DELTA LANDSCAPES

EXECUTIVE SUMMARY

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SAN FRANCISCO ESTUARY INSTITUTE & THE AQUATIC SCIENCE CENTER

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SACRAMENTO - SAN JOAQUIN DELTA CONSERVANCY

A California State Agency

December 2017

SAN FRANCISCO ESTUARY INSTITUTE PUBLICATION #853

SUGGESTED CITATION

San Francisco Estuary Institute-Aquatic Science Center. 2017. *Delta Landscapes Executive Summary.* A Report of SFEI-ASC's Resilient Landscapes Program, Publication #853, San Francisco Estuary Institute-Aquatic Science Center, Richmond, CA.

Version 1.0, published December 2017.

REPORT AVAILABILITY

Report is available at www.sfei.org

COVER CREDITS

Cover imagery courtesy Google Earth Pro

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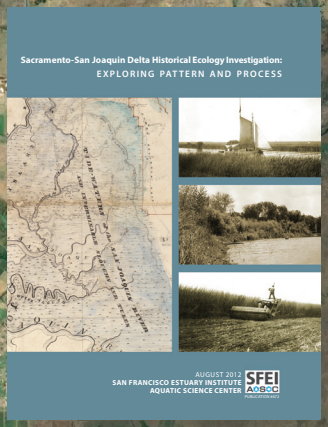


PUBLISHED AUGUST 2012

PUBLISHED OCTOBER 2014

PUBLISHED NOVEMBER 2016

Imagining a healthy Delta ecosystem in the future and taking bold, concrete steps toward that future requires an understanding and vision of what that healthy ecosystem looks like.

Image courtesy of Google.

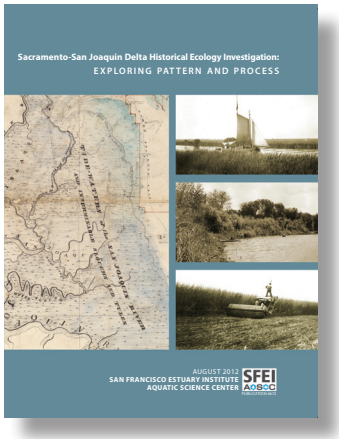
DELTA LANDSCAPES
EXECUTIVE SUMMARY

The Sacramento-San Joaquin Delta supplies freshwater to a large portion of California's cities and agriculture, supports an agricultural economy and culture, and is home to native wildlife found nowhere else in the world. This complex region is hampered by many environmental challenges, including an over-allocated water supply, invasive species, water quality problems, novel ecosystems that no longer support desired functions, aging infrastructure, and a complex management structure. Beyond these challenges, sea level rise, other impacts from climate change, and earthquakes pose significant risks to Delta ecosystems, agriculture and water supply. There is general consensus that ecosystem restoration and planning for future resilience needs to take place, within the context of the Delta's unique culture and economy.

Imagining a healthy Delta ecosystem in the future and taking bold, concrete steps toward that future requires an understanding and vision of what that healthy ecosystem could look like. For a place as extensive, unique, and modified as the Delta, critical knowledge can be acquired through the study of the past, investigating the Delta as it existed just prior to the substantial human modifications of the past two centuries. Though the Delta is irrevocably altered, its history is still relevant. Underlying geologic and hydrologic processes still influence the landscape. Native species adapted to live in the historical ecosystems, so restoring functional landscapes that reflect historical patterns can increase the success of restoration efforts.

The Delta Landscapes project investigates the historical ecosystems of the Delta and how they have been modified in the current landscape in order to produce a holistic, aspirational approach to restoration of desired ecological functions. The project goes beyond immediate planning horizons and mandated protection of particular species to explore how restoration of large-scale processes of sediment and water could drive a broad suite of ecological benefits. Restoration or emulation of such processes requires large areas and long time scales. The Delta Landscapes project produced three reports, summarized here, that speak to the past, present, and potential future Delta. The final report, *A Delta Renewed*, provides a framework for how individual projects planned in the near-term can contribute to a coherent, long-term vision of improving ecosystem function across the Delta. The purpose of this planning framework is to foster more effective and economical restoration of desired functions in a smaller footprint, because each project is contributing to improving a larger system, than could be achieved by projects planned in isolation that each focus on more narrow, varied benefits. The project is purposefully conceived to address only ecological benefits, in the context of a working agricultural landscape with critical water-supply and cultural considerations. The reports can contribute to discussions where social and economic benefits are also evaluated in planning the future Delta landscape. *A Delta Renewed User Guide* was developed to help different audiences access the information in this report and apply it effectively.

This research was conducted at the request of the California Department of Fish and Game (CDFG) and the Ecosystem Restoration Program (ERP).



