migratory birds (Golet et al 2011).

Willow riparian scrub habitat once occurred in much of the Delta on low-lying natural levees beside rivers and creeks in long, narrow ribbons. This riparian habitat type is characterized by woody scrub or shrubs (e.g., willows) with taller trees absent or sparse (Whipple et al 2012). The dense and shrubby understory is favored for nesting by the western yellow-billed cuckoo (ERP 2014), yellow-breasted chat (CDFW 2005), least Bell's vireo (Olson & Gray 1989, ERP 2014), common yellowthroat (Nur et al. 2005), and the California yellow warbler.

The Swainson's hawk, which was formerly abundant in California with a wide breeding range, (Grinnell & Miller 1944, Bloom 1980, Garrett & Dunn 1981) is now a state-listed threatened species, due to loss of foraging and nesting habitat. The population decline is due in part to widespread habitat loss to urban development in the Central Valley (Estep & Teresa 2001). Grasslands, pastures, and agricultural fields near water that are bordered by stands of riparian trees can serve as home territories for breeding Swainson's hawks. Conservation management of grasslands and suitable agricultural areas (grain and alfalfa fields) can also serve to preserve unique native habitats within these land types that benefit other at-risk species such as valley oak woodland, vernal pools, and interior wetlands.

Species like the greater sandhill crane (*Grus canadensis tabida*) can benefit from managed agricultural lands. Post-harvest mulching and flooding of corn fields, like those on the conservation farmlands of Staten Island in the central Delta, provide excellent foraging and roosting habitat for greater sandhill cranes overwintering along their migration route. The conversion of agricultural lands to almond production and vineyards has inflated the value of cropland in California and drought has reduced the acreage of rice fields which serve as surrogate wetlands for waterfowl. Given the extensive loss of wetland habitats in the Delta for sandhill cranes, managed agriculture in the Central Valley can serve to provide crucial habitat along the Pacific flyway for these threatened species.

Aside from protecting large areas of continuous habitat for the benefit of avian species, management and enhancement projects should aim to provide connectivity between habitats and lower perimeter-to-area ratios to reduce negative edge effects such as increased nest predation. The density of three subspecies of song sparrow found in the San Francisco Bay estuary, including the Suisun song sparrow, were greater in larger marshes that were not isolated from each other and not adjacent to urban areas (PRBO 2002). Additionally, Suisun song sparrow nests were the least successful and experienced the highest levels of predation in isolated marsh habitats with higher perimeter-to-area ratios. Although habitat improvement projects tend to be completed in small sections over time as funding becomes available, landscape-level features should be considered whenever possible in conservation planning.

APPENDIX 4. INTERVIEW QUESTIONS

From May to August 2015 scientists and engineers from government agencies (California Department of Fish and Wildlife, California Department of Water Resources, National Marine Fisheries Service, U.S. Geological Survey, U.S. Army Corps of Engineers, Sacramento Area Flood Control Agency), nongovernmental organizations (The Nature Conservancy and River Partners), UC Davis, and consulting firms that have experience in levee-related habitat improvement projects were interviewed. The goals of the interview process included:

1. Develop a list of levee-related habitat improvement projects that have been conducted, are ongoing, or are planned;
2. Collect documentation, including project descriptions, monitoring reports and cost data, on levee-related habitat improvement projects; and
3. Determine general lessons learned from habitat improvement efforts.

Interviewees' questions included:

Project description

- What levee-related projects is the interviewee aware of?
    - When was the project(s) conducted?
    - What was the target habitat(s)?
    - What were the state performance measure(s)?
    - What agencies, companies, or institutions were involved?
    - Was the project(s) for enhancement, restoration, or onsite/offsite mitigation?

Project Duration

- What was the start and end date for the project(s)?
    - What were the original and actual completion dates?
    - What was the duration of monitoring?

Budget

- What were the original and final costs of the project?

- What amount of the project was related to habitat improvements?
- What was the monitoring budget?
- Was there any unforeseen costs?
- How was the project funded?
- Who can we contact for additional project budgetary information?

Monitoring

- Is monitoring data available for project?
- If so, what monitoring was conducted and are the reports (digital or hard copy) available?
- Who may we contact for project monitoring data?

General lessons learned

- What general lessons were learned from the project?
- Were there any complications and/or difficulties in project implementation?
- Were there any unintended consequences and/or benefits?

APPENDIX 5. HABITAT IMPROVEMENT PROJECTS REVIEWED

Note: Includes both habitat mitigation and habitat enhancement efforts.

