# DEVEREUX SLOUGH LONG TERM MONITORING PROGRAM: FIELD MANUAL

# TABLE OF CONTENTS

# CHAPTER ONE: INTRODUCTION

## *Goals of the monitoring program*

The goal of this monitoring program is to develop a comprehensive understanding of the Devereux Slough ecosystem and the dynamic changes of this estuary over long-term scales. The Devereux Slough Monitoring Program (DSMP) was formed to define the basic information needs for managing the Devereux estuarine system, to develop a scientific framework with standard methods for monitoring estuaries and for interpreting the results, and to regularly report the findings to the public.

This manual was developed by the DSMP Coordinator and interns in coordination with Coal Oil Point Reserve (COPR). This protocol was developed as a tool to track changes in wetland parameters and determine if these changes are naturally occurring or caused by human disturbance, and ecosystem level responses to restoration and management activities. With long term monitoring, we can present conclusions on ecosystem conditions as an important step in the adaptive management process. A long term monitoring program can provide information to the size and direction of biotic and abiotic changes within Devereux Slough before, during, and after management actions. The goals of this volunteer monitoring program are to:

- Promote stewardship of estuaries, particularly in restoration and protection
- Characterize the ambient condition of the slough
- Describe whether slough condition is improving degrading or staying the same
- Define seasonal patterns in slough conditions
- Identify and monitor sensitive species population numbers (i.e. Endangered Tidewater Goby and threatened Snowy Plover)
- Generate consistent long term data to be used in assessment of health of Devereux Slough and restoration and other management efforts
- Provide step by step instructions to accomplish the above mentioned goals

Estuary volunteer monitoring programs give the community and students an invaluable opportunity to intimately know the many unique and valuable characteristics of the estuarine environment. As people learn more about how an estuary functions and come to recognize its signs of distress, their concern for its future is increased. So too is their commitment to its protection. The fact is, we will take care of something when we value it.

Volunteer estuary monitoring programs can create citizen leaders who work to reduce pollution, increase education, and better manage our coastal areas, all with the purpose of protecting some very special places. By donating their time and talents to a monitoring program, volunteers offer a priceless, enduring legacy to the future. We are collectively responsible for the preservation our natural world for the future generations of people, animals and plants that call an estuary "home.

## About this manual

This manual is organized into 9 chapters: Chapters 1-4 present an introduction to estuarine monitoring and the Devereux Slough ecosystem. Chapters 5-8 focus on methodologies for monitoring specific biotic and abiotic estuarine parameters and the significance of each one of these measures. The final chapter of this manual is dedicated to maintenance of equipment, databases and protocols. Organization of the Manual

The manual is organized into eleven chapters: Chapters 1-4 present an introduction to estuarine monitoring and the Devereux Slough ecosystem. Chapters 5-8 focus on methodologies for monitoring specific biotic and abiotic estuarine parameters and the significance of each one of these measures. The final Chapters of this manual are dedicated to data sheets, equipment management and additional figures and maps.

Specifically, the chapters are organized as follows:

*Chapter 1: Introduction*

The introduction outlines the purpose of this manual and provides general information about the Devereux Slough and the Devereux Slough Monitoring Program.

*Chapter 2: California Estuaries: Importance and Threats*

This chapter introduces the concept of an estuary and the major problems that face California's estuarine systems. It also discusses the reasons long-term monitoring of estuaries is essential to help in management and protection of these important natural resources.

*Chapter 3: Natural and Cultural History of Devereux Slough*

This chapter details the historical and current attributes of the Devereux Slough and Coal Oil Point Reserve by discussing land use change and landscape characteristics.

*Chapter 4: Monitoring Program Design*

This chapter covers the basics of planning, implementing and maintaining the DSMP. Included in this chapter are the…

*Chapter 5: Hydrology*

This section discusses several water quality parameters that are monitored through the DSMP including temperature, dissolved oxygen, salinity, turbidity and nutrient loading. The chapter gives information on the usefulness of each parameter, sampling directions and data recording.

*Chapter 6: Fish*

This section outlines the sampling methodology for monitoring fish species within the Devereux System.

*Chapter 7: Invertebrates*

*Chapter 8: Vegetation*

This section discusses the implications and importance of vegetation

monitoring in wetland ecosystems. It describes the parameters being monitored including point intercept, percent cover, relative abundance, species composition, species richness, species evenness, and occurrence frequency. Changes in vegetation due to current and past restoration projects are also discussed.

*Chapter 9: Maintenance*
This section explains how to maintain equipment, sampling sites, and proper storage of all materials necessary for the operation of DSMP.

*Monitoring Manual for the Devereux Slough Ecosystem, Coal Oil Point Reserve*, is a guide for the long term-monitoring of the slough depicting field methodologies, data management and analysis, equipment maintenance and management suggestions. The guide describes the role of volunteer/paid interns and program coordinators in the efforts to monitor and manage this unique system.

This manual focuses on the concepts, plans and methods developed over a four-year period on-site at Coal Oil Point Reserve. The manual was developed with the help of COPR's staff, numerous undergraduate volunteers, interns, and the modification of current estuarine monitoring techniques (see reference section).

This manual provides a framework for coordinators and volunteers to collect accurate data in a consistent fashion. By using this approach, volunteer data can be used to compare current data with past collections to observe changes and patterns in the slough ecosystem functioning.

## Intended Audience

This manual is intended to be a guide for coordinators and participants in the DSMP. Other such programs may be managed by environmental groups, educational institutions, or government agencies. This program is managed by COPR. The mission statement of the Reserve is: "***to contribute to the understanding and wise management of the Earth and its natural systems by supporting university-level teaching, research and public service at protected natural areas throughout California."*** As such, the volunteers for the DSMP learn important field methodologies and data analysis techniques while contributing to the monitoring and management of this protected system.

## What can I get from the volunteer experience?

1. You, as a volunteer, will learn more about estuarine and wetland science. By familiarizing yourself with the biotic and abiotic (non-living chemical and physical factors) characteristics of Devereux Slough, you will have a better understanding of this dynamic and unique ecosystem and the high biodiversity that inhabits it
2. You will learn not only about taking Secchi disk transparency readings, but also about other water quality tests.

3. You will become proficient at a variety of field sampling techniques including fish trapping and seining methodologies, hydrological monitoring (such as oxygen, salinity and temperature measurements, and stream nutrient sampling), GPS use, and vegetation monitoring.
4. By summarizing the information that you collect, we will be able to assess the changes in water quality and biological composition and Devereux Slough.
5. After we have summarized the data, we will be able to compare the water quality of Devereux with other Central Coast estuaries.
6. Once we have several seasons' worth of data, we can begin to assess the long-term trends in estuary.

## The role of Volunteer Monitors

Volunteer monitoring is very important because it provides much-needed data to scientists and resource managers. You do not need a college degree in biology to be a volunteer monitor — all you need is enthusiasm and a willingness to learn.
Efficient use of resources is needed to accurately evaluate the impacts to estuarine ecology, the feasibility of proposed mitigation projects, and the effects of restoration actions. Volunteer monitors can play a pivotal role by providing resource managers with much needed field data. Volunteers, resource managers, and scientists all benefit from this type of partnership. Volunteer monitors receive training in wetland science and assessment and become active in local resource planning and decision-making.

Volunteer participation monitoring programs is not a new phenomenon. For many decades volunteers have been counting birds, taking Secchi disc readings in lakes, and collecting stream invertebrates to provide valuable data to state and federal agencies. Counts, surveys, and simple tests are well suited for volunteers that do not have the scientific training or the time to devote to large-scale research projects.

## *How to Use This Manual*

The DSMP Manual should be used in combination with the rigorous onsite training. Volunteers involved with the DSMP should familiarize themselves with the monitored parameters and obtain a general understanding of the science involved in each of these measurements, why we monitor them and what each parameter is telling us about the Devereux Slough Ecosystem. Volunteers should also study the associated field guides to become familiar with the biota and fauna within the system. This manual can help with all of these objectives. The manual also gives a step by step break down of the field and data entry methodologies as well as a brief background as to how these methods were developed. The manual can be used in the field as a resource for Volunteers after receiving onsite training. The appendices to this manual include identification guides and

field guides to supplement field monitoring training.

## *Designing a Monitoring Plan*

The frequency of monitoring and the type of characteristics measured change over time as the restoration project develops, both structurally and functionally. Three different restoration monitoring phases are identified and described: post-implementation, intermediate, and long-term. The emphasis on which types of characteristics are monitored changes as the system matures.

# CHAPTER TWO: CALIFORNIA ESTUARIES; IMPORTANCE AND THREATS

## *What is an Estuary?*

An estuary is a partially enclosed body of water formed where freshwater from rivers and streams flows into the ocean, mixing with the salty sea water. Estuaries and the lands surrounding them are places of transition from land to sea, and from fresh to salt water. According to a paper by Perillo (1995), discussing different definitions of estuaries: "An estuary is a semi-enclosed coastal body of water that extends to the effective limit of tidal influence, within which sea water entering from one or more free connections with the open sea, or any other saline coastal body of water, is significantly diluted with fresh water derived from land drainage, and can sustain euryhaline biological species from either part or the whole of their life cycle." (Perillo 1995.)

Estuaries come in all shapes and sizes and go by many different names, often known as bays, lagoons, harbors, inlets, or sounds. (Note not all water bodies by those names are necessarily estuaries. The defining feature of an estuary is the mixing of fresh and salt water, not the name.) Some familiar examples of estuaries include San Francisco Bay, Puget Sound, Chesapeake Bay, Boston Harbor, Goleta Slough, Elkhorn Slough and Morro Bay Estuary.

Estuaries and coastal lagoons are among the earth's most biologically productive ecosystems and they provide essential habitats for birds, fish, invertebrates and many other species. The loss of estuaries and their communities has been of growing concern over the past three decades. Rates of loss of coastal wetlands in the US resulting from human activities has been as high as 8,000 ha a year over the past three decades (Elliott & McLusky 2002; Pritchard 1967).

The estuary itself is a rather well-defined body of water, bounded at its mouth by the ocean and at its head by the upper limit of the tides. It drains a much larger area, however, and pollutant-producing activities near or in tributaries even hundreds of miles away may still adversely affect the estuary's water quality. Fresh water flowing in from tributaries is relatively light and overrides the wedge of more dense salt water moving in from the ocean. This density differential often causes layering or stratification of the water, which significantly affects both circulation and the chemical profile of an estuary (Roman *et al.* 2000).

## *Why are Estuaries Important?*

Estuaries are critical for the survival of many species. Tens of thousands of birds, mammals, fish, and other wildlife

depend on estuarine habitats as places to live, feed, and reproduce. Estuaries provide ideal spots for migratory birds to rest and refuel during their journeys. Hundreds of marine organisms, including most commercially valuable fish species, depend on estuaries at some point during their development (USEPA 2001-2004).

Besides serving as important habitat for wildlife, the wetlands that fringe many estuaries also perform other valuable services. Water draining from the uplands carries sediments, nutrients, and other pollutants. As the water flows through fresh and salt marshes, much of the sediments and pollutants are filtered out. This filtration process creates cleaner and clearer water, which benefits both people and marine life (USEPA 2001-2004). Wetland vegetation acts as a natural buffer between the land and ocean, absorbing flood waters and urban runoff. Salt marsh grasses and other estuarine plants also help prevent erosion and stabilize the shoreline (McDonald 2000).

Among the cultural benefits of estuaries are recreation, scientific knowledge, education, and aesthetic values. Estuaries are often the cultural centers of coastal communities, serving as the focal points for local commerce, recreation, celebrations, customs, and traditions (Kennish 2002a). As transition zones between land and water, estuaries are invaluable laboratories for scientists and students, providing countless lessons in biology, geology, chemistry, physics, history, and social issues. Estuaries also provide a great deal of aesthetic enjoyment, bird watching opportunities and other recreational activities.

Nationwide, commercial and recreational fishing, boating, tourism, and other coastal industries provide more than 28 million jobs. There are 25,500 recreational facilities along the U.S. coasts almost 44,000 square miles of outdoor public recreation areas ocean and bay beaches- nearly 70% of the U.S. population (EPA. 2002.).

In short, estuaries provide us with a whole suite of resources, benefits, and services. Some of these can be measured in dollars and cents, others can not. Estuaries are an irreplaceable natural resource that must be managed carefully for the mutual benefit of all who enjoy and depend on them.

## *Why Protect Estuaries?*

The loss of coastal wetlands and their unique communities has been of growing concern over the past three decades. A wide range of local, state, federal and private programs have been created to support the national policy of wetland "No Net Loss" (Whigham 1999). The economy of many coastal areas is based primarily on the natural beauty and bounty of estuaries. When those natural resources are imperiled, so too are the livelihoods of the many people who live and work there. 110 million Americans- around half the U.S. population- now live in coastal areas, including the shores of estuaries. Coastal counties are growing three times faster than counties elsewhere in the nation (Kennish 2002b).

Unfortunately, this increasing concentration of people is upsetting the natural balance of estuarine ecosystems and threatening their integrity. Channels have been dredged, marshes and tidal

flats filled, waters polluted, and shorelines reconstructed to accommodate human housing, transportation, and agriculture needs (EPA. 2002.). Stresses caused by overuse of resources and unchecked land use practices have resulted in unsafe drinking water, beach and shellfish bed closings, harmful algal blooms, unproductive fisheries, loss of habitat, fish kills, and wildlife, and a host of other human health and natural resource problems (Kennish 2002b).

As our population grows, the demands imposed on our natural resources increase. So too does the importance of protecting these resources for all their natural, economic, and aesthetic values (Elkhorn Slough Estuarine Sanctuary Advisory Committee 1985).

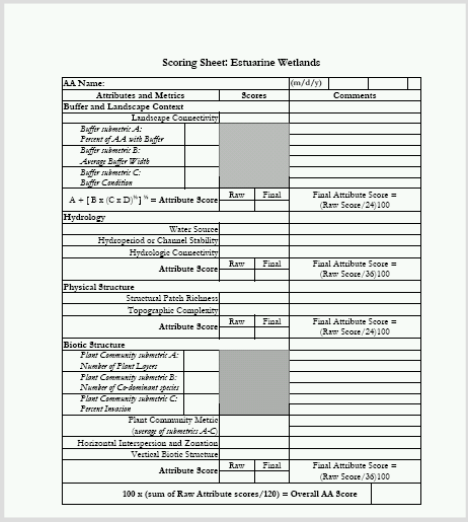
To develop and implement an effective plan for a comprehensive estuarine monitoring network, it is important to understand the nature and dynamics of estuaries in general, and also to understand the details of the particular estuary, embayment, harbor, or river to be monitored. These details include the bathymetry, tidal range, circulation patterns, and pollution problems that are being encountered.

The estuarine environment is a complex blend of continuously changing habitats. Unlike fresh water rivers and lakes, estuaries can produce a wide range in the values of physical and chemical parameters that will be recorded, and frequent changes occur in these values both with tidal cycles and meteorological events. In streams, rivers, and lakes, water quality parameters are more likely to fluctuate within a well-defined range largely determined by rainfall and season, and these values are often homogenous throughout the water body. In an estuary, in contrast, these parameters can change abruptly in time and space, are dependent on the measurement location, and may or may not reflect general environmental conditions throughout the estuary (USEPA 2001-2004).

Combined with these natural variations are changes caused by human intervention, including modification of flow and bathymetry (for example, through construction of barriers to flow or dredging) and the input of pollutants, including excess nutrients and toxics.. Typical pollution problems in estuaries include nutrient enrichment leading to accelerated eutrophication (excessive plant growth); low dissolved oxygen (DO) levels associated with eutrophication and/or flow restrictions; toxics in the water column or sediments, particularly petroleum hydrocarbons and heavy metals from point discharges and non-point source runoff; algal blooms, which can be toxic to marine organisms and humans; and the proliferation of invasive species. Humanity strongly impacts biogeochemistry, hydrological and ecological processes on both local and global scales. We seem to challenge the capacity of ecosystems to cope with events and disturbances (Folke *et al.* 2004).

## *Monitoring of California's Estuaries*

There are a variety of local, state and federal efforts to monitoring the estuarine systems of the Pacific coast. These include programs designed by the National Estuaries Program, California Wetlands Monitoring Program, California Coastal Water Quality Monitoring, California Rapid Assessment, San Francisco Estuaries Institute, and others.



Scoring Sheet: Estuarine Wetlands

| AA Name: | | | | (m/d/y) | | | |
|---|---|---|---|---|---|---|---|
| Attributes and Metrics | | Scores | | Comments | | | |
| Buffer and Landscape Context | | | | | | | |
| Landscape Connectivity | | | | | | | |
| *Buffer submetric A: Percent of AA with Buffer* | | | | | | | |
| *Buffer submetric B: Average Buffer Width* | | | | | | | |
| *Buffer submetric C: Buffer Condition* | | | | | | | |
| A = [ B x (C x D)$^{1/2}$ ]$^{1/2}$ = Attribute Score | | Raw | Final | Final Attribute Score = (Raw Score/24)100 | | | |
| Hydrology | | | | | | | |
| Water Source | | | | | | | |
| Hydroperiod or Channel Stability | | | | | | | |
| Hydrologic Connectivity | | | | | | | |
| Attribute Score | | Raw | Final | Final Attribute Score = (Raw Score/36)100 | | | |
| Physical Structure | | | | | | | |
| Structural Patch Richness | | | | | | | |
| Topographic Complexity | | | | | | | |
| Attribute Score | | Raw | Final | Final Attribute Score = (Raw Score/24)100 | | | |
| Biotic Structure | | | | | | | |
| *Plant Community submetric A: Number of Plant Layers* | | | | | | | |
| *Plant Community submetric B: Number of Co-dominant species* | | | | | | | |
| *Plant Community submetric C: Percent Invasive* | | | | | | | |
| Plant Community Metric (average of submetrics A-C) | | | | | | | |
| Horizontal Interspersion and Zonation | | | | | | | |
| Vertical Biotic Structure | | | | | | | |
| Attribute Score | | Raw | Final | Final Attribute Score = (Raw Score/36)100 | | | |
| 100 x (sum of Raw Attribute scores/120) = Overall AA Score | | | | | | | |

California Rapids Assessment Field Scoring data sheet

The Estuary Resource Group of the Environmental Monitoring and Assessment Program (EMAP) in 1999 sampled habitats along the Pacific coast. EMAP is a national program of the U.S. Environmental Protection Agency (EPA) that uses a probability-based sampling design to periodically characterize ecological conditions at regional and national spatial scales.
Some important goals of an estuarine monitoring program include:

## *Estuarine Management*

NEED to write

**GOALS OF A MONITORING PROGRAM**

- To educate the public about water quality issues.
- To build a constituency of citizens to practice sound water quality management at a local level and build public support of water quality protection.
- To increase awareness about a problem in the estuary, such as the documentation of illegal discharges into the water.
- To promote stewardship and conservation of estuaries
- To establish baseline conditions where no prior information exists.
- Generate quality data to be used in the assessment of the health of a marsh and in restoration or protection efforts.
- To determine water quality changes through time.
- To identify current and emerging problems, such as pollution sources, habitat loss, or the

# CHAPTER 3: NATURAL AND CULTURAL HISTORY OF DEVEREUX SLOUGH

## *Study System and Background*

The Devereux watershed is approximately 9.7 sq. km in size. Devereux Creek is the only major stream. Devereux slough is a seasonally open estuary located on the central coast of California classified under the California Wetlands Classification System, Ferren et al. (1995) as a Canyon Mouth Estuary. It is impounded most of the year by a natural sand barrier and is influenced by tidal water two to three times annually (Davis 1990; Ferren Jr. *et al.* 1987). As part of the University of California Natural Reserve System (NRS) (Coal Oil Point Reserve, COPR), Devereux slough is the location of numerous recreational, educational, public outreach, and research activities.

In the past few decades 85% of the Devereux watershed has been developed or modified. A development project by the University, the City of Goleta, and the Ocean Meadows Golf Course was submitted to the California Coastal Commission to build over 5 housing complexes that will be adjacent to Devereux slough (Barbara 2002).

Devereux slough is valuable location to attempt this integration of science and management because it is a relatively small system (200 hectares) and the entire slough lies within the jurisdiction of the University of California's Natural Reserve System, COPR. There have been sporadic research projects that have measured snapshots of various parameters (oxygen, temperature, invertebrate composition, fish diversity, bird diversity, bathymetry, and salinity. Although management recommendations have been made in the past as well as the creation wetlands management plan which includes the Devereux slough (Davis et al., 1990), the slough has not been actively managed and recommendations from these studies have not been implemented. No systematic and regular study has been conducted at this system. In the fall of 2003, a consistent data collection was initiated when weekly collection of nutrient and sediment loading from Devereux Creek into the estuary began. Then the collection of information on a variety of other biotic and social parameters was also begun. A detailed study of the slough, incorporating an analysis of the changes since the studies of the last decade, is essential to guide future development in the watershed and restoration of the slough and convince managers that recommendations should be followed.

