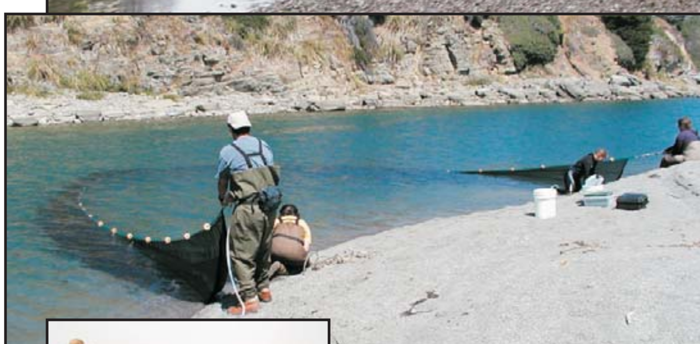
Gualala Estuary and Lower River Enhancement Plan: Results of 2002 and 2003 Physical and Biological Surveys



May 19, 2005

Prepared for:

Sotoyome Resource Conservation District

and

California Coastal Conservancy

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KAMMAN HYDROLOGY & ENGINEERING, INC.

Gualala Estuary and Lower River Assessment and 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 (Klamt et al., 2003).

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(GRWC)) 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 River Watershed including the Estuary and Lower River Project. This estuary study is intended to complement and expand on the NCWAP study.

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 estuary conditions. The enhancement plan provides specific recommendations for the protection of the Gualala estuary and Lower River and its natural resources.

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..

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,
- 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., 2003) 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). Through the limited observation of the terrestrial and marsh conditions present, it appears that restoration opportunities that fortify native dune and dune scrub vegetation at the lower study area, and enhance the quality of native riparian tree and shrub species in the middle reach of the study area, will reinforce the native plant communities of the area. As is the case of many north coast habitats, disturbed soils in the Gualala River estuary area show rapid encroachment of invasive and non-native species that include, but are not limited to pampass grass (*Cortaderia selloana*), scotch broom (*Cytisus spp*), and various thistle species. This report does not purport to deliver expertise on the composition of invasive species or approach to manage these threats to the ecological balance, but suggests further attention and action to enhance native riparian and terrestrial/marsh species.

1.3 Study Participants

1.3.1 Steering Committee

The SCC and the grantee formed a Steering Committee (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 GRWC and the general public took place annually. ECORP and KHE provided a mid-study report and updates to the Steering Committee and TAC, 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. ECORP and KHE provided additional volunteer time to educate the public about the study when requested by local stakeholder groups.

The outreach efforts included a critique and review of the contents of this final report by stakeholder groups and private individuals. It is important that the community outreach, similar to that provided through this study, continue as a follow up in order to ultimately accomplish any recommendations expressed within this report. For this reason, community education and outreach about the report recommendations and general needs for the ecological integrity of the Gualala River Estuary and Lower river should be a priority component for future project based activities, management plans, and implementation strategies that result from this report.

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,
- addressed project issues as they occurred and developed adaptive management strategies to rectify and document these issues, and
- provided 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, ECORP, and SRCD) presents the summary of findings, and Chapter 5.0 (prepared by KHE, ECORP, and SRCD) presents the summary of findings, and enhancement planning recommendations.

1.5 Acknowledgements

Significant contributions were made to this study from the following individuals and entities: Elmer Dudik and Robert Klamt with the North Coast Regional Water Control Board coordinated and supervised a significant water quality monitoring program in the estuary during the study period. Their data and findings were integral to developing an understanding of estuary and lower river water quality conditions. Elmer Dudik also provided additional insight into characterizing the linkage between summer water quality and algal blooms (see Section 3.3.4 of this report). Volunteers who provided hours to tireless assistance in the implementation of study field tasks included Jamie Hall (photo-

point monitoring, fishery seining, surveying, and more), Don Kemp, and Steve May of Surf Market (Photo-Point Monitors); and Ron Rolleri, Robert Keeble, Dan Munton, Adam Crook, and Tegner Weiseth (fishery seine net volunteers). In addition, Gualala Redwoods Inc. was generous in providing the study team with available information, data, and access to/through their property.

1.6 References

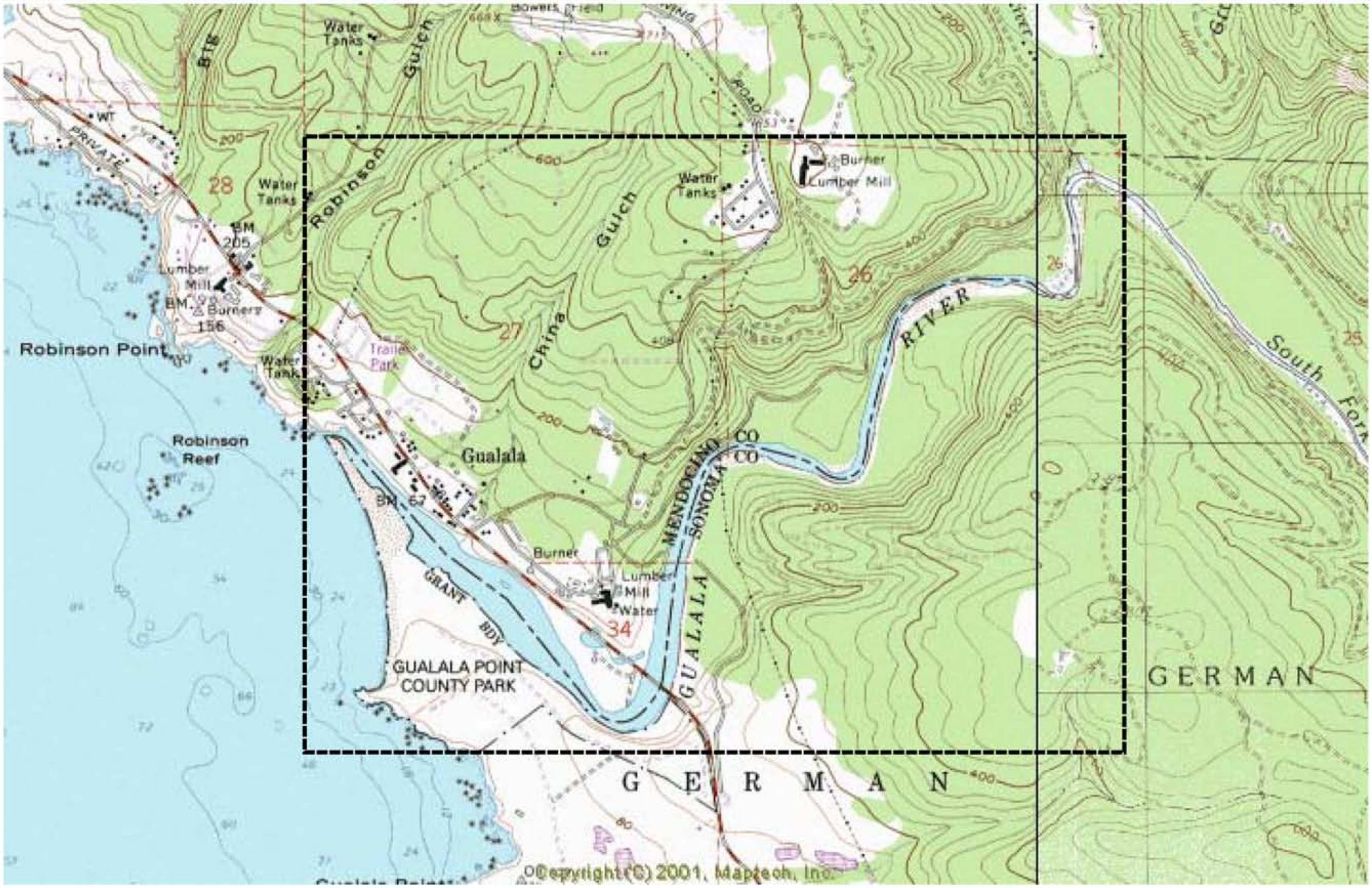
Klamt, R.R., LeDoux-Bloom, C., Clements, J., Fuller, M., Morse, D., and Scruggs, M.,2003, Gualala River watershed assessment report, North Coast Watershed Assessment Program. California Resources Agency and California Environmental Protection Agency, Sacramento, CA, 367p. (plus Appendices).

CHAPTER 2.0 HYDROLOGY AND GEOMORPHOLOGY INVESTIGATIONS

2.1 Introduction: Study Objectives and Approach

The lower Gualala River and its coastal estuary 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 estuary 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 can also be referred to as a “coastal lagoon” (Sorensen et al., 1993). It will be, however, referred to as an estuary or coastal estuary for reader convenience throughout this report. 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 estuary 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 estuaries go through a seasonal progression of morphological change. In winter, the estuary 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 estuary inlet closure, the main source of water to the estuary is fresh water



Source: USGS 7.5-Minute Gualala Quadrangle

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Project Study Area

FIGURE

2.1

inflow. Periodic wave over-wash also significantly impacts barrier beach morphology and estuary 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 estuary physical and biological systems. Between August of 2002 and December 2003, specific monitoring activities and analyses completed as part of this study included:

1) Continuous estuary water level monitoring,
2) Estimation of daily freshwater inflow to the estuary,
3) Completion of 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 estuary freshwater inflow estimates,
4) Development of a detailed water budget for the estuary to estimate seepage rates and net transfers of water between estuary and ocean,
5) Completion of annual cross-sectional profiles of the estuary and estuary inlet,
6) Assistance in the coordination and implementation of a photo-monitoring program of the barrier beach and estuary inlet conditions,
7) Completion of a review of historical aerial photographs and maps to identify historical changes in estuary and lower river morphology,
8) Assessment of the local tide and wave climate acting on the estuary barrier beach using available tide, wave and wind data from nearby NOAA tide gages and offshore buoys,
9) Assistance in the monitoring of general water quality parameters (emphasis on salinity) throughout the estuary,
10) Qualitative assessment of sediment transport through the lower river and estuary 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 estuary reaches; and

11) Coordination and contract management 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 estuary. 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 offshore 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.

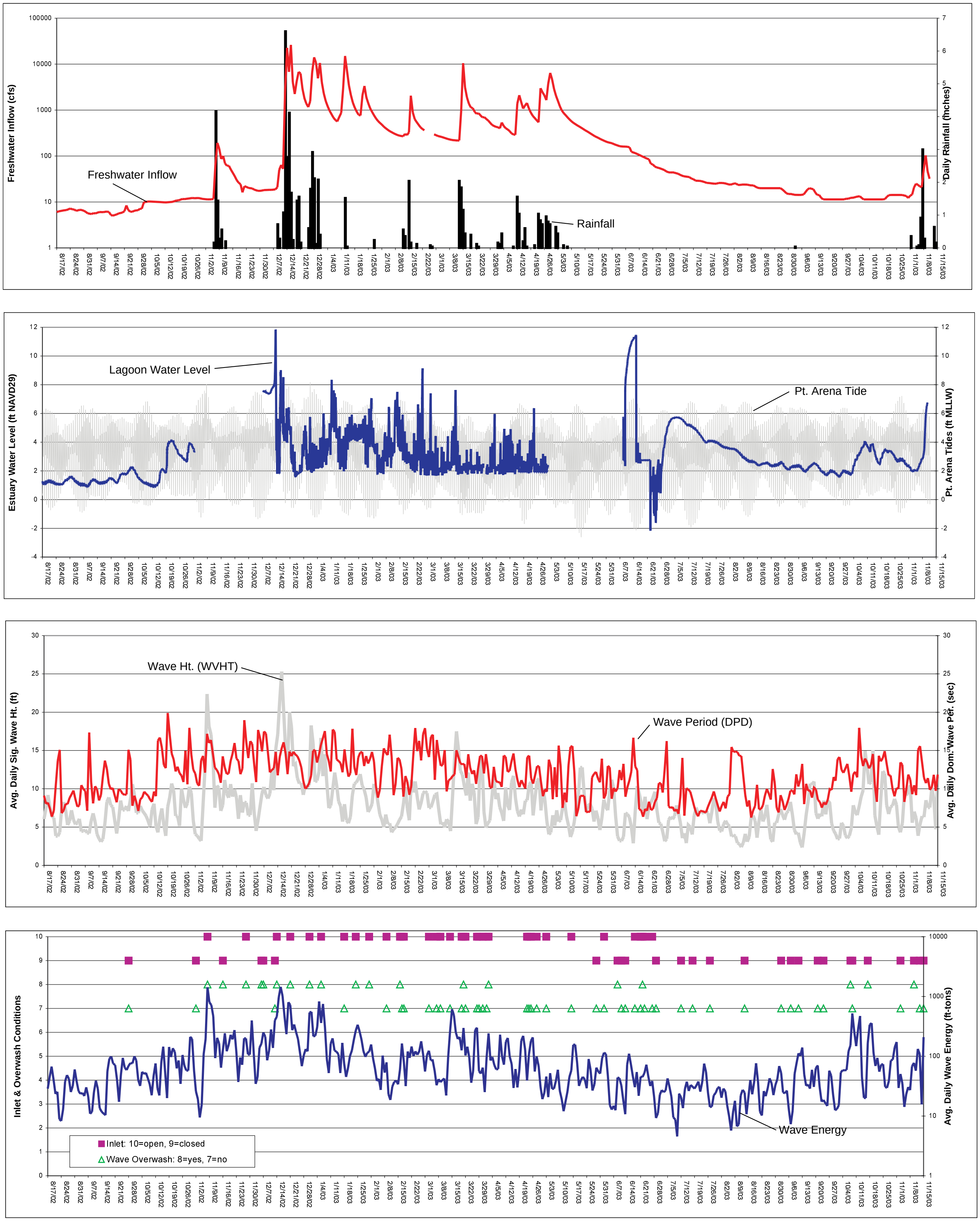
2.2.1 Precipitation

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. 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 for 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 seasonal and daily rainfall distribution for the study period reflects the general meteorological 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 2003) April average of 2.79-inches. These late season rains sustained high inflow to the estuary, which was the primary cause for the late season breach on June 15, 2003.

2.2.2 Estuary Freshwater Inflow

For the study period, freshwater inflow to the estuary 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.

[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.



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Hydrologic Monitoring Results

FIGURE

2.2

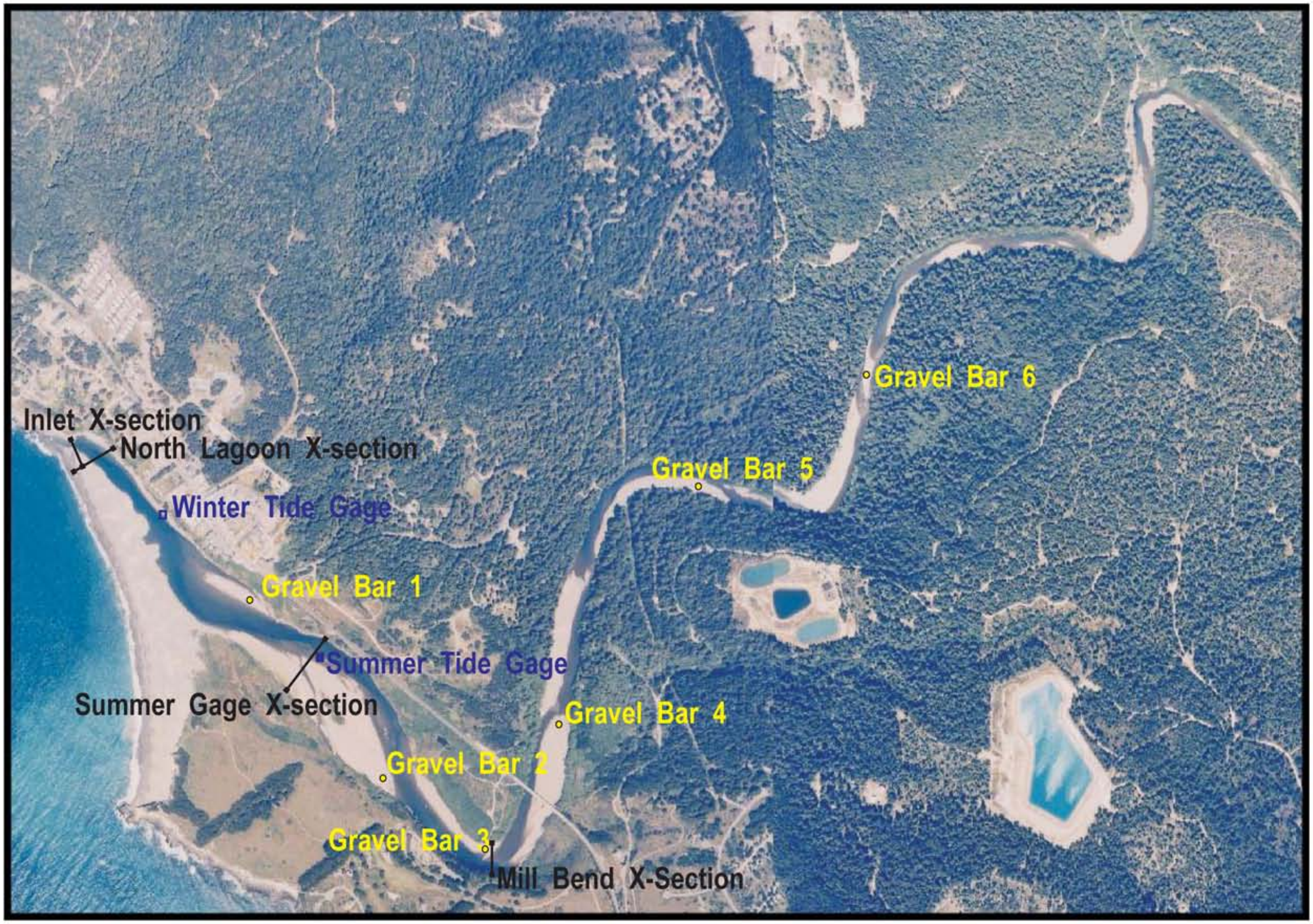
Estimated freshwater inflow to the estuary over the study period is presented in the top panel of Figure 2.2 along with daily rainfall totals. Inflow responses to storms and the rise and post-winter recession in the baseflow rates are clearly evident. Although the on-setof winter storms is not out of the ordinary during the study period, the combination of continued storm pulses and sustained elevated baseflows to the estuary through June of 2003 are notable differences to long-term average conditions. As a result, the persistence of elevated estuary inflow delayed the full closure of the barrier beach and also promoted the complete fresh water filling of the estuary by early June of 2003, leading to overtopping and breaching of the barrier beach.

2.2.3 Estuary Water Levels

Estuary 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 riprap filled log-crib in the middle portion of the estuary on August 16, 2002. In anticipation of damage or loss of the instrument during high winter flows, the gage was relocated to the east bank of the estuary (lower portion), 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 estuary water levels are illustrated on the second panel (from top) of Figure 2.2. Coverage of the full range of estuary water levels was not achieved at either gauging location. As a result, the water levels are truncated over the lower range. Periods of missing records also exist for the periods of November/December 2002 and May/June 2003. Missing monitoring data resulted from logger maintenance problems.

The seasonal changes in estuary water levels are captured in the water level record. In August through early November 2002, the barrier beach remained intact. Daily diurnal



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Tide Gage, Cross-Section, and Pebble Count Locations

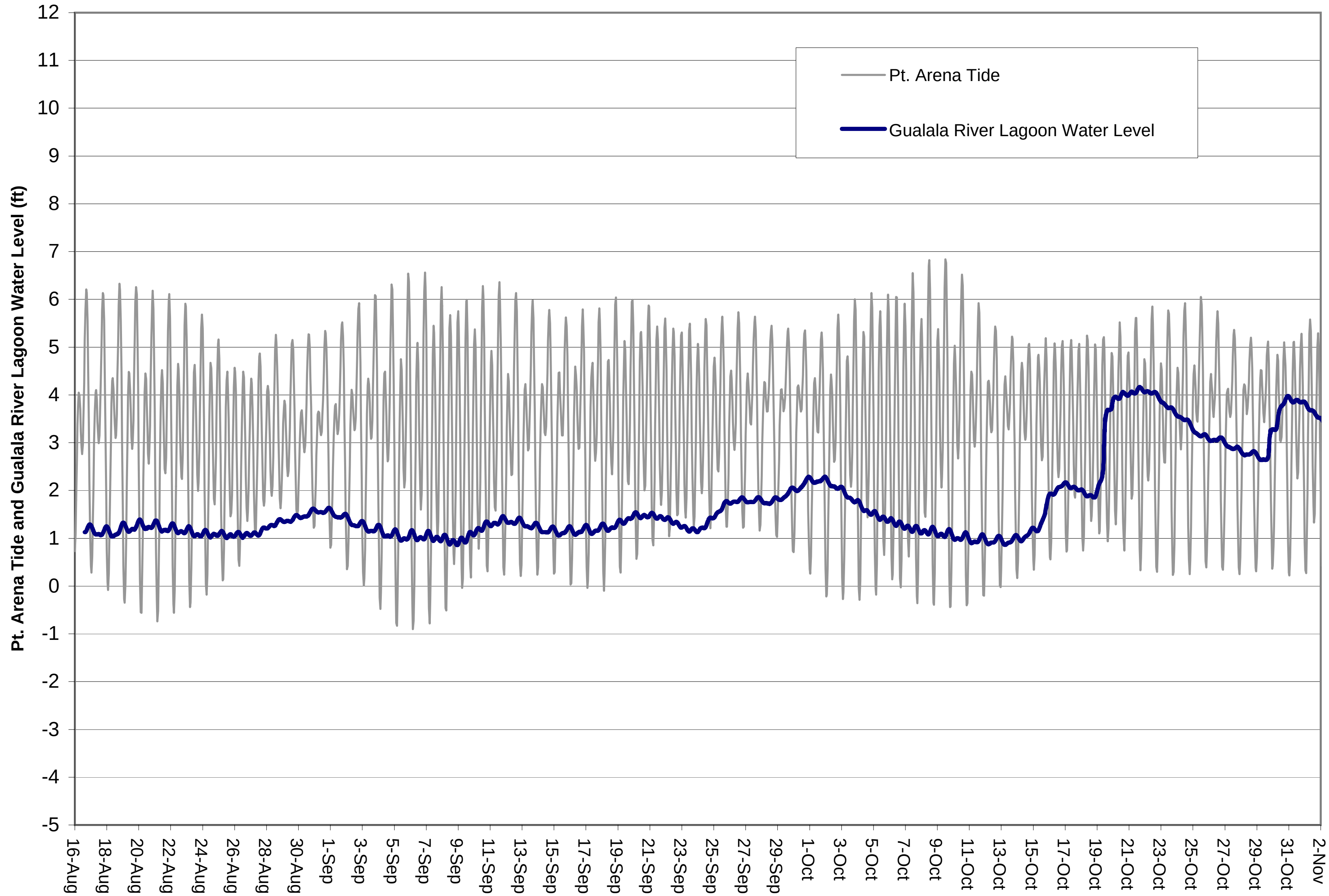
FIGURE

2.3

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 (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 eroded down to the daily MLLW tide level – an elevation well below the tide gage monitoring range. Subsequent recorded 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 by the vertical migration of daily minimum water levels.

The June 15, 2003 breach also resulted in a drop in estuary water levels by at least 9 feet as seen in Figure 2.2. Again, the drop in water level was likely greater than indicated (by at lease several feet) when compared to the MLLW-levels recorded at the Pt. Arena tide gage. The estuary water level record indicates a rapid reconstruction of the barrier beach over the two-week period following the breach event with estuary water levels again rising in response to relatively high inflow rates. Inflow and the seepage rate through the barrier beach "stabilize" in early July 2003, as estuary 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 estuary water levels by up to 2-feet, wave over-wash contributed a significant volume of water to the estuary in the late fall period of 2003. With the advent of the first storm of the winter season on November 10, 2003, estuary water levels rise more sharply until the barrier



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Lagoon Water Level vs. Pt. Arena Tide (August 15 - November 2, 2002)

FIGURE 2.4

GRE tide gage.xls,Figure 2-4

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 estuary.

2.2.4 Ocean Tides

Ocean tides for Point Arena Cove reported by NOAA are plotted against estuary water levels in Figure 2.2. These tides are representative of ocean water level conditions adjacent to the Gualala River coastal estuary. 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 estuary 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 estuary 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, theoretically, keep the inlet open indefinitely.

2.2.5 Wave Climate

For purposes of this report, the wave climate acting on the Gualala River coastal estuary 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 estuary 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.

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:

$$WVE = (w*L*WVHT^2)/8$$

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

$$L = 5.12*DPD^2$$

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 estuary 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-Estuary-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 estuary morphology during the study period.

Historic Conditions

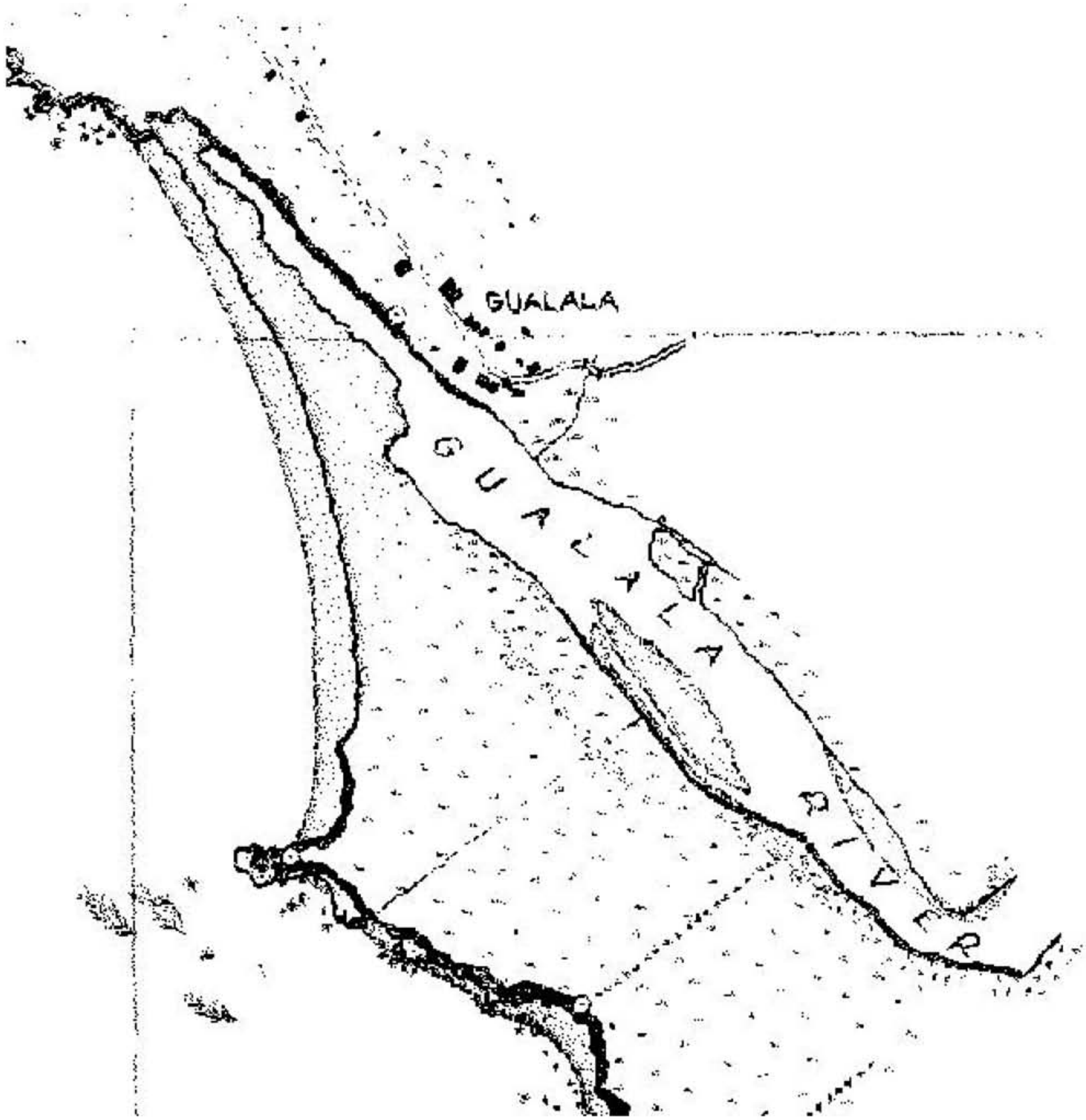
Numerous aerial photographs of the lower Gualala River and estuary were obtained and reviewed as part of this analysis. Sources of photographs included the California Department of Forestry and Fire Protection, WAC Corporation of Eugene, Oregon, and Pacific Aerial Surveys of Oakland, California. In addition, 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 (month/day unknown)
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 estuary-barrier beach system during any given year. A review of aerial photographs indicated no notable changes in the physical setting and character of the estuary beyond those that likely fall within the natural seasonal variability. For example, no significant repositioning or erosion of various bar forms within the lower river or estuary 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 estuary water level conditions between aerial images. Thus, no definitive conclusions were reached with respect to whether estuary bathymetry has changed over time.

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 feet of the bedrock cliff marking the north end of the estuary. There are anecdotal accounts of the breach occurring closer to the south end of the beach during extreme flood events during an El Niño period. However, these types of breaches start out as overtopping along the entire



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Assessment and Enhancement Plan

1929 U.S. Coast and Geodetic Survey Map

FIGURE

2.5

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

A program of near-weekly photo-point monitoring of the Gualala River estuary/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 in 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 estuary water level;
- Presence and estimate of high water erosion lines;
- Water color in terms of the presence of significant sediment inflow to the estuary (brown color) or presence of salt-water in estuary (turquoise color); and
- Presence of flood debris or kelp in/on the estuary and beach.

Photo point observations provided the most definitive chronology of barrier beach breaching and reconstruction over the study period. Illegal breaches from human activity, which can significantly affect the natural cycle of open and closed inlets and result in decreased survival of juvenile salmonids rearing in the estuary, were not observed during the study period, although natural breaches did occur. 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.

A pair of estuary/barrier-beach surveys was completed over the study period in order to capture and quantify changes in cross-sectional estuary profiles between September 28,

TABLE 2.1

Photo-Point Monitoring Observations
Gualala Lower River and Coastal Lagoon Assessment and Enhancement Plan

DATE	TIME	Weather	INLET				Wave Overwash (active)			Wave Overwash (previous)				Water Level			Flood Debris		High Water Erosion lines (Active)		(Previous)		Water Color (Sedimentation)			Water Color (Salt Water Exchange)			Kelp in Estuary	
			Open	U	Closed		Yes	No		Yes	U	No		Low	Med	High	Yes	No	yes	No	Yes	No	Yes	U	No	Yes	U	No	Yes	No
5/29/2002	U	clear			Closed	9		No	7			No*	6			High		No		No	Yes				No	Yes				No
8/16/2002	U	cloudy			Closed	9		No	7		U*		6			High		No		No	Yes*				No			No		No
9/28/2002	U	clear			Closed	9		No	7			No	5		Med			No		No		No			No			No		No
11/2/2002	U	clear			Closed	9		No	7	Yes			6		Med			No		No		No			No		U*			No
11/8/2002	U	cloudy	Open			10	Yes		8	Yes			6			High	Yes			No		No	Yes			Yes				No
11/11/2002																														
11/16/2002	U	partly cloudy			Closed	9	Yes		8	Yes			6			High	Yes		yes			No	Yes			Yes			Yes	
11/28/2002	U	cloudy	Open			10	Yes		8	Yes			6			High	Yes		yes			No	Yes				U*		Yes	
12/6/2002	U	cloudy			Closed	9	Yes		8	Yes			6			High		No		No		No			No	Yes			Yes	
12/7/2002	U	clear			Closed	9	Yes		8	Yes			6			High		No		No		No			No	Yes			Yes	
12/13/2002	11:30	Rain			Closed	9		No	7	Yes			6			High		No		No		No			No	Yes			Yes	
12/14/2002	11:30	Rain	Open			10	Yes*		8	Yes			6			High		No	yes			No	Yes					No		No
12/21/2002	U	clear	Open			10	Yes*		8	Yes			6			High		No	yes		Yes		Yes					No		No
12/31/2002	U	partly cloudy	Open			10	Yes		8	Yes			6			High		No				No	Yes					No		No
1/6/2003	15:45	clear	Open			10	Yes		8			No	5			High		No				No	Yes					No		No
1/18/2003	12:25	clear	Open			10		No	7	Yes			6			High		No	yes		Yes		Yes			Yes*				No
1/24/2003	15:00	overcast	Open			10	Yes		8	Yes			6			High		No	yes		Yes				No	Yes*				No
1/31/2003	U	clear	Open			10	Yes		8	Yes			6			High		No		No	Yes				No	Yes*				No
2/9/2003	U	clear	Open			10		No	7	Yes			6			High		No	yes		Yes				No	Yes*				No
2/16/2003						10			8				6																	
2/17/2003	17:00	clear	Open			10		No	7	Yes			6			High		No		No	Yes				No	Yes*				No
2/18/2003	U	clear	Open			10		No	7	Yes			6		Med			No	Yes		Yes				No	Yes*				No
3/3/2003	U	clear	Open			10		No	7	Yes			6		Med			No	Yes		Yes				No	Yes*				No
3/7/2003	U	clear	Open			10		No	7	Yes			6		Med			No		No	Yes				No	Yes*				No
3/9/2003	U	clear	Open			10		No	7	Yes			6		Med			No		No	Yes				No			No		No
3/14/2003	U	cloudy	Open			10		No	7	Yes			6			High		No	Yes		Yes		Yes					No		No
3/20/2003	U	cloudy	Open			10		No	7	Yes			6			High		No	Yes		Yes		Yes			Yes				No
3/21/2003	U	clear	Open			10	Yes		8	Yes			6			High		No		No	Yes				No	Yes*				No
3/22/2003	U	clear	Open			10		No	7	Yes			6			High		No		No	Yes				No	Yes*				No
3/28/2003	U	clear		U*		10		No	7	Yes			6			High		No		No	Yes				No	Yes				No
3/29/2003	U	clear		U*		10		No	7	Yes			6			High		No		No	Yes				No	Yes				No
3/31/2003	U	clear	Open			10		No	7	Yes			6			High		No		No	Yes		Yes					No		No
4/2/2003	16:40	overcast	Open			10		No	7	Yes			6			High		No	Yes		Yes				No	Yes				
4/3/2003	*					10			8				6																	
4/23/2003	U	cloudy		U*		10		No	7	Yes			6			High		No		No	Yes				No	Yes**				No
4/24/2003	U	cloudy		U*		10		No	7	Yes			6			High		No		No	Yes				No	Yes**				No
4/25/2003	U	Partly cloudy	Open			10		No	7	Yes			6			High		No	Yes*		Yes		Yes					No		No
4/28/2003	11:40	rain	Open			10		No	7	Yes			6			High		No	Yes*		Yes		Yes					No		No
5/3/2003	13:40	clear	Open			10		No	7	Yes			6			High		No	Yes		Yes		Yes			Yes				No
5/16/2003	11:00	clear	Open*			10		No	7	Yes			6			High		No	Yes		Yes				No	Yes**				No
5/29/2003	U	clear			Closed	9		No	7	Yes			6			High		No		No	Yes				No	Yes*				No
6/2/2003	U	clear	Open			10		No	7	Yes			6			High		No		No	Yes				No	Yes*				No

TABLE 2.1

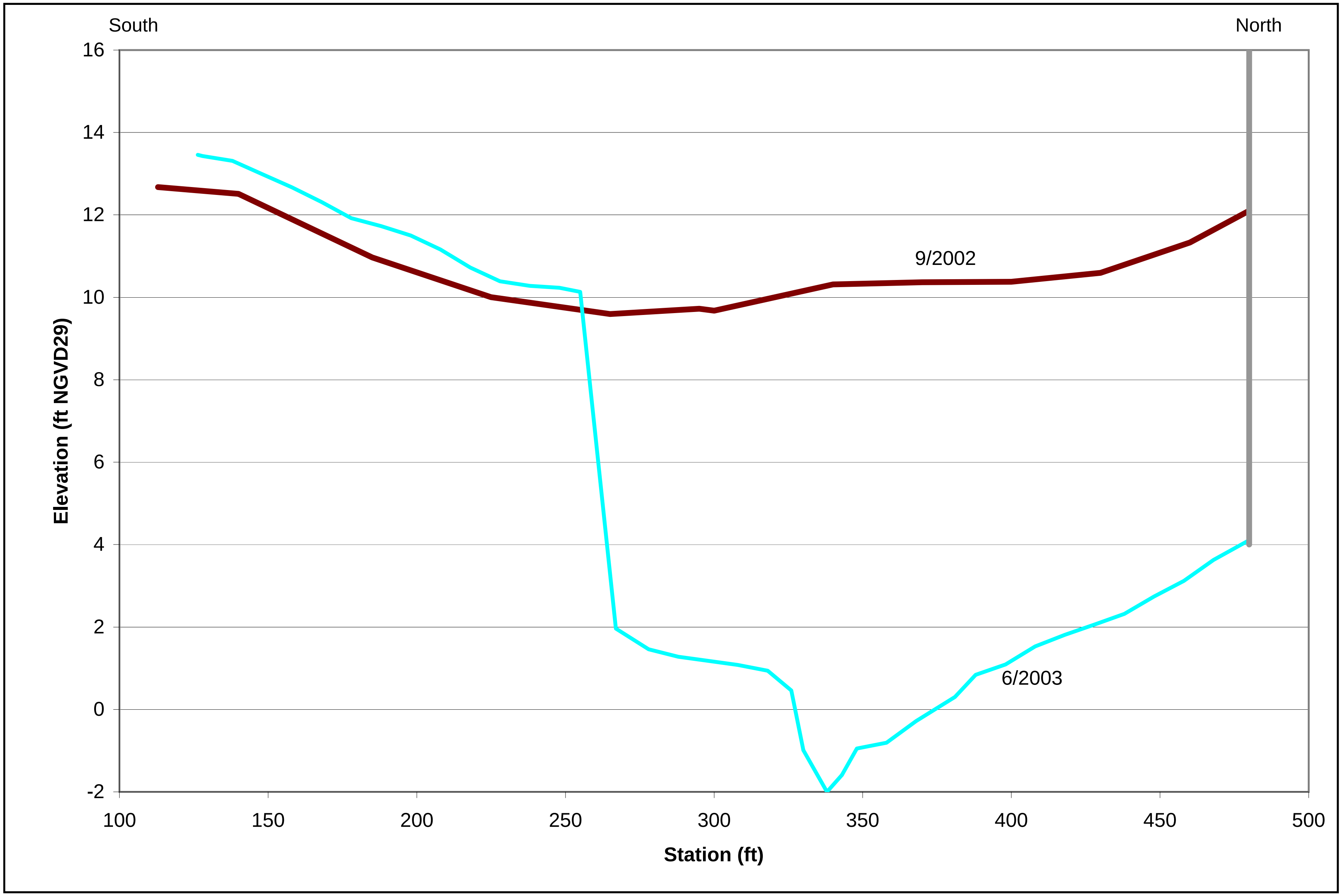
Photo-Point Monitoring Observations
Gualala Lower River and Coastal Lagoon Assessment and Enhancement Plan

DATE	TIME	Weather	INLET				Wave Overwash (active)			Wave Overwash (previous)				Water Level			Flood Debris		High Water Erosion lines (Active)		(Previous)		Water Color (Sedimentation)			Water Color (Salt Water Exchange)			Kelp in Estuary	
			Open	U	Closed		Yes	No		Yes	U	No		Low	Med	High	Yes	No	yes	No	Yes	No	Yes	U	No	Yes	U	No	Yes	No
6/6/2003																														
6/9/2003	U	overcast			Closed	9	Yes*		8	Yes*			6			High		No	Yes**	No					No	Yes***				No
6/11/2003	U	clear			Closed	9		No	7	Yes			6			High		No		No		No			No	Yes*				No
6/13/2003	10:40	clear			Closed	9		No	7	Yes			6			High		No		No		No			No			No		No
6/18/2003	12:30	clear	Open			10		No	7			No	5		Med			No	Yes		Yes				No			No		No
6/21/2003	U	clear	Open			10		No	7			No	5		Med			No		No	Yes				No			No		No
6/22/2003	*					10			8				6																	
6/23/2003	14:40	clear	Open			10		No	7	Yes			6		Med			No	Yes		Yes				No			No		No
6/27/2003	U	clear	Open			10		No	7	yes*			6			High		No		No	Yes				No	Yes**				No
6/29/2003	14:15	clear			Closed	9		No	7	yes*			6			High		No		No	Yes				No	Yes**				No
7/12/2003	12:00	clear			Closed	9		No	7			No	5			High		No		No		No			No			No		No
7/18/2003	14:48	clear			Closed	9		No	7			No	5			High		No		No	Yes*				No			No		No
7/27/2003	12:52	Foggy			Closed	9		No	7			No	5			High		No		No	Yes*				No			No		No
8/14/2003	12:45	overcast			Closed	9		No	7			No	5			High		No		No	Yes*				No			No		No
9/2/2003	U	overcast			Closed	9		No	7			No	5			High		No		No	Yes*				No			No		No
9/7/2003	U	cloudy			Closed	9		No	7			No	5			High		No		No	Yes*				No			No		No
9/11/2003	10:10	clear			Closed	9		No	7			No	5			High		No		No	Yes*				No			No		No
9/21/2003	16:40	clear			Closed	9		No	7			No	5			High		No		No	Yes*				No			No		No
9/24/2003	9:40	overcast			Closed	9		No	7			No	5			High		No			Yes*				No			No		No
10/8/2003	U	clear			Closed	9	Yes		8			No	5			High		No		No		No			No		U*			No
10/9/2003	U	clear			Closed	9		No	7	Yes			6			High		No		No		No			No	Yes*				No
10/17/2003	13:50	clear			Closed	9	Yes		8	Yes			6			High		No		No	Yes				No	Yes		No		No
11/3/2003	11:16	clear			Closed	9		No	7	Yes			6		Med			No			Yes				No			No		No
11/10/2003	10:30	clear			Closed	9	Yes		8	Yes			6			High		No		No		No			No	Yes				No
11/13/2003	10:34	overcast			Closed	9		No	7	Yes			6			High		No		No		No			No		U*			No
11/15/2003	U	overcast			Closed	9		No	7	Yes			6			High		No		No		No			No		U*			No
11/19/2003	15:20	overcast			Closed	9		No	7	Yes			6			High		No		No		No			No		U*			No
11/30/2003	U					10			8				6																	
12/2/2003	10:30	overcast			Closed	9		No	7	Yes			6			High		No		No		No			No			No		No
12/3/2003	11:12	clear	Open			10		No	7	Yes			6		Med			No	Yes		Yes		Yes					No		No
12/7/2003	U	cloudy	Open			10		No	7	Yes			6		Med			No	Yes		Yes		Yes					No		No
12/15/2003	U	clear	Open			10	Yes		8	Yes			6		Med			No	Yes		Yes		Yes			Yes				No
12/16/2003	U	cloudy	Open			10	Yes		8	Yes			6			High		No	Yes		Yes		Yes			Yes				No
12/28/2003	14:37	cloudy	Open			10	Yes*		8	Yes			6			High		No	Yes		Yes		Yes			Yes				No

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 in a N-S direction and 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 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 estuary. 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 estuary (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 estuary.

Further to the south, upstream of the barrier beach, changes in the cross-sectional profile of the estuary 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



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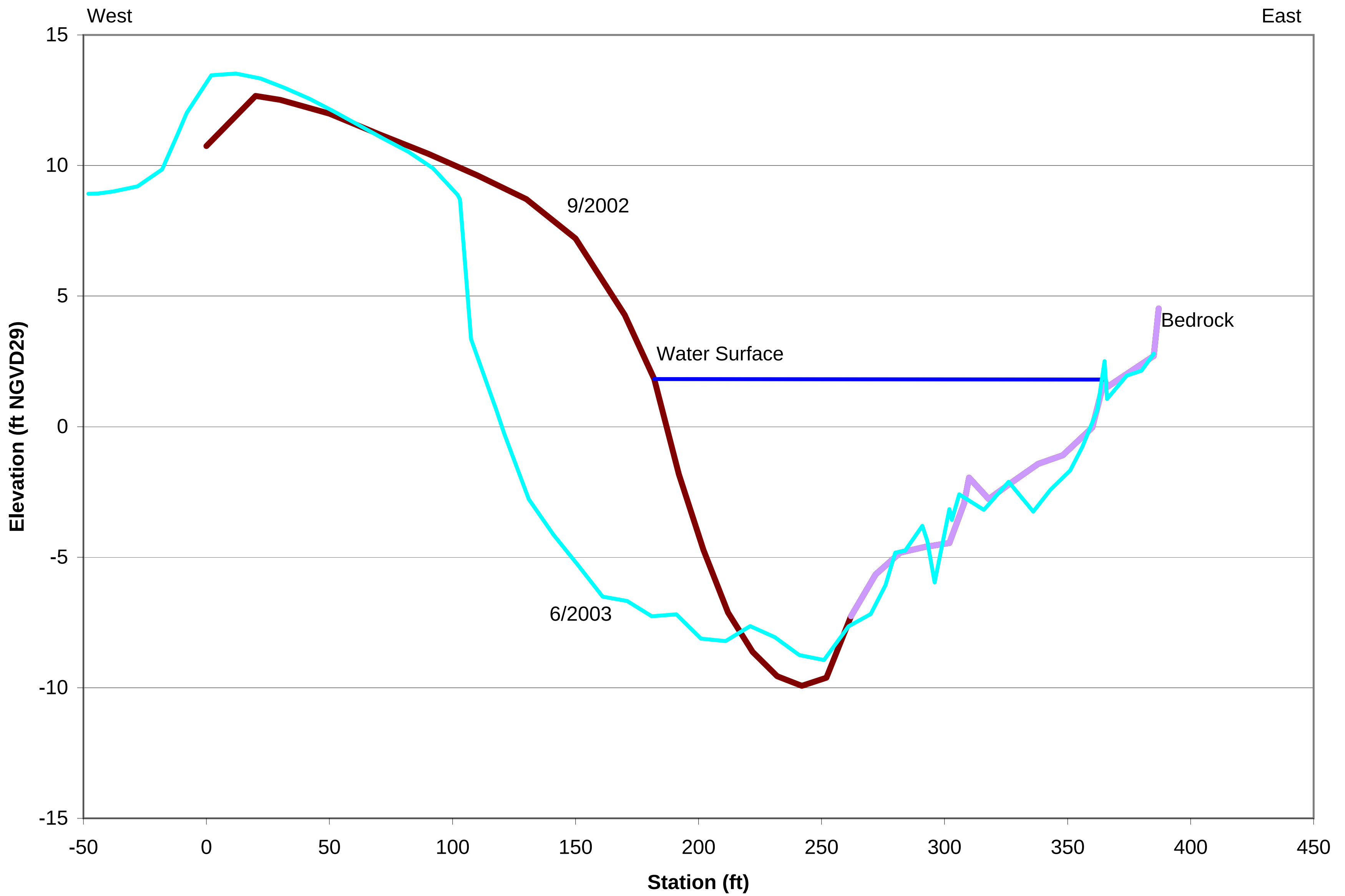
Lower Gualala River and Coastal Lagoon Assessment and Enhancement Plan

Cross-Sectional Profiles of Lagoon Inlet - 9/28/02 and 6/22/03

FIGURE 2.6



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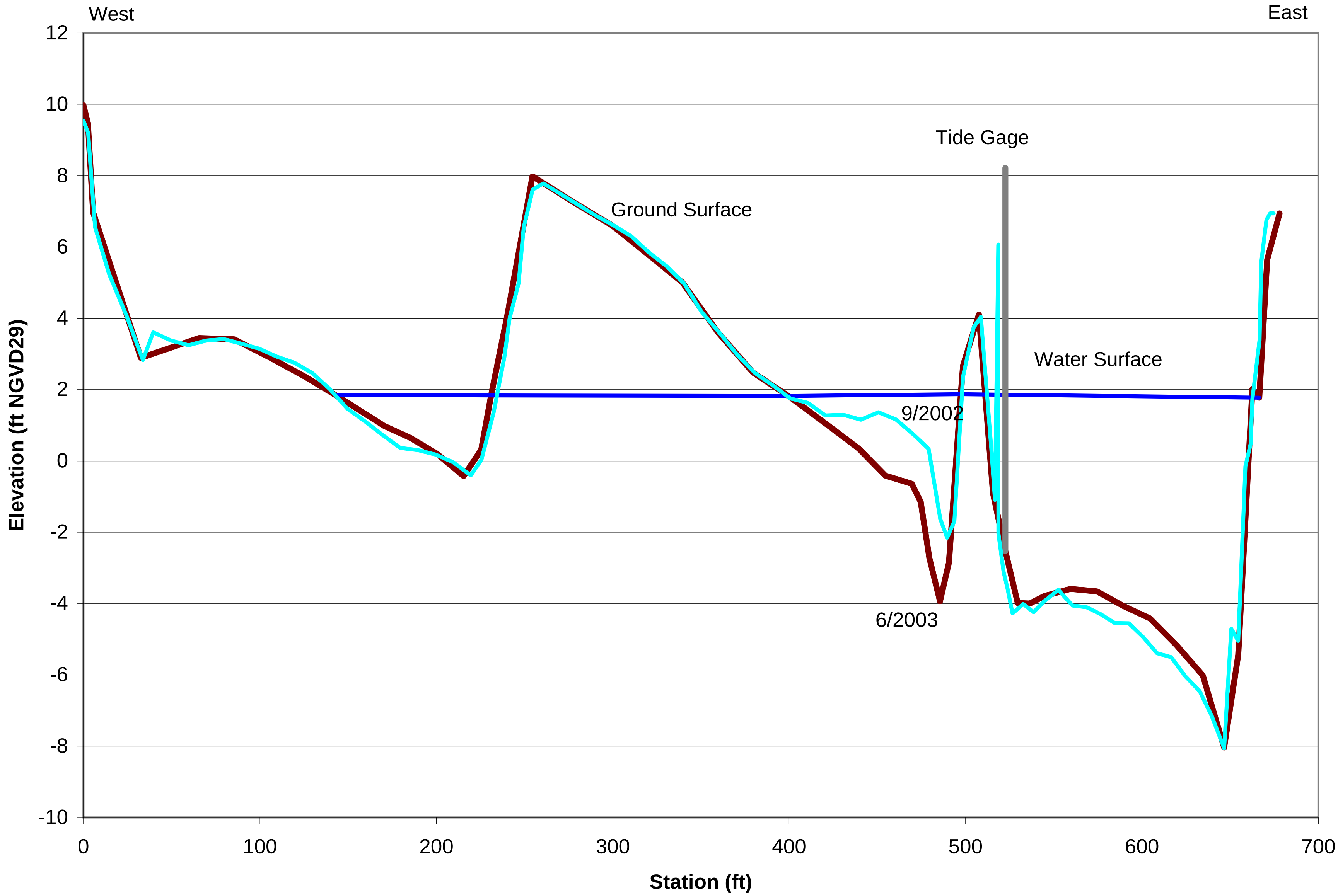
Lower Gualala River and Coastal Lagoon Assessment and Enhancement Plan

Cross-Sectional Profiles at **North** End of Lagoon - 9/28/02 and 6/22/03

FIGURE 2.7

Cross Sections.xls,Figure 2-7



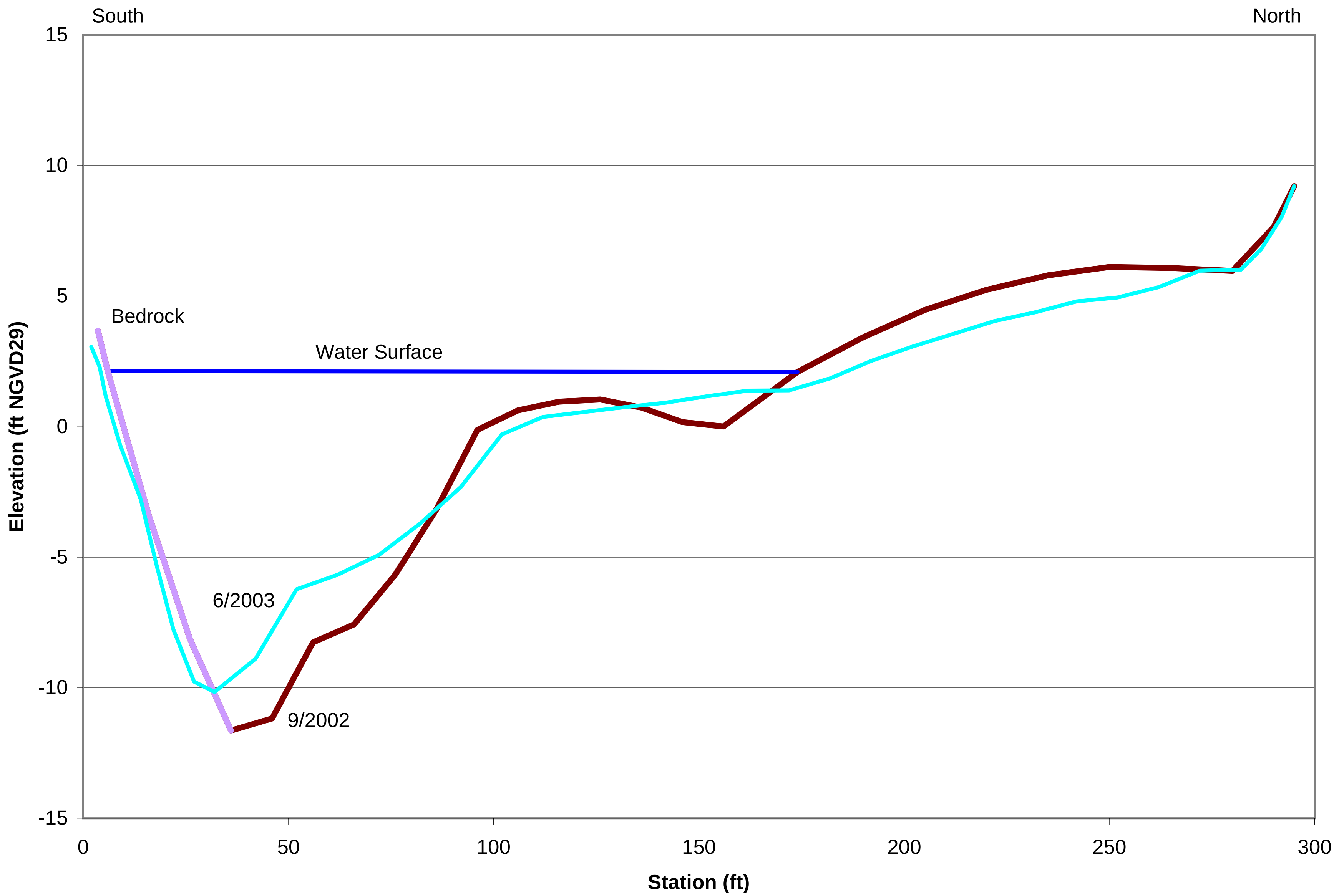
Kamman Hydrology & Engineering, Inc.

Lower Gualala River and Coastal Lagoon Assessment and Enhancement Plan

Cross-Sectional Profiles at Summer Tide Gage - 9/28/02 and 6/22/03

FIGURE 2.8

Cross Sections.xls,Figure 2-8



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& Engineering, Inc.

Lower Gualala River and Coastal Lagoon Assessment and Enhancement Plan

Cross-Sectional Profiles at Mill Bend - 9/28/02 and 6/22/03

FIGURE
2.9

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 change in bar morphology 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 estuary 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 Estuary Morphodynamics

Combining all of the data and observations collected over the study period (photo-point monitoring, estuary cross-sectional surveys, estuary 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 estuary morphology. This section of the report attempts to describe these changes in terms of dominant physical processes and consequences to estuary 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 estuary 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 estuary that overtop and incise through the barrier beach.

The cycle of Gualala River coastal estuary barrier-beach breaching and reconstruction can be described in terms of beach/estuary 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 estuary. 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 estuary 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 estuary water levels associated with increased freshwater inflows. As seen throughout the winter of 2002/03, the resultant estuary inlet will remain open after breaching as long as there is sufficient freshwater inflow to the estuary combined with tidal prism 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 in combination with tidal exchange.

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 estuary 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 estuary over spilling the barrier beach. In the evening of June 15, 2003, there was an extreme difference in water surface elevation between estuary 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 estuary over a span of 24 hours. Based on a post-breach cross-sectional survey (see Figure 2.6) and recorded estuary 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 estuary (see Figure 2.2). By early July 2003, outflows from the estuary (as evaporation and seepage through the barrier beach) exceeded inflow and estuary water levels began to decline. Equilibrium between estuary inflow and outflow was again reached by mid-August of 2003, resulting in relatively static estuary water levels and barrier beach morphology until the onset of wave over-wash events in early October 2003.

2.4 Estuary 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 estuary and barrier beach development.

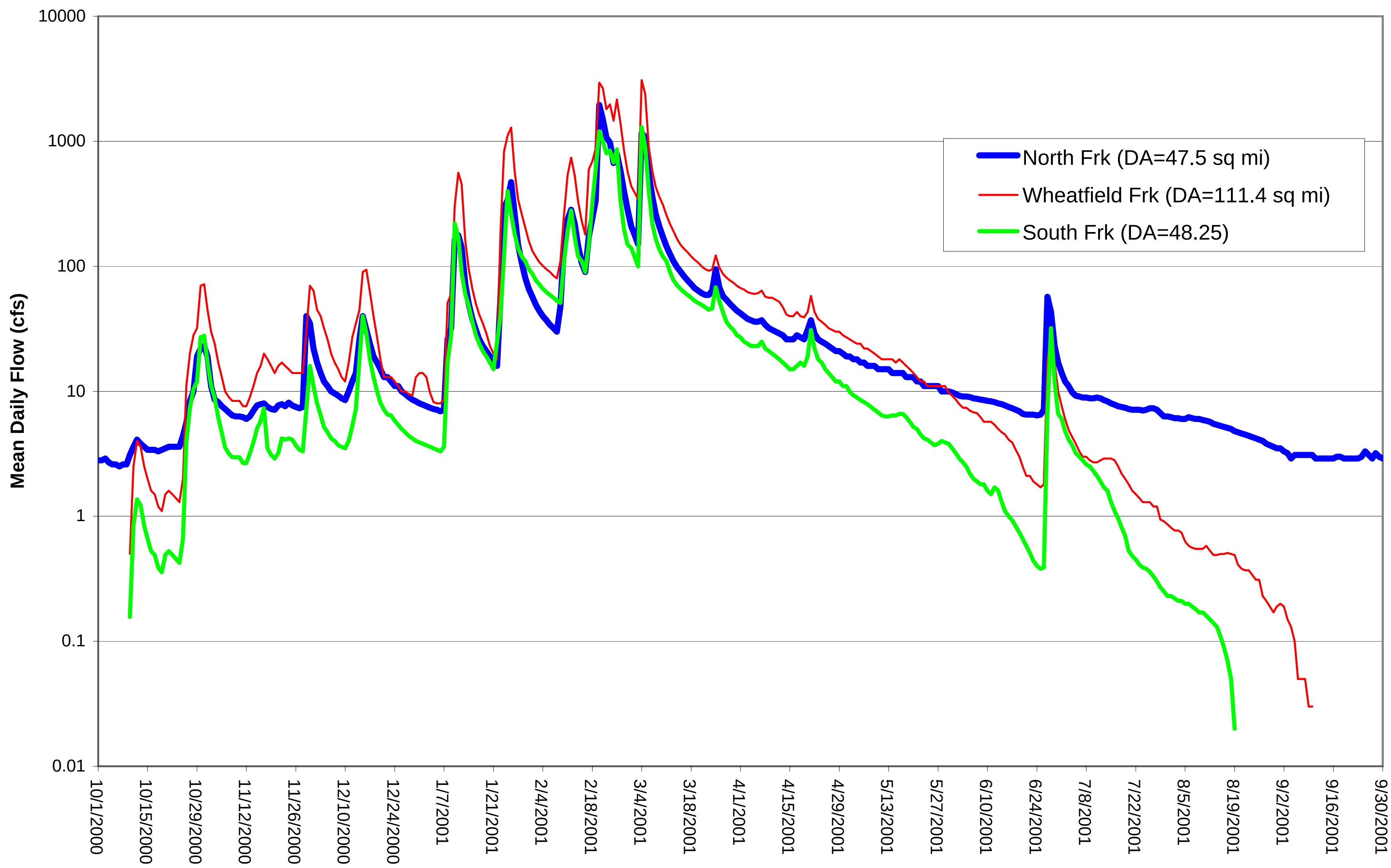
The short-term cycles of barrier beach/inlet breaching and reconstruction over the winter season result in sharp changes in estuary salinity. The RWQCB monitoring results for the period February 19-24, 2003 indicate that during periods when the majority of the inlet is partially closed and experiencing limited tidal exchange during high tide periods (i.e., estuary water level fluctuations up to only 2-feet) the estuary 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 estuary during flood tide, raising estuary 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 estuary 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 estuary 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 estuary water levels and concentrations quickly return to the freshwater range during ebb tidal periods due to relatively high freshwater inflow rates.

Monitoring of estuary 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 estuary 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 estuary 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 estuary 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, estuary 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 estuary 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 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.



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Lower Gualala River and Coastal Lagoon Assessment and Enhancement Plan

Daily Flow Rates - North Fork, South Fork, and Wheatfield Fork (WY 2001)

FIGURE 2.10

2001 Flow Analysis.xls,Figure 2-9

Although the Gualala River coastal estuary 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 estuary 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 estuary 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 estuary 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 including Redwood Creek in Humboldt County, Santa Clara River in Ventura County, Malibu Creek in Los Angeles County, and Pescadero, San Gregorio, Waddell, and Pomponio Creeks in San Mateo County (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 estuary functioned in a natural and healthy manner during the “normal” and “below average” water year-type conditions and was dominated by fresh-water conditions. High salinity conditions were quickly flushed by freshwater inflows during ebb tidal cycles when the inlet was open or diluted during closed inlet conditions.

2.5 References

Ambrose, R.F. and Orme, A. R., 2000, Lower Malibu Creek and estuary 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.

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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/or 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. In addition, outmigration (including timing of outmigration) of juvenile steelhead was not directly studied.

3.2 Methods

3.2.1 Water Quality

To evaluate potential water quality affects on salmonids present in the estuary, 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 versus closed estuarine conditions, was conducted.

3.2.2 Aquatic Ecology

To adequately sample and evaluate aquatic habitats and species in the estuary, 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 estuary. 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 becomes 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 Mill Bend, or the "GRI (Gualala Redwoods, Inc.) Beach" located 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 North Coast Watershed Assessment

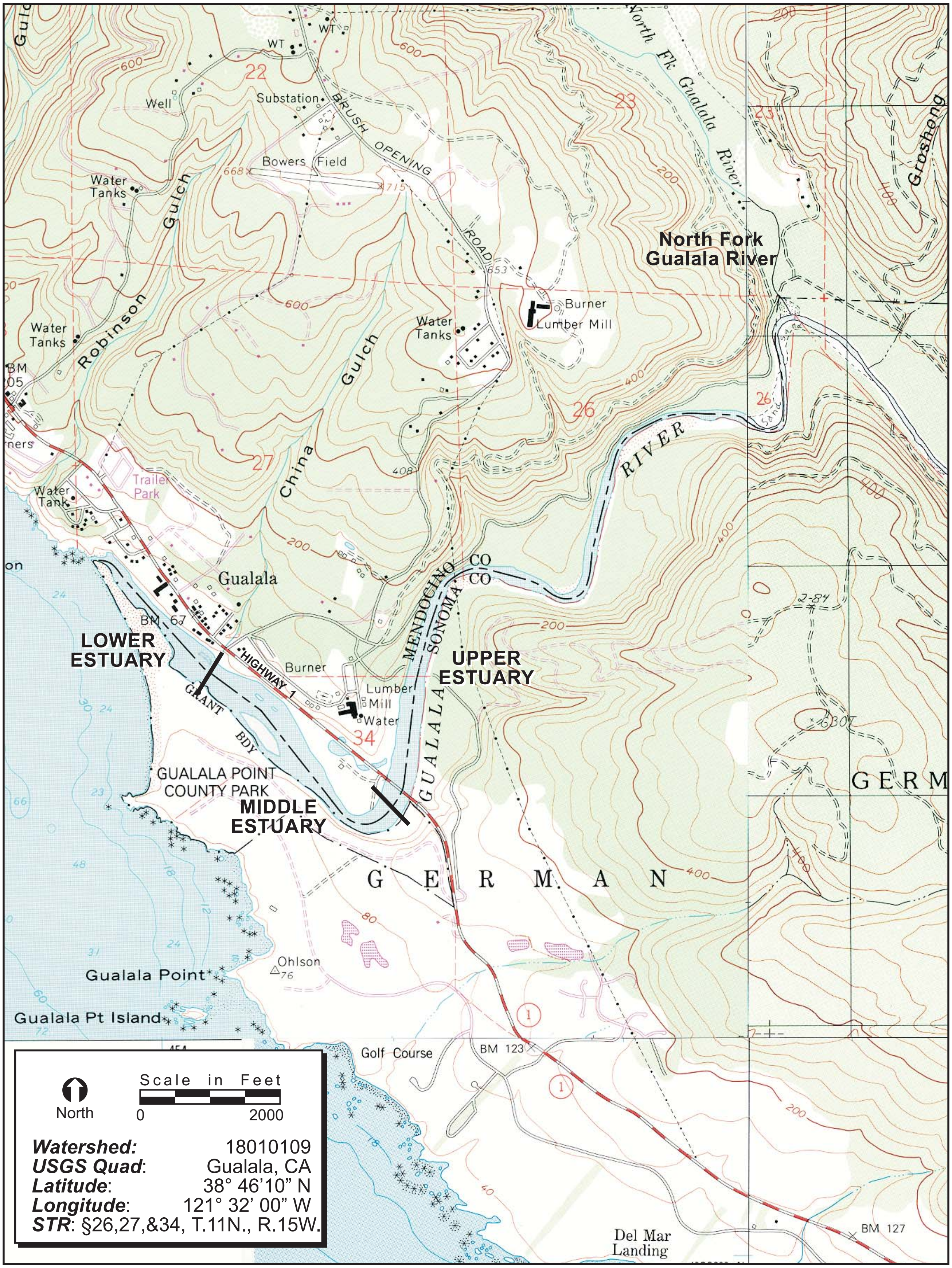

FIGURE 3.1 Project Site and Vicinity Map

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, four distinct habitat subsystems are present in the Gualala estuary:

1) marine,
2) brackish,
3) freshwater estuary, and
4) riverine.

A marine subsystem is present only during short transitional periods, with limited distribution in the lower estuary, when the mouth of the estuary has breached. Significant amounts of marine water can also enter the estuary during heavy surf conditions.

The brackish water subsystem is an extension of the marine subsystem, and is also transitional in nature in the Gualala estuary. Brackish water conditions can extend upstream farther than marine conditions, and for slightly longer time periods. However, the tendency of the Gualala estuary is toward a closed, freshwater state.

The freshwater estuary subsystem is by far the most common habitat type in the Gualala estuary. Even after breaches, or inputs of marine water from heavy surf conditions, the Gualala estuary generally returns to freshwater conditions within a short time period (days to weeks).

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 can become limiting due to both natural and human-induced factors. Such limiting factors include streamflow volume (which affects the amount of available fish habitat), water temperature, habitat quality, and stream sedimentation due to past logging practices, road building, and other land use practices. These and other watershed-specific issues have been addressed in the 2003 NCWAP report (Klamt *et. al*. 2003).

2002 Season

Field sampling was initiated in June 2002 and was conducted every three weeks through November 2002. A total of 6 monthly sampling events were completed (June through November). 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 large accumulations of filamentous algal, a decision was made to decrease sampling in the upper section. In general, filamentous algae is pervasive throughout the lower river and in some areas of the estuary from mid-summer through late-fall. These blooms did not appear to adversely impact steelhead juveniles during the 2002 or 2003 sampling seasons; in fact, steelhead fry were often observed using filamentous algae as cover. During the mid-summer to late fall period, the lower river is very shallow. The channel in this part of the river is wide and without significant riparian or other shaded cover (except along the channel edges) that would reduce or limit solar radiation input, a major factor conducive to algal and/or other macrophytic plant growth. Increased stream temperatures during the mid-summer and fall months reflect the increases in solar radiation and often exceed 20 ºC. In combination, the elevated water temperatures and increases in solar radiation would favor the growth of macroalgae and other aquatic plants providing sufficient nutrients are available. Nutrient loading can and may occur in the Gualala River watershed from anthropomorphic sources, such as agricultural runoff, campgrounds, and septic systems. However, these factors are outside the scope of this study.

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 to 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 the onset of late-fall wave overwash and increased estuary salinity, and

- that based on observations reported by CDFG biologists during summer snorkel surveys in the North Fork Gualala River, Coho salmon may still be present in the estuary[2].

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, the 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. A total of 7 monthly sample events were completed during the 2003 season (February and May through October).

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 to the other side of the river. Also, in some backwater areas, a two-person 10-meter seine was 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

[2] Juvenile Coho salmon were reported (but not confirmed) to NOAA fisheries personnel to have been stranded immediately after the early summer breach event on June 15, 2003.

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 calculation of population estimates within the estuary for each sampling event. 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.

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 estuary conditions. A second set of samples was collected in 2003 in the middle estuary (RM 0.8) during the May sampling effort, while the estuary 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.

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 during this closed lagoon period (Appendix B-1 through B-4). Water temperatures ranged from about 18.0 – 19.0 °C, salinity readings were slightly above zero (freshwater dominated), 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).

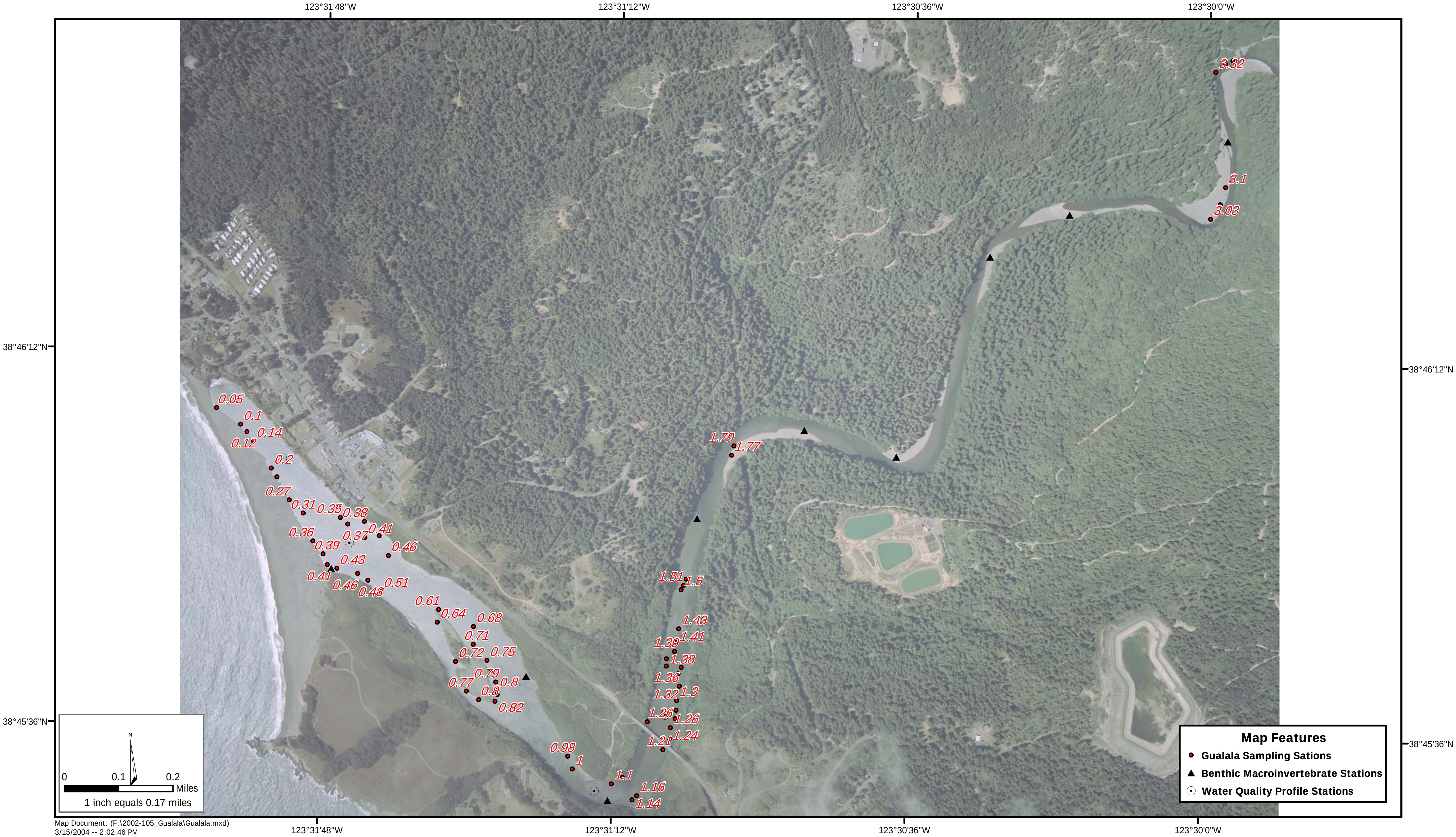

Figure 3.2: Gualala Estuary Sampling Site Locations

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ENVIRONMENTAL CONSULTANTS

As expected, water quality profiles obtained in June 2003 under open estuary conditions (after June 15, 2003 breach) were substantially different than water quality profiles obtained during closed estuary conditions that were 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 at Mill Bend, 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).

August:

Two water quality profiles were obtained at Mill Bend in August 2002. 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, ranging from 21.1 to 25.0°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 summer 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 (2002) 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 the effects of increased salinity concentrations due to wave overwash extending 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 (2002), 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 profiles were collected 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 2.0, the estuary 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 and/or wave overwash. 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 barrier beach 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 (and at levels appropriate for juvenile steelhead survival) throughout the water column regardless of location within the estuary. During February and April sampling events, water temperatures averaged 10.0 to 11.4°C, with DO ranging from 9.5 to 12.7 mg/L.

May:

In May, salinity stratification (0 to 21 ppt) was evident at the Tide Gage (Appendix B-23) at depths below 5.0 ft, but conditions appeared to be well-mixed near the mouth (Appendix B-22). As would be expected, TDS levels mimicked the salinity curve. Above the stratified layer, water quality parameters were similar throughout the estuary: 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).

<u>Continuous Temperature Recorders</u>

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 estuary 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 both 2002 and 2003, the Gualala River estuary was primarily for most of the year, except when the estuary 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 month and estuary section for 2002 and 2003 at the Gualala estuary.

2002 Sampling Events	**Number of Hauls**			
	Lower Estuary	**Middle Estuary**	**Upper Estuary**	**Total**
June	10	7	2	19
July	12	3	2	17
August	25	8	2	35
September	28	7	1	36
October	31	7	2	40
November	12	10	8	30
Total	**118**	**42**	**17**	**177**

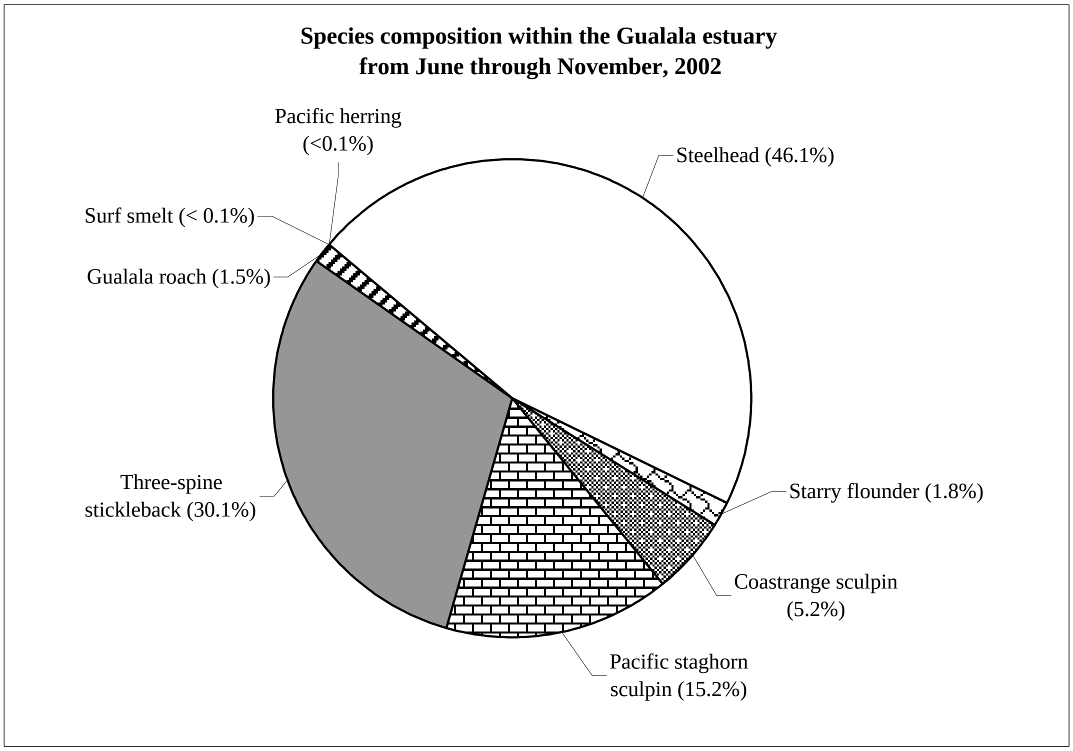
2003 Sampling Events	**Number of Hauls**			
	Lower Estuary	**Middle Estuary**	**Upper Estuary**	**Total**
February	10	7	4	21
May	9	2	1	12
June	8	2	15	25
July	7	6	3	16
August	15	2	6	23
September	18	6	5	29
October	30	8	10	48
Total	**97**	**33**	**44**	**174**

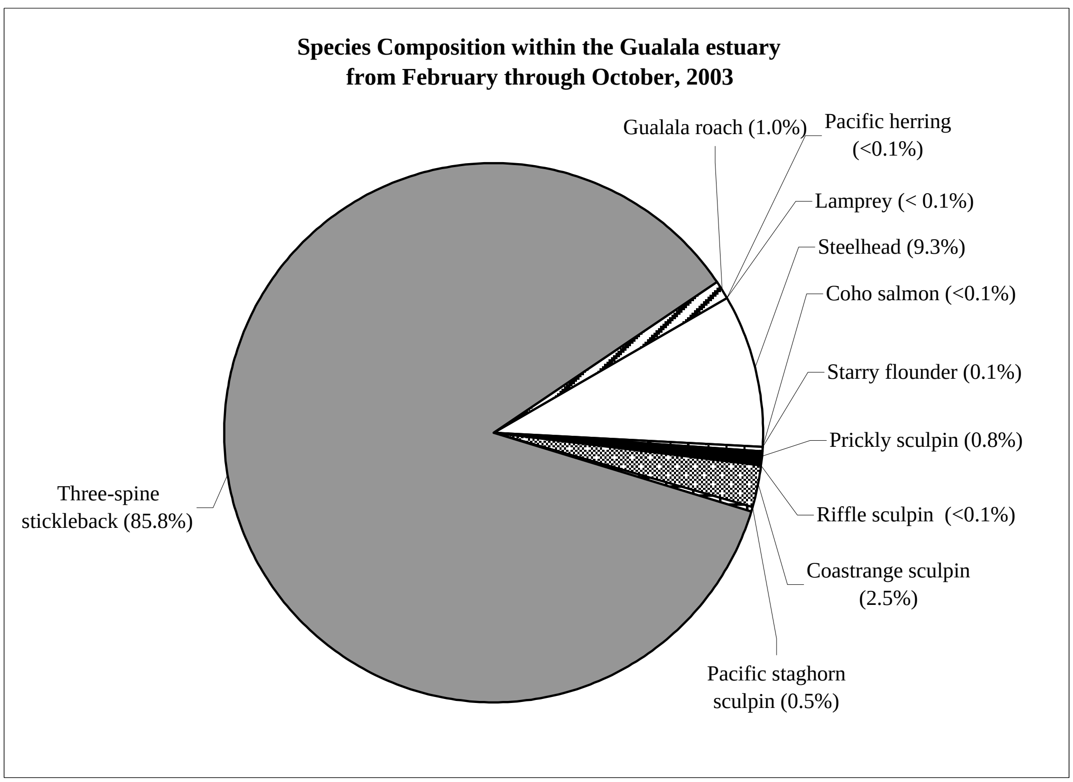
Table 3.2 Summary of fish abundance in the Gualala estuary by species and sampling event from June through November 2002, and from February through October 2003.