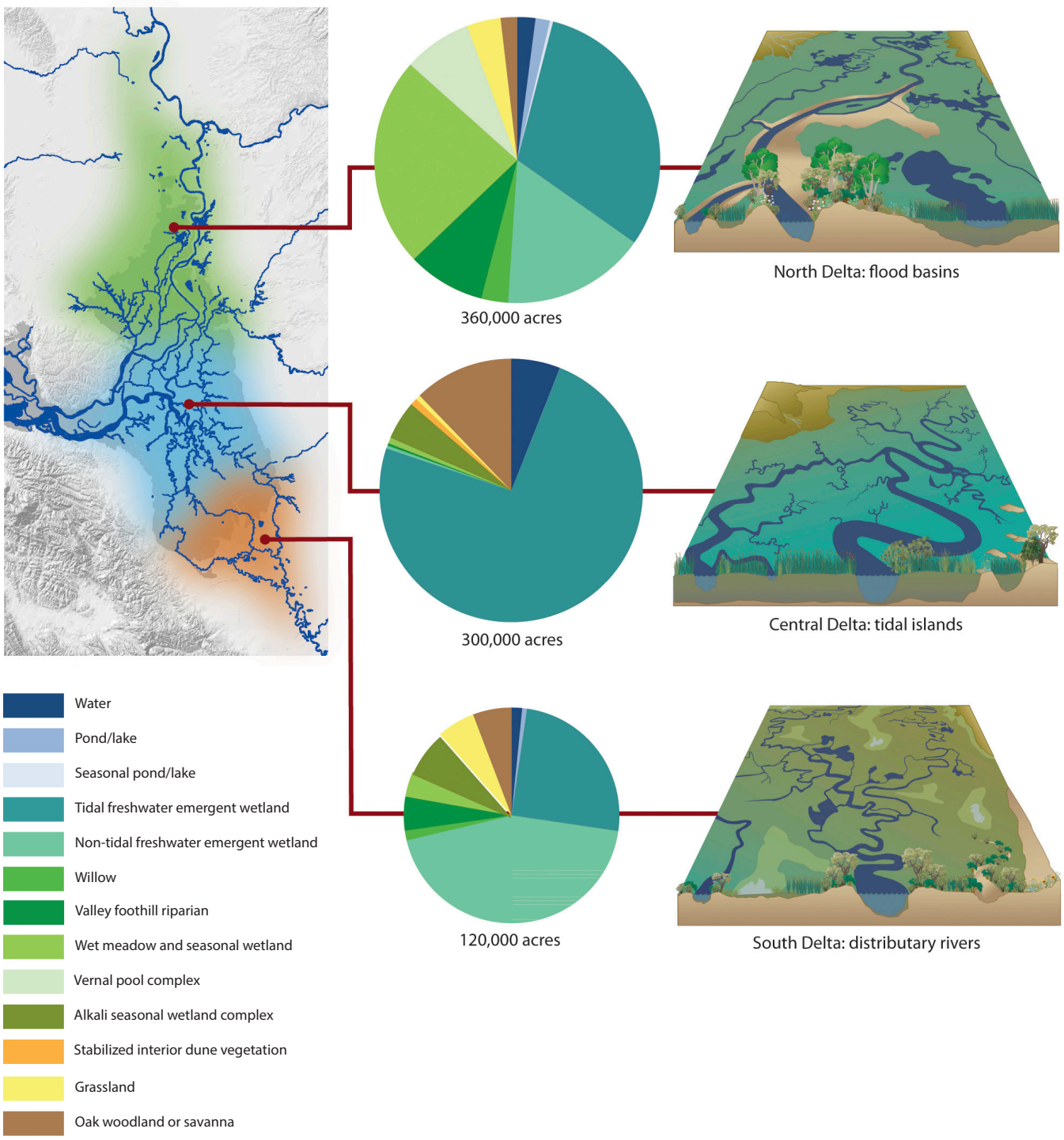
Delta Historical Ecology Study

The *Sacramento-San Joaquin Delta Historical Ecology Investigation* provides foundational information needed to develop large-scale restoration efforts appropriate for the Delta setting. This report documents early 1800s landscape patterns and processes in the Delta. The extent and distribution of historical habitat types are described, and the driving physical processes examined. Thousands of historical cartographic, textual, photographic, and artistic materials were synthesized in order to interpret and reconstruct the historical Delta.

The historical reconstruction of the Delta revealed large-scale patterns that existed within the Delta, and the Delta Historical Ecology report describes three primary Delta landscapes: the central Delta, where a freshwater tidal wetland was interwoven with myriad tidal channels; the north Delta, with flood basins lying parallel to the riparian forests of the Sacramento River and its distributaries; and the south Delta, where branching distributary networks supported a broad floodplain that gradually merged with tidal wetlands.

The tidal islands of the central Delta historically consisted primarily of tidal freshwater emergent wetland, supporting a matrix of tule, willows, and other species. These wetlands were tidally influenced, wetted daily and inundated by the monthly spring tides, if not more frequently. Topographic relief was slight, with the marsh plain approximating high tide levels. During high river stages in the wet season, entire islands were often submerged with several feet of water. Large tidal sloughs with low banks intersected to form islands. Like capillaries, numerous small branching tidal channels wove through the wetlands, bringing the tides onto the wetland plain. Channel density and sinuosity in the central Delta were greater than in the less tidally-dominated northern and southern parts of the Delta (but lower than the brackish and saline marshes of the estuary downstream). In the western central Delta, sand mounds rose above the wetland plain, providing dry land in an otherwise wet landscape. Where the tidal wetlands transitioned to upland, the Delta supported alkali seasonal wetlands, grassland, oak savannas, and oak woodlands.

Historically the flood basins of the north Delta lay parallel to the rivers, accommodating large-magnitude floods occurring regularly on the Sacramento River and other streams that discharged their annual flows at the basin margins. Inundation could persist for several months. The north Delta flood basins contained broad zones of non-tidal freshwater emergent wetland relatively free of channels, which graded into tidal freshwater emergent wetland. Dense stands of tules over ten feet (3 m) tall grew in these basins. Large lakes occupied the lowest and most isolated positions within the expansive wetlands, and few tidal channels penetrated far into the dense emergent vegetation. Some areas within tidal elevations may have been seasonally isolated from the tides due to supra-tidal natural levees along the rivers. The adjoining natural levees were covered by a dense multi-layered riparian forest, usually between a half a mile to a mile (0.8-1.6 km) in width. The upland margin was lined primarily by seasonal wetlands. At the upland margin of the north Delta, willow thickets could be found at the “sinks” (distributary networks) of larger creeks as they entered the flood basins.