Project Title	Target habitat and project type	M, E, R, and/or D*	Program Management**	Monitoring data types: Monitoring Data?	Vegetation	Fish	Birds	Water Quality	Hydrology	Budgetary data
Sherman Island Mayberry Slough Levee Setback Habitat Project	levee setback	E	DWR, Hanford ARC	X	X					X
Twitchell Island Habitat Improvement Project/Levee Setback Planting	levee setback	E	DWR, Hanford ARC	X	X					
Beaver Slough Habitat Improvement Project on Canal Ranch	levee revetment, planting benches	E	MBK Engineers, RD 2086, DWR DLP	X	X					
Lower American River SAFCA Restoration Sites	biotechnical improvments, planting benches	E	SAFCA, USACE, RD 1000	X	X	X				
Emergency Levee Repair Project by DWR	levee revetment, planting benches	M/E	DWR	X		X				
Decker Island Habitat Development/Levee Improvement Project	tidal marsh	M/E	DWR DLP, DFW	X	X	X	X			
Stockton Deep Water Ship Channel (Venice Cut & Donlon Island)	dredged material islands (DMI), tidal marsh, riparian habitat	E	USFWS, USACE	X	X	X	X			
Bradford Island Tract 19	riparian, scrub shrub, and wetland restoration	M	DFW, RD 2059	X	X					
San Joaquin River NWR – Ecosystem Restoration & Floodwater Attenuation Project	riparian habitat levee enhancement	R	DWR, USFWS, River Partners	X	X					X
Cosumnes Floodplain Mitigation Bank	floodplain	M	Westervelt Ecological Services	X	X	X		X	X	X
Oneto-Denier Floodplain Easement	floodplain	R	TNC, USDA NRCS	X					X	
Biotechnical restoration methods for bank protection	riparian habitat, tidal marsh, biotechnical erosion control	E	CALFED 2012 P12 project conducted by Jeff Hart	X	X					
Monier Lifetile Levee Planting: Vierra Unit; 2008	riparian habitat for Riaparian brush rabbit refugia on abandoned USACE levee	E	River Partners contracted by Monier Lifetile	X	X					
Bethel Island 10 acre Site	freshwater marsh, scrub shrub	M	DWR DLP, DFW							
Grizzly Slough	unclear	M	DWR DLP, DFW							
Hotchkiss 1000 lineal feet (1995 Repair)	scrub shrub	M	DWR DLP, DFW							
Mandeville 1,350 foot On-Site	scrub shrub	M	DWR DLP, DFW							
Medford - Fields 23, 24, 25, 36 & 51A	freshwater marsh, riparian forest, scrub-shrub	M	DWR DLP, DFW							
Pace Preserve (Wright-Elmwood)	freshwater marsh, riparian forest	M	DWR DLP, DFW	X	X	X	X	X		
Sherman Island Parcel 11	freshwater marsh, riparian forest, scrub-shrub	M	DWR DLP, DFW							
Terminous Mitigation Area	riparian forest, scrub shrub	M	DWR DLP, DFW							
Twitchell 2, 4.04 and 8.08 acre site	freshwater marsh, riparian forest, scrub-shrub, grassland	M	DWR DLP, DFW							
Grand Island Bank Revegetation	shaded riverine aqautic	E	DWR DLP, DFW	X	X					X
In-Channel Island Demo	biotechnical erosional control	D	DWR DLP, DFW							
Staten Island Channel Bank Stabilization	planting bench, riparian habitat, tidal marsh	D	DWR DLP, DFW							
Tyler Island Levee Protection and Habitat restoration Pilot Project	biotechnical erosional control	D	DWR DLP, DFW							
Orwood and Palm Tracts (36+00 to 190+00)	SRA	E	DWR DLP, DFW							X
Orwood and Palm Tracts (60+00 to 398+00)	SRA	E	DWR DLP, DFW							X
Lower Roberts Island (256+00 to 820+00, 50+00 to 254+00)	SRA	E	DWR DLP, DFW							X
Lower Roberts Island (44+00 to 740+00)	SRA	E	DWR DLP, DFW							X
Upper Jones Tract (90+00 to 240+00)	SRA	E	DWR DLP, DFW							X
Upper Jones Tract (3+00 to 90+00, -6+00 to 90+00, -6+00 to -2+00)	SRA	E	DWR DLP, DFW							X
Woodward Island (0+00 to 15+00, 385+00 to 471+00)	SRA, TM, non tidal FM	E	DWR DLP, DFW							X
Woodward Island (1+00 to 465+00)	SRA, TM	E	DWR DLP, DFW							X

* Mitiagation (M), enhancement (E), restoration (R), and/or demonstration project (D).

**Program management acronymns
California Bay-Delta Program - CALFED
California Department of Fish and Wildlife - DFW
California Department of Water Resources - DWR
DWR Delta Levees Program - DWR DLP
Reclamation district - RD
Sacramento Area Flood Control Agency - SAFCA

**Program management acronymns (continued)
The Nature Conservancy - TNC
United States Army Corps of Engineers - USACE
United States Fish and Wildlife Service - USFWS
Unites States Department of Agriculture - USDA
USDA Natural Resources Conservation Service - NRCS