2002 Sampling Events	Event Number	Steelhead	Coho Salmon	Starry flounder	Prickly sculpin	Riffle sculpin	Coastrange sculpin	Pacific staghorn sculpin	Three-spine stickleback	Gualala roach	Pacific herring	Surf smelt	Lamprey	Total
June 19-20	1	159	0	13	0	0	39	23	41	82	3	2	0	**362**
July 10-12	2	696	0	99	0	0	3	295	199	18	0	0	0	**1,310**
August 1-2	3	820	0	13	0	0	124	106	95	0	0	0	0	**1,158**
August 12-13	4	833	0	28	0	0	0	509	457	11	0	0	0	**1,838**
September 4-6	5	1,135	0	22	0	0	189	407	591	1	0	0	0	**2,345**
September 25-27	6	825	0	19	0	0	229	214	1044	12	0	0	0	**2,343**
October 21-22	7	275	0	1	0	0	0	64	757	40	0	0	0	**1,137**
October 24	8	372	0	0	0	0	0	1	0	0	0	0	0	**373**
November 26-27	9	11	0	2	0	0	0	73	161	0	0	0	0	**247**
Total		**5,126**	**0**	**197**	**0**	**0**	**584**	**1,692**	**3,345**	**164**	**3**	**2**	**0**	**11,113**

2003 Sampling Events	Event Number	Steelhead	Coho Salmon	Starry flounder	Prickly sculpin	Riffle sculpin	Coastrange sculpin	Pacific staghorn sculpin	Three-spine stickleback	Gualala roach	Pacific herring	Surf smelt	Lamprey	Total
February 18-19	10	84	0	9	0	0	89	1	34	0	0	0	1	**218**
May 19-20	11	233	1	1	0	3	92	41	164	0	0	0	0	**535**
June 17-18	12	342	0	3	1	1	5	145	905	68	1	0	0	**1,471**
July 22-23	13	620	0	1	18	0	0	69	200	180	0	0	0	**1,088**
August 22-23	14	520	0	16	14	0	439	5	10,152	5	0	0	0	**11,151**
September 23-24	15	940	0	9	4	0	170	1	14,969	134	0	0	0	**16,227**
October 27-28	16	1108	0	2	305	1	104	0	8,485	93	0	0	0	**10,098**
October 30	17	621	0	6	40	0	286	0	6,425	1	0	0	0	**7,379**
Total		**4,468**	**1**	**47**	**382**	**5**	**1,185**	**262**	**41,334**	**481**	**1**	**0**	**1**	**48,167**

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





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. A single juvenile Coho salmon (102 mm in length) was collected in the lower estuary during the May sampling event. No other Coho salmon were collected during the study. Anecdotal information obtained from CDFG snorkel surveys and local residents indicated the possible presence of juvenile Coho salmon in the upper watershed. It is therefore likely that this individual was an outmigrant. 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 estuary 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

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

2002 Sampling Events	Estuary Section	Species									Total Number
		Steelhead	Coho Salmon	Starry flounder	Coastrange sculpin	Pacific staghorn sculpin	Threespine stickleback	Gualala roach	Pacific herring	Surf smelt	
June	Lower Estuary	81	0	13	21	23	4		3	2	147
	Middle Estuary	54	0		6		11	73			144
	Upper Estuary	24	0		12		26	9			71
	Total	**159**	**0**	**13**	**39**	**23**	**41**	**82**	**3**	**2**	**362**
July	Lower Estuary	104	0	57		233	55				449
	Middle Estuary	426	0	42		62	102	18			650
	Upper Estuary	166	0		3		42				211
	Total	**696**	**0**	**99**	**3**	**295**	**199**	**18**			**1,310**
August	Lower Estuary	1,486	0	39	10	191	335	9			2,070
	Middle Estuary	67	0	1	80	358	135	1			642
	Upper Estuary	100	0	1	34	66	82	1			284
	Total	**1,653**	**0**	**41**	**124**	**615**	**552**	**11**			**2,996**
September	Lower Estuary	1,813	0	41	392	439	1,001	1			3,687
	Middle Estuary	140	0		26	175	632	12			985
	Upper Estuary	7	0			7	2				16
	Total	**1,960**	**0**	**41**	**418**	**621**	**1,635**	**13**			**4,688**
October & November	Lower Estuary	487	0	1		15	620	40			1,163
	Middle Estuary	161	0	1		57	78				297
	Upper Estuary	10	0	1		66	220				297
	Total	658	0	3		138	918	40			1,757
	Overall Total	**5,126**	**0**	**197**	**584**	**1,692**	**3,345**	**164**	**3**	**2**	**11,113**

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

2003 Sampling Events	Estuary Section	Species: Steelhead trout	Coho Salmon	Starry flounder	Prickly sculpin	Riffle sculpin	Coastrange sculpin	Pacific staghorn sculpin	Threespine stickleback	Gualala roach	Pacific herring	Lamprey	Total Number
February	Lower Estuary	45		7			16	1	32			1	102
	Middle Estuary	30		2			65		1				98
	Upper Estuary	9					8		1				18
	Total	**84**		**9**			**89**	**1**	**34**			**1**	**218**
May	Lower Estuary	229	1	1		3	69	41	158				502
	Middle Estuary	3					23		6				32
	Upper Estuary	1											1
	Total	**233**	**1**	**1**		**3**	**92**	**41**	**164**				**535**
June	Lower Estuary	210		3				72	876		1		1,162
	Middle Estuary	23						3	3	23			52
	Upper Estuary	109			1	1	5	70	26	45			257
	Total	**342**		**3**	**1**	**1**	**5**	**145**	**905**	**68**	**1**		**1,471**
July	Lower Estuary	202		1				64	18				285
	Middle Estuary	317			12			5	82				416
	Upper Estuary	101			6				100	180			387
	Total	**620**		**1**	**18**			**69**	**200**	**180**			**1,088**
August	Lower Estuary	182		16	1		418	5	9,535	2			10,159
	Middle Estuary	72					5		9				86
	Upper Estuary	266			13		16		608	3			906
	Total	**520**		**16**	**14**		**439**	**5**	**10,152**	**5**			**11,151**
September	Lower Estuary	387		8	2		130	1	8,353	24			8,905
	Middle Estuary	52		1			16		2,909				2,978
	Upper Estuary	501			2		24		3,707	110			4,344
	Total	**940**		**9**	**4**		**170**	**1**	**14,969**	**134**			**16,227**
October	Lower Estuary	1,076		2	2	1	344		8,060	1			9,486
	Middle Estuary	496		4			26		1,000	1			1,527
	Upper Estuary	157		2	343		20		5,850	92			6,464
	Total	1,729		8	345	1	390		14,910	94			17,477
	Overall Total	**4,468**	**1**	**47**	**382**	**5**	**1,185**	**262**	**41,334**	**481**	**1**		**48,167**

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.

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 areas with submerged vegetation and filamentous algae. This species was substantially more abundant in the catch in 2003 than in 2002, likely a result of increased sampling in riverine habitat 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 (YOY) 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 estuary 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 numbers of coast range 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), at least partially due to increased sampling effort in riverine habitat. 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 was 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).

Annual differences in steelhead catch reflect annual (and seasonal) variation in several biological and physical factors. Other than biological variation (e.g., numbers of adult spawners, spawner-recruitment functions, age class specific mortality), the amount and quality of physical habitat directly affects the number of steelhead that are available to

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 2003.

2002 Sampling Events	Date(s)	Age 0+ Length Range (mm)	Age 0+ Number Caught	Age 0+ Percent Caught	Age 1+ and Older Length Range (mm)	Age 1+ and Older Number Caught	Age 1+ and Older Percent Caught	Total No.
1	June 19-20	29 - 79	118	74.2	81 - 182	41	25.8	159
2	July 10-12	41 - 84	475	68.2	85 - 188	221	31.8	696
3	August 1-2	37 - 84	145	17.7	85 - 206	675	82.3	820
4	August 12-13	49 - 89	191	22.9	90 - 194	642	77.1	833
5	September 4-6	51 - 89	150	13.2	90 - 198	985	86.8	1,135
6	September 26-27	71 - 99	76	9.2	100 - 234	749	90.8	825
7	October 21-22	77 - 104	33	12.0	107 - 214	242	88.0	275
8	October 24	77 - 104	54	14.5	105 - 208	318	85.5	372
9	November 26	0 - 104	0	0.0	139 - 212	11	100.0	11
	Total		**1,242**			**3,884**		**5,126**

2003 Sampling Events	Date(s)	Age 0+ Length Range (mm)	Age 0+ Number Caught	Age 0+ Percent Caught	Age 1+ and Older Length Range (mm)	Age 1+ and Older Number Caught	Age 1+ and Older Percent Caught	Total No.
10	February 18-19	51 - 104	33	39.3	107 - 230	51	60.7	84
11	May 19-20	32 - 79	62	26.6	80 - 137	171	73.4	233
12	June 17-18	26 - 84	272	79.5	85 - 138	70	20.5	342
13	July 22-23	51 - 84	142	22.9	85 - 161	478	77.1	620
14	August 21-23	67 - 89	60	11.5	90 - 198	460	88.5	520
15	September 23-24	73 - 99	201	21.4	100 - 203	739	78.6	940
16	October 27-28	82 - 104	44	4.0	105 - 221	1,064	96.0	1,108
17	October 30	86 - 104	27	4.3	105 - 238	594	95.7	621
	Total		**841**			**3,627**		**4,468**

rear in the estuary. The condition of the estuary (i.e., open vs. closed) during the late spring/early summer outmigration period can have a major impact on the estuarine population. If given the opportunity (i.e., open estuary conditions), smolt steelhead will voluntarily outmigrate from the estuary to the ocean. This is in contrast to large breach events, as occurred in 2003, when the estuary at bankfull level breached, causing a drop in surface water elevation of close to 10 feet. A breach of this magnitude likely causes many juvenile steelhead, as well as other fish species and aquatic organisms, which may not be fully ready to enter seawater to be flushed from their refugia.

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 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 condition factor of each fish was calculated using the following formula:

$$\textit{Condition Factor} = \frac{\textit{Length}^3}{\textit{Weight} \times 100{,}000}$$

where length is measured in mm, weight is measured in grams, 100,000 is a unit conversion factor, and condition factor is dimensionless. In general, the closer the ratio is to 1.0, the healthier the fish. 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. This may suggest slightly more stressful conditions during transient periods in 2002 (i.e., short periods of warm water temperature), than were observed in 2003.

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

2002 Sampling Events	Estuary Section	Mean Condition Factor	Number Caught	Condition Factor Range Minimum	Maximum
June, 2002	Lower Estuary	1.1	38	0.9	1.4
	Middle Estuary	1.1	3	1.1	1.2
	Upper Estuary	a	0	–	–
July, 2002	Lower Estuary	1.2	98	0.7	1.5
	Middle Estuary	1.1	122	0.6	1.7
	Upper Estuary	1.4	1	1.4	1.4
August, 2002	Lower Estuary	1.1	1306	0.7	1.9
	Middle Estuary	1.0	3	0.9	1.1
	Upper Estuary	1.1	8	0.7	1.2
September, 2002	Lower Estuary	1.1	1672	0.6	2.2
	Middle Estuary	1.2	56	0.9	1.5
	Upper Estuary	1.2	6	1.0	1.3
October, 2002	Lower Estuary	1.1	468	0.9	1.3
	Middle Estuary	1.2	85	1.1	1.8
	Upper Estuary	1.2	7	1.1	1.3
November, 2002	Lower Estuary	1.0	2	1.0	1.1
	Middle Estuary	1.1	9	0.9	1.3
	Upper Estuary	a	0	–	–

[a] = No age 1+ or older fish were collected from this estuary section during this sampling event

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

2003 Sampling Events	Estuary Section	Mean Condition Factor	Number Caught	Condition Factor Range	
				Minimum	Maximum
February, 2003	Lower Estuary	1.0	44	0.9	1.1
	Middle Estuary	1.0	5	0.9	1.1
	Upper Estuary	1.0	2	1.0	1.0
May, 2003	Lower Estuary	1.1	168	0.8	1.3
	Middle Estuary	0.8	2	0.7	0.9
	Upper Estuary	1.1	1	1.1	1.1
June, 2003	Lower Estuary	1.1	67	0.9	1.5
	Middle Estuary	a	0	–	–
	Upper Estuary	1.0	3	1	1.1
July, 2003	Lower Estuary	1.1	166	0.8	1.2
	Middle Estuary	1.1	260	0.7	1.5
	Upper Estuary	1.1	52	1.0	1.3
August, 2003	Lower Estuary	1.1	178	0.9	1.3
	Middle Estuary	1.1	57	0.7	1.3
	Upper Estuary	1.0	225	0.7	1.4
September, 2003	Lower Estuary	1.0	353	0.8	1.4
	Middle Estuary	1.1	47	1.0	1.3
	Upper Estuary	1.1	339	0.7	1.4
October, 2003	Lower Estuary	1.1	1052	0.5	1.5
	Middle Estuary	1.1	461	0.8	1.4
	Upper Estuary	1.0	145	1.0	1.3

[a] = No age 1+ or older fish were collected from this estuary section during this sampling event

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 estuary 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 estuary remained closed throughout the 2002 sampling period; however, in 2003 the estuary 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).

Differences between 2002 and 2003 in the apparent annual steelhead population estimates are most likely due to the violation of the assumption of a closed estuarine system in 2003. Although large numbers of juveniles were collected during the sample events in spring 2003, very few were subsequent recaptured, likely due to their emigration from the estuary (open estuary conditions were present through July). This

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.

				Recaptured from Sampling Event								
2002 Sampling Events	**Event Number**	**No. of Age 1+ and Older Steelhead Collected**	**No. of Age 1+ and Older Steelhead Given a Traceable Mark**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
June 19-20	1	41	41	–								
July 10-12	2	221	213	8	0							
August 1-2	3	675	664	3	4	4						
August 12-13	4	642	554	10	18	54	6					
September 4-6	5	985	803	5	24	65	76	8				
September 25-27	6	749	543	0	11	43	58	80	13			
October 21-22	7	242	169	2	5	14	19	16	16	1		
October 24	8	318	0	0	2	7	29	30	24	34	0	
November 26-27	9	11	0	0	0	1	0	0	0	0	0	0
Total		**3,884**	**2,987**	**28**	**64**	**188**	**188**	**134**	**53**	**35**	**0**	**0**

				Recaptured from Sampling Event							
2003 Sampling Events	**Event Number**	**No. of Age 1+ and Older Steelhead Collected**	**No. of Age 1+ and Older Steelhead Given a Traceable Mark**	**10[a]**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
February 18-19	10	51	46	4[b]							
May 19-20	11	171	171	0	0						
June 17-18	12	70	70	0	0	0					
July 22-23	13	478	476	0	0	0	2[b]				
August 21-23	14	460	457	0	0	0	1	0			
September 23-24	15	739	727	0	0	0	0	7	2[b]		
October 27-28	16	1,064	994	0	5	7	2	2	40	11[b]	
October 30	17	594	0	0	4	1	0	0	9	28	na
Total		**3,627**	**2,941**	**4**	**9**	**8**	**5**	**9**	**51**	**39**	**na**

[a] sample event 10 recaptures were minimal due to estuary breach event (i.e., breach occurred after week 10)

[b] recaptured from same sampling event

na - not applicable (no traceable marks given during sampling event 17)

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

2002 Sampling Events	**Sampling Event**	**Captured**	**M_t (Marked fish at large)**	**R**	**C_tM_t**	**M_tR_t**	**$C_tM^2_t$**	**$R^2_tC_t$**	**N**	**s^2**	**s**	**95% CI**
June 19-20	1	159.0										
July 10-11	2	696.0	41.0	8.0	2.9E+04	3.3E+02	1.2E+06	4.5E+04	**3170.7**	44543.9	211.1	**2.4**
August 1-2	3	820.0	280.0	7.0	2.3E+05	2.0E+03	6.4E+07	4.0E+04	**28700.0**	20090.0	141.7	**69.3**
August 12-13	4	833.0	965.0	82.0	8.0E+05	7.9E+04	7.8E+08	5.6E+06	**9684.9**	1867028.0	1366.4	**3.0**
September 4-6	5	1135.0	1607.0	170.0	1.8E+06	2.7E+05	2.9E+09	3.3E+07	**10666.3**	8200368.6	2863.6	**1.7**
September 25-27	6	825.0	2510.0	192.0	2.1E+06	4.8E+05	5.2E+09	3.0E+07	**10729.3**	6082551.1	2466.3	**2.2**
October 21-22	7	275.0	3114.0	72.0	8.6E+05	2.2E+05	2.7E+09	1.4E+06	**11730.8**	237596.9	487.4	**12.4**
October 24	8	372.0	3313.0	126.0	1.2E+06	4.2E+05	4.1E+09	5.9E+06	**9704.2**	843689.9	918.5	**5.6**
November 26-27	9	11.0	3313.0	1.0	3.6E+04	3.3E+03	1.2E+08	1.1E+01	**18221.5**	1.4	1.2	**8234.3**

2003 Sampling Events	**Sampling Event**	**Captured**	**M_t (Marked fish at large)**	**R**	**C_tM_t**	**M_tR_t**	**$C_tM^2_t$**	**$R^2_tC_t$**	**N**	**s^2**	**s**	**95% CI**
July 22-23	13	478.0										
August 21-23	14	460.0	478.0	1.0	2.2E+05	4.8E+02	1.1E+08	4.6E+02	**109940.0**	460.0	21.4	**811.8**
September 23-24	15	739.0	938.0	7.0	6.9E+05	6.6E+03	6.5E+08	3.6E+04	**86647.8**	36210.9	190.3	**72.1**
October 27-28	16	1064.0	1677.0	44.0	1.8E+06	7.4E+04	3.0E+09	2.1E+06	**39651.7**	2059902.2	1435.2	**4.4**
October 30	17	592.0	2741.0	37.0	1.6E+06	1.0E+05	4.4E+09	8.1E+05	**42701.9**	810445.7	900.2	**7.5**

M_t = total # fish marked @ large

C_t= total sample taken day t

R_t = recaptures for day t

N = Pop Est.

s = standard deviation

s^2 = sample variance

results in a biased, elevated population estimate. In addition, there are several factors affecting estuarine population estimates that we cannot address because of the lack of available data, including the annual adult escapement, size of the annual spawning population, annual spawning success, success of hatch, age class specific survival, other watershed-wide movement patterns, and other population dynamics. These "upper watershed" factors were not the focus or objective of the current study.

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). Reasons for the differences in Jolly-Seber population estimates are similar to those given above for the Petersen-Schnabel estimator, although a closed system is not an assumption for the Jolly-Seber estimator. For this reason, it is likely that the true population estimates are more likely reflected in the ranges given by the Jolly-Seber estimates.

Carrying Capacity

It is uncertain whether the estuary is at its full carrying capacity with regards to rearing. Bathymetry appears unchanged since the early part of the twentieth century, and so it is doubtful that estuarine conditions have worsened substantially since that point in time. However, in relation to the overall population of salmonids in the Gualala river system, it is clear that the estuary is not the limiting factor to production. It is more likely that degraded habitat conditions upstream are limiting production of steelhead, and thus the numbers of young steelhead that are available to utilize the estuary. This is at least partially supported by the relatively high proportion of young of the year (YOY) steelhead present in the estuary. Normally, the majority of YOY (other than the initial downstream dispersal of fry) will remain in their natal tributaries, at least until fall freshets, which tend to initiate outmigration. In the absence of high quality rearing

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

2002 Sampling Events	**Sampling Event (t)**	**Captured**	m_t	u_t	n_t	s_t	R_t	Z_t	α	**Mt**	**Nt**	ϕ_t	λ_t
June 19-20	1	41	0	41	41	41	28	na	0.02	0.0	**na**	1.9	na
July 10-11	2	221	8	213	221	221	64	20	0.04	76	**1,882.3**	1.0	12.987869
August 1-2	3	675	7	668	675	675	184	77	0.01	288	**24,366.6**	0.7	0.3040607
August 12-13	4	642	82	560	642	642	182	179	0.13	711	**5,507.7**	1.3	1.3305726
September 4-6	5	985	170	815	985	981	126	191	0.17	1647	**9,496.0**	1.0	1.0062504
September 25-27	6	749	192	557	749	748	40	125	0.26	2476	**9,620.0**	0.2	1.0491029
October 21-22	7	242	72	170	242	242	34	93	0.30	718	**2,389.0**	0.5	0.9333155
October 24	8	318	126	192	318	318	0	1	0.40	445	**1,117.8**	na	na
November 26-27	9	11	1	10	11	11	na	na	na	na	**na**	na	na

2003 Sampling Events	**Sampling Event (t)**	**Captured**	m_t	u_t	n_t	s_t	R_t	Z_t	α	**Mt**	**Nt**	ϕ_t	λ_t
July 22-23	13	478	0	478	478	476	3	17	0.002	2,027	**971,052.8**	0.35	0.59
August 22-23	14	460	1	459	460	455	9	19	0.004	867	**199,935.7**	0.24	0.61
September 23-24	15	739	7	732	739	724	49	21	0.011	312	**28,813.8**	0.52	0.67
October 27-28	16	1,064	56	1,008	1,064	991	28	14	0.054	535	**9,994.1**	na	na
October 30	17	594	42	552	594	0	*na*	*na*	*na*	*na*	**na**	na	na

m_t = # of marked fish caught in sample t

u_t = # of unmarked fish caught in sample t

n_t = total # of fish caught in sample t ($n_t = m_t + u_t$)

s_t = # of fish released after sample t (n_t - # of accidental deaths)

R_t = # of s_t fish released at sample t and caught again in some later sample (refer to "Method Table B" below for calculation)

Z_t = # of fish marked before sample t, not caught in sample t, but caught in some sample after t (refer to "Method Table B" below for calculation) conditions within those natal tributaries, the remaining rearing habitat is limited primarily to the estuary. The fact that the Gualala estuary is typically a closed, freshwater system - unlike many other north coast estuaries, including the Noyo, Little, Navarro, and Garcia Rivers - makes the Gualala estuary a suitable place for YOY to rear. Survival of outmigrants is a function of their size at outmigration. Survival of age 1+ and older outmigrant steelhead (to adult stage) is much greater than that for YOY outmigrants, except when YOY have had a chance to rear in the highly productive conditions present in the Gualala estuary.

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 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 estuary, 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 (see Figure 3.4). In 2003 (open estuary), 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

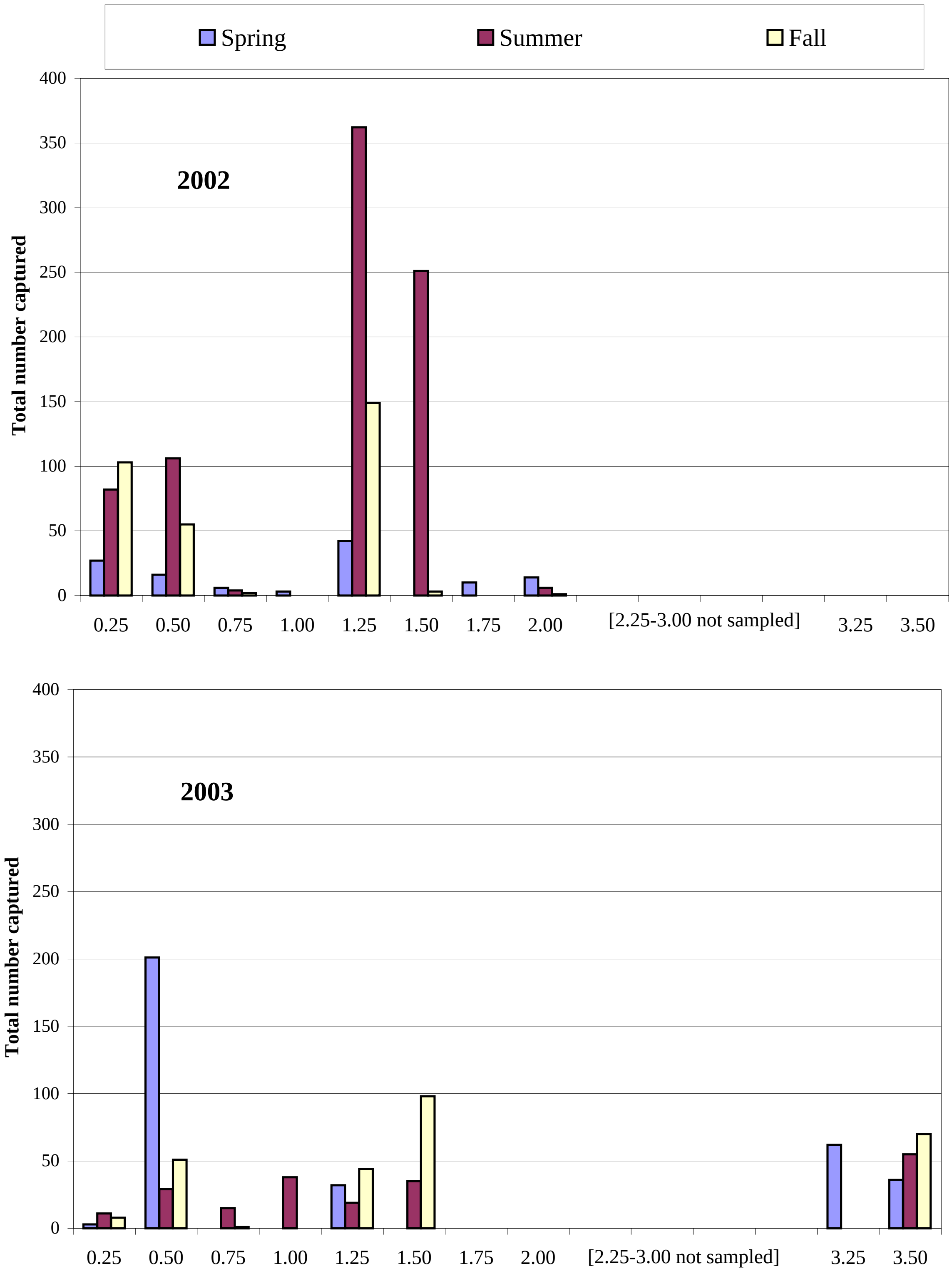


Figure 3.4 Total number of YOY steelhead captured by season from all hauls within each distance category, Gualala estuary.

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 was likely due to the seasonal reduction of rearing habitat in smaller 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 abundance throughout the estuary. The dispersal was likely a result of the estuary 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, YOY steelhead were captured throughout the estuary, again with the highest numbers occurring in the upper estuary. Riverine conditions in the upper estuary favor the presence of YOY pre-smolt steelhead relative to the more saline conditions present in the lower estuary. YOY steelhead in the upper estuary were observed to be brightly colored, retaining parr marks and native rainbow trout coloration typical of resident (stream dwelling) rainbow trout. In contrast, most fish collected from the lower estuary were in the process of smoltification, and were generally bright silver in color. Smoltification is the physiological process by which juvenile anadromous salmonids (including steelhead and coho salmon) prepare to enter the salt-water environment after spending their early life history in freshwater. Factors that may affect the onset of smoltification include changes in water chemistry, water temperature, and photoperiod (day length).

<u>Age 1+ and older steelhead</u>

During the spring of 2002, age 1+ and older steelhead were captured (albeit in low abundance) throughout the lower to middle estuary (see Figure 3.5). This is likely a result of the closed estuary conditions, which precluded outmigration from the estuary.

In contrast, the open estuary conditions in the spring of 2003 allowed for passage of smolt steelhead out of the estuary over an extended period of time. 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).

The steelhead smoltification process is driven by a number of factors, sometimes competing, including water temperature, photoperiod, streamflow, and any number of "stressor" variables (e.g., loss of habitat, exposure to adverse water quality conditions, exposure to toxic substances). In the current context, many of the steelhead that were captured in the lower and middle estuary were observed to be undergoing smoltification, as evidenced by their silvery color and deciduous scales. When the opportunity arises (breached estuary), they actively outmigrate to the ocean.

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 estuary 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.

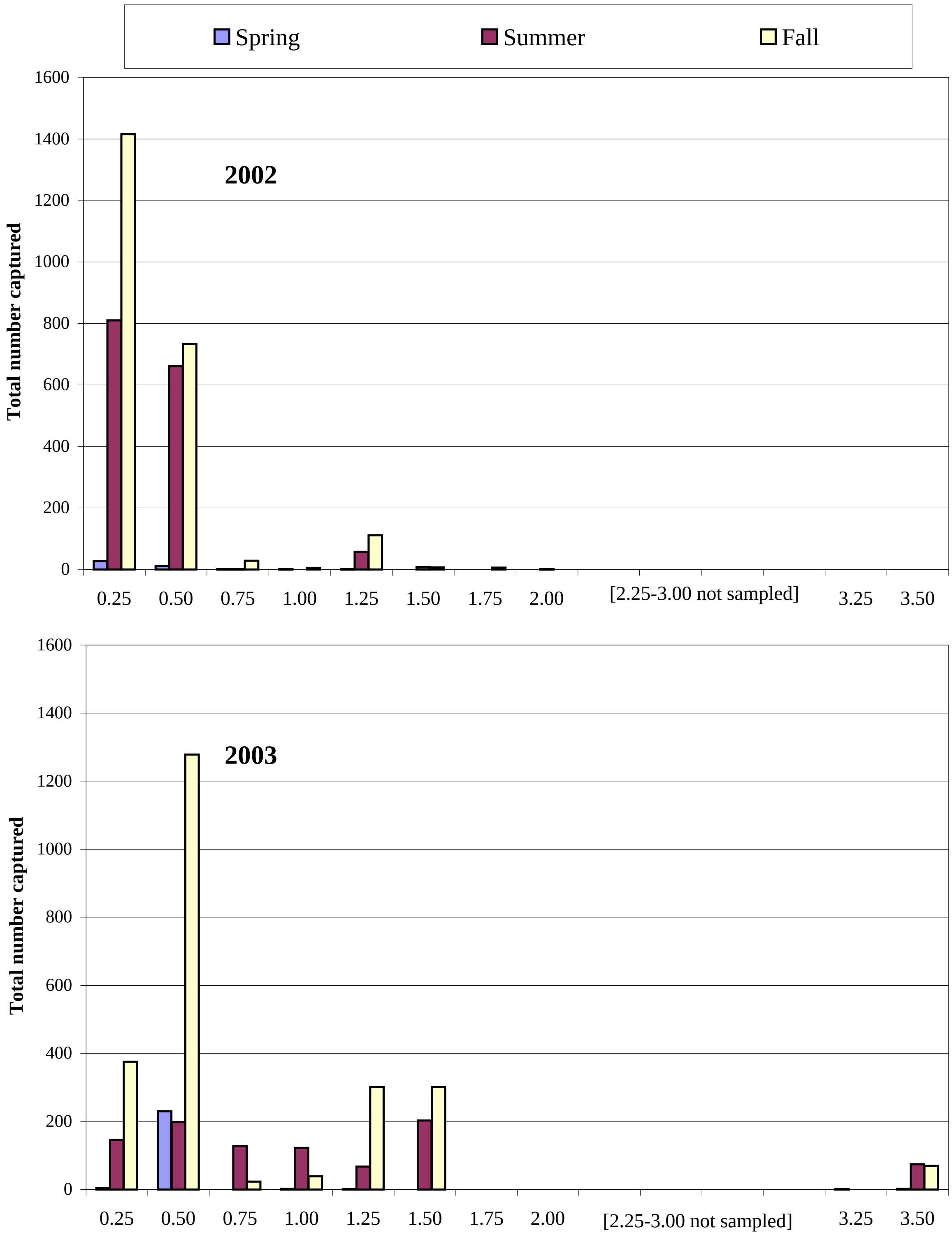


Figure 3.5 Total number of one year and older steelhead captured by season from all hauls within each distance category, Gualala estuary.

Mean Number of Steelhead Captured per Haul

Age 0+ steelhead

In 2002 during closed estuary 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 estuary environments. During the spring sampling period when the estuary 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 estuary 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).

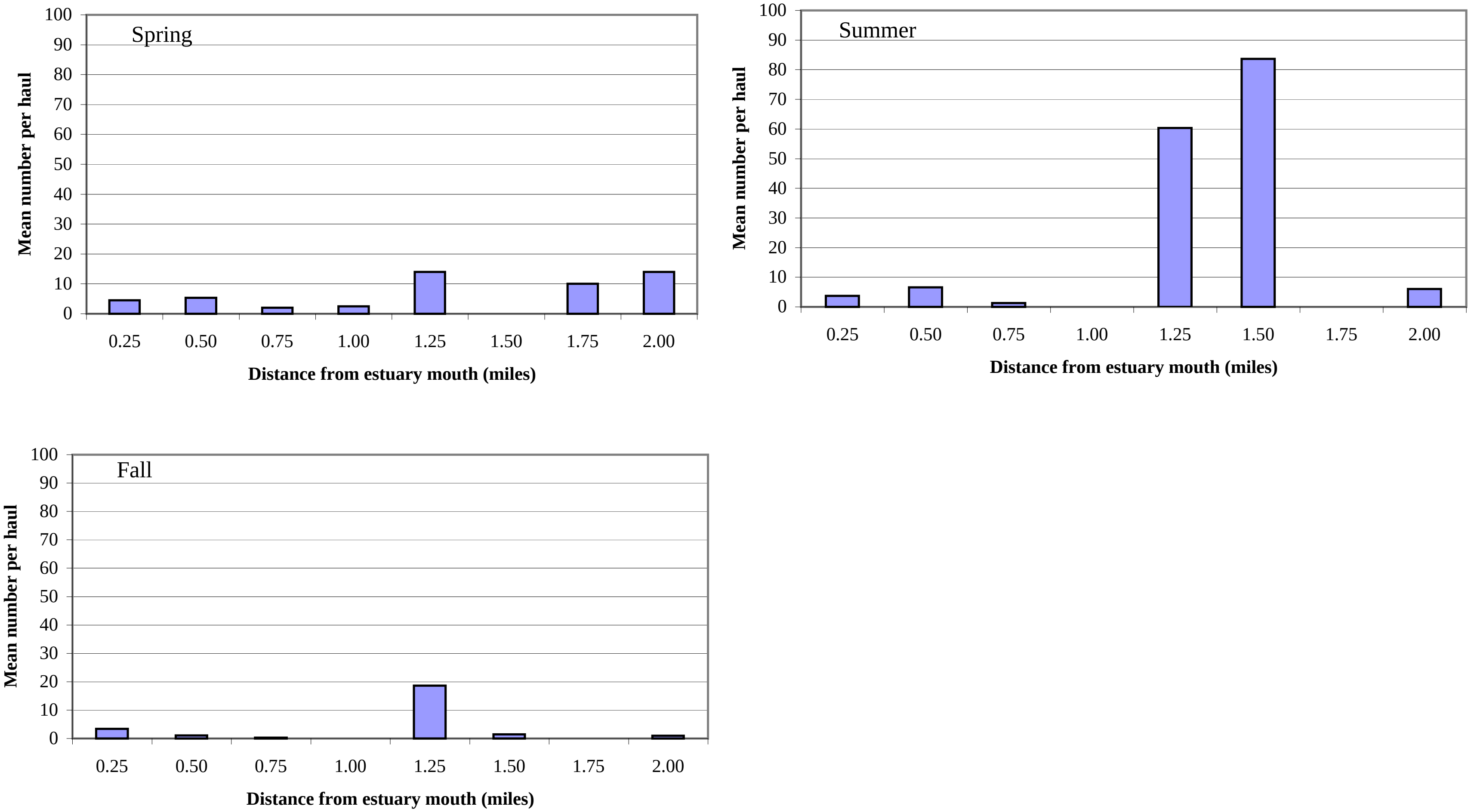


Figure 3.6 Mean number of YOY steelhead captured per haul during spring, summer, and fall 2002, Gualala estuary.

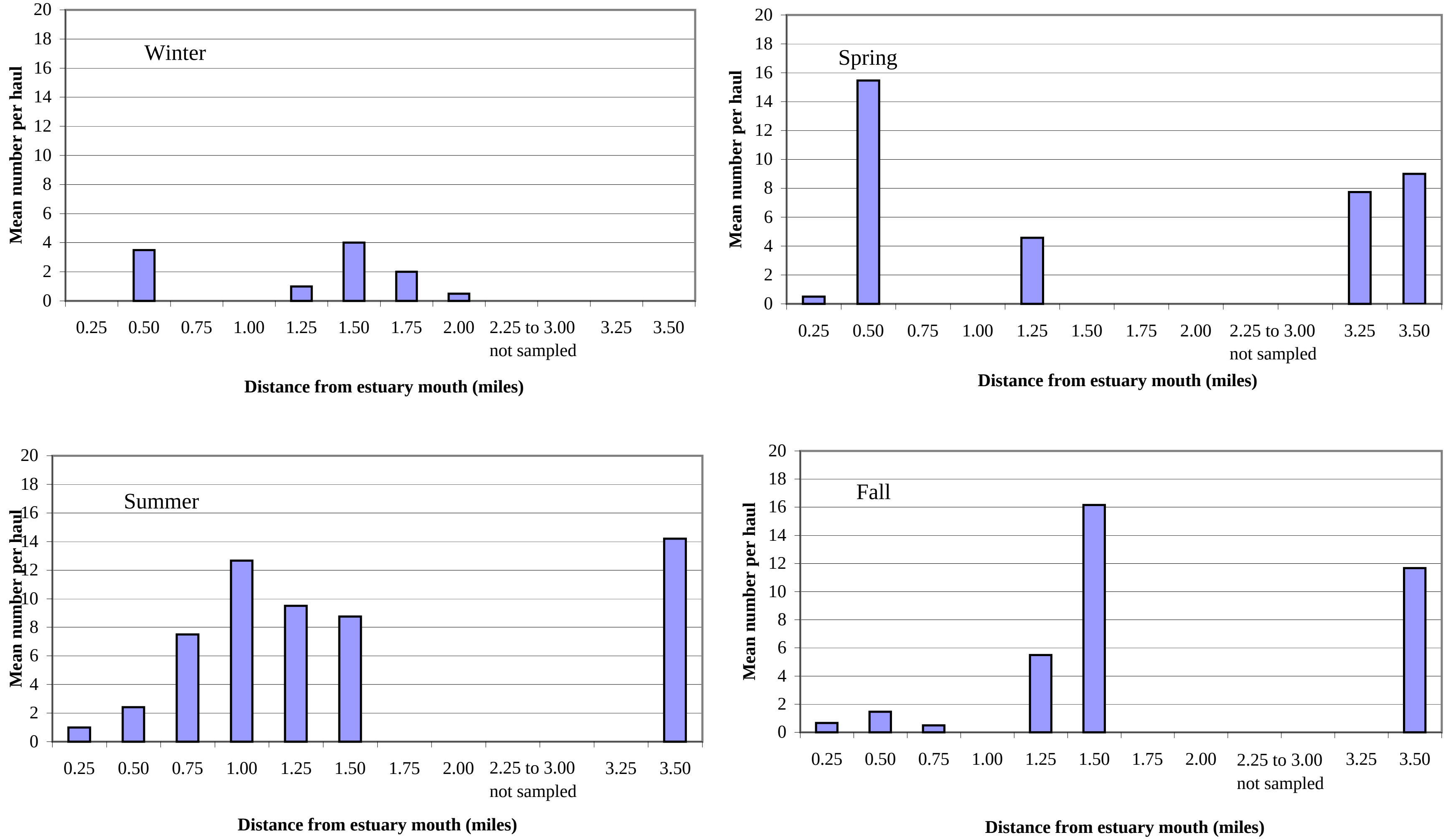


Figure 3.7 Mean number of YOY steelhead captured per haul during 2003, Gualala estuary.

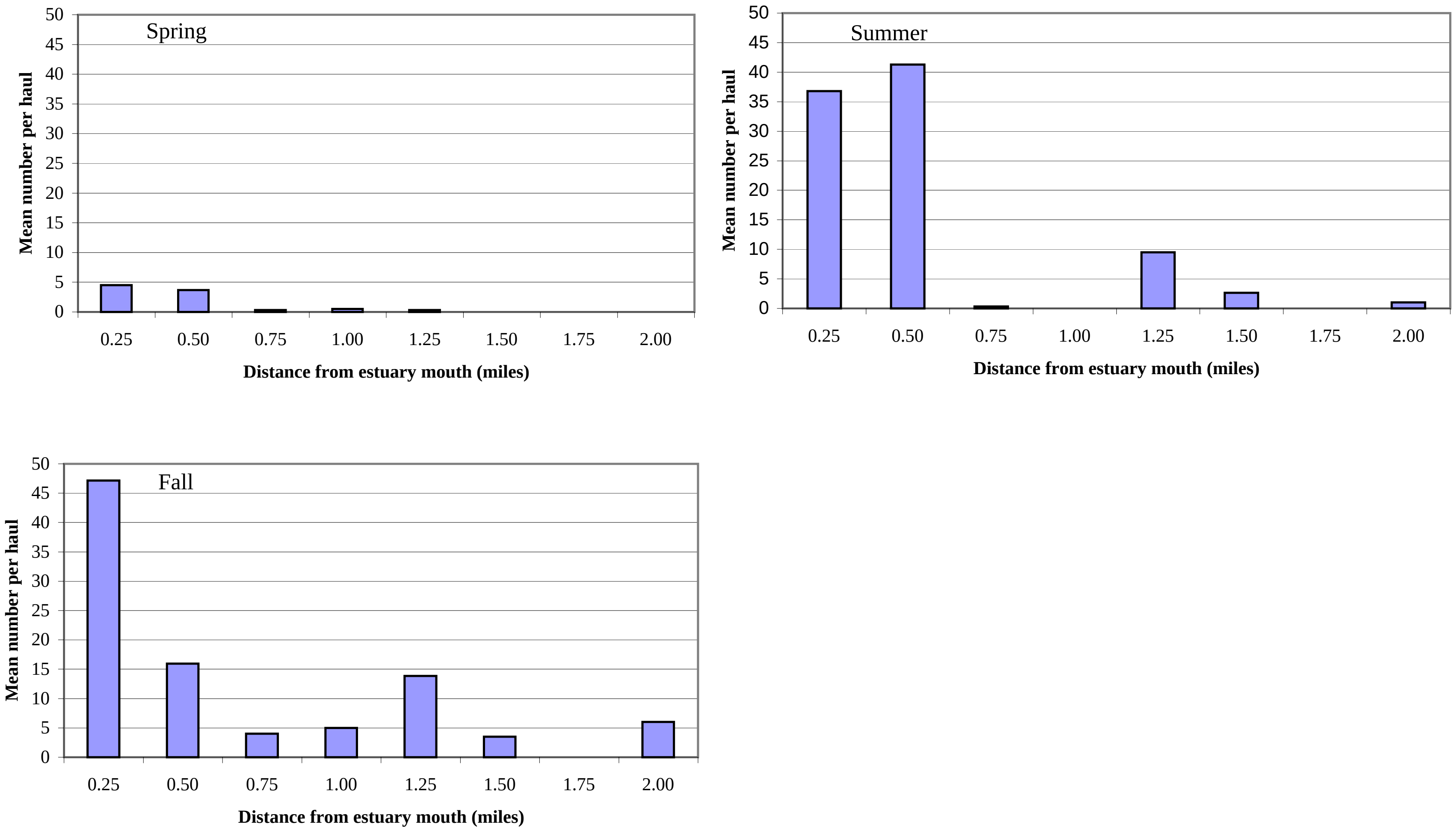


Figure 3.8 Mean number per haul of one year & older steelhead captured during 2002, Gualala estuary.

In the spring of 2003 (open estuary), 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 estuary), 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 estuary 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

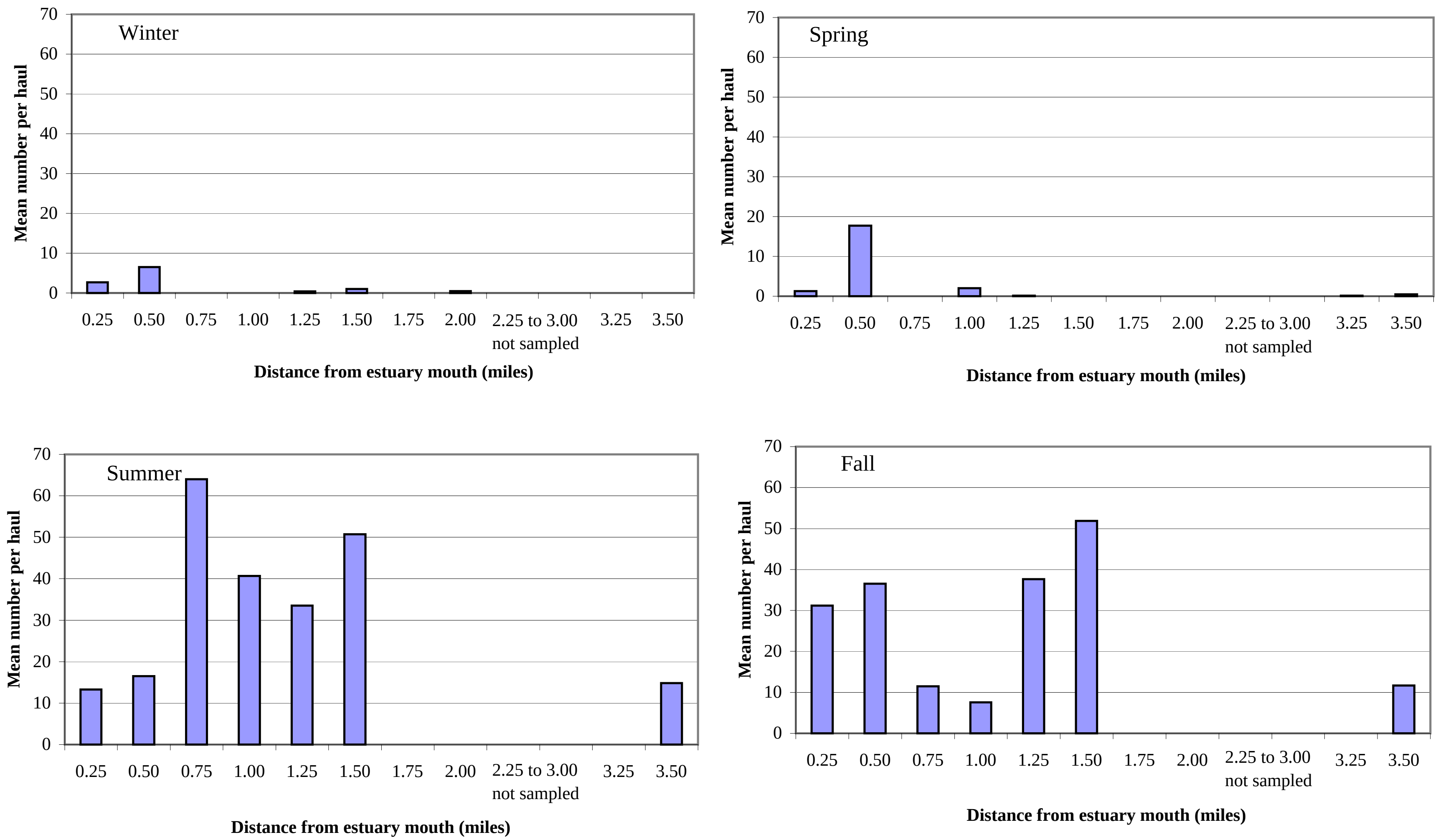


Figure 3.9 Mean number per haul of one year & older steelhead captured during 2003, Gualala estuary.

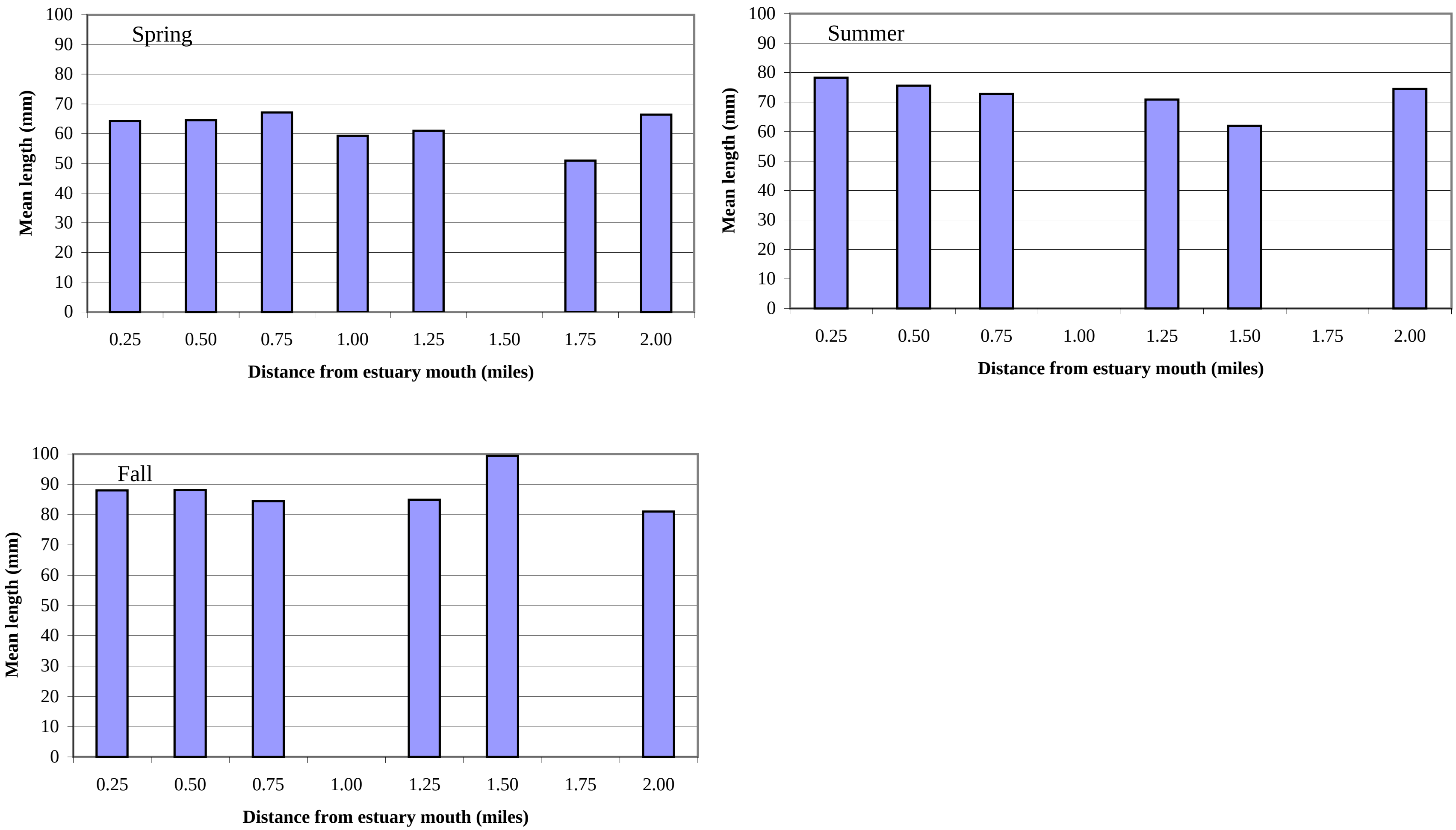


Figure 3.10 Mean length of YOY steelhead captured by distance category during spring, summer, and fall 2002, Gualala estuary.

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 estuary 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 estuary 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.

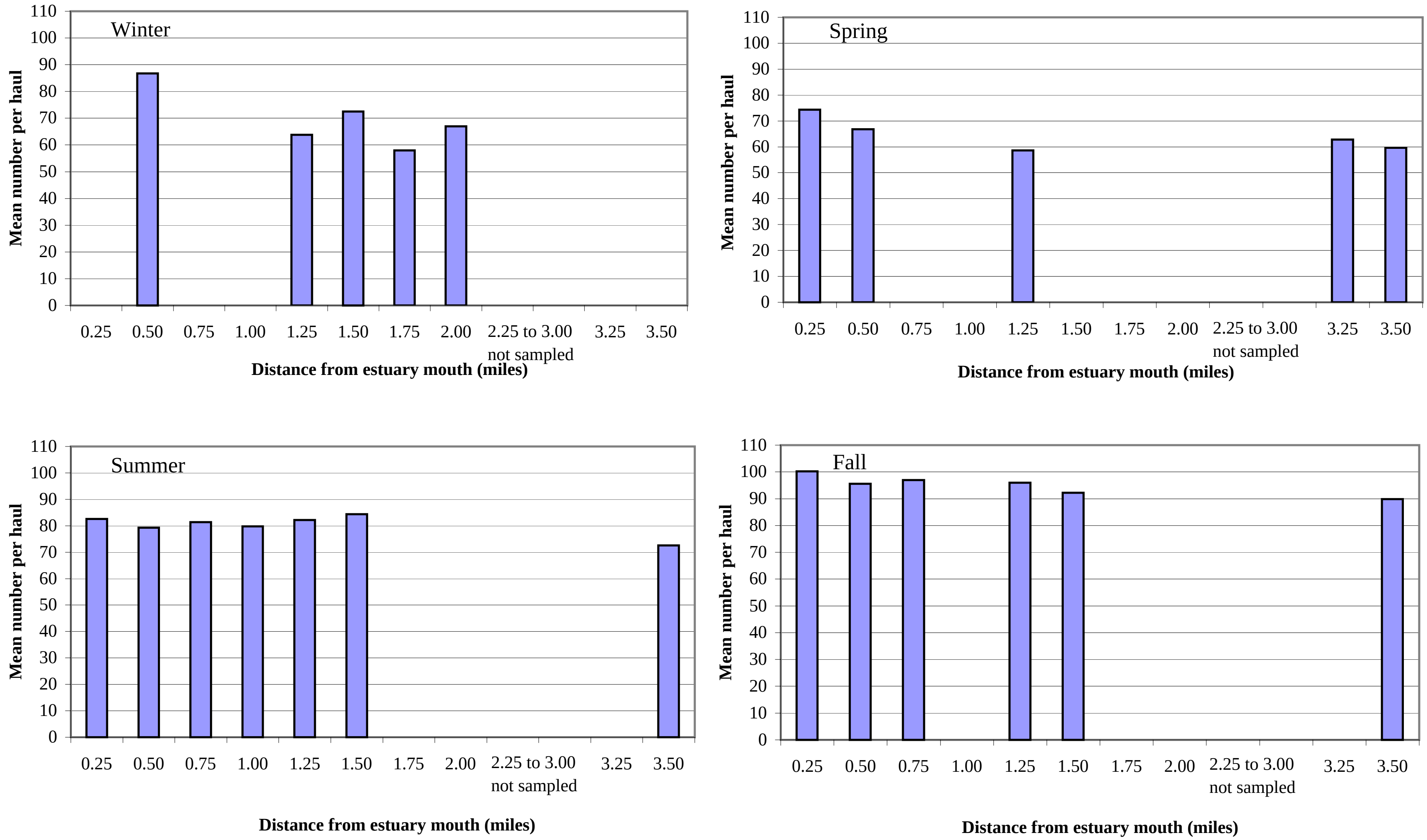


Figure 3.11 Mean length of YOY steelhead captured by distance category during spring, summer, and fall 2003, Gualala estuary.

Age 1+ and older steelhead

One-year and older steelhead were distributed throughout the estuary, during all 2002 sampling events under open estuary 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 estuary 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.

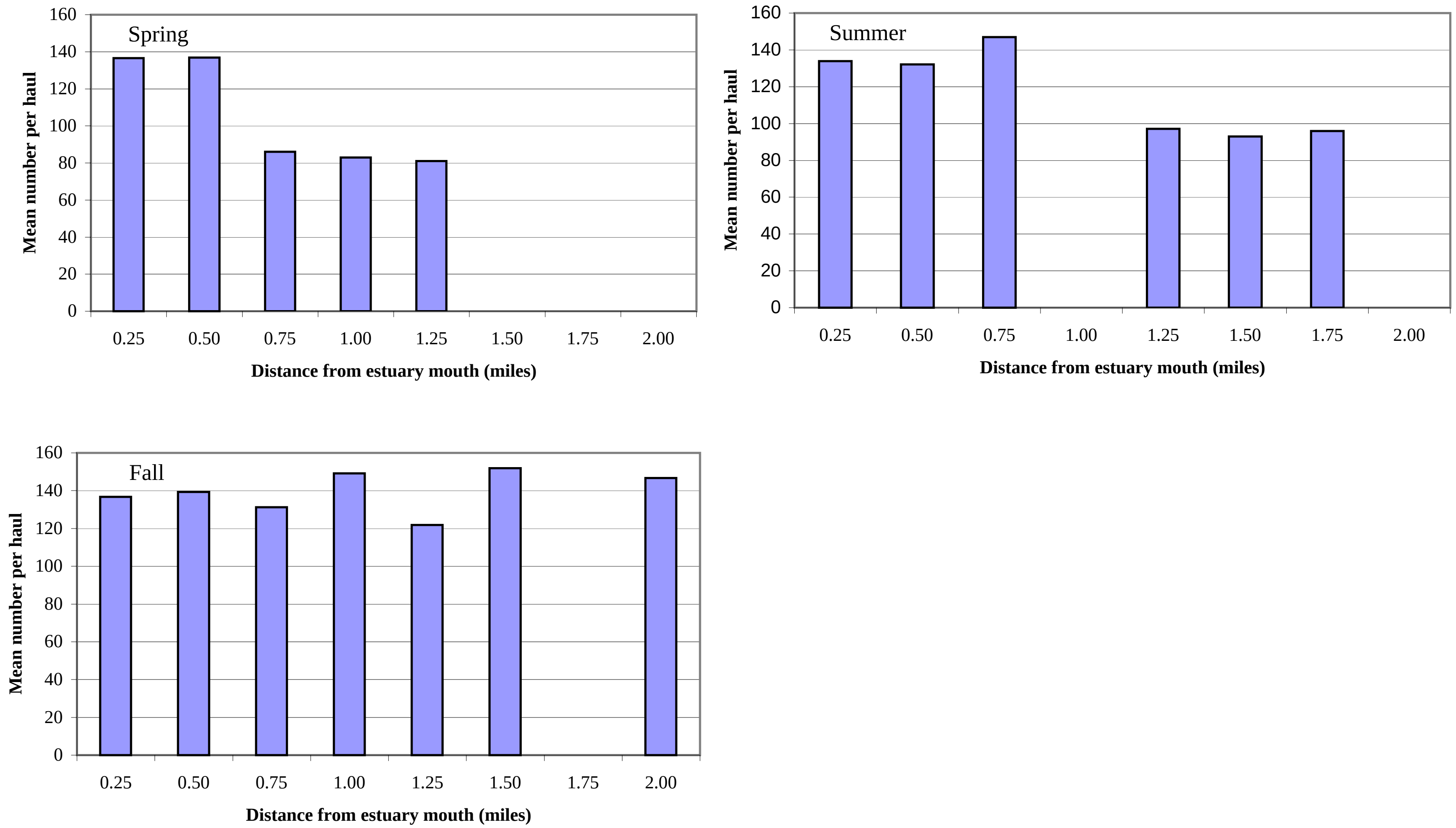


Figure 3.12 Mean length per haul of one year & older steelhead captured during 2002, Gualala estuary.

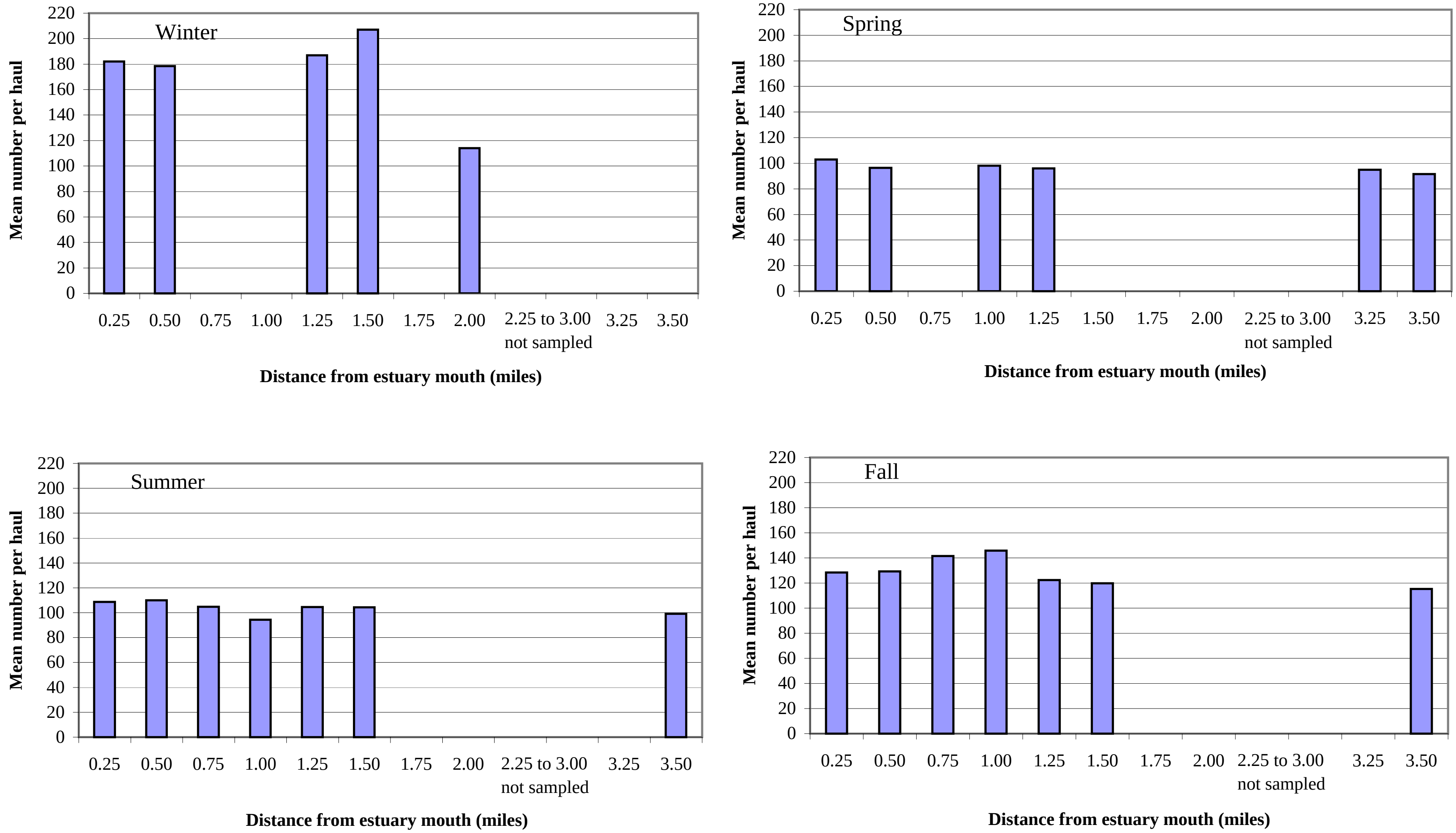


Figure 3.13 Mean length of of one year & older steelhead captured by distance category during spring, summer, and fall 2003, Gualala estuary.

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 age 0+ and age 1+ steelhead. Many of the steelhead contained both insect and zooplankton taxa. Non-insect taxa (e.g, neomysis) were the least abundant prey items in age 0+ and age 1+ fish, but become the most important dietary component for older (age 2+) age classes. 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 Macroinvertebrate Surveys

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.

Substrate complexity was determined based on the combination of two habitat parameters, epifaunal substrate/available cover, and embeddedness. The substrate complexity score (SC Score) is the sum of these two parameters determined during field analysis. The range for substrate complexity is 0 to 40 with the following categories:

Category	SC Score
• Optimal	40 to 32
• Sub-optimal	31 to 22
• Marginal	21 to 12
• Poor	11 to 0

Microhabitat data were collected using the CDFG California Stream Bioassessment Procedure (CSBP) Physical/Habitat Quality form that rates a sample reach for 10 habitat categories. Each category has a rating scale from 0 to 20, and ratings are summed to provide the total Physical Habitat Quality Score (PHQ Score). The CSBP PHQ Score is similar to the EPA's Physical Habitat Quality Score, which is used throughout the U.S.

Category	PHQ Score
• Optimal	200 to 150
• Sub-optimal	149 to 100
• Marginal	99 to 50
• Poor	49 to 0

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 (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 estuary 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 (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 California bay, coast redwood, Douglas fir, 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 (sub-optimal) and a Physical Habitat Quality score of 140 (sub-optimal).

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,

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 RM* 3.2				**Middle Reach : RM 1.6 to RM 2.0**				**Lower Reach: RM 0.4 to RM 1.14**				**Lower Reach: RM 0.8, May 2003**			
	1	2	3	**Mean**	1	2	3	**Mean**	1	2	3	**Mean**	1	2	3	**Mean**
Sampling information																
Sampling notes:									Three 5-m sweeps in widgeon grass bed	Gravel kick appx 6 sq. ft. followed by three sweeps	Vegetation sweep and grab @ Mill Bend					
Date Sampled				**7/11/2002**				**7/11/2002**				**7/12/2002**				**5/20/2003**
Time Sampled				**9:00**												**14:45**
GPS	10S0456646	10S0456633	10S0456149		10S0455802	10S0455478	10S0455478		N/A	N/A	N/A					
UTM	4292282	4292043	4291853		4291219	42921138	4290892		N/A	N/A	N/A					
Site characteristics																
Canopy cover (%)	0	35	95	**43.3**	15	0	2	5.7	N/A	N/A	N/A		0	0	0	**0**
Gradient (%)	<1	<1	1	**<1**	<1	<1	<1	<1	N/A	N/A	N/A		<1	<1	<1	**<1**
Transect Location (m)	31	15.0	12.0		25	20	18		N/A	N/A	N/A		25	29.5	37.5	
Elevation (ft)				**53**				**13**								
Reach Length (m)				**967**				**850**								**75**
Physical characteristics																
Riffle Length (m)	60.0	25.0	15.0	**33.3**	43.0	34.0	22.0	**33.0**	N/A	N/A	N/A					**71.6**
Avg. Riffle Width (m)	9.0	13.5	9.4	**10.6**	17.0	12.3	25.0	**18.1**	N/A	N/A	N/A		37.5	36.6	37	**37.0**
Avg. Riffle Depth (ft)	0.28	0.27	0.3	**0.3**	0.52	0.55	0.72	**0.6**	N/A	N/A	N/A		1.69	1.39	1.50	**1.5**
Riffle Velocity (ft/s)	1.9	1.1	2.6	**1.9**	0.6	0.5	0	**0.4**	N/A	N/A	N/A		2.4	3.00	2.91	**2.8**
Substrate Complexity	31	31	31	**31.0**	31	31	31	**31.0**	N/A	N/A	N/A		35	35	35	**35.0**
Embeddedness (%)	5	5	10	**6.7**	10	25	35	**23.3**	N/A	N/A	N/A		5	5	5	**5.0**
Substrate Consolidation	Low	Low	Low	**Low**	Low	Med	Med	**Med-Low**					Low	Low	Low	**Low**
Specific Conductance (μ s/cm)				**180**				**260**				**301**				**0.1**
Dissolved Oxygen (mg/l)				**7.3**				**7.8**				**7.0**				**8.8**
Dissolved Oxygen (%)				**74.4**				**92.1**				**79.9**				**104.7**
Water Temp (C°)				**17.3**				**23.2**				**21.5**				**24.6**
Total Dissolved Solids (g/l)				**0.138**				**0.175**				**0.209**				**0.0**
Salinity (ppt)				**0.10**				**0.13**				**0.15**				**0.0**
Physical Habitat Quality Score				**121**				**140**				**N/A**				**136**
Substrate Composition																
Fines (<0.1")	25	25	50	**33.3**	50	35	40	**41.7**	100	20	25	**48.3**	40	40	40	**40.0**
Gravel (0.1-2")	70	72.5	49	**63.8**	30	40	50	**40.0**	0	60	0	**20.0**	50	50	50	**50.0**
Cobble (2-10")	5	2.5	1	**2.8**	20	25	10	**18.3**	0	20	0	**6.7**	10	10	10	**10.0**
Boulder (>10")	0	0	0	**0.0**	0	0	0	**0.0**	0	0	75	**25.0**	0	0	0	**0.0**
Bedrock (solid)	0	0	0	**0.0**	0	0	0	**0.0**	0	0	0	**0.0**	0	0	0	**0.0**
Riparian Vegetation	willow, bunchgrass, redwood, Douglas fir, ash, alder				bay laurel, willow, alder, ash, cedar, horsetail, nutsedge				N/A				Riparian area located approximately 15 meters or greater from waters edge.			
	Additional Notes:								N/A = data not taken as collection technique and site selection							
	* River Mile (RM) calculated from estuary mouth.								did not conform to CSBP type sampling in lower estuary site i							
									July 2002.							

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 (sub-optimal), and a Physical Habitat Quality score of 121 (sub-optimal).

<u>CSBP Metrics</u>

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 estuary 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 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

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

	Upper Reach - RM 2.4 to RM 3.2* (2002)			Middle Reach - RM 1.6 to RM 2.0			Lower Reach - RM 0.4 to RM 1.1 (2002)			Lower Reach - RM 0.8		
	Mean	CV	Total	Mean	CV	Total	Mean	CV	Total	Mean	CV	Total
Estimated Abundance	1391.4	52.1	4174.2	3601.1	62.7	10803.2	1778.5	47.5	5335.6	1853.9	43.1	5561.6
Taxa Richness	38.0	14.7	69.0	16.3	12.7	34.0	10.0	148.0	19.0	9.3	16.4	15.0
Percent Dominant Taxon	23.1	29.7	13.3	85.0	10.3	85.0	69.0	13.1	55.8	64.8	13.7	65.1
EPT Taxa	14.0	31.1	27.0	4.0	86.6	10.0	0.3	1732.1	1.0	0.3	173.2	1.0
EPT Index (%)	33.3	33.1	33.2	5.1	64.7	5.1	0.3	897.4	0.3	0.2	173.2	0.2
Sensitive EPT Index	14.0	53.8	13.9	0.9	173.2	0.9	0.0	0.0	0.0	0.2	173.2	0.2
Ephemeroptera Taxa	6.0	16.7	9.0	3.0	57.7	7.0	0.3	1212.4	1.0	0.0	NA	0.0
Plecoptera Taxa	3.7	31.5	7.0	0.3	173.2	1.0	0.0	0.0	0.0	0.0	NA	0.0
Trichoptera Taxa	4.3	70.5	11.0	0.7	173.2	2.0	0.0	0.0	0.0	0.3	173.2	1.0
Dipteran Taxa	9.3	16.4	17.0	4.0	66.1	8.0	1.3	312.2	3.0	1.7	34.6	2.0
Percent Dipteran	22.9	68.5	22.6	4.6	73.5	4.6	1.5	162.3	1.4	1.1	36.7	1.1
Non-Insect Taxa	9.3	6.2	17.0	6.0	28.9	10.0	7.0	21.8	11.0	5.0	0.0	7.0
Percent Non-Insect	26.5	42.3	26.9	89.3	6.9	89.3	97.2	6.1	97.3	98.0	1.4	97.9
Percent Chironomidae	19.5	68.4	19.1	4.5	71.6	4.5	1.5	158.4	1.4	0.0	NA	0.0
Percent Hydropsychidae	0.3	173.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA	0.0
Percent Baetidae	13.7	13.9	13.7	0.6	51.5	0.6	0.3	109.9	0.3	0.0	NA	0.0
Shannon Diversity	2.8	9.7	3.2	0.8	46.6	0.8	1.1	21.6	1.4	0.8	7.3	0.9
Tolerance Value	4.1	18.5	4.0	0.7	59.3	0.7	2.6	11.4	2.5	2.7	28.4	2.7
Percent Intolerant	13.4	45.3	13.4	0.6	129.9	0.6	0.0	0.0	0.0	0.0	NA	0.0
Percent Tolerant	2.8	25.5	2.8	0.4	114.7	0.4	20.0	1.1	18.6	31.4	31.8	31.1
Percent Collectors	48.4	27.4	48.4	95.4	0.8	95.4	95.2	4.4	95.2	97.7	1.5	97.6
Percent Filterers	3.5	78.5	3.5	0.0	NA	0.0	0.5	173.2	0.5	0.0	NA	0.0
Percent Grazers	25.7	36.9	25.8	1.3	91.7	1.3	0.0	0.0	0.0	0.9	81.5	0.9
Percent Predators	18.1	16.4	18.0	2.6	49.4	2.6	4.3	81.0	4.3	0.6	79.5	1.0
Percent Shredders	1.8	103.4	1.8	0.3	173.2	0.3	0.0	0.0	0.0	0.2	173.2	0.2

CV = Coefficent of Variation

* River Mile (RM) calculated from the estuary mouth.

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

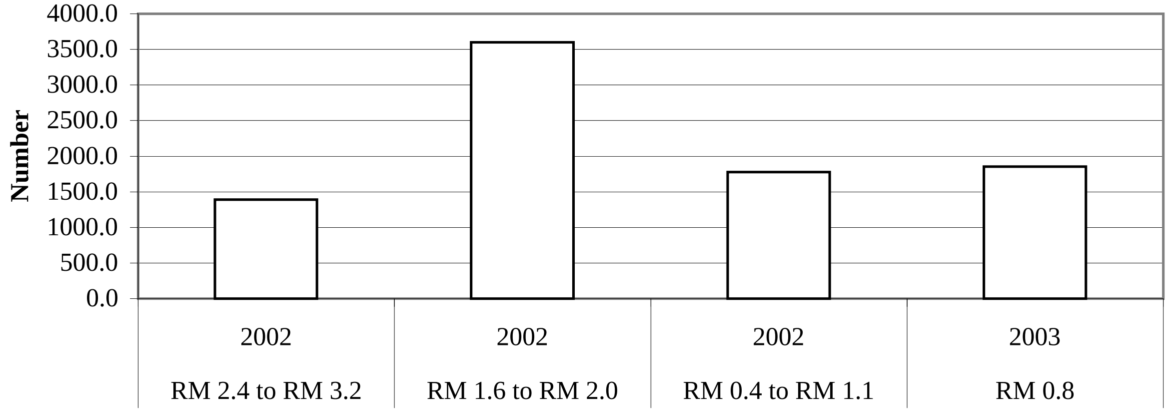


Figure 3.15. Taxa Richness for Benthic Macroinvertebrates in the Lower Gualala River and Estuary, July 2002 and May 2003

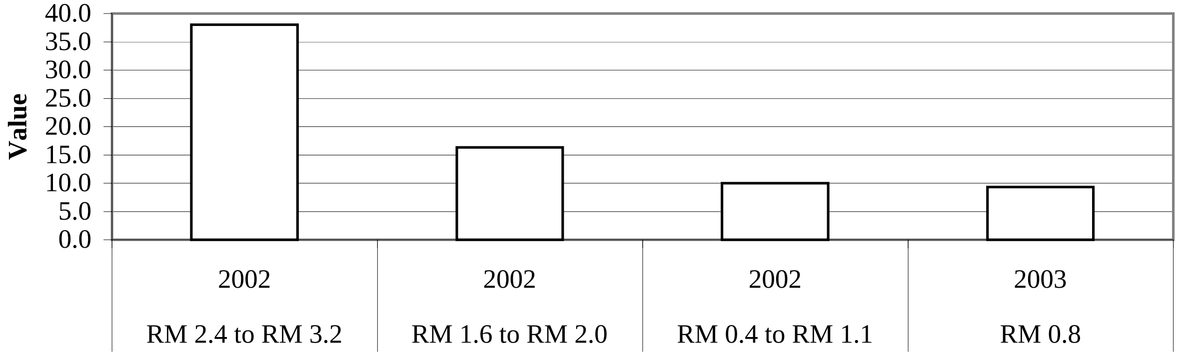
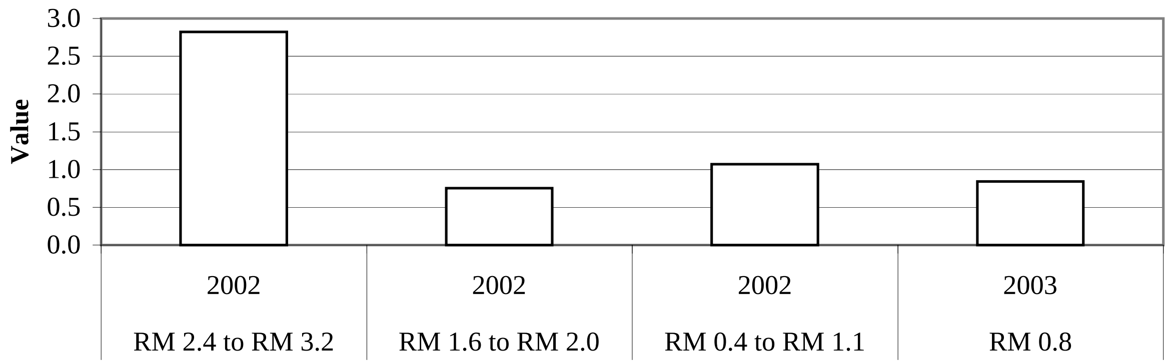


Figure 3.16. Shannon Diversity Indices for Benthic Macroinvertebrates in the Lower Gualala River and Estuary, July 2002 and May 2003



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.

3.3.4 Seasonal Algae and Macrophytic Plant Growth/Decay

The following section provides a description of algae and macrophytic plant growth and decay observed in the Gualala Estuary in the summer during both years of the monitoring period. Most of the accounts presented below are based on the field observations and interpretation of Elmer Dudik, North Coast Regional Water Quality Control Board.

Lower Estuary

During both summers of the estuary study, large mats of algae were observed forming in the lower river and estuary. Based solely on field observations, algal mat growths appear to consist of *Cladophora*, *Spirogyra*, *Hydrodictyon*, or *Rhizoclonium*, but are dominated by *Cladophora*, *Rhizoclonium,* or *Spirogyra*. Extensive growths of *Spirogyra* were ruled out because growths did not display the growth-associated characteristics - typically large, usually slippery-slimy, mats that age yellow-brown. *Hydrodictyon* typically requires actively flowing water and conditions in the lower estuary were more stagnant with diffuse flow during the summer field monitoring events. In contrast, algal blooms are usually associated with massive increases in planktonic, typically unicellular to short stranded microalgae that discolor the water. Algal blooms that were observed in the estuary may have been promoted by longer summer days providing increased solar input.

Extensive populations of Widgeon grass (*Ruppia maritima*), an aquatic, seed bearing flowering plant were also observed during the summer periods. Both algae and widgeon grass consume dissolved oxygen (DO) during the day and produce carbon dioxide at night. Flows were also reduced to the lower estuary from upstream resulting in a reduced input of more oxygen rich freshwater. During the RWQCB's September sampling event, the algal mats and large portions of the Widgeon grass were undergoing senescence and beginning to bacterially decompose. This led to increased oxygen consumption via respiration by the bacteria, reflected in the sample results for September having the lowest DO levels when compared to the other sampling periods. The algae and Widgeon grass mats were probably the largest source of nutrients to the bacteria. The October 23, 2003 RWQCB sampling showed that DO levels rebounded to as high as 19 mg/L, likely a result of wave-wash over the barrier beach, as evidenced by sand deltas and erosional channels observed leading from the ocean to the estuary that day. Dissolved oxygen concentrations remained low in the lower water column at the Mill Bend site, as before.

Most of the estuary during the mid- to late summer low flow period is shallow, and without riparian or other shaded cover that would reduce or limit solar radiation inputs, another factor conducive to algal and/or other macrophytic plant growth. Stream temperatures during the mid- to late summer months reflect increase solar radiation and hovered around 20 ºC. In October, water temperatures dropped to 15 - 16 ºC at all locations. In combination, the elevated water temperatures and increased in solar radiation favors the growth of macroalgae and other aquatic plants, provided sufficient nutrients are available.

The observations and measurements described above suggest that during the mid- to late summer period, there is enough phosphorous from natural inputs to promote the extensive algal and plant growth. In turn, the primary nutrient sources to the lower estuary that could contribute to any form of eutrophication are the algal mats and, perhaps, the Widgeon grass during senescence. However, under existing conditions, it is speculated that end-point eutrophication, as experienced in many closed systems like lakes and ponds, probably does not have a chance to occur in the Gualala Estuary because of the relatively high freshwater inflow, and occasional wave wash under high surf conditions. The estuary alignment with prevailing summer winds also allow for regular mixing of the water column in the lower estuary. The above-mentioned factors in the Gualala Estuary tend to prevent a "closed system" from forming where bacterial decomposition could proceed to produce truly hypoxic or anaerobic conditions.

Upper Estuary

The upper estuary from the Hwy 1 bridge was completely freshwater during the June and October Regional Board's 2003 sampling events. Populations of algae on the bottom along with "streamers" and surface accumulations in the water column were observed over this period. There was noticeable flow in the lower river that provided a source of dissolved oxygen. Two locations sampled upstream of the bridge in October had DO concentrations of 9.6 and 10.3 mg/L. Plant matter present during the late summer probably undergoes bacterial decomposition, releasing more nutrients into the cycle, but not to the point of eutrophy because freshwater inflow prevents the lower river from stagnating. Water temperatures also increased in an upstream direction during the June sample period, but decreased during October due to the arrival of mostly overcast, late summer fog sampling. Thus, it appears that increases in temperature, along with increases in sunlight, helped to stimulate the growth of macroalgae and other aquatic plants, but not planktonic algae.

A natural seasonal cycle of primary productivity by algae and other aquatic plants is evident in the Gualala River estuary. This is followed by the seasonal senescence and eventual bacterial decomposition of the aquatic plants, lowering DO levels during the late summer, particularly when flows from upstream are reduced and wave-wash over the sandbar is nonexistent. The relatively small size of the estuary and perennial freshwater inflow are important variables in maintaining a freshwater dominated, health estuary.

3.4 Discussion

During the two years of sampling conducted in the lower Gualala River and estuary by ECORP, water quality and habitat conditions varied in response to river flow. During 2002, the estuary remained closed until the first November storm event. The fact that the estuary remained closed throughout spring and summer, and into fall resulted in generally favorable rearing conditions (predominantly freshwater). In addition, water temperatures were generally suitable, with the exception of a few days of increased water temperatures (see 2002). 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. This pattern of repeated breaching resulted in increase salinity values during summer, a time when young of the year and older juvenile steelhead are migrating to the estuary to continue freshwater rearing. The importance of this estuarine rearing stage is to rapidly increase their size (in particular, weight) prior to entering the Pacific Ocean. Survival of outmigrating smolt steelhead increases with size (i.e., weight), presumably because they are better able to withstand stress associated with the transition from fresh to salt water conditions. In addition, the amount of available habitat is increased over that found in the stream. The areal extent of habitat is increased in the estuary when conditions are otherwise suitable (i.e., water quality). Under freshwater conditions, prey items are more abundant and the juvenile steelhead are more able to rapidly increase weight.

In 2002, the estuary 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/estuary fluctuated between primarily freshwater and brackish to marine conditions.