## *Cultural History of COPR*

The 170 acre Coal Oil Point Reserve (COPR) is one of the best remaining examples of a coastal-strand environment in Southern California. COPR protects a wide variety of coastal and estuarine habitats. Largely undisturbed coastal dunes support a rich assemblage of dune vegetation, while older and more stable backdunes are covered with southern coastal scrub habitat. In the heart of the reserve is Devereux Slough. Thousands of migratory birds visit throughout the year. Located adjacent to the Santa Barbara campus, the reserve provides a unique and accessible research and teaching resource, which is used by many university courses, including botany, ecology, biodiversity field methods, natural history, marine biology, invertebrate zoology, and environmental studies.

This natural area and the surrounding land have gone through extreme changes over the centuries. From the use by native peoples to a privately owned ranch and an adjacent US Marine Corps base, some of the more obvious impacts on the naturally environment can be easily identified.

Earliest evidence of human inhabiting the area is about 10,000 years ago, which is also the documented human inhabitation in CA, by the Chumash peoples. There is an abundance of evidence of the Chumash on Channel Islands as well as the interaction of island and mainland people for commerce between there and mainland. Back then, the ocean level was much lower and having less water to cross, it was easier to travel back and forth. It is likely that the ocean now covers the remains of these ancient villages. When sailing North along the Californian Coast, Juan Cabrillo, a Spanish explorer in the mid-1500's, documented over 1,000 Chumash native people at Goleta Slough. During this time the Goleta and Devereux slough were joined and part of an essential wetland for the livelihood of the Chumash people. The Chumash were frequent visitors of Coal Oil Point as they natural tar seeps provided a variety of uses such as canoe sealant.

With the Spanish settlement of the California Coastal areas and the creation of the missionary network, a number of European settlers to this area increased over the next centuries and with them, so did the changes and manipulations of the land here. Agriculture, the fur trade, and developments with roads were evident at first. 1895 marked the first crude oil drill and through the industrial age, the heaviest impacts were made, lasting longer than any others and are still continue today. By 1900, there were over 300 oil derricks. In 1950, the first off-shore oil drilling platform was constructed. Platform Holly is located one fourth of a mile of shore as is used as a loading station to transform oil. Crude oil is pumped from this platform and stored in storage tanks located on leased University property. Every two weeks or so, a barge comes and takes the oil to a refinery in the Los Angeles area to be processed. Today, the SB Channel is one of the major gas and oil producing regions in our nation.

Coal Oil Point (COP) is named for its natural oil seeps. The most intense area of natural seepage in the Santa Barbara Channel is the COP seep field about 15 km west of the city of SB. The COP

seeps produce large oil slicks that extend for up to 10km from their vents and have been extensively studied by remote sensing techniques. The oil in the slicks evaporates as it ages on the ocean surface and is converted to isolated tar globules. These tar calls often wash ashore, resulting in the abundant tar found on southern CA beaches. All of the tar found on SB's beaches as well as 55% of the tar on LA County's beaches is derived from the COP seeps.

This era represents high level of oil activity: Oil catastrophe in 1969 showed us how dangerous this type of harvesting could be. Over 100 miles of coastline was slicked with oil and resulted in the death of thousands of seabirds and other wildlife.

In the late 1800's over 4500 acres of land, of which COPR is a part, was sold as part of the Spanish-Mexican land grant program. During the 18$^{th}$ and 19$^{th}$ and 20$^{th}$ centuries, land grants were made to individuals and groups in the Santa Barbara area during the Spanish period of California history. The Goleta area was originally a 4400-acre ranch granted by the Mexican government in 1846 to Daniel Hill. The village was laid out in 1875, and within two years contained a church, store, lumber yard, blacksmith shop, schoolhouse, post office and a wharf.

In 1919 Colonel Campbell purchased 500 acres of land from Daniel Hill, adjacent to land that had recently been purchased by Mr. Storke. This land encompassed the Devereux Sough as well as the dunes and grasslands to the west of the slough. The Campbells were an affluent family from Chicago. Mr. Campbell, an English Colonel, meet his wife while she was visiting her sister abroad in Asia. After marrying they moved to Chicago, where Mrs. Campbell's father owned extensive property. In 1919 the Campbell's decided they wanted to create a vacation retreat on the west coast. They settled on Santa Barbara, which at the time was the center of movie production. They purchased the 500 acres of land with the idea of building a luxury estate and planting extensive citrus orchards. However, when finding the soil at COP much to saline to support the citrus trees, they began to set up a productive chicken ranch.

During the 30 years that the Campbell's owned the land encompassing COPR, the area was most heavily impacted by the road that was built along the edge of the slough, which separated the 2 fingers from the slough, and the non-native Cypress and Eucalyptus trees that were panted to distinguish the boundary of their property. Unfortunately Colonel Campbell never saw the completion of his estate. He passed away four years after the purchase of the land. Mrs. Campbell completed the estate and ran the chicken ranch for 20 years after his death. After she passed away in the early 1940's her family did not want to deal with maintaining the property. Now only remnants of structures built by the Cambell family remain, including Mr. Campbell's gravestone and pillars to a former gate.

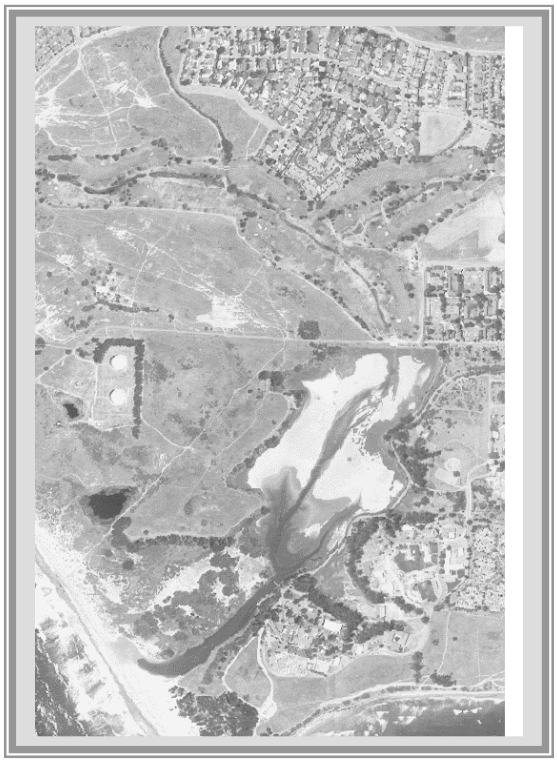
In 1945, the Devereux Foundation bought the area the land for a relatively inexpensive price. Devereux is a non-profit organization providing services around the nation

for persons with emotional, developmental & educational disabilities. At the same time, the University of California, placed a Santa Barbara campus on an area formerly used as a U.S. Marine Corps base. In the late 1960's the Devereux foundation sold a majority of its property to the University of California, keeping only the main buildings for its campus. The University incorporated 158 acres of this land into the University's Natural Reserve System in the late 1960's. Many of the buildings still used today, including COPR's office, were originally part of the Devereux School.

The last 2 decades have proved to offer the most conscious ecological management as part of the NRS. As a protected area for research and education, COPR offers opportunities for many conservation programs and research projects. Examples of these projects include the Grey Whale Count, PISCO, and the Snowy Plover Recovery Project. The Snowy Plover Recovery Project is an example of one project that has gained national recognition for it's outstanding success in the restoration and stewardship of a natural habitat that was no longer suitable for this threatened species.

The Devereux Slough watershed covers 2330 acres, of which over 60% is developed land. The watershed is bounded by the foothills of the Santa Ynez Mountains to the north, Storke Road and Isla Vista to the east, the Pacific Ocean to the south, and Ellwood Canyon to the west the elevations range from sea level to 580 feet above mean sea level. The slough itself is 48 acres. Lower areas of the watershed are generally urbanized while the upper areas consist primarily of native coastal sage scrub, chaparral vegetation, and agricultural lands. Natural annual average runoff has increased over time with urban development and now exceeds 690 acre-feet per year. The watershed drains from the foothill area downstream towards U.S. Highway 101 via natural tributaries of Devereux Creek. The Devereux Creek drains through Santa Barbara Shores, Ellwood Mesa, Ocean Meadows Golf Course, and the Coal Oil Point Reserve.

The Devereux Slough and its watershed have been extensively altered over the past century. Aerial photographs from 1929 indicate that the upper reaches of the slough contained large areas of unaltered mudflats.) Land use surrounding the slough was agriculture and open space.



## *REFERENCES CHAPTERS 1-4*


Amborse R. F. (1995) Coastal Wetland Resources of the Santa Barbara County Mainland. *Final Report to the County of Santa Barbara* Environmental Science and Engineering Program, University of California, Los Angeles.

Barbara C. o. S. (2002) Joint Proposal fir the Ellwood-Devereux Coast. *Santa Barbara County* www.sbcountyplanning.org.

Christensen N., Bartuska A., Brown J., Carpenter S. R., D'Antonio C., Francis R., Franklin J., MacMahon J., Noss R. F., Parsons D. J., Peterson C. H., Turner M. G. & Woodmansee R. G. (1996) The Report of the Ecological Society of Americal Committee on the Scientific Basis for Ecosystem Management. *Ecological Applications* 6: 665-691.

Davis F. W. (1990) University of California Santa Barbara campus wetlands management plan, part 4, recommendations for enhancement, restoration, and public access, a Report to the California Coastal Conservancy and University of California, Santa Barbara.

Elkhorn Slough Estuarine Sanctuary Advisory Committee (1985) Elkhorn Slough National Estuarine Sanctuary Management Plan pp. 1-137. Sanctuary Programs Division, National Oceanic and Atmospheric Administration and The Resource Agency, California Department of Fish and Game.

Elliott M. & McLusky D. S. (2002) The Need for Definitions in Understanding Estuaries. *Estuarine, Coastal and Shelf Science* 55: 815-827.

EPA. U. S. (2002.) Methods for Evaluating Wetland Condition: Introduction to Wetland BiologicalAssessment. *Office of Water, U.S. Environmental Protection Agency, Washington, DC.* EPA-822-R-02-014.

Ferren Jr. W. R., Capralis D. & Hickson D. (1987) Campus Wetlands Management Plan, Part I, Technical Report on the Botanical Resources of West and Storke Campuses. *Herbarium Report No. 12, University of California, Santa Barbara*.

Folke C., Carpenter S. R., Walker B., Scheffer M., Elmqvist T., Gunderson L. & Holling C. S. (2004) Regime shifts, resilience, and biodiversity in ecosystem management. *Annual review of ecological evolution systems* 35: 557-581.

Gray A. N. (2000) Adaptive ecosystem management in the Pacific NorhtwestL a case study from coastal oregon. *Ecology and Society* 4: online: http://www.consecol.org/vol4/iss2/art6/.

Grumbine R. E. (1994) What is Ecosystem Management? *Conservation Biology* 8: 27-38.

Kennish M. J. (2002a) Environmental threats and environmental future of estuaries. *Environmental Conservation* 29: 78-107.

Kennish M. J. (2002b) Environmental threats and environmental future of estuaries. *Environmental Conservation* 29: 78-107.

Levin S. (1998) Ecosystems and the biosphere as complex adaptive systems. *Ecosystems* 1: 431-436.

McDonald M. (2000) EMAP overview: objective, approaches, and achievements. *Environmental Monitoring and Assessment* 64: 3-8.

Perillo G. M. E. (1995.) Geomorphology and Sedimentology of Estuaries. Definitions and Geomorphologic Classifications of Estuaries. *Development in Sedimentology* 53.

Pritchard D. W. (1967) What Is an Estuary: A Physical Viewpoint. *Estuaries. G. H. Lauff (ed.).*

*American Association for the Advancement of Science. Publication No. 83. Washington, DC. 757.*

Roman C. T., Jaworski N., Short F. T., Findlay S. & Warren R. S. (2000) Estuaries of the Northeastern United States: Habitat and land use signitures. *estuaries* 23: 743-764.

USEPA (2001-2004) Environmental Monitoring and Assessment Program , West Coast Pilot 2002 Intertidal Assessment: California Intensification. *Office of Water, U.S. Environmental Protection Agency*.

Whigham D. F. (1999) Ecological issues related to wetland preservation, restoration, creation and assessment. *The Science of the Total Environment* 240: 31-40.

# CHAPTER 5: HYDROLOGY

## *Monitoring Goal:*

To determine the status and yearly, seasonal, daily trends of nutrient loading, dissolved oxygen, salinity measurement, temperature and turbidity in Devereux Slough and maintain a data base with these measurements.

## *Introduction*

Of all the parameters used to characterize the condition of estuaries, water quality characteristics are often the best indicators of the estuary's health. These parameters include dissolved oxygen content, salinity, nutrient levels, bacteria content and turbidity (water clarity). An estuary with little or no oxygen cannot support healthy levels of plant life or animals. Monitoring water quality can allow managers to determine what inputs and processes control different water quality variables.

Keeping track of water quality status and trends requires close monitoring of a number of physical, chemical, and biological parameters. A systematic and well-planned monitoring program can identify water quality problems and help answer questions critical to their solutions (Macauley *et al.* 1999). These questions include:

• Is there a problem?
• If so, how serious?
• Does the problem affect only a portion of the estuary, or the entire body of water?
• Does the problem occur sporadically, seasonally, or year round?
• Is the problem a naturally occurring phenomenon or caused by human intervention, or a combination of the two?

If monitoring activities have not been undertaken in the past, the monitoring project can be used to establish a baseline even if a pollution problem has not been identified. If reliable historical data exist for comparison, the current monitoring project can document changes in the estuary from past to present. These data may serve as a warning, alerting environmental managers to the development of an environmental problem, or on the positive side, confirm the effectiveness of restoration initiatives (USEPA 2001-2004).

Many different parameters contribute to overall water quality, including the amount of oxygen in the water, the concentration of nutrients available to marine life, and turbidity (the number of particles in the water blocking sunlight). Water temperature, salinity and dissolved oxygen are parameters that affect the distribution and impact of pollutants and the resulting health of a body of water. How all these parameters vary down through the water column is also important. The current state of technology allows scientists to measure these parameters continuously at different depths (Papas & Holmes unpublished). Continuous monitoring lets us see whether or not the management initiatives used by many

towns in the state are working to improve water quality.

Monitoring can be conducted at regular sites on a continuous basis ("fixed station" monitoring); at selected sites on an as-needed basis or to answer specific questions (intensive surveys); on a temporary or seasonal basis (for example, during the summer at bathing beaches); or on an emergency basis (such as after a spill). Increasingly, monitoring efforts are aimed at determining the condition of entire watersheds—the area drained by rivers, lakes, and estuaries (Caffrey *et al.* 1997). This is because scientists have come to realize the impact of land-based activities on the waters that drain the land, and the interconnectedness of all types of waterbodies, including those beneath the ground. Without knowledge of the current conditions, i.e., a baseline, we cannot draw viable conclusions about the effectiveness of our management actions and decisions (Carlisle *et al.* 2002).

## *Parameters*

### Turbidity

Turbidity is a measure of water clarity, that is, the ability of water to transmit light, and is influenced by the level of suspended material in the water column. Turbidity is often measured visually using a Secchi disk (Carlisle *et al.* 2002). Turbid waters are caused by suspended sediments, phytoplankton or decomposing material. Suspended material concentration is the amount of material that is suspended in the water column and is measured as the amount of material retained in a filter. Smaller particles are considered dissolved solids (EPA. 2001). The sum of suspended and dissolved solids is referred to as total solids. All three measures are recorded in terms of mg/l. Elevated levels of suspended material and turbidity occur naturally through erosion, storm runoff, and the input of plant material on a seasonal basis. Turbidity can also be an indicator of primary productivity in an estuarine system (Glasgow & Burkholder 2000). Anthropogenic inputs of nutrients can exasperate primary growth. Excessive nutrient loading causes eutrophication (algal growth) (Caffrey 2004).

Sources of turbidity in estuary waters include

- soil erosion from construction, forestry, or agricultural sites
- waste discharge
- urban runoff
- eroding banks
- excessive algal growth (eutrophication)

Turbidity and total solids often increase sharply during and immediately following a rainfall, especially in developed watersheds. These parameters can also indicate degraded water quality if the elevated levels are caused by excessive erosion due to upland development (Anderson *et al.* 2002). Sedimentation, where solids settle out of the water column onto the estuary bottom, is a priority concern in many estuaries, making turbidity monitoring an important part of most estuary water quality monitoring programs (Cailliet *et al.* 1977). Specifically in Devereux Slough, sedimentation is a main concern of estuary functioning. As described in chapter 3, sedimentation in the north western corner of the slough has created a large sediment plume causing the slow

filling of this area of the system. Monitoring sediment levels and turbidity will help to track sedimentation before and after management actions.

Some of the physical effects of excessive suspended materials include:

• clogged fish gills that inhibit the exchange of oxygen and carbon dioxide
• reduced resistance to disease in fish
• reduced growth rates
• altered egg and larval development
• fouled filter-feeding systems of animals
• hindered ability of aquatic predators from spotting and tracking down their prey

Higher concentrations of suspended solids can serve as carriers of toxins, which readily cling to suspended particles. This is particularly a concern where pesticides are being used for crops or for golf courses and urban neighborhoods. Where solids are high, pesticide concentrations may increase well beyond those of the original application as the irrigation water travels down irrigation ditches and stream channels, ultimately into estuaries (Caffrey *et al.* 2002).

## Dissolved Oxygen

Oxygen enters estuarine waters directly from the atmosphere as well as through aquatic plant photosynthesis. Currents (caused by freshwater inflow or tidal influence) and wind-generated waves boost the amount of oxygen in the water by putting more water in contact with the atmosphere. In the water, oxygen is dissolved and can be measured. Dissolved oxygen (DO) is the level of oxygen in the water column in molecular form that is available to support life and is reported in milligrams per liter (mg/l) or as a percentage of saturation. The DO level is controlled by mixing at the air/water interface, temperature and salinity, the level of photosynthesis (which produces oxygen), and decomposition of organic material (which depletes oxygen). Generally, DO levels of greater than 4 mg/l indicate an adequate supply of DO to support species growth and activity, while levels from 1-3 mg/l indicate hypoxic conditions, which are detrimental to life. DO below 1 mg/l indicates anoxia, a condition in which no life that requires oxygen can be supported (Carlisle *et al.* 2002).

DO is one of the most important factors controlling the diversity and abundance of estuarine species. It is vital for most animals and plants except for a few species that can survive under conditions with little or no oxygen. Animals and plants require oxygen for respiration— a process critical for basic metabolic processes (Haskins 2002). In addition to its use in respiration, oxygen is needed to aid in decomposition. An integral part of an estuary's ecological cycle is the breakdown of organic matter done by microbial bacteria that need oxygen to conduct this process. Decomposition of large quantities of organic matter by bacteria can severely deplete the water of oxygen and make it uninhabitable for many species (Dauer *et al.* 1992).

Increased nutrient loading from agricultural runoff, golf courses and sewage intensifies the consumption of DO. Excessive nutrients causes an increase in algal growth (algal blooms). The phytoplankton (algae) eventually die, fall to the bottom and decompose, therefore utilizing all oxygen on the

bottom of the estuary (Engle *et al.* 1999). Although nutrients from human activities are a major cause of depleted oxygen, low oxygen conditions may also naturally occur in estuaries relatively unaffected by humans (Caffrey 2003).

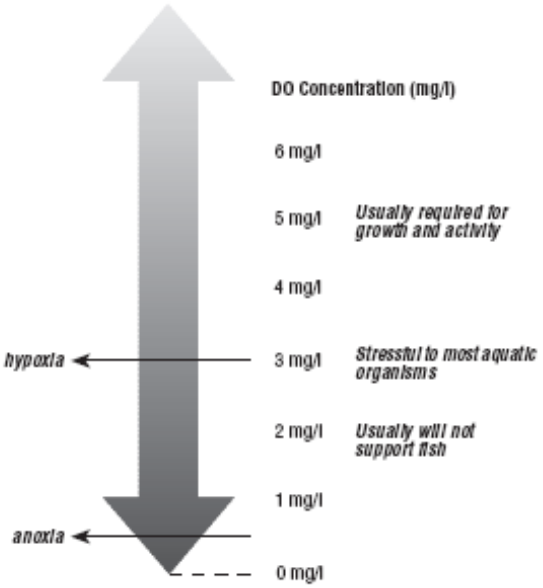
DO levels and nutrients can be associated in another way. At low DO (often anoxic conditions) nutrients such as phosphorus that are bound to particles in the sediment, are released from these bonds. This is an in-estuary process that can increase eutrophication levels. Other pollutants may also be released from sediments under low oxygen conditions, potentially causing problems for the estuarine ecosystem (EPA. 2002.). Oxygen availability to aquatic organisms is complicated by the fact that its solubility in water is generally poor. Salt water absorbs even less oxygen than fresh water (e.g., seawater at 10°C can hold a maximum dissolved oxygen concentration of 9.0 mg/l, while fresh water at the same temperature can hold 11.3 mg/l). Warm water also holds less oxygen than cold water (e.g., seawater can hold a dissolved oxygen concentration of 9.0 mg/l at 10°C, but that concentration drops to 7.3 mg/l when the temperature increases to 20°C). Therefore, warm estuarine water can contain very little dissolved oxygen, and this can have severe consequences for aquatic organisms (Carlisle *et al.* 2002).

