DRAFT, January 20, 2016—Please Do Not Cite or Quote

Delta Stewardship Council

Improving Habitats along Delta Levees:

A Review of Past Projects and Recommended Next Steps

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January 2016

Proposed Final Draft

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

CDBW	California Division of Boating and Waterways
CDFW	California Department of Fish and Wildlife
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
CRP	Cosumnes River Preserve
CVFPP	Central Valley Flood Protection Plan
CVP	Central Valley Project
DISB	Delta Independent Science Board
DLHAC	Delta Levees and Habitat Advisory Committee
DLIS	Delta Levee Investment Strategy
DMI	Dredged Material Island
DWR	California Department of Water Resources
EIR	Environmental Impact Report
ESA	Endangered Species Act
ETL	Engineering Technical Letter
FESSRO	FloodSAFE Environmental Stewardship and Statewide Resources Office
FL	Fork Length
IAV	Invasive Aquatic Vegetation
IEP	Interagency Ecological Program
ITP	Incidental Take Permit
IWM	Instream Woody Material
MAST	Management, Analysis, and Synthesis Team
MHHW	Mean Higher High Water
MLLW	Mean Lower Low Water
MOU	Memorandum of Understanding
MWL	Mean Water Level
NGO	Non-governmental Organization
NMFS	National Marine Fisheries Service
NRRSS	National River Restoration Science Synthesis
NWR	National Wildlife Refuge
O&M	Operations and Maintenance
PRBO	Point Reyes Bird Observatory
RD	Reclamation District
SAFCA	Sacramento Area Flood Control Agency
SAIL	Salmonid/Steelhead/Sturgeon Assessment Indicators by Life Stages
SAM	Standardized Assessment Methodology
SAV	Submerged Aquatic Vegetation
SWP	State Water Project
SWRCB	State Water Resources Control Board
TNC	The Nature Conservancy
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service

Author Contributions

The development of this paper was designed and supervised by Jessica Davenport and Darcy Austin. Monitoring reports and cost information were collected by Daniel Livsey and Daniel Huang, who also conducted expert interviews. Reports, data, and literature were analyzed by Jahnava Duryea, Daniel Livsey and Daniel Huang. All five authors contributed to writing the manuscript.

Acknowledgments

This report would not have been possible without the inspiration and support of numerous colleagues. Carl Wilcox of the California Department of Fish and Wildlife (CDFW) identified the need for a review of the effectiveness of past habitat projects related to state levee investments. Cindy Messer of the Delta Stewardship Council (Council) served as the executive sponsor for the project. Dan Ray, Cindy Messer, Dustin Jones, Rainer Hoenicke, Lauren Hastings and Maggie Christman of the Council and Larry Roth of Arcadis all provided valuable input during the development of the report.

We are extremely grateful for the guidance provided by our advisory committee: Gilbert Cosio, MBK Engineers; Campbell Ingram, Delta Conservancy; Dave Mraz and Bryan Brock, California Department of Water Resources (DWR); Chris Neudeck, Principal Engineer, KSN, Inc.; Ramona Swenson, ESA PWA; Michael Tucker, NOAA Fisheries; and Carl Wilcox, CDFW.

We would also like to thank the following people for their insightful comments on various drafts: Brian Atwater, U.S. Geological Survey (USGS); Peter Buck, Sacramento Area Flood Control Agency (SAFCA); Gilbert Cosio, MBK Engineers; William Darsie, KSN, Inc.; Jim Starr, Anna Burkholder and Mark Philipp, CDFW; and Charles Tyson, Jennifer Hogan, and Randy Mager, DWR.

Finally, we wish to express our sincere gratitude to those who gave interviews and provided monitoring reports and cost data for past projects. Interviewees include several of our advisory committee members, as well as Jon Burau and Fred Feyrer, USGS; Carson Jeffres and John Durand, UC Davis; Jeff Hart, Hart Restoration, Inc.; Sara Sweet and Judah Grossman, The Nature Conservancy; Brian Mulvey, Judy Soutier, and Alicia Kirchner, U.S. Army Corps of Engineers; Julie Rentner, River Partners; Lori Smith and Eric Hopson, U.S. Fish and Wildlife Service; Kim Forrest, CDFW; Anitra Pawley, DWR; KC Sorgen, SAFCA; and Trevor Kennedy and Kari Burr, Fishery Foundation of California.

EXECUTIVE SUMMARY

This review of habitat improvements along Delta levees was conducted to support the development of the Delta Stewardship Council's (Council) Delta Levee Investment Strategy (DLIS), which focuses on flood risk reduction as the primary purpose of State levee investments. The report is intended to provide guidance to the Council to ensure that those investments also contribute to long-term improvement of river corridors, with net benefits for fish and wildlife.

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 Plan includes 14 regulatory 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. This report is intended to support the application of best available science and adaptive management to habitat improvements along Delta levees.

It should be noted that levee-related habitat improvements alone are not expected to provide all the ecosystem benefits needed by native species. These projects take place within the larger context of ecosystem restoration in the Delta and Suisun Marsh, which will require more natural functional flows, restoration and conservation of a wide range of habitat types[1], improved water quality, and the management of nonnative invasive species. Nevertheless, given its significant role in Delta levee

[1] The tradeoff associated with protecting productive farmland behind levees that also provides important terrestrial or seasonal wetland habitat versus breaching levees in order to restore aquatic habitat is an important issue. It will be addressed in the Delta Levee Investment Strategy, but it is beyond the scope of this paper.

investments, the State must ensure that these habitat projects are part of a program that provides a net benefit for aquatic species in the Delta.

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 Delta levees, must be consistent with a net long-term habitat improvement program and have a net benefit for aquatic species in the Delta.

In addition, levee construction and maintenance frequently results in impacts to habitat that must be mitigated according to the requirements of multiple regulatory agencies. Generally, regulatory agencies prefer that mitigation occurs on-site with in-kind functions. Due to various constraints, off-site 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).

Improvement of habitat along levees, whether for mitigation or enhancement, is challenging due to a range of regulatory and liability constraints. For example, the current nationwide policy of the U.S. Army Corps of Engineers (USACE) requires removal of trees and most shrubs from a "vegetation-free zone" on and around levees under their jurisdiction, and also prevents 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) required reevaluation of this policy by November 2015, but the reevaluation process had not yet been funded as of December 2015. In the meantime, the USACE allows local sponsors to apply for a variance, but the procedures for obtaining one are burdensome. Moreover, 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 levees fail. Despite these constraints, it still possible to improve habitats along levees, especially in the waterside area beyond the vegetation-free zone (Figure 2).

Purpose and Approach

The purpose of this paper is to explore the question of how to ensure that future State levee investments, which are primarily aimed at flood risk reduction, also contribute to fulfilling the two State-level environmental mandates described above: 1) achieving the coequal goals, particularly with respect to ecosystem restoration; and 2) providing a net benefit for aquatic species in the Delta. The paper provides a review of past projects, summarizes lessons learned from monitoring reports and through interviews with experts about which habitat designs may provide greater benefits to target native species, and provides guidance to ensure that project effectiveness can be better evaluated in the future. The paper also provides information about the costs of multi-benefit projects that combine levee construction and habitat improvements, as well as the costs of projects that improve habitats along levees but do not involve levee construction, e.g., projects that use riparian plantings to stabilize levee slopes and provide erosion control.

To collect the information required for our review of the effectiveness of habitat improvements along Delta levees, we conducted interviews with experts and, through coordination with other agencies and stakeholders, obtained project descriptions and associated monitoring reports and cost information. Project effectiveness was evaluated in terms of the project's stated objectives, performance measures, monitoring, and results, and whether or not a project could be shown to benefit target species.

Summary of Analysis

Our review of habitat projects found that the majority of reports used vegetation monitoring as a means of measuring success. 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.

Summary of Project Design Considerations

Despite our inability to draw firm 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 the design of future projects. We examined four main levee structural modifications and related habitats: setback levees, adjacent levees, extra-wide levees, and planting benches (Figure 1, Figure 2, and Table 1).

Measuring Project Effectiveness and Lessons Learned

Monitoring the response of fish and wildlife to habitat improvement projects is an essential part of determining whether the projects are providing benefits to target species. Our review of monitoring reports from past habitat improvement projects confirmed the value of monitoring programs that measured project effectiveness in terms of both the amount of established structure (e.g., vegetation or woody material) and the wildlife response (e.g., use of habitat enhancement features by target species).

One of the primary lessons learned from this review is that habitat improvement techniques that have been shown to be highly effective in other systems may have beneficial, neutral, or even deleterious impacts on wildlife in the Delta. For example, although instream woody material (IWM) has been shown to benefit salmonids in other ecosystems, along the lower Sacramento River, high-density IWM increased occupation of invasive predatory fish by 20-fold while decreasing occupation of Chinook salmon fry by about 75% compared to control sites that lacked high-density IWM (FISHBIO 2015). However, IWM in low to medium densities correlated with enhanced occupation of salmonids and decreased invasive predatory fish (FISHBIO 2015).

Another important lesson is that planting riparian vegetation can be beneficial to native fish, even along levees protected by rock revetments. Along the lower American River, multiyear *post hoc* snorkel surveys indicated that out-migrating juvenile salmonids utilized riprapped reaches with riparian habitat and channel margin enhancements (e.g., shallow benches and IWM) at nearly the same frequency as control sites (i.e., “natural” non-riprapped levee slopes) (Fishery Foundation 2006).

These types of observations, learned directly from wildlife response monitoring, can provide the basis for developing Delta-specific best practices that maximize the potential for effective habitat restoration efforts.