The three primary landscapes of the Delta. This graphic illustrates, at left, the general region of the north Delta flood basins landscape (green), the central Delta tidal islands landscape (blue), and the south Delta distributary rivers landscape (orange). The landscapes were characterized by different assemblages and relative proportions of habitat types, as can be seen in the pie graphs in the middle column. Although the landscapes share many habitat types, the way they were arranged along the differing Delta landforms was distinct. Habitat characteristics also differed between landscapes. For example, channels were more sinuous in the central Delta, ponds and lakes were generally smaller and more connected to major river channels in the south Delta, and natural levees were large and hosted a wide and complex riparian forest in the north Delta. Conceptual diagrams illustrating these landscapes are shown in the third column.

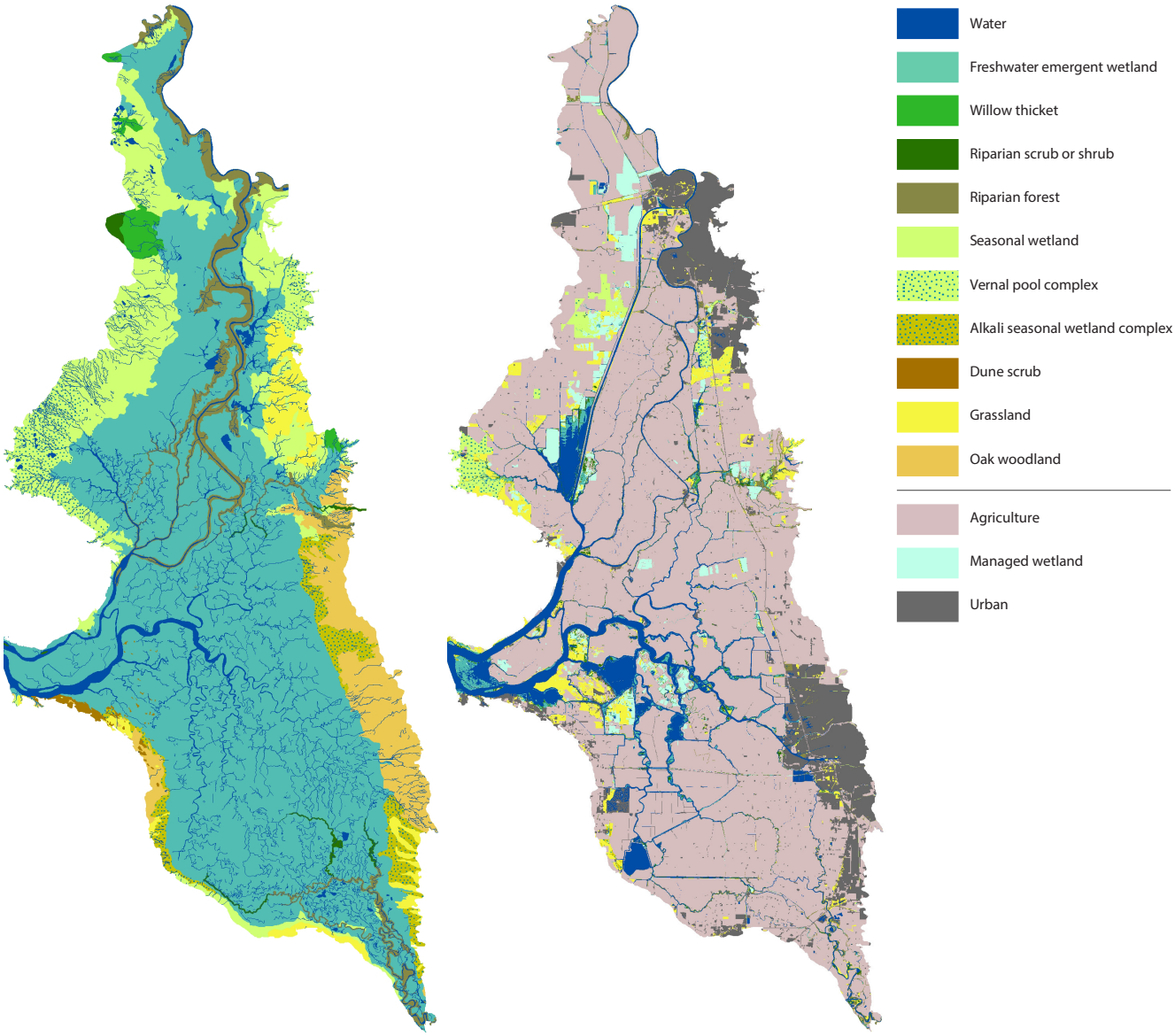
from the *Sacramento-San Joaquin Delta Historical Ecology Investigation*, page xxii.

The south Delta was historically shaped by the three distributary branches of the San Joaquin River. These branches produced numerous secondary overflow channels that serviced the floodplain, which broadened downstream and merged gradually with tidal wetlands. This complex network of distributary channels was associated with levees of various heights. Some parts of the main channels were prone to accumulating large woody debris, which likely obstructed flow. Ponds and lakes were generally smaller, less numerous, and more closely tied to the river than in the north Delta. A variety of habitat types were interspersed within the emergent wetland, including willow thickets, seasonal wetlands, and grasslands, as well as perennial and seasonal ponds and lakes. In comparison to the north Delta, a greater proportion of the riparian vegetation on natural levees in the south Delta was composed of willows and other shrubs. Also, particularly in the southernmost extent, the floodplain was occupied by willows and other trees as well as tule. Whereas wetlands and vernal pools made up a significant proportion of the upland edge at the Delta margin in the north Delta, alkali seasonal wetland complex, grassland, and oak woodland or savanna habitat types were found along the south Delta edge.

The historical Delta had high spatial and temporal variability. Within the context of relatively stable landscape patterns, the Delta experienced droughts and deluge that generated great variability in environmental conditions. Seasonal variation was expressed differently in different Delta landscapes. While the influence of daily tides muted seasonal differences in flows and water availability within the central Delta, more seasonal variation was evident in the north and south Delta.