As mentioned above, estuarine conditions are very dynamic and oxygen levels, in particular, may change sharply in a matter of hours. Because DO levels are affected by a variety of factors including sunlight, currents, salinity etc, it is difficult to utilize infrequent snap shot DO levels as indicators of the system (Carlisle *et al.* 2002). For example, the water at the surface midday is often oversaturated with DO due to atmosphere inputs and excessive photosynthesis. During the night, without sunlight, photosynthesis stops and plants and other organisms consume the available oxygen and DO levels decline. Surface water DO levels may also decrease if the weather is cloudy (less sunlight). DO levels in estuaries also fluctuate seasonally as well as with depth. Temperature differences between the surface and deeper parts of the estuary may be quite distinct during the warmer months (EPA. 2002.).

Oxygen transfer among depth may also become difficult during periods of stratification (no mixing in water column). Vertical stratification in estuarine waters (warmer, fresher water over colder, saltier water) during the late spring to summer period can prevent the transfer of DO throughout the water column. In a well-stratified estuary, very little oxygen may reach lower depths and the deep water may remain at a fairly constant low level of DO. An increase in freshwater input or wind induced circulation can cause Do to mix throughout the column, supplying oxygen to the anoxic lower waters. Most animals and plants can grow and reproduce unimpaired when DO levels exceed 5 mg/l. When levels drop to 3-5 mg/l, however, living organisms often become stressed. If levels fall below 3 mg/l, a condition known as hypoxia, many species will move elsewhere and immobile species may die. A second condition, known as anoxia, occurs when the water becomes totally depleted of oxygen (below 0.5 mg/l) and results in the death of any organism that requires oxygen for survival. Figure

(5.1) summarizes DO thresholds (EPA. 2002.).

**Figure 5.1:** Dissolved Oxygen Thresholds



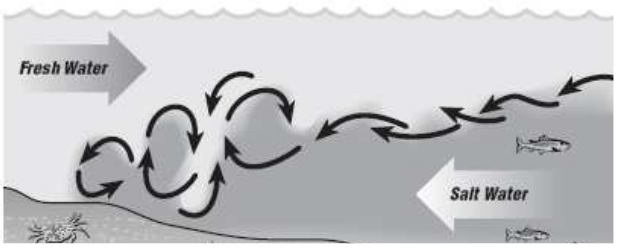

## Salinity

Salinity is also considered an important chemical parameter in estuaries. Salinity is the amount of salts dissolved in water expressed in parts per thousand (ppt) or 0/00. It controls the type of species that can live in an estuary but also influences physical and chemical processes such as flocculation and the amount of DO in the water column (Scharler & Baird 2003). Estuaries generally exhibit a gradual change in salinity levels throughout the length of the system. Tidal flooding, freshwater inflow, and evaporation are the main factors controlling salinity levels in estuaries (Montagana *et al.* 2002).

The most decipherable result of salinity in estuaries is the vegetation zonation patterns (see vegetation chapter). Salinity can control the types of plants and animals that can live in estuaries. Dominant salt marsh plants require a specific salinity range (*Spartina alterniflora, Spartina patens, and Saprtina virginca).* Measurements of salinity can help to explain the diversity, distribution, and abundance of plants and animals in and estuary. Extreme changes in salinity, such as those caused by drought, storm water, and golf course runoff, can greatly affect the numbers and types of species in an estuary (Broenkow & Smith 1972). Salinity also helps control the flocculation (formation of masses) of particles. The particles that enter an estuary dissolved in freshwater may clump together and increase turbidity. Generally, salinity increases with water depth unless the estuarine water column is well mixed (Dickert & Tuttle 1980).

Salinity, along with water temperature, is the primary factor in determining the stratification of an estuary. When fresh and salt water meet, the two do not readily mix. Fresh water is less dense than salty water and will overlie the wedge of seawater pushing in from the ocean. Storms, tides, and wind, however, can eliminate the layering caused by salinity and temperature differences by thoroughly mixing the two masses of water (Yamada 1996).

**Figure 5.2:** Salinity Mixing



Salinity is often an important factor when monitoring many key water quality variables.

For example:

• Most dissolved oxygen meters require knowledge of the salinity content in order to calibrate the meter properly.
• If you are interested in converting the dissolved oxygen concentration (usually expressed as mg/l or parts per million) to percent saturation (amount of oxygen in the water compared to the maximum it could hold at that temperature), you must take salinity into account. As salinity increases, the amount of oxygen that water can hold decreases.

## Temperature

Temperature, probably the most easily measured parameter, is a critical factor influencing several aspects of the estuarine ecosystem. It influences biological activity and many chemical variables in the estuary (MacGinitie 1935). For instance, increased temperature decreases the level of oxygen that can be dissolved in the water column. Water temperature influences the rate of plant photosynthesis, the metabolic rates of aquatic organisms, and the sensitivity of organisms to toxic wastes, parasites, diseases, and other stresses. Temperature is recorded in degrees Celsius (Centigrade) or Fahrenheit (Feaster & Conrads 1999).

Temperature is a trigger for many species to conduct specific events such as migration and reproduction. Organisms function at maximum efficiency at specific temperatures. Temperature shifts of more than 1°-2°C can cause thermal stress and shock. Long-term temperature changes can affect the overall distribution and abundance of estuarine organisms. Often, during winter months, the water column is fairly well mixed and temperatures are similar on the surface and the bottom. In spring and summer, the uppermost layer of an estuary grows warmer and mixing between this surface water and the cooler bottom water slows. Then in Fall, the temperature on the surface cools and the cold freshwater from storm input mixes with the bottom water. As the surface water moves down, mixing occurs and nutrients from the bottom are redistributed toward the surface. This introduction of nutrients to surface waters fuels phytoplankton growth. Temperature is not generally constant from the water surface to the bottom (EPA. 2001). An estuary's water temperature is a function of:

• depth
• season
• amount of mixing due to wind, storms, and tides
• degree of stratification (layering) in the estuary
• temperature of water flowing in from the tributaries
• human influences (e.g., release of urban storm water, warm water discharged golf courses and agriculture).

## Nutrients

Inputs of nutrients to estuaries have grown with increasing population growth and the intensive use of fertilizers in agriculture. Excessive nutrient inputs result in algal growth and reduced oxygen conditions. Phosphorus and nitrogen are key water quality

parameters in estuaries. Nutrient concentrations vary according to surrounding land use, season, and geology (Tchobanoglous & Schroeder 1987).

Nutrients are chemical substances used for maintenance and growth that are critical for survival. Plants require a number of nutrients—carbon, nitrogen, phosphorus, oxygen, silica, magnesium, potassium, calcium, iron, zinc, and copper—to grow. Of these nutrients, nitrogen and phosphorus are of particular concern in estuaries for two reasons because they are the main nutrients involved in plant growth and because the amounts of both of these nutrients have increased substantially over the past century due to anthropogenic inputs (Moustafa *et al.* 1998).

When an excess of either of these nutrients enters a system eutrophication may occur, an event in which excessive algal blooms dominant the estuarine system. When this algae dies, decomposition occurs which causes a depletion in oxygen levels. Surface waters that are full of this abundance in algal growth may cause a barrier for sunlight penetration. Aquatic vegetation requires light for photosynthesis. If the water is too full of algae at the surface level, the submerged vegetation below may die. When these organisms die, decomposing bacteria use can consume the oxygen in the bottom waters as they break down this organic matter. This can cause the water to become anoxic. These events may result in fish and shellfish kills and be harmful to human health (Carlisle *et al.* 2002).

There are several different sources of nitrogen and phosphorus for estuarine systems, both natural and human induced. Natural sources of nitrogen and phosphorus in the estuary include:

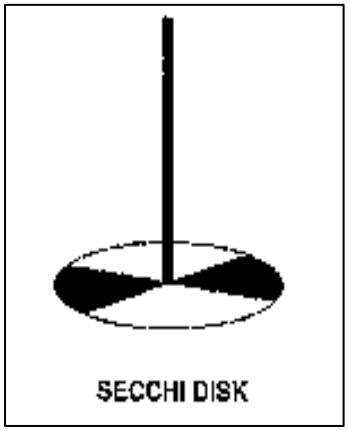
- fresh water that runs over geologic formations rich in phosphate or nitrate;
- decomposing organic matter and wildlife waste; and
- the extraction of nitrogen gas from the atmosphere by some bacteria and bluegreen algae (known as nitrogen fixation).

The three major anthropogenic sources of nutrients are atmospheric deposition, surface water, and groundwater. Atmospheric sources include fossil fuel burning by power plants and automobiles. Surface water inputs include point and nonpoint source discharges: effluent from wastewater treatment plants, urban stormwater runoff, lawn and agricultural fertilizer runoff, industrial discharges, and livestock wastes. Groundwater sources are primarily underwater seepage from agricultural fields and failing septic systems. Nutrient concentrations are usually greatest during spring and early summer, when fertilizer use and water flow from tributaries and irrigation activities are high (Carlisle *et al.* 2002).

## *Testing Equipment*

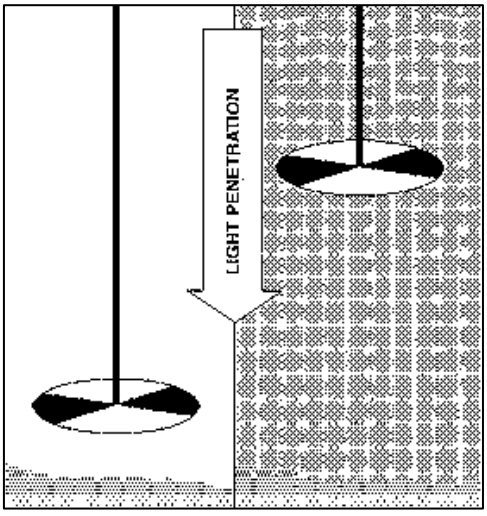
**Figure 5.3:** Testing Equipment

| | |
|---|---|
| Backpack | Binoculars (optional) |
| Pen/Pencil | Data Sheet (Figure 1.6) |
| Secchi Disk | YSI-85 DOSCT Meter |
| Zip Ties | DI Water Bottle |
| | PVC apparatus |




## Secchi Disk

Secchi Depth is a measure of turbidity, an indication of how cloudy or muddy the water is (clarity). Water clarity, measured by secchi disks, remains a popular indicator for many monitoring programs due to its relative inexpensiveness and ease of use. Freshwater secchi disks most commonly used in estuarine monitoring are 20 centimeters in diameter with alternating black and white sections to enhance visibility.




## Binoculars

Optionally used in conjunction with the secchi disk to record secchi depth measurement.

## YSI-85 Dissolved Oxygen, Conductivity and Salinity Meter

The YSI Model 85 Handheld Dissolved Oxygen, Conductivity and Salinity Meter is designed for use in the field and lab. The full users manual can be obtained at: https://www.ysi.com/DocumentServer/DocumentServer?docID=WQS_85_MANUAL

The Meter requires calibration each time it is powered off and on. To accurately calibrate the YSI Model 85, the approximate altitude of the water sample is needed.

Power on the YSI-85 Meter by pressing and releasing the **ON/OFF** button. Press the **MODE** button until dissolved oxygen is displayed in either **mg/L** or **%**. Wait until the dissolved oxygen reading stabilizes. Usually 15 minutes is

required after turning the instrument on. To begin calibration, make sure the measurement probe is stored securely in the built in calibration chamber and the sponge inside the calibration chamber is wet. This provides a 100% water saturated air environment for the probe ideal for dissolved oxygen calibration. Simultaneously press and hold the ▲ and ▼ buttons for one second before releasing. The display will prompt for local altitude in hundreds of feet. Adjust the reading to an appropriate value with the ▲ or ▼ buttons and press **ENTER**. The meter should now display **CAL** in the lower left of the display with the calibration value displayed in the lower right of the display. The current dissolved oxygen reading is displayed as a large number in the center of the LCD. Once this number stabilizes, press **ENTER**. The display should then read **SAVE** before returning to the normal operation mode.

The YSI-85 Meter has five modes measuring dissolved oxygen in both milligrams per liter and percentage, conductivity, specific conductance and salinity. These are viewed as large numbers on the display. The instrument will also measure temperature regardless of mode. This is viewed as a small number on the display.

**Figure 5.5:** Instrument Display


To cycle through the modes, press and release the **MODE** key. The instrument is in the percent mode when the large numbers on the display are followed by a **%** symbol. The instrument is in the milligrams per liter mode when the large numbers on the display are followed by a **mg/L** symbol**.** The instrument is in the conductivity mode when either **µS** or **mS** follow the large numbers on the display and **°C** is not flashing. The instrument is in the specific conductance mode when either **µS** or **mS** follow the large numbers on the display and **°C** is flashing on and off. The instrument is in the salinity mode when the large numbers on the display are followed by a **ppt** symbol. When not in use, the measurement probe should always be stored in the built in calibration chamber. To keep the electrolyte from drying out, store the probe in the calibration chamber with the small piece of sponge.

At times, the YSI may flash an error message. See Apendix 3 for a list of these errors and solutions.

## Hydrology Data Sheet

Used to record measurements.

## Pen/Pencil

Used to write measurements and other notes on the hydrology data sheet.

## Clipboard

Used to secure hydrology data sheet.

## DI (Distilled) Water Bottle

Used to rinse off probe after each use.

## PVC Pipe Apparatus

(picture) This device is used to obtain standardized and consistent measurements at the sampling locations at or near the mouth of the slough. The YSI probe is to be attached to the end of the PVC pipe and deployed from a stationary location. The pipe has a cork on the end, that when plugged, allows the pipe to float on the surface of the water. When the cork is removed, the pipe sinks to the bottom of the Slough, equidistance from where the surface water measurements were taken. The pipe consists of a cork (or rubber stopper) attached to the end of the 15 foot PVC pipe via rubber bands or zipties.

# *Sampling Considerations*

## Conductivity and Salinity

Conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum **cations** (ions that carry a positive charge). As the concentration of salts in the water increases, electrical conductivity rises—the greater the salinity, the higher the conductivity. Conductivity is also affected by temperature. At higher temperatures, conductivity is also higher. Conductivity is measured with a probe and a meter. Conductivity meters require temperature correction and accurate

Salinity is also commonly measured using Parts Per Thousand (PPT) (0/00). This is a measure of the relative concentration of salt, usually sodium chloride, in a given water sample, higher salinity means higher dissolved salts. . The salinity of ocean water is in the range 33-38 parts per thousand.

## Dissolved Oxygen

In estuarine systems, sampling for DO throughout the year is preferable to establish a clear picture of water quality. Sampling once to twice a week is generally sufficient to capture the variability of DO in the estuary. Since DO fluctuates throughout the day, DO measurements need to be taken at about the same time every day. The electronic meter measures DO based on the rate of molecular oxygen diffusion across a membrane. The results from a DO meter are extremely accurate, providing the unit is well maintained, calibrated, and the membrane is handled carefully.

**Figure 5.5:** Dissolved Oxygen Saturation Levels

| Temperature °C | Oxygen Saturation Concentration (mg/l) | | | | |
|---|---|---|---|---|---|
| | Salinity: 0 ppt | 9 ppt | 18 ppt | 27 ppt | 36 ppt |
| 0.0 | 14.6 | 13.7 | 12.9 | 12.1 | 11.4 |
| 1.0 | 14.2 | 13.4 | 12.5 | 11.8 | 11.1 |
| 2.0 | 13.8 | 13.0 | 12.2 | 11.5 | 10.8 |
| 3.0 | 13.5 | 12.7 | 11.9 | 11.2 | 10.5 |
| 4.0 | 13.1 | 12.3 | 11.6 | 10.9 | 10.3 |
| 5.0 | 12.8 | 12.0 | 11.3 | 10.6 | 10.0 |
| 6.0 | 12.4 | 11.7 | 11.0 | 10.4 | 9.8 |
| 7.0 | 12.1 | 11.4 | 10.8 | 10.2 | 9.6 |
| 8.0 | 11.8 | 11.2 | 10.5 | 9.9 | 9.4 |
| 9.0 | 11.6 | 10.9 | 10.3 | 9.7 | 9.2 |
| 10.0 | 11.3 | 10.6 | 10.0 | 9.5 | 9.0 |
| 11.0 | 11.0 | 10.4 | 9.8 | 9.3 | 8.8 |
| 12.0 | 10.8 | 10.2 | 9.6 | 9.1 | 8.6 |
| 13.0 | 10.5 | 10.0 | 9.4 | 8.9 | 8.4 |
| 14.0 | 10.3 | 9.7 | 9.2 | 8.7 | 8.2 |
| 15.0 | 10.1 | 9.5 | 9.0 | 8.5 | 8.1 |
| 16.0 | 9.9 | 9.3 | 8.8 | 8.4 | 7.9 |
| 17.0 | 9.7 | 9.2 | 8.7 | 8.2 | 7.8 |
| 18.0 | 9.5 | 9.0 | 8.5 | 8.0 | 7.6 |
| 19.0 | 9.3 | 8.8 | 8.3 | 7.9 | 7.5 |
| 20.0 | 9.1 | 8.6 | 8.2 | 7.7 | 7.3 |
| 21.0 | 8.9 | 8.4 | 8.0 | 7.6 | 7.2 |
| 22.0 | 8.7 | 8.3 | 7.9 | 7.5 | 7.1 |
| 23.0 | 8.6 | 8.1 | 7.7 | 7.3 | 7.0 |
| 24.0 | 8.4 | 8.0 | 7.6 | 7.2 | 6.8 |
| 25.0 | 8.3 | 7.8 | 7.4 | 7.1 | 6.7 |
| 26.0 | 8.1 | 7.7 | 7.3 | 7.0 | 6.6 |
| 27.0 | 8.0 | 7.6 | 7.2 | 6.8 | 6.5 |
| 28.0 | 7.8 | 7.4 | 7.1 | 6.7 | 6.4 |
| 29.0 | 7.7 | 7.3 | 7.0 | 6.6 | 6.3 |
| 30.0 | 7.6 | 7.2 | 6.8 | 6.5 | 6.2 |
| 31.0 | 7.4 | 7.1 | 6.7 | 6.4 | 6.1 |
| 32.0 | 7.3 | 7.0 | 6.6 | 6.3 | 6.0 |
| 33.0 | 7.2 | 6.8 | 6.5 | 6.2 | 5.9 |
| 34.0 | 7.1 | 6.7 | 6.4 | 6.1 | 5.8 |
| 35.0 | 7.0 | 6.6 | 6.3 | 6.0 | 5.7 |

***DO saturation**, or potential DO level, is the highest DO concentration possible under the environmental limits of temperature and salinity. As salinity increases, the amount of oxygen that water can hold decreases substantially. For example, at 20°C, 100% DO saturation for fresh water (for which salinity is zero) is 9.09 mg/l. At the same temperature, 100% saturation for water with 36 parts per thousand (ppt) salinity is 7.34 mg/l.* [Figure 1.5] *summarizes DO saturation levels for different salinities and temperatures at sea level. **Percent saturation** is the amount of oxygen in the water relative to the water's potential DO saturation. It is calculated as follows: Percent saturation = measured DO x 100 DO saturation*
*(Excerpted and adapted from Green, 1998.)*

## *Sampling Procedure*

Record all measurements on the Hydrology Data Sheet (Figure 1.6). NOTE: return all equipment to the backpack in its appropriate pocket immediately when finished field collection to prevent equipment misplacement.

### DV00 – Bridge

Upon arriving at the location, immediately power on the YSI-85 meter and set aside (leaving probe in meter). This allows the meter enough time to stabilize before use.

To measure secchi depth, first locate a shaded patch of water away from direct sunlight but still visible without an additional light source. Hold the secchi apparatus over bridge railing. Unwind the rope attaching the secchi disk and slowly lower the disk into the shaded patch of water until the disk completely disappears. Raise the disk slightly until it is again visible and approximate the depth the disk disappears by using the colored hash marks on the rope. Red marks designate 0.1-meter increments, blue for 0.5-meters and yellow for 1.0-meters.

Remove the probe from the calibration YSI-85 Dissolved Oxygen, Conductivity and Salinity Meter calibration chamber and attach it to the leading rope of the Pulley Apparatus (closest rope to the bridge). Pull on the rope and lower the

probe into the water until it is just completely submerged. Press the **MODE** button on the front of the meter to cycle through the modes. Wait until each reading stabilizes before recording. Record temperature, salinity, conductivity and dissolved oxygen in both % and mg/L on the Hydrology Data Sheet for the DV00 location. Lower the probe an additional 0.5 meters as denoted by the attached meter stick and record measurements at the 0.5-meter depth. Continue until the pulley encounters significant resistance and cannot be further lowered.

