1

Introduction

Peter B. Moyle, Amber D. Manfree, and Peggy L. Fiedler

Suisun Marsh has always been regarded as a remarkable place, made especially attractive by its abundance of fish, wildlife, and useful plants. The remarkable nature of Suisun Marsh stems from the coincidence of a number of factors.

Size. At about 470 km^2, the Marsh is often referred to as the largest brackish-water marsh on the western coast of North America (see box 1.1). While this claim is debatable, Suisun Marsh is certainly the largest such marsh in California.

Connectivity. Located in the middle of the San Francisco Estuary (see see maps 1 and 2 in color insert), the Marsh is tightly linked to Suisun Bay. Both have strong interactions, through the movement of water and organisms, with both the Sacramento–San Joaquin Delta upstream and San Francisco Bay downstream. The Sacramento River delivers fresh water to the Marsh, and strong tides mix it with salt water pushed upstream from the Pacific Ocean, so the Marsh's salinity varies with place and season. From a terrestrial perspective, the Marsh is linked to both the Fairfield–Suisun City urban area and the watersheds above them, as well as to more natural areas to the north, including the Potrero Hills and the vernal-pool prairies (e.g., Jepson Prairie) that have further connections to the North Delta and the Yolo Bypass. On an even larger scale, the Marsh is an important stop on the Pacific Flyway, providing habitat for waterfowl and shorebirds migrating from the Arctic to the tropics, as well as for those wintering in central California.

Biodiversity. Suisun Marsh and the uplands around it, such as the Potrero Hills, support diverse habitats for both resident and migratory species. This habitat

BOX 1.1. DEFINING SUISUN MARSH

Brenda J. Grewell

Suisun Marsh is a well-marked entity on maps, yet its exact boundaries depend on who is defining it. Usually, the Marsh is defined by political boundaries, to exclude (among other things) urban areas and large areas of open water. The most commonly used definition is that found in the Suisun Marsh Habitat Management, Preservation, and Restoration Plan (or "Suisun Marsh Plan"; U.S. Bureau of Reclamation et al. 2011), which indicates total acreage as being roughly 100,000 acres, including 405 km^2 (52,000 acres) of managed wetlands, 104 km^2 (25,700 acres) of tidal bays and sloughs, 31 km^2 (7,700 acres) of tidal marshlands, and 68 km^2 (16,700 acres) of uplands, mostly lowland and hillside grasslands, although some agricultural and developed areas are included. The numbers are obviously rounded, which suggests that the actually boundaries are somewhat ill defined, despite being legal boundary lines. The Suisun Marsh Plan boundary, used by the Suisun Resource Conservation District for their planning, excludes some existing and historical tidelands because it accepts Highway 12 and other roads as boundaries rather than more natural watershed or elevational boundaries.

The San Francisco Bay Area Wetland Ecosystem Goals Project (1999) and the U.S. Fish and Wildlife Service Recovery Plan for Tidal Marsh Ecosystems, Northern and Central California, take a broader geographic approach. Both of these efforts set the eastern boundary of the Suisun region at approximately Broad Slough and extend the southern boundary to include all tidelands bordering Suisun and Honker bays. This means that Suisun Marsh includes Brown's Island and the extensive tidal marshlands on state, federal, and private lands on the Contra Costa shoreline, in contrast to the usual southern boundary that follows the deep-water channel through the middle of Suisun Bay. Both reports also extend the regional western boundary of the Marsh into Carquinez Straits, therefore including the city of Benicia and Southampton Marsh/Bay. These areas are more similar to the central Suisun Bay region than they are to areas west of Dillon Point, such as the Napa River and San Pablo Bay. Also included, if vaguely, are the lower reaches of major streams, including Green Valley Creek, Sacramento River, Suisun Creek, and Walnut Creek. The total area encompassed by these documents is 360 km^2 (89,000 acres) of wetlands, channels, and bays and 91 km^2 (22,500 acres) of adjacent uplands, or 451 km^2 (111,500 total acres).

Just to confuse things further, according to the 1959 Delta Protection Plan, the legal boundary of the Delta includes a portion of Suisun Marsh. The western boundaries of this "legal" Delta include Montezuma Slough almost up to the salinity control gates, the Contra Costa shoreline of Suisun Bay to a line drawn through Honker Bay, Simmons Point–Chipps Island, and the shoreline well west of the city of Pittsburg.

In this book, we use the greater Suisun Marsh ecosystem as our reference rather than adopting the more limited circumscriptions used by Suisun Resource Conservation District or the Suisun Marsh Plan (see map 2 in color insert). But because most studies use the standard boundaries, we are often left with the statistics they generate. However, in discussing Suisun Marsh as an ecological entity, we are largely discussing a region that arbitrarily ends in the middle of Suisun Bay. This means that we have, for the most part, excluded discussion of the fringing marshes on the southern side of the Bay in northern Contra Costa County, partly because we know much less about these marshes than we do about the core Suisun Marsh. We consider, nevertheless, that many of the challenges they face in the future are similar to those of the main Marsh.

management areas with over 300 km of dikes that separate marshlands from intervening sloughs. Management of most of these duck clubs and wildlife areas today focuses on producing resident mallard and attracting migratory waterfowl in winter. Yet increasing numbers of protected areas are maintained as habitat for rare species such as salt marsh harvest mouse (*Reithrodontomys raviventris*), reflecting future changes in land management.

At the same time, the Marsh is continually invaded by alien species, symbolized by the perennial pepperweed (*Lepidium latifolium*) that often dominates dikes and other upland areas, and by the giant reed (*Arundo donax*) that is moving into marshy areas. Aggravating these invasions, duck clubs are often managed for alien plant species to provide food for ducks. New species of fish and aquatic invertebrates invade on a regular basis, such as shimofuri goby (*Tridentiger bifasciatus*) and Siberian prawn (*Exopalaemon modestus*). Meanwhile, native fishes such as delta smelt (*Hypomesus transpacificus*) decline. Novel assemblages of organisms, featuring species from all over the world, have been formed and are constantly changing as new species arrive and native species decline (some to extinction), presenting new challenges for managers. As discussed in chapter 9, Suisun Marsh is a dynamic ecosystem, requiring new, adaptive approaches with firm, widely agreed-upon goals for what our society wants the Marsh to be like in the future.

Change will continue in the Marsh at an accelerated pace. Most conspicuously, sea level is rising. Best estimates are that it will rise by 0.8–1.5 m by 2100, with high tides, storm surges, and floods pushing the water higher (Cayan et al. 2009; Knowles 2010). It is widely accepted that most present estimates of sea-level rise are conservative (Rahmstorf et al. 2012) and that occasional megafloods can be expected from extreme precipitation events (Dettinger and Ingram 2013), so change may be unexpectedly fast. Meanwhile, sediment supplies from inflowing

diversity is reflected in the large array of plants and animals, especially native species: 200+ plant species, 180+ bird species, 45 mammal species, 15 reptile and amphibian species, 60 species of butterflies, and 50+ species of fish. Some of these, such as Suisun song sparrow (*Melospiza melodia maxillaris*) and Suisun thistle (*Cirsium hydrophilum* var. *hydrophilum*), are largely endemic to the Marsh.

History. Suisun Marsh has a long history of wildlife conservation, especially of waterfowl. Early duck-club owners successfully protected the Marsh from various schemes to use it for waste disposal or urban development. The Marsh exists today as a center of fish and wildlife diversity because of its continued management as a wetland ecosystem, albeit with a focus on waterfowl hunting. Most of the land in the Marsh proper is either privately owned duck clubs or public space devoted to hunting and wildlife management.

Open Space. Being on an urban fringe, the Marsh provides a major oasis of natural habitats in a rapidly developing area. The success of Rush Ranch Open Space as a nature center in the northeast quadrat of the Marsh demonstrates that it is increasingly important as open space for urban-weary humans. But its "vacant" nature also means ongoing competition to use it for other purposes, for example as a destination for toxic runoff or for disposal of wastewater from sewage treatment.

Research. In part because Suisun Marsh is so accessible to several major universities, it is an important area for environmental research, as the chapters in this book illustrate. With the growing realization of the importance of estuarine wetlands (Batzer and Sharitz 2006; Silliman et al. 2009), especially along the San Francisco Estuary (Palaima 2012), Suisun Marsh has increasingly become a focal point for wetlands research, including studies related to ecological functions and wetland conservation under various sea-level-rise scenarios.

Not surprisingly, with all these attributes, Suisun Marsh is increasingly looked upon as a major conservation area and wetland mitigation site to compensate for future development throughout the San Francisco Estuary. Just how actions in Suisun Marsh can mitigate declines in natural habitat in other parts of the Estuary is not entirely clear. The Marsh is already intensely managed as wild lands, and large segments of it are likely to transition to "natural," brackish-water, intertidal wetlands or to open water, given the inevitability of sea-level rise. Whatever the reasons, it is clear that the Marsh will have increasing value to society as a protected natural area as time goes on, despite its history of constant change. In the past 150 years alone, it has been transformed from a natural tidal marsh used as a bountiful source of food and fiber by local Miwok people to farmland and pasture, and then to a highly managed collection of waterfowl

rivers are diminishing, while subsidence in nontidal areas due to specific land-management practices is continuing apace. Given that much of the Marsh is at or below sea level, large portions are likely to become permanently open-water, subtidal habitat, as dikes give way or are breached in the not-so-distant future.

Planning efforts for the future Marsh are under way, but the Suisun Marsh Habitat Management, Preservation, and Restoration Plan (or "Suisun Marsh Plan"; U.S. Bureau of Reclamation et al. 2011) focuses on maintaining the Marsh in its present state as much as possible, even as lands subside and increasingly higher tides spill over existing dikes. This status quo focus may be possible within a 30-year time frame, especially for areas of higher elevation. But as time goes on, the contemporary ecological conditions and processes will become less and less sustainable, in particular because one key emphasis of the Suisun Marsh Plan is to dredge tidal channels, a management practice certain to exacerbate the effects of sea-level rise (chapters 3 and 8).

So what is the long-term future of Suisun Marsh? As the analyses presented in this book illustrate, there is no doubt that Suisun Marsh will continue to function as open space in an increasingly urbanized environment and as important habitat for wildlife, fish, and plants (although salt-tolerant species will become increasingly important) for at least the next century. The distribution and severity of such changes will depend on the rate of sea-level rise and our response to it. Under one long-term scenario, tidal water will eventually flood the streets of Suisun City (Knowles 2010). However, a Marsh that contains more tidal habitat than at present is more likely to help buffer urban areas from tidal flooding.

To some degree, the direction and extent of future change to Marsh habitats can be managed, as we explore in four scenarios in chapter 9. One future, for example, is to continue to manage the Marsh as a series of independent, "postage stamp" units, as is largely done today with the 158 private duck hunting clubs and the handful of public wildlife areas. In this future, the best waterfowl hunting habitat likely will belong to whoever builds the highest and strongest dikes or begins with the highest-elevation land along the Marsh fringes.

Another potential scenario generally envisions the Marsh as one area with unified wetland management. For example, one strategy might be to construct the biggest dike possible along some strategic line of defense across the Marsh, protecting marshlands behind it and, eventually, urban areas from saltwater incursion. This, of course, is what has been done in areas like the Netherlands and in New Orleans, at enormous expense. From an ecological point of view, a more desirable scenario (and one more likely to succeed) is to work *with* sea-level rise and other change stressors to create a "new" marsh with as many desirable features as possible (e.g., natural tidal channels). This latter scenario, of course, would require regulatory agencies, local landowners, and other California citizens to agree upon just what features are the most desirable.

FIGURE 1.1. Two oblique aerial views of Suisun Marsh from ca. 1909 (left) and ca. 2006 (right), looking south down Suisun Slough. Note that while major slough structure appears to be similar, many sloughs have been channelized or cut off by dikes from the main sloughs. (1909 photo courtesy of Solano Historical Society. 2006 photo by Peter B. Moyle.)

The scenario that comes the closest to fitting reality in 100 years or so will depend on how well existing information and projections of environmental change are used. This book is designed to provide an introduction to these subjects to start the process of rethinking the future of Suisun Marsh, much as Lund et al. (2007, 2010) have done for the Delta. In the following chapters, we

- review the ecological history of Suisun Marsh;
- describe, to the best of our knowledge, the present-day Marsh and how it functions;
- describe the status and trends of the biota, focusing on plants, fish, waterfowl, and terrestrial vertebrates;
- describe the forces of change for the Marsh, especially sea-level rise; and
- examine alternative futures for the Marsh.

We realize that our approach omits much information present in the previous plans, reports, and publications about the Marsh. However, we anticipate that this book will be most useful if it presents a broad overview reflecting new

information on the Marsh and new syntheses of this information. Our goal is to encourage managers to look for and implement a plan for a "soft landing" for the Marsh ecosystem, rather than waiting for a hard crash caused by rapid environmental change. Our general attitude is that of reconciliation ecology (Rosenzweig 2003), which treats humans as an integral part of every ecosystem and recognizes that conservation will work best if this truism is taken into account. We recognize that the Marsh has been altered by humans since the beginning of its 6,000-year history (chapter 2), yet it retains many of its fundamental characteristics as a tidal system of sloughs and marshlands (figure 1.1). Regardless of how the Marsh changes in the future, it will continue to be a major area of open space, tidal sloughs, and marshlands, as well as important habitat for fish and wildlife in an increasingly urbanized landscape.

REFERENCES

Batzer, D. P., and R. R. Sharitz, eds. 2006. Ecology of Freshwater and Estuarine Marshes. Berkeley: University of California Press.

Cayan, D., M. Tyree, M. Dettinger, H. Hidalgo, T. Das, E. Maurer, P. Bromirski, N. Graham, and R. Flick. 2009. Climate change scenarios and sea level rise estimates for the California 2008 Climate Change Scenarios Assessment. Draft paper, California Energy Commission, CEC-500–2009–014-D.

Dettinger, M. D., and D. L. Ingram 2013. The coming megafloods. Scientific American 308(1): 64–71.

Knowles, N. 2010. Potential inundation due to rising sea levels in the San Francisco Bay region. San Francisco Estuary and Watershed Science 8: 1–19.Lund, J., E. Hanak, W. Fleenor, W. Bennett, R. Howitt, J. Mount, and P. B. Moyle. 2010. Comparing Futures for the Sacramento–San Joaquin Delta. Berkeley: University of California Press.

Lund, J., E. Hanak., W. Fleenor, W., R. Howitt, J. Mount, and P. Moyle. 2007. Envisioning Futures for the Sacramento–San Joaquin Delta. San Francisco: Public Policy Institute of California.

Palaima, A., ed., 2012. Ecology, Conservation, and Restoration of Tidal Marshes: The San Francisco Estuary. Berkeley: University of California Press.

Rahmstorf, S., G. Foster, and A. Cazenave. 2012. Comparing climate projections to observations up to 2011. Environmental Research Letters 7: 044035.

Rosenzweig, M. L. 2003. Win-Win Ecology: How the Earth's Species Can Survive in the Midst of Human Enterprise. Oxford: Oxford University Press.

Silliman, B. R., E. D. Grosholz, and M. Bertness, eds. 2009. Human Impacts on Salt Marshes: A Global Perspective. Berkeley: University of California Press.

U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, and California Department of Fish and Game. 2011. Suisun Marsh Habitat Management, Preservation, and Restoration Plan. Final environmental impact statement/environmental impact report. U.S. Bureau of Reclamation, Sacramento.

GEOSPATIAL DATA SOURCES

CalAtlas. 2012. California Geospatial Clearinghouse. State of California. Available: http://atlas.ca.gov/. Accessed: 2012.

Contra Costa County. 2013. Contra Costa County Mapping Information Center. Available: http://www.ccmap.us/. Accessed: January 2013.

Gesch, D., M. Oimoen, S. Greenlee, C. Nelson, M. Steuck, and D. Tyler. 2002. The National Elevation Dataset. Photogrammetric Engineering and Remote Sensing 68: 5–11.

Solano County. 2013. Geographic Information Systems Homepage. Solano County Department of Information Technology. Available: http://www.co.solano.ca.us/depts/doit/gis/. Accessed: November 2012.

U.S. Geological Survey. 2013. National Hydrography Dataset (Watershed Boundary Dataset). Available: http://nhd.usgs.gov/wbd.html. Accessed: November 2010.