Estuary Subbasin

TABLE OF CONTENTS

LIST OF FIGURES 1

LIST OF TABLES 2

Estuary Subbasin 3

- Introduction 3
- Hydrology 3
- Geology 4
  - *Faulting and Seismicity* 4
  - *Fluvial Geomorphology* 6
- Vegetation 8
- Land Use 11
  - *Native Americans* 11
  - *Agriculture, Pastures, and Dairies* 11
  - *Changes to Estuarine Habitat from Land Use* 11
  - *Navigation and Shipping* 12
  - *Commercial Fishing in the Estuary 1853-1922* 13
- Water Quality 13
- Fish and Habitat Relationships 18
- Fishery Resources 19
- Commercial Fishing in the Estuary 1853-1922 and Price Creek Hatchery 1897-1915 23
  - *The Early Fishery* 23
  - *The Canneries and the Boom Years* 24
  - *Price Creek Hatchery 1898-1915* 26
  - *1900-1921 The Last Years of the Salmon Fishery* 27
  - *Supplementary Findings and Fishery Synopsis* 28
  - *Historic Chinook Salmon Population Estimate* 28
- Responses to Assessment Questions 34
- Subbasin Conclusions 37

LIST OF FIGURES

Figure 1. Estuary Subbasin locator map and CalWater Units. 5

Figure 2. Eel River Syncline 6

Figure 3. Geology of the Estuary Subbasin.. 7

Figure 4. Vegetation of the Estuary Subbasin. 9

Figure 5. Change in saltmarsh habitats from 1854 to 2005 10

Figure 6. Eel River estuary 1885 map showing salt marsh designation 12
Figure 7. Examples of various sality profiles. 14
Figure 8. Locations of temperature monitoring sites in the Estuary Subbasin. 15
Figure 9. McNulty Slough dissolved oxygen and pH results from 2004-2007. 16
Figure 10. McNulty Slough salinity and turbidity results from 2004-2007. 16
Figure 11. Mean fork lengths of juvenile Chinook salmon captured from lower, middle and upper sampling sites in the Eel River estuary 1994. 21
Figure 12. Catch per seine haul of juvenile Chinook salmon from lower, middle and upper estuary sampling sites 1994. 22

LIST OF TABLES

Table 1. Length of named sloughs located in the Eel River Estuary assessment area. 4
Table 2. Vegetation of the Estuary Subbasin. 9
Table 3. Maximum weekly average temperatures and maximum daily average temperatures collected in the Estuary Subbasin. 15
Table 4. Chemical testing in McNulty Slough 2005-2006, Wiyot Tribe 2007..... 17
Table 5. Water chemistry results in the Estuary Subbasin (Ziemer and Anderson 2001). 17
Table 6. Fish species observed from the Eel River Estuary. Observers are also shown. 20
Table 7. Annual reported commercial catches of Chinook salmon from the Eel River estuary1857-1922. 29
Table 8. Seasonal and spatial distribution of fish captured in Eel River estuary. 32

Estuary Subbasin

Eel River estuary downstream from Fernbridge (RM 7).

Introduction

The Eel River estuary is located approximately 13 miles south of Eureka in Humboldt County. The Estuary Subbasin includes approximately 24 square miles of delta wetlands, pastures and hillsides that form the Hawk Slough and portions of the Salt River and Palmer Creek CalWater 2.2 Planning Watersheds (Figure 1). Fernbridge, at river mile (RM) 7 is located at the upper extent of the Estuary Subbasin channel. Elevations in the subbasin range from sea level at the river mouth to approximately 700 feet in upland areas near Table Bluff. Most of the delta lands are relatively flat. The town of Loleta is located at the base of rolling hills at an elevation of approximately 50 feet above sea level. The location of Loleta helps prevent the town from flooding during large winter storms that periodically inundate the delta lands. The Estuary Subbasin does not include the Salt River or its tributaries. The Salt River watershed, although hydrologically connected to the Eel River estuary, is treated as a distinct assessment subbasin in this report.

Hydrology

The Eel River estuary is a sand bar built estuary that typically remains open to tidal exchange year-round. Tides are mixed diurnal, with two lows and two highs of unequal size generally occurring within a 24-hour period. Because of the influence of tides, estuaries are mixing zones where freshwater and sea water meet. More specifically, Cowardin et al. (1979) defines estuaries as tidal habitats and adjacent tidal wetlands that are semi-enclosed by land and have open access to the ocean, with ocean-derived water at least occasionally diluted by freshwater runoff from the land. The upstream limit of estuaries can be defined where salinity measures less than 0.5 parts per thousand (ppt) during the period of average annual low flow (Day et al. 1989). By this definition, the Eel River estuary extends inland to at least Fernbridge where salinities of 2-11ppt. have been measured (Cannata 1995). The pulse of high tides can be observed above Fernbridge and it has been noted that the affect of tides can extend to the confluence with the Van Duzen River (Van Kirk 1996). There is a lag

time of approximately one hour for high tides to extend from the river mouth to Fernbridge.

The Estuary Subbasin contains five freshwater tributaries connected to 30 miles of named slough channels. Another 30 miles of unnamed sloughs (shown on USGS topographic maps) meander throughout its floodplain (Table 1). Tidal flows are contained on major sloughs by levees and tide gates built by settlers to the area in the latter 1800s and early 1900s. Thus natural tidal connectivity and drainage patterns between slough channels, freshwater streams and their adjacent wetlands have been altered for many decades by the levee and tide gate systems.

The estuary receives runoff from approximately 3,500 miles of stream channels that drain nearly 3,700 square miles of the mountainous Eel River Basin. Stream flows into the estuary are measured at the USGS gauging station at Scotia. Mean annual discharge to the estuary is approximately 5.4 million acre-feet. The highest recorded annual discharge into the estuary was 12.6 million acre feet in 1983 and the lowest was 410,000 acre feet in the drought of 1977. The peak flow or maximum discharge into the estuary was recorded on December 23, 1964 when the gauging station near Scotia measured 752,000 cubic feet per second (USGS website). The Land Use section of this report (pgs. 11-12) addresses the effects of levees and tidegate development and the altered hydrology of the estuary.

Table 1. Length of named sloughs located in the Eel River Estuary assessment area.

Slough name	Length of freshwater (miles)	Length of brackish water (miles)	Total length (miles)
Mosley Slough	0	1.4	1.4
Sevenmile Slough	0	3.8	3.8
McNulty Slough	4.8	3.4	8.2
Hawk Slough	2	3.6	5.6
Quill Slough	2.2	2.8	5
Hogpen Slough	1.8	1.2	3
Ropers Slough	1.4	1.2	2.6
Total Length	**12.2**	**17.4**	**29.6**

The estuary is vulnerable to sea level rise and increasing storm intensity associated with projected climate change. Specific impacts include saltwater inundation of grazing land, and loss and/or landward migration of tidal marshes. In addition, increased winter storm intensity could increase freshwater inflows and sediment delivery,and also initiate higher ocean wave and flood generated erosion. The complex interactions of climate change may alter the size, shape and ecologic functions of the estuary (Heberger et al. 2009; Scavia et al. 2002).

Geology

The estuary is located in a broad alluvial valley formed within the NW-SE trending Eel River syncline (Figure 2). The syncline is formed by active tectonic forces inherent to the region. The syncline is subsiding in elevation by an average of 1-3 mm per year while Table Bluff (anticline) rises by a similar amount. Although the average annual delta subsidence rate is relatively small, major movements of 1 or 2 meters may occur during large earthquakes that occur in intervals of 200 to 500 years (Li and Carver 1992) or lesser movements occur with smaller events.

The hills on the estuary's northern, eastern, and southern sides are composed of Quaternary river terrace deposits and sedimentary formations of the Wildcat group (Figure 3). The hills composed of the Wildcat Group are unstable and very susceptible to erosion. The western edge is bordered by sandy beaches forming a sand spit composed of marine shoreline deposits and sand dunes. The subbasin's subsurface geology consists of sedimentary formations of the Wildcat Group to a depth of over 9,000 feet.

Faulting and Seismicity

The estuary is located in a seismically active area where frequent earthquakes occur due to the complex interactions of the Mendocino Triple Junction. This junction is where the Gorda, North American, and Pacific plates meet. The convergent boundary between the North American and Gorda plates, called the Cascadia Megathrust, is located offshore and adjacent to the subbasin. It is the current subduction zone and complex tectonic structure is responsible for many small earthquakes and infrequent large-scale earthquakes. The Cascadia Megathrust, which is believed to have an earthquake recurrence rate of roughly 500 to 600 years (Witter and Patton 2006) can generate earthquakes of magnitude 8 and greater. Megathrust earthquakes cause very rapid uplift or subsidence of the coastal land in adjacent areas and could create large tsunamis. It is estimated from Japanese tsunami records that in January of 1700 a magnitude~9 earthquake was generated along the Cascadia Megathrust.

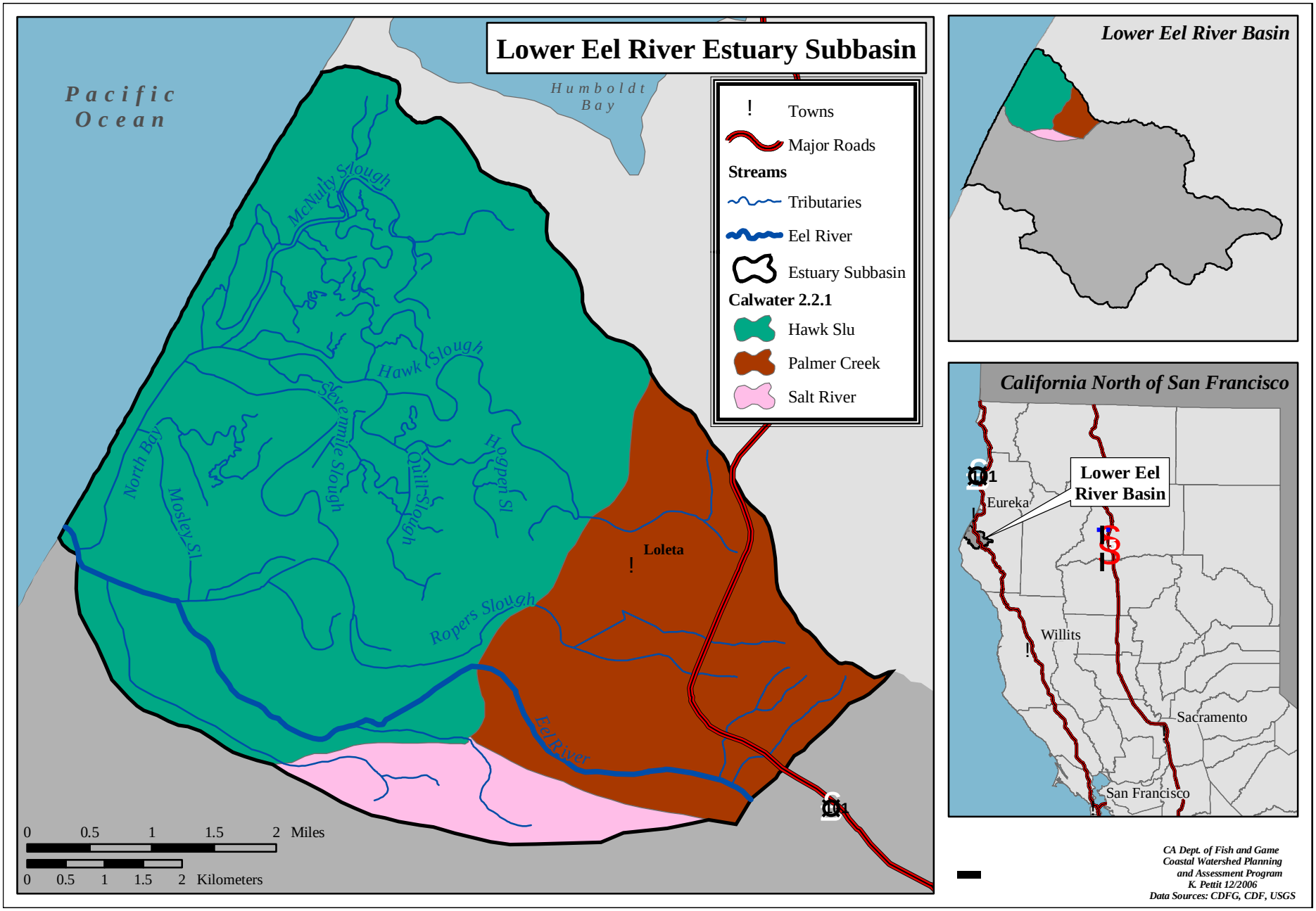

Figure 1. Estuary Subbasin locator map and CalWater Units.

In addition to the Mendocino Triple Junction, the Little Salmon Fault runs along the northern boundary of the subbasin. It may cause earthquakes, which can initiate landsliding and liquefaction. The Little Salmon Fault is believed to have an earthquake recurrence rate of roughly 600 to 700 years (Witter & Patton 2006).

The 1906 San Francisco earthquake (estimated magnitude 7.9), which ran along the San Andreas Fault from San Juan Bautista to Cape Mendocino, caused significant morphological modifications to the estuary including subsidence of several acres of land of over one foot at several sites especially on Cock Robin and Cannibal islands. It was reported that all along the Salt River land slid into the river (Dengler 2006).

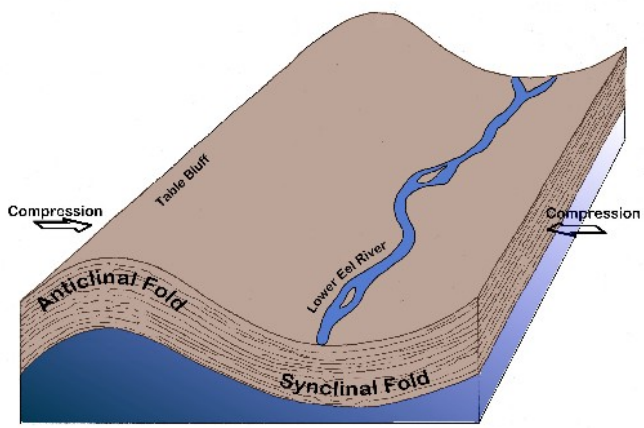

Figure 2. Eel River Syncline

Fluvial Geomorphology

The Eel mainstem flows approximately eight miles from Fernbridge to the river mouth. Because the Eel River Delta and estuary are relatively flat landscapes, the river and slough channels have very low stream gradients. Low gradient reaches of rivers and streams are depositional reaches because they tend to accumulate sediments delivered from higher gradient reaches upstream.

The estuarine channels were once deep enough to allow 12-foot draft shipping vessels access into Port Kenyon and barges up the Eel River past Fernbridge. A review of bathymetry maps produced in 1869 showed that depths near the river mouth were 10 to 16 feet and the North Bay and lower portions of McNulty Slough ranged between 9 to 13 feet. The North Bay channel ranged from 10 to 14 feet deep, and the river thalweg and pools around Cock Robin Island were from 25 to 31 feet deep.

A comparison of bathymetry maps produced in 1888 and 1921 show a decreasing trend in depth of the lower main river channel thalweg, pools and the lower Salt River (Laird et al. 2007). The levees along the Salt River were considered a cause for the loss of depth, and the subject of a lawsuit of the 1890s. It was thought that the levees blocked tidal flows into wetlands, reduced tidal prism and promoted accumulation of sediments in navigation channels (Swickard 1899; Roberts 1992). The tidal prism is the volume of water that is exchanged within the estuary between high and low tides. The exchange of tide water scours sediment and transports it to the sea which helps maintain depths of estuarine channels. After an appeal, the court agreed that the construction of levees and the ensuing reduction of the tidal prism were responsible for the filling of the channels.

However, no actions were taken to restore the tidal prism. Instead, additional levees were built to confine the north slough channels and other areas. Consequently, the Salt River channel continued to fill with sediments, which eventually stopped navigation to Port Kenyon. Today it is generally accepted that the natural morphology and function of the Eel River estuary has been altered by the presence of levees, tide gates, and the associated decrease of tidal prism (SCS 1993).