Water depth is recorded as the lowest point the YSI-85 Meter probe reaches while attached to the pulley system. When the probe encounters significant resistance, record a set of final readings for that depth while making a note of the depth next to the readings. Also record that depth under the "water depth" field on the Hydrology Data Sheet.

When finished with the measurement, raise the probe and disengage it from the pulley system. Rinse the probe with DI water before reinserting probe into the calibration chamber. Make sure that sponge in the probe holder is always moist.

Record any additional comments in the appropriate space on the Data Sheet.

**DV01 – Stream Mouth**

Power on the YSI-85 Dissolved Oxygen, Conductivity and Salinity Meter and calibrate the dissolved oxygen reading to a 0 meter (sea level) altitude.

To take surface measurements, remove the probe from the calibration chamber and lower it into the water until it is just completely submerged. Press the **MODE** button on the front of the meter to cycle through the modes. Wait until each reading stabilizes before recording. Record temperature, salinity, conductivity and dissolved oxygen in both % and mg/L on the Hydrology Data Sheet for the DV01 location.

Lower the probe into the water until it touches the bottom, allowing for significant slack in the cable. Repeat the above procedure and record the corresponding measurements for the bottom. Power off the YSI-85 Meter and store the probe in the calibration chamber.

## DV02 – End of Skunk Fence

Power on the YSI-85 Dissolved Oxygen, Conductivity and Salinity Meter and calibrate the dissolved oxygen reading to a 0 meter (sea level) altitude.

To take surface measurements, remove the probe from the calibration chamber and attach it to the leading end of the PVC Pipe Apparatus using the Velcro strap. Secure the attached cork to the end of the pipe, blocking the flow of water into the pipe. Extend the Apparatus out into the water. The pipe should float. Make minor adjustments to the pipe until the probe is just completely submerged. Press the **MODE** button on the front of the meter to cycle through the modes. Wait until each reading stabilizes before recording. Record temperature, salinity, conductivity and dissolved oxygen in both % and mg/L on the Hydrology Data Sheet for the DV02 location.

Withdraw the PVC Pipe Apparatus and remove the cork. Extend the pipe into

the water, allowing for the pipe and probe to sink to the bottom. Repeat the above procedure and record the corresponding measurements for the bottom. Power off the YSI-85 Meter and store the probe in the calibration chamber.

## *Data Entry*

Immediately after field data collection, enter the data from your datasheet into the database in the Reserve field office. The database consists of an Excel Workbook for the sample year with worksheets for each sample date. The Workbook also contains summary worksheets at end of the daily sample sheets which contain information on yearly trends. The workbooks are set up similarly to the hard data sheets so information can be input in the same format (see figure 1.6).

Once data is entered in the appropriate cells, the workbook will automatically graph trends in salinity, DO, and water temperature (for DV00) in the graphs on the left so sampler can look at a depth profiles for that day's hydrologic conditions. This data can be analyzed to find trends in weekly, monthly, and seasonal salinity, DO and temperature profiles.

Once the sample year is complete, the DSMP coordinator needs to complete summary worksheets to compile that year's data. This information can be used to create isopleths for salinity, oxygen and temperature profiles for DV00, and graph seasonal trends for the other sampling sites.

This data will be useful in explaining and/or coordinating trends in the other monitored paramaters such as presence and absence of certain fish and invertebrate species. The data can also be used to determine mixing and stratification regimes of the estuary. Data can then be used to compare salinities, DO and temperature and different sampling stations within the estuary. This may provide some insight on the spatial extent of freshwater inundation, anoxic and aerobic conditions and temperature differences within the Slough which may help explain the distribution of flora and fauna.

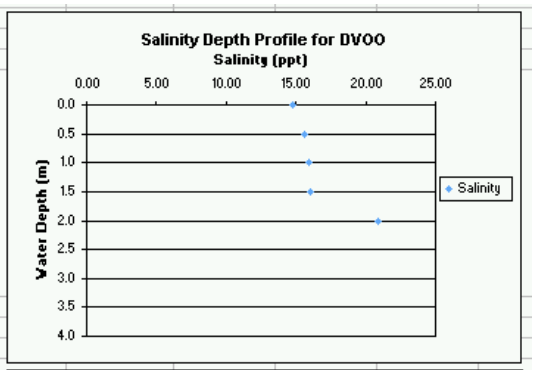
This data can also be compared to different estuaries along the Central California Coast. This may provide insight about the effect of restoration and seasonal flushing of the Slough.

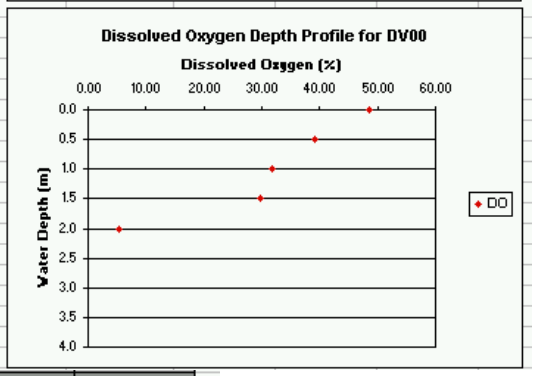
However, comparing average salinity and DO data is subjective. Errors in measurement may include inaccurate calibration of instrument, measuring at different times of day and locations, inadequate submersion of probe, instrument accuracy, Cell-constant error, solution temperature offset, cell contamination (including air bubbles) electrical noise, galvanic effects

**Hydrology Data Sheet**

| | | | | | | |
|---|---|---|---|---|---|---|
| **Date:** | 1/21/2007 | | | | | |
| **Samplers:** | Hadley | | | | | |
| **Location:** | **Water Depth (m)** | **Conductivity (mS)** | **Salinity (ppt)** | **Dissolved Oxygen %** | | |
| **DV00** | **0.0** | 24.22 | 14.80 | 48.60 | | |
| | **0.5** | 25.62 | 15.60 | 39.10 | | |
| | **1.0** | 26.01 | 15.90 | 31.70 | | |
| | **1.5** | 26.13 | 16.00 | 29.80 | | |
| | **2.0** | 33.42 | 20.90 | 5.30 | | |
| | **2.5** | | | | | |
| | **3.0** | | | | | |
| | **3.5** | | | | | |
| | **4.0** | | | | | |
| | **4.5** | | | | | |
| **DV01** | **Surface** | 0.00 | 0.00 | 65.20 | | |
| | **Bottom** | 28.20 | 17.20 | 12.10 | | |
| **DV02** | **Surface** | 24.00 | 14.60 | 56.50 | | |
| | **Bottom** | 25.06 | 15.20 | 42.60 | | |
| **DV03** | **Surface** | | | | | |
| | **Bottom** | | | | | |

| | |
|---|---|
| **Secchi Depth (DV00):** | 35 |
| **Water Depth (DV00):** | 200 |
| **Notes:** | sunny and mild. Slight breeze |



Date _____ Samplers _____

Location Bridge (DV00)

Secchi Depth _____ (cm)

Water Depth _____ (cm)

| | Salinity | | Dissolved Oxygen | |
|---|---|---|---|---|
| **Surface:** | _____ | °C | _____ | °C |
| | _____ | ppt | _____ | mg/L |
| | _____ | cond | _____ | % |
| **0.5 m:** | _____ | °C | _____ | °C |
| | _____ | ppt | _____ | mg/L |
| | _____ | cond | _____ | % |
| **1.0 m:** | _____ | °C | _____ | °C |
| | _____ | ppt | _____ | mg/L |
| | _____ | cond | _____ | % |
| **1.5 m:** | _____ | °C | _____ | °C |
| | _____ | ppt | _____ | mg/L |
| | _____ | cond | _____ | % |
| **2.0 m:** | _____ | °C | _____ | °C |
| | _____ | ppt | _____ | mg/L |
| | _____ | cond | _____ | % |
| **2.5 m:** | _____ | °C | _____ | °C |
| | _____ | ppt | _____ | mg/L |
| | _____ | cond | _____ | % |
| **3.0 m:** | _____ | °C | _____ | °C |
| | _____ | ppt | _____ | mg/L |
| | _____ | cond | _____ | % |
| **3.5 m:** | _____ | °C | _____ | °C |
| | _____ | ppt | _____ | mg/L |
| | _____ | cond | _____ | % |

Location Creek Mouth (DV01)

| | Salinity | | Dissolved Oxygen | |
|---|---|---|---|---|
| **Surface:** | _____ | °C | _____ | °C |
| | _____ | ppt | _____ | mg/L |
| | _____ | cond | _____ | % |
| **Bottom:** | _____ | °C | _____ | °C |
| | _____ | ppt | _____ | mg/L |
| | _____ | cond | _____ | % |

Location End of Skunk Fence (DV02)

| | Salinity | | Dissolved Oxygen | |
|---|---|---|---|---|
| **Surface:** | _____ | °C | _____ | °C |
| | _____ | ppt | _____ | mg/L |
| | _____ | cond | _____ | % |
| **Bottom:** | _____ | °C | _____ | °C |
| | _____ | ppt | _____ | mg/L |
| | _____ | cond | _____ | % |

Location Estuary Opening (DV03)

| | Salinity | | Dissolved Oxygen | |
|---|---|---|---|---|
| **Surface:** | _____ | °C | _____ | °C |
| | _____ | ppt | _____ | mg/L |
| | _____ | cond | _____ | % |
| **Bottom:** | _____ | °C | _____ | °C |
| | _____ | ppt | _____ | mg/L |
| | _____ | cond | _____ | % |

Other Comments _____

| SYMPTOM | POSSIBLE CAUSE | ACTION |
|---|---|---|
| 1. Instrument will not turn on | A. Low battery voltage<br>B. Batteries installed wrong<br>C. Meter requires service | A. Replace batteries<br>B. Check battery polarity.<br>C. Return system for service |
| 2. Instrument will not calibrate (Dissolved Oxygen) | A. Membrane is fouled or damaged<br>B. Probe anode is fouled or dark<br>C. Probe cathode is tarnished<br>D. System requires service | A. Replace membrane & KCl<br>B. Clean anode<br>C. Clean cathode<br>D. Return system for service |
| 3. Instrument will not calibrate (Conductivity) | A. Cell is contaminated | A. See "Maintenance" Section |
| 4. Instrument "locks up" | A. Instrument has rec'd a shock<br>B. Batteries are low or damaged<br>C. System requires service | A & B. Remove battery lid, wait 15 seconds for reset, replace lid.<br>C. Return system for service |
| 5. Instrument readings are inaccurate (Dissolved Oxygen) | A. Cal altitude is incorrect<br>B. Probe not in 100% $O_2$ saturated air during Cal procedure<br>C. Membrane fouled or damaged<br>D. Probe anode is fouled or dark<br>E. Probe cathode is tarnished<br>F. System requires service | A. Recalibrate w/correct value<br>B. Moisten sponge & place in Cal chamber w/ probe & Recal<br>C. Replace membrane<br>D. Clean anode<br>E. Clean cathode<br>F. Return system for service |
| 6. Instrument readings are inaccurate (Conductivity) | A. Calibration is required<br>B. Cell is contaminated<br>C. Tempco is set incorrectly<br>D. Reference temperature incorrect<br>E. Readings are or are not temperature compensated | A. See "Calibration" Section<br>B. See "Maintenance" Section<br>C. See "Advanced Setup" Section<br>D. See "Advanced Setup" Section<br>E. See "Making Measurements" Section |
| 7. LCD displays "LO BAT"<br>Main display flashes "off" | A. Batteries are low or damaged | A. Replace batteries |
| 8. Main Display reads "OVEr"<br>(Secondary display reads "ovr")<br>(Secondary display reads "sulr") | A. Conductivity reading is >200 mS<br>B. Temperature reading is >65°C<br>C. Temperature reading is <-5°C<br>D. Salinity reading is >80 ppt<br>E. User cell constant cal K is >5.25<br>F. DO temperature is >46°C<br>G. DO % saturation is >200%<br>H. DO concentration is >20 mg/L | In all cases, check calibration values and procedures; check advanced setup settings.<br><br>If each of these are set correctly, return instrument for service. |
| 9. Main display reads "Unit" | A. User cell constant cal K is <4.9<br>B. DO current too low to calibrate | A. Recalibrate instrument using known good conductivity standard. Follow cell cleaning procedure in the Maintenance section.<br>B. Replace membrane, clean probe |
| 10. Main display reads "rEEr" | A. Reading exceeds user selected manual range. | A. Use the mode key to select a higher or lower manual range, or set system to autoranging. |
| 11. Main display reads "PEEr" | A. User cell constant cal K is 0.0<br>B. Incorrect sequence of keystrokes. | A. See "Advanced Setup" section.<br>B. Refer to manual section for step by step instruction for the function you are attempting. |

## *REFERENCES CHAPTER 5*

Anderson D. M., Gliber P. M. & Burkholder J. M. (2002) Harmful algal blooms and eutrophication: Nutrient sources, composition, and consequences. *estuaries* 25: 704-726.

Broenkow W. W. & Smith R. E. (1972) Hydrographic observations in Elkhorn Slough and Moss Landing Harbor, California, October 1970 to November 1971 pp. 1-74. Moss Landing Marine Laboratories and California State University, Fresno, CA.

Caffrey J. M. (2003) Production, respiration, and net ecosystem metabolism in U.S. estuaries. *Environmental Monitoring and Assessment* 81: 207-219.

Caffrey J. M. (2004) Factors controlling net ecosystem metabolism in US estuaries. *estuaries* 27: 90-101.

Caffrey J. M., Harrington N. & Ward B. (2002) Biogeochemical processes in a small California estuary. *Marine Ecology-Progress Series* 233: 39-53.

Caffrey J. M., Shaw S., Silberstein M., De Vogelaere A., White M., Parker K. & Thomasberg K. (1997) Central bay estuarine water quality monitoring program 1988-1997. Elkhorn Slough National Estuarine Research Reserve.

Cailliet G. M., Antrim B., Ambrose D., Pace S. & Stevenson M. (1977) Species composition, abundance and ecological studies of fishes, larval fishes and zooplankton in Elkhorn Slough. In: *Ecologic and Hydrographic Studies of Elkhorn Slough, Moss Landing Harbor, and Nearshore Coastal Waters, July 1974 to June 1976* (eds. J. Nybakken, G. Cailliet & W. Broenkow) pp. 216-386. Moss Landing Marine Laboratories, Moss Landing, CA.

Carlisle B. K., Donovan A. M., Hicks A. L., Kooken V. S., Smith J. P. & Wilbur A. R. (2002) A Volunteer's Handbook for Monitoring New England Salt Marshes. *Massachusetts Office of Coastal Zone Management, Boston, M.A.*

Dauer D. M., Rodi A. J. & Ranasinghe J. A. (1992) Effects of low dissolved oxygen events on the macrobenthos of the lower Chesapeake Bay. *estuaries* 15.

Dickert T. G. & Tuttle A. E. (1980) Elkhorn Slough watershed: Linking the cumulative impacts of watershed development to coastal wetlands pp. 1-473. Institute of Urban and Regional Development, University of California, Berkeley, CA.

Engle V. D., Summers J. K. & Macauley J. M. (1999) Dissolved oxygen conditions in northern gulf of meixico estuaries. *Environmental Monitoring and Assessment* 57.

EPA. U. (2001) Environmental Monitoring and Assessment Program (EMAP): National

Coastal Assessment Quality Assurance Project Plan 2001-2004. *Environmental Protection Agency, Office of Research and Development, National Health*

*and Environmental Effects Research Laboratory, Gulf Ecology Division, Gulf Breeze, FL.*

*EPA/620/R-01/002.*

EPA. U. S. (2002.) Methods for Evaluating Wetland Condition: Introduction to Wetland BiologicalAssessment. *Office of Water, U.S. Environmental Protection Agency, Washington, DC.* EPA-822-R-02-014.

Feaster T. D. & Conrads P. A. (1999) Characterization of Water Quality and Simulation of Temperature, Nutrients, Biochemical Oxygen Demand, and Dissolved Oxygen in the Wateree River, South Carolina, 1996-98 pp. 90. U.S. Geological Survey.

Glasgow H. B. & Burkholder J. M. (2000) Water quality trends and management implications from a five-year study of a eutrophic estuary. *Ecological Applications* 10: 1024-1046.

Haskins J. (2002) Water quality monitoring in Elkhorn Slough. In: *Ecosystem Observations* pp. 14. Monterey Bay National Marine Sanctuary.

Macauley J. M., Summers J. K. & Engle V. D. (1999) Estimating the ecological condition of the estuaries of the Gulf of Mexico. *Environmental Monitoring and Assessment* 57: 59-83.

MacGinitie G. E. (1935) Ecological aspects of a California marine estuary. *American Midland Naturalist* 16: 629-765.

Montagana P. A., Alber M., Doering P. & Connor M. S. (2002) Freshwater inflow: science, policy and management. *estuaries* 25: 1243-1245.

Moustafa M. Z., Fountaine T. D. & James R. T. (1998) The response of a freshwater wetland to long-term 'low love' nutrient loads: nutrients and water budget. *Hydrobiologia* 364: 41-53.

Papas P. & Holmes J. (unpublished) Review of wetland assessment Methods. *Version 1.0* Department of Sustainability and Environment.

Scharler U. M. & Baird D. (2003) The influence of catchment management on salinity, nutrient stochiometry and phytoplankton biomass of Eastern Cape estuaries, South Africa. *Estuarine, Coastal and Shelf Science* 56: 735-748.

Tchobanoglous G. & Schroeder E. D. (1987) *Water Quality*. Addison-Wesley Publishing Company, Menlo Park, California.

USEPA (2001-2004) Environmental Monitoring and Assessment Program , West Coast Pilot 2002 Intertidal Assessment: California Intensification. *Office of Water, U.S. Environmental Protection Agency*.

Yamada K. E. (1996) Water quality monitoring at the Elkhorn Slough National Estuarin Research Reserve pp. 1-62. University of Dubuque, Dubuque, Iowa.

# CHAPTER 6: VEGETATION

## *Monitoring Goal*

To record the seasonal and yearly changes in community composition of vegetation in the Devereux Ecosystem and maintain a database of these trends to determine long term changes. The goals for vegetation monitoring are: (1) Determine species composition, species diversity, species evenness and percent cover (2) determine wetland/upland transition zone (4) to create a habitat classification scheme based on vegetation type, and (5) to record changes in these above parameters.

Surveying wetland vegetation is an important aspect of assessing the current condition of the wetland ecosystem, assessing the ecosystem's potential for supporting animal populations, and tracking environmental and biological changes over time.

## *Introduction*

Estuarine plants serve a number of important functions including: 1) primary introduction of energy into the ecosystem 2) provide shelter and habitat for invertebrates, insects, amphibians, fish and birds 3) soil stabilization 4) absorption of toxins and pollutants 5) critical feeding and nursery grounds for birds and fish 6) and nutrient cycling. (cite)The sheer bulk of the plants often buffers the shoreline and minimizes erosion by dampening the energy of incoming waves. Plant roots bind the sediments on the estuary bottom and retard water currents. By minimizing water movement, this vegetation allows suspended sediments to settle and improves water clarity (EPA. 2002) .

To develop effective management strategies for the entire wetland, it is important to analyze changes in the community composition of the vegetation ecosystem. Vegetation monitoring is a simple and effective way to determine the condition of a wetland and to track changes over time. Wetland vegetation provides useful biological, chemical, and physical information about the wetland ecosystem and surrounding area. Plant species differ in their response to physical and chemical changes of the environment and the diversity and special adaptations of the wetland plants provide an array of information about the wetland. (citation)

Vegetation in estuarine systems have evolved adaptations to cope with the wide daily and seasonal fluctuations in salinity, water temperature, and dissolved oxygen. In these systems, different plant species have varying tolerances to water parameters, so changes in their distribution can be used as an indicator of changes in salinity, dissolved oxygen and temperature (Earle and Kershaw, 1988). Some organisms have evolved special physical structures to cope with changing in these factors. For example, *Salicornia virginica* (pickleweed), a plant that is commonly found in salt marshes, has special filters on its roots to remove salts from the water it absorbs and fleshy features to help retain water (Reilly 1979). This adaptation allows *Salicornia* to be extremely successful in habitats that are too saline for plant species with a lower tolerance to salinity.

By observing the existing vegetation communities, and tracking changes in the plant community composition it is possible to determine how weather patterns, urban development, and other historical changes affect certain parameters of the estuarine wetland. Shifts in the dominate species of a particular habitat may provide an indication of hydrological water quality changes that have taken place (i.e. regular flooding, nutrient inputs etc.) as well as an indication of what organisms may inhabit the system. Changes in plant distributions lag behind environmental changes, thus the vegetation is an indicator of long-term conditions, more than a measure of current events (Dennison *et al.* 1993).