Setback levees, constructed several hundred feet behind an existing levee, restore wide contiguous swaths of seasonal floodplain habitat by allowing reestablishment of natural riverine processes. In many parts of the Delta, however, particularly where islands are deeply subsided, setback levees are often infeasible because placing the huge amount of fill needed to bring the land up to floodplain elevation would be prohibitively expensive. Adjacent levees, constructed immediately behind an existing levee, often involve leaving the existing levee in place to protect the new levee from erosion. Adjacent levees, however, do not follow the conceptual model of providing ecosystem benefits through reestablishment of floodplain processes, and have not been monitored adequately to determine whether there are positive benefits to native species in the Delta. Given the high cost of setback levees where Delta islands are at subtidal elevations and the uncertain ecological benefits of adjacent levees, expanding or modifying existing levees into "extra-wide" levees may be a more cost-effective option and may be more likely to be supported by landowners because they require less land conversion. Extra-wide levees (sometimes referred to as habitat levees) allow the levee to be graded to create a gradual waterside slope on which riparian, shaded riverine aquatic, and tidal marsh habitat can be established (Figure 2). In lieu of or in combination with an extra-wide levee or an adjacent 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 (broken rock) covered with a mixture of soil and rocks that can support tidal marsh and/or riparian vegetation.

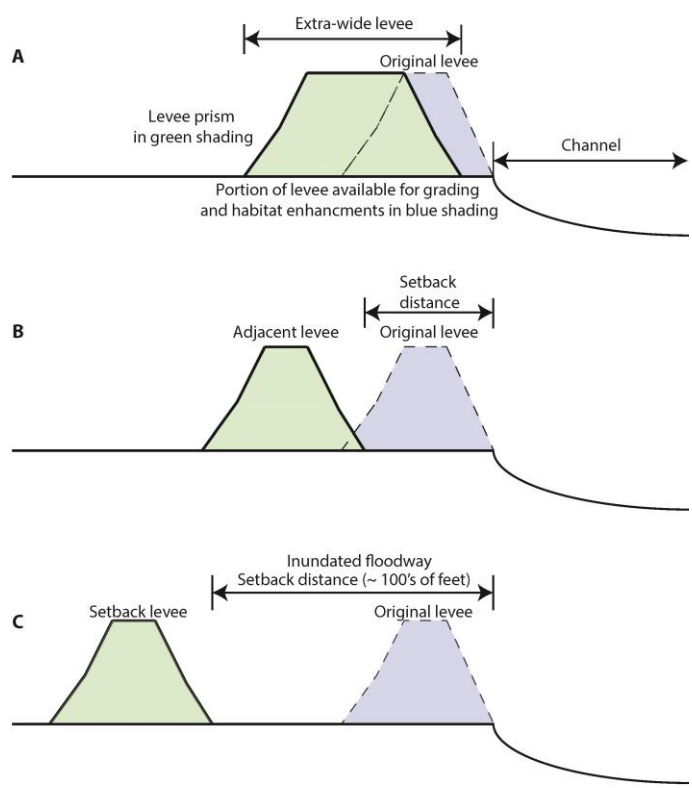

Figure 1. Illustrations of extra-wide, adjacent, and setback levees.

Figure 2. Diagram of an extra-wide levee with a planting bench on waterside toe of levee.
[1] Vegetation management zone (VMZ) in the diagrams is the same as the "vegetation-free zone" defined in the USACE's national policy, described above. Note that the riprap placed in planting bench along waterside levee slope for erosion control is also designed to prevent levee damage from burrowing mammals. Adapted from DWR 2014.

Table 1. Principal considerations for Delta levee structures and related habitats.

	Setback levee	Adjacent levee	Extra-wide levee	Planting bench[a]
Definition	A levee constructed several hundred feet behind an existing levee which allows for removal of a portion of the existing levee and creation of additional floodplain connected to the channel.	A levee constructed immediately behind an existing levee. It may not necessarily result in removal of the existing levee.	A levee that has been widened to shift the regulated levee prism landward, creating more space for habitat improvement next to the channel and enhancing flood protection.	A terrace that creates a stable structure for establishing vegetation.
Habitat Benefits	Restores wide contiguous swaths of seasonal floodplain habitat by allowing reestablishment of natural riverine processes.	May not achieve same ecosystem benefits as a setback levee, since it does not allow natural riverine processes to fully reestablish.	May not achieve same ecosystem benefits as a setback levee, but may provide more benefits than an adjacent levee since it allows for a gradual waterside slope on which riparian, shaded riverine aquatic, and tidal marsh habitat can be established.	May be installed on waterside levee slope to provide appropriate depths and elevations for establishing shaded riverine aquatic habitat.
Constraints/ Opportunities[b]	Foundation of a setback levee and the land between original levee and new setback levee should be no lower than intertidal elevation in order to achieve floodplain habitat; cost of fill is prohibitive for setback levees on deeply subsided islands.	Useful when maintaining an existing levee in a highly erosive environment is more expensive in the long-term than shifting the prism of the levee landward (e.g., Twitchell Island levees).	By shifting the regulated levee prism landward, construction of an extra-wide levee creates more options for habitat improvement on waterside slope.	Planting benches may be infeasible in locations with especially high water velocity and steep bathymetric gradients on waterside slope because of erosion issues.
Land Conversion Considerations[c]	Required setback distance for habitat benefits is generally several hundred feet and would require substantial conversion of dry land to seasonal floodplain.	Requires less conversion of land than setback levees, but more than an extra-wide levee.	Requires less conversion of land than setback levees and adjacent levees.	Planting benches inherently replace shallow and intertidal habitats.

[a] Planting benches can be installed as a standalone feature along the waterside slope of a traditional Delta levee, or in association with construction of an adjacent levee or extra-wide levee.
[b] All levees face a common constraint related to soil type: Peat soils make for poor, unstable foundations for a new levee. Options to stabilize peat soils (e.g., soil compaction) are expensive. In addition, all habitat improvements that increase vegetation cover also increase the risk of attracting burrowing animals (e.g., beavers) that can undermine levee integrity.
[c] Land converted from levee-protected dry land to seasonal floodplain can often still be used for some types of farming and recreation.

Cost Analysis

The main objective of the cost 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. We assessed cost ranges of multi-objective levee projects that included both risk reduction aspects and habitat improvements using data provided to us by California Department of Water Resources (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). Based on the cost data available for these projects, we were unable to differentiate the costs of restoring the riparian habitat from the costs associated with the engineering design and construction of the levee improvement work. The levee improvement work is usually the fundamental driver of the costs of these projects, and the scale of construction work will be different depending on engineering design considerations. As such, the total cost of a multi-objective project is not a good indicator of the cost of the habitat restoration component.

DWR staff also provided data on two pilot-scale on-site riparian habitat enhancements along levees whose costs ranged from $80 to $200 per linear foot; in comparison, off-site mitigation credits from a mitigation bank at the edge of the Delta cost $61 per linear foot. Credits purchased from this same bank cost $62,295 to $120,000 per acre[2] for riparian forest and freshwater marsh habitat, while the cost of off-channel habitat created in the interior Delta islands ranged from $45,000 to $563,800 per acre.

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[2] Also includes required buffer acreage that comprises the mitigation bank.

Recommended Next Steps

Based on the findings of the review, we recommend taking several steps to improve habitat project siting and ensure that project siting and effectiveness can be better evaluated in the future:

1. **Develop appropriate performance measures as part an adaptive management plan.** As required by Delta Plan Policy G P1, habitat improvement projects along levees should have adaptive management plans that include appropriate performance measures, including fish and wildlife response, to assess effectiveness in providing benefits to target species.
2. **Track the incremental cost of habitat improvements.** DWR has recognized the importance of breaking down the costs of multi-benefit projects into habitat and flood risk reduction components. The Council supports DWR's proposal to make such a cost breakdown a requirement for receiving grant funding.
3. **Carefully consider the tradeoffs associated with on-site and off-site mitigation.** Destruction of shaded riverine aquatic habitat and emergent vegetation by placement of bank erosion control riprap along key migratory corridors for salmon should be mitigated on-site or at least elsewhere along the same corridor. If habitat is created in areas of the Delta that are not along these corridors, then the mitigation would not be expected to provide the same ecological benefits to salmon. 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, especially if it facilitates the creation of larger and more interconnected habitat patches.
4. **Use landscape-scale planning to guide project location and design.** As landscape-scale restoration planning is conducted in the Delta, as recommended in the Delta Plan, it will provide a framework for siting and designing projects to increase habitat connectivity and function. For example, efforts should be made to link together fragmented patches of habitat to build towards large contiguous habitat corridors.
5. **Measure fish and wildlife response through a standardized regional monitoring program.** By establishing a regional monitoring framework (similar to the CDFW-led Interagency Ecological

Program Tidal Wetlands Monitoring Project Work Team framework), 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. Additional and long-term funding is needed for this programmatic monitoring.

6. **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. We envision that the Delta Science Program could become involved with the DLHAC, or a subcommittee thereof, to consult on habitat project siting and design.

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 or Delta stakeholders. Implementing them, however, will take leadership, persistence, and adequate long-term funding. Council staff looks forward to working together with our colleagues to address the issues raised in this paper.

INTRODUCTION

The Delta Stewardship Council (Council) has undertaken the development of a Delta Levees Investment Strategy (DLIS) to 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 regulatory 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 recommended 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, non-governmental 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 fifteen projects for which monitoring reports were available, twelve had data on vegetation, six had fish data, and three had bird data (see table in Appendix 4). 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.

It should be acknowledged that levee-related habitat improvements alone are not expected provide all the ecosystem benefits needed by native species. These projects take place within the larger context of ecosystem restoration in the Delta and Suisun Marsh, which will require more natural functional flows, restoration and conservation of a wide range of habitat types[3], improved water quality, and the management of non-native invasive species, as stated in the Delta Plan. Nevertheless, given its significant role in Delta levee investments, the State must ensure that these habitat projects are part of a program that provides a net benefit for aquatic species in the Delta. Our hope is that this review will be helpful in identifying data gaps, clarifying future needs, and providing recommendations for

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[3] The tradeoff associated with protecting productive farmland behind levees that also provides important terrestrial or seasonal wetland habitat versus breaching levees in order to restore aquatic habitat is an important issue. It will be addressed in the Delta Levee Investment Strategy, but it is beyond the scope of this paper.

enhancing the adaptive management process for habitat improvements undertaken within the context of flood risk reduction.