Figure 3.17. EPT Indices for Benthic Macroinvertebrates in the Lower Gualala River and Estuary, July 2002 and May 2003

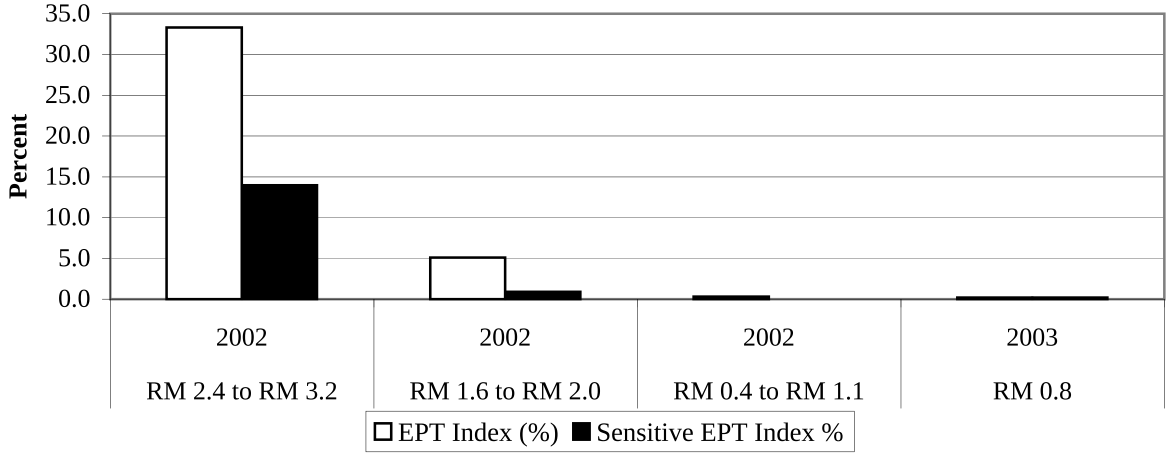


Figure 3.18. Percentage of Non-Insect Taxa Metric for Benthic Macroinvertebrates in the Lower Gualala River and Estuary, July 2002 and May 2003

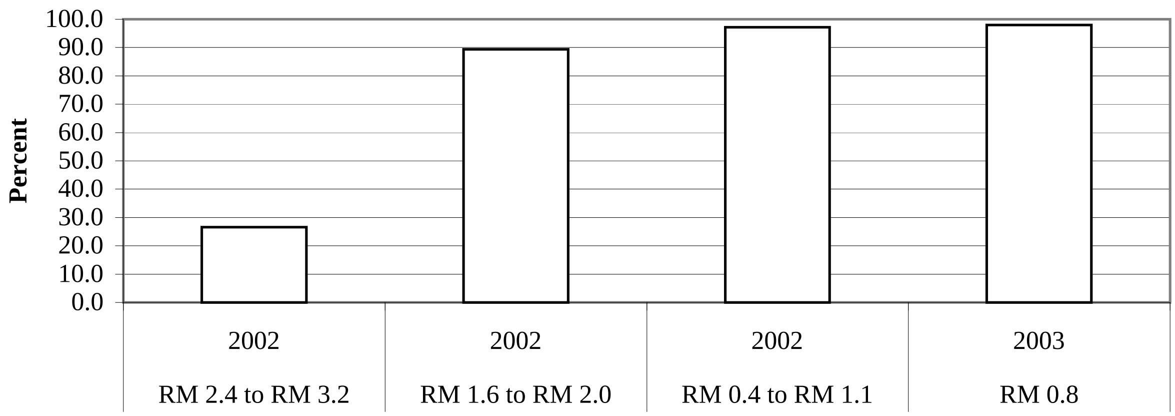
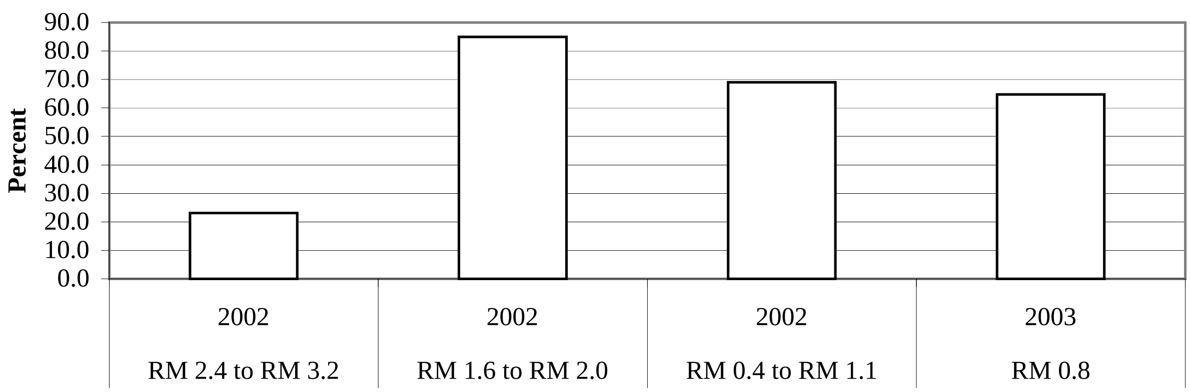


Figure 3.19. Dominant Taxa Metric for Benthic Macroinvertebrates in the Lower Gualala River and Estuary, July 2002 and May 2003



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 estuary 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 estuary 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 estuary 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. In the fall, ocean wave-overwash created saline conditions on the bottom in the lower and lower-middle estuary. As the fall progressed, continued wave-overwash steadily increased surface and bottom salinities in the lower and middle estuary, until the estuary 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 the estuary. During eleven days in July and early August, temperatures generally exceeded the thermal maximum for steelhead, however areas of lowered water temperature (thermal refugia) were sometimes present in deep water. 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 of a few hours. Based on continuous temperature data collected within the estuary, surface water temperatures exceeded 25 ºC for up to 6 hours per day over the eleven days. Based on this analysis, it appears that water temperatures throughout the estuary were generally favorable for steelhead rearing in the estuary in 2002, except for short periods (maximum 6 hours) during late July/early August. A portion of the catch during the early August sampling event appeared to be stressed (lethargic behavior) from warm water and air temperatures

<u>2003</u>

Steelhead were less abundant in the catch in 2003 than in 2002, likely due to greater emigration during the spring 2003 when the estuary was open. Young-of-the-year steelhead were captured in relatively low numbers during February and May when the estuary was open. However, the numbers of YOY fish substantially increased during the June sampling event, which was likely associated with the estuary 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 estuary 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. 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 estuary 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 in the estuary 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 in July 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 estuary. During closed estuary conditions in 2002 when surface waters were calm, conditions may have favored those predators that rely on eyesight (e.g., otters, osprey, and other avian predators) to locate prey. However, the total affect of these predators on juvenile steelhead population numbers within the estuary is unknown.

3.4.1 Benthic Macroinvertebrates

Benthic community sampling, although limited, was conducted to examine the food resources for the fish community. The 2002 NCWAP report on the Gualala Watershed (Klamt *et. al*., 2002) describes the upper watershed as having a good biotic rating based upon an IBI community evaluation approach. Based on the results of the current study effort, including assessments of water quality, fish populations, and the benthic community, the lower river and estuary also appear to provide suitable habitat and food resources for maintaining steelhead and other fish aquatic species.

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

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CHAPTER 4.0 SUMMARY OF CONCLUSIONS

4.1 Introduction

This section summarizes the key findings and conclusions regarding overall condition and aquatic health of the Gualala River coastal estuary determined from each the hydrology and geomorphic, water quality, and aquatic ecology investigations. These conclusions/hypotheses are based predominantly on data and observations collected during the 2002 and 2003-study period. Adult steelhead escapement and juvenile outmigration study components were not part of the scope of this coastal estuary and lower river study.

4.2 Summary

Overall General Observation:

- The estuary appears to be in good biotic condition based upon hydrology, water quality, fish population and benthic invertebrate community conditions.

Hydrology and Water Quality Observations:

- Seasonal changes to the Gualala River coastal estuary geomorphology and water quality occur throughout the year in a fairly predictable manner, and are controlled by subtle shifts in the balance of natural processes, most notably freshwater inflow and wave energy.

- The hydrologic and water quality characteristics of the coastal estuary control the extent and quality of aquatic habitat. Any significant change in the magnitude or timing of a physical condition or process (e.g., climate, water diversions that decrease freshwater inflow, degraded water quality conditions from land use practices) will likely have a significant adverse effect on estuary ecology.

- In order to maintain healthy conditions for steelhead rearing in the estuary, an ample supply of good quality inflow needs to be maintained and protected. This can be assessed quantitatively through additional study (e.g., PHABSIM analysis), however it is also assessed by the ability of the estuary to maintain freshwater conditions during closure.

Fisheries Specific – Summary Points:

- Anecdotal information obtained from local residents and CDFG snorkel surveys, as well as the capture of one juvenile Coho salmon in the estuary indicate that a remnant coho salmon population may be present in the Gualala River Watershed.

- Adverse physical, biologic, or water quality conditions in the estuary were not identified as a limiting factor to Coho salmon populations in the Gualala River estuary. An exception to this would be unseasonably warm estuarine water temperatures, most notably in the shallow lower river and upper estuary, often associated with low inflow conditions. The factors limiting Coho in the basin appear to be associated with degraded habitat conditions in the upstream portions of the watershed.

- Surface water temperatures exceeded 25-degrees C for several hours per day for short durations during the summer in 2002. Although it appears that areas of thermal refugia do exist in the estuary, unseasonably warm water temperatures may sometimes be a limiting factor on steelhead rearing in the coastal estuary.

- Steelhead rearing capacity in the coastal estuary is generally good for pre-smolt and smolt steelhead under existing conditions. However, additional deep pool habitat, and increased cool water inflow would increase summer thermal refugia.

- Habitat conditions within the estuary appear to be adequate to accommodate steelhead rearing, even with the high degree of inter- and intra-annual variability in the hydrology and water quality of the coastal estuary.

- The estuary is generally dominated by freshwater conditions throughout the rearing season. During periods of barrier breaches and wave overwash, saline water enters the estuary, affecting water quality upstream as far as Mill Bend. As long as there is a good supply of inflow, salinity stratification maintains shallow freshwater lenses. When the barrier beach reforms, the estuary quickly returns to generally freshwater conditions.

- Salinity increases in the lower to middle estuary due to late-fall wave overwash caused juvenile steelhead in these sections to seek freshwater conditions in the upper estuary. As expected, there was evidence of juvenile steelhead out-migration during breeching.

- The benthic invertebrate communities transition from riverine (insect) to estuarine dominated species well above the Highway 1 Bridge in the upper reach of the estuary. The dominant juvenile steelhead food source in the estuary is an isopod (zooplankton), *Gnorimosphaeroma sp.*.

- The low number of juveniles found in the estuary during the spring and early summer of 2003 likely resulted from emigration associated with the late-season breach that drained the estuary on June 15, 2003.

- Young-of-the-year (YOY) steelhead were typically more abundant in the upper estuary, especially during periods of low flow and lower estuary stratification. During this time, the upper estuary provides preferred riverine conditions for YOY. When the entire estuary was dominated by freshwater conditions, YOY and older juveniles tended to be distributed evenly throughout the estuary.

- Scores for "Substrate Complexity" and "Physical Habitat Quality" indicated the presence of good habitat conditions for both juvenile steelhead rearing and prey items throughout the estuary.

Other limiting factor considerations:

- Field observations suggest that predation on aquatic species by mammals and birds are high throughout the late spring through summer period. The affect of this predation on juvenile steelhead population within the estuary is unknown.

Mid-summer through late-fall filamentous algal blooms are pervasive throughout the lower river and estuary. These blooms appear to occur naturally in north coast streams and result from increasing water temperature and photoperiod, as well as a supply of both natural and human-induced nutrients. The presence of these filamentous algal blooms did not appear to adversely impact steelhead juveniles during the 2002 and 2003 sampling seasons, however dense accumulations could displace fish from otherwise useable habitat.

- As to some specific limiting factors that can be caused by anthropogenic behaviors, no unnatural-illegal breaches were observed to occur during the study period. Artificial estuary breaches can have a significant negative effect on the survivability of anadromous species. Additionally, while illegal off road vehicle use is known to occur in the lower river, no data were collected that would indicate whether this activity results in significant adverse affects to juvenile salmonids. General community education that addresses these types of human behaviors is important components to the continued stewardship of the ecological resources found in the Gualala River Watershed.

- Land use and impact was not analyzed in this study. In general, the available reports such as the NCWAP report (Klamt et al., 2003), and the analysis set forth in the TMDL- sediment document (December 2001) characterize the origin, land use history, and future recommendations for land use relative to improvement of watershed conditions.

- Through the limited hydrologic analysis of sediment movement conducted through this study, sediment transport through the estuary and lower river did not appear to be a limiting factor for fisheries populations within the estuary. Very high suspended sediment values are known to adversely affect rearing salmonids. However, no suspended sediment sampling or monitoring was completed as part of this study.

- Land use practices related to timber harvest, forest conversion, and agricultural development (vineyards) were not critiqued as a portion of this study. For those practices, the authors note that successful compliance with the Forest Practices Act, and all applicable county, state, and federal regulations, as well as community stewardship of the land, are the best safeguards to ameliorate negative impacts to the watershed. The authors note that the Gualala has a developing tradition of effective landowner- stakeholder group forums to address these matters in a constructive manner.

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CHAPTER 5.0 ENHANCEMENT PLAN AND RECOMMENDATIONS

5.1 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 estuary. 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 estuary, 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.

It is encouraging to note that during the timeframe of the study, the estuary and lower river appeared to be healthy and productive and estuary condition was not a limiting factor to coho and steelhead rearing. In contrast, it is important to acknowledge that the Gualala River Watershed, upstream of the estuary, remains designated as an impaired water body for sediment and temperature, and will require substantial and long-term efforts to improve overall conditions. The inhabitants of the Gualala River Watershed are in a unique position to implement watershed recovery strategies and actions: the watershed has an active and sophisticated citizenry interested in its future recovery; there has been an analysis of upper watershed conditions provided by the North Coast Watershed Assessment Program project (Klamt, 2003); there have been updates to the fisheries work conducted in response to issues raised in the NCWAP report (Gualala River Implementation Summary, 2003); preliminary TMDL analyses for both sediment (2001) and temperature (2002) have been completed; and several projects for upland restoration including retirement of old roads, instream large woody debris enhancement, and comprehensive trend monitoring for water temperature, channel morphology, and upland habitat monitoring (e.g., riparian inventories) have all been funded and completed. It should also be noted that the voluntary and proactive compliance of landowners in the

Gualala River Watershed is promising, and should be further encouraged to ensure long-term protection and enhancement of the watershed.

5.2 Existing Resource Management Activities and Regulatory Compliance

The main resource management and restoration guidance documents for the Gualala River watershed is the 2003 NCWAP report, follow up Implementation Summary reports, and TMDL studies and documents. The NCWAP program and follow up Implementation Summary reports provide important summaries and status about the watershed (estuary and lower river excluded) and specific areas of concern for restoration in each sub-basin. The NCWAP report recommendations point to the need to repair and retire as necessary the vast road network in the watershed, put more large woody debris in the streams to improve habitat complexity and provide refugia, and most importantly ensure that land management practices adequately provide for the protection and enhancement of instream habitat.

In a more limited way, the TMDL sediment document also summarizes conditions that deserve further attention in different sub-basins. While the North Coast Regional Water Quality Control Board TMDL implementation plan is still some years short of its required implementation (2007 for sediment, 2011 for temperature), each year landowners in the watershed have continued to “treat” significant portions of road in specific sub-basins. For example, 80% of the roads have received sediment reduction treatments in the Fuller Creek sub-basin, through voluntary projects, primarily funded by State and federal funds, that did not come about from mitigation or other forced action.

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.

5.3 Management Goals and Objectives

The overall goal of this enhancement plan is to sustain and improve the natural vitality and biodiversity of natural resources within the lower Gualala River and coastal estuary, much of which is dependant upon resource protection and recovery actions in the upper watershed. This goal includes the need to ensure that natural resources are not diminished, and when possible, to improve the unique and diverse aquatic and surrounding riparian, wetland, and upland 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: a) the 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. Primary protection and restoration efforts focus on: protecting freshwater inflow to the estuary; reducing sediment production from the upper watershed; enhancing aquatic habitats throughout the watershed; reducing human-derived nutrient loads to the estuary; and fostering voluntary participation of landowners in resource protection and restoration efforts. No priority or level of importance is implied by the order in which objectives are presented below.

OBJECTIVE 1: To protect the current supplies, and enhance, if necessary, freshwater inflow to the coastal estuary.

Desired Outcome: To protect water quality and aquatic habitats by maintaining the natural seasonal cycle of coastal estuary and barrier beach morphology..

Implementation Activities:

- Discourage the development of any surface water diversions in the watershed that independently or cumulatively have a significant impact on reducing the inflow to the coastal estuary, especially during summer and fall months.
- Discourage development of surface-water influenced wells that have impart similar significant adverse impact on summer base flows or recharge to the local groundwater system impacts to those stated above.
- Ensure that future residential and agricultural 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.
- Restore a program of monitoring summer base flows in major tributary channels.

- 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 with willing partners.
- Seek to establish partnerships that provide for working landscapes consistent with the protection and enhancement of Gualala River ecological resources.
- Identify restoration planning needs and projects in watershed tributaries referenced by existing studies such as the NCWAP report.

Constraints:

- Existing legal and illegal water diversions.
- Natural variability in climate and stream flows.
- Data gaps for implementation of restoration goals.

OBJECTIVE 2: To eliminate any potential for unnatural breaching of the barrier beach.

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

Implementation Activities:

- Develop an educational and public awareness program to alert local residents of impacts to estuary ecology due to artificial breaching.
- Post sign at kiosk at County Park informing public about beneficial attributes of a coastal estuary system and ecological risks of artificial breaching.

Constraints: Funding availability for educational outreach has been scant for watershed groups in the recent past.

OBJECTIVE 3: To assess and minimize possible input of toxics or excessive nutrient loads to the estuary.

<u>Desired Outcomes</u>:

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

<u>Implementation Activities</u>:

- Assess and reduce 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, if present.
- Educate and reduce the potential for illegal or irresponsible dumping.

Encourage Best Management Practices in both developed/urban areas and upper watershed, using existing programs and documents such as the SRCD House and Garden Audit, Farm Planning and Backyard Stewardship Programs.

<u>Constraints</u>:

- Identify funding sources.
- Landowner participation.

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

<u>Desired Outcome</u>: Protect and enhance aquatic habitat for resident fish and organisms as well as for avian and other wildlife species that rely on aquatic habitats for food not only in the lower river and estuary, but also throughout the entire watershed.

Implementation Activities:

- Expand on NCWAP report ranking charts at sub-basin priority levels for fisheries, instream, and upland restoration work. The natural sequence is to continue this work with the following steps:
    a. Identify highest priority sub-basins for restoration; identify and rank priority projects in the top sub-basins
    b. Integrate restoration rankings with NCWAP series maps that address these factors and prioritize projects in each sub-basin
    c. Cross-reference and chart multiple target restoration goals from agency and group sources (SCC, DFG, SWRCB, GRWC, etc) and identify benchmarks to satisfy the goals. This tool is useful for cross-agency communication.
    d. Address data gaps and provide funding to complete data collection where landowner permission is gained
- Continue to encourage more environmentally friendly logging and land development practices, (including BMPs). Ensure consistency with Forest Practice Rules.
- Develop an educational and public awareness program to alert local residents of the impact of off-road vehicles in streambeds and associated upland areas, and other related topics.
- Conduct sediment source analysis for priority roads and related features identified in the NCWAP report maps as potential contributors of fine sediment.
- Repair and Retire logging roads, and treat other upslope sediment sources identified in the NCWAP report maps and identified through field reconnaissance.
- Land conversion and acquisition.
- Pursue property acquisitions or easements that provide for working landscapes consistent with the protection of the Gualala's ecological resources
- Long-term monitoring of estuary profiles to track changes in morphology.
- Evaluate potential effects of instream gravel mining relative to degradation or creation (through pool construction or channel modification) of instream habitat.

Constraints:

- Identify funding sources.
- Landowner participation.

OBJECTIVE 5: Implement public outreach efforts for landowner sediment reduction and instream habitat improvement project development once sub-basin priorities are met and supporting data available.

Desired Outcome: Improve habitats for aquatic species and reduce the threat of adverse impacts to the estuary from sediment and water quality impairments.

Implementation Activities:

- Develop a series of parcel map databases to guide outreach process appropriate to sub-basin priority needs.
- Develop and document outreach.
- Identify and fund prioritized enhancement projects.
- Conduct necessary pre-project inquiries such as sediment source investigations, planting designs, and specific permitting requirements.
- Conduct pre and post monitoring of project effectiveness and relate monitoring to existing trend monitoring underway for the larger watershed.
- Provide watershed wide education and networking about watershed project accomplishments and restoration project developments.

Constraints:

- Identify funding sources.
- Landowner participation.

OBJECTIVE 6: To increase public awareness of the importance of dune and dune scrub vegetation.

Desired Outcome: Improve habitats for sensitive native plants and nesting birds.Encourage public awareness of sensitive 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 further develop and facilitate consensus of watershed resource management plan goals, objectives, and implementation strategies and prepare a watershed resource management and restoration implementation plan.

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

Implementation Activities:

- Utilize the GIS developments already provided to the watershed such as the sophisticated road routing layer that can identify and track both road related restoration features (down to specific culvert replacements), and stream related restoration as well.
- Develop a large wood inventory budget on a watershed wide basis that predicts natural woody deposition rates into streams.

- Develop a water budget that addresses flow rate and quantity issues needed to provide a healthy ecosystem to offset impairment conditions.
- Provide the capacity for data development, management, quality control, and data entry that updates NCWAP digital databases, report addendums, map development, etc.
- Coordinate/meet with local landowners and agency staff to revise and approve the resource management and restoration plan.
- Work with stakeholders to develop an implementation strategy for proposed management actions.
- Develop public education and stewardship programs.

Constraints: Interest and financing.

OBJECTIVE 8: Evaluate the condition of terrestrial, riparian and wetland habitats bordering the lower river and estuary with the aim at developing management and restoration strategies to protect improve them.

Desired Outcome: To delineate riparian and wetland areas; develop a comprehensive list of plants and wildlife residing along the lower river and estuary; identify endangered and sensitive plant and animal species residing and/or utilizing the lower river and estuary; develop a map of plant species, communities, habitat zones, and species distribution; describe the use and dependence of bird and wildlife species on the lower river and estuary aquatic system; and identify opportunities to preserve and improve habitat for plant and animal species and the healthy linkage to the adjacent aquatic ecosystems.

Implementation Activities:

- Conduct the specific biologic, botanical and ecologic surveys and studies necessary to address the specific outcomes listed above.

Constraints:

- Competition from non-native and exotic species.
- Majority of surrounding property is under private ownership.
- Heavy public access through the County Park.

OBJECTIVE 9: 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 any or all of the Objectives (1 through 8) listed above.

Constraints:

- Interest and financing.

5.4 Summary of Recommendations

In an effort to assist local resource management entities with implementation of the estuary protection and enhancement strategies outlined above, the following list of data collection and analysis tasks are proposed. A brief description of the rational and need for these items and how they will contribute to protection and enhancement of the coastal estuary is also provided.

1. Identify and quantify the volume of existing and proposed surface water diversions and groundwater extractions in the river basin in terms of percent of estimated annual flow at selected locations. The objective of this investigation is to determine the degree of reduction in freshwater inflow to the coastal estuary and attempt to identify the minimal seasonal inflow needs to maintain healthy conditions. This study should also assess potential impacts to changes in North Fork Gualala River summer

baseflow, the main summer/fall source of surface inflow to the lower river and estuary.

2. Continue river flow monitoring at existing USGS gauges. These data are necessary to accurately and reasonably quantify freshwater inflow to the estuary. Again, these data along with concomitant estuary water level and water quality monitoring will assist in identifying minimum freshwater inflow requirements to maintain healthy juvenile steelhead rearing conditions.

3. Complete a detailed water budget of the estuary to quantify the magnitude and importance of groundwater inflow and barrier beach seepage (outflow) in maintaining favorable freshwater conditions in the estuary during the summer and fall periods.

4. Perform an impact assessment of mammal and bird predation on juvenile steelhead populations in the coastal estuary. The objective of this analysis is to determine the relative significance/stress predation has on juvenile steelhead populations in the estuary.

5. Complete biologic and botanical assessments to map wetlands, inventory riparian and upland wildlife species (esp. endangered and sensitive species), and identify and map native and exotic plant species in and around the study area, with emphasis on dune and scrub vegetation and marsh ecology in the lower and middle reaches corresponding to the county parks and private landowner parcels. Prepare an exotic removal and planting plan to address future restoration and management efforts.

6. Continue a hydrologic/geomorphic monitoring program including: weekly photo-monitoring; continuous estuary water level monitoring; seasonal estuary morphology surveys; gravel bar pebble counts; and bimonthly or event-driven water quality monitoring of the coastal estuary. The objectives of this work are consistent with those outlined in the Hydrology Section of the report. Collecting this information

during a wider variety of water year types will be necessary to: 1) understand the effects of reduced freshwater inflow; 2) identify periods and conditions associated with poor rearing habitat (not observed during the 2002 and 2003 sampling seasons); and 3) assist in quantifying the minimum freshwater inflow rate to maintain healthy aquatic ecological conditions.

7. Implement a nutrient, toxic chemical, and general water quality parameter monitoring program to determine: 1) the source of nutrients fueling algal blooms in the lower river and estuary and threat of eutrophication from instream, near-stream, and upstream (upslope) sources; 2) collect and identify the algae and aquatic plants of concern; 3) collect chlorophyll and nutrient samples and conduct sediment oxygen demand sampling and analyses; 4) identify and evaluate the relative importance of other hydrologic and water quality factors contributing to algal blooms; 5) evaluate if any chemical applications within the watershed are impacting the lower river and coastal estuary; and 6) identify and quantify historic, existing and future potential nutrient sources including septic systems, agricultural operations, and other potential sources. It cannot be overstated that, together with decreased freshwater inflow rates, increased nutrient loads pose the greatest threat to long-term health of aquatic habitat in the estuary.

8. Continue fish sampling pursuant to the methods and approach followed as part of this investigation. The objective of this continued sampling is to evaluate population and habitat conditions over a broader range of water year-type conditions and to test population estimators over a broad range of conditions.

9. Conduct fish escapement surveys to better understand affects of spawning stock on extent of production and recruitment.

10. Better investigate the use of the lower river and North Fork as summer/fall refugia during periods of increased salinity in the estuary associated with wave overwash.

11. Expand on the results and interpretations of this study with previously published work on the north coast for purposes of regional watershed recovery planning. Integrate the findings from this narrow scope of work into the broader watershed perspective.

LIST OF APPENDICES

APPENDIX A

Hydrology

APPENDIX A.1

Methodology for Estimating Freshwater Inflow to Gualala River Coastal Lagoon

Kamman Hydrology & Engineering, Inc.

The primary objective of this analysis is to develop a daily freshwater inflow record for the Gualala River Coastal Lagoon; the study period for the analysis ranges from 10/1/00-1/31/04. The following is a brief description of the methodologies used in constructing the inflow record.

The contributing watershed was broken into 7 tributaries: Wheatfield Fork, South Fork, North Fork, Rockpile, Buckeye, Pepperwood, and the Remaining South Fork. The average daily flow for each tributary was calculated, or estimated, for each day of the period of analysis (10/1/00 – 1/31/04), and the sum of the daily flow values was used to estimate the daily freshwater input to the Estuary.

DAILY TRIBUTARY INFLOW: Wheatfield Fork, South Fork, and North Fork

Wheatfield Fork (WF)

- Data was obtained from the California Department of Water Resources (DWR) or the United States Geological Survey (USGS) for the following parameters and dates:
  - FLOW: 10/1/00-9/30/02; 6/10/03-11/29/03; 12/3/03-1/31/04
  - STAGE: 10/1/01-2/23/03; 2/28/03-1/31/04
- Missing daily flow values for 10/1/02-2/23/03; 2/28/03-6/9/03; and 11/30/03-12/2/03 were calculated from a derived stage-flow equation/relationship (i.e., a rating curve) for WY 2002.
- WF Rating Curve: Upon analysis of the rating curve, it was separated into 3 parts and 3 different equations (see Figures 1 and 2).
  - For stage <= 3.69 ft: (WF Q) = $4\text{x}10^{-32}(h)^{57.146}$ [$R^2 = 0.9817$]
  - For stage <= 3.78 ft: (WF Q) = 75(h) – 266.5 [$R^2 = 1.0$]
  - For stage > 3.78 ft: (WF Q) = $81.83(h)^2 - 589.58(h) + 1076.6$ [$R^2 = 0.9973$]
  - *Q = flow (cfs); h = stage (ft)*

South Fork (SF)

- Data was obtained from the California Department of Water Resources (DWR) or the United States Geological Survey (USGS) for the following parameters and dates:
  - FLOW: 11/18/00-9/30/02
  - STAGE: 10/1/01-9/30/02; 12/23/03; 12/26/03; 12/29/03
- A rating curve was developed for the SF for WY 2002. However, only 3 mean daily stage values (above) exist outside the range of dates that have reported flow values. Thus, the rating curve is presently not useful for predicting flows.

Missing daily flow values for 10/1/00-11/17/00; and 10/1/02-1/31/04 were calculated via a regression analysis with the WF.

- Flow-Regression (WF vs. SF): SF flows were predicted using the following regression equation (see Figure 3):
  - $(SF\ Q) = 0.3265(WF\ Q)^{1.0835}$ [$R^2 = 0.9694$]
  - *note*: SF flows <= 0.1 were omitted from the regression

North Fork (NF)

- Data was obtained from the California Department of Water Resources (DWR) or the United States Geological Survey (USGS) for the following parameters and dates:
  - FLOW: 10/1/00-9/30/02
  - STAGE: 10/1/01-9/30/02; 12/11/02-2/23/03; 2/26/03-1/31/04
- A rating curve was developed for the NF for WY 2002. However, the rating curve predicted unusually high summer/base flows for the NF (WY 2003) compared to the USGS WF flow data for that same time period. It was noticed that the stage values for the NF in the summer of 2003 were consistently about 1-foot higher than the stage values in the summer of 2002. Thus, a change in channel geometry likely occurred between these two periods and may account for the pronounced discrepancies in the predicted base flow values. For higher flows (ca. above 200 cfs), the rating curved predicted reasonable NF flow values, but it cannot be determined at this point what effect a potential change in channel geometry has on these predicted NF flow values as well. For these reasons, the rating curve is not being used at this time.

  Missing NF daily flow values for 10/1/02-1/31/04 were calculated via a regression analysis with the SF. An initial regression was done for both SF vs. NF and WF vs. NF for WY 2001-2002, and the R^2 value was slightly better for the overall SF vs. NF regression. Because of distinctly different relationships (particularly for the lower flows), or trends (i.e., an obvious shift in the regression line and data), for WY 2001 vs. 2002, only WY 2002 was used for the final regression equations.

- Flow-Regression (SF vs. NF): Upon analysis of the data, the regression curve was separated into 2 parts and 2 different equations. NF flows were predicted using the following regression equations:
  - For SF stage <= 4.7 ft: $(NF\ Q) = 1.8361(SF\ Q) + 7.7646$ [$R^2 = 0.9615$]
  - For SF stage > 4.7 ft: $(NF\ Q) = 3.2334(SF\ Q)^{0.8142}$ [$R^2 = 0.9533$]
  - *note*: SF flows <= 0.1 were omitted from the regression
  - *note*: 10/31/01 was omitted from the regression (outlier)

Daily unit runoff values (cfs/mi^2) were then calculated for the above 3 tributaries

DAILY TRIBUTARY INFLOW: Rockpile, Buckeye, Pepperwood Creeks and remaining drainage area.

Unit runoff values (cfs/mi^2) were calculated for all 7 tributaries based on field data collected by Kamman Hydrology & Engineering, Inc. (KHE) on 9/4/2002, 9/27/2002, and 11/1/2002 (see Table A-1-1). All flow measurements were completed using standard flow measurements to the procedures and protocols outlined in:

Rantz, S.E., 1982, Measurement and computation of streamflow, Volume 1. Measurement of stage and discharge. U.S. Geological Survey Water Supply Paper 2175, 284p.

All flow measurements were completed near the confluence with the main-stem Gualala River. Based upon similarities among unit runoff values for the various tributaries, the daily unit runoff values calculated for the 3 tributaries above were used as surrogates in order to derive complete flow records (daily time step) throughout the period of analysis for the 4 remaining tributaries (*below*).

Rockpile (RP)
(RP Q) = (SF q)(RP da)
where: *q = unit runoff* (cfs/mi^2)
da = drainage area (mi^2)

Buckeye (BU)
(BU Q) = (WF q)(BU da)

Pepperwood (PW)
(PW Q) = (NF q)(PW da)

Remaining South Fork (remSF)
(remSF Q) = (SF q)(remSF da)

TABLE A.1.1
Base Flow Measurements on Select Gualala River Tributaries

Location		Q (cfs)	Temp (C)	Temp (F)	Cond. (uS)
South Fork at Switchville	8/16/2002	11.73	19.90	67.82	209.20
	9/4/2002	8.44	20.90	69.62	212.00
	9/27/2002	7.35	16.40	61.52	218.00
	11/1/2002	8.08	12.7	54.86	216.00
North Fork USGS gage location	9/4/2002	3.87	16.30	61.34	189.00
	9/27/2002	3.01	15.60	60.08	188.00
	11/1/2002	3.31	11.30	52.34	190.00
North Fork at North Gualala Water Company Well 5	9/4/2002	2.15	16.40	61.52	185.90
	9/27/2002	1.92	15.70	60.26	182.00
	11/1/2002	1.77	12.40	54.32	182.50
North Fork at Confluence wth Little North Fork	9/4/2002	3.38	15.70	60.26	194.90
	9/27/2002	3.21	15.10	59.18	193.00
	11/1/2002	2.55	12.50	54.50	194.00
Pepperwood Creek Near mouth	9/4/2002	0.17	13.20	55.76	211.50
	9/27/2002	0.21	13.20	55.76	211.50
	11/1/2002	0.17	8.40	47.12	207.10
Rockpile Creek.	9/4/2002	0			
	9/27/2002	0			
	11/1/2002	0			
Buckeye Creek	9/4/2002	0.59	16.90	62.42	253.80
	9/27/2002	0.64	15.00	59.00	256.00
	11/1/2002	0.98	10.20	50.36	247.90
Sourth Fork at Sea Ranch well	9/4/2002	1.04	20.20	68.36	265.70
	9/27/2002	1.24	16.80	62.24	253.00
	11/1/2002	1.61	15.00	59.00	263.50
Sourth Fork at USGS gage location	9/4/2002	0			
	9/27/2002	0			
	11/1/2002	0			
Wheatfield Fork at USGS gage location	9/4/2002	0.63	20.20	68.36	265.70
	9/27/2002	0			
	11/1/2002	0			

APPENDIX A.2

Results of Pebble Count Analysis

Kamman Hydrology & Engineering, Inc.

Pebble counts and grain-size distribution analyses followed the methods outlined in the following documents:

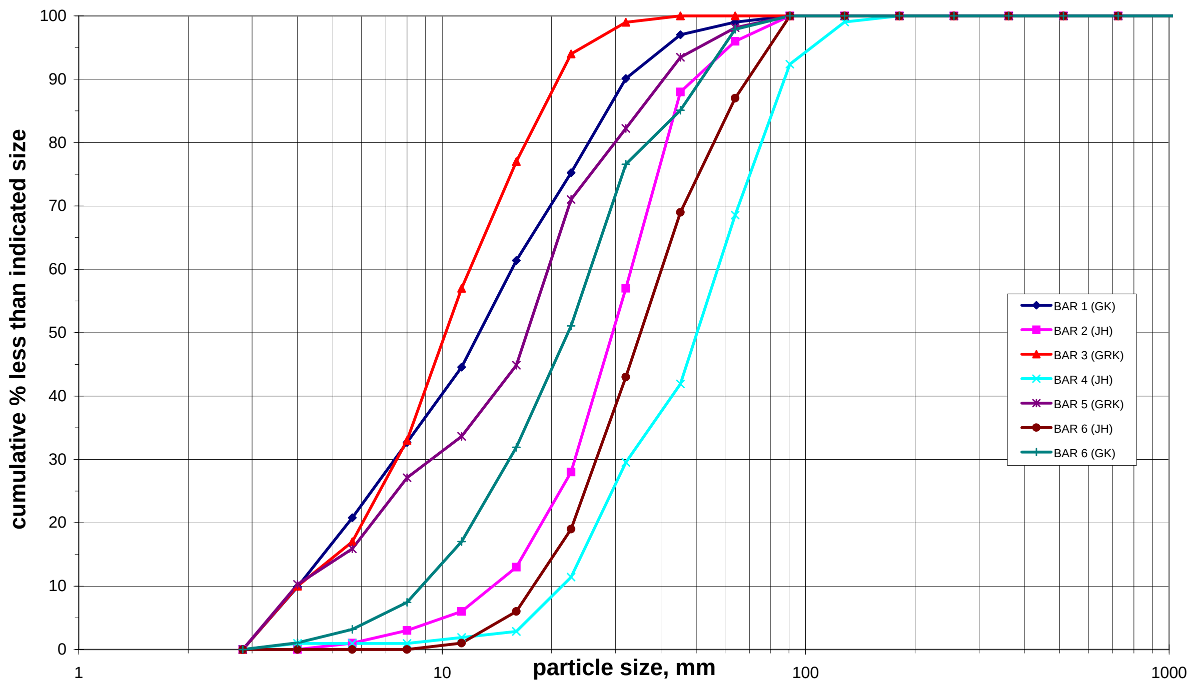
Bunte, K. and Abt, S.R., 2001, Sampling surface and subsurface particle-size distributions in wadable gravel- and cobble-bed streams for analyses in sediment transport, hydraulics, and streambed monitoring. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, General Technical Report RMRS-GTR-74, May.

Kondolf, G.M., 1997, Application of the pebble count: noteson purpose, method, and variants. Journal of the American Water Resources Association, vol. 33, no.1, February, pp. 79-87.

Grain size distributions are presented on the following graphics. See report text for sample dates and locations.

FIGURE A.2.1
Pebble Count Grain-Size Distributions
Gualala Lower RIver and Coastal Lagoon Assessment and Enhancement Plan

Results from September 2002 Sampling



Results from June 2003 Sampling

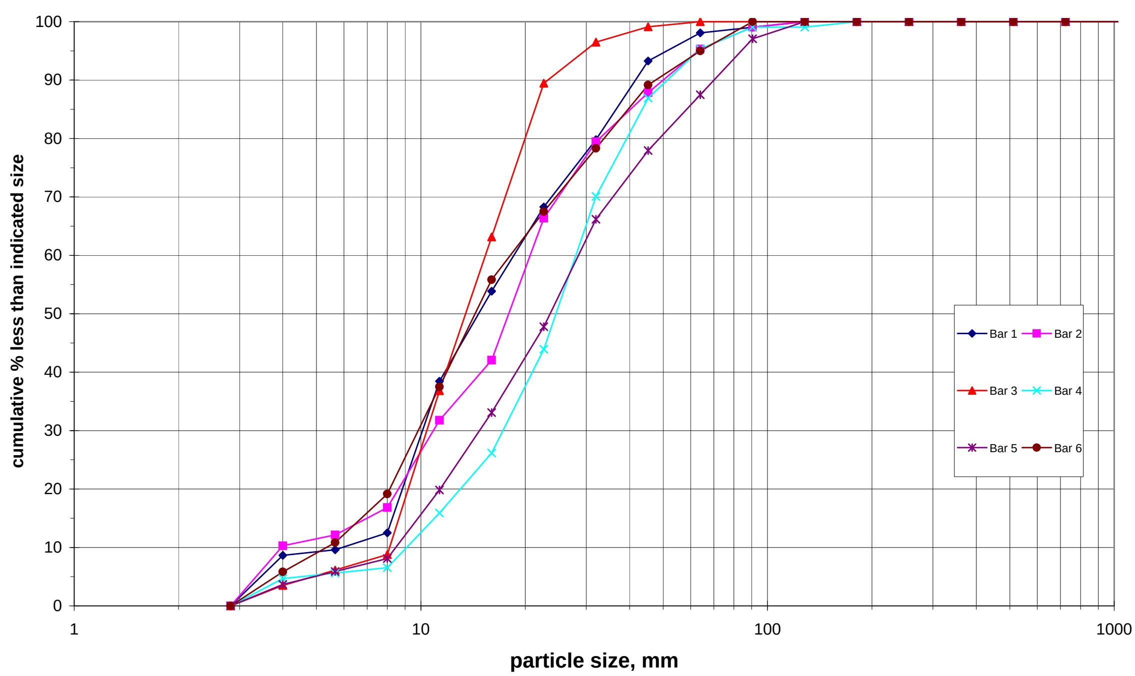
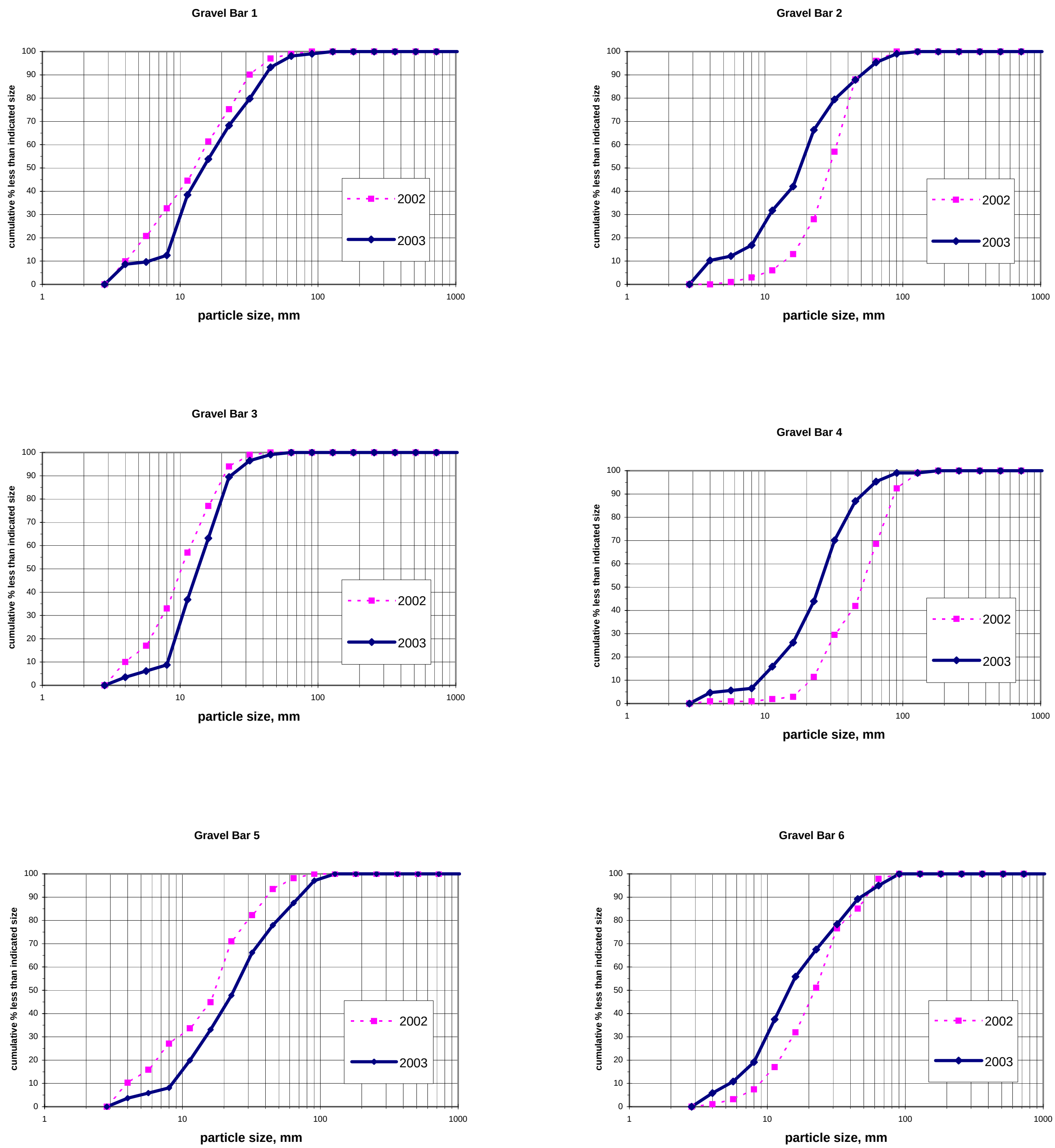


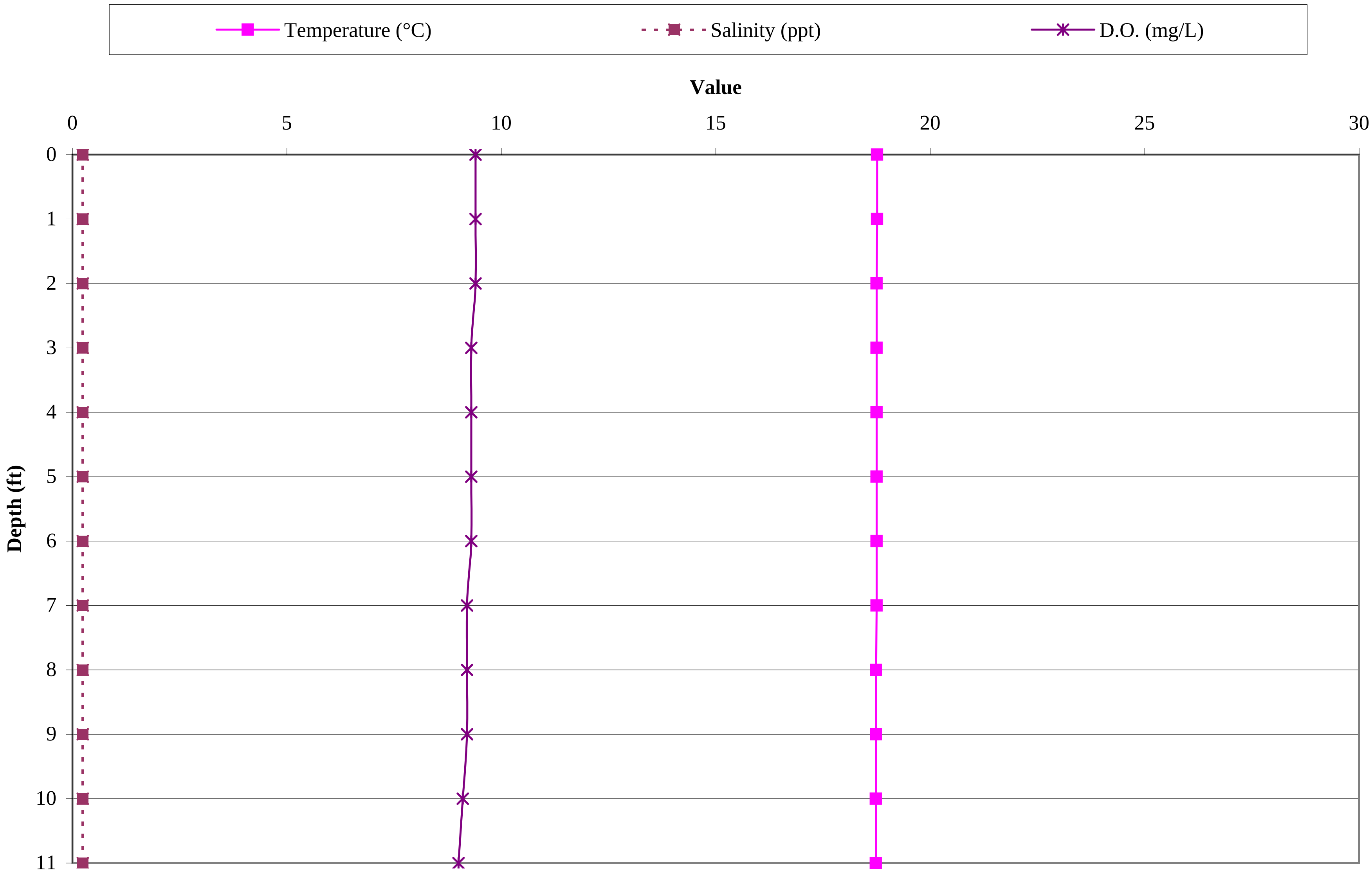
FIGURE A.2.2
Pebble Count Grain-Size Distributions
Gualala Lower RIver and Coastal Lagoon Assessment and Enhancement Plan



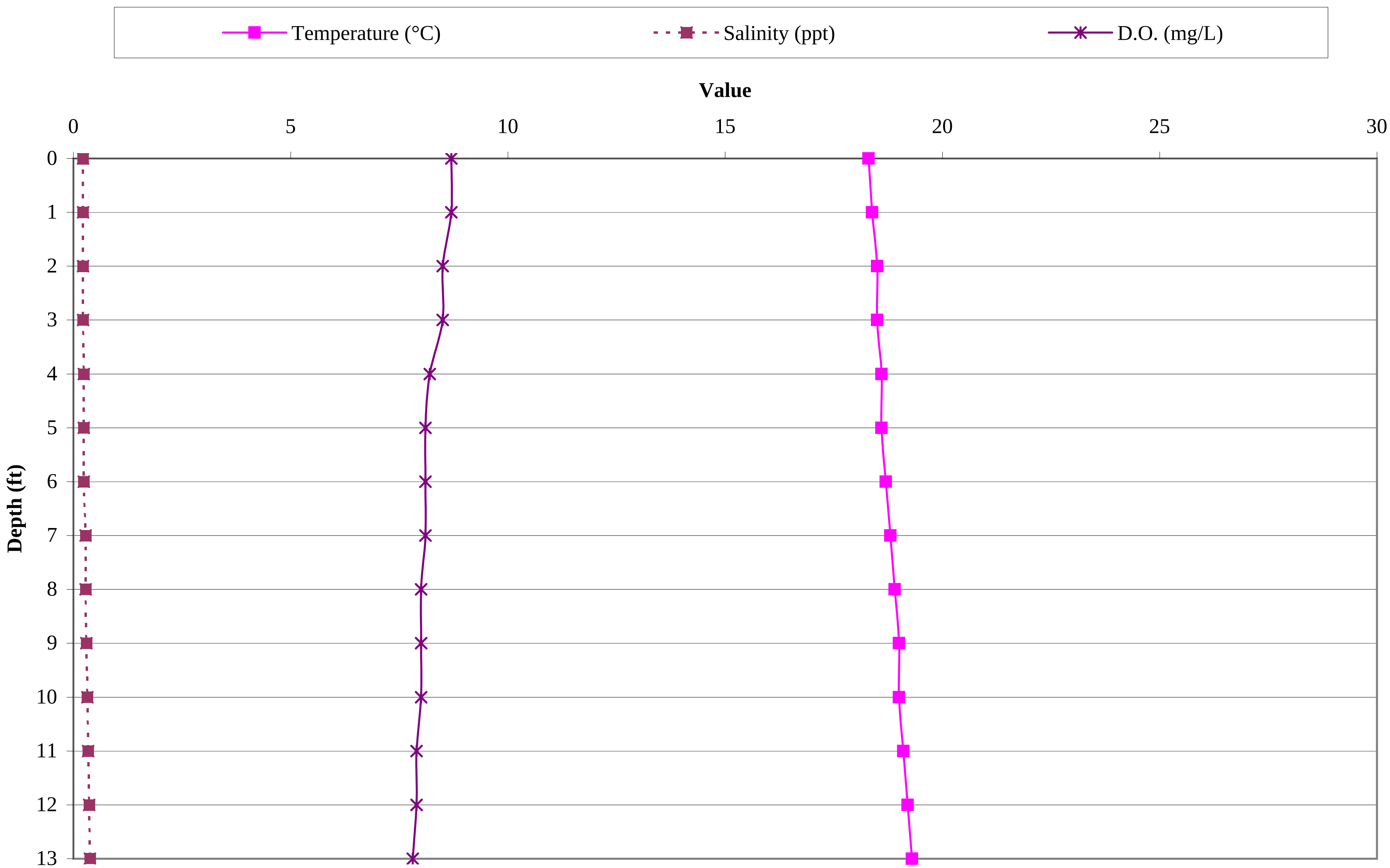
APPENDIX B

Water Quality

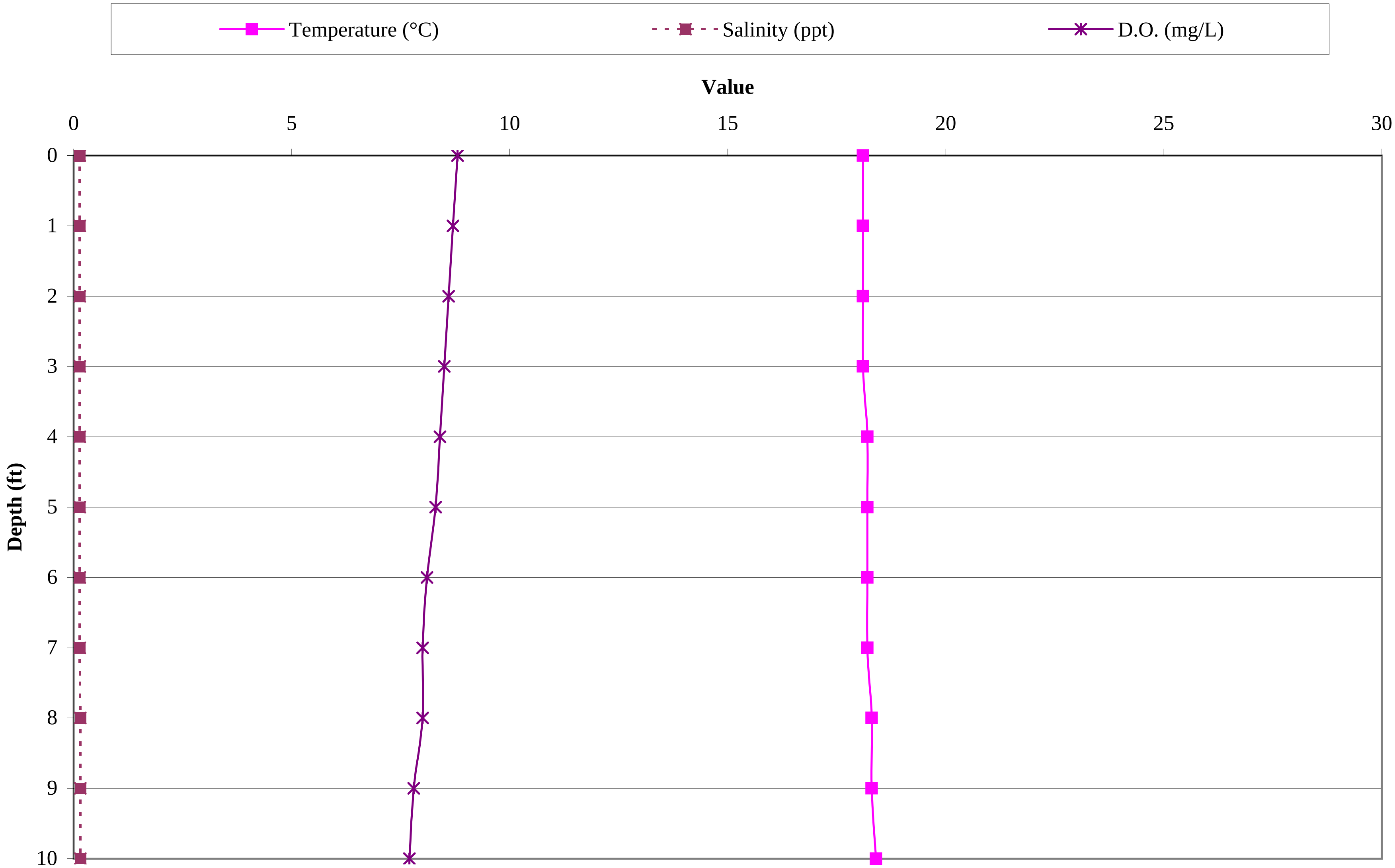
Appendix B-1. Gualala Water Quality Depth Profile - Mouth of the Estuary - 6/12/02.



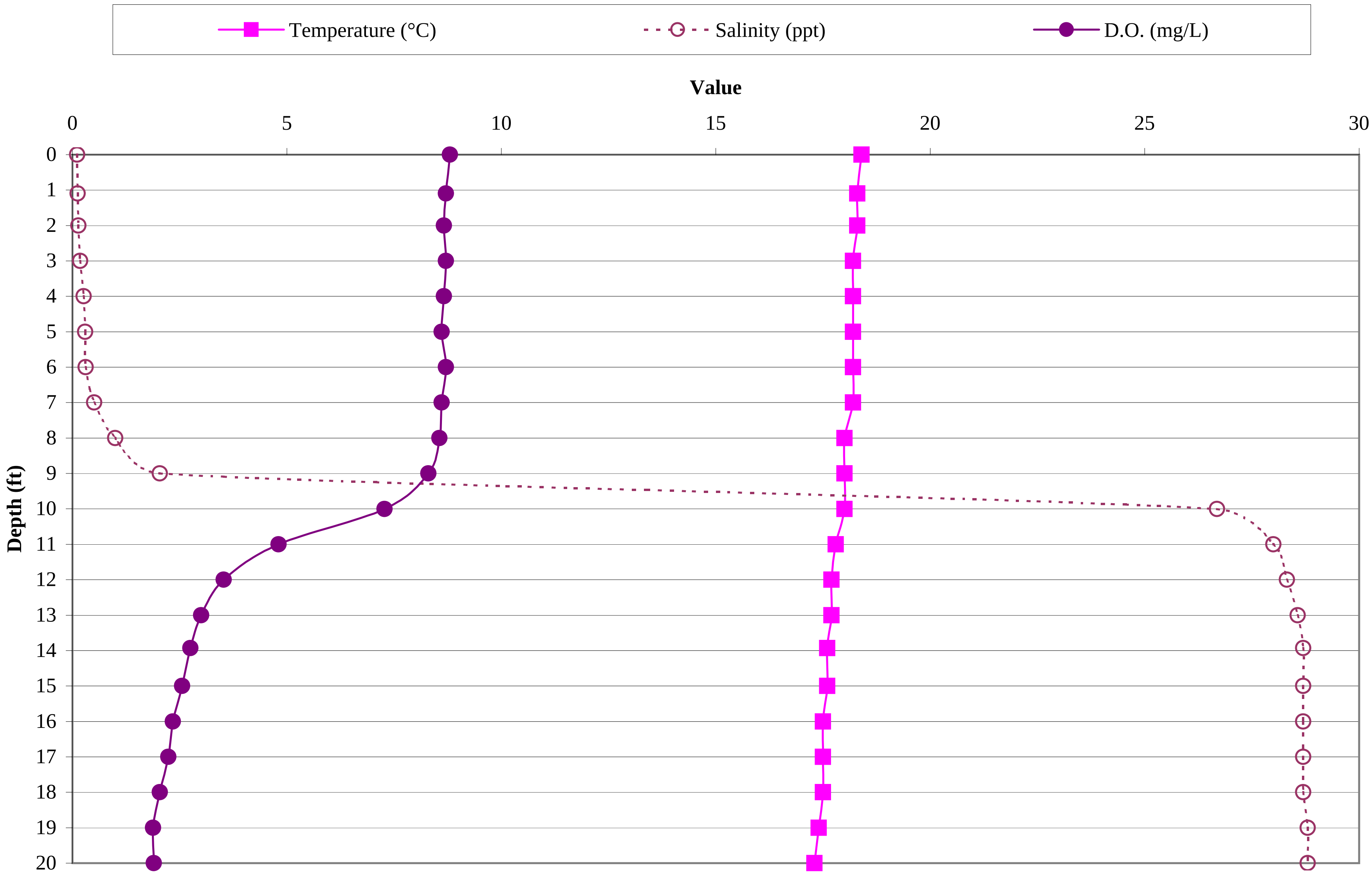
Appendix B-2. Gualala Water Quality Depth Profile - Tide Guage -6/12/02.



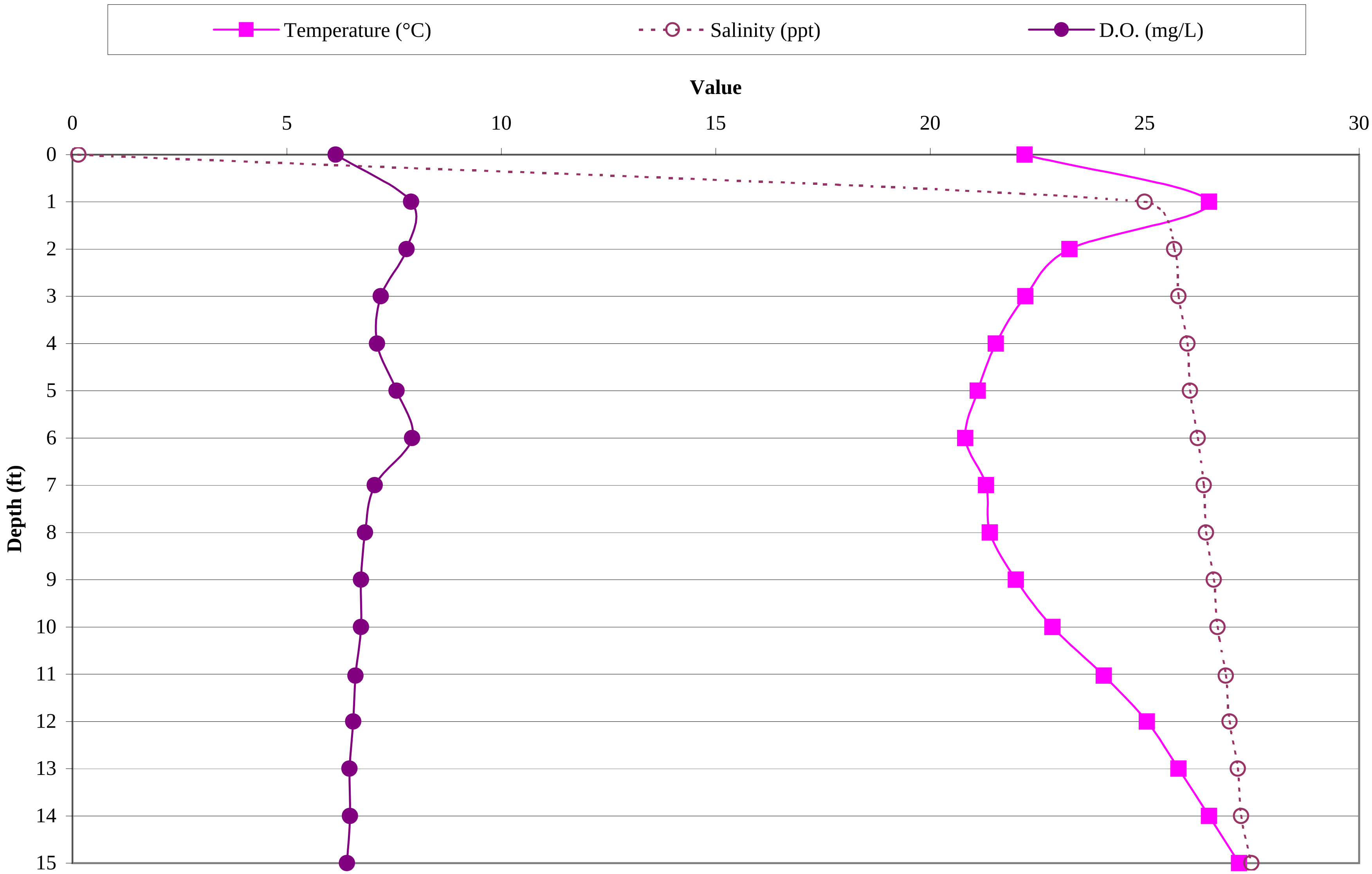
Appendix B-3. Gualala Water Quality Depth Profile - China Gulch - 6/12/02.



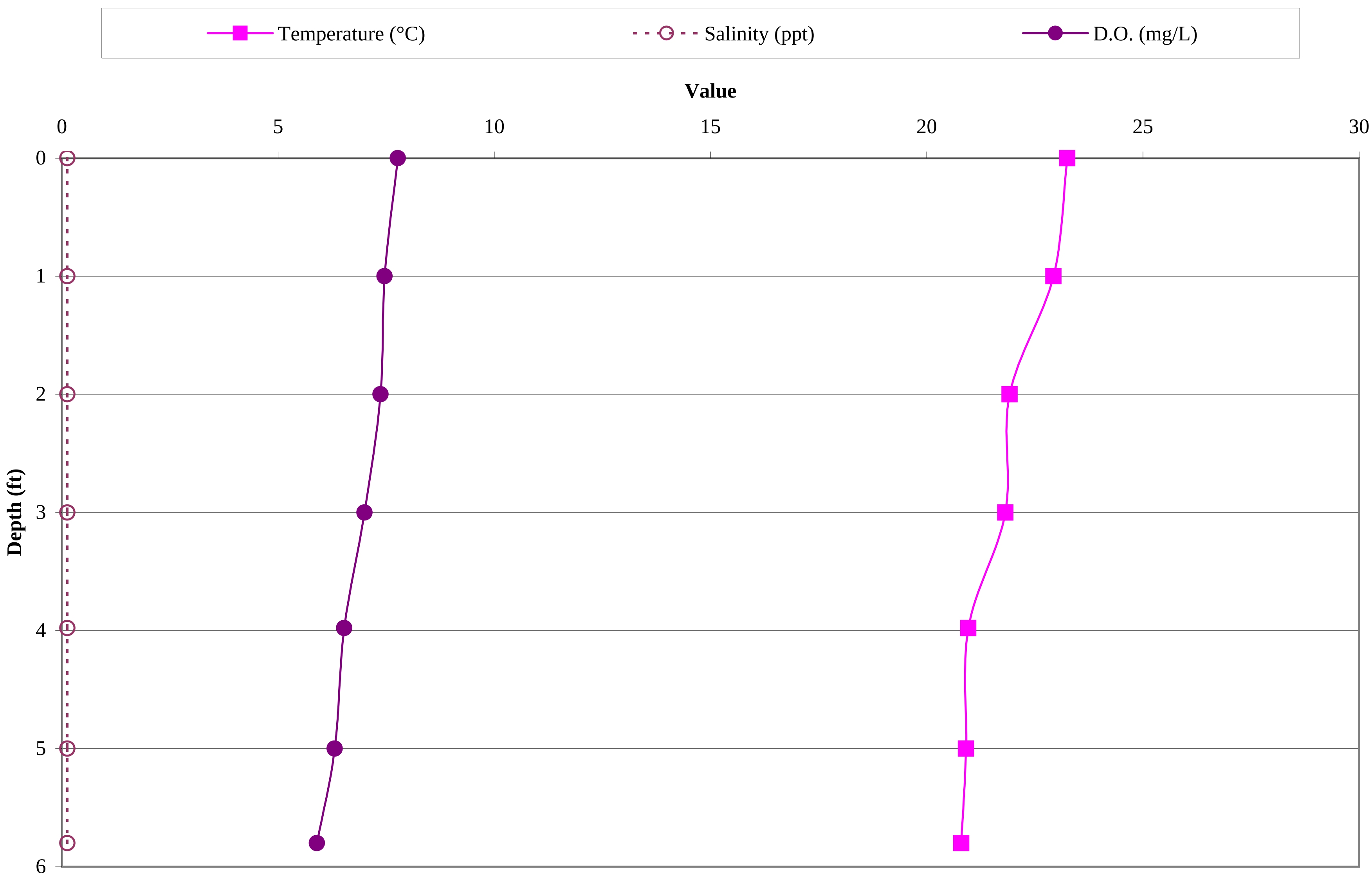
Appendix B-4. Gualala Water Quality Depth Profile - Mill Bend - 6/12/02.



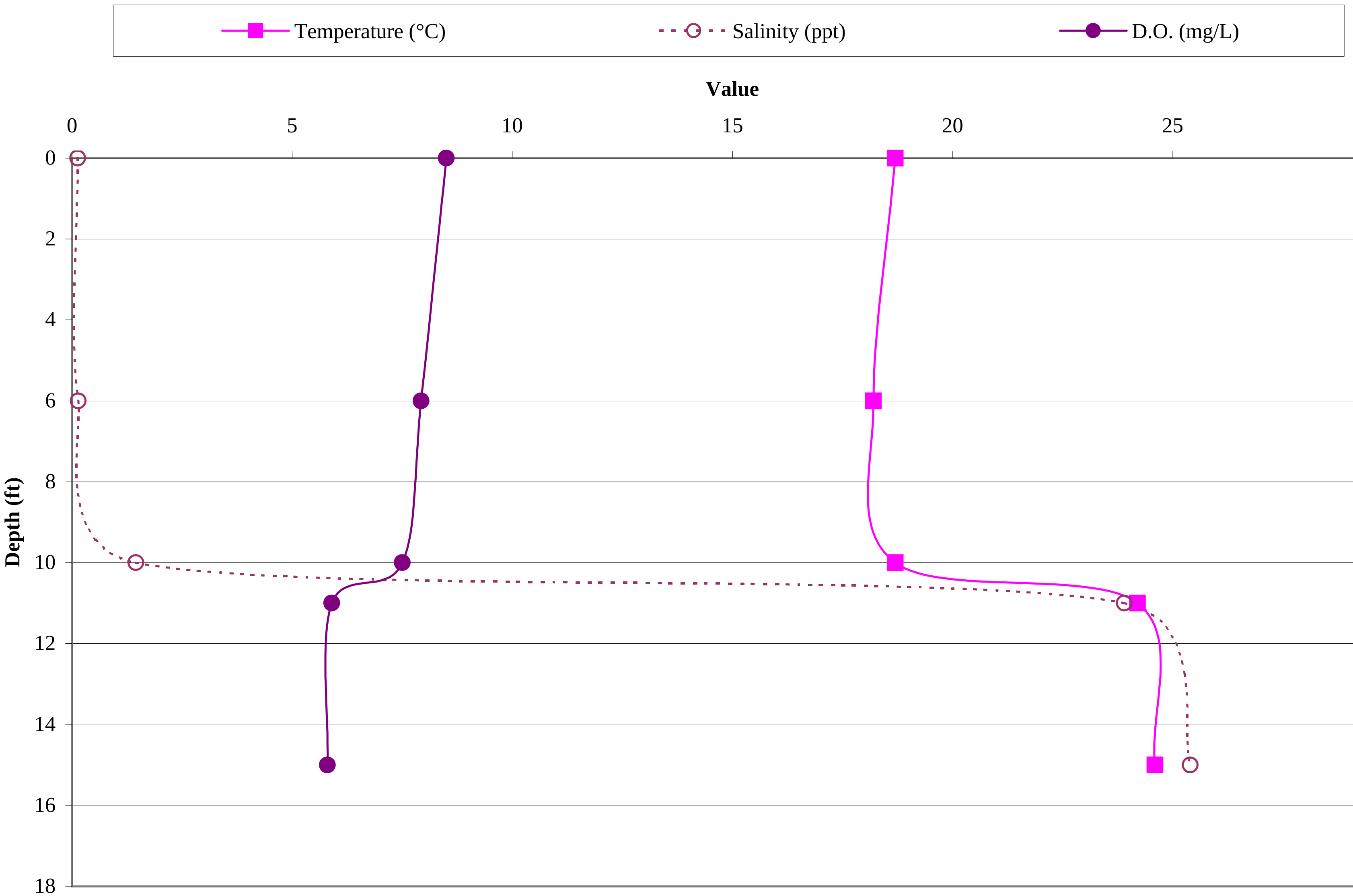
Appendix B-5. Gualala Water Quality Depth Profile - Mill Bend - 7/11/02.



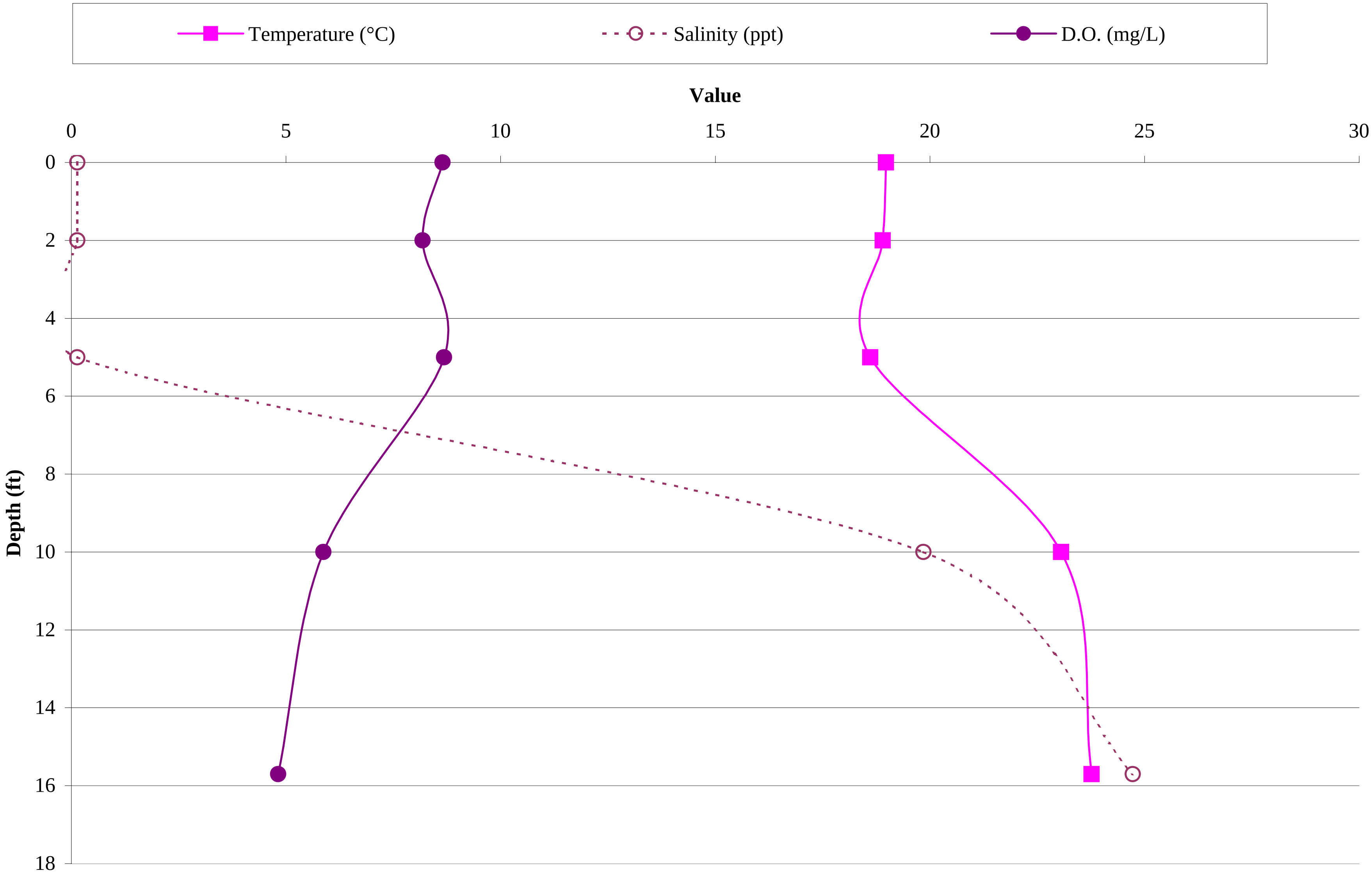
Appendix B-6 Gualala Water Quality Depth Profile - Above Highway 1 Bridge - 7/11/02.