In addition to the tidal prism, estuarine channels are also scoured by the surge of winter storm flows during outgoing tides. The combination of outgoing tides and large river flows is a major force in estuarine channel maintenance. Inspection of aerial photographs show the channel has remained in a similar configuration since the 1964 flood event, which shifted the main channel flow from the south to the north side of Cock Robin Island. The flood delivered large volumes of sediments that accumulated in the main estuary channel filling deep pools and raised channel bed elevations. Significant changes in channel depths occurred in the four to five miles of main river below Fernbridge to Cock Robin Island. In this section of the river channel established deep pools, such as Singley Pool, and others once used by salmon and their anglers, filled in from the accumulated sediments. The flood events of 1955 and 1964 also eroded large amounts of shoreline and widened the estuary main channel (Van Kirk 1996).

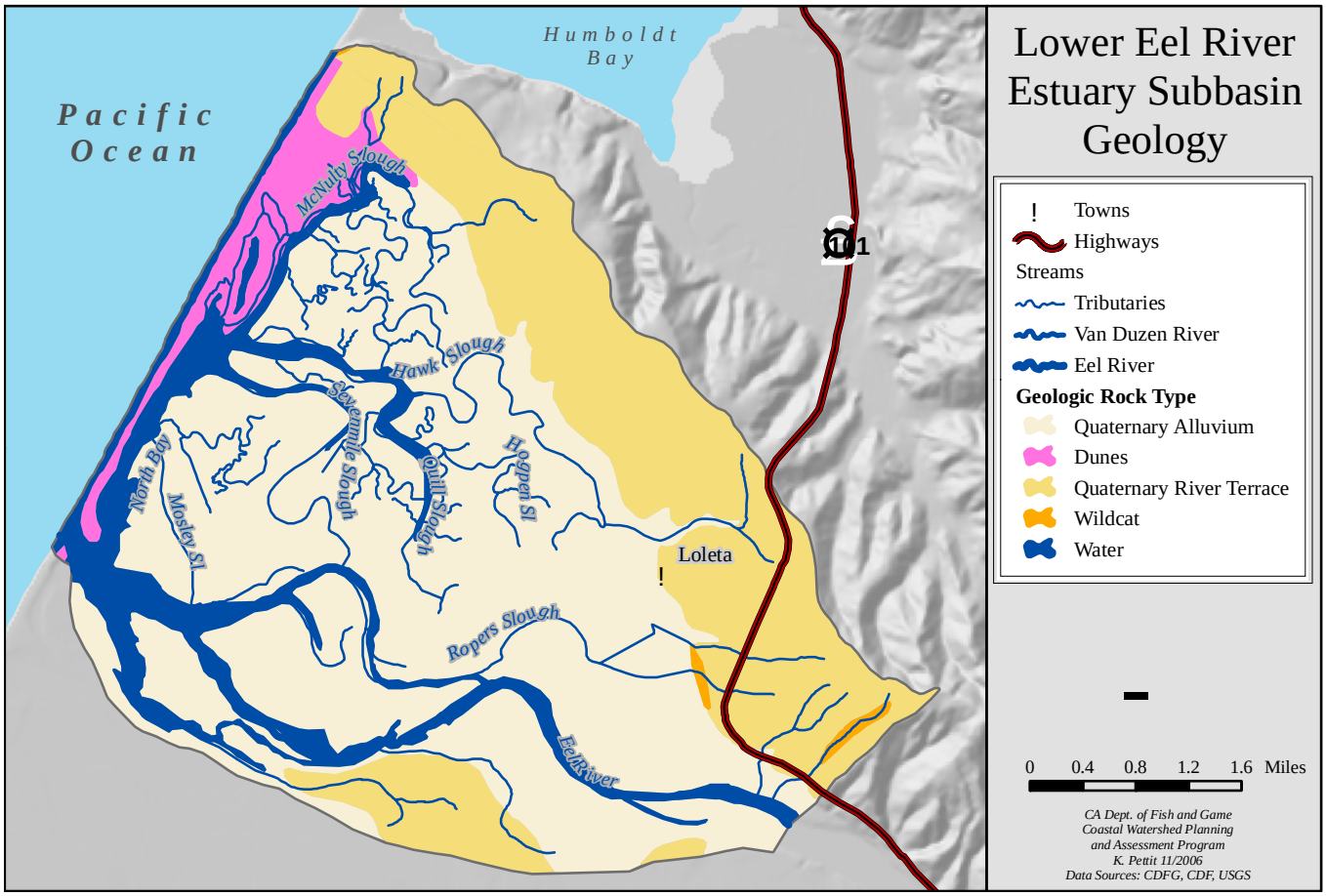

Figure 3. Geology of the Estuary Subbasin..

It has been over forty years since the 1964 flood and the channel still lacks the deep pools that once existed. This suggests that excessive sediments are still transported into the estuary from upstream sources. In contrast to the main channel, depths in the North Bay were similar to bathymetry maps produced in the 1800s. In 1994, maximum depths in the North Bay were from 10 to 14 feet deep during a moderated high tide (Cannata, 1995). The depths of the North Bay likely fluctuate with dynamic annual changes in estuarine morphology including the location of the river mouth.

The location of the estuary mouth has migrated north and south along the sand spit over recent years. The mouth location affects drainage dynamics, sediment deposition and wave action within the estuary. Movement of the mouth is likely related to variations of longshore transport of sands from ocean currents, but also related to debris accumulations, tides, and flood flows. During the 1990s, the river mouth migrated along the sand spit approximately 1.5 miles to the north (across from Sevenmile Slough) and 0.3 mile to the south of Crab Park. After the New Year's flood of 1997 and during the summer of 1997, McNulty Slough and Hawk Slough channels were isolated from the North Bay by a dry sand bar that formed between the two water bodies. At that time the Eel River channel flowed slightly to the north of Crab Park and the sloughs formed a separate channel to the sea nearly two miles to the north. The intervening sand bar formation was associated with large amounts of wood debris that accumulated in the area during the years winter storms.

The location of the mouth also affects how the lower delta drains during winter floods and where wave action will strike the shore. Observations indicate that flood waters drain slower from the southern estuary area if the mouth is located in its northern extent compared to when the river flows to sea across from Crab Park (Bruce Slocum, personnel communication). When the main river channel flows into the northern estuary area, flood flows must bend around Crab Park to reach the mouth located to the north, increasing the distance and time for flood flows to reach the sea. The location of the mouth also directs ocean waves that enter and strike the estuarine shoreline. This wave energy can cause significant erosion of loosely consolidated or sandy shorelines that do not have protection provided by woody debris, riparian or salt marsh vegetation.

Vegetation

Prior to Euro-American settlements, vegetation surrounding the estuary included redwood, spruce, fir and hardwood forests, native grass, and salt marsh plants (Roberts 1992). Most of the original forest stands were cleared and converted to farm lands and livestock grazing pastures by early settlers. A comparison of maps made in 1855 and 2005 show large expanses of wetland and salt marsh vegetation have also been converted to pasture (Figure 4). Approximately 10 percent of the original salt marsh remains today representing a change from 5,740 acres of salt marsh in 1855 to 560 acres in 2005. This does not include changes in the Salt River Subbasin, which shows a similar decline of wetlands.

Based on estimates provided by the USFS CALVEG classification scheme, 55 percent of the land in the Estuary Subbasin is now agricultural vegetation (mostly grass pastures) (Figure 4, Table 2). Approximately 23 percent of the area is composed of herbaceous vegetation, which is mostly composed (~74%) of grass pastures. Together herbaceous grass lands and agricultural land comprise over 70 percent of the Estuary Subbasin. The remaining portion of the herbaceous vegetation is salt marsh vegetation which covers approximately 6 percent of the subbasin.

Cottonwood, alder, and willow form a narrow belt of riparian trees that line much of the main river banks. The riparian belt once extended much further landward forming large forest stands. The largest remaining old growth riparian forest survives between the main channel and Roper's Slough (B. Slocomb personnel communication). The original stands of redwood, spruce, and Douglas fir, are now nearly absent.

At least two exotic and invasive plants, dense-flowered cordgrass (*Spartina densiflora)* and dwarf eelgrass (*Marina japonica*) have been introduced to the Eel River estuary. The cordgrass has spread across much of the estuarine wetlands. It tends to displace native marsh species, can exacerbate sediment accumulations in wetlands, and may cause other undesirable changes to the estuarine ecosystem. Taylor and Hastings (2004) state that plants growing at low densities are able to spread vegetatively rapidly. To control the spread of cordgrass they recommend removal of low density subpopulations over high density subpopulations. Eradication projects have had success in clearing areas of invasive cordgrass around Humboldt Bay with gas powered weed eaters. No efforts have been planned to control *S. densiflora* in the Eel estuary.

Dwarf eelgrass was first observed in May 2008 in McNulty Slough (S. Schlosser, Calif. Sea Grant). Dwarf eelgrass may grow quickly on intertidal mudflat areas, some of which were previously free from any form of vegetation. Once established it binds and accumulates sediments at a higher rate than native eelgrass. This may dramatically alter the natural habitat and change the types and numbers of animal species living in the mud. The settlement of dwarf eelgrass can also change the feeding area and food content for many shorebirds and waterfowl. In addition, the sediment accumulation resulting from the growth of dwarf eelgrass on mudflats could allow the invasive dense-flowered cordgrass (S. densiflora) to colonize additional habitat. This is of concern because the invasive cordgrass can decrease bay and estuary fringes, mudflats, and important feeding areas for waterfowl and shorebirds (Kirsten Ramey CDFG personal communication).

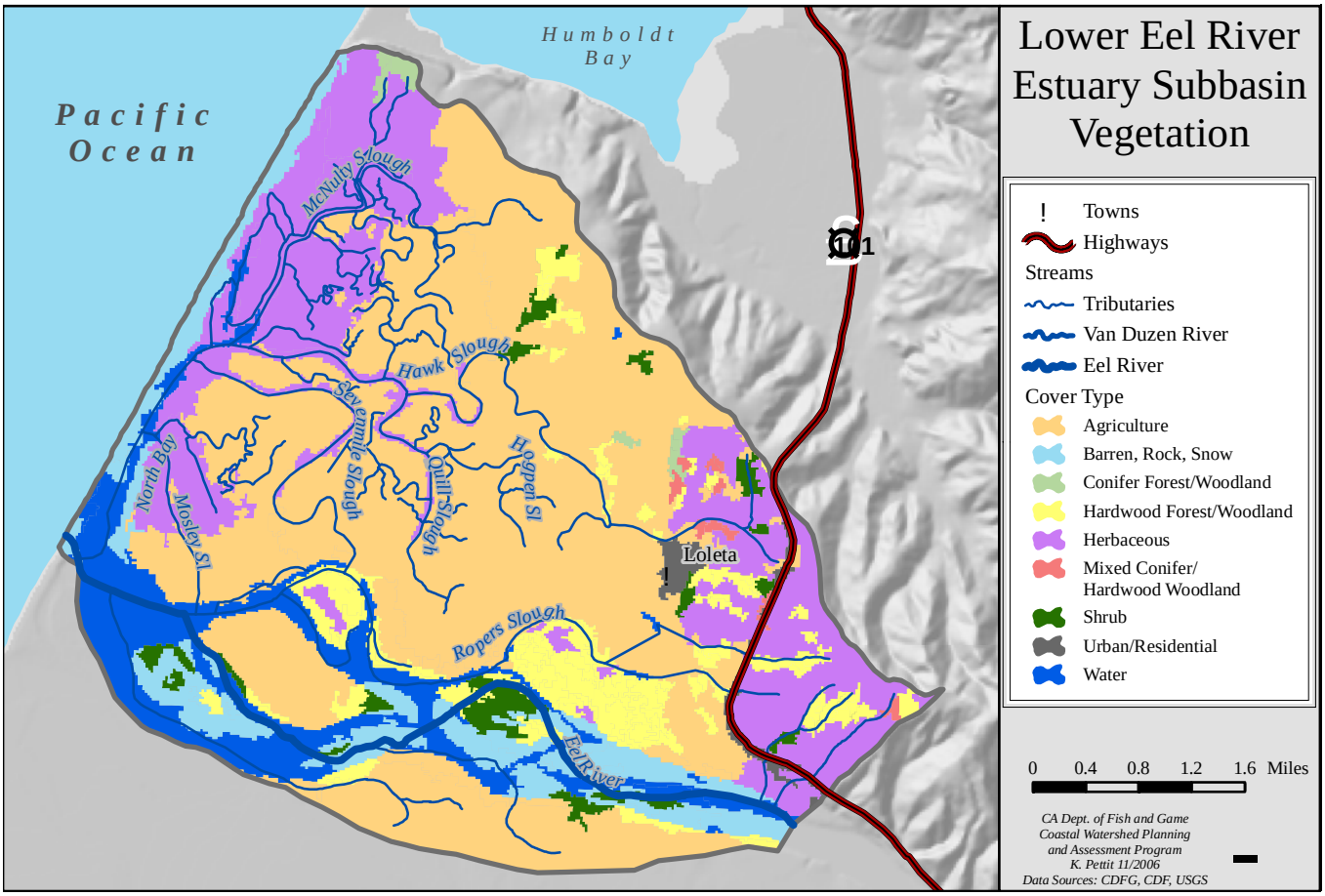

Figure 4. Vegetation of the Estuary Subbasin

Table 2. Vegetation of the Estuary Subbasin. These statistics exclude the classification of water. Data from CALVEG, USFS

Vegetative Cover Type	Percent of Subbasin	Primary Vegetation Type	Percent of Cover Type
Agriculture	55	Agriculture	100
Herbaceous	23	Annual Grass/Forb alliance	74
		Pickleweed – Cordgrass Alliance	25
		Tule/Cattail Alliance	<0.1
Barren	9	Barren	71
		Dunes	29
Hardwood	9	Red Alder Alliance	43
		Mixed Riparian Hardwoods Alliance	20
		Willow Alliance	20
		Black Cottonwood Alliance	16
		Eucalyptus Alliance	1
Shrub	2	Willow (Riparian Scrub) Alliance	100
Urban	1	Urban	100
Conifer	1	Sitka Spruce Alliance	100
Mixed (conifer stand with hardwood)	<1	Sitka spruce Alliance	100