I. BACKGROUND

Recommendations for future levee-related habitat improvements should be guided in part by an analysis of how historical habitats functioned; 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. Numerous other stressors impact the Delta ecosystem such as water diversions, dam construction in the Delta watershed, and discharge of nutrients and toxic substances (Luoma et al. 2015). We focus the discussion below on past habitat changes as levee-related habitat is the primary focus of this review.

Historical Habitats of the Delta

Located in Northern California, the San Francisco Estuary is the largest estuary on the west coast of North and South America, receiving runoff and snowmelt from 40% 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 European 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 800,620 acres) 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., willow, cottonwood, sycamore, and oak) 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, 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 has supplied water for agricultural, urban, and wildlife uses throughout the state through the Central Valley Project (CVP) since 1958 and through the State Water Project (SWP) since 1968. 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% 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% of riverbanks, 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 ecosystem of the Delta, with reduced flow and turbidity, higher temperatures, high contaminant loads, and invasive aquatic vegetation (IAV) provide conditions that support an undesirable, non-native 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 remains, naturally established riparian vegetation or tule beds exist in discontinuous, narrow bands. Over 95% 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 bird 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 while 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 (Special 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 twenty 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 Council and its mandate to develop and approve 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 (SB) 34 mandated that the Delta Levees Program, which includes the Delta Levees Subventions Program and Special Projects Program, results in no net long-term loss of riparian, fisheries, and wildlife habitat (Water Code sections 12314(d) and 12987(c)). In 1992, the California Resources Agency (now the California Natural Resources Agency), DWR, the Reclamation Board (now the Central Valley Flood Protection Board), and the California Department of Fish and Game (now California Department of Fish and Wildlife) 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 passage of Assembly Bill 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 due to a suite of issues, including: concerns that such habitat could very easily be destroyed if there is a need for emergency levee repairs; complications in maintaining existing easements and right-of-ways; and coordination complexities since the levees are often owned by a multitude of different landowners. As a result, mitigation for impacts to riparian vegetation on levees may occur off-site (e.g., interior of the island).

Habitat Mitigation vs. Enhancement

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 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) also may impose mitigation requirements related to 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 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 over 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), which is authorized to enforce the federal “no net wetland loss” policy, can mandate mitigation for impacts to riparian habitats that are also jurisdictional wetlands under the federal Clean Water Act. The State Water Resources Control Board (SWRCB) is currently developing a 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.

Delta Plan Policy G P1 requires that projects that are deemed covered actions under the Delta Plan include mitigation measures equivalent to or exceeding those listed in the Delta Plan Program Environmental Impact Report (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."

Mitigation requirements and ratios are determined by the regulatory agencies. For the Delta Levees Program, CDFW follows a set of standard mitigation ratios for riparian forest, scrub shrub, freshwater marsh, and shaded riverine aquatic habitat.

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 to establish 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) 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 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 (RDs). 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), and earmark a portion of the funding for long term maintenance and monitoring of habitat.

II. PURPOSE AND APPROACH

The purpose of this paper is to explore the question of how to ensure that future State levee investments, which are primarily aimed at flood risk reduction, also contribute to fulfilling the two environmental mandates described above: 1) achieving the coequal goals, particularly with respect to ecosystem restoration; and 2) providing a net benefit for aquatic species in the Delta. The paper provides a review of past projects, summarizes lessons learned from monitoring reports and through interviews with experts about which habitat designs may provide greater benefits to target native species, and provides guidance to ensure that project effectiveness can be better evaluated in the future. The paper also provides information about the costs of multi-benefit projects that combine levee construction and habitat improvements, as well as the costs of projects that improve habitats along levees but do not involve levee construction, e.g., projects that use riparian plantings to stabilize levee slopes and provide erosion control.

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 FloodSAFE Environmental Stewardship and Statewide Resources Office (FESSRO) of the California Department of Water Resources (DWR) for the Delta Levees Program. The mission of the Delta Levees Program's habitat enhancement is to restore and enhance sustainable and diverse habitats, particularly shaded riverine aquatic, channel margin, wetlands, riparian forest, scrub shrub, and uplands, in a mosaic that benefits the overall ecological health of the Delta and its native species. FESSRO characterized several of those different levee-related habitat types in a diagram (Figure 3), including: freshwater marsh (tidal and non-tidal); shaded riverine aquatic; 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.

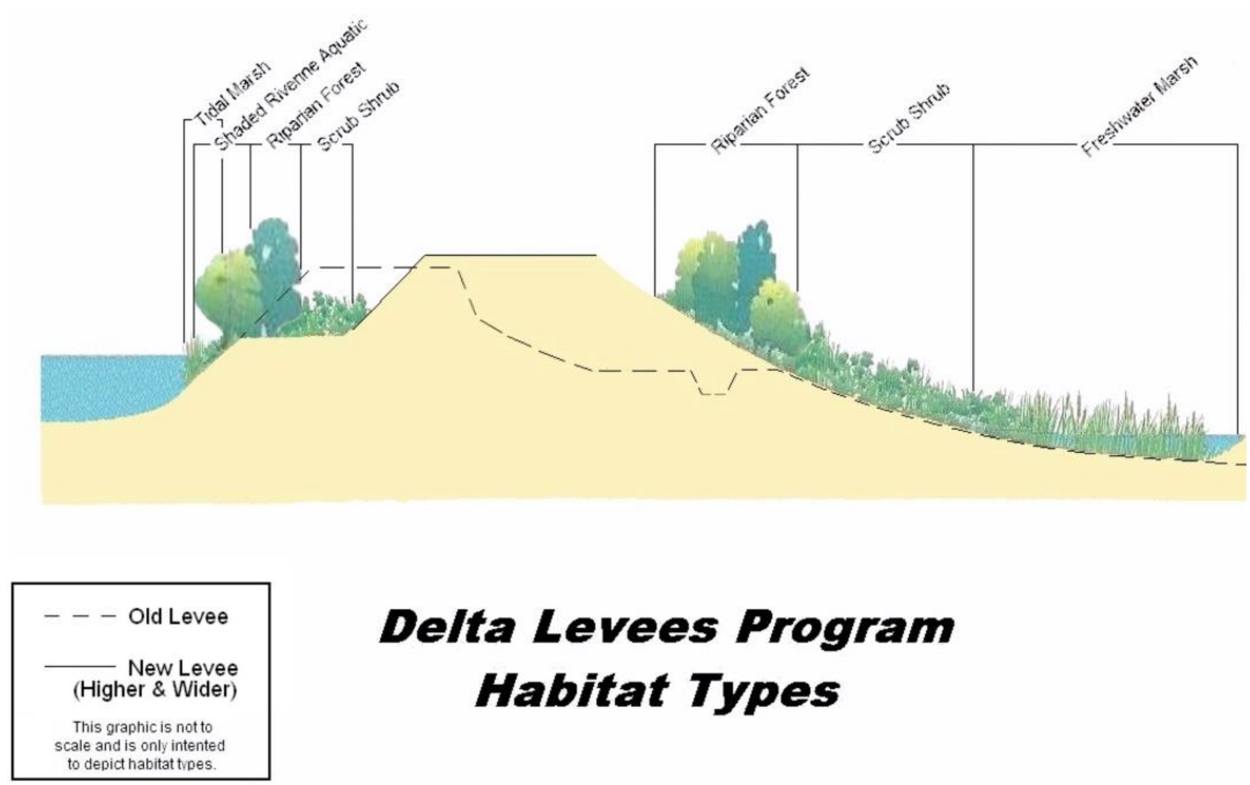


Figure 3. Cross-section of a levee and related habitats on a subsided island as defined by FESSRO.
Note: for purpose of this review, scrub shrub and riparian forest are categorized as riparian habitats. Source: DWR 2015a.

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. Shaded riverine aquatic habitat is the near-shore aquatic area occurring at the interface of a river and adjacent woody riparian habitat. Shaded riverine aquatic 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 shaded riverine aquatic habitat is the presence 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 and is generally characterized as a relatively shallow aquatic area (typically less than 4.5 feet deep) with emergent vegetation like tules, bulrushes, and cattails. Tidal marsh may occur along the levees of slower moving water from one foot 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). Channel margin habitat (sometimes referred to by FESSRO as "Fish Friendly Levee Habitat") provides soft bank substrates across a range of elevations that include tidally submerged benches to seasonally-inundated riparian habitat (i.e., shaded riverine aquatic). Channel margin habitat provides shallower depths and slower velocity than in the adjacent channel, which provides Delta-specific rearing and outmigration habitat for juvenile salmonids.

Information Gathering

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. Information about fifteen levee-related habitat improvement projects (mapped in Figure 4) 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 1 for details). Council staff also 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, in which habitat improvements were incorporated where levee construction work occurred, as well as habitat mitigation projects that occurred off-site.

Research Objectives

The majority of the projects evaluated were planned prior to the adoption of the Delta Plan regulations (2013), which require ecosystem restoration projects that are covered actions to have adaptive management plans; therefore, we do not assess whether or not the project used 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.

The main objective of the cost 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.