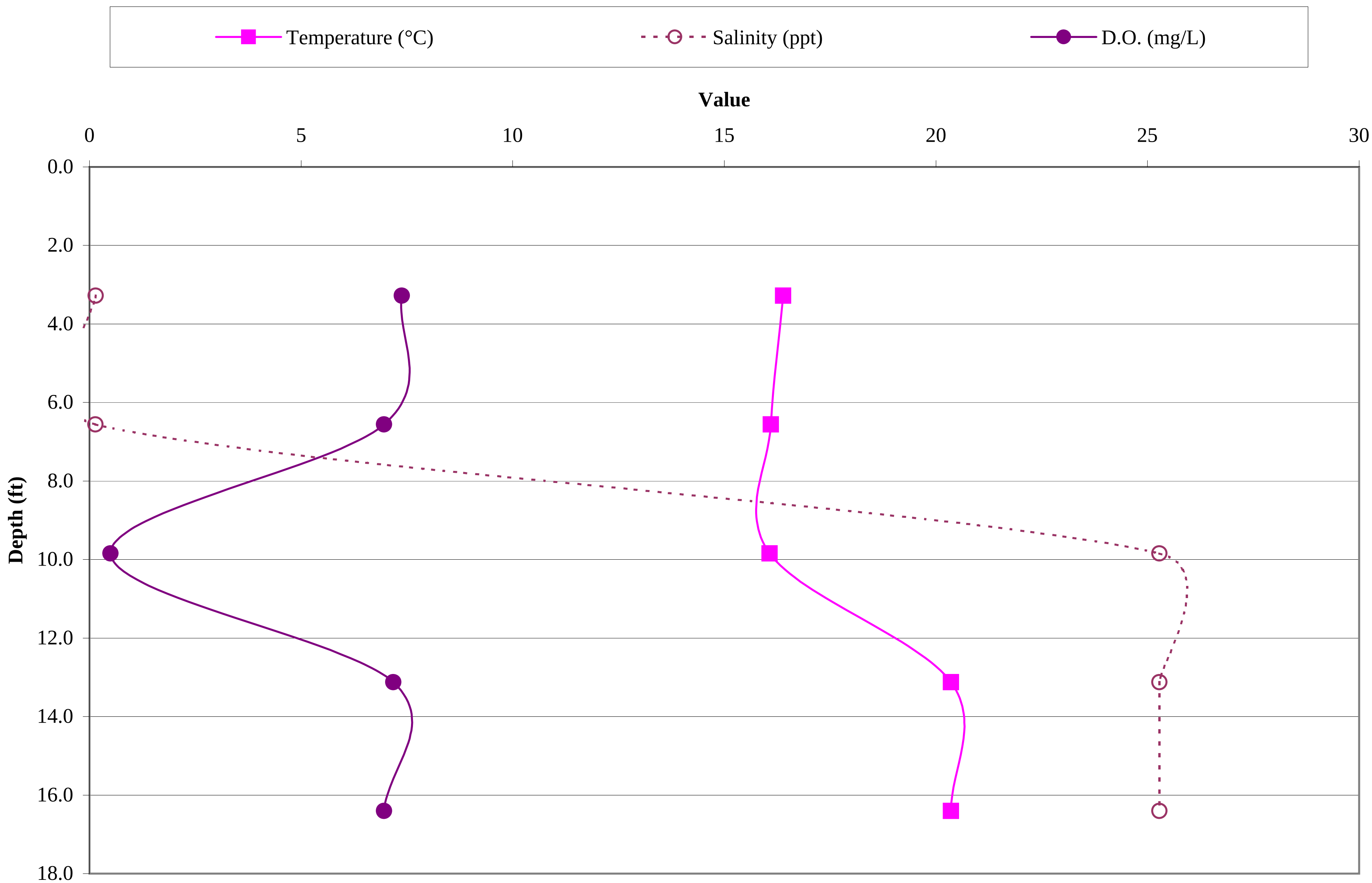
Appendix B-7. Gualala Water Quality Depth Profile - Mill Bend - 8/2/02



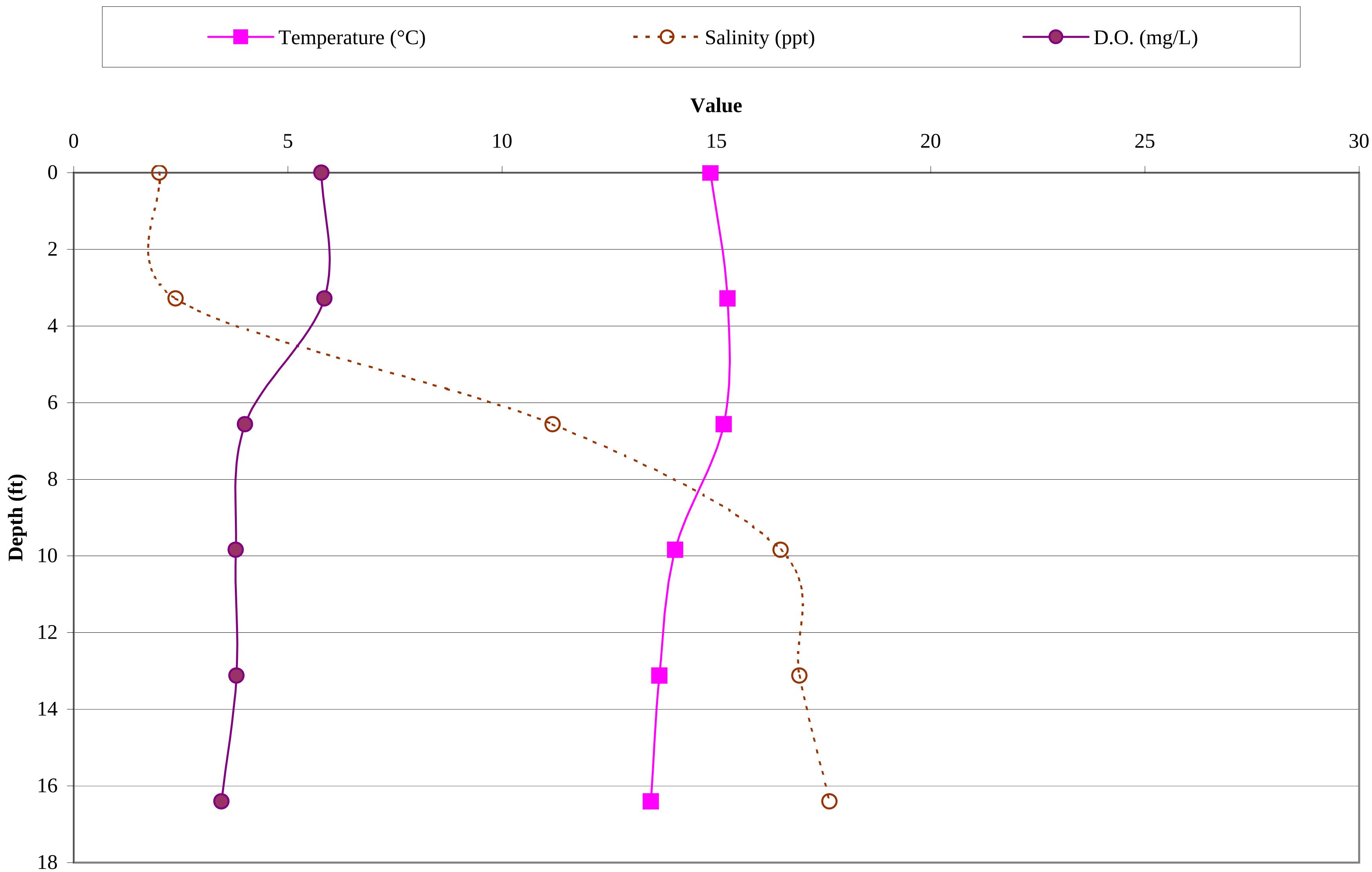
Appendix B-8. Gualala Water Quality Depth Profile - Mill Bend - 8/13/02



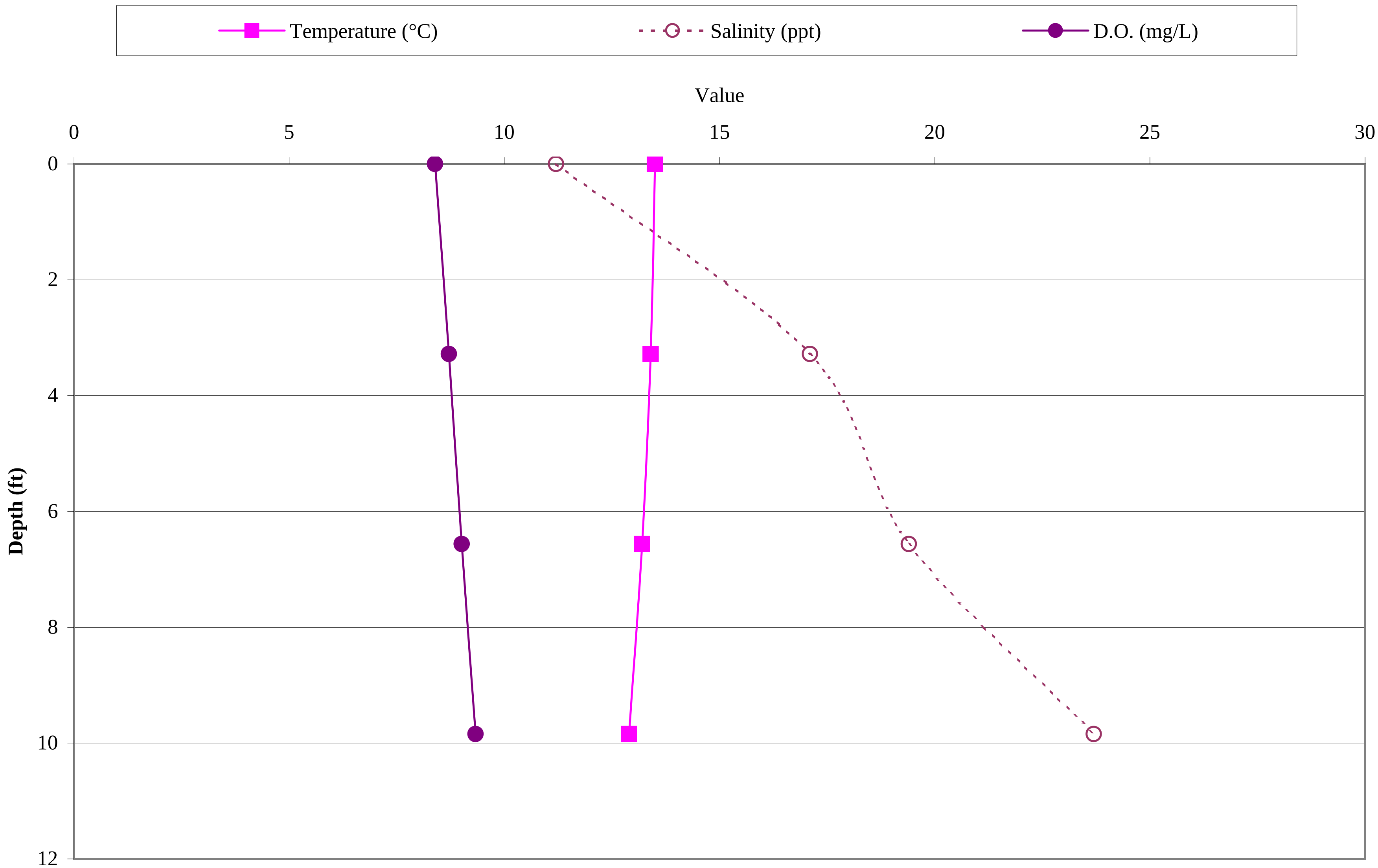
Appendix B-9. Gualala Water Quality Depth Profile - Mill Bend - 9/27/02

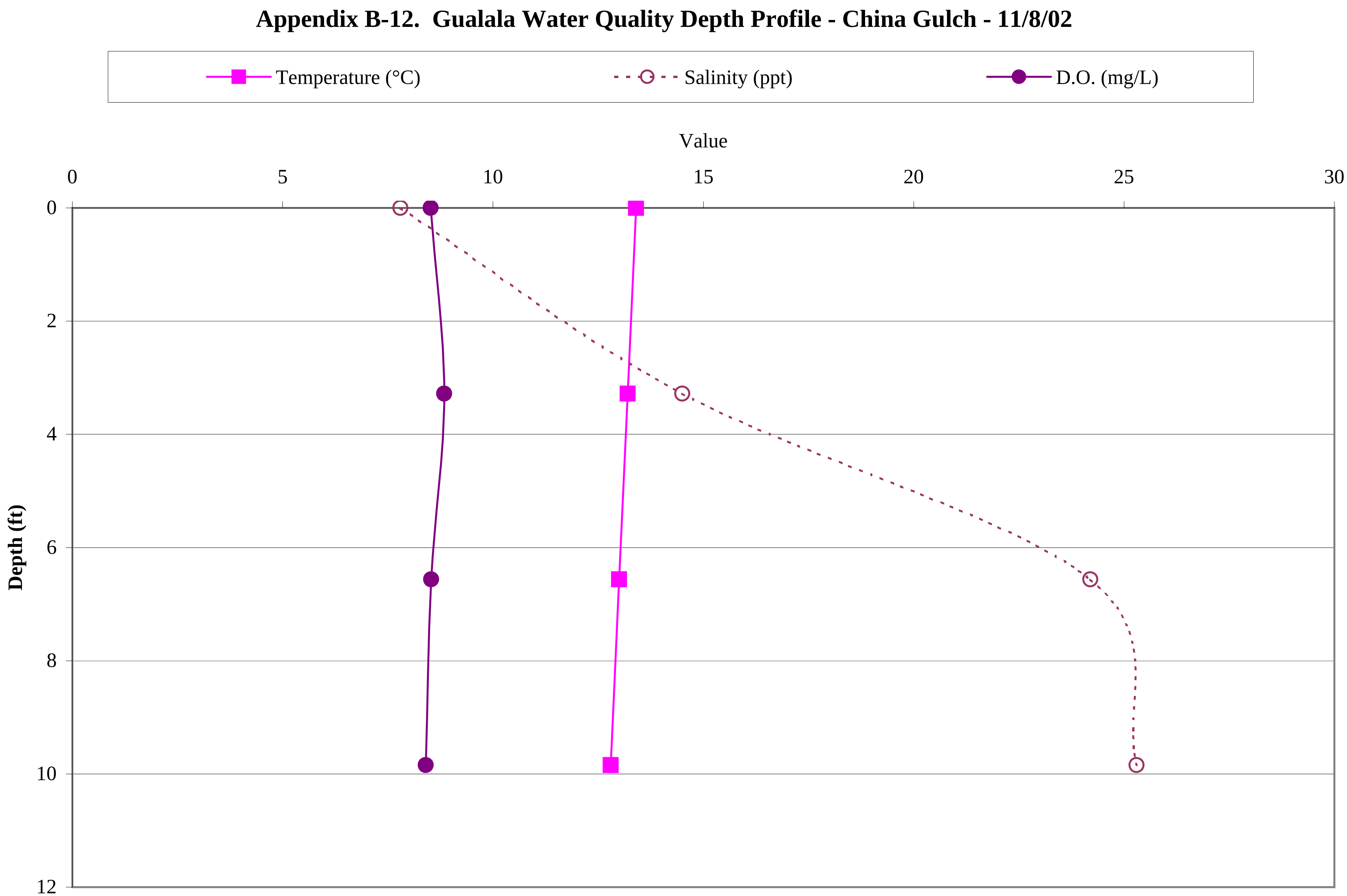


Appendix B-10. Gualala Water Quality Depth Profile - Mill Bend - 10/24/02



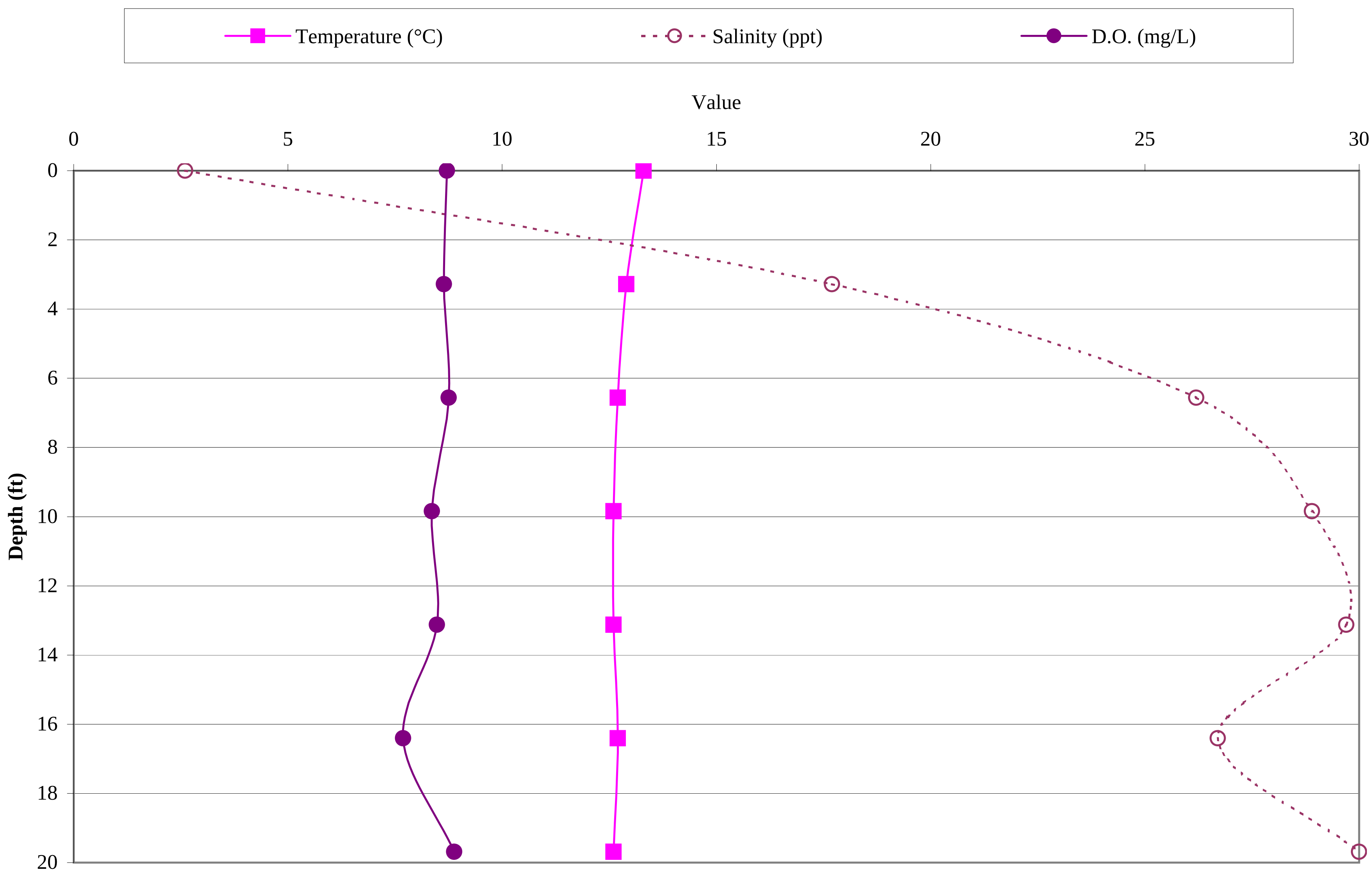
Appendix B-11. Gualala Water Quality Depth Profile - Mouth of the Estuary - 11/8/02



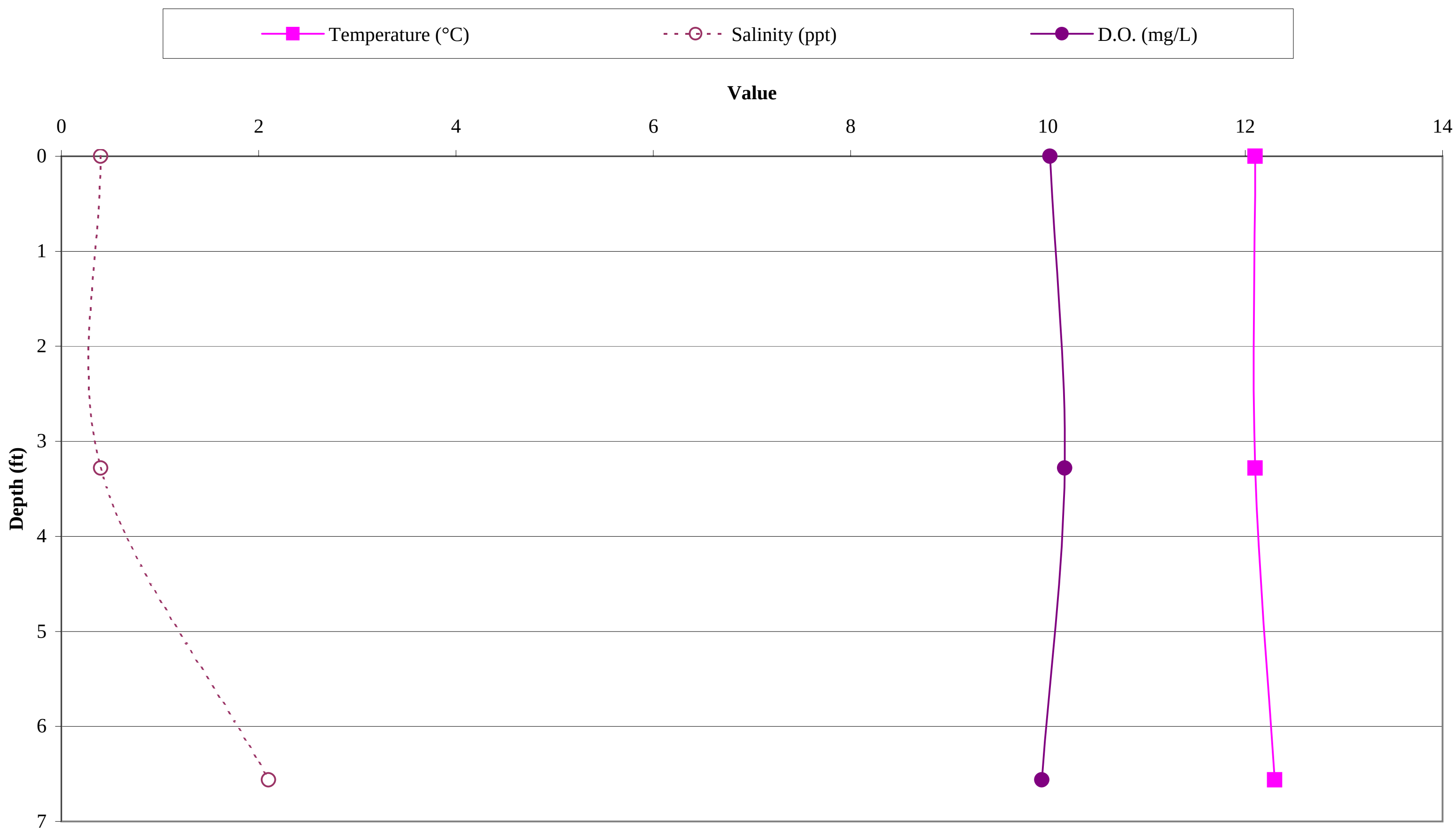


Appendix B-12. Gualala Water Quality Depth Profile - China Gulch - 11/8/02
Temperature (°C)
Salinity (ppt)
D.O. (mg/L)
Value
0
5
10
15
20
25
30
Depth (ft)
0
2
4
6
8
10
12

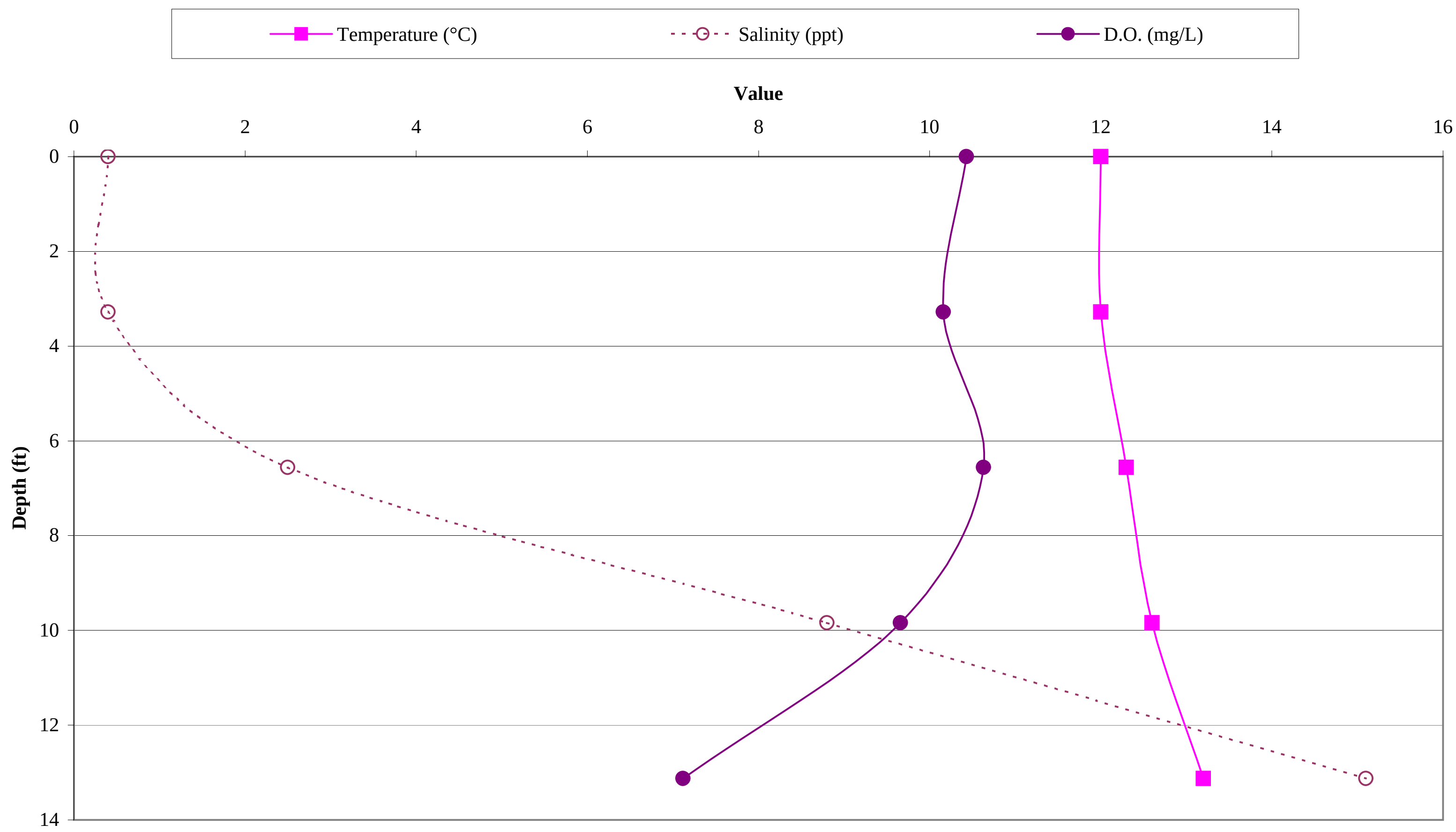
Appendix B-13. Gualala Water Quality Depth Profile - Mill Bend - 11/8/02



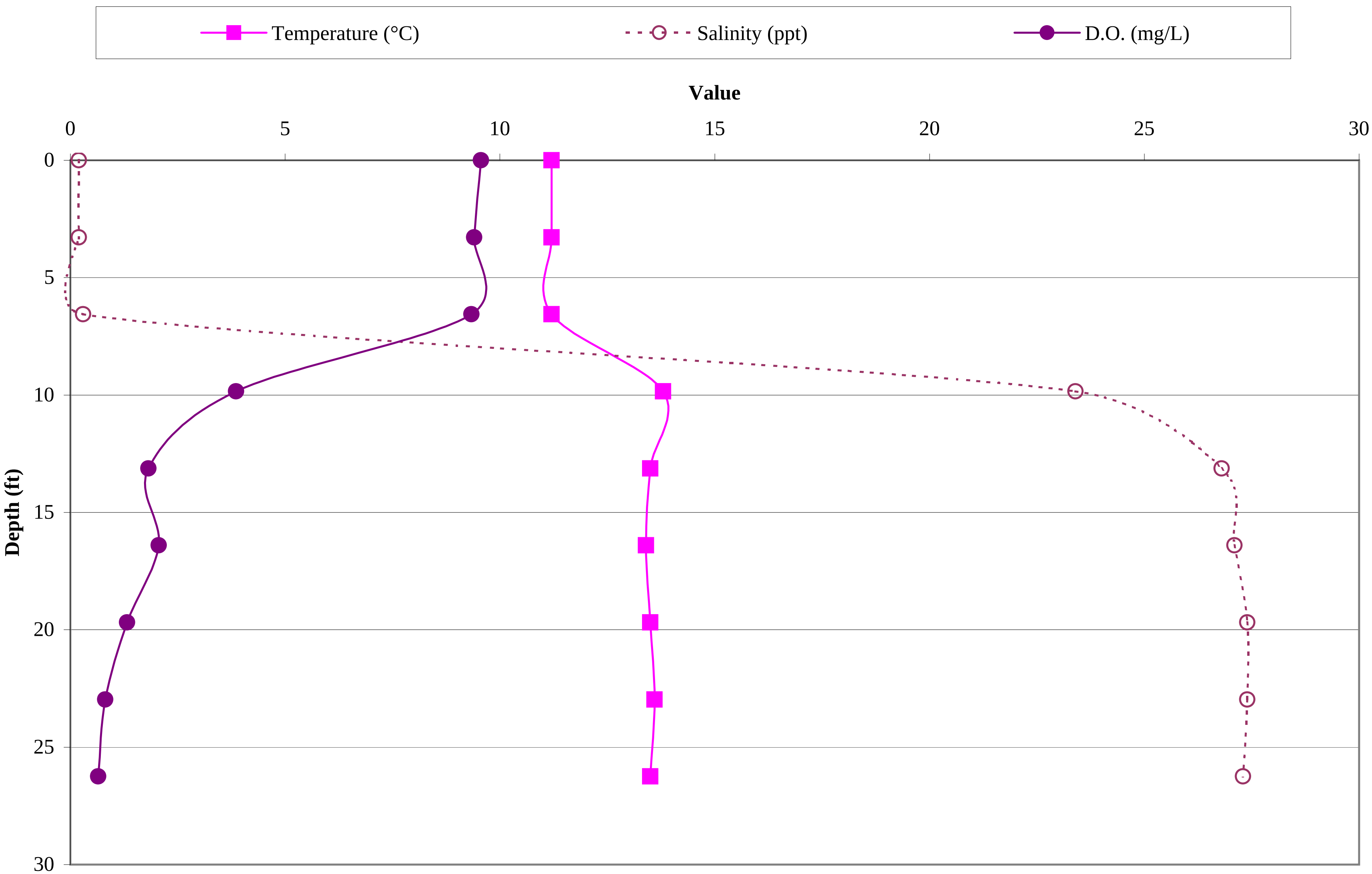
Appendix B-14. Gualala Water Quality Depth Profile - Mouth of Estuary - 11/23/02



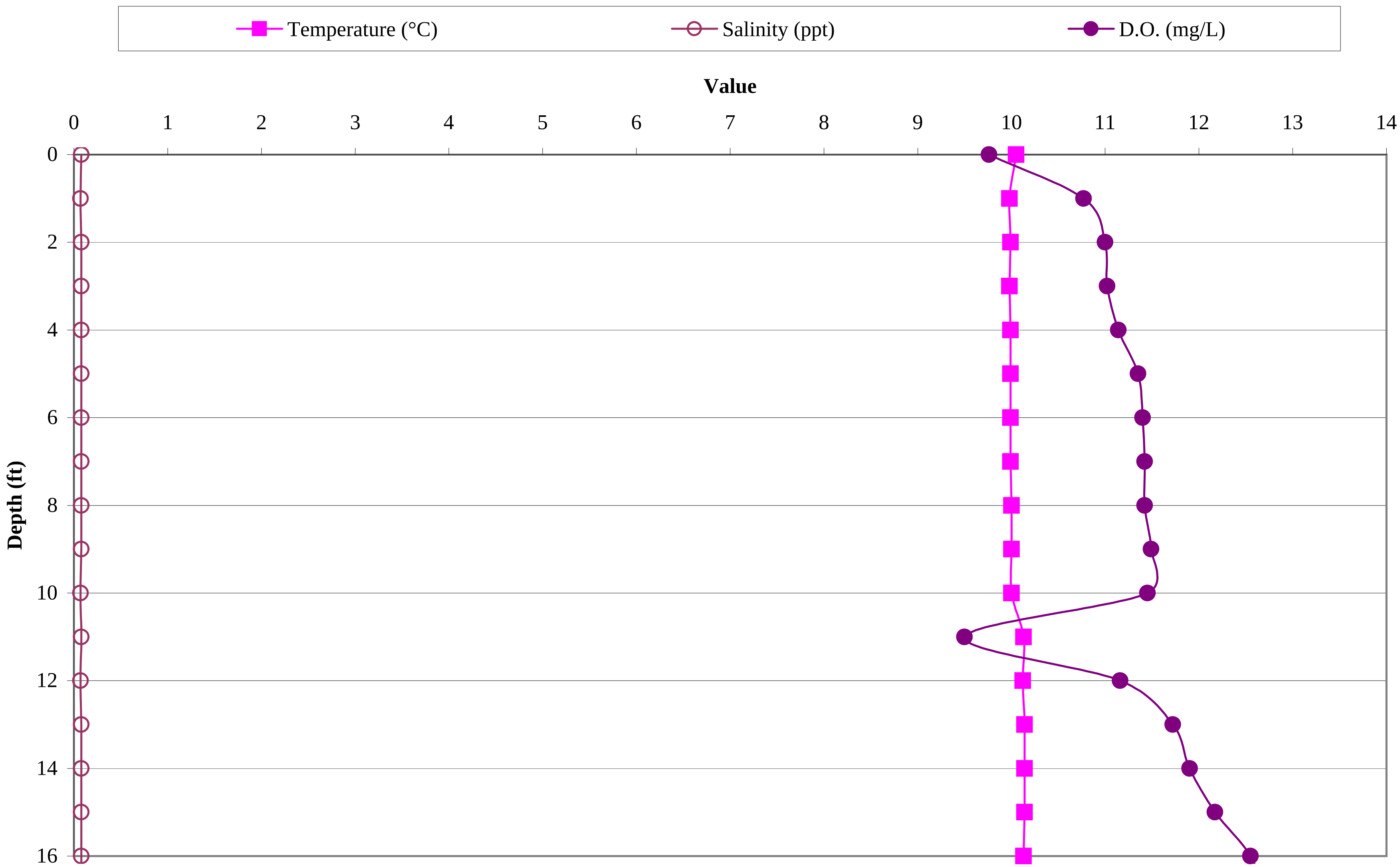
Appendix B-15. Gualala Water Quality Depth Profile - China Gulch - 11/23/02



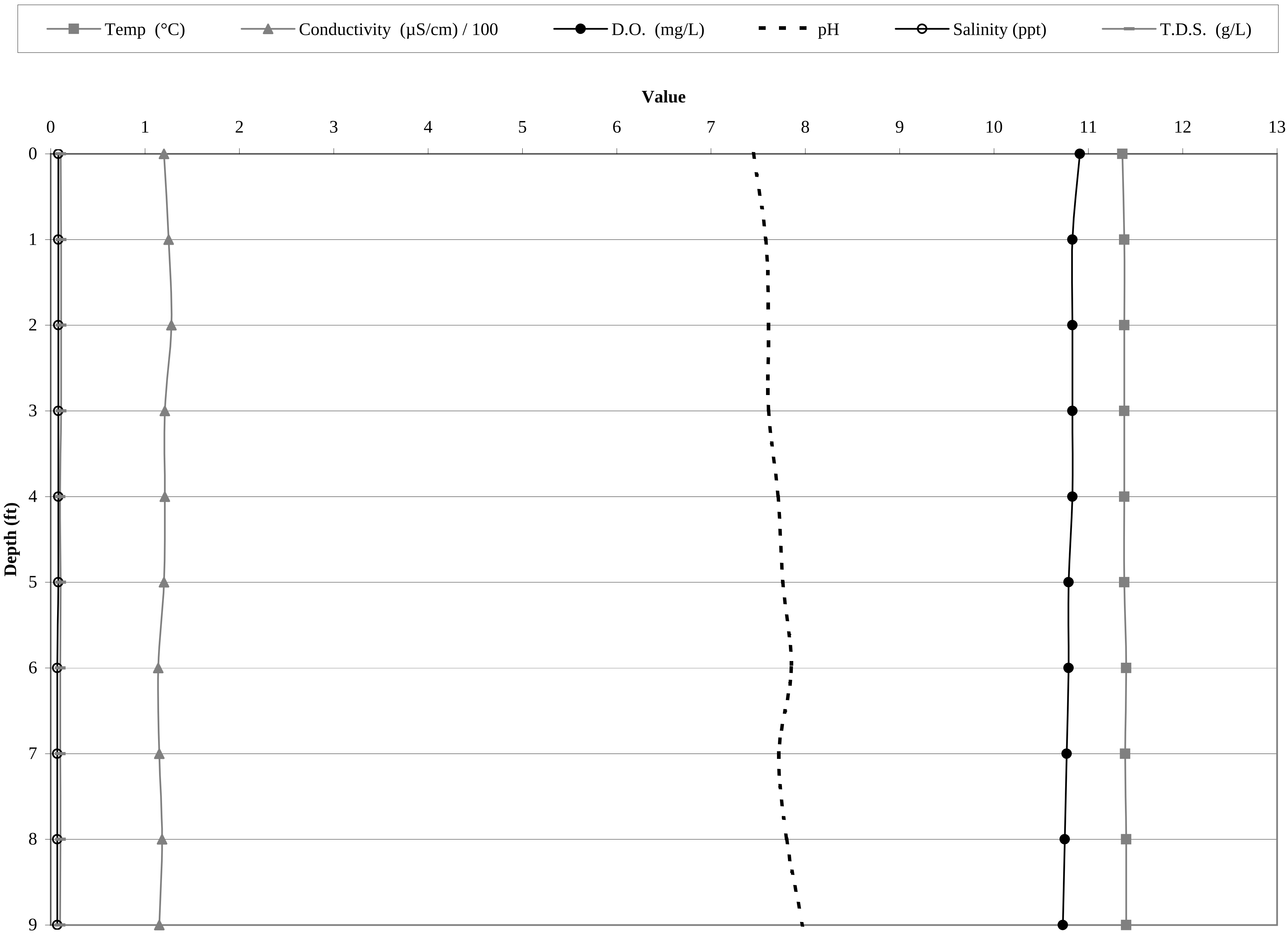
Appendix B-16. Gualala Water Quality Depth Profile - Mill Bend - 11/23/02



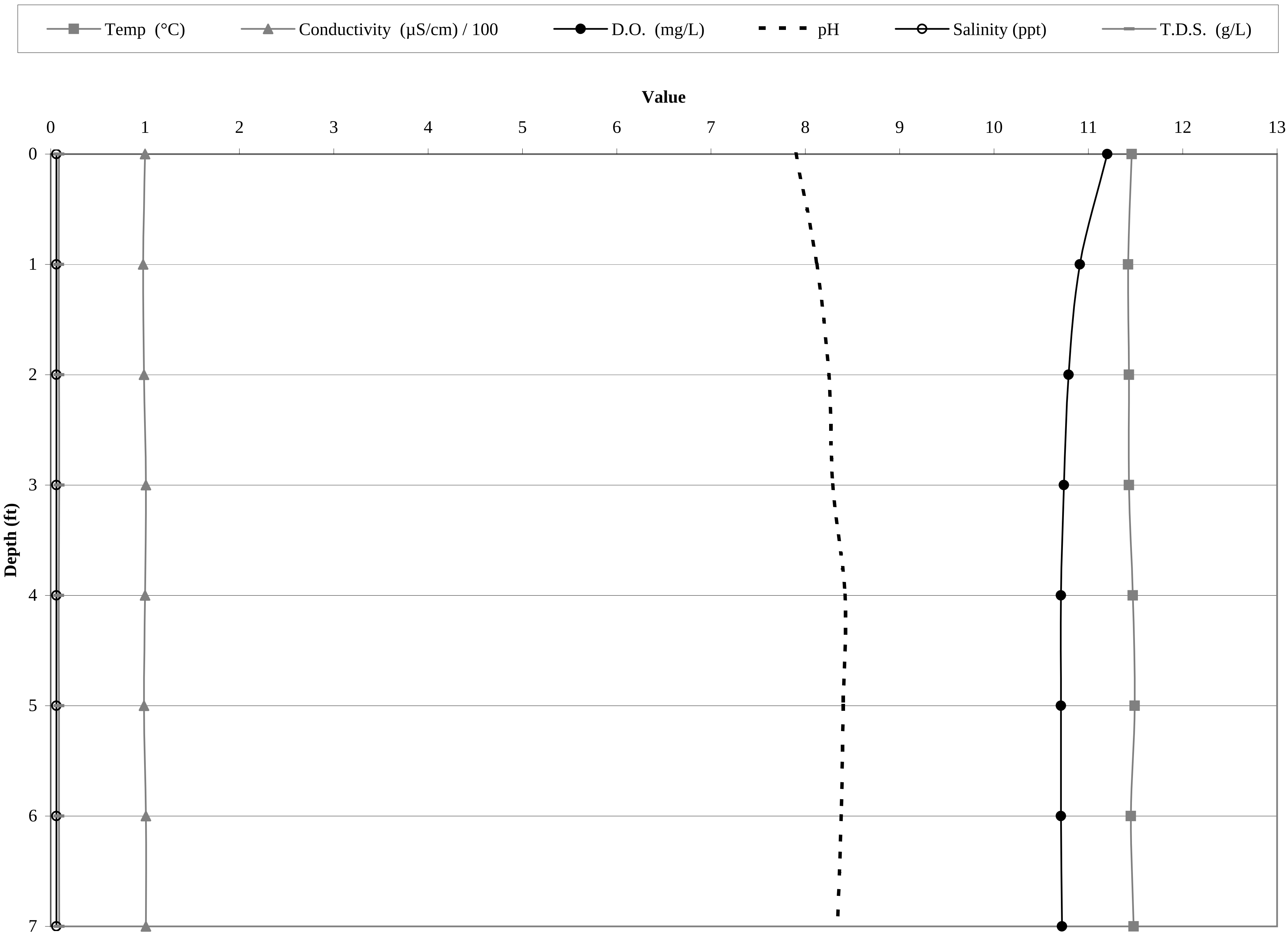
Appendix B-17. Gualala Water Quality Depth Profile - Mill Bend - 2/18/03



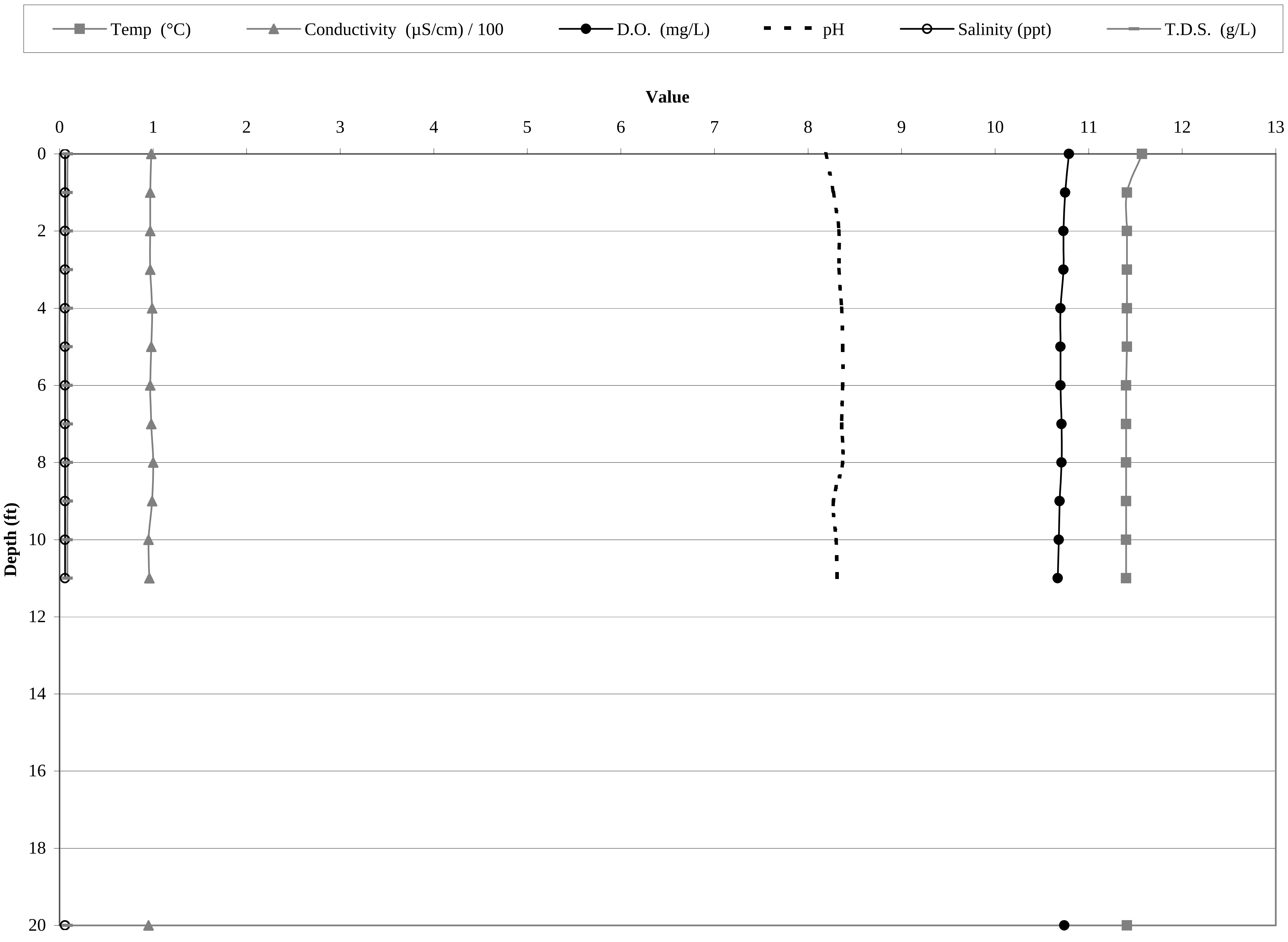
Appendix B-18. Gualala Water Quality Depth Profile - Mouth of Estuary - (4/28/03)



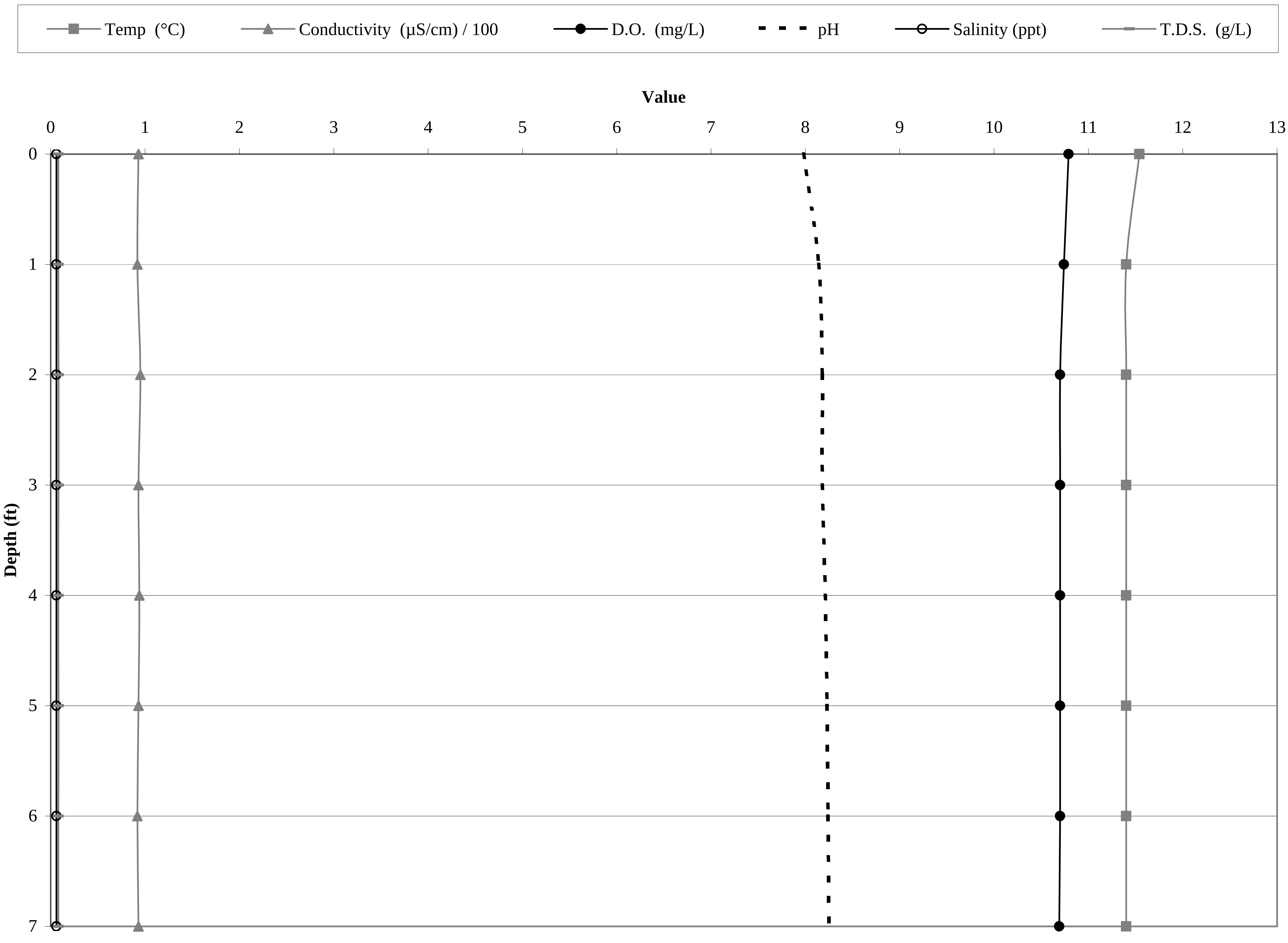
Appendix B-19. Gualala Water Quality Depth Profile - China Gulch - (4/28/03)



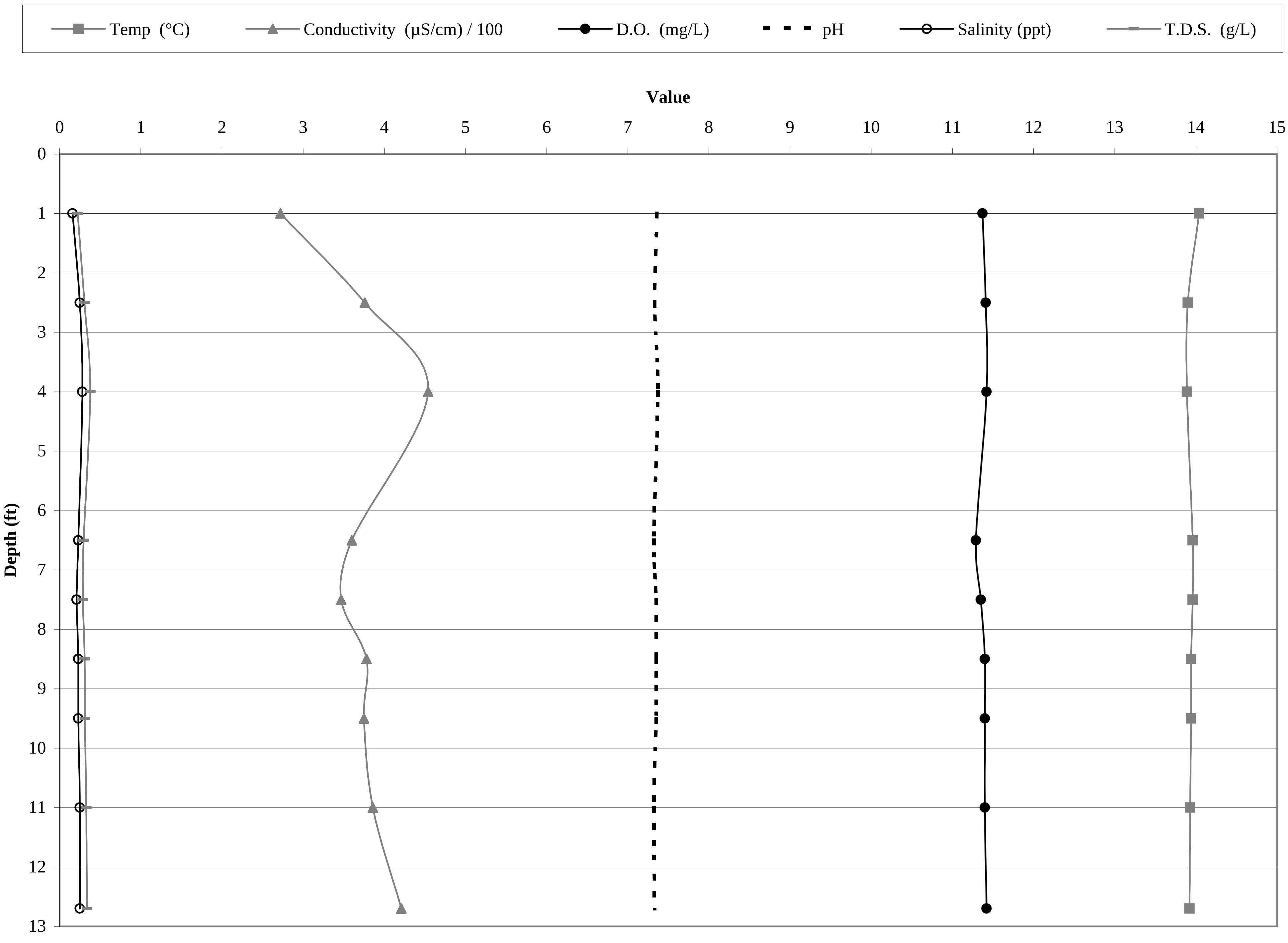
Appendix B-20. Gualala Water Quality Depth Profile - Mill Bend - (4/28/03)



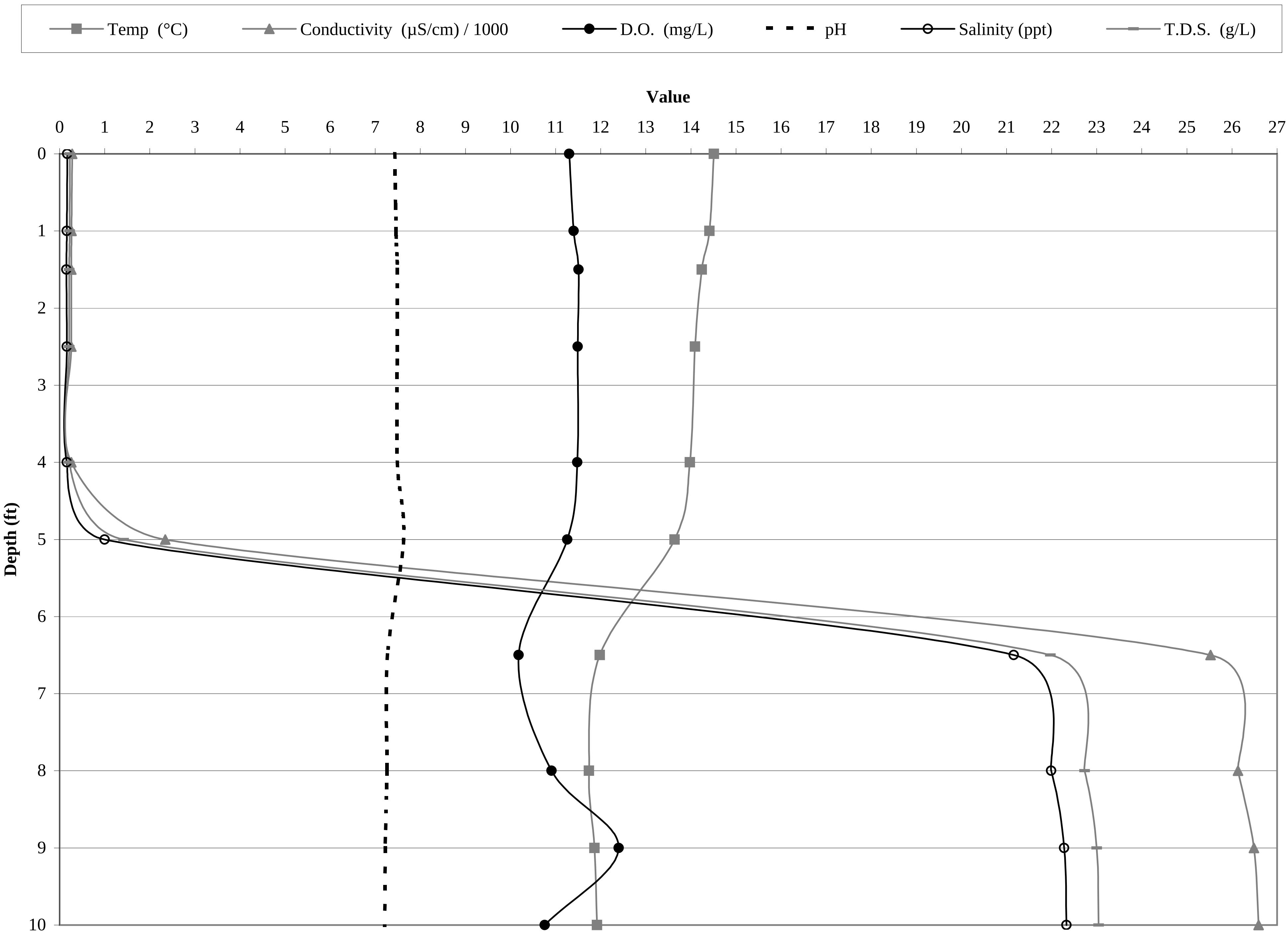
Appendix B-21. Gualala Water Quality Depth Profile - Above Highway 1 Bridge - (4/28/03)



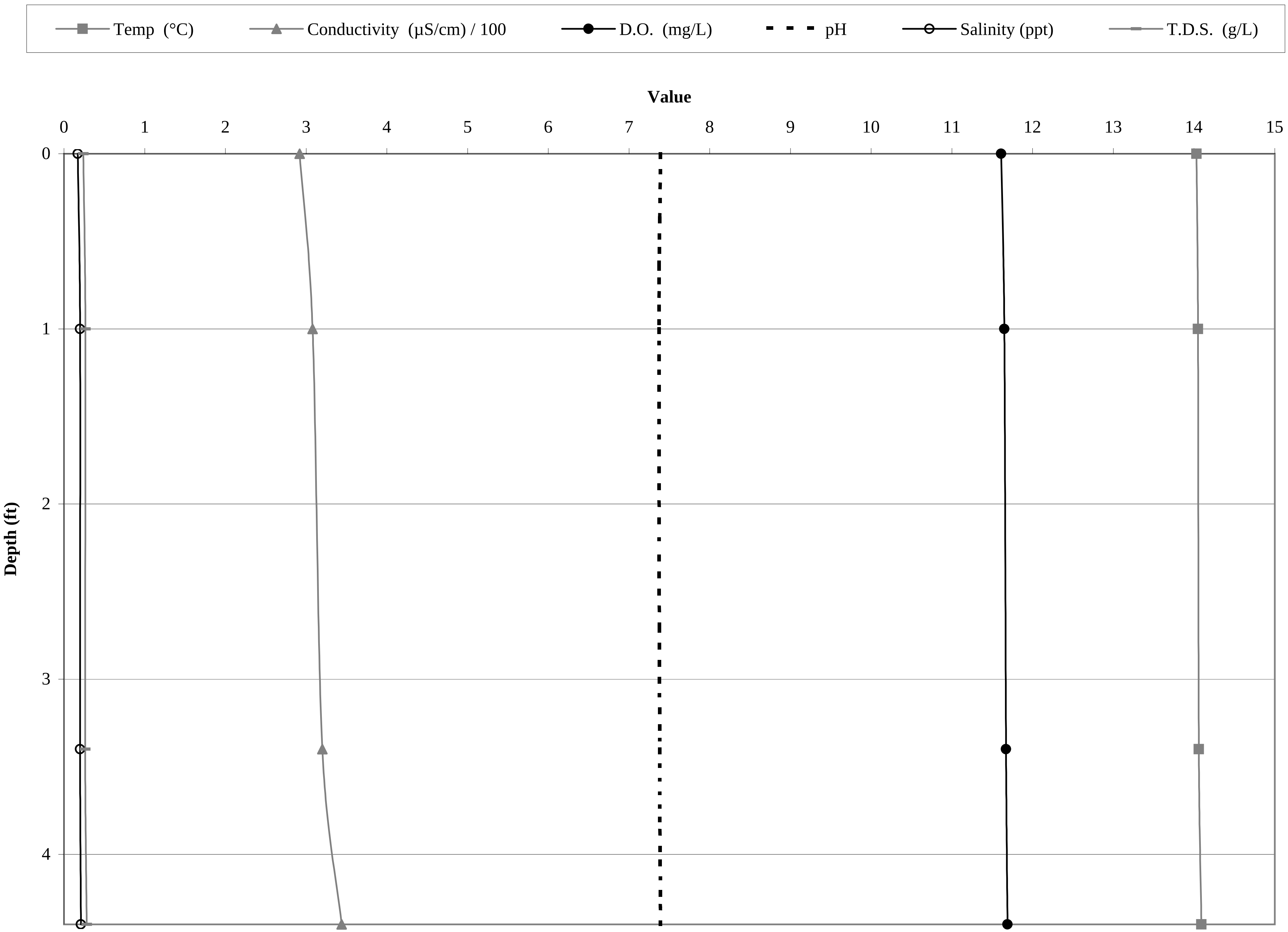
Appendix B-22. Gualala Water Quality Depth Profile - Mouth of Estuary- (5/19/03)



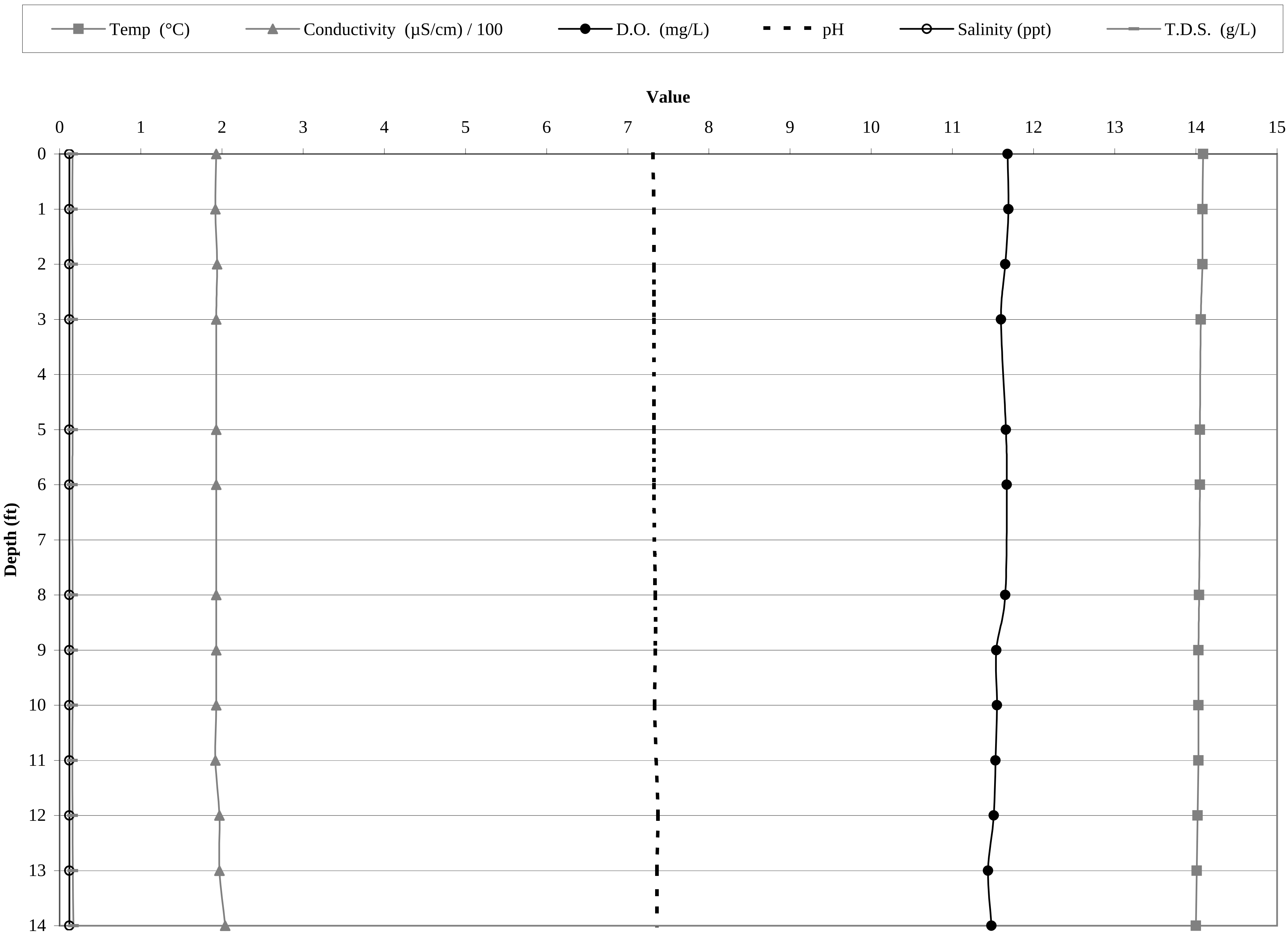
Appendix B-23. Gualala Water Quality Depth Profile - Tide Gage - (5/19/03)



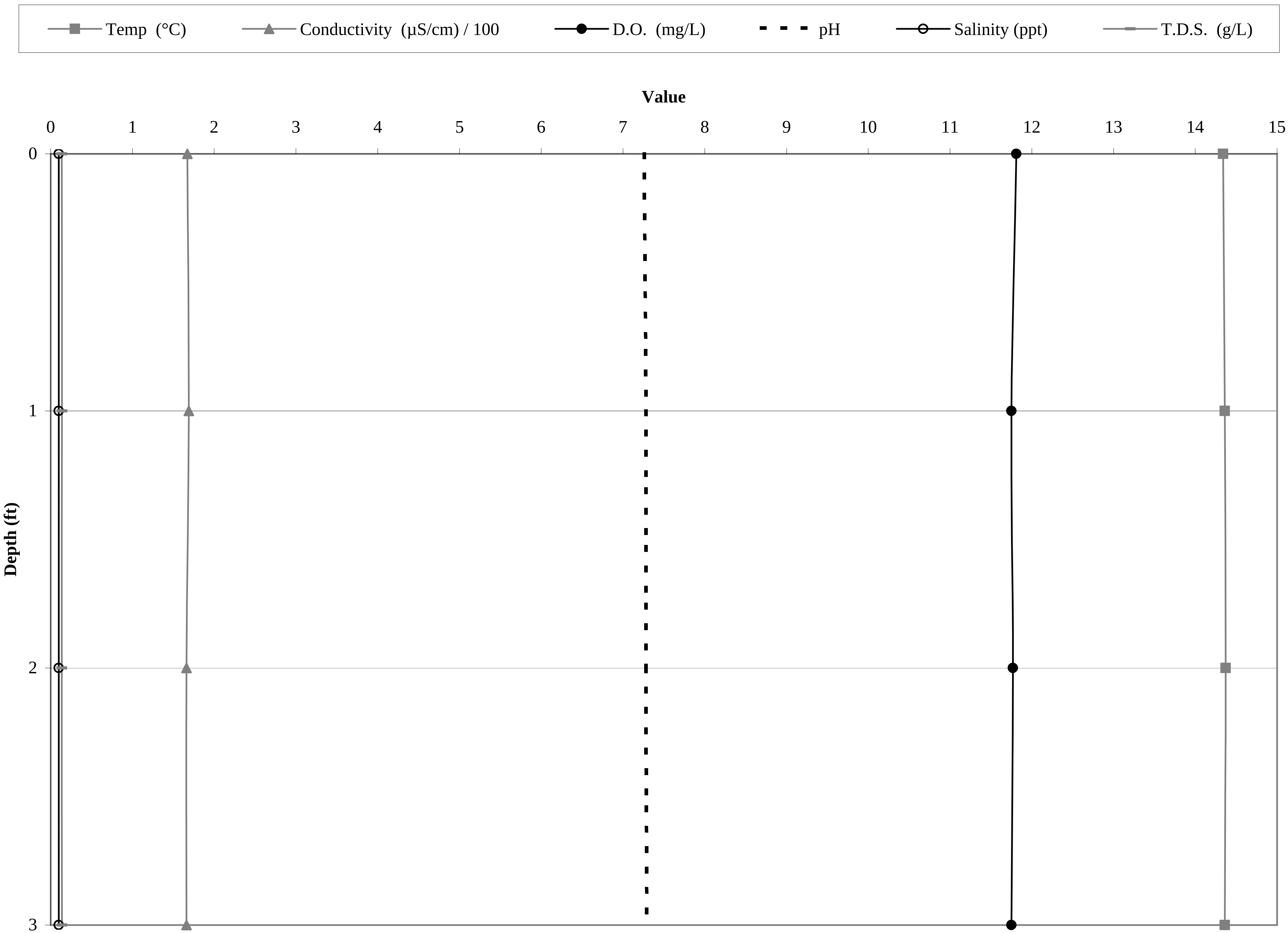
Appendix B-24. Gualala Water Quality Depth Profile - China Gulch - (5/19/03)



Appendix B-25. Gualala Water Quality Depth Profile - Mill Bend - (5/19/03)

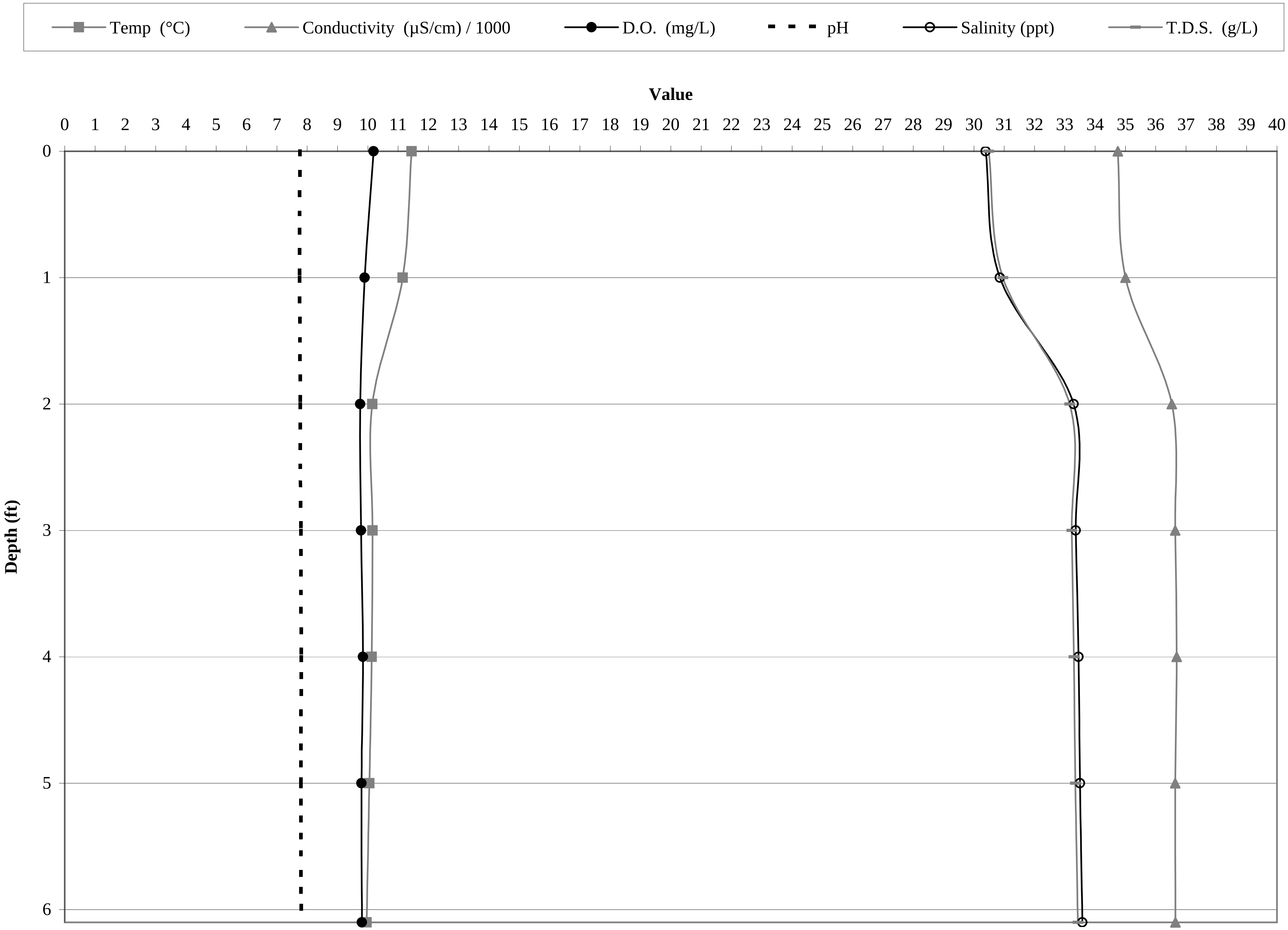


Appendix B-26. Gualala Water Quality Depth Profile - Above Highway 1 Bridge - (5/19/03)



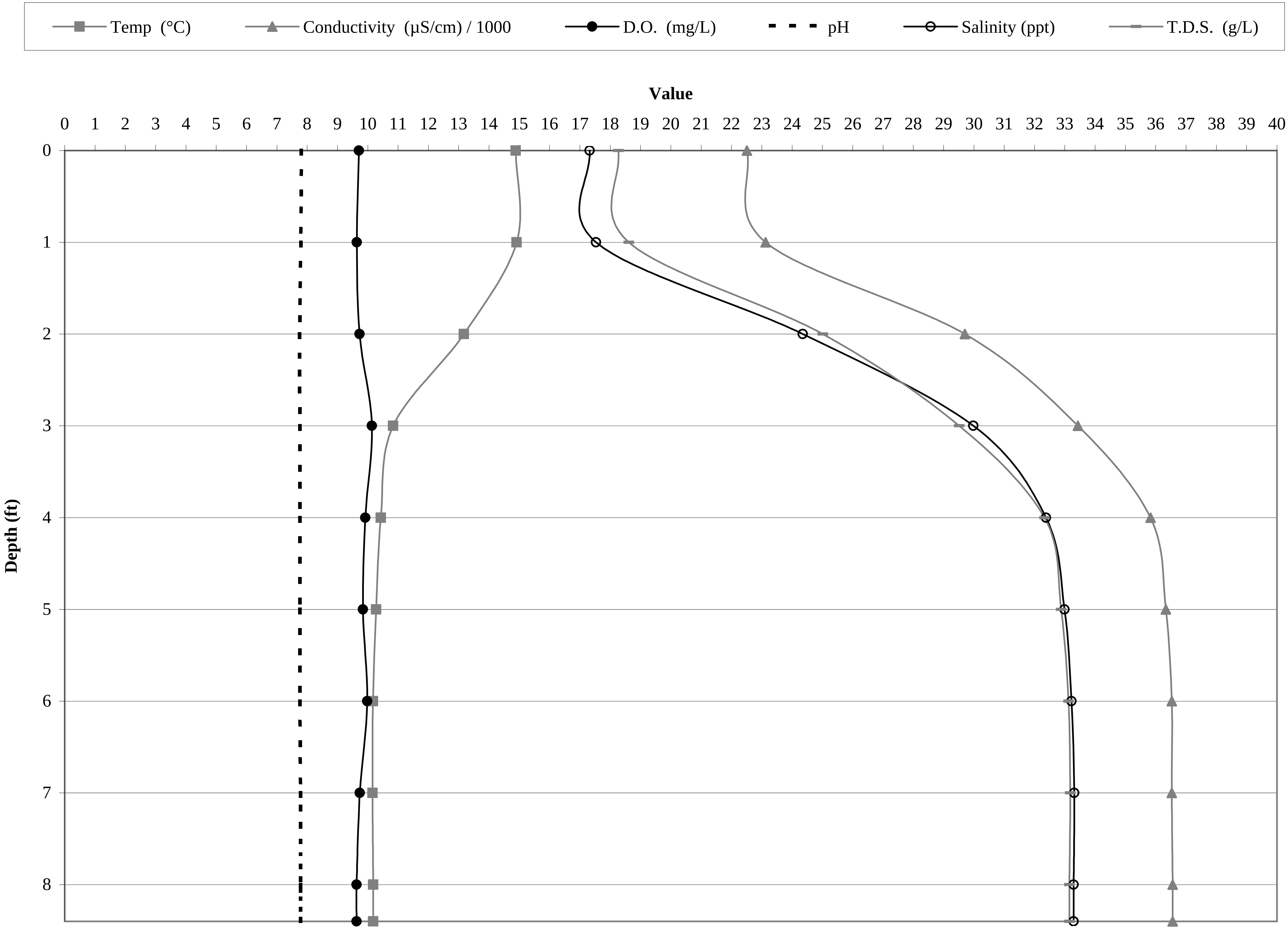
Time: 1330

Appendix B-27. Gualala Water Quality Depth Profile - Mouth of Estuary- (06/17/03)



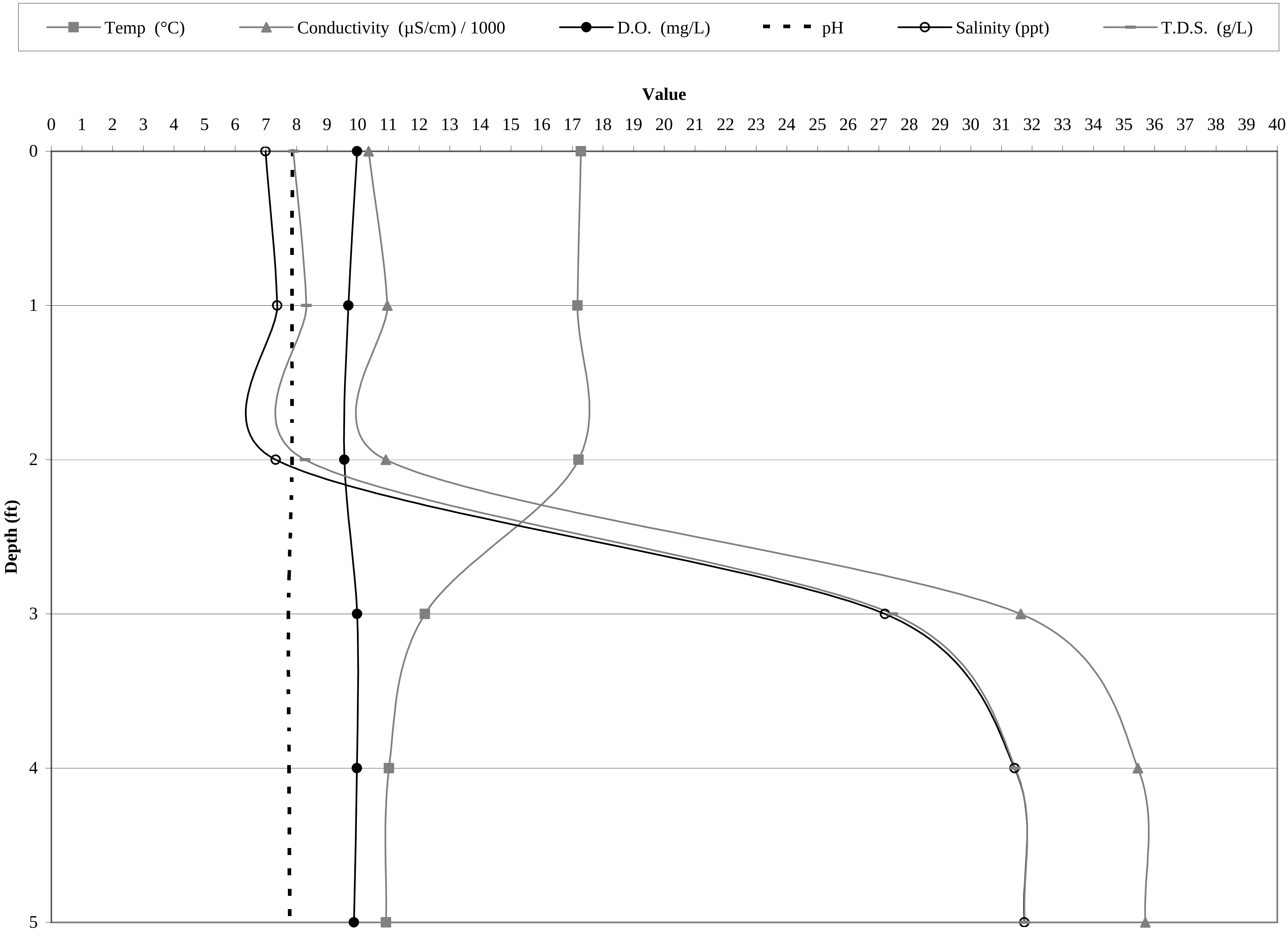
Time: 1400

Appendix B-28. Gualala Water Quality Depth Profile - Tide Gauge- (06/17/03)



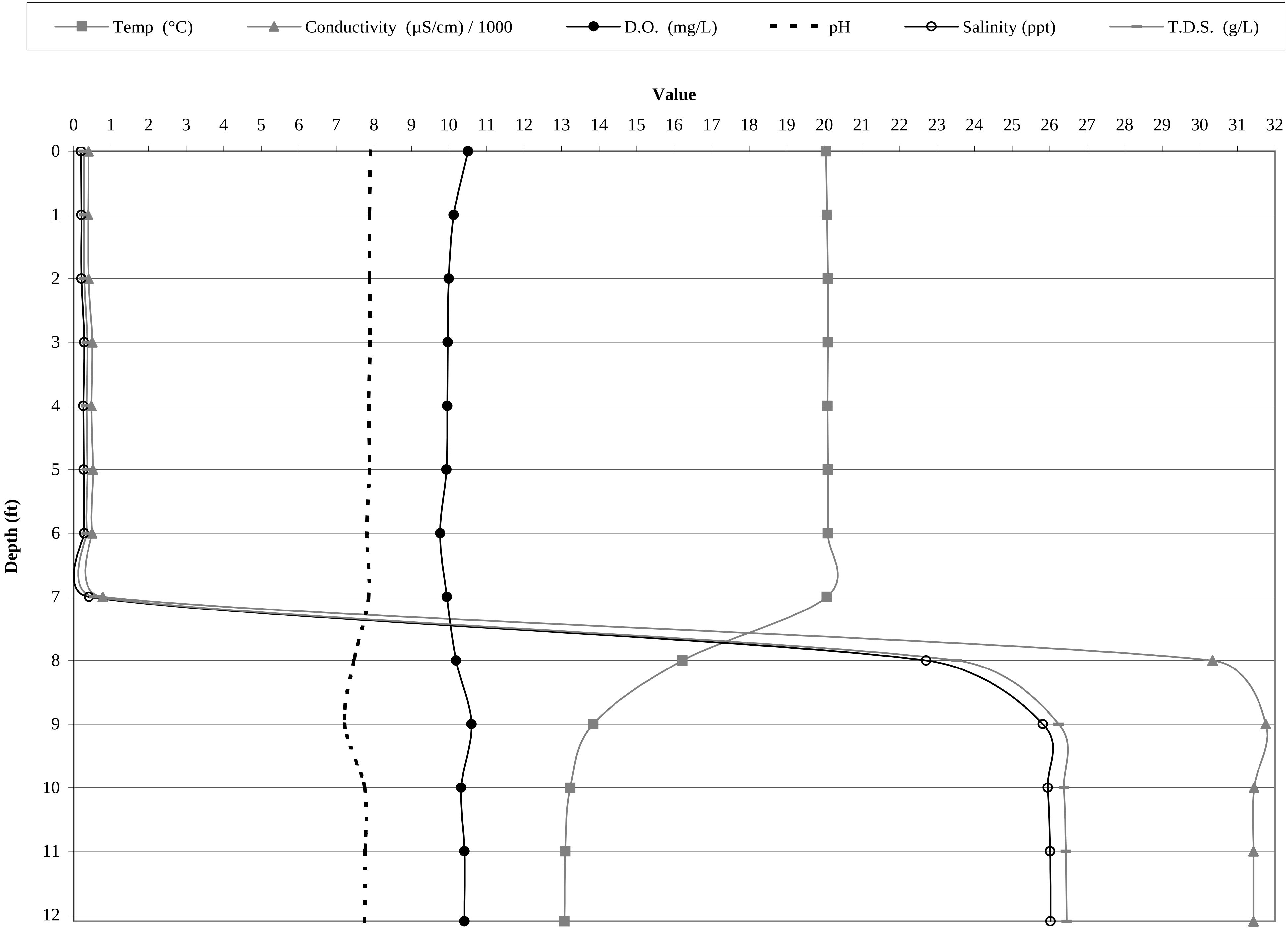
Appendix B-29. Gualala Water Quality Depth Profile - China Gulch - (06/17/03)

Time: 1430



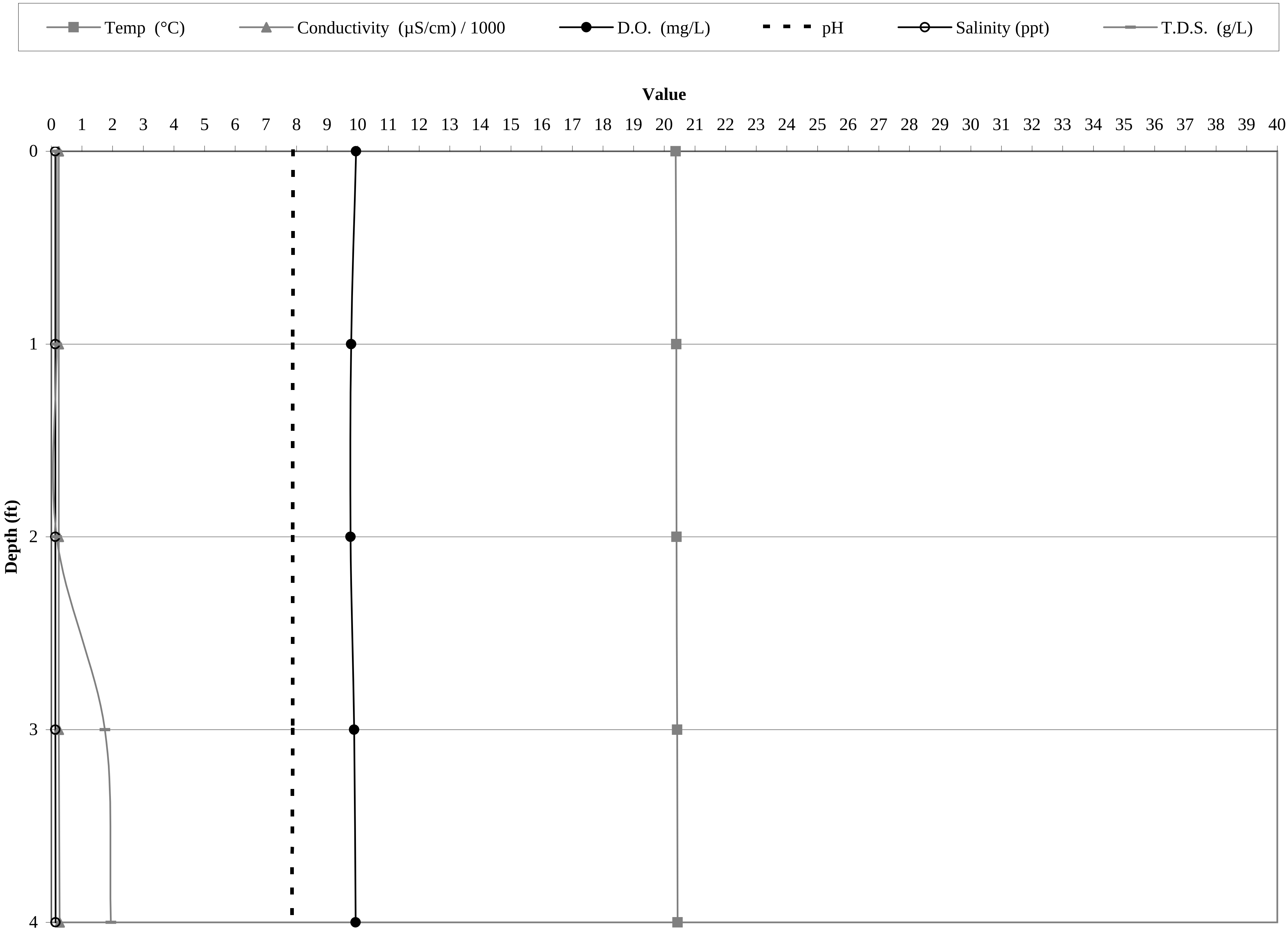
Appendix B-30. Gualala Water Quality Depth Profile - Mill Bend - (06/17/03)

