

Chapter 2: Elkhorn Slough Estuarine Habitats

Introduction

This chapter provides a brief introduction to Elkhorn Slough's estuarine habitats including subtidal channels, tidal creeks, mudflats, salt marshes, and tidal brackish marshes. It describes the key characteristics and a few representative species for each habitat type. The main factors that influence the distribution and extent of tidal wetlands are reviewed. Brief histories and site descriptions of selected wetland complexes in Elkhorn Slough are also provided.

Factors Controlling Estuarine Habitat Extent and Distribution

There are a number of factors that control tidal wetland composition, distribution, and function. The main controlling or forcing factors are climate and basin geomorphology as shown in Figure 5 (Mitsch and Gosselink 2000). The hydrology, physiochemical environment, and biota, however, are all factors that can be modified during restoration efforts. The linkages and feedback processes need to be clearly understood to predict restoration outcomes.

Chapter Summary Points

- Elkhorn Slough contains 293 acres of subtidal channels and tidal creeks, 1,605 acres of mudflats, and 796 acres of intertidal salt marshes and tidal creeks.
- Factors such as climate, geomorphology, and hydrology shape the distribution of the estuarine habitats in Elkhorn Slough.

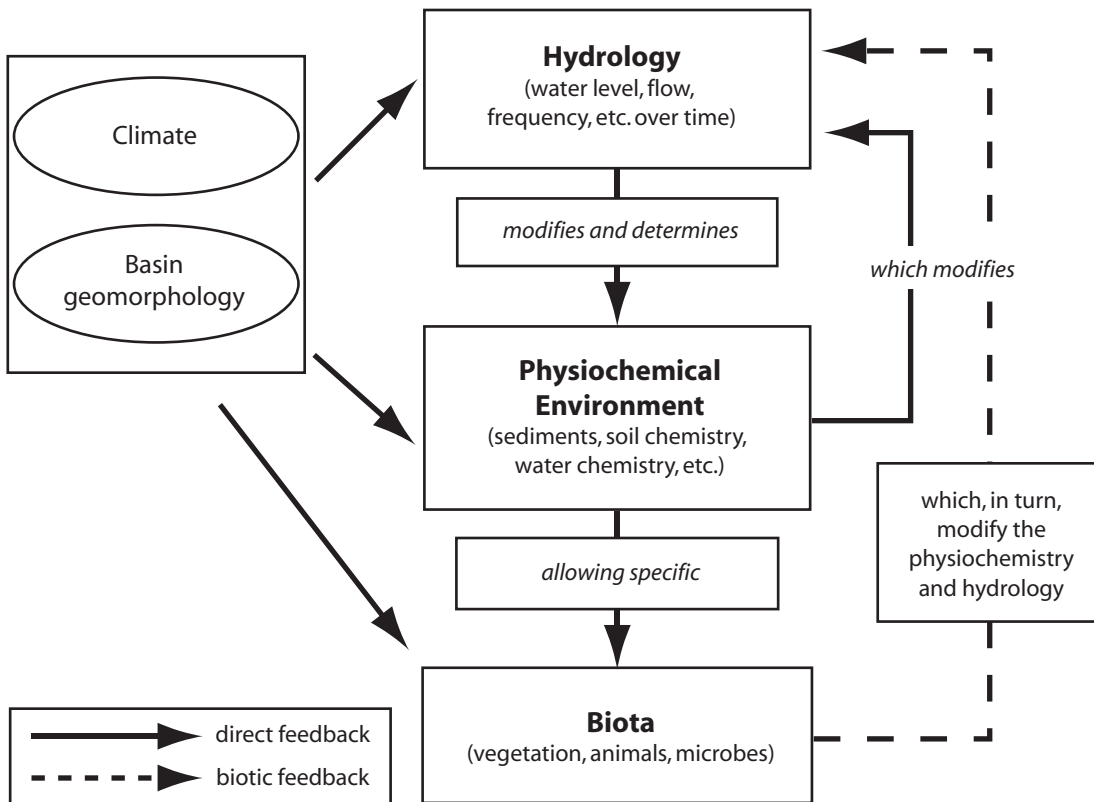


Figure 5. Conceptual model illustrating habitat controlling factors (climate, geomorphology) and the effects of hydrology on wetland function and the biotic feedbacks that affect wetland hydrology (Mitsch and Gosselink 2000).

Chapter 2: Elkhorn Slough Estuarine Habitats

Geomorphic Evolution

Elkhorn Slough was part of a larger regional estuarine network that has been closely linked to changes in sea level in the past 20,000 years. During the last glacial period, sea level was approximately 390 feet (120 meters) lower than it is today, and a freshwater river flowed through Elkhorn Valley to the modern shelf edge of the Monterey Bay (Schwartz 1986). About 18,000 years ago, the earth's glaciers began to melt, and sea level rose rapidly. Eventually, ocean water entered the mouths of Elkhorn and Moro Cojo Sloughs and converted these former streambeds into high-energy tidal inlets, which were then colonized by oysters and clams (Hornberger 1991, Schwartz 1986). As sea-level rise slowed 7,000 or 8,000 years ago, tidal energy decreased, sediment began to accumulate in local tidal wetlands, and mudflats and salt marshes developed (Hornberger 1991, Schwartz 1986, West 1988). As sediment deposition continued, mudflats became vegetated and salt marshes expanded.

