MALIBU LAGOON:
A Baseline Ecological Survey

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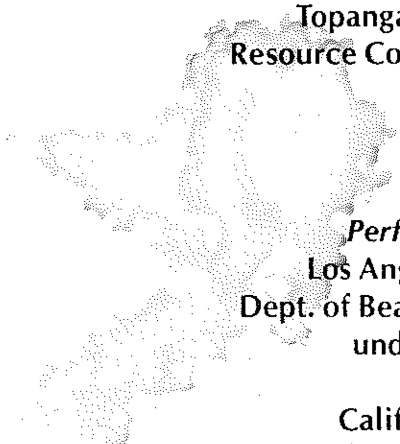

Performed for
Los Angeles County,
Dept. of Beaches and Harbors
under SB 959
and
California State
Dept. of Parks and Recreation
under Grant #4-400-7171

cover by LD&A Marketing Communications

PREFACE

Approximately 67,000 acres - covering valleys and mountains, natural parklands and suburban developments - form the largest perennial drainage system within the Santa Monica Mountains. Altered through human intervention, the extensive Malibu Creek watershed terminates at Malibu Lagoon, one of the last remaining estuaries in Los Angeles county.

Lagoon wetlands are endangered ecosystems. Wetlands serve as vital components within regional hydrologic systems. Additionally, they are critical in maintaining resident biotic (plant and animal) assemblages and as stopover grounds for waterfowl and shorebirds migrating along the Pacific Flyway.

Renewed awareness of the environmental importance of wetland habitats has sparked governmental and individual conservation efforts. Restoration of these endangered ecosystems has a heightened level of priority among the public.

Malibu Lagoon has been heavily impacted by human use. It has been used as a general dump site by many, including Caltrans, and the original acreage has been diminished by urban development. However, since 1983, Malibu Lagoon has been undergoing the slow process of restoration, initiated and managed by the California State Department of Parks and Recreation (DPR).

Careful management by DPR, complimented by allowing natural restoration processes to occur, has resulted in a wetland resource of increased ecological and recreational value. The initial restoration stages consisted of recontouring and revegetating the previously degraded landscape for habitat reconstruction. Progress has been made toward fulfilling the ecological potential of this Lagoon.

The subject of this study is to gather baseline ecological and physical data of the Malibu Lagoon ecosystem. The Topanga-Las Virgenes Resource Conservation District (TLVRCD), as commissioned by the Los Angeles County Department of Beaches & Harbors and the State Department of Parks & Recreation, has measured and documented physical and ecological conditions for the full year cycle from May 1987 through June 1988. This is the first study of such wide scope undertaken for the Malibu Lagoon. Previous studies have concentrated on single faunal or floral groups and resultant information has been drawn upon for background and methodologies.

To facilitate wise management of environmental resources leading to positive change, TLVRCD believes that scientists, public officials and citizens must actively exchange information and ideas within a framework of comprehension, accessibility and community interest.

As this is a baseline study, to be used to compare present Lagoon conditions with future environmental change, TLVRCD has put emphasis on communicating to both the scientist and layperson. It is a research paper that adheres to scientific standards with an additional emphasis on interpretation to lay terms.

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ACKNOWLEDGEMENTS

This report reflects the efforts of many people besides the authors listed. Without the enthusiastic support of the following data collectors, our understanding of Malibu Lagoon would be sorely lacking.

Gaby de Benedictus
Lucienne Bouvier
Mark Darcy
Leo French
Nancey Helsley
Brian Hill
Pearl Hsiung
Brenda Huie
Robert Jensen Sr.
Kyle LaBrache
Annette Landreau
Mickey Long
Marcia Matz
Melissa Miller
Lyle Nichols
Kris Randall
Mike Reader
Debbie Shafer
Joel Washburn

These loyal observers were exceptionally dedicated and deserve special thanks:

Lois Boylen-Cota
Chuck Cleeves
Wendi Gladstone
Joyce Halley
Avis F. Keedy
Nelson Takayama
Lori Willis

For his continuing expertise and support in this project, we wish to extend our thanks to Bill Tippets, California Department of Parks and Recreation (DPR).

We also want to thank the Los Angeles County Fish and Game Commission and DPR for equipment used to collect data.

In addition, the following people gave of their expertise in various subject areas in order to assure that our analysis was as accurate and up-to-date as possible. Many thanks to:

Chapter 1.0: Darrick Danta, CSUN; Ruth Brodrick, TLVRCD

Chapter 2.0: Ed McComb, Jim Colbaugh and Scott Quaddy, Las Virgenes Municipal Water District; Larry Young, LA County Health Dept.; Chris Nagler, CA Water Resources Division

Chapter 3.0: Joy Zedler, SDSU; Phillip Rundel, UCLA; Bob Muns, Rancho Santa Ana; Avis Keedy; Richard Campbell, Rick Aguayo, and Mary Thoroughgood, USDA Soil Conservation Service; Wayne Ferren, Herbarium, UCSB

Chapter 4.0: Chuck Cleeves, Jon Sloan, CSUN

Chapter 5.0: Leslie Harris, USC Hancock Foundation; Chris Nordby, SDSU

Chapter 6.0: Chris Nordby, SDSU; Hans Kuch, Los Angeles County Museum of Natural History (LACMNH) Crustacean Lab

Chapter 7.0: Camm Swift and Marty Meisler, LACMNH Ichthyology Lab; Lyle Nichols, CSUN

Chapter 8.0: Kimball Garrett, LACMNH; Lois Boylen-Cota; Sanford Wohlgemuth and Tom Howell, LA Audubon

Chapter 9.0: Lesley Devine, TLVRCD Board President

And last, but certainly not least, the authors wish to extend special thanks to all Board members and staff at the Topanga-Las Virgenes Resource Conservation District office. Without the competent and enthusiastic support of these dedicated people, this report would never have seen publication.

1.0 OVERVIEW OF MALIBU LAGOON

1.1 INTRODUCTION

This initial chapter provides background information on estuarine environments, describes the environmental setting, and briefly outlines the restoration process.

Malibu Lagoon is one of the last remaining estuaries in Los Angeles County. It is a small (5.2 hectares; 13 acres), shallow water embayment occurring at the terminus of the Malibu Creek watershed. The total land area plus the aquatic lagoon area is 14.7 hectares (36.1 acres). This lagoon is a remnant of a once more extensive group of estuaries within the southern California region from Point Concepcion to the international border with Mexico.

Southern California has a long history of human occupation and consequent landscape disturbance which continues to impact all estuaries in the region. Estuaries in southern California have been reduced in total acreage by more than 75% when compared with the original acreage of pre-European settlement. This extensive and continuous loss of estuarine habitat has awakened human awareness regarding the intrinsic values embodied within these ecosystems. For humans to uncover and discern the full value of estuaries, we must first begin the process of examination and study of these wetland environments. This allows us to acquire the specific knowledge and understanding leading to firm conclusions regarding the significance of estuaries as part of our global natural heritage.

At Malibu Lagoon the process of examination is underway. This Lagoon exhibits a mix of both natural and non-natural characteristics that make its study difficult, interesting, and critically important. The Malibu Lagoon ecosystem presently receives a combination of natural seasonal freshwater input and a substantial additional non-natural input of freshwater from imported sources. This environmental stress changes the biogeochemical conditions (i.e., salinity and freshwater balance) in the Lagoon and can challenge even adaptable organisms living within Malibu Creek and Malibu Lagoon. Identifying all of the non-natural water inputs and the pollutants they may contain and then assessing their cumulative effect upon the Lagoon's biota is beyond the scope and intent of this project. It is a research and management challenge for future studies.

An additional characteristic of Malibu Lagoon is that while it does contain highly variable levels of biological pollutants (i.e., coliform bacteria), it presently has no significant levels of toxic chemicals associated with industrial pollutants. This is an extremely positive factor in assessing the Lagoon's long-term restoration potential.

For current and future Lagoon management, determining the complex combination of natural and human-generated change is vitally important, especially its cumulative effect upon the Lagoon biota. This will potentially improve the quality of management decisions for the entire Malibu Creek and Lagoon ecosystems.

Adding to its ecological significance within southern California is Malibu Lagoon's important role as a stopover and wintering area for birds migrating along the Pacific Flyway. It also functions as an essential nursery habitat for some fish species, and is the southernmost stream in North America within the range of the anadromous steelhead (Oncorhyncus mykiss), a sea-run rainbow trout. Additionally, Malibu Creek and Malibu Lagoon play a critical role in the overall functioning of the local hydrologic system of the Malibu Creek watershed. Finally, Malibu Lagoon serves as a valuable educational and recreational resource for urban dwellers learning to understand and enjoy their shared inherited resources.

1.2 ESTUARIES IN THE ENVIRONMENT

Estuaries are interface regions (ecotones) between aquatic habitats of the earth's land masses and marine habitats of oceans or seas. Some are deep water complexes while others are shallow wetlands occurring at the lower elevational limits of watersheds (Ferren 1985). At this area of intermixing between fresh and salt water environments, where concentrations of sea derived salts are .05% or higher, a distinct ecosystem, the estuary, is found. Pritchard (1967) states that "An estuary is a semi-enclosed coastal body of water which has a free connection with the open sea and within which seawater is measurably diluted with fresh-water derived from land drainage." Lagoons, however, are somewhat different, as they frequently do not maintain this free and continuous connection with the open sea.

Frequently, estuaries are geographically isolated from each other due to their unique physiographic formation requirements. Thus, they become "islands" of unique habitat-type surrounded by habitats of dissimilar type, either natural or human-made. When a distinct geographic area (i.e., an estuary) is isolated from other similar areas by either physical or biological barriers, levels of endemic or unique organisms tend to evolve (Ferren 1985). This situation, along with the present rarity of ecologically intact, unaltered examples of estuaries, increases the ecological significance of our global system of estuarine environments.

During the past 30,000 years sea level has risen approximately 130 meters as a result of the melting of major continental glaciers of the Pleistocene epoch. Geologically the world's estuaries are quite young, generally having been formed approximately 5,000 years ago when the seas reached their present level (Thurman 1975).

Globally, estuaries exhibit a wide variety of characteristic features of geomorphology, water circulation, biogeochemistry and ecology (Wolfe and Kjerfve 1986). A characteristic feature of estuary systems in southern California is that they are "frequently intermittent and exhibit unique characteristics relative to the majority of estuarine systems" (Onuf 1987, Zedler 1986).

Southern California estuarine ecosystems, such as Malibu Lagoon, are principally influenced by the following physical factors: tidal circulation, precipitation, freshwater runoff, evaporation, and wind (Ferren 1985). It is important to note that most of the world's estuaries are also influenced, to a significant extent, by human-generated alteration.

Salinity regimes in southern California estuaries are highly variable (Zedler & Nordby 1986), both temporally and spatially, depending upon factors such as local climate patterns, evaporation, seasonal ocean circulation, human-generated inputs, and intermittent major climatic perturbations (e.g., hurricanes, El Nino).

Estuaries located in southern California are usually termed intermittent in nature. This condition is principally due to the aridity of the environment which means that stream flow into estuaries will either completely cease or greatly decrease in volume each summer. For example, in southern California most of the annual precipitation falls in a few large winter storms (Rose 1982). When this seasonal precipitation tendency is combined with high spring, summer, and fall evaporation rates and watersheds of relatively small area with steep relief, the amount of surface or near-surface water can be quite low for prolonged periods (Onuf 1987). Since the majority of physical factors stated above which affect lagoon systems in southern California fluctuate widely, estuarine biota generally exhibit a high degree of physiological and behavioral plasticity in order to persist.

1.3 LOCATION

Malibu Lagoon is located in Los Angeles County, California, west of Malibu Pier (Fig. 1.1), latitude 34 degrees 1' 58" North and longitude 118 degrees 40' 50" West. Malibu Creek, which cuts North-South through the steep-sided Malibu Canyon gorge, empties into the Lagoon and contributes freshwater, sediments, nutrients, detritus, and human-generated inputs (urban runoff) into this Lagoon ecosystem. Malibu Creek is one of several streams which drain the coastal side of the Santa Monica Mountains. This mountain range is part of the east-west trending Transverse Range province in southern California (Fig. 1.2).

The Santa Monica Mountains of southern California stretch approximately 75 km (47 miles) westward from Griffith Park, in the City of Los Angeles, to Point Mugu in Ventura County. The width of this mountain range averages 12 km (7.5 miles), while elevations range from sea level to 948 meters (3,110 feet) above sea level at Sandstone Peak (Rose 1982). This coastal range with its varied topographic relief and climatic gradients harbors a diversity of habitats. Rugged steep slopes, deep moist canyons, and arid ridgetops characterize this Mediterranean-type ecosystem.

These mountains represent a unique mix of land ownership. In 1978, the Santa Monica Mountains National Recreation Area was established in an effort to preserve parklands, while maintaining general multiple-use goals. Within the area legally bounded by the National Recreation Area, land is owned by Federal, State, and County agencies, as well as private camps, homeowners, and other land-holding agencies. Malibu Lagoon is part of Malibu Creek State Park within the National Recreation Area.

1.4 CLIMATE

The Santa Monica Mountains, including Malibu Lagoon, are characterized by mild, wet winters and hot, dry summers. Amounts of precipitation vary widely: The Santa Monica pier receives approximately 330 mm annually; while approximately 635 mm fall at the Topanga Canyon fire station. The distribution of rainfall is influenced primarily by the distance from the Pacific Ocean and the sudden steep topographical relief of the mountains. Precipitation, therefore, is generally greater in the mountains than inland flatlands, usually ranging from 450-650 mm annually (Plantrich 1986).

Onshore and offshore breezes are an integral part of this coastal ecosystem, for they influence patterns of frequent coastal fog invasion, which can penetrate deeply within the canyon systems. These moisture laden fogs are important to much of the native vegetation within its influence, particularly during the dry summer months. Being near the ocean and exhibiting a diverse physical relief, the Santa Monica Mountains display a great variety of microclimatic conditions. These conditions are primarily influenced by differences in the slope, slope aspect, elevation, soil type, fire history, rainfall patterns, proximity to the coast (thus, changes in fog/moisture intrusion) and existing vegetation on each site (Rose 1982).

1.5 MALIBU CREEK WATERSHED

The Malibu Creek watershed is the largest perennial drainage system within the Santa Monica Mountains, comprising a total of approximately 27,115 hectares (67,000 acres) (Tjaden 1978). Malibu Lagoon forms at the terminus of Malibu Creek, a typical result of the fluvial processes of stream erosion, transportation, and deposition of sediments. The most significant fluvial (running water as a land-forming agent) processes occur during winter, when seasonal storms create intense flooding of stream channels within these mountains (Rose 1982). These winter floods erode and carry the vast majority of the total yearly sediment load of streams in the Santa Monica Mountains. Precipitous slopes characterize this watershed and are a major factor influencing runoff velocity and erosion. Geologic composition of these steep, rugged slopes is massive, hard tertiary rock, mainly of the Sespe sandstone formation. Deep canyons, such as Malibu Canyon, are believed to be formed entirely from erosion, rather than fault displacement (Sharp 1978). Soils on these slopes are highly erodible (USDA Soil Conservation Service 1967) and contribute heavily to the dynamic nature of Malibu Lagoon. During late spring, summer, and fall, local streams experience a gradual decline of water discharge, which corresponds with local precipitation patterns, temperatures, and evaporation rates. This temporarily changes Lagoon conditions and further challenges the overall adaptive resilience of organisms living there.

Malibu Creek is classified as a stream in its "youthful" stage. Streams of this type are characterized by high velocity and energy, and a low sediment load relative to its total sediment load capacity (McIntyre 1985). Stream slope, velocity, water volume, and available erodible materials determine, in part, the sediment load, which is deposited in increasing increments as water is slowed by various physical impediments. Malibu Creek, especially during storms, becomes a formidable channel cutting machine that deposits much of its sediment load as it nears and finally reaches the Lagoon. As the creek nears the sea, stream slope declines and consequently its velocity begins to decrease. When streamwaters finally enter the sea its velocity abruptly decreases as it "backs up," and sediment deposition increases in the slow water. This fluvial process contributes significantly to the formation and dynamic nature of the Malibu Lagoon environment. It is a process governed principally by geologic and climatic conditions, and increasingly by humans.

Historic annual hydrologic and sediment cycles are currently disrupted by excessive non-seasonal imported domestic water released into many local streams (Rose 1982), including Malibu Creek. Within the Malibu Creek watershed the majority of non-seasonal domestic water release is from the Tapia Water Reclamation Facility of the Las Virgenes

Municipal Water District. Tapia is a tertiary wastewater treatment plant and presently releases about 8-10 million gallons of water per day (MGD) into Malibu Creek from October through June. These non-natural water sources can exert extreme stress upon much of the native biota (plants and animals) inhabiting the Malibu Creek and Malibu Lagoon ecosystem. In an attempt to present a comprehensive and contextually relevant study of Malibu Lagoon, management considerations regarding excess domestic water input will be addressed in the final chapter.

1.5.1 SOILS

Soils occuring within the general Malibu Lagoon area are typical of a coastal valley floor alluvial landform. The following soils predominate this sloping alluvial fan: Elder sandy loam, Sorrento loam, Riverwash, and Coastal Beach.

Elder sandy loams are deep, well-drained soils that develop on level to moderately (9%) sloping alluvial fans and valley floors. They are mildly to moderately alkaline, and comprise approximately 0.4 percent of the total Malibu area.

Sorrento loam is also a deep, well-drained soil, typical of alluvial landforms. These soils occur on 0-2% slopes. The pH is slightly acid to neutral. This soil type represents 0.4% of the Malibu area.

Riverwash is a miscellaneous land-type consisting of deposited sand, gravel, and stones with some silt and clay. As its name implies, Riverwash occurs in stream channels.

Coastal Beach (miscellaneous land-type), is comprised of sandy, stony, or cobbly coastal beaches and related landward sand dunes. It is important to note that due to urban development, none of the historic sand dune habitat remains at Malibu Lagoon. Beaches total about 0.7% of the land in Malibu (U.S.D.A. Soil Conservation Service 1967). Other soil types, not generally found in the Malibu Lagoon area, comprise the other approximately 98.5% of soils found in the Malibu area.

1.6 CULTURAL HERITAGE

Although it is beyond the scope of the present study to detail the early cultural heritage of the Malibu Lagoon area, it is important to acknowledge its significance within the contextual framework of Malibu Lagoon.

Hunting and gathering societies have long occupied southern California. The archaeological records indicate a trend towards greater cultural complexity in the course of early occupation (Leonard 1971, Lundberg 1965, Grant 1978).

The earliest substantial evidence of human occupation in the Santa Monica Mountains is from approximately 5500-5000 B.C. These people are believed to have migrated into coastal southern California about 7000-6000 B.C. (Leonard 1971).

Four coastal areas within the Santa Monica Mountains have been identified as major sites of early occupation. The Sweetwater Mesa site near the mouth of Malibu Canyon overlooking Malibu Lagoon is identified as a major area of occupation. Carbon 14 analysis dates the site at 6310 plus or minus 100 B.P. and 6870 plus or minus 100 B.P. (Leonard 1971).

Cultures of the early prehistoric periods tended to use less of the resource base than later cultures inhabiting the same geographic area. This coastal zone of occupation exhibits a very high resource diversity, year-round productivity, and abundance of flora and fauna (Leonard 1971), which later cultures, such as the Chumash, utilized more extensively than earlier inhabitants.

The Chumash Indian culture belongs to a broad linguistic and cultural-geographic assemblage of people, known as Hokan, who were dispersed throughout various portions of California (Kroeber 1976, Landberg 1965). The southeasterly coastal range extent of known Chumash culture is the rancheria of Humaliwu adjacent to Malibu Creek in Malibu Canyon (Grant 1978). There are believed to be at least six to eight linguistic divisions within the Chumash culture, with the coastal Chumash divided into three. The Ventureno geolinguistic group occupied the coastal area between Ventura and Malibu Canyon (Grant 1978, Kroeber 1976).

Malibu Creek and Malibu Lagoon have a rich cultural and biological heritage. The full potential for education, recreation and restoration in this area has yet to be tapped.

1.7 PRE-RESTORATION

The deposition of sand, gravel, cobbles, and muds forms a delta, comprising Malibu Lagoon and the immediate surrounding lowland environment. Before modern development the Malibu Lagoon ecosystem was significantly larger than at present. The spectrum of plant and animal species exhibited a greater species richness and abundance in pre-modern development times. For instance, many native species of flora disappeared because of development; consequently, exotic and weedy species became established.

Discussing pristine or undisturbed conditions of a geographic area, especially in southern California, often in reality becomes a discussion of the "degree of disturbance." As stated earlier, Malibu Lagoon and its adjacent areas were occupied and its resources utilized by humans for approximately 5000 years. However, the resources used by early inhabitants were inherently conserved or protected on a sustained-yield basis. Early permanent inhabitants did not or could not strip the resource base faster than it could be reproduced and maintained through natural biological vigor.

Modern development in the 1900's began the process of ecological degradation as the Lagoon area and adjacent land were used as a general fill site, Caltrans dump site, and area of urban development. Additionally, areas have been sprayed with a mixture of 80% diesel oil and 20% pesticide, called Golden Bear IIII (Tjaden 1978), in order to combat a perceived mosquito problem.

1.8 RESTORATION PROCESS

In April 1978 the California State Department of Parks and Recreation (DPR) issued an environmental impact report and resource management plan for Malibu Lagoon. This report states policies and objectives of the DPR regarding Malibu Lagoon and provides policies for the preservation, interpretation, and public use of the natural and cultural resources of this State Park. The DPR's goal was and currently is "...to preserve and restore as much of the natural landscape and biotic communities as possible, while providing facilities to make the outstanding resource values found here available to the public for its enjoyment." (Tjaden 1978).

Prior to restoration, the site was comprised of landfill, native and non-native vegetation, and two baseball fields (Fig. 1.3). After planning by DPR and cooperating researchers, the restoration process began in 1983 when DPR contoured the land and excavated three channels approximately 30 feet wide with sloping mudflats rising to proposed Pickleweed (Salicornia virginica) marshes and upland habitat (Fig. 1.4). Where necessary, due to grading, the area was re-vegetated with native vegetation along an elevational gradient consistent with known data regarding this and other estuarine systems. The Post-restoration (post-grading and re-planting) management recommendations proposed and implemented by DPR include, but are not limited to, the following:

1. Construction of a series of bridges and trails in order to facilitate beach access. This also serves to keep human traffic from cumulatively impacting the delicate and limited ecosystem.

2. Managing water levels within the Lagoon by periodically breaching the sandbar with the Department of Parks and Recreation's bulldozer when water levels reach 1.07 meters (3.5 feet), for the purpose of reducing extensive periods and levels of water impoundment. This will

reduce mosquito breeding success, and possible flooding of Malibu Colony septic tank drain fields, which may become a source of pollution.

Research by Topanga-Las Virgenes Resource Conservation District (TLVRCD) is centered on documenting the current physical and ecological conditions at Malibu Lagoon, thus facilitating management of this ecosystem. The District's project was a one-year ecological study that began in May 1987.

1.8.1 ENVIRONMENTAL EDUCATION AND INTERPRETATION AT MALIBU LAGOON

The interpretive goal of the Department of Parks and Recreation at Malibu Lagoon State Beach is to "...provide visitors with awareness and appreciation of the significant recreational, natural, and cultural resources...(Tjaden 1978)" In order to facilitate this educational goal the TLVRCD in 1985 entered into a cooperative agreement with DPR and began implementation of the Malibu Lagoon Marine Science School Program. These environmental education programs provide school children with a "hands-on" learning experience. In addition, students actually assist in selected portions of our ongoing research as they learn about estuarine ecosystems. We see this student participation as a significant investment towards a bright future in the intelligent conservation of our shared ecosystems.

1.9 OUTLINE OF CHAPTERS

This report is organized as follows. Chapter Two discusses the spectrum of water quality parameters that were measured and analyzed. Chapter Three includes the vegetation survey along the Lagoon's elevational profile. The fourth chapter describes sediment profiles found in the Lagoon and relates this data to the distribution of infauna found within the sediments. Chapter five identifies and quantifies benthic infauna (Polychaete worms and Jacknife clams) found in sediment samples in Malibu Lagoon. Chapter Six discusses the epifaunal organisms, (shrimp and crabs) that were surveyed. Chapter Seven examines diversity and population trends for fishes of the lagoon from five sampling (seining) stations within the Lagoon. Chapter Eight provides species occurrence lists and general seasonal population trends of birds using Malibu Lagoon. The final Chapter provides a summary of the Lagoon status with site-specific considerations for future management of Malibu Lagoon as an integral functioning component of the Malibu Creek watershed.

1.10 LITERATURE CITED

Day, J.H. 1980. "What is an Estuary?" South African Journal of Science, 76: pp. 198.

Ferren, W.R. Jr. 1985. Carpenteria Salt Marsh Environment, History, and Botanical Resources of a Southern California Estuary. Herbarium Dept. of Biological Sciences, University of California, Santa Barbara, Publication No. 4, pp. 300.

Grant, C. 1978. In Handbook of North American Indians. Ed. R.F. Heizer: pp. 505-520.

Hasz, L. 1982. "Malibu Lagoon: A Local Resource." California State University Northridge, Unpub. pp. 10.