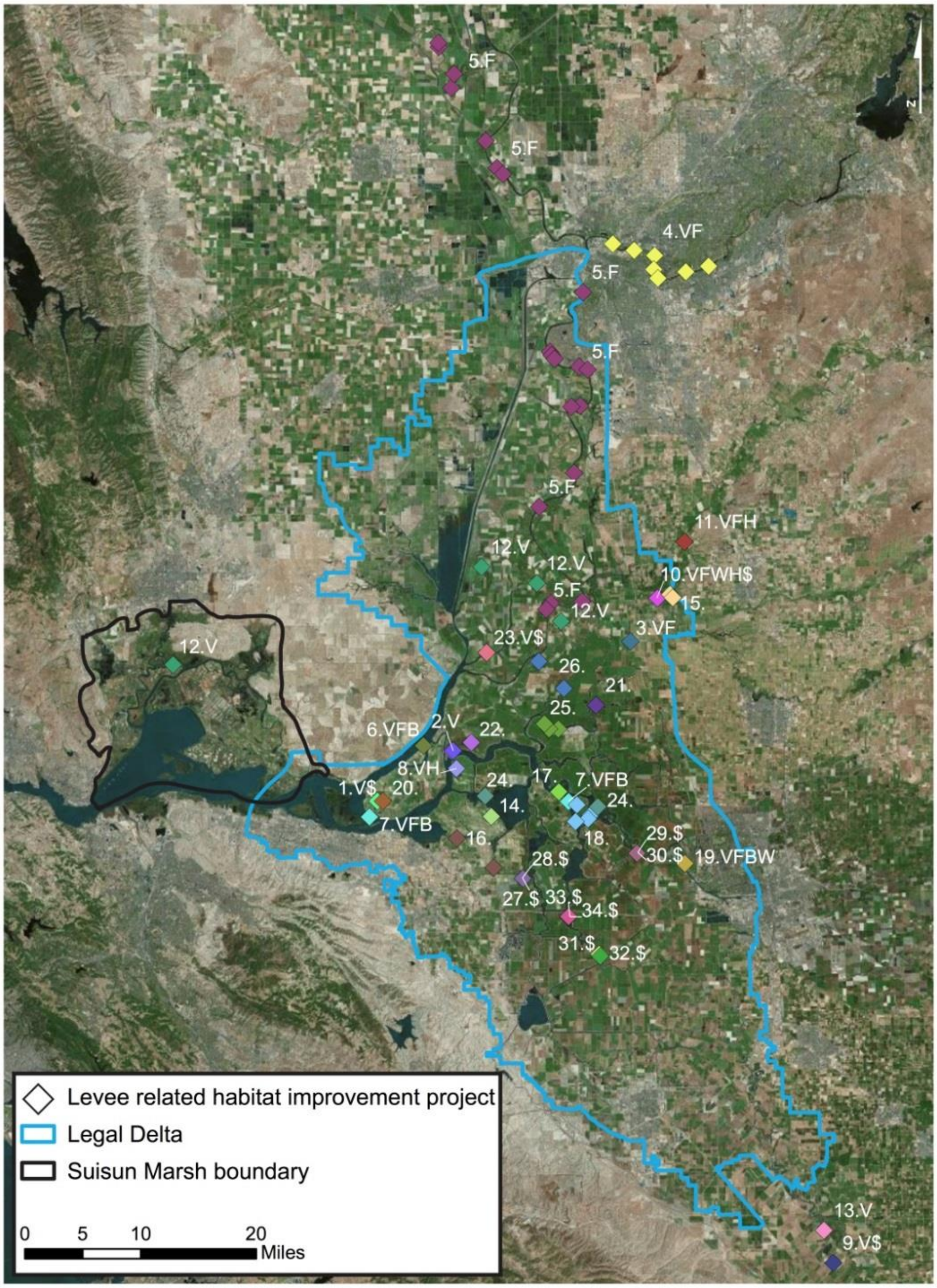


Figure 4. Map of levee-related habitat improvement projects reviewed. These projects were implemented by various state and federal agencies. Numerals indicate project number in Table A5.1. Symbols following numerals indicate if project has reports pertaining to: vegetation (V), fish (F), birds (B), water quality (W), and hydrology (H) monitoring and/or budgetary data ($). Project references 27-34 are approximately located.

III. ANALYSIS

Analytical Challenges

Council staff'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 (an exception is the 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 control 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.

In our costs analysis review we were unable to specifically isolate 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 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.

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; Block et al. 2001). Although vegetation performance measures are an important component of baseline monitoring, more wildlife response monitoring is 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). Furthermore, fundamental questions, such as what scale of habitat areas is needed to outweigh adverse edge effects within each target habitat, remain undefined. These scale questions must be considered for effective restoration, including what is the effective riparian forest width and area needed to enhance ecological value for bird habitat and terrestrial species? Another fundamental question could be asked for shaded riverine aquatic habitat in the Delta—would it provide significant water temperature benefits to native fish? Much of 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 benefits to fish (Greenberg et al. 2012).

Provided below are some considerations needed when designing habitat along levees for the benefit of native fish and avian species. A more complete analysis of the needs of these species is provided in Appendix 1, Lessons Learned from Past Projects and Research Studies.

<u>Native Fish Requirements</u>

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 salmonids. 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 improved channel margin habitat for native fish, especially juvenile salmon

Channel margin habitat with overhanging riparian vegetation (i.e., shaded riverine aquatic), slower water velocities and soft bank substrates provide important habitat for migrating juvenile salmon. Calmer, shallow waters provide a habitat for small juvenile salmon where they can rest and feed, and find refuge from larger, predatory fish. Shaded riverine aquatic habitat can provide an important source of food to the aquatic system as insects fall off riparian vegetation overhanging the river (Murphy and Meehan 1991; Smokorowski and Pratt 2006), while vegetation debris entering the river (e.g., falling leaves, woody debris) can also contribute to the aquatic foodweb. The overhanging vegetation also provides cover for small native fish from predation by birds.

Shaded riverine aquatic habitat 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 this habitat provides could be increasingly important with climate change. A recent study indicates that if all trees were removed from levees Delta, water temperatures would increase by 0.2°F Delta-wide and up to 7°F within narrower channels; along deeper and wider channels, however, the cooling benefits decrease (Greenberg et al. 2012).

The placement of riprap within channel margin habitat has been linked to degradation in habitat suitability for juvenile salmon in the Delta. Non-native fish predators can hold in the gaps of the riprap and ambush smaller fish as they move to and from 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 avoiding riprapped habitat or because they are suffering high predation loss (Schmetterling et al. 2001; Garland et al. 2002; McLain and Castillo 2009).

Although the importance of restored channel margin habitat for juvenile salmonids is widely viewed as critical for restoring populations, recent acoustic fish telemetry surveys indicate that migrating salmonids may not effectively utilize established or restored channel margin habitat because we do not fully understand the influence of such factors as the length, depth, bank slope, vegetative make up (tules to willows), and location on habitat utilization (Jon Burau, pers. comm. 2015). Habitat utilization studies are needed to determine the influence of these factors on the suitability of channel margin habitat enhancements in improving survival and condition of juvenile salmonids emigrating from the Delta.

2. Importance of providing the appropriate density of IWM.

Placing IWM is a common technique in salmon habitat restoration projects for areas such as the Pacific Northwest. Larger IWM (> 4 inches diameter) have been found to benefit juvenile Chinook salmon since it creates refuge from faster flow velocities and provides daytime cover for them from avian and fish predators (Zanjanc 2013). However, adding more IWM does not necessarily create better habitat for juvenile salmon. A study conducted along the lower Sacramento River showed that in areas with IWM in low and medium densities, Chinook salmon fry occupation increased by two- to three-fold; however, in areas with a “high density” of IWM, occupation by Chinook salmon fry dropped 75% as presence of non-native predatory fish increased twenty-fold. In the Delta where there are many species of introduced, warmwater fish predators, high densities of IWM may simply create more spots for them to hide and ambush small native fish. Further study of how IWM density, size, and location affects non-native predatory fish and native aquatic species along river corridors and tidally-influenced Delta channels must be conducted before we assume IWM will invariably provide a net benefit to aquatic species.

Bird Requirements

Larger riparian or marsh areas with connectivity between habitats will benefit avian species by providing protection, food resources, and nesting areas. The width of riparian habitat along the river channels of the Delta has decreased dramatically and is now measured in feet instead of miles. In general, riparian corridors that are a minimum of 100 meters (109 yards) wide are needed to provide foraging and nesting opportunities for neotropical migrant birds (e.g., orioles, flycatchers, warblers, and vireos). Riparian bird populations are typically more successful in areas with larger habitat patches that are not isolated from one another and located away from urban areas. Conversely, increased nest predation is often associated with smaller, isolated riparian patches.

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 and elsewhere to the Delta, due to the Delta's unique ecological and hydrodynamic setting and highly altered physical state. The best locations for restoring more natural functional flows to create wetland habitats are in flood bypasses, such as the Yolo Bypass, and other areas ranging from intertidal to upland elevations on the outer edges of the Delta, because of the constraints to natural overbank flooding on subsided islands in the central Delta.

Design Considerations for Setback Levees

Setback levees 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). Planning of setback levees as a habitat restoration option should consider the Delta-specific constraints discussed below and utilize indices that integrate floodplain inundation frequencies and life-cycles of target species such as the integrative method for quantifying floodplain habitat developed by Matella and Jagt (2014).

The draft Central Valley Flood System Conservation Strategy (DWR 2015c) lists several factors that should be considered when determining if a setback levee is appropriate for a given location. One of those factors, stating that "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 questions should be addressed for setback levees in the Delta:

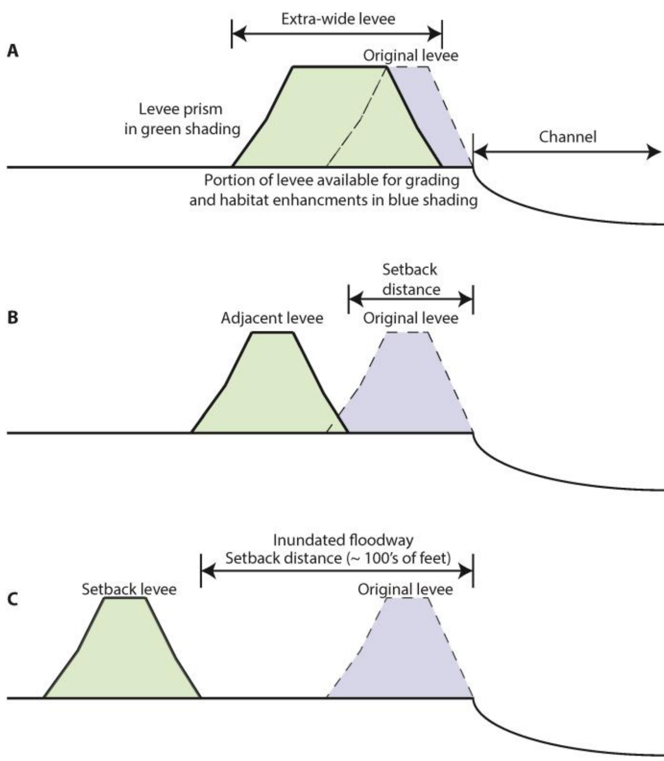
- Is the setback distance great enough to allow the channel to reinitiate riverine geomorphic processes (e.g., channel-migration, sedimentation, and cut-offs)?
- Is the inundated floodway created by the setback at intertidal to upland elevations?
- What are the timing, duration, and frequency of flood 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 yards and many Delta landowners do not readily support levee projects that would cause loss of productive farmland. The second critically important consideration for the Delta is that most Delta islands, especially islands within the central Delta, 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 can be brought to grade, a considerable expense. A third consideration is that unlike upstream areas of the Sacramento and San Joaquin River watersheds, soils in much of the Delta are comprised of peat which makes 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 may add many millions of dollars per mile of new setback levee. Because of these considerations setback levees are most appropriate in the upper reaches of Delta waterways where land lies at intertidal to upland elevations (Delta Plan 2013) and mineral soils with low levels of organic carbon are more commonly found (Deverel & Leighton 2010). Finally, there are numerous other challenges to implementing setback levee projects that are not unique to the Delta, including, but not limited to: finding willing landowners to provide land; complications in protecting existing structures and utilities; and maintaining access for mineral rights holders.