Time: 1545

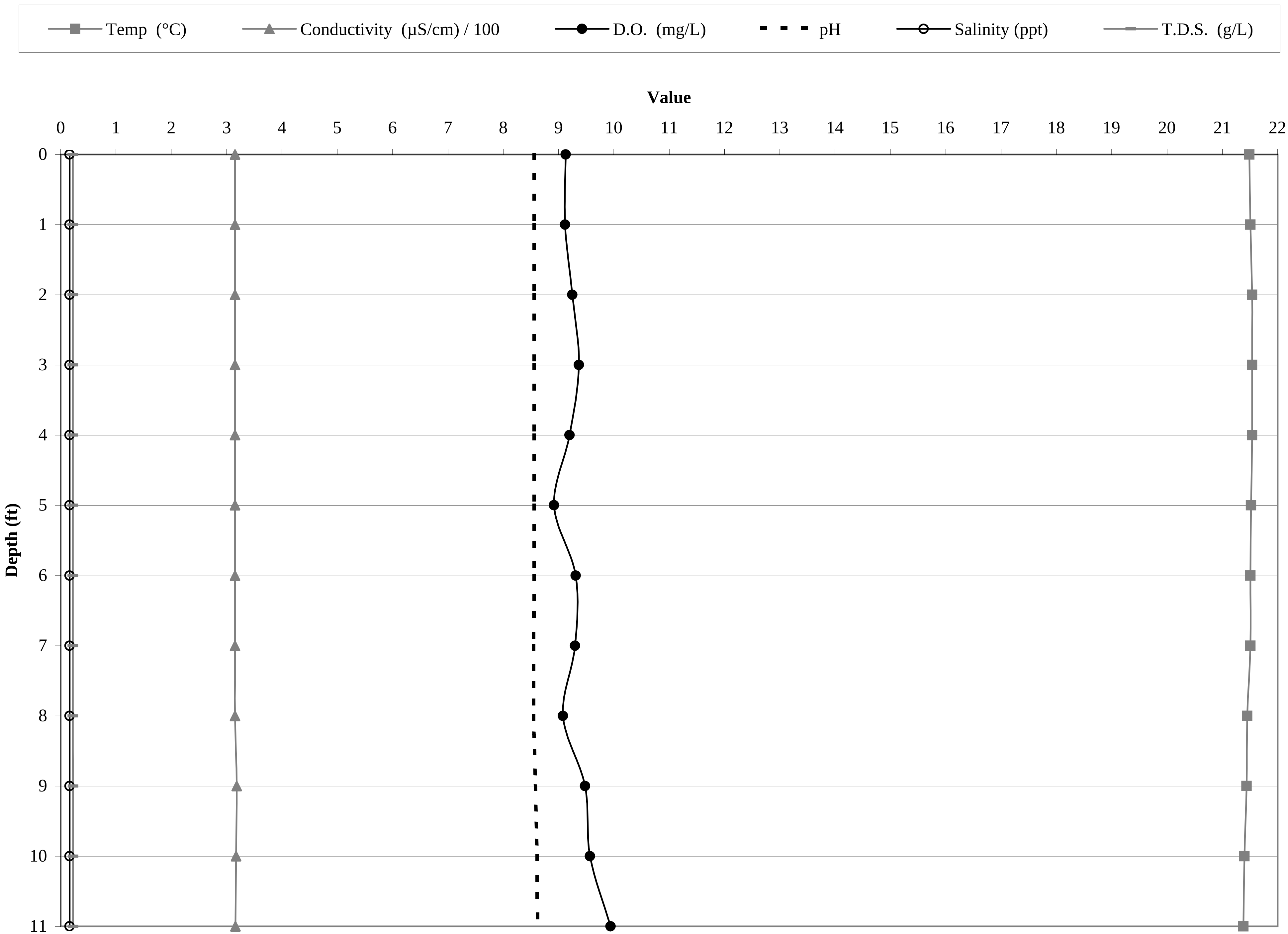


Appendix B-31. Gualala Water Quality Depth Profile - Above Highway 1 Bridge - (06/17/03)

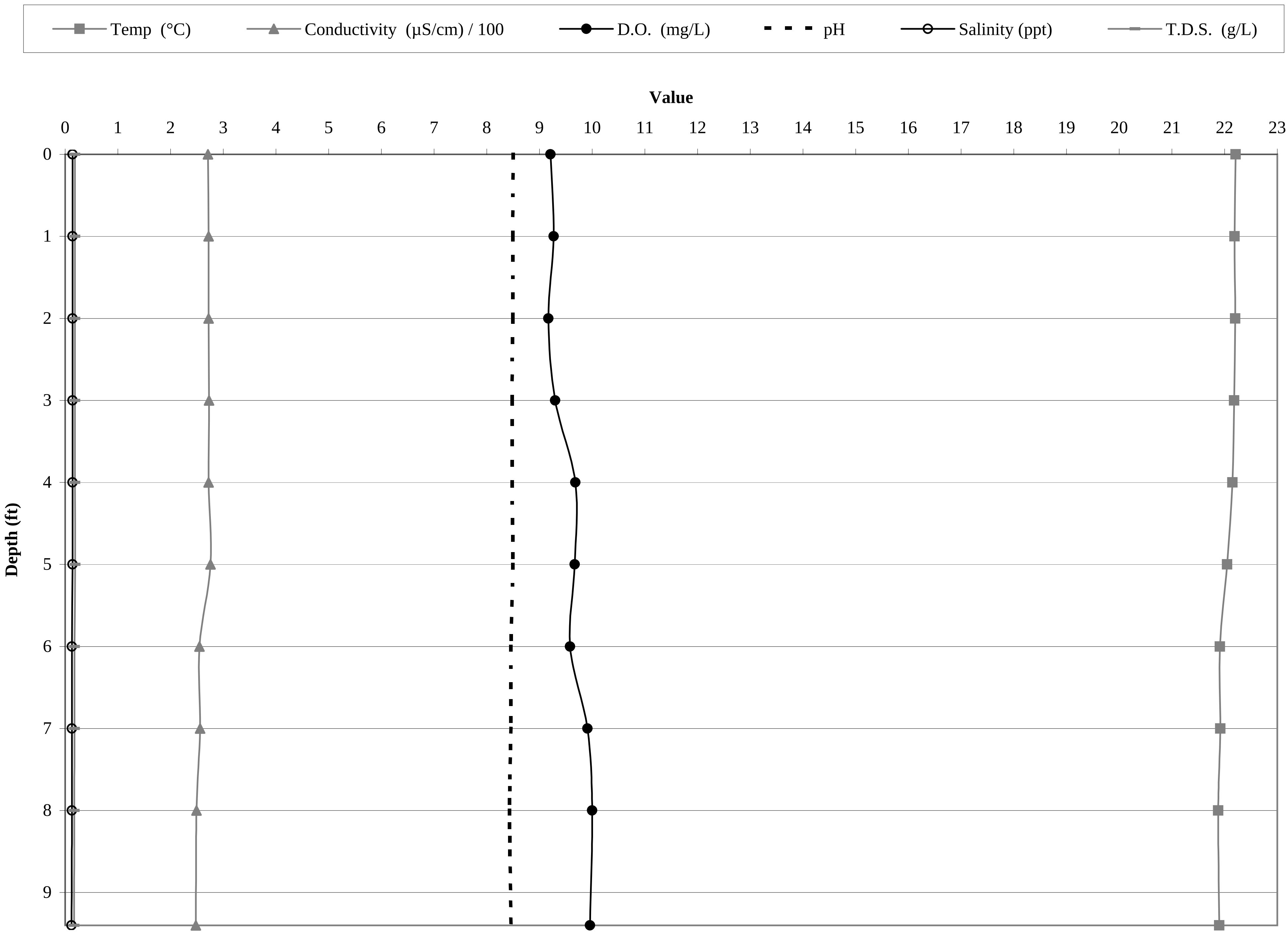
Time: 1600



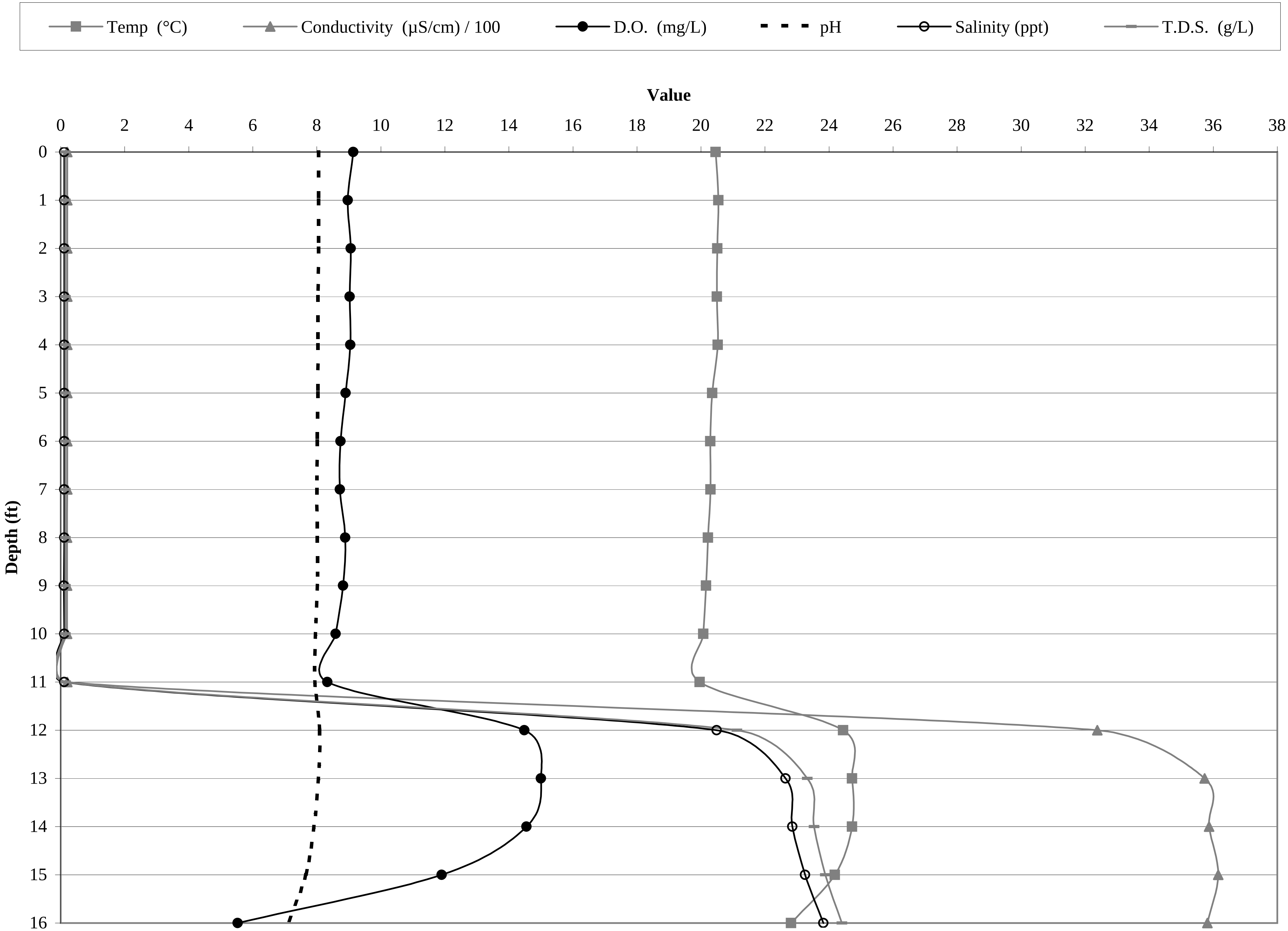
Appendix B-32. Gualala Water Quality Depth Profile - Mouth of Estuary- (07/22/03)



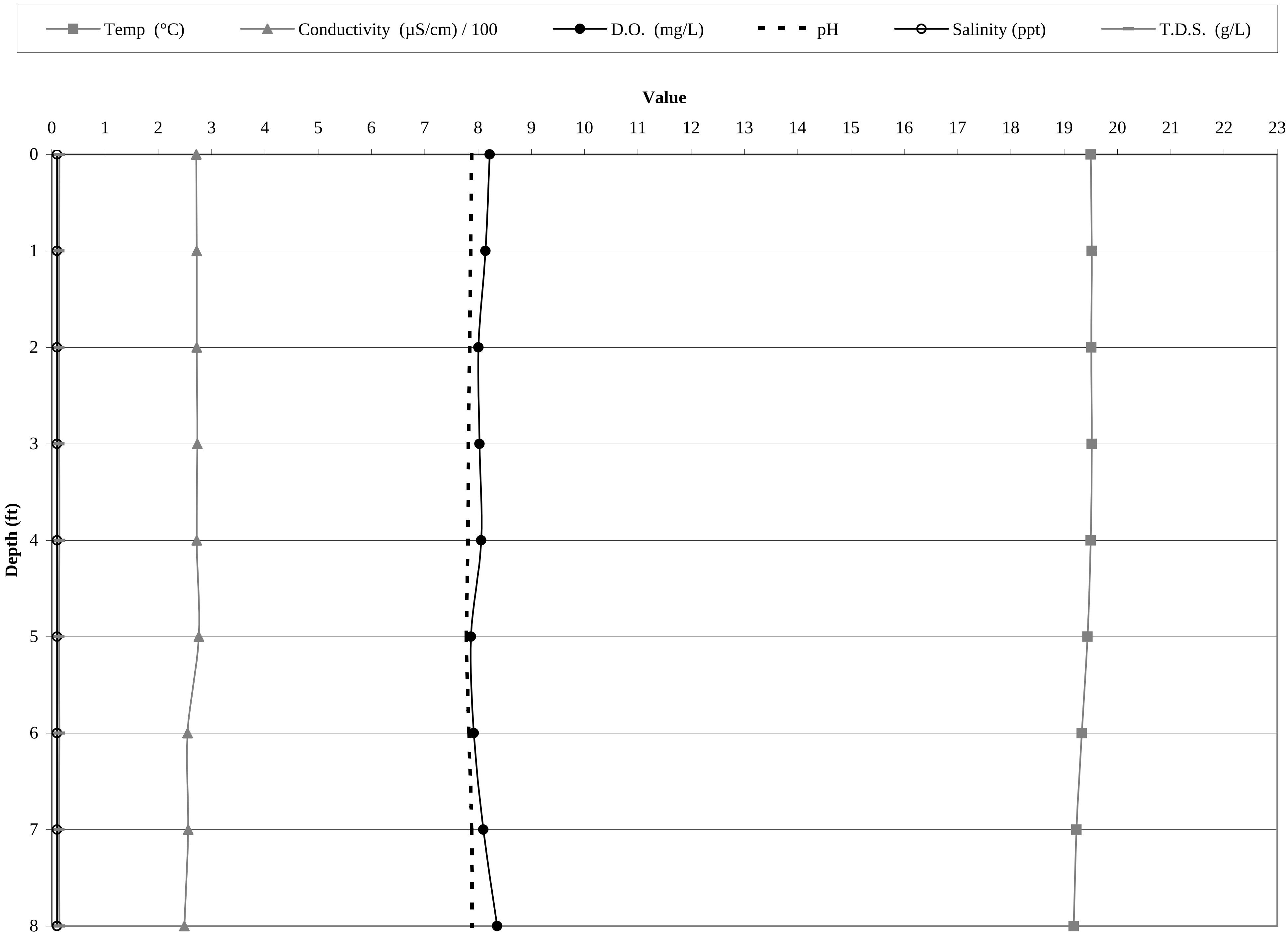
Appendix B-33. Gualala Water Quality Depth Profile - China Gulch - (07/22/03)



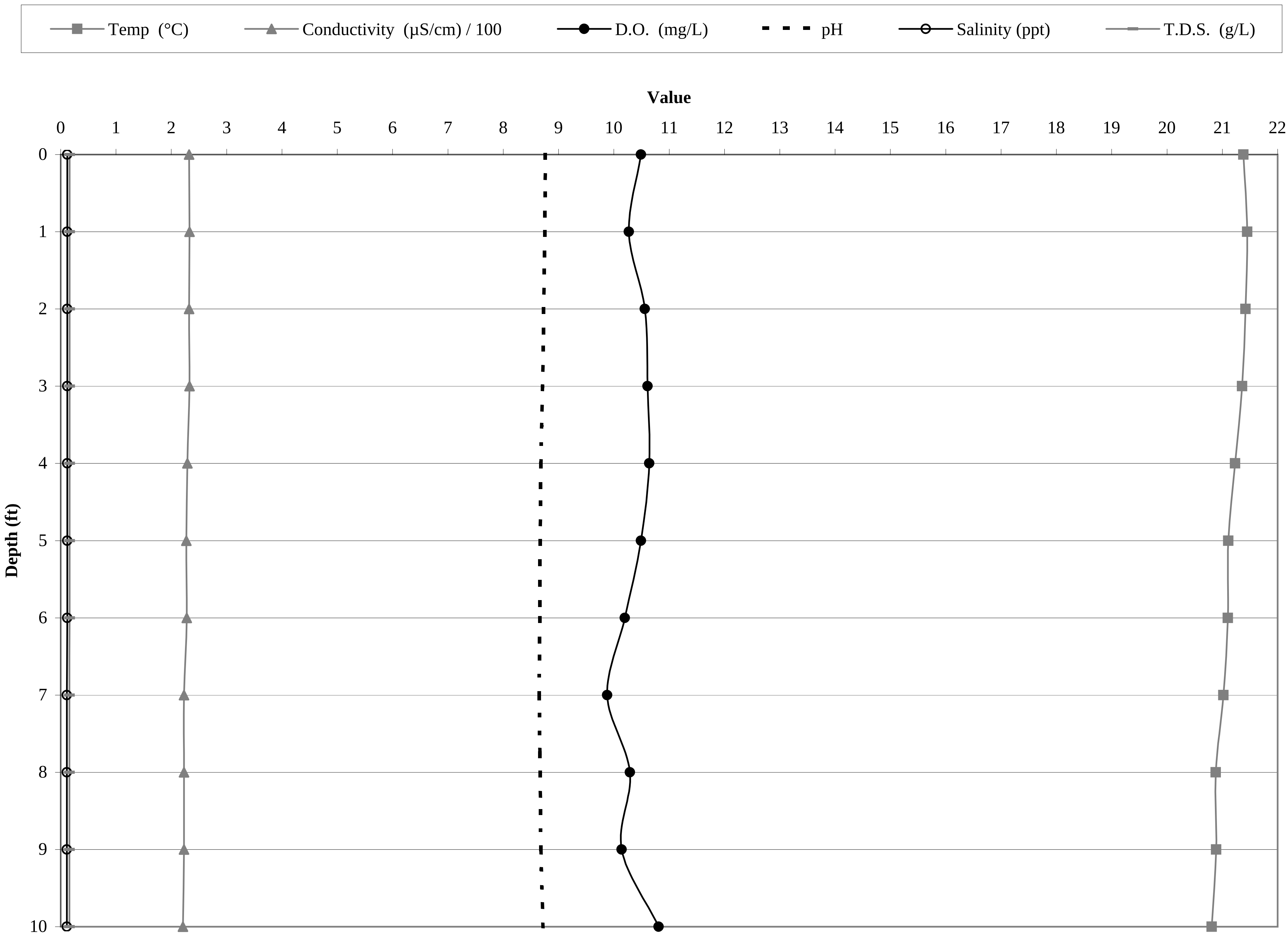
Appendix B-34. Gualala Water Quality Depth Profile - Mill Bend - (07/22/03)



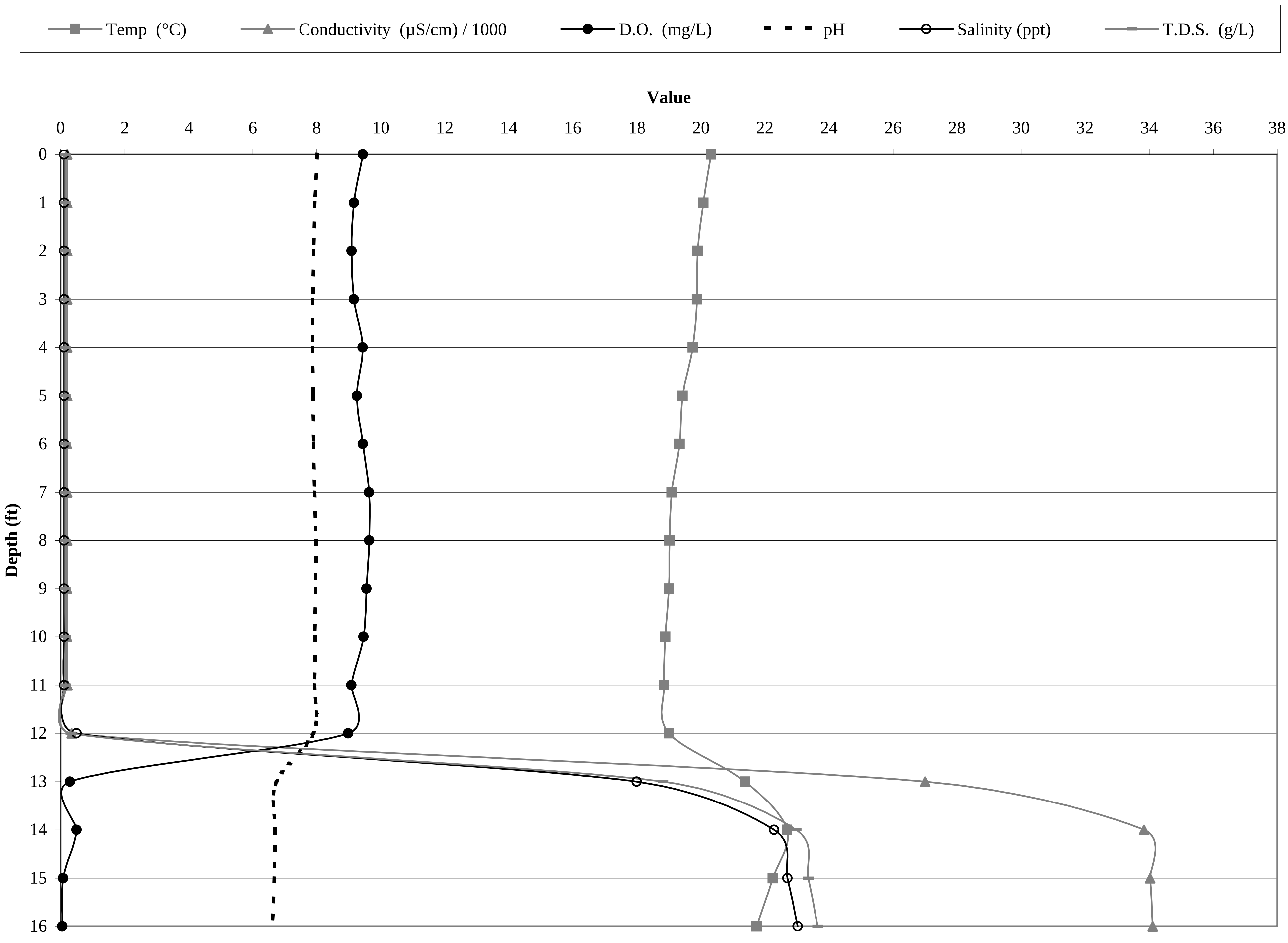
Appendix B-35. Gualala Water Quality Depth Profile - Above Highway 1 Bridge - (07/22/03)



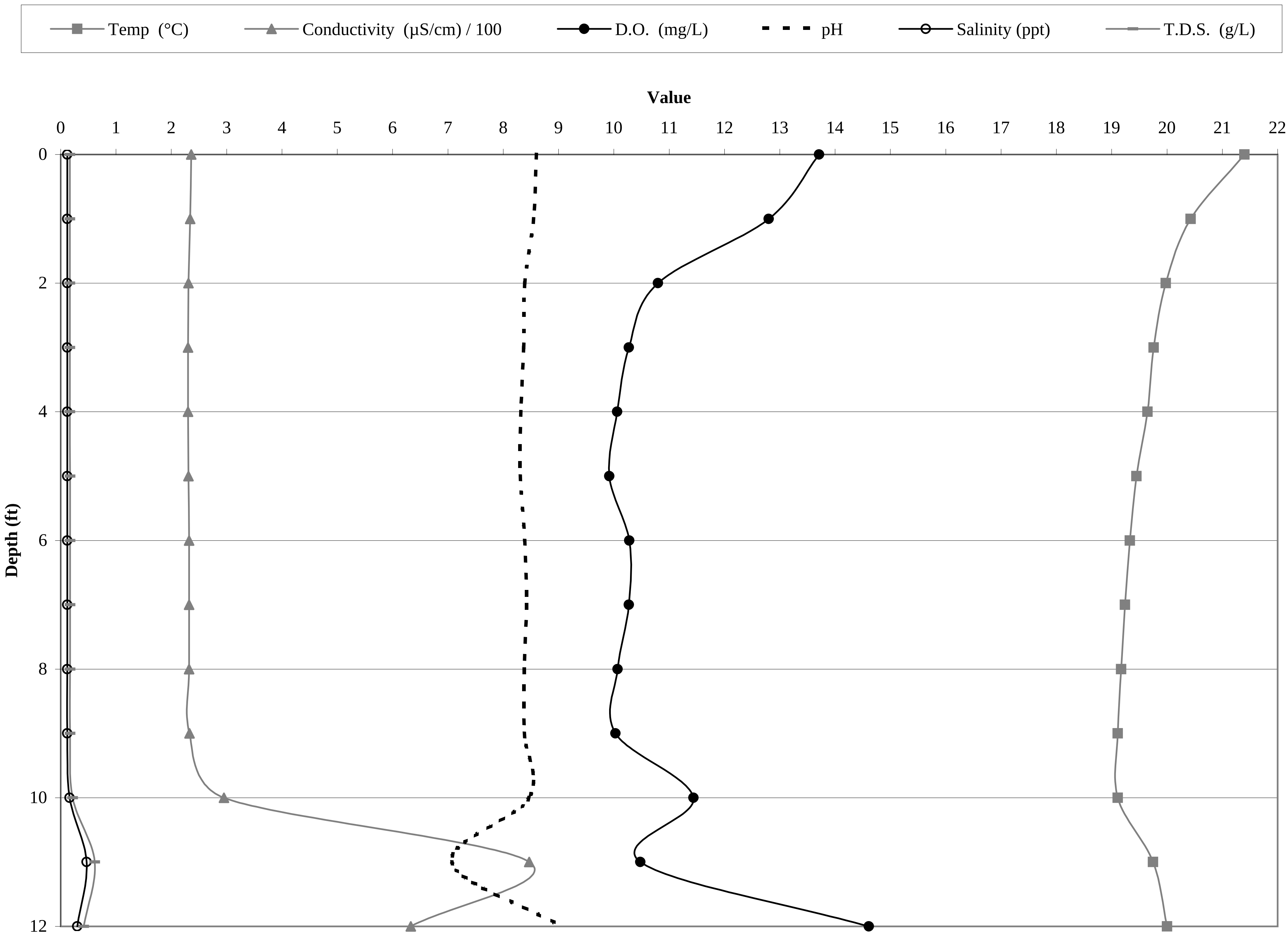
Appendix B-36. Gualala Water Quality Depth Profile - Mouth of Estuary - (08/23/03)



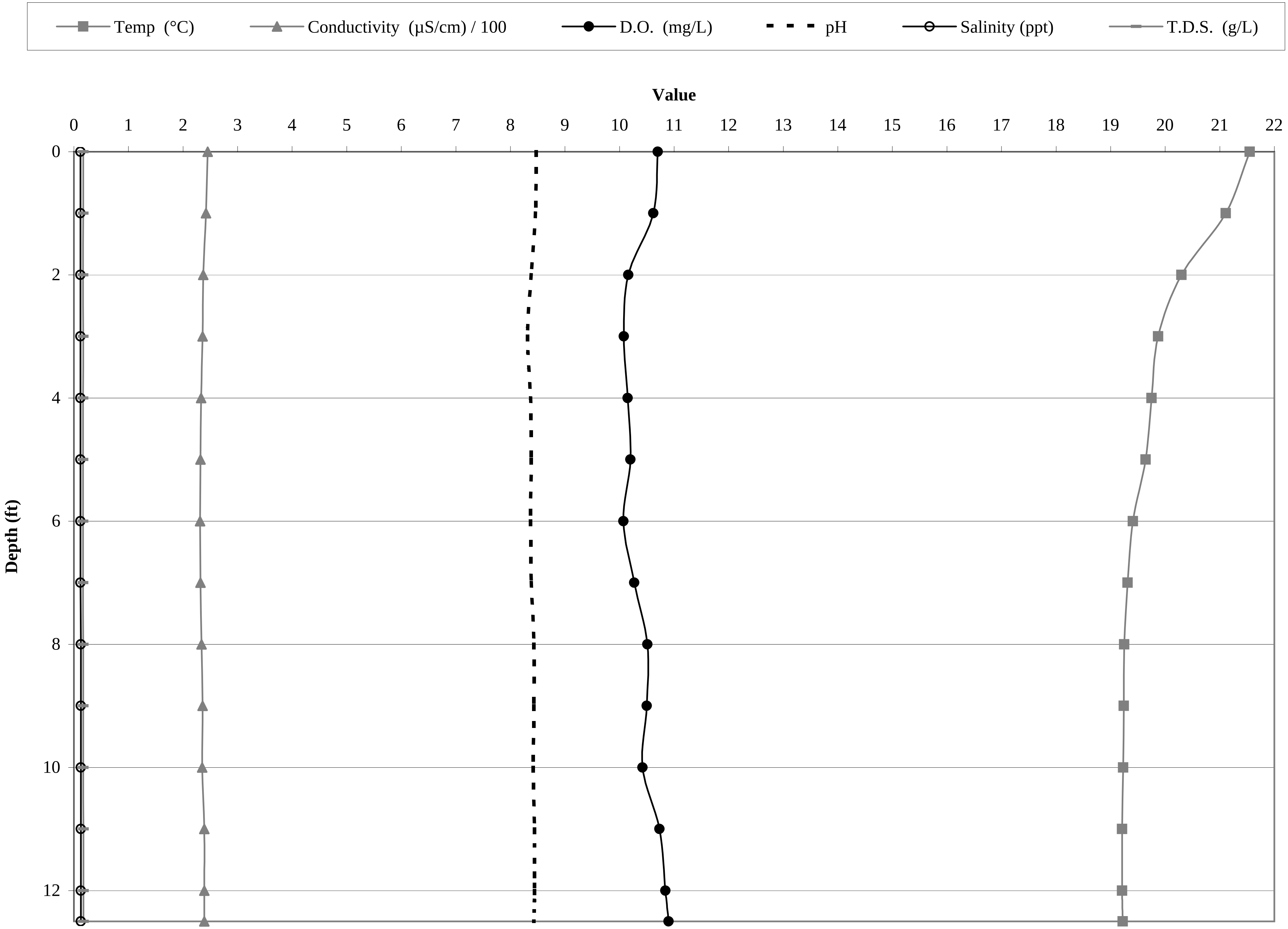
Appendix B-37. Gualala Water Quality Depth Profile - Mill Bend - (08/23/03)



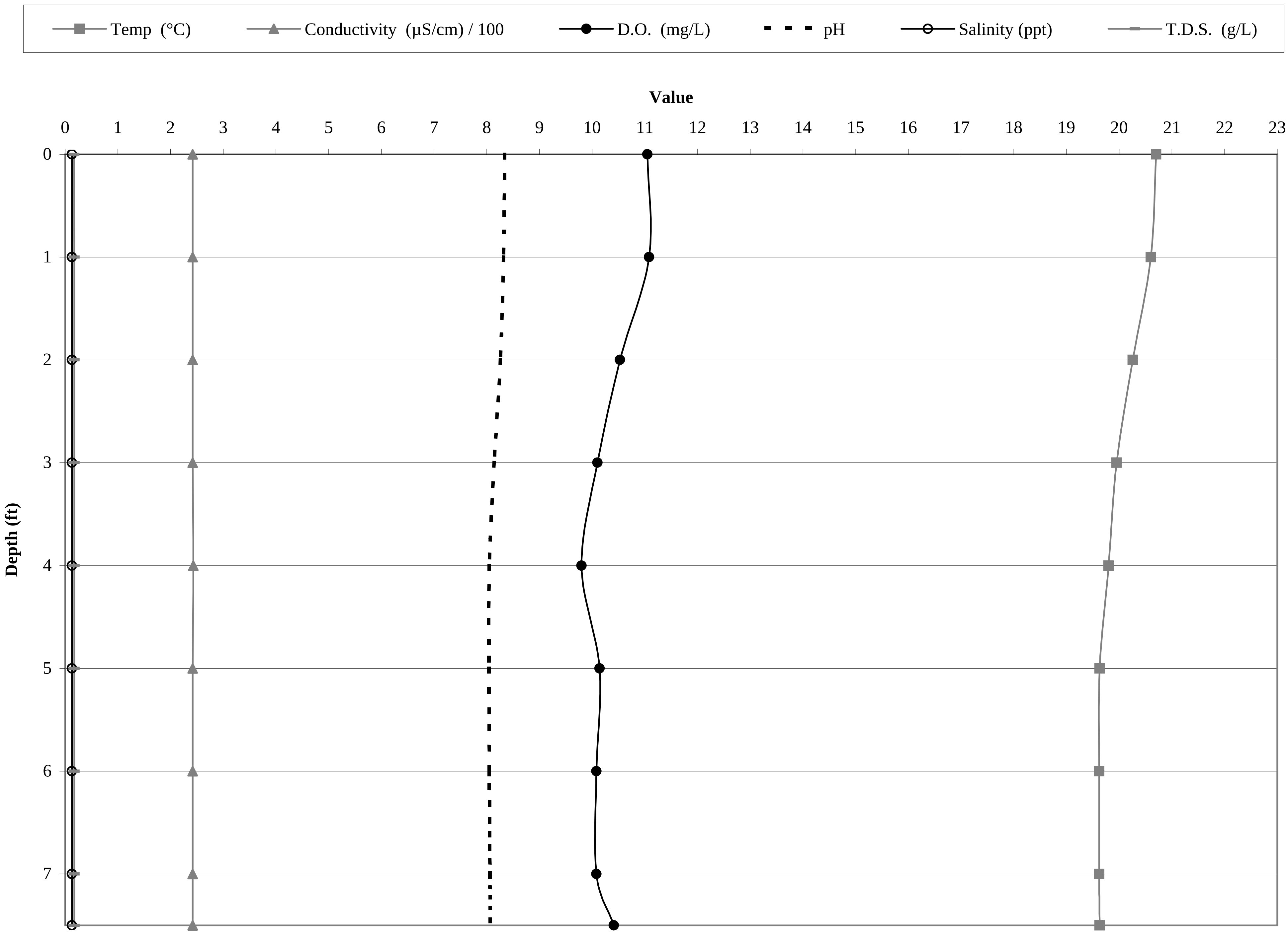
Appendix B-38. Gualala Water Quality Depth Profile - Mouth of Estuary- (9/22/03)



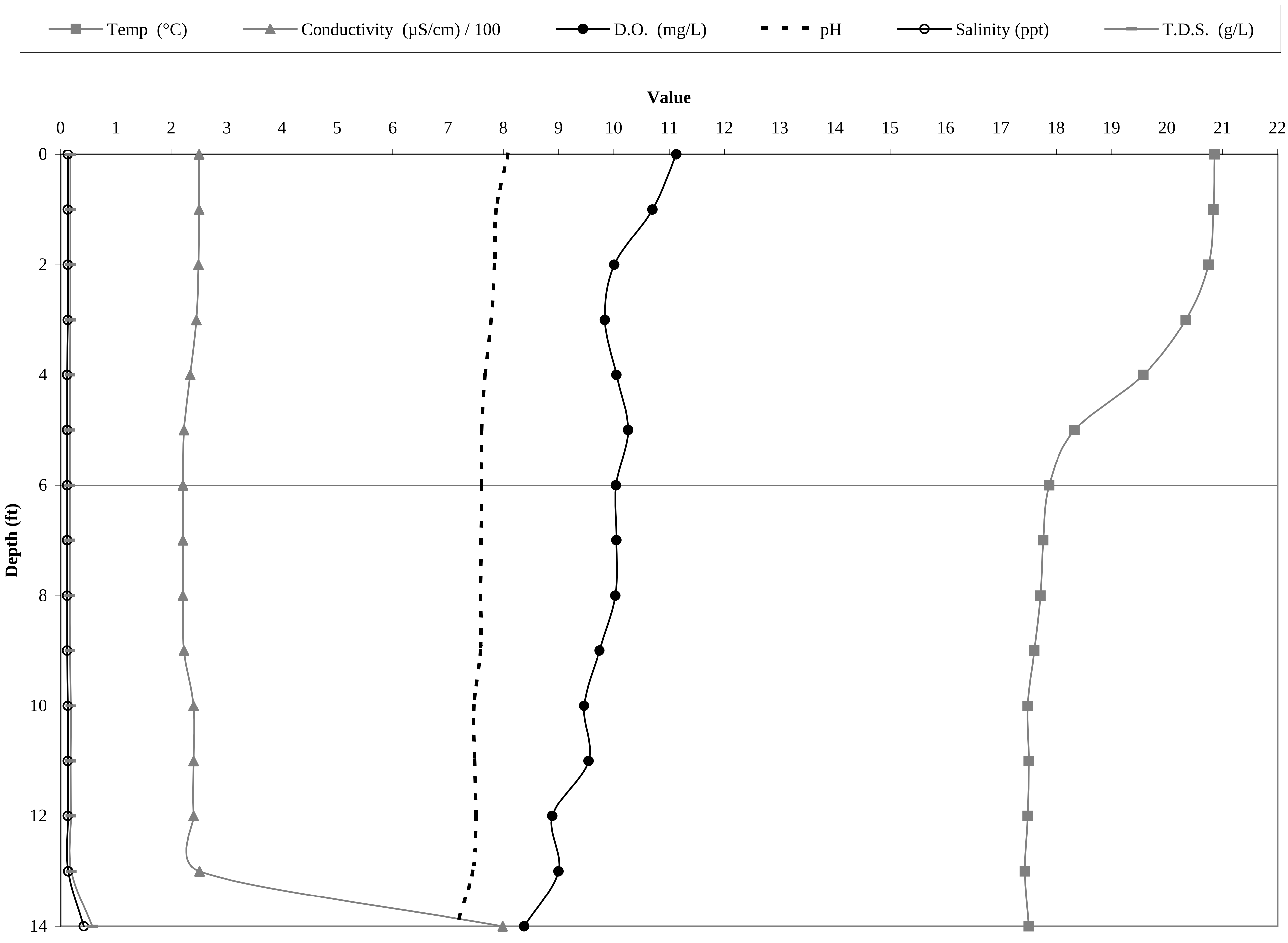
Appendix B-39. Gualala Water Quality Depth Profile - Tide Guage - (9/22/03)



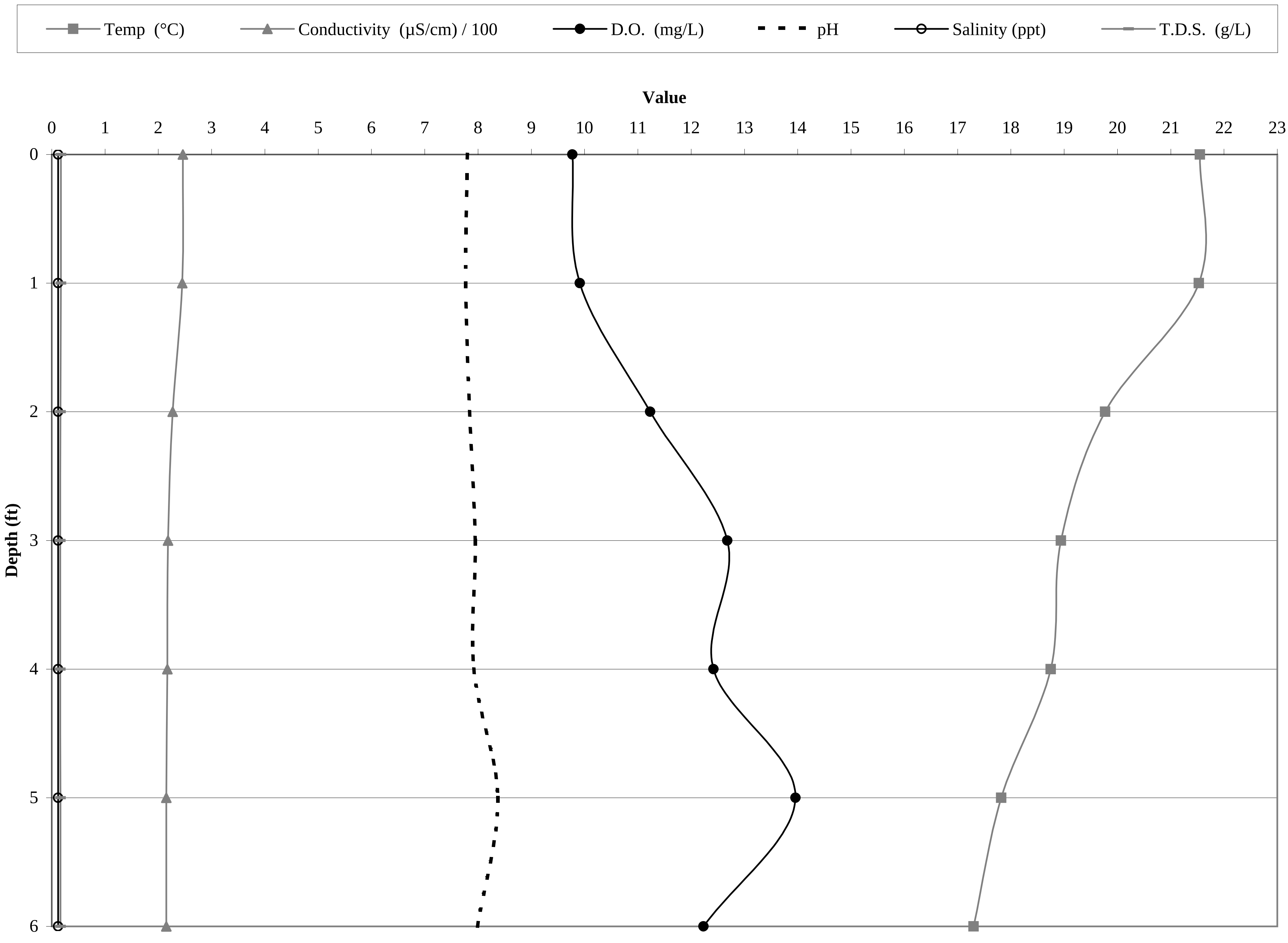
Appendix B-40. Gualala Water Quality Depth Profile - China Gulch - (09/22/03)



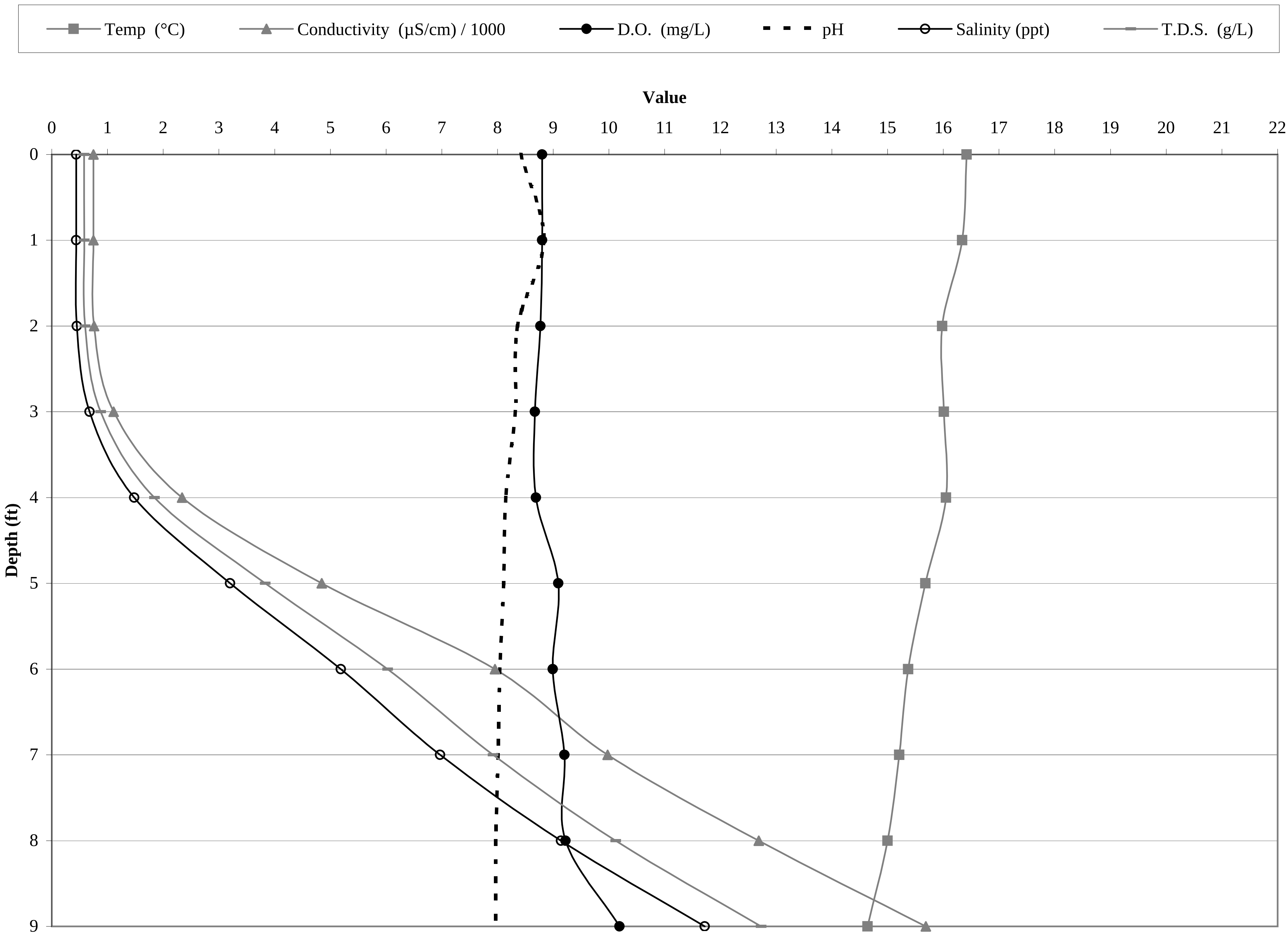
Appendix B-41. Gualala Water Quality Depth Profile - Mill Bend - (9/22/03)



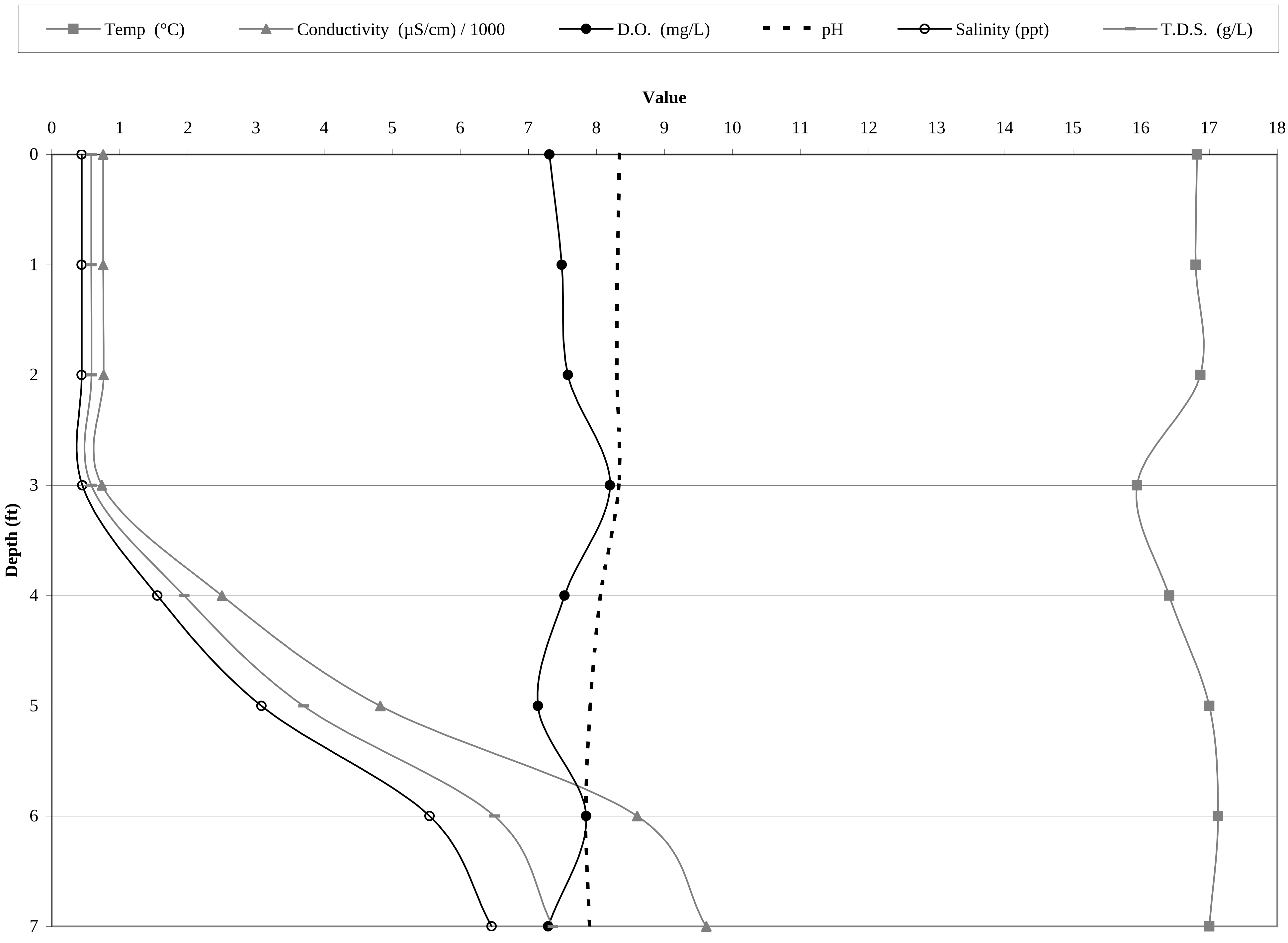
Appendix B-42. Gualala Water Quality Depth Profile - Above Highway 1 Bridge - (09/22/03)



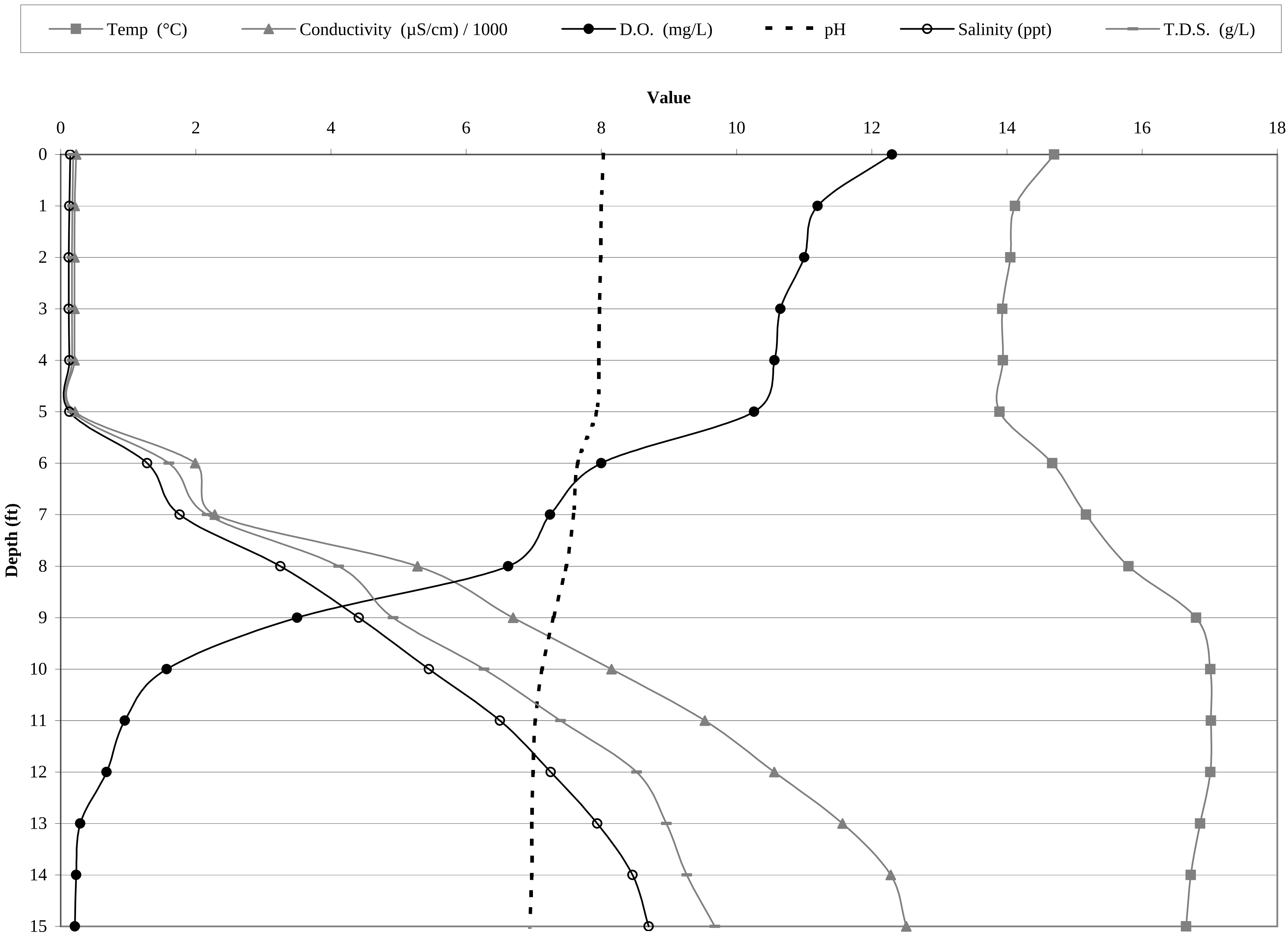
Appendix B-43. Gualala Water Quality Depth Profile - Mouth of Estuary- (10/27/03)



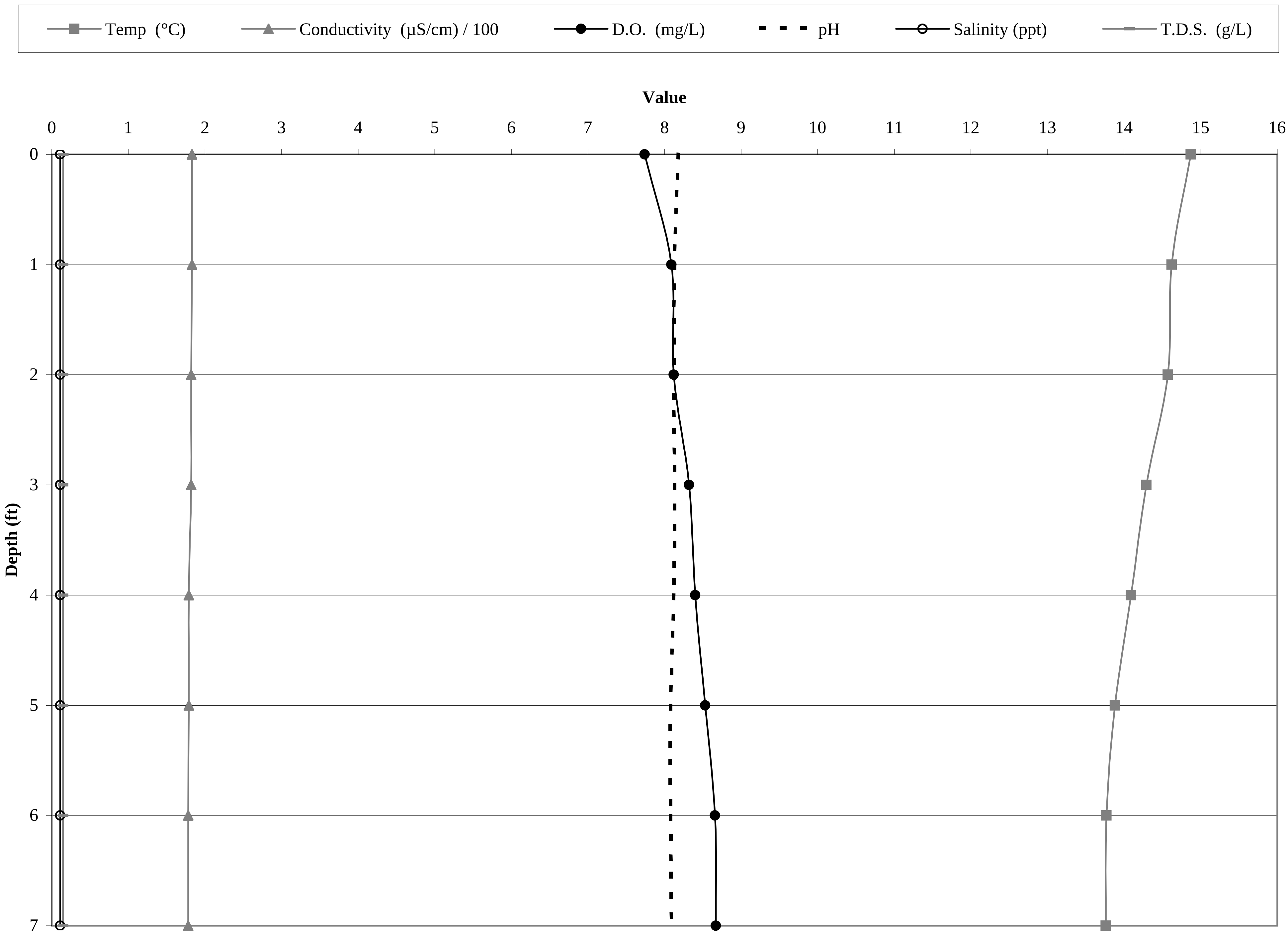
Appendix B-44. Gualala Water Quality Depth Profile - China Gulch - (10/28/03)

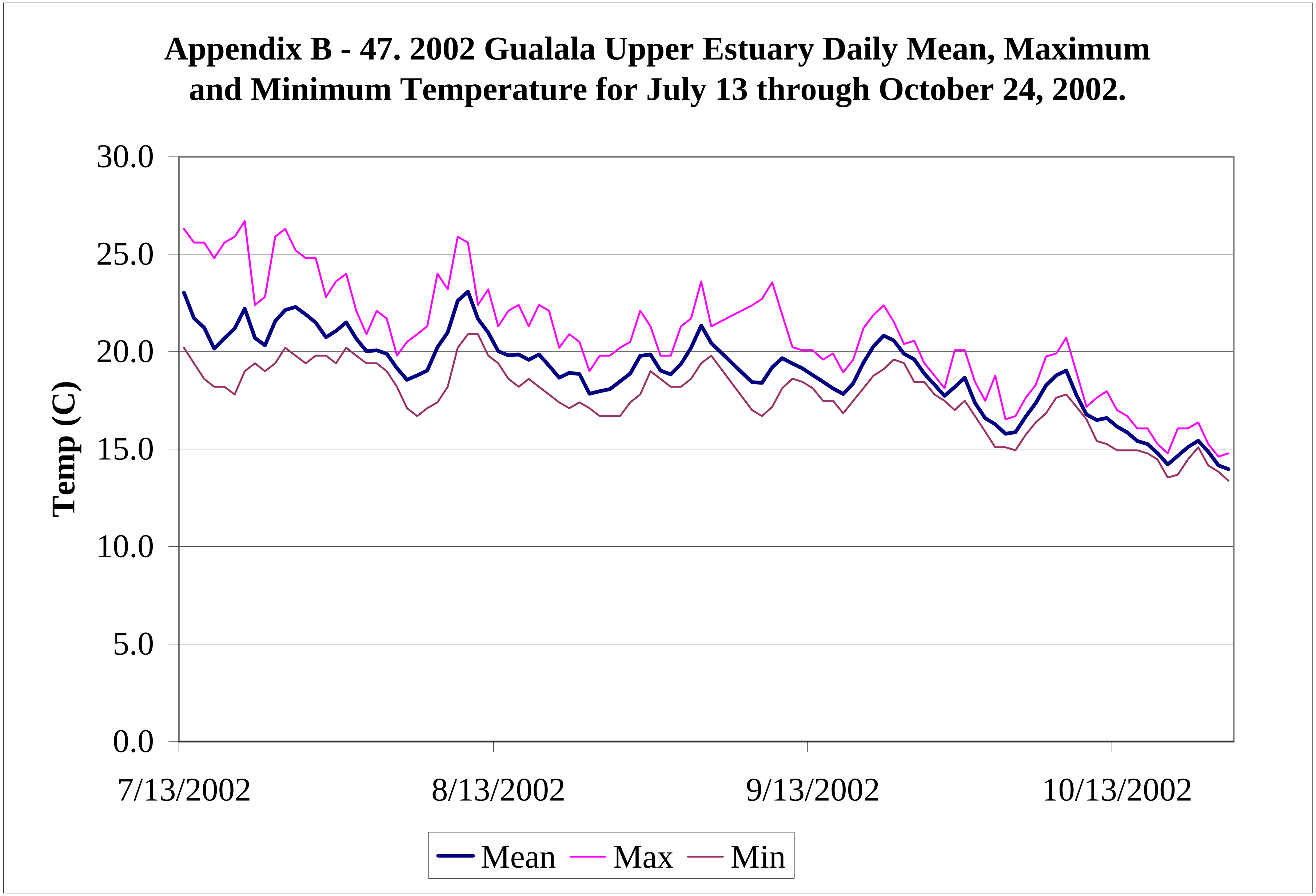


Appendix B-45. Gualala Water Quality Depth Profile - Mill Bend - (10/28/03)

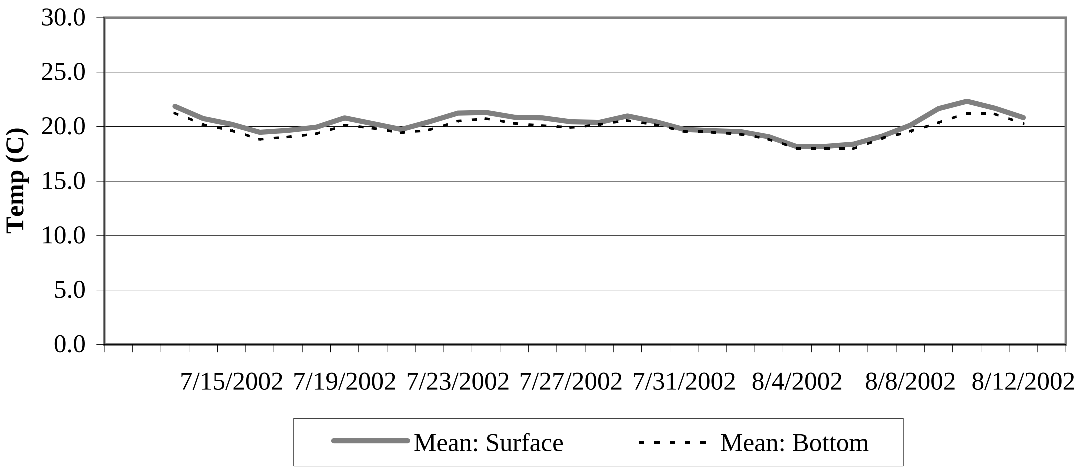


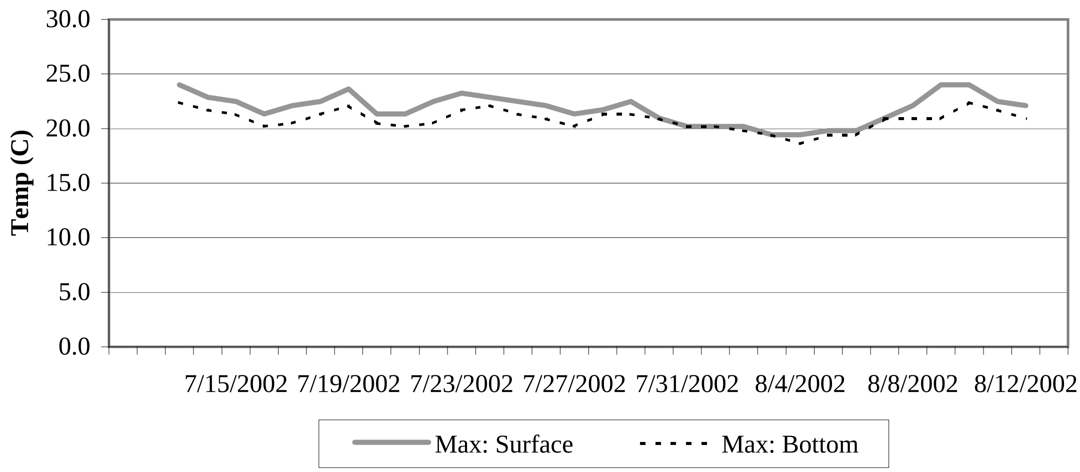
Appendix B-46. Gualala Water Quality Depth Profile - Above Highway 1 Bridge - (10/28/03)

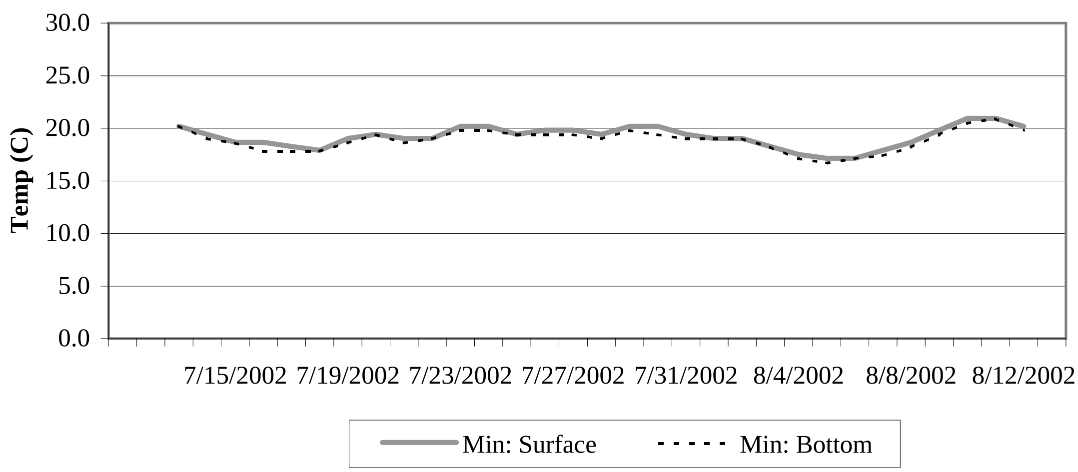



Appendix B - 47. 2002 Gualala Upper Estuary Daily Mean, Maximum and Minimum Temperature for July 13 through October 24, 2002.
Temp (C)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
7/13/2002
8/13/2002
9/13/2002
10/13/2002
Mean
Max
Min

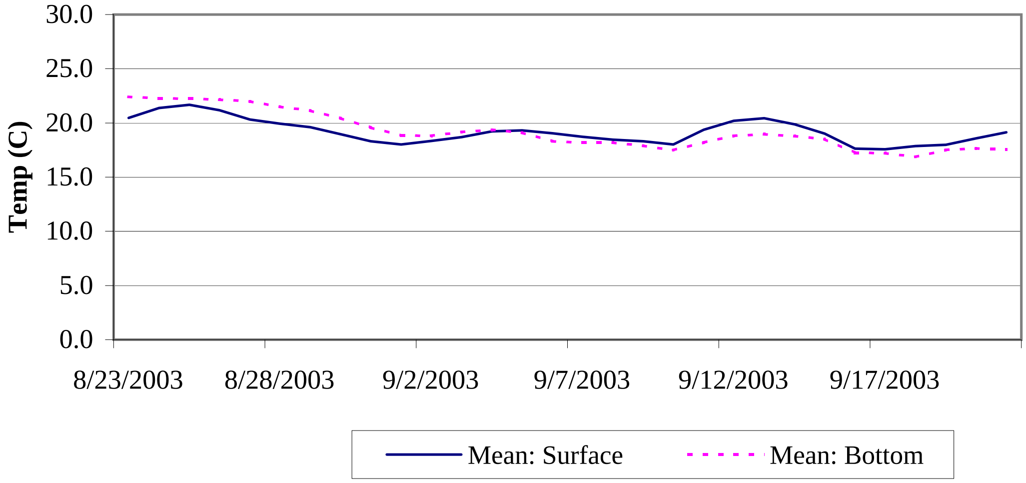
Appendix B - 48. 2002 Gualala River Middle Estuary Daily Mean, Maximum and Minimum Temperatures for July 13 through August 12, 2002

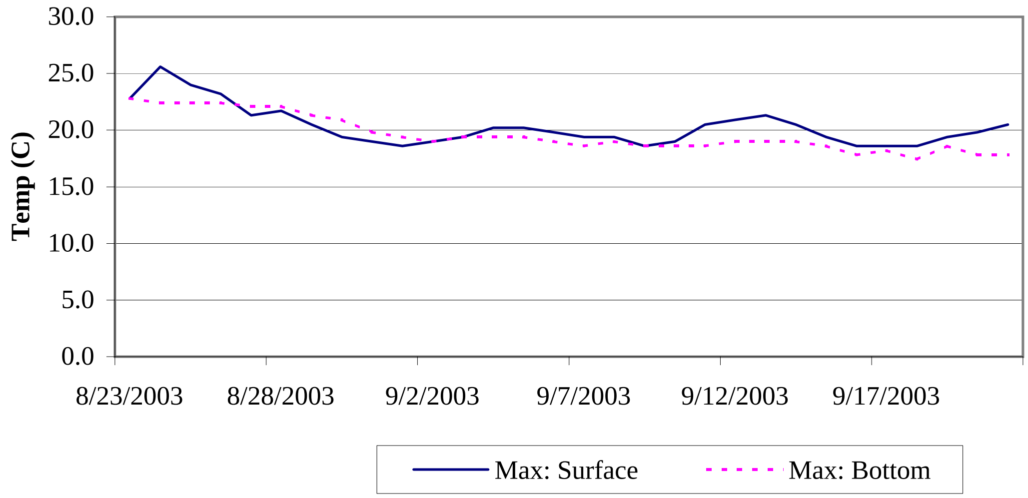


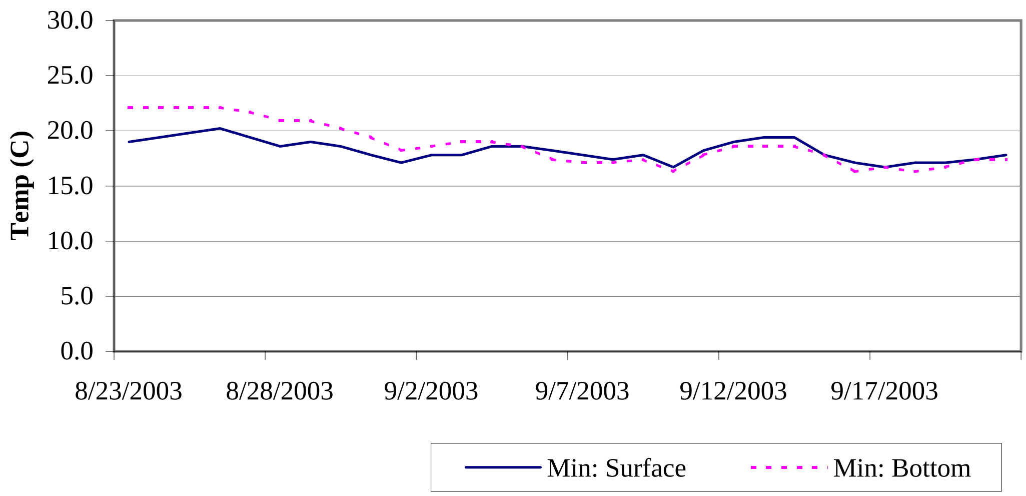




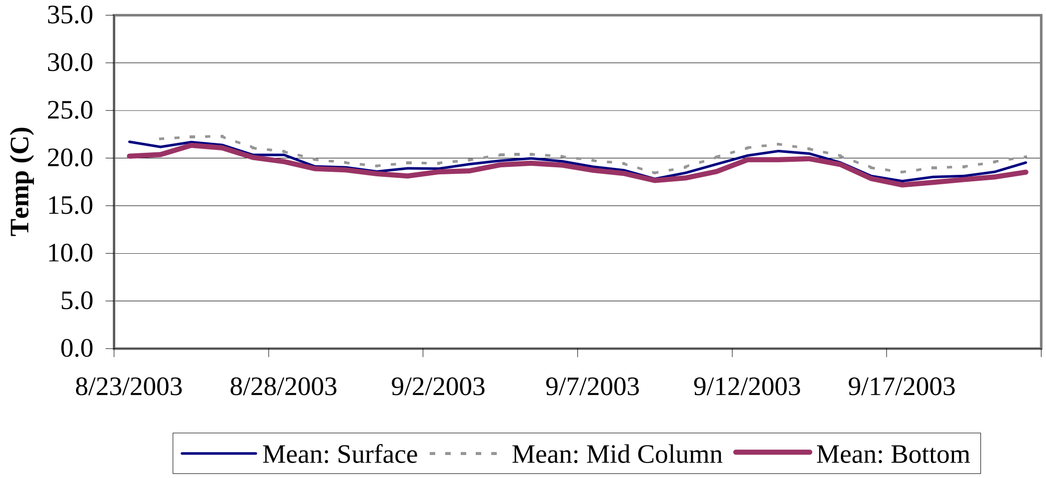
Appendix B - 49. Gualala River Estuary Mill Bend Daily Mean, Maximum and Minimum Temperatures for August 23 through September 21, 2003

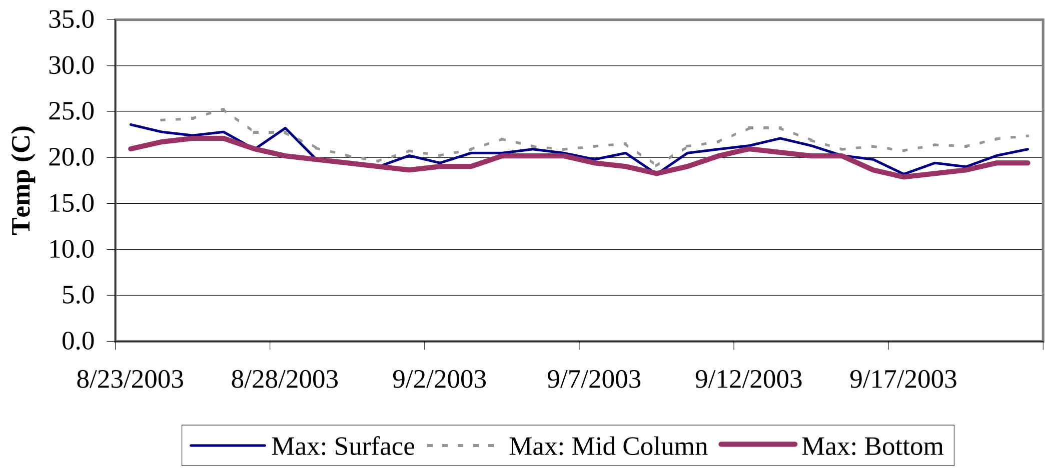


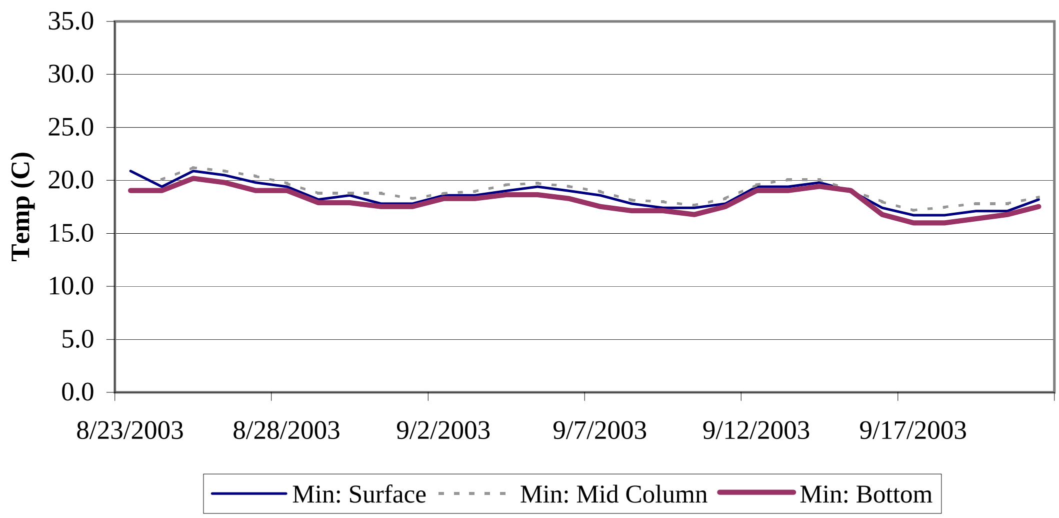




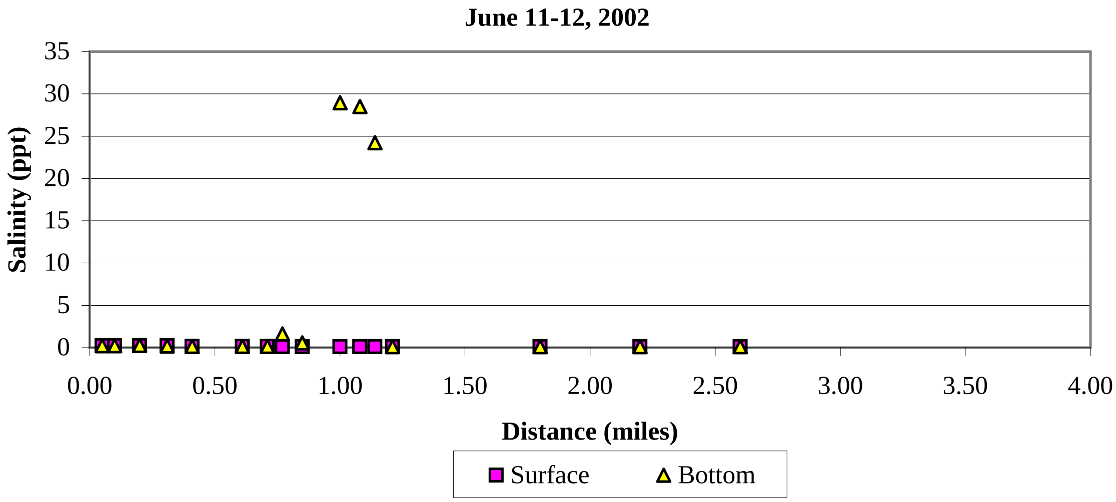
Appendix B - 50. Gualala Middle Estuary Daily Mean, Maximum and Minimum Temperatures from August 23 through September 21, 2003.

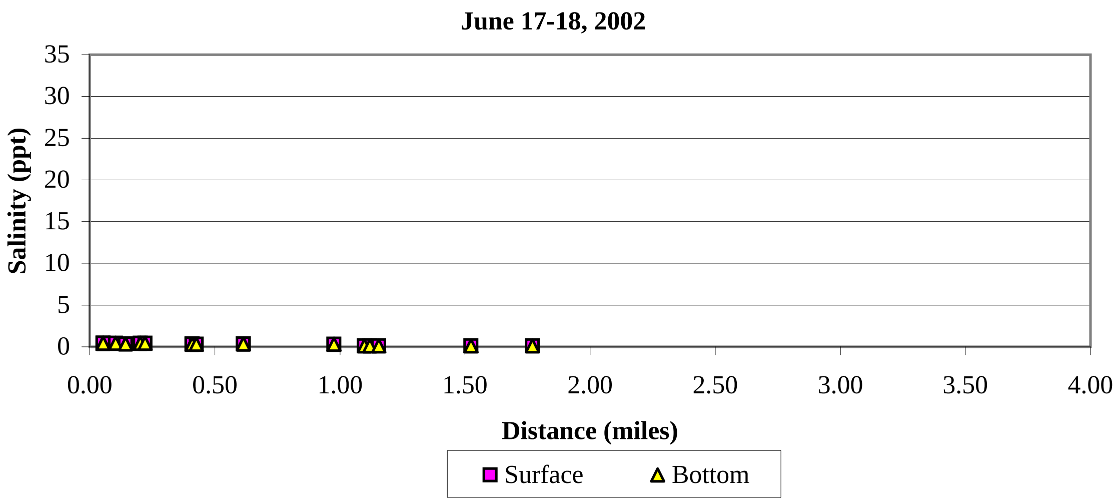


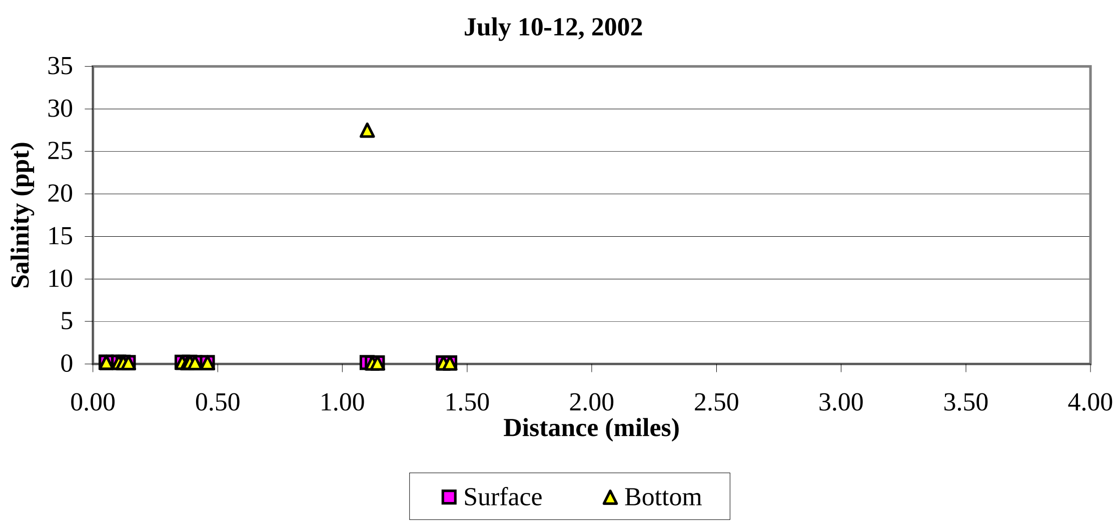




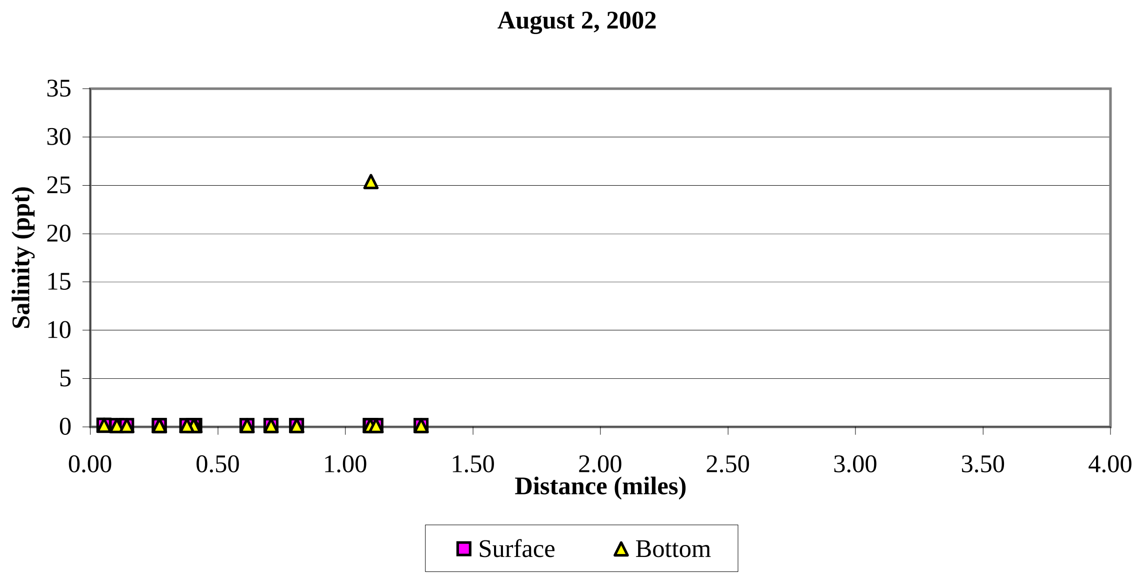
Appendix B-51. Salinity vs. Distance in the Gualala River Estuary, 2002-2003.