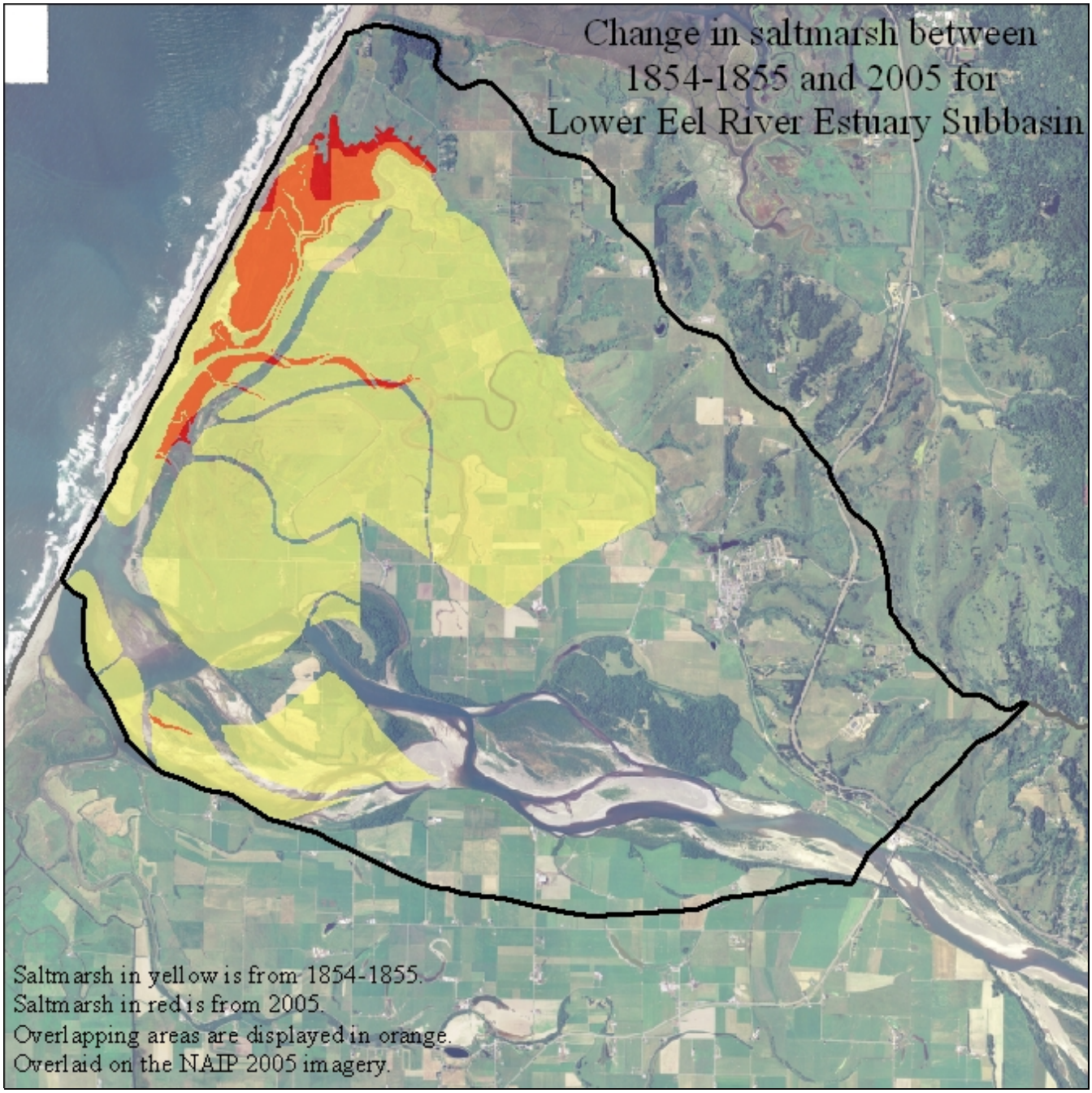

Figure 5. Change in saltmarsh habitats from 1854 to 2005

Land Use

Native Americans

In the 1850s, there were approximately 1500 to 2000 Wiyot people living around Humboldt Bay and the Eel River estuary. The abundant fishery resources including salmon, and plant foods available along the coast were sufficient to provide a local food supply for the Wiyot. When Euro-Americans began to settle and develop coastal areas of Humboldt County, the Wiyot way of life was changed. Many Eureka area settlers thought the only way to remedy the differences between cultures was to drive the Wiyot off their traditional lands, effectively forcing them to abandon traditional hunting, fishing and gathering methods and onto reservations in or outside of Humboldt County. The February 25, 1860, early morning massacre of Wiyot people on Indian Island combined with simultaneous raids on villages on the Eel River and the south spit of Humboldt Bay killed a large portion of the Wiyot Tribe. By 1910 only 100 Wiyot people remained within Wiyot territory (Van Kirk 1996, Wiyot website: http://www.wiyot.com/_history.htm). Today, there are approximately 150 Wiyot people residing in the Table Bluff Reservation and there are over 300 Wiyot people enrolled with the tribe who reside elsewhere (Wiyot website).

Agriculture, Pastures, and Dairies

Many early settlers in the Eel River delta built farms on the area's fertile soil. Among those were Seth and Stephen Shaw and Willard Allen who settled in Loleta in 1851. Loleta was originally called Swauger's Station; its current name is Indian-derived, meaning "pleasant place at the end of the water" (Loleta Chamber of Commerce 2006). The Shaw brothers soon crossed the Eel River to settle in Ferndale (Parry 1963). Ferndale received its name from the luxuriant growth of ferns that stood in the prairie country on the Shaw farm. It was noted that while "riding on horseback, the ferns reached such a height that at times it was impossible to see your way out" (Van Kirk 1996). Initially potatoes and other row crops were cultivated in areas around Loleta, and Ferndale. Wheat and oats were also crops grown in the lower regions of Table Bluff (Parry 1963).

Soon, the fertile soils of the delta were found to produce grasses excellent for livestock grazing. By the 1870s, coincident with a decline in potato prices, grazing of cattle for dairy farming became the major land use within the area, giving Ferndale its first nickname of "Cream City." By the end of 1917, there was one cow for every 1.5 acres of cultivated land (Parry 1963). Many creameries that started up as individual farms consolidated into the Diamond Springs Creamery between 1884 and 1917. Later the Diamond Springs Creamery became the Loleta Creamery. Then in the late 1980s, the Humboldt Creamery Association purchased Loleta's creamery. Most of the land in the Estuary Subbasin is still used for production of dairy and beef products. The rich delta grasslands continue to produce high quality beef and dairy products that are economically important to the area. Some row crops are still planted and pasture grasses are bailed for winter feed, but grazing dairy and beef cattle remains the most common use of land.

In order to convert the delta's forest and marsh lands to farm and grazing land, much of the Estuary Subbasin's riparian and forested/scattered trees were cleared and miles of levees were built to contain slough channels. Although much of the lower delta was originally designated as Salt marsh tidelands by 1885 (Figure 6) and was not eligible for claiming for homesteads, work was done to develop and claim these lands. The salt marsh tideland designation was somehow changed to overflow lands, which led to further development of the salt marsh. By 1870, most of the arable land had been claimed and cleared (nearly 12,000 acres). While most of the salt marsh area near Table Bluff had been claimed, it was not until 1889 that these areas began to be drained (Van Kirk 1986).

Changes to Estuarine Habitat from Land Use

The large scale conversion of tidal marshes to pastures did not come without a cost. The construction of levees and tide gates to drain salt marsh changed drainage patterns, reduced tidal prism and decreased habitat and food supply for fish and wildlife throughout the estuary. The reduction of tidal prism allowed the estuary channels to accumulate sediments, which added to flooding problems (Williams 1988). Swickard (1899) estimated a reduction of tidal prism of about 877,000 cubic yards (about 543 acre feet) that was caused by damming the southern salt marshes by early settlers to the area. Roberts (1992): states "It is my impression that the area of salt marsh north of the river was larger than the area addressed by Swickard, and the diking which occurred east of McNulty Slough probably reduced the tidal prism even more than did the actions addressed in Swickard's deposition". Recommendations for delta improvements in Roberts (1992) focus strongly on

increasing the tidal prism and include levee removal as the best option to obtain this objective. Roberts (1992) states the best candidate sites for levee removal include both sides of McNulty Slough and its tributaries, and the land west of McNulty slough. Roberts also recommends further restorations to extend in the northwestern delta should be expanded rapidly outward from earlier project sites.

In addition, many of the dairies experienced problems with waste management and non-point source pollution to the estuary channels and delta grounds water. Waste often flowed into low lying areas, and former slough channels. During times of heavy precipitation, these sloughs often became active transporting waste into the estuarine wetlands. The Humboldt County Resource Conservation District (HCRCD) established a program to assist local dairy farmers to manage dairy waste. The HCRCD program helped dairies to increase the size of constructed liquid waste lagoons and helped develop systems to deliver manure to fields, and help manage overflow problems due to floods.

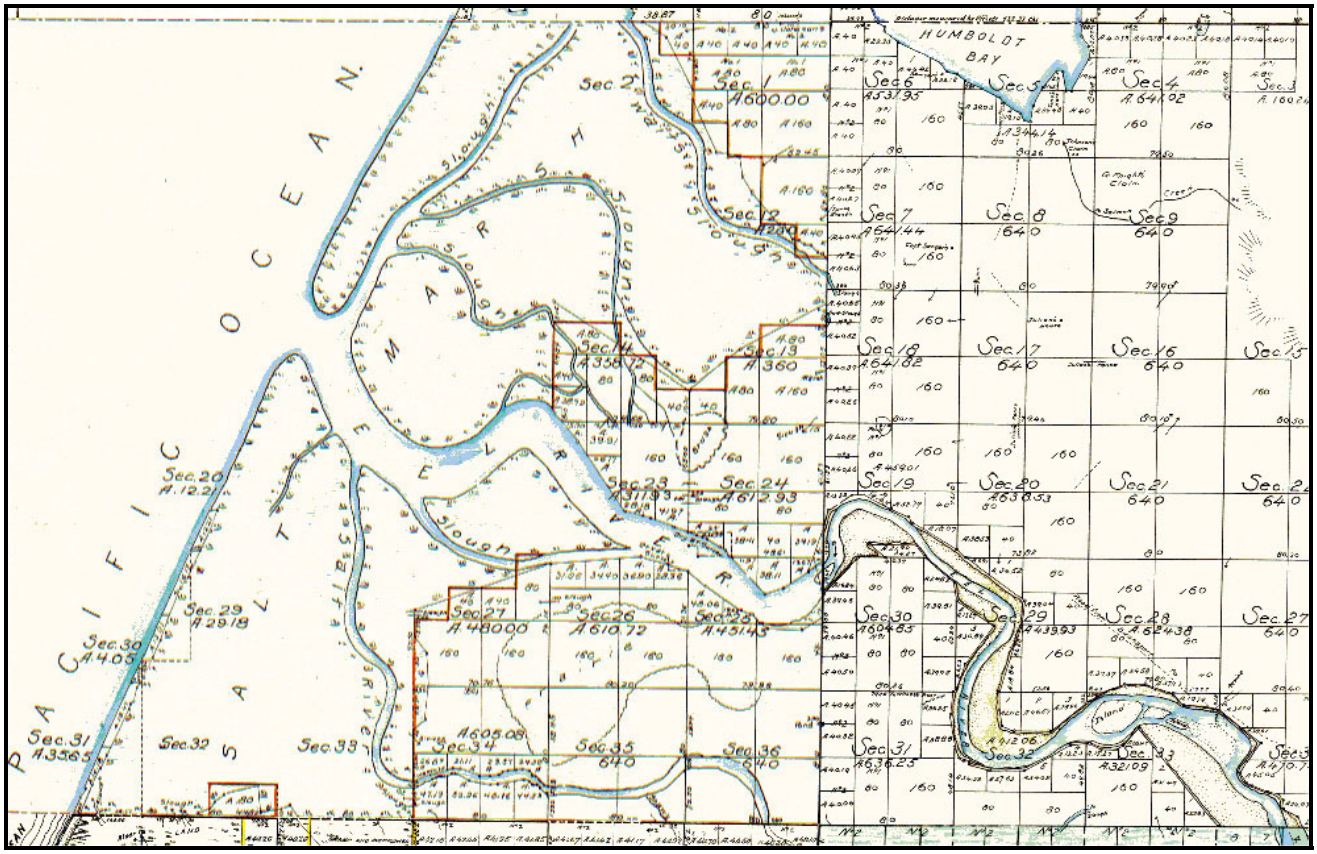

Figure 6. Eel River estuary 1884 map showing salt marsh designation and sections of converted wetlands and forest lands

Navigation and Shipping

The Eel River was first considered navigable by the General Morgan party in 1850. Later that year, the estuary was first entered from the sea when the schooner Ryerson mistakenly crossed the Eel River bar while searching for the entrance to either the Klamath River or Humboldt Bay (Van Kirk 1996). Over the following years, several trips into the river were made by various ships carrying supplies to and exporting goods from Eel River Delta settlements. The ships sailed from the estuary into the tidal Salt River where they found safe harbor at Port Kenyon. The trade prompted the formation of the Eel River Navigation Company in October, 1865 (Van Kirk 1996). Although the entrance to the Eel River was shallow and at times impassable, Port Kenyon soon became an important port for the shipping of crops, dairy products, cattle and salmon to San Francisco.

In 1878 the steamer Thomas Whitelaw was built to make regular runs between the Eel River and San Francisco carrying mail, passengers and cargo (Van Kirk 1996). Later, other vessels made Port Kenyon and Ferndale a regular port of call, but the entrance to the Eel River proved hazardous to navigation as ships occasionally ran aground or were stranded on the sand bar across the river mouth (Van Kirk 1996). The passage into the river was eventually judged too risky

for ships and Humboldt Bay soon became the only harbor in the county.

Commercial Fishing in the Estuary 1853-1922

Commercial fishing for salmon and steelhead began in the Eel River estuary by 1853 and continued until 1921. Over the years, the fishery involved several hundred fishermen, salt packing facilities, smoke houses, canneries, fresh fish merchants, shipping and a fish hatchery. Based on the reported catches annual Chinook salmon harvests ranged from approximately 20,000 in the early years of the fishery to near 150,000 caught in 1904. Harvests of up to 500,000 pounds of steelhead and near 400,000 pounds of coho per year also were reported. (U.S. Commision of Fish and Fisheries1887; Wilcox 1896; Cobb 1930). The commercial fishery closed in the estuary in 1921 (Bureau of Commercial Fisheries 1928; Parry 1959, Van Kirk 1996). A more detailed review of the commercial fishery is presented in the Fishery Resource section of this report (pp. 23-31).

Eel River Wildlife Areas

In the mid to latter 1800s wildlife was noted as abundant in the Eel River Delta (Van Kirk 1996). At that time grizzly bears and elk roamed the delta area. More recently, Monroe et al. (1974) noted that over 40 species of mammals and 200 species of birds use the delta area. Several bird species and most mammals are residents, while large numbers of migratory birds depended on the area for seasonal feeding and resting grounds, including shore birds, wading birds, tundra swans, ducks, and raptors. Nesting areas exists for cormorants, egrets, herons and numerous additional bird species in sparse clumps of riparian forests located along the estuary channel. Federal and state protected species including bald eagles, peregrine falcons and snowy plover find refuge in the estuary area. Aleutian geese, a species that has recovered from near extinction, utilize the area's grasslands for feeding.

The California Department of Fish and Game manages wildlife areas to allow for public use while maintaining wildlife populations and habitat. The Eel River Wildlife Areas consist of the Table Bluff Ecological Preserve and the Ocean Ranch, Cannibal Island, and Cock Robin Island management units. These areas are seasonally open to waterfowl hunting, and open year round for fishing, hiking and other opportunities for public use.

Water Quality

Effects from Land Use Upstream

The water quality and sediment supply of the estuary are linked to watershed characteristics and events that occur in the 3700 square mile Eel River Basin. One of the most significant events affecting the estuary was the December rain on snow event which caused the flood of 1964. At that time, approximately one – half of the basin's naturally erosive terrain was disrupted by clear cut tractor logging. Hill slopes and soils were destabilized by the removal of trees, construction of roads and tractor skid trails. During the rain on snow storm event, the disrupted hill slopes eroded and added enormous amounts of sediments to the stream network. Much of the huge sediment load was transported by storm flows to the estuary. By the end of the 1965 rainy season, the deep pools of the lower river and estuarine channel that once held large runs of salmon were filled with sediments (Fisk et al. 1966). After many years pools and structural features have re-established, but not to pre-flood conditions. The procession of natural restoration of channel bed features to the pre-flood condition is impeded by localized erosion and delivery of excessive amounts of sediments generated by past and present land (USEPA 2007).

Salinity and Temperature

Primary factors affecting fish distribution within the estuary are salinity and water temperature. These water quality parameters are influenced by complex relationships between seasonal changes in freshwater flows, ocean tides, channel morphology, land use, and coastal fog climate. In general, the main channel (Eel River) has three zones: 1) freshwater, 2) brackish water or mixing zone; and 3) a marine (sea water) zone. The extent of these zones is controlled by the seasonal mixing patterns of river and tidal flows. The mixing of these distinct water masses affects water temperature, salinity, and fish distribution.

Salinity in the estuary is strongly related to the changes in seasonal discharge of river flows and daily high and low tides. Salinty in the estuarine waters ranges from fresh, river flow (salinity < 0.5ppt) to hypersaline, sea water (salinity >35 ppt) (Cannata 1995). Flood flows caused by large winter rain storms can temporally inundate the estuary with freshwater, but after peak flows subside, high tides move a mass or wedge of sea water back into the lower estuary. The mixing of river flows and tidal seawater produces salinity gradients that extend vertically from the

surface to the bottom waters and horizontally upstream from the river mouth. (Figure 5). Thus, the highest salinity is generally found near the mouth and the lowest salinity is found near Fernbridge, approximately 7 miles upstream.

The decrease in river flow during the summer/fall season allows greater influence by marine tides which shifts the conditions in the upper estuary channel from predominantly fresh to include tidally driven brackish water (1-15 ppt.). A high tide of summer/fall can push brackish water in the main river channel upstream of Fernbridge. A salinity measurement of 11 ppt was made near Fernbridge in October, 1994 (Cannata 1995). In the 1800s, tidewater was noted to extend to the confluence with the Van Duzen River (RM 14) (Van Kirk 1996). It is unclear whether the tidewater referred to in 1880's newspapers was freshwater under the influence of tides or brackish water. During the warm summer season, when evaporation rates are high, the sea water can become hyper-saline or saltier that sea water in slough channels where reduced exchange of water occurs between tides.