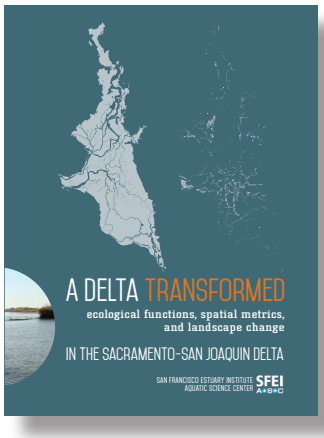
Landscape-scale habitat patterns were a reflection of the Delta's broad physical gradients and landforms. Patterns shifted depending on gradients, including tidal to fluvial influence (e.g., flood frequency, duration, magnitude, and extent), brackish to freshwater, low to high elevations, hot to cool temperatures, and peat to clay to loam soils. The historical landscapes exhibited gradual transition zones between habitat types that allowed movement and adaption along physical gradients, in contrast to the sharper transitions that exist today.

Sailboat on Delta waterway. Photograph by Grove Karl Gilbert, 1905, courtesy of the USGS Photographic Library.



Land cover change between the early 1800s and early 2000s. The change in land cover is illustrated in bar chart (A) and map (B) form. The dramatic shift from a majority of freshwater emergent wetlands historically to agriculture and urban development today is the most strikingly visible change. The area of open water (including areas of floating aquatic vegetation) has actually increased, in large part due to flooded islands such as Franks Tract and Mildred Island. The early 1800s view is based on the historical habitat type mapping performed in this study. The early 2000s summary is based on mapping performed by the California Department of Fish and Game from field work performed and aerial imagery taken between 2002 and 2005 (early 2000s data: Hickson and Keeler-Wolf 2007).

from the *Sacramento-San Joaquin Delta Historical Ecology Investigation*, pages 92-93.

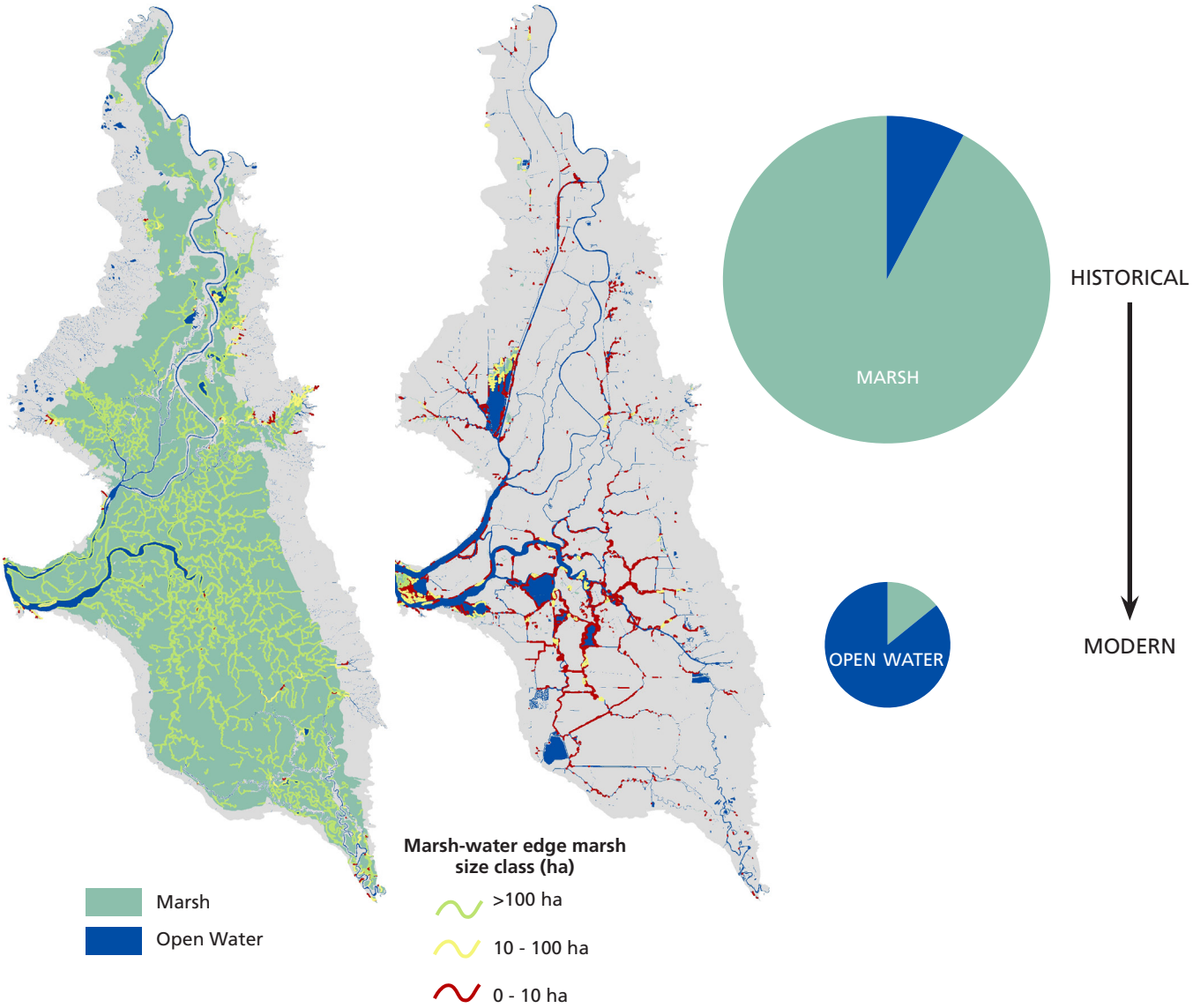


A Delta Transformed

A Delta Transformed builds on the Delta Historical Ecology study by quantifying change in the Delta from the early 1800s to the early 2000s using landscape metrics. In total, thirteen metrics are detailed in the report, including channel length, marsh patch size, riparian width, and extent of seasonally inundated habitats. These metrics were designed to directly bear upon important ecological functions that supported native species. Ecological functions related to life-history support for wildlife at both the population and community levels are analyzed in detail for this report. These functions included:

- Life history support for native fish (Chapter 4)
- Life history support for marsh wildlife (Chapter 5)
- Life history support for waterbirds (Chapter 6)
- Life history support for riparian wildlife (Chapter 7)
- Life history support for marsh-terrestrial transition zone wildlife (Chapter 8)

The Delta has undergone a massive physical and biological transformation during the past two centuries. The native plant and animal species that lived and evolved in the Delta now reside in a completely different environment. With the benefit of historical research and contemporary ecological knowledge, we can infer how the pre-development Delta supported native wildlife, and identify the missing functions in today's landscape.



***A Delta Transformed* metric examples: marsh to open water ratio and marsh to open water adjacency.** These metrics quantify important aspects of how the Delta environment provides life history support for native fish. Marshes directly influence the character and quality of aquatic habitats. These metrics shows a shift in marsh to open water ratio from 100:1,182 to 100: 62, and a reduction in marsh to open water adjacency from 3,823km of open water adjacent to marshes >100ha historically to 31 km today. These change have implications for food web support and marsh access for native fish, marsh wildlife, and waterbirds.

from *A Delta Transformed*, pages 44-45.

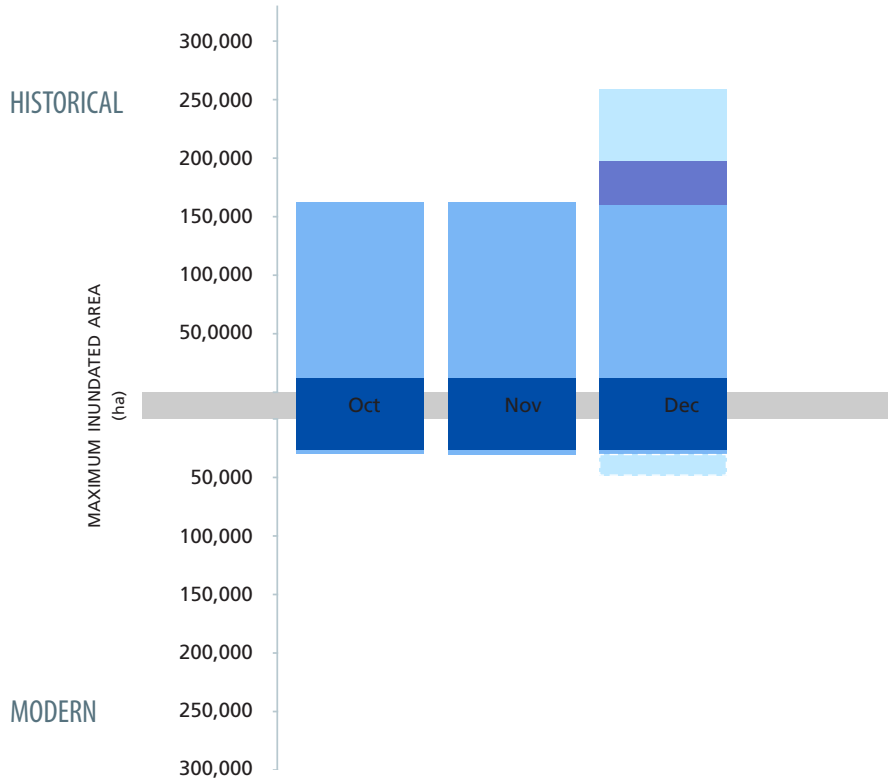
Near Isleton (left). Photograph, 2012, courtesy of Michele Ursino (Creative Commons).

Most fundamentally, the historical Delta was a vast wetland complex composed of an array of habitat types, primarily freshwater marsh, defined by varying cycles of inundation. Differential patterns of flooding, from both rivers and tides, created and maintained tule marshes, lakes, seasonal wetlands, willow thickets, and riparian forests. The disconnection of natural flooding processes due to the construction of levees has profoundly altered the Delta landscape, reducing the natural resilience of the Delta's landforms and wildlife populations. The excavation of channels and building of levees created a dichotomous landscape of dry land and open water where much more variable and dynamic wetlands once existed.

The habitats that dominated the Delta historically have been reduced to small fractions of their former extent. This decrease has affected the population viability of native wildlife by reducing the size, variability, and connectivity of many populations. The reduced extent of endemic habitats, such as vernal pools and alkali wetlands, may have significant consequences for biodiversity in the region. As a result of the diking of marshes, dendritic channel networks have been lost, with ecological consequences for native fish and other taxa. The loss of high-productivity marsh and floodplain habitats has reduced the food resources available for fish and waterbirds. Historically there was considerable geomorphic and hydrological heterogeneity within Delta habitats, creating diverse options for wildlife. The modern Delta has lost connectivity within and among terrestrial and wetland habitat types. The one exception is large channels, which have become over-connected, reducing in-channel heterogeneity and altering flows.

Metrics developed for *A Delta Transformed* are useful not only for understanding change from the historical to the modern landscape, but potentially useful for tracking restoration success as well.

***A Delta Transformed* metric example: innundation patterns.** The historical Delta exhibited dramatic seasonal variation in flooding. This seasonal variation in flooding is reflected in the life histories of the native fish species that evolved here. Today, a decrease in the extent of inundation across the Delta has been accompanied by a decrease in the spatial-temporal variability of inundation (right).



from *A Delta Transformed*, pages 40-41.