## *Interactions between the fauna and biota*

The plant species composition influences the animals that are able to reside in the wetland. Several endangered and rare animals have coevolved their life cycle with certain plant species, and therefore preserving the plant species will aid in the conservation of the endangered animal. For example, Devereux Slough is currently the northernmost estuary inhabited by the endangered Belding's Savannah Sparrow (Holmgren, 1996). This dark brown bird lives year round in coastal marshes and depends on the seeds of certain types of vegetation example? in this ecosystem for its survival. Several other wetland birds are also restricted to areas dominated by specific plants example?.

Several types of insects also require specific wetland and upland plants to complete their lifecycle. For example, the Pygmy Blue butterfly lay their larvae in the salicornia beds of the wetland, and the adults use the upland plant Coast Golden Bush, *Isocoma menziesii*, as a nectar source. (cite)
By monitoring the populations over time, we can better determine the ecosystem conditions. Since vegetation functions as land stabilizers, prevent coastal erosion, and provide habitat for a variety of organisms, gauging transitions in vegetative species can indicate types of organisms excepted to be present and soil stability (Worley 2005)

Habitat fragmentation, which is the emergence of discontinuities (fragmentation) in an organism's preferred environment, can influence the abundance and distribution of birds. Decreases in patch size increase the amount of edge habitat, which can allow greater invasion by exotic species, predators, and brood parasites (Hagan and Johnston 1992, Donovan et al. 1995). Fragmented habitats may act as population sinks and result in local extinctions unless immigration occurs from source habitats (Pulliam 1988, Howe et al. 1991, Pulliam et al. 1992, Stacey and Taper 1992).

Fragmentation is especially severe in coastal California, where about 75% of the resettlement acreage of coastal wetlands has been lost to development (Zedler 1982, Zedler and Powell 1993). This degradation has produced a highly fragmented landscape that may have a negative influence on the Belding's Savannah Sparrow (*Passerculus sandwichensis beldingi*). Thus, the population dynamic's of Belding's Savannah Sparrow may reflect the effects of fragmentation.

## *Paramaters*

### Transect

A transect is a line across an area to be sampled, marked by a tape measure (you bring the tape in the field with you each time); Permanent markers are installed to facilitate in locating transect endpoints. GPS coordinates of each transect end are also recorded.

### Quadrat

Refers to a grid (we use one meter square wooden grid) you place over the vegetation to count percent cover and identify species.

### Percent Cover

Vegetative cover is one measurement used to indicate the growing conditions for wetland plants in estuary systems. It refers to the percent of a defined area (quadrat) covered by each plant species. The estimation of ground cover entails an observer standing over the quadrat and visually estimating the cover of each species present. It is particularly valuable for characterizing the distribution of common species that make up the bulk of the biomass in a tidal wetland and less valuable for identifying rare species (Vasey et al., 2002)

Cover is typically estimated using standard cover classes such as the Braun Blanquet cover scale. (<1-5%, 6-25%, 26-50%, 51-75%, 76-100%). With this method, the observer must decide which cover class should be assigned to each species within the quadrat. Conversion to specific cover ranks helps to increase similarity in sampling procedure.

### Point Intercept

The point intercept method is often thought to be the least biased method of measuring cover because the observer only needs to record the species that is intercepted or hit at each point. In this method a rod or measuring stick is held vertical at each point and dropped straight through the canopy to the sampling point on the ground. At each point, all species that touch the rod are recorded (Roman et al., 2001).

### Water Depth

Water depth is measured at the bridge and used as a relative comparison between sampling days. Vegetation sampling is only conducted when the water depth at the bridge reads between insert depths here. This is important because a decrease in percent cover could be due to greater water depth.

## *Experimental Design*

### Transect placement

Four permanent vegetation transects were placed across the estuary, according to the systematic random

sampling technique described by Elzinga et al. 1998. The locations of the transects were determined by first creating a base line down the center of an aerial photograph of the estuary.

Due to the irregular shape of the estuary two separate base lines were drawn, one from the mouth of the river to the bridge and one from the bridge to the opening with the ocean.

Six lines were drawn perpendicular to the base line, dividing the estuary into five equal segments. The lines that were drawn at the bridge location and at the opening with the ocean were omitted due to constraints of sampling in those areas, and the other four lines were used to determine the locations of the permanent transects. The location of the transect lines were determined in this way to allow for good interspersion of sampling throughout the estuary, which is important for an accurate representation of the species found at the estuary. Two additional transects were set up down the center of the north and south fingers of the estuary.

These long transect lines were used to determine the locations of the transects that are monitored by subdividing the long transect lines into two shorter 50 meter transects. The starting points of the monitored transects were determined by topography, in which the transects started at the 10 foot elevation mark at the location where the long transect line intersected the upland area, and systematically continued 50 meters along the long transect line that headed towards the opposite side of the estuary (See Figure 6-1). A GPS compass was used to walk 50 meters along the long transect line that crossed over the estuary to the opposing upland edge. Starting at the 10 foot elevation mark allowed for the sampling of the transition between buffer zone, upland, and low marsh habitats.


FIGURE 6-1

**Buffer Zone Transects**

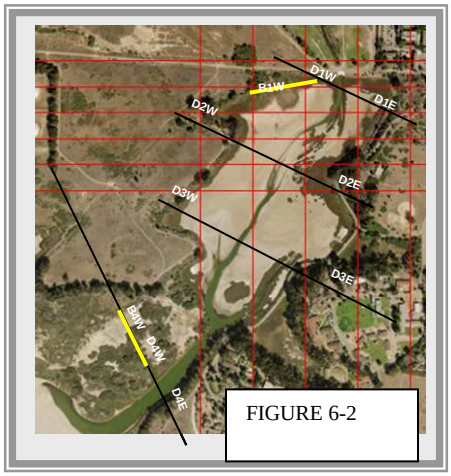



FIGURE 6-2

Two buffer zone transects were set up to determine the upland vegetation. The buffer zone is a transitional habitat point which is important for the animal species that utilize upland vegetation as well as wetland plants The buffer transect B4W started at the beginning of transect B4W and continued 50 meters west following the original long transect line (see Figure 6-2)

The buffer transect B1W was determined by heading south west toward D2W from D1W along the shore of the estuary.

## Sampling

*When to sample*

The transects are to be sampled twice a year, once in early spring and once in late summer/early fall when the water level measured at the bridge is between *2-6 feet(???).* This is very important for accurate comparisons of the data between the years, because if the water level is higher than 20 meters much of the vegetation is submerged, resulting in species diversity and percent cover values to appear lower than previous sampling times.

*Transect sampling*

The transects are sampled according to systematic sampling, were the 1 $m^2$ quadrats are placed every 5 meters along the transect, starting at the 0 meter mark i.e. (0,5,10,15,20m ect.) The species richness, percent cover and community composition are determined for each quadrat.

*Percent cover*

Point intercept method of measuring percent cover (described by Elzinga et al 1998) is employed in conjunction with the visual estimate in order to get an accurate estimate of the vegetation cover. The point intercept method is useful because it is often considered the least biased method of determining percent cover, while the visual estimate more efficiently samples species that are rare or have low cover values (Elzinga et al 1998).

a) Point intercept

The point intercept method for estimating vegetation species coverage is a method in which the observer records each species that is intercepted by a vertical point at a set interval along a transect. In our study, the point intercept is sampled every five meters along the right side of the transect. For this method a slender stick is lowered perpendicular to the transect tape and every plant species that comes in contact with the stick is recorded. Bare ground, leaf litter, trash, and water are also recorded if they intersect the point being sampled.

INSERT PICTURE OF US DOING THIS

b) Visual Estimate

The visual estimate of percent cover is determined in accordance with the Braun-Blanquet cover class system. This cover class system is as follows:

| **CODE** | **PERCENT** |
|---|---|
| 0.5 | 0-1%, |
| 1 | 2-5%, |

| | |
|---|---|
| 2 | 6-25%, |
| 3 | 26-50%, |
| 4 | 51-75%, |
| 5 | 76-95%, |
| 6 | 96-100%. |

Each species in the quadrat is assigned the cover class that most accurately described the percent cover of that species. A cover class is also assigned to any trash, leaf litter, bare ground, and water that are present in each quadrat.

### *How to Enter the Data*

After completing field data collection immediately return to lab and enter data into an empty template in the vegetation database (name of file). Each transect has a corresponding worksheet in your vegetation database and each year will have a separate workbook.

### *Data analysis*

Once you enter and compile data into a spreadsheet, you can begin to analyze and compare the data. Many different tools and techniques exist to analyze biological data. This section provides a detailed description of four types of **variables**: species richness, species evenness, community composition, and occurrence frequency.

### Species Richness

The Actual number of different species that were found along a particular transect.

# Species Evenness

Species evenness is a measure of how uniform species abundance and distribution are in the sample transect. This parameter is calculated when the data is analyzed using the Shannon Weiner index of evenness When all species in a community have equal abundances, then the evenness is maximal (numbers range from 0-1). If 90 % of the transect is *Salicornia* and 10% is *Frankenia* then the community has low species evenness. If the transect has 50% *Salicornia* and 50% Frankenia, then species evenness is high.

### Community Composition

Community composition refers to the types of species that occur in a community, and particularly the similarity or difference between different transects and/or years. To examine community composition using our database, after entering data into an empty template.

# Occurrence Frequency

This term refers to how frequently you find a particular species in the transect. (see appendix)

## Relative Abundance

The abundance of individuals of a particular species, divided by the total abundance of all individuals counted in that sample. To find, divide the number of each species by total individual and you will get relative abundance (denoted $P_i$)

$$P_i = \frac{\text{number of individual of species i}}{\text{Number of individual}}$$

## Occurrence Frequency

Tells you of how many times a species was present, of those times, how many of those "present" was species i.

## Species diversity

This is the number of different species (species richness) weighted by the relative abundance. High species diversity measures can mean either more species in the community, more even abundance of the species that are there, or both. There are a variety of ways to combine information on both numbers of species and their relative abundance. The most common measurement of species diversity is the Shannon Index.

The Shannon Index is derived from diversity ratios. Suppose we draw an individual organism from the community at random. If we could guess the identity of that species in advance most of the time because either there were few species or one or two species were very abundant, then species diversity would be low and the Shannon Index would be low. If, on the other hand, we have a small chance of guessing the identity of the species because there were many species all more-or-less equally abundant, then the Shannon Index would be high.

To calculate the Shannon Index we first must calculate the relative abundances of each species ($p_i$) as described above and then plug those values into this equation:

$$H = -\sum_{i=1}^{s}[p_i \times \ln(p_i)]$$

Where H is the Shannon Index. Higher values of H indicate a more diverse system in which there are greater numbers of more types of species in the system.
The species evenness index is calculated as

$$E = \frac{H}{H_{max}}$$

Where $H_{max}$ is the maximum possible value of H and is calculated by the ln S. The Evenness index gives you a value between 0-1 where 1 represents complete evenness in which each species has equal representation in the community and populations numbers are equal.

**Field Checklist**

## *Equipment*

- Pencils (2)
- Several Data Sheets: Percent cover and point intercept
- List of common and scientific names of plants
- Meter Stick
- Field Guide
- Transect tape (in meters)

Design of sampling protocol
When to sample
Methodologies (how to identify and percent cover…)
Entering data
Data base
Field checklist (i.e. make sure you have transect measuring tape and quadrat…)
Cover class apendix

- Map of the locations of the transects


- Digital Camera (optional) to take picture of unknown plant species

While in field remember to:

- Write down the water depth at bridge
- Take point intercept every meter
- Percent cover every 5 meters
- Make note of anything strange that you observe
- Write down date, names of samplers, and transect code

**Remember to enter the data into your spreadsheet right away!**

GLOSSARY:

**Emergent vegetation**: a plant growing or protruding above the water surface

**Exotic**: Any species of plant that has been introduced to the wetland (non-native).

**Macrophytes**: Those plants with vegetative parts that are permanently or seasonally submerged in, or emerge from water or float on the water surface.

**Quadrat**: An area of ground surface, in this case one square meter in size, used as a sampling unit in population studies

**Transect**: A line across a habitat or habitats along which organisms are sampled in order to study changes that may occur along the line

## Appendix

## Status of Coal Oil Point Reserve Restoration and Enhancement Program

(extracted from the Coal Oil Point Reserve Management Plan 2004)

**Status**. COPR has a number of exotic and invasive species that have degraded natural habitats and displaced native species. COPR has started removing the most invasive species such as *Acacia*, pampas grass, iceplant, and *Myoporum* (Figure 7). Grazing and fire, which were natural phenomena at COPR, are now absent owing to fire suppression and loss of large native grazers. California native species of non-local origin have been introduced in the past to the Reserve as part of soil remediation projects, by accident, or by unauthorized planting. There have been great efforts to remove these plants to avoid hybridization with local genotypes and to limit confounding effects Below is a summary of each project:

*Eastern dune restoration*: (area 1 in Figure 7). This site is located on the south-east corner of the Reserve and measures approximately 6 acres. The area was restored from 1998 to 2002 with the help of volunteers. Before it was restored, the site was dominated by acacia and there were almost no native species on site except for some nightshade, willows, and a small patch of *Scirpus mexicanus*. When the acacia was removed, the bare area revealed a complex landscape with dune and sandy loam soils. The dunes were planted with seeds collected from plant species found on the dunes on the west side of the slough. On the sandy loam soil seedlings of coastal scrub species were planted to mimic the vegetation growing on the west side of the slough. Plants were grown in the Reserve's greenhouse from seeds collected on the Reserve.

*Slough margin restoration*: (area 2 in Figure 7). This site is located immediately south of the bridge over the Devereux slough channel. Before it was restored in 2002 the area was dominated by a number of exotic shrubs such as *Acacia*, *Myoporum*, and large *Eucalyptus* trees. Some native species such as Coastal Scrub Oak (*Quercus agrifolia*), Mugwort (*Artemisia douglasiana*), and California brome (*Bromus carinatus*) occurred in the gaps and edges of the thick exotic vegetation. The exotic shrubs and trees were planted years ago for a landscape project. All exotic brush species were removed, eucalyptus trees were trimmed to within 2 meters from the ground, and coastal scrub species and oak trees were planted. All plants used in this restoration project, except the California Sunflower and Lemonade Berry, were propagated from seeds collected from plants found on the Reserve, and were grown in the Reserve greenhouse. Seeds of the California sunflower were collected at Goleta beach and Lemonade Berries were collected at the UCSB's north bluff because there was no source of seed for these species on the Reserve. A professional arborist removed the trees and shrubs and the area was planted with natives with help of numerous volunteers of the Santa Barbara Chapter of the Audubon Society.

*Slough margin, eastern edge*: (area 3 in Figure 7) The eastern margin of the slough was restored in 1999 through a grant provided by the Coastal Resource

Program (CRP) (Number 46-A-98) in collaboration with the Santa Barbara County. The project included restoration of the slough margin and the vernal pool on west campus, the installation of benches and educational signs, and planting of vegetation to screen buildings. The slough margin was dominated by iceplant that was killed by covering it with black plastic for 8 weeks. None of the natural plant community endemic to this very degraded site remained to provide a model for restoration. We used the plant communities found at nearby wetland sites (e.g. Hollister Ranch and Carpinteria Salt Marsh Reserve), which are similar to COPR but less degraded, to determine which species to plant and their distributions in the restored areas. Seedlings of several species from COPR were propagated in the Reserve's greenhouse.

*North-east corner*. (area 4 in Figure 7). This area was dominated by iceplant and restored in 2000 by students from the Goleta Family School under the supervision of the Reserve Director. Students removed the iceplant by hand and collected seeds of native plants on the Reserve and cultivated them in the Reserve's greenhouse. Restoration on this site is ongoing; the remaining exotic trees and iceplant will be removed (see site 1, Table 3.2 and Figure 3.1).

*Northern margin*: (area 5 in Figure 7). The project to restore the northern margin of the slough began in 2000 when a large *Meleleuca* was removed from the wetland edge.

*Vernal pool project:* (area 6 in Figure 7). The vernal pool was created in 1987 as a mitigation project for the UCSB West Campus Faculty Housing project. It was the first vernal pool reconstruction project attempted by the UCSB Museum of Systematics and Ecology and was moderately successful. Currently, the deep areas of the pool function as a vernal marsh that rarely dries up, and the shallower edges as a vernal pool that dries up seasonally.

*Dune pond project*: (area 7 in Figure 7). The main goal of this project was to eradicate Pampas Grass from the Reserve. In 2000 one acre of pampas grass was removed from the dune pond margin using a backhoe and disposed off-site. Isolated clumps of pampas grass were sprayed with glyphosate and left on-site to decompose. Small plants including curly dock and cockle burr were removed by hand.

Need to include the WCB grant
We might not need to include the areas that are not surrounding the wetland


Figure 7. Map showing areas evaluated for the grassland/scrubland restoration plan (Appendix 3) and restored areas (areas 1-8) described in the Restoration and Enhancement Program.

Restored areas 1-8

A. Grassland: mostly exotic species

B. Coastal scrub

C. Native grassland/ scrub mix

N
W
E
S

0 100 200 Meters

Coal Oil Point Reserve
Management Plan, 2003
University of California
Santa Barbara
UC Natural Reserve System

## *REFERENCES CHAPTER 6*

Dennison W. C., Orth R. J., Moore K. A., Stevenson J. C. & al e. (1993) Assessing water quality with submersed aquatic vegetation. *BioScience* 43: 86-94.

EPA. U. S. ( 2002) Methods for Evaluating Wetland Condition: Using Vegetation To

Assess Environmental Conditions in Wetlands. *Office of Water, US* Environmental Protection AgencyWashington DC. EPA-822-R-02-020.

Reilly M. E. (1979) The salt marsh vegetation of Elkhorn Slough. In: *The Western Society of Naturalists 60th Annual Meeting Abstracts of Symposia and Contributed Papers* pp. 3-4, California State Polytechnic University, Pomona CA.

Worley K. (2005) Mangroves as an Indicator of Estuarine Conditions in Restoration Areas. *in Estuarine Indicators* CRC Press.

Braun-Blanquet, J. 1965. Plant Sociology: the Study of Plant Communities. London: Hafner.

Collier, Christine L., Powell, Abby N. 1998. Reproductive Success of Belding's Savannah Sparrows in a Highly Fragmented Landscape. The Auk 115(2):508-513.
6 pages.

**CARLISLE ET AL, A VOLUNTEER HANDBOOK FOR MONITORING NEW ENGLAND SALT MARSHES, 2002**

Elzinga, C. L., Salzer, D.W., Willoughby, J.W. 1998. Measuring and Monitoring Plant Populations. Technical Reference 1730-1. Denver, CO: Bureau of Land Management.

Vasey, M., Callaway, J., Parker, V.T. 2002, Wetlands Regional Monitoring Program Plan, San Francisco State University, San Francisco, CA.

Roman, C. T. et al, 2001, Monitoring Salt Marsh Vegetation, A protocol for the long-term coastal ecosystem monitoring program at Cape Cod national Seashore, USGS, Wellfleet, MA, 02667.

# CHAPTER 7: FISH

## *Monitoring Goal*

To determine the yearly and seasonal trends in fish community composition, diversity, and size class of fish found in Devereux Slough, and maintain a database with these measurements.

## *Introduction*

Estuaries have long been thought of as important sites for fish both as a nursery and permanent habitats (Elliott & Hemingway 2002).Fish are an important part of the food web in estuaries and make up a large portion of the estuarine biomass and biological diversity. (insert information from estuarine indicators book) Fish have been used for many years to indicate whether waters are clean or polluted and what native populations have been eradicated from the system. Knowing just whether fish live in the waters is not enough - we need to know what kinds of fish are there, how many, and their health. Fish are excellent indicators of watershed health because:

- Fish populations and individuals generally remain in the same area during summer seasons
- Communities are persistent and recover rapidly from natural disturbances
- Comparable results can be expected from an unperturbed site at various times
- Fish have large ranges and are less affected by natural microhabitat differences than smaller organisms. This makes fish extremely useful for assessing regional and macrohabitat differences
- Most fish species have long life spans (2-10+ years) and can reflect both, long-term and current water resource quality
- Fish continually inhabit the receiving water and integrate the chemical, physical, and biological histories of the waters
- Fish represent a broad spectrum of community tolerances from very sensitive to highly tolerant and respond to chemical, physical, and biological degradation in characteristic response patterns
- The sampling frequency for trend assessment is less than for short-lived organisms
- Taxonomy of fishes is well established, enabling professional biologists the ability to reduce laboratory time by identifying many specimens in the field
- Distribution, life histories, and tolerances to environmental stresses of many species of North American fish are documented in the literature

It is difficult to sample fish species in estuaries because their distribution and abundance varies greatly spatially throughout the estuary and over time. Unlike other monitored parameters such as plants and benthic invertebrates, fish are highly mobile and are therefore difficult to capture. But despite these challenges, fish are fun to study because of their size and physical characteristics and can be important indicators of

estuarine conditions and in many cases are the catalyst for wetlands restoration (Burdick et al. 1999).
Scientists do not fully understand the influence of estuarine degradation on fish but are aware that many species are sensitive to changes in dissolved oxygen, salinity and nutrient levels that result from pollution and surface runoff. Major human disturbances from upwatershed land use changes can lead to an increase in sediment load, alterations in hydrology, changes in vegetation or introduction of invasive species.