Hudson, T. and Blackburn, T.C. 1979. The Material Culture of the Chumash Interaction Sphere. Vol. 1. Ballena Press, Los Altos, California. pp. 386.

Kjerfve, B. 1986. Comparative Oceanography of coastal Lagoons. In Estuarine Variability. Ed. D.A. Wolfe. Academic Press, Inc., Orlando, New York, London. pp. 63-83.

Kroeber, A.L. 1976. Handbook of the Indians of California. Dover Publications, Inc., New York. pp. 995.

Landberg, L.C.W. 1965. The Chumash Indians of Southern California. Southwest Museum papers No. 19, Highland Park, Los Angeles, California. pp. 158.

Leonard, Nelson N. III 1971. Natural and Social Environments of the Santa Monica Mountains (6000 B.C. to 1800 A.D.). Dept. of Anthropology, University of California, Los Angeles. pp. 97-135.

McIntyre, M.P. 1985. Physical Geography. John Wiley and Sons, New York. pp. 534.

Onuf, C.P. 1987. The Ecology of Mugu Lagoon, California: An Estuarine Profile. U.S. Fish and Wildlife Service Biol. Rep. 85 (7.15). pp. 122.

Pielou, E.C. 1975. Ecological Diversity. John Wiley and Sons, New York, London. pp. 165.

Plantrich, R. 1986. Fire Management Plan/Santa Monica Mountains National Recreation Area. U.S. Dept. of the Interior/National Park Service. pp. 103.

Pritchard, D.W. 1967. What is an Estuary: Physical Viewpoint. In Estuaries, Ed. G.H. Lauff. Am. Assoc. Adv. Sci., Washington, D.C. pp. 757.

Reid, G.K. and Wood, R.D. 1976. Ecology of Inland Waters and Estuaries, Second Edition. Van Nostrand Company, New York, Toronto, London. pp. 485.

Rose, P.W., Ochsner, D.C., Klubnikin, K. Plantrich, R., and Thomas, T.W. 1982. Draft Natural Resource Management Plan/Environmental Assessment. Santa Monica Mountains National Recreation Area, U.S. Dept. of the Interior/ National Park Service. pp. 322.

Sharp, R.P. 1978. Geology Field Guide Southern California. Kendall/Hunt Publishing Company, Dubuque, Iowa. pp. 208.

Thurman, H.V. 1975. Introduction to Oceanography. C.Merrill Publishing Company, Columbus, Ohio. pp. 441.

Tjaden, A., Roberts, J. and Pierce, K. 1978. Malibu Lagoon State Beach Resource Management Plan, General Development Plan, and Environmental Impact Report. State of California Department of Parks and Recreation. pp. 33.

U.S. Dept. of Agriculture--Soil Conservation Service 1967. Soils of the Malibu Area--California; With Farm and Non-farm Interpretations. USDA and SCS in cooperation with Topanga-Las Virgenes Soil Conservation District and Los Angeles County Dept. of the County Engineer. pp. 34.

Wolfe, D.A. and Kjerfve, B. 1986. Estuarine Variability: An Overview. In Estuarine Variability. Ed. D.A. Wolfe. Academic Press, Inc., Orlando, New York, London. pp. 3-17.

Zedler, J.B. and Nordby, C.S. 1986. The Ecology of Tijuana Estuary: An Estuarine Profile. U.S. Fish and Wildlife Services Biol. Rep. 85 (7.5). pp. 104.

Zedler, J.b. 1982. The Ecology of Southern California Coastal Salt Marshes: A Community Profile. U.S. Fish and Wildlife Service. FWS/OBS-81/54. pp. 110. [Second printing with corrections 1984].

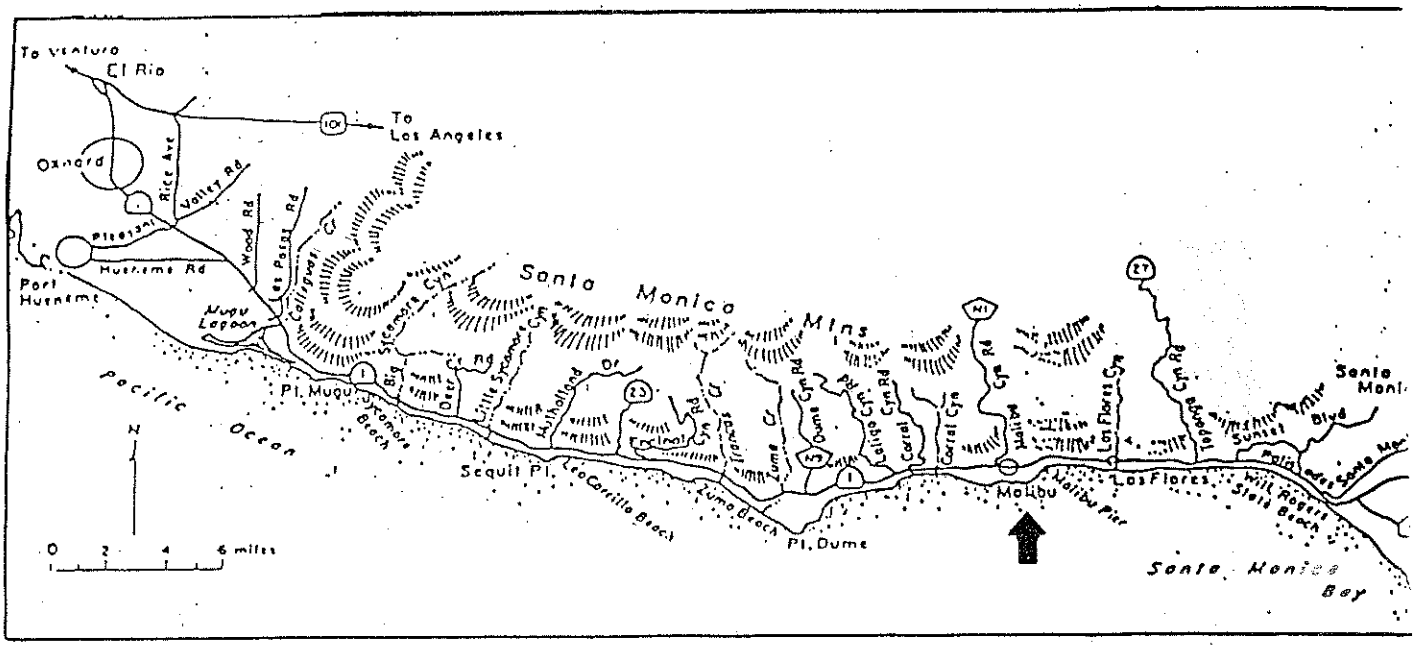


Figure 1.1 Santa Monica to Oxnard, arrow points to Malibu Creek Watershed.

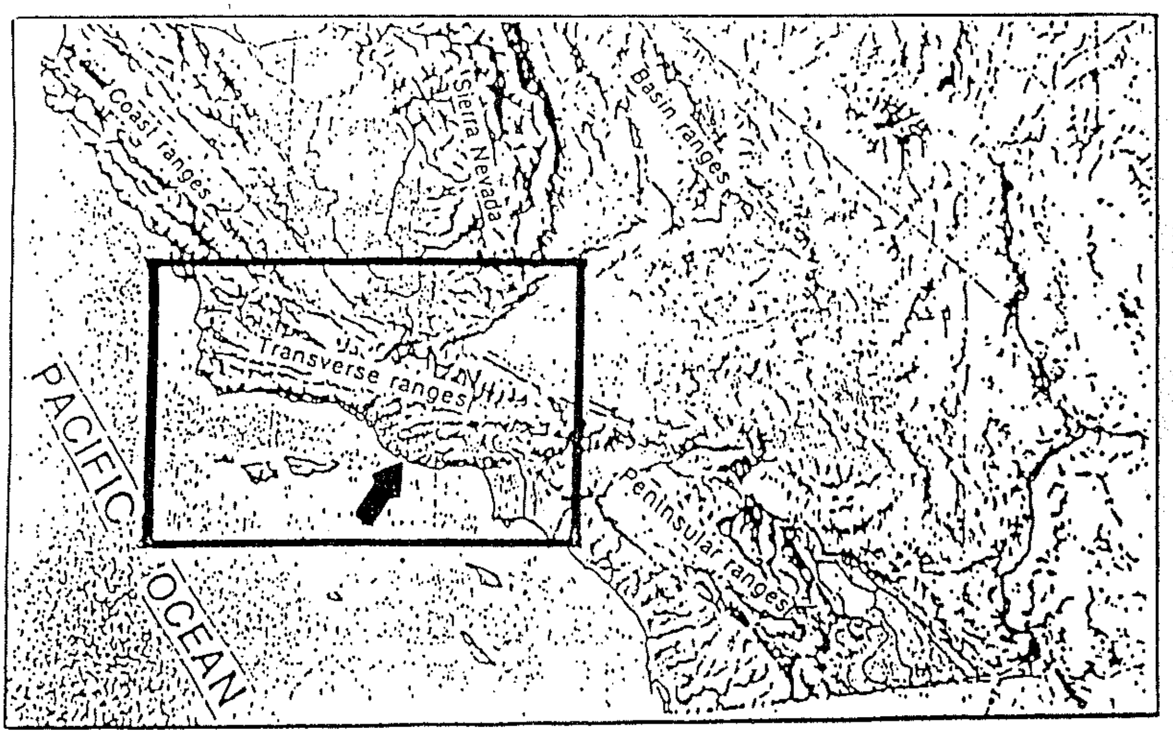


Figure 1.2 Transverse Ranges, arrow points to Santa Monica Mountains.

Figure 1.3 Pre-restoration of Malibu Lagoon
Aerial Photo, MAY 1973

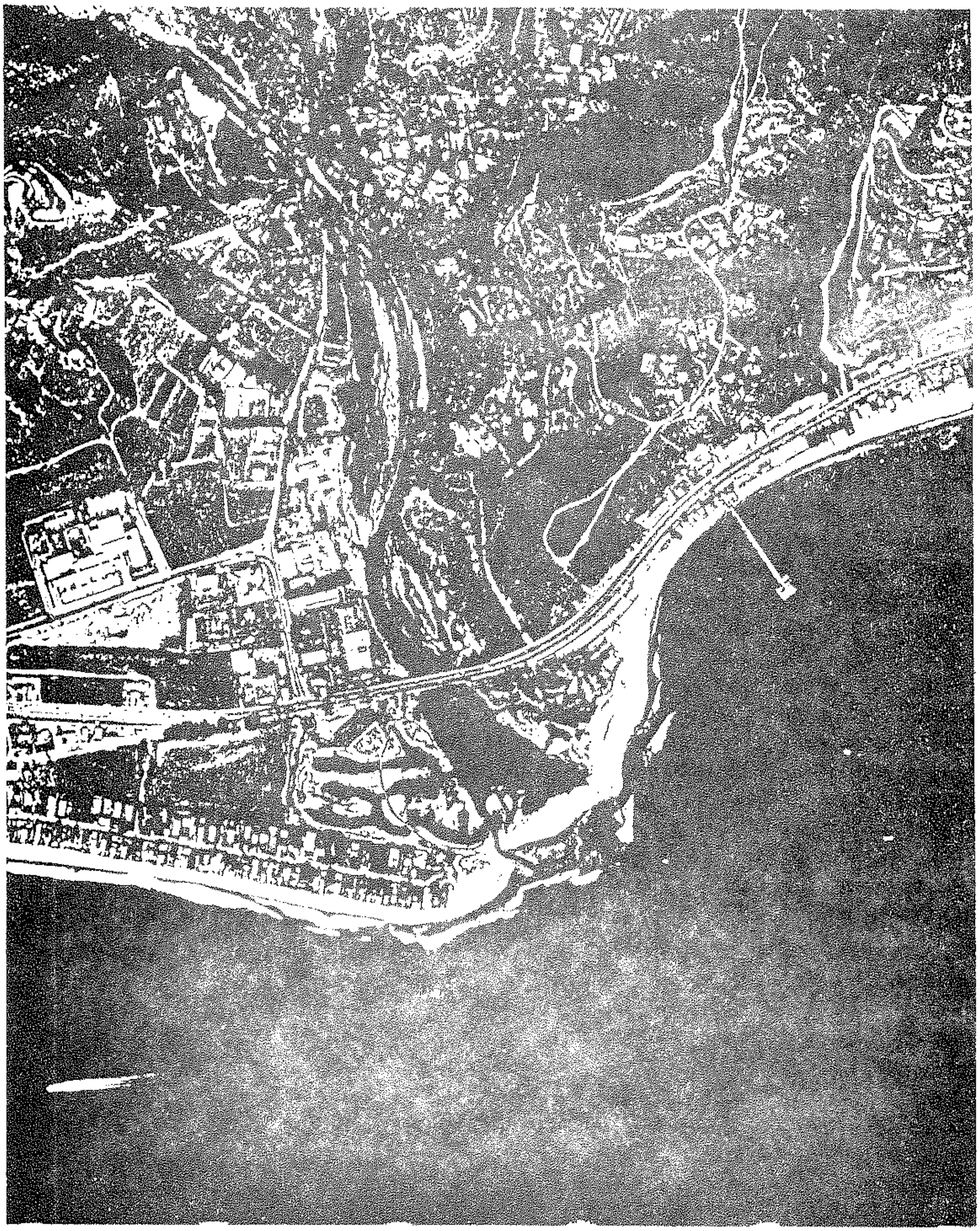


Figure 1.4 Malibu Lagoon after restoration

2.0 PHYSICAL AND CHEMICAL PARAMETERS OF MALIBU LAGOON

2.1 INTRODUCTION

Physical and chemical parameters associated with water quality exert a major influence on biological activity in an aquatic ecosystem. It is critical to the understanding of the Malibu Lagoon ecosystem that these variables be monitored and correlated with major physical and chemical occurrences (events) at the Lagoon.

Malibu Lagoon represents a complex hydrologic environment affected by the physiography, tidal inundation and influx of fresh water from Malibu Creek. Only by repeated sampling can insight into how all these factors are related, as well as their effect on the biota, be determined.

2.2 OBJECTIVES

The main objective is to correlate changes in the physical and chemical parameters of the Lagoon to biological events and overall activity. Flora and fauna of estuarine ecosystems depend on some degree of variability in their environment. Where biological and biochemical limits occur for different species in Malibu Lagoon is of great importance when considering future restoration and management plans.

In addition to recording normal fluctuations of salinity, temperature, dissolved oxygen, pH, turbidity and water depth, special events that occur are also documented. These include storms, sewage spills, heavy influx of freshwater released from the Tapia Water Reclamation Facility, and closure of the mouth of the Lagoon. To determine whether chemical pollutants were present, water samples were sent for analysis to the UCLA Biomedical and Environmental Studies Lab.

The physical and chemical parameters are recorded weekly, with additional information on salinity, pH, and temperature, as well as general Lagoon conditions added biweekly by student groups visiting the Lagoon. Student data have been collected since October 1986, and although it probably contains some errors, they still provide a solid basis of information concerning water quality fluctuations over time. In addition, a twenty-four hour continuous survey of Lagoon conditions was conducted in May, 1988 to provide insight into the daily cycle of the Lagoon.

In trying to incorporate an historical perspective, data from pre-restoration and current stations monitored by Tapia are considered, as well as that gathered immediately following the initial restoration (1983) by Lynn Hasz, a graduate student at CSUN.

2.3 METHODOLOGY

2.3.1 PHYSICAL AND CHEMICAL PARAMETERS

Grab samples of both surface and bottom water are collected at 3-5 stations in the Lagoon when depths are 50cm or greater. In shallow areas, only a mid-level sample is collected (Map A). Data are collected weekly by project researchers. At each station the following methodology is used to collect data.

SALINITY: Using a calibrated Atago (S/Mill) hand held refractometer, salinity is measured to the nearest part per thousand (ppt). This instrument is calibrated from 0-100%. Sample water is placed on the instrument and read by 3 people, to insure accuracy. Accurate readings depend on temperature calibration, thus allowing for a 2-4 ppt error.

TEMPERATURE: Water temperature is determined using an immersion thermometer and recorded in degrees Celsius.

Air temperature is measured with the Yellow Springs Instrument (YSI) Model 057 dissolved oxygen meter in degrees Celsius.

pH: Tri-reagent ColorpHast pH strips are dipped in the sample and read. These values are accurate to the nearest whole number.

DISSOLVED OXYGEN: Using a YSI Model 057 dissolved oxygen meter calibrated for temperature and salinity, the probe is immersed in the water, moved slowly back and forth (1 ft/sec) and allowed to steady. Readings are in milligrams/liter and accurate to the nearest 0.2 mg/l. The probe is held first near the surface and then near the bottom, or mid-level in shallow areas.

TURBIDITY: Using a LaMotte test kit, turbidity is measured in Jackson Turbidity Units (JTU), which is accurate to the nearest 5 JTU.

2.3.2 STUDENT GENERATED PHYSICAL DATA (Malibu Lagoon Tours)

Twice a week from October to June and once a week during the summer months, visiting student groups recorded the salinity and temperature of the surface and bottom water at two locations in the Lagoon (Map A: S1 and S2). Salinity is measured using a LaMotte salinity test kit, in parts per thousand. Temperature is collected using an immersion thermometer in degrees Celsius. Beginning in September 1987, the students also collected the pH at these two stations once a week using Tri-reagent ColorpHast test strips. Due to the

MAP A Study Stations at Malibu Lagoon

numbers of observers and data collectors, these data may be less accurate. However, it does document the wide variation of salinity and temperature found on a short-term basis, as well as indicates seasonal trends.

2.3.3 TRACE ELEMENT ANALYSIS

Once a month in conjunction with other data collection, water samples are collected and sent to the UCLA Biomedical and Environmental Studies Lab for analysis. These samples are taken from five stations in the Lagoon (Map A). They are tested for levels of cation and anion presence, which would indicate the presence of toxic chemicals in the Lagoon.

2.3.4 TOTAL COLIFORM COUNTS, LA COUNTY DEPARTMENT OF HEALTH

Data obtained from the LA County Health Department includes the total coliform counts found at their sample station, which is on the Surfrider Beach, halfway between Malibu Pier and the Adamson House. Samples are taken there once a week, although from May through November 1987, data was only collected monthly. No total coliform samples are taken within the Lagoon itself. Total coliform is measured in units of MPN (Most Probable Number).

2.3.5 TAPIA WATER RECLAMATION FACILITY

This tertiary water treatment plant of the Las Virgenes Municipal Water District is located approximately five miles upstream on Malibu Creek. As part of their own monitoring program of Malibu Creek, data on the water quality both upstream and downstream of the plant is recorded once a week. Adjacent to Malibu Lagoon two water quality monitoring stations are located on both the upstream (at Cross Creek Road, station "R4") and downstream sides of the Pacific Coast Highway bridge. Tapia Station R11 is quite close to student site 2, as well as to Station E (Map A), as designated by the Resource Conservation District observers.

2.3.6 24 HOUR LAGOON SURVEY

The objective of this sub-section of the study was to observe conditions in the Lagoon continuously for 24 hours in order to better understand the daily cycle of the Lagoon, as well as changes occurring due to the arrival of fresh water released from Tapia. By monitoring changes in water level, salinity, temperature, pH, dissolved oxygen, turbidity, and also trying to determine current flow through different channels of the Lagoon, a perspective on water movement, flow rates, and turnover of water in the channels might be obtained. See Map A for locations. At the time of the study, the Lagoon entrance was closed by a sand bar. Therefore, ocean influences were not seen until the entrance was bulldozed open at the end of the 24 hour watch.

2.4 OBSERVATIONS

Variability is the most noticeable factor in water quality at Malibu Lagoon. As was noted during the 24 hour survey, once the entrance was opened, even though the tide was theoretically rising, almost the entire Lagoon emptied out within two hours. The water quality parameters reflected this dramatic change and showed that for the times the entrance is silted shut, the primary influence in the Lagoon is the incoming freshwater from Tapia. This can cause flooding over much of the peninsula area between channels and allows the Lagoon to assume characteristics often found in enclosed bodies of water, such as increased temperatures, reduced dissolved oxygen and low salinity.

Generally, pH remained in the range of 6.5 - 9.5 at all stations throughout the year (Fig. 2.1), with an average of 7.3. A few peaks occurred in October and February. These same dates are a time of unusual readings of all water quality parameters in the Lagoon. Interestingly, the highest recorded pH was in B Channel, which is very shallow and typically shows exposed mud at low tide. Could it be that the nutrients trapped in the sediments are influencing the water quality here? It is also possible that residual "suds" raise the pH after the Lagoon has drained. pH levels recorded by Tapia at their station (R11) near the PCH bridge were consistently higher than those found elsewhere in the Lagoon. Sewage has a pH of around 8, and the effluent leaving the Tapia plant is between 6 and 6.5. The large amount of bird guano, which is high in uric acid, may serve to lower the pH in the other more widely utilized roosting areas.

In analyzing the trends over the year (Fig. 2.2), it appears that salinity increases at the end of each month, corresponding to a tidal cycle of low high or neap tides. This could also be tied to the pattern of salt water intrusion. Average ocean water has a salinity of 34-36 ppt. Salinity in B channel exhibited a wide range, from 0-34 ppt with an average of 19.1 ppt. There is a well defined salt lens present in the deepest channel (C station), where extremes tied to the tidal cycle. Surface samples at C station ranged from 2-35 ppt with an average of 17.6 ppt, while bottom samples ranged from 6-37 ppt, with an average of 23.4 ppt. The salinity at E station, located in the main body of the Lagoon is typically less saline, but also shows well developed layering and variability, dependent on the condition of the Lagoon entrance. Surface samples here can be as low as 0 ppt, but usually were a little more saline (34 ppt), and

Fig. 2.1 Average monthly pH of Stations A, B, C, D, E, Malibu Lagoon, 1987-1988.