Design Considerations for Adjacent Levees

Adjacent levees (see Figure 5 for definition) cost more, on average, than typical levee improvement projects because they require a substantial amount of fill, and like setback levees, also require stabilization of soil foundations. In addition, 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 adequately 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 (Chris Neudeck, personal communication 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 flood risk reduction measure. In addition, DWR and CDFW staff helped incorporate habitat enhancement aspects into this project with the intended goal of creating riparian habitat and providing channel margin habitat for Delta fish. 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. However, 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.



Extra-wide levee - A levee that has been widened to shift the regulated levee prism landward, creating more space for habitat improvement next to the channel and providing enhanced flood protection.

Adjacent levee - A levee constructed behind an existing levee which allows for removal of a portion of the existing levee. An "adjacent levee" may not necessarily result in removal of the existing levee. Adjacent levees differ from "setback levees" in that the setback distance is not optimized to restore riverine geomorphic processes.

Setback levee - A levee constructed behind an existing levee which allows for removal of a portion of the existing levee and creation of additional floodplain connected to the stream. In the Delta, a "setback levee" may not necessarily result in removal of the existing levee (Delta Plan, 2013). The setback distance must be optimized to restore natural riverine processes necessary for establishing sustainable riparian habitats (Stromberg et al. 2007; Shafroth et al. 2010; Golet et al, 2013). Placement of setback levees should conider factors outlined in DWR (2015).

Figure 5. Illustration and definitions of extra-wide, adjacent, and setback levees.

Design Considerations for Extra-wide Levees

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 upland elevations. This design would allow riparian habitat, shaded riverine aquatic habitat, and fringing tidal marsh 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 (Figure 6; Fishery Foundation of California 2006).

Extra-wide levees may provide more habitat benefits than adjacent levees since the riparian, shaded riverine aquatic, and fringing tidal marsh habitat are interconnected along a single slope that ideally gently grades into the channel (Figure 6; FISHBIO 2015). Extra-wide levees require less conversion of land than setback levees, and the reduced loss of farmland may be acceptable to local landowners on larger Delta Islands considering the substantial flood protection benefit.

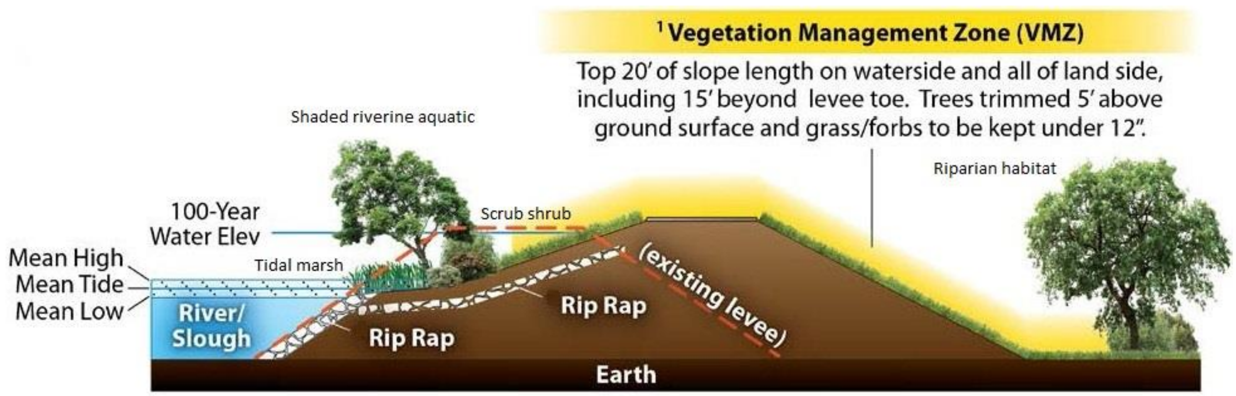


Figure 6. Schematic of extra-wide levee with waterside slope of levee graded into planting bench.
[1] Vegetation management zone (VMZ) of FESSRO is determined by vegetation free zone of USACE. Adapted from DWR 2014.

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 Figure 2) 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 regular 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., IWM) nearly as much as "natural" (i.e., non-riprapped) levee slopes (Fishery Foundation of California 2006). However, in years with very low flow, river stage fell to an elevation below the channel-margin enhancement projects. Use of these areas by out-migrating juvenile salmonids fell by about 83% while 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 have been successfully implemented by Jeff Hart to establish tule marsh at Grand Island (Hart 2006) and alders have been successfully planted on a waterside bench at Canal Ranch (EA Engineering, Science, and Technology 1996). 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

On-Site Riparian Habitat Improvement

DWR provided cost information for Delta levee construction projects that incorporated habitat elements on-site (Table 2). 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 (Table 2). The scope of these projects involved much fewer 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).

Table 2. Costs of Multi-Objective Levee Improvement Projects with On-Site Habitat Improvement*

Project Location	Linear Feet of Project	Cost Per Linear Foot
Multiple Objective Levee Improvement Projects		
Lower Jones Tract	2550	$2,300
Orwood and Palm Tract, Project 1	1000	$3,200
Orwood and Palm Tract, Project 2	2000	$2,800
Lower Roberts Tract, Project 1	1400	$2,200
Lower Roberts Tract, Project 2	2800	$1,400
Upper Jones Tract, Project 1	1600	$2,200
Upper Jones Tract, Project 2	3100	$1,400
Woodward Island, Project 1	1000	$5,200
Woodward Island, Project 2	1000	$5,100
Habitat Demonstration Projects		
Tyler Island	2000	$80
Grand Island	1000	$200

Source: DWR staff
*Costs were standardized to 2015 dollars, with an inflation correction factor based on the U.S. Bureau of Labor Statistics' Consumer Price Index.

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 larger amounts of habitat in fewer projects instead of many smaller projects (see Figure 7). However, site specific considerations and levee condition can influence this and make the costs of restoring riparian habitat on levees highly variable.

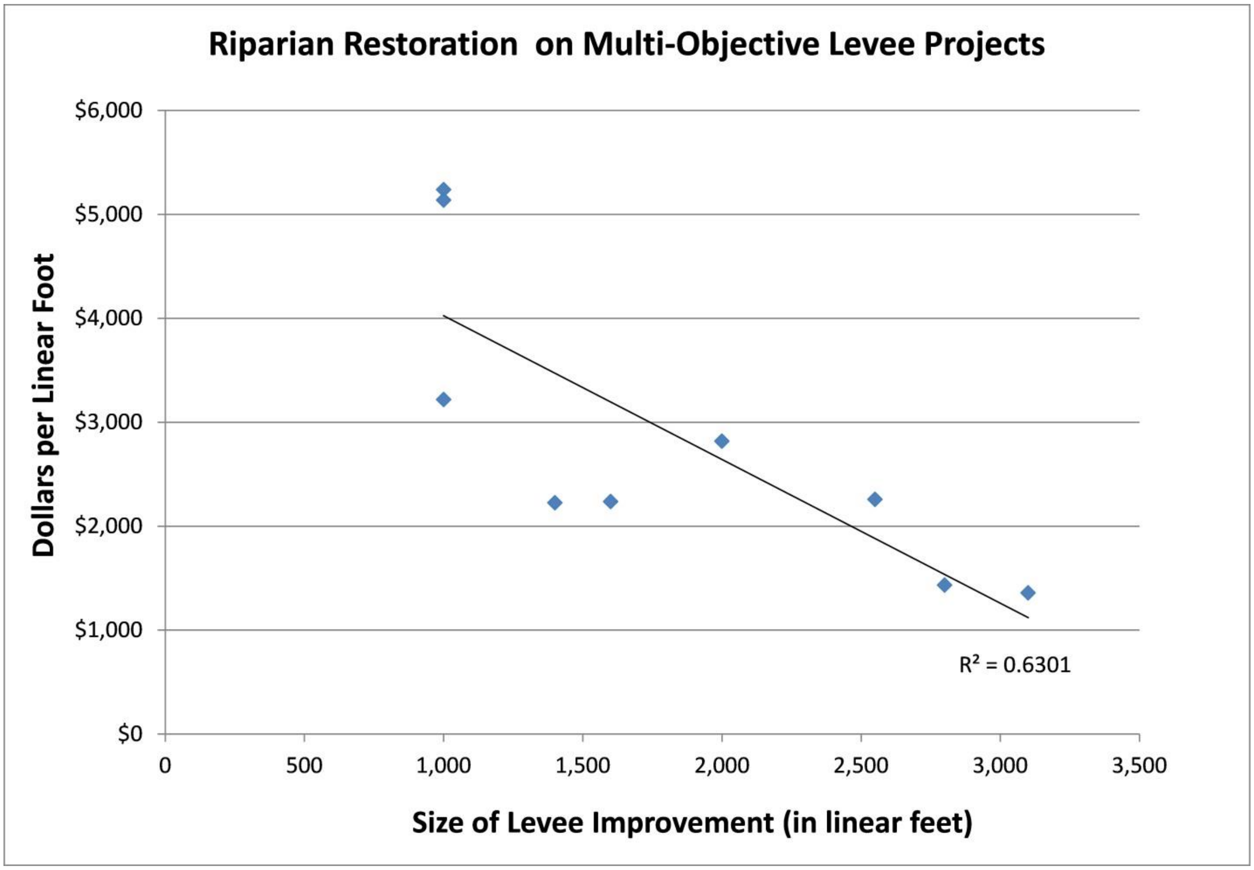


Figure 7. Relationship between size of multiple-objective levee improvement projects* and total cost of project. **These projects all include on-site habitat improvements within the levee prism.*

Off-Site Mitigation Banks

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 Floodplain 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 3). If engineering constraints limit 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.