SEASONAL SHORT-TERM FLOODING

Short-term fluvial inundation

- intermediate recurrence (~10 events per year)
- low duration (days to weeks per event)
- generally shallower than seasonal long-duration flooding

SEASONAL LONG-DURATION FLOODING

Prolonged inundation from river overflow into flood basins

- low recurrence (~1 event per year)
- high duration (persists up to 6 month)
- generally deeper than seasonal short-term flooding

TIDAL INUNDATION

Diurnal overflow of tidal sloughs into marshes

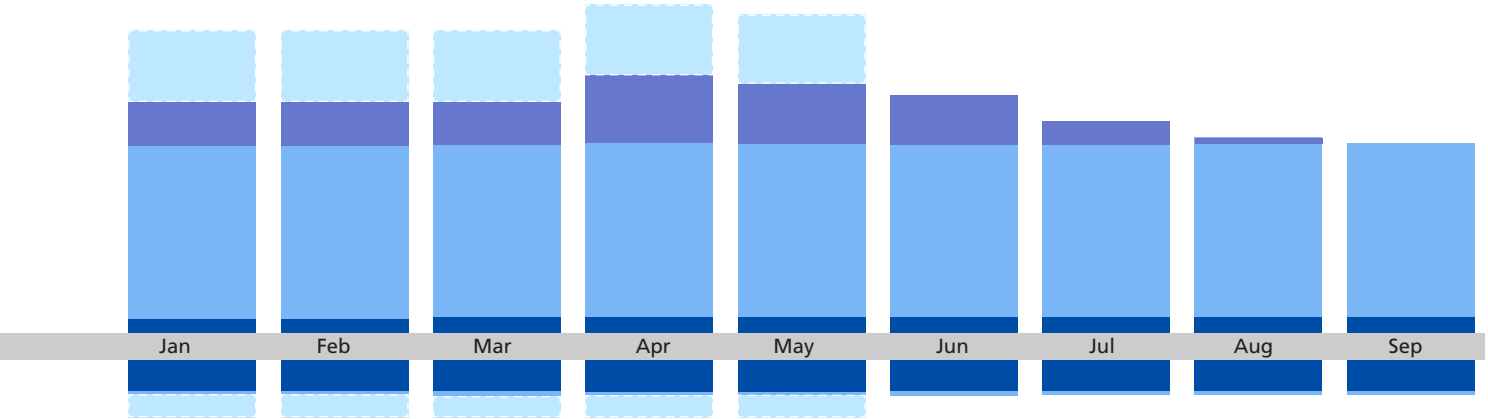
- high recurrence (twice daily)
- low duration (<6 hrs per event)
- low depth ("wetted" up to 0.5 m)

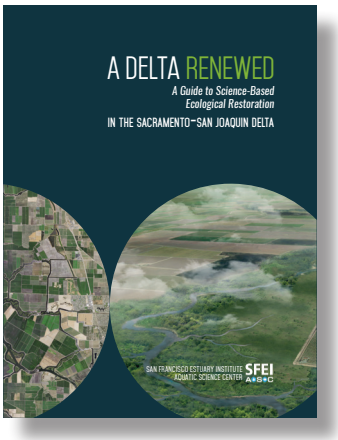
PONDS, LAKES, CHANNELS, & FLOODED ISLANDS

Perennial open water features (with the exception of historical intermittent ponds and streams)

- recurrence not applicable (generally perennial features)
- high duration (generally perennial features)
- variable depth

Chinook salmon. Photograph courtesy of Dan Cox (USFWS).

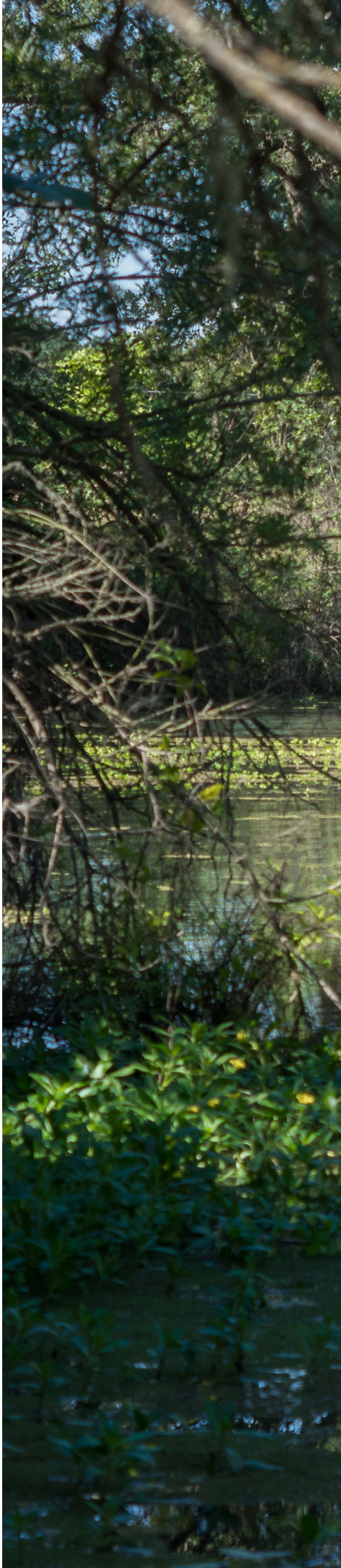




A Delta Renewed

A Delta Renewed aims to inform and contribute to ongoing planning efforts by providing a science-based, big-picture perspective on how to re-establish a landscape that functions well for people and native wildlife. *A Delta Renewed* outlines regional recommendations and on-the-ground strategies to help contextualize, design, implement, and manage future Delta landscapes that can support desired ecological functions over the long term, like healthy native fish populations, a productive food web, and support for endangered species. To develop this guidance, we evaluated the landscape patterns and processes that supported wildlife in the historical Delta, measured how they have changed, and assessed the potential for establishing smaller, modified landscapes in the future Delta that are resilient, productive, sustainable, and supportive of people and native wildlife. The report contributes to Delta planning by providing a large-scale, long-time-frame perspective on restoration opportunities, using a systems approach designed to benefit a holistic suite of desired ecological functions, not just a few rare species. *A Delta Renewed* is a blueprint for creating new, reconciled landscapes that integrate natural and cultural processes, and maximize resilience to climate change, invasive species, and other challenges.