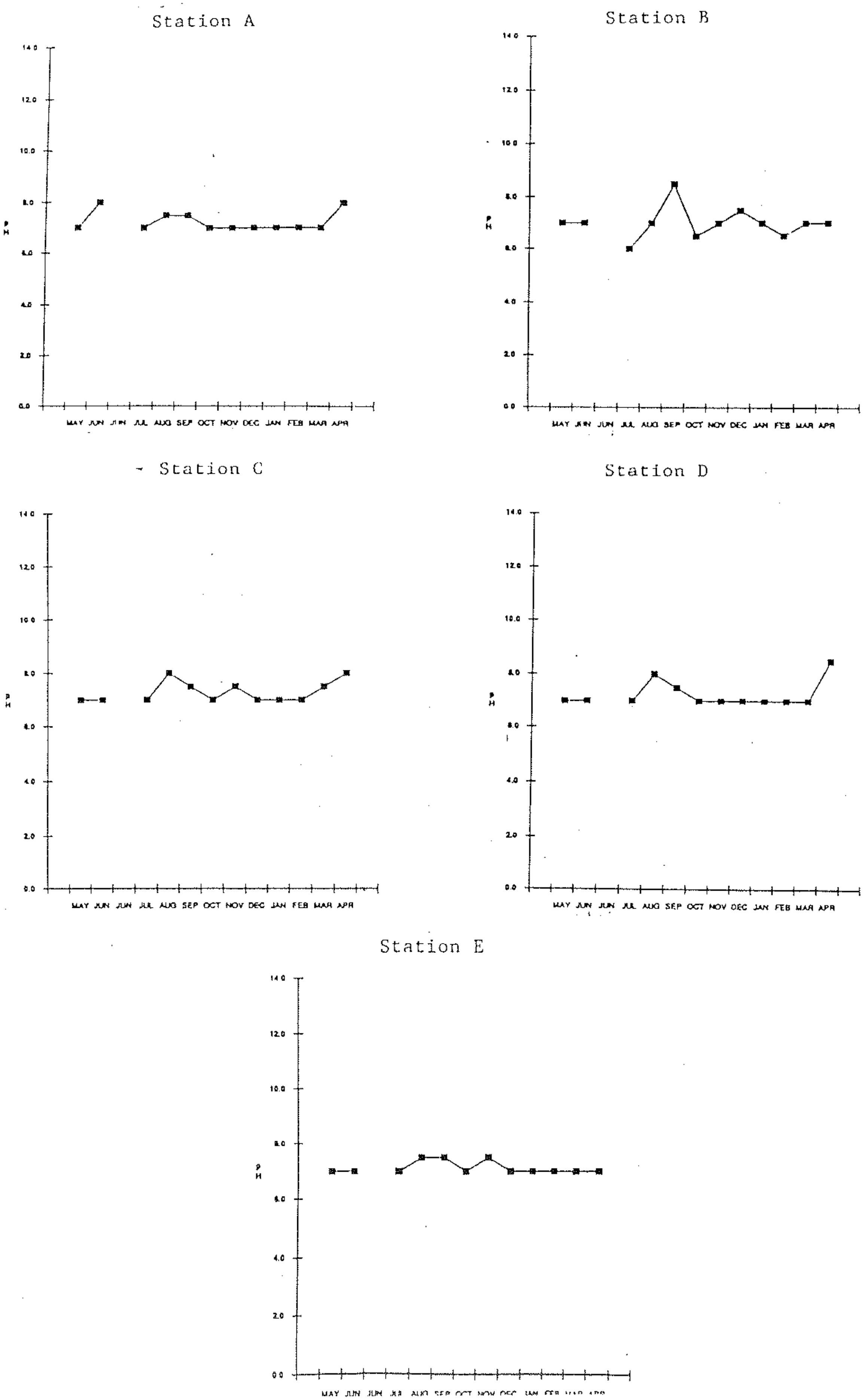
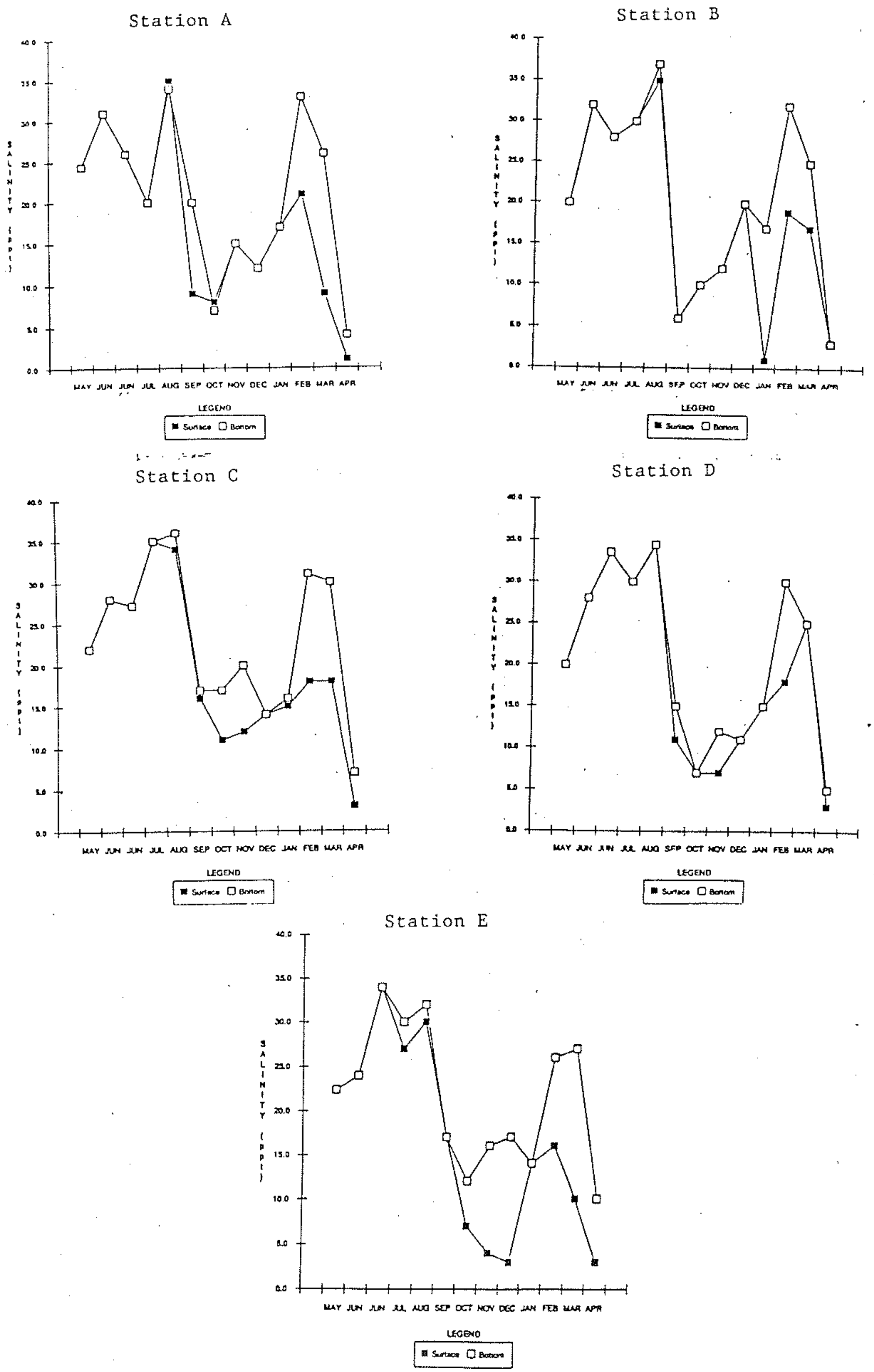


Fig. 2.2 Average monthly salinity (ppt) of Stations A, B, C, D, E, Malibu Lagoon, 1987-1988.



averaged a slightly higher reading of 19.3 ppt. These values stress the significance of fresh water input on the Lagoon ecosystem. It was also determined towards the end of the survey that the salinometer needed continuous re-calibration to reflect temperature change, thus potentially allowing a range of error of as much as 2-4 ppt in all data.

Another widely variable component of Lagoon water quality is the water temperature. This is to be expected, due to the shallow nature of the area and the strong influence of weather conditions. There are, however, a few noticeable trends. Over the year, the temperature increases through the summer and fall, only to decline in the winter beginning around early December (Fig. 2.3). Typically B station remains the warmest (average 19.4 C), and E station is more mixed with less obvious differences between surface and bottom temperatures. Station C often illustrates an interesting temperature inversion, with warmer water on the bottom. This condition is observed most frequently when data is collected prior to an incoming tide, or when the Lagoon entrance is closed. This may be an effect of water circulation patterns when the sand bar at D station blocks water movement in and out of the channel. A strong separation of temperature between surface and bottom water masses is characteristic. The general range of temperatures in Malibu Lagoon is between a low of 10 C and a high of 26.5 C, with an average of 18.5 C.

The levels of dissolved oxygen in the Lagoon show seasonal variability, with lowest levels occurring in the fall and early winter followed by steadily increasing levels through late winter and spring (Fig. 2.4). In keeping with trends shown by other parameters, dissolved oxygen levels at B Station tend to remain within a range of 4.6 to 14.2 mg/l, with an average of 10.6 mg/l. At C station, the range is slightly different (5.6-13.0 mg/l) and shows some variability in surface to bottom highs and lows. At times, the surface levels are higher than those on the bottom, and other times lower. The levels at E station tend to be consistently a little higher (2.1-20.0 mg/l), with a surface average of 11.2 mg/l and bottom average of 14.3 mg/l. This is no doubt related to the fact that ocean water is characteristically high in dissolved oxygen and is a result of the tidal intrusion and the effects of wind mixing.

Turbidity ranged between 10-20 JTU on the average at all stations (Fig. 2.5). One notable exception occurred in January, when all stations showed a dramatic increase with an extreme of 150 JTU at station C. This correlates to a period of heavy rains in the beginning of the month. It also points to the impact of floatables such as suds and debris, and road runoff from the vicinity of Malibu Colony which enter the Lagoon in the channel near C station, as well as farther back in all the channels.

Fig. 2.3 Average monthly temperature (°C) of Stations A, B, C, D, E, Malibu Lagoon, 1987-1988.

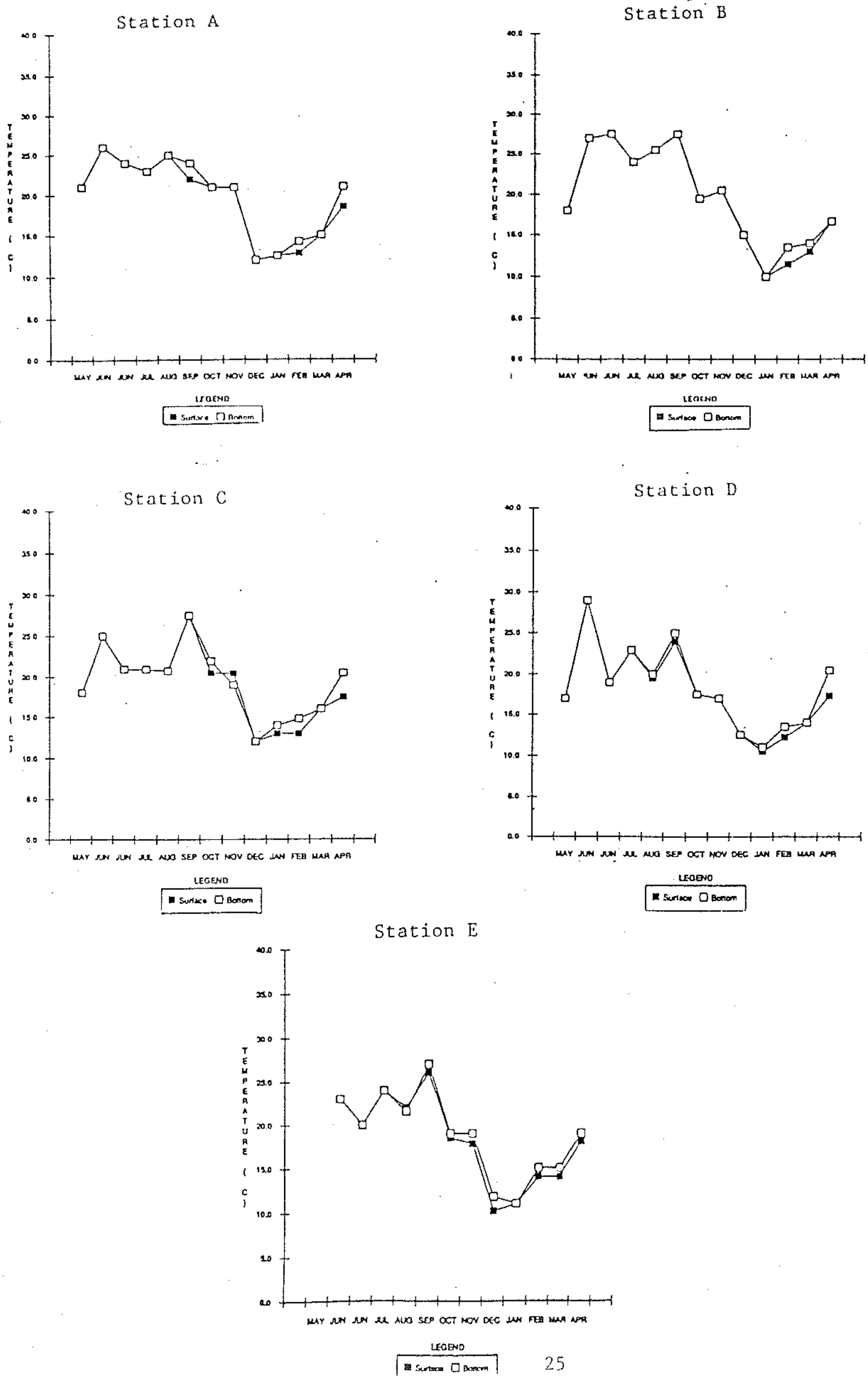


Fig. 2.4 Average monthly dissolved oxygen (mg/l) of Stations A, B, C, D, E, Malibu Lagoon, 1987-1988.

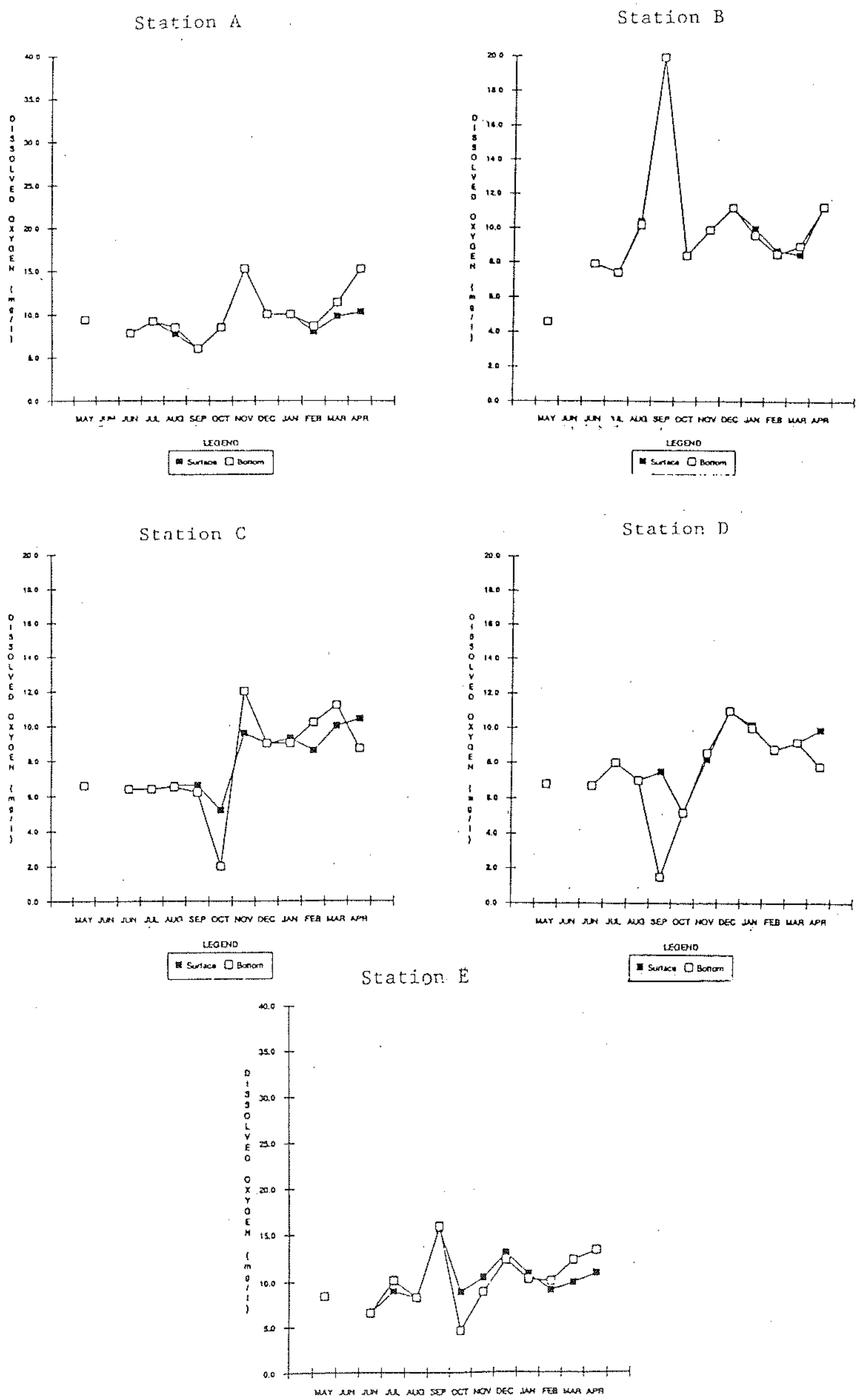
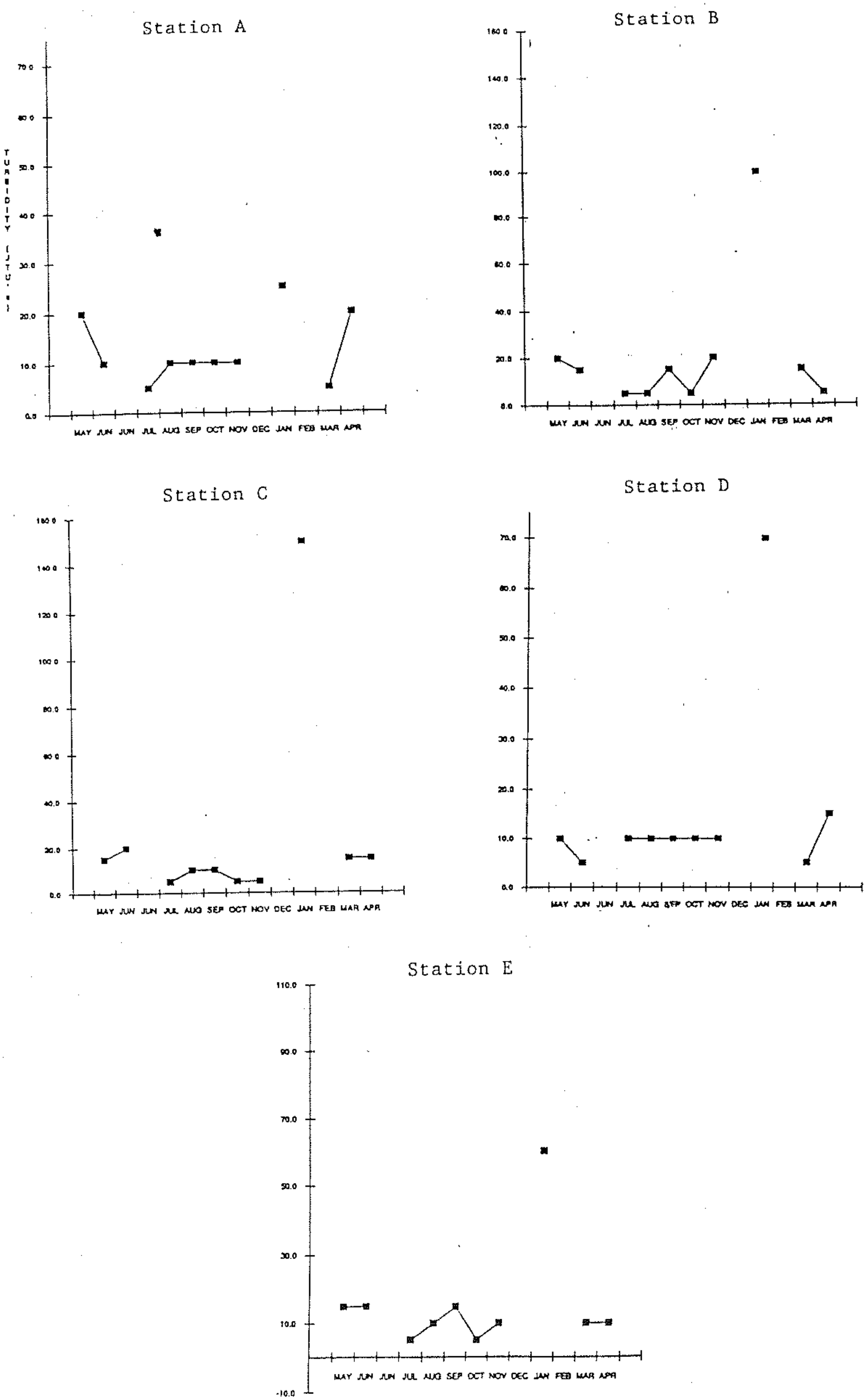


Fig. 2.5 Average monthly turbidity (JTU) of Stations A, B, C, D, E, Malibu Lagoon, 1987-1988.



Data collected over the past two years by the students participating on Malibu Lagoon School Tours substantiates the wide variability of temperature and salinity noted during this project. The locations where students collected data correspond roughly to Stations D and E. Station D is close to S1, and E is close to S2, but closer to the entrance (Map A). As can be seen in Figures 2.6 and 2.7, the trends recorded for both salinity and temperature are similar to those shown for Stations D and E. Frequent data points spread over a wider range of tidal stages add important detail to the less frequent data collection called for by this project.

The data collected by the Las Virgenes Municipal Water District, the agency responsible for monitoring the Tapia Water Reclamation Facility, seen on Figure 2.8, also confirms the trends of other observations. It should be noted that water released by Tapia consistently meets or exceeds the standard criteria levels for water quality. The only exceptions are some occasionally higher levels of dissolved oxygen, and slightly higher values for pH, which still remain within accepted safe levels, but are at the high end of the range. It appears that the quality of fresh water entering Malibu Lagoon from the Tapia plant and Malibu Creek is not adversely affecting the condition of the main Lagoon. However, the high volume of fresh water has a tremendous impact on the ecosystem.

Several elements (B, Ca, Co, Cu, K, Li, Mg, Mn, Mo, Na, Ni, P, Se, V, Zn) are considered essential for healthy growth of plants and animals, unless they exceed a certain amount. Above certain levels, some elements such as copper and magnesium become toxic. In Malibu Lagoon, all of these are found in concentrations which are within the limits set by the Water Quality Criteria, or are lower. Cobalt, lithium, and vanadium are needed for healthy microorganism and algae growth, and the low levels of these might warrant further investigation. If anything, the concern should be for the low levels of those elements necessary for maintaining healthy plants and animals. Manganese is of particular concern, as it is consistently below the lower limits of the range set for the health of the biota.

Of the other elements which are considered to be nonessential for growth, only titanium is toxic to both plants and animals when high levels are present. Selenium and copper are unique in that they are potentially toxic to animals when found in high concentrations, but are necessary in small amounts. Im Malibu Lagoon, they are all found within acceptable limits.

The general trend is that the levels of many elements increases in the summer months, with samples from E station consistently lower than those found in the rest of the Lagoon. This could be due to the circulation patterns in the Lagoon,

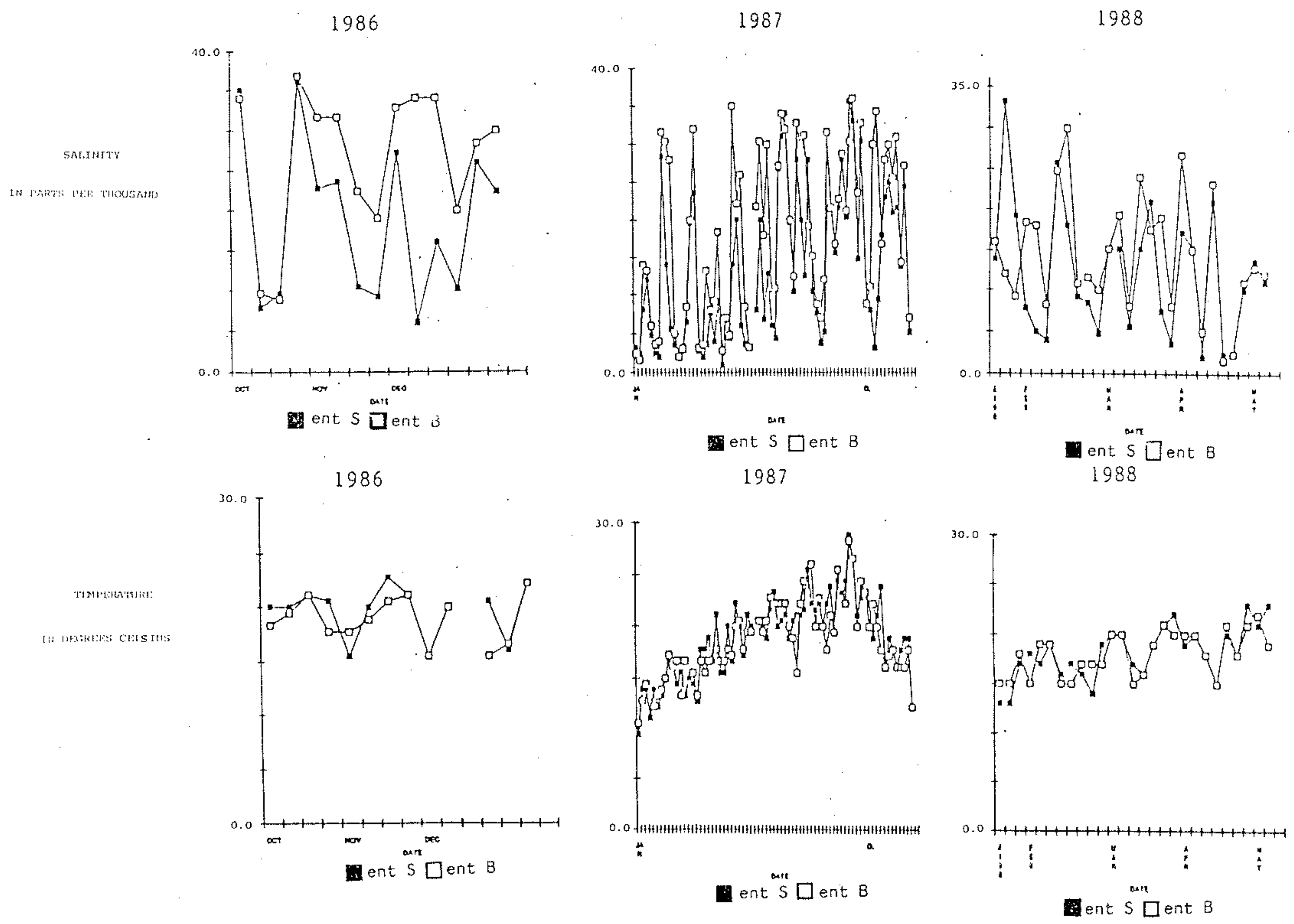


Fig. 2.6 Entrance Salinity (ppt) and Temperature (°Celsius) surface and bottom samples from Malibu Lagoon School Tours 1986-1988 (Site S1).