This chapter provides volunteer monitors with the tools and instructions necessary to monitor the presence and relative abundance of the fish in Devereux Slough and investigate the seasonal and temporal variations of these species.

## *Parameters*

### Fish Species

Common fish found in Devereux Slough include: (Please see fish manual (appendix C) for detailed description of each fish species)

- California killifish (Fundulus parvipinnis)
- Topsmelt (Atherinops affinis)
- Arrow goby (Clevelandia ios)
  Pacific staghorn sculpin (Leptocottus
- armatus)
- Striped mullet (Mugil cephalus)
  California halibut (Paralichthys californicus)
- Diamond turbot (Hypsopsetta guttulata)
- Longjaw mudsucker (Gillichthys mirabilis)

### Species Richness

This is strictly the number of species found in the sample.

**Simpson's Index of Diversity**

Simpson's Diversity Index is a measure of diversity. In ecology, it is often used to quantify the biodiversity of a habitat. It takes into account the number of species present, as well as the abundance of each species. This index is a measure of concentration of species. The Simpson's index is used for this parameter instead of the commonly used Shannon index (see chapter 6) because the Simpson's index of diversity is a measurement that accounts for the richness and the percent of each subspecies from a biodiversity sample within a zone. Although similarly to the Simpson's index, the Shannon measurement takes into account subspecies richness and proportion of each subspecies within a zone, it is better suited for measuring diversity in a specified plot.

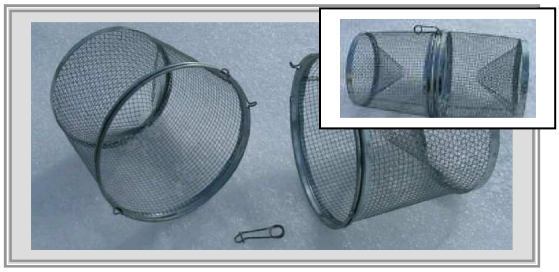
### Size Class

Length data are particularly valuable and are often the most commonly collected information from fish samples. The length recorded may be either total, fork, or standard. We use total length in this monitoring program. Total length is the length between the anterior and posterior extremes (see appendix C). Size-

frequency data can be used to determine growth patterns and life stage of population.(Elliott & Hemingway 2002)

## *Equipment*

There is a variety of sampling equipment used to monitor and sample estuarine fish. In this program we use two main methods for capturing the fish at Devereux Slough: seines and minnow traps. It is important that both of these methodologies are employed on a regular basis to ensure that the entire fish community may be sampled. Both of these methods miss some fish species that the other captures due to mesh size, fish behavior and sampling restraints described below.



### Minnow traps

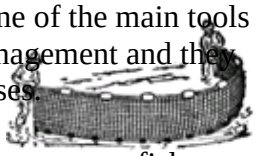
Minnow traps are a passive method for sampling fish and baited and deployed at each sampling location for a 24 hour

period.

The traps are in sets of two attached by rope and split off into two ropes at the end.

### *Seine Net*

A seine net is a large fishing net that hangs vertically in the water by attaching weights along the bottom edge and floats along the top. A seine net can be of anything from 10 to 1200 metres in length and visually looks similar to a standard anglers landing net. The nets used for the DSMP are 5-20 meters in length. The seine is one of the main tools applied in fishery management and they have a multitude of uses.



Mainly they are used to remove fish from a water body for either stock reduction or survey purposes. Seines can be applied to almost any water body or type. They tend to be most successful on lakes and reservoirs where large expanses of water are clearly visible as this allows plenty of working area. As nets are pulled up bank sides the more area behind the waters edge, the easy the job becomes. Canals can be dragged down with smaller seines and rivers can be surveyed using two or more nets applying wrap around techniques.

### Glass Fish Viewer

The glass fish viewer (in this case a square flower vase) is used to identify fish while in the field. The viewer is filed halfway with slough water and the fish under question is placed (alive) in the water in the viewer. The

fish can then swim in the viewer making it easier to see all markings, fins etc. to make identification possible.

### Fish Identification Guide

The fish ID guide (see appendix ?) was created specifically for the fish in Devereux Slough. The guide details with visual aids, identification parameters for the fish species found in Devereux Slough. Habitat preference, life history and distinguishing characteristics are also outlined in the guide. This guide should be taken to the field during each sampling event and if possible, each volunteer should have their own copy.

### Buckets.

Small 2-5 liter buckets should be taken to the field to place fish when there are too many fish caught in net to count. These fish can be placed in the bucket full of slough water to ensure they can be IDed and thrown back into the slough without the risk of dessication.

### Clipboard

Wooden clipboard should be brought to field every sampling even to hold writing utensils, data sheets, and field guides and to enable the recorder a hard surface to record data.

### Data Sheet

The data sheet consists of one field sheet (see figure?) to record fish numbers…

## *Sampling Considerations*

Sampling should be done at regular intervals throughout the year. Sampling should also be done after any event of that may cause unusual conditions. For example:

- Immediately after the slough breeches
- After any noticeable fish kills
- During extreme periods of high salinity, low oxygen or extreme temperature
- Any major runoff events/adjacent development

## *Sampling Procedure*

Many fish are readily harmed by excessive handling, (topsmelt especially), which should be kept to a minimum.

### Minnow traps

1. You will need a total of two sets of two minnow traps for each sampling

date (total of eight sets for the four sampling locations)

*A minnow trap set consists of four half buckets resulting in two complete minnow traps attached by rope (see figure under equipment)

2. At each of the four sampling locations, set traps from designated sampling point (see map in Appendix)

3. Prior to setting traps, put five pieces of Pedigree dog food in each of the four minnow traps at each site.

4. Once traps have dog food and are closed, throw traps out at designated point

a. At the skunk fence (DV02) and estuary mouth (DV03) throw the traps out as far as possible from shore

b. At the bridge (DV00) traps should be lowered from the bridge to halfway down the water column and tied to one of the bridge posts. Make sure that the traps are at least 2 meters from the bottom so fish will not die over night if the bottom waters go anoxic.

c. At the stream mouth (DV01) lower traps (one set from each bank) from the west and east banks of the creek mouth and tie to rocks on bank.

5. Immediately following trap setting, take water quality measurements (salinity, temperature, and dissolved oxygen) (see chapter three).

6.. Retrieve the traps no more than 24 hours following setting. Traps should sit over night.

7. Once traps are brought up, immediately ID fish and count numbers of each species. Classify each fish by size (see Appendix 3).

8. If traps have an abundance of fish in them they can be emptied into a water bucket. Count fast and efficiently to prevent fish kills.

9. Use the fish viewer for IDing any unknown fish.

10. Record fish numbers and size on data sheet. Use a different data sheet for each location, but not for each trap. A total of four traps should be recorded on each data sheet (four data sheets per day for each of four sampling locations)

.

## Seining

**COLLECTING SPECIMENS**

There will be 5 seine hauls total: 4 sweeps in alternating directions (counted as 4 hauls), with the blocking seines brought in together and counted as 1 haul

After each seine haul, fishes will be kept in shaded, aerated buckets. Fishes will be measured after all seine hauls are complete.

Seining is conducted monthly based on equipment accessibility and field assistants' availability. Fish monitoring protocols suggest sampling on a bi-yearly or quarterly basis (Desmond *et al.* 2002; Jordan *et al.* 2007b) but due to the dynamic conditions of Devereux Slough,

a monthly seining routine more adequately captures transitions in fish abundance and species composition.

Fish are collected from each habitat using two blocking nets and a 10 meter or 15 meter seine with 3-mm square delta grade mesh. At each station a linear distance is measured parallel to the channel and two blocking nets are deployed to confine all the fish within this area. The seine is then swept between the two blocking nets and across the channel to the opposite bank if channel width is less than 15 meters, or to mid channel at larger widths (i.e. near the mouth of the slough) (one – 3 passes to ensure entire blocked off area was swept). During periods of high water levels and deep channels, the blocking method is not used. Instead rapid sweeps are made parallel to the shoreline. Sweeps are approximately 20 meters in length to ensure that enough fish can be captured but the distance was not too long so as not to enable the fish to eventually escape before the seine is brought to the shore.

Two field assistants are needed to pull the seine. Each assistant takes hold of the poles at either end of the seine. One assistant remains close to shore while the other assistant wades out to the center of the channel until the net is pulled taught. The two seiners travel at the same speed forward constantly tapping the poles to the ground to ensure that the net always remains on the bottom of the slough. The two field assistants continue to push the seine while the remaining field assistants wade down from the seine towards the net while vigorously thrashing and kicking the substrate to scare fish out of sediment burrows and vegetation. Kick seining is used because it has been shown historically to be the most successful method in surveying fish in shallow estuaries and streams (Jackson & Harvey 1997; Warren & Burr 1994). While the field assistants are sweeping the net forward, care is taken so that the floats remain out of water at all times so fish cannot escape over the net, as well as making certain that leaded weights remain on the substrate constantly to ensure that fish do not get away beneath the net. Before a seine sweep is conducted, a visual inspection determines the ending location on the shoreline so that both seiners know exactly when to start pulling the seine shore bound. Capture efficiency for seines is based on the efficiency of encirclement as the net is pulled into shore. Although the total net area across the estuary remained constant, the quantity and area of individual panels varies as the characteristics of sampling sites changes. This is mainly due to seasonal changes in vegetation, channel width and depth. Individual sampling efforts are tailored based on these conditions. However, overall sampling sites (starting point from shore) remain the same each month.

Once both seiners begin to head towards shore, additional field assistants help to keep the net on the sediment by dragging the bottom along the estuary floor and folding the seine up like a taco once it reaches the shore. Immediately after bringing the seine onto shore, assistants identify fish, count, classify by size and record numbers. This is done in a very rapid manner and fish are immediately returned to the water after they are counted. To prevent exposure to air too long, which can cause a mild narcosis and prolonged durations of swimming impairment (from 1 to 6 h) (Mitton

1994), only the first 100 fish of each species are recorded per seining attempt . Fish are identified, measured, counted, recorded and returned. Individuals that are unique or difficult to identify are preserved and brought to the lab for correct identification (Briggs & O'Connor 1971; Jordan *et al.* 2007a).

Some things to consider when attempting increase capture efficiency of the net are the fishes' swimming speed relative to the speed of the seine movement, direction of evasive movements, and the size of the fish (Hopkins 2001). Seine sampling has been recorded (Hopkins et al 1991) as having a 7% bias in overestimating population sizes.

Up to 50 fish per species will be measured to the following size classes (mm): 0-4.9, 5-9.9, 10-14.9, etc. After 50 individuals have been measured for each species, remaining fish will be counted.

## *Data Entry*

## *Data Analysis*

Analysis:
Diversity

## *References*

Elliott M. & Hemingway K. L. (2002) Fishes in Estuaries. *Blackwell Science* Oxford.

Burdick, D., R. Buchsbaum, C. Cornelisen, and T. Diers.1999. *Monitoring Restored and Created Salt Marshes in the Gulf of Maine: Framework and Data Collection Methods to Guide Monitoring Programs that Involve Volunteers.*Based on: Salt Marsh Monitoring Workshop, June 2,

1998, Castle Hill, Ipswich, Massachusetts. Sponsored by: Massachusetts Audubon Society and Gulf of Maine Council on the Marine Environment.

# Chapter 8: INVERTEBRATES

## *Background*

Coastal wetlands often host a variety of invertebrates species that burrow in mudflats and salt marshes or swim in the tidal creeks. Snails, mussels, crabs and shrimp are the most common animals in tidal areas. However, in estuaries such as Devereux slough which are rarely open to tidal influence, less conspicuous animals such as insects, amphipods, isopods and worms are the invertebrate species which dominate. Salt marsh invertebrates exhibit a wide range of tolerance for physical and chemical conditions such as salinity and temperature changes. Species occupy different areas of the salt marsh depending on their tolerance different conditions….

Invertebrates include aquatic insects, freshwater crustaceans (e.g., amphipods, crayfish), aquatic annelids (worms), zooplankton, and immature stages of certain terrestrial insects (e.g., Lepidoptera) that occur mainly in wetlands. The term "macroinvertebrate" or "macrofauna" refers to the larger organisms clearly visible to the unaided eye, as opposed to microinvertebrates, which include most smaller zooplankton, such as rotifers.

## *Invertebrates as Indicators*

The biomass and biodiversity of benthic invertebrates in estuaries and coastal embayments is often high. It declines if communities are affected by prolonged periods of poor water quality especially when anoxia and hypoxia are common (Nixon, 1999). Nitrification and denitrification are enhanced because a range of oxygenated and anoxic micro-habitats are created by benthic invertebrates. Loss of nitrification and denitrification (and increased ammonium efflux from sediment) in coastal and estuarine systems is an important cause of hysteresis which can cause a shift from clear water to a turbid state (Harris, 1999)

Changes in the macrofauna (and flora) cause changes in nutrient storage pools and in the flux of nutrients between microfauna (and flora) and macrofauna and flora. Macrofauna are also important constituents of fish diets and thus are an important link for transferring energy and nutrients between trophic levels and driving pelagic fish and crustacean production. It is for these reasons and others, that benthic invertebrates are extremely important indicators of environmental change.

Measurements of change in benthic marine communities have for several decades been widely used in identifying and monitoring human impacts on the estuaries. Macrobenthic analyses have proven to be useful in assessing the environmental impacts of coastal discharges (Anderlini et al, 1992), chemical contamination of sediments (Van Hoeyweghen, 1999), and introduced marine pests (Cohen, 2000). This is largely because benthic organisms are relatively non-mobile and integrate effects of pollutants over time.

Macrobenthic monitoring programs are almost always a compromise between

the scientific ideal and political, financial and logistical constraints. The costs of biological monitoring are relatively high compared to physical or chemical monitoring (largely because of the labour intensive nature of field sampling and laboratory analysis). But physical/chemical data are only an indirect measure of ecosystem health. Direct monitoring of the biota is the only way in which an unequivocal assessment of ecosystem health can be obtained.

Methods of sampling benthic invertebrate populations vary with the types of organisms under study, and the type of bottom. Many organisms that live on, rather than within, the bedforms can be captured by trawls, dredges and seine nets similar to those used by commercial fisheries. Unfortunately, most of these methods are semi-quantitative at best, and do not always provide reliable estimates of population sizes.The sampling efficiency of trawls and dredges, for example, is greatly influenced by variations in the composition and topography of the seafloor [28,29]. Furthermore sample size is difficult to determine for trawls and dredge gear, and even harder to replicate, as vessel speed and length of tow are not easily controlled [30].

Diver sampling is arguably the optimum quantitative approach to sampling large epibenthic assemblages [26]. The sampling efficiency of a diver-operated sled is not directly affected by undulations in the bedforms or by variations in bottom type. The sample size is predetermined and can be consistently replicated in space and time. In addition, the physical collection of biological samples facilitates accurate identifications of epibenthic species encountered and provides more precise estimates of species abundance and biomass. Unfortunately the dive survey method is labour intensive and relatively more expensive than trawling, and dredging. More importantly, it cannot be employed in deep waters (30 m) where dive time is restrictive, and in areas of high turbidity where poor visibility can strongly influence collection efficiency.

To capture smaller invertebrates that live beneath the surface of sediments, the sampling device must be capable of digging into the sediments. A large variety of corers and grab samplers have been developed for this purpose (*e.g.* Petersen grab, Smith-McIntyre grab, Knudsen sampler, and Barnett-Hardy corer) [30]. Most of these apparatus are geared at taking quantitative samples of sediments of known area and depth. Their performance, however, varies with sediment structure and depth. Many corers and grab samples, for example, are unable to sample animals inhabiting coarse sand and gravel, as they are unable to penetrate and keep these sediments when being brought to the surface of the water. Because of its ability to sample quantitatively a wide range of sediment types and a broad range of depths, the spring-loaded $0.1m^2$ Smith-McIntyre grab has found general acceptance among oceanographers and benthic ecologists.

There are very good arguments that have been made that indicate any changes caused by humans are only significant and important if they cause a fluctuation that is greater than the average fluctuation that occurs naturally within the population. Monitoring change in ecology is actually relatively straightforward. The real difficulties lie

in interpreting the CAUSES of such changes, particularly when people try to delineate cause (*e.g.* human impacts), when they have only been monitoring change. The detection of cause is an experimental design issue and cannot be reached via simple monitoring. There are some very well documented approaches that now allow temporal and spatial variation to be incorporated into the experimental designs so that impacts caused by humans can be detected [37-42], in a context of a naturally variable world [42-43]. These have been tested in a number of situations and work. Moreover, examining the entire assemblage/community tends to provide a more powerful test of whether there has been a human impact (still making use of appropriate experimental designs) than monitoring a single population, especially when the population may have been chosen because it was believed to be an "indicator". The excellent work done in Europe (Plymouth Marine Laboratories) has shown this very clearly and even developed new statistical techniques that can be used to analyse the community data.

Bioindicators for Assessing Ecological Integrity of Prairie Wetlands Report # EPA/ 600/ R-96/ 082 September 1995

## EQUIPMENT

Field equipment:

- Dipnet (picture)
- Alcohol (Ethyl or Isopropyl)
- Ziplock bags
- Labels
- Permanent Marker
- Coffee Cans
- Magnifying Lens
- Cooler
- Forceps
- Sieve

Sorting and identification Equipment (lab)

- Bagged and labeled samples
- Alcohol
- Small glass beaker
- Squeeze bottle
- Plastic bucket
- White sorting tray
- Magnifying lamp
- Forceps
- Invertebrate sample recording sheet
- Petri dish
- Probe
- Dissecting microscope (10x-40x)

## *SAMPLING METHODS*

Several methods for sampling invertebrates in estuaries have been outlined in wetland assessment literature (Desmond et al. 2002, E.P.A 2002). Due to the small size and infrequent tidal influence of Devereux slough, the following methods have been adopted for this monitoring:

- Core sampling: Macrofauna are sampled at each inundated habitat type in the estuary including slough channel, mouth, emergent vegetation, and stream opening by coring. Samples are taken with a coffee can as a cylindrical core one foot deep. To sort samples in a timely manner, one core is taken at each location each sampling date. Cores are taken twice a year. Samples are preserved at brought back to the lab for sorting and identification. Samples are identified to family.

- Multihabitat dipnet samples are taken throughout the slough twice a year. Invertebrates are brought back to the slough for sorting and identification. Dipnets are used to collect invertebrates from shallow water environments. Using this method you can expect to find polychaete worms, amphipods, and isopods.
- Salinity, dissolved oxygen, and temperature measurements are taken with each sample.

## Specific Sampling Instructions:

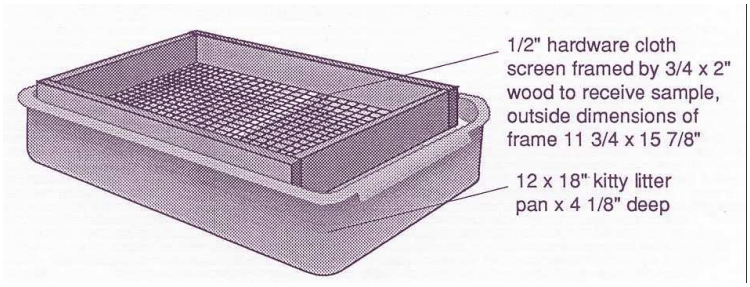
DIPNETS

The Dipnets are quickly swept outwards and downward and then back in (through the water column), and should be done about 3 times for each sample, two samples for each location.

Place the entire dipnet contents on top of a (mm) sieve set over one or two small pans containing sieved water (Figure 1). The frame is placed so no open screen area projects beyond the pans of water below. Over a period of five-ten minutes the vegetation is spread apart on the hardware cloth to allow the invertebrates to drop or crawl out into the pans below.

After ten minutes a second dipnetting effort is done in a nearby area, the vegetation from the first dip net effort is removed, and the second net's contents are placed on the cleared screen. The spreading process is repeated for about 10 minutes, after which the vegetation is again discarded. Any large organic material (whole leaves, twigs, algal or macrophyte mats) should be rinsed, visually inspected for invertebrates, and discarded.