Table 3. DWR Bulk Credit Program Costs.

Habitat Type	Cost Information	Notes
Shaded Riverine Aquatic Habitat	$61	Per linear foot
Riparian Forest	$62,295	Per acre*
Scrub shrub	$62,295	Per acre*
Freshwater Marsh	$120,000	Per acre*

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

* includes required buffer acreage that comprises the mitigation bank

The Delta Levees Program has also funded off-site mitigation and enhancement projects to create riparian and freshwater wetland habitats. These habitat improvement efforts occurred in the interiors of Delta islands and not directly on levees. The average cost per acre of these projects is in a similar range as the costs of the Bulk Credit Program (see Table 4).

Table 4. DWR and CDFW Off-Channel Habitat Mitigation and Enhancement Projects*

Project Location	Acreage	Total Cost (in millions)	Price per acre (in thousands)	Created Habitat Types
Bradford Island	50	$2.2	$45.0	Freshwater marsh; Scrub shrub; Riparian forest
Sherman Island (Parcel 11)	5.67	$0.77	$135.6	Riparian forest: Freshwater marsh; Scrub shrub
Decker Island	26	$14.7	$563.8	Tidal freshwater marsh; Riparian forest

Source: DWR staff

*Costs were standardized to 2015 dollars, with an inflation correction factor based on the U.S. Bureau of Labor Statistics' Consumer Price Index.

<u>Adjacent and Setback Levees</u>

As described previously, adjacent levees involve constructing a new levee in close proximity to or immediately adjoining an existing levee, while setback levees involve constructing a new levee behind an existing levee at a sufficient distance to allow for the reestablishment of natural riverine processes. In the mid-2000's, DWR constructed adjacent 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). However, due to unique circumstances, some costs typically associated with these types of levee projects were not included in this cost assessment. First, the land where these particular projects took place was owned by DWR, so the cost of purchasing the land was not incorporated. Second, berms were placed on the landward toe of the levee many years prior to the construction of the adjacent levee, which helped stabilize the normally unstable peat soil. The cost of constructing these berms are unknown and was not included as costs for these adjacent levee projects. Third, these adjacent levees were constructed next to the existing levee, decreasing the volume of fill and contributing to major savings in materials costs compared to constructing a setback levee.

Planned setback levees in the Delta are expected to be significantly more expensive than the adjacent levees undertaken in the past. 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 (RD 1601 2014) place the estimate for future construction of setback levees along the southern portion of Twitchell Island around approximately $4,300 per linear foot ($23 million per linear mile). The cost of the setback levee for the

Southport Project is substantially larger than DWR's past Delta adjacent levee projects because it includes the cost of land acquisition in an urban area, and the newly constructed levees will be fully setback from the existing levees.

Table 5. Cost of adjacent and setback levees in the Delta[a]

Adjacent/Setback Levee Location	Status	Linear Feet	Total Cost (in millions)	Cost per Linear Foot (in thousands)
Sherman Island	Implemented	6,000	$12.9	$2,200[b]
Twitchell Island	Implemented	2,400	$2.5	$1,000[b]
Southport (West Sacramento)	Planned	29,300	$373.7	$12,700[c]
Twitchell Island	Planned	20,380	$88.0	$4,300[d]

a Costs were standardized to 2015 dollars, with an inflation correction factor based on the U.S. Bureau of Labor Statistics' Consumer Price Index.
b Source: DWR staff
c Source: USACE 2014
d Source: RD 1601, 2014

Of all the habitat improvement options considered, setback levees generally are one of the most expensive options when 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 adjacent 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.

IV. RECOMMENDED NEXT STEPS

Based on the findings of the review, we suggest taking the following steps to improve the siting and design of future restoration, enhancement, and mitigation projects and ensure that effectiveness can be clearly 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. Develop appropriate performance measures as part an adaptive management plan.

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 develop adaptive management plans with documented resources for implementation. 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., Standardized Assessment Methodology [SAM]; Management, Analysis, and Synthesis Team [MAST]; Salmonid/Steelhead/Sturgeon Assessment Indicators by Life Stages [SAIL]) for 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).

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 will be spent on future levee improvements and maintenance, as well as habitat enhancement and associated monitoring in the Delta. It will be essential to select appropriate performance measures, including fish and wildlife response, to assess effectiveness in providing benefits to target species. By identifying quantifiable criteria at the outset of a project, we will be better able to measure success.

2. Track the incremental cost of habitat improvements.

Accurate 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 allowing them to segregate costs and giving them flexibility in selecting the most 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.

3. Carefully consider the tradeoffs associated with on-site and off-site mitigation.

During our review, we observed that on-site 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 become 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 project levees 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 flood-water conveyance by changing the performance or reliability of the channel to safely carry flood flows or by impairing levee structure.

Our review indicated there have been successful examples where on-site 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.

Off-site mitigation, such as creation of marsh and riparian forest in the interior portions of islands, was often used for projects in the Delta Levees Program 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. 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, especially if it facilitates the creation of larger and more interconnected habitat patches.

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 acre) habitat cannot be adequately mitigated by many smaller mitigation sites (e.g., twenty 10 acre 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 Sacramento Valley 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 on-site 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, then the mitigation would not be expected to provide the same ecological benefits to salmon.

4. 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 parcels). 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 the Delta ecosystem.

The Delta Plan calls for 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 place 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 habitat improvement opportunities. Projects should not be undertaken independently of one another; once priority areas are identified, smaller projects can be sited so that they build incrementally towards establishing continuous corridors of riparian forest.

5. **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 indices that can be measured quickly and inexpensively. Three years of post-project vegetation management (e.g., irrigation and weed-control efforts) and compliance monitoring to verify that projects were constructed as designed and permitted is typical in this system. 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. Additionally, data from past restoration projects along the Sacramento River indicate that short-term monitoring (i.e., three years of compliance monitoring) conducted until management efforts cease tends to overestimate the survival of native trees and shrubs, so is an unreliable predictor of overall restoration success (Moore et al. 2011).Therefore, research and monitoring focusing on fish and wildlife response, as well as vegetation monitoring, is needed to determine whether projects are actually 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).

Collecting fish and wildlife response monitoring data at sites before and after habitat improvement efforts and concurrently at control sites is the most ideal monitoring approach, because it makes it possible to isolate the effects of the habitat improvement work from other variables (e.g., drought). Such an approach is not possible for projects that have already been implemented and did not have effectiveness monitoring from the start. Going back and monitoring these past projects though is still highly recommended, especially since it will reveal insights about the evolution of levee habitat projects in the years and decades following construction and the responses of fish and wildlife to mature restoration sites.

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 performance measures and response indicators 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 are 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 requires obtaining incidental take permits (ITPs) from CDFW, as well as Section 7 permits from the federal wildlife agencies (USFWS and NMFS). 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, track fish response to levee-related habitat projects. Such a monitoring program is being developed by the IEP

Tidal Wetland Monitoring Project Work Team to assess future tidal marsh projects, especially the response of fish species to tidal marsh restoration. Concurrently, DWR is building upon the work of the Tidal Wetland Monitoring Project Work Team and will seek to implement a similar monitoring program for assessing levee-related habitat projects. One 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.

6. **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.

V. 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 inform 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 AND THE INTERVIEW PROCESS

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 Shaded Riverine Aquatic Habitat

Of the fifteen projects reviewed, twelve projects improved or restored riparian habitat and seven improved or restored shaded riverine aquatic habitat (see Appendix 4). 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. All of the projects that implemented riparian or shaded riverine aquatic habitat 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.

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 shaded riverine aquatic habitat 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 during the planning phase.

Importance of Vegetated Banks for Salmonids

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 salmonids was 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 (e.g., waterside planting benches) 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. Analysis of gastric contents suggested that a high proportion of juvenile salmonids actively used the mitigated levee repair sites not only as a migratory corridor, but also for rearing and foraging (FISHBIO 2014). In addition to providing foraging benefits for small fishes, vegetated channels play an important role in predator avoidance (Gewant & Bollens 2012).

Impacts of Riprapped Banks on Juvenile Salmonids

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). Similarly, a study by McLain & Castillo (2009) in the Northwestern Delta documented reduced densities of Chinook salmon fry observed along riprapped levees compared to shallow beaches along levees. Fish predators, like introduced bass, are also associated with riprap because they can hold in the gaps of the riprap and ambush smaller fish (e.g., juvenile salmon) as they try to utilize nearshore habitat.

In areas of the Delta that are prone to high erosion (e.g., a result of boat wakes or high water velocities) levees may need to be riprapped to provide adequate flood risk reduction, in spite of the impacts to native fish. In such circumstances, it is still possible to enhance the nearshore levee habitat for native fish species by providing ample vegetative cover. Snorkel surveys of channel margin enhancement sites along the Lower American River found that riprapped sampling units with high vegetative 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 bank edge show relatively high utilization by young salmon (Fishery Foundation of California 2006).

Importance of Restoring Channel Margin Habitat across a Range of Elevations

River stage plays a crucial role in determining the habitat usage of channel margin enhancement sites by salmonids. The amount of cover available in enhanced rocked (riprapped) sites and non-rocked sites decreased greatly when river flows and stage fell below 2000 cubic feet per second (cfs) and 18 feet, 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.