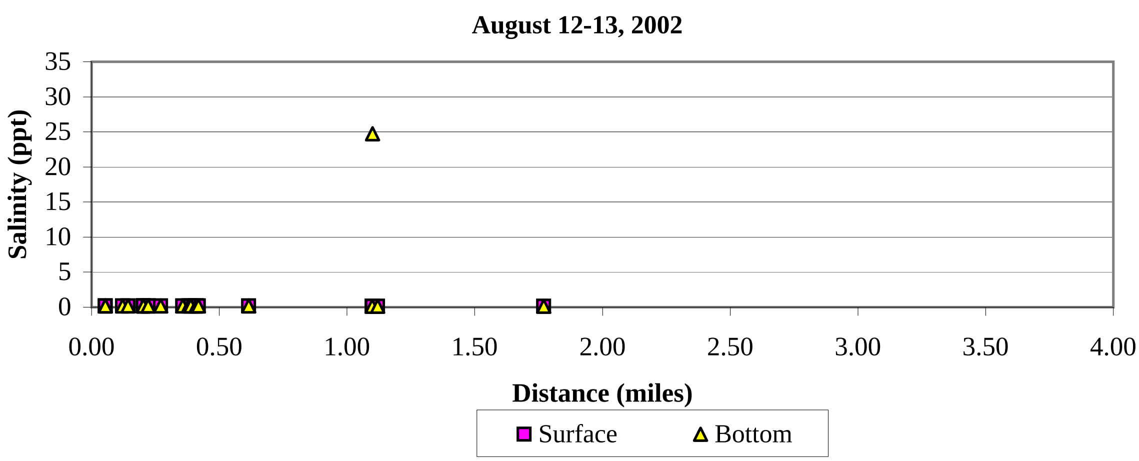


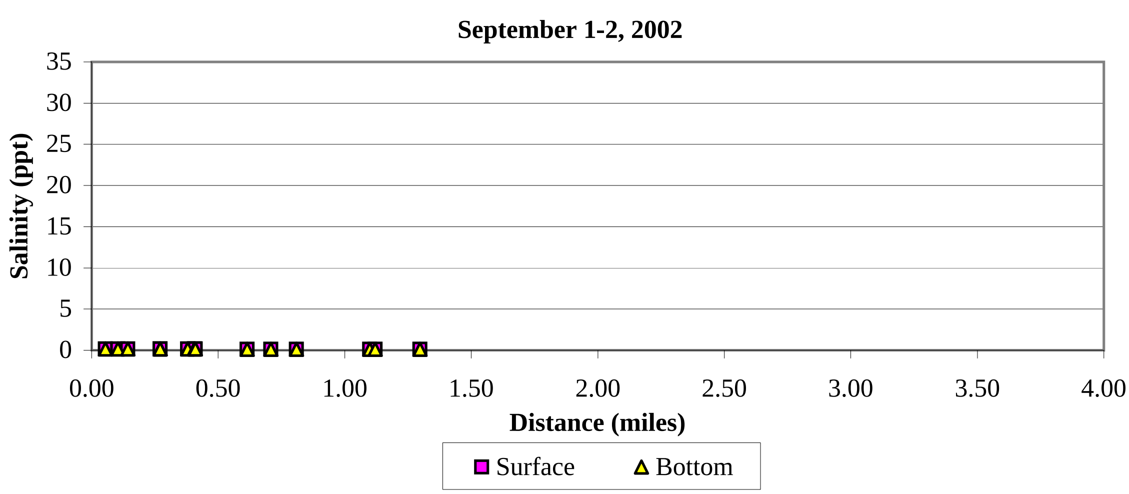




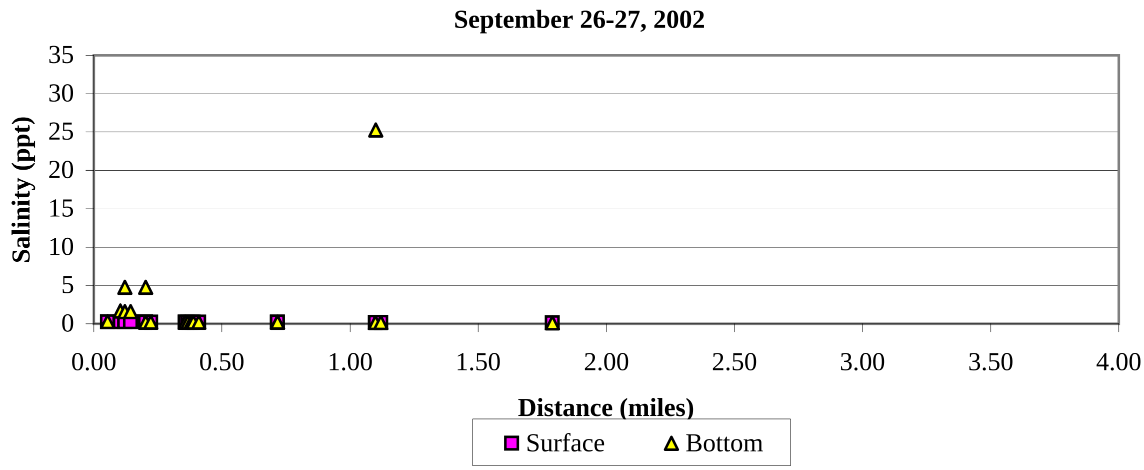
Appendix B-51. (Cont.) Salinity vs. Distance in the Gualala River Estuary, 2002-2003.

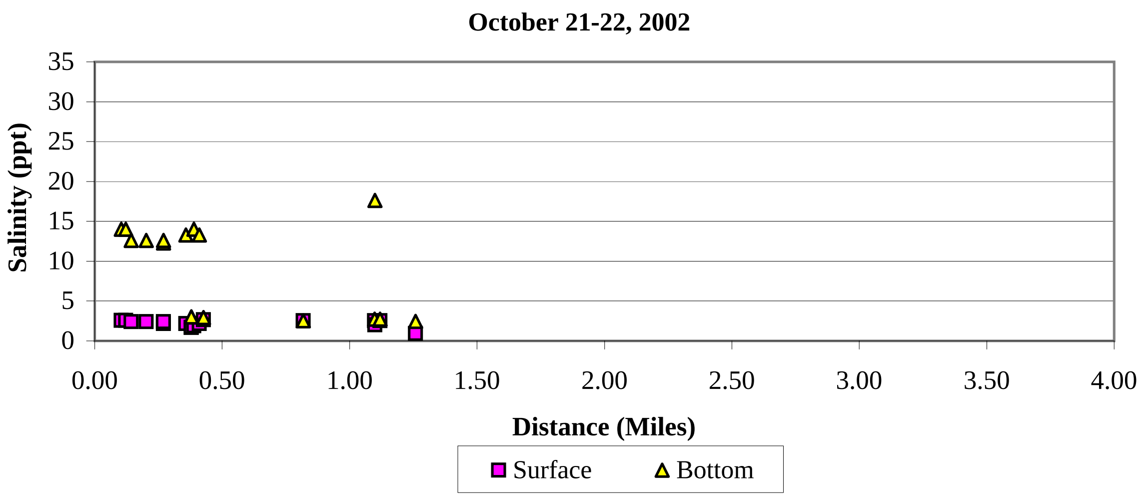


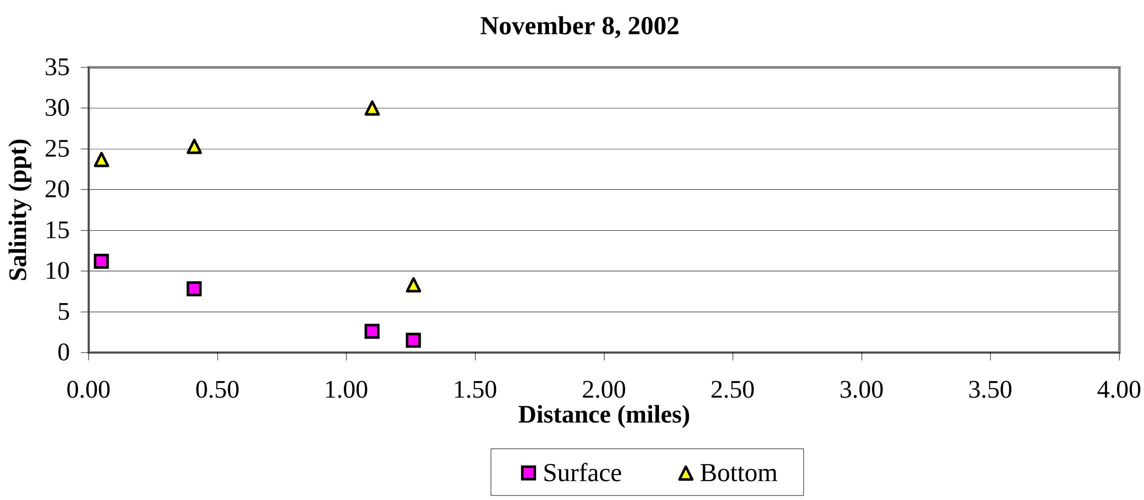




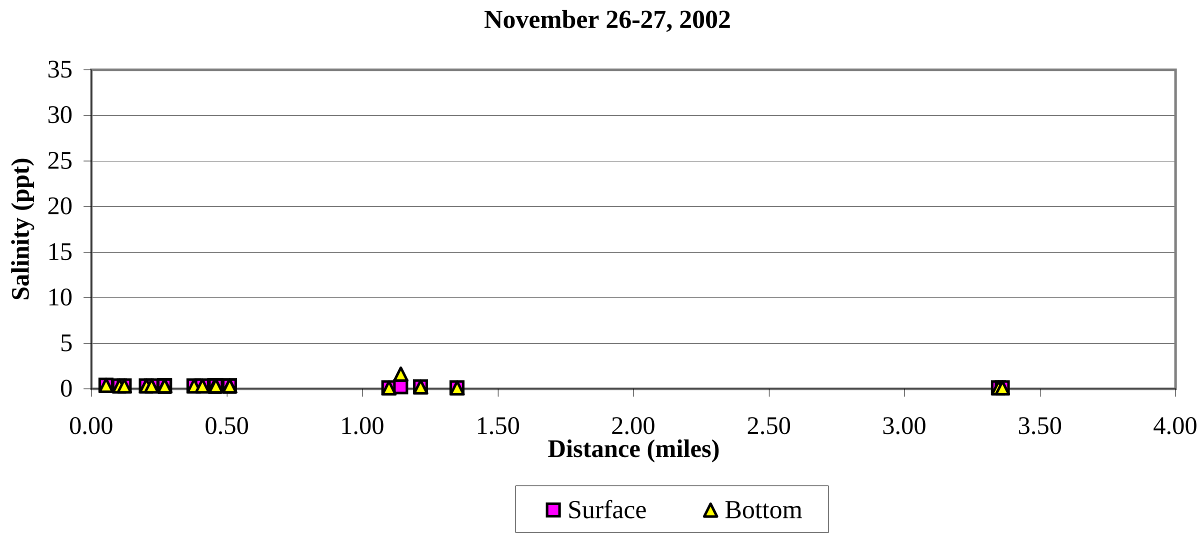
Appendix B-51. (Cont.) Salinity vs. Distance in the Gualala River Estuary, 2002-2003.

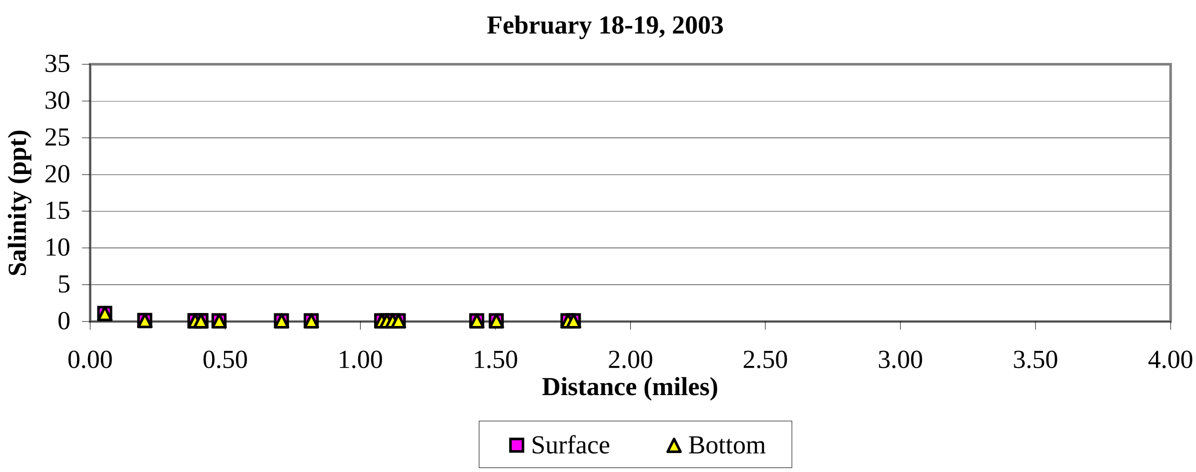


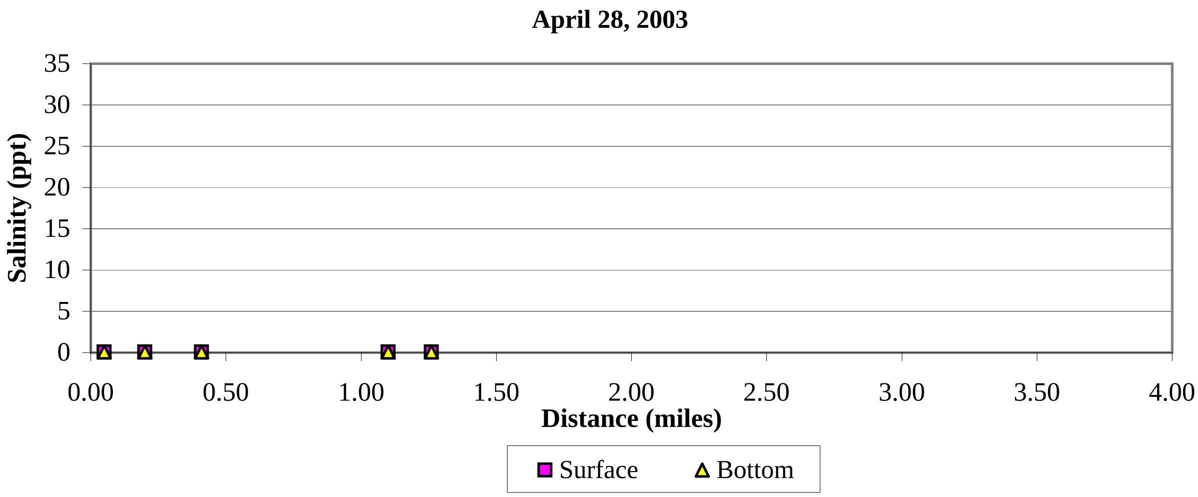




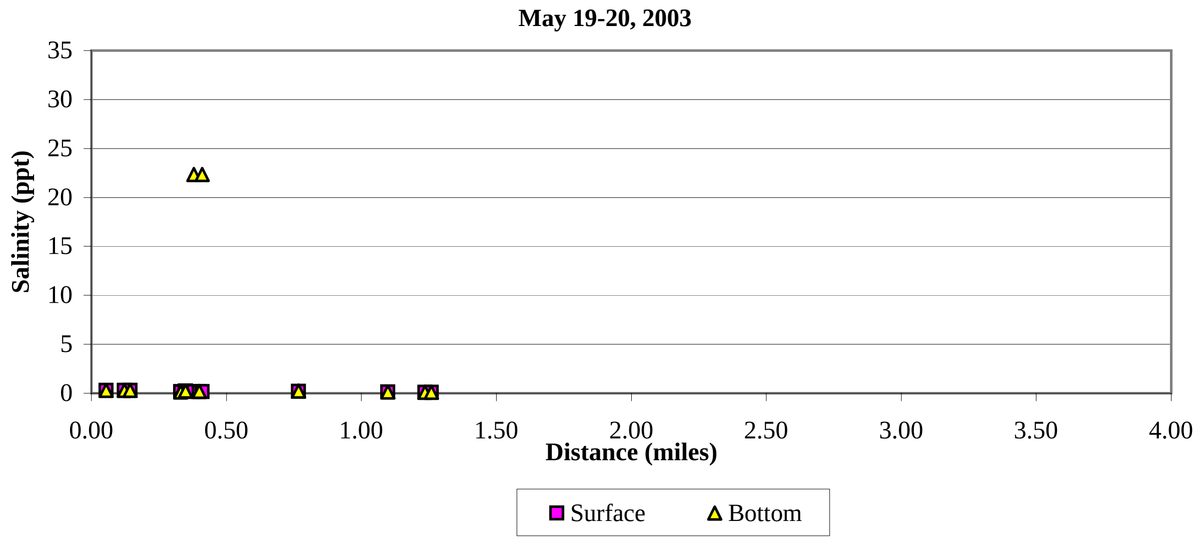
Appendix B-51. (Cont.) Salinity vs. Distance in the Gualala River Estuary, 2002-2003.

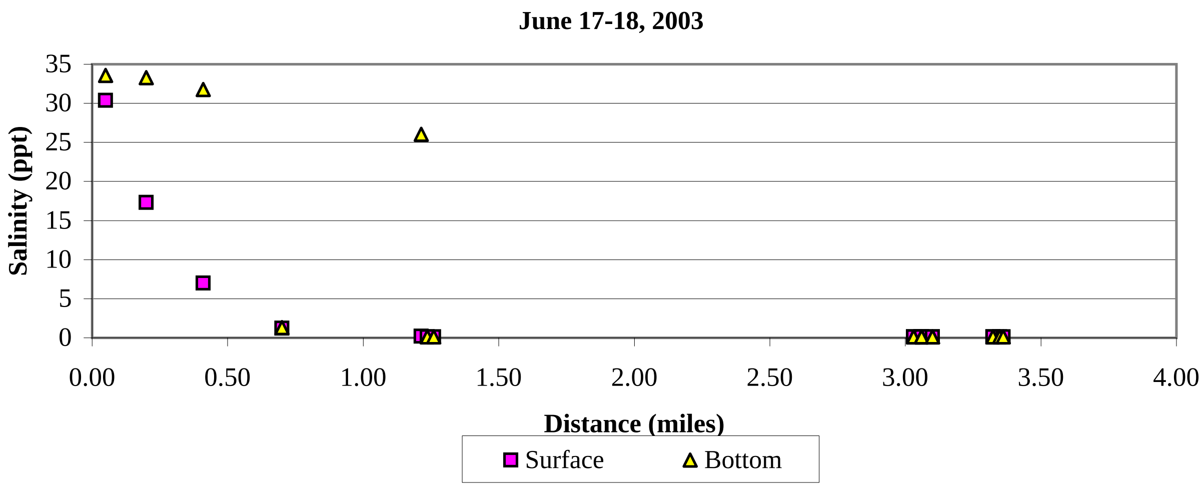


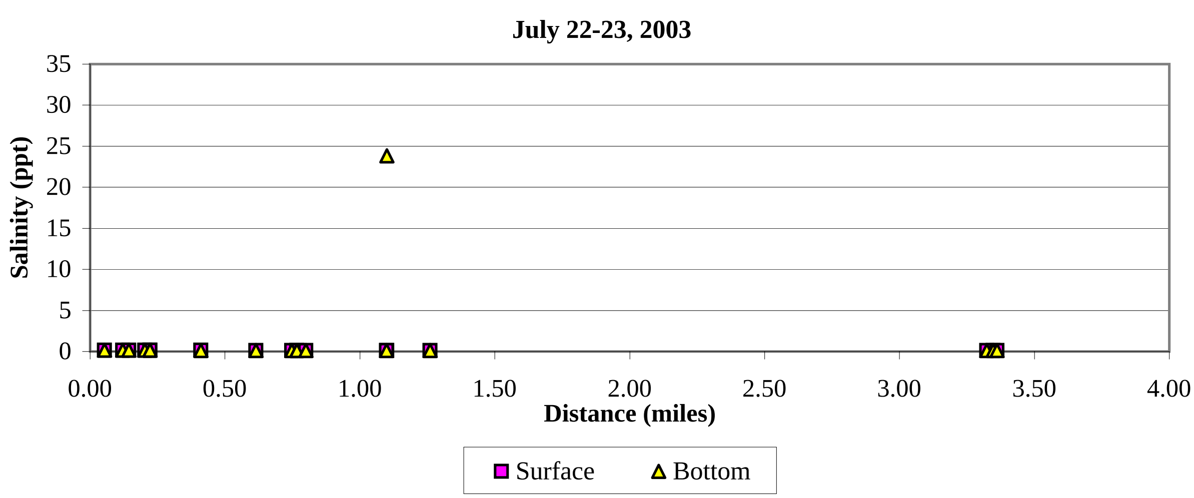




Appendix B-51. (Cont.) Salinity vs. Distance in the Gualala River Estuary, 2002-2003.

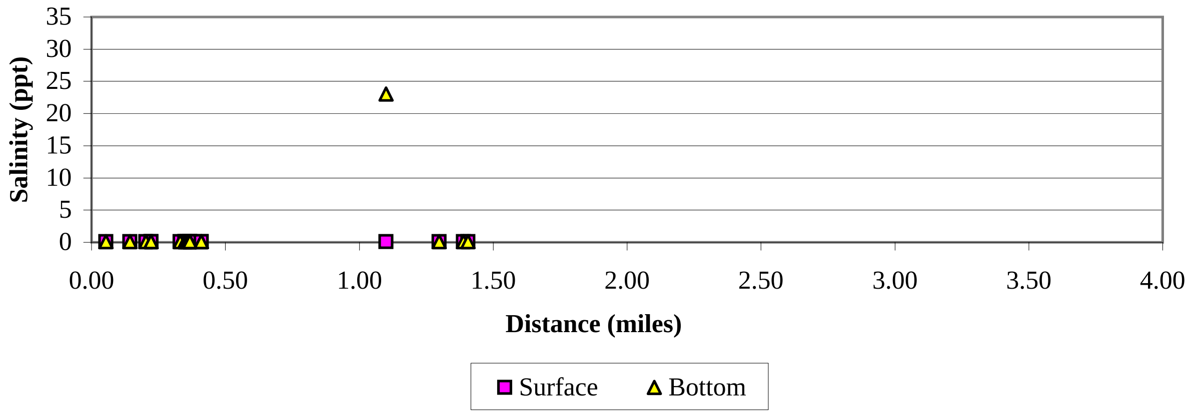




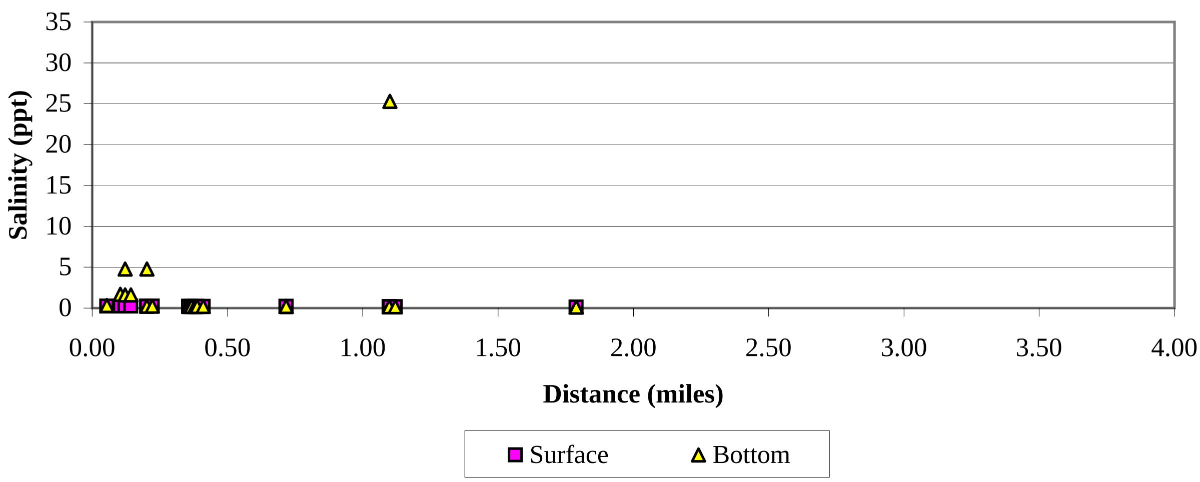


Appendix B-51. (Cont.) Salinity vs. Distance in the Gualala River Estuary, 2002-2003.

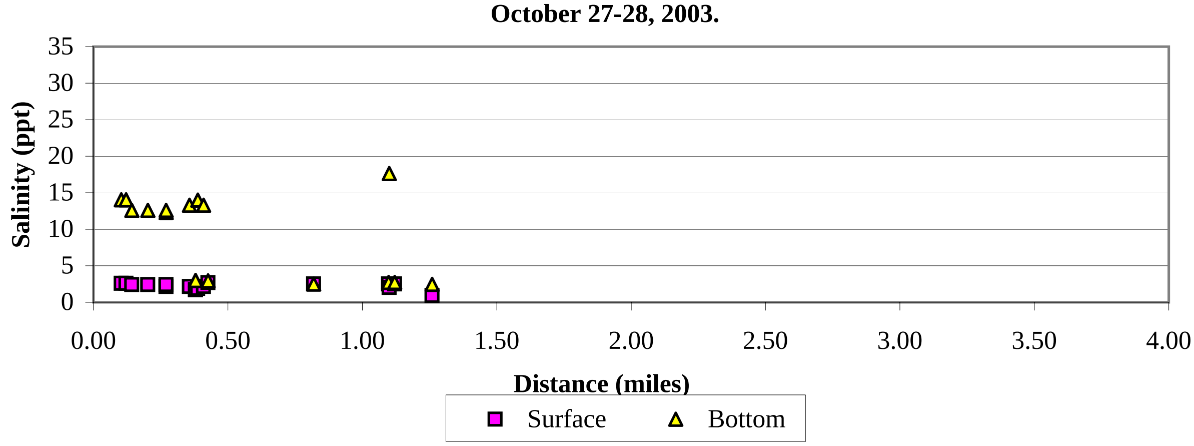
August 21-23, 2003



September 23-24, 2003



October 27-28, 2003.



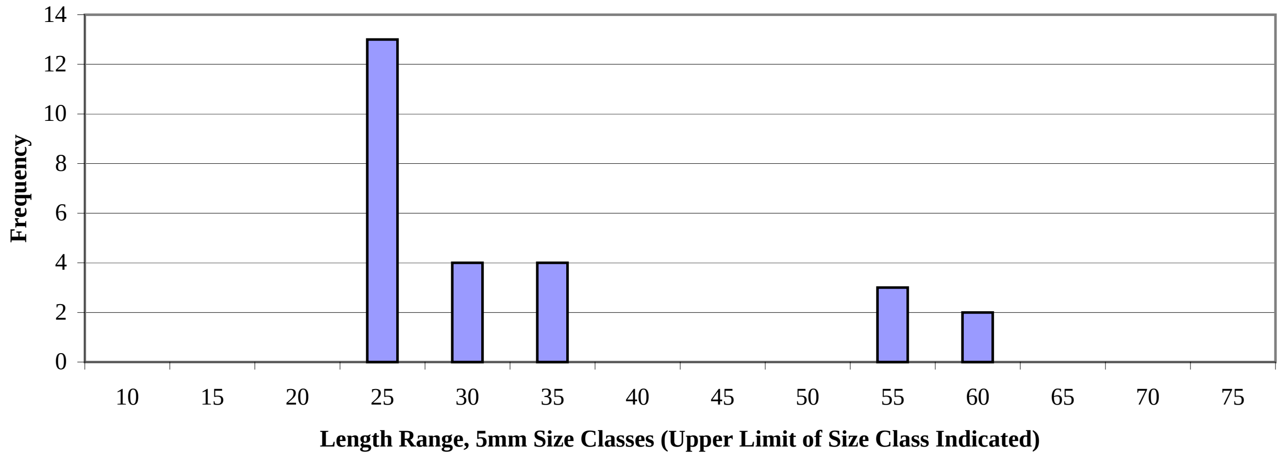
APPENDIX C

Fish Species Length Frequency Histograms

Appendix C-1.1. Three-Spine Stickleback Length Frequency during June 2002 Sampling Event for the Lower Gualala Estuary.

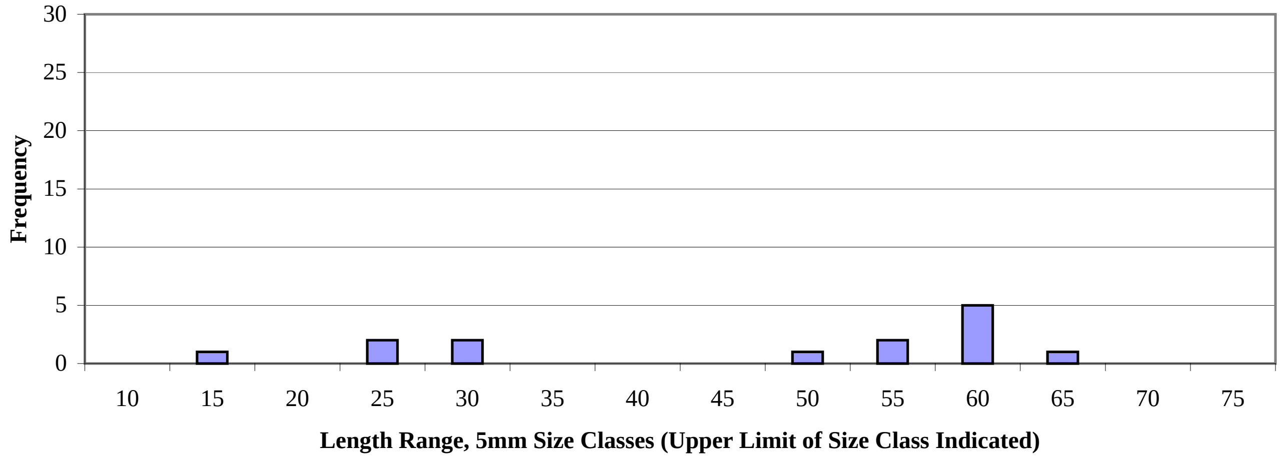
Appendix C-1.2. Three-Spine Stickleback Length Frequency during June 2002 Sampling Event for the Middle Gualala Estuary.

Appendix C-1.3. Three-Spine Stickleback Length Frequency during June 2002 Sampling Event for the Upper Gualala Estuary.



Appendix C-1.4. Three-Spine Stickleback Length Frequency during July 2002 Sampling Event for the Lower Gualala Estuary.

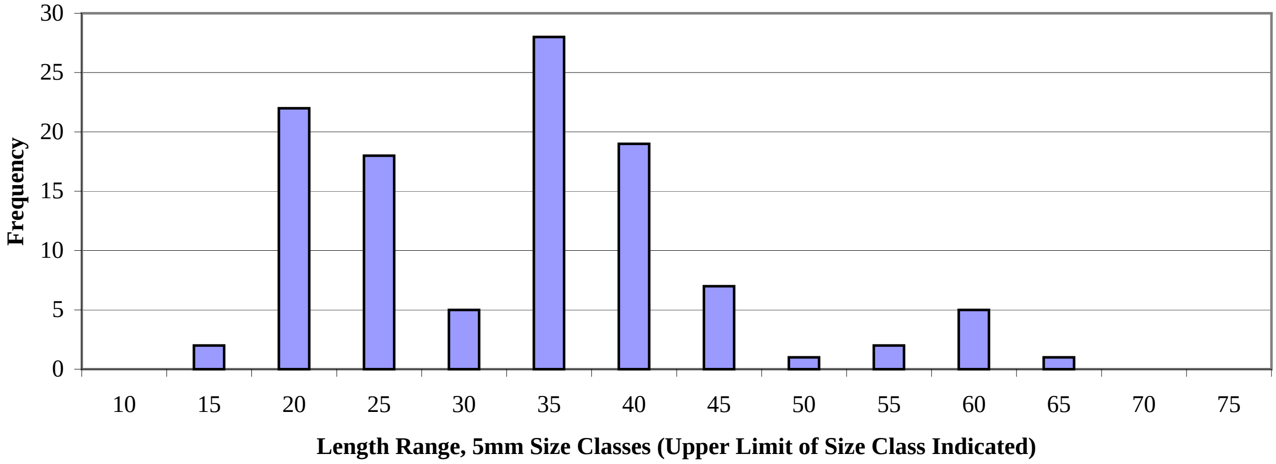
Appendix C-1.5. Three-Spine Stickleback Length Frequency during July 2002 Sampling Event for the Middle Gualala Estuary.



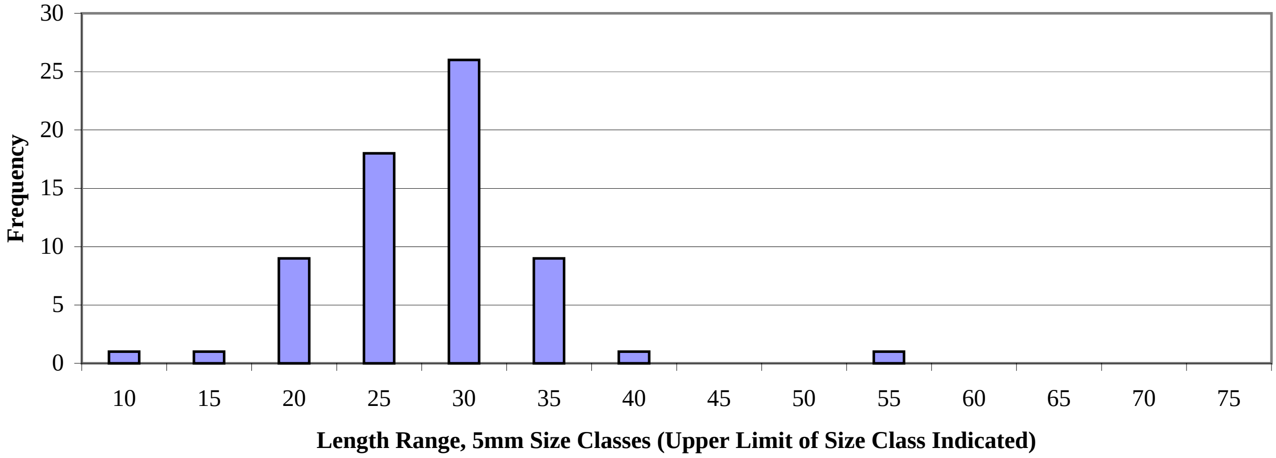
Appendix C-1.6. Three-Spine Stickleback Length Frequency during July 2002 Sampling Event for the Upper Gualala Estuary.

APPENDIX C-1

Appendix C-1.7. Three-Spine Stickleback Length Frequency during August 2002 Sampling Events for the Lower Gualala Estuary.



Appendix C-1.8. Three-Spine Stickleback Length Frequency during August 2002 Sampling Events for the Middle Gualala Estuary.

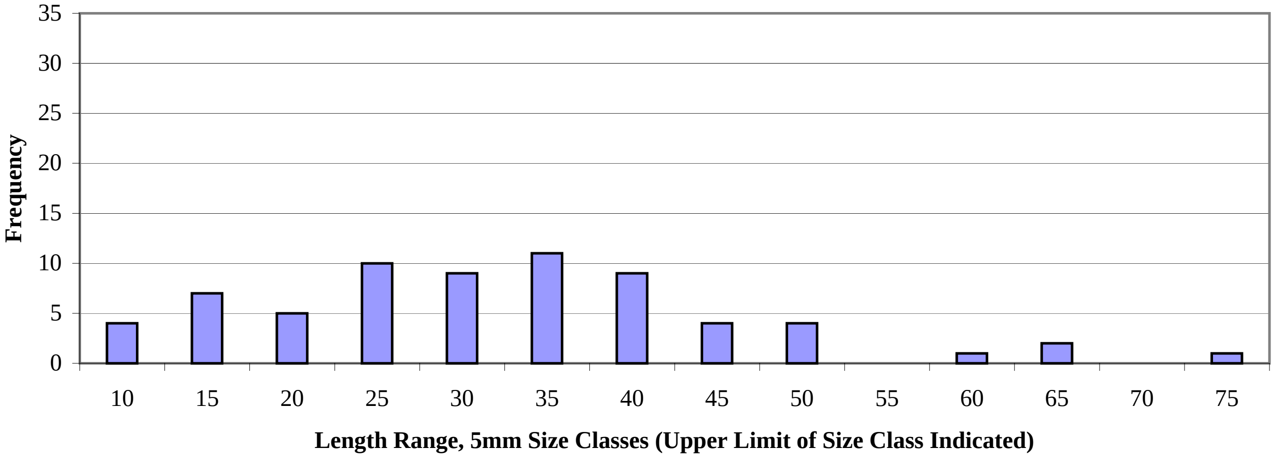


Appendix C-1.9. Three-Spine Stickleback Length Frequency during August 2002 Sampling Events for the Upper Gualala Estuary.

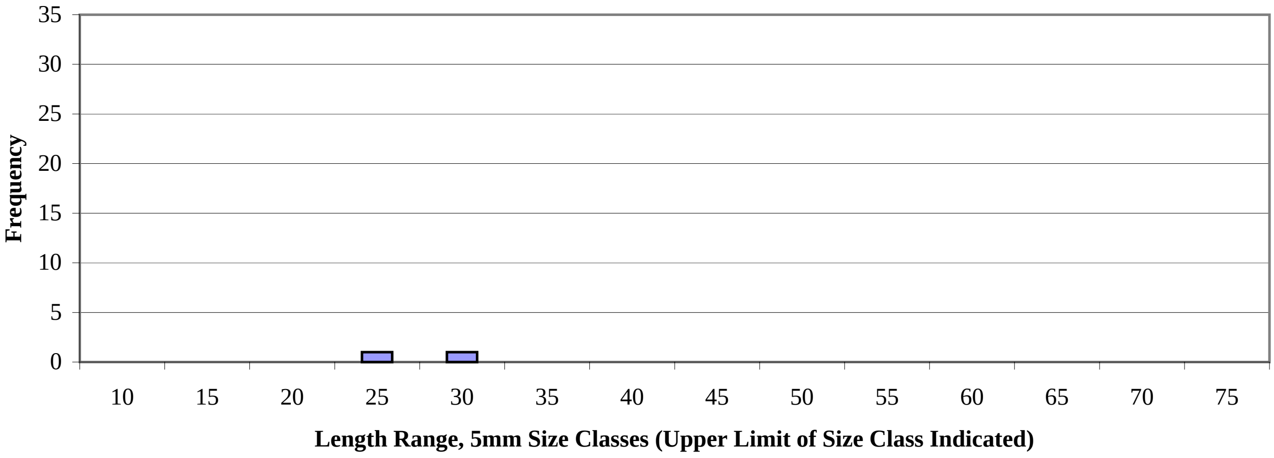
APPENDIX C-1

Appendix C-1.10. Three-Spine Stickleback Length Frequency during September 2002 Sampling Events for the Lower Gualala Estuary.

Appendix C-1.11. Three-Spine Stickleback Length Frequency during September 2002 Sampling Events for the Middle Gualala Estuary.



Appendix C-1.12. Three-Spine Stickleback Length Frequency during September 2002 Sampling Events for the Upper Gualala Estuary.



Appendix C-1.13. Three-Spine Stickleback Length Frequency during October-November 2002 Sampling Events for the Lower Gualala Estuary.

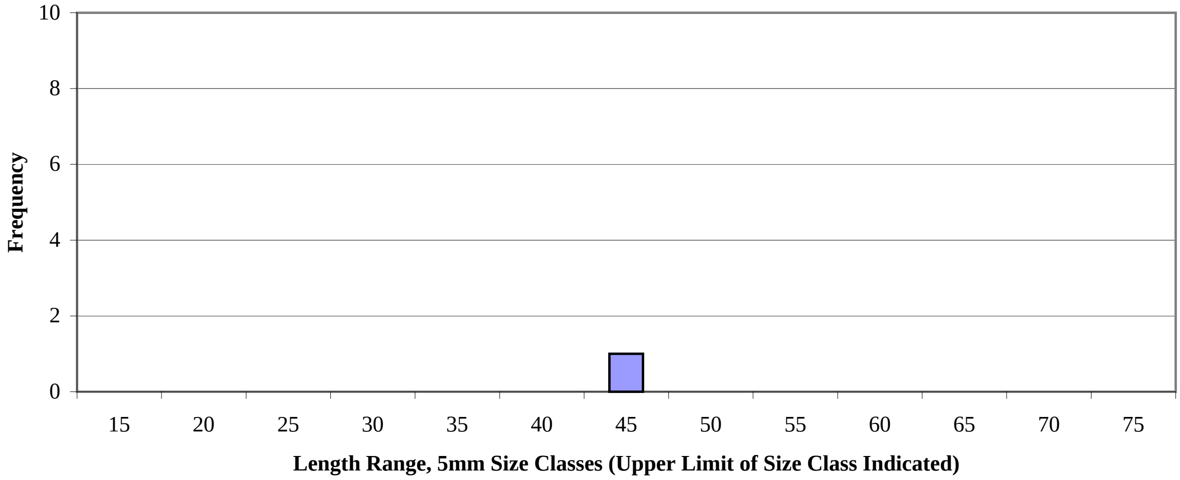
Appendix C-1.14. Three-Spine Stickleback Length Frequency during October-November 2002 Sampling Events for the Middle Gualala Estuary.

Appendix C-1.15. Three-Spine Stickleback Length Frequency during October-November 2002 Sampling Events for the Upper Gualala Estuary.

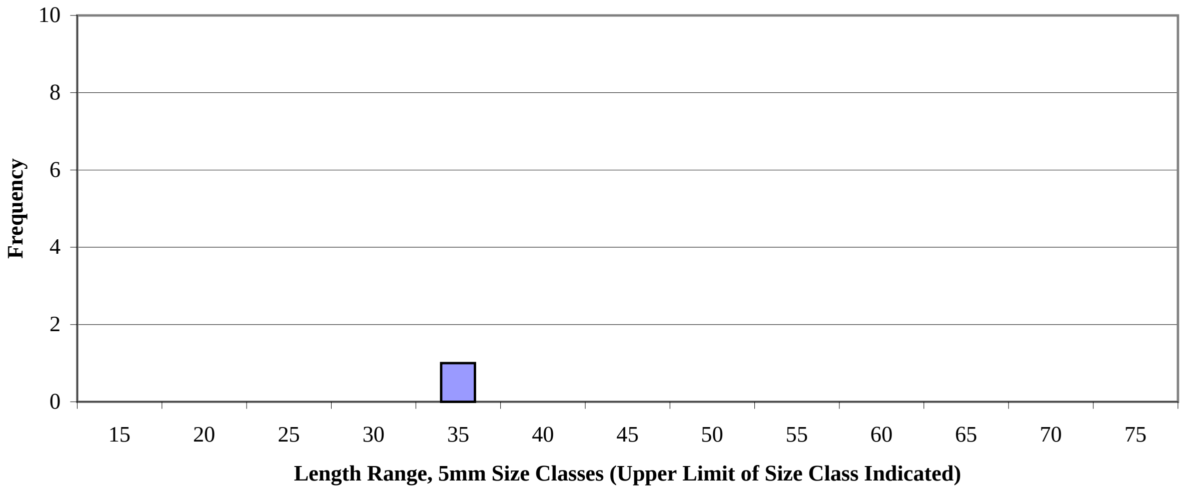
APPENDIX C-1

Appendix C-1.16. Three-Spine Stickleback Length Frequency during February 2003 Sampling Event for the Lower Gualala Estuary.

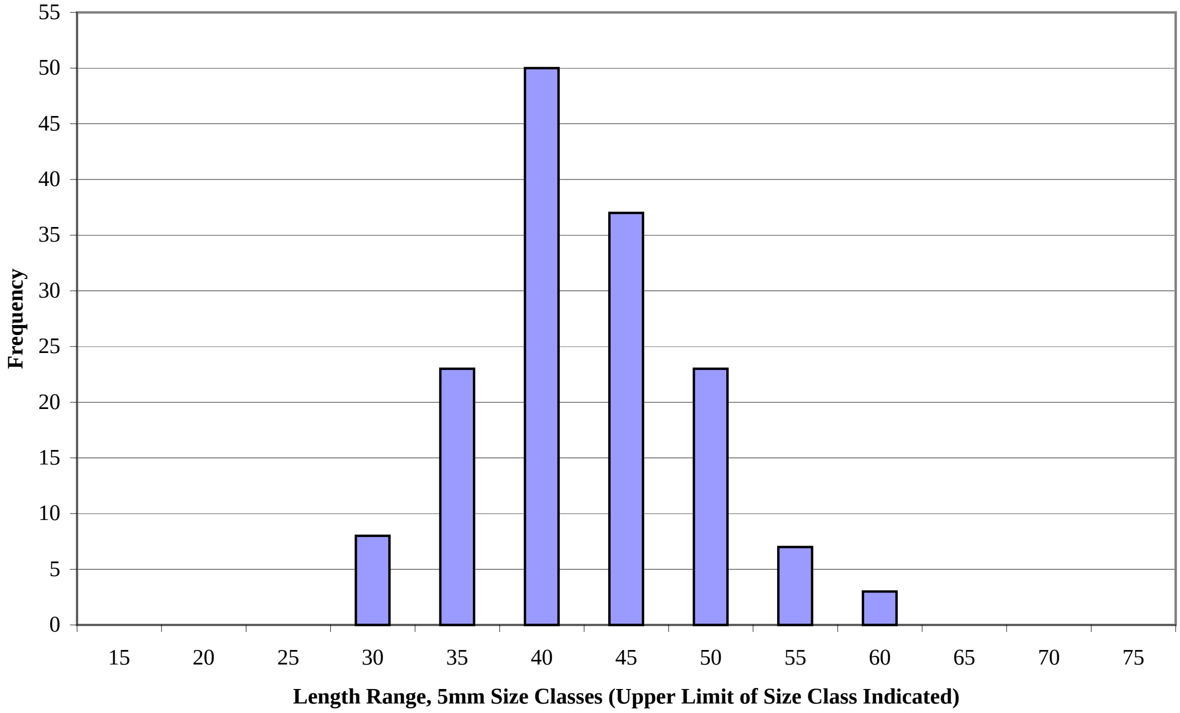
Appendix C-1.17. Three-Spine Stickleback Length Frequency during February 2003 Sampling Event for the Middle Gualala Estuary.



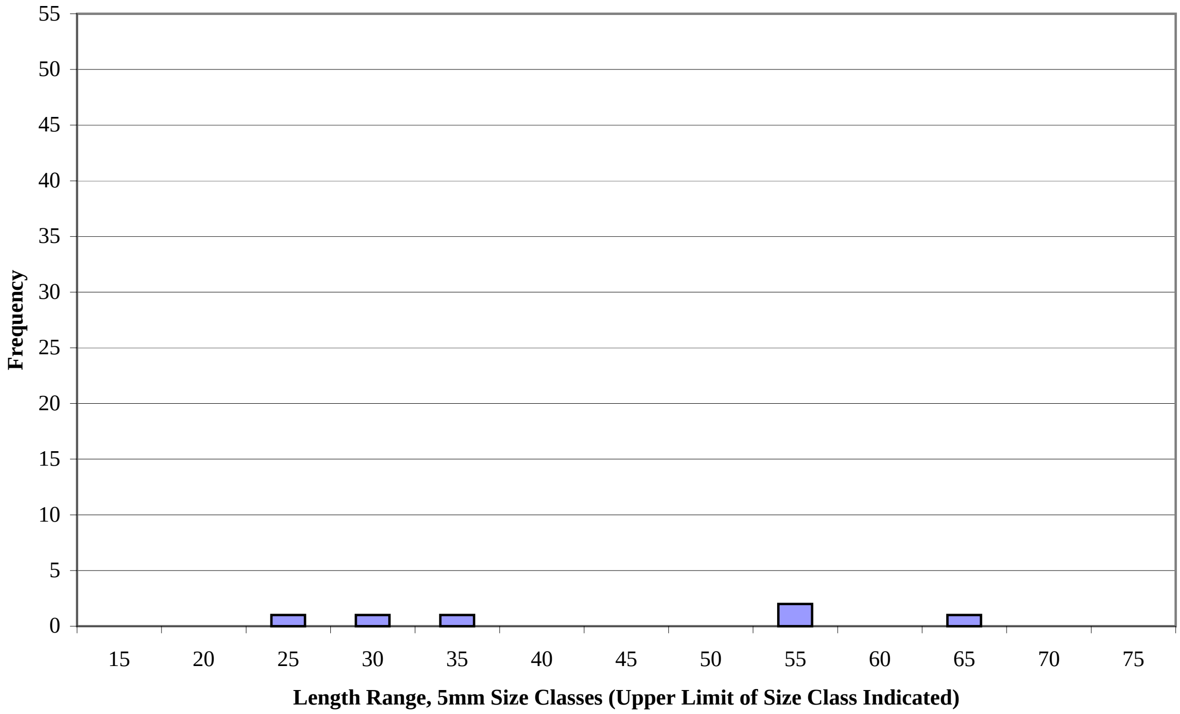
Appendix C-1.18. Three-Spine Stickleback Length Frequency during February 2003 Sampling Event for the Upper Gualala Estuary.



Appendix C-1.19. Three-Spine Stickleback Length Frequency during May 2003 Sampling Event for the Lower Gualala Estuary.

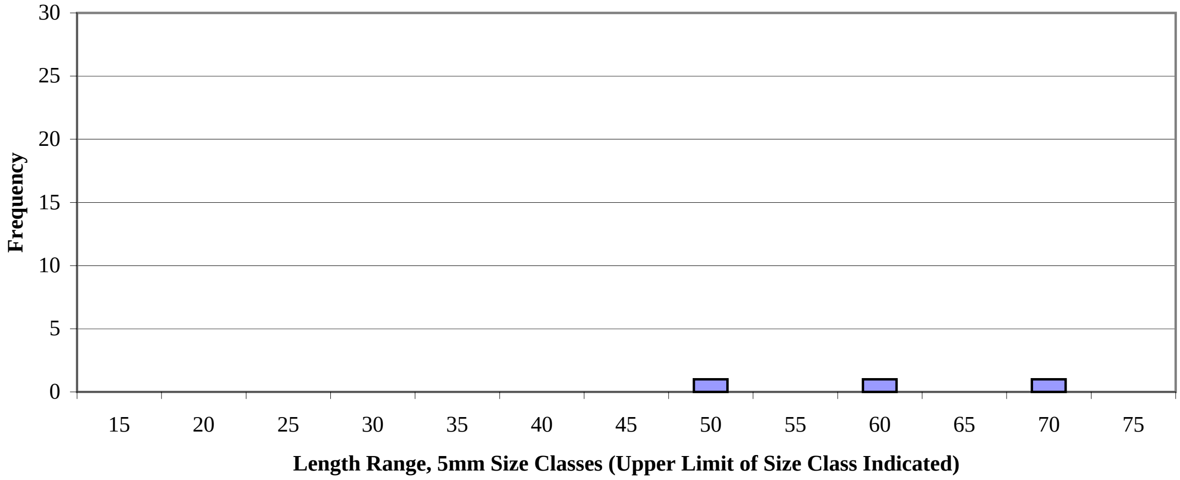


Appendix C-1.20. Three-Spine Stickleback Length Frequency during May 2003 Sampling Event for the Middle Gualala Estuary.

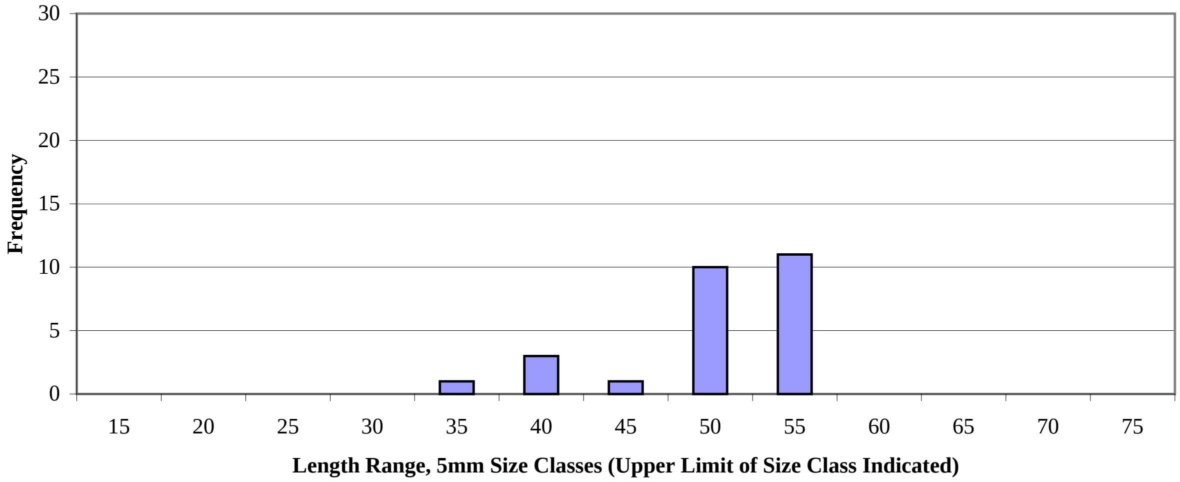


Appendix C-1.21. Three-Spine Stickleback Length Frequency during June 2003 Sampling Event for the Lower Gualala Estuary.

Appendix C-1.22. Three-Spine Stickleback Length Frequency during June 2003 Sampling Event for the Middle Gualala Estuary.

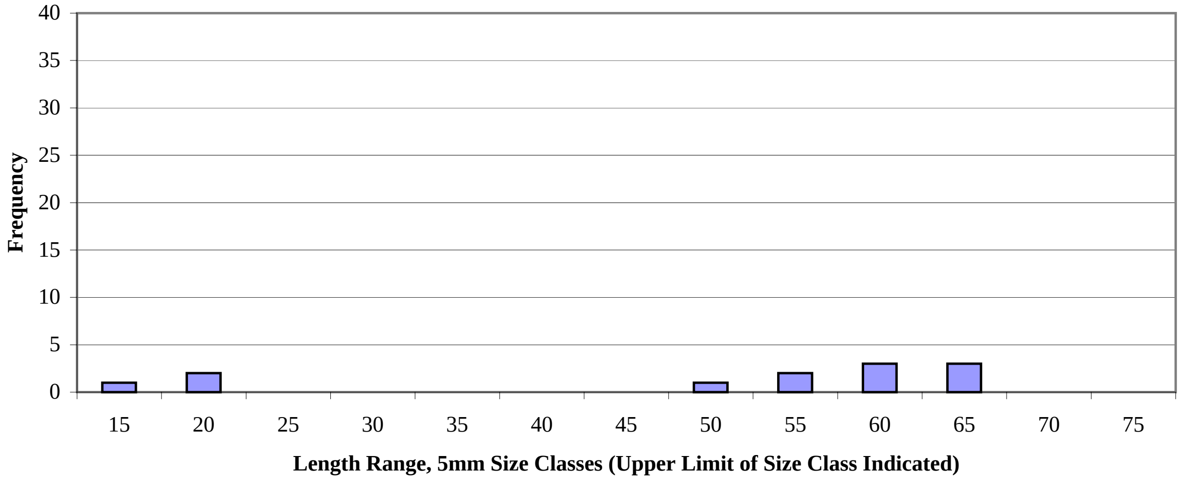


Appendix C-1.23. Three-Spine Stickleback Length Frequency during June 2003 Sampling Event for the Upper Gualala Estuary.

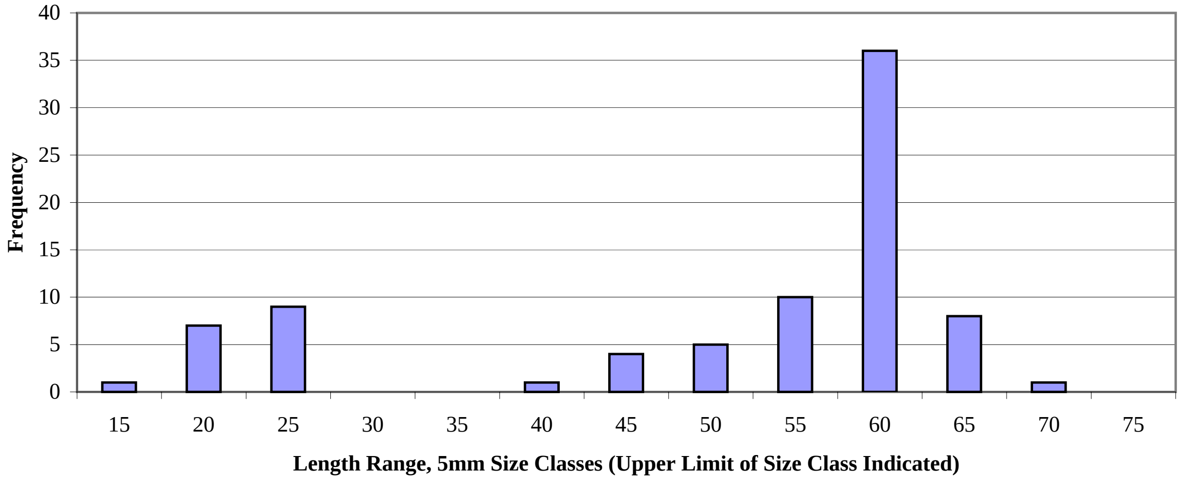


APPENDIX C-1

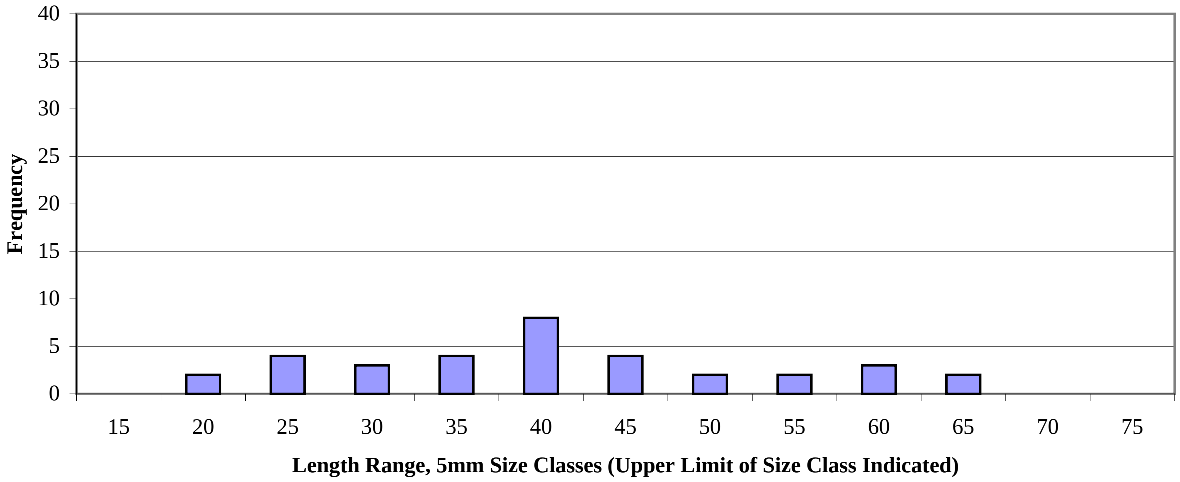
Appendix C-1.24. Three-Spine Stickleback Length Frequency during July 2003 Sampling Event for the Lower Gualala Estuary.



Appendix C-1.25. Three-Spine Stickleback Length Frequency during July 2003 Sampling Event for the Middle Gualala Estuary.

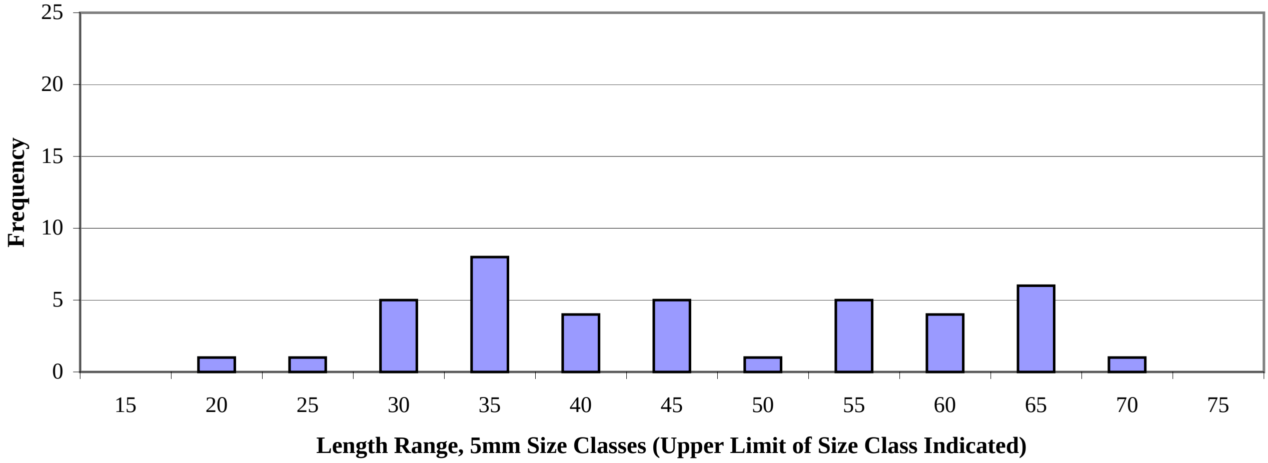


Appendix C-1.26. Three-Spine Stickleback Length Frequency during July 2003 Sampling Event for the Upper Gualala Estuary.



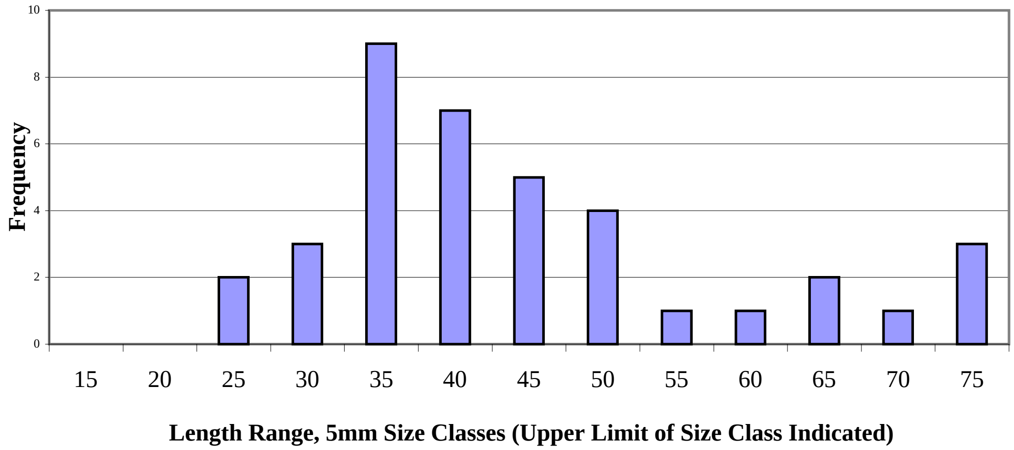
Appendix C-1.27. Three-Spine Stickleback Length Frequency during August 2003 Sampling Event for the Lower Gualala Estuary.

Appendix C-1.28. Three-Spine Stickleback Length Frequency during August 2003 Sampling Event for the Upper Gualala Estuary.



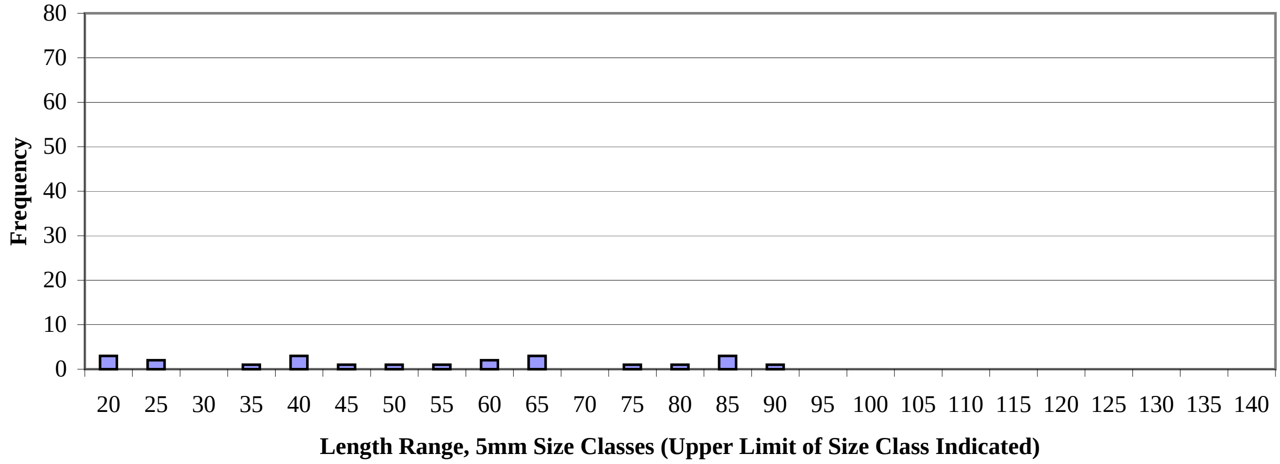
Appendix C-1.29. Three-Spine Stickleback Length Frequency during September 2003 Sampling Event for the Lower Gualala Estuary.

Appendix C-1.30. Three-Spine Stickleback Length Frequency during October 2003 Sampling Event for the Lower Gualala Estuary.



APPENDIX C-2

Appendix C-2.1. Pacific Staghorn Sculpin Length Frequency during June 2002 Sampling Event for the Lower Gualala Estuary.



Appendix C-2.2. Pacific Staghorn Sculpin Length Frequency during July 2002 Sampling Event for the Lower Gualala Estuary.

Appendix C-2.3 Pacific Staghorn Sculpin Length Frequency during July 2002 Sampling Event for the Middle Gualala Estuary.

APPENDIX C-2

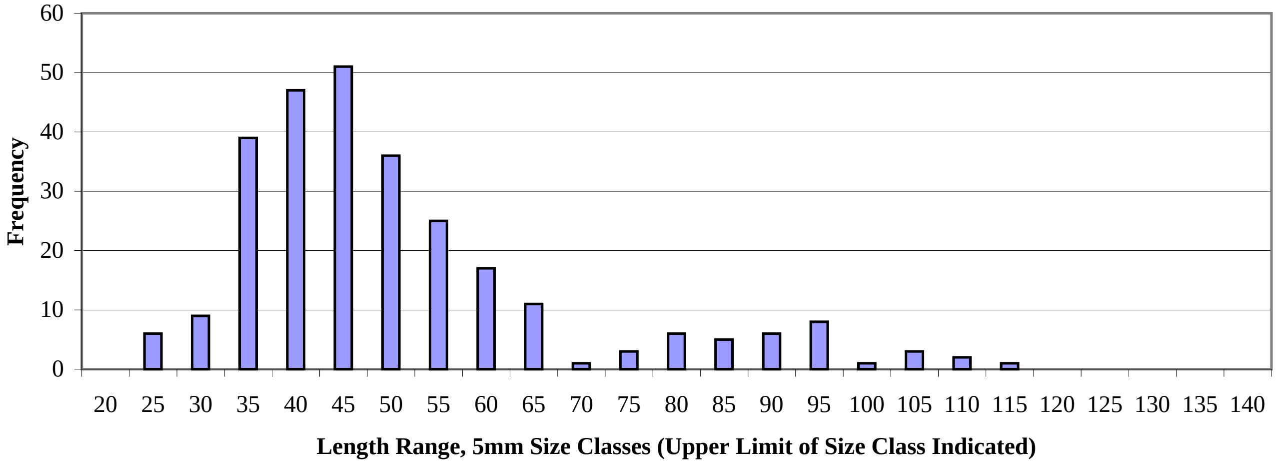
Appendix C-2.4. Pacific Staghorn Sculpin Length Frequency during August 2002 Sampling Events for the Lower Gualala Estuary.

Appendix C-2.5. Pacific Staghorn Sculpin Length Frequency during August 2002 Sampling Events for the Middle Gualala Estuary.

Appendix C-2.6. Pacific Staghorn Sculpin Length Frequency during August 2002 Sampling Events for the Upper Gualala Estuary.

APPENDIX C-2

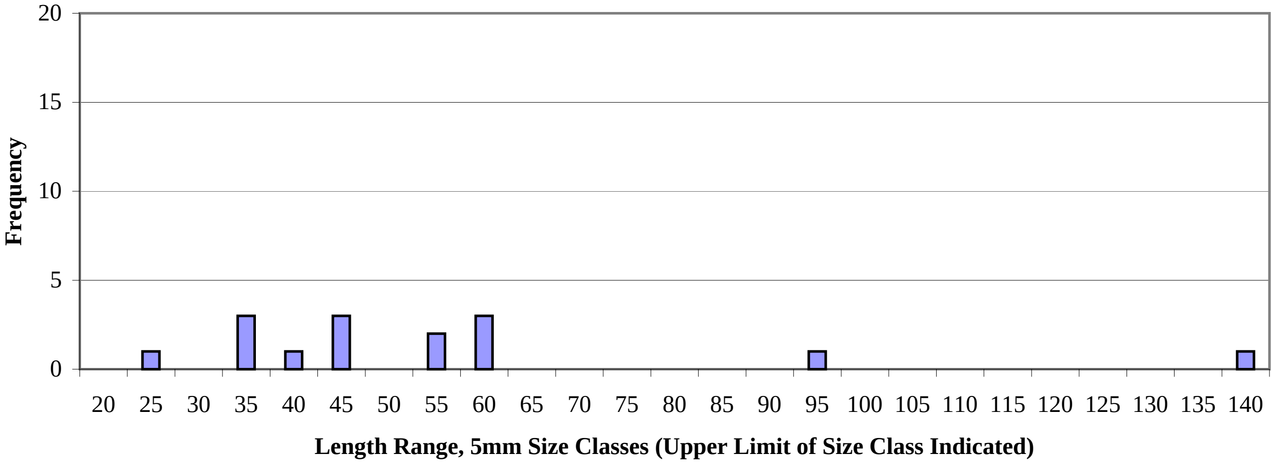
Appendix C-2.7. Pacific Staghorn Sculpin Length Frequency during September 2002 Sampling Events for the Lower Gualala Estuary.



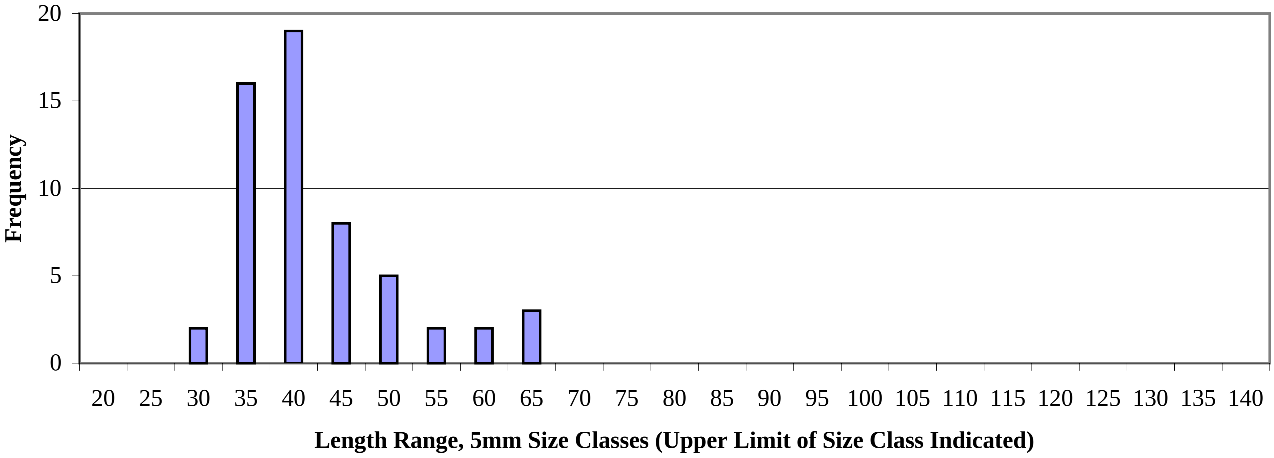
Appendix C-2.8. Pacific Staghorn Sculpin Length Frequency during September 2002 Sampling Events for the Middle Gualala Estuary.

Appendix C-2.9. Pacific Staghorn Sculpin Length Frequency during September 2002 Sampling Events for the Upper Gualala Estuary.

Appendix C-2.10. Pacific Staghorn Sculpin Length Frequency during October-November 2002 Sampling Events for the Lower Gualala Estuary.



Appendix C-2.11. Pacific Staghorn Sculpin Length Frequency during October-November 2002 Sampling Events for the Middle Gualala Estuary.

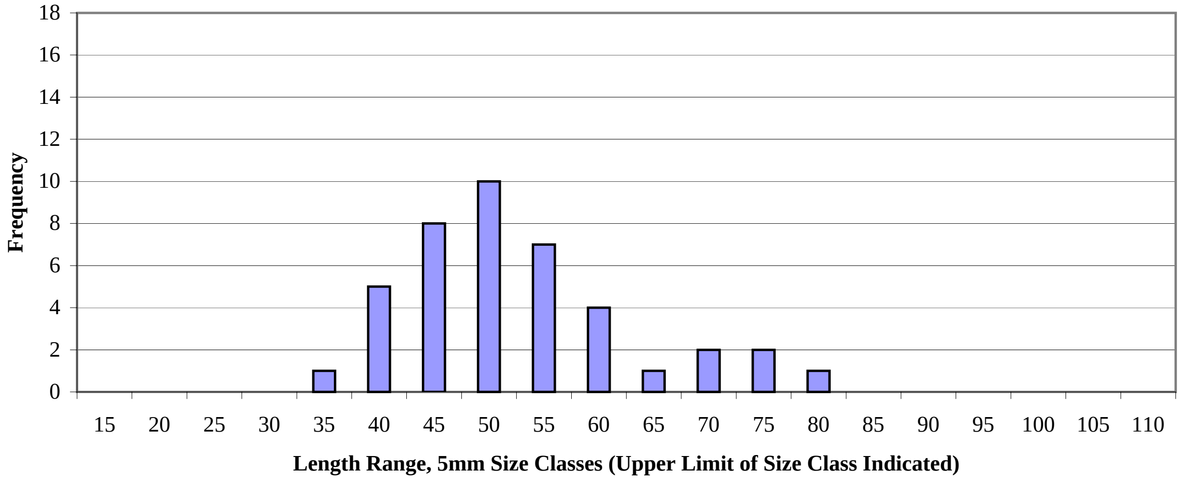


Appendix C-2.12. Pacific Staghorn Sculpin Length Frequency during October-November 2002 Sampling Events for the Upper Gualala Estuary.

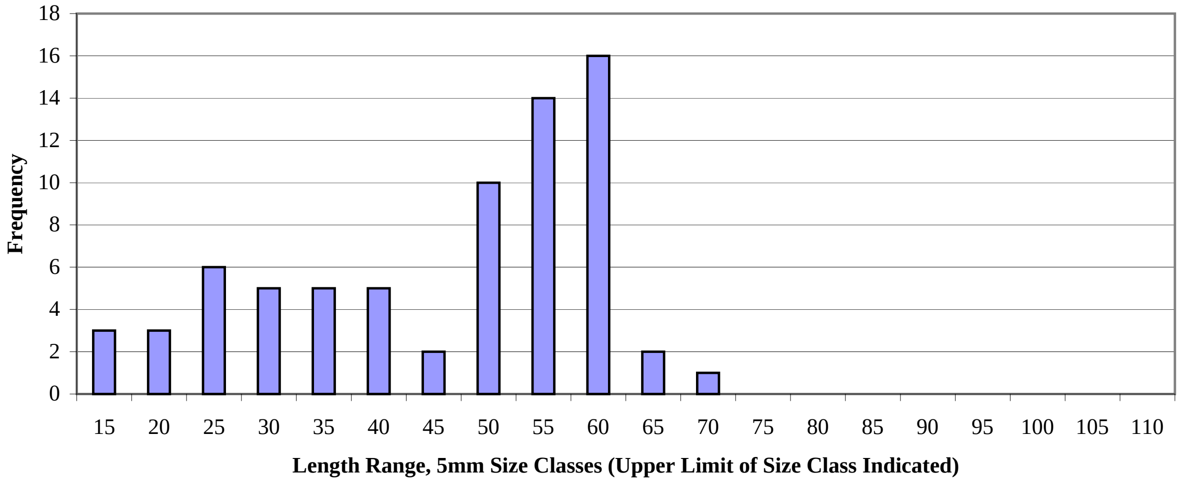
APPENDIX C-2

Appendix C-2.13. Pacific Staghorn Sculpin Length Frequency during February 2003 Sampling Event for the Lower Gualala Estuary.

Appendix C-2.14. Pacific Staghorn Sculpin Length Frequency during May 2003 Sampling Event for the Lower Gualala Estuary.

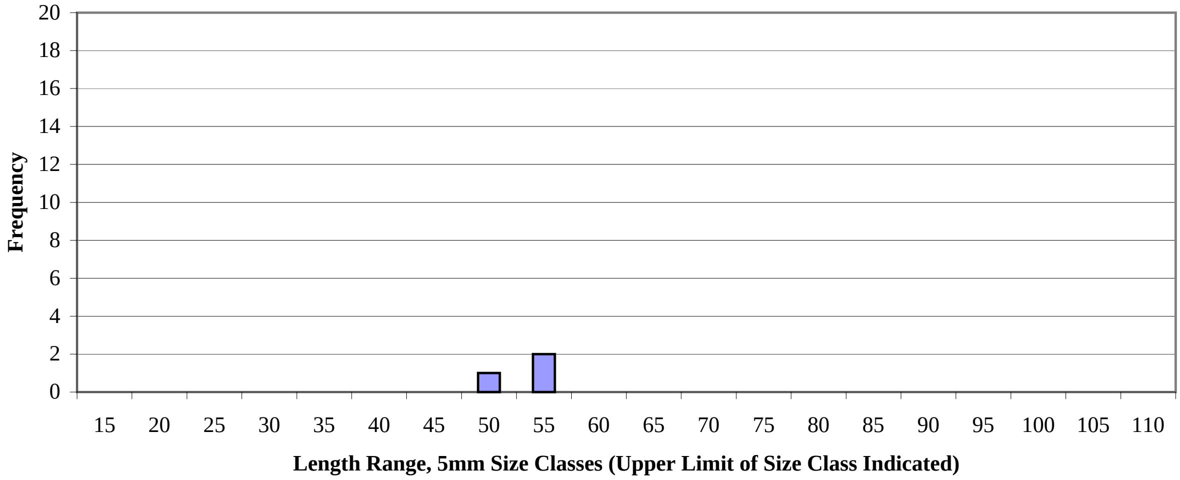


Appendix C-2.15. Pacific Staghorn Sculpin Length Frequency during June 2003 Sampling Event for the Lower Gualala Estuary.

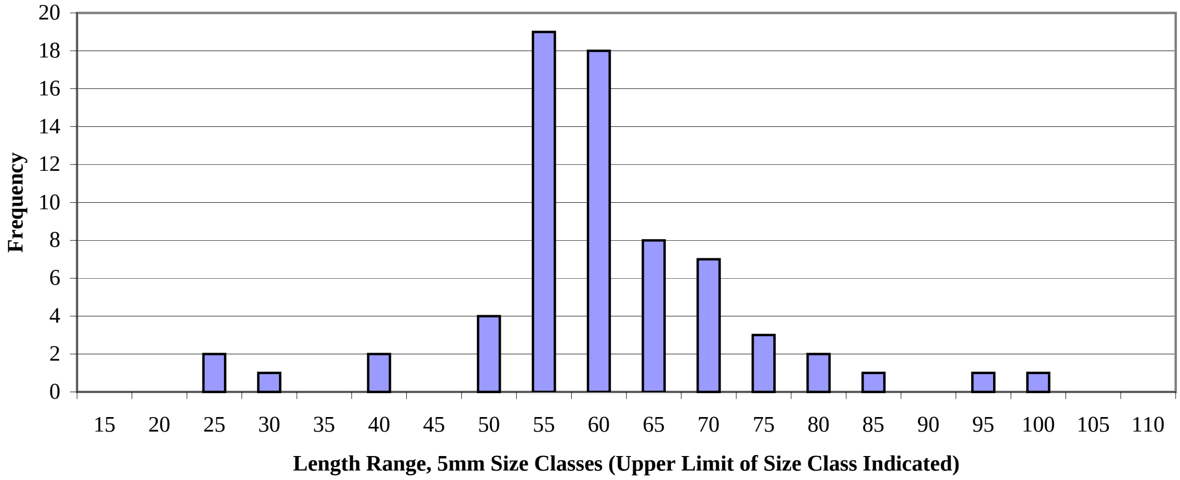


APPENDIX C-2

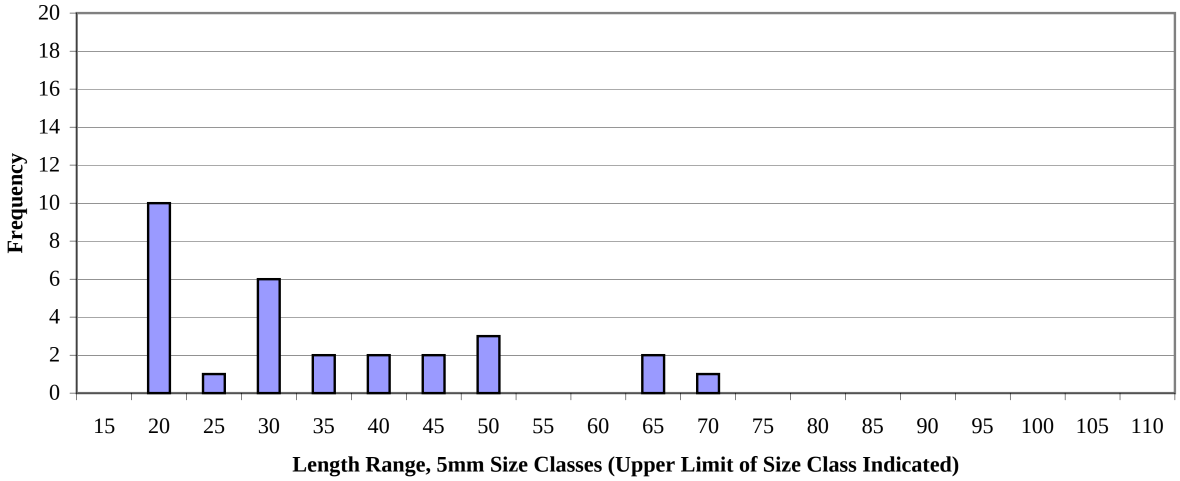
Appendix C-2.16. Pacific Staghorn Sculpin Length Frequency during June 2003 Sampling Event for the Middle Gualala Estuary.



