Bothin Marsh Geomorphology, Ecology, And Conservation Options

Introduction

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Introduction

Report Overview

This report was produced on behalf of the Marin County Parks based on review of the science related to restoration and protection of tidal marshes in upper Richardson Bay, Marin County, California.

The authors are thankful for the opportunity to produce this report. We were able to apply our collective century of experience as investigative wetland and watershed scientists to a familiar locale, and in the processes learn from each other's expert perspectives. Adequately covering the breadth of subject matter would not have been possible without such a diverse and experienced team. We especially Veronica Pearson, Marin County Parks, for her support and guidance.

We produced this report as six standalone Chapters with two Appendices. This approach separates an otherwise massive report into a set of six technical references that we hope will be useful to current and future environmental planners, scientists, and engineers working in Richardson Bay and beyond. This report covers the following major subjects.

Chapter 1:	Tidal marsh formative processes
Chapter 2:	Sea level rise and adaptation management strategies
Chapter 3:	History and causes of physical environmental change
Chapter 4:	Ecological response to environmental change
Chapter 5:	Conservation options
Chapter 6:	Synthesis of key findings
Appendix 1:	Review of regional tidal marsh plant and wildlife technical literature
Appendix 2:	Guide to common vascular plants in the Bothin Marsh Complex

Although the Chapters are designed as standalone references, there is a flow of information from one Chapter to the next, and the content of one Chapter can be better understood if the preceding Chapters have been read. Chapters 1-3 are especially helpful to understand Chapters 4-5. The concluding Chapter is a succinct summary and synthesis of the previous five Chapters. The two Appendices can be especially useful to amateur and professional wetlands botanists.

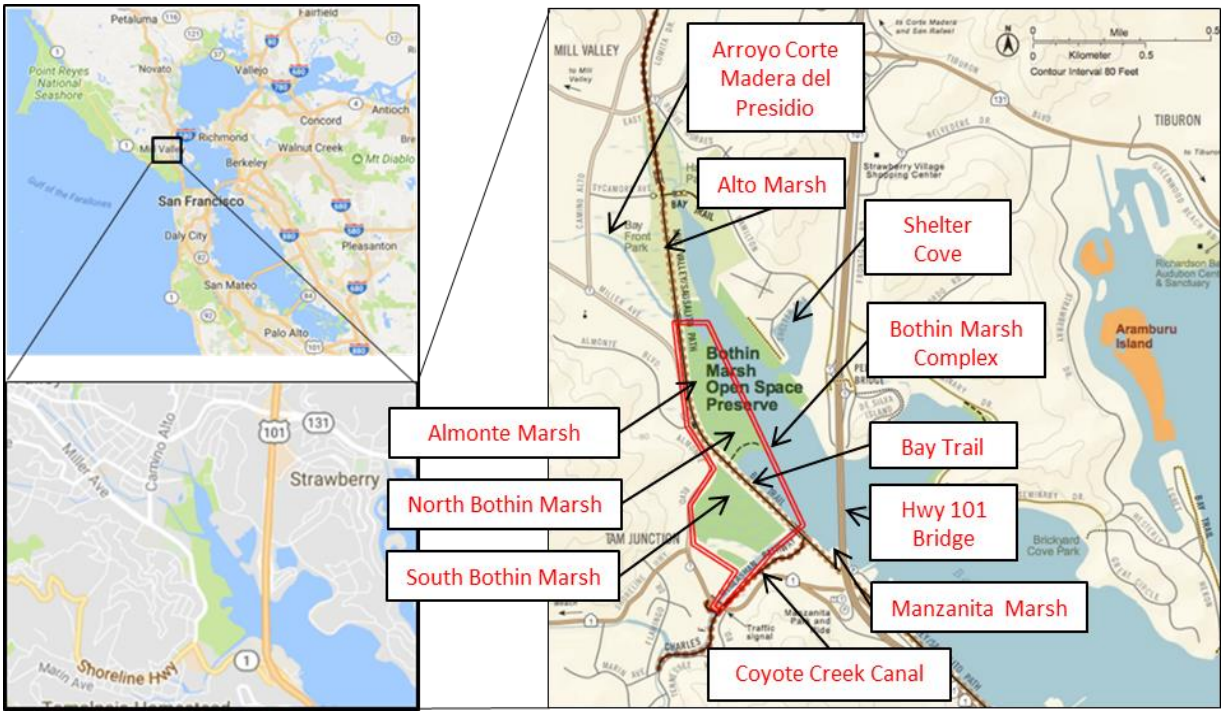
This is one of many scientific reports focused on the tidal marshes of upper Richardson Bay, herein called the Bothin Marsh Complex (see the Section on Setting below). The other reports on Bothin Marsh and Richardson Bay are narrower in scope. This report reviewed those reports and a wealth of additional relevant technical information, representing more than three hundred documents and more than two hundred maps and other images, spanning the period from 1795 to the present.

This report focuses on restoring and conserving the natural functions and values of the Bothin Marsh Complex. It does not comprehensively address the critically important social-economic aspects of adaptation to sea level rise. Chapter 2 identifies some of the common adaptation strategies and methods to facilitate societal adaptions in the Bay Area and other coastal regions of the U.S. However, this report mainly addresses the threats of sea level rise to tidal marsh ecosystems in upper Richardson Bay, north of the Highway 101 Bridge. For the purposes of this report, this area is referred to as the Bay. Other areas of the San Francisco Estuary are identified by their full names.

Setting

Prior to the end of the last ice age, the V-shaped valley that is now occupied by the Bay drained southeast to what was then the most southern extent of the Sacramento River. Waters draining from valley would have met the antecedent Sacramento River as it headed out the Golden Gate and across the Gulf of the Farallones to the Continental Shelf. With the melting of the polar icecaps, sea level rose through the Golden Gate and began creating San Francisco Estuary about 10,000 years ago (Atwater *et al.* 1977). By about 6000 years ago, as the rate of sea level rise declined from about 0.75 inches per year (about 6 feet per century) to 0.075 inches per year (about 0.6 feet per century), tidal water began entering Richardson Bay. A profile of the Pleistocene stream that drained into the nascent Bay, indicates that it sloped between 100 and 130 feet per mile. Over time, the submerged valley was filled with up to 150 feet of tidal sediment (Connor 1983). The Bay bottom changes to a virtual cliff face where it meets the greater San Francisco Bay near the Golden Gate. In its natural state, the Bay bottom was remarkably uniform in depth and sediment type. A modern profile of the Bay bottom varies only between 5 and 50 feet per mile (Means, 1965). Over geologic and historical time, the gradient of the Bay has continued to flatten.

Richardson Bay trends southeast-northwest, and is separated by Strawberry Peninsula into two roughly parallel sub-bays or arms. The northern arm is shorter but broader and extends between Belvedere Island and Strawberry Point. The southern arm is longer and narrower, and extends between Strawberry Point and Sausalito. The southern arm is commonly referred to as Richardson Bay, given that it is crossed by the Richardson Bay Bridge. The Bay was formally named Pickleweed Inlet by the U.S. Board of Geographic Names in 1979. This report does not use the name Pickleweed Inlet.



Map of the Bothin Marsh Complex and its component marshes in upper Richardson Bay in relation to the Arroyo Corte Madera del Presidio and Coyote Creek as the focus of this report.

Eastward aerial view of upper Richardson Bay and the Bothin Marsh Complex. Wikimedia Commons (By Bento00 (Own work) [Public domain], via Wikimedia Commons).

Two streams, Arroyo Corte Madera del Presidio and Coyote Creek, are by far the largest watersheds draining to Richardson Bay. Their areas are 5.7 square miles and 3.3 square miles, respectively. They account for 78% of the total catchment for the Bay. Both streams drain into the upper Bay. They receive about 90% of their rain between October and April, with an average of 36 inches per year. Seasonal max/min temperatures are 41.5 ^{0}F/59.6 ^{0}F for the wet season and 50.5^{0}F/86.5 ^{0}F for the dry season U.S. National Weather Service (https://www.weather.gov/phi/localclimate).

Local data for vegetation, land use, and human demographics are reported below.

Demographic and land cover statistics for the lands draining to upper Richardson Bay (EcoAtlas, December 2017. https://www.ecoatlas.org/).

Human Demographics	
Population Size	59,582
Population Density	5,207 per mi^2
Housing Units	27,036
Housing Unit Density	2,363 per mi^2

Land Cover	
Land Cover Class	**Percent of Profile Data**
Developed Open Space	46%
Low Intensity Development	32%
Medium Intensity Development	20%
High Intensity Development	2%

Upland habitat Abundance		
Habitat Type	**Area (acres)**	**Area (%)**
Urban	2,363	32.4%
Coastal Oak Woodland	1,175	16.1%
Montane Hardwood	954	13.1%
Mixed Chaparral	584	8.0%
Annual Grass	520	7.1%
Coastal Scrub	487	6.7%
Eucalyptus	421	5.8%
Montane Hardwood-Conifer	313	4.3%
Montane Riparian	48	0.7%

This technical report includes technical terms that may be unfamiliar to some readers. Common terms are defined when first used in each Chapter. This glossary is provided for terms used in this Report.

Term	Basic Meaning in This Report
Accretion	Process of maintaining or gaining height of tidal marsh or flat due to sedimentation
Alluvial fan	Fan-shaped deposit of sediment by a creek at its mouth
Autochthonous Sediment	Organic material produced by marsh plants adding to accretion
Backshore	Boundary between tidal marsh and upland
Beach	Unvegetated sloping foreshore of highly mobile sediment
Berm	Elevated ribbon of land, raised bank, or terrace bordering a channel or foreshore
Delta	An alluvial fan subject to tidal submergence
Drainage Network	System of channels conveying water from one to another
Eco-Geomorphic Unit	Land features formed and maintained by interactions between physical and biological processes.
Erosion	Loss of tidal lands or uplands due to actions of wind and water
Fetch	Length of water surface over which wind blows
Foreshore	Boundary between tidal marsh and tidal flat or shallow subtidal area
Lag Surface	Layer of coarse sediments preventing erosion of underlying finer sediments
Levee	Elevated strip of land or raised bank along a channel or foreshore; higher than a berm.
Managed Retreat	Planned relocation of people and built environment out of sea level rise migration space.
Mean High Water	Average of all high tides for a designated number of tide cycles
Mean Higher High Water	Average of higher of two daily high tides for a designated number of tide cycles
Mean Low Water	Average of all low tides for a designated number of tide cycles
Mean Lower Low Water	Average of lower of two daily low tides for a designated number of tide cycles
Mean Sea Level	Average of hourly heights of the tide during the National Tidal Datum Epoch.
Migration Space	Area of uplands the tides will submerge at a designated future time
Panne	Shallow high marsh pond subject to seasonal desiccation
Run-up	The action of waves reaching lands above the height of the high tide.
Scarp	Very steep channel or foreshore bank caused by erosion
Sedimentation	Process of sediment deposition or creation at a tidal, subtidal, or upland surface
Sediment Transport	Process of water carrying or moving sediment
Shell Hash	Sediment consisting of broken shellfish shells
Splay	Fan-shaped sediment deposit smaller and less maintained than an alluvial fan
Subtidal	Below Mean Lower Low Water
Supratidal	Above the maximum height of the tide
Suspended sediment	Sediment contained within a volume of water
Terrigenous sediment	Sediment transported by upland runoff and not by tide
Tidal	Sedimentation or anything else depending upon tides or within the tidal zone
Tidal Flat (mud or sand)	Unvegetated tidal lands between Mean Lower Low water and the foreshore
Tidal Marsh	Vegetated tidal lands between the foreshore and backshore
Tidal Prism	A tidal prism is the volume of water in an estuary or inlet between mean high tide and mean low tide, or the volume of water leaving an estuary at ebb tide
Tidal Zone	Area between Mean Lower Low Water and maximum high tide
Watershed	Area of upland or tidal land draining to a point or place
Wind-wave	Waves of water created by wind blowing along a fetch

Citations

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