Importance of Soft Substrates and Gently Sloping Banks for Salmonids

Juvenile Chinook salmon and steelhead were found in greater numbers over sand/silt substrate rather than substrate composed predominantly of large rock, and preferred areas with gently sloping banks (FISHBIO 2014). Additionally, areas with these habitat characteristics significantly reduce occupancy by smallmouth bass (*Micropterus dolomieu*), one of the most abundant introduced predatory species, greater than 150 mm (5.9 in) fork length (FL) (FISHBIO 2014). Inversely, smallmouth bass was found to be ten times more prevalent over rocky substrate compared to areas with sand/silt substrate and more prevalent along shores with steeply sloping banks.

Importance of Using Appropriate Amount of IWM

Habitat features such as low- or medium-density submerged vegetation or 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, high density IWM negatively affected the use of habitat by fry by about 75% compared to similar sites that lacked high-density IWM. This may be related to the finding that habitat use of the piscivorous smallmouth bass increases by 20-fold with increasing density of IWM in nearshore habitats compared to locations lacking IWM (FISHBIO 2014). 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 (FISHBIO 2014).

Influence of Habitat Characteristics on Salmonid Outmigration Behavior

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 ≥ 1hour) 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.

Importance of Anticipating Tree Mortality

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 shaded riverine aquatic habitat project goals. Typically, this means that more plantings must be made during the contracted maintenance period to achieve stated shaded riverine aquatic 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.

Lessons Learned – Seasonal Floodplain Habitat

Setting back levees can create seasonal floodplain habitat between the old levee and the new levee that provides valuable habitat for native species. Although none of the projects we reviewed involved setting back levees in a manner that would restore a natural floodplain corridor, studies in the Yolo Bypass have demonstrated the value that seasonal floodplains can have for rearing juvenile salmonids. 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 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.

Lessons Learned – Riparian Habitat

Restoration and habitat enhancement is vital 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, given 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 formerly existed 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.

Importance of Vegetation Structure and Assemblage

Canopy closure is another factor that contributes to the complexity of a habitat. In riparian forest restoration experiments along the Sacramento River, four of seven native understory species had greater survival under low-light conditions (i.e., greater canopy cover) and canopy cover was more effective than grass-specific herbicide at reducing the amount of non-native understory vegetation (Moore et al. 2011). Native understory species that are light-tolerant should be planted along with overstory species during initial restoration efforts and shade-loving species can be introduced into restoration sites with well-established canopies post hoc. Few native understory species have been found to naturally colonize restoration sites where only overstory trees and shrubs were planted (Holl and Crone 2004; McClain et al. 2011).

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). 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. Findings such as these should help direct restoration planting design to include a diverse understory.

Importance of Successional Stage of Riparian Forest in Utilization by Avian Species

Many restoration sites, although varying in trajectory in vegetation characteristics as they mature, show a sigmoidal bird response representing an initial rapid increase in bird abundance or diversity followed by a plateau (Nur et al. 2006). 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 (ten 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.

For riparian restoration projects, species numbers and richness (i.e., number of species present) tends to increase as succession continues on a site and mature canopies develop (Gardali et al. 2006; Golet et al. 2008). 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). On Venice Cut and Donlon Islands, which were created via deposition of dredged materials, marsh and riparian vegetation established through natural colonization; this process resulted in the creation of 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 122 species of birds began to utilize the habitats, with abundance increasing as acreage and quality of vegetative cover developed (England et al. 1990).

The northern tip of Decker Island in the western Delta was restored in 2000 (14 acres) and 2004 (12 acres) as a multi benefit project, creating a mosaic of aquatic and terrestrial habitat, while supplying excavated material to nearby islands for levee rehabilitation. Native trees, shrubs and grasses were planted to provide freshwater emergent wetland and riparian habitat for wildlife. Bird surveys conducted several years after project completion (2007-2008) found higher bird densities (number of birds detected per acre) for almost all species at the restoration site than for the reference site. 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. This 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 mature trees.

Importance of Habitat Connectivity and Patch Size

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 Sacramento River, showed an increase in avian abundance not only at restoration sites, but also in adjacent remnant forest patches, suggesting that positive spill-over effects may be occurring (Golet et al. 2008). 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 (Nur et al. 2006).

Riparian length by width class is one type of metric used to determine life history support status for riparian wildlife (Robinson et al. 2014). In general, riparian habitat benefits to target species scale with riparian habitat corridor size (Golet et al. 2003; Golet et al. 2013; Gardali et al. 2006; England et. al. 1990). For example, stretches of riparian forest that represent "optimal" habitat (> 500 meters (547 yards)) for the endangered yellow-billed cuckoo have decreased by 91% (Robinson et al. 2014). A "suitable" habitat patch for the yellow-billed cuckoo has been defined as 101-198 acres of willow-cottonwood (riparian) forest 100 meters (109 yards) wide or greater, with at least 2.47 acres of dense nesting habitat per pair (Laymon & Halterman 1989). The majority of riparian habitat existing today is of "unsuitable" width (<109 yards) to support the yellow-billed cuckoo (Laymon & Halterman 1989). In general, riparian corridors a minimum of 109 yards wide are needed to provide foraging and nesting opportunities for neotropical migratory birds (Golet et al. 2011).

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.

Importance of Considering Physical and Biological Factors when Restoring Riparian Habitat

Restoration of riparian vegetation requires an understanding of local site characteristics. A few key criteria to consider include the following: topography, soil types, depth to groundwater, location, and extent of native and non-native plant species (Stillwater Sciences 2011). 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). Riparian habitat plantings in the San Joaquin River National Wildlife Refuge (NWR) were planned based upon field elevations, observed depth to water table, and habitat needs of the target species. This planning helped with the success of the San Joaquin River NWR riparian restoration project in providing a measurable benefit for its key target species, the endangered riparian brush rabbit (*Sylvilagus bachmani riparius*) (River Partners 2003; River Partners 2014; ESRP 2012).

Given suitable elevations and soil inundation levels, recruitment of riparian vegetation can also occur naturally. Riparian tree species naturally established on islands constructed within Delta channels using dredged material in elevation zones of 0.0 to 3-3.5 feet above Mean Water Level (MWL); these trees were inundated daily but also exposed for more than half the time (England et al. 1990). Willow (*Salix* spp.) development was rapid on these islands, tending to occur at higher elevations and growing most readily on or near peat soils (England et al. 1990).

APPENDIX 2. RECOMMENDATIONS REGARDING THE USE OF ADAPTIVE MANAGEMENT

Recommendations given in this section follow "A Nine Step Adaptive Management Framework" presented in Appendix C of the Delta Plan. 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 a 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 proposed using specific terminology for channel alteration projects based on resulting ecosystem function and geomorphic variability (see Figure 8). Restoration, enhancement, and erosion control and containment are a subset of terms applicable to stream and river bank improvement efforts.

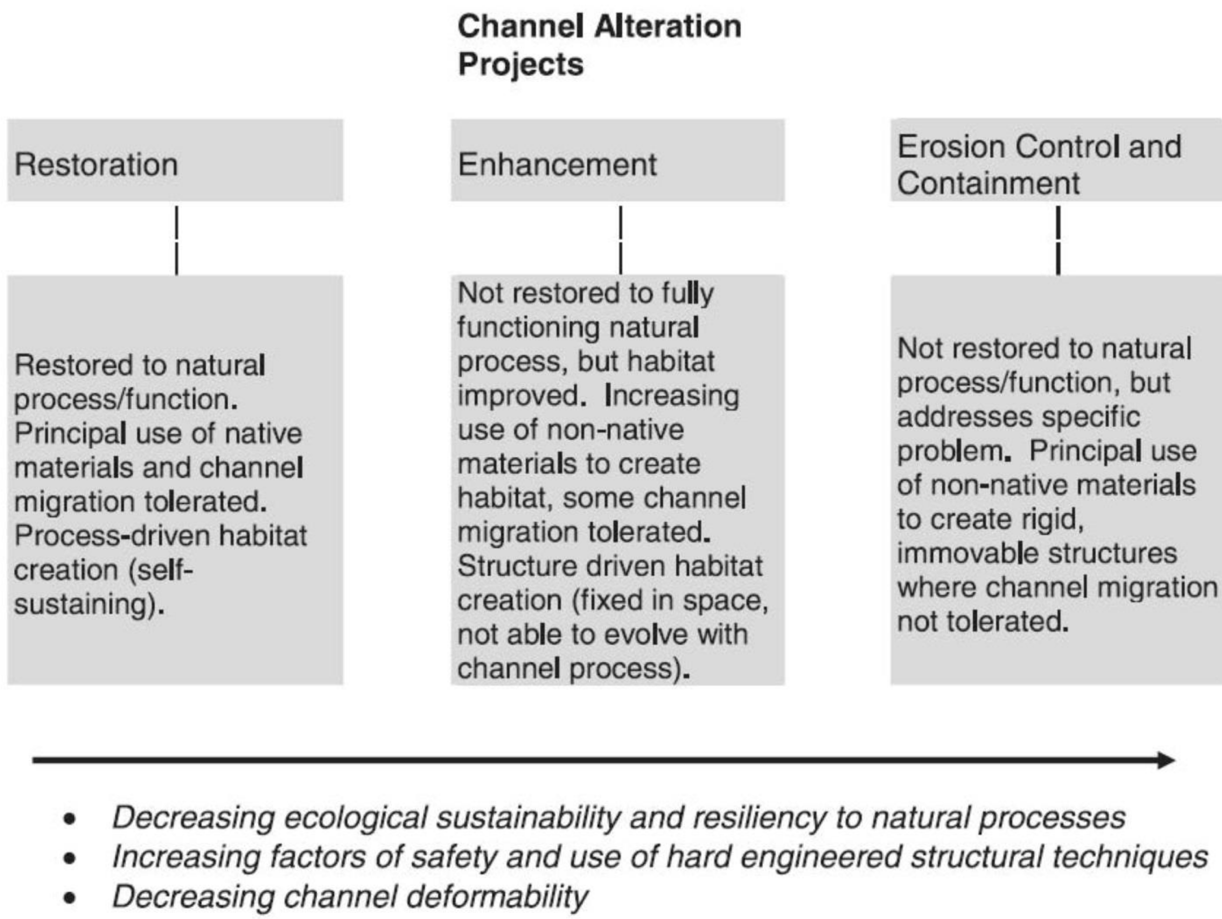

Figure 8. Geomorphic restoration project type continuum from Gillilan et al. 2015

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). This predictive model was 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, 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). 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.