Appendix C-2.17. Pacific Staghorn Sculpin Length Frequency during June 2003 Sampling Event for the Upper Gualala Estuary.



Appendix C-2.18. Pacific Staghorn Sculpin Length Frequency during July 2003 Sampling Event for the Lower Gualala Estuary.



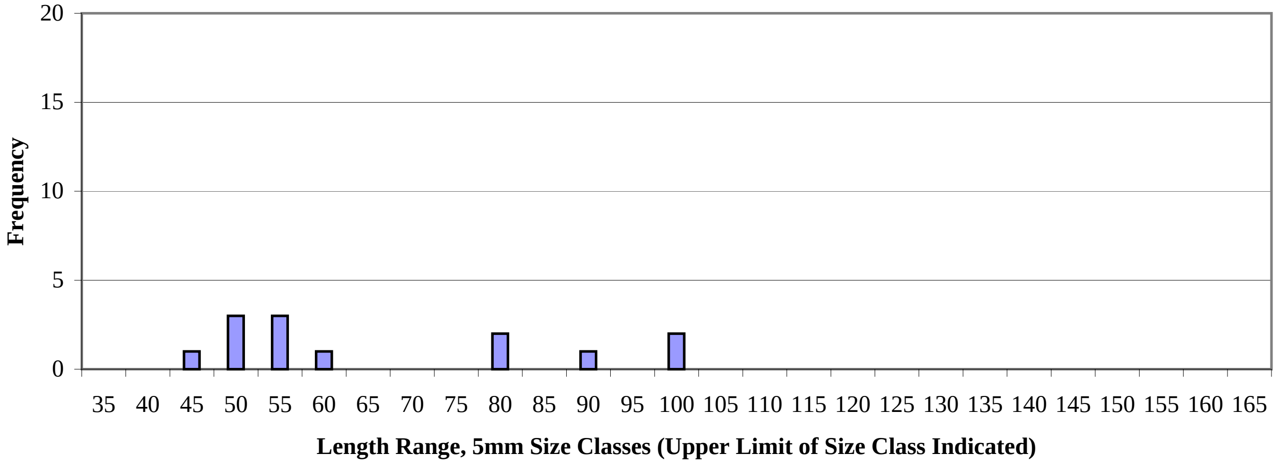
Appendix C-2.19. Pacific Staghorn Sculpin Length Frequency during July 2003 Sampling Event for the Middle Gualala Estuary.

Appendix C-2.20. Pacific Staghorn Sculpin Length Frequency during August 2003 Sampling Event for the Lower Gualala Estuary.

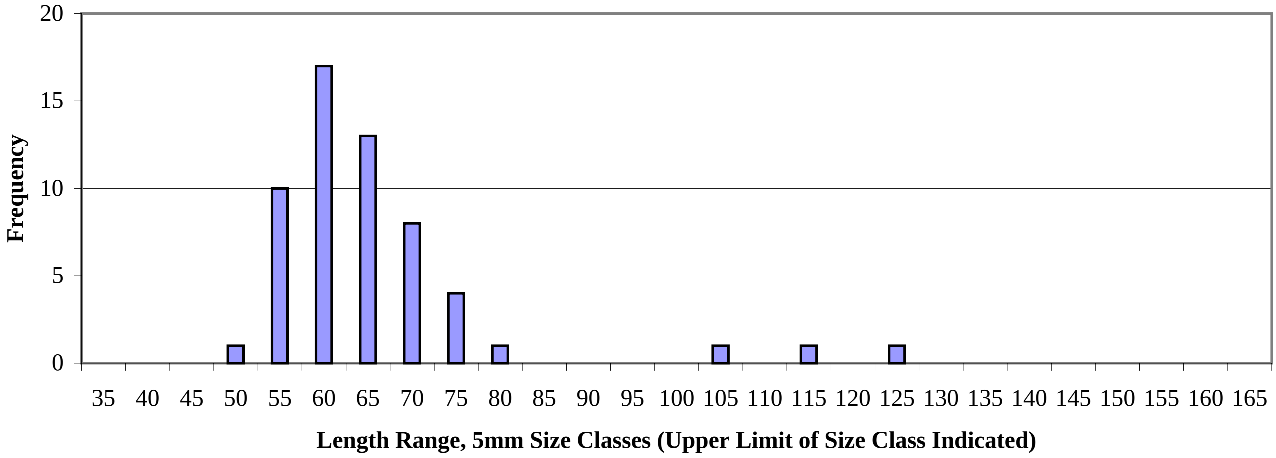
Appendix C-2.21. Pacific Staghorn Sculpin Length Frequency during September 2003 Sampling Event for the Lower Gualala Estuary.

APPENDIX C-3

Appendix C-3.1. Starry Flounder Length Frequency during June 2002 Sampling Event for the Lower Gualala Estuary.



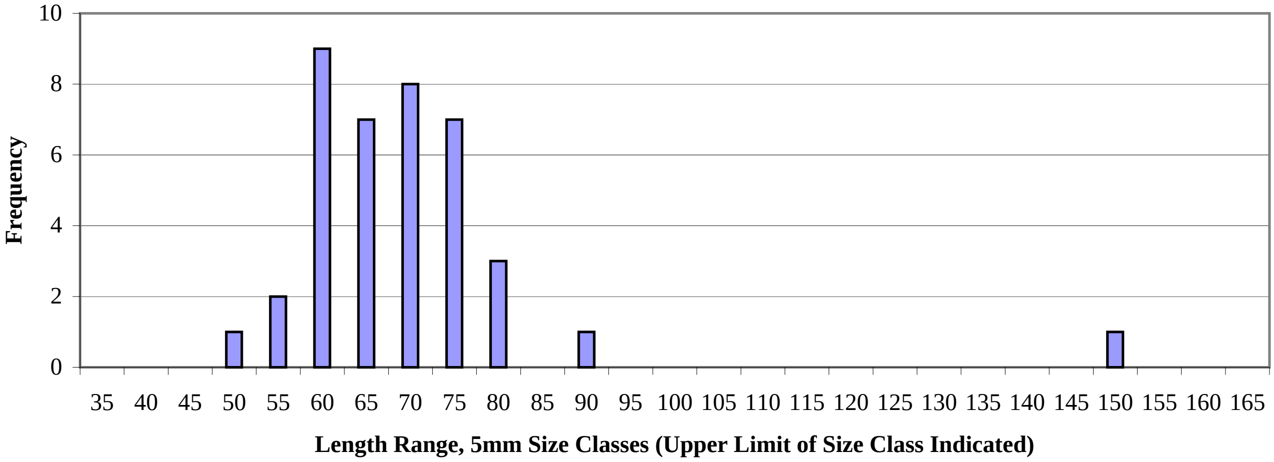
Appendix C-3.2. Starry Flounder Length Frequency during July 2002 Sampling Event for the Lower Gualala Estuary.



Appendix C-3.3. Starry Flounder Length Frequency during July 2002 Sampling Event for the Middle Gualala Estuary.

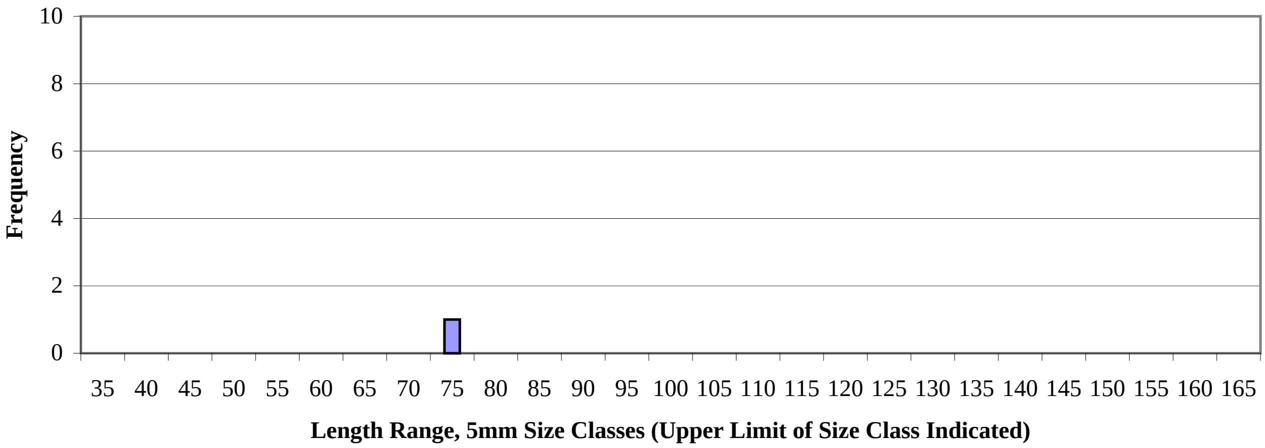
APPENDIX C-3

Appendix C-3.4. Starry Flounder Length Frequency during August 2002 Sampling Events for the Lower Gualala Estuary.



Appendix C-3.5. Starry Flounder Length Frequency during August 2002 Sampling Events for the Middle Gualala Estuary.

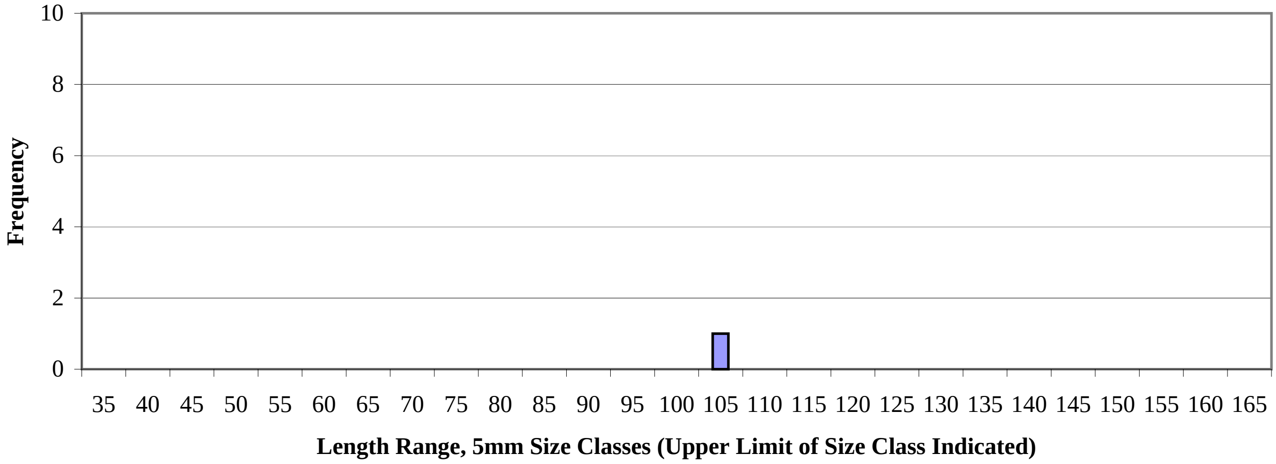
Appendix C-3.6. Starry Flounder Length Frequency during August 2002 Sampling Events for the Upper Gualala Estuary.



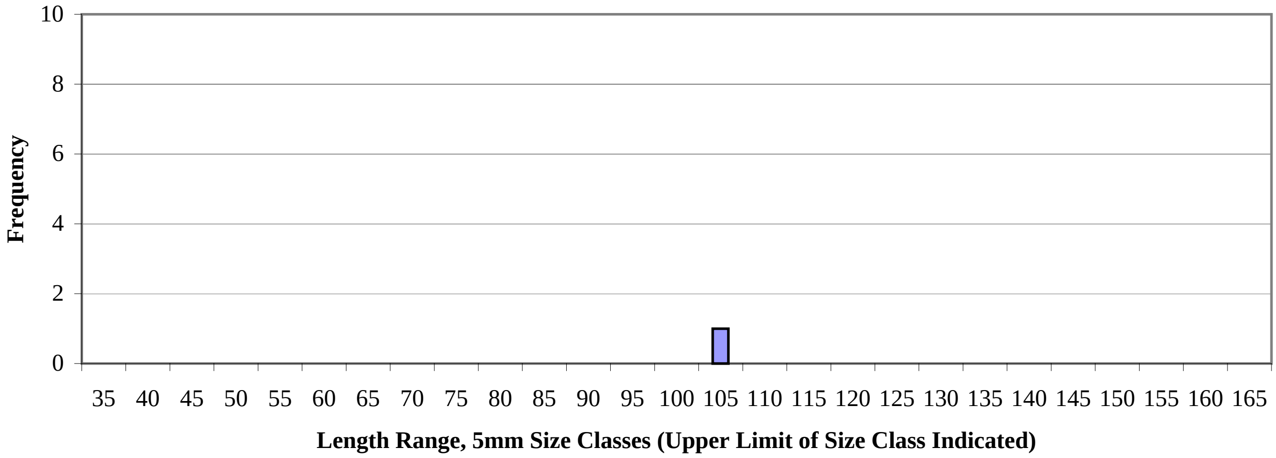
Appendix C-3.7. Starry Flounder Length Frequency during September 2002 Sampling Events for the Lower Gualala Estuary.

APPENDIX C-3

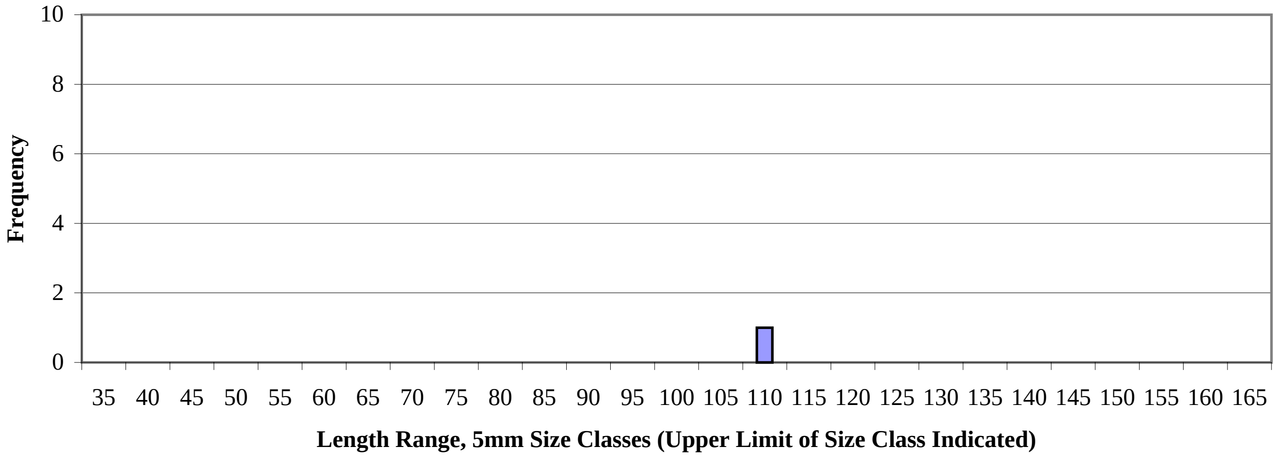
Appeindix C-3.8. Starry Flounder Length Frequency during October-November 2002 Sampling Events for the Lower Gualala Estuary.



Appendix C-3.9. Starry Flounder Length Frequency during October-November 2002 Sampling Events for the Middle Gualala Estuary.



Appendix C-3.10. Starry Flounder Length Frequency during October-November 2002 Sampling Events for the Upper Gualala Estuary.

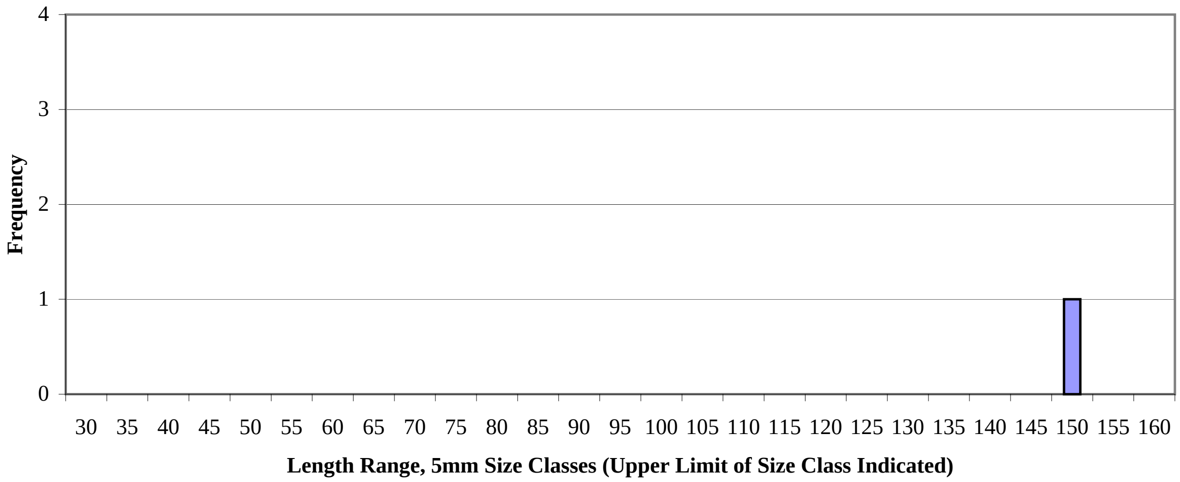


APPENDIX C-3

Appendix C-3.11. Starry Flounder Length Frequency during February 2003 Sampling Event for the Lower Gualala Estuary.

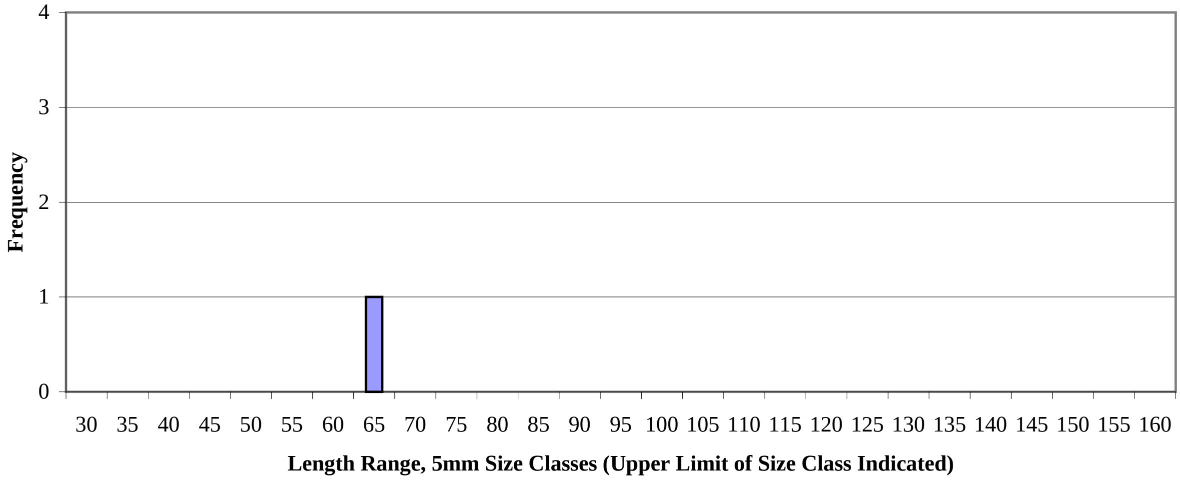
Appendix C-3.12. Starry Flounder Length Frequency during February 2003 Sampling Event for the Middle Gualala Estuary.

Appendix C-3.13. Starry Flounder Length Frequency during May 2003 Sampling Event for the Lower Gualala Estuary.



Appendix C-3.14. Starry Flounder Length Frequency during June 2003 Sampling Event for the Lower Gualala Estuary.

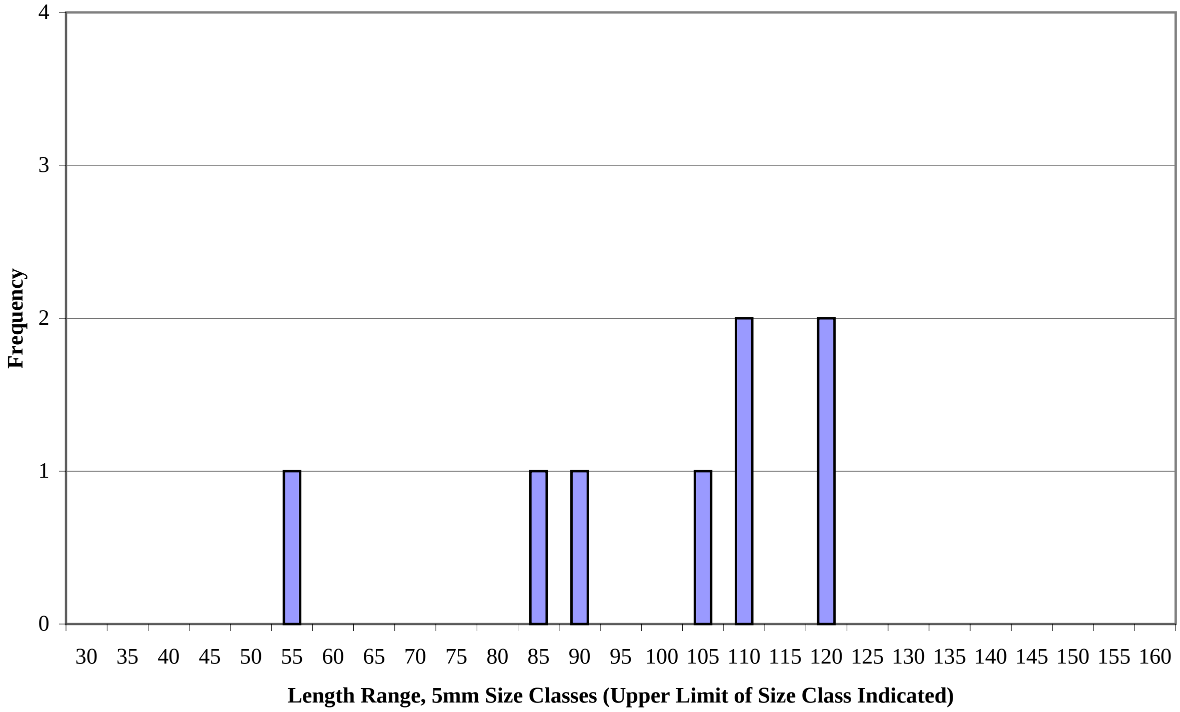
Appendix C-3.15. Starry Flounder Length Frequency during July 2003 Sampling Event for the Lower Gualala Estuary.



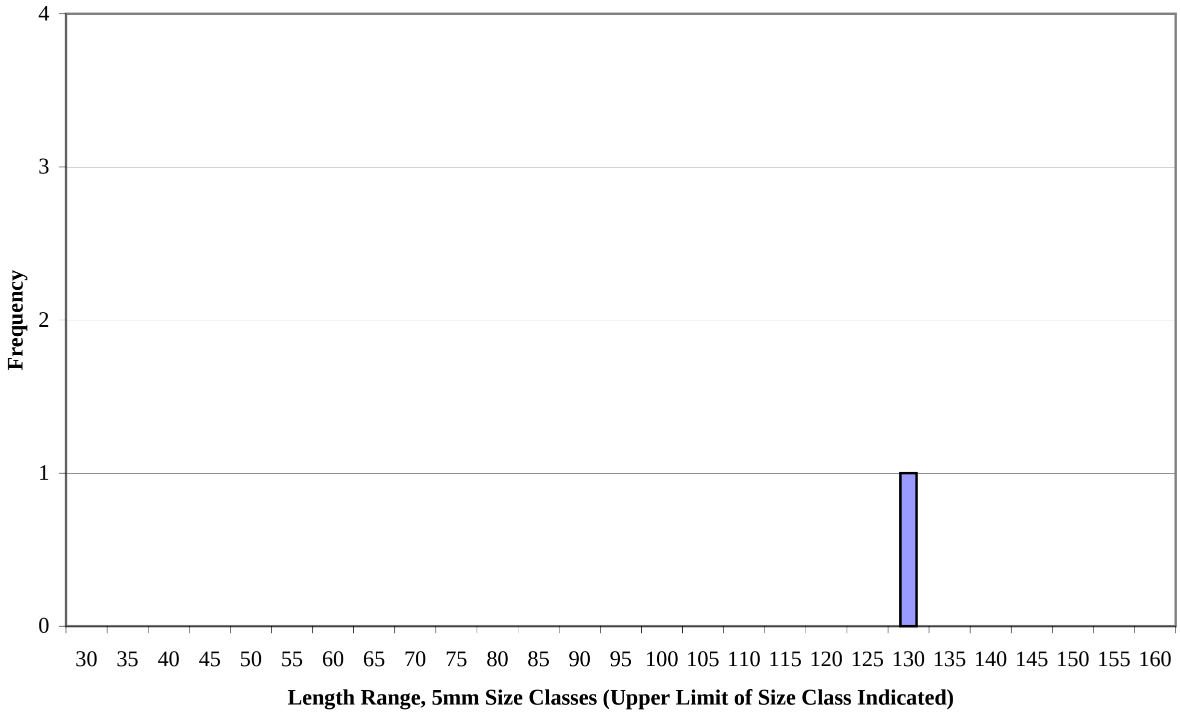
Appendix C-3.16. Starry Flounder Length Frequency during August 2003 Sampling Event for the Lower Gualala Estuary.

APPENDIX C-3

Appendix C-3.17. Starry Flounder Length Frequency during September 2003 Sampling Event for the Lower Gualala Estuary.



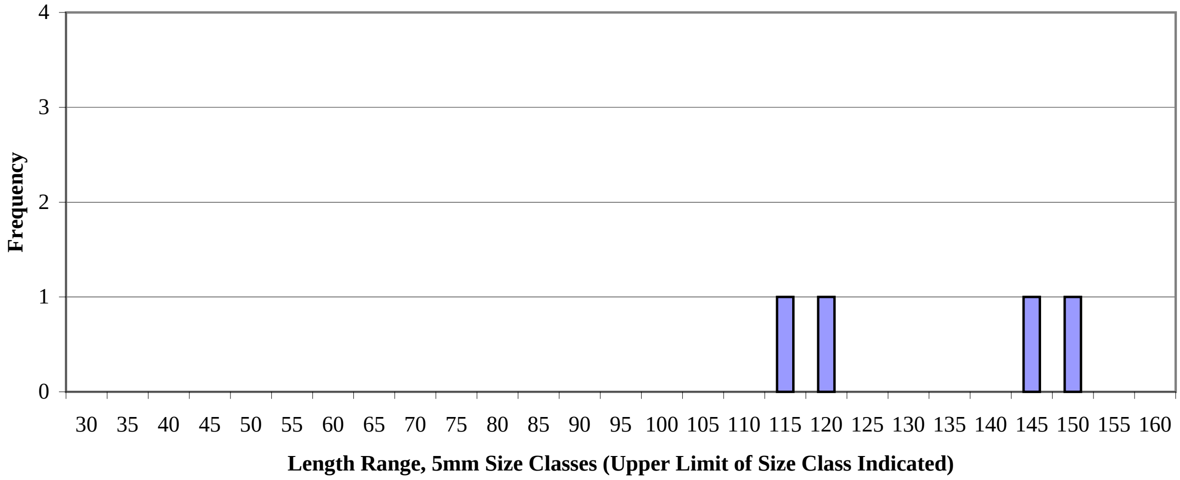
Appendix C-3.18. Starry Flounder Length Frequency during September 2003 Sampling Event for the Middle Gualala Estuary.



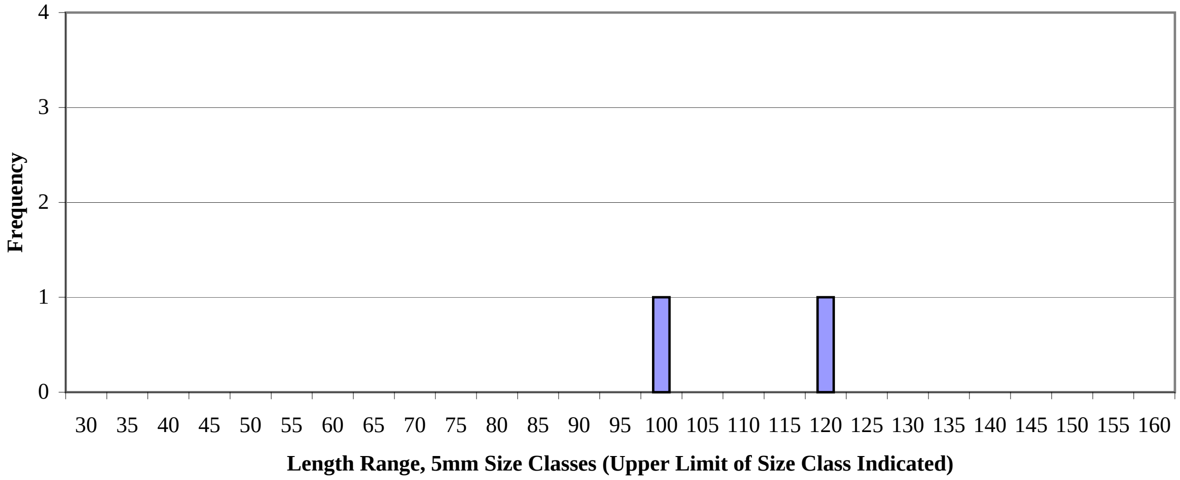
APPENDIX C-3

Appendix C-3.19. Starry Flounder Length Frequency during October 2003 Sampling Event for the Lower Gualala Estuary.

Appendix C-3.20. Starry Flounder Length Frequency during October 2003 Sampling Event for the Middle Gualala Estuary.

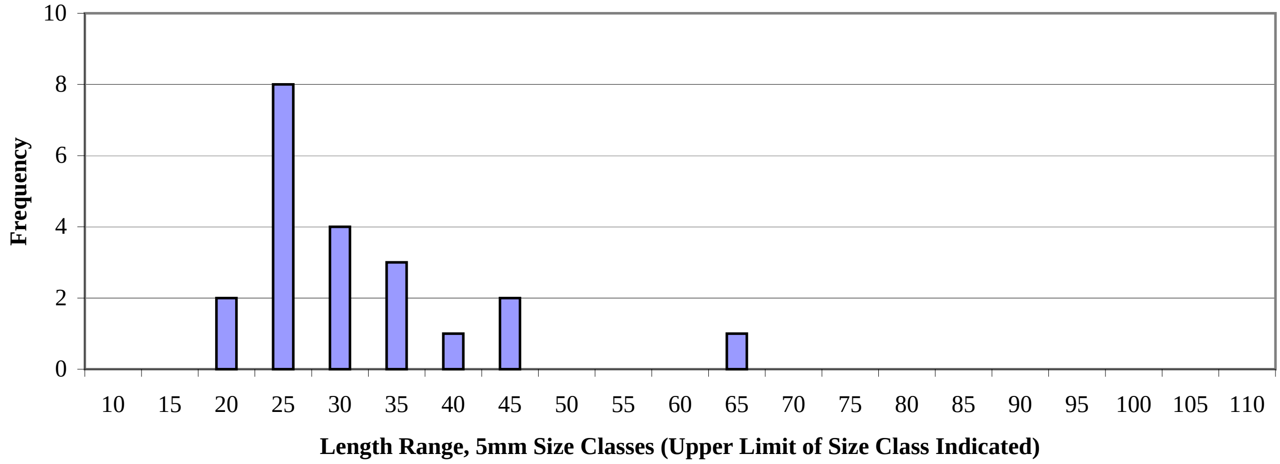


Appendix C-3.21. Starry Flounder Length Frequency during October 2003 Sampling Event for the Upper Gualala Estuary.

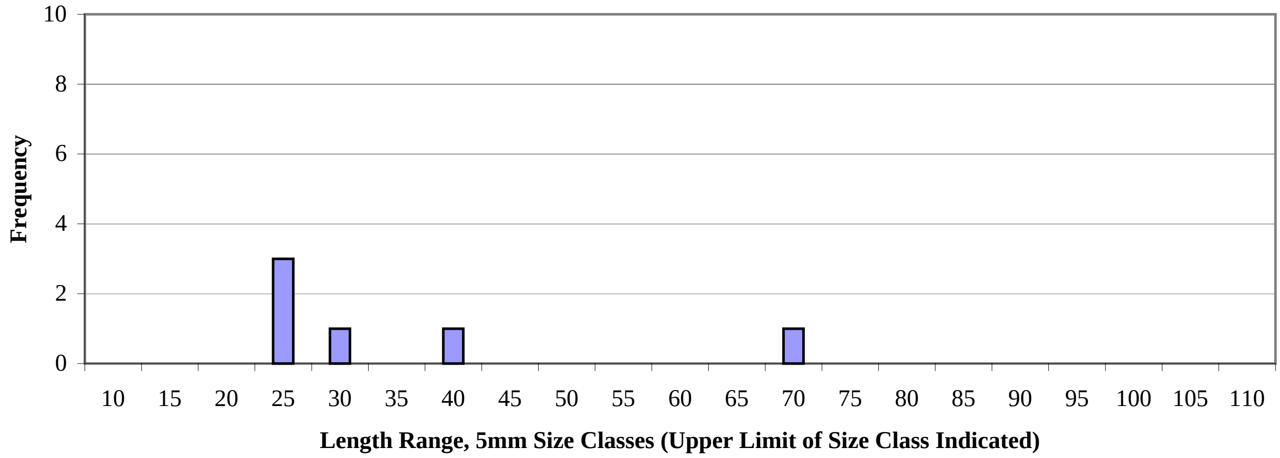


APPENDIX C-4

Appendix C-4.1. Coastrange Sculpin Length Frequency during June 2002 Sampling Event for the Lower Gualala Estuary.



Appendix C-4.2. Coastrange Sculpin Length Frequency during June 2002 Sampling Event for the Middle Gualala Estuary.

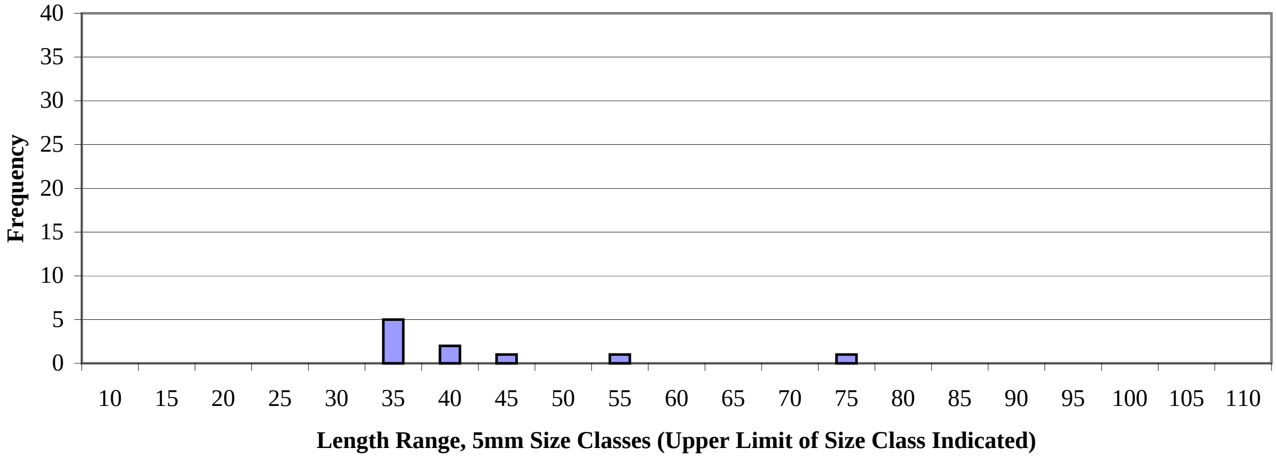


Appendix C-4.3. Coastrange Sculpin Length Frequency during June 2002 Sampling Event for the Upper Gualala Estuary.

APPENDIX C-4

Appendix C-4.4. Coastrange Sculpin Length Frequency during July 2002 Sampling Event for the Upper Gualala Estuary.

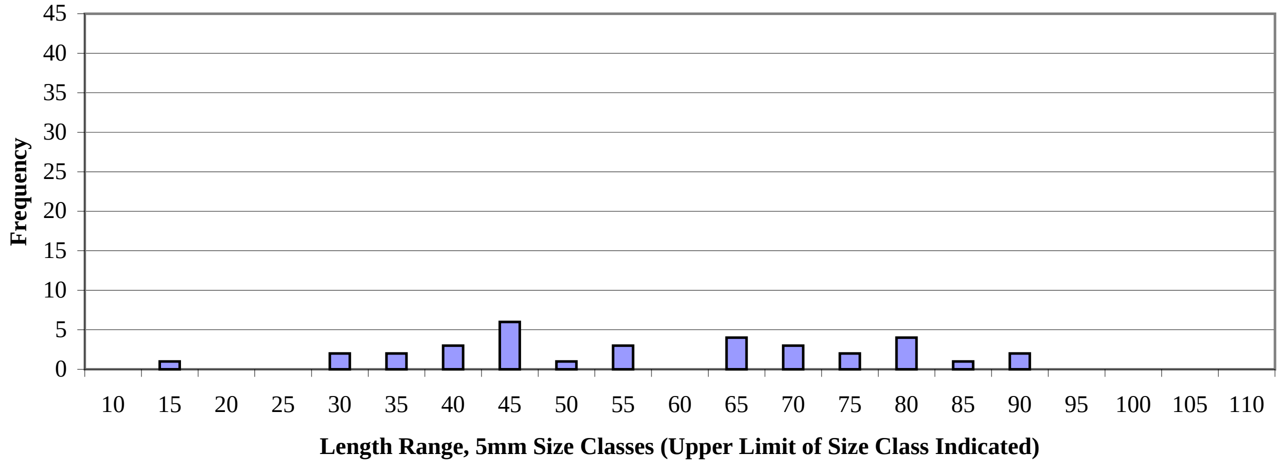
Appendix C-4.5. Coastrange Sculpin Length Frequency during August 2002 Sampling Events for the Lower Gualala Estuary.



Appendix C-4.6. Coastrange Sculpin Length Frequency during August 2002 Sampling Events for the Middle Gualala Estuary.

APPENDIX C-4

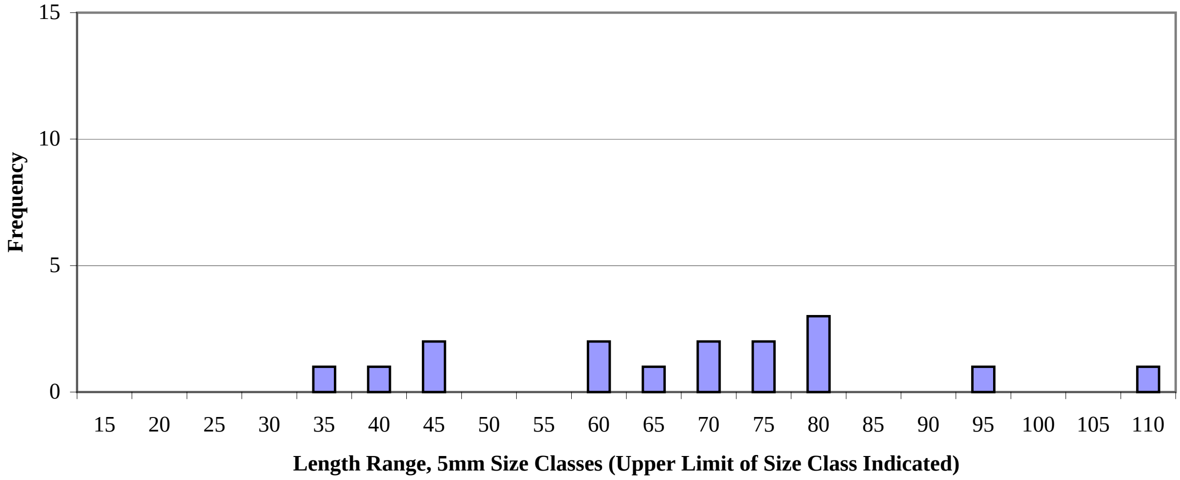
Appendix C-4.7. Coastrange Sculpin Length Frequency during August 2002 Sampling Events for the Upper Gualala Estuary.



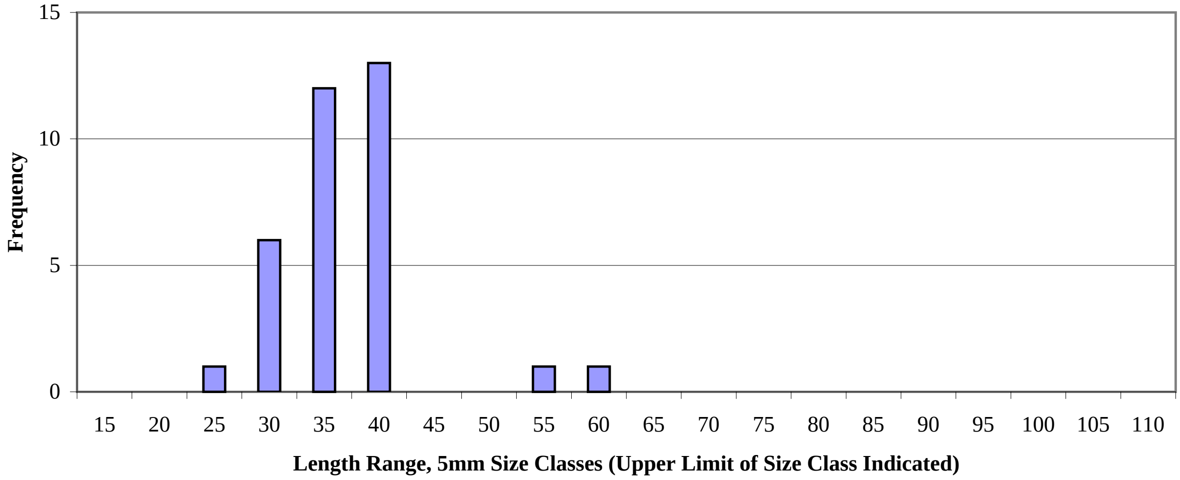
Appendix C-4.8. Coastrange Sculpin Length Frequency during September 2002 Sampling Events for the Lower Gualala Estuary.

Appendix C-4.9. Coastrange Sculpin Length Frequency during September 2002 Sampling Events for the Middle Gualala Estuary.

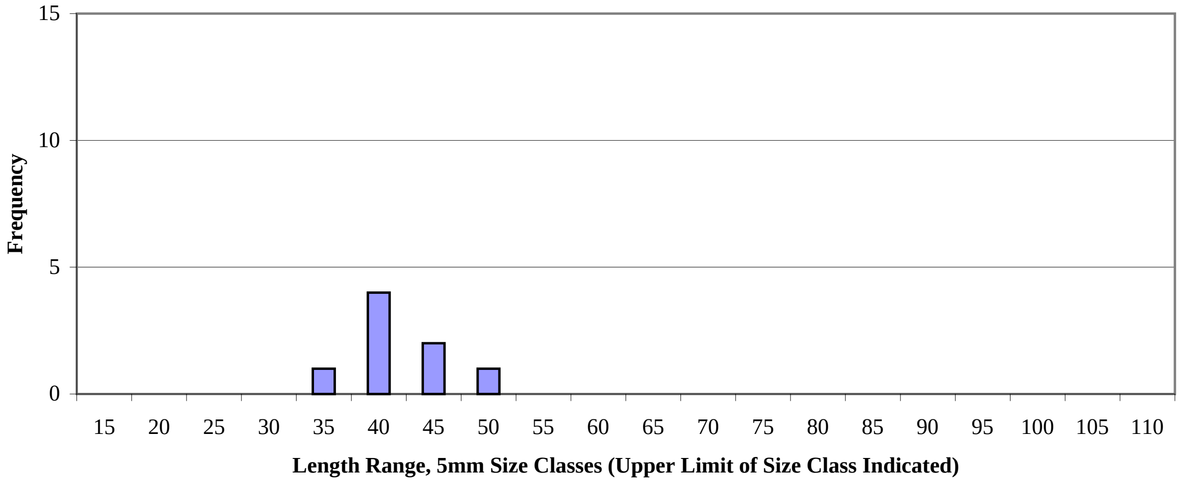
Appendix C-4.10. Coastrange Sculpin Length Frequency during February 2003 Sampling Event for the Lower Gualala Estuary.



Appendix C-4.11. Coastrange Sculpin Length Frequency during February 2003 Sampling Event for the Middle Gualala Estuary.

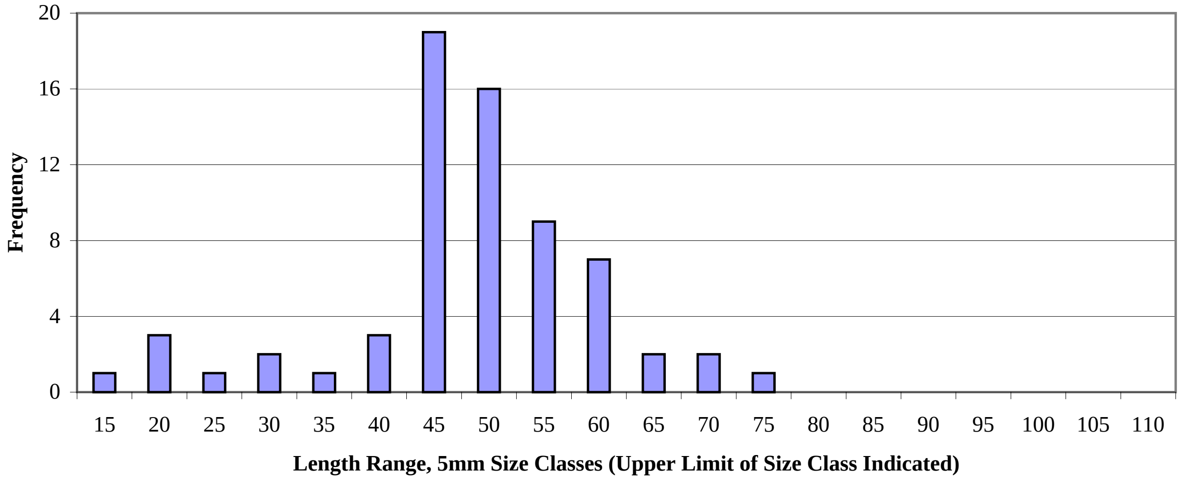


Appendix C-4.12. Coastrange Sculpin Length Frequency during February 2003 Sampling Event for the Upper Gualala Estuary.

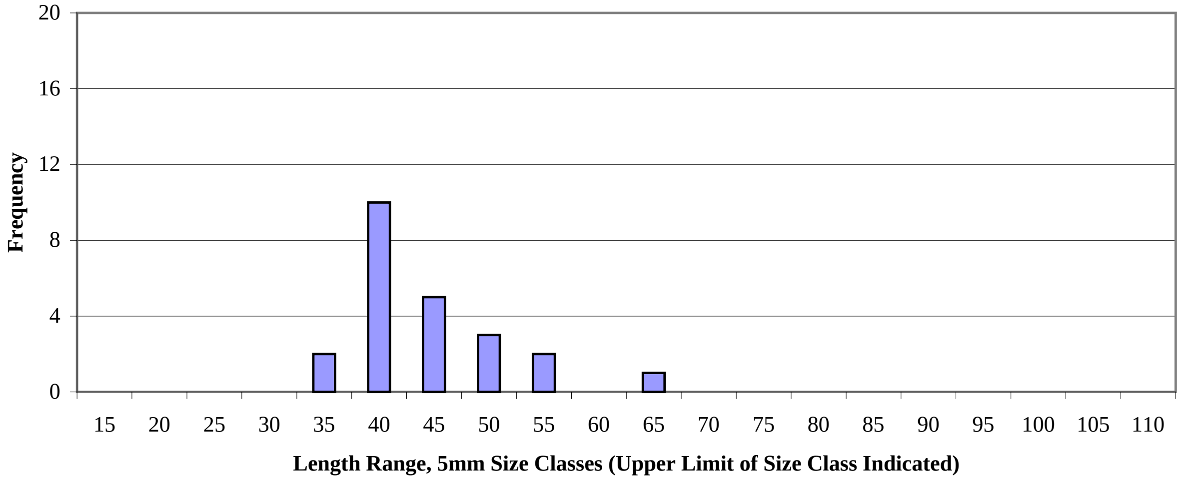


APPENDIX C-4

Appendix C-4.13. Coastrange Sculpin Length Frequency during May 2003 Sampling Event for the Lower Gualala Estuary.

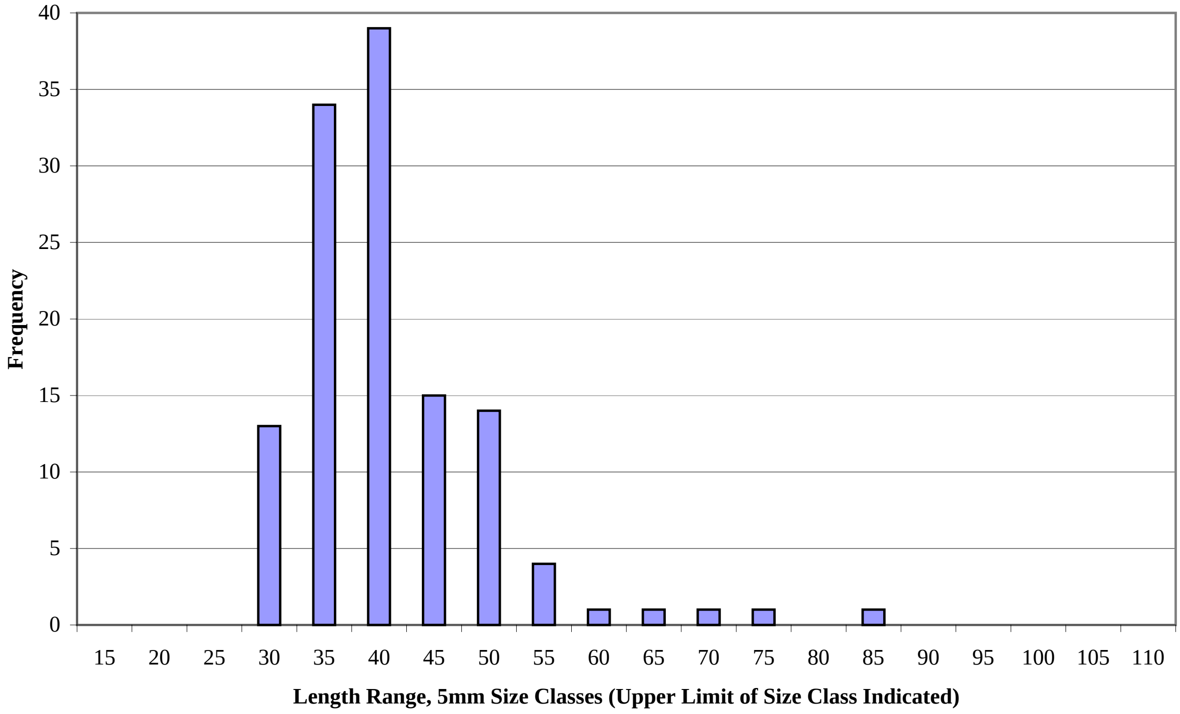


Appendix C-4.14. Coastrange Sculpin Length Frequency during May 2003 Sampling Event for the Middle Gualala Estuary.

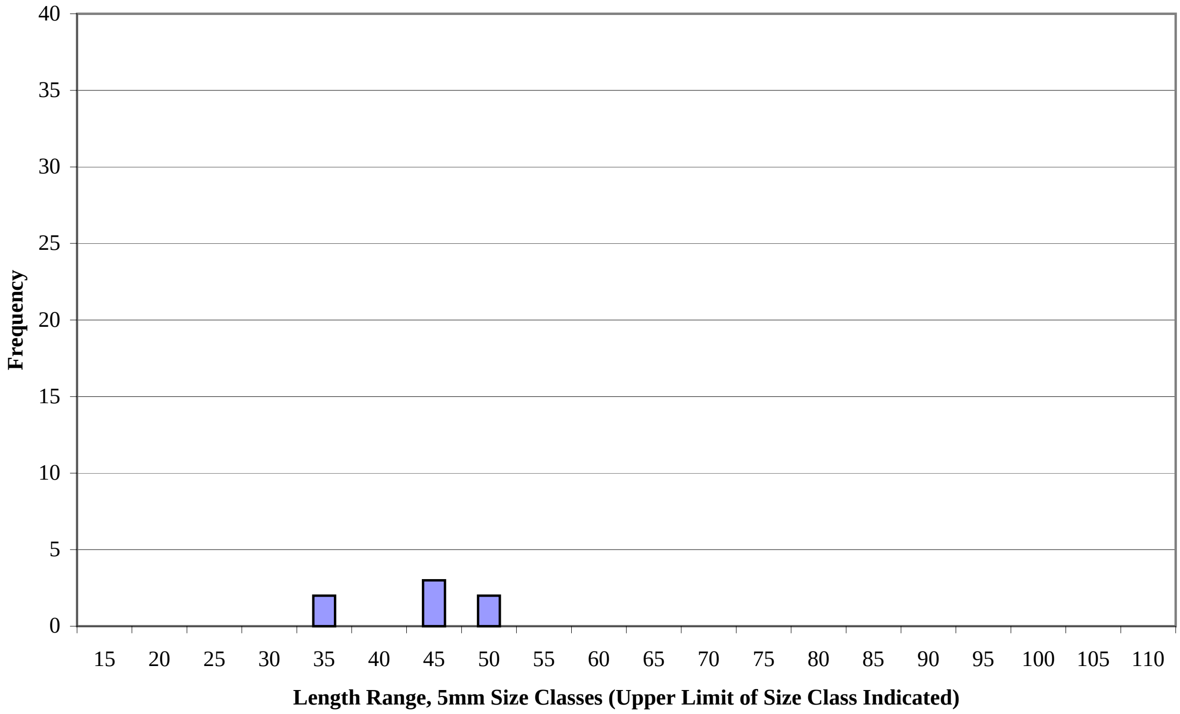


Appendix C-4.15. Coastrange Sculpin Length Frequency during June 2003 Sampling Event for the Upper Gualala Estuary.

Appendix C-4.16. Coastrange Sculpin Length Frequency during August 2003 Sampling Event for the Lower Gualala Estuary.

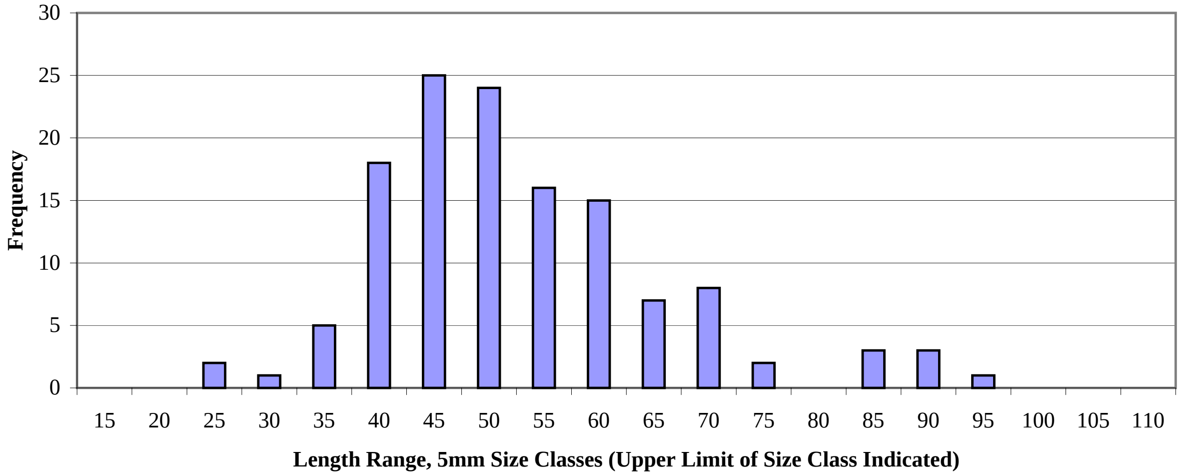


Appendix C-4.17. Coastrange Sculpin Length Frequency during August 2003 Sampling Event for the Upper Gualala Estuary.

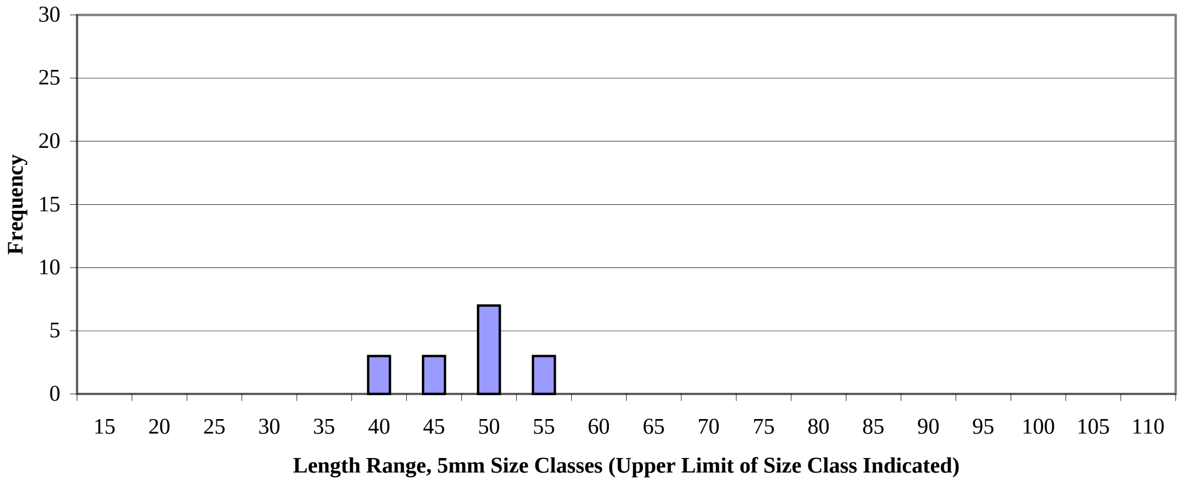


APPENDIX C-4

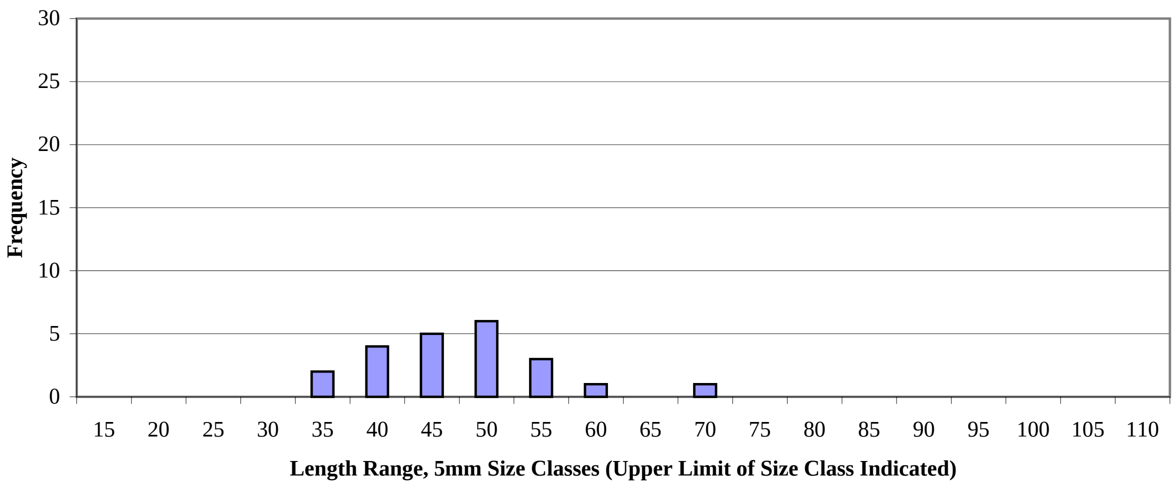
Appendix C-4.18. Coastrange Sculpin Length Frequency during September 2003 Sampling Event for the Lower Gualala Estuary.



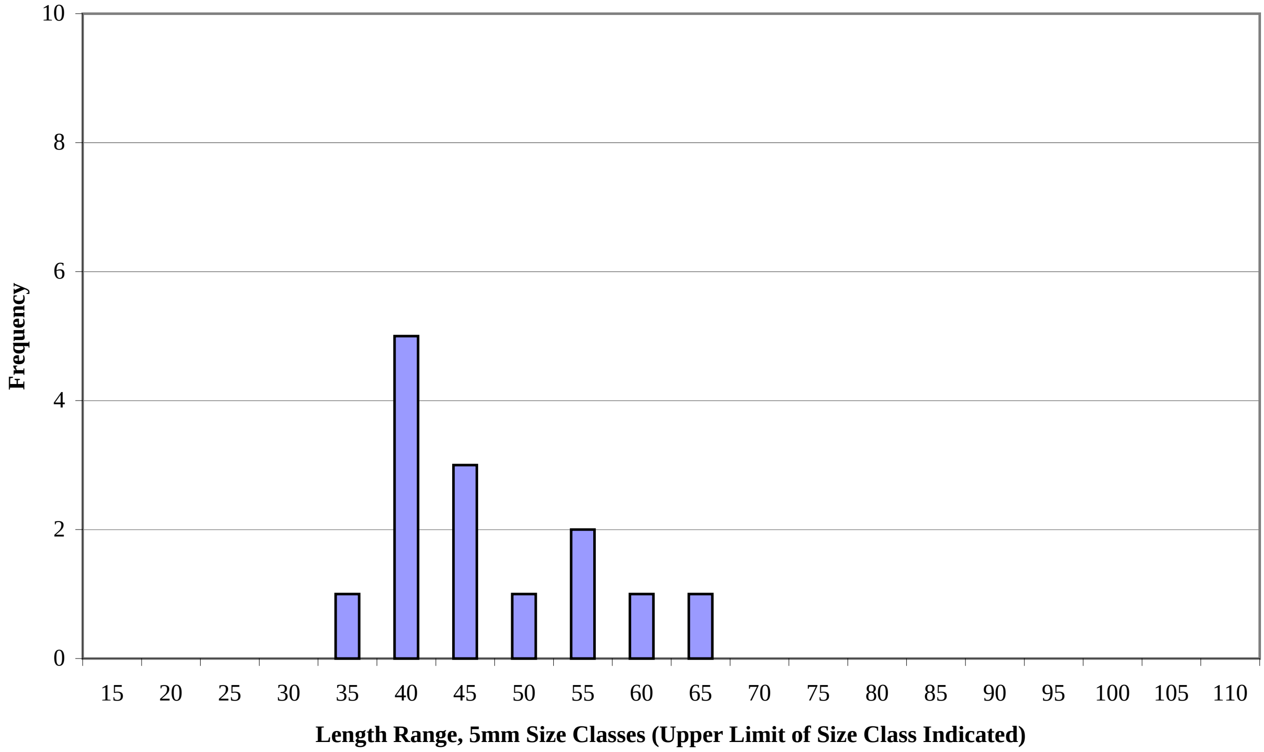
Appendix C-4.19. Coastrange Sculpin Length Frequency during September 2003 Sampling Event for the Middle Gualala Estuary.



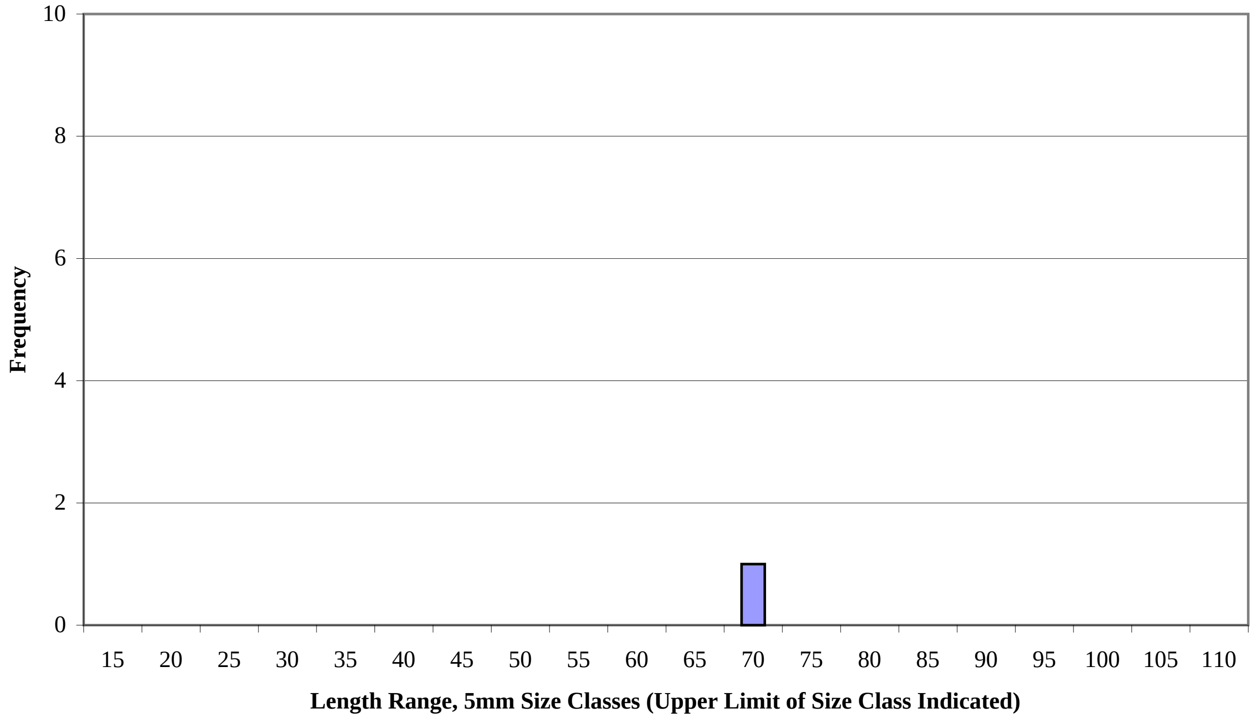
Appendix C-4.20. Coastrange Sculpin Length Frequency during September 2003 Sampling Event for the Upper Gualala Estuary.



Appendix C-4.21. Coastrange Sculpin Length Frequency during October 2003 Sampling Event for the Lower Gualala Estuary.



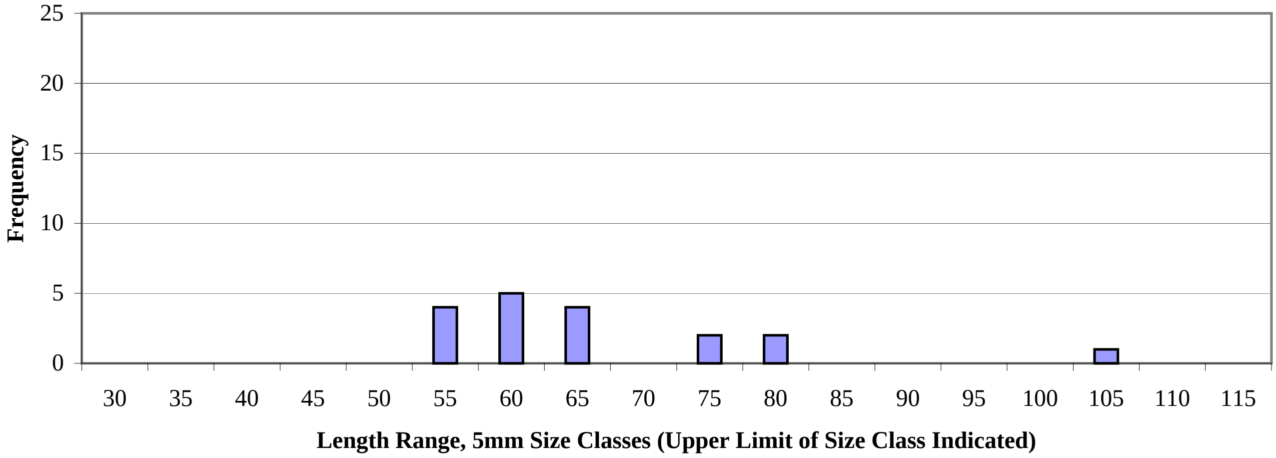
Appendix C-4.22. Coastrange Sculpin Length Frequency during October 2003 Sampling Event for the Middle Gualala Estuary.



APPENDIX C-5

Appendix C-5.1. Gualala Roach Length Frequency during June 2002 Sampling Event for the Middle Gualala Estuary.

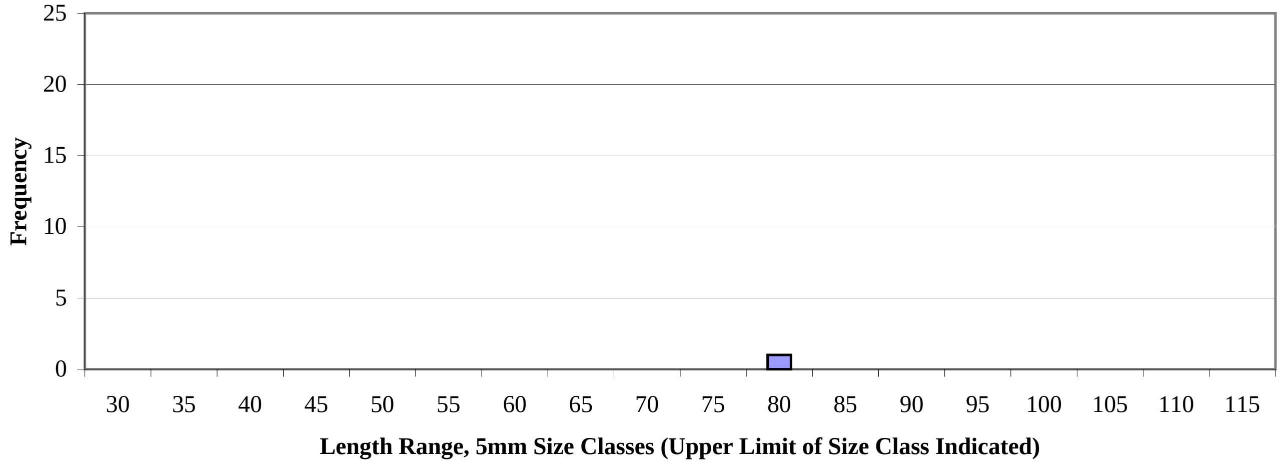
Appendix C-5.2. Gualala Roach Length Frequency during July 2002 Sampling Event for the Middle Gualala Estuary.



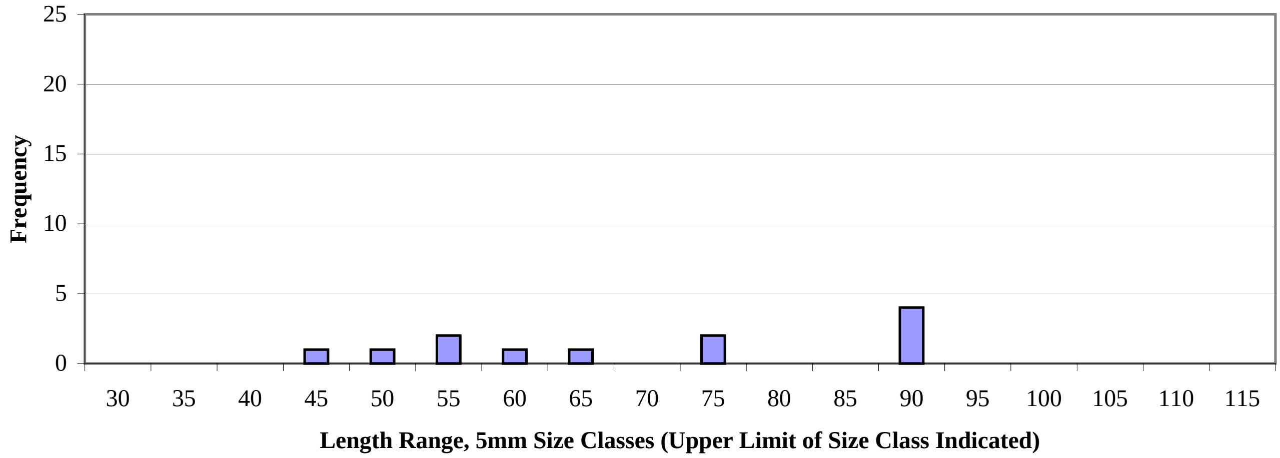
Appendix C-5.3. Gualala Roach Length Frequency during August 2002 Sampling Events for the Lower Gualala Estuary.

APPENDIX C-5

Appendix C-5.4. Gualala Roach Length Frequency during September 2002 Sampling Events for the Lower Gualala Estuary.



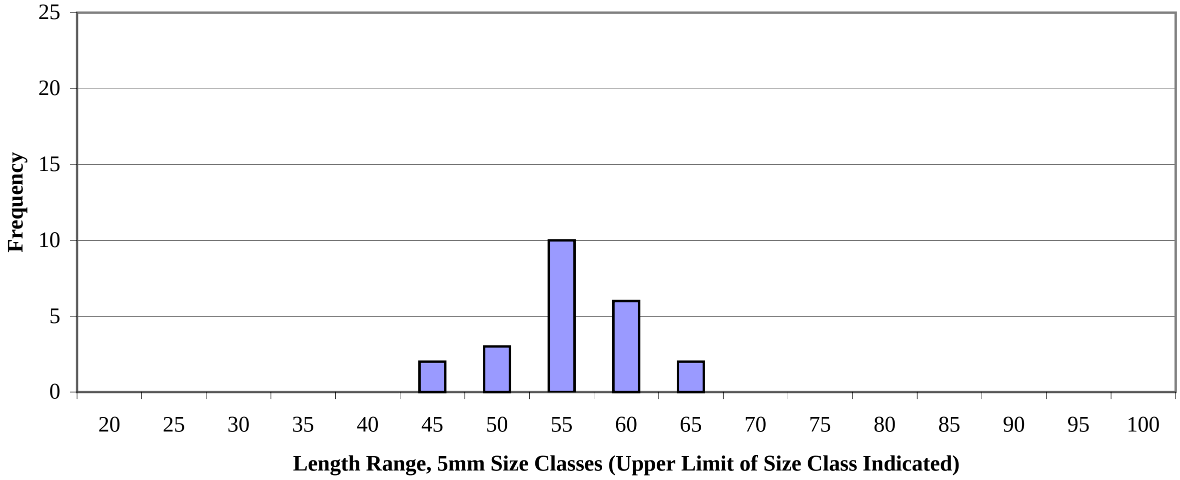
Appendix C-5.5. Gualala Roach Length Frequency during September 2002 Sampling Events for the Middle Gualala Estuary.



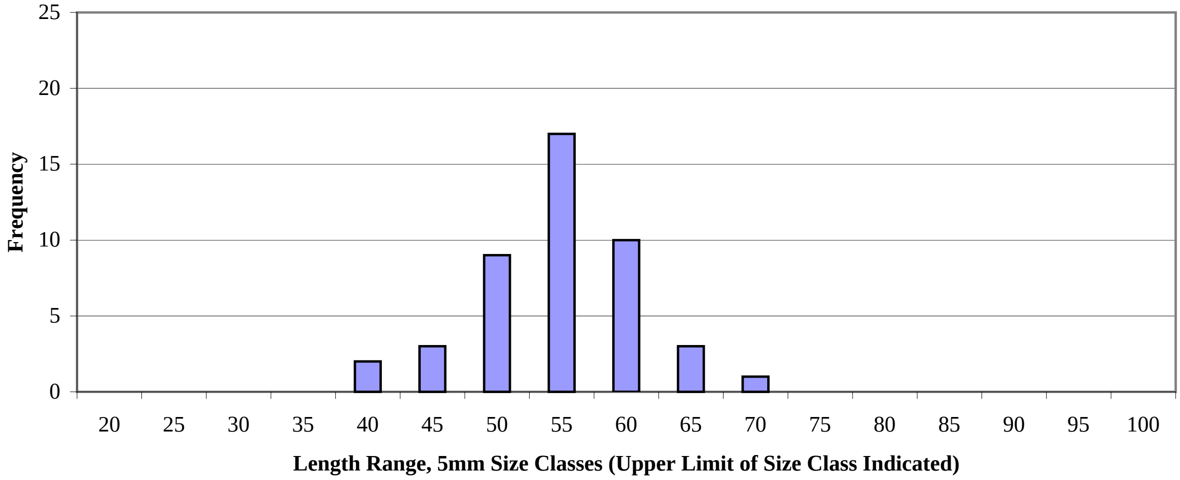
Appendix C-5.6. Gualala Roach Length Frequency during October-November 2002 Sampling Events for the Lower Gualala Estuary.

APPENDIX C-5

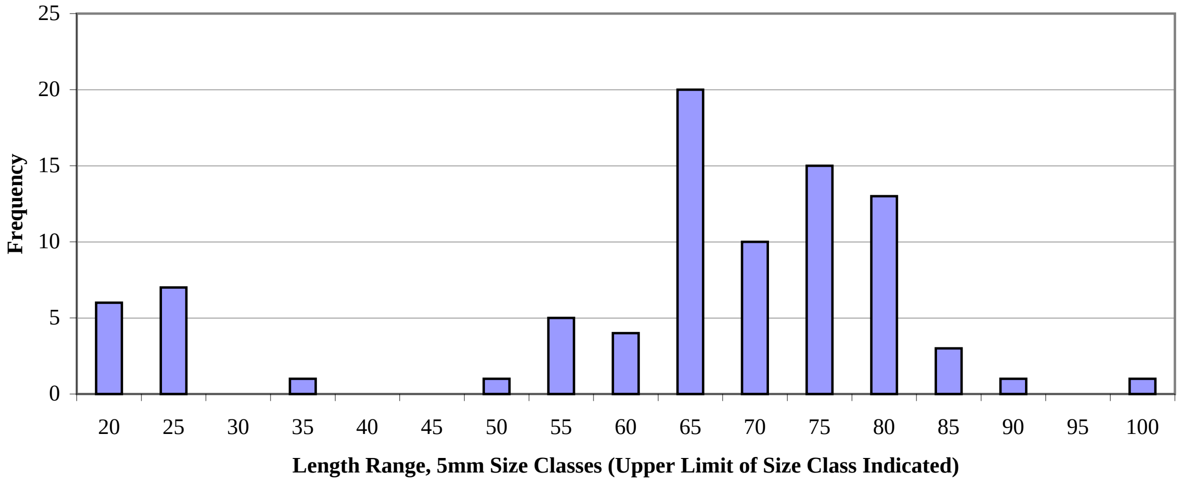
Appendix C-5.7. Gualala Roach Length Frequency during June 2003 Sampling Event for the Middle Gualala Estuary.



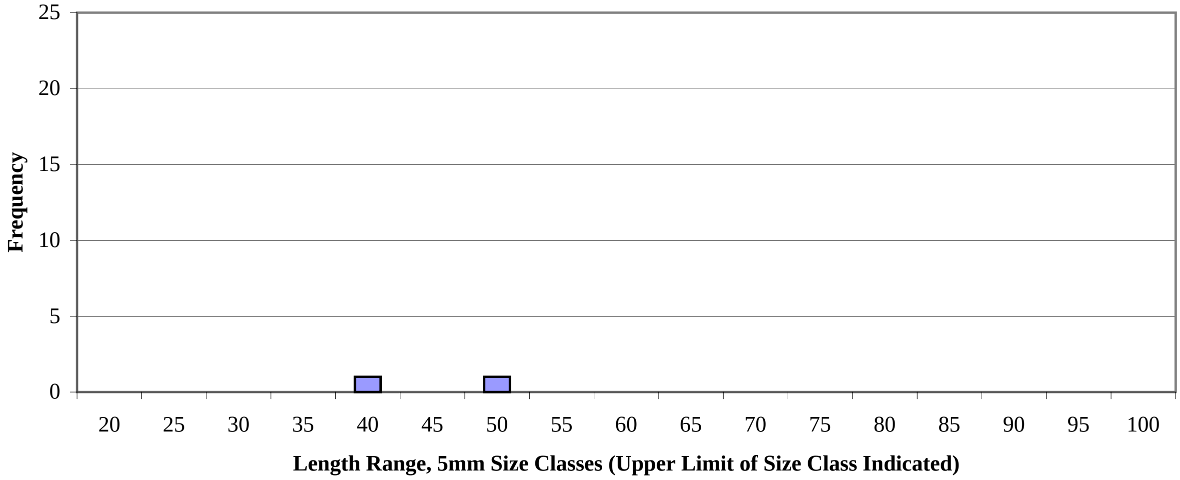
Appendix C-5.8. Gualala Roach Length Frequency during June 2003 Sampling Event for the Upper Gualala Estuary.



Appendix C-5.9. Gualala Roach Length Frequency during July 2003 Sampling Event for the Upper Gualala Estuary.