Like salinity, water temperatures in the Eel River estuary vary depending on the season, location, channel depth, heights of tides and river discharge. Seasonal water temperature can range from ambient sea water (~50-55 F) to ambient river water (~38-75 F) (Puckett 1977 and Cannata 1994-95 field notes). During the winter, the coldest water is usually found on the surface when river flows exposed to cold air flow into the estuary. Conversely, in summer as river flows decline, the coldest water is delivered by ocean tides. Tides push a wedge of cold seawater up the main estuarine channel that mixes with the warmer fresh or brackish water of the middle and upper estuary zones.

In 1996 and 2000 the Humboldt County Resource Conservation District (HCRCD) continuously monitored sites in major slough channels, and the lower mainstem for water temperature in the Eel River estuary. Maximum weekly average temperatures (MWAT's) collected from those sites ranged form 56 to 71°F (Table 4). No locations within the estuary obtained seasonal maxima considered lethal for anadromous salmonids (≥ 75°F). The HCRCD data were collected from a single depth at each location. However, a vertical profile of the water column is most desired when collecting temperature data in an estuary.

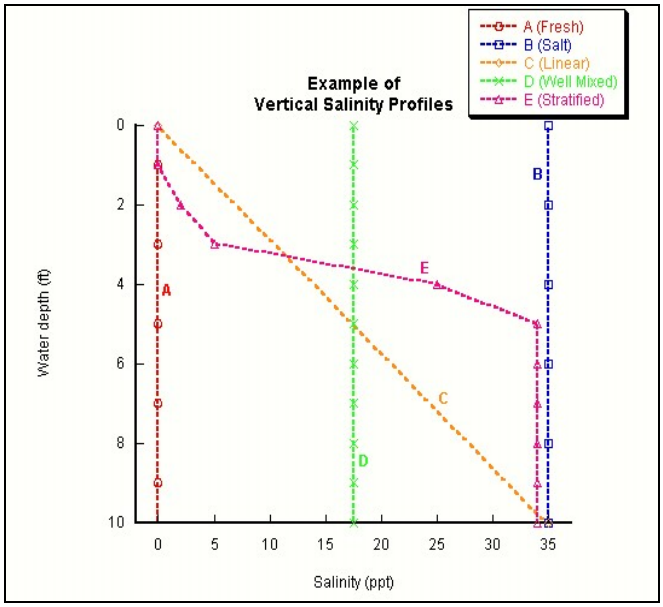

Figure 7. Examples of various sality profiles.

Vertical salinity profiles collected in the estuary 1994-95 show that large differences in salinity can occur between the surface and bottom waters.

Water Chemistry

Nutrients are often limiting factors in the biological capacity of a freshwater stream. However, estuaries are naturally high in nutrients as they receive sources of carbon, nitrogen and phosphates from both fresh and sea water sources. The mixing of fresh and sea water helps to precipitate nutrients and keeps them within the estuary. The abundance of dissolved nutrients fuels primary productivity beginning the food web. Decaying algae and wood in the estuary add to the food and nutrient supply.

An excess of nutrients can degrade water quality by fueling toxic algal blooms that increase biological demand either through respiration or decomposition. Typically, tidal exchange prevents high concentrations of nutrients from causing toxic blooms or eutrophication. However, areas with poor circulation or delivery of high loads of nutrients such as dairy waste or agricultural runoff can become toxic zones. Other sources of nutrients and pollutants are commonly municipal and industrial wastewater facilities, storm runoff, and agricultural operations. Pollutants are a concern where they interfere with the biological function of aquatic organisms, or where they could be a threat to those that consume them. Naturally occurring heavy metals are often found in much smaller concentrations.

The North Coast Regional Water Quality Control Board (NCRWQCB) has set water quality objectives for the following parameters in estuaries of the North Coast: Dissolved Oxygen (above 5.0 mg/L 100% of

the time);Fecal Coliform (no more than 10% of samples in a 30 day period should exceed 400 per 100mL); pH: between 6.5 and 8.5 (NCRWQCB 2006d).

The Wiyot Tribe has sampled water quality in McNulty Slough since December 2004 (Figure 9 and Figure 10). The sampling location is at the seaward side of the tide-gate located just south of McNulty Lane, adjacent to the old Wiyot Rancheria. The site is sampled for physical parameters every two weeks during mid and high tides; a water quality sonde device is deployed for approximately ten minutes and samples for 3-5 minutes at four-second intervals. Additionally, chemical sampling is performed quarterly.

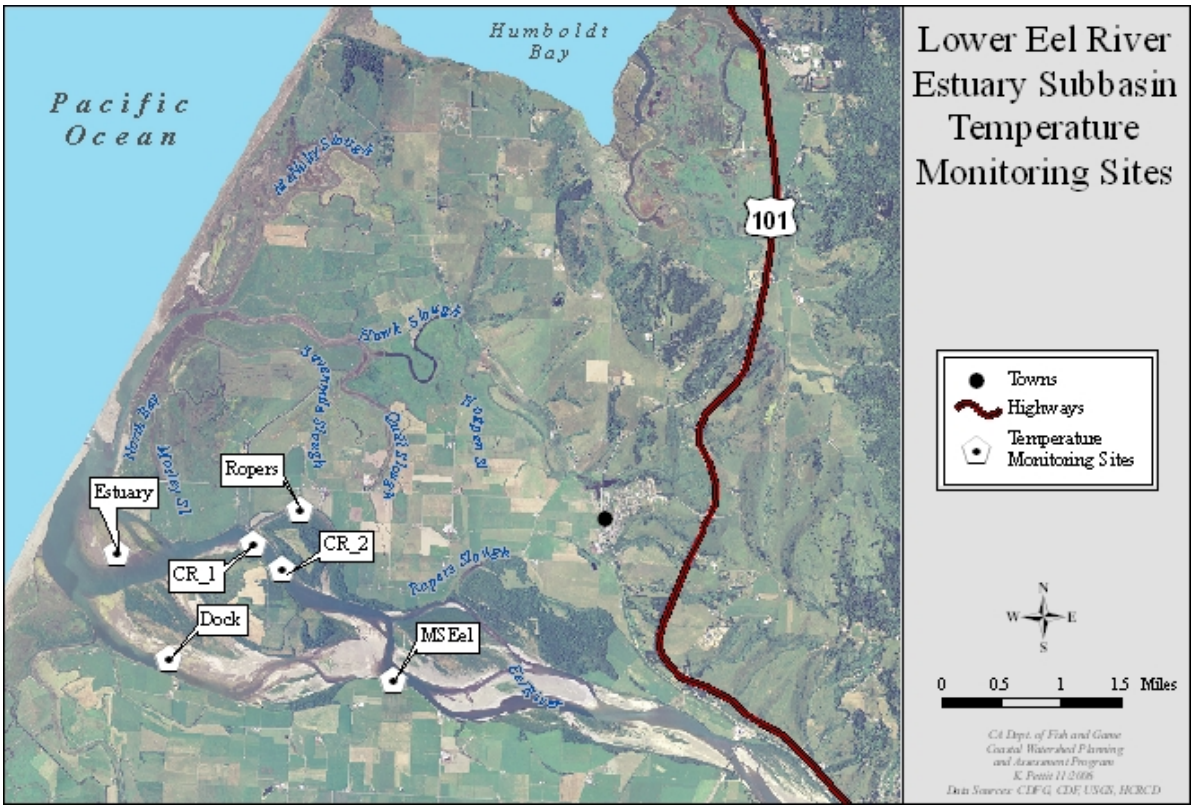

Figure 8. Locations of temperature monitoring sites in the Estuary Subbasin.

Table 3. Maximum weekly average temperatures and maximum daily average temperatures collected in the Estuary Subbasin. See map above for temperature site.

Site	MWAT (°F)	Max Daily Average (°F)	Years of Data
1552_1	56	57	1
1552_2	56	57	1
Est	57	58	1
Dock	59	60	1
CR_2	62	62	1
Ropers	62	63	1
CR_1	68	69	1
MSEel	71	72	1

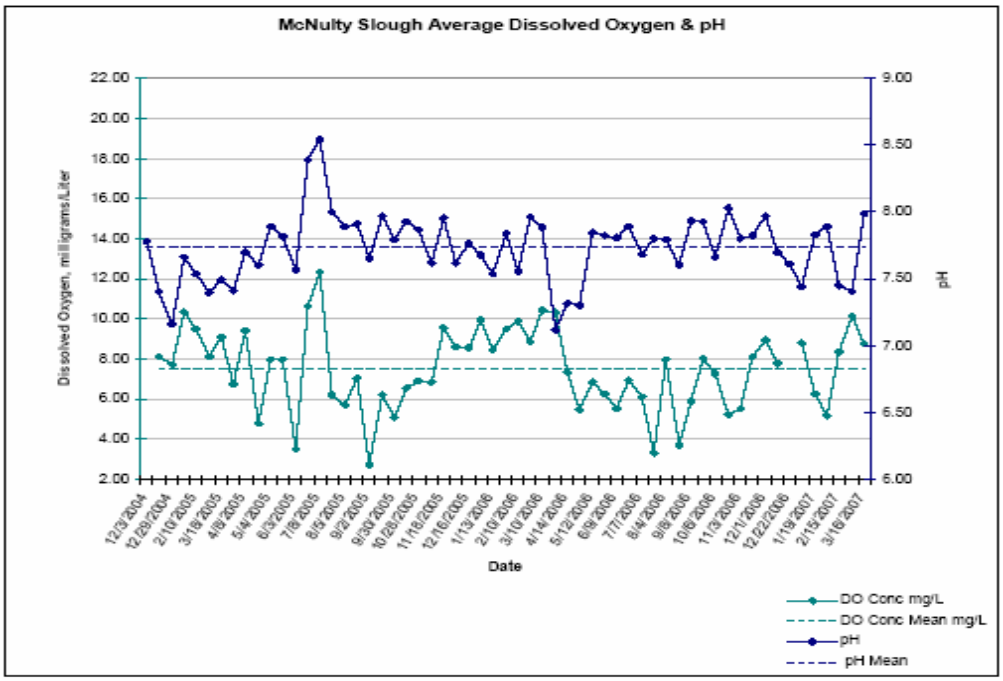

Figure 9. McNulty Slough dissolved oxygen and pH results from 2004-2007, Wiyot Tribe 2007.

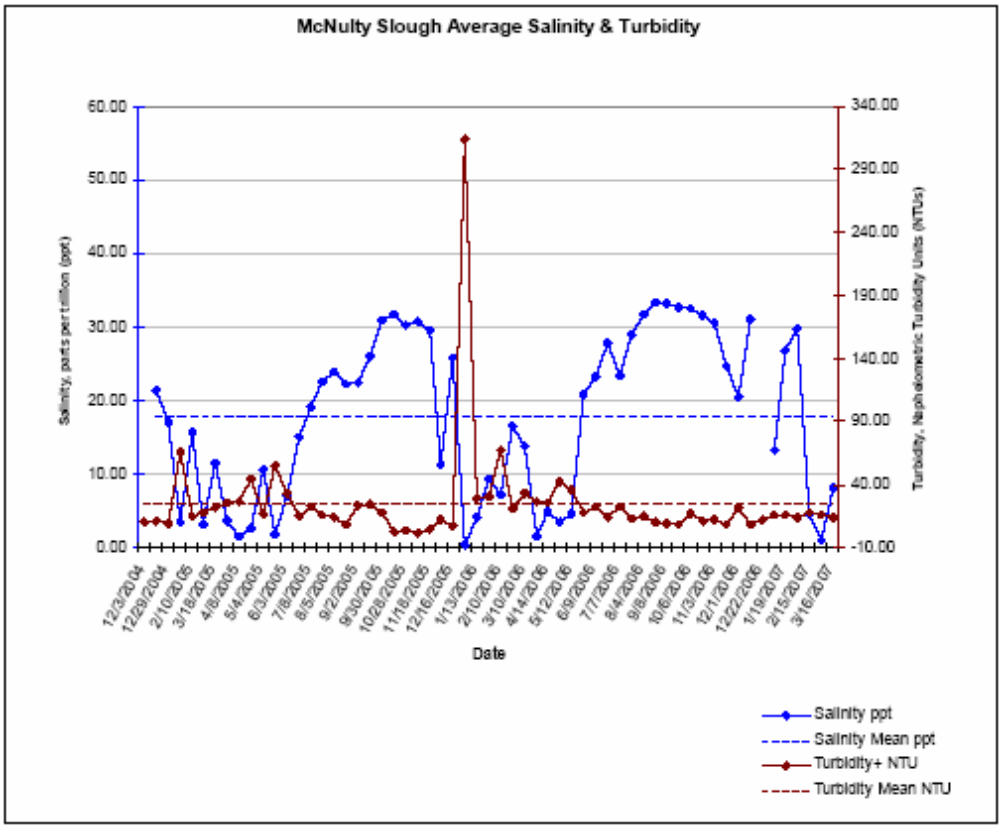

Figure 10. McNulty Slough salinity and turbidity results from 2004-2007, Wiyot Tribe 2007.

Table 4. Chemical testing in McNulty Slough 2005-2006, Wiyot Tribe 2007.

		Sample Medium			Sample Analysis Results											
					Coliform							TPHCs				
Sample Site	Date	Water Column	Sediment	Tissue	Total (Coliform/100m	Fecal (Coliform/100m	Total Nitrogen (mg/L)	Total Phosphorus (mg/	TSS (mg/L)	Dioxin	PCBs	Gasoline (ug/L)	Diesel (ug/L)	Oil (ug/L)	Priority Metals	SVOCs (ug/L)
McNulty Slough	5/4/2005	X			300	50	1.2	0.12				ND	ND	ND	ND	
McNulty Slough	8/19/2005	X			300	60	1.3					ND	ND	ND	ND	
McNulty Slough	12/2/2005	X			≥1500	1600	ND	0.087				ND	ND	ND	ND	
McNulty Slough	3/17/2006	X			≥1500	900	1.4	ND				ND	ND	ND	ND	
McNulty Slough	7/20/2006	X			50	17	ND	0.022				ND	ND	ND	ND	
McNulty Slough	11/3/2006	X			170	110	ND	0.18	16			ND	ND	ND	ND	

PCBs	Poly Chlorinated Biphenols	TPHCs	Total Petroleum Hydrocarbons
SVOCs	Semi Volatile Organic Compounds	TSS	Total Suspended Solids

ND = Not Detected

Dissolved oxygen levels in McNulty Slough fell below 5.0mg/L three times in 2005 and twice in 2006. The levels recorded for pH were within the range deemed suitable by the Water Board except for one occasion in July 2005, where pH was recorded above 8.5. Turbidity remained either below or slightly above 30 ntu for most of the study period. In January 2006, turbidity levels jumped from near 20 ntu to 320 ntu in two weeks, later to fall back to 30 ntu in another two weeks (Wiyot Tribe 2007).

The Wiyot Tribe has also conducted quarterly fecal coliform and chemical testing at the McNulty Slough site for the past two years (Table 4). Fecal coliform was low for most of the sample dates; however, coliform levels greatly exceeded the Water Board's recommendation of 400/100mL in December 2005 and March 2006.

There were no hydrocarbons or priority metals (antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, or zinc) detected in the water column at the McNulty Slough site (Wiyot Tribe 2007).

The Eel River Delta Animal Waste Project was funded to improve farm waste management practices at participating dairies. Two sites in the Estuary Subbasin were sampled during this project: Peterson Ditch at Copenhagen Road (PD) and a tributary to Quill Slough, south of Cannibal Island Road (QS). Temperature, pH, conductivity, salinity, and dissolved oxygen measurements were collected twice before improvements were made to nearby dairies; the results are presented in Table 6.

Dissolved oxygen levels are barely above the Water Board targets of 5.0 mg/L for saline waters at the tributary to Quill Slough (QS) in 1998 and 2000. Sampling was conducted again after animal waste management improvements had been made but there was not enough flow to test water quality (Ziemer and Anderson 2001).

Table 5. Water chemistry results in the Estuary Subbasin (Ziemer and Anderson 2001).

Site	Date	Time	pH	Conductivity	Salinity (ppt)	Dis. O2 (mg/L)
Tributary to Quill Slough	10-1-1998	11:00	8	379 µS	.01	5.0
Tributary to Quill Slough	2-9-2000	10:00	7.8	297 µS	.01	5.2
Peterson Ditch	3-2-1996	17:00	7.8	11.58 mS	0.7	9.0
Peterson Ditch	3-28-1996	09:25	-	-	11.2	8.0

Wastewater Treatment Facilities

The Estuary Subbasin contains two wastewater treatment facilities that discharge into the Eel River Basin: the Loleta municipal wastewater treatment facility and the Humboldt Creamery, located at Fernbridge. A third facility, the Ferndale wastewater treatment facility, is located in the Salt River Subbasin and discharges into the Salt River about three miles upstream form the confluence with Eel River. As of 2008 all of these facilities are being reviewed as part of the permit renewal process.