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 makes 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 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 wildlife, 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 invasive species. Considering that the origin of materials used to construct most Delta levees is unknown, pre-construction evaluation of the soil conditions on-site 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 in 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% 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% of respondents) and lack of staff or time (32% 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 while adaptive management is still possible. Too often the analysis, synthesis, and evaluation of monitoring data is either not conducted or done immediately 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 they 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 the CALFED Bay-Delta Ecosystem Restoration Program (ERP) 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%) and many claimed that their projects were partially successful (36%) (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 investment, 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, non-governmental organizations (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 database of 4,023 stream restoration projects by mining existing databases and requesting agency records. Data fields included project year, location, basin size, project size, objective(s), responsible agency and contact information, planning and construction dates, project activities, monitoring components, 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. 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), non-governmental organizations (The Nature Conservancy and River Partners), UC Davis, and consulting firms with 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.

Interview questions included:

<u>Project description</u>

- What levee-related projects is the interviewee aware of?
    - When was the project(s) conducted?
    - What was the target habitat(s)?
    - What were the stated performance measures?
    - What agencies, companies, or institutions were involved?
    - Was the project(s) for enhancement, restoration, or on-site/off-site mitigation?

<u>Project Duration</u>

- What were the start and end dates 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?
- Were there any unforeseen costs?
- How was the project funded?
- Who can we contact for additional project budgetary information?

Monitoring

- Is monitoring data available for the 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 4. HABITAT IMPROVEMENT PROJECTS REVIEWED

Table A5.1

Habitat improvement projects

List of projects reviewed for this report. Note: Includes both habitat mitigation and habitat enhancement efforts.

Project	Target Habitat or Project Type	M, E, R, and/or D[a]	Program Management[b]
1. Sherman Island Mayberry Slough Levee Setback Habitat Project	adjacent levee	E	DWR, Hanford ARC
2. Twitchell Island Habitat Improvement Project/Levee Setback Planting	adjacent levee	E	DWR, Hanford ARC
3. Beaver Slough Habitat Improvement Project on Canal Ranch	levee revetment, planting benches	E	MBK Engineers, RD 2086, DWR DLP
4. Lower American River SAFCA Restoration Sites	biotechnical improvments, planting benches	E	SAFCA, USACE, RD 1000
5. Emergency Levee Repair Project by DWR	levee revetment, planting benches	M/E	DWR
6. Decker Island Habitat Development/Levee Improvement Project	tidal marsh	M/E	DWR DLP, DFW
7. Stockton Deep Water Ship Channel (Venice Cut & Donlon Island)	dredged material islands (DMI), tidal marsh, riparian habitat	E	USFWS, USACE
8. Bradford Island Tract 19	riparian, scrub shrub, and wetland restoration	M	DFW, RD 2059
9. San Joaquin River NWR – Ecosystem Restoration & Floodwater Attenuation Project	riparian habitat levee enhancement	R	DWR, USFWS, River Partners
10. Cosumnes Floodplain Mitigation Bank	floodplain	M	Westervelt Ecological Services
11. Oneto-Denier Floodplain Easement	floodplain	R	TNC, USDA NRCS
12. Biotechnical restoration methods for bank protection	riparian habitat, tidal marsh, biotechnical erosion control	E	CALFED 2012 P12 project
13. 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
14. Bethel Island 10 acre Site	freshwater marsh, scrub shrub	M	DWR DLP, DFW
15. Grizzly Slough	unclear	M	DWR DLP, DFW
16. Hotchkiss 1000 lineal feet (1995 Repair)	scrub shrub	M	DWR DLP, DFW
17. Mandeville 1,350 foot On-Site	scrub shrub	M	DWR DLP, DFW
18. Medford - Fields 23, 24, 25, 36 & 51A	freshwater marsh, riparian forest, scrub-shrub	M	DWR DLP, DFW
19. Pace Preserve (Wright-Elmwood)	freshwater marsh, riparian forest	M	DWR DLP, DFW
20. Sherman Island Parcel 11	freshwater marsh, riparian forest, scrub-shrub	M	DWR DLP, DFW
21. Terminous Mitigation Area	riparian forest, scrub shrub	M	DWR DLP, DFW
22. Twitchell 2, 4.04 and 8.08 acre site	freshwater marsh, riparian forest, scrub-shrub, grassland	M	DWR DLP, DFW
23. Grand Island Bank Revegetation	shaded riverine aqautic	E	DWR DLP, DFW
24. In-Channel Island Demo	biotechnical erosional control	D	DWR DLP, DFW
25. Staten Island Channel Bank Stabilization	planting bench, riparian habitat, tidal marsh	D	DWR DLP, DFW
26. Tyler Island Levee Protection and Habitat restoration Pilot Project	biotechnical erosional control	D	DWR DLP, DFW
27. Orwood and Palm Tracts (36+00 to 190+00)	SRA	E	DWR DLP, DFW
28. Orwood and Palm Tracts (60+00 to 398+00)	SRA	E	DWR DLP, DFW
29. Lower Roberts Island (256+00 to 820+00, 50+00 to 254+00)	SRA	E	DWR DLP, DFW
30. Lower Roberts Island (44+00 to 740+00)	SRA	E	DWR DLP, DFW
31. Upper Jones Tract (90+00 to 240+00)	SRA	E	DWR DLP, DFW
32. Upper Jones Tract (3+00 to 90+00, -6+00 to 90+00, -6+00 to -2+00)	SRA	E	DWR DLP, DFW
33. Woodward Island (0+00 to 15+00, 385+00 to 471+00)	SRA, TM, non tidal FM	E	DWR DLP, DFW
34. Woodward Island (1+00 to 465+00)	SRA, TM	E	DWR DLP, DFW

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

[b] 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

[b] 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

Table A5.1 (continued)

Habitat improvement projects

List of projects reviewed for this report. Note: Includes both habitat mitigation and habitat enhancement efforts.

Project	Monitoring Data Types: Monitoring Data	Vegetation	Fish	Birds	Water Quality	Hydrology	Budgetary Data	Reference
1. Sherman Island Mayberry Slough Levee Setback Habitat Project	M	V					$	Hanford Applied Restoration and Conservation, 2012
2. Twitchell Island Habitat Improvement Project/Levee Setback Planting	M	V						RD1601, 2014
3. Beaver Slough Habitat Improvement Project on Canal Ranch	M	V						EA Engineering, Science, and Technology, 1996
4. Lower American River SAFCA Restoration Sites	M	V	F					Fishery Foundation of California, 2006
5. Emergency Levee Repair Project by DWR	M		F					FISHBIO, 2014
6. Decker Island Habitat Development/Levee Improvement Project	M	V	F	B				Rockriver, 2008
7. Stockton Deep Water Ship Channel (Venice Cut & Donlon Island)	M	V	F	B				England et. al., 1990
8. Bradford Island Tract 19	M	V				H		Stillwater Sciences, 2011
9. San Joaquin River NWR – Ecosystem Restoration & Floodwater Attenuation Project	M	V					$	River Partners, 2014
10. Cosumnes Floodplain Mitigation Bank	M	V	F		W	H	$	Nur, et. al., 2006
11. Oneto-Denier Floodplain Easement	M	V	F			H		Viers et. al., 2015
12. Biotechnical restoration methods for bank protection	M	V						Hart, 2006
13. Monier Lifetile Levee Planting: Vierra Unit; 2008	M	V						River Partners, 2008
14. Bethel Island 10 acre Site								California Department of Water Resources, 2015d
15. Grizzly Slough								California Department of Water Resources, 2015d
16. Hotchkiss 1000 lineal feet (1995 Repair)								California Department of Water Resources, 2015d
17. Mandeville 1,350 foot On-Site								California Department of Water Resources, 2015d
18. Medford - Fields 23, 24, 25, 36 & 51A								California Department of Water Resources, 2015d
19. Pace Preserve (Wright-Elmwood)	M	V	F	B	W			Little, 2012
20. Sherman Island Parcel 11								California Department of Water Resources, 2015d
21. Terminous Mitigation Area								California Department of Water Resources, 2015d
22. Twitchell 2, 4.04 and 8.08 acre site								California Department of Water Resources, 2015d
23. Grand Island Bank Revegetation	M	V					$	California Department of Water Resources, 2015d
24. In-Channel Island Demo								California Department of Water Resources, 2015d
25. Staten Island Channel Bank Stabilization								California Department of Water Resources, 2015d
26. Tyler Island Levee Protection and Habitat restoration Pilot Project								California Department of Water Resources, 2015d
27. Orwood and Palm Tracts (36+00 to 190+00)							$	California Department of Water Resources, 2015d
28. Orwood and Palm Tracts (60+00 to 398+00)							$	California Department of Water Resources, 2015d
29. Lower Roberts Island (256+00 to 820+00, 50+00 to 254+00)							$	California Department of Water Resources, 2015d
30. Lower Roberts Island (44+00 to 740+00)							$	California Department of Water Resources, 2015d
31. Upper Jones Tract (90+00 to 240+00)							$	California Department of Water Resources, 2015d
32. Upper Jones Tract (3+00 to 90+00, -6+00 to 90+00, -6+00 to -2+00)							$	California Department of Water Resources, 2015d
33. Woodward Island (0+00 to 15+00, 385+00 to 471+00)							$	California Department of Water Resources, 2015d
34. Woodward Island (1+00 to 465+00)							$	California Department of Water Resources, 2015d