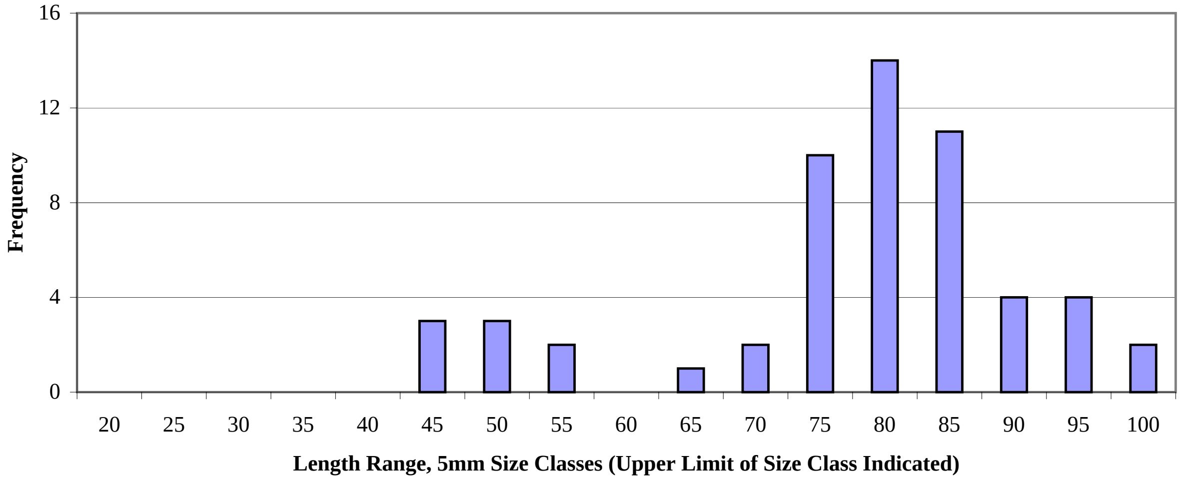
Appendix C-5.10. Gualala Roach Length Frequency during August 2003 Sampling Event for the Lower Gualala Estuary.



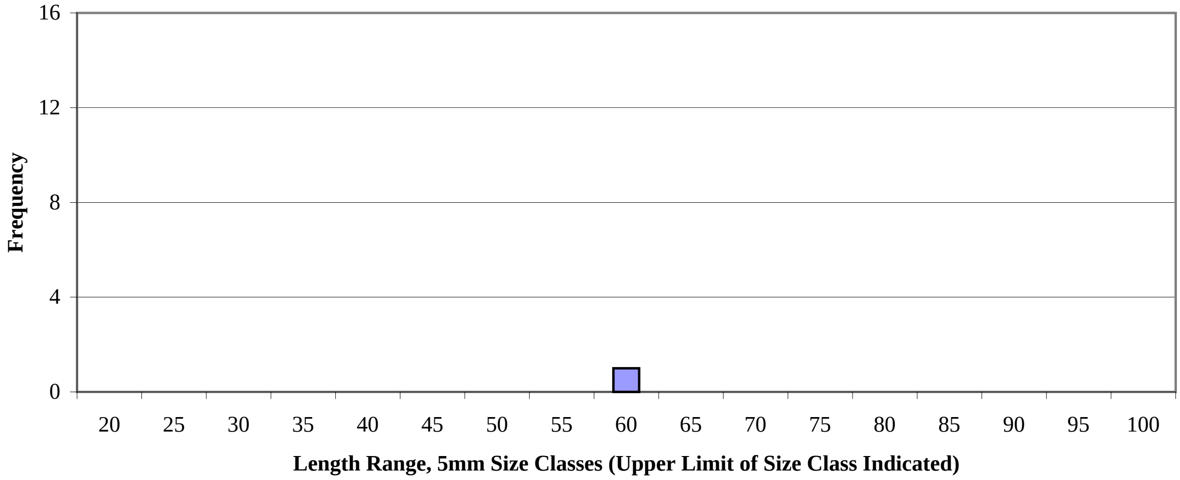
Appendix C-5.11. Gualala Roach Length Frequency during August 2003 Sampling Event for the Upper Gualala Estuary.

Appendix C-5.12. Gualala Roach Length Frequency during September 2003 Sampling Event for the Lower Gualala Estuary.

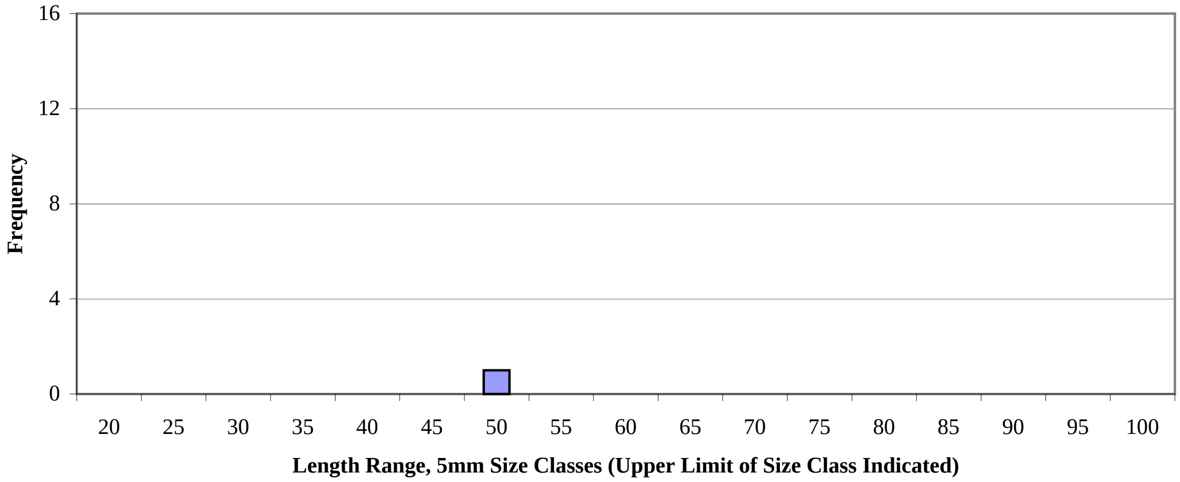
Appendix C-5.13. Gualala Roach Length Frequency during September 2003 Sampling Event for the Upper Gualala Estuary.



Appendix C-5.14. Gualala Roach Length Frequency during October 2003 Sampling Events for the Lower Gualala Estuary.



Appendix C-5.15. Gualala Roach Length Frequency during October 2003 Sampling Events for the Middle Gualala Estuary.



Appendix C-5.16. Gualala Roach Length Frequency during October 2003 Sampling Event for the Upper Gualala Estuary.

APPENDIX C-6

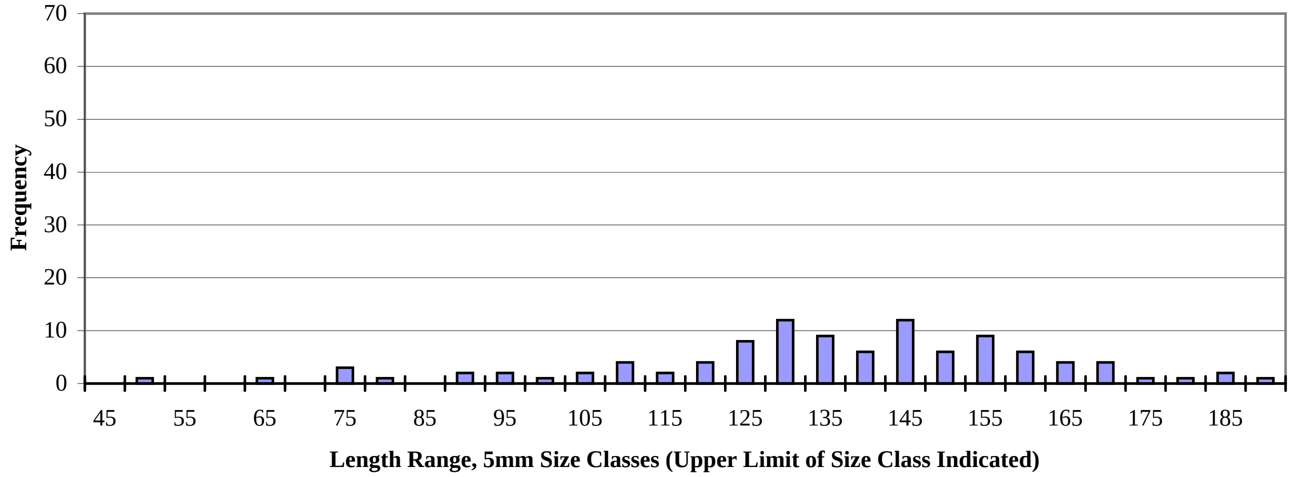
Appendix C-6.1. Steelhead Length Frequency during June 2002 Sampling Event for the Lower Gualala Estuary.

Appendix C-6.2. Steelhead Length Frequency during June 2002 Sampling Event for the Middle Gualala Estuary.

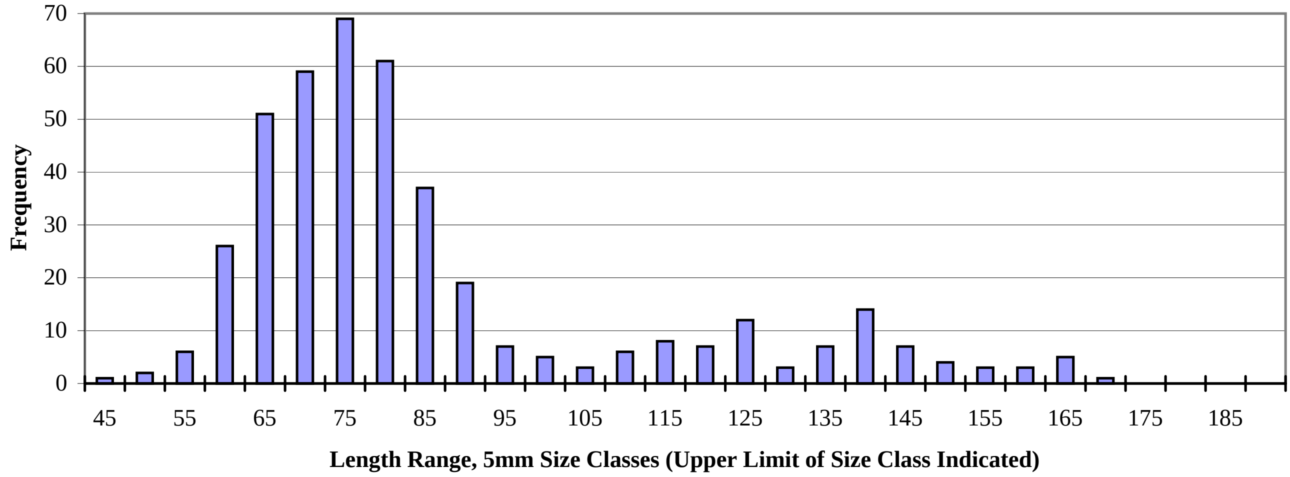
Appendix C-6.3. Steelhead Length Frequency during June 2002 Sampling Event for the Upper Gualala Estuary.

APPENDIX C-6

Appendix C-6.4. Steelhead Length Frequency during July 2002 Sampling Event for the Lower Gualala Estuary.



Appendix C-6.5. Steelhead Length Frequency during July 2002 Sampling Event for the Middle Gualala Estuary.



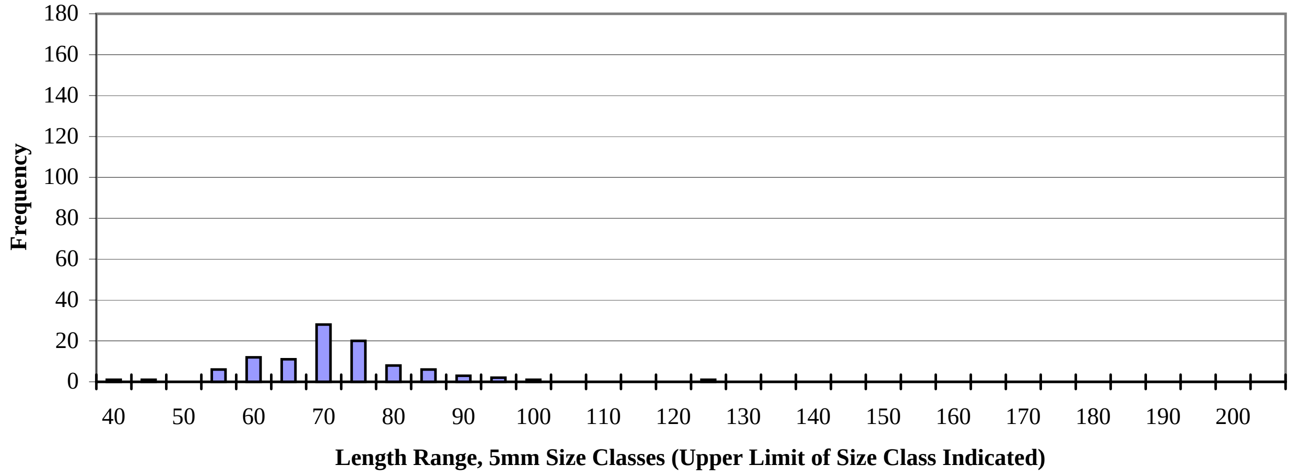
Appendix C-6.6. Steelhead Length Frequency during July 2002 Sampling Event for the Upper Gualala Estuary.

APPENDIX C-6

Appendix C-6.7. Steelhead Length Frequency during August 2002 Sampling Events for the Lower Gualala Estuary.

Appendix C-6.8. Steelhead Length Frequency during August 2002 Sampling Events for the Middle Gualala Estuary.

Appendix C-6.9. Steelhead Length Frequency during August 2002 Sampling Events for the Upper Gualala Estuary.



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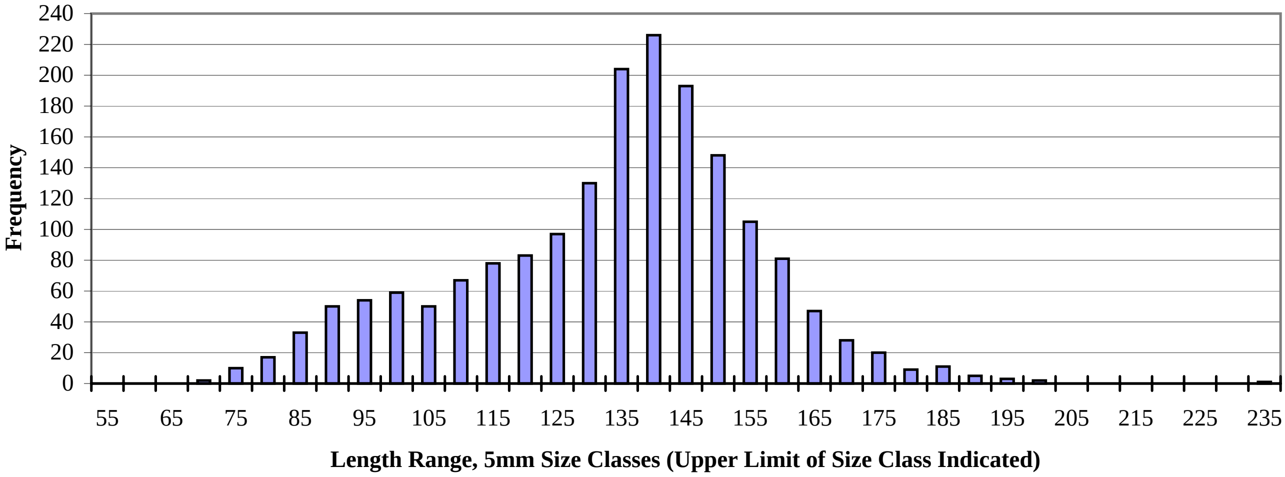
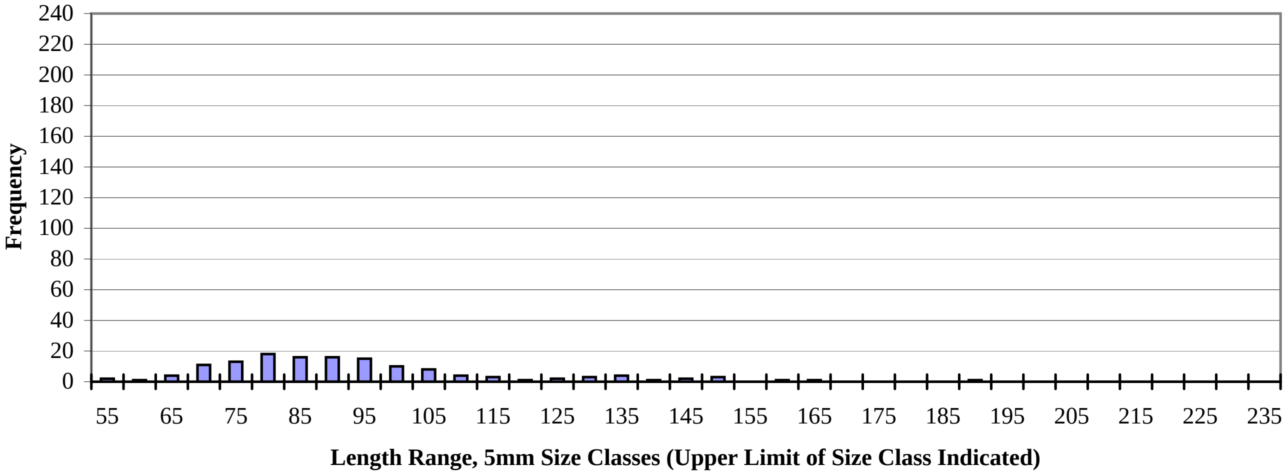
Appendix C-6.10. Steelhead Length Frequency during September 2002 Sampling Events for the Lower Gualala Estuary.



Appendix C-6.11. Steelhead Length Frequency during September 2002 Sampling Events for the Middle Gualala Estuary.



Appendix C-6.12. Steelhead Length Frequency during September 2002 Sampling Events for the Upper Gualala Estuary.

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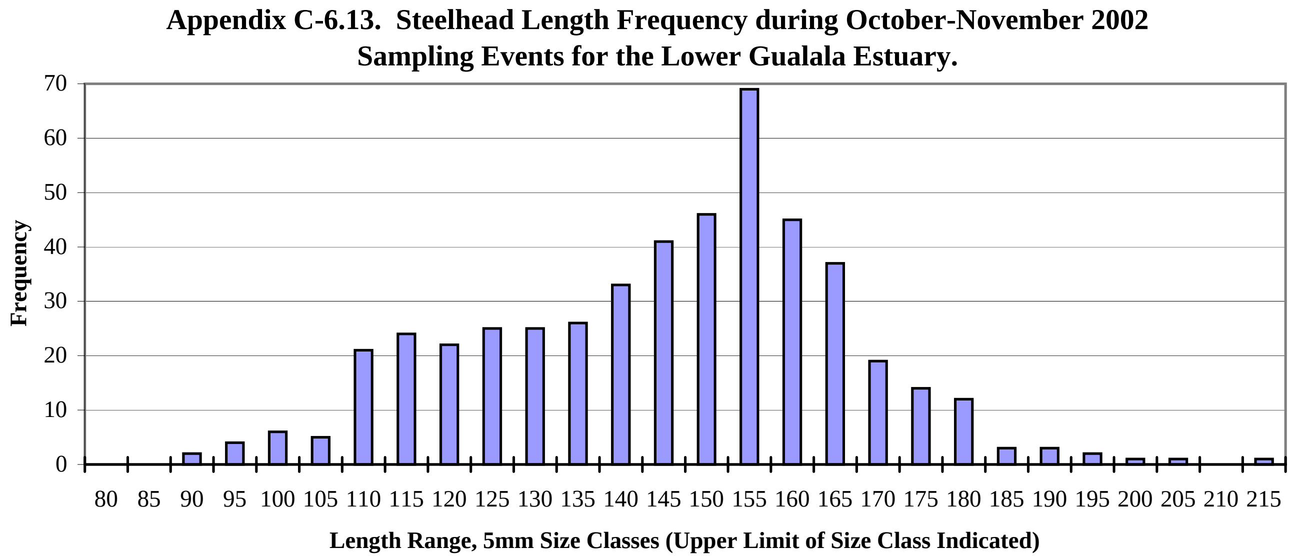
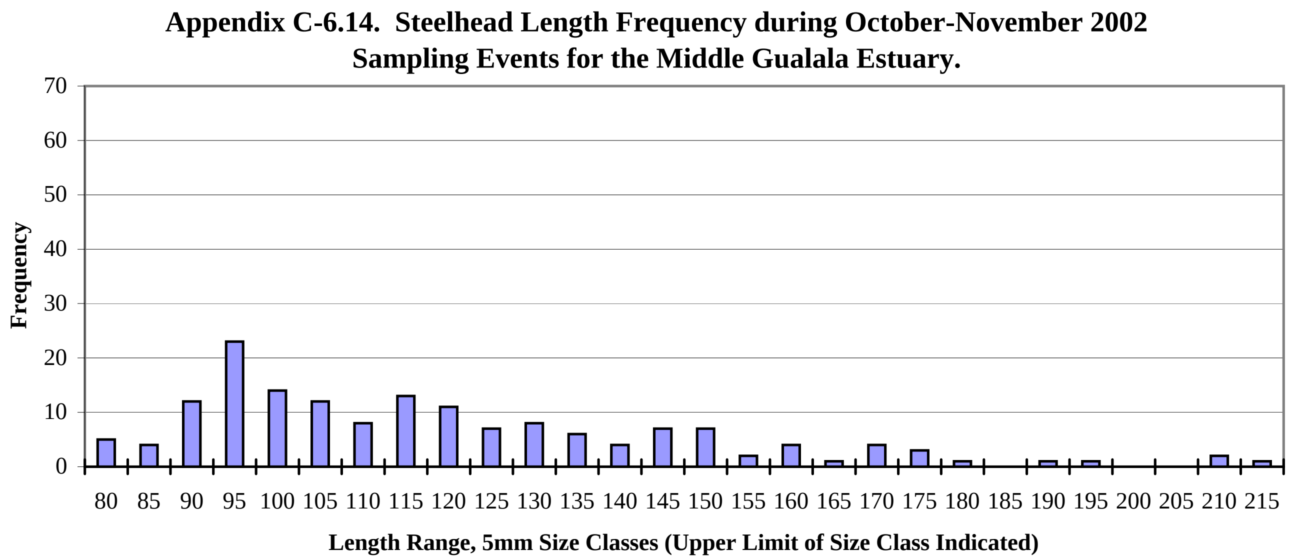
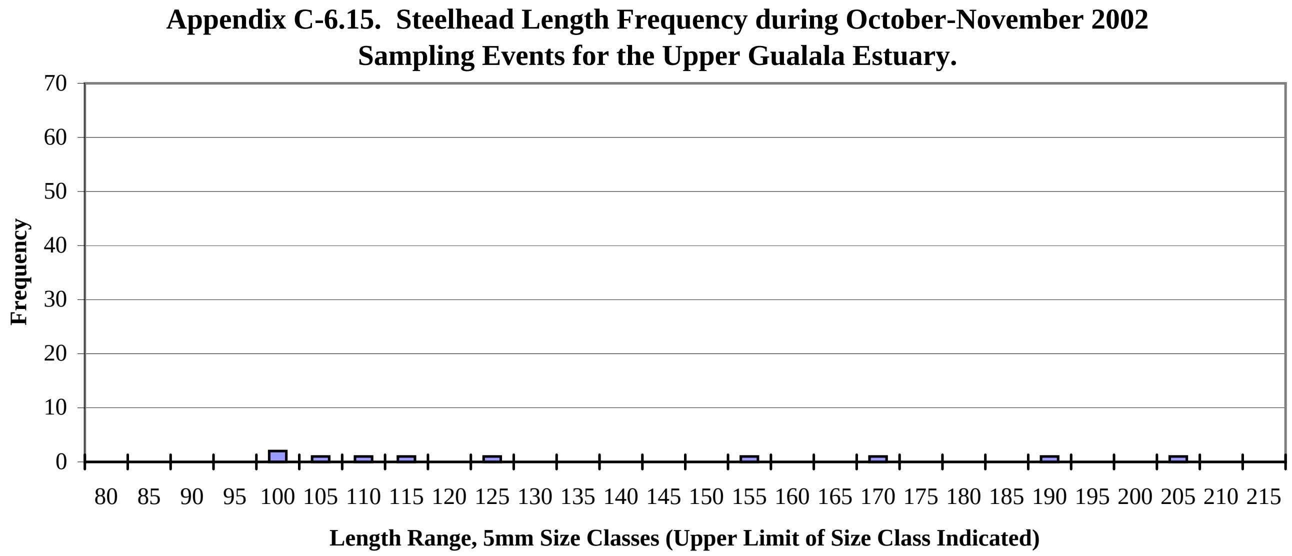


Appendix C-6.13. Steelhead Length Frequency during October-November 2002
Sampling Events for the Lower Gualala Estuary.
Frequency
0
10
20
30
40
50
60
70
80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195 200 205 210 215
Length Range, 5mm Size Classes (Upper Limit of Size Class Indicated)



Appendix C-6.14. Steelhead Length Frequency during October-November 2002
Sampling Events for the Middle Gualala Estuary.
Frequency
0
10
20
30
40
50
60
70
80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195 200 205 210 215
Length Range, 5mm Size Classes (Upper Limit of Size Class Indicated)



Appendix C-6.15. Steelhead Length Frequency during October-November 2002
Sampling Events for the Upper Gualala Estuary.
Frequency
0
10
20
30
40
50
60
70
80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195 200 205 210 215
Length Range, 5mm Size Classes (Upper Limit of Size Class Indicated)

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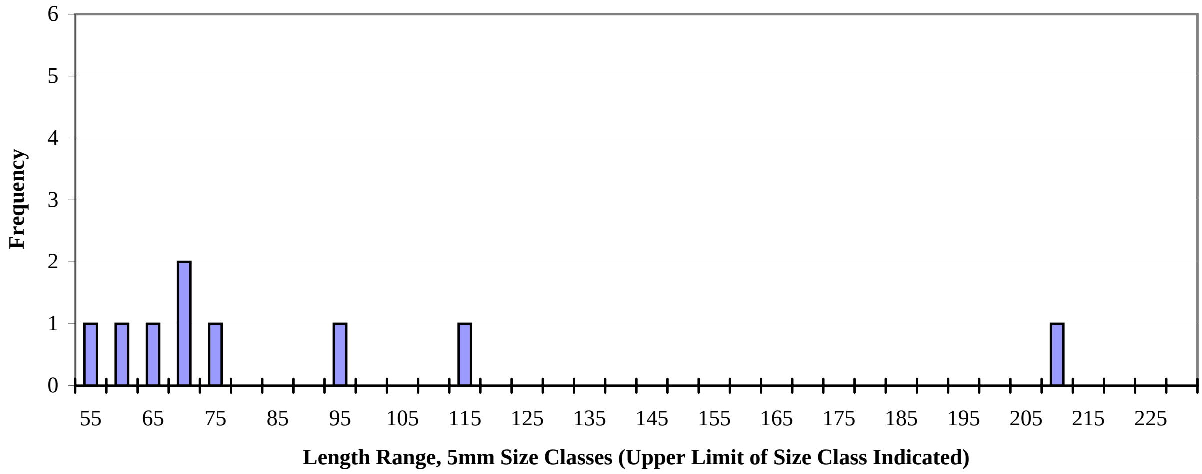
Appendix C-6.16. Steelhead Length Frequency during February 2003 Sampling Event for the Lower Gualala Estuary.

Appendix C-6.17. Steelhead Length Frequency during February 2003 Sampling Event for the Middle Gualala Estuary.

Appendix C-6.18. Steelhead Length Frequency during February 2003 Sampling Event for the Upper Gualala Estuary.



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Appendix C-6.19. Steelhead Length Frequency during May 2003 Sampling Event for the Lower Gualala Estuary.

Appendix C-6.20. Steelhead Length Frequency during May 2003 Sampling Event for the Middle Gualala Estuary.

Appendix C-6.21. Steelhead Length Frequency during May 2003 Sampling Event for the Upper Gualala Estuary.

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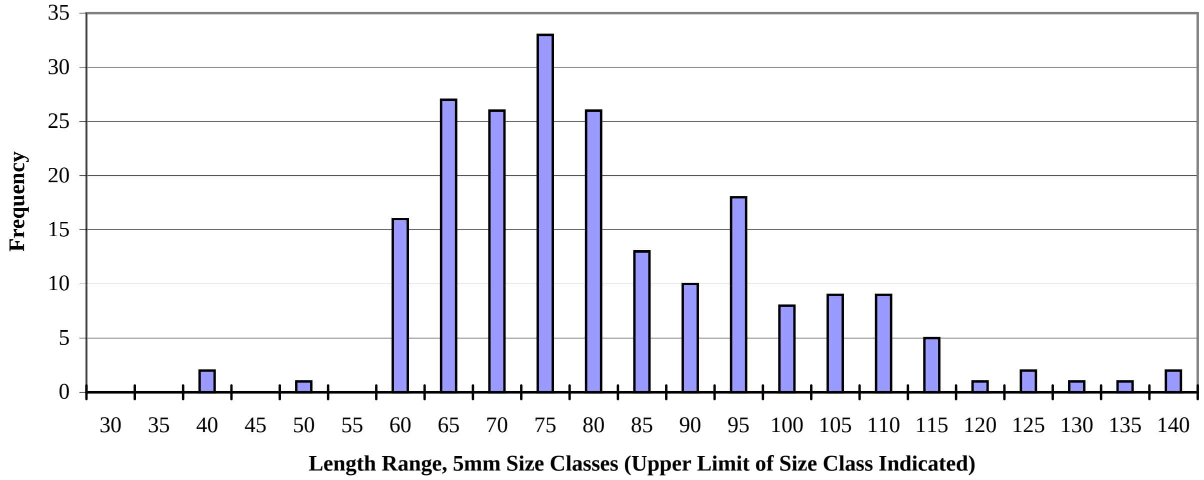
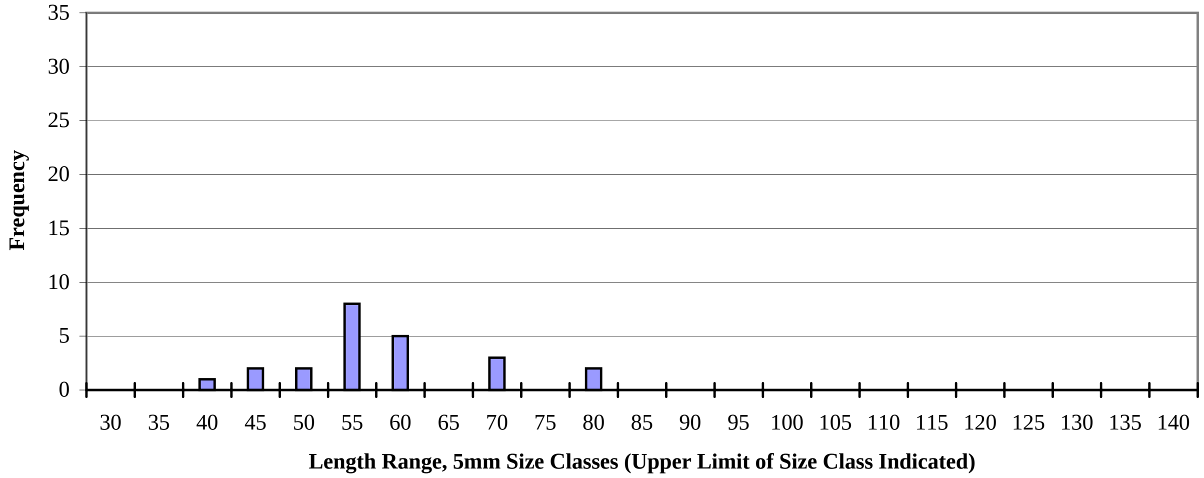
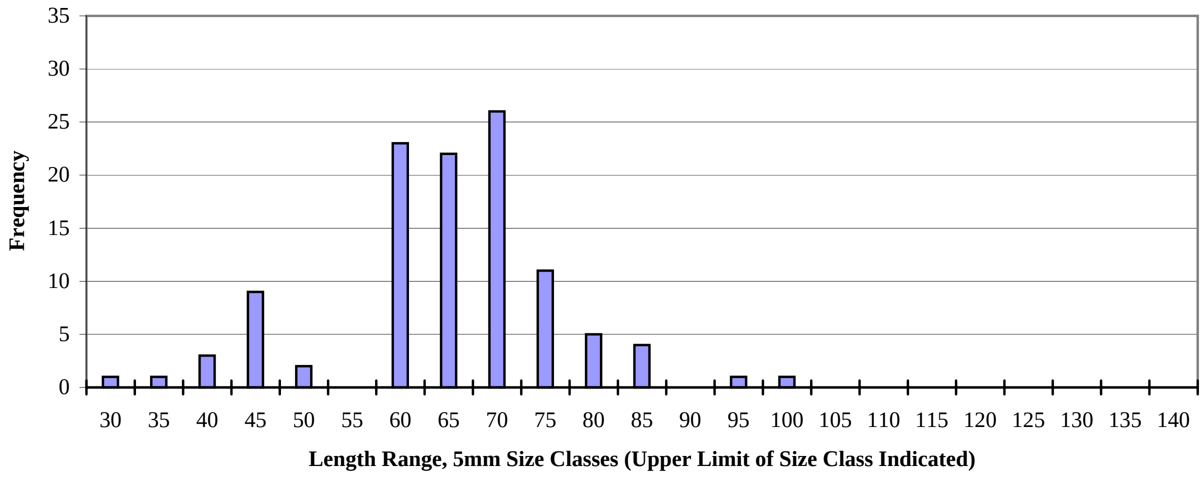
Appendix C-6.22. Steelhead Length Frequency during June 2003 Sampling Event for the Lower Gualala Estuary.



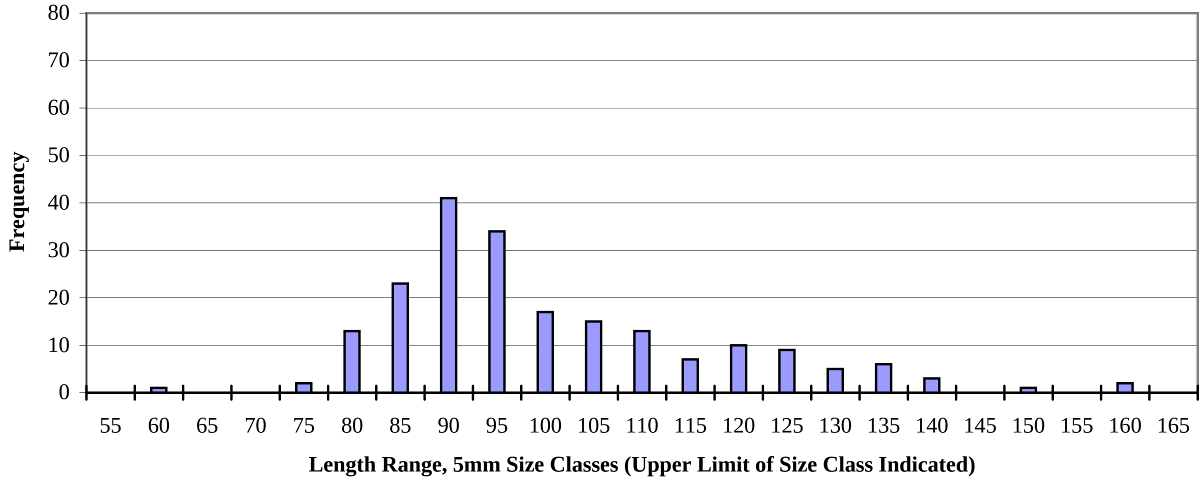
Appendix C-6.23. Steelhead Length Frequency during June 2003 Sampling Event for the Middle Gualala Estuary.



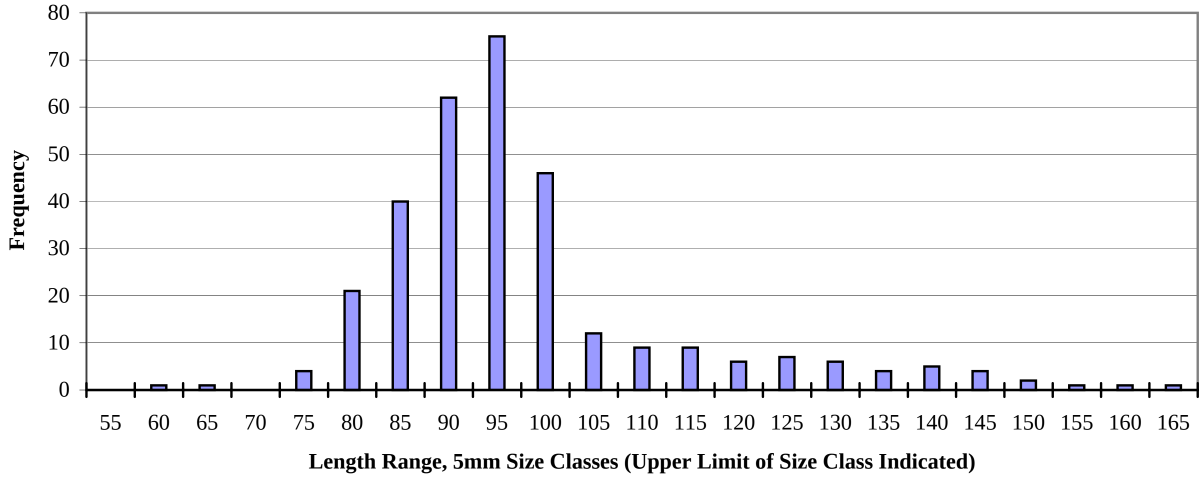
Appendix C-6.24. Steelhead Length Frequency during June 2003 Sampling Event for the Upper Gualala Estuary.



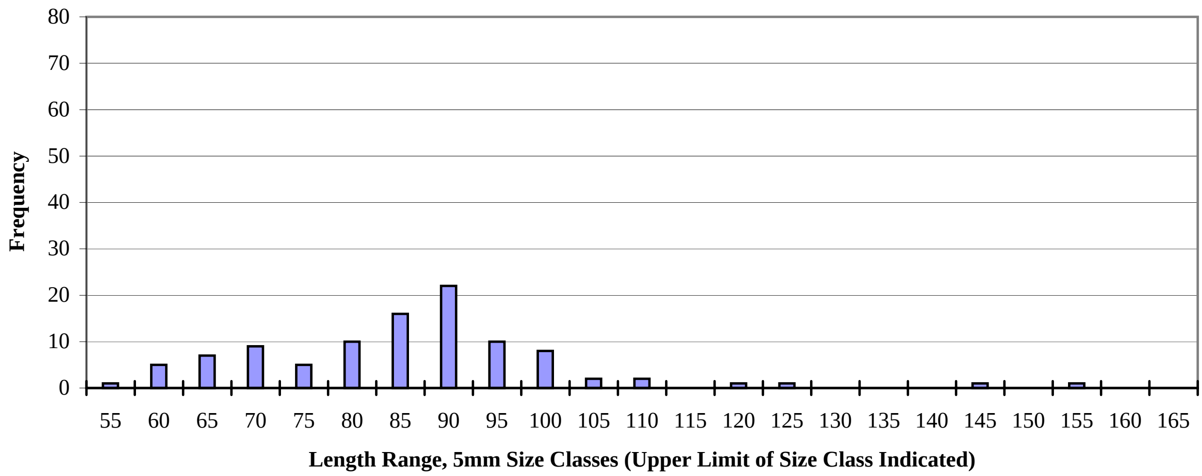
Appendix C-6.25. Steelhead Length Frequency during July 2003 Sampling Event for the Lower Gualala Estuary.



Appendix C-6.26. Steelhead Length Frequency during July 2003 Sampling Event for the Middle Gualala Estuary.



Appendix C-6.27. Steelhead Length Frequency during July 2003 Sampling Event for the Upper Gualala Estuary.



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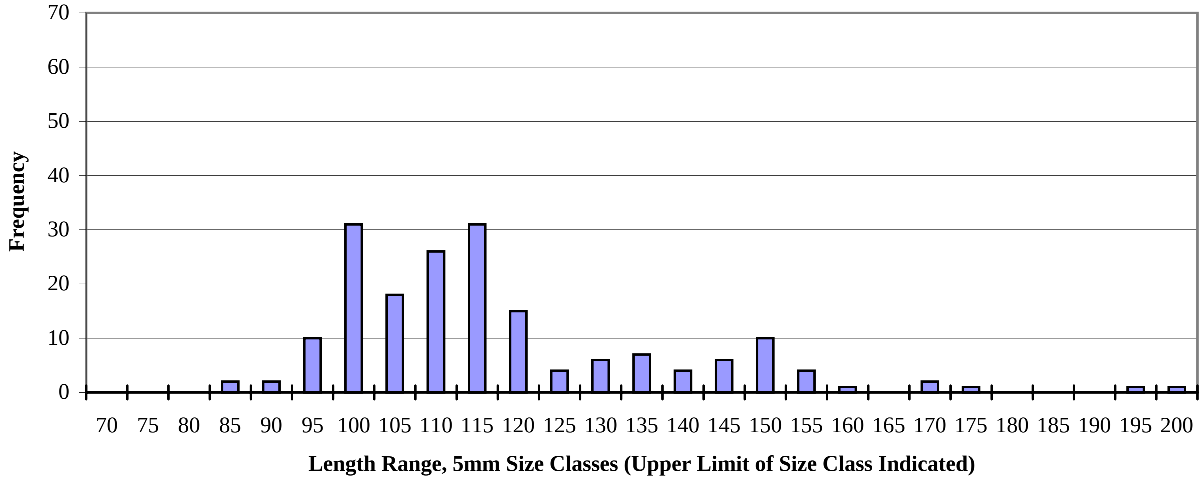
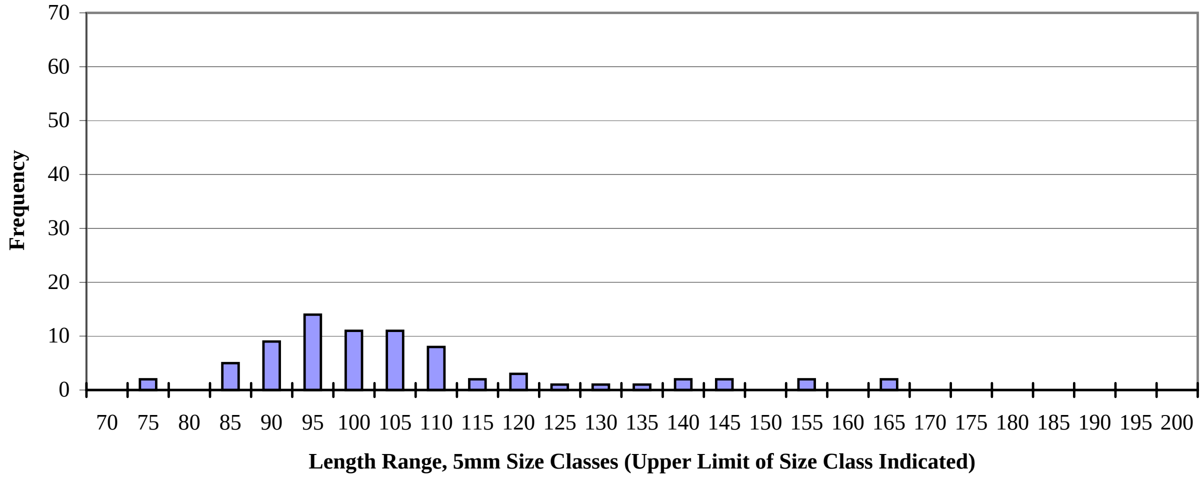
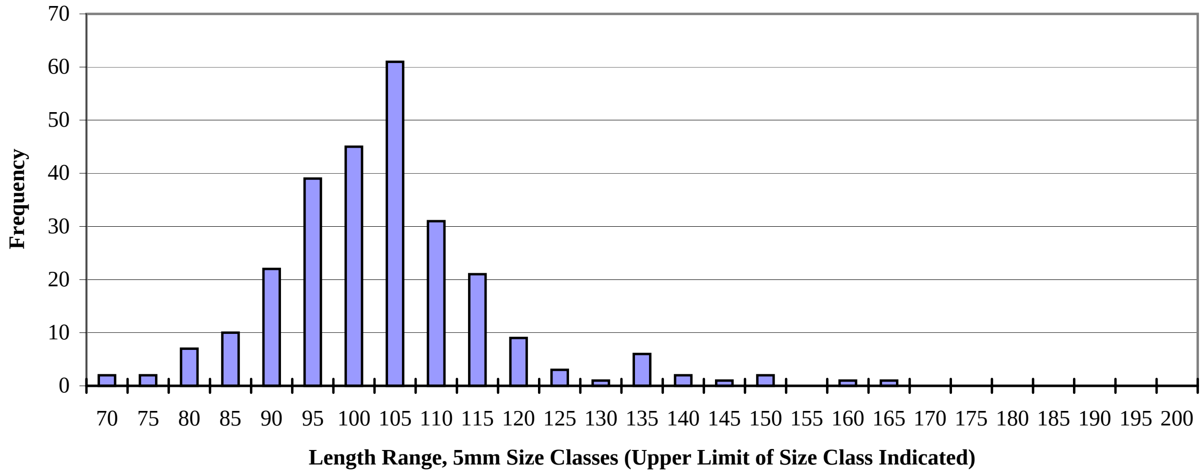
Appendix C-6.28. Steelhead Length Frequency during August 2003 Sampling Event for the Lower Gualala Estuary.



Appendix C-6.29. Steelhead Length Frequency during August 2003 Sampling Event for the Middle Gualala Estuary.



Appendix C-6.30. Steelhead Length Frequency during August 2003 Sampling Event for the Upper Gualala Estuary.



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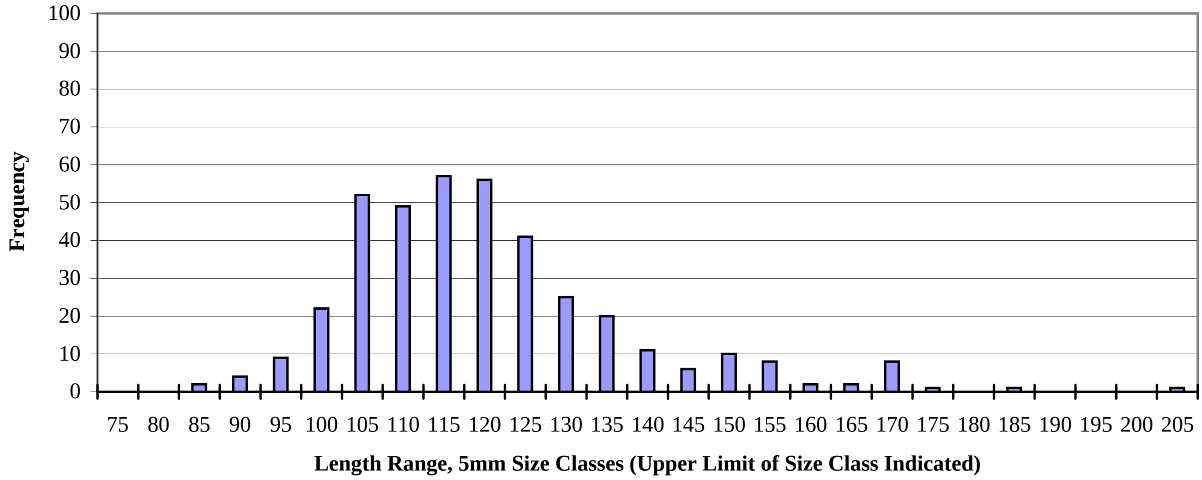
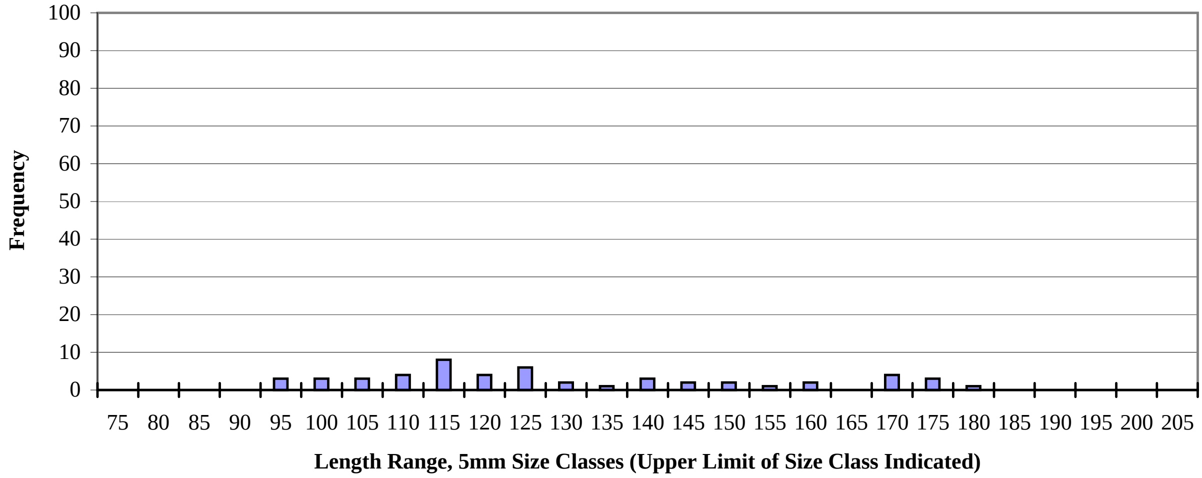
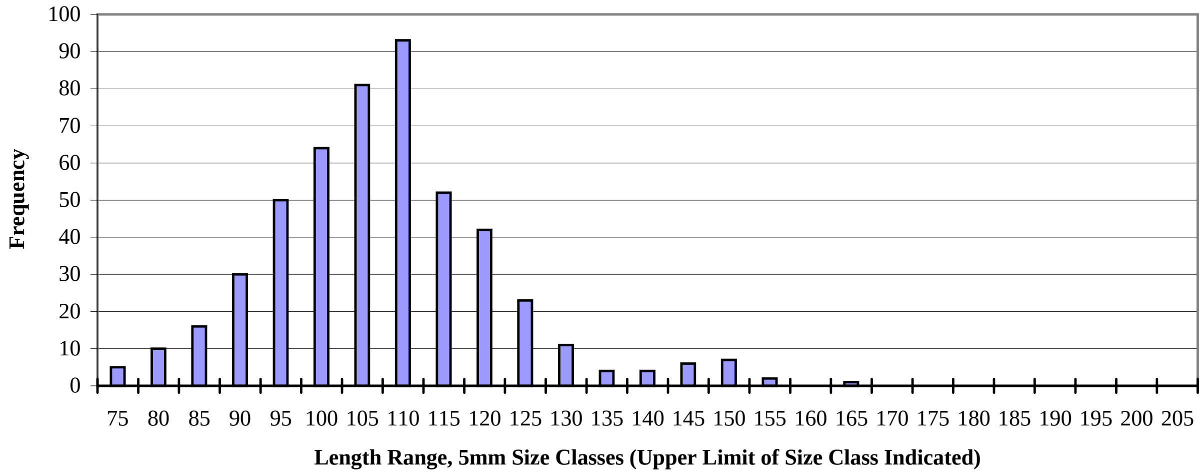
Appendix C-6.31. Steelhead Length Frequency during September 2003 Sampling Event for the Lower Gualala Estuary.



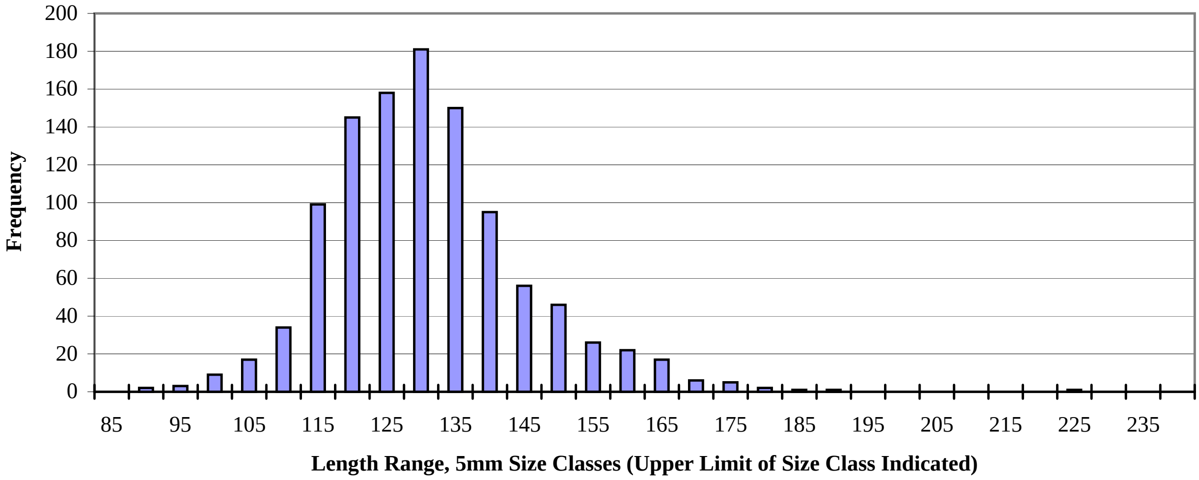
Appendix C-6.32. Steelhead Length Frequency during September 2003 Sampling Event for the Middle Gualala Estuary.



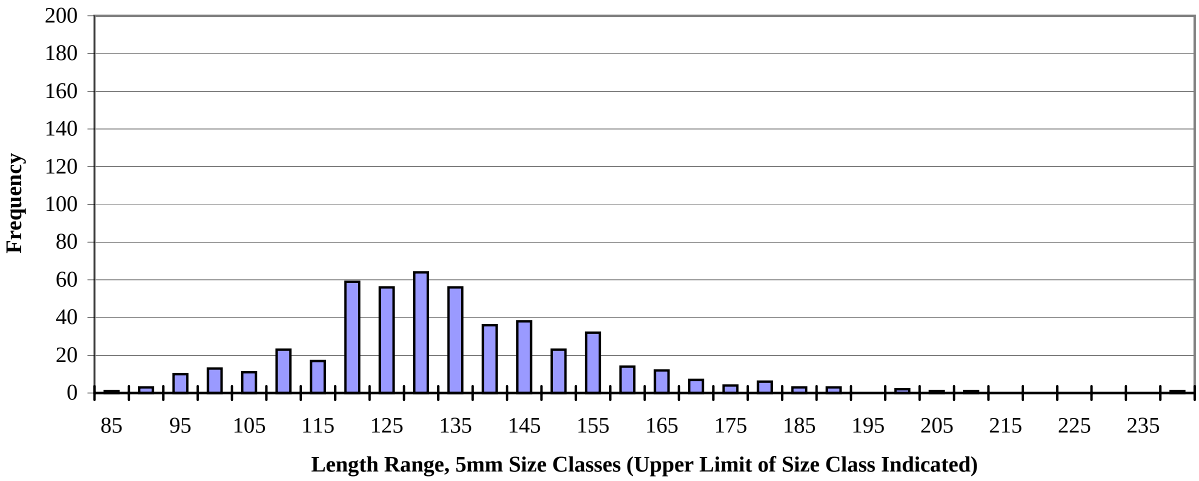
Appendix C-6.33. Steelhead Length Frequency during September 2003 Sampling Event for the Upper Gualala Estuary.



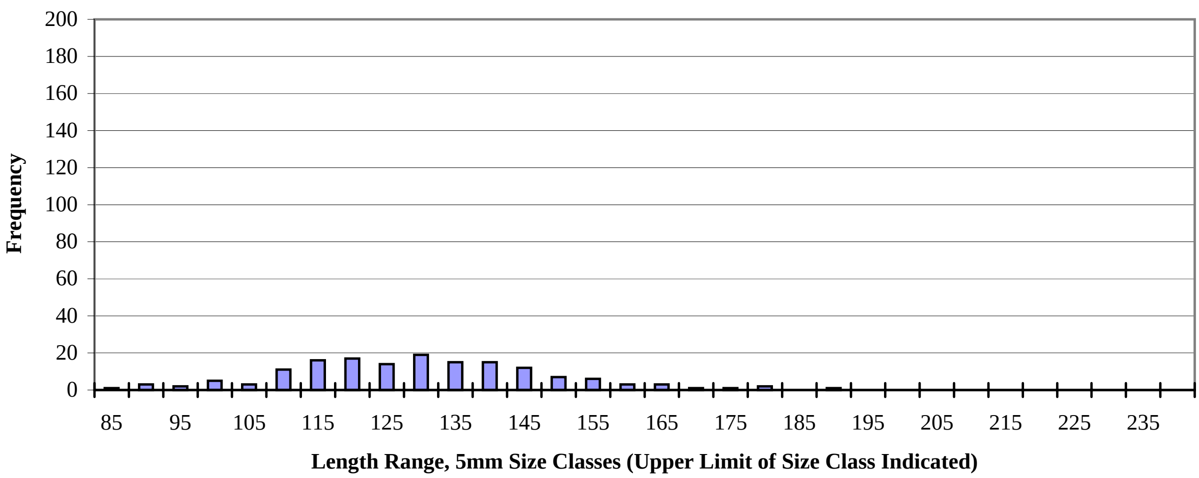
Appendix C-6.34. Steelhead Length Frequency during October 2003 Sampling Events for the Lower Gualala Estuary.



Appendix C-6.35. Steelhead Length Frequency during October 2003 Sampling Events for the Middle Gualala Estuary.



Appendix C-6.36. Steelhead Length Frequency during October 2003 Sampling Events for the Upper Gualala Estuary.



Appendix C-7.1. Gualala Estuary Project: Age 1+ Steelhead Population Estimates using Jolly-Seber Method, 1st Season.

Date	Sampling Event (t)	Captured	m_t	u_t	n_t	s_t	R_t	Z_t	α	Mt	Nt	ϕ_t	λ_t
June 19-20, 2002	1	41	0	41	41	41	28	na	0.02	0.0	**na**	1.9	na
July 10-11, 2002	2	221	8	213	221	221	64	20	0.04	76	**1,882.3**	1.0	12.987869
August 1-2, 2002	3	675	7	668	675	675	184	77	0.01	288	**24,366.6**	0.7	0.3040607
August 12-13, 2002	4	642	82	560	642	642	182	179	0.13	711	**5,507.7**	1.3	1.3305726
September 4-6, 2002	5	985	170	815	985	981	126	191	0.17	1647	**9,496.0**	1.0	1.0062504
September 25-27, 2002	6	749	192	557	749	748	40	125	0.26	2476	**9,620.0**	0.2	1.0491029
October 21-22, 2002	7	242	72	170	242	242	34	93	0.30	718	**2,389.0**	0.5	0.9333155
October 24, 2002	8	318	126	192	318	318	0	1	0.40	445	**1,117.8**	na	na
November 26-27, 2002	9	11	1	10	11	11	na	na	na	na	**na**	na	na

m_t = # of marked fish caught in sample t

u_t = # of unmarked fish caught in sample t

n_t = total # of fish caught in sample t ($n_t = m_t + u_t$)

s_t = # of fish released after sample t (n_t - # of accidental deaths)

R_t = # of s_t fish released at sample t and caught again in some later sample (refer to "Method Table B" below for calculation)

Z_t = # of fish marked before sample t, not caught in sample t, but caught in some sample after t (refer to "Method Table B" below for calculation)

a_t = proportion of animals marked:

α_τ = proporiton of animals marked:

$$\alpha_t = \frac{m_t + 1}{n_t + 1}$$

M_t = # of marked fish in the population:

$$M_t = \frac{(s_t + 1)Z_t}{R_t + 1} + m_t$$

N_t = estimated population size before time t:

$$N_t = \frac{M_t}{\alpha_t}$$

Method Table B:

	Time of Capture (t) (t = sample event #)								
	1	2	3	4	5	6	7	8	9
Time of Last Capture (event #)									
1	-	8	3	10	5	0	2	0	0
2		0	4	18	24	11	5	2	0
3			4	54	65	43	14	7	1
4				6	76	58	19	29	0
5					8	80	16	30	0
6						13	16	24	0
7							1	34	0
8								0	0
Total Marked, m_t	0	8	7	82	170	192	72	126	1
Total Unmarked, u_t	41	213	668	560	815	557	170	192	10
Total Caught, n_t	41	221	675	642	985	749	242	318	11
Total Released, s_t	41	221	675	642	981	748	242	318	11

= do not use same week recaptures

Example of how to compute R_t and Z_t (for t = 4):

sum of area

$R_4 = 182$

$Z_4 = 179$

ϕ_t = probability of survival (ration of number of marked fish at the start of sample t+1 to the number of fish at the end of sample t :

$$\phi_\tau = \frac{M_{t+1}}{M_t + (s_t - m_t)}$$

λ_t = dilution rate; an estimate of the number of fish to the population through birth and immigration :

$$\lambda_\tau = \frac{N_{t+1}}{\phi_t[N_t - (n_t - s_t)]}$$

Appendix C-7.2. Gualala Estuary Project - 2nd Season: Age 1+ Steelhead Population Estimates using Jolly-Seber Method.

Date	**Sampling Event (t)**	**Captured**	m_t	u_t	n_t	s_t	R_t	Z_t	α	**Mt**	**Nt**	ϕ_t	λ_t
July 22-23, 2003	13	478	0	478	478	476	3	na	0.002	0	**na**	0.19	na
August 22-23, 2003	14	460	1	459	460	455	9	2	0.004	92	**21,252.1**	0.12	2.38
September 23-24, 2003	15	739	7	732	739	724	49	4	0.011	65	**6,012.5**	0.45	3.09
October 27-28, 2003	16	1,064	44	1,020	1,064	991	28	9	0.042	352	**8,327.4**	na	na
October 30, 2003	17	594	37	557	594	*na*	*na*	*na*	*na*	*na*	**na**	na	na

m_t = # of marked fish caught in sample t
u_t = # of unmarked fish caught in sample t
n_t = total # of fish caught in sample t ($n_t = m_t + u_t$)
s_t = # of fish released after sample t (n_t - # of accidental deaths)
R_t = # of s_t fish released at sample t and caught again in some later sample (refer to "Method Table B" below for calculation)
Z_t = # of fish marked before sample t, not caught in sample t, but caught in some sample after t (refer to "Method Table B" below for calculation)

a_t = proportion of animals marked:
α_τ = proporiton of animals marked:

$$\alpha_t = \frac{m_t + 1}{n_t + 1}$$

M_t = # of marked fish in the population:

$$M_t = \frac{(s_t + 1)Z_t}{R_t + 1} + m_t$$

N_t = estimated population size before time t:

$$N_t = \frac{M_t}{\alpha_t}$$

Method Table B:					
	Time of Capture (t)			**(t = event #)**	
	13	14	15	16	17
Time of Last Capture (event #)					
13	2[a]	1	0	2	0
14		0	7	2	0
15			2[a]	40	9
16				11[a]	28
Total Marked, m_t	0	1	7	44	37
Total Unmarked, u_t	478	459	732	1,020	557
Total Caught, n_t	478	460	739	1,064	594
Total Released, s_t	476	455	724	991	0

[a] = recaptured from same sampling event

= do not use same week recaptures

Example of how to compute R_t and Z_t (for t = 15):

sum of area

R_{15} = 49
Z_{15} = 4

ϕ_t = probability of survival (ration of number of marked fish at the start of sample t+1 to the number of fish at the end of sample t :

$$\phi_\tau = \frac{M_{t+1}}{M_t + (s_t - m_t)}$$

λ_t = dilution rate; an estimate of the number of fish to the population through birth and immigration :

$$\lambda_t = \frac{N_{t+1}}{\phi_t[N_t - (n_t - s_t)]}$$

APPENDIX D

Benthic Macroinvertebrate Data

Appendix D. Lower Gualala River and Estuary Benthic Macroinvertebrate Survey Results, July 2002 and May 2003 .

			Upper Reach: RM 2.4 to RM 3.2				Middle Reach : RM 1.6 to RM 2.0			
	TV	FFG	EC-510	EC-511	EC-512	Total	EC-513	EC-514	EC-515	Total
PHYLUM ARTHROPODA										
Class Insecta										
Coleoptera (adults)										
Dytiscidae	5	p		1		1				
Uvarus subtilis	5	p								
Elmidae	4	c	3			3				
Narpus sp.	4	c	1		1	2				
Optioservus sp.	4	g	29	25	69	123	1			1
Rhizelmis nigra	2	g								
Zaitzevia sp.	4	c	7		3	10				
Coleoptera (Larvae)										
Dytiscidae	5	p								
Oreodytes sp.	5	p								
Elmidae	4	c								
Optioservus sp.	4	g	8	15	3	26	2	1		3
Zaitzevia sp.	4	c	3	2	1	6				
Psephenidae										
Eubrianax edwardsi	4	g								
Diptera										
Ceratopogonidae	6	p								
Ceratopogonidae pupa	6	p	3			3				
Atrichopogon sp.	6	c								
Bezzia sp./ Palpomyia sp.	6	p	7		2	9			1	1
Probezzia sp.	6	p								
Chironomidae	6									
Chironominae	6	c								
Chironominae pupa	6	nf		1		1	1			1
Chironomini	6	c	2	2		4				
Tanytarsini	6	c	86	20	26	132	3	10	14	27
Orthocladiinae	5	c	18	3	6	27			6	6
Orthocladiinae pupa	5	nf			6	6			1	1
Krenosmittia sp.	1	c							1	1
Podonominae	6	c	3	1		4				
Tanypodinae	7	p	1	9	6	16		4	1	5
Tanypodinae pupa	7	nf						1	1	2
Dolichopodidae	4	p		1		1				
Empididae	6	p								
Chelifera sp.	6	p	3			3				
Dolicocephala sp.	6	p								
Hemerodromia sp.	6	p	2		1	3				
Simuliidae	6	f								
Prosimulium sp.	3	f								
Simulium sp.	6	f			8	8				
Tanyderidae	1									
Protanyderus sp.	1				1	1				
Tipulidae	3	s	2			2				
Antocha sp.	3	c	2			2				
Hexatoma sp.	2	p		1	1	2				
Hemiptera										
Corixidae	8	p								
Sigara sp.	8	p							2	2
Naucoridae	5	p								
Ambrysus sp.	5	p						1		1
Sialidae	4	p								
Sialis sp.	4	p						1		1
Odonata										
Gomphidae	4	p								
Ophiogomphus sp.	4	p		1		1	1			1
Ephemeroptera										
Baetidae	4	g								
Baetis sp.	5	c	16	1	16	33	1			1
Diphetor hageni	5	c	21	50	32	103		2		2
Fallceon quilleri	4	c							3	3
Ephemerellidae	1	c		2		2		2		2
Attenella sp.	2	c	2		7	9				
Serratella sp.	2	c	8	21		29				
Heptageniidae	4	g	7	20	11	38	3	2		5
Leucrocuta/Nixe sp.	3	g		7		7		2		2
Isonychiidae	2	c								
Isonychia velma	2	c	2		3	5				
Leptophlebidae	2	c								
Paraleptophlebia sp.	4	c		3		3		10	19	29

Appendix D. Lower Gualala River and Estuary Benthic Macroinvertebrate Survey Results, July 2002 and May 2003 .

	TV	FFG	Upper Reach: RM 2.4 to RM 3.2 EC-510	EC-511	EC-512	Total	Middle Reach : RM 1.6 to RM 2.0 EC-513	EC-514	EC-515	Total
Plecoptera										
Chloroperlidae	1	p	15		11	26		2		2
Paraperla sp.	0	p	1			1				
Suwallia sp.	1	p		6		6				
Nemouridae	2	s								
Malenka sp.	2	s	1	2	1	4				
Perlidae	1	p	2			2				
Calineuria californica	2	p		1	6	7				
Pteronarcyidae	0	s								
Pteronarcys sp.	0	s	1			1				
Trichoptera										
Glossosomatidae	0	g								
Glossosomatidae pupa	0	nf		11		11				
Glossosoma sp.	0	g		1		1				
Protoptila sp.	1	g	2	12	1	15				
Hydropsychidae	4	f		2		2				
Cheumatopsyche sp.	5	f		1		1				
Hydropsyche sp.	4	f	5			5				
Hydroptilidae	4	g								
Hydroptilidae pupa	4	nf	5			5				
Hydroptila sp.	6	g	2			2				
Lepidostomatidae	1	s								
Lepidostoma sp.	1	s		10		10		1		1
Rhyacophilidae	0	p								
Rhyacophila sp.	0	p	1			1				
Sericostomatidae	3	g								
Gumaga sp.	3	s		1		1		2		2
Subphylum Chelicerata										
Class Arachnoidea										
Acari										
Hydrodromidae	5	p								
Hydrodromia sp.	5	p		4	2	6				
Hygrobatidae	5	p								
Atractides sp.	8	p	1	4	2	7				
Corticacarus sp.	8	p								
Hygrobates sp.	8	p			1	1				
Lebertiidae	8	p								
Lebertia sp.	8	p	6	5	3	14	1		1	2
Scutolebertia sp.	8	p								
Limnessidae	5	p								
Limnesia sp.	5	p							4	4
Pionidae	5	p								
Tiphys sp.	5	p							2	2
Sperchontidae	8	p								
Sperchon sp.	8	p			1	1				
Sperchonopsis verrucosa	8	p	3			3				
Torrenticolidae	5	p								
Torrenticola sp.	5	p	19	20	20	59	1	1	1	3
Unioncolidae	5	p								
Unionicola sp.	5	p								
Undetermined	5	p	3			3				
Subphylum Crustacea										
Class Malacostraca										
Amphipoda										
Corophiidae										
Corophium sp.	4	c	1	2	1	4	2	7	8	17
Gammaridae	4	c								
Gammarus sp.	4	c	4			4		2	8	10
Talitridae										
Hyalella azteca	8	c								
Isopoda										
Sphaeromatidae										
Gnorimosphaeroma sp.		c	1		94	95	291	282	236	809
Mysidacea										
Mysis sp.		f		19		19				
Class Ostracoda										
Ostracoda	8	c								
PHYLUM COELENTERATA										
Class Hydrozoa										
Hydroida										
Hyridae										
Hydra sp.	5	p								

Appendix D. Lower Gualala River and Estuary Benthic Macroinvertebrate Survey Results, July 2002 and May 2003 .

	TV	FFG	Upper Reach: RM 2.4 to RM 3.2 EC-510	EC-511	EC-512	Total	Middle Reach : RM 1.6 to RM 2.0 EC-513	EC-514	EC-515	Total
PHYLUM MOLLUSCA										
Class Gastropoda										
<u>Prosobranchia</u>										
Pleuroceridae	6	g								
Juga sp.	7	g	6	38		44	1			1
PHYLUM NEMATODA	5	p	1			1				
PHYLUM PLATYHELMINTHES										
Class Turbellaria										
<u>Tricladida</u>										
Planariidae	4	p		2		2	1			1
Polycelis coronata	1	om								
PHYLUM ANNELIDA										
Class Oligochaeta	5	c			2	2	1			1
Class Polychaeta										
Nerediae										
Nereis sp.		c								
PHYLUM NEMERTEA										
Class Enopla										
Tertastemmatidae										
Prostoma sp.	8	c		2		2				
Total			316	329	348	993	310	333	309	952
Abundance Calculation										
Extra BMIs			0	4	0		0	0	0	
Grids Picked			4	4	5		1	5	1	
Total Grids			12	12	32		20	32	8	
Estimated Abundance			948.0	999.0	2227.2	4174.2	6200.0	2131.2	2472.0	10803.2
CSBP Metric Calculation										
Taxa Richness			43.0	39.0	32.0	69.0	14.0	18.0	17.0	34.0
Percent Dominant Taxon			27.2	15.2	27.0	13.3	93.9	84.7	76.4	85.0
EPT Taxa			16.0	17.0	9.0	27.0	2.0	8.0	2.0	10.0
EPT Index (%)			28.8	45.9	25.3	33.2	1.3	6.9	7.1	5.1
Sensitive EPT Index			11.1	22.5	8.3	13.9	0.0	2.7	0.0	0.9
Ephemeroptera Taxa			6.0	7.0	5.0	9.0	2.0	5.0	2.0	7.0
Plecoptera Taxa			5.0	3.0	3.0	7.0	0.0	1.0	0.0	1.0
Trichoptera Taxa			5.0	7.0	1.0	11.0	0.0	2.0	0.0	2.0
Dipteran Taxa			11.0	8.0	9.0	17.0	2.0	3.0	7.0	8.0
Percent Dipteran			40.8	11.6	16.4	22.6	1.3	4.5	8.1	4.6
Non-Insect Taxa			10.0	9.0	9.0	17.0	7.0	4.0	7.0	10.0
Percent Non-Insect			14.2	29.2	36.2	26.9	96.1	87.7	84.1	89.3
Percent Chironomidae			34.8	10.9	12.6	19.1	1.3	4.5	7.8	4.5
Percent Hydropsychidae			0.0	0.9	0.0	0.3	0.0	0.0	0.0	0.0
Percent Baetidae			11.7	15.5	13.8	13.7	0.3	0.6	1.0	0.6
Shannon Diversity			2.9	3.0	2.5	3.2	0.4	0.8	1.1	0.8
Tolerance Value			4.8	4.1	3.3	4.0	0.3	0.7	1.1	0.7
Percent Intolerant (0-2)			11.1	20.4	8.9	13.4	0.0	1.5	0.3	0.6
Percent Tolerant (8-10)			3.2	3.3	2.0	2.8	0.3	0.0	1.0	0.4
Percent Collectors			57.0	33.1	55.2	48.4	96.1	94.6	95.5	95.4
Percent Filterers			1.6	6.7	2.3	3.5	0.0	0.0	0.0	0.0
Percent Grazers			17.1	35.9	24.1	25.8	2.3	1.5	0.0	1.3
Percent Predators			21.5	16.7	16.1	18.0	1.3	2.7	3.9	2.6
Percent Shredders			1.3	4.0	0.3	1.8	0.0	0.9	0.0	0.3
Total Percentages			98.4	96.4	98.0	97.6	99.7	99.7	99.4	99.6

Appendix D. Lower Gualala River and Estuary Benthic Macroinvertebrate Survey Results, July 2002 and May 2003 .

			Lower Reach: RM 0.4 to RM 1.14				Lower Reach: RM 0.8, May 2003			
	TV	FFG	EC-516	EC-517	EC-518	Total	EC-110	EC-111	EC-112	Total
PHYLUM ARTHROPODA										
Class Insecta										
Coleoptera (adults)										
Dytiscidae	5	p								
Uvarus subtilis	5	p			4	4				4
Elmidae	4	c								
Narpus sp.	4	c								
Optioservus sp.	4	g								
Rhizelmis nigra	2	g								
Zaitzevia sp.	4	c								
Coleoptera (Larvae)										
Dytiscidae	5	p								
Oreodytes sp.	5	p			1	1				
Elmidae	4	c								
Optioservus sp.	4	g					1	5		6
Zaitzevia sp.	4	c								
Psephenidae										
Eubrianax edwardsi	4	g					1	1	1	3
Diptera										
Ceratopogonidae	6	p								
Ceratopogonidae pupa	6	p								
Atrichopogon sp.	6	c								
Bezzia sp./ Palpomyia sp.	6	p								
Probezzia sp.	6	p					1	1		2
Chironomidae	6						4	2	3	9
Chironominae	6	c	2			2				
Chironominae pupa	6	nf								
Chironomini	6	c								
Tanytarsini	6	c	1		2	3				
Orthocladiinae	5	c			9	9				
Orthocladiinae pupa	5	nf								
Krenosmittia sp.	1	c								
Podonominae	6	c								
Tanypodinae	7	p								
Tanypodinae pupa	7	nf								
Dolichopodidae	4	p								
Empididae	6	p								
Chelifera sp.	6	p								
Dolicocephala sp.	6	p								
Hemerodromia sp.	6	p								
Simuliidae	6	f								
Prosimulium sp.	3	f								
Simulium sp.	6	f								
Tanyderidae	1									
Protanyderus sp.	1									
Tipulidae	3	s								
Antocha sp.	3	c								
Hexatoma sp.	2	p								
Hemiptera										
Corixidae	8	p								
Sigara sp.	8	p			3	3				
Naucoridae	5	p								
Ambrysus sp.	5	p			1	1				
Sialidae	4	p								
Sialis sp.	4	p								
Odonata										
Gomphidae	4	p								
Ophiogomphus sp.	4	p						1		1
									1	1
Ephemeroptera										
Baetidae	4	g								
Baetis sp.	5	c								
Diphetor hageni	5	c								
Fallceon quilleri	4	c			3	3				
Ephemerellidae	1	c								
Attenella sp.	2	c								
Serratella sp.	2	c								
Heptageniidae	4	g								
Leucrocuta/Nixe sp.	3	g								
Isonychiidae	2	c								
Isonychia velma	2	c								
Leptophlebidae	2	c								
Paraleptophlebia sp.	4	c								

Appendix D. Lower Gualala River and Estuary Benthic Macroinvertebrate Survey Results, July 2002 and May 2003 .

	TV	FFG	Lower Reach: RM 0.4 to RM 1.14				Lower Reach: RM 0.8, May 2003			
			EC-516	EC-517	EC-518	Total	EC-110	EC-111	EC-112	Total
Plecoptera										
Chloroperlidae	1	p								
Paraperla sp.	0	p								
Suwallia sp.	1	p								
Nemouridae	2	s								
Malenka sp.	2	s								
Perlidae	1	p								
Calineuria californica	2	p								
Pteronarcyidae	0	s								
Pteronarcys sp.	0	s								
Trichoptera										
Glossosomatidae	0	g								
Glossosomatidae pupa	0	nf								
Glossosoma sp.	0	g								
Protoptila sp.	1	g								
Hydropsychidae	4	f								
Cheumatopsyche sp.	5	f								
Hydropsyche sp.	4	f								
Hydroptilidae	4	g								
Hydroptilidae pupa	4	nf								
Hydroptila sp.	6	g								
Lepidostomatidae	1	s								
Lepidostoma sp.	1	s								
Rhyacophilidae	0	p								
Rhyacophila sp.	0	p								
Sericostomatidae	3	g								
Gumaga sp.	3	s						2		2
Subphylum Chelicerata										
Class Arachnoidea										
Acari										
Hydrodromidae	5	p								
Hydrodromia sp.	5	p								
Hygrobatidae	5	p								
Atractides sp.	8	p								
Corticacarus sp.	8	p								
Hygrobates sp.	8	p								
Lebertiidae	8	p								
Lebertia sp.	8	p		1		1		1	1	2
Scutolebertia sp.	8	p								
Limnessidae	5	p								
Limnesia sp.	5	p	2		3	5				
Pionidae	5	p								
Tiphys sp.	5	p								
Sperchontidae	8	p								
Sperchon sp.	8	p								
Sperchonopsis verrucosa	8	p								
Torrenticolidae	5	p								
Torrenticola sp.	5	p						1		1
Unioncolidae	5	p								
Unionicola sp.	5	p	22	1	3	26				
Undetermined	5	p								
Subphylum Crustacea										
Class Malacostraca										
Amphipoda										
Corophiidae										
Corophium sp.	4	c	50	19	31	100	4		1	5
Gammaridae	4	c								
Gammarus sp.	4	c	20	42	20	82				
Talitridae										
Hyalella azteca	8	c					98	78	135	311
Isopoda										
Sphaeromatidae										
Gnorimosphaeroma sp.		c	228	271	45	544	203	269	184	656
Mysidacea										
Mysis sp.		f	5			5				
Class Ostracoda										
Ostracoda	8	c			177	177				
PHYLUM COELENTERATA										
Class Hydrozoa										
Hydroida										
Hyridae										
Hydra sp.	5	p	1			1				

Appendix D. Lower Gualala River and Estuary Benthic Macroinvertebrate Survey Results, July 2002 and May 2003 .

	TV	FFG	Lower Reach: RM 0.4 to RM 1.14 EC-516	EC-517	EC-518	Total	Lower Reach: RM 0.8, May 2003 EC-110	EC-111	EC-112	Total
PHYLUM MOLLUSCA										
Class Gastropoda										
Prosobranchia										
Pleuroceridae	6	g								
Juga sp.	7	g								
PHYLUM NEMATODA	5	p								
PHYLUM PLATYHELMINTHES										
Class Turbellaria										
Tricladida										
Planariidae	4	p								
Polycelis coronata	1	om								
PHYLUM ANNELIDA										
Class Oligochaeta	5	c		1		1	4			4
Class Polychaeta										
Neredidae										
Nereis sp.		c	6	1		7	2	2	3	7
PHYLUM NEMERTEA										
Class Enopla										
Tertastemmatidae										
Prostoma sp.	8	c								
Total			337	336	302	975	318	363	326	1007
Abundance Calculation										
Extra BMIs			7	7	0					
Grids Picked			5	9	7		5	3	1	
Total Grids			12	64	48		16	16	8	
Estimated Abundance			825.6	2439.1	2070.9	5335.6	1017.6	1936.0	2608.0	5561.6
CSBP Metric Calculation										
Taxa Richness			10.0	7.0	13.0	19.0	9.0	11.0	8.0	15.0
Percent Dominant Taxon			67.7	80.7	58.6	55.8	63.8	74.1	56.4	65.1
EPT Taxa			0.0	0.0	1.0	1.0	0.0	1.0	0.0	1.0
EPT Index (%)			0.0	0.0	1.0	0.3	0.0	0.6	0.0	0.2
Sensitive EPT Index			0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.2
Ephemeroptera Taxa			0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0
Plecoptera Taxa			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trichoptera Taxa			0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0
Dipteran Taxa			2.0	0.0	2.0	3.0	2.0	2.0	1.0	2.0
Percent Dipteran			0.9	0.0	3.6	1.4	1.6	0.8	0.9	1.1
Non-Insect Taxa			8.0	7.0	6.0	11.0	5.0	5.0	5.0	7.0
Percent Non-Insect			99.1	100.0	92.4	97.3	97.8	96.7	99.4	97.9
Percent Chironomidae			0.9	0.0	3.6	1.4	0.0	0.0	0.0	0.0
Percent Hydropsychidae			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percent Baetidae			0.0	0.0	1.0	0.3	0.0	0.0	0.0	0.0
Shannon Diversity			1.1	0.7	1.4	1.4	0.9	0.8	0.8	0.9
Tolerance Value			1.3	0.8	5.9	2.5	2.7	1.9	3.4	2.7
Percent Intolerant (0-2)			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percent Tolerant (8-10)			0.0	0.3	59.6	18.6	30.8	21.8	41.7	31.1
Percent Collectors			91.1	99.4	95.0	95.2	97.8	96.1	99.1	97.6
Percent Filterers			1.5	0.0	0.0	0.5	0.0	0.0	0.0	0.0
Percent Grazers			0.0	0.0	0.0	0.0	0.6	1.7	0.3	0.9
Percent Predators			7.4	0.6	5.0	4.3	0.3	1.1	0.3	1.0
Percent Shredders			0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.2
Total Percentages			100.0	100.0	100.0	100.0	98.7	99.4	99.7	99.7