After both sweeping efforts are completed, the contents in the two small pans are poured through a 200 micron nytex nylon net sieve to drain out the water. The sieve is made with 15 cm length of 4" diameter PVC pipe with the net glued on one end with a ring of the PVC. The contents of the sieve is back-flushed with 100% alcohol with a strong squirt-bottle into a sample bag, thus combining the two dip net efforts into one dip net sample. The goal is to end up with 80% alcohol final concentration. Care must be taken to re-preserve samples containing a large catch of invertebrates, or to divide the sample between two plastic zip-lock bags (sample #, jar 1 of 2, jar 2 of 2). The bag should have not more than 1/3 volume of invertebrates to alcohol. The bags are labeled with permanent marker with **date, sample number and sample type** (dipnet or core)




CORE SAMPLES

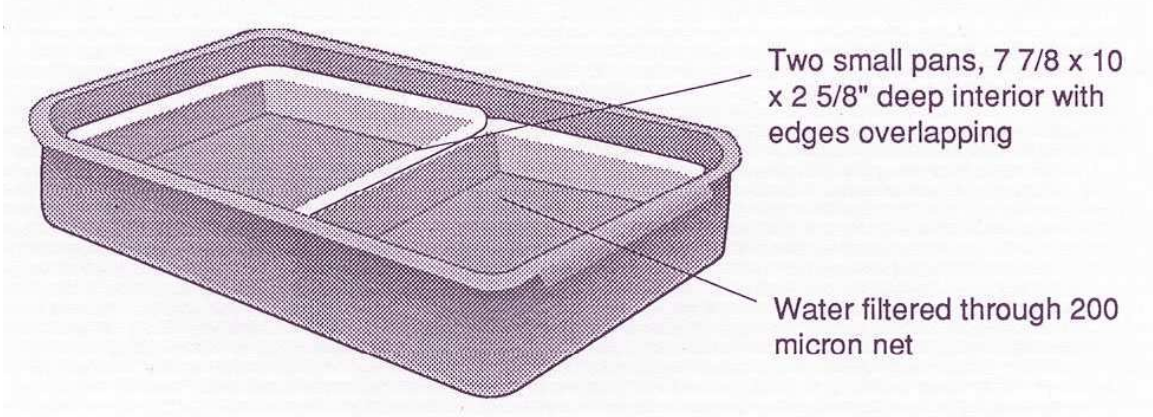
A small distance from the dipnet sample location, place corer to the floor sediment, and collect sediment. Take two of these samples per sample site.

Corer should be filled about 2-3 inches and entire sediment sample placed in ziplock bag to be sorted in lab. The contents of the corer are back-flushed with estuary water into the sample bag. Alcohol is then added to preserve sample. The goal is to end up with about

an 80% alcohol final concentration. The bags are labeled with permanent marker with **date, sample number and sample type** (dipnet or core)

During the field sampling, Field Data Sheet One should be filled out for each sample site (see appendix).

This should be done three times a year- once in May or June, once in July, and once in September. Both methods should be used each time.



## *In-Lab Methods*

The samples are brought back to the lab for sorting and identification.

The first sorting process will sort invertebrates from debirs (sediment, algae etc) into one sample vial for later identification.

Place sample contents in a large flat pan with a light-colored (preferably white) bottom. The bottom of the pan should be marked with a numbered grid pattern, each block in the grid measuring 5 x 5 cm. (Sorting using a gridded pan is only feasible if the organism movement in the sample can be slowed by the addition of club soda or tobacco to the sample. If the organisms are not anesthetized (or preserved),100 organisms should be removed from the pan as randomly as possible.)

Samples too large to be effectively sorted in a single pan may be thoroughly mixed in a container with some water, and half of the homogenized sample placed in each of two gridded pans. Each half of the sample must be composed of the same kinds and quantity of debris and an equal number of grids must be sorted from each pan, in order to ensure a representative subsample.

Add just enough water to allow complete dispersion of the sample within the pan; an excessive amount of water will allow sample material to shift within the grid during sorting. Distribute sample material evenly within the pan.

Use a random numbers table to select a number corresponding to a square within the gridded pan. Remove all organisms from within that square and proceed with the process of selecting squares and removing organisms until the total number sorted from the sample is within 10 percent of 100. Any organism that is lying over a line separating two squares is considered to be in the square containing its head. In those instances where it is not possible to determine the location of the head (worms for instance), the organism is considered to be in the square containing the largest portion of its body. Any square sorted must be sorted in its entirety, even after the 100 count has been reached.

Removed organisms should be placed in a jar with 75-80% alcohol mixture and labeled with the same label as the zip lock bag from which it came (**date, sample number and sample type** (dipnet or core).

After 100 or more organisms have been removed, check the entire contents for any taxonomic group that has been missed.

Fill out data sheet 2 with corresponding information. These jars can be set aside to be identified at a later date (preferable less than 6 months later).

IDENTIFICATION:

Each organism is viewed under the microscope, identified to the genus and species, and placed into a small glass jar of 80% ethyl alcohol. Identification tags should be printed out and placed in the jar with the sample. The microscope should be stored in a glass case. Each species should be recorded on a data sheet, as well as the abundance, location, and date of the samples.

Create a **composite sample** for each station by pouring the vial contents of the D-Net sample and auger sample into one petri dish. Make sure that no organisms remain in the vials.
Place the petri dish under the dissecting scope set at 10X magnification, and in a deliberate, systematic manner, scan back and forth, identifying organisms as you go. You may need to increase the magnification to see finer details.

Using Weiss (1995), Pollock (1998), and other references, identify the invertebrates to family level. Record and count each **taxon** Data sheet 3.

Immediately after you identify and record a specimen, return it to a labeled vial two-thirds filled with 70% or higher concentration alcohol. There should be one vial per sample station per sample date.

Label and safely pack the vials so that someone can reexamine specimens or identify them to a lower level of taxonomy at some future date.

If you have doubts about an organism's identity, consult with a marine invertebrate specialist. Place the specimen in question in a separate vial with alcohol and a complete label. Send the specimens to a specialist for verification, and add to your records later. Alternatively, arrange to have a **taxonomist** present during an identification session to provide assistance.

.

RECORDING:

## *References Chapter 8:*

Nixon, S.W 1988, cited in Harris 1999. Comparison of the biogeochemistry of lakes and estuaries: ecosystem processes, functional groups, hysteresis effects and interactions between macro- and microbiology. *Marine and Freshwater Research* 50, 791-811.

Harris, G.P. 1999. Comparison of the biogeochemistry of lakes and estuaries: ecosystem processes, functional groups, hysteresis effects and interaction between macro- and microbiology. *Marine and Freshwater Research* 50, 791-811.

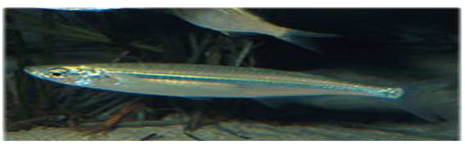
Anderlini, V.C. and Wear, R.G. (1992). The effects of sewage and natural seasonal disturbances on benthic macrofaunal communities in Fitzroy Bay, Wellington, New Zealand. *Marine Pollution Bulletin*. 24, 21-26.

Guns M., Van Hoeyweghen P., Vyncke W. and Hillewaert H.(1999). Trace metals in selected benthic invertebrates from Belgian coastal waters (1981-1996). *Marine Pollution Bulletin*. 38, 1184-1193.

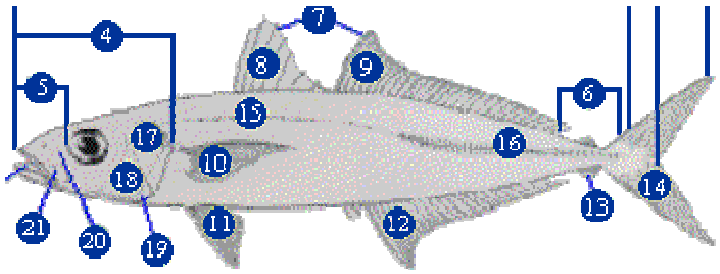
Cohen, B.F., Currie, D.R. and McArthur, M.A. (2000). Epibenthic community structure in Port Phillip Bay, Victoria, Australia. *Marine and Freshwater Research*. 51, 689-702

# APPENDIX A

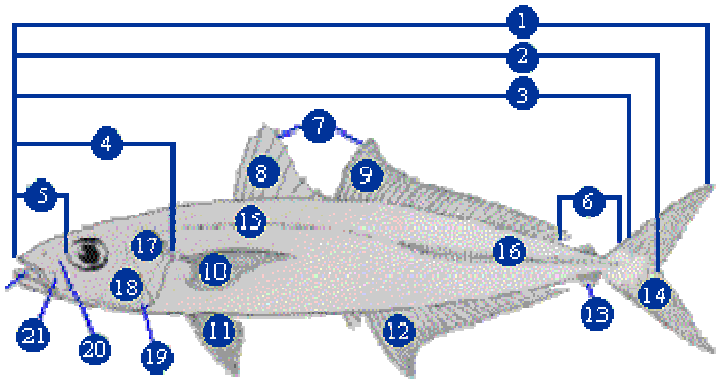
# Fish Guide for Devereux Slough, COPR

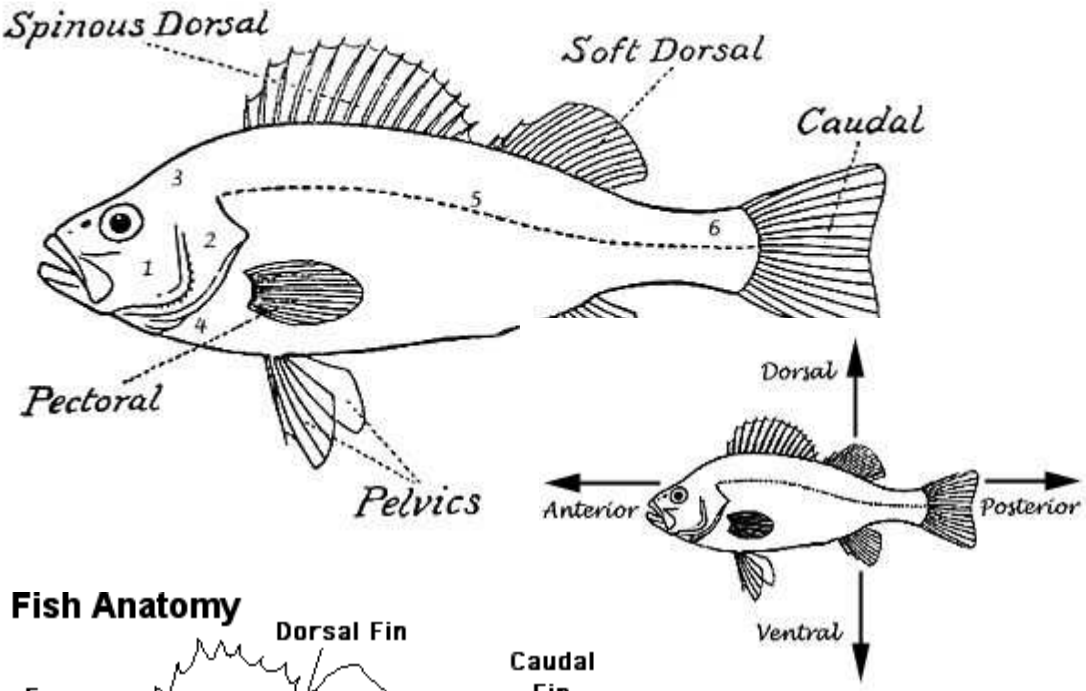


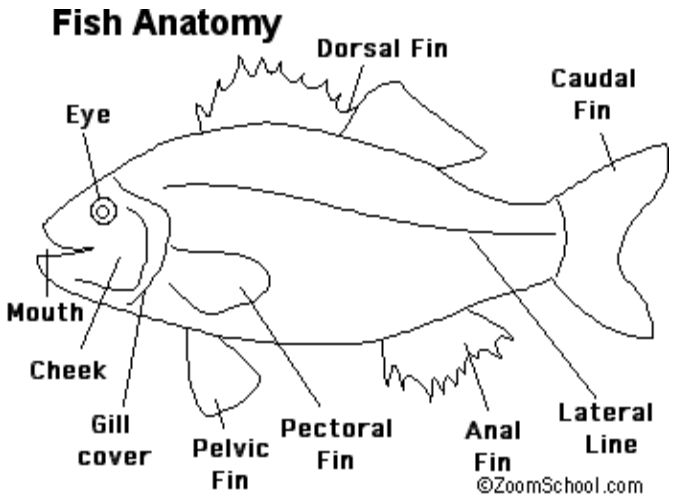
# Parts to know when Identifying Fish

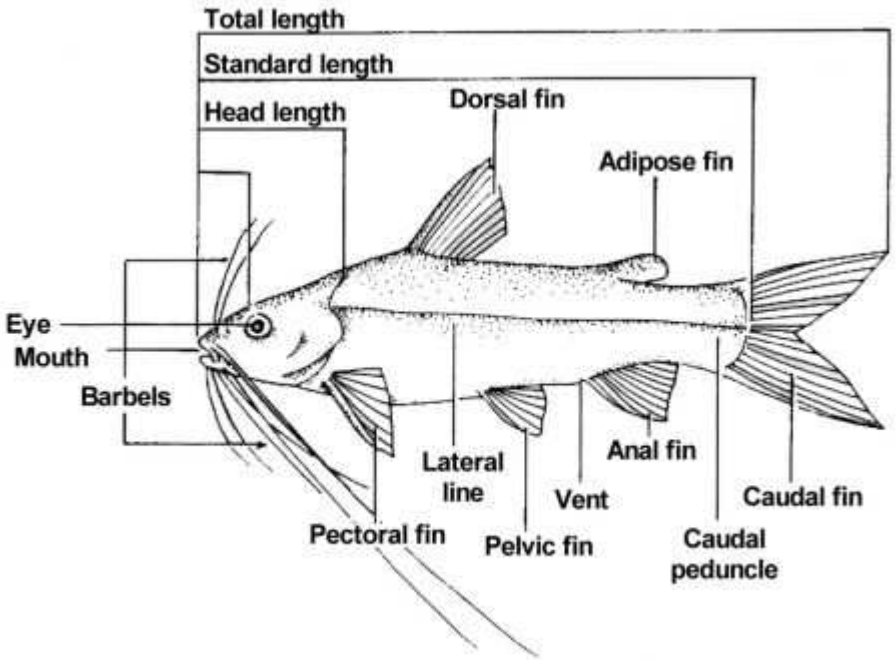



| | |
|---|---|
| **1.** Total Length | **2.** Fork Length |
| **3.** Standard Length | **4.** Head Length |
| **5.** Snout Length | **6.** Caudal peduncle (where the body attaches to the tail) |
| **7.** Fin rays, spinous (unsegmented) and soft (segmented) | **8.** First (spinous) dorsal fin |
| **9.** Second (soft) dorsal fin | **10.** Pectoral fin |
| **11.** Pelvic (ventral) fin | **12.** Anal fin |
| **13.** Finlet | **14.** Caudal (tail) fin |
| **15.** Lateral line | **16.** Scutes (bone-like projections |
| **17.** Opercle (gill cover) | **18.** Preopercle (cheek) |
| **19.** Interopercle | **20.** Adipose eyelid |
| **21.** Supramaxilla (rear portion of upper jaw bone) | **22.** Premaxilla (forward portion of upper jaw bone) |



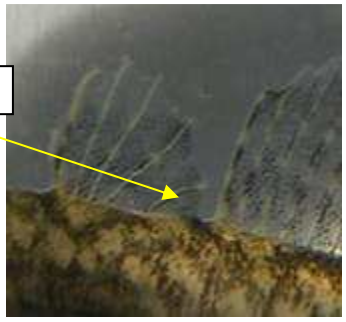

Spinous Dorsal
Soft Dorsal
Caudal
1
2
3
4
5
6
Pectoral
Pelvics
Dorsal
Anterior
Posterior
Ventral


Fish Anatomy
Dorsal Fin
Caudal Fin
Eye
Mouth
Cheek
Gill cover
Pelvic Fin
Pectoral Fin
Anal Fin
Lateral Line
©ZoomSchool.com

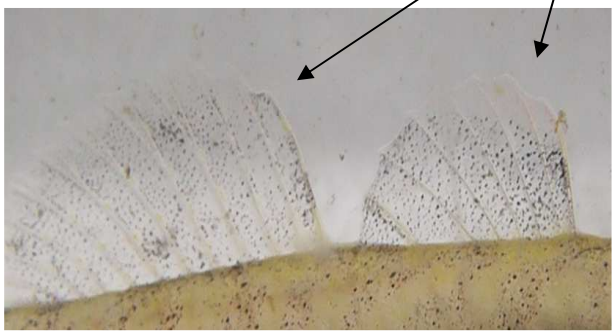

Total length
Standard length
Head length
Dorsal fin
Adipose fin
Eye
Mouth
Barbels
Lateral line
Anal fin
Vent
Caudal fin
Pectoral fin
Pelvic fin
Caudal peduncle

# Common Name: Tidewater Goby  Scientific Name: *Eucyclogobius newberryi*

## GENERAL DESCRIPTION OF SPECIES:

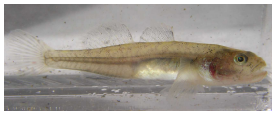



**Identifying Characteristics:** The tidewater goby is a small fish, rarely exceeding 2 inches in length, and is characterized by large pectoral fins and a ventral sucker-like disk formed by the complete fusion of the pelvic fins. The characteristics that separate the tidewater goby from other goby species within its range include the close spacing between the first and second dorsal fins, the clear/yellow tip of the first dorsal fin, the short maxillary bone, and the presence of two intraorbital pores




**General Habitat:** A member of the family Gobiidae, the tidewater goby is the only species in the genus Eucyclogobius and is almost unique among fishes along the Pacific coast of the United States in its restriction to waters with low salinities in California's coastal wetland habitats. All life stages of tidewater gobies are typically found at the upper end of lagoons in areas of low salinity (commonly less than 10 parts per thousand).

The tidewater goby typically occurs in loose aggregations of a few to several hundred individuals on the substrate in shallow water less than 3 feet deep (Swift et al. 1989), although gobies have been observed at depths of 4.9 to 7.6 feet (Dan Holland, University of Southwestern Louisiana, in litt. 1993). Peak nesting activities commence in late April through early May, when male gobies dig a vertical nesting burrow 10 to 20 centimeters deep in substrate that usually contains a coarse sand component. Male gobies remain in the burrows to guard eggs, which adhere to the walls of the burrow until hatching. Larval gobies are found midwater around vegetation until they become benthic (Swift et al. 1989). Although the potential for year round spawning exists, it is probably unlikely because of seasonal low temperatures and disruptions of lagoons during winter storms. Ecological studies performed at two sites documented spawning occurring as early as the first week in January (Swenson in litt. 1993). Although usually associated with lagoons, the tidewater goby has been documented in ponded freshwater habitats as far as 5 miles upstream from San Antonio lagoon in Santa Barbara County (Irwin and Stoltz 1984).



**Common Name: Tidewater Goby** **Scientific Name: *Eucyclogobius newberryi***

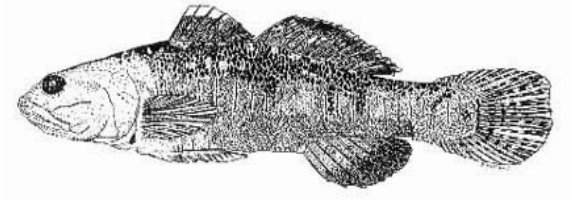
## HISTORICAL INFORMATION AND DISATRIBUTION

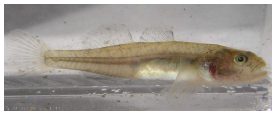
**Status** : Since 1900, the tidewater goby has disappeared from nearly 50 percent of the coastal lagoons within its historic range, including 74 percent of the lagoons south of Morro Bay in central California. The tidewater goby was first described as a new species (Gobius newberryi) by Girard (1856), from specimens collected in the San Francisco Bay area. Based on Girard's specimens, Gill (1862) reassigned Gobius newberryi to the newly described genus Eucyclogobius (Eschmeyer 1990).

**Reasons for Decline:** Coastal development projects that result in the loss of coastal saltmarsh habitat are currently one of the major factors adversely affecting the tidewater goby. Many coastal marshes have been drained and reclaimed for residential and industrial developments. Several coastal water bodies are subject to artificial breaching as a flood control measure. Waterways have been dredged for navigation and harbors resulting in permanent and direct losses of wetland habitats, as well as indirect losses due to associated changes in salinity.
Furthermore, upstream water diversions adversely affect the tidewater goby by altering downstream flows, thereby diminishing the extent of habitats that occurred historically at the mouths of most rivers and creeks in California. Alterations of flows upstream of coastal lagoons have already changed the distribution of downstream salinity regimes. Since the tidewater goby has a relatively narrow salinity tolerance, changes in salinity distributions due to upstream water diversions may adversely affect both the size and distribution of goby populations (D. Holland, Univ. of Southwestern Louisiana, pers. comm., 1991).