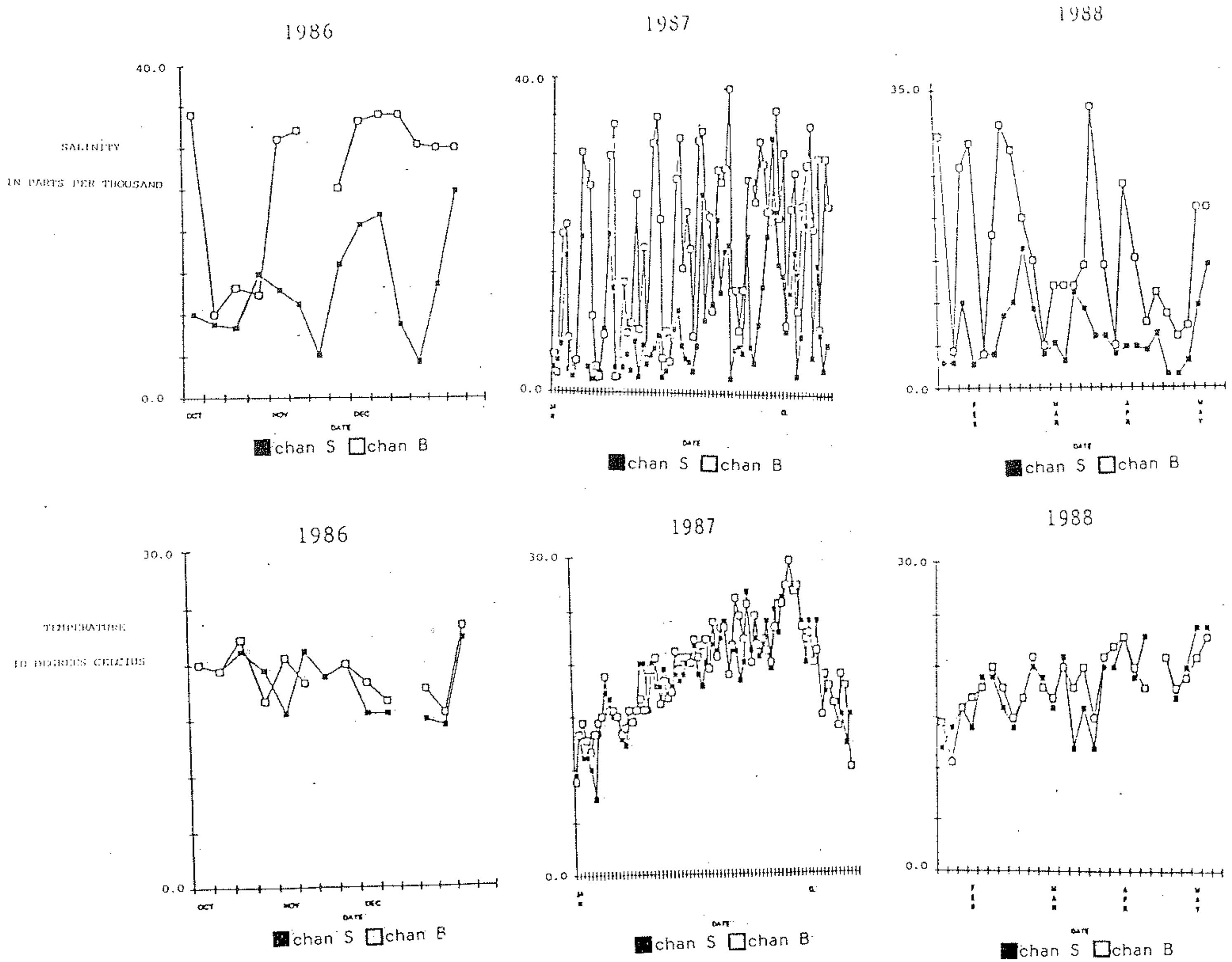


Fig. 2.7 Channel Salinity (ppt) and Temperature (Celsius) surface and bottom samples from Malibu Lagoon School Tours (Site S2).

Fig. 2.8 Table of Water Quality Data, monthly averages of samples from Site R11 (near the PCH bridge), collected by Tapia Wastewater Treatment Plant, 1987-1988.

Date	Temperature (C)	pH	Dissolved Oxygen (mg/l)	Turbidity
1987				
May	23.5	8.1	13.4	2
June	24.4	8.1	9.8	4.7
July	26.8	7.9	12.6	1.7
August	24.7	8.0	9.1	1.5
September	23.4	7.8	10.2	2.2
October	21.3	8.1	10.4	1.5
November	18.0	8.0	10.3	15.0
December	13.9	7.6	11.6	6.5
1988				
January	13.7	8.2	12.2	10.0
February	16.0	8.0	13.1	2.8
March	18.1	8.0	11.8	4.4
April	19.9	8.2	9.9	1.6
May	20.9	8.2	12.1	3.7
June	23.7	8.6	16.2	4.0

*Note: Dissolved oxygen levels lower than 7mg/l are considered to be in violation of limits set.

which allow water in the back channels to sit for longer periods than that in the main body of the Lagoon. It is also known that many of these elements precipitate out of solution when levels of dissolved oxygen increase, and therefore are more likely to be in solution during summer months when dissolved oxygen levels are lower.

Total coliform bacteria data is collected by Tapia near the PCH bridge (site R11), as well as at other stations both upstream and downstream from the plant. These, in addition to the data collected weekly by the LA County Department of Health outside the Lagoon on the surfing beach were collated with the intention of illustrating any relationship between levels of coliform in the Lagoon and those on the beach (Figure 2.9). If these data are examined with relation to tidal stage, rainfall and Lagoon entrance closure, a few trends begin to appear, but much still remains unclear.

First, it should be noted that total coliform levels as measured on the Surfrider Beach rose above levels considered safe for body contact (500 MPN/100ml), only 3 times during the 1987-88 survey. When this occurred in December 1987, the Lagoon levels recorded by Tapia were lower than those on the beach. In both January and March, the Lagoon (R11) levels were higher. In each case, these levels occurred after a period of heavy rainfall. The average count along the beach for the 14 months of the survey was 209 MPN/100ml. This is not surprising, since coliform bacteria cannot survive the high salinity of ocean water and die off rapidly upon exposure.

In the area of the Lagoon where samples were collected by Tapia (Site R11 near the PCH bridge), the total coliform levels were extremely variable, with an average of 1100 MPN/100ml. A week to week change of 100 MPN/100ml to over 2000 MPN/100ml was not uncommon. The extreme peaks always followed rainfall, but did not seem to be directly tied to Lagoon closure. Tidal influences were much stronger, with high counts during or following spring tides. Occasionally there were also high levels during mid-cycle or neap tipes, but these were always in association with entrance closure or heavy rainfall.

Overall, total coliform counts seem to be higher in the winter months when there is greater rainfall. It is interesting to note that there were also occasions when total coliform levels in the Lagoon were lower than those on the beach, and in both cases this was during spring tides, with an open Lagoon entrance. Sampling the levels of bacteria in other areas of the Lagoon, particularly C channel near the drainage pipes, and the main Lagoon would provide further insight into where the bacteria source is, and how water circulation within the Lagoon affects total coliform population peaks and declines. It is noted in the original restoration plan (LA County Department of Regional Planning 1982).

DATE 1987	TAPIA Site R11	LA COUNTY Surfrider Beach	ENTRANCE	TIDE
May 5	1000		-	mid
12	200	20	-	spring
19	3300		-	mid
26	<100		-	neap
June 2	1400		-	mid
9	1600	20	C	spring
16	900		-	mid
23	300		-	
30	1700		-	neap
July 7	800		-	mid
14	1100	300	-	spring
21	400		-	
28	-		-	
Aug. 4	<100		C	mid
11	<100	<20	O	spring
18	100		-	mid
25	100		C	neap
Sept. 1	<1000		-	mid
8	500	300	-	spring
14	>1600/<500		-	mid
22	500		-	neap
29	3000		C	mid
Oct. 6	500		-	spring
*13	1750	40	O	mid
*19	500		barely O	neap
27	2400		-	mid
Nov. 3	3500	500	O	spring
10	1000	40	O	mid
16		110	-	
23		80	-	neap
24	1000		-	
30		40	-	spring
Dec. 1	1250		O	
7		1100	O	mid
8	1000		O	
*14		<20	O	
*15	2250		O	
*22	750	110	O	neap
29	1250	500	O	mid

DATE 1988	TAPIA Site R11	LA COUNTY Surfrider Beach	ENTRANCE	TIDE
Jan. *4		130	O	spring
*5	1750		O	
11		170	O	mid
12	1750		O	
19	1300	1100	O	neap
25		20	-	mid
26	500		-	
Feb. 1		130	-	spring
2	3700		-	
8		40	-	mid
9	1000		-	
16	2800		O	neap
22		130	-	mid
23	500		-	
*29		1300	O	mid
Mar. 1	1700		-	spring
7		70	-	
8	500		-	mid
14		20	-	neap
15	150		-	
21		40	-	mid
22	300		-	
28		300	-	
29	200		-	spring
Apr. 4		500	-	
5	1850		-	
11		20	O	mid
12	50		C (opened 13th)	
*18		300	O	neap
*19	300		O	
*25		170	O	mid
*26	500		O	
May 2		40	O	spring
3	TNTC		O	
9		<20	O	mid
10	2300		O	
16		20	O	neap
17	1000		O	
23		220	O	mid
24	TNTC		O	
31	1900	20	C	spring
June 6		130	O	mid
7	<100		O	
13		40	-	neap
14	1250		-	
20		130	-	mid
21	900		-	
27		80	-	spring
28	150		-	

NOTE:
* indicates day of rainfall
TNTC = Too numerous to count
- indicates that no specific note was made of entrance condition
MPN = Most Probable Number

Fig. 2.9 Table of total coliform bacteria counts (MPN/100ml) from Tapia Water Reclamation Facility and Los Angeles County Department of Health, correlated to tidal stage and precipitation, and status of Lagoon entrance, 1987-1988.

1982) that improperly maintained septic systems drain into the Lagoon when the water table rises. More information is needed in order to more clearly understand the relationship of coliform counts in the Lagoon to those found along the beach.

A few trends appeared during the 24 hour survey of the Lagoon which documented more completely the daily cycle. As might be expected due to photosynthesis, levels of dissolved oxygen rose during the day to a high of 14 mg/l around 6:00pm, and fell during the night to lows of around 7 mg/l (Figure 2.10). The closed entrance at the time of the survey meant that the water level in B channel reached a high of 5.2 ft before the bulldozer arrived. There was a temperature inversion with differences of up to 7 degrees between colder surface water and warmer bottom water, probably due to the continuous influx of fresh water from Malibu Creek. One diurnal cycle documented was that of pH, which went from a consistent daytime reading of 8.5 to a nighttime low of 6.5 (Figure 2.11). The following day it returned to 8.5 at the same time the entrance was opened and the Lagoon emptied.

2.5 DISCUSSION

Salinity and temperature are normally quite variable in an estuarine situation as a result of tidal influences. At Malibu Lagoon this situation is further complicated by unnatural and irregular influx of large volumes of fresh water from the Tapia Water Reclamation Facility of the Las Virgenes Municipal Water District and the constantly changing status of the mouth of the Lagoon. As compared to other Southern California estuaries, the low salinities found at Malibu Lagoon put it in the class of brackish, not salt water marshes (Zedler 1982). Due to an agreement with Southern California Edison, the Las Virgenes Municipal Water District releases excess water during off-peak hours, thus inundating Malibu Creek with large amounts of water in short time periods. Tapia has no way of holding excess water for extended time periods (i.e. more than a day) in order to release it on a more consistent basis, except in their percolation ponds. Instead, when they are unable to sell reclaimed water, Tapia discharges large volumes into Malibu Creek. This often occurs during the winter, when precipitation already increases the volume of water in the Creek naturally. The results of this irregular flooding most noticeably affects the distribution and health of various plant species in the Lagoon, but also the animals. Most common estuarine plants require short intervals of low salinity in order for seed germination and establishment to occur. These natural "windows" are normally provided by seasonal rainfall. At Malibu Lagoon, the normal seasonal pattern is lost and a more erratic pattern imposed, resulting in a non-zonated pattern of vegetative distribution. Animals normally found in estuarine habitats tend to tolerate

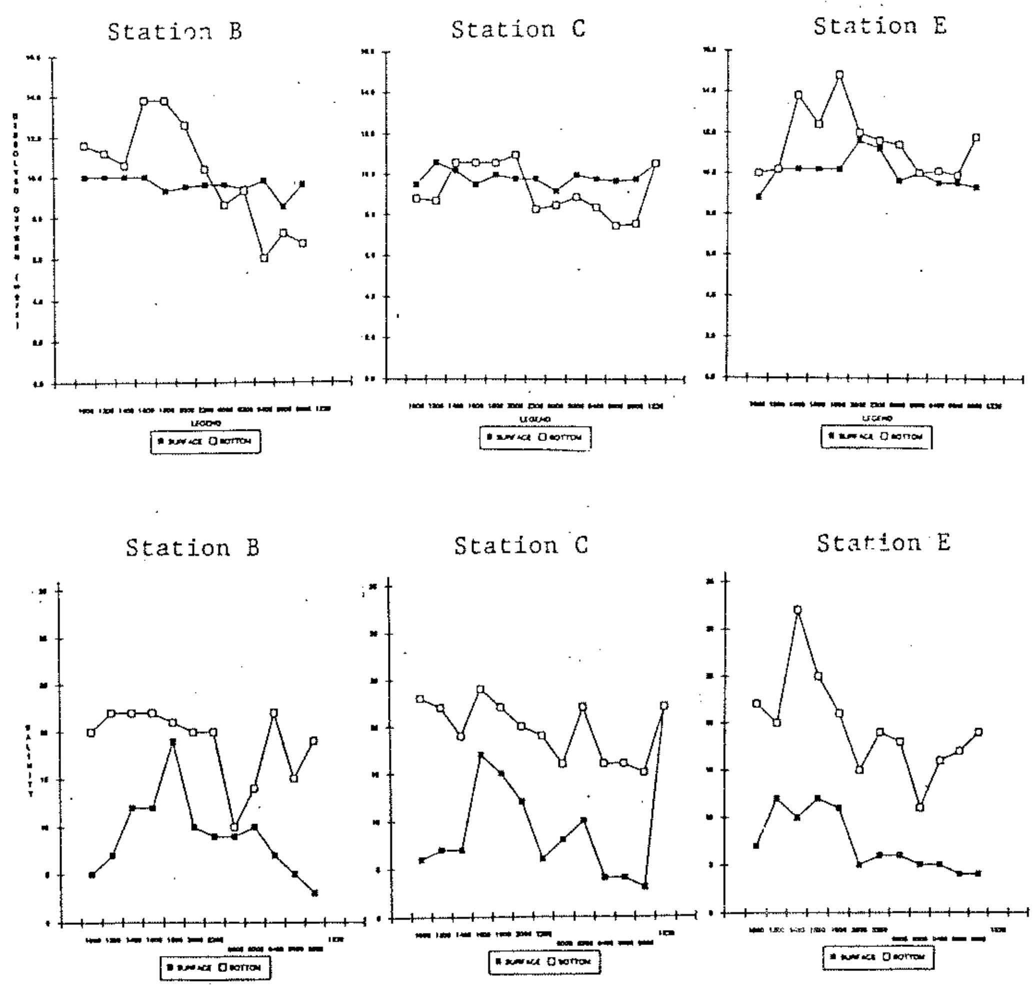


Fig. 2.10 Dissolved Oxygen (mg/l) and Salinity (ppt) from Stations B, C, E, Malibu Lagoon 24 Hour Survey, 31 May - 1 June 1988.

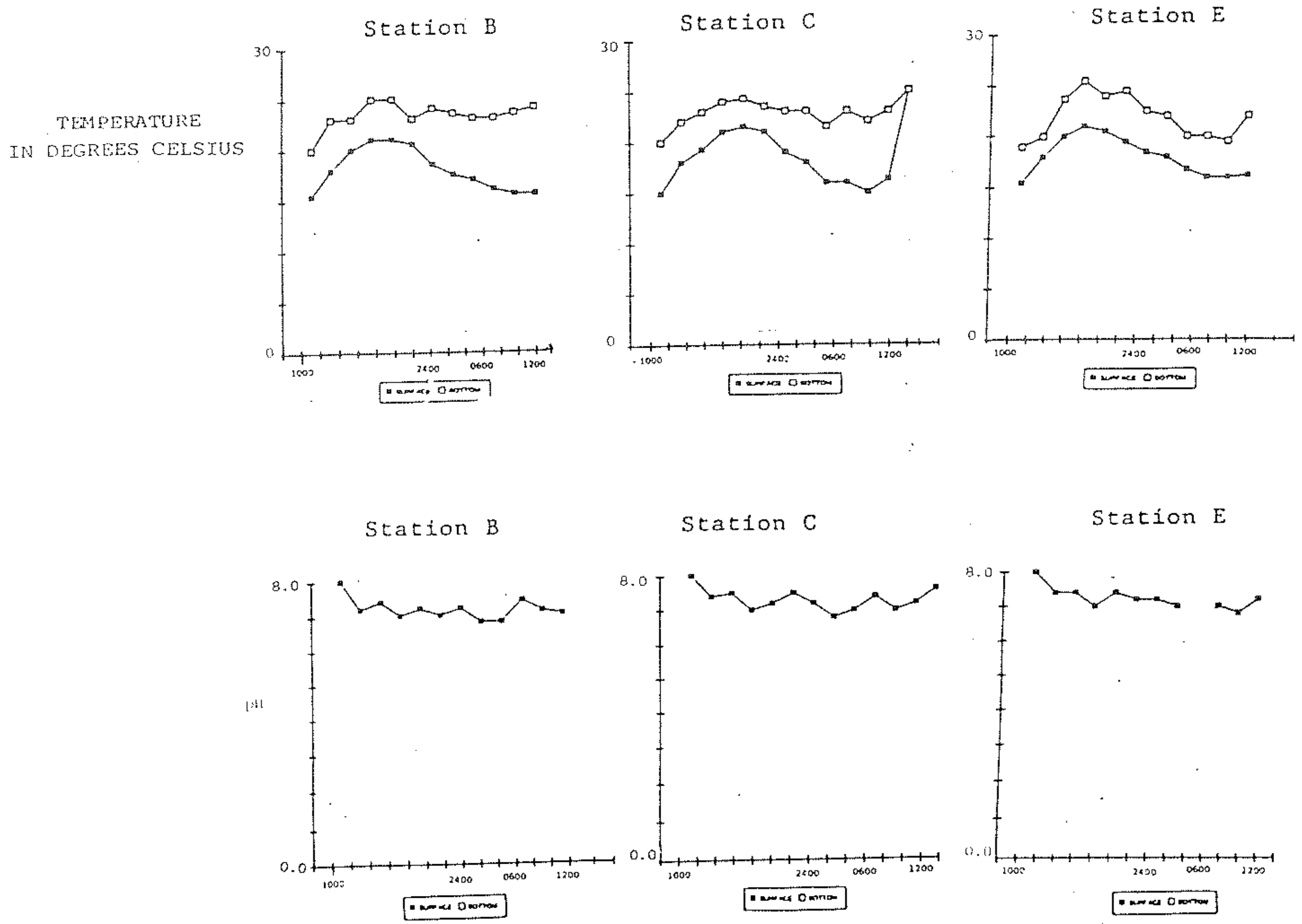


Fig. 2.11 Temperature (° Celsius) and pH from Stations B, C, E, Malibu Lagoon 24 Hour Survey, 31 May - 1 June 1988.

wider ranges of temperature and salinity, but the addition of non-seasonal fresh water in Malibu Lagoon definitely favors those with higher tolerance to fresh and brackish water.

A further problem occurs when the mouth of the Lagoon closes due to sedimentation. This is a normal seasonal pattern, with summer closure and winter opening as a result of wave action and sediment loads distributed by littoral currents. The natural tendency is for the entrance to occur further southeast, closer to the Adamson house, rather than near the Malibu Colony beach. The entrance is artificially maintained at its present location close to the Colony by bulldozing the beach berm and sandbar at periodic intervals (usually twice per month). The Department of Parks and Recreation is mandated to maintain an entrance and open it if the water level in the Lagoon exceeds 3.5 ft. Sometimes, though, the time lag between closure and re-opening is quite extended (from two to eight days), potentially creating stressful conditions for those organisms in the Lagoon which depend on the tidal circulation.

The results of the UCLA Biomedical and Environmental Study Lab analysis indicate that there are low to negligible levels of trace elements and industrial/chemical pollutants in the Lagoon. Several elements such as iron, nitrates, and phosphates were not studied, and since these potentially affect plant growth, future studies need to include them. However, the Lagoon is frequently deemed contaminated because of high levels of total coliform bacteria (above 500 MPN/100ml is considered unsafe for body contact), although the only data on coliform counts in the Lagoon is collected by Tapia where the Creek enters the main Lagoon, and not by the state or county. Hence, biological pollution is of great concern.

Although the coliform bacteria species used in water quality tests are not pathogenic organisms, high levels do indicate possible presence of other potential pathogens such as viruses, parasites, and other bacteria. Coliforms are used as an indicator of water quality because they are easily measured. Coliform bacteria cannot tolerate high salinity, and therefore die off quickly in ocean water. They can, however, multiply rapidly in impounded waters such as those found at times in the Lagoon. As yet, there is no consistent data on total coliform levels in the Lagoon. Future research on this topic is important to clarify issues surrounding the source of bacteria. It is important to note that the length of Malibu Creek, like all creeks exposed to urban runoff, is also considered unsafe for human contact. According to the Tapia data, levels of coliform upstream above the treatment plant are also high.

The local mythology surrounding the "pollution" of Malibu Lagoon warrants some discussion. Rumors exist about the source of pollution, suggesting that Tapia and Pepperdine sewage treatment plants dump sewage into the Lagoon, and that bird feces also add to the contamination. Some beach users perpetuate the idea that when the entrance of the Lagoon is opened, the contaminated water is responsible for a host of ailments, particularly ear infections. Coliform bacteria do not cause ear infections, however there may be other pathogens present which have not been identified in the coliform tests (Chris Denny, M.D., pers. comm.). Since no data are collected in the main body of the Lagoon, it is difficult to directly support or refute this idea.

What is the source of these bacteria? This question is key to understanding the biological pollution of Malibu Lagoon. There are several potential sources, but the data are not sufficient to pinpoint which one or combination are responsible for the high levels of bacteria found in the Lagoon. Water can carry coliform bacteria from other areas further upstream, and conditions in the Lagoon are such that the bacteria can multiply. It takes only a matter of hours for a low population to explode. Other potential sources are the septic tanks, leach fields and road runoff of the nearby houses and businesses along Malibu, Cross Creek and Serra Roads. The water table in this area is quite high, and increased water levels in the Lagoon caused by tides, storms or Lagoon entrance closure probably cause these septic systems to overflow. There are several drainpipes from the Malibu Colony fire access road which dump directly into C channel of the Lagoon and the restoration plan (LA County Dept. of Regional Planning 1982) documented improperly placed leach fields as well. It is here that surface layers of soap bubbles and scum are most frequently observed.

In addition, instances when the beach is not opened to swimmers are interesting to examine. There were only three occasions during the 14 month survey when beach coliform counts exceeded standard safe levels, although the beach was not opened to swimmers on other occasions. In April, 1988, there was a period of heavy rainfall that coincided with a spring tide. The Lagoon entrance was open. Despite the fact that both Tapia and LA County Department of Health samples indicate coliform levels well below hazardous levels, the lifeguards issued a health warning on April 19th, encouraging swimmers not to enter the water. It takes a minimum of 96 hours to obtain the results of coliform tests, and thus values taken on the 19th by both Tapia and LA County would not have been available. The results from the previous week indicated very low levels.

Clearly there are numerous issues involved in resolving the problem of coliform pollution. First and foremost, more consistent maintenance of the Lagoon entrance could prevent the possible effects of impounded water breeding high populations of bacteria, although in the summer this is contrary to the natural regime. Although the State is responsible for opening the entrance any time the Lagoon water level exceeds 3.5 ft, in reality their one bulldozer is often working somewhere else and is not available for immediate correction of the Lagoon entrance condition. Secondly, the possibility of creating more percolation/retention ponds on Malibu Creek near the release site of Tapia might also help by decreasing the volume of water entering the Lagoon in short periods of time. This possibility needs to be further explored as the Tapia plant expands and the volume of water released increases from around 8-10 million gallons per day to an average of 16-20 million gallons per day. Thirdly, examination of the septic systems of private property adjacent to the Lagoon, with suggestions for either upgrading existing septic systems or replacing them with sewers are options that deserve consideration.

There were several times during the course of the study when a period of unusual conditions prevailed. In October, January, and February, all parameters in the Lagoon showed wider ranges than "normal." This may be tied to the closure of the Lagoon entrance, or periods of heavy rainfall. Each of these events occurred around the time when the mouth was silted over and little or no ocean water was entering the Lagoon. During these periods, extreme changes in temperature, dissolved oxygen, and salinity occurred. Clearly there is much yet to be learned about how these variables interact.

One significant question that remains to be examined is how long it takes water to circulate through the Lagoon. The use of current meters during the 24 hour survey revealed that the current is too weak to be measured by a Pygmy-Gurley meter, although equipment problems definitely affected this result. Observations indicated a strong correlation of surface water movement to wind direction, as could be expected. By measuring depth in each channel on the hour for 24 hours, it was found that the Lagoon fills from the Creek end first (A' channel rose faster than the others), and when the entrance was opened, A' channel was the last to drain.

Before further changes to the channels are made in the next phase of reconstruction, it is important to more accurately describe the flow pattern and turnover rate of Lagoon waters, particularly waters in the back channels. Distribution of sediments and nutrients could be greatly affected by the proposed changes, which entail digging a connecting channel between the ends of channels A, B, and C. As some runoff from the nearby houses seems to drain into C channel, there is also the question of how much and to what extent pollution would spread once those channels are connected.

In correlating the data from the wide variety of sources available, it is clear that extreme variability is the norm at Malibu Lagoon. This study did not include measurements of nitrates and phosphates, nutrients that are crucial to any aquatic ecosystem. Data from the Tapia samples taken along

Malibu Creek indicates that the level of these nutrients decreases as the water flows downstream, but still meets the low threshold needed to foster algae growth. The water released from the tertiary plant is 97% clean, but does retain nitrates and phosphates in solution. The study done in 1983 by Lynn Hasz recorded such low levels that data was no longer collected after several months. The levels found today are an unknown which needs to be included in future studies.