This report offers guidance for creating and maintaining landscapes in the Sacramento-San Joaquin Delta that support desired ecological functions, while retaining the overall agricultural character and water-supply service of the region. Based on extensive research into how the Delta functioned historically, how it has changed, and how it is likely to evolve, we discuss where and how to re-establish the dynamic natural processes that can sustain native Delta habitats and wildlife into the future. The approach, building on work others have piloted and championed, is to restore or emulate natural processes where possible, establish an appropriate mosaic of habitat types at the landscape scale, use multi-benefit management strategies to increase support for native species in agricultural and urban areas, and allow the Delta to adapt to future uncertainties of climate change, levee failure, and human population growth. With this approach, it will be critical to integrate ecological improvements with the human landscape: a robust agricultural economy, water infrastructure and



North Delta. Photograph by Shira Bezalel (SFEI-ASC).

diversions, and urbanized areas. Strategic restoration that builds on the history and ecology of the region can contribute to the strong sense of place and recreational value of the Delta.

This report is a guide for resource managers, planners, local governments, and other decision makers who are working to integrate the protection, restoration, and enhancement of Delta ecosystems with agriculture, water management, and other uses. Developed as a technical resource using the best available science, this report is not a policy document. The recommendations can be used by individual agencies through their own particular processes.

Major goals of this report are to:

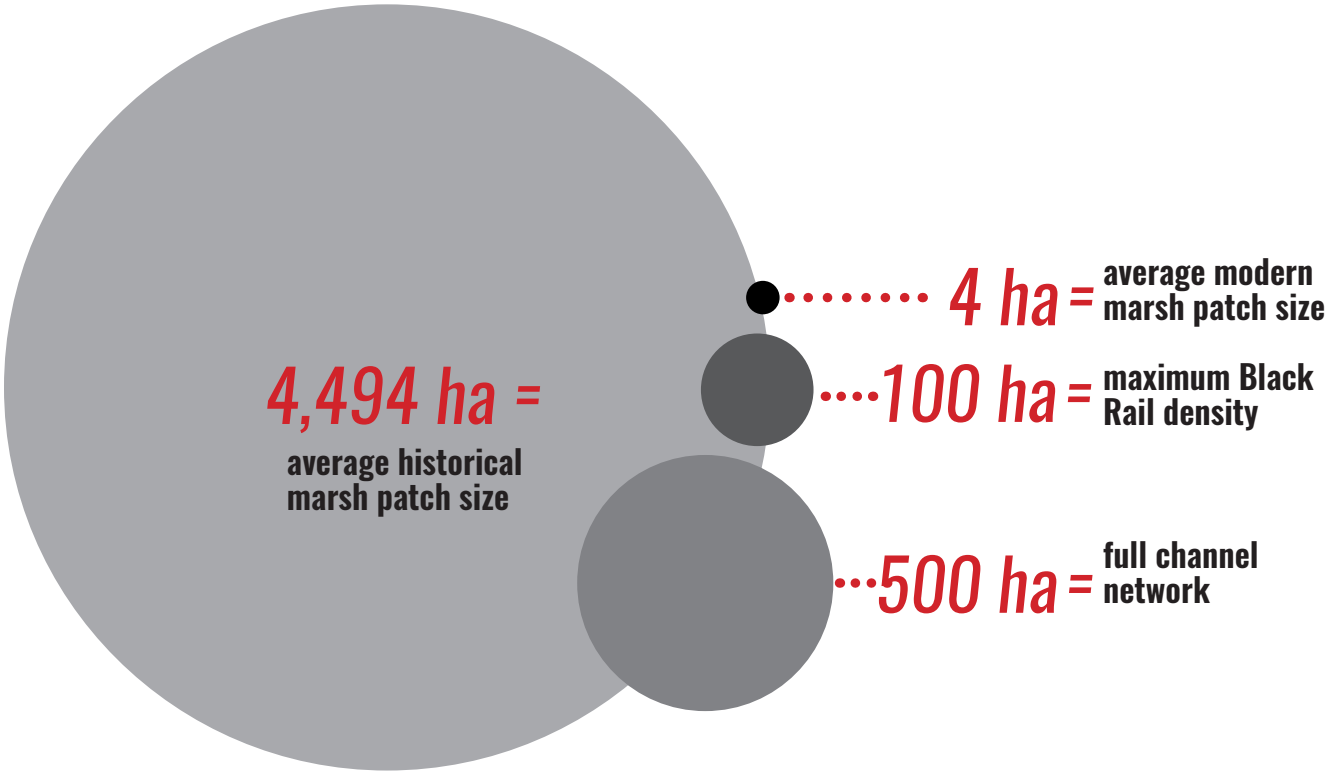
- Guide restoration planning and design at regional, landscape, and project scales
- Inform stakeholder planning and visioning processes
- Track at the regional scale how local projects are adding up to larger landscapes, and provide advice for optimal, value-added outcomes
- Guide restoration funding priorities

A Delta Renewed provides recommendations related to guiding principles, process-based strategies, and desired ecological functions.

GUIDING PRINCIPLES (Chapter 2) These guiding principles are general considerations that apply across conservation planning, restoration, and management activities in the Delta. The goal of these principles is to maximize desired ecological functions both in the short term and over long time frames.