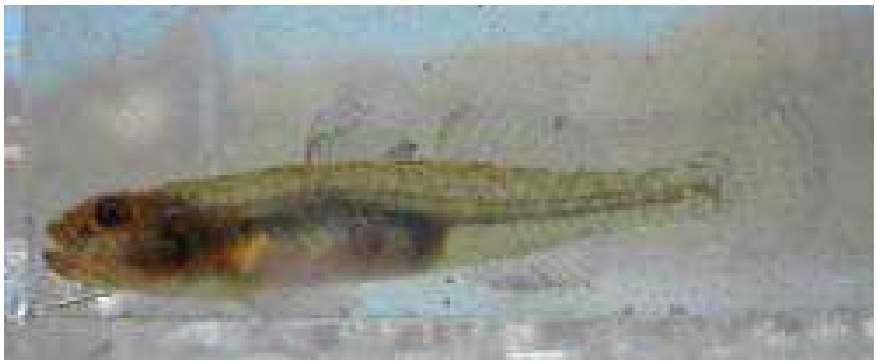
Finally, the accidental and purposeful introduction of both native and non-native species, particularly predatory fishes and amphibians, have been responsible for drastic reductions in populations where these organisms are present. The introduction of competitive species is another interspecific cause of decline.

## IDENTIFICATION





**Common Name: Tidewater Goby** **Scientific Name: *Eucyclogobius newberryi***



Common Name: **Longjaw Mudsucker** Scientific Name: ***Gillichthys mirabilis***

## GENERAL DESCRIPTION OF SPECIES

### IDENTIFICATION

Longjaw Mudsuckers can live out of water for 6-8 days if kept moist. This fish are often used as bait and can be caught in traps. They spawn from January-July. Female lays several thousand club-shaped eggs in nest built by male. Longjaw Mudsuckers are often confused with Tidewater gobies which have an oblique (not horizontal) mouth.

Habitat - tidal flats, bays, coastal sloughs; prefers mud bottom in shallow water

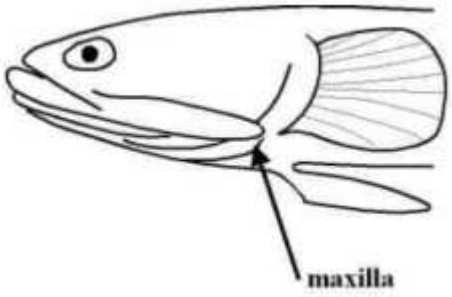
## HISTORICAL INFORMATION AND DISATRIBUTION

Distribution - Tomales Bay (northern CA) to Gulf of California and inhabits tidal flats, bays and coastal sloughs. They prefer mud bottom in shallow water. Non-emerging air-breather.

## IDENTIFICATION

Mouth very large, extending to pectoral fin base or beyond; 80-100 scales in lateral series. Can grow up to 21 cm.

Jaw is moderately long in young and is huge in adults. Anal fin is short. Color - Body lighty brown, sometimes almost yellow, other times nearly black; sometimes five irregular black blotches on back down to middle of sides, a sixth blotch across occiput; a series of smaller blotches along horizontal septum alternate with large blotches, occasionally form continuous line; black blotch on end of caudal peduncle often extends onto base of caudal fin rays. Head light brown, frequently black on snout, lip, upper one thrid of opercle, and under eyes; cheek sometimes with reticulations of darker brown; entire head sometimes black; throat and chin yellow to dusky, chin often dark brown or black. Pectoral fin dusky, lighter toward margin, without barring; upper half of base dark brown. Pelvic fins yellow, with or without scattered, contracted chromatophores. Both dorsal fins and anal fins usually heavely pigmented, almost black, dusky in pale specimens, margins white. Second dorsal fin rarely with traces of two to three horizontal stripes. Anal fin sometimes lighter proximally. Caudal fin dusky, often lighter at posterior margin (Barlow 1961).



**Common Name: Longjaw Mudsucker** **Scientific Name: *Gillichthys mirabilis***


# *Gillichthys mirabilis*

**Common Name: California killifish** **Scientific Name: *Fundulus parvipinnis***

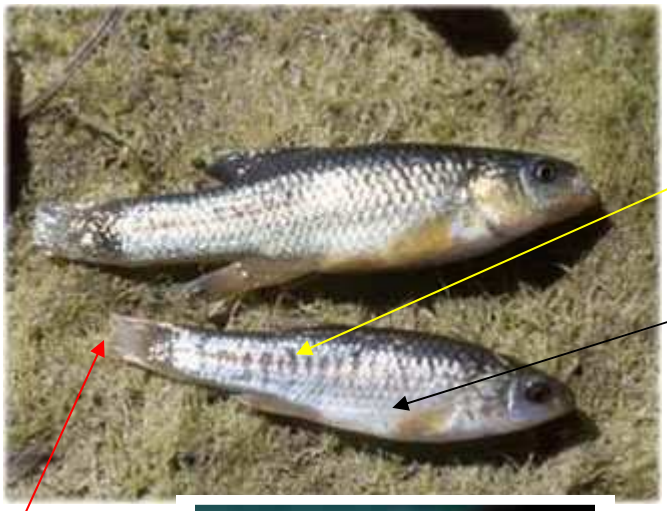
## GENERAL DESCRIPTION OF SPECIES

It has blue, green and purple. It is very small. It moves with its tail. Small fish with a rounded caudal fin and one spineless dorsal fin. The mouth points upward for feeding on the surface and they feed on insects and their larvae.

## HISTORICAL INFORMATION AND DISATRIBUTION

They are common in bays and salt marshes near the shore. Their range is from Morro Bay to Baja

## IDENTIFICATION

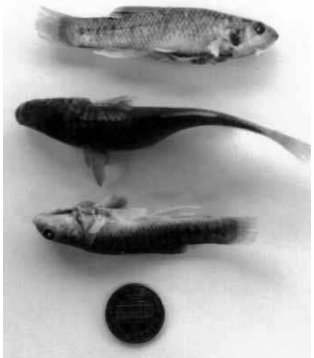


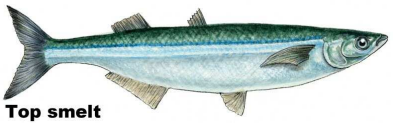
The anal fin usually opposite the dorsal fin.
Usually short dark bars on the side

Often a faint side stripe.

Breeding males are dark brown to blackish.

Have round/square caudal fins






**Common Name: Topsmelt** **Scientific Name:** ***Atherinops affinis***

## GENERAL DESCRIPTION OF SPECIES

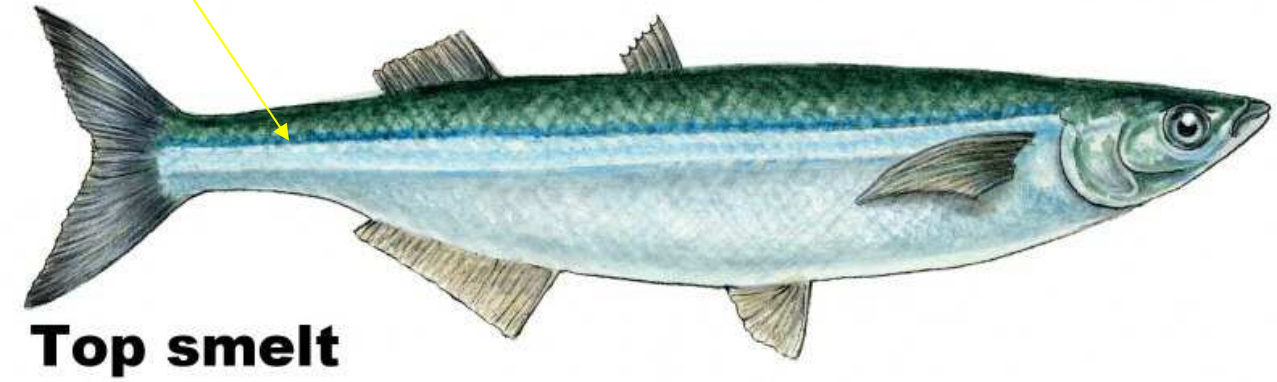
Topsmelt have a prolonged spawning period from April through October, with a peak in May and June. Observations of various sized ova within individual ovaries indicate that eggs may be deposited more than once during a single spawning season. Spawning takes place in vegetated areas where elongate filaments on the eggs become entangled with the substrate. Hatching may occur over a wide range of salinities. Within the estuary the larvae swim in small schools near the surface of both shallow and open water. Topsmelt larvae are particularly abundant in tidal basins Juvenile topsmelt generally move into the open water of the estuary and coastal kelp beds. Topsmelt mature in their second year and may live 6-9 years.

## HISTORICAL INFORMATION AND DISATRIBUTION

Topsmelt are found from Vancouver to Southern California.

## IDENTIFICATION

Two dorsal fins. The first one is small with five to nine spines on it. There are 5-8 scales between the dorsal fins. Can be up to 37 cm. The anal fin begins beneath the first dorsal fin. The mouth is small at the tip of the snout. The jaw teeth are forked. Green above with a bright silver side stripe.




**Common Name: Mosquitofish** **Scientific Name: *Gambusia affinis* (NON-NATIVE)**

## GENERAL DESCRIPTION OF SPECIES

The mosquitofish, *Gambusia affinis,* is native to southern and eastern portions of the United States. Originally introduced into California as early as 1922, they have been one of the most effective non-insecticidal and non-chemical methods of controlling mosquitoes for over eighty years. Mosquito fish do not lay eggs, but rather give birth to live young. These fish, therefore, require no special environment, as most other fish do, for depositing and hatching their eggs. They breed throughout the summer and new broods are produced at intervals of about six weeks, with 50 to 100 young in a single brood. The young are approximately 1/4 inch in length when born and grow to a maximum size of about three inches. They are ready to begin the work of destroying mosquito larvae at once. Mosquitofish can eat mosquito larvae as fast as the larvae hatch from eggs, as many as 100 per day. The earliest brood of the season, born in April and May, become sexually mature and produce young when six to eight weeks old. Mosquitofish live 2-3 years and can tolerate a wide range of temperatures.

A large female can eat 100-200+ mosquito larvae in a day! More often mosquito fish will eat other tasty insect larvae and fish fry. One scientist examined the stomachs of over 2000 mosquito fish and found only a small percentage of mosquito larvae. Instead, aquatic insects and fry made up most of their diet. For this reason, they are best used in small ponds where fry of other species are not desired. I keep mine in tub ponds too small for other fish. There is debate over how efficient mosquito fish are at mosquito control. Generally, mosquito fish will not drastically reduce mosquito larvae populations in large bodies of water. Instead, they will eat other insects and fry preferentially. This can have a detrimental affect on insect and native fish populations. For this reason, mosquito fish should not be introduced into natural waters in which they are not native. In personal ponds, they usually will eat most small insect larvae present, including mosquito larvae.

A new study in late 1999 indicates that mosquito fish may be a major part of the decline of small frogs and newts in California. Apparently, mosquito fish prefer to eat Pacific treefrog tadpoles more than mosquito larvae. So, be aware that mosquito fish may also eat small amphibian larvae including those of frogs, toads, salamanders, and newts. This is yet another reason to keep these fish out of natural waters. My mosquito fish did not appear to reduce the number of green frog tadpoles in their pond most likely because these frogs and their tadpoles are relatively large and the adults laid many eggs.


**Common Name: Mosquitofish  Scientific Name: *Gambusia affinis* (NON-NATIVE)**

## HISTORICAL INFORMATION AND DISATRIBUTION

Mosquito fish have negative ecological impacts anywhere they are introduced. This a particularly predaceous species, easily out competing native species of minnow for available forage or harassing those competitors until death. They have been especially devastating in the American Southwest interacting with a wide range of threatened or endangered fish species; most recognized is the Gila topminnow. The decline of up to twenty species has been linked to the introduction of Mosquito fish outside of its native range. Recent studies suggest California's declining amphibian populations can be linked to Mosquito fish introductions as well.

On the other hand, there is a positive aspect of mosquito fishes. Mosquito fish are important to the mosquito control program. They eat mosquito larvae as fast as they hatch from the eggs laid by mosquitoes on the surface of the water. In California they are furnished alive and without charge for stocking ornamental ponds, unused or "out-of-order" swimming pools and animal watering troughs. They require no feeding and care is limited to protecting them from garden sprays and from chlorine or other chemicals used to clean the pond. The Shasta Mosquito and Vector Control District also stocks thousands of these fish each year in artificial lakes, reservoirs, waste water disposal lagoons, natural creeks and drainage channels to eliminate the need for frequent spraying with mosquito pesticides

## IDENTIFICATION

**Maximum length:** Males 0.5 to 2 inches, females 1 to 3 inches
**Colors:** Natural brownish gray
**Temperature preference:** 60 to 80 degrees F, can survive 33 to 100 degrees F
**pH preference:** 7 to 8
**Hardness preference:** Moderate to hard
**Salinity preference:** 1 Tablespoon per 5 to 15 gallons
**Compatibility:** Not recommended for community tanks or ponds with other fish present, especially if you wish to have fry of other species survive
**Life span:** 1 to 3 years

Dorsal spines (total): 0; Dorsal soft rays (total): 7-9; Anal spines: 0; Anal soft rays: 9-10. Origin of dorsal fin opposite 7th anal ray. Length of anal base much less than half distance from caudal. 8 horizontal scale rows between back and abdomen. Ventrals terminate immediately before anal fin. Pelvic fins reach ventrals.

**Common Name: Mosquitofish Scientific Name: *Gambusia affinis* (NON-NATIVE)**


**Common Name: Arrow Goby** **Scientific Name: *Clevelandia ios***

## GENERAL DESCRIPTION OF SPECIES

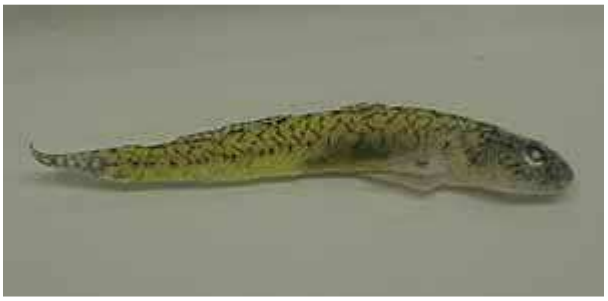
Common in estuaries, lagoons, and tidal sloughs with a sand and mud bottom, marine to fresh water. During low tides the arrow goby will retreat to a burrow in the substrate until the tide changes.

## HISTORICAL INFORMATION AND DISATRIBUTION

The arrow goby ranges from the Gulf of California to the Straits of Georgia, British Columbia, inhabiting coastal lagoons, estuaries, and tidal sloughs (MacDonald 1972). The arrow goby has been reported as the most abundant goby in Richardson Bay (Eldridge 1977) and in Moss Landing Harbor and Elkhorn Slough

## IDENTIFICATION

**Wide gap between dorsal fins**. Mouth is large and the jaw extends well beyond eye. The anal fin is long. It is pale olive or tan to gray and speckled with black. Some individuals have white spots on side and head. The dorsal fin is dotted with strips. The males usually have a black stripe on the anal fin, and the females rarely have this stripe. Can be up to 5.7 cm.




**Common Name: Stripped Mullet** **Scientific Name: *Mugil cephalus***

## GENERAL DESCRIPTION OF SPECIES

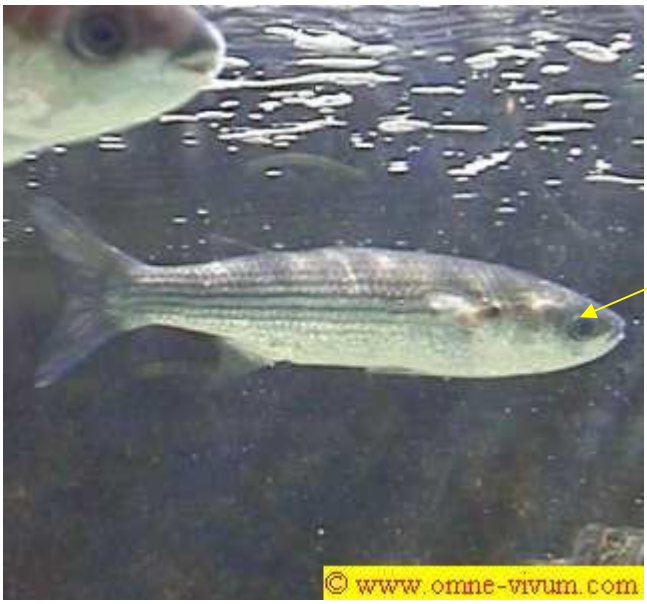
The striped mullet, *Mugil cephalus*, can attain 18" in length and reach approximately 3 pounds. Body shape is cylindrical anteriorally, becoming somewhat laterally compressed toward the posterior. Adult coloration is bluish-gray or greenish above, becoming silver along the sides of the body, and white on the ventral surface. There are 6-7 black horizontal bars along the sides of the body, and no obvious lateral line. The pectoral fins are placed high on the shoulders, and the pelvic fins are abdominal. *M. cephalus* has a blunt snout, and a small, somewhat upturned mouth.

## HISTORICAL INFORMATION AND DISATRIBUTION

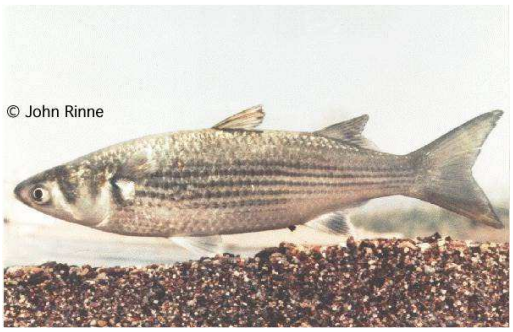
*Mugil cephalus* occurs worldwide from approximately 42° N to 42° S where it inhabits estuarine intertidal, freshwater and coastal marine habitats. In the western Atlantic Ocean, *M. cephalus* ranges from Cape Cod to Brazil, including the Gulf of Mexico, Caribbean, and West Indies.

## IDENTIFICATION

Two dorsal fins, the first has four spines. Mostly silvery and chunky. There are faint stripes on the side. Newly hatched larvae of *M. cephalus* measure approximately 2.2 - 2.6 mm (0.87 - 1.0 inch) (Bensam 1987; Eda et al. 1990). Larval pigmentation consists of thick, stellate chromatophores covering the body, except in the posterior region. Additionally, larvae and early postlarvae of *M. cephalus* possess a midlateral row of stellate melanophores. This pigmentation pattern helps distinguish *M. cephalus* larvae from those of other mullet genera (Bensam 1987).




There is a fleshy translucent area around the eye.



Common Name: **Staghorn Sculpin** Scientific Name: *Leptocottus armatus*

## GENERAL DESCRIPTION OF SPECIES

This sculpin is easily distinguishable from its more common relatives by the shape of the uppermost of its three cheek spines, which is broad, flat, and with three short, sharp branches at its tip[1] instead of cylindrical and single pointed; also its anal fin (16 to 18 rays) originates well in front of its second dorsal fin instead of behind the latter, and its two dorsal fins are separated by a distinct space instead of being practically continuous at the bottom of the notch that separates them. Furthermore, the spines characteristic of the top of the head and shoulders of our other sculpins are either lacking on the staghorn or are very short, and the corners of its gill covers are rounded instead of sharp. Distinctive also, if less obvious, is the fact that the top of its head is more or less prickly or warty.

The 3-rayed ventral fins reach only about to the vent on young fry of 1¾ to 2 inches, but they [page 453] become relatively longer with growth until at maturity they reach considerably beyond the point of origin of the anal fin, farther in males of breeding age than in females. The first dorsal fin has 11 or 12 spines; the second dorsal 15 to 17 soft rays. The caudal and pectoral fins and the general shape of the fish are of the usual sculpin type.

### *Color—*

Described as dark brownish or gray above, the sides as marked with dark crossbands or with alternate light and dark greenish spots; the lower surface as white or yellowish with an irregular line of demarkation between dark sides and pale belly. The dorsal and pectoral fins are pale, the former with 3, and the latter with 4 or 5 irregular dark brown or black crossbands. The ventral and anal fins are yellow rayed, with membranes of the same color as the belly.

**Size—**

Up to about 10 inches long.

**General range—**

Arctic Ocean and North Atlantic, south to northern Norway on the European coast; on the American coast it ranges southward along the outer coast of Labrador[3] to the Gulf of St. Lawrence, where it is generally distributed along the north shore[4] and is characteristic of the icy water on the banks in the southern side, according to Huntsman, and it has been reported as far as Eastport, Maine, as a stray.

**Occurrence in the Gulf of Maine—**

The most southerly record for this Arctic sculpin, and the only one for the Gulf of Maine, is of a specimen caught at Eastport, Maine, in 1872, and now in the United States National Museum. It is only as a very rare stray from colder waters to the north that it ever reaches our Gulf.