As is typical, this study seemed to generate more questions than it answered. Now that there is a comprehensive database, continued data collection could potentially provide better answers. Data concerning the impact of the Pepperdine sewage treatment plant, as well as that of the commercial area along Cross Creek Road is needed to complete the picture. Water quality is absolutely critical to the overall health of the Lagoon, and it is important that future studies incorporate information on levels of nitrates and phosphates in an attempt to determine the levels of these compounds introduced by runoff and septic tank overflow. Further investigation of water circulation may explain the distribution of benthic organisms and plant species. Based on the observations taken during this year, fresh water influx is a greater factor in the ecosystem than is salt water. What changes might occur as a result of more regular entrance maintenance? Would the creation of percolation/retention ponds mitigate the volume of water coming down the Creek? How might we encourage a greater diversity of benthic organisms? What will happen to the established system if the channels are re-graded and connected? Clearly there is much yet to discover.

2.6 SUMMARY

1. Salinity, temperature, dissolved oxygen, and pH vary tremendously in Malibu Lagoon, sometimes with extremes occurring in short time spans.

2. Malibu Lagoon is more characteristic of a brackish water ecosystem rather than salt water, and has a low diversity of invertebrates and fish, characteristic of estuaries receiving high volumes of fresh water input.

3. Distribution of plants and animals is reliant upon the physical and chemical parameters of the watershed. Changes in the water quality could potentially affect the entire ecosystem.

4. Freshwater input from the Tapia Water Reclamation Facility is of high quality, but does affect the overall water quality when impounded by closure of the Lagoon entrance. This potentially provides good growing conditions for coliform bacteria.

5. Department of Parks and Recreation frequently does not immediately open the Lagoon entrance when levels reach 3.5 ft. The impounded water stresses the septic systems of nearby homes and businesses by raising the water table. It is possible that the elevated water table results in sewage overflow into the Lagoon.

6. High coliform bacteria counts are frequently found in streams associated with urban areas. The counts along Malibu Creek are high above the Tapia Water Reclamation Facility, less than 2 MPN/100ml for water released from Tapia, and high again in Malibu Lagoon where impounded water provides ideal growing conditions. Non-point sources of pollution along the Creek need to be identified. The homes and businesses located along Malibu Creek and Malibu Lagoon are potential sources of this pollution.

7. No chemical toxics were found in Malibu Lagoon.

8. Further studies of coliform sources, water circulation patterns, and overall water quality are needed to provide a more complete understanding of the ecology of the watershed.

LITERATURE CITED

Denny, Dr. Christopher. 1988. (personal communication) UCLA School of Medicine.

Gough, L. P. et al. 1979. Element Concentrations Toxic to Plants, Animals, and Man. U.S. Geological Survey Bulletin 1466. pp.80.

Hasz, L. 1983. Malibu Lagoon: A Local Resource. CSUN. unpub. pp.10.

L.A. County Department of Regional Planning. 1982. Proposed Malibu Local Coastal Plan: Research Analysis and Appendices. Coastal Studies Section.

Las Virgenes Municipal Water District Malibu Creek Monitoring Program. Monthly Summaries, May 1987 - June 1988.

Mitchell, M. and Stapp, W. 1986. Field Manual for Water Quality Monitoring. Thompson-Shore Printers. pp.10-64.

Nordby, C. and Covin, J. 1988. Physical-Chemical and Biological Monitoring of Los Panasquitos Lagoon. Los Penasquitos Lagoon Foundation.

Rand, M. C., ed. 1976. Standard Methods for the Examination of Water and Wastewater. 14th Ed. American Public Health Association. pp.99, 135, 715.

Tjaden, A., Roberts, J., and Pierce, K. 1978. Malibu Lagoon Surfing Beach Resource Management Plan, General Development Plan, and Environmental Impact Report. State of California, Department of Parks and Recreation.

Trussell, R. R. et al. 1980. Las Virgenes Municipal Water District, Triunfo County Sanitation District Malibu Creek Study 1979. James M. Montgomery, Consulting Engineers, Inc. pp.3:1-36.

Zedler, J. B. 1982. The Ecology of Southern California Coastal Salt Marshes: A Community Profile. U. S. Fish and Wildlife Service FWS/OBS-81/54. pp.110.

Zedler, J. B., Koenigs, R., and Magdych, P. 1984. Freshwater Release and Southern California Coastal Wetlands. San Diego Association of Governments. pp.51.

Zedler, J. B. and Nordby, C. 1986. The Ecology of Tijuana Estuary: An Estuarine Profile. U.S. Fish and Wildlife Services Biological Report 85 (7.5). pp.104.

3.0 VEGETATIVE SURVEY OF MALIBU LAGOON

3.1 INTRODUCTION

Over the years, Malibu Lagoon has experienced a great many changes which have dramatically altered the natural flora of the area. When the Lagoon was used by the Chumash Indians, particular plant species were husbanded for use in basketmaking and food. The Indians were known to utilize the area, so that even prior to the historical period, the Lagoon has been a somewhat altered ecosystem.

The value of the Lagoon vegetation and its ability to recycle wastes, buffer against the ravages of storms and stabilize the coastline is one of the main reasons for conducting this study. However, in recent history Malibu Lagoon has met with many changes. Most recently, it was filled in to provide space for baseball fields and parking lots. In 1982-83, a restoration project began which entailed removal of much fill, comprehensive re-grading and landscaping, with the inclusion of trails and visitor use areas.

In the five intervening years, recovery has resulted in the re-establishment of vegetation and reintroduction of some the more characteristic estuary animals. In trying to evaluate the success of the Phase I restoration, as well as maximize the possibility of further enhancement when Phase II begins, a comprehensive survey of the Lagoon vegetation was necessary.

3.2 OBJECTIVES

The distribution and diversity of vegetation in Malibu Lagoon are of great interest, especially within the context of further restoration. A comprehensive survey of vegetation was conducted in September 1987, and repeated again in April 1988. These months were selected as they are indicative of the end of one growing season, prior to the fall rains, and the start of another. The survey consisted of several components.

First, a preliminary botanical inventory was carried out. The list of all species found in the area was compiled and verified by experts. Specimens were collected and prepared to form the basis of an herbarium collection. In the spring, further data were collected for those species dormant or not identifiable in the fall. A list of flora has been compiled for visitors to Malibu Lagoon.

Second, in order to monitor changes in the transitional vegetative zones over time, three permanent transects of the back-channel area in a NE - SW orientation were established. Repeated surveys in these fixed locations should provide a long-term, quantitative index of community structure and dynamics, soil salinity, elevation changes and habitat preferences. These transects were repeated in April 1988, and will be available for continuing surveys in the future.

Third, the data will be used to determine ways of encouraging and enhancing the return of native estuarine vegetation in the Lagoon.

3.3 METHODOLOGY

3.3.1 BOTANICAL INVENTORY

A preliminary list of all species present in the Lagoon was compiled by repeated surveys covering the entire area in September 1987 and April 1988 (Figure 3.1). Questionable specimens were collected and their identification verified by Bob Muns (Rancho Santa Ana Botanic Garden) and Wayne Ferren (UCSB). These surveys concentrated solely on vascular plants. Taxonomy and nomenclature is according to Ferren, 1985 and Munz, 1974.

At the time of reconstruction in 1979-82, several methods were used to landscape the area following grading. In addition to re-seeding the *Salicornia virginica* originally from the Lagoon, several species endemic to the Channel Islands were introduced according to the plans of the landscape architect. The inventory takes into account all natives, introduced natives, and opportunistic exotic invaders that have self-seeded, or were contaminants of the hydro-seeding process.

Herbarium specimens were also collected for use in educational programs, as well as to provide a historical perspective of the estuary documenting the species present. These specimens are stored at the office of the Topanga-Las Virgenes Resource Conservation District.

3.3.2 ELEVATION PROFILE

Three 100 meter transects of the back-channel area in a NE - SW direction were established (Figure 3.2).

AIZOACEAE
- Carpobrotus edulis
- Gasoul crystallinum
- G. nodiflorum
- Malephora crocea
- Tetragonia tetragoniodes

AMARANTHACEAE
- Amaranthus albus

ANACARDIACEAE
- Schinus terebinthifolia

APIACEAE
- Apium graveolens
- Corium maculatum
- Foeniculum vulgare

ARECACEAE
- Washingtonia

ASTERACEAE
- Achillea
- Ambrosia chamissonis
- A. psilostachya
- Artemisia californica
- A. dauglasiana
- Baccharis glutinosa
- B. pilularis consanguinea
- Centaurea melitensis
- Chrysanthemum coronarium
- Cirsium californicum
- Conyza bonariensis
- C. canadensis
- Coreopsis gigantea
- Cotula coronopifolia
- Cynara cardunculus
- Heterotheca grandifolia
- Hypochoeris glabra
- Jaumea carnosa
- Latuca serriola

ASTERACEAE
- Malacothrix saxatilis
- Picris echioides
- Senecio vulgaris
- Silybum marianum
- Sonchus oleraceus
- Xanthium strumarium

BETULACEAE
- Alnus rhombifolia

BORAGINACEAE
- Heliotropium curassavicum

BRASSICACEAE
- Brassica geniculata
- Cakile maritima
- Lepidium latifolium
- L. oblongum
- Lobularia maritima
- Raphanus sativus

CAPRIFOLIACEAE
- Sambucus mexicana

CARYOPHYLLACEAE
- Spergularia bocconii
- S. marina

CHENOPODIACEAE
- Atriplex lentiformis
- A. patula hastata
- A. semibaccata
- Atriplex sp.?
- Bassia hyssopifolia
- Beta vulgaris
- Chenopodium album
- C. ambrosioides
- C. murale
- Salicornia virginica
- Salsola iberica

CONVOLVULACEAE
- Calystegia macrostegia
- Cuscuta salina

CUPRESSACEA
- Cupressus

CYPERACEAE
- Cyperus alternifolius
- Scirpus acutus
- S. californicus
- S. robustus

EUPHORBIACEAE
- Euphorbia terracina
- Euphorbia sp?
- Ricinus communis

FABACEA
- Lotus scoparius
- Medicago polymorpha
- Melilotis albus
- M. indicus
- Trifolium pratense
- T. repens
- Vicia villosa

FRANKENIACEAE
- Frankenia grandiflora

GERANIACEAE
- Erodium cicutarium
- E. moschatum

HYDROPHYLLACEAE
- Phacelia ramosissima

JUNCACEAE
- Juncus sp.

JUNCAGINACEAE
- Triglochin concinnum

LAMIACEAE
- Marrubium vulgare
- Stachys rigida

MALVACEA
- Malacothamnus fasciculatus
- Malva nicaeenis
- Malva parviflora

MYOPORACEAE
- Myoporum laetum

MYRUCACEAE
- Myrica californica

PAPAVERACEAE
- Eschscholzia californica

PINACEAE
- Pinus sp?

PLANTAGINACEAE
- Plantago coronopus
- P. lanceolata
- P. major

PLUMBAGINACEAE
- Limonium californicum

POACEAE
- Arundo donax
- Bromus diandrus
- B. mollis
- B. rubens
- B. wildenovii
- Cortaderia atacamensis
- Crypsis niliacea
- Cynodon dactylon
- Distichlis spicata
- Echinochloa crusgalli
- Elymus condensatus
- Festuca
- Hordeum murinum
- Hordeum sp.
- Leptochloa uninervia
- Lolium perenne
- Oryzopsis miliacea
- Parapholis incurva
- Pennisetum clandestinum
- Polypogon monspeliensis
- Sorghum halepense

POLYGONACEAE
- Erigonum giganteum
- E. fasciculatum
- Polygonum aviculare
- Rumex conglomeratus
- R. crispus

PRIMULACEAE
- Anagallis arvensis

ROSACEAE
- Lyonothamnus floribundus
- Prunus lyonii

SALICACEAE
- Salix hindsiana
- S. lasiolepis

SCROPHULARIACEAE
- Galvezia speciosa
- Veronica anagallis-aquati

SOLANACEAE
- Lycopersicum esculentum
- Nicotiana glauca
- Solanum douglasii
- S. nodiflorum

STERCULIACEAE
- Fredmontodendron sp.

URTICACEAE
- Urtica holosericea

Figure 3.1 Flora of Malibu Lagoon, 1987-1988

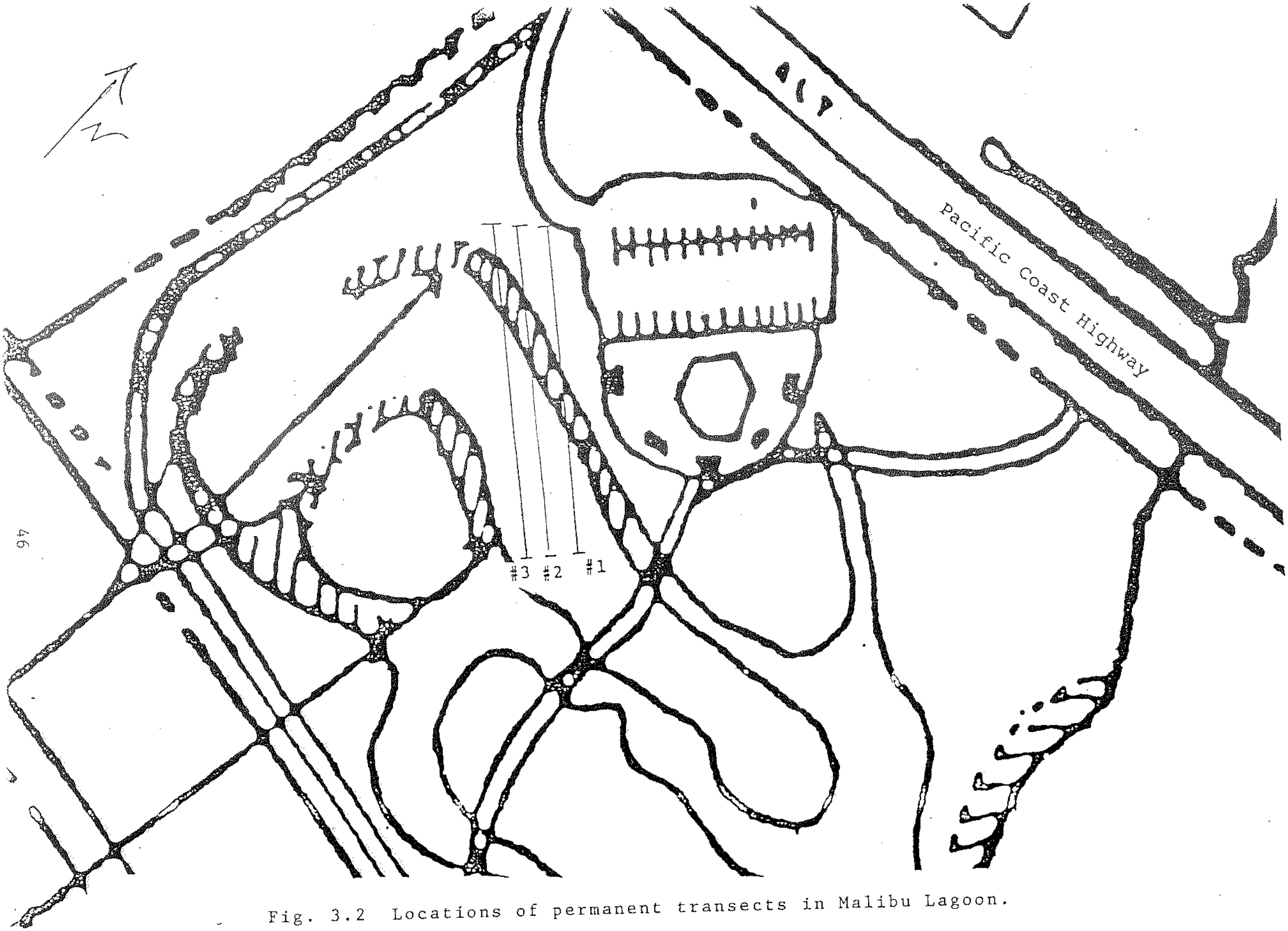


Fig. 3.2 Locations of permanent transects in Malibu Lagoon.

Along Transect #1, stakes were placed at 5 meter intervals so that accurate replication of the elevation data can be obtained in the future. Elevation changes along the transect were measured by using stadia poles and a line level. At each 5 meter interval, a soil sample was collected and labeled, and a square meter quadrant of vegetation was surveyed using the stake as the center point.

3.3.3 PLOT SURVEYS OF VEGETATION

Along Transect #1, one square meter of vegetation was surveyed at 5 meter intervals, using meter sticks to delineate the quadrant boundaries. Information recorded included: total number of individuals/clumps/stems of each species, maximum height, average height, soil type and visible moisture content, condition (blooming, dead, alive, dormant,etc.). Percent cover by class was determined according to Zedler and Nordby, 1986.

PERCENT COVER BY CLASS

1	less than 1%	4	26-50%
2	less than 5%	5	51-75%
3	6-25%	6	76-100%

Transects #2 and #3 were marked with stakes only at the start and the end (100 meters). No elevations were recorded. At 5 meter intervals along these lines, plot surveys of 0.25 square meter quadrants were conducted, including the same information as in Transect #1.

3.3.4 SOIL SALINITY

At each 5 meter interval along Transect #1 a soil sample was collected. Due to predominantly dry samples, a 50 cc collecting bottle was filled with soil and sent to the USDA Soil Conservation Service, Antelope Valley Resource Conservation District for analysis. There the conductivity of the uniform soil paste was determined (according to Richards 1954). To convert the conductivity units (mmhos/cm) to salinity in parts per thousand (ppt), the formula [mmhos/cm x 640 = _____ mg/liter/ 1000 = _____ppt] was used.

3.4 OBSERVATIONS

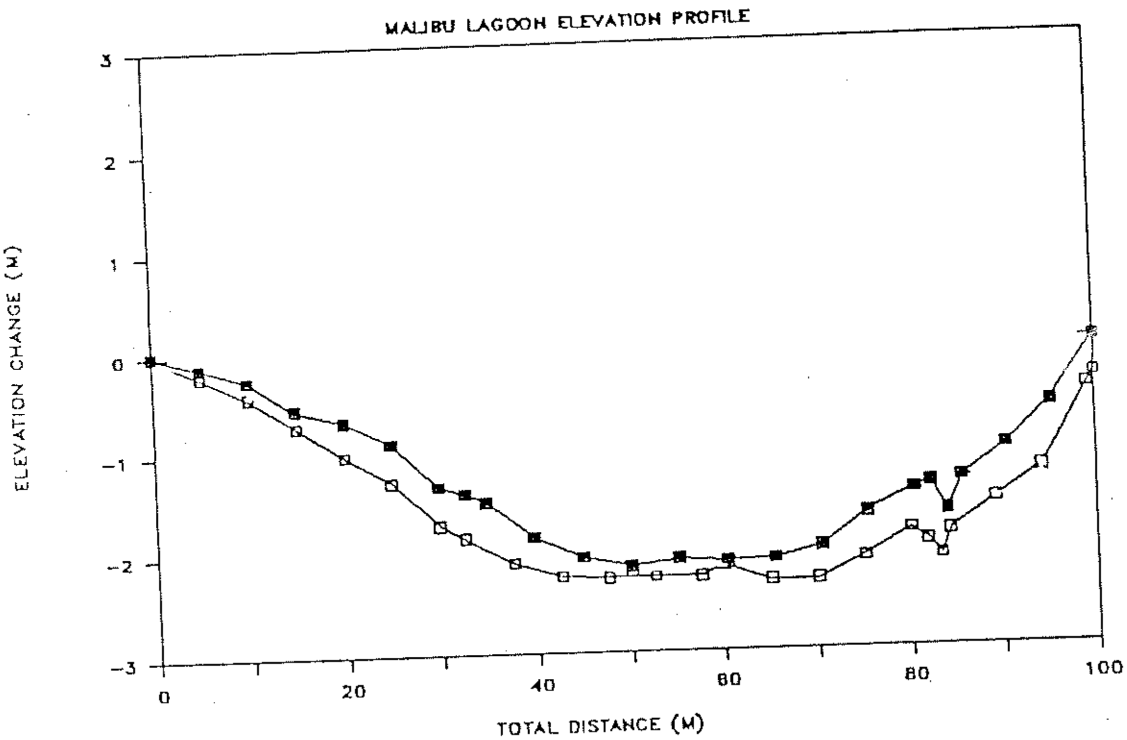
The botanical inventory revealed a total of 133 species of vascular plants in Malibu Lagoon (Figure 3.1). In addition to the native estuarine species, a wide variety of naturalized exotics and non-estuarine natives are also found at the Lagoon. This opportunistic growth has produced an ecosystem with little resemblance to less disturbed, zonated Southern California coastal salt marshes. It is important to note that Malibu Lagoon currently receives influx of large volumes of fresh water from the release of reclaimed waste water by the Tapia Water Reclamation Facility, which is located upstream on Malibu Creek. This surely plays a dominant role in the distribution of plants in Malibu Lagoon.

Another key factor influencing species distribution is their elevation with respect to incoming waters, both fresh and salt. Gradient along the channels is an important factor in determining the rate and extent of inundation. Normal slope is less than 0.7% in most estuaries (Zedler 1982). At Malibu Lagoon, the banks are steeper, and although they have moderated over time, they only become mud flats at the very ends of the back channels. The elevation profiles documented increased sedimentation during the winter of 1987-88, with an average increase of 18 cm (Figure 3.3). Channel A is included in the transects, and the width of the channel, as well as its depth indicate slow filling due to sedimentation. This effect may also be enhanced by the continued spread of the California Bullrush (*Scirpus californicus*) stands in the channel.

The distribution of species in less disturbed estuaries demonstrates a zonation based on the salt tolerance of the dominant species and their ability to withstand inundation. At Malibu Lagoon, the combined factors of restoration landscaping producing steep banks and higher than normal levels of fresh water have caused the natural zones to disappear. It has also been found in other areas that a period of little or no flow is as important a factor as periodic increased flow (Zedler, Koenigs and Magdych 1984). Thus the distribution is very mixed and the data is not sufficient to determine which of the many factors, or combinations thereof, are responsible.

The plot surveys and soil salinity data indicate that although the vegetation is disturbed, the underlying order could be related to salinity. Most estuarine species tolerate a range of between 15 and 50 ppt, with each species showing preference for a more narrow range. There are three dominant halophytes (salt tolerant species) at Malibu Lagoon: *Distichlis spicata*, *Jaumea carnosa*, and *Salicornia virginica*.

Fig. 3.3 Elevation profiles of transect #1, Malibu Lagoon, September 1987 and April 1988.



□ September 1987 ■ April 1988

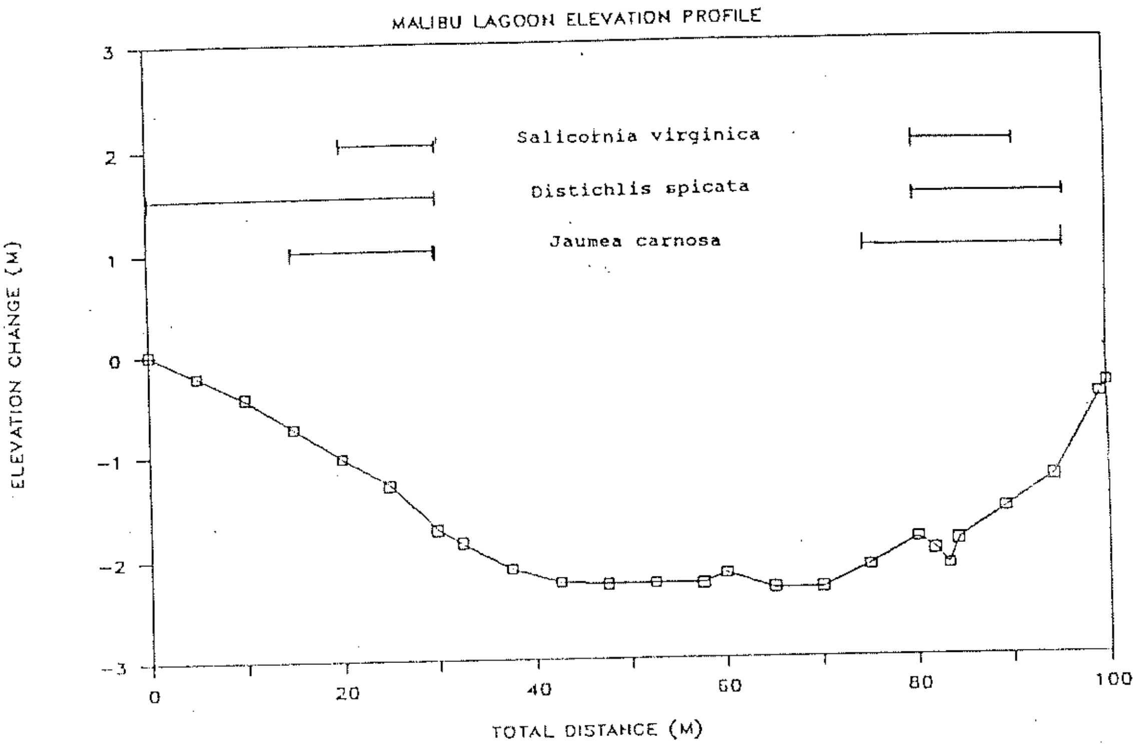
Under conditions common in other salt marshes, pickleweed (Salicornia virginica) is often the first emergent plant to establish dominance due to its perennial habit, vegetative reproduction, and ability to tolerate hypersaline soils. At Malibu Lagoon, the area surveyed NW of the visitor path appears to foster the growth of Jaumea carnosa and Distichlis spicata more than the pickleweed (Figure 3.4). This could be a reflection of the soil composition, which is mostly sand and fill, slowly being covered by decayed organic sediments carried by the water. It also could indicate that fresh to brackish water is more commonly present. Distribution of pickleweed follows points of higher soil salinity. It is not common in less saline areas. Salinity data for that channel was not collected, but in the adjacent channel (B), the range was from 0 to 34 ppt, with an average of 19.1 ppt. Despite the fact that pickleweed is usually larger in size than either of the other two dominant species, the data indicate that it was not only less numerous when counting individuals, but also when comparing percent cover (Figure 3.5). Over the winter months, the pickleweed appeared to die off, and during the April survey most plants were dried, with growth only at the tips.

Consequently, Jaumea carnosa and Distichlis spicata vie with each other for dominance. They too are found in hypersaline soils, but most often occur in less saline places. Perhaps the lower salinities found at Malibu Lagoon gives them the competitive advantage over pickleweed. This is somewhat unusual as Jaumea carnosa usually has difficulty competing with pickleweed. Pickleweed generally requires only a brief window of fresh water in order for its seeds to germinate, but if this period is extended, the germination rate is not as high (Zedler, Koenigs and Magdych 1984). Jaumea, on the other hand, germinates well in fresh water, and this may explain its relative competitive advantage at Malibu Lagoon.

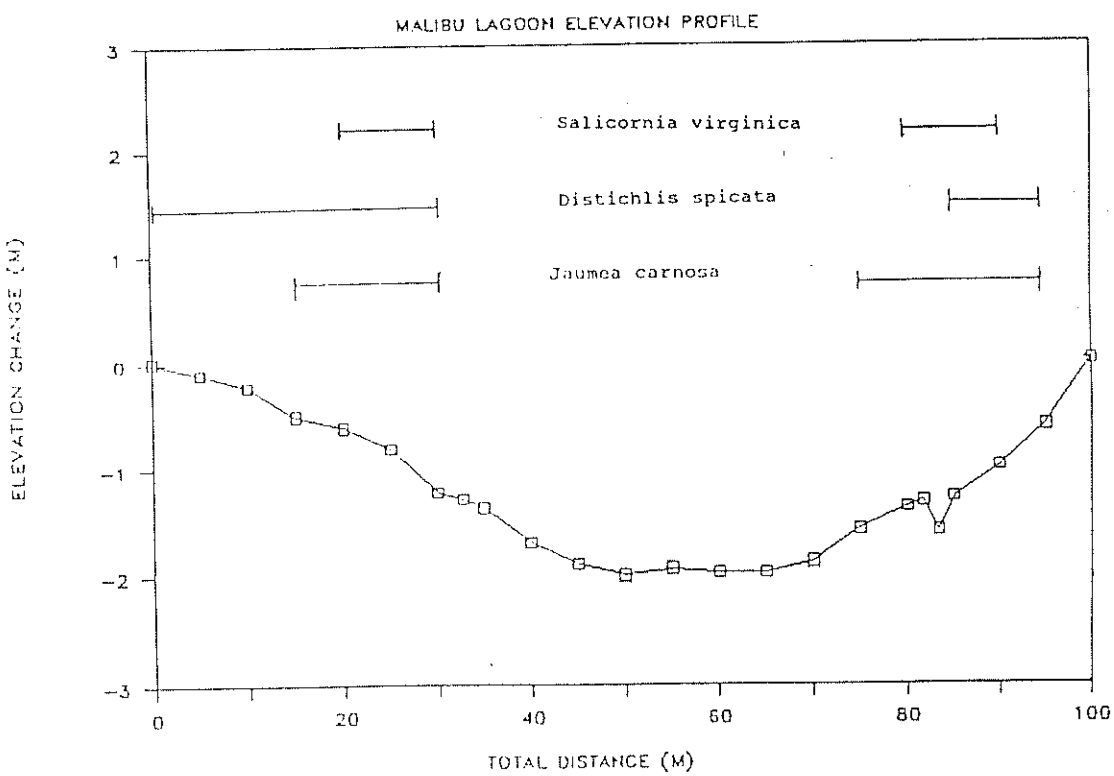
An interesting observation was that the parasitic plant Dodder (Cuscuta salina) covered large areas of Jaumea, and only rarely any other species. In areas where pickleweed and Jaumea were mixed, this was especially obvious. The reason for this preference is unclear, but warrants further investigation. Typically, salt marsh dodder is associated with pickleweed.

Distichlis spicata generally prefers less tidal inundation and sandy soils that provide good drainage. It may be that the fill left from the pre-restoration period has not yet been converted into more finely textured hypersaline soils, and still retains better drainage potential due to the high sand and gravel content.

Fig. 3.4 Relative distribution of three dominant halophyte species (*Jaumea carnosa*, *Distichlis spicata*, *Salicornia virginica*) in Malibu Lagoon, September 1987 and April 1988.



SEPTEMBER 1987



APRIL 1988

Fig. 3.5 Percent cover and total number of individuals for three dominant halophytes, Malibu Lagoon, 1987-1988

Total number of individuals
(0.25 meter square)

Species / Transect	#1 Sept.	#1 Apr.	#2 Sept.	#2 Apr.	#3 Sept.	#3 Apr.
Distichlis spicata	465	213	636	308	308	277
Jaumea carnosa	397	159	510	251	503	408
Salicornia virginica	35	22	154	28	220	116

Mean Cover By Class (Zedler)
(0.25 meter square)

Species / Transect	#1 Sept.	#1 Apr.	#2 Sept.	#2 Apr.	#3 Sept.	#3 Apr.
Distichlis spicata	4.8	5.2	4.1	4.4	3.4	3.5
Jaumea carnosa	4.6	5.1	3.5	4.0	3.8	4.5
Salicornia virginica	4.0	3.25	2.6	2.5	2.6	2.6

Note: Only 0.25 of the 1 meter square value for transect #1 was included in these figures.

PERCENT COVER BY CLASS (Zedler)

Class	Cover	Class	Cover
1	less than 1%	4	26-50%
2	less than 5%	5	51-75%
3	6-25%	6	76-100%

Visually, pickleweed appears to be the most dominant species in the Lagoon, especially in the area between the trail and the main Lagoon. No quantitative data is available to support that observation, but it would be interesting to pursue. Despite apparent visual dominance, it has been shown to be the least common of the 3 dominant halophyte species in the transected area.

Of the 133 species found at Malibu Lagoon, only a total of 39 were counted in the transects, which indicates their limited distribution, and the curious dispersal pattern of species. The number of species varied both seasonally and within transects. A total of 3 species were noted only in September, and 12 only in April (Figure 3.6). This data reinforces the need to repeat the transects at different seasons in order to obtain a more comprehensive understanding of the plant community.

In September, only 8 of the total species counted (20) were common to all 3 transects. Sixteen species were found in only one transect, and transect #2 had the lowest overall number of species (9). The April survey recorded a total of 35 species, of which 26 were common to all three transects. Again, transect #2 had the lowest diversity in comparison to that found in #1 and #3, which could be due to the wide salt pannes and dryness of the center part of the peninsula.

The majority of species found are naturalized exotics and other native plants normally not found in estuaries. Malibu Lagoon has a very small number of estuarine species in comparison with those found in other Southern California salt marshes (Figure 3.7). These two facts are important points to be considered when planning further restoration of the Lagoon. Eradication of all exotics would be costly and difficult, but a management plan that allows for the enhancement of native estuarine species needs to be established.

Perhaps the major variable effecting both distribution and growth of plants in Malibu Lagoon is the soil salinity (Figure 3.8). As might be expected, the salinities were much lower in April following the winter rains. The range in September was from 0.448 ppt near the trail to 34.56 ppt across the channel near the driveway by the entrance kiosk, with an average of 11.6 ppt. In April, the higher peninsula area remained fairly constant at 0.512 ppt, but the salinity increased noticeably at the other end of the transect to 27.52 ppt, with an overall average of 6.84 ppt. Greater variety of species was noted in areas with soil salinities of less than 15 ppt, which corresponds to the first 30 meters of the transect. Highest salinities corresponded to salt pannes found along the transect where there was little or no vegetation. The salinity of soil samples taken from

Fig. 3.6 Species found in all transects, Malibu Lagoon, 1987-88

SPECIES	FALL	SPRING	CSM	NATIVE	NATURALIZED EXOTIC
Ambrosia psilotachya	x	x		x	
Anagallis arvensis		x			x
Atriplex lentiformis	x			x	
A. patula hastata	x	x			x
A. semibaccata	x	x			x
A. species?	x	x			
Avena fatua	x	x			x
Baccharis glutinosa	x	x		x	
B. pilaris		x		x	
Bromis diandrus	x	x			x
B. mollis	x	x			x
B. wildenovii		x			x
Chrysanthemum coronarium		x			x
Conzya sp.		x			
Coreopsis gigantea	x			x	
Cressa truxillensis		x		x	
Cuscuta salina	x	x	x		
Cynodon dactylon	x	x		x	
Distichlis spicata	x	x	x		
Enteromorpha intestinalis (*)	x	x	x		
Festuca sp.	x	x			x
Foeniculum vulgare	x	x			x
Frankenia grandiflora	x	x	x		
Gasoul nodiflorum		x			x
Gnaphalium sp.		x		x	
Hypochoeris glabra		x			x
Jaumea carnosa	x	x	x		
Lolium perenne		x			x
Lotus scoparius	x			x	
Medicago polymorpha		x			x
Melilotus indicus	x	x			x
Parapholis incurva	x	x			x
Pennisetum clandestinum	x	x			x
Picris echoides	x	x			x
Polygonum aviculare		x			x
Salicornia virginica	x	x	x		
Scirpus californicus	x	x	x		
Sonchus oleraceus	x	x			x
Spergularia marina	x	x	x		

(*) drift algae consistently found along channel banks
CSM - Coastal Salt Marsh Species

Fig. 3.7 Comparison of Southern California coastal salt marsh vegetation, prepared by Bob Muns, with information from Zedler, 1982.

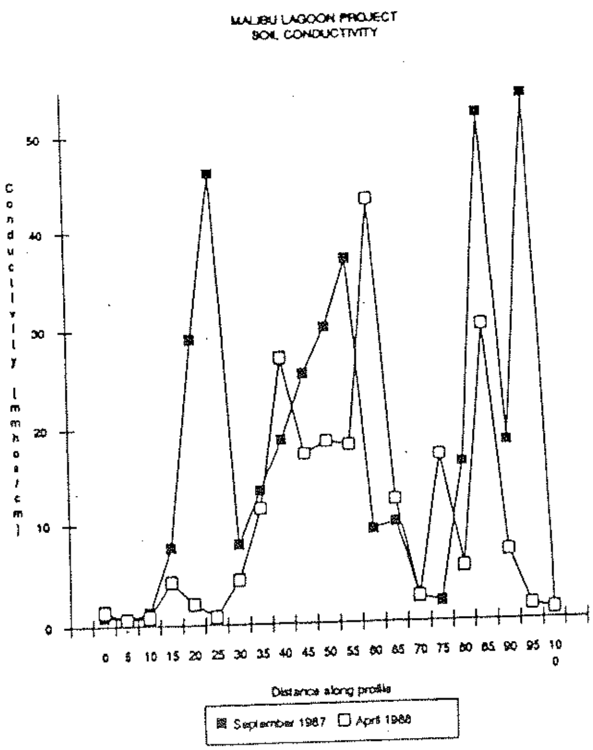
Common Name		Coastal Salt Marsh Species \ Coastal Salt Marshes	Tijuana Estuary	Torrey Pines Salt Marsh	Upper Newport Bay Marsh	Bolsa Chica Salt Marsh	Ballona Wetland	Malibu Lagoon	Point Mugu Lagoon Marsh	Carpinteria Salt Marsh
Spike Rush	High Marsh	Juncus acutus	●	●	●	●			●	●
Goldfields	High Marsh	Lasthenia glabrata	●	●					●	●
Alkali Weed	High Marsh	Cressa truxillensis	●	●	●		●		●	●
Salt Bush	High Marsh	Atriplex watsonii	●		●	●			●	●
Pickleweed		Salicornia subterminalis	●	●	●	●	●		●	●
Salt Marsh Bird's Beak		Cordylanthus maritimus	●		●				●	●
Sea Lavender		Limonium californicum	●	●	●	●		○	●	●
Shore Grass		Monanthochloe littoralis	●	●	●	●			●	●
Alkali Heath		Frankenia grandifolia	●	●	●	●	●	●	●	●
Succulent Arrow Grass		Triglochin concinnum	●		●			●	●	●
Sea Blite		Suaeda californica	●	●	●	●	●		●	●
Salt Grass		Distichlis spicata	●	●	●	●	●	●	●	●
Salt Marsh Dodder		Cuscuta salina	●	●	●	●		●	●	●
Jaumea		Jaumea carnosa	●	●	●	●	●	●	●	●
Saltwort	Low Marsh	Batis maritima	●		●	●			●	
Annual Pickleweed	Low Marsh	Salicornia bigelovii	●		●	●			●	
Pickleweed	Low Marsh	Salicornia virginica	●	●	●	●	●	●	●	●
Cordgrass	Low Marsh	Spartina foliosa	●		●	●			●	

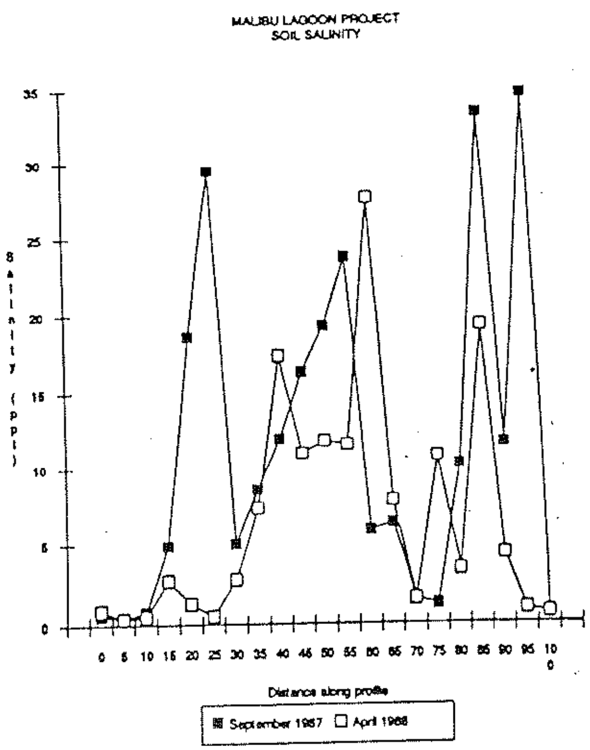
Fig. 3.8 Soil conductivity (mmhos/cm) and salinity (ppt) of transect #1, Malibu Lagoon, September 1987 and April 1988.

Distance Along Profile (Meters)	September Conductivity (mmhos/cm)	September Salinity (ppt)	April Conductivity (mmhos/cm)	April Salinity (ppt) **
0	0.9	0.57	1.4	0.896
5	0.7	0.448	0.6	0.384
10	1.2	0.768	0.8	0.512
15	7.6	4.864	4.2	2.688
20	29	18.56	2	1.28
25	46	29.44	0.8	0.512
30	7.8	4.992	4.3	2.752
35	13.3	8.512	11.4	7.296
40	18.6	11.904	27	17.28
45	25.4	16.256	17.1	10.944
50	30	19.2	18.4	11.776
55	37	23.68	18	11.52
60	9.1	5.824	43	27.52
65	9.8	6.272	12.1	7.744
70	2.4	1.536	2.4	1.536
75	1.9	1.216	16.8	10.752
80	15.9	10.176	5.2	3.328
85	52	33.28	30	19.2
90	18.1	11.584	6.7	4.288
95	54	34.56	1.4	0.896
100	1	0.64	1	0.64

* Questionable sample number due to difficulty reading sample label.

** Conversion: mmhos/cm x 640 = ____mg/liter / 1000 = ____ppt





the channel did not change markedly over the winter season, possibly indicating a relatively stable interstitial environment.

3.5 DISCUSSION

It is known that two major limiting factors affecting distribution and density of estuarine vegetation are soil salinity and elevation along a tidal gradient. Due to the dredging of the steep-banked channels in Malibu Lagoon at the time of restoration, there has been a remarkably opportunistic recolonization, showing little zonation common to an undisturbed system. Normally, a 0.7% slope is needed to provide the periodically inundated substrates which foster more regular zonation patterns (Zedler 1982). Because some planting was done of both native and non-native species, there is a large diversity of species. According to the preliminary list, there are a total of 133 species represented in the area. Of these 5.3% are native to estuarine habitats, 29.7% are natives, but planted as part of the landscaping effort, and 65% are introduced species which seed themselves.

The influence of varied water levels and the erratic circulation pattern of the Lagoon channels also has a strong influence on the distribution of species. During times when the mouth of the Lagoon is closed, freshwater levels can get high enough to seriously effect more halophytic species such as pickleweed (Zedler 1982), as well as those whose root systems require periodic drying out. One other important consideration is the quality of the water in this system. During times of heavy rains and high tides, waste water from the storm drains and septic systemss of nearby houses have been observed in the back channels. The long term effects of introducing these nutrients, especially nitrates and phosphates, and other possible pollutants is unclear.

Freshwater outflow from the Tapia Water Reclamation Facility represents another problem. The volume of water released varies seasonally, which makes for erratic inundations of silt and other sediments, as well as nutrients such as nitrates and phosphates. When high volume corresponds to spring tides and the closure of the Lagoon entrance, the water level in the Lagoon rises dramatically. More consistent monitoring of the Lagoon water levels, fresh and salt, in the future will help explain patterns of vegetation distribution and density.

Inundation of fresh and salt water in turn influences the residual salinity of the soils. The normal ranges for Southern California estuaries extends from the 45 ppt usually found during the dry season/years, to a range of 15-20 ppt during the rainy season, to lows of 0-20 ppt in wet years (Zedler 1986). At Malibu Lagoon the data for September indicate a range of 0.44 ppt in the higher elevations to 34.5 ppt found in a small depression near the furthest edge of the back-channel, with a range of 0.57 ppt to 27.52 ppt in April. The soil salinity along the transect showed wide variation and repeated surveys need to be done before any consistent patterns along the transect will emerge. This data does correlate to the overall water quality information which would categorize Malibu Lagoon as a brackish, rather than salt marsh ecosystem.

Distribution of vegetation follows some unusual patterns as a result of high levels of disturbance. Starting at the higher elevations, species common to more upland habitats (roadsides, coastal scrub, cultivated areas, disturbed coastal habitats) dominate. Shrubs such as Atriplex (sp.) and Baccharis glutinosa are common. These plants are associated with exotic grasses and dry soils. The dominant vegetation for these areas consists of the grasses.

Moving towards the lower elevations from the upland area, it becomes clear that three halophytic species dominate the area, Distichlis spicata, Jaumea carnosa, Salicornia virginica. Despite the fact that visual observations would lead one to conclude that Salicornia virginica is the dominant species, this proved false when actual counts were made. These plants are larger and woody, so that they are more obvious, but the truly dominant halophyte of Malibu Lagoon is Jaumea carnosa. The extended periods of fresh water inundation and steeper bank gradients seem to have provided a competitive advantage for germination and establishment of this species.

Along the channel banks, mats of drift algae (Enteromorpha intestinalis) were common. Periodic algal blooms occurred, but how these are related to nutrients provided by wastewater is not clearly documented. Several large stands of Scirpus californicus are found along the NE banks. These were planted during the restoration process and their spread through the channel needs to be closely monitored. They provide necessary nesting habitat for numerous birds, but could overtake the whole channel if not managed.

Also conspicuously absent from any area in the Lagoon is *Spartina foliosa*, commonly known as Salt Marsh Cordgrass. This could be the result of numerous factors such as extreme soil salinity, insufficient tidal circulation, or erratic freshwater influx. It is not known whether Malibu Lagoon ever had any Cordgrass, but certainly the heavy manipulation of estuaries by man has had a tremendous impact on the presence of this species in other estuaries.

Consistent monitoring along these transects should be very interesting, as Malibu Lagoon seems to be somewhat different from other Southern California estuaries in its vegetative pattern. How long will *Jaumea carnosa* and *Distichlis spicata* dominate? How does the water circulation through the Lagoon effect growth along the channels? What is the average salinity of the water in the back channels? What effects do the nutrients from run-off have on growth rates of different species? There is still much to learn, and continued monitoring following Phase II of the restoration is essential.

Malibu Lagoon, like other estuaries, is a vital part of the entire ecosystem of the coast. As the press of humanity increases, it becomes even more important to maintain estuaries, not only for recreation and as wildlife habitat, but also because of the important role they play in recycling wastes naturally, enhancing watersheds and providing a buffer against storms. The flora of Malibu Lagoon are an essential basis for the stability of the entire Lagoon, and greater understanding of how the system functions will allow a well infcrmed and useable management plan to be formulated.

3.6 SUMMARY

1. The reconstructed topography of Malibu Lagoon created steep channel banks which have been slowly filling in over the past 5 years to allow more natural tidal inundation patterns to return.

2. High volumes of fresh water influence the distribution of plant species, favoring those with greater tolerance to brackish rather than salt water.

3. There are 133 species thus far recorded at Malibu Lagoon. Of these, only 5.3% are native estuarine species. The majority (65%) are introduced and self-seeding exotics. Only 29.7% are native California species.

4. In contrast to other Southern California estuaries, Jaumea carnosa and Distichlis spicata are more prevalent than the more typical Salicornia virginica. Dodder (Cuscuta salina) preferentially parasitizes Jaumea. There is no evidence that any species of Spartina was present in Malibu Lagoon.

5. Future management of the Lagoon needs to carefully control introduced exotics and enhance the re-establishment of native estuarine species. Further information is also needed about the effects of nutrients introduced by runoff and water circulation patterns.

6. Malibu Lagoon provides a natural laboratory to document the restoration succession and patterns of vegetation in a disturbed ecosystem.

7. The flora of Malibu Lagoon is essential to the integrity of the ecosystem and allows the estuary to continue to act as a natural buffer zone against storms, recycle wastes and provide food, shelter and nursery areas for numerous organisms.

3.7 LITERATURE CITED

Ferren, W.R. 1985. Carpentaria Salt Marsh: Environment, History, and Botanical Resources of a Southern California Estuary. University of Southern California, Publication #4.

Ferren, W.R. 1988. personal communication to Jean Dillingham.

Muns, R. 1988. Flora of Malibu Lagoon. unpubl. pp. 4.

Munz, P. 1974. Flora of Southern California. University of California Press. pp. 1086.

Raven, P. H. et al. 1986. Flora of the Santa Monica Mountains, California. 2nd Ed. Southern California Botanists Special Publication No. 2. 181pp.

Richards, L.A. 1954. Diagnosis and Improvement of Saline and Alkaline Soils. U.S. Department of Agriculture. Agriculture Handbook No.60.

Zedler, J.B. 1984. Salt Marsh Restoration: A Guidebook for Southern California. La Jolla, CA: Sea Grant College Program, Institute of Marine Resources, University of California. pp.2.

Zedler, J.B. 1982. The Ecology of Southern California Salt Marshes: A Community Profile. U. S. Fish and Wildlife Service FWS/OBS-81/54. 110pp.

Zedler, J.B. and Nordby, C. 1986. The Ecology of Tijuana Estuary, California: An Estuarine Profile. U. S. Fish and Wildlife Services Biological Report 85(7.5) 104pp.

Zedler, J.B., R. Koenig and P. Magdych. 1984. Streamflow for the San Diego and Tijuana Rivers. San Diego Association of Governments. 51pp.

4.0 SEDIMENT SURVEY

4.1 INTRODUCTION

Sediments and currents, both in an estuary and along the beach, control those morphologic features which characterize any estuary. Deposition of sediments plays a crucial role in the distribution of benthic invertebrates. Most species are adapted to living within a narrow framework of sediment size and composition. The rate and type of sedimentation contributes to the establishment of benthic populations and their longevity (Komar 1976). At Malibu Lagoon, scouring and deposition of both fine and coarse sediments have led to the development of mud flats, tidal islands, sand bars, and relatively deep channels. These morphologic features control both the distance of salt wedge intrusion and the rate of tidal flushing.

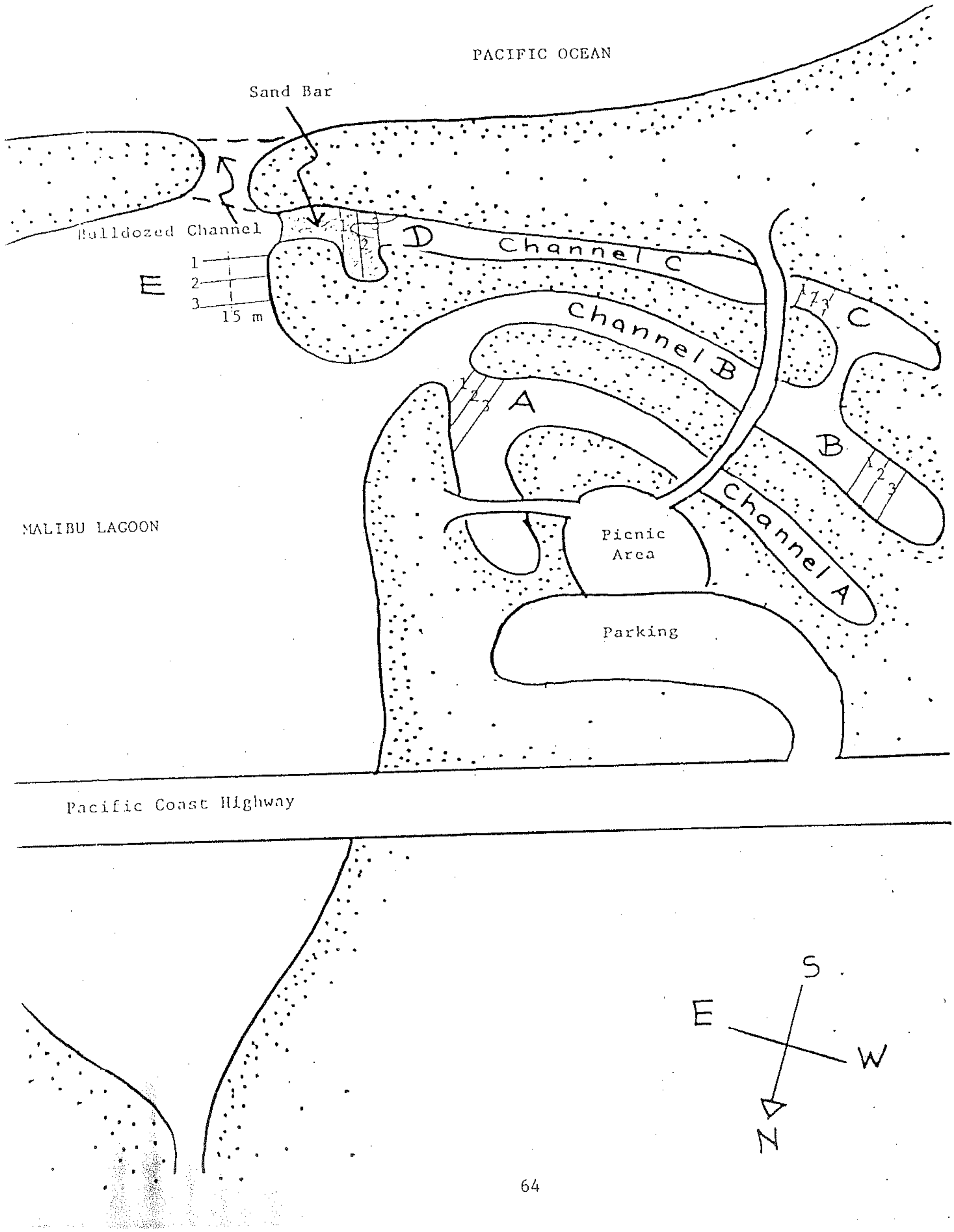
In 1983, approximately 36 acres of the Lagoon were restored. This included most of the study area where channels were dredged with U-shaped cross section and steep sloping banks. In the five year period since restoration the Lagoon has changed only slightly in morphologic features, with partial to complete infilling of the channels.

This is in sharp contrast to the Lagoon before restoration. Historically the study area was a flood plain, a vast consolidated upland area with features that contained grasses and small shrubs. The wetland area was significantly larger, and in the area of the present-day Malibu Colony was a large sand dune. Drainage from an extensive watershed flowed into the year-round Malibu Creek, characterized by very low flow during the summer months which allowed a sand spit to seal the ocean entrance. During winter storm periods, this entrance would be forced open by high water flows from the creek.

4.2 OBJECTIVES

The main objective of this survey is to study the distribution of sediments in the Lagoon as a measure of the recovery process after the 1983 restoration, when newly constructed clay-bottomed channels were free of any sediments. A second objective is to measure changes in sediment depth and composition in the Lagoon over time. By classifying and measuring sediments in core samples along different gradients at the Lagoon, a better understanding of this ecosystem may result.

MAP 4 A: SEDIMENT SAMPLING STATIONS AT MALIBU LAGOON



4.3 METHODOLOGY

All data is collected bi-monthly at five stations (A-E) located throughout the Lagoon (Map 4A). Surveys were made in November 1987 and January, March, and September 1988. Stations A, B, C, and D were sampled across an entire channel. Station E was sampled for at least 30 m into the main Lagoon. During each survey only one transect was made at each of the stations. In order to not unduly damage these soft sediment habitats the transects were offset by 20 feet for each survey. This offset is not believed to have biased the results since the stations appeared to be relatively uniform between transect lines. In all cases the western-most transect is labeled 1, with transect numbers increasing to the southeast. Three different transects were made at each station.

Samples are taken at 5 meter intervals from a fixed point on both banks, beginning and ending at the edge of the vegetation. A large core device, 15.6 cm in diameter and 61.5 cm long, is used to collect the sample (Fig. 4.1). This sample is examined and described. Information recorded includes: total depth, presence and width of any layers, a qualitative description of grain size and composition (organic vs. inorganic) and the presence of organisms.

At each of the sampling locations, a metal meter stick is manually pushed into the sediment as far as it will go. During the 1983 Lagoon restoration the channels were cut out of consolidated clays (Hasz 1983) which are essentially impenetrable by hand. Therefore, this technique provided an approximate measure of sedimentation over time. These measurements also give some indication of recent patterns of sedimentation or erosion.

4.4 OBSERVATIONS

The main Lagoon substrates are composed mainly of coarser grained sediments, mostly smaller cobble, gravels, and sands. At edges of the peninsulas on the west side of the Lagoon are short, almost vertical banks composed of clay, which were formed during the restoration process. Vegetation in this area is on top of the flat peninsulas, and none is evident along the shoreline. The seaward edge of the Lagoon is bordered by a spit composed of beach sands.

Stream flow from storms, and from tertiary treated sewage wastewater generated by the Tapia Water Reclamation Facility, maintained an open entrance throughout the winter months. Major storms in late October and December 1987, and in January 1988 scoured a channel through the Lagoon, maintaining an entrance until mid-April. A late arctic storm in April again flushed out the entrance channel, yet the entrance to the

Fig. 4.1 Diagram of sampling device used at Malibu Lagoon for sediment and invertebrate infauna surveys.

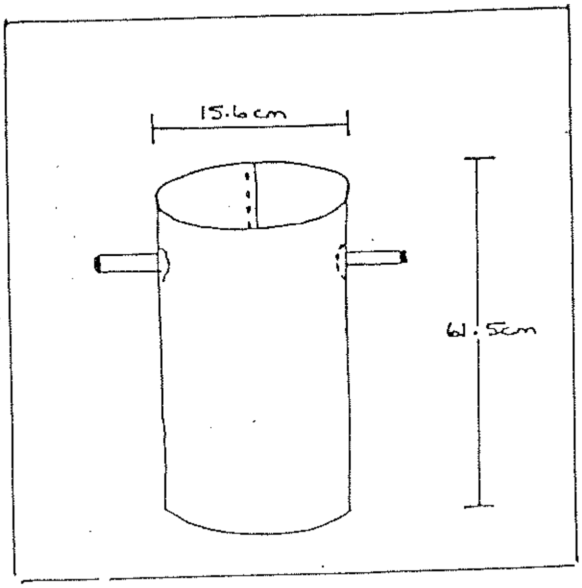


Fig. 4.2 Average amount of sedimentation in channels at 5 stations within Malibu Lagoon since 1983 restoration; includes changes in sedimentation patterns, Nov. 1987 - Sept. 1988.

STATION	AVER. SED. DEPTH (cm)	CHANGES IN SEDIMENTATION PATTERNS
A	40	-
B	43	-
C	36	-
D	extremely variable	15 m-wide sandbar formed beginning in October 1987 blocks water circulation in Channel D (Map 4 A) when water levels are below 2.75 ft.
E	*24	Winter 1987 storms eroded sandbar beyond 15 m from shore, by approximately 21 cm.

* average depth, 5-15 m from shore

Lagoon was closed after only three days. From this period on, California Department of Parks and Recreation (DPR) has experienced difficulty in maintaining an open entrance, with six closures noted in just eight weeks. When Lagoon water levels exceed 3.5 ft, DPR is mandated to open the entrance to the Lagoon near Malibu Colony. The longshore transportation of sand along the ocean beach and tidal action bring sand through the entrance, where it is deposited in slower moving water in areas near the entrance. Tidal action also brings in organic material, in the form of drift coastal algae, which is deposited both in the main Lagoon and inlet channels.

When left unmanaged, the sand bar at the entrance gradually moves eastward, toward Malibu Pier. Beginning in October 1987, when a deep water channel existed at the managed entrance location, a meander began to develop in the channel, with the formation of a sand bar on the west side. By the beginning of December, the sand bar had increased substantially to the east (approximately 600 m from a marked signpost), and the channel showed a strong oxbow configuration. In early May, this natural entrance was filled with sand by Los Angeles County Lifeguards, followed by a new entrance, cut at the former "managed site" near Malibu Colony.

Station E, the only study site within the main Lagoon, appears to be subject to alternating periods of rapid deposition and erosion. A sand bar of medium to coarse grained sand had been previously deposited along the west shore of the Lagoon. This sand bar extended at least 45 m eastward across the Lagoon. It was maintained from September 1987 through January 1988. Between January and March 1988 extensive erosion occurred, removing that portion of the sand bar which extended more than 15 m from shore. The thickness of sediments at distances greater than 15 m from shore decreased by approximately 21 cm.

All of the stations within the dredged channel system (A, B, C, and D) showed a significant amount of infilling since the 1983 restoration (Figure 4.2)

Station D, at the entrance to Channel C is the site nearest the ocean entrance and has been subjected to rapid deposition. Much of the channel was infilled between the January and March 1988 surveys, with sands overlaying sediments composed of fine sand mixed with some mud. The development of a small sand bar, 15 m in width, at the entrance to this channel (Map 4A) in October 1987 has affected the patterns of water movement when the levels in the Lagoon are below 2.75 ft. At lower water levels, water on outgoing tides must exit from the B channel. Drift coastal algae is often deposited, adding pockets of organic material. Sediment depths have increased in this channel by about 18 cm on the north side, and *Salicornia virginica* has begun to colonize this area.

Station C has the most diverse sediments of the survey. These vary from light colored beach sands to highly organic black silts and muds. A large amount of sedimentation has occurred here since the 1983 restoration, averaging 36 cm at the center of the channel. However no measureable changes occurred during this study. Drift coastal algae is often carried as far up as this study site.

The furthest study site from the main Lagoon and the channel entrance is Station B. This is the best example in the Lagoon of a mudflat. Sediments are deep, mostly unconsolidated fine, organic muds in the center of the channel, grading into some coarser silts and fine sands near the edges of the salt marsh vegetation. This vegetation, dominated by Jaumea, is encroaching into the channel, approximately 2 m on the north side and almost 4 m on the south side. Sediment thickness at this location has not changed significantly during this study. The average thickness of sediments deposited since 1983 in the center of the channel was 43 cm. There is a shallow, but well-defined channel for water in the middle of the inlet. At low tide, the mud-flat is usually exposed. Elevations of the peninsula between channels B and A has also increased, with an average of 18 cm more sediments noted in the April 1988 vegetative survey than was recorded in September 1987.

Station A is near the exit of two small inlets which enter the main Lagoon. This study site is composed of highly organic fine muds and clay. Drift algae and holdfasts are regularly carried, and deposited in this channel by tidal currents. The average thickness of the sediment in the center of the channel at Station A was 40 cm.

Water circulation patterns in the Lagoon remain largely unstudied. Observations made during a 24 hour survey in June 1988 indicate that when the entrance to the Lagoon is opened by the bulldozer, water flows faster out of Channel C than from Channel B. Flow out of both channels have been clocked at a 1 inch drop in water level in slightly less than 2 minutes. It is only when water levels in the Lagoon drop below 2.75 ft. that circulation patterns in the inlet channels change. At that point the sand bar at the mouth of Channel C is exposed, and water from all the inlets must flow out Channel B.

4.5 DISCUSSION

From these surveys, trends in sedimentation patterns and distribution of sediments, including sand spit growth along the beach, have been noted. The general circulation patterns observed may affect the distribution of sediments throughout the Lagoon.

Sedimentation patterns reflect both the patterns of water movement and the velocity of flow. As expected, faster moving water near the creek and ocean entrance results in the deposition there of coarser particles (cobble, gravel, and sand). Slow flowing water carries fine sediments (mud, silt, fine sand) into the inlets. The addition of drift coastal algae was noted in all study sites except Station B and provided material which is eventually incorporated into sediments as a major organic component. Water circulation patterns in the Lagoon remain to be studied if the sedimentation patterns are to be fully understood. For instance, the building of a sand bar at the entrance of C channel has significantly altered water flow patterns in the B and C inlets, directing all flow through channel B when water levels are below 2.75 ft. The result is that water often stagnates at Station D.

Sediments carried during storm activity and by large volumes of fresh water from the Tapia facility most likely accelerate the rate of downstream deposition. As stream discharges increase, the sediment load which a stream can carry increases proportionally (Lutgens and Tarbuck 1986). Measurements of the present carrying capacity of Malibu Creek and downstream sedimentation in Malibu Lagoon need to be made. Management of an ocean entrance to maintain water quality in the Lagoon throughout the year has surely increased the rate of deposition of both sand and organic material (drift algae) near this managed entrance. During periods of natural closure, from April until the first winter storms occur, no deposition would be expected to occur by ocean transport.

During periods of closure, water continues to enter the Lagoon from the Tapia plant and from Creek drainage. Due to difficulty in getting the one bulldozer to the Lagoon to open the entrance when water levels reach the mandated 3.5 ft, water volumes in the Lagoon are often high, reaching levels as high as 5.2 ft. The management of the position of the entrance has been debated among homeowners in the Malibu Colony and the surfing community, and the L.A. County Department of Beaches and Harbors, who provide lifeguard services for the outer beach. The natural entrance to the Lagoon, which is to the east of the managed entrance, prevents lifeguard vehicles from reaching the lifeguard tower near Malibu Colony. The provision of an emergency vehicle at this site would end any need for management of the entrance for emergency lifeguard services.

Since water exits rapidly upon opening of the entrance, fine sediments may be carried away. Station B is least affected by the rapid drop in water levels as the shallow configuration of its channel holds low volumes of water. The deeper channel configuration found at Stations A, C, and E can carry larger volumes of fast-moving water, and has the potential of moving greater amounts of sediment. The scouring capacity of water was exemplified by the rapid erosion of the sand bar at Station E in the main Lagoon in January 1988, when a major storm occurred in conjunction with a very high tide. Waves were breaking into the Lagoon. The storm cut a channel through the beach berm and the water level dropped quickly with the rapidly outgoing tide (about 1 in/5 min). The scouring we observed at Station E is likely to have occurred during this period.

The compromise position of the entrance has clearly affected sedimentation patterns in the Lagoon. Deposition of beach sand will always occur at the mouth of the Lagoon. Any channel located near an ocean entrance will quickly fill with sediment. Therefore, the position of the Lagoon entrance cannot be near a restored channel if that channel and associated water circulation patterns are to be maintained. For proper management of Malibu Lagoon the choices are to move the main Lagoon entrance eastward, or alter the channel configuration.

Historic patterns of sedimentation and water flow in the Lagoon indicated a slow progression of infilling which was also noted in this study. It is likely that increased water flow from the Tapia facility will accelerate this process. A management plan needs to be developed by the agencies and organizations who affect the entire watershed so that a comprehensive management plan can be developed for the future. What occurs upstream and along the beaches clearly affects the Lagoon.

4.6 SUMMARY

1. The rather deep channels designed and built during the 1983 Lagoon restoration project are filling with sediment. Grain size of the sediment varies with water velocity and volume in each channel.

2. Beach sands are deposited inside the mouth of the Lagoon. Because of the proximity of the Lagoon's managed entrance to Channel C these deposits are filling the opening to this inlet (Map 4A).

3. The Tapia Water Reclamation Facility plans to increase its discharge of tertiary treated waste water into Malibu Creek. The resulting increase in water flow will increase the volume of sediments deposited in the Lagoon by an unknown amount.

4. Opening of the entrance needs to be timed to coincide with an outgoing high tide for the entrance to remain open for any time. To minimize the removal of sediments, water levels should not be permitted to rise above the mandated 3.5 ft. More regular opening, or a permanent method of regulating water flow to the Lagoon needs to be considered in the final management plan.

5. This study has only touched on the information needed concerning sedimentology and patterns of water circulation in Malibu Lagoon. Future studies should include:

a. direct measurement of depositional and/or erosional rates

b. circulation patterns within the Lagoon

c. salt wedge intrusion

d. beach berm height

e. mapping the natural migration of the Lagoon entrance over time

f. monitoring the volume of water in Malibu Creek

6. The management of the entire watershed by those agencies and organizations affecting it are clearly needed if Malibu Lagoon is to become a functional estuary.

LITERATURE CITED

Davis, R.A, Jr. 1983. Depositional Systems- A Genetic Approach to Sedimentary Geology. Prentice Hall.

Hasz, L. 1983. Malibu Lagoon: A Local Resource. CSUN. unpublished. pp.10.

Kennett, James. 1982. Marine Geology, pp. 286-298. Prentice Hall. pp.787.

Komar, Paul, D. 1976. Beach Processes and Sedimentation, pp.203-223. Prentice Hall.

Lutgens, Frederick K. and Edward J. Tarbuck 1986. Essentials of Geology, 2nd edition, Charles E. Merrrill Co. pp.346.

Nordby. C. and J. Covin 1988. Physical, Chemical and Biological Monitoring of Los Penasquitos Lagoon. Los Penasquitos Foundation. Unpublished.

U.S. Congress, Office of Technology Assessment. Wastes in Marine Environments, 1987. OTA-O-334 (Washington, D.C.; U.S. Government Printing Office. pp.304.

5.0 BENTHIC INFAUNA SURVEY

5.1 INTRODUCTION

One way to measure the recovery of Malibu Lagoon since the 1983 restoration is to examine the density and diversity of organisms colonizing the sediments, such as invertebrate worms and clams. It seems that these creatures are particularly sensitive to changes in their environment, and their presence or absence can be used to indicate the relative "health" of an estuary (Crippen and Reish 1969). In polluted habitats, large numbers of only a few species are common. Species diversity is often lower when salinities fall below 8-9 ppt. Also, size and composition of sediment particles produce strong limits, as well as the rate of deposition. These species tend to be tolerant of low levels of dissolved oxygen and are principally scavenger feeders (Crippen and Reish 1969).

One concern at Malibu Lagoon is the steep gradient of the banks along the inlets, which dramatically affects the distribution of sediments and the rate at which tidal inundation occurs. In less disturbed estuaries, the bank gradient rarely exceeds 0.7% (Zedler 1982) which allows a more gentle and extended tidal flushing, and there is a more definite pattern of zonation related to tidal inundation which effects the distribution of both plants and animals. With further modifications of the estuarine hydrology of Malibu Lagoon pending, it is important to begin understanding the current population status of sediment dependent organisms.

5.2 OBJECTIVES

The main objective of this study is to identify and quantify the population of benthic infauna found in the lagoon, and monitor both population distribution and density over time.

5.3 METHODOLOGY

Benthic infauna surveys are done bi-monthly in conjunction with the sediment profiles. These samples were collected at low tide, and the tidal range in the survey area is 4-5 feet. See map A for exact locations.

MAP A Study Stations at Malibu lagoon

5.3.1. POLYCHAETE WORM SAMPLING

In order to randomize the sampling, a plastic lid is thrown into the channel. The place where it lands along the sediment profile is measured and distance from the North bank recorded. A total of three #1 cores (14 cm diameter x 13.9 cm depth) are then taken there, at 1 meter intervals parallel to the bank. Each core is examined for evidence of polychaete habitation, either worm tubes, worms, or both. In addition, the sediments are carefully described. A cross section of the core is taken and all worm tubes counted.

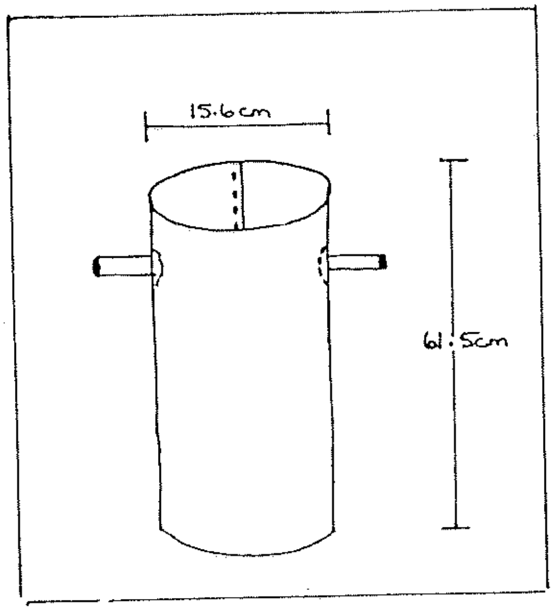
The standard methodology (according to Zedler and Nordby 1986) for determining density of worms requires the use of a "clam gun" which is equivalent to a #3 can (15.6 cm diameter x 17.0 cm depth). Three replicates of this size were unmanageable within the time framework, so only 1 core sample was taken along the sediment transect. After recording sediment description and depth of core, the sample is sieved through a fine 1 mm wire mesh screen. Worm tubes and worms are separated out and measured by volume displacement in a graduated cylinder. However, it appeared that the counting of worm tubes in the core cross section seemed to give a more accurate measurement of worm population than did the volumetric displacement which was biased due to the adherence of sediment particles to the tubes. As a result, cross-sectional counting was instituted as the standard measure in the September 1987 survey. Data from earlier surveys was not included in analysis.

5.3.2 CLAM SURVEY

The same core samples as those used for the polychaetes are also used for counting clams. Initially, the clams were escaping from the #3 cores, and on occasion this still occurs. However, the design and use of a new, large coring device (15.6 cm x 61.5 cm depth) has produced a better capture rate. This device was designed and made by Bob Jensen, Jr. specifically for our sediment samples (Figure 5.1). It is made of metal stovepipe, with pipe handles near the top, secured into fittings. By covering the top of the core with a #3 plastic coffee can lid, the enclosed sample can be removed for examination. The clam capture rate increased dramatically with the use of this tool, as it prevented the clams from escaping and allowed greater core depth.

Information collected includes: condition of clam (alive, dead), shell length, shell height at beak, diameter of any clam burrows. The burrow diameter is measured in the hope of being able to predict clam size from empty burrows in the future.

Fig. 5.1 Diagram of clam sampling device used at Malibu Lagoon for clam survey.



5.4 OBSERVATIONS

Repeated sampling at 5 locations in Malibu Lagoon revealed an infauna limited to two species of invertebrates; a spionid polychaete, Polydora nuchalis and a tellinid bivalve, Tagelus californianus. The two species will be discussed separately.

5.4.1 POLYCHAETE OBSERVATIONS

Only one species of Polychaete, Polydora nuchalis has been consistently identified in the sediments of Malibu Lagoon. Several different species are known to inhabit nearby waters (Smith 1975), but close examination of samples from Malibu Lagoon indicated a monoculture (Harris, pers. comm.). Polydora nuchalis is a species of segmented worm (Annelida) most frequently found in estuaries having the correct range of sediment sizes necessary for tube construction, feeding and burrowing, as well as a wide range of salinity (Woodwick 1953). In general, populations of polychaetes seem to peak during the spring and summer, with high adult mortality following reproduction and prior to resettlement of free floating larvae (Woodin 1974, Reish 1971).

Polydora nuchalis (Figure 5.2) found in Malibu Lagoon are segmented and transparent, ranging in length from 2-10 mm. The tubes they construct are a result of their burrowing into the sediment (Ricketts and Calvin 1985), and consist of consolidated fine silts. In some cases, the tubes can be extracted intact, but those at Malibu Lagoon were thin, somewhat flimsy and no greater than 15-20 mm long. It was very difficult to separate out the tubes and worms from the surrounding sediments. Methodology established by Zedler and Nordby, 1986 for other Southern California estuaries is based on separating out worms and tubes to be measured volumetrically. In order for this survey to be comparable to that of other estuaries, this methodology was initially followed. However, the displaced volume results (done only with the #3 sample) from Malibu Lagoon are biased due to the inclusion of inseparable sediments in volume measurement (Figure 5.3). In order to obtain more accurate results, a new methodology was instituted in September 1987 which allows comparison to data from other areas, but also reflected the characteristics of the species particular to Malibu Lagoon.

Taking a cross section of the core and counting the visible tubes seemed to be a more reliable indicator of population density for Polydora nuchalis. Therefore, the tubes found on the top of each core (both from the #3 and #1 cores) were counted, and then the core was cross-sectioned

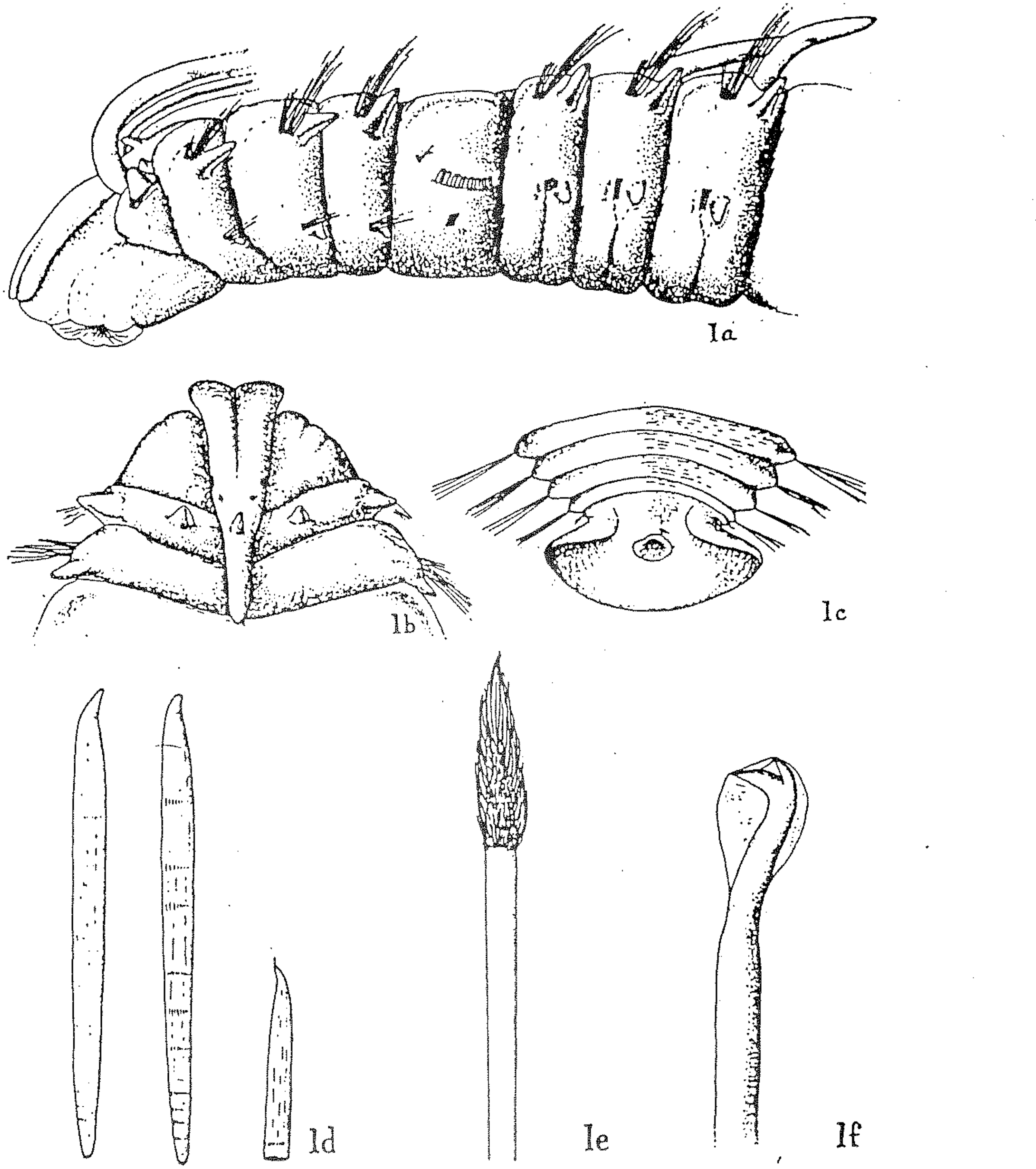
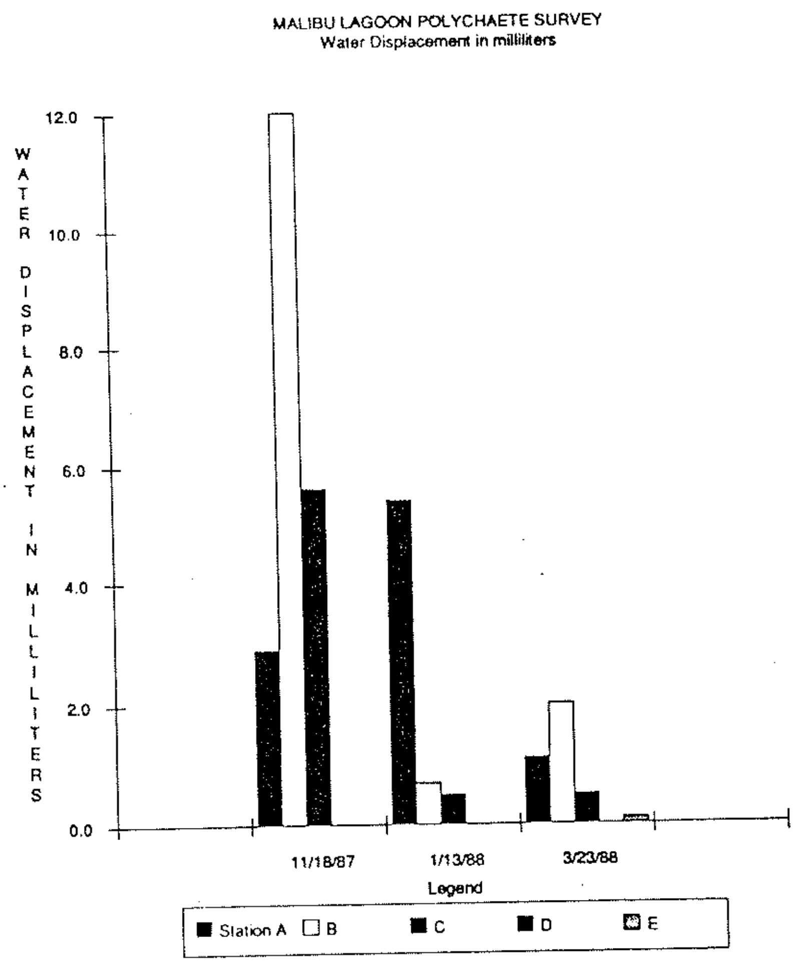


Fig. 1. Polydora nuchalis, n. sp.: a) Anterior end, in left lateral view, X53;) anterior end, in dorsal view, X53; c) pygidium, in posterior dorsal view, Xte; d) stout pines of the modified fifth segment showing new, worn, and developing spines, X122;) companion seta of the modified fifth segment, X529; f) ventral hooded hook from the eventh segment, X710.

Fig. 5.2 Illustration of Polydora nuchalis, from Woodwick, 1953 (fig.1).

Fig. 5.3 Volume measurements of Polychaete worm survey, according to methodology of Zedler and Nordby, 1986, from 5 stations at Malibu Lagoon.



in 2-5 cm intervals to determine how far down into the core the burrows extended. Although individual tubes were quite short, clusters of tubes frequently extended down to depths of up to 36 cm. They extended down to 14 cm on the average. Often the tubes protruded slightly above the sediment surface making them readily visible for counting. Since only one worm per tube was observed, an accurate population density can be determined with this methodology. In future studies, fewer replicates per transect would be another way to reduce the impact of the study.

Density seems to be tied closely to habitat and sediment distribution. Greater numbers of worms were found at stations A, B, and C (Figure 5.4), all of which share common characteristics. The sediments are mostly composed of organic mud (rich in hydrogen sulfide), clay, and silt, with lots of decaying algae on the surface. The mud flats at station B are usually exposed at low tide, while those of stations A and C generally remained covered by a few centimeters of water. Higher concentrations of worms were found towards the center of the channels, rather than along the banks. By contrast, stations D and E are less muddy and composed mostly of sands and gravels. Data collected in early samples indicated that prior to the influx of sand, worms were abundant. This illustrates the direct relationship of sediment deposition and composition to the distribution of these organisms. These 2 stations are also closest to the influence of incoming ocean water, with potentially stronger currents capable of removing sediments and their worm inhabitants.

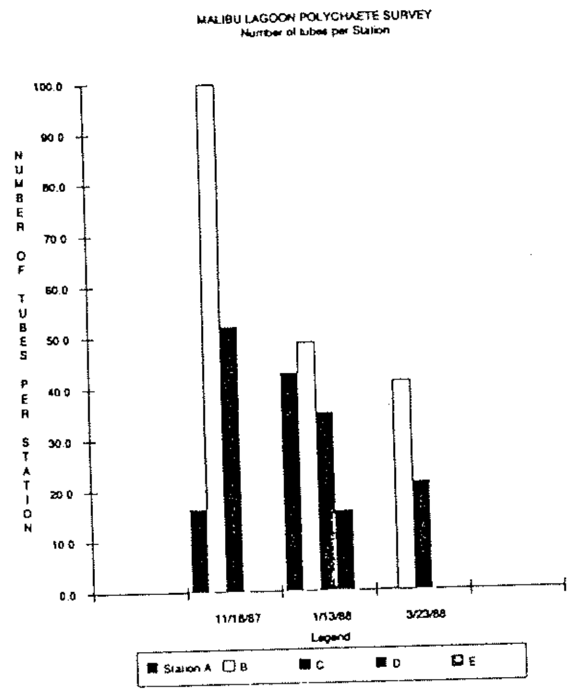
It is not clear how water quality parameters effect the population of *Polydora nuchalis* in Malibu Lagoon. In other areas, species of polychaetes seem to tolerate moderate to high levels of turbidity, extremes in water temperature (probably moderated by less variability in interstitial temperature), and variable salinity. The most significant limiting factor documented is dissolved oxygen, and no species of polychaetes are found in water having levels less than 0.3 mg/l (Crippen and Reish 1969). Malibu Lagoon has extremely variable ranges of salinity, temperature and dissolved oxygen (which only occasionally drops below 7 mg/l), due to the influx of water from the ocean and Malibu Creek. Extended periods of fresh water inundation from the Tapia Water Reclamation Facility, impounded due to the closure of the Lagoon ocean entrance, may also be a limiting factor, although no interstitial water samples were taken to see if the salinity, temperature and dissolved oxygen changes extended into the sediments. In other locations, random population fluctuations have been documented that are not explainable (Woodin 1974). No correlations were observed in this study between *Polydora nuchalis* density and the chemical parameters measured in the Lagoon.

Fig. 5.4 Average number of tubes found in cross section counts of #1 and #3 cores from 5 stations at malibu Lagoon.

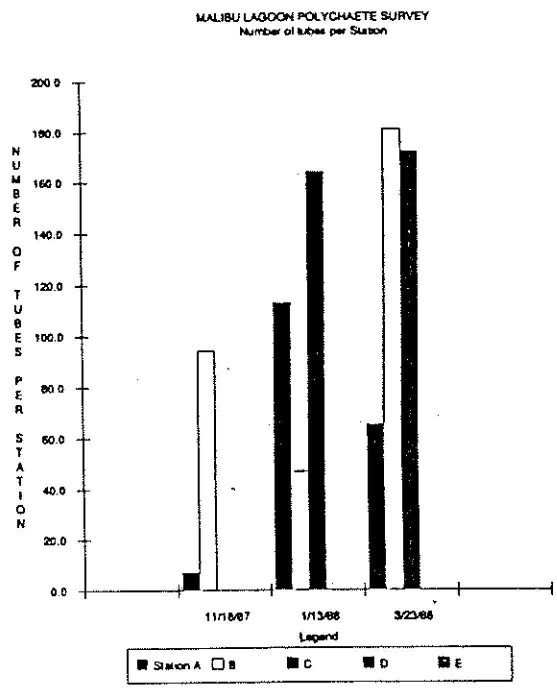
MALIBU LAGOON POLYCHAETE SURVEY
Average Number of Tubes per Station

DATE 1# can	STATION A	B	C	D	E
11/18/87	16.3	99.7	52.0	0.0	0.0
1/13/88	42.7	46.7	35.0	15.7	0.0
3/23/88	0.3	41.0	21.3	0.0	0.0

3# can	A #	Displ.	B #	Displ.	C #	Displ.	D #	Displ.	E #	Displ.
11/18/87	7.0	2.9	94.0	12.0		5.6	0.0	0.0	0.0	0.0
1/13/88	113.0	5.4	47.0	0.7	164.0	0.5	0.0	0.0	0.0	0.0
3/23/88	65.0	1.1	161.0	2.0	172.0	0.5	0.0	0.0	0.0	0.1



#1 Core



#3 Core

Station B had the largest population of polychaetes. It is the most shallow channel and the only area besides station D that is consistently exposed at low tide. It is also one of the preferred feeding sites for probing shorebirds. Station C also had a very high density, but always has a minimum water level of several centimeters, and fewer feeding shorebirds. The effects of predation by shorebirds is unknown. The dynamics of the population, seasonal differences, reproduction, response to changing environmental conditions, etc. require a larger database. Observations from the Fall 1988 school tours indicates an increase in population, indicating that late summer and early fall is a time of seasonal reproduction. This study should be extended for several years in order to document trends.

5.4.2. CLAM SURVEY OBSERVATIONS

Only one species of bivalve, the California Jacknife Clam (Tagelus californianus, Figure 5.5) was found in the Malibu Lagoon survey. These animals are common residents of intertidal mud flats that are somewhat sandy as well. They range from Monterey Bay, south to Panama. These clams can reach a length of 10 cm, and the shell is elongated with the hinge in the center. They are able to move quickly through the sediments, using a long, flexible and very strong foot which cannot be withdrawn totally into the shell, thus leaving gapes at each end of the clam where the shell doesn't completely close. This is one of its most characteristic features. Burrows extending down as far as 50 cm have been recorded, and the clam moves freely up and down within these permanent homes. It mostly resides near the surface, so as to be able to extend the 2 siphons used for filter feeding (Ricketts and Calvin 1985), but will descend into the burrow when threatened by predators.

Those specimens found at Malibu Lagoon ranged in length from 30.5 to 67.5 mm., with heights of 13.0 to 23.5 mm (Figure 5.6, 5.7). Although samples were collected in September, November, January and March, no seasonal difference in size class was noted. Thus the pattern of reproduction remains to be determined. A difference in distribution was very definite, and again seemed to correlate to sediment characteristic preferences. The greatest density of clams was found at station C, where the sediments are composed of organic mud, clay and silt, and there is a continuous covering of at least several centimeters of water. Stations B and A also had substantial populations, in contrast to stations D and E, where the only clams found were dead, empty shells following the covering of original muds with sands. These seemed to have been transported from other areas of the lagoon. It is interesting to note that although there were greater numbers

Fig. 5.5 Tagelus californianus indicating standard measurements taken for clam survey from 5 stations at Malibu Lagoon. (Illustration from Reish 1972).

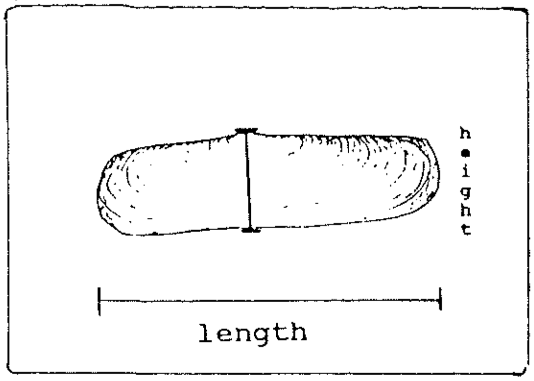


Fig. 5.6 Average length of Jacknife Clams (<u>Tagelus californianus</u>) from 5 stations at Malibu Lagoon.

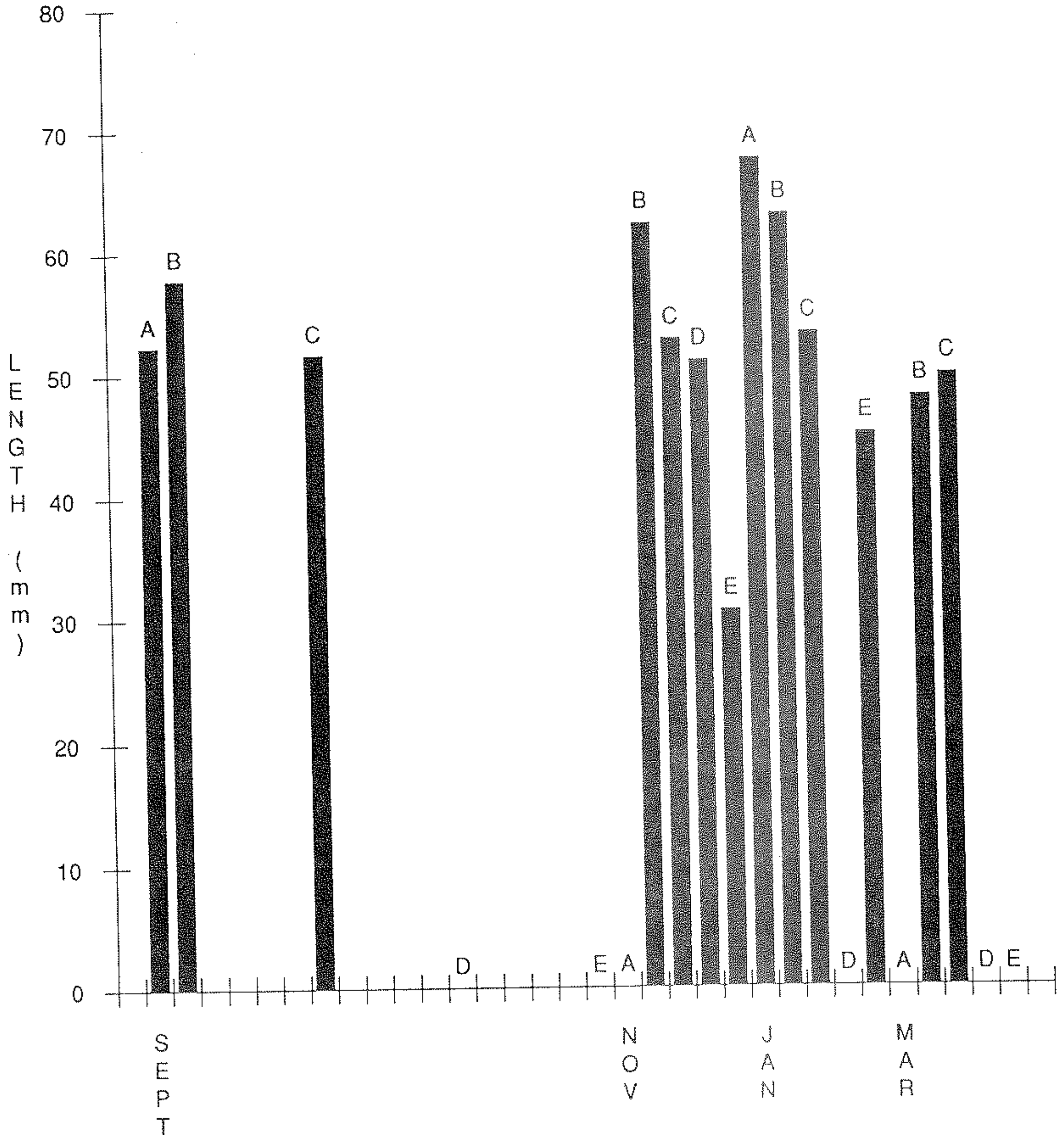
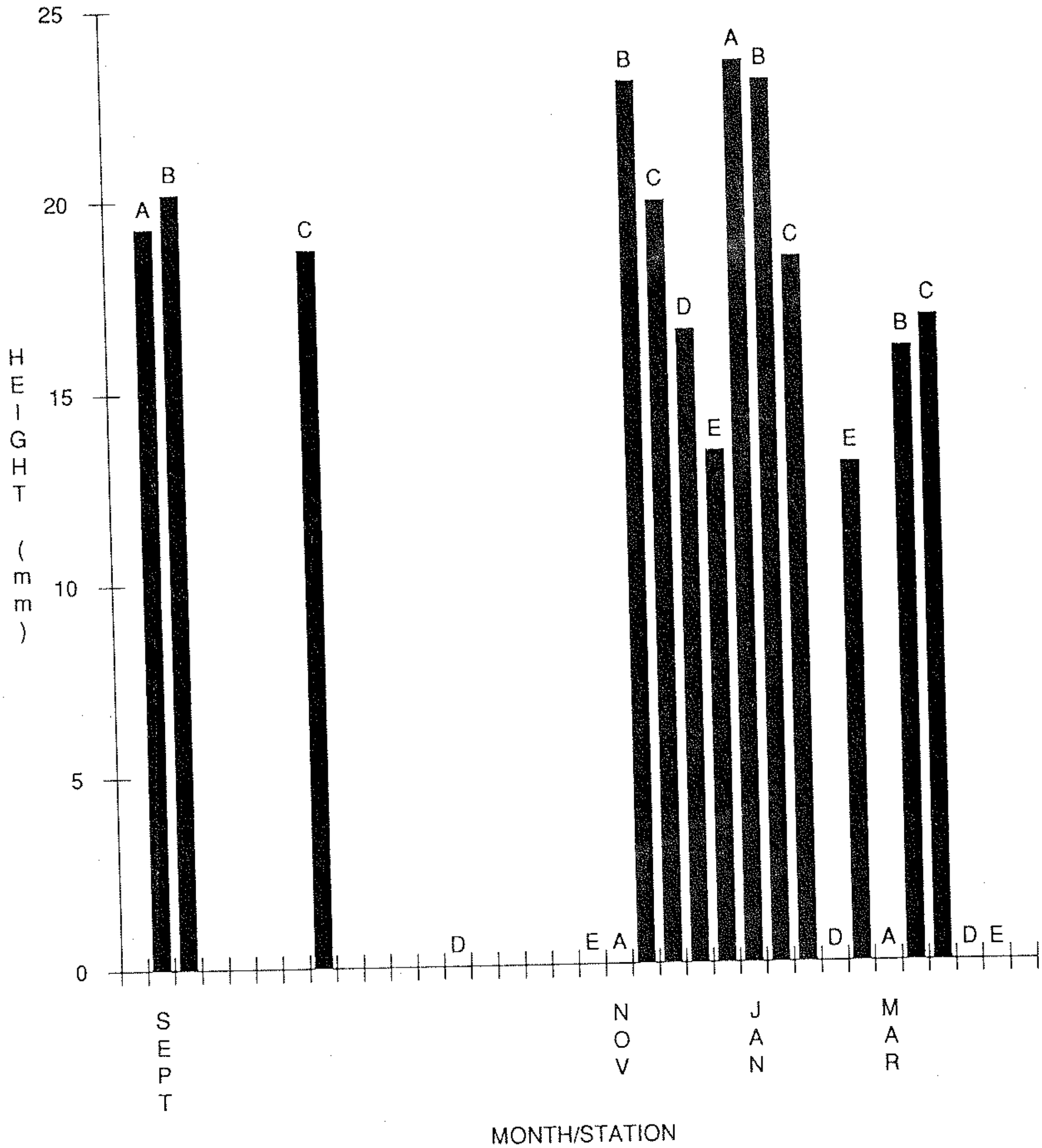


Fig. 5.7 Average height of Jacknife Clams (<u>Tagelus californianus</u>) from 5 stations at Malibu Lagoon.



of clams found at station C, they were of a slightly smaller average length than those found in A or B. This channel is where most observed pollution occurs. (Refer to Chapter 2.0). The potential relationship of this to clam size is not clear.

In trying to establish a consistent ratio between burrow width and clam width, all burrow diameters that were not distorted by the sample collection were measured. It appears that there is a strong correlation between shell height and burrow diameter (Figure 5.8), and with more data, it should be possible to construct a table allowing extrapolation of clam height, and potentially length as well, of those animals that escape collection. There seems to be a very strong correlation in our sample of length to height (Figure 5.9). Further data is needed in order to verify and establish such a table.

A potentially interesting fact that emerged from this study was that the clams were definitely concentrated at specific level in the sediments. Clumps of clams would be found at the exact same depth at all stations, with a maximum of 38 cm and average of 20.1 cm. This seemed to correspond to strata of mixed organic mud/clay and sand. It is not clear why they demonstrate this preference, but it could be related to optimal sediment composition, protection from predators, or inability to penetrate lower strata. Initially these layers appeared anaerobic, but became more aerobic in the spring.

A total of 96 clams were collected in the course of this survey, and of this 59 (61%) were alive (Figure 5.10). Empty shells buried in the sediment cores make up the difference. No live clams were ever found at stations D and E after September 1987. Many live clams were present there in the June sample (data not included in analysis due to changing methodology). The sand bar which formed in September at station D, also closed off the channel and allowed water to sit in C channel for extended periods of time. It is not clear which of these two factors played the dominant role in the population decline. Stations B and C showed similar percentages of live populations, with station C falling off consistently throughout the survey, and both having no live clams in the March sample. The cause of this is unclear. In contrast, the population at station A had a die-off in January (0% alive) and had recovered to 100% alive by March. No documented events occurred in the lagoon at that time which could be specifically tied to this observation. School tour records indicate that surveys from the bridges show large die-offs following major rainstorms. Although no data was collected, a large die-off (100+) of clams occurred in early October 1987. This seemed directly related to a film of soap bubbles and foam that was concentrated in C channel for several days during Lagoon

Fig. 5.8 Correlation between shell height and burrow diameter of Jacknife Clams (*Tagelus californianus*) at Malibu Lagoon.