In addition to municipal wastewater, the Loleta wastewater treatment facility accepts wastewater from both the Humboldt Creamery facility located in Loleta and the Loleta Cheese Factory; both are considered "high strength" waste. The facility is designed to process 100,000 gallons per day (gpd), and ranges from 56,000gpd to 522,000gpd over the year (NCRWQCB 2004b). The facility currently discharges year-round into an oxbow, essentially a wetland, of the Eel River. During the winter, these percolation/evaporation ponds overflow into the Eel River. The new permit mentioned above will address alternatives to discharging into this wetland, such as pasture irrigation during the summer and upgrading the facility or piping effluent to the Eel River during winter months. A Cease and Desist order was issued in 2004 for facility operations compliance, which was later resolved and rescinded.

Currently, Humboldt Creamery discharges between 63,000 and 160,000 gallons per day (gpd) of "non-contact condensate" to the Eel River. This is a very low volume discharge of basically clean, drinking quality water that is regulated because it is warmer than the Eel River (NCRWQCB, 2002, L. Bernard NCRWQCB, personal communication). Temperature is monitored in Eel River to a depth of 10 feet and no adverse conditions have been detected thus far. Wastewater that contains milk solids from the cleaning of equipment is used for irrigation on a nearby agricultural pasture (249,000gpd – 450,000gpd). Investigation into the impacts to groundwater will be conducted during the re-permitting process (L. Bernard, NCRWQCB, personal communication).

Fish and Habitat Relationships

Estuarine Habitats

The estuary can be divided into four zones based on channel characteristics and mixing regimes of tidal marine water with freshwater river flows: (1) a marine dominated lower estuary zone (North Bay) that extends from the river mouth upstream to near Cock Robin Island bridge; (2) North Slough channels and associated salt marsh. These include McNulty, Hawk, Sevenmile and other slough channels located to the north of the mains river channel; (3) a middle estuary zone, subject to strong salt and fresh water mixing. This includes the channel from Cock Robin Island bridge upstream to where Fulmor Road dead ends near the main channel; and (4) an upper estuary zone that is more riverine and characterized by fresh water and/or brackish water into the summer, but subject to daily tidal action. This is the area from approximately one mile above Fulmor Road to just above Fernbridge. The actual limits between these zones are variable, and are subject to seasonal change in the river discharge and daily tidal cycles. The distribution of estuarine fish is largely related to the salinity and water temperature of these zones.

Within these generalized zones occur more specific habitat types including small, meandering slough channels, intertidal mudflats, intertidal sandflats, intertidal gravel/cobble, eel grass beds and emergent marsh. These diverse habitats play important roles in reproduction, feeding, rearing, and for physiologic adaptations for fish that utilize the estuary. A brief description of the estuary's habitat types adapted from Cowardin (1979) and Simenstad and Tanner (1991) are presented below.

Intertidal Mudflats: This habitat type consist of unvegetated, mud substrate shores covered and exposed by high and low tidal cycles. Mudflats are found in the slough channel areas including the Salt River and often occur between vegetated, emergent marsh habitats and subtidal channels. Mudflats can be steepened shores in areas where slough channels are confined by levees.

Intertidal Sandflats: These sandflats are unvegetated, gentle sloped, sand substrate shores covered and exposed by high and low tidal cycles. Sandflats and sandy beaches are found in the North Bay in the vicinity of Crab Park. Sand flats also occur where McNulty slough joins the North Bay and what may be referred to as muddy sands border northern edges of Cock Robin Island.

Intertidal Gravel/Cobble: This habitat can be steep or gently sloped shores covered and exposed by high and low tidal cycles. Gravel and cobble bottoms are found in the more riverine portions of the upper and middle zones of the Eel Estuary including just above the Cock Robin Island Bridge to Fernbridge. Gravel and cobble often provides substrate for growths of macroalgae including Ulva spp. Gravel and Cobble can form large bars in the more riverine areas of the upper estuary zone.

Emergent Marsh: Includes intertidal shores of unconsolidated mud or sand colonized by rooted plants that are periodically inundated with flood and/or tidal water. Emergent marsh is found along the eastern shore of the North Bay, and along banks of the Salt River, and in most of the slough channels throughout the estuary.

Eel Grass Beds: Eel grass (*Zostera pacifica*) is a rooted vascular plant that grows in shallow mud and sand bottoms. Eel grass is found in areas where brackish water or sea water predominates year round. Most of the known eel grass grows in the Salt River and its tributary slough channels, although small patches have been observed in McNulty slough (J. Mello, CDFG, personal communication).

Subtidal Soft Bottom: Includes unconsolidated sand, mud, and gravel/cobble bottoms that remain submerged during tide cycles. Subtidal sand, mud, and gravel/cobble are generally found in the estuary adjacent and the similar intertidal substrate type noted above. Subtidal bottoms in the north slough channels and Salt River often support growths of the macroalgae *Gracilaria* spp. and *Ulva* spp. and rooted aquatic plants such as pond weeds (*Potomageten* spp.)

Water Column: the habitat considered from just off the streambed bottom to the water surface. The water column is directly linked to most other habitat types in the estuary and is a connection between them. Pelagic fish spend most of their time swimming in the water column.

Fishery Resources

The importance of maintaining the diversity and dynamics of aquatic habitats within the Eel River Estuary for anadromous salmonids and other fish and wildlife is well documented (Murphy and Dewitt 1951, Monroe et al. 1974, Puckett 1976, Roberts 1992, Higgins in Roberts 1992, and Hassler and Cannata 1995). Although natural processes of the estuary ecosystem have been altered or impaired by land management, the estuary still provides essential spawning, nursery and feeding grounds to several commercially and recreationally important species. No major port or industrial developments have occurred that pose additional threats to the ecosystem. At least forty-five fish species have been collected from the Eel River estuary (Table 7) and several invertebrates including the commercially important Dungeness crab (*Cancer magister*). Many of these fishery resources depend on the estuary habitats to complete a critical life history stage such a spawning or juvenile rearing. The estuary provides critical habitat for eight fish species listed under the federal and/or state endangered species acts or are state special concern species.

All but five species collected from the estuary are native to the system. The five non-native introductions are the anadromous American shad (*Alosa sapidissima)* and freshwater species: Sacramento pikeminnow (*Ptychochelis grandis)*, California roach (*Hesperoleucas symmetricus*) brown bulhead (*Ameiurus nebulosus*) and green sunfish (*Lepomis cyanellus*). No non-native marine fish species have been collected from the estuary.

Chinook salmon

Chinook salmon are among the most valuable and popular fish that rely on the Eel River estuary for essential habitat. Once abundant, populations estimated at over 500,000 fish historically returned to the Eel River to spawn (NOAA 2002). As a part of their anadromous lifecycle, these fish migrate through or reside in the estuary twice: once as juveniles and again as spawning adults. Present populations are not precisely known, but Eel River Chinook salmon numbers are likely less than five percent of the historic estimate provided by NOAA (2002).

Chinook salmon use the estuary as transitional habitat as they move between sea water and fresh water during upstream and downstream migrations. As adults, the salmon hold in the estuary for weeks or longer until fall or winter rains augment river flows enough to promote passage into upstream spawning grounds. Juveniles acclimate to seawater during seaward migrations and also find nursery area where they feed and grow in the relative safety of the estuary before entering the ocean.

The use of the Eel River estuary by juvenile Chinook was first noted by Murphy and Dewitt (1951). They reported seeing “incredible numbers” of juvenile Chinook in the lower Eel River during late June and July, then the numbers “generally declined as the season progressed”. They captured juvenile Chinook near Fernbridge (RM 7) using beach seines up until August 15 in 1950. They also noted the presence of “large numbers” of juvenile Chinook in the tidewater and at the mouth of the estuary. Subsequent studies detailing juvenile Chinook use of the estuary were Puckett (1977) and Cannata and Hassler (1995). Both of these studies noted that the Eel River estuary is critical habitat for all juvenile salmonid species and that juvenile Chinook were most abundant during June and July. However, the large numbers of Chinook juveniles reported as visible by Murphy and Dewitt (1951) were not observed in the latter studies.

Table 6. Fish species observed from the Eel River Estuary. Observers are also shown.

Species	Murphy and De Witt (1951)	Monroe et al. (1974)	Puckett (1977)	Cannata and Hassler (1995)
ANADROMOUS SPECIES				
Pacific lamprey, *Lampetra tridentata*	x	x	x	x
[1] Green sturgeon, *Acipenser medirostris*	x	x		x
[1,2]White Sturgeon, *Acipenser transmontanus*				
American shad, *Alosa sapidissima*	x	x	x	x
[1]Coastal cutthroat trout, *Oncorhynchus clarkii*	x	x		x
[1]Steelhead, *Oncorhynchus mykiss*	x	x	x	x
[1]Chinook salmon, *Oncorhynchus tshawytscha*	x	x	x	x
[1]Coho salmon, *Oncorhynchus kisutch*	x	x	x	x
Eulachon, *Thaleichthys pacificus*				
[1]Longfin smelt, *Spirinchus thaleichthys*		x	x	x
MARINE or ESTUARINE SPECIES				
Pacific herring, *Clupea harengus*	x	x	x	x
Pacific sardine, *Sardinops sagax*	x	x		x
Northern anchovy, *Engraulis mordax*		x	x	x
Surf smelt, *Hypomesus pretiosis*		x	x	x
Pacific tomcod, *Microgadus proximus*	x	x		
Topsmelt, *Atherinops affinis*	x	x	x	x
Bay pipefish, *Syngnathus leptorhynchus*	x	x	x	x
Kelp greenling, *Hexagrammos decarammus*		x		
Cabezon, *Scorpaenichthys marmoratus*		x	x	x
Pacific staghorn sculpin, *Leptocottus armatus*	x	x	x	x
Coastrange sculpin *Cottus aleuticus*		x	x	x
Prickly sculpin *Cottus asper*		x	x	x
Buffalo sculpin *Enophrys bison*			x	x
Tidepool sculpin *Oligocottus maculosus*				x
Ringtail snailfish, *Liparis rutteri*				x
Threespine stickleback, *Gasterosteus aculeatus*	x	x	x	x
Jack mackerel, *Trachurus symmetricus*				x
Redtail surfperch *Amphistichus rhodoterus*		x	x	x
Walleye surfperch *Hyperprosopon argenteum*			x	x
Shiner surfperch *Cymatogaster aggregate*	x	x	x	x
Silver surfperch *Hyperprosopon ellepticum*				x
Pile surfperch *Rhacochilus vacca*	x	x		

Species	Murphy and De Witt (1951)	Monroe et al. (1974)	Puckett (1977)	Cannata and Hassler (1995)
Saddleback gunnel *Pholis ornata*		x	x	x
Pacific sandlance *Ammodytes hexapterus*			x	
[1,3]Tidewater goby *Eucyclogobius newberryi*				
Bay goby *Lepidogobius lepidus*				x
Sand sole *Psettichthys melanostictus*			x	x
English sole *Parophrys vetulus*			x	x
Starry flounder *Platichthys stellatus*	x	x	x	x
Speckled sanddab *Citharichthys stigmaeus*		x		x
FRESHWATER SPECIES				
California roach *Hesperoleucas symmetricus*		x	x	x
Humboldt sucker *Catostomus occidentalis humboldtiensis*	x	x	x	x
Brown bullhead *Ameiurus nebulosus*	x	x	x	
Sacramento pikeminnow *Ptychochelis grandis*				x
Green sunfish *Lepomis cyanellus*	x			

[1] *threatened or endangered under ESA; CESA orCalifornia special concern species.*
[2] *Observation by Michelle Gilroy CDFG.*
[3] *Observation made by Greg Goldsmith, USFWS*

Puckett (1977) and Cannata and Hassler (1995) research demonstrated that Chinook salmon increased in size in the estuary over spring and summer months (Figure 11). In June 1994, Chinook smolts captured near Fernbridge had an average 85 mm mean fork length (FL). Smolts captured in June from the middle and lower estuary averaged over 100 and 120 mm FL respectively. Size appears to be a factor governing the movement into higher salinity water and their movement to sea. It may also influence their arrival timing to the estuary. Specimens collected from the middle and lower estuary continued to increase in size over the summer. In 1994, the peak abundance of juvenile Chinook catches in the estuary was in July. The peak period of ocean entry occurred by August as catch per unit effort was much lower then compared to earlier months (Figure 12) and no salmon were collected in the upper estuary after mid July. This suggests that the seaward migration from the river to the estuary was complete by mid July, which is consistent with previous downstream migrant studies (Puckett et al. 1968; 1976).

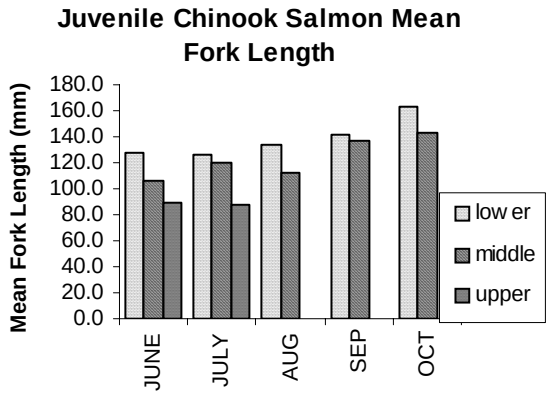

Figure 11. Mean fork lengths of juvenile Chinook salmon captured from lower, middle and upper sampling sites in the Eel River estuary 1994.

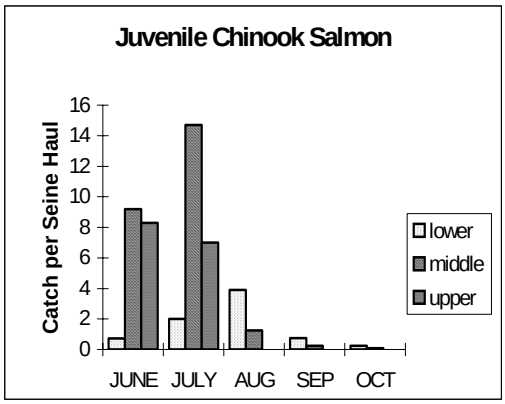

Figure 12. Catch per seine haul of juvenile Chinook salmon from lower, middle and upper estuary sampling sites 1994.

Three criteria have been suggested by Healey (1982) to evaluate the specific importance of estuarine habitats for juvenile salmon: (1) the existence of alternate nursery habitats; (2) the proportion of the population that utilizes alternate habitats opposed to estuarine habitats; and (3) the length of residence in estuarine habitats. By evaluating these criteria, Eel River Chinook strongly depend on the estuarine habitat. Alternate rearing habitat is scarce, as much of the Eel River is thermally lethal to salmonids during the summer and juveniles utilize the estuary for nursery areas for extended periods before entering the ocean phase of their life cycle.

Research has shown that Chinook in Oregon rivers seldom return as adults if they enter the ocean at a size less than 100 millimeters in length (Nicholas and Hankin 1988) and that estuaries often provide the habitat where juveniles obtain the size needed to increase the chances of survival (Riemers 1976, Puckett 1977, Cannata and Hassler 1995).

Coho salmon

Counts made by CDFG 1938-1975 at Benbow Dam on the South Fork Eel River indicate a significant decline in the Eel River coho population size over the last several decades. Counts averaged 10,000 coho per year from 1938-1963 with a peak count of approximately 25,000 coho in 1947 and a low count of 2,120 in 1959. Counts averaged approximately 2,200 from 1964-1975 with a peak of 14,300 in 1963 low count of 509 coho in 1975, which was the last year of counts on record. Considering the significantly reduced size of the coho population and the habitat alterations of the estuary, it is difficult to determine how the estuary historically functioned as coho habitat by studies of present conditions.