PROCESS-BASED STRATEGIES (Chapter 4) Restoration and management actions that incorporate naturalistic physical processes are essential to the future of the Delta, particularly in light of sea-level rise and other future changes. The long-term aim of process-based restoration is to create dynamic, resilient ecosystems, rather than static habitat patches and rigid engineered structures. Restoration of critical processes, such as beneficial flooding and sediment delivery, creates and maintains habitats, fuels the food web, and enables ecosystems to recover after disturbance and continue to support native wildlife as baselines shift, which will become more important as climate change accelerates. This approach requires large spatial scales, long time frames, and coordination of complex management regimes across the Delta landscape, including a multitude of landowners, regulations, and land-uses.

Sandhill Cranes at Cosumnes River Preserve.
Photograph courtesy of Bob Wick (BLM).



A Delta Renewed: Landscape Configuration and Scale Guideline Example

For each process-based strategy, *A Delta Renewed* provides physical process guidelines and landscape configuration and scale guidelines. This example shows guidance for considering tidal marsh size. Though small marshes have some value, marshes should be as large as possible since the functions they support increase with size. For example, marshes as small as 1 ha can support some California Black Rails, but the density of rails is maximized once marshes reach approximately 100 ha in size.

from *A Delta Renewed*, page 46.

The critical processes to restore are organized into five major zones in the Delta. We detail strategies for restoring:

- Tidal zone processes in intertidal areas, channels and flooded islands, and subsided areas;
- Tidal-fluvial transition zone processes by improving the connection between streams and floodplains;
- Fluvial processes along streams and their floodplains as they enter the Delta;
- Wetland-terrestrial transition zone and terrestrial processes around the periphery of the Delta; and
- Ecological processes within areas of human land use, through wildlife-friendly farming and urban greening.

These strategies fit into the current and future Delta landscapes in ways that may not duplicate historical locations and configurations. Supporting native wildlife and other ecological functions in the Delta will require layering multiple strategies in particular configurations across varying temporal and spatial scales. The guidelines presented here should be integrated with other resource-management considerations, such as phasing of projects across time, land-ownership, permitting, engineering requirements, and monitoring.

ECOLOGICAL FUNCTION RECOMMENDATIONS (Chapter 5) The ecological functions discussed in *A Delta Renewed* were chosen to reflect desired support for native wildlife that has been degraded over time. Recommendations are provided for the following ecological functions:

- ***Life-history support for native fish***
- ***Life-history support for marsh wildlife,***
- ***Life-history support for riparian wildlife,***
- ***Life-history support for waterbirds***
- ***Life-history support for terrestrial species around the Delta's periphery***
- ***A productive food web; and***
- ***Overall native biodiversity.***

We illustrate at two different scales how these functions could be restored: conceptual maps of landscape configurations at the Delta-wide scale, and schematics of how the process-based strategies fit together at a more localized scale. The process-based strategies are designed to work together to support desired ecological functions in the future Delta: recovering lost support for native species and helping them persist in a changing environment.

from *A Delta Renewed*, pages 110-111 (by Yiping Lu, UC Berkeley).

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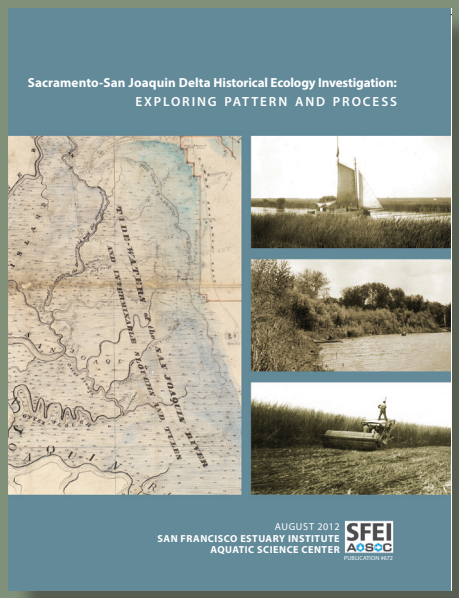

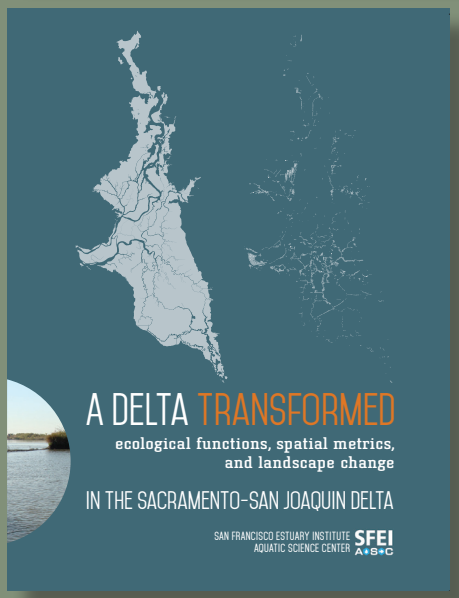

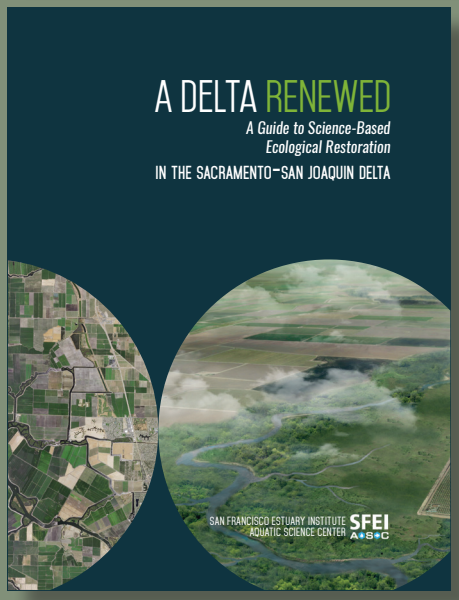

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ISBN 978-0-9989244-6-5
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