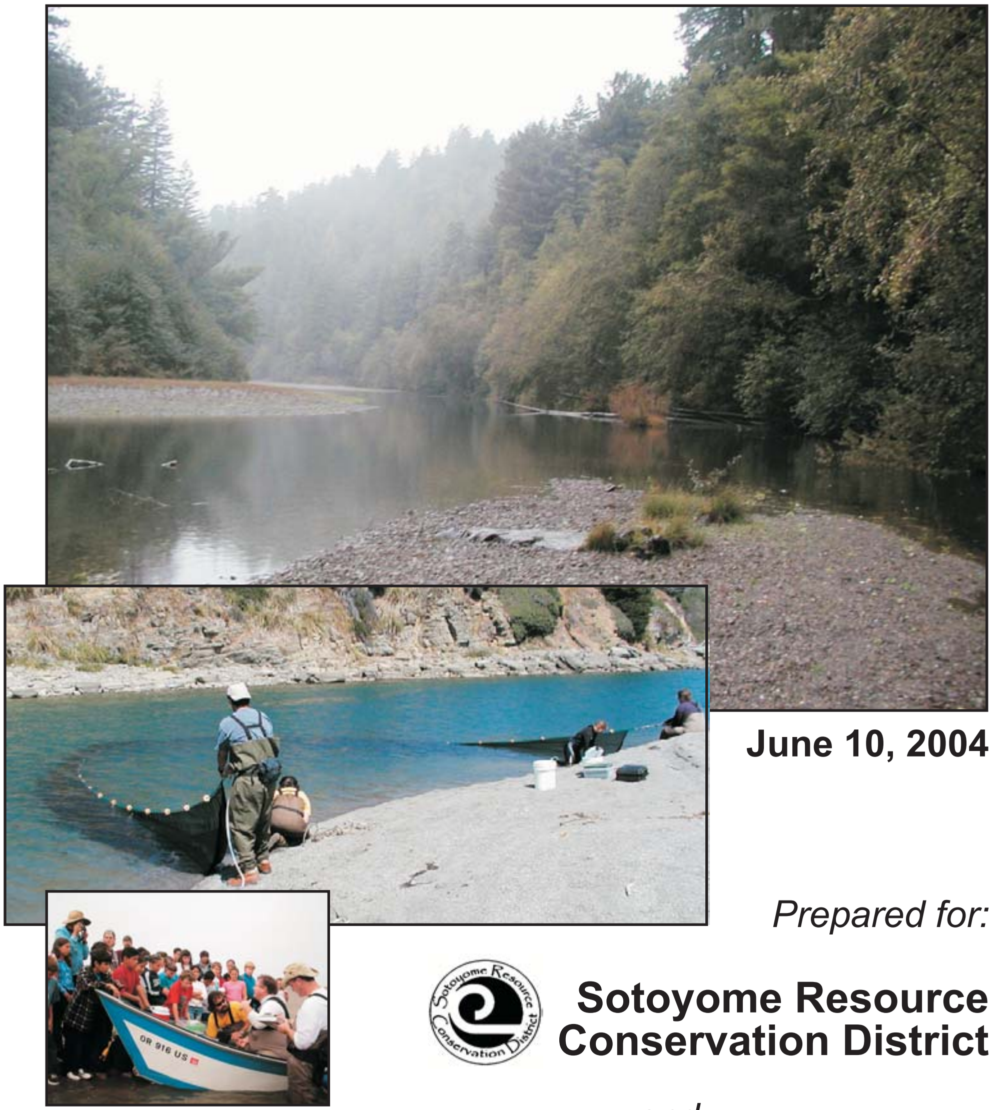
Gualala Estuary and Lower River Enhancement Plan: Results of 2002 and 2003 Physical and Biological Surveys



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CHAPTER 1.0 INTRODUCTION

The Gualala River estuary is located on the northern coast of California, about 37 miles north of the town of Jenner. Although the Gualala River has historically been an important system for steelhead and coho salmon fisheries, knowledge of the dynamics of anadromous salmonid fisheries has been limited to anecdotal information, with little focused study. The State Coastal Conservancy (SCC) has been involved with studies on the lower Gualala River since 1995, beginning with a grant for a literature search of existing data associated with the ecological integrity of the Gualala River watershed. Information provided from that work effort demonstrated that there were significant gaps in the literature relative to the lower river and estuary. Since then, the California Department of Fish and Game issued the final report of the North Coast Watershed Assessment Program (NCWAP) Gualala Watershed studies.

Acknowledging the importance of coastal estuaries to the overall health of coastal watersheds and the existing lack of data on the lower Gualala River, the Sotoyome Resources Conservation District (SRCD), the SCC, and the Gualala River Watershed Council ("Council") resolved to broaden the scientific understanding of the Gualala watershed, particularly the lower river and estuary. As a result, ECORP Consulting, Inc. (ECORP) and Kamman Hydrology & Engineering (KHE) were contracted by the SRCD to assess the lower river and estuary in 2002 and 2003, and develop recommendations for an enhancement plan for the Gualala Estuary and Lower River Project.

1.1 Goals

The overall goals of the Gualala Estuary and Lower River Project were to:

- collect baseline data on steelhead to develop population estimates,
- determine possible impairing factors on ecological productivity,
- identify further research needs, and

- develop recommendations for an Enhancement Plan

To address these goals, ECORP and KHE conducted an assessment of the existing physical, water quality, and biological habitat conditions, including use of the estuary by juvenile salmonids during open and closed lagoon conditions. The enhancement plan provides specific recommendations for the protection of the Gualala estuary and lower river and its natural resouces.

1.2 Objectives

The objectives for the Gualala Estuary and Lower River Project are outlined below for each of the project components.

1.2.1 Hydrologic and Geomorphic Analyses Objectives

The general objectives of the Hydrologic and Geomorphic study component were to describe historic and seasonal hydrologic, hydraulic, and geomorphic characteristics and processes in the estuary, and evaluate these issues relative to habitat quality for anadromous salmonids.

Specifically, these objectives were to:

- describe the existing and historic morphology of the estuary and lower river,
- characterize the magnitude and variability of freshwater inflow to the estuary (especially summer base-flows,;
- attempt to identify changes in river base flow rates as a result of upstream diversions,
- characterize physical processes controlling the opening and closing of the estuary inlet,
- evaluate sediment transport characteristics of the lower river and estuary, and

- describe temporal variation and linkages between inlet morphology, freshwater inflow, and water quality in the estuary.

1.2.2 Water Quality Objectives

The objective of the Water Quality Study Component was to:

- provide seasonal water quality profiles throughout the Gualala Estuary, including temperature, dissolved oxygen, pH, conductivity and/or salinity, and turbidity.

1.2.3 Aquatic Ecology Objectives

The objectives of the Aquatic Ecology Study Component were to:

- determine distribution and abundance of salmonids in the Gualala Estuary,
- describe seasonal habitat conditions in the Gualala Estuary,
- describe seasonal habitat availability in the Gualala Estuary,
- develop a species list and relative abundance of all observed fish, birds and mammals, and if possible given budget considerations,
- determine adult steelhead use and timing of migration through the Gualala Estuary.

1.2.4 Terrestrial and Marsh Ecology Objectives

The objectives of the Terrestrial and Marsh Ecology Component were to:

- delineate wetland areas *(The US Army Corp of Engineer criteria will be utilized, but will not be performed to a level of verification by the Corps. Wetlands including any one of the three Corps delineation standards, hydrology, vegetation, and soil type, will be duly delineated and incorporated into the project map),*
- develop a list of plant species in and around the lower estuary floodplain area,
- map plant species, communities, and species distribution,
- describe use of the lower estuary floodplain area by wildlife, and

- develop a list of species observed in the wetland/floodplain area during the assessment period.

It became apparent as the study progressed that the objectives of the terrestrial and marsh ecology component could not be addressed, due mainly to budgetary considerations. This issue was addressed before the Steering Committee and the Technical Advisory Committee (see below), and the decision was made to focus our studies on the aquatic ecology, hydrology, and geomorphic components of the study. The reader is directed to the Gualala River Watershed Assessment Report (Klamt et al 2002) that contains recent information on the Gualala River watershed, including both aquatic and terrestrial components. That report was a product of the North Coast Watershed Assessment Program (NCWAP).

1.3 Study Participants

1.3.1 Steering Committee

The SCC and the grantee formed a Steering Committee to oversee the implementation of the work plan, track the budget, and ensure project completion; consistent with the requirements of the contract between the grantee and the SCC.

1.3.2 Estuary Technical Advisory Committee

A Technical Advisory Committee (TAC) was established to assist the Steering Committee in developing a work plan that would meet the defined goals and objectives of the project. The TAC included agency personnel with expertise in the fields of fisheries biology, geomorphology, hydrology, water quality, and coastal processes. The primary responsibility of the TAC was to ensure that; work-plan tasks were conducted consistent with the contractual requirements, protocols and sampling methodologies were scientifically sound, and that study results were provided to the Steering Committee in a timely manner.

1.3.3 Public Participation

Outreach to the full Council and the general public took place annually. ECORP and KHE provided annual reports to the Steering and Technical Advisory committees, describing project status and results of various study components. This flow of information provided opportunities for adaptive management of the project during the assessment and enhancement plan development phases.

1.4 Project Management

Project Management efforts were conducted by the SRCD. The SRCD worked closely with ECORP, KHE, and the SCC to ensure that the scope of work was implemented in an efficient and effective manner. The Project Assistant to the Council and the administrative support team at the SRCD conducted daily administrative project oversight, and in particular:

- coordinated with subcontractors, field agents, SRCD staff, volunteers and other groups/individuals involved with the implementation effort,
- troubleshoot project issues as they occur and develop adaptive management strategies to address and document these issues, and
- provide mechanisms and coordination for public outreach and public involvement

This document has been prepared to address each of the objectives by project study component. Chapter 2.0 (prepared by KHE) addresses hydrology and geomorphology study components. Chapter 3.0 (prepared by ECORP) addresses water quality and aquatic ecology study components. Chapter 4.0 (prepared by KHE and ECORP) presents enhancement planning recommendations.

CHAPTER 2.0 HYDROLOGY AND GEOMORPHOLOGY INVESTIGATIONS

2.1 Introduction: Study Objectives and Approach

The lower Gualala River and its coastal lagoon comprise a highly dynamic system. The study area is indicated in Figure 2-1 and consists of the lower Gualala River between the confluence with the North Fork Gualala River and Pacific Ocean. Seasonally, the Gualala river mouth varies between an estuary with open connection to the ocean (typically winter) and closed to semi-closed lagoon behind a beach barrier (typically during summer). Given the shallow, fresh-water dominated, and closed-off nature of the Gualala River coastal water body, it is referred to as a “coastal lagoon” throughout this report (Sorensen et al., 1993). The duration and extent of these end-member states is controlled by the dominance of a variety of physical processes that control the construction or breaching of the barrier beach.

The goal of this investigation is to identify and describe the dominant physical characteristics and processes controlling aquatic and riparian habitats of the Gualala River coastal lagoon with emphasis on salmonid fishery habitat. Kamman Hydrology & Engineering, Inc. (KHE) developed and implemented the study based on a conceptual morphological and process model for California coastal river mouth systems. This model assumes that a river mouth inlet is controlled by various complementary and competing forces that breach or reconstruct barrier beaches. Typically, California coastal lagoons go through a seasonal progression of morphological change. In winter, the lagoon inlet commonly breaches and remains open due to storm flows. Once the inlet is open, tidal action aids in the inlet scour process. This also floods the estuary with high salinity waters. As winter storm flows subside, waves build up the barrier beach using sand, migrating along the shoreline (littoral drift), forming a sand-spit between the ocean and estuary. After lagoon inlet closure, the main source of water to the lagoon is fresh water

inflow. Periodic wave over-wash also significantly impacts barrier beach morphology and lagoon water quality.

This study focused on monitoring and/or characterizing a suite of hydrologic, geomorphic, and coastal conditions and processes to better understand the linkage and/or trends between lagoon physical and biological systems. Between August of 2002 and December 2003, specific monitoring activities and analyses completed as part of this study included:

1) Continuously monitor lagoon water levels;
2) Estimate daily freshwater inflow to the lagoon;
3) Complete a series of baseflow measurements on primary tributary channels to the South Fork Gualala River between the Pacific Ocean and Valley Crossing (Twin Bridges) to develop lagoon freshwater inflow estimates;
4) Develop a detailed water budget for the lagoon to estimate seepage rates and net transfers of water between lagoon and ocean;
5) Complete annual cross-sectional profiles of the lagoon and lagoon inlet;
6) Assist in the coordination and implementation of a photo-monitoring program of the barrier beach and lagoon inlet conditions;
7) Complete a review of historical aerial photographs and maps to identify historical changes in lagoon and lower river morphology;
8) Assess the local tide and wave climate acting on the lagoon barrier beach using available tide, wave and wind data from nearby NOAA tide gages and offshore buoys;
9) Assist in the monitoring of general water quality parameters (emphasis on salinity) throughout the lagoon;
10) Qualitatively assess sediment transport through the lower river and lagoon during the study period using survey results, field observations, and grain size information from repeat pebble counts at selected bars within the lower river and lagoon reaches; and

11) Coordinate and contract for the preparation of an aerial photogrammetric image of the project area;

As indicated in Section 1.0, this study was designed to further elaborate and expand on the North Coast Watershed Assessment Plan (NCWAP) salmonid habitat investigation of the lower river and lagoon. As such, it was originally intended that the results of this study and associated resource management and enhancement recommendations would serve as a companion document to the final Gualala NCWAP report. Therefore, this Section of the report builds on the physical science data and information presented in the NCWAP report and appendices (Klamt et al., 2003). This report does not attempt to duplicate or summarize the hydrologic and geomorphic information presented in the NCWAP report, except as needed.

2.2 Physical Setting

The existing and historic meteorologic and hydrologic characteristics of the Gualala River watershed are presented in detail in the 2003 Final NCWAP report. This section of the report provides a more detailed description of on-shore and off-shore hydrologic and hydrodynamic conditions experienced during and leading up to the study period. Where appropriate, study period conditions are compared to long-term average or median conditions.

2.2.1 Precipitation

Based on analysis of long-term records, precipitation in the study area is distinctly seasonal, with up to 90-percent of total rain falling during the 5 months of November through March. Most precipitation comes with the passage of multiple low-pressure fronts associated with storms lasting several days in duration. It is reported that hourly precipitation in excess of 1-inch is uncommon along north coast watersheds (Rantz, 1967).

With the exception of the last two months, the study period (August 2002 through November 2003) falls within water years[1] WY2002 and WY2003. Based on analysis of long-term rainfall records for area gages, the rainfall totals for the study period are comprised of near average (92-percent of average for WY2002) to below average (83-percent of average for WY 2003) year types. Daily precipitation totals at the Venado rain gage for the study period are presented in the top panel of Figure 2-2. Daily values of the Venado gage, located in the Russian River drainage, are presented here because there are no readily available daily rainfall totals from the Gualala River watershed for the study period. The peak daily rainfall total was 6.6-inches on December 13, 2002, with other notable (>3-inch) daily rainfall totals occurring on November 7, 2002, December 27, 2002, and November 8, 2003. Early season barrier breaches occurred during each of these storms. The multi-day storm rainfall distribution for the study period reflects the general characteristics described above. However, April 2003 was an exceptionally wet month compared to long-term monthly averages. April 2003 rainfall totals for the Fort Ross rain gage were 6.39-inches compared to the long-term (1905 to present) April average of 2.79-inches. These late season rains sustained high inflow to the lagoon, which was the primary cause for the late season breach on June 15, 2003.

2.2.2 Lagoon Freshwater Inflow

For the study period, freshwater inflow to the lagoon was estimated using a variety of data sources and technical methods. In general, unit runoff estimates and regression equations were developed for segments of the Gualala River using, a) available data for Gualala River watershed stream flow gages maintained by the U.S. Geological Survey and California Department of Water Resources over the study period, and b) late season base flow measurements completed by KHE on major tributaries to the South Fork Gualala River. A more detailed summary of the methods and data used to develop the inflow record are presented in Appendix A.

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[1] A " water year" is defined as the 12-month period, October 1 through September 30 and is designated by the calendar year in which it ends.

Estimated freshwater inflow to the lagoon over the study period is presented in the top panel of Figure 2-2 along with daily rainfall totals. Inflow responses to storms and the rise and post-winter recession in the baseflow rates are clearly evident. Although the on-set of high seasonal inflow is not out of the ordinary during the study period, the combination of continued storm pulses and sustained elevated baseflows to the lagoon through June of 2003 are notable differences to long-term average conditions. As a result, the persistence of elevated lagoon inflow delayed the full closure of the barrier beach and also promoted the complete fresh water filling of the lagoon by early June of 2003, leading to overtopping and breaching of the barrier beach.

2.2.3 Lagoon Water Levels

Lagoon water levels were monitored on a 15-minute time interval over the study period. A Global Water-brand XL-14 water level logger (deployed in a 10-foot long, 2-inch diameter PVC stilling well) was secured to the rip-rap filled log-crib in the middle portion of the lagoon on August 16, 2002. In anticipation of damage or lose of the instrument during high winter flows, the gage was relocated to the east bank of the lagoon, adjacent to the Surf Market in early November 2002. The logger and stilling well were secured to an existing iron pipe, cemented into boulders at the base of the cliff. This gage is referred to as the winter gage location while the subsequent site is referred to as the summer gage location. Both gage locations are indicated on Figure 2-3.

Monitored lagoon water levels are illustrated on the second panel (from top) of Figure 2-2. Coverage of the full range of lagoon water levels was not achieved at either gauging location. As a result, the water levels are truncated over the lower range. Periods of missing record also exist for the periods of November-early December 2002 and May/June 2003. Missing monitoring data resulted from logger maintenance problems.

Figure 2-3 Tide Gage, Cross-Section, and Pebble Count Locations

The seasonal changes in lagoon water levels are captured in the water level record. In August through early November 2002, the barrier beach remains intact. Daily diurnal fluctuations in water level up to a few tenths of a foot are present, resulting from a weak connection to ocean tides - likely a pressure response through the barrier beach sand (see Figure 2-4). Water level fluctuations of 0.5- to 1.0-foot over this period result from waves overtopping the barrier beach (wave over-wash).

The water level record in early December 2002 captures the second barrier breach of the season on December 13, 2002 (the first breach occurred during the storm of November 6-7, 2002, but no water level data is available for this event). Over 10-feet of water level drop was recorded during the December 2003 break, but the change in water level was likely several feet greater as the outlet through the barrier beach likely eroded down to the daily MLLW tide level – an elevation well below the tide gage monitoring range. Subsequent water levels through December 2002 and into May 2003 fluctuate broadly due to varying degrees of freshwater inflow and tidal exchange through the breach. Repeat cycles of breach infilling (barrier reconstruction) and subsequent erosion are seen in the water level record over this period in the form of daily to weekly fluctuations in low water levels.

The June 15, 2003 breach also resulted in a drop in lagoon water levels by at least 9 feet as seen in Figure 2-2. Again, the drop in water level was likely greater (i.e., at least several feet) than indicated by the tide gage record. The lagoon water level record indicates a rapid reconstruction of the barrier beach over the two-week period following the breach event with lagoon water levels again rising in response to relatively high inflow rates. Inflow and the seepage rate through the barrier beach equilibrate in early July 2003, as lagoon water levels level off and begin to fall in response to receding inflow rates (see Figure 2-2). The small amplitude (tenths of a foot) tidal signature returns to the water level record upon complete closure by early July 2003 with higher amplitude increases resulting from wave over-wash occurring in the late fall-early winter of 2003. As seen in the rise in lagoon water levels by up to 3 feet, wave over-wash

Figure 2-4 Lagoon Water Level vs. Pt. Arena Tide (August 15-November 2, 2002) contributes a significant volume of water to the lagoon in the late fall period. With the advent of the first storm of the winter season on November 10, 2003, lagoon water levels rise more sharply until the barrier beach is overtopped, followed by a precipitous drop in water levels of over 8-feet as waters quickly scour and erode a deep outlet, draining the lagoon.

2.2.4 Ocean Tides

Ocean tides for Point Arena Cove reported by NOAA are plotted against lagoon water levels in Figure 2-2. These tides are representative of ocean water level conditions adjacent to the Gualala River coastal lagoon. The diurnal and semidiurnal components of the tides at Arena Cove are mixed, resulting in a daily tidal regime with two high waters and two low waters, with the levels in each set displaying different magnitudes. Based on mean tidal statistics for the Arena Cove gage, the observed range between MHHW and MLLW is almost 5.9-feet. During lagoon inlet formation, the maximum scour depth through the barrier breach is controlled by the minimum (MLLW) tide range over the inlet formation period. Exchange of tidal waters between ocean and lagoon also work to keep the inlet open. Thus, the magnitude of tidal range plays an important role in scouring and maintaining an open inlet in two ways. First, the tidal range will control the total volume (tidal prism) exchanged through the inlet. The greater the tidal prism, the greater scour potential to maintain an open inlet. Secondly, it appears from a plot of Arena Cove tides that the daily higher-high water normally precedes the lower-low water, creating a maximum seaward gradient through the inlet during the larger of the semidiurnal ebb tide events. Velocities and scour potential are greatest during this period and, if acting with no external influences that reconstruct the inlet, the net tidally induced scour could possibly keep the inlet open indefinitely.

2.2.5 Wave Climate

For purposes of this report, the wave climate acting on the Gualala River coastal lagoon barrier beach refers predominantly to wave height and frequency. The waves most important to barrier-beach formation and destruction are generated by winds blowing for sufficient duration and over a long-enough distance (fetch) to create wind waves. The wave climate off the Northern California coast is influenced primarily by atmospheric-ocean interactions over the north Pacific Ocean (Ambrose and Orme, 2000).

The wave climate acting on the Gualala River lagoon barrier beach over the study period is best characterized by a series of wave variables measured at the NOAA buoy located approximately 19-miles offshore from Point Arena. These variables include:

- Significant wave height (WVHT), calculated as the average of the highest one-third of all wave heights during a 20-minute monitoring period; and
- Dominant wave period (DPD), calculated as the period with the maximum wave energy; and

These values were used to estimate corresponding deep-water wave energy (WVE) approaching the coastline and acting on the Gualala River Mouth, WVE was calculated as the product of the wavelength and the square of the WVHT, as follows:

$$\mathrm{WVE} = (\mathrm{w}*\mathrm{L}*\mathrm{WVHT}^2)/8$$

Where WVE is expressed in ft-tons, w is the weight of a cubic foot of water (64 lbs) and L is wavelength. The wavelength (L) is calculated pursuant to Bascom (1980), as follows (assuming deep-water waves):

$$\mathrm{L} = 5.12*\mathrm{DPD}^2$$

Plots of WVHT, DPD, and WVE over the study period are presented in Figure 2-2. Noise in the data is attributable to interference of two or more sets of wind-waves originating from different sources/locations. It's also worth noting that the wave climate is unrelated to the tidal regime. Some generalities about the wave climate data presented on Figure 2-2 include:

- There is a general seasonal cycle of higher wave energy in winter and lower wave energy in summer expressed by the sinusoidal shape to the annual plot of wave energy;
- Periods of maximum WVHT and WVE and short DPD have the greatest destructive effect on the barrier beach;
- Maximum WVHT and WVE that typically accompany storms combine with high lagoon inflow to breach the barrier beach; and
- Periods of long DPD (swell) and low to modest WVHT typically dominate in summer and result in barrier beach construction/buildup.

2.2.6 Barrier Beach-Lagoon-Lower River Morphology

The following section summarizes the results of an investigation into historical changes in estuary morphology. This discussion is followed by further description of the study results that describe the changes and processes observed to be controlling barrier-beach formation, destruction and lagoon morphology during the study period.

Historic Conditions

Numerous aerial photographs of the lower Gualala River and lagoon were obtained and reviewed as part of this analysis. Sources of photographs included the California Department of Forestry and Fire Protection, WAC Corporation of Eugene, Oregon, and Pacific Aerial Surveys of Oakland, California. In addition, historic USGS topographic maps and a 1929 U.S. Coast and Geodetic Survey map of the coastline were reviewed. The following aerial photographs were reviewed.

1. 1936
2. 5/12/1961
3. 2/20/1967
4. 5/04/1980
5. 6/16/1981
6. 4/21/1984
7. 8/01/1989
8. 6/17/1992
9. 3/25/1996
10. 5/19/1996
11. 4/13/1999
12. 5/19/1999
13. 4/02/2000
14. 4/22/2002
15. 7/02/2003

As discussed in greater detail below, there are notable and large-scale seasonal changes in the lagoon-barrier beach system during any given year. A review of aerial photographs indicated no notable changes in the physical setting and character of the lagoon beyond those that likely fall within the natural seasonal progression/variability. For example, no significant repositioning or erosion of various bar forms within the lower river or lagoon was observed. Interestingly, the large bar located on the west side of the summer tide gage appears to be the same size and in the same location in all photographs and on the 1929 geodetic survey map (Figure 2-5). Determining changes in the size of longitudinal and point bars on aerial photographs, in an attempt to qualitatively identify changes in sediment deposition patterns, was not possible due to highly varying river flow and lagoon water level conditions between aerial images. Thus, no definitive conclusions were reached with respect to whether lagoon bathymetry has changed over time.

Figure 2-5 1929 U.S. Coast and Geodetic Survey Map

The inlet breach also appears to occur at the north end of the barrier beach in all photographs, either immediately adjacent to or within several hundred yards of the bedrock cliff marking the north end of the lagoon. There are anecdotal accounts of the breach occurring closer to the south end of the beach during extreme flood events during an El Nino period. However, these types of breaches start out as overtopping along the entire barrier length. Because of the coastline geometry, net coastal wave climate, and littoral sand transport patterns, it appears that the south end of the barrier beach is consistently higher in elevation than the north end, suggesting that most barrier breaching will set up at the north end of the beach except during extreme, overwhelming flood events.

Changes Over Study Period

The near-weekly photo-point monitoring of the Gualala River lagoon/barrier beach was very helpful in capturing and documenting the variability in the seasonal cycles of system evolution. A summary of photo-point observations is presented in Table 2-1. The following information and observations are included on the Table:

- Whether the inlet (barrier beach breach) is open or closed;
- Occurrence of active wave over-wash;
- Evidence for previous wave over-wash;
- Estimated lagoon water level;
- Presence and estimate of high water erosion lines;
- Water color in terms of the presence of significant sediment inflow to the lagoon (brown color) or presence of salt-water in lagoon (turquoise color); and
- Presence of flood debris or kelp in/on in lagoon and beach.

Photo point observations provided the most definitive chronology of barrier beach breaching and reconstruction over the study period. Observations of whether the inlet was open or closed and periods of active wave over-wash are also presented graphically on the lower pane of Figure 2-2.

Table 2-1 Photo-Point Monitoring Observations (1 of 2)

Table 2-1 Photo-Point Monitoring Observations (2 of 2)

A pair of lagoon/barrier-beach surveys was completed over the study period in order to capture and quantify changes in cross-sectional lagoon profiles between September 28, 2002 and June 22, 2003. Cross-sectional survey locations are indicated on Figure 2-3 while profiles are presented on Figure 2-6 through Figure 2-9. The September 2002 and June 2003 profiles are presented together on each location-specific graphic. The September 2002 surveys reflect closed inlet conditions during the late summer of 2002 while the 2003 surveys capture the post-late season breach of June 15, 2003. Although the inlet was open to tidal exchange in late June 2003, the survey occurred during a period of barrier beach reconstruction and inlet infilling. Figure 2-6, a profile completed parallel to the north end of the barrier beach, illustrates the difference in closed versus breached beach conditions. Note that the breach of June 2003 was still over 200 feet wide and over 8-feet deep at the time of the survey.

Figure 2-7 presents east-west cross-sectional profiles through the north end of the lagoon. The west end of this section is located in the barrier beach while the east end is located at the base of the cliff-face (see Figure 2-3). The substrate encountered in this section consisted entirely of barrier beach sand along the western part of the transect and bedrock along the eastern portion. The difference in barrier beach morphology between surveys is striking in this section as the beach in September 2002 encroaches much further into the lagoon (east) than in June 2003. This contrast illustrates the phenomenon of landward migration of the barrier beach during the summer beach reconstruction phase in the form of wave over-wash lobes. The net effect is the migration of sediment from the beach face and crest to the landward side of the barrier, resulting in landward (eastern) migration of the barrier beach into the lagoon.

Further to the south, upstream of the barrier beach, changes in the cross-sectional profile of the lagoon are not as dramatic. At the summer gage profile location, there appears to be some infilling of the small channel on the west side of the gage and minor scour of the channel to the east (see Figure 2-8). Apart from these changes, survey results indicate there was little change in the size and shape of the large central bar and far western

Figure 2-6 Cross-Secional Profiles of Lagoon Inlet – 9/28/02 and 6/22/03

Figure 2-7 Cross-Secional Profiles at North End of Lagoon – 9/28/02 and 6/22/03

Figure 2-8 Cross-Secional Profiles at Summer Tide Gage – 9/28/02 and 6/22/03

Figure 2-9 Cross-Secional Profiles at Mill Bend – 9/28/02 and 6/22/03 channel over the study period, even in response to the high flow events of December 2002. It is worth noting that with the exception of bedrock on the east bank and the rip-raped filled crib island that serves as the summer tide gage location, the entire bed along this section consists of river derived sand, gravel and cobbles. It is unclear, based solely on a visual inspection of Figure 2-8, if the summer gage cross-section experienced net aggradation or degradation between survey events.

Cross-sectional survey results at Mill Bend display a redistribution of river derived sand and gravel from the upper-most portion of bar to the deep pool at the toe of bar between September 2002 and June 2003 (see Figure 2-9). With the exception of the bedrock that comprises the left (south) bank, the majority of material that makes up the point bar is river sand, gravel and cobble. Again, visual comparison of cross-sectional profiles at Mill Bend does not provide a clear indication of whether there was net aggradation or degradation of the point bar at Mill Bend between survey dates.

Monitoring of point bar grain size also indicates the redistribution and/or turnover of gravel in lower river bars over the study period. Pebble counts were completed on a total of six gravel bars within the upper lagoon and lower River on 9/13/02 and 9/24/03. Gravel bar sample locations are indicated on Figure 2-3. The grain size distribution graphs for each sampling event are provided in Appendix A along with a comparison between 2002 and 2003 sample events. The significant results of this analysis were: 1) grain size distributions varied widely among bars during the 2002 sample period with the mean grain size (D50) varying between 10mm and 50mm; 2) grain size distribution varied significantly less between bars sampled in 2003, with D50's ranging from approximately 14mm to 23mm; 3) no pattern of down-stream fining in grain-size was observed during either sampling event; and 4) grain size distributions varied noticeably between sample dates at all six point bars ,suggesting sediment turn-over along the entire sampled reach during the winter of 2002/03.

2.3 Lagoon Morphodynamics

Combining all of the data and observations collected over the study period (photo-point monitoring, lagoon cross-sectional surveys, lagoon water level recordings, grain-size sampling, freshwater inflow, and wave climate data) provides a detailed description of the cause and effect relationships that control the Gualala River coastal lagoon morphology. This section of the report attempts to describe these changes in terms of dominant physical processes and consequences to lagoon habitats.

In general, the Gualala River mouth follows a seasonal pattern where the barrier beach breaches during the first major floods of the winter rainy season. The typical wave climate (lower wave energy) and low freshwater inflows of summer allow for infilling of the inlet and reconstruction of the beach barrier. As was observed over the study period, there are several cycles of barrier breaching and partial reconstruction throughout the seasonal transitions between end member states. However, the highly variable climate of Northern California may lead to similarly unpredictable lagoon conditions. For example, barrier beach formation may be delayed during wet years due to prolonged high inflow and destructive wave energy. Closure of the beach during moderate inflow may allow for high water levels to develop in the lagoon that overtop and incise through the barrier beach.

The cycle of Gualala River coastal lagoon barrier-beach breaching and reconstruction can be described in terms of beach/lagoon morphology and dominant physical processes controlling that form. A chronological description of these evolving morphodynamic states follows. It is important to realize that the timing, resultant form, and duration of these phases are not “set in stone,” and this synthesis simply reflects the conditions that existed over the study period.

During the summer months of July through September, the barrier could be described as stationary, implying a beach in equilibrium with environmental forces. Characteristics and typical conditions that give rise to this form include: low wave energy with waves dominated by low amplitude swells, neap tidal conditions, prolonged absence of freshwater inflow, and absence of storm waves. This is typically a period of beach face construction. The beach face also displays the lowest gradient normal to the shoreline during this state.

With an increase in wave energy (high magnitude, long period waves) into late fall (October and November), a state of onshore barrier beach migration develops. Notable characteristics of this stage include, continued minimal freshwater inflows, onshore sediment transport and a lower gradient beach face slope, and most notably, wave over-wash. The wave over-wash pushes sand off the crest of the beach, creating over-wash lobes that build off the barrier backslope, extending for significant distance into the lagoon. These prominent features account for the significant change observed in barrier beach morphology captured in the cross-sectional surveys described above and illustrated in Figure 2-7. These features also give rise to steep back barrier beach slopes both above and below the lagoon water surface.

As wave energy increases with the advent of winter storms, beach-face erosion overtakes beach replenishment due to a net increase in destructive, high magnitude, low period waves, especially at higher tide stages. These processes also lead to a characteristically steeper winter beach face. Partial to whole-scale breaching occurs as a result of high lagoon water levels associated with increased freshwater inflows. As seen throughout the winter of 2002/03, the resultant lagoon inlet will remain open after breaching as long as there is sufficient freshwater inflow to the lagoon to counter constructive wave activity at the beach face. This is typically a punctuated process whereby the magnitude of constructive and destructive forces changes on a daily basis with the inlet morphology following suite. For example, the initial breaches in early November of both 2002 and 2003 did not occur until the onset of the first storms and relatively high freshwater inflow. In both cases, inlets quickly filled with sand and the barrier beach reformed due to a rapid recession of inflow rates back to relatively low late-fall magnitudes.

Conversely, barrier breaches that occur later in the winter season (e.g., December of 2002) remain open primarily due to sustained high magnitude freshwater inflow rates.

The breaching event of June 15, 2003 was unique in that it was not triggered by a single storm inflow pulse, but resulted from a gradual lagoon filling from relatively high seasonal base flows sustained by the above average April 2003 rainfall contributions to the watershed. Breaching in this instance occurred as a result of the lagoon over spilling the barrier beach. In the evening of June 15, 2003, there was an extreme difference in water surface elevation between lagoon and ocean water surfaces, as the breach occurred during the lower-low water stage of a spring tide cycle. As a result, an estimated 564-acre-feet of water drained from the lagoon over a span of 24-hours. Based on a post-breach cross-sectional survey (Figure 2-6) and recorded lagoon water levels, it is estimated that the erosive energy from this event resulted in an approximately 250-foot wide breach of over 10-feet deep.

Barrier beach reconstruction after the June 15, 2003 breach was relatively rapid and freshwater inflows began refilling the lagoon (see Figure 2-2). By early July 2003, outflows from the lagoon (as evaporation and seepage through the barrier beach) exceeded inflow and lagoon water levels began to decline. Equilibrium between lagoon inflow and outflow was again reached by mid-August of 2003, resulting in relatively static lagoon water levels and barrier beach morphology until the onset of wave over-wash events in early October 2003.

2.4 Lagoon Water Quality and Habitat Relations

The majority of water quality monitoring for this study was completed by ECORP Consulting, Inc. (presented in Chapter 3.0 of this report) and North Coast Regional Water Quality Control Board staff (RWQCB) (Dudik, 2003). KHE completed supplemental water quality monitoring on several occasions throughout the study period. This section of the report provides a summary of project water quality-monitoring results as they relate to the morphodynamic stages of lagoon and barrier beach development.

The short-term cycles of barrier beach/inlet breaching and reconstruction over the winter season result in sharp changes in lagoon salinity. The RWQCB monitoring results for the period February 19-24, 2003 indicate that during periods when the majority of the inlet is partially closed and experiencing limited tidal exchange during high tide periods (i.e., lagoon water level fluctuations up to 2-feet) the lagoon becomes a freshwater system, except for the deeper portions of pools along Mill Bend. With the advent of higher wave energy, wave overwash and barrier breaching, like that seen on February 24, 2003, high salinity waters quickly invade the lagoon during flood tide, raising lagoon salinities to 20 parts per thousand (ppt) near the summer tide gage and up to17 ppt at Mill Bend. These same monitoring results indicate that salinities quickly fall back to the freshwater range later in the day as the lagoon drains during the ebb tide and high freshwater inflow essentially flush the system.

RWQCB water quality monitoring results for the period May 30-June 2, 2003 indicate that the inlet is still open but the effects of salinity intrusion do not appear to encroach up to Mill Bend even though lagoon water levels fluctuate by up to 5-feet in response to daily tidal cycles. Over this monitoring period, salinity concentrations range between 0.0 and 17 ppt at the summer tide gage site, but remain entirely within the freshwater range in the shallow portions of Mill Bend. Where seen, shallow water salinity concentrations rise and fall in concert with tidally induced changes in lagoon water levels and concentrations quickly return to the freshwater range during ebb tidal periods due to relatively high freshwater inflow rates.

Monitoring of lagoon water quality on June 26, 2003 was completed during the inlet/beach reconstruction phase following the late season breach of June 15, 2003. The RWQCB reports that the inlet was essentially closed at this time as also indicated by the lagoon water level record. Water level and photo-point monitoring data indicate open inlet conditions bracket this event during the days leading up to and preceding the sampling event. Water quality monitoring during this event consisted of completing a series of 12 evenly spaced vertical profiles from the inlet mouth to upstream of the Highway 1 Bridge. Results of water quality monitoring indicate stratified conditions from the Ocean up to the Highway 1 Bridge, consisting of a 2.5- to 3.0-layer of freshwater overlying saline water. The boundary between fresh and saline water was sharp and laterally continuous. A repeat of this same water quality monitoring approach on July 30, 2003, one month after final barrier beach construction, revealed the lagoon consisted entirely of freshwater with the exception of remnant saline pockets in the deepest parts of the Mill Bend pool.

Water quality monitoring in the mid-summer to early fall (July through September) during the static stage reveals the lagoon is a freshwater body with the exception of the stagnant saline pocket trapped at depths (greater than 8-feet) in the Mill Bend pool. The October 23, 2003 water quality monitoring, completed by the RWQCB, occurred during a phase of periodic wave overwash. As a result of the overwash, lagoon salinities were elevated to varying degrees (concentrations ranging from 0.43 to 9.16 ppt) between the former inlet location and the Highway 1 Bridge. Well-developed stratified conditions did not exist, although higher salinities were detected in deeper pools.

Based on results of hydrologic monitoring and investigations, the North Fork Gualala River is an important source of baseflows to the lower Gualala River during the late season periods when the lagoon is prone to high salinity conditions. Figure 2-10 presents a comparison of daily flows at the USGS gages on the North Fork, South Fork, and Wheatfield Fork during WY2001. Although there are flows contributing to the lower river from the South Fork (not represented in Figure 2-10), the geologic and land-use conditions in the North Fork simply allow it to contribute a greater runoff per unit area than the other major tributaries feeding the lower river.

Figure 2-10 Daily Flow Rates – North Fork, South Fork, and Wheatfield Fork (WY2001)

Although the Gualala River coastal lagoon adjusts in a predictable manner to natural conditions and processes, it is important to realize that the changes are controlled by subtle shifts in the balance of physical forces. The hydrologic and water quality characteristics within the coastal lagoon throughout the year control the extent and quality of aquatic habitat for resident species. Thus, any change to the timing or magnitude of any given characteristic or physical process brought about by human activity may have significant adverse affects on the lagoon ecology. Wave climate and tidal conditions are not likely to change over the long term. However, changes in freshwater inflow and sediment delivery rates may introduce instability and adverse impacts to lagoon habitat quality. There are numerous examples of how changes in water delivery and mechanical barrier breaches have adversely impacted aquatic habitats in other California coastal river systems (Redwood National Park, 1983; Environmental Science Associates 2003; Ambrose & Orme, 200; Smith, 1990 & 1987; and Swanson et al, 1990). Based on the monitoring completed over the study period, it appears that the Gualala Coastal lagoon functioned in a natural and healthy manner during the “normal” and “below average” water year-type conditions and was dominated by fresh-water conditions.

2.5 References

Ambrose, R.F. and Orme, A. R., 2000, Lower Malibu Creek and lagoon resource enhancement and management. Final report to the California State Coastal Conservancy, University of California, Los Angeles, May.

Bascom, W., 1980, Waves and beaches, the dynamics of the ocean surface. Anchor Books, New York, 366p.

Dudik, E., 2004, Gualala River estuary water quality physical-chemical sampling, February 19 – October 23, 2003. North Coast Water Quality Control Board, January 23, 65p.

Environmental Science Associates, 2003, McGrath State Beach Natural Resources Management Plan Final. Prepared for: California Department of Parks and Recreation, Channel Coast District, Santa Barbara, CA, 169p.

Klamt, R.R., LeDoux-Bloom, C., Clements, J., Fuller, M., Morse, D., and Scruggs, M., 2003, Gualala River watershed assessment report, North Coast Watershed Assessment Program. California Resources Agency and California Environmental Protection Agency, Sacramento, CA, 367p. (plus Appendices).

Rantz, S.E., and Thompson, T.H., 1967, Surface-water hydrology of California coastal basins between San Francisco Bay and Eel River. U.S. Geological Survey Water-supply Paper 1851, 60p.

Redwood National Park, 1983, Management alternatives for the Redwood Creek estuary. Prepared by Redwood National Park, March, 50p.

Smith, J.J., 1990, The effects of sandbar formation and inflows on aquatic habitat and fish utilization in Pescadero, San Gregorio, Waddell and Pomponio Creek estuary/lagoon systems, 1985-1989. Prepared under interagency agreement 84-04-324, between Trustees of California State University and the California Department of Parks and Recreation, Department of Biological Sciences, San Jose State University, San Jose, CA, December 21, 38p.

Smith, J.J., 1987, Aquatic habitat and fish utilization of Pescadero, San Gregorio, Waddell and Pomponio Creek estuary/lagoon systems. Prepared under interagency agreement 4-823-6004, between Trustees of California State University and the California Department of Parks and Recreation, Department of Biological Sciences, San Jose State University, San Jose, CA, May 31, 32p.

Sorensen, J.C., Gable, F., and Bandarin, F., 1993, The management of coastal lagoons and enclosed bays. Proceedings from Coastal Zone 93, 8th symposium on coastal and ocean management, New Orleans, LO, July 19-23, 1993, American Society of Civil Engineers, New York, 293p.

Swanson, M.L., M. Josselyn, and J. McIver, 1990, McGrath State Beach Santa Clara River Estuary Natural Preserve Restoration and Management Plan. Prepared for: The California Department of Parks and Recreation, Central Coast Region, Monterey, CA, October, 74p.

CHAPTER 3.0 AQUATIC ECOLOGY

3.1 Introduction

The aquatic monitoring tasks were the responsibility of ECORP, including fish and benthic macroinvertebrate monitoring, and water quality monitoring.

The objective of the Water Quality Study Component was to:

- provide seasonal water quality profiles throughout the Gualala Estuary, including temperature, dissolved oxygen, pH, conductivity and salinity.

The objectives of the Aquatic Ecology Study Component were to:

- determine distribution and abundance of salmonids in the Gualala Estuary,
- describe seasonal habitat conditions in the Gualala Estuary,
- describe seasonal habitat availability in the Gualala Estuary,
- develop a species list and relative abundance of all observed fish, birds and mammals, and if possible given budget considerations,
- determine adult steelhead use and timing of migration through the Gualala Estuary

Adult steelhead use and timing of migration was not addressed in this report due to budget considerations.

3.2 Methods

3.2.1 Water Quality

To evaluate potential water quality affects on salmonids present in the lagoon, especially during low flow conditions, water quality profiles (i.e., parameter measurements with depth) were obtained concurrently with all fish sampling efforts. Water quality profiles consisted of a series of measurements recorded at prescribed intervals, from the surface to the bottom of the water column. Profile data parameters included temperature, dissolved oxygen, conductivity, salinity, and pH. Additionally, continuous recording temperature units were used to record water temperatures 0.5 meters below the surface and 0.5 meters off the bottom at selected locations.

All water quality data were tabulated and graphed by site location and date. An analysis of water quality conditions at varying estuary water surface levels, as well as open vs. closed estuarine conditions, was conducted. Based on this analysis, a range of preferable water surface levels was identified to assist in potential management of the estuary.

3.2.2 Aquatic Ecology

To adequately sample and evaluate aquatic habitats and species in the lagoon, the estuary was divided into three sections: lower estuary section, middle or transitional section, and upper or riverine section (Figure 3.1). These divisions were based primarily on habitat characteristics, substrate types, and flow conditions within the lagoon. The lower estuary section extends from the mouth of the river [River Mile (RM) 0.0] upstream to a point where the coastal vegetation community become established along the south bank at RM 0.4. The middle estuary (i.e., transitional section) extends from the upstream end of the lower estuarine section to just upstream of the GRI (Gualala Redwoods, Inc.) Beach (just downstream of the Highway 1 Bridge), RM 0.4 to RM 1.2. The upper estuary (i.e., riverine section) extends from the Highway 1 Bridge at RM 1.2, upstream to the confluence with the North Fork Gualala River at RM 3.4.

Aquatic Habitat Types

Aquatic habitat types within the Gualala River estuary were measured using standard techniques developed by the CDFG and utilized in the North Coast Watershed

Figure 3.1 Project Site and Vicinity

Assessment Program (NCWAP) studies. Habitat types were based primarily on the combined affects of differences in salinity, depth, and substrate parameters within the estuary. In general, three distinct habitat subsystems are present in the Gualala estuary: marine, brackish, freshwater lagoon, and riverine. The brackish water subsystem is normally the area near the estuary mouth, and is characterized by high wave or tidal energy, course sand or rocky substrates, and moderate salinities. The riverine subsystem often consists of a narrow, subtidal river channel that may be seasonally influenced by salt water, or may contain freshwater throughout the year.

3.2.2.1 Fisheries

This study was designed to collect fisheries data throughout the Gualala estuary to develop population estimates for juvenile steelhead residing in the estuary, and to describe fish species composition and abundance. Sampling within the estuary was focused on summer through fall months to obtain fish population data during summer and fall low-flow conditions. During this time period, habitat for juvenile steelhead in other portions of the basin is generally limiting due to both natural and human-induced factors, and in turn affects steelhead carrying capacity in the estuary.

2002 Season

Field sampling was initiated in June 2002 and was conducted every three weeks through November 2002. Fish sampling was conducted using a 100-foot bagged beach seine (1/8 inch delta mesh). Samples were collected within the three estuary sections (upper, middle, and lower) to obtain sufficient data to describe fish and macroinvertebrate distribution patterns relative to different water quality and substrate conditions present within the three estuary sections. Approximately 20 hauls were completed within the estuary during each sampling event. Beach seining was complemented by quantitative assessments of habitat quality, substrate evaluation, and water quality measurements.

Originally, the fisheries sampling design was conducted every three weeks beginning in late spring and extending through the fall, to provide sufficient data to characterize the steelhead population structure and to calculate population estimates for the estuary. However, during the 2002 August sampling event, riverine sampling upstream of the Highway 1 bridge became difficult due to dense blooms of filamentous algae. Because of the extreme difficulty associated with sampling in areas with algal blooms, a decision was made to decrease sampling in the upper section.

During the initial October sampling, an additional sampling day was added following the normal mark/recapture sampling event to independently estimate the steelhead population at that time. Also, the fall 2002 sampling effort was extended into November to take advantage of the fact that the estuary remained closed, and we could gain further understanding of steelhead use of the estuary in late fall.

2003 Season

From further discussions at the TAC meeting after the first year of sampling had been completed, two general issues arose:

- that upstream migration of juvenile steelhead from the lower estuary into the upper estuary or river may occur during breaching, and
- that based on observations reported by CDFG biologists during summer snorkel surveys in the NF Gualala River, Coho salmon may still be present in the estuary.

To address the above issues, field sampling in 2003 began in February to evaluate the presence/absence of Coho salmon in the estuary, since Coho salmon are known to utilize estuarine habitats elsewhere along the California coastline early in the year (Cannata 1998). Also, sampling effort was increased in the riverine section of the estuary to obtain additional data for evaluating the potential for upstream migration of juvenile steelhead during late fall. The increase in the number of upstream hauls likely had an affect on abundance estimates for some species (in particular, three-spine stickleback) for 2003, as compared to the 2002.

After the February sampling event, sampling was resumed in May, and then continued monthly through October 2003.

Sampling Protocols

Seining was the primary method for fish sampling throughout the estuary. In most cases, the seine was deployed parallel to the shoreline, at a distance of about 75 feet from the shoreline, from an inflatable boat. At least a four-person crew then pulled the seine into shore. However, in the riverine section near the confluence with the North Fork, the seine was set along one side of the river channel and pulled across the river channel to the other side of the river. Also, in some backwater areas, a two-person 10-meter seine was also used to sample in and around submerged and emerged vegetation. Fish caught in the beach seine were identified to species, then measured to fork length (to the nearest mm) and weighed (to the nearest 0.1 gram). All specimens were immediately returned to the water, except for steelhead 80 mm or greater in length, which were fin-clipped and marked with a freeze brand to identify the catch from each sampling event. Additionally, during each sampling event, lengths were recorded for a representative number of fish species other than salmonids (i.e., the first 30 recorded of each species).

Population Analysis

Marking and subsequent recapture of steelhead allowed for population estimates within the estuary at **Time sub-i**. Steelhead population estimates were made using two different estimators; a modified Petersen (Schnabel and Schumacher, (Ricker, 1975)) mark/recapture strategy, and the Jolly-Seber estimator. The modified Petersen estimator assumes a closed system with no recruitment or mortality. The Jolly-Seber method assumes an open system and allows a calculation of survival for each sampling event.

Each estimator functions independently of the other, which provides two different approaches to estimating population size.

Individual steelhead lengths and weights were also used to assess fitness of Gualala River juvenile steelhead in the estuary throughout the summer and fall. Fish size and fitness were compared to fish from other north coast systems sampled by CDFG, and from other past sampling efforts (e.g., Sonoma County EIRs).

Data collected during the two sampling years were tabulated by date and estuary section to document the temporal and spatial distribution patterns of steelhead within the estuary. These data were also compared against physical habitat characteristics and water quality parameters, using non-parametric statistics to analyze potential limiting factors in estuary productivity. Standard analytical techniques were incorporated, including calculation of condition factor, development of length-frequency histograms, and the calculation of tri-weekly population estimates from mark-recapture sampling.

Steelhead Stomach Analysis

Steelhead stomach analyses were completed on all steelhead mortalities associated with field sampling. Steelhead mortalities were placed into labeled jars with 10% buffered formalin, and transported to the ECORP Consulting, Inc. laboratory facilities in Roseville for later analysis. A few specimens were analyzed together due to mixing of stomach contents when specimens were prepared for fixation. Each fish was dissected and the entire digestive system examined. Organisms were identified to lowest taxonomic level depending on the condition of the specimen.

3.2.2.2 Benthic Macroinvertebrate Surveys

Benthic macroinvertebrate (BMI) sampling in the Gualala estuary was conducted in three reaches: lower reach - RM 0.4 to RM 1.1; middle reach - RM 1.6 to RM 2.0; and upper reach - RM 2.5 to RM 3.2. In 2002, three sites per reach were sampled during the July fish sampling event under closed lagoon conditions. A second set of samples was collected in 2003 in the middle estuary (RM 0.8) during the May sampling effort, while the lagoon was breached and the river was flowing to the ocean. During breach conditions, riffle habitat becomes more abundant and is similar to that found in the upstream riverine reach.

Sampling was conducted with a kick-net according to the CDFG California Stream Bioassessment Procedure (CSBP) protocols for streams and rivers. Three 1 ft x 2 ft areas along each transect were sampled using a D-framed kick net with standard mesh (0.5 mm). The three samples were placed into a bucket, elutriated using a standard sieve (0.5 mm mesh; #35 sieve), and processed to remove excess fine sediment and debris. The remaining sample was placed into a container with 95% ethanol and then stained with Rose Bengal dye.

A modified sampling method was used to collect benthic macroinvertebrates in the lower (non-flowing) part of the estuary. In this lower section, three distinct areas were chosen to collect samples: one in an area of widgeon grass, one in a gravel area, and one along the Mill Bend area. During sampling, a five to six foot area was agitated and multiple sweeps with the kick-net were performed to collect the sample. The samples were then placed into a 0.5 mm sieve, and large pieces of course particulate organic matter (CPOM) were inspected for clinging organisms and then discarded.

In the laboratory, each sample was placed into a grid-lined sub-sampling pan (5-cm square cells). A random number table was used to choose random grids and all material (detritus and invertebrates) was removed from the pan. The sub-sample was sorted using stereo dissecting microscopes at 10X magnification. A total of 300 organisms were removed from each sample for identification. Any remaining macroinvertebrates were removed from the subsample, enumerated, and placed into a separate labeled vial (i.e., sample ID, date collected, amount of subsample and number of macroinvertebrates) containing 70% ethanol. The taxonomic identification of organisms was conducted according to the CSBP Level III protocols (genus and species).

3.3 Results

3.3.1 Water Quality

Water quality data were collected from June through November 2002, and from February through October 2003. Sampling was conducted during both closed (2002) and open (2003) conditions. During most sampling events, water quality profile data were collected in association with fish sampling efforts. Water quality profiles consisted of a series of measurements recorded at equal intervals from the water surface to the bottom of the water column. Profile measurements included; temperature, dissolved oxygen (D.O.), conductivity, salinity, pH, and turbidity as total dissolve solids (T.D.S.). Water temperatures were also recorded at 0.5 meters below the surface and at 0.5 meters above the bottom. All water quality data was tabulated and graphed by site location and date. These data were also grouped for analysis of open vs. closed estuarine conditions.

In addition to collecting water quality data at fish sampling sites, profiles were also taken at specific locations throughout the estuary during each sampling event. These additional water quality stations were located in the following areas:

- mouth of estuary,
- near the tide gage,
- near China Gulch,
- Mill Bend, and
- 100 m above Highway 1 Bridge

The locations of all water quality profile sampling stations are provided in Figure 3.2. Raw water quality profile data are provided in Appendix B, by sampling year, month, and estuary location.

Figure 3.2 Gualala Estuary Sampling Site Locations

Water Quality Depth Profiles

Water quality depth profiles were collected at selected locations within the estuary in conjunction with most fish sampling events in 2002 and 2003. The following section describes the general water quality conditions present within the estuary during these sampling periods.

Summer Period (June through August)

June:

In June 2002, water quality profiles obtained in the lower and middle estuary up to Mill Bend, showed well-mixed conditions for all parameters (Appendix B-1 through B-4). Water temperatures ranged from about 18.0 – 19.0 °C, salinity readings were slightly above zero, and D.O. varied from about 7.0 – 9.0 mg/L. The water quality profile at the long pool at Mill Bend showed that salinity stratification (from 0 to 27 ppt) had occurred between 9.0 and 10.0 ft deep (see Appendix B-4). Water temperatures remained relatively constant with depth ranging from about 17.0 – 18.0°C; however, D.O. levels decreased substantially from about 8 to 9 mg/L in the surface layer, to about 3 mg/L at a depth of 12 ft. Below 12 ft. depth, D.O. continued to drop to a minimum value of about 2 mg/L on the bottom (20 ft deep).

As expected, water quality profiles obtained in June 2003 under open lagoon conditions showed a substantially different environment in the estuary relative to the closed lagoon conditions present in 2002. At the mouth of the estuary, marine conditions dominated the water column with salinities and associated T.D.S values ranging from about 30.5 ppt on the surface to 33.5 ppt on the bottom (at 6 ft deep) (Appendix B-27). Water temperature, D.O., and pH values were relatively consistent with depth: averaging 11.0°C, 10.0 mg/L, and 7.8, respectively.

Moving upstream from the mouth, profiles collected at the tide gage and at China Gulch indicated more brackish conditions (7-17 ppt) on the surface (upper 2 ft of the water column) (Appendix B-28 and B-29), below which, salinity returned to about 33 ppt. As before, the T.D.S. profile mimicked the salinity curve. Water temperatures decreased from a range of 15.0 to 17.0°C on the surface, to about 11.0°C at a depth of 3 ft. Values obtained for both D.O. and pH were relatively constant throughout the water column, with values averaging about 10.0 mg/L and 8.0, respectively.

The profile obtained at Mill Bend (Appendix B-30) also showed the increased presence of freshwater, but also showed salinity stratification from less than 0.5 ppt in the surface layer, to about 24 ppt between the depths of 7 and 8 ft. The water temperature profile showed a substantial drop in temperature at and below the stratification layer (from 20.0°C to about 13.0°C), with no associated decrease in D.O. Both D.O. and pH values were relatively stable throughout the water column, with values ranging between 10.0 and 11.0 mg/L and 7.0 to 8.0, respectively.

Water quality data collected at the shallow (4 ft deep) site 100 m above the Highway 1 Bridge showed the same general profile and parameter values as that described above for the upper 7-ft of the water column at Mill Bend (Appendix B-31).

July:

During the July 2002 sampling effort, Mill Bend was the only site that water quality profiles were collected. By July, salinity stratification (from 0 to 25 ppt) occurred at the surface between 0 and 1-foot of water (Appendix B-5). Water temperatures in the stratification layer increased substantially (~22.5 – 26.5°C), then decreased below the salinity wedge to a minimum temperature of about 21.0°C, and then gradually increased again to a maximum temperature of about 27.0°C at the bottom (~15 ft deep). Dissolved oxygen levels fluctuated slightly with increasing depth, but values were generally between 7.0 to 8.0 mg/L. Well-mixed freshwater conditions were observed above the Highway 1 Bridge (Appendix B-6).

Water quality data collected during the July 2003 sampling effort showed a change in the estuary from primarily marine conditions to a freshwater environment. Profiles obtained in the lower and middle estuary up to Mill Bend documented well-mixed conditions, with salinities <0.5 ppt (Appendix B-32 and B-33). Water temperatures throughout the water column were warm, ranging from 21.5°C at the mouth of the estuary to slightly over 22.0°C at China Gulch. Dissolved oxygen values were relatively consistent with depth, ranging between 9.0 and 10.0 mg/L; and a stable pH of 8.5. As noted earlier, T.D.S. values paralleled the salinity readings.

At the Mill Bend station, stratified conditions were still present, ranging from 0 on the surface to about 21 ppt on the bottom (Appendix B-34). Water temperature increased from 20.5°C in the surface layer to about 24.0°C below the stratified layer. Total dissolved solids increased proportionately with increasing salinity. Dissolved oxygen levels in the upper 11.0 ft of the water column averaged about 9.0 mg/L. However, D.O. levels within and below the stratification layer showed a substantial increase in concentration, which must be considered an anomalous response to increased salinity and temperature. As noted in June, values for pH were relatively stable with depth, ranging from 7.0 to 8.0.

At the shallow site 100 m above the Highway 1 Bridge, water quality data showed the same general profile and parameter values, except for D.O., which was slightly lower in July at about 8.0 to 8.5 mg/L (Appendix B-35).

*Augus*t:

As in July 2002, August 2002 water quality profiles (collected on two separate dates) were only obtained at Mill Bend. On August 2, salinity stratification (from 0 to about 25 ppt) was still present at the site, but had moved from the surface into deeper water between 10.0 and 11.0 ft deep (Appendix B-7). The water column above the stratification layer was well mixed, with water temperatures averaging about 18.0°C, and D.O. values around 8.0 mg/L. Within and below the stratification layer, water temperatures increased sharply to about 25.0°C at a depth of about 15 ft., and D.O. levels dropped to about 6.5 mg/L. On August 13, a second profile was obtained at Mill Bend that generally showed deteriorating water quality conditions at the site (Appendix B-8). The stratified layer (from 0 to about 22 ppt) had expanded into shallower water, and was now located between 5.0 and 11.0 ft deep. Surface waters had remained about the same (18.0°C), and temperatures at and below the stratification layer were still warm, averaging about 23.0°C. Below the stratified layer, D.O. levels continued to drop, ranging between 4.5 and 6.0 mg/L between 10 ft deep and the bottom (15 ft deep).

In August 2003, water quality profiles were obtained at the mouth of the estuary, and at Mill Bend. At the mouth, water column conditions showed well-mixed conditions reflecting a freshwater environment (Appendix B-36). Water temperatures throughout the water column were still warm, averaging >21.0°C. Dissolved oxygen levels fluctuated slightly with depth, but were generally between 10.0 and 11.0 mg/L. Values for pH (about 8.8) were stable with depth.

At Mill Bend, salinity stratification (0 to about 22 ppt) had moved slightly deeper, occurring between 12.0 and 13.0 ft deep (Appendix B-37). In the water column above the stratification layer, water quality parameters were generally similar (except surface water temperature which dropped to an average of about 19.5°C) to the values obtained at the mouth of the estuary. At and below the stratification layer, water temperatures increased to a maximum of about 23.0°C, D.O. decreased rapidly to just above zero from 13 ft deep to the bottom (16 ft deep), and pH decreased slightly to about 7.0.

Fall Period (September through November)

September:

In late September 2002, the water quality profile at the long pool at Mill Bend showed that salinity stratification (from 0 to 25 ppt) had occurred between about 6 and 10 ft deep (Appendix B-9). Surface water temperatures were about 17 °C, but increased rapidly to about 21.0°C below the stratified layer. Dissolved oxygen levels decreased substantially in the saline layer from about 7.5 mg/L at about 6 ft deep, to <1.0 mg/L at 10 ft deep. Below 10 ft deep, D.O. increased rapidly again and at 13 ft deep, was back to surface concentrations.

Profiles obtained in late September 2003 showed relatively well mixed conditions from the tide gage upstream to the Highway 1 Bridge (Appendix B-39 through B-42), as observed during the summer months (see Appendix B-31, B-35, and B-42). At the mouth, the profile indicated some influence of ocean wave-wash, with slightly increased salinity below 10 ft deep (Appendix B-38). Salinities throughout the estuary were <0.5 ppt., and surface water temperatures were generally warm (between 20.5 and 21.5°C); however, water temperatures decreased with depth. In the lower estuary (from the mouth to China Gulch), water temperatures below a depth of about 2 ft were generally 2.0 to 3.0°C cooler than on the surface. The greatest decrease in temperature occurred at the stations located at Mill Bend and 100 m above the Highway 1 Bridge where water temperatures below a depth of about 4 ft were >3.0°C cooler than surface temperatures. The substantial decrease in temperature observed at the station above the Highway 1 Bridge is unusual considering the shallow depth. D.O. levels fluctuated with depth at most sites, but were generally in the range of 9.0 to 11.0 mg/L; and pH values averaged between 8.0 and 9.0.

October:

The water quality profile at Mill Bend showed that the salinity stratification had weakened slightly (relative to September) to a maximum salinity of 17 ppt, within a depth range of about 6 ft (Appendix B-10). Surface waters had cooled slightly from September to about 15.0°C, and decreased further to about 13.5°C below the salinity wedge. Dissolved oxygen concentrations on the surface were low (about 6.0 mg/L) and decreased to about 4.0 mg/L within and below the stratification layer.

Water quality profiles collected in late October 2003 showed evidence of salt-water intrusion throughout the lower and middle estuary, up to and including Mill Bend (Appendix B-43 through B-45). Upstream of Mill Bend (station located 100 m above the Highway 1 Bridge), the estuary was still well mixed, with a salinity of < 0.5 ppt, water temperatures between 13.5 to 15.0°C, D.O. levels between 7.5 and 8.5 mg/L, and a pH of around 8.2 (Appendix B-46).

Below Mill Bend, salinity stratification began at a depth of about 3 ft and gradually increased with depth to a maximum of 12 ppt on the bottom. As expected, profiles for conductivity and T.D.S. mimicked the increasing salinity gradient. Water quality profiles for D.O., pH, and temperature showed little change with depth during this period, regardless of location in the lower or middle estuary. In general, D.O. levels ranged from about 7.5 to 10.0 mg/L, pH levels were between 8 and 8.5, and temperatures ranged from about 15.0 °C on the bottom to 17.0 °C in the middle and upper water column.

At Mill Bend in October, salinity stratification began at about 5 ft deep, and gradually increased to around 9 ppt on the bottom (15 ft deep) (Appendix B-45). As in the lower estuary, conductivity and T.D.S. values generally paralleled the salinity gradient. Dissolved oxygen levels decreased slightly from the surface to 5 ft deep (12 to 10 mg/L), then dropped rapidly below that point to about 2 mg/L at 10 ft deep. Below a depth of about 8.5 ft, D.O. levels were low (< 5 mg/L). Water temperatures varied according to depth and salinity concentration. Surface water temperatures to a depth of 5 ft averaged about 14.0 °C, then increased steadily to a depth of 9 ft and stabilized at around 17 °C. Values for pH were generally similar (7 to 8) throughout the water column.

November:

November water quality profiles were only obtained in 2002. Two sampling efforts were conducted during this month (November 8 and 23); however, only Mill Bend was sampled on November 23. Profiles collected on November 8 in the lower and middle estuary showed that surface waters were more saline than during the October sampling period (Appendix B-11 through B-13). As noted in Chapter Two, the lagoon was partially breached during the storm of November 6-7. Surface water salinity was greatest at the mouth (12 ppt), and then decreased steadily moving up the estuary, to about 3 ppt at Mill Bend. Salinity stratification at the lower and middle estuary stations generally increased linearly from the surface to a maximum salinity of about 25 ppt on the bottom (10 ft deep). Temperature and D.O. values in the lower and middle estuary remained relatively consistent with depth and between stations. Water temperatures during this period ranged from about 13.0 to 14.0 °C, and D.O. levels varied between 8.0 and 9.0 mg/L.

At Mill Bend, the salinity gradient was stronger and more pronounced than in the lower portions of the estuary (see Appendix B-13). Salinity increased steadily from the surface (~3 ppt) to about 27 ppt at a depth of about 6 ft, and then slowly increased to a maximum salinity of about 30 ppt on the bottom (20 ft). In contrast to conditions present during the October sampling period, water temperatures did not increase and D.O. levels did not decrease below the stratification layer. Water temperature values remained relatively constant with depth (13.0 to 14.0 °C), as were D.O. levels (8 to 9 mg/L).

By the November 23 sampling event, surface salinities at the mouth and at upstream locations showed a substantial decrease from the earlier November 8 sampling effort (Appendix B-14 through B-16). At the mouth of the estuary, a slight increase in salinity occurred below 3 ft deep, likely a result of tidal influences. The water quality profile obtained at Mill Bend on November 23 (see Appendix B-16) was more similar to the profile collected in October (see Appendix B-10) at Mill Bend than to the profile obtained on November 8 (see Appendix B-13). On November 23, salinity stratification occurred between the 7 and 10 ft deep, with a corresponding increase in salinity from 0 to about 25 mg/L (see Appendix B-16). Water temperature increased from about 11.5 °C on the surface to about 14+ °C below the stratified layer. Dissolved oxygen levels showed the same substantial decline within and below the stratification layer, from about 9 mg/L on the surface to about 2 mg/L at a depth of 13 ft.

Salinity stratification was also present at China Gulch located below Mill Bend (see Appendix B-15). Stratification began at a depth of about 4 ft, and gradually increased with depth to a maximum of 15 ppt on the bottom. Temperature showed little change with depth; however, D.O. decreased with depth below about 7 ft deep to a minimum value of about 6.5 mg/L.

Late Winter/Spring 2003 (February through May)

Field sampling in 2002 began in June, and as a result winter/spring data is not available. However, water quality data were collected in the late winter and spring of 2003, during February, April, and May. During the latter part of this period, the sand bar at the mouth of the lagoon was breached and the Gualala River flowed directly to the ocean.

February/April:
Freshwater conditions dominated the estuary for the three-month period. Water quality profiles obtained at various locations within the estuary showed well-mixed conditions in the estuary (Appendix B-17 through B-21). During each of the three sampling events conducted during the winter/spring period, measured values for temperature, salinity/conductivity, pH, total dissolved solids, and generally for dissolved oxygen, were similar throughout the water column regardless of location within the estuary.

May:
In May, the water quality profile at the Tide Gage (Appendix B-23), showed salinity stratification (0 to 21 ppt) at depths below 5.0 ft, but was not stratified at the mouth (Appendix B-22). As would be expected, TDS levels mimicked the salinity curve. Above the stratified layer, water quality parameters were similar to that found throughout the estuary during the May sampling effort: water temperatures averaged about 14.0°C, D.O. levels were between 11.0 and 12.0 mg/L, and pH values were around 7.5. Below the stratified layer, water temperatures decreased to about 12.0°C, D.O. levels fluctuated from about 10.0 to 12.5 mg/L, and pH decreased slightly to an average of about 7.0.

Well-mixed freshwater conditions dominated the estuary from China Gulch upstream (Appendix B-24 through B-26).

Continuous Temperature Recorders

In 2002, Hobo continuous recording temperature recorders were placed in the estuary to monitor water temperatures during the summer period at selected locations within the Gualala estuary. During the study period, some of the temperature recorders were lost or stolen (high recreational use area), and others were lost due to burial by sand. In July and August 2002, water temperatures in the upper estuary exceeded 25 ºC (thermal maximum for steelhead) on 11 days (Appendix B-47). On the 11 days that the temperature exceeded 25 ºC, the duration of the exceedance ranged from one to six hours. Hourly maximum temperature readings ranged from 25.2 to 26.7 ºC on those days. During the same time period, bottom and surface water temperatures recorded in the middle estuary did not reach 25 ºC (Appendix B-48).

In 2003, none of the continuous temperature data recorders for the month of July were recovered from the estuary. Consequently, new recorders were deployed in August 2003. Continuous temperature data for August and September showed that water temperatures exceeded 25 ºC on only two days in August 2003 (Appendix B-49 and B-50). On the two days that the temperature exceeded 25 ºC, the duration was only one-hour each day. Hourly maximum temperature readings did not exceed 25.6 ºC on the two days.

Salinity Patterns in the Estuary

Salinity patterns within the estuary are graphically presented for each site visit for both 2002 and 2003 (Appendix B-51). The graphs include all available salinity data obtained from both profile data and spot measurements made at individual haul locations. Surface and bottom salinities are presented by river mile, from the mouth to the upper estuary.

The estuary was closed throughout all sampling events in 2002, except for the last sampling effort on November 23. With the exception of the deep hole at Mill Bend (RM 1.1), the estuary was predominantly freshwater in 2002. Ocean wave-wash began to increase bottom salinities at the mouth of the estuary by late September 2002, and continued to increase through the October and November sampling events. By the early November sampling event, surface waters began to show increased salinities ranging from 11 ppt near the mouth to about 3 ppt at Mill Bend (mile 1.2). However, the lagoon breached between the November 8 and the November 26 and 27 sampling events, flushing the saline water from the bottom of the pool at Mill Bend. Following this breach event, the entire estuary was freshwater (see Appendix B-51) and remained fresh through the February 2003 sampling period.

The estuary was open during the May and June 2003 sampling events. In May, salinities of about 22 ppt were recorded on the bottom at RM 0.4. By June, salinities (ranging from 25-33 ppt) were recorded on the bottom upstream as far as the Highway 1 Bridge (mile 1.2); surface waters showed salinities ranging from 30 ppt near the mouth to about 5 ppt in the lower-middle estuary (RM 0.41) (Appendix B-51). As in 2002, the deep hole at Mill Bend contained saline water throughout the 2003 summer and fall sampling periods. As observed in 2002, ocean wave-wash in late September and October 2003 increased bottom salinities in the lower estuary.

In general, the Gualala River estuary was primarily freshwater in both 2002 and 2003 for most of the year, except when the lagoon was open and when ocean wave-wash contributed saline water to the estuary.

3.3.2 Aquatic Ecology

3.3.2.1 Fisheries

Sampling Effort

Survey efforts were similar between the two years, with a mean number of 19 hauls per month in 2002, and 21 hauls per month in 2003 (Table 3.1). However, in 2002, 90 percent of the sampling effort was concentrated in the middle and lower estuary sections, whereas in 2003, 75 percent of the sampling effort occurred in these lower two sections. In the upper (riverine) section, the number of hauls increased from 10 percent in 2002, to 25 percent in 2003, as requested by the TAC. The location and river mile of all fish sampling efforts is provided in Figure 3.2.

Species Composition and Abundance

Species composition and abundance data for all sampling events in 2002 and 2003 are provided in Table 3.2 and are summarized below.

2002 Sampling Results

A total of eight fish species were collected in the Gualala River and estuary during surveys in 2002. Ninety percent of the catch consisted of steelhead, threespine stickleback, and Pacific staghorn sculpin. Steelhead comprised the majority of the catch at 46.1%, followed by threespine stickleback at 30.1% (Figure 3.3). The remaining nine percent of the catch consisted primarily of coastrange sculpin and Gualala roach, along with a few surf smelt and Pacific herring. Table 3.3 provides a numerical breakdown of all species captured in 2002 by month and reach (upper, middle, and lower). In general, estuarine species (Pacific staghorn sculpin and starry flounder) were more abundant in 2002 (comprising 17% of the catch) than in 2003 (<0.6% of the catch).

Table 3.1 Total number of hauls per sampling event, month, and estuary section for 2002 and 2003 at the Gualala estuary.

Table 3.2 Summary of fish abundance in the Gualala estuary by species and sampling event from June through November 2002, and from February through October 2003.

Figure 3.3 Species composition within the Gualala estuary during the 2002 and 2003 sampling seasons

Table 3.3 Fish species, and numbers of individuals captured in the Gualala estuary in 2002 by sampling month and estuary section.

Because of the large number of steelhead captured in 2002, the primary focus of the sampling effort was rapid processing of steelhead to prevent mortality, with less emphasis on non-salmonid species. Steelhead was the most likely species to suffer stress related mortality during thermal highs, which occurred in July and August. To prevent steelhead mortality, only visual estimates of stickleback abundance were made, especially YOY. Substantial blooms of filamentous algae severely hindered sampling in the upper section from July through the end of summer. As a result, sampling frequency in the upper estuary in 2002 was reduced.

2003 Sampling Results

A total of eleven fish species were collected during the 2003 surveys. The majority of the catch (95 percent) consisted of threespine stickleback and steelhead. However, in contrast to 2002, threespine stickleback dominated the catch at 86%, with steelhead comprising only 9% of the catch (see Figure 3.3). The remaining five percent consisted primarily of coastrange sculpin and Gualala roach, with lower numbers of prickly sculpin and Pacific staghorn sculpin. Additionally, a few Pacific lamprey ammocoete, starry flounder, riffle sculpin, Pacific herring, and one juvenile coho salmon were captured in 2003. The single Coho salmon was collect during the May sampling event. Table 3.4 provides a numerical breakdown of all species captured in 2003 by month and section (upper, middle, and lower). Overall, conditions in the lagoon in 2003 appeared to favor freshwater species.

In 2003, steelhead were generally not as abundant in most hauls, especially from May through July. Therefore, hauls could be processed quickly. Consequently, there was additional time available to process the large number of threespine stickleback in the associated filamentous algae that was abundant in the catch. In addition, more hauls were completed in the upper section in 2003, than in 2002, which also increased the threespine stickleback catch over that from 2002.

Table 3.4 Fish species, and numbers of individuals captured in the Gualala estuary in 2003 by sampling month and estuary section.

Non-Salmonid Fish Species, 2002-2003 Overall Results

The following section presents a brief analysis of selected fish population data of the more abundant species collected in the estuary in 2002 and 2003.

Threespine stickleback (*Gasterosteus aculeatus*)

Threespine stickleback were abundant throughout the estuary, especially in vegetated areas. This species was substantially more abundant in the catch in 2003 than in 2002, likely a result of increased upstream sampling in 2003 (see tables 3.3 and 3.4). However, during both years, stickleback occurred in the greatest numbers in the lower estuary. In general, stickleback abundance was greatest from August through October. Length-frequency analyses show that adults and juveniles were found together throughout the estuary during this time period in both 2002 and 2003 (Appendix C-1).

In both 2002 and 2003, young-of-the-year stickleback began appearing in the catch as early as July, with continued breeding through October. YOY stickleback were also present in the catch during the February 2003 sampling effort in the lower estuary, indicating a possible bi-modal breeding pattern in the estuary.

Pacific staghorn sculpin (*Leptocottus armatus*)

Pacific staghorn sculpin were substantially more abundant in the estuary in 2002 than in 2003 (see tables 3.3 and 3.4). Length-frequency analyses for both sampling years indicate that all Pacific staghorn sculpin captured were juveniles, with the majority ranging in size from about 25 to 65 mm (fork length) (Appendix C-2). This species was captured throughout the estuary during most sampling events, but were most abundant in the lower and middle estuary. Young-of-the-year Pacific staghorn sculpin began to appear in the catch in June of both years. In 2003, sampling conducted after lagoon closure (July through October) yielded increasingly lower numbers of fish.

Starry flounder (*Platichthys stellatus*)

As with Pacific staghorn sculpin, starry flounder were substantially more abundant in the estuary in 2002 than in 2003 (see tables 3.3 and 3.4). Starry flounder were captured during most sampling events in both years, with the greatest numbers occurring in the lower and middle estuary. The greatest numbers of flounder were collected in July 2002, with lower numbers of individuals captured through the remainder of the season. In 2003, starry flounder comprised a small percentage of the catch, with the highest numbers occurring in the August hauls. Length-frequency analyses for sampling years indicate that the majority of the fish captured were juveniles (generally less than 160 mm in length) (Appendix C-3). Small numbers of young-of-the-year flounder began to appear in the catch during the June sampling event in both years.

Coastrange sculpin *(Cottus aleuticus)*

Coastrange sculpin were more abundant in the estuary in 2003 than in 2002 (see tables 3.3 and 3.4). This species was captured throughout the estuary in both years and during most sampling events, but were most abundant in the lower and middle estuary. Length-frequency analyses for the two sampling years indicate that the majority of the fish captured were juveniles (Appendix C-4). The highest number of coastrange sculpin were captured during the August and September sampling events in 2002, and during the August through October sampling events in 2003.

Gualala roach *(Lavinia symmetricus parvipinnis)*

Gualala roach is a subspecies of the California roach and is found primarily in the Gualala River system. Gualala roach were more abundant in the catch in 2003 than in 2002 (see tables 3.3 and 3.4). This species was captured during most sampling events throughout the estuary; however, the highest numbers consistently occurred in the middle and upper estuary, especially in areas with aquatic and riparian vegetation. Gualala roach were conspicuously absent from the catch during the February and May, 2003 sampling events. Young-of-the-year roach first appeared during the July sampling event in 2003, but were not present during 2002 sampling events. Length-frequency analysis indicates that multiple year classes were present in the estuary (Appendix C-5).

3.3.2.2 Steelhead Population Estimates

Distribution and Abundance

The total number of steelhead captured during each year were relatively similar; 5,126 fish in 2002, and 4,468 fish in 2003 (Table 3.5). Steelhead comprised 46.1% of the catch in 2002, and only 9.3% of the catch in 2003 (see Figure 3.3). The low percentage of steelhead to total catch in 2003 was due to the extremely large numbers of stickleback collected in that year. Steelhead were captured within all three-estuary sections throughout both sampling years. During most sampling events in both years, the majority of steelhead were collected in the lower and middle estuary sections (see tables 3.3 and 3.4).

Age and Growth

Length-frequency histograms bimodal peaks indicate the presence of age 0+ and age 1+ and older steelhead age classes in 2002. The 2003 data do not have a distinctive bimodal trend; however, the length ranges indicate that multiple year classes of steelhead were also collected throughout 2003. Length-frequency histograms are provided separately by month and year for each of the three estuary sections (Appendix C-6). With the exception of June and July 2002, and June 2003, age 1+ and older fish dominated the catch (see Table 3.5). The data also indicate that the majority of steelhead captured in the lower and middle estuary were age 1+ and older, while age 0+ fish were collected in similar numbers in all three-estuary sections, though in greater abundance in the upper estuary during spring (Table 3.6). Young-of-the-year (YOY) steelhead first appeared in

Table 3.5 Steelhead number, length range, and percent by age class for each sampling event in the Gualala estuary from June through November 2002, and from February through October 2002.

the catch during the June sampling event in 2002, and during the May sampling effort in 2003. Growth of juvenile steelhead in the estuary is illustrated by the monthly length-frequency histographs for each sampling year.

Table 3.6. Distribution of age 0+ and age 1+ and older steelhead by estuary section for 2002 and 2003.

Estuary Section	Year	Number of Steelhead		Total No.
		Age 0+	Age 1+ and older	
Lower Estuary	2002	387	3584	3971
	2003	303	2028	2331
	Total	**690**	**5612**	**6302**
Middle Estuary	2002	570	278	848
	2003	161	832	993
	Total	**731**	**1110**	**1841**
Upper Estuary	2002	285	22	307
	2003	377	767	1144
	Total	**662**	**789**	**1451**

General condition of steelhead in the Gualala estuary

Steelhead condition factor was determined for all fish collected during each sampling event in 2002 (Table 3.7) and 2003 (Table 3.8). The mean condition factor for all fish collected in both 2002 and 2003, regardless of capture location or age class, was about 1.1. However, the range of condition factor values was generally greater during each sampling event in 2002, than in 2003.

Population Estimates

Two different population estimators, Peterson-Schnabel and Jolly-Seber, were used to estimate the steelhead population in the Gualala estuary in 2002 and 2003. The Peterson-

Schnabel method assumes that the lagoon is closed during the sampling period, while the Jolly-Seber method assumes an open system during the sampling period and includes all marked fish that are re-captured on subsequent sampling events. Population estimates for each method were calculated following the last sampling event of the year.

The Petersen-Schnabel method uses fish re-capture data in conjunction with the overall sampling results to estimate population size. All steelhead 80 mm or larger (age 1+ and older) were marked with a freeze brand or fin clipped each sampling event to allow for identification of re-captured fish in subsequent sampling efforts. A summary of the number of age 1+ steelhead captured and marked, and the numbers of fish re-captured during each sampling event is provided in Table 3.9.

The lagoon remained closed throughout the 2002 sampling period; however, in 2003 the lagoon was open during the first three sampling events. Consequently, the February, May, and June sampling data were not included in the 2003 population estimate. The resulting Petersen-Schnabel overall population estimates for steelhead in the Gualala estuary during 2002 and 2003 are provided in Appendix C. Petersen-Schnabel population estimates for age 1+ and older steelhead generally ranged from 9,704 to 11,731 in 2002, and from 39,652 to 42,702 in 2003 (Table 3.10).

All sampling data collected in 2002 and 2003 were used in calculating the Jolly-Seber annual population estimates. The Jolly-Seber overall population estimate of steelhead in the Gualala estuary is provided in Appendix C. Population estimates for age 1+ and older steelhead ranged from 2,389 to 9,496 in 2002, and from 9,994 to 28,814 in 2003 (Table 3.11).

3.3.2.3 Steelhead Abundance By Age Class

For analytical purposes, steelhead catch data was separated according to age class: YOY versus age 1+ and older fish. The following section discusses the results of fish sampling

Table 3.7 Steelhead mean condition factor by month and estuary section for age 1+ and older fish captured in 2002.

Table 3.8 Steelhead mean condition factor by sampling event and estuary for age 1+ and older fish captured in 2003.

Table 3.9 Summary of age 1+ steelhead collected, branded, and recaptured per sampling event within the Gualala estuary from June through November 2002, and from February through October 2003.

Table 3.10 Age 1+ and older steelhead population estimates for the Gualala estuary 2002 and 2003, using the Petersen-Schnabel Method.

Table 3.11 Age 1+ and older steelhead population estimates for the Gualala estuary for 2002 and 2003, using the Petersen-Schnabel Method.

efforts by year and age class during the spring (May-June), summer (July-August), and fall (September-October). Total number of steelhead captured and mean number of steelhead captured per haul, are provided relative to distribution (by river mile) within the estuary. Due to differences in water year type and associated water quality parameters within the estuary in 2002 and 2003 (closed versus open lagoon, respectively), sampling results are also discussed in relation to changes in seasonal habitat conditions. The two years of sampling occurred in two very different water year types, with the estuary being closed prior to sampling in 2002, and remaining open in 2003 through mid-July.

Total Number of Steelhead Captured by Year

Age 0+ steelhead

During the spring 2002 sampling events, YOY steelhead were captured in relatively low numbers throughout the estuary (Figure 3.4). In 2003 (open lagoon), YOY were also distributed throughout the estuary; however, the highest numbers of YOY steelhead were captured in the lower portion of the middle estuary (see Figure 3.4).

The increased number of steelhead in the lower part of the estuary is likely associated with the higher outflows in spring 2003, which tended to push fish lower in the estuary.

In the summer of 2002, the highest number of YOY were captured in the upper estuary, with smaller numbers occurring in the lower to middle estuary. The high numbers of YOY in the upper estuary is likely due to recent outmigration of YOY steelhead from rearing tributary streams. In contrast, YOY steelhead that were concentrated in the lower middle estuary in the spring of 2003, had dispersed and by the summer sampling were distributed in similar numbers throughout the estuary. The dispersal was likely a result of the lagoon closing in early July, which created similar water quality and associated habitat conditions throughout the entire estuary.

Figure 3.4 Total number of YOY steelhead captured by season from all hauls within each distance category, Gualala estuary.

During the fall sampling events for both 2002 and 2003, YOY steelhead were captured throughout the estuary, with the highest numbers occurring in the upper estuary.

Age 1+ and older steelhead

During the spring of 2002, age 1+ and older steelhead were captured (albeit in low abundance) throughout the lower to middle estuary (Figure 3.5). This is likely a result of the closed lagoon conditions, which precludes the movement of fish out of the estuary. In contrast, the open lagoon conditions in the spring of 2003 allowed for smolt movement out of the estuary. As a result, fish were actively migrating out of the system and were not captured in large numbers at any location. The highest numbers of fish were collected in the lower middle estuary (see Figure 3.5).

In the summer of 2002, the highest number of age 1+ and older steelhead were captured in the lower to lower-middle estuary. Few fish age 1+ and older were captured at other locations within the estuary. Steelhead were concentrated in the lower estuary where conditions were appropriate for smoltification to occur. In summer 2003, age 1+ and older steelhead, which were concentrated in the lower estuary in the spring, had become more abundant throughout the estuary. This re-distribution was likely a result of the lagoon closing in early July, which created similar water quality and associated habitat conditions throughout the entire estuary.

During the fall sampling events for both 2002 and 2003, age 1+ and older steelhead were captured throughout the estuary, with the highest numbers occurring in the lower to lower-middle estuary. In 2002, few fish were captured in the upper estuary. However, in 2003, steelhead were also captured in relatively high numbers in the upper estuary, likely due to the improved water quality conditions present in 2003 relative to water quality parameters in 2002.

Figure 3.5 Total number of one year and older steelhead captured by season from all hauls within each distance category, Gualala estuary.

Mean Number of Steelhead Captured per Haul

Age 0+ steelhead

In 2002 during closed lagoon conditions, YOY steelhead were generally concentrated in the upper estuary. The mean number of YOY steelhead captured per haul was highest in the upper estuary during all sampling periods, with the highest number of fish captured during the summer sampling events (Figure 3.6).

In 2003, the distribution of YOY steelhead varied relative to water quality conditions associated with both open and closed lagoon environments. During the spring sampling period when the lagoon was open, the mean number of YOY steelhead captured per haul was highest in the lower and upper sections of the estuary. At the beginning of the summer sampling period the lagoon closed (early July). During this time period, YOY fish were most abundant in the middle and upper estuary; with the highest mean number of steelhead captured per haul occurring in the upper estuary. By the fall sampling period, virtually all of the YOY fish were captured in the upper estuary (Figure 3.7). During the single sampling event conducted in February, YOY steelhead were captured in both the middle and upper estuary, with the highest mean number of fish per haul occurring in the upper estuary.

Age 1+ and older steelhead

Throughout the 2002 sampling season, the mean number of age 1+ and older steelhead per haul was highest in the lower and middle estuary sections. In the spring, only a small number of fish were captured per haul. During the summer and fall sampling events, the mean number of fish captured per haul increased substantially, with the highest number occurring in the lower estuary (Figure 3.8).

Figure 3.6 Mean number of YOY steelhead per haul captured during spring, summer, and fall 2002, Gualala estuary.

Figure 3.7 Mean number of YOY steelhead per haul captured captured during 2003, Gualala estuary.

Figure 3.8 Mean number per haul of one year & older steelhead captured during 2002, Gualala estuary.

In the spring of 2003 (open lagoon), the majority of the age 1+ and older steelhead were captured in the middle estuary, with the highest mean number of fish per haul occurring in the lower portion of the middle estuary. During the summer and fall, age 1+ and older steelhead were distributed throughout the estuary (Figure 3.9). During the summer sampling period (closed lagoon), age 1+ and older fish were most abundant in the middle and upper estuary; with the highest mean number of steelhead captured per haul occurring in the middle estuary. By the fall sampling period, the highest mean number of age 1+ and older fish captured per haul occurred in the upper estuary, followed by slightly lower numbers in the lower and lower middle estuary. During the single sampling event conducted in February, age 1+ and older steelhead were distributed throughout much of the estuary. However, as during the spring sampling events, the highest mean number of fish captured per haul occurred in the lower portion of the middle estuary.

Low numbers of age 1+ and older fish were captured during spring sampling in both years (see figures 3.8 and 3.9), however, the majority of this age-class was collected in the lower estuary.

Mean Length of Steelhead Captured per Haul

Age 0+ steelhead

Young-of-the-year (age 0+) steelhead were distributed throughout the estuary, during all 2002 sampling events, under closed lagoon conditions. During the spring sampling period, the mean lengths of YOY captured per haul generally ranged from about 60 to 67 mm mean length (Figure 3.10), with the largest fish captured in the lower and lower-middle estuary, and in the upper portion of the upper estuary. This same general pattern continued into the summer sampling period. The largest fish (now 70 to 77 mm mean length) remained in the lower and lower-middle estuary, and in the upper portion of the upper estuary (mile 2.00). Between these two areas, the mean lengths of YOY steelhead

Figure 3.9 Mean number per haul of one year & older steelhead captured during 2003, Gualala estuary.

Figure 3.10 Mean length of YOY steelhead captured by distance category during spring, summer, and fall 2002, Gualala estuary.

decreased steadily moving upstream through the estuary to a minimum mean length of 62 mm at mile 1.50 in the upper estuary. By the fall sampling period, all of the largest YOY fish (now 100 mm mean length) were captured in the upper estuary at mile 1.50, where the smallest mean length fish were captured during the summer sampling events. The mean length of YOY steelhead captured at other locations in the estuary generally ranged from 80 to 88 mm mean length. In 2002, the highest mean number of YOY captured per haul occurred in the upper estuary during all three sampling periods.

As in 2002, YOY steelhead were distributed throughout the estuary during all sampling periods in 2003. During the spring sampling period when the lagoon was open, the mean length of YOY steelhead was highest in the lower estuary (about 75 mm) (Figure 3.11). Mean lengths of YOY fish captured per haul were lower (ranging from about 60 to 67 mm) at other stations within the estuary. After the lagoon had closed in early July, summer sampling efforts showed that the largest fish (81 to 84 mm mean length) were distributed throughout the estuary. Smaller fish (about 72 mm mean length), moving downstream from upstream spawning locations, were captured at stations higher in the estuary (mile 3.50). During the fall sampling events, the largest fish (100 mm mean length) were captured in the lower estuary. Sampling conducted upstream of the lower estuary, showed that mean lengths of fish captured steadily decreased with increasing distance from the mouth.

During the single event sampling effort conducted in February, steelhead were captured throughout the estuary, with the largest fish (about 87 mm mean length) occurring in the lower estuary. Fish captured elsewhere in the estuary ranged in size from 58 to 72 mm mean length). These fish were part of the 2002 cohort, and their small size was likely due to slower growth rates in cooler upstream habitats and/or late spawning efforts.

Figure 3.11 Mean length of YOY steelhead captured by distance category during spring, summer, and fall 2003, Gualala estuary.

Age 1+ and older steelhead

One-year and older steelhead were distributed throughout the estuary, during all 2002 sampling events under open lagoon conditions. During the spring sampling period, the mean lengths of age 1+ and older fish captured per haul generally ranged from about 92 to 103 mm mean length (Figure 3.12), with the largest fish captured in the lower estuary. As expected, the smallest fish were captured high in the upper estuary (mile 3.50). During the summer sampling period (following the lagoon closure in early July), larger fish (105 to 110 mm mean length) were relatively evenly distributed throughout the estuary; however, the largest fish were still in the lower and lower-middle estuary. By the fall sampling period, the largest fish (141 to 146 mm mean length) had moved upstream to the area around Mill Bend. The smallest fish were again captured in the upper estuary.

During the single event sampling effort conducted in February 2003, steelhead were captured throughout the estuary (Figure 3.13), with the largest fish (about 210 mm mean length) occurring in the upper estuary at mile 1.50. Slightly smaller fish were captured throughout the lower and middle estuary, with the smallest fish (about 110 mm mean length) occurring at higher locations in the upper estuary. These smaller fish were likely part of the 2002 cohort, and their small size was likely due to slower growth rates in cooler upstream habitats and/or late spawning efforts.

In 2003, the highest mean number of age 1+ and older fish captured per haul generally occurred in the lower estuary during all four sampling periods.

Stomach Analyses

Despite careful handling procedures, some steelhead mortalities occurred as a result of processing and fish marking efforts. Stomach analyses were conducted on all steelhead mortalities to obtain baseline information on the types of prey items being consumed.

Figure 3.12 Mean length per haul of one year & older steelhead captured during 2002, Gualala estuary.

Figure 3.13 Mean length of one year & older steelhead captured by distance during spring, summer, and fall 2003, Gualala estuary.

When possible, prey species were also categorized by age class. The taxa were divided into three groups: insect (including terrestrial or aquatic adults), zooplankton (Amphipoda and Isopoda), and non-insect taxa (mites, mollusks, nematodes, and Oligochaetes).

Fish mortalities were not separated according to the estuary section in which they were collected; however, prey species identified in the stomach contents of individual steelhead often provided anecdotal information on feeding location within the estuary. A summary of the dietary components (by percent) of age 0+, 1+, and 2+ and older steelhead is provided in Table 3.12. Zooplankton (*Gnorimosphaeroma* sp., C*orophium* sp., and *Ramellogammarus* sp.) was one of the most abundant prey items found in the stomachs of all steelhead age classes. Many of the steelhead contained both insect and zooplankton taxa. Non-insect taxa were the least abundant prey items. Most of the insect taxa were associated with riverine (flowing water) conditions in the upper estuary; however, feeding observations (during sampling events) and stomach analyses show that steelhead were also actively feeding on midge adults and emerging pupa in the middle and lower estuary. Insect taxa consisted of adult ants, all life stages of midges, corixids, and thrips (Order: Thysanoptera). It is likely that steelhead in the estuary feed opportunistically on a variety of prey items depending on seasonal availability and abundance. In 2002, one steelhead collected in the lower estuary regurgitated sand lances when captured.

Table 3.12. Summary of the primary dietary components of steelhead captured in the Gualala estuary in 2002 and 2003

	Age 0+	**Age 1+**	**Age 2+ and older**
Percent Insect	25.5	31.3	0.0
Percent Non-Insect	6.1	4.3	100.0
Percent Zooplankton	68.4	64.4	0.0
N	14	19	2

3.3.3 Benthic Macroinvertebrates

The following section provides a brief summery of the general habitat conditions recorded for each of the three sections, including; riparian vegetation present, substrate composition, Substrate Complexity score, and Physical Habitat Quality score. Additional site information and water quality data for each section is presented in Table 3.13.

Site Descriptions

Lower Reach - RM 0.4 to 1.1

The lower reach extended from RM 0.4 to RM 1.1. Riparian vegetation consists primarily of California bay, willow, ash, and alder. Horsetail and nutsedge were also present along the banks. The dominant substrates were fines (41.7%) and gravel (40.0%). This section received a Substrate Complexity score 31.0 (sub-optimal), and a Physical Habitat Quality score of 140 (sub-optimal).

In May 2003, BMI sampling was conducted at RM 0.8 while the lagoon was breached. The samples were collected in riffle habitat, which had formed near the upstream end of the island as a result of the breach. This site received a Substrate Complexity of 35.0 (sub-optimal) and a Physical Habitat Quality score of 136 (sub-optimal). The dominant substrates were gravel (50.0%) and fines (40.0%).

Middle Reach - RM 1.6 to 2.0

This 850 meter reach extended upstream of the Highway 1 Bridge to RM 2.0 (near campground). Riparian vegetation consisted of Bay laurel, willow, alder, ash, cedar, blackberry and nutsedge. The substrate was dominated by fines (41.7%) and gravel (40%). This reach received a Substrate Below the stratified layer Complexity score 31.0 (sub-optimal) and a Physical Habitat Quality score of 140 (sub-optimal).

Table 3.13 Physical habitat and water quality data collected during Benthic macroinvertebrate surveys in the lower Gualala River and Estuary, July 2002 and May 2003.

Upper Reach - RM 2.4 to 3.2

This 967-meter reach began at the campground and extended upstream near the confluence with the north fork. Riparian vegetation consists primarily of redwood, Douglas fir, ash, and alder. Bunchgrass was also present along the banks. The dominant substrates were gravel (63.8%) and fines (33.3%). This section received a Substrate Complexity score of 31.0 (sub-optimal), and a Physical Habitat Quality score of 121 (sub-optimal).

CSBP Metrics

Benthic macroinvertebrate sampling was conducted in all three estuary reaches in July 2002, to characterize the benthic macroinvertebrate community relative to food availability for juvenile steelhead. Based on the results, species composition and associated biological metrics for each of the estuary sections reflected changes from a riverine environment in the upper estuary to a more estuarine environment in the middle and lower estuary. In May 2003, while the lagoon was breached, a second set of BMI samples were collected in the middle estuary where a riffle had formed at the top of the island to access if the benthic taxa had shifted toward a more riverine fauna. The riffle was sampled using CSBP protocols.

Table 3.14 provides a summary of the metrics specified by the CSBP for each of the reaches in the Gualala estuary. However, due to the lack of CSBP defined tolerance values and Functional Feeding Group (FFG) designations for the dominant taxa (*Gnorimosphaeroma* sp.) in the estuary, Tolerance metrics (TV, Percent Tolerant Organisms, and Percent Intolerant Organisms) and the FFG metrics are not relevant. A FFG designation of collector was assigned for this taxon.

The estimated abundance of benthic macroinvertebrates was highest in the transitional section and lowest in the riverine area (Figure 3.14). Taxa richness, Shannon Diversity

Table 3.14 Summary of the Benthic macroinvertebrate metrics for the lower Gualala River and Estuary, July 2002 and May 2003.

Figure 3.14 Estimated Abundance of Benthic Macroinvereberates in the lower Gualala River and Estuary, July 2002 and May 2003.

Figure 3.15 Taxa Richness for Benthic Macroivertebrates in the Lower Gualala River and Estuary, July 2002 and May 2003.

Figure 3.16 Shannon diversity Indices for Benthic Macroivertebrates in the Lower Gualala River and Estuary, July 2002 and May 2003.

Index and the EPT Indices were highest in the upper estuary (riverine habitat) and declined downstream in the estuarine environment (figures 3.15 through 3.17). The percentage of non-insect taxa is presented in Figure 3.18. This metric shows the change in the BMI community that occurs between the upper reach, which is dominated by insect taxa, and the lower reaches, which are dominated by zooplankton taxa. The dominant taxa metric in the upper reach was split among the three samples; a midge tribe (Tanytarsini), a mayfly (*Baetis* sp.) and an isopod (*Gnorimosphaeroma* sp.), while zooplankton taxa; isopod (*Gnorimosphaeroma* sp.) and amphipods (*Corophium* sp. and *Gammarus* sp. in the 2002 grab samples, *Hyalella azteca* in the 2003 sample) were dominant taxa in the middle and lower reaches (Figure 3.19). The benthic macroinvertebrate community begins to shift toward a community dominated by estuarine organisms in the upper reach (RM 2.4) as indicated by the isopod (Gnorimosphaeroma sp.) was 27% of the sample.

3.4 Discussion

During the two years of sampling conducted in the lower Gualala River and lagoon by ECORP, water quality and habitat conditions varied in response to river flow. During 2002, the lagoon remained closed until the first November storm event. In 2003, the estuary remained open into May, breached again for a short period in the middle of June, and breached again during the first storm event in November. In 2002, the lagoon was predominantly freshwater throughout the summer and early fall, except for the pocket of saline water in the deep pool at Mill Bend. However, water quality conditions in 2003 were highly variable associated with high spring runoff and an open estuary into mid July. As a result, the estuary/lagoon fluctuated between primarily freshwater and brackish to marine conditions.

Figure 3.17 EPT Indices for Benthic Macroivertebrates in the Lower Gualala River and Estuary, July 2002 and May 2003.
Figure 3.18 Percentage of Non-Insect Taxa Metric for Benthic Macroivertebrates in the Lower Gualala River and Estuary, July 2002 and May 2003.
Figure 3.19 Dominant Taxa Metric for Benthic Macroivertebrates in the Lower Gualala River and Estuary, July 2002 and May 2003.

2002

Young-of-the-year steelhead were relatively abundant in the catch from June through early September, with decreased numbers recorded for the remainder of the sampling season. During the spring, YOY steelhead were captured in highest numbers in the lower and middle estuary up to the Highway 1 Bridge. In summer, YOY were substantially more abundant in the catch from Mill Bend upstream to mile 1.50, but were also captured in higher numbers in the lower estuary. By fall, total numbers of YOY had decreased above Mill Bend, with similar numbers recorded for the lower estuary.

Age 1+ and older fish were captured in low numbers throughout the estuary in the spring, likely due to emigration prior to lagoon closure. However, by the summer period there was a substantial increase in the number of age 1+ and older fish, which were most abundant in the lower estuary, but were also captured in increasing numbers in the vicinity of the Highway 1 Bridge. In the fall, even higher numbers of steelhead were captured in the lower and lower-middle estuary, and in the vicinity of the Highway 1 Bridge. During this period, age 1+ and older steelhead were captured in highest numbers in the lower estuary. Sampling conducted in November after the lagoon had breached showed that few age 1+ and older fish were still present in the lower and lower-middle estuary, likely due to emigration following the lagoon breach. During the spring and summer periods, the largest age 1+ and older steelhead were captured in the lower and lower-middle estuary.

Water quality conditions were generally favorable for steelhead throughout the summer and fall, except in the deep pool at Mill Bend, where salinity stratification often created poor water quality conditions with warm water temperatures and very low dissolved oxygen levels. This assessment is supported by the mean condition factor (1.1), which is slightly above normal, which indicating healthy popultations. In the fall, ocean wave-wash created saline conditions on the bottom in the lower and lower-middle estuary. As the fall progressed, continued wave-wash steadily increased surface and bottom salinities in the lower and middle estuary, until the lagoon breached in November. Based on the

2002 sampling data, the distribution of YOY steelhead did not appear to be affected by the increased salinities in the lower and middle estuary.

In general, water temperatures were adequate for steelhead rearing throughout most of the year, except for eleven days in July and early August when temperatures exceeded the thermal maximum for steelhead. There is some discrepancy among investigators as to the thermal maximum for steelhead; Raleigh *et al*. (1984) reported 25 ºC, other investigators (Jobling, 1981 and Lee and Rinne, 1980) report 26 ºC, and Moyle (2002) found that temperatures of 24–27 ºC are lethal to steelhead, except for very short exposures. Based on continuous temperature data collected within the estuary, the longest period of time that surface water temperatures exceeded 25 ºC over the eleven days was for 6 hours, with most of the exceedance durations lasting about three to four hours in the afternoon.

2003

Steelhead were less abundant in the catch in 2003 than in 2002, likely due to emigration during the spring when the lagoon was open. Young-of-the-year steelhead were captured in relatively low numbers during February and May when the lagoon was open. However, the numbers of YOY fish substantially increased during the June sampling event, which was likely associated with the lagoon closing in late May. Variable numbers of YOY steelhead were captured from July through September, with a significant drop in numbers occurring during the October sampling events. During the spring, YOY steelhead were captured in highest numbers in the lower-middle estuary, with reduced numbers of fish in the upper estuary. In summer, YOY were captured in similar numbers throughout the estuary. By fall, total numbers of YOY were highest in the upper estuary above the Highway 1 Bridge; however, fish were also captured in slightly lower numbers in the middle estuary. In the winter and spring, the largest YOY were captured within the lower and lower-middle estuary. During the summer and fall, the largest YOY were distributed throughout the estuary, as noted in 2002.

Except for the lower estuary, one-year and older fish were captured in very low numbers throughout the estuary during the spring sampling event. This is likely due to emigration prior to lagoon closure in late May. By the summer period, these fish were relatively evenly distributed throughout the estuary. In the fall, the highest numbers of age 1+ and older fish were captured in the lower and lower-middle estuary as observed in 2002, with lower numbers present from Mill Bend upstream into the upper estuary. During the winter, spring and summer periods, the largest age 1+ and older steelhead were evenly distributed throughout the estuary.

As in 2002, water quality conditions were generally favorable for steelhead throughout the summer and fall, except in the deep pool at Mill Bend, where salinity stratification often created poor water quality conditions with warm water temperatures and very low dissolved oxygen levels. This assessment is supported by the mean condition factor (1.1), which is slightly above normal, which indicates that the fish were healthy. Similar to 2002, ocean wave-wash in the fall created saline conditions on the bottom in the lower and lower-middle estuary. As the fall progressed, continued wave-wash steadily increased surface and bottom salinities in the lower and middle estuary, until the lagoon breached in November. Based on the 2003 sampling data, the distribution of YOY steelhead appeared to be affected by the increased salinities in the lower and middle estuary during the summer and fall. As salinities increased in the lower and middle estuary, YOY steelhead appeared to migrate upstream into fresher water.

In general, water temperatures were adequate for steelhead rearing throughout most of the year, except for two days in July when temperatures exceeded the thermal maximum for steelhead. Based on continuous temperature data collected within the estuary, the longest period of time that surface water temperatures exceeded 25 ºC over the two days was for 1-hour.

The numbers of steelhead present within the estuary may be affected by predation, especially river otter and various avian species, including white pelican, osprey, mergansers, gulls, and cormorants. During sampling events in both years, these predators were observed actively feeding on steelhead throughout the lagoon. During closed lagoon conditions in 2002 when surface waters were calm, conditions may favor those predators that rely on eyesight to locate prey. However, the total affect of these predators on juvenile steelhead population numbers within the lagoon is unknown.

3.4.1 Benthic Macroinvertebrates

The limited benthic community sampling conducted in this study were to examine the food resources for the fish community. In a 2002 report on the Gualala Watershed (LeDoux-Bloom, 2002), rates the upper watershed as having a good biotic rating based upon an IBI community evaluation approach. The estuary appears to be in good biotic condition based upon water quality, fish population and benthic community.

Based on the limited benthic sampling conducted in 2002 and 2003, two discrete benthic communities were identified within the Gualala River estuary. Sampling indicated that the benthic community begins to transition from a riverine or insect dominated community to an estuarine or non-insect dominated community at mile 2.4 in the upper reach. An isopod (*Gnorimosphaeroma* sp.), was the dominant taxa found in the samples from the mouth to the transition area. Based on a sample size of 35 fish, stomach analyses showed that this organism (which was the most abundant organism in the samples) was the dominant food item in most fish examined. This observation is consistent with most salmonid species, which are known to be opportunistic feeders on the most abundant food items present in the environment (Raleigh et.al. 1984).

3.5 References

Cannata, S. P. 1998. Observations of Steelhead (Oncorhynchus mykiss), Coho Salmon (O. kisutch) and Water Quality of the Navarro River Estuary/Lagoon May 1996 to December 1997. Humboldt State University Foundation.

Jobling, M. 1981. Temperature tolerance and the final preferendum – rapid methods for the assessment of optimal growth temperatures. J. Fish Biology. 19: 439-455.

LeDoux-Bloom, C. M. 2002. Assessment of Anadromous Salmonids and Stream Habitat Conditions of the Gualala River Basin, California. California Department of Fish and Game, North Coast Watershed Assessment Program, Fort Bragg, CA. 2 December 2002. 110 pp. *IN*: Klamt, R.R., C. LeDoux-Bloom, J. Clements, D. Morse and M. Scruggs. 2002. Gualala River Watershed Assessment Report. North Coast Watershed Assessment Program, 367 pp plus Appendices. California Resources Agency, and California Environmental Protection Agency, Sacramento, California.

Lee, R.M. and J. N. Rinne. 1980. Critical thermal maxima of five trout species in the southwest United States. Trans. Am. Fish. Soc. 109:632-635.

Moyle, P. B. 2002. Inland Fishes of California, Revised and Expanded. University of California Press. 502 pp.

Raleigh, R. F., T. Hickman, R. C. Solomon, and P. C. Nelson. 1984. Habitat suitability information: Rainbow trout. U.S.Fish Wildlife Service. FWS/OBS-82/10.60. 64 pp.

Ricker, W. E. 1975. Computations and Interpretation of Biological Statistics of Fish Populations. Bulletin of the Fisheries Research Board of Canada, Bulletin 191: 382 pp.

CHAPTER 4.0 ENHANCEMENT PLAN AND RECOMMENDATIONS

4.1 Introduction

This section describes management and enhancement opportunities that will meet the goal of sustaining and improving natural resources within the lower Gualala River and coastal lagoon. This section also identifies and describes constraints on resource management efforts based on the hydrologic and biologic assessments described in the previous sections. Although the geographic focus of this section is on the lower river and lagoon, successful implementation of strategies will require a watershed-based approach towards protection and enhancement. It is intended that this information serve as a planning and operational guide to assist landowners and interested parties in conserving, managing, and enhancing natural resources.

Opportunities for enhancing aquatic habitat and fish populations depend on physical habitat conditions, water availability, access to habitat by fish, and access to property for implementation. The key actions include flow-related measures to manage and sustain summer freshwater inflow to the lower river and coastal lagoon, and enhancement and protection of physical habitat. To gain support in the privately owned lower basin, a public education and outreach program should be implemented to foster voluntary participation by landowners in restoration efforts.

4.2 Existing RMPS and Regulatory Compliance

With the exception of the 195-acre Gualala Point Regional Park, which is managed by the Sonoma County Regional Parks Department and a combined 219 acres of State and Federal lands in the Wheatfield and main-stem South Fork watersheds, the vast majority of the watershed (190,773-acres) is privately owned (Klamt et al., 2003). Apart from several general resource management plan (RMP) objectives applicable to all Sonoma

County Regional Parks, actions that may impact natural and biological resources activities in the watershed, including restoration efforts, fall under the purview of mandatory federal and state environmental statutes. These statutes include, but are not limited to: the National Environmental Policy Act (NEPA) and California Environmental Quality Act (CEQA), federal Clean Water Act and state Porter-Cologne Water Quality Act, Federal Endangered Species Act (FESA) and California Endangered Species Act (CESA), and State Forest Practice Act. The Gualala River has also been designated an impaired water body (for sediment) by the U. S. Environmental Protection Agency (USEPA) and North Coast Regional Water Quality Control Board (who must set total maximum daily loads (TMDLs) for the constituents that are causing the impairment).

A number of actions identified in this section would require CEQA and/or NEPA review if they were to be implemented. Most of the proposed management recommendations can be performed under a negative declaration or a mitigated negative declaration. Management recommendations that involve Federal or state-listed wildlife species may require consultation under FESA and CESA. When considering implementation of management recommendations that may affect sensitive plants and animals Responsible parties should also anticipate in coordinating with state and federal resource agencies, including the California Department of Fish and Game and U.S. Fish and Wildlife Service.

4.3 Management Goals and Objectives

The overall goal of this management plan is to sustain and improve the natural vitality and biodiversity of natural resources within the lower Gualala River and coastal lagoon. This goal includes the need to ensure that natural resources are not diminished, and when possible, to improve the unique and diverse aquatic habitats and the natural physical processes that sustain these habitats. To achieve this qualitative goal, objectives were developed to identify specific and measurable desired outcomes resulting from implementing a specific management action. Thus, each management and enhancement plan objective listed below includes a brief discussion of the a) specific implementation and/or management activities (opportunities) proposed to achieve the objective, b) the desired outcome of the objective, and c) known constraints associated with implementation of an activity. No priority or level of importance is implied by the order in which objectives are presented below.

OBJECTIVE 1: To protect and enhance freshwater inflow to the coastal lagoon.

<u>Desired Outcome</u>: To maintain the seasonal cycle of coastal lagoon and barrier beach morphology, and to protect water quality and aquatic habitats.

<u>Implementation Activities</u>:

- Discourage the development of any further surface water diversions in the watershed that independently or cumulatively reduce inflow to the coastal lagoon, especially during summer and fall months.
- Protect high summer base flows discharged from the North Fork Gualala River watershed.
- Discourage development of surface-water influenced wells that impart similar impacts to those stated above.
- Ensure that future residential and farming development projects do not adversely impact summer base flows or recharge to local groundwater systems.
- Encourage the implementation of water conservation measures throughout the watershed to reduce existing cumulative impacts.
- Implement a program of monitoring summer base flows in major tributary channels.
- Identify illegal diversions within the watershed.
- Establish minimum flows in watershed tributaries, where necessary and where heavily impacted by diversion, to protect salmonid rearing habitat.
- Land acquisition or creation of conservation easements.

Constraints:

- Overwhelming majority of watershed is under private ownership and control.
- Existing water rights.
- Natural variability in climate and stream flows.

OBJECTIVE 2: To eliminate unnatural breaching of barrier beach.

Desired Outcome: To maintain the seasonal cycle of coastal lagoon and barrier beach morphology, and to protect aquatic habitats.

Implementation Activities:

- Discourage landowners from artificially breaching barrier beach in the future (this does not appear to be a historic or current problem).
- Develop an educational and public awareness program to alert local residents of impacts to lagoon ecology due to artificial breaching.
- Post sign at kiosk at County Park informing public about beneficial attributes of a coastal lagoon system.

Constraints: Open access to public.

OBJECTIVE 3: To eliminate toxic chemical and excessive nutrient loads to the lagoon.

Desired Outcomes:

- Improved aquatic habitat for avian and other wildlife species that rely on aquatic habitats for food.
- Protect lagoon from eutrophication.
- Reduce algae growth in lower river and lagoon.

Implementation Activities:

- Eliminate the use of toxic herbicides, pesticides and other agricultural chemicals in the watershed.
- Investigate cumulative impacts of septic system and water treatment discharges, if any.
- Ameliorate dysfunctional septic systems.
- Eliminate illegal or irresponsible dumping.
- Encourage BMPs in both urban areas and upper watershed.

Constraints: Overwhelming majority of watershed is under private ownership and control.

OBJECTIVE 4: To reduce excessive sediment supplies to lower river and lagoon.

Desired Outcome: Improved aquatic habitat for avian and other wildlife species that rely on aquatic habitats for food.

Implementation Activities:

- Encourage more environmentally friendly logging practices, (BMPs, etc.).
- Reduce the number of logging roads.
- Retire obsolete logging roads.
- Land conversion and acquisition.
- Long-term monitoring of lagoon profiles to track changes in morphology.
- Evaluate effects of instream gravel mining.

Constraints: Overwhelming majority of watershed is under private ownership and control.

OBJECTIVE 5: To enhance habitat values of riparian and wetland vegetation.

Desired Outcome: Improve habitat for avian and other wildlife species and increase habitat diversity.

Implementation Activities:

- Non-native plant removal.
- Replanting of native vegetation.
- Elimination of summer off-road vehicle traffic within river corridor.
- Enhancement and expansion of existing tidal and freshwater wetlands, including some County Park lands along the lagoon and the former mill site on the inside of Mill Bend.

Constraints:

- Overwhelming majority of watershed is under private ownership and control.
- Competition from exotic species.

OBJECTIVE 6: To increase habitat quality of dune and dune scrub vegetation.

Desired Outcome: Improve habitats for sensitive native plants and nesting birds.

Implementation Activities:

- Education and stewardship programs through community and County Park.
- Reduced/improved trail access and signage through/from County Park.
- Removal of non-native (competing) plant species.

Constraints:

- Heavy public access through County Park.
- Presence and competition from exotic species.

OBJECTIVE 7: To facilitate consensus of management plan goals, objectives, and implementation strategies and develop an implementation plan.

Desired Outcome: Buy-in of local landowners, resource/regulatory agencies, and other local stakeholders.

Implementation Activities:

- Coordinate/meet with local landowners and agency staff to revise and approve management plan.
- Work with stakeholders to develop an implementation plan for proposed management actions.
- Develop public education and stewardship programs.

Constraints: Interest and financing.

OBJECTIVE 8: To protect and enhance steelhead and Coho salmon habitat.

Desired Outcome: Improve habitats for spawning and rearing steelhead and Coho salmon.

Implementation Activities:

- Implementation of Objectives 1 through 7.

Constraints:

- Interest and financing.
- Overwhelming majority of watershed is under private ownership and control.

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Hydrology

APPENDIX B

Water Quality

APPENDIX C

Fish Species Length Frequency Histograms

APPENDIX D

Benthic Macroinvertebrate Data