During fish studies of the estuary (1973-74 and 1994-95), relatively small numbers of juvenile coho salmon were observed during winter, spring and summer seasons. In 1974, coho were observed most often in the middle and upper estuary zones but were also found in Salt River and North Slough channels (Puckett 1977). During 15 months of fish sampling in 1994-95 Cannata and Hassler observed only five juvenile coho. This small sample may reflect a decline in coho populations in the Eel River Basin compared past years. In December 1994, a single juvenile coho was a captured in December near Crab Park (lower estuary) and 1+coho were captured in February 1995 after a large flood event. These coho appeared to be seeking shelter from high river flows. They were captured in calm areas of the lower estuary near the confluence with Salt River. Presence of juvenile coho in December and February suggests that the estuary provides an important refuge area for coho that may be flushed from tributaries during high winter storm runoff, or Eel River coho naturally move to the estuary during winter months. Coho presence and wide distribution across estuarine habitats also suggests the estuary is a rearing area and an important transition area between freshwater and the marine environment

Studies of other estuaries have shown coho rearing in estuarine habitats for a range of days to months before migrating to sea or moving back into freshwater habitat to over-winter (Tschaplinski 1982, Maahs and Cannata 1998, Cannata 1998, Miller and Sadro 2003 and Wallace 2007). It is unclear how modifications to wetland habitats have altered juvenile coho utilization patterns in the Eel River estuary, but the loss of salt marsh and freshwater ecotones may deny coho use of critical habitat.

Adult coho also depend on the Eel River estuary as staging areas and acclimating between the sea water and fresh water during upstream spawning migrations. Although coho were part of the commercial salmon harvest from the estuary 1850s to 1922, they were not always counted separately in catch records. A review of sport fishing census records (1966 to 1987) shows that adult coho were seldom reported caught by anglers in the Eel River estuary (Day 1966, Lee 1976, McCloud 1986 and Preston 1987). Apparently adult coho moved through the estuary quickly during upstream migrations.

Steelhead

Juvenile and adult steelhead can by found in the Eel River estuary year-round. A review of historic sport fishing and commercial fishing records show peaks of

adult steelhead entering the estuary in winter and spring. These peaks represent the onset of winter and summer run fish respectively. However, records show that adult steelhead were also caught in the fall and summer months. The winter run stock has the largest population in the basin and based on sport fishing records, the summer run fish have shown a decline from historic numbers and they are now rarely caught in the estuary. There is a half-pounder run in mid to late summer that is a popular sport fishery. Half-pounder steelhead range in size from about ten to seventeen inches.

Juvenile steelhead are mostly found in the upper estuary zone during the summer and fall seasons. They seem to prefer the fresh and slightly brackish waters found there. However, juvenile steelhead were found by Puckett (1977) and Cannata (1994-95) in all areas of the estuary over their study periods.

The importance of steelhead estuarine rearing is less studied than for the Chinook and coho. But, studies of the esturaries and/or lagoons of the Gualala, Garcia, Navarro, Mattole, and Eel rivers, Redwood Creek and Humboldt Bay tributaries show that steelhead use these habitats year-round indicating that estuarine rearing is an important life history pattern (Zedonas 1992; Higgins 1995, Ridenhour and Hofstra 1994; Cannata 1998; Anderson 2000, ECORP 2004 and Wallace 2007). Studies of the Navarro River observed accelerated growth rates for steelhead that rear in the estuary/lagoon compared to upstream areas (Cannata 1998 and R.Bush, UCD written communication).

Commercial Fishing in the Estuary 1853-1922 and Price Creek Hatchery 1897-1915

The Early Fishery

The early commercial salmon fishery was started by a few men that organized companies or teams of fishermen. They claimed fishing sites along the lower estuary channel adjacent to a deep pool or deep reach where salmon would congregate. Beach seines of 360 to 480 feet long and 20 to 26 feet deep were used to catch salmon (Wainwright 1965 and Van Kirk 1996). To accommodate a large net, the fishing sites were first cleared of large wood snags, often with the help of local Weott tribesmen. The tribesmen dove deep into the water and attached ropes necessary to haul out the snags (Wainwright 1965). To catch the salmon, beach seines were set into the river, swept through the pool containing fish and hauled ashore by teams of men or with the aid of teams of horses. A Humboldt Times (December 1857) article provides one of the first descriptions of the salmon fishery in the estuary:

"The net spoken of in my last, on Eel River, has actually taken from October l8th to Nov. 5 (in all eighteen days) l6,000 salmon filling 880 barrels of 200 pounds each and the balance of three fisheries on the river have had a fair share of success"

The "three fisheries" referred to in the above article were separate companies with fishing sites along the lower estuary channel. Each company employed 10-14 men. They built barrels for packing salted salmon, cleared the river of snags, and hauled seine nets to capture fish. Barrels holding approximately 200 pounds of fish and half barrels holding 100 pounds of fish were used to ship salmon to San Francisco (Van Kirk 1996). Using the information provided in the 1857 newspaper article, the average weight per fish for those 16,000 salmon packed into barrels was approximately eleven pounds. Salmon packed into barrels were first processed to remove the head, viscera, gills, and prepared for market. Processing removed approximately 30 percent by weight from the round fish (Scofield W. 1926; Z. Grader, PCFFA, personnel communication). The average whole fish was likely near sixteen pounds when caught. A similar article recorded in the November 9, 1861 edition of the Humboldt Times stated that a single seine haul netted 2,600 salmon equal to 140 barrels at 200 pounds each (average dressed weight of ~11 pounds per salmon).

The first reported catches did not note differences between the salmonid species. The catch was likely dominated by Chinook salmon but also may have included some numbers of coho salmon and steelhead. Chinook salmon began to enter the estuary in August, but the fishing season usually began in October when fish were present in sufficient numbers for harvesting. Most of the harvesting was over by the end of November and before the peak runs of coho salmon and steelhead entered the river (Van Kirk 1996).

The first regulated season was from September 15 to November 25, 1859 (Wainwright 1965). However, enforcement of the regulations was difficult. The river conditions and the number of barrels available for packing generally limited the numbers of salmon caught by each fishing company in a season.

In many years, high river flows or floods made it impossible to fish with large nets. Such seasons occurred in 1859 and 1860 when floods came to the estuary at the same time as the main runs of salmon. The bulk of the salmon run passed freely to upstream

spawning grounds escaping the commercial fishery. In January 1862 a flood hit the estuary causing bank erosion, damage to fish houses, smoke houses and property loss including hundreds of barrels of packed salmon that were washed away (Wainwright 1965; Van Kirk 1996). It became evident early on in the fishery that river conditions at the time fish were present would influence annual harvests.

The early commercial fishery brought significant numbers of jobs and revenues to Humboldt County. In 1859, there were seven or eight fishing and packing companies working along the lower six miles of the river (Van Kirk 1996). Over the next 20 years the business of salmon fishing continued to grow, the number of fishermen increased, but the numbers of salmon harvested and prices paid for fish varied considerably (3 to 10 cents per pound for salted fish). Prices and demand also influenced the annual fishing effort and harvests. In 1861 prices dropped to three cents per pound and in 1862 fishing effort on the Eel River was "not extensive" "owing to the decline in prices", (Wainwright 1965). In 1868, Titus F. Cronise wrote in *The Natural Wealth of California. H.H. Bancroft & Co., S.F.*:

"The salmon-fishery at the mouth of this river [Eel] is the most prolific in the State; and the fish are said to have a finer flavor than those caught either to the north or south of this point. The annual catch here, which ranges from eleven hundred to three thousand barrels, might be greatly enlarged were there more of a local consumption or better facilities for shipping the fish to a market".

It is important to note that packing companies referred to in Wainwright's (1965) and Van Kirk's (1996) compilations of newspaper articles were not canneries. The fishing companies caught and packed salmon into barrels. Packing salmon in salt preserved the fish and allowed for shipping to San Francisco and other ports. When ice became available, fresh salmon was shipped from Port Kenyon to San Francisco. Prior to the widespread availability of ice there were times when the catch was so large the fish could not be processed before they spoiled. These likely were not included in catch records. The Weekly Humboldt Times wrote on November 10, 1877, "We learn that the fisheries on Eel River are taking salmon in immense quantities--more and faster than can be taken care of."

The Canneries and the Boom Years

During research for this report, we found reference to only three canneries that operated in the estuary. Dungan and J. B. Requa built the first cannery on the Eel River in 1869. However, no available records estimated the number of fish they packed into cans. The Pacific Coast Packing Company built by the Cutting and Packing Company of San Francisco in 1877 operated until 1889. It was located in Ramseyville on Cock Robin Island. The Port Kenyon salmon processing and cold storage plant, later renamed the Tallant cannery operated from 1906 to 1911 (Parry 1959). There may have been smaller canneries that operated in addition to those mentioned above, but no records were found to document their participation in the fishery. The U.S. Commission of Fish and Fisheries (1887) notes only one cannery on the Eel River for 1877-78. However, Van Kirk (1996) provided this quote from *History of Humboldt County California 1882. Wallace W. Elliot & Co. Publishers:*

"There are four canneries on Eel River, where are annually put up large quantities of salmon in cans. Cutting & Co. have the largest establishment with a capacity of 200 cases per day. In 1880 the number of cases put up amounted to 3,000"

Canneries did not operate continuously during the life of the fishery. There were many years when the fishermen had to sell to other markets. But while in operation, a cannery provided a local market where fishermen could easily sell salmon and get back to the business of fishing. The commercial fishery had changed from limited by the number of barrels on hand for salt packing and the fresh fish market to a nearly unlimited demand of fish for canning purposes (Parry 1959, Van Kirk 1996). Approximately fifty to sixty percent and as much as 70 percent of the annual salmon catch was sold to a cannery if they were buying. The remainder was packed in barrels, smoked, or sold as fresh. In 1887, the Pacific Coast Packing Company Cannery received 266 tons (70%) of the 375 tons (~50,000 fish) reported harvested that year. Those 266 tons yielded 7,500 cases of cans and each case held 48 one-pound cans. The canning process attained approximately 67 percent yield by weight of whole fish. Such a high yield may be attributed to large fish having less waste than smaller fish. Typical salmon canning yields range from 55 to 65 percent depending on fish size. In some years catches were so large that the cannery could not can all of the salmon they received. These surplus supplies were salted and packed in barrels, while some spoiled before they were processed (Van Kirk 1996). It was soon evident, that even with a cannery in place; markets could be saturated with such a large supply of salmon coming from the Eel River.

The prices paid for fish were often a contentious issue between fishermen, cannery operators and fresh fish markets. Fresh fish either sold to local Eureka markets or shipped by steamer to San Francisco out of

Port Kenyon or Eureka. Some fish was smoked locally. In most years, it was more profitable to sell salted fish or sell to a fresh fish buyer rather than sell to a cannery. Only the few long-established fishing companies were set up to salt and pack their catch in barrels and the fresh fish market price could change suddenly based on supply and demand. It was practical for many fishermen to sell to the cannery at a price below the fresh and salted fish market levels and get back to the fishing grounds quickly. Another cannery was built at the foot of F Street in Eureka in 1881 to meet the growing market. The Eureka cannery received salmon from the Eel River, Humboldt Bay and Mad River.

The canneries expanded the market for Eel River salmon and allowed more fishermen to participate in the fishery. Most of these were gill net fishermen. They harvested salmon and steelhead as far upstream as Price Creek near RM 12 on the Eel River. In 1886, there were 12 seines and 70 gill nets working in the estuary. The fishery included a second run (late fall) of Chinook salmon harvested in December and January. Steelhead were harvested until the end of March. Sometimes salmon undesirable for human consumption were caught. They were near spawning condition, reducing their quality as food. These fish should have been allowed to go upstream to spawn. The fishermen and public were aware of this waste of fish which brought attention to the lack of regulations on the fishery (Van Kirk 1996).

Market forces, weather, floods and unpredictable salmon runs were part of the venture of the commercial fishery. In some years the fishing business was less prosperous due to smaller runs of salmon entering the river, or early floods would allow the majority of a run to pass upstream before river conditions were suited for fishing. Then a boom year would arrive and saturate markets. Politics of labor relations was also an issue. The cannery preferred to employ Chinese people, but the people of Humboldt County did not approve of bringing in foreigners, claiming the loss of jobs for locals. Many discussions between cannery management and local politicians were in regards to cannery labor (Wainwright 1965 and Van Kirk 1996).

A summary of cannery records from the Pacific Coast Packing Company 1877-1887 printed in the Ferndale Enterprise in 1887 showed the cannery produced an average of 8,140 cases per year with a range of 3,500 cases (18,500 fish) in 1877 to 12,500 (67,000 fish) in 1886. Each case contained 48 one-pound cans of salmon. The cannery did not operate in 1879 because of a large pack of 11,900 cases from the prior year still flooded the market (Van Kirk 1996).

After 1885 turned out a low salmon catch, local citizens and sport fishers began to suspect the fishery was in decline due to excessive harvests. However, in 1886 an estimated 2 million pounds of salmon (~125,000 fish) was caught from the beginning of November to December 12th. The 1886 harvest was one of the largest ever taken from the estuary. The cannery paid 30 dollars per ton, received half of the harvest and canned 12,500 cases of salmon. At 48 one pound cans per case those 12,500 cases weighed 600,000 pounds which equals a sixty percent yield from the reported one million pounds sold to the cannery. The fresh fish market brought as high as 60 dollars per ton and the salt packed salmon brought about 45 dollars per ton (Van Kirk 1996).

Based on the relatively low harvests of 1882 to 1885 (annual average of ~40,300 fish), the US Board of Fish Commission in 1888 reported that the salmon catches on the Eel River were beginning to decline (USBFC 1888-1890). However, in 1888 a large run of salmon produced large harvests once again. The cannery did not operate leaving the markets flooded with fish. Fresh fish sold for as little as one cent per pound (20 cents/ton) (Van Kirk 1996). As presented in Van Kirk (1996), a November 3, 1888 newspaper article from the Ferndale Enterprise stated "Salmon in Abundance"; this article described the large salmon runs of 1888 and its influence on the market:

> "*An immense run of salmon started in Eel River and fish have been more than plentiful in that stream ever since. Swett & Fulmore have been making enormous hauls, they having already caught about all they are prepared to take care of and intend ceasing fishing this week. Wm. Ellery tells us that there are more fish in Eel River this year than he ever saw before and he has been fishing on that stream about 30 seasons. The fact of the cannery not running limits the market and those not prepared to salt are left to either ship to San Francisco fresh or sell their fish for what they can get to those who can handle them*".

In 1889, another large run of salmon entered the estuary. There were days when the number of fish caught exceeded the canning process capabilities, causing excess fish to spoil. The cannery pack was over 12,000 cases of salmon (approximately 900,000 pounds of whole fish). In addition to the cannery pack, over one million pounds of fish was either sold to fresh markets or salted and packed into barrels (Wilcox 1896).

The large salmon and steelhead runs continued in 1890 as over 1.1 million pounds of salmon and 311,000 pounds of steelhead were reportedly harvested (Wilcox 1905). Van Kirk (1996) presented an excerpt from the Ferndale Enterprise, dated 03 Nov 1888, which described the abundant salmon run:

> "*Since last Thursday night, Eel River has been literally alive with salmon and the fishermen on the river have had all the fish they could handle. Sunday night the Legg Bros. caught 30 tons at one draw, probably the largest haul ever made on the river. Since then five to ten ton hauls have been of frequent occurrence*".

Due to a saturated canned market from the previous year's catch, the cannery in 1890 was once again not in operation. An excerpt from the Ferndale Enterprise dated March 21, 1890 reported that there was still "about 400 tons of canned and barreled salmon at the cannery awaiting shipment" from the Eel River (Van Kirk 1996). Without a cannery willing to buy fish, the large catches flooded the fresh fish market and drove down prices. With such an abundance of salmon on the market, fishing effort would slow or cease altogether until the demand and prices for fresh fish increased (Parry 1959; Wainwright 1965 and Van Kirk 1996). According to Wilcox (1896) between 1889 and 1892 over one million pounds per year of salmon was harvested in Humboldt County. The Eel River was the principle source of these fish.

In 1891, catches of salmon (~74,000 fish reported) dropped again compared to recent years of large harvests. The high demand for fresh fish at good prices in San Francisco markets made less fish available for canning. Consequently, the cannery owned by Pacific Coast Packing Company closed. In 1892 the lack of fall rains may have contributed to fewer salmon available to the fishery resulting in below average (~55,000 fish reported) harvest. The following five years had some good salmon catches but overall the season's harvests were below the late 1880s average.

In the early 1890s, large runs of steelhead in December through March became an important source of income for the fishermen. For example, approximately 500,000 pounds of Eel River steelhead sold outside the county in 1892 (Wilcox 1899-1900). An excerpt from the Ferndale Enterprise (Dec. 17, 1886) describes this steelhead run: "Now comes the run of what is known as steel-heads, which will continue until the lst of April… A good number of the Eel River fishermen expect to catch a large number of these during the next three months". These large runs of steelhead may have helped fishermen to offset the reduced salmon runs during this period.

The percent harvest of the Eel River salmon spawning run is not known. Harvest rates certainly increased in the 1880s over the early years of the fishery as the numbers of fishermen increased. Unregulated harvest estimates from Oregon coastal rivers range from 35 to 88 percent depending on stocks (Gresh et al. 2000; Meengs and Lackey 2005). During the mid 1890s, the State Fish and Game increased regulations on the commercial fishery with various rules and laws. The laws included net restrictions, shortened seasons and closed areas. The management of the commercial salmon fishery, declining catches, and less opportunity for profits led to a decline in the number of commercial fishermen. Although the laws were difficult to enforce, commercial fishing effort reduced and the goal of allowing greater numbers of salmon to escape to spawning grounds was achieved (Wilcox 1899-1900; Van Kirk 1998).

It is unclear if regulations alone were responsible for the declining catches or if there were other factors at work. For example, in 1895, 376 fishermen caught 277,000 pounds of Chinook (17,300 fish or 46 fish per fisherman), 136,000 pounds of coho (~13,600 fish) and 409,000 pounds of steelhead. In 1899, there were only a 185 fishermen; they caught 176,000 pounds of Chinook (11,000 fish or 60 fish per fisherman), 60,000 pounds of coho and 114,000 pounds of steelhead (Wilcox 1899-1900). Occasionally, harvests of Pacific herring, Pacific sardines and smelt were taken in beach seines and Dungeness crabs were also harvested from the estuary to supplement commercial fishermen's incomes.

Price Creek Hatchery 1898-1915

In the 1890s, public opinion of declining salmon stocks prompted requests to State Fish and Game for a hatchery on the Eel River. After reconnaissance studies a hatchery site was selected on Price Creek, a tributary located about 12 miles upstream of the Eel River mouth. The Price Creek Hatchery was built in 1897. In January of 1898, the hatchery received its first shipment from the Battle Creek hatchery in Shasta County of 8 million Chinook salmon eggs. Over the following 15 years, the Price Creek hatchery annually received between 885,000 and 9 million Chinook salmon eggs from hatcheries on Battle Creek and Mill Creek in the Sacramento Basin. The eggs were released soon after hatching as fry in Price Creek and the lower Eel River (Van Kirk 1996).

1900-1921 The Last Years of the Salmon Fishery

Wilcox (1900) reported that "fish were more plentiful in 1900 than at any time since 1895" and the 1901 season produced a harvest of 851,000 lbs of salmon by Eel River fishermen. This run coincided with the third year of hatchery releases, the first year of expected returns to the hatchery and after several years of regulations that shortened the season and closed areas to commercial fishing. In 1904, the commercial fishery harvested over 2.2 million pounds of Chinook, 133,000 pounds of coho, and 53,000 pounds of steelhead (Wilcox 1907 Report of Commissioner of Fish and Fisheries). Since there was no cannery, the great majority of salmon sold to fresh fish markets. People believed that the large harvest could be attributed to both "artificial propagation and legal protection" (Wilcox 1907). However, the relatively large harvest of coho salmon, which were not part of the hatchery project, suggests natural production of salmon was high for these year classes and the large harvest may be part of the cyclic pattern of population dynamics similar to earlier years. The relatively small catch of steelhead may be attributed a shortened season which ended January 31 1905 instead of extending until April as in past years of large harvests. The large winter storms in of 1904-05 also made fishing for steelhead difficult (Van Kirk 1996).

The last cannery built on the Eel River estuary was in 1905-06. The cannery and a cold storage plant was added to the existing Port Kenyon packing plant located near the confluence of the Eel and Salt rivers. One reason for building the cannery was many fish caught by the fishermen were below the minimum size (15 lbs) or were below the minimum quality desired for mild curing, which was performed to create the highly desirable product of salmon lox. The mild curing process used only high quality, large fish. These fish were often only a portion of a fisherman's catch (Scofield 1925). A cannery operation combined with packing and cold storage facilities could allow a company to buy a fisherman's entire catch, mild cure the large high quality fish and process into cans the small or lesser quality fish. This had benefits for both the fishermen and the cannery and resulted in less waste of fish (Scofield 1925, Parry 1959). However, in 1908, there was low demand for mild cured salmon, so the entire Port Kenyon facility closed for that year. The Port Kenyon cold storage plant operated in 1909 and during 1910 and 1911, the cannery was leased to and operated by N.W. Tallant. The facility referred to as the Tallant Cannery was closed after the 1911 season, not for the lack of fish but because of disputes over wholesale prices paid by the cannery, operating costs that controlled cannery profits and the increasing competition and increased demand for fresh fish in San Francisco (Parry 1959, Van Kirk 1996).

Meanwhile a shortage of eggs at the Sacramento hatcheries reduced shipments to the Price Creek Hatchery. There were attempts to obtain ripe eggs from Eel River Chinook and coho salmon, but these efforts were unsuccessful. Beginning in 1902, steelhead fry from the Outlet Creek hatchery and from the Snow Mountain Egg Collecting Station (both located in the Upper Eel River basin) were released from the Price Creek hatchery (Report of Board of Fish and Game Commissioners 1910). In 1910, 47,000 coho fry from Santa Cruz were released into Price Creek.

The Price Creek Hatchery closed in 1915 due to a landslide that damaged the diversion dam needed to provide the facility's water supply. A new hatchery site on Steelhead Creek near Alderpoint was thought a better location for propagating Eel River salmon. Thus, in 1916, the hatchery buildings from Price Creek were moved to a site near the mouth of Steelhead Creek allowing the Fort Steward Hatchery to begin operations. The Fort Seward Hatchery operated from 1916-1942.

The addition of stocked salmon by the Price Creek Hatchery was viewed with varying degrees of success. In his annual report to the State Fish and Game Commission (1915), W.H. Shelbley, Superintendent of Hatcheries, speaks of the Price Creek hatchery as follows:

> "*Price Creek hatchery has been under the supervision of Mr. W.O. Fassett, who has successfully operated this station for the past fourteen years. We are pleased to note that the salmon are yet plentiful in Eel River and do not show any signs of a decrease, although the fishing has been as heavy as in past years".*

Others felt that releasing salmon fry immediately after hatching in the lower river did not give these small fish much of a chance for survival; however, there were large commercial catches in the early 1900s that coincided with hatchery releases. Five years after hatchery releases of salmon the commercial harvest increased to over 1,500,000 pounds. However, these larger catches were in sync with cyclic patterns of natural variation in run sizes seen throughout the commercial fishery. The increased harvest trend of coho salmon during the same years was without assistance from the hatchery. Coho were not reared in the hatchery until 1910.

After further gear restrictions, other management actions and public interventions the commercial fishery closed on the Eel River by California legislation in 1922. The closure was also related to the growing presence of the ocean troll salmon fishery that harvested high quality fish at sea. State Fish and Game managers felt that the salmon populations would be at risk from the combined ocean and in-river harvests. The Report of Commissioner of Fish and Fisheries (1918) and the Division of Fish and Game Fish Bulletin No. 20 (1929) presents the last records found that document the commercial harvests from the Eel River estuary. The average reported harvest for the years 1918-1921 was 31,200 fish.

Another management consideration for the closure of the commercial fishery was the construction of Cape Horn Dam in the upper Eel River by the Snow Mountain Electric Company. The dam blocked access to important spawning grounds for anadromous salmonids and the water diversion reduced important flows needed for fish passage into the upper basin to spawn. Lastly, there was the public concern of using taxpayer money to pay for hatchery operations, but having the canneries receiving the profitable benefits. An excerpt from the State Board of Fish Commission (1988-90) remarks these sentiments, "the business of the canneries should cease or else the government should abandon stocking".

Table 7 presents the reported number of barrels, and the pounds of fresh fish sold by Eel River fishermen and the reported amount of fish canned for years where adequate data was available. Note that these figures are mostly below the actual annual salmon harvest because they do not always include the number of fresh, smoked, or salted fish that were also harvested each year, which may amount to an additional 25-35 percent of the catch (Report of Board of Fish and Game Commissioners 1910). These harvest data give us some idea of how many fish were caught and sold. In addition, sport fishermen and spear fishermen harvested an untold number of fish annually that are not accounted for in the overall totals.

Supplementary Findings and Fishery Synopsis

A substantial amount of anecdotal information describing run size, run timing, species composition and harvest records is presented in past newspaper articles summarized by Wainwright (1965) and Van Kirk (1996). These articles tell of at least two fall runs of Chinook in the Eel River: 1) an early Fall run often caught in the estuary from as early as August, but mostly caught October through mid-November and 2) a second peak in catches that occurred in late fall, from mid-November through December and sometimes in January. The newspaper articles also tell of adult steelhead caught in the estuary year round mostly by sportfishers. The steelhead fishery had peaks in April, May, June representing a summer run and a winter run that peaked in December thru March. The steelhead half pounder run was strongest in August and September. The harvest records reported in newspaper articles were supported by reviews of published reports by the U.S Fish Commission, State Fish Commission, Bureau of Fisheries, CDFG, and others.

The commercial harvest that took place for nearly seventy years was certainly an early perturbation to the Eel River salmon stocks. A close examination of harvest records and detailed review of historic information show that market factors, labor disputes, and annual variation of run size were significant factors contributing to the harvest history of the commercial fishery.

The introduction of Chinook salmon from Price Creek Hatchery was from Sacramento Basin stocks. According to recent genetic studies, the Eel River stocks appeared to be distinct from Sacramento Basin stocks. Any contribution in numbers or genetic markers from hatchery stocks from outside the Eel Basin appears lost over time (Good, et al 2005).

Historic Chinook Salmon Population Estimate

Historic salmon population estimates for rivers along the west coast have been based on in-river commercial harvests involving cannery production and other sources of catch data. The methods used to make historic run size estimates include the following: 1) converting the reported annual harvests from cannery records etc. to a number of fish caught for each year; 2) selection of a time series to best predict run size; 3) approximate and apply annual harvest rates; and 4) the addition of unreported harvests and spoiled or waste fish to reported catch (Lichatowich 1989; Gresh et al. 2000; Meengs and Lackey 2005).

Methods used to estimate the historic Chinook salmon run size in the Eel River were adapted from those described above. The reported harvests of salmon salted in barrels, cases of cans, or pounds sold to fresh fish markets were converted to numbers of salmon as shown in Table 7. Synthesizing information on the fishery proved challenging because of the various ways salmon was processed and marketed and the

inconsistent reporting records. Many years have incomplete data so they underestimate the actual catch.

Table 7. Annual reported commercial catches of Chinook salmon from the Eel River estuary1857-1922. The amount of fresh fish sold to local and San Francisco markets was not available for most years which represented at least a 25 percent addition to cannery and/or salted totals shown (report of Board of Fish and Game commissioners 1910). Little or no catch data was found for years 1861- 1873 and 1905-1909. The weight of fish sold to canneries is based on the number of cans produced and reflects a yield of 60% to cans from whole fish. The estimated number of Chinook salmon harvested was derived by dividing the estimated pounds of fish harvested by 16 pounds per salmon.

Year	Estimated Pounds Sold to Cannery	Reported Number of Cases of Cans	Reported Number of Barrels	Reported Pounds Packed in Barrels	Estimated Pounds Caught for Packing in Barrels	Reported Pounds Sold Fresh	Estimated Total Pounds Harvested	Estimated Number of Salmon Harvested
1857			1,200	240,000	300,000	na[1]	300,000	18,750
1858			2,000	400,000	500,000	na	500,000	31,250
1859								
1860			1,100	220,000	275,000		275,000	17,200
1874			3000 a	300,000	375,000		375,000	23,450
1876			3000	600,000	750,000	138,000	750,000	46,875
1877	680,000	8,500	2763	276,300	345,400	na	1,025,400	64,090
1878	952,500	11,900	3,600a	360,000	450,000	na	1,402,000	87,625
1880	672,000	8,400	1,237	123,700	154,600	60,000	886,600	55,400
1881	488,000	6,100	564	56,400	70,500	278,000	836,500	52,300
1882	696,000	8,700	na	na	na	na	696,000	43,500
1883	720,000	9,000	na	na	na	na	720,000	45,000
1884	640,000	8,000	na	na	na	na	640,000	40,000
1885	448,000	5,600	na	na	na	89,000	537,000	33,550
1886	1,000,000	12,500	na	na	na	1,000,000	2,000,000	125,000
1887	532,000	7,500	3,000	30,000	37,500	188,000	757,000	47,300
1888	Big runs,	huge	catches	noted , but no		harvest	numbers	available
1889	960,000	12,000	na	na	435,600	na	1,400,000	87,500
1890							>1,000,000	62,000
1891	na	na	na	na	na	na	1,110,000	69,375
1892	na	na	na	na	na	na	825,000	51,560
1895			na	na	na	277,325	277,325	25,875
1899			na	na	na	258,000	258,000	15,175
1901			na	na	na	na	851,000	53,190
1902			na	na	na	na	1,100,000	68,750
1904			na	na	na	na	2,300,000	143,750
1910		6,000	na	na	na	na	430,000	26,875
1911		8,400	na	na	na	na	600,000	37,500
1912		11,000	na	na	na	na	790,000	49,375

Year	Estimated Pounds Sold to Cannery	Reported Number of Cases of Cans	Reported Number of Barrels	Reported Pounds Packed in Barrels	Estimated Pounds Caught for Packing in Barrels	Reported Pounds Sold Fresh	Estimated Total Pounds Harvested	Estimated Number of Salmon Harvested
1914			na	na	na	na	1,120,000	70,000
1915			na	na	na	586,000	586,000	36,625
1916			na	na	na	na	950,00	59,375
1917			na	na	na	na	700,000	43,750
1918			na	na	na	na	400,000	25,000
1919			na	na	na	na	800,000	50,000
1920			na	na	na	na	370,000	23,125
1921			na	na	na	na	300,000	18,750

[1] Not available with sufficient data to be included or separated from reported totals.

The second highest five-year mean harvest (1878, 1886, 1889, 1902, 1914) was selected with the assumption that large harvest years occurred with large runs and optimal fishing conditions and high harvest rates through most of November. The record reported harvest in 1904 of 143,750 Chinook salmon were not included in the five years averaged for highest reported harvest because returns from Price Creek Hatchery releases may have contributed to the year's catch. A review of the five years of catch data shows that the great majority, if not all the catch came before December, making the harvest predominantly of fall runs of Chinook salmon. Markets, especially the cannery, were often saturated by the large catches in November. The large catches and saturated market reduced or stopped fishing efforts later in the season. Fishing seasons also limited the harvest to the fall run.

Historical reports, as in the Ferndale Enterprise November 22, 1889, note that rains and high river flows in late November and into winter often allowed much of the later fall Chinook run and coho run to pass freely upstream (Van Kirk 1996). Therefore, based on the selected harvest years for analysis, the number of late fall Chinook run entering the river December and January would not be included in the historic population estimate as the great majority of harvest were concluded before December for those years.

To account for wasted or spoiled fish and other unreported catches, 20 percent of the annual catch is added to each year (Gresh et al. 2000; Meengs and Lackey 2005). This may be conservative as The Report of Board of Fish and Game Commissioners (1910) estimated that unreported salmon sold to the fresh fish market composed 25 percent of the annual catch from the Eel River.

Three harvest rates 35, 60 and 80% were divided into the mean catch total ± 95% CI (2nd highest five year mean = 105,330 ±34,000) to produce total run sizes. The three catch rates should encompass the actual catch and Chinook salmon run size during the years of the Eel River commercial fishery (Table 8). However, because the larger harvest years were used, the harvest rates of 60 and 80 percent likely produce the best approximate historic run size of fall run Chinook salmon.

*Table 8. Estimated historic fall Chinook run size based on commercial harvest data.**

Harvest Rate (%)	Estimated Run Size
35%	300,940 ± 97,150
60%	175,550 ± 56,665
80%	131,660 ± 42,500

* Estimates primarily include late fall run (fish caught after December 1st).

For a historical run size estimate comparison, Meengs and Lackey (2005) used a 23-pound average per Chinook and predicted a historic run of 154,000 Chinook over a similar time period for the Rouge River. The Rouge River is a 5,200 square mile basin with 220 miles of mainstem channel compared to the 3,600 square mile Eel River Basin with 200 mainstem miles.

Other Fishery Resources

In addition to the anadromous salmonids, several marine, resident estuarine and freshwater fish species also rely on the diversity of habitats and the productive estuarine waters for spawning, feeding,

and rearing. These include special concern species such as the federally listed as threatened green sturgeon, longfin smelt and tidewater goby. However, juvenile nursery habitat is one of the areas most important attributes. The Eel River estuary is utilized for juvenile nursery areas by several important fishery resources including Dungeness crabs. English sole, starry flounder surfperch spp, sturgeon, smelt spp. and Pacific herring.

Many fish show preferences to specific areas while others spread widely across the estuary and some are only occasional visitors or are drawn in by tidal currents. Less conspicuous species such as federally endangered tidewater goby rely on unique protected areas for year round habitat. Chamberlain (2006) suggests that preferred tidewater goby habitats may be areas with low velocity tidal currents and/or stable areas with infrequent tidal exchange. Such habitats can be found in upper and lateral extents of tidal sloughs and marshes.

A few species are very abundant for a period of time, mostly spring to fall (surf smelt, top smelt, anchovies, English sole, sardines, herring). Some are present year round (salmonids, starry flounder, staghorn sculpin, stickleback) and species that are represented by a relatively few individuals that occasionally find their way in the estuary eg. jack mackerel). Most of the occasional visitors are marine species. Some species may be seldom found in the estuary because their populations are far below historic numbers (green sturgeon, white sturgeon, and longfin smelt). The comparison shown in Table 8 of the fish observations of Puckett (1973-74) and Cannata and Hassler (1994-95 field data) help to show spatial and temporal relationships of fish and estuarine habitats. Fish presence is related to variables, such as seasonal river discharge, salinity regimes, tides, water temperature, bottom substrate and migratory or reproductive strategies. The physical conditions are constantly changing due to the dynamic nature of the estuary. Due to salinity gradients, it is possible to catch a freshwater fish and a marine fish at the same site where fresh water flows on the surface and seawater flows along the bottom.

It is important to consider all of the species and habitat types that are found in the estuary when developing management plans. Maintaining viable populations of this diverse group of fishery resources depends on the estuarine ecosystem to retain natural processes and diversity of habitats. Thus, maintaining and improving habitat diversity, such as properly functioning tidal marshes, will likely benefit the estuarine ecosystem and its fishery and wildlife resources. Simenstad (1983) states:

"…it is only at the community level that ecological relationships among biotic and abotic components can be interpreted in terms of the functional processes which effect the dynamics of the systems structure and production. Thus the role of riverine inputs, estuarine circulation, salinity gradients, nutrient and material fluxes, and sediment structure in determining the composition, distribution, and standing stock of estuarine biota can be translated into management recommendations for the maintenance of key processes."

Table 9. Seasonal and spatial distribution of fish captured in Eel River estuary. Captured by Puckett in 1973-74 (P), Cannata and Hassler 1994-95 (X), or both (O). W = Winter (December - February); Sp = Spring (March – May); S = Summer (June-August); and F =Fall (September - November). North Slough= McNulty and Hawk Slough channels; Lower Channel= North Bay to Cock Robin Island Bridge; Middle Channel= main channel from Cock Robin Island Bridge to Fulmor Road; Upper Channel= main channel from Fulmor Road to Fernbridge.

Fish Species		North Sloughs				Lower Channel				Salt River				Middle Channel				Upper Channel			
		W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F
Anadromous	Juvenile Chinook salmon		X	P	P		X	O	O		X	O	P	X	O	O	O		O	O	P
	Juvenile Coho salmon		P	P	P	X	O			X		P			P				P		
	Juvenile Steelhead trout	P	O	P	P	P	P	O		P		O	P	P	P	X	O		P	O	O
	Juvenile Cutthroat trout											X									
	Green sturgeon															X					X
	Pacific lamprey	P				X									X						
	American shad															X				O	X
	Longfin smelt	X	O			O	X	X		P				P							
Estuarine or Marine	Surf smelt		O	O	O	O	O	O	O	O	O	O	O			O	O				O
	Pacific herring		O	O	O			O	O			O	O			O	X			O	P
	Pacific sardine							X	X			X				X	X				
	Northern Anchovy		P		O			X								X	X				
	Top smelt			O	O			O	X		P	X	O			O	O				
	Staghorn sculpin	O	O	O	O	O	O	O	O	P	X	O	O	P	X	O	O			X	
	Prickly sculpin	O				O	X	X	P	P		O	X			X	X		P	X	X
	Bay pipefish		P	O	P			X	X			O				O	X				
	Shiner surfperch		O	O	O		O	X		P	X	O	O		P	O	O				P
	Redtail surfperch		P	P	P	O		P	O	P		P			P	P					
	Walleye surfperch			P					X												
	English sole		O	O	X			O	X			X	X			O	X				
	Starry flounder	O	O	O		O	P	X	O	P	P	O	O	P	P	O	O			O	O
	Sand sole								O												
	Cabezon							O	X												

Fish Species		North Sloughs				Lower Channel				Salt River				Middle Channel				Upper Channel			
		W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F
	Saddleback gunnel		O	O					P			P				O	P				
	Stickleback		O	X	P	X	O	X		X	O	O	X		O	O	X		O	O	O
	Tidepool sculpin								X												
	Bay goby								X												
	Ring-tail snailfish								X												
	Buffalo sculpin								X												
	Jack mackerel								X												
Freshwater	Sacramento sucker	P				P				P			P	P	P				O	O	O
	California roach				P	X				X					X	X			P	O	O
	Sacramento pikeminnow		X	X		X	X	X			X	X			X	X			X	X	

Responses to Assessment Questions

What are the history and trends of the size, distribution, and relative health and diversity of salmonid populations?

- Juvenile salmonids of the Eel River use an estuarine rearing life history strategy. They have been observed in the estuary on a year-round basis;
- Spawning runs of adult Chinook salmon begin to enter the estuary in August and hold there until fall rains provide sufficient flows to allow upstream passage to spawning grounds. Adult Chinook continue to enter the estuary through January;
- Adult coho salmon generally enter the estuary November to February on their way to upstream spawning areas;
- From 1853 to 1922 the estuary supported a large commercial fishery. Reported peak annual harvests was 2.3 million pounds of salmon (~150,000 fish) and over 500,000 pounds of steelhead (~62,500 fish);
- Anecdotal reports from the mid 1800s to early 1900s tell of adult steelhead found in the estuary year-round. Today winter steelhead runs typically range between November to April and summer runs generally range from March to June;
- Due to declining populations Chinook, coho and steelhead receive protection under either or both state and federal endangered species acts;
- Data collected from fish counting stations at Van Arsdale and Benbow show significant declines of Eel River salmonid populations. The rate of decline increased after floods of 1955 and 1964.

What are the current salmonid habitat conditions? How do these conditions compare to desired conditions?

- A diverse group of fishery resources including salmonids depend on the estuarine ecosystem to retain most of its natural function and diversity of habitats;
- The Eel River estuary provides critical habitat and nursery area for anadromous salmonids and several other important fishery resources;
- The loss and alterations of salt marsh and freshwater ecotones may deny coho use of critical habitat;
- Water temperature is generally suitable for anadromous salmonids year round. Although the upper channel reach near Fernbridge can warm above 70F during summer months;
- Dissolved oxygen levels can drop below 5ppm in McNulty and other slough channels. This may be a signal of nutrient loading and/or poor circulation;
- The reduction in tidal connectivity and loss of area due to sedimentation, levees, and flood gates has contributed to an overall loss in the estuary tidal prism;
- Roberts (1992) estimated that salt marsh surrounding the estuary once covered at least 15 square miles or close to 10,000 acres;
- Approximately ten percent of the original tidal wetlands and salt marsh habitats remain in the Estuary Subbasin;
- In the past, the estuarine channels were deeper, more diverse, and more complex compared to present conditions;
- There is a shortage of large wood needed to help scour accumulated sediments and for structural and shelter elements for salmonids. Large wood is removed by salvage operators and firewood collectors.

What are the past and present relationships of geologic, vegetative, and fluvial processes to estuarine habitat conditions?

- The Eel River is composed of soft Franciscan rock, fragile soils, widespread tectonic deformation of the underlying rocks, recent rapid uplift, and high winter and spring rainfall and subsequently carries the second highest suspended sediment load per drainage area in the world;

- Since the estuary receives runoff from the entire Eel River Basin, it is influenced by cumulative watershed effects such as river discharge, water temperature and rates of sediment deposition;
- High rates of sedimentation in the estuary are related to severe erosion in the upstream subbasins;
- The morphology of the estuary channels and adjacent lands are continually changing as result of high flows that erode, channel banks and deliver sediments. Seismic movement, land use activities, wind and wave action, and longshore currents also influence estuary morphology;
- Many formerly deep pools in the estuary are now filled by excessive sediment delivered by flood events;
- The delta area is naturally prone to flooding during high winter flows;
- Ocean tides and river floods play a major role in shaping estuarine channels;
- The tidal prism is significantly reduced compared to historic conditions;
- The location of the mouth affects lower delta drainage during winter floods and where wave action will strike the shore;
- Riparian vegetation plays an important role to help stabilize estuarine channel banks;
- Much of the native redwood, spruce and other conifers that once lined the channel banks have been removed;
- Climate change may initiate cumulative interactions between sea level rise, sediment delivery from upstream sources and local erosion.

How has land use affected these natural processes?

- The estuarine main channel has widened and shallowed from excessive sediment delivery linked to land use upstream and destabilization of channel banks from removal of riparian vegetation;
- The loss of approximately 90 percent of original wetland habitat and tidal prism is from land conversion and the affects of levees and tide gates. The network of levees and tide gates in the Eel River estuary has reduced channel connectivity and blocked the ebb and flood of the ocean tides;
- Swickard (1899) estimated a reduction of tidal prism of about 877,000 cubic yards (about 543 acre feet) that was caused by the early damming the southern salt marshes;
- The diking which occurred east of McNulty Slough probably reduced the tidal prism even more than did the actions addressed in Swickard's deposition;
- The reduction in salt marsh habitat area and loss of channel connectivity and complexity has altered the natural ecosystem process involved with nutrient cycling, food production, and resulted in a loss of habitat area and diversity.

Based upon these conditions, trends, and relationships, are there elements that could be considered to be limiting factors for salmon and steelhead production?

- A loss of channel connectivity due to levees and tide gates adjacent wetlands and sloughs, limits rearing area, nutrient cycling, food production, and habitat diversity available to salmonids and other valuable fishery resources;
- A loss of channel depth may limit the carrying capacity for adult salmon holding in the estuary before rains allow passage upstream to spawning areas;
- The reduction of tidal prism limits available wetland habitat and limits scour potential needed to maintain slough channel functions;
- A relative paucity of woody debris in the estuary may limit shelter habitat needed by juvenile salmonids during large winter runoff flows and also limits cover to escape from predators.

What watershed and habitat improvement activities would most likely lead toward more desirable conditions in a timely, cost effective manner?

Flow and Water Quality Improvement Activities:

- Insure the supply of freshwater inflows are provided for maintaining estuarine habitat diversity and to drive

ecosystem processes that fish, wildlife, and vegetative communities depend on for part or all of the life history cycles;

- Use levee set backs, reconfiguration, or levee removal strategies to develop a wider flood plain that restores natural sinuosity, improves connectivity with sloughs and adjacent wetlands in North Slough channels or other areas constricted by levees;
- Increase tidal prism by modifying tide gates and/or removing leveesto restore tidal and riverine flow and connectivity between the main channel and slough channels and adjacent wetlands;
- Continue to prevent or reduce cattle waste and agricultural and dairy by-products from entering stream and slough channels;
- Take measures to ensure that water treatment facilities in Fortuna, Fernbridge, Loleta, Ferndale and other nearby areas do not contaminate estuarine waters.

Erosion and Sediment Delivery Reduction Activities:

- Land managers should work to maintain and/or establish adequate streamside protection zones to encourage growth of riparian vegetation to help stabilize stream banks;
- Increase slough channel scour potential by restoring tidal prism in historic tidal wetland areas;
- Continue efforts such as road improvements, good maintenance, and decommissioning and other erosion control practices associated with all land use activities throughout the Eel River basin to reduce sediment delivery to the estuary;
- Armour eroding banks near Fernbridge or other such areas with bioengineered techniques that secure large wood pieces into banks and integrate live trees into the stabilization project.

Riparian and Instream Habitat Improvement Activities:

- Where feasible, restore or improve width of riparian vegetation stands with native vegetation (Sitka spruce, cottonwood, redwood, alder willow) along the banks of lower Eel River and slough channels;
- Work to restore natural functioning tidal and drainage patterns within the McNulty Slough portion of the Ocean Ranch Wildlife Area and other north slough area channels and wetlands. The project should address water temperature, water flow regimes and other parameters needed to promote seasonal and/or year round use by fishery resources;
- Candidate sites for levee removal include both sides of McNulty Slough and its tributaries, and the land west of McNulty slough. The northwestern delta should be expanded rapidly outward from earlier project sites;
- Consider conservation easements or land acquisitions that would promote the removal or modification of tide gates and levees in order to restore tidal prism and tidal wetlands;
- Develop policy or regulations that prohibit or reduce wood removal from within the estuarine channel banks (0.25 mile upstream from Fernbridge to the river's mouth) and out to 50 feet from the high tide shore line of the North Bay. Such regulations should protect wood pieces on stream banks needed to reduce potential from further bank and beach erosion, provide instream shelter during high flows for fish, and protect bank restoration projects;
- Develop plans to eradicate or control the spread of invasive *Spartina densiflora*. An optimal strategy for low to medium sized budgets is to remove *Spartina* in areas where it grows in low density subpopulations.

Education, Research, and Monitoring Activities:

- Develop an inclusive estuarine ecosystem management and monitoring plan that works with natural processes to restore tidal connectivity to wetlands and increases tidal prism;
- Investigate potential impacts form sea level rise, increased storm intensity and other impacts to the estuary related to climate change;
- Add to baseline data regarding habitat utilization by all estuarine species;
- Study and assess the status of estuarine conditions needed to complete specific life history requirements for salmonids and other estuarine dependant fish and invertebrate species;

- Continue and expand water quality monitoring (including temperature and D.O).of nutrient levels that may be elevated from runoff from cattle pastures, sewage treatment facilities or other sources;
- Monitor the progress of natural succession (biotic and abiotic) and fish and wildlife resource utilization within the Ocean Ranch wildlife area. This should include the estuarine area and the fresh water impoundment;
- Determine the percentage of adult Chinook returning to the Eel River that show extended estuary rearing patterns by using scale analysis or other means;
- Investigate operations of tide gates on McNulty Slough, Hawk Slough, Centerville Slough and others to determine effects and/or loss of properly functioning saltwater/freshwater ecotone;
- Investigate dynamics of breaching the seaward levee at the south end of McNulty Slough to increase tidal prism and develop connectivity between wetlands and other sites to restore wetland connectivity.

Subbasin Conclusions

The Eel River estuary is a critically important nursery, rearing and transition habitat for juvenile and adult salmonids and other valuable fishery resources. Nine fish species that utilize the estuary receive protection under the Federal or State endangered species acts, which emphasize the importance of the estuarine habitat for fishery resources. Even with a major loss of wetland area from a system of levees and tide gates, the estuary has retained much of its natural character. No major port or large industrial development projects presently impact the character of the Eel River Delta. However, cumulative effects from land use actions in the Eel River Basin and within the estuary coupled with dynamic flood events have altered the morphology of the estuarine channels. The result is a reduction of valuable habitat area, loss of unique habitat complexity and degraded habitat quality for fishery and wildlife resources.

The increase of tidal prism by re-establishing functional wetlands is likely the most feasible and practical action to achieve immediate benefits to increase productivity and restore fishery habitats.

A large portion of the North Slough channels and lower river are designated wildlife areas managed by CDFG. These areas are prime locations for estuarine ecosystem improvement projects. Options for improvements on private lands should be fully explored through an adaptive Eel River estuary management plan. The plan should consider maintenance of existing land use while promoting restoration of fundamental estuarine ecosystem functions, promote community level ecological relationships among biotic and abiotic components and protect against degradation of existing upland and wetland delta habitats. The plan or any developed projects should also consider potential effects from the rise in sea level and other factors associated with climate change.