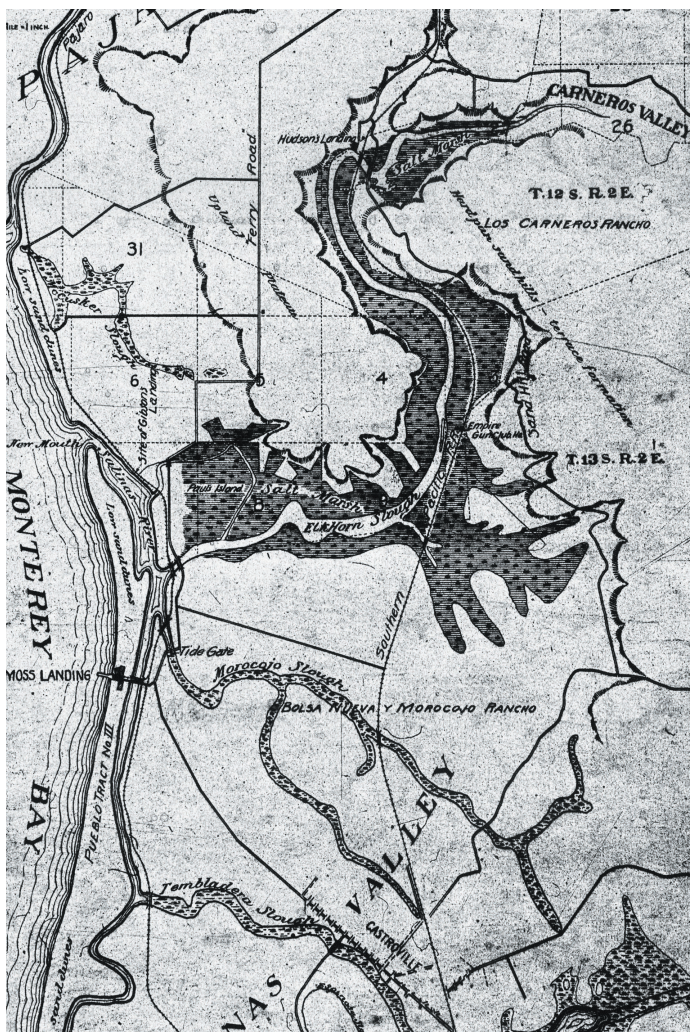


Figure 6. Map (c. 1909) illustrating the interconnected estuarine network of Elkhorn Slough, Moro Cojo Slough, Tembladero Slough, and the Salinas River before the Salinas River was diverted.

Over the last 5,000 years, estuarine environments have existed in Elkhorn, Moro Cojo, Bennett, Tembladero, and McClusky Sloughs as well as the lower stretches of the Salinas and Pajaro Rivers (Figure 6, Hornberger 1991, Schwartz 1986, West 1988). Like most estuaries, these wetlands received variable amounts of oceanic and freshwater influence over time. Fluctuations have been based on the shifting Salinas River mouth (diverted c. 1909), the location of freshwater springs, seasonal rain inputs, and sandbars that formed on the shore. The majority of the estuarine system appears to have been dominated for thousands of years by tidally influenced salt marshes and mudflats along main channels and tidal creeks, while the upper margins have harbored brackish or freshwater marshes (Hornberger 1991, Schwartz 1986, Watson 2006, West 1988).

It is possible that during certain periods of time, the entrance to Elkhorn Slough closed seasonally. Although scientific evidence proving this point is lacking, other California estuaries with similar morphologies and lack of cordgrass have intermittent tidal connections. In addition, there is increasing evidence that Elkhorn Slough was dominated by brackish and freshwater wetlands for an extended period approximately 3,000 years ago. During this time it was possible that Elkhorn Slough was separated from tidal influence by a permanent sandbar (Watson 2006, West 1988). However, for the last 2,000 years, salt marsh vegetation and marine-influenced diatoms, invertebrates, and fish have

Chapter 2: Elkhorn Slough Estuarine Habitats

dominated Elkhorn Slough and adjacent estuaries (Schwartz 1986, Hornberger 1991, Watson 2006). Local geologists hypothesize that the Pajaro River played an important and changing role in Elkhorn Slough's environment over time and provided freshwater and sediment inputs during episodic flood events like the 1995 Pajaro River flood. More detailed information and a timeline of known historic geological and hydrological events can be found on the Tidal Wetland Project web pages at <http://www.elkhornslough.org/tidalwetlandproject>.

The geomorphology, or shape and elevation of the landscape, can particularly be affected in California by long-term tectonic movements as well as seismic events. Three major earthquakes (magnitude 7.0 – 7.9) have occurred in the region in the past 150 years (USGS 2007). One took place in 1868 along the Hayward fault (7.0), and another in 1989 at Loma Prieta (7.1) (USGS 2007). The great earthquake of 1906 (8.25) resulted in many cracks in the mud at Moss Landing and eastward movement of the local sand-spit. Reportedly, subsidence at the Moss Landing pier changed the water depth from 6 feet (1.8 meters) deep before the earthquake to 18 or 20 feet (5.5 or 6.1 meters) after the earthquake, and caused nearby land subsidence of 2 feet (0.6 meters) (Lawson 1908). There has also been subsidence in Elkhorn Slough habitats, which could be due to a number of factors such as groundwater withdrawal, diking, and tectonic events. However, the relative importance of groundwater withdrawal compared with tectonic events in causing subsidence needs further research.

Climate

Elkhorn Slough typically has a mild and dry Mediterranean climate with monthly mean air temperatures ranging from 52-59°F. Rainfall is less than 0.2 inches per month (5 mm/month) between June and September, but the average rainfall at the Elkhorn Slough Reserve in December and January is 3 inches per month (76 mm/month) (Caffrey et al. 2002). Stronger winds occur in the afternoon between April and September, which can enhance mixing of tidal waters. Observed sea-level rise trends for California have ranged from 3.9 to 7.9 inches (10 to 20 cm) per century, and are predicted to increase over the next decade (Cayan et al. 2006). Sea-level rise predictions also include an increase in the occurrence of extreme tide events, which may increase the vulnerability of tidal marsh species to predation and exacerbate shoreline erosion.

Tidal Hydrology

Elkhorn Slough is a partially-mixed estuary, characterized by a weak stratification that is mixed during spring ebb tides. The tides in Elkhorn Slough are mixed semi-diurnal with a mean daily tide range of 5.6 feet (1.7 m) and a low-low tide that follows a high-high tide. The spring tide range is 8.2 feet (2.5 m) and the neap tide range is 3 feet (0.9 m) (Broenkow and Breaker 2005). The tide range is the difference in the level between successive high and low tides. It takes approximately 25 to 30 minutes for high tide to travel from the mouth to the upper sections of Elkhorn Slough (L. Breaker and N. Nidziedo, pers. comm.). Tidal currents in Elkhorn Slough are ebb-dominant, so ebb tides have stronger velocities and are shorter in duration than flood tides. The resulting potential for sediment erosion and transport is thus greater on ebb (outgoing) tides than flood (incoming) tides and partially contributes to the net export of sediment from the estuary. Maximum depth-averaged tidal currents in the lower portion of the main channel are approximately 2.9 mph (1.3 m/s) with RMS (root mean square) velocities of 0.7 mph (0.33 m/s) (pers. comm. Nick Nidziedo). Velocities near the Highway 1 Bridge can approach 3.4 mph (1.5 m/s) (Broenkow and Breaker 2005). Tidal current data from Acoustic Doppler Current Profilers (ADCP) from February 2005 to mid-May 2006 are available online at <http://www.mbari.org/lobo>.

Chapter 2: Elkhorn Slough Estuarine Habitats

Water Chemistry

The salinity in the main channel of Elkhorn Slough ranges from 0.5 to 37 parts per thousand (ppt) (Table 1). Evaporation exceeds the rate of freshwater input during the dry summer and fall, resulting in hypersaline conditions in the upper third of Elkhorn Slough until the first winter rainfall. Recent hydrodynamic and nutrient analyses demonstrate that waters from the Old Salinas River Channel can be carried up the estuary as far as Kirby Park by tidal currents (Johnson et al. in press, Monismith et al. 2005). Freshwater inputs also enter Elkhorn Slough from Carneros Creek at the head of the estuary with discharge rates between 7 and 1,300 cubic feet per second (0.2 and 38 cubic m/s) from December to April (Caffrey et al. 2002).

Table 1. Salinity data for the Elkhorn Slough channel (J. Needoba and J. Haskins, pers. comm.).

Channel Location	Salinity Average (Date)	Salinity Maximum (Date)	Salinity Minimum (Date)
Near Kirby Park	31 ppt (2005/2006)	37 ppt (July 2005/2006)	0.5 ppt (January 2005) 0.9 ppt (April 2006)
Just west of Seal Bend	32 ppt (2005/2006)	34-35 ppt (July 2005/2006)	5.4 ppt (March 2005) 9.5 ppt (April 2006)
Just east of the Highway 1 Bridge	32 ppt (2006)	36 ppt (2006)	19 ppt (2006)

Elkhorn Slough Estuarine Habitats

Estuarine habitats include subtidal areas that are covered by water even at low tide and intertidal areas that are covered with water during high tide, but are exposed during low tide. The main types of the 2,694 acres (1,090 hectares) of estuarine habitats found in Elkhorn Slough are listed below (Figures 7 and 8, Table 2). The distribution of these habitats is largely dependent on physical factors such as water depth, which depends on elevation.

Chapter 2: Elkhorn Slough Estuarine Habitats

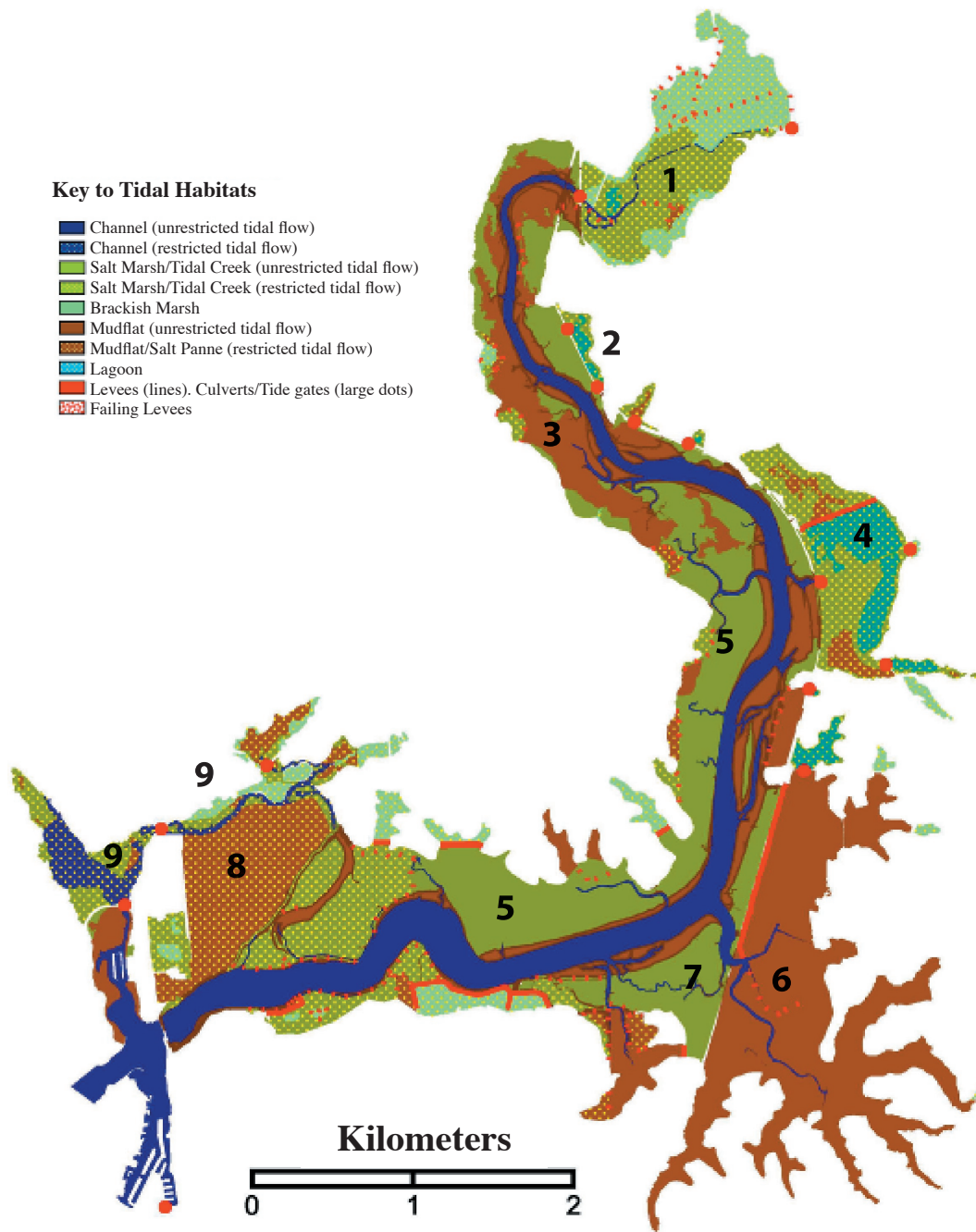


Figure 7. Spatial representation of Elkhorn Slough estuarine habitats based on GIS analysis of aerial photographs. The numbers refer to specific wetland complexes (Table 3, Page 20). The red dots indicate water control structures and red and white lines indicate levees.

Chapter 2: Elkhorn Slough Estuarine Habitats

Figure 8. Estuarine habitat zones adapted from *Design Guidelines for Tidal Wetland Restoration* (PWA and Faber 2004)

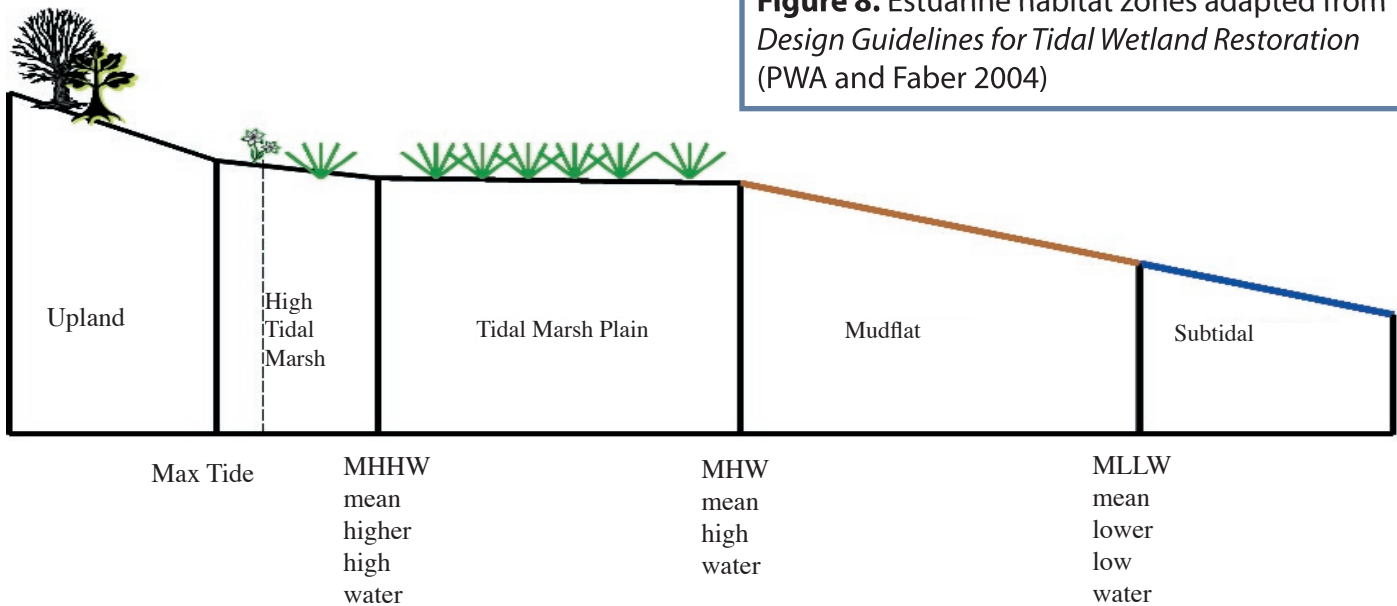


Table 2. Acreage of Elkhorn Slough estuarine habitats (ESNERR, unpublished data).

ESTUARINE HABITAT TYPE	ACREAGE	PERCENT OF TOTAL
Salt Marsh and Tidal Creeks (intertidal)	796 acres (322 hectares)	29.5 %
Mudflats (intertidal)	1,605 acres (649 hectares)	59.6 %
Channels and Tidal Creeks (subtidal)	293 acres (119 hectares)	10.9 %

Subtidal Channel Habitat

Location: Subtidal channel habitats occur below the elevation of the low tidemark or Mean Lower Low Water (MLLW) where the substrate is continuously submerged.

Representative Species: Some areas are covered with submerged vegetation such as eelgrass (*Zostera marina*) and various algal species are widespread. Diverse invertebrates inhabit all subtidal areas. One large species found in greater abundance here than anywhere else in the world is the fat innkeeper worm (*Urechis caupo*). Numerous diving birds such as the brown pelican (*Pelecanus occidentalis*) and double-crested cormorant (*Phalacrocorax auritus*) use channel habitats. Among the many fish species inhabiting the channel, a few examples are the bat ray (*Myliobatis californica*) and shiner surfperch (*Cymatogaster aggregata*). Federally threatened southern sea otters (*Enhydra lutris nereis*) also commonly use channels as a sheltered area to rest and feed.

Chapter 2: Elkhorn Slough Estuarine Habitats

Key Characteristics: Elkhorn Slough channel habitats have substrates largely composed of material such as organic matter, mud, sand, and gravel. The fine-grained material in the Elkhorn Slough channel is often cohesive, particularly as a result of unconsolidated material eroding away in the past few decades. The channel depth averages about 9.8 feet (3 meters) but is as deep as 32.8 feet (10 meters) near the Highway 1 Bridge crossing and as shallow as 1.6 feet (0.5 meters) at the head of the estuary.

Mudflat Habitat

Location: Mudflat habitats are found between the elevations of Mean Lower Low Water (MLLW) and Mean High Water (MHW) and typically occur between channel habitats and marsh habitats. Because they are intertidal, mudflats are usually covered with water during high tide and exposed during low tide.

Representative Species: Lower mudflats support some eelgrass and algal species but are devoid of other vegetation. Similar to subtidal habitats, the soft sediment hosts a large variety of tiny invertebrates, as well as some large species such as gaper clams (*Tresus nuttallii*). Birds such as marbled godwits (*Limosa fedoa*), willets (*Catoptrophorus semipalmatus*), and sandpipers (*Calidris* spp.) are commonly seen feeding on these mudflat animals that are a key resource for migratory shorebirds. Fish species such as various gobies reside in the mudflats, and other species such as sharks, rays, and southern sea otters forage on large benthic invertebrates.

Key Characteristics: Mudflats serve an important function in estuarine chemical cycles. Currently mudflats are the most abundant habitat type in Elkhorn Slough.

Tidal Creek Habitat

Location: Tidal creeks form networks in salt and tidal brackish marsh complexes.

Representative Species: Tidal creeks provide habitat for estuarine fish such as the arrow goby (*Clevelandia ios*), a species that is also common in intertidal and subtidal mudflats.

Key Characteristics: Prior to high rates of eroding tidal creeks in Elkhorn Slough, these habitats served an important function of nursery grounds (i.e. food and shelter) for numerous species of juvenile fishes. Tidal creeks serve an important function of water conveyance and drainage onto and off of the marsh surface as well as the transfer of sediment and nutrients between marshes and the main estuarine channel.

Salt Marsh Habitat

Location: Salt marsh habitat occurs at elevations of approximately 4.6 feet (1.4 meters) above MLLW and high marsh is over 5.3 feet (1.6 meters) above MLLW. The majority of a salt marsh habitat is a flat plain, although some areas near tidal creeks, ponded areas, and upland transitions have more varied topography and greater plant diversity. Salt marshes characteristically contain persistent emergent plant species.

Chapter 2: Elkhorn Slough Estuarine Habitats

Representative Species: Low and middle elevation salt marshes are dominated by pickleweed (*Sarcocornia pacifica*, formerly *Salicornia virginica*) and are usually inundated during high tide and exposed during low tide. High salt marsh is flooded irregularly (usually exposed at least 10 continuous days) and vegetation consists of species such as salt grass (*Distichlis spicata* var. *stolonifera*), alkali heath (*Frankenia salina*), and jaumea (*Jaumea carnosa*). In many areas, floating rafts of macroalgae (*Ulva* spp.) cover the salt marsh. The state listed California black rail (*Laterallus jamaicensis coturniculus*) is one of the few birds that exclusively uses tidal marsh habitat for resting, foraging, and breeding. The California black rail has not yet been observed in Elkhorn Slough, but is severely threatened by habitat loss. Most waterbirds, such as the great egret (*Casmerodius albus*) and long-billed curlew (*Numenius americanus*), utilize salt marshes as a roosting site during high tides.

Key Characteristics: Elkhorn Slough currently lacks cordgrass (*Spartina foliosa*), which dominates tidal creek and mudflat margins in many other California salt marshes. Vegetated marshes serve an important function in both the uptake of nutrients and to buffer shoreline erosion.

Salt Panne Habitat

Location: Another habitat that is mostly devoid of vegetation is salt panne habitat, which occurs as bare patches within high salt marshes. Salt pannes are typically flooded in the winter (with rain and extreme tides) and dry with a salty crust in the summer.

Representative Species: In the winter, salt pannes provide habitat for waterbirds and in the summer provide habitat for shorebirds such as the western snowy plover (*Charadrius alexandrinus nivosus*) and the American avocet (*Recurvirostra americana*).

Artificially Restricted Tidal Exchange Habitat

Location: A number of estuarine habitats in Elkhorn Slough currently have muted tidal hydrology due to levees or water control structures such as tide gates or culverts.

Representative Species: In sites with moderate tidal exchange (e.g. 5-50 percent of full tidal range of 8.2 feet), animal species composition in the marshes, channels, creeks, and mudflats is broadly similar to habitats described above. In sites with very limited tidal exchange (e.g. <5 percent of full tidal range), animal species composition differs, with much lower representation by marine species (such as shorebirds, sharks, clams, etc.) and greater representation by brackish species such as the federally endangered tidewater goby (*Eucyclogobius newberryi*) and brackish water snail (*Tryonia imitator*). Plant communities in areas with very limited tidal exchange are very similar to those with full tidal exchange; areas with muted tidal exchange have significantly reduced plant diversity in the high marsh zone.

Key Characteristics: Historically, artificially restricted estuarine habitats did not occur in Elkhorn Slough. But while the water control structures are artificial, the brackish conditions found in some of these sites may be more representative of some historical estuarine conditions. Due to diking, many of these wetland areas have subsided and in many areas with muted tidal exchange, marshes have converted to open water lagoon or mudflat habitat.

Chapter 2: Elkhorn Slough Estuarine Habitats

Tidal Brackish Marsh Habitat

Location: Tidal brackish marsh occurs where saltwater is diluted by freshwater during much of year, salinity ranges between 0.5 to 18 ppt, and it floods extensively (or is in shallow water).

Representative Species: Tidal brackish marshes are characterized by a mix of persistent fresh and saline emergent plants such as bulrush (*Bolboschoenus maritimus* and *Schoenoplectus* spp. formerly *Scirpus* sp.), cattail (*Typha* sp.), and pickleweed. Pickleweed grows at higher elevations than bulrush and cattail in brackish marshes.

Key Characteristics: The plant and animal species are particularly adapted for a range of saltwater to freshwater conditions. In Elkhorn Slough, most of the tidal brackish habitat currently occurs in sites behind water control structures.

Tidal Marsh/Upland Ecotone Habitat

Location: Tidal Marsh/Upland ecotone habitats occur where tidal marsh transitions to upland vegetation. This transition zone may be inundated only on extreme high tide or flood events. This habitat is typically above the maximum tide elevation and functions as an important high tide refuge for tidal marsh species.

Representative Species: Tidal marsh/upland ecotone habitat usually contains high marsh plants and upland plants such as creeping wild rye (*Leymus triticoides*) and coyote brush (*Baccharis pilularis*), as well as dozens of non-native species. The California vole (*Microtus californicus*) and song sparrow (*Melospiza melodia*) commonly occur at this wetland-upland interface.

Site Descriptions for Selected Elkhorn Slough Wetland Complexes

Brief histories and site descriptions of selected wetland complexes in Elkhorn Slough are described below. Additional information about a number of these sites can be found in Appendix C. Although the conservation and restoration of estuarine habitats in lower Moro Cojo Slough is part of the Tidal Wetland Project scope, descriptions of this area are not included because it is the subject of other restoration planning efforts.

Table 3. Site names for selected Elkhorn Slough tidal wetland complexes. The site numbers refer to the locations in Figure 7 (Page 16).

Site Number	Site Name
1	Blohm-Porter Marsh Complex
2	Azevedo Ponds Wetland Complex
3	Upper Slough Marsh Complex
4	North Marsh Complex
5	Lower Slough Marsh Complex
6	Parsons Slough Wetland Complex
7	Yampah Marsh Complex
8	Salt Pond Wetland Complex
9	Bennett Slough/Struve Pond Wetland Complex

Chapter 2: Elkhorn Slough Estuarine Habitats

1. Blohm-Porter Marsh Complex



Figure 9. Photograph of the Blohm-Porter Marsh complex.

The Blohm-Porter Marsh complex, located at the head of Elkhorn Slough, is approximately 246 acres (100 hectares) between Elkhorn Road and Blohm Road (Figure 7). In the past, this area was dominated by tidal brackish marsh. A railroad embankment and bridge was built in 1872 between the Blohm-Porter Marsh complex and the main channel of Elkhorn Slough. Cattle have grazed parts of the Blohm-Porter Marsh complex since the mid 1800s. In the 1940s, a large earthen dam was constructed at the southern end of this area for the purpose of impounding freshwater and restricting tidal inundation to the northern areas. Around the same time, it was observed that water tables were being lowered by land use that reduced the flow and presence of freshwater springs and altered surface flows from Carneros Creek. The construction of the Harbor in 1947 increased tidal inundation to the Blohm-Porter Marsh complex. Around 1951, a linear section of the area was filled for the construction of Elkhorn Road, while culverts and tide gates were installed to allow one-way flow from the Blohm-Porter Marsh to Elkhorn Slough. The 1989 earthquake destroyed the tide gates and caused the road to subside. Consequently, from 1989 to 1995, tidal waters regularly flooded the Blohm-Porter Marsh complex.

In 1996, Monterey County Public Works installed new culverts and tide gates (with flaps allowing one-way flow) under Elkhorn Road.

2. Azevedo Ponds Wetland Complex



Figure 10. Photograph of the Azevedo Ponds wetland complex.

The Azevedo Ponds wetland complex is located on the eastern side of Elkhorn Slough (Figure 7). The wetland areas are named Northern Azevedo Pond (12 acres/5 hectares), Middle Azevedo Pond (6 acres/3 hectares), and Southern Azevedo Pond (2 acres/1 hectare). In some reports, the Northern Azevedo Pond is further divided into north and south sections. The Azevedo Marshes are separated from the main channel system by a railroad embankment built in 1872 that has openings with wooden box culverts in the berm. Many of the wetland areas also have additional structures such as levees or culverts that restrict tidal exchange. The wetlands and surrounding upland areas were purchased in 1991 by the Monterey County Agricultural and Historic Lands Conservancy and The Nature Conservancy through a State Coastal Conservancy grant. Agricultural use was pulled back from the edges of these pocket marshes for the establishment of 100-ft wide vegetated buffers strips from 1994 to 1995. The Elkhorn Slough Foundation and The

Nature Conservancy are currently working on wetland enhancement projects for the Northern and Southern Azevedo Pond areas which should be completed by spring 2008.

3. Upper Slough Marsh Complex



Figure 11. Photograph of the Upper Slough Marsh complex.

The Upper Slough Marsh complex is located on the northwestern section of Elkhorn Slough north of the Big T Creek (Figure 7). A few small areas on the western edge of this complex were diked by 1956. After 1947, the tidal creeks started to deepen and widen through erosion and marsh areas started to deteriorate in interior areas due to increased tidal inundation. By 2005, hundreds of acres of marsh vegetation in the Upper Slough Marsh complex died converting these marshes to mudflats and open water areas.

4. North Marsh Complex



Figure 12. Photograph of the North Marsh wetland complex.

The North Marsh wetland complex is a 183-acre (74-hectare) area located on eastern side of Elkhorn Slough (Figure 7). This complex includes Estrada Marsh, Campagna Marsh, and North and South Strawberry Marshes. This area was historically dominated by salt marsh with a complex of tidal creeks. Between 1869 and 1872, Elkhorn Road was constructed on the east side and a railroad was built along the west side of the wetland complex reducing tidal exchange. A number of large, artificial freshwater ponds were created in the 1900s in the North Marsh wetland complex for waterfowl hunting. By 1956, the entire complex was removed from tidal exchange by a series of levees primarily for cattle grazing. The diking and draining of the tidal marsh areas during this time caused the marsh sediment to dry out, compact, decompose, and subside by approximately 1.9 feet (0.6 meters). The California Department of Fish and Game acquired North Marsh in 1980 and Estrada Marsh in 1993 as part of the Elkhorn Slough National Estuarine Research Reserve. Tidal action was returned to the North Marsh wetland complex in 1986 through four tide gates. North Marsh is currently dominated by a mix of open water, mudflat, and fringing salt marsh habitat and continues to be managed with tide gates due to the subsidence and the low-lying Elkhorn Road.

5. Lower Slough Marsh Complex



Figure 13. Photograph of the Lower Slough Marsh complex.

The Lower Slough Marsh complex extends from the marsh area north of Seal Bend to the Big T Creek in the northwestern section of Elkhorn Slough (Figure 7). This area includes the Rubis Creek marsh areas. A few small marsh areas on the western edge of this complex were diked by 1956 and converted to freshwater ponds. After 1947, the tidal creeks started to deepen and widen through erosion and marsh areas started to deteriorate in interior areas due to increased tidal inundation. By 1956, many areas of marsh vegetation in the Lower Slough Marsh complex had deteriorated, converting these marshes to mudflats and open water areas. There has been a brief recovery of marsh, but the tidal creeks are continuing to erode and interior marsh dieback is still occurring in these areas.

6. Parsons Slough Wetland Complex



Figure 14. Photograph of the Parsons Slough Marsh complex.

The Parsons Slough wetland complex is a 429-acre (174-hectare) area located in the southeastern section of Elkhorn Slough (Figure 7). This complex includes South Marsh and the Five Fingers area. In the past, the Parsons Slough wetland complex was dominated by tidal salt marsh and tidal creeks. Numerous levees and dikes were created in this area starting in 1872 with a railroad embankment that blocked off a number of tidal creek connections. In the 1900s, duck ponds were created converting tidal marsh habitat to artificial freshwater ponds. The entire Parsons Slough wetland complex was diked and drained by the 1960s, converting many acres to pastureland. As a result, this area has subsided and the average elevation is approximately 2.4 feet (0.7 meters) lower than what can support marsh vegetation. The main areas are dominated by mudflat areas with some subtidal creeks, fringing tidal marsh, and created tidal marsh islands. During the winter of 1982-1983, the levee at the Parsons mouth breached during a storm event, allowing tidal waters to enter. A 1980s restoration project in South Marsh created channels, habitat islands, and reconnected tidal waters. Since that time, bank erosion has significantly decreased the width and length of these habitat islands since they were first constructed.

7. Yampah Marsh Complex



Figure 15. Photograph of the Yampah Marsh complex.

The Yampah Marsh complex is a 98-acre (40-hectare) area located in the southeastern part of Elkhorn Slough (Figure 7). Yampah Marsh has never been diked, but the marsh is currently degrading at rapid rates. This complex may be suitable for pilot sediment addition or retention projects to restore degrading marsh habitat.

8. Salt Ponds Wetland Complex



Figure 16. Photograph of the Salt Ponds wetland complex.

The Salt Ponds wetland complex, located northeast of the Elkhorn Slough mouth, is a 153-acre (62-hectare) area (Figure 7). This area was historically dominated by salt marsh with a complex of tidal creeks. The Monterey Bay Salt Works company completely diked this tidal marsh area by 1931 for salt production. The California Department of Fish and Game acquired the former salt ponds as part of the Moss Landing Wildlife Area. The area is managed primarily as nesting and breeding habitat for the western snowy plover (*Charadrius alexandrinus nivosus*), a federally threatened species. The numerous ponds also provide habitat for wintering waterfowl and shorebirds.

9. Bennett Slough/Struve Pond Wetland Complex



Figure 17. Photograph of the Bennett Slough/Struve Pond wetland complex.

The Bennett Slough/Struve Pond wetland complex, located northeast of the Elkhorn Slough mouth, is approximately 140 acres (57 hectares) (Figure 7). It includes the old Elkhorn Slough mouth area north of Jetty Road, the Bennett Slough channel (around the Salt Ponds), Bennett Ponds, and Struve Pond. The main areas are dominated by tidal mudflats, salt marsh, and tidal creeks, and also contain tidal brackish marsh and freshwater ponds. Prior to the 1850s, the Bennett Slough channel meandered around hundreds of acres of tidal marsh. Levees constructed by the Monterey Bay Salt Works company in 1931 blocked off the main eastern connection of the Bennett Slough channel. During the same time, levees were also constructed, blocking the tidal creek connections to create Bennett Ponds. The coast highway was reconfigured by 1931 and road embankments with culverts were built between Bennett Slough and Struve Pond. The creation of the Moss Landing Harbor in 1947 relocated the Elkhorn Slough mouth to the south and the construction of Jetty Road reduced tidal exchange to the Bennett Slough area. Before 1956, an earthen levee was constructed in Struve Pond by landowners to create a freshwater pond. The 1989

earthquake caused Jetty Road to collapse, which temporarily increased tidal exchange to Bennett Slough. California State Parks rebuilt Jetty Road in 1991 and replaced the single culvert with a six-culvert system, making the tidal exchange greater than the 1947-1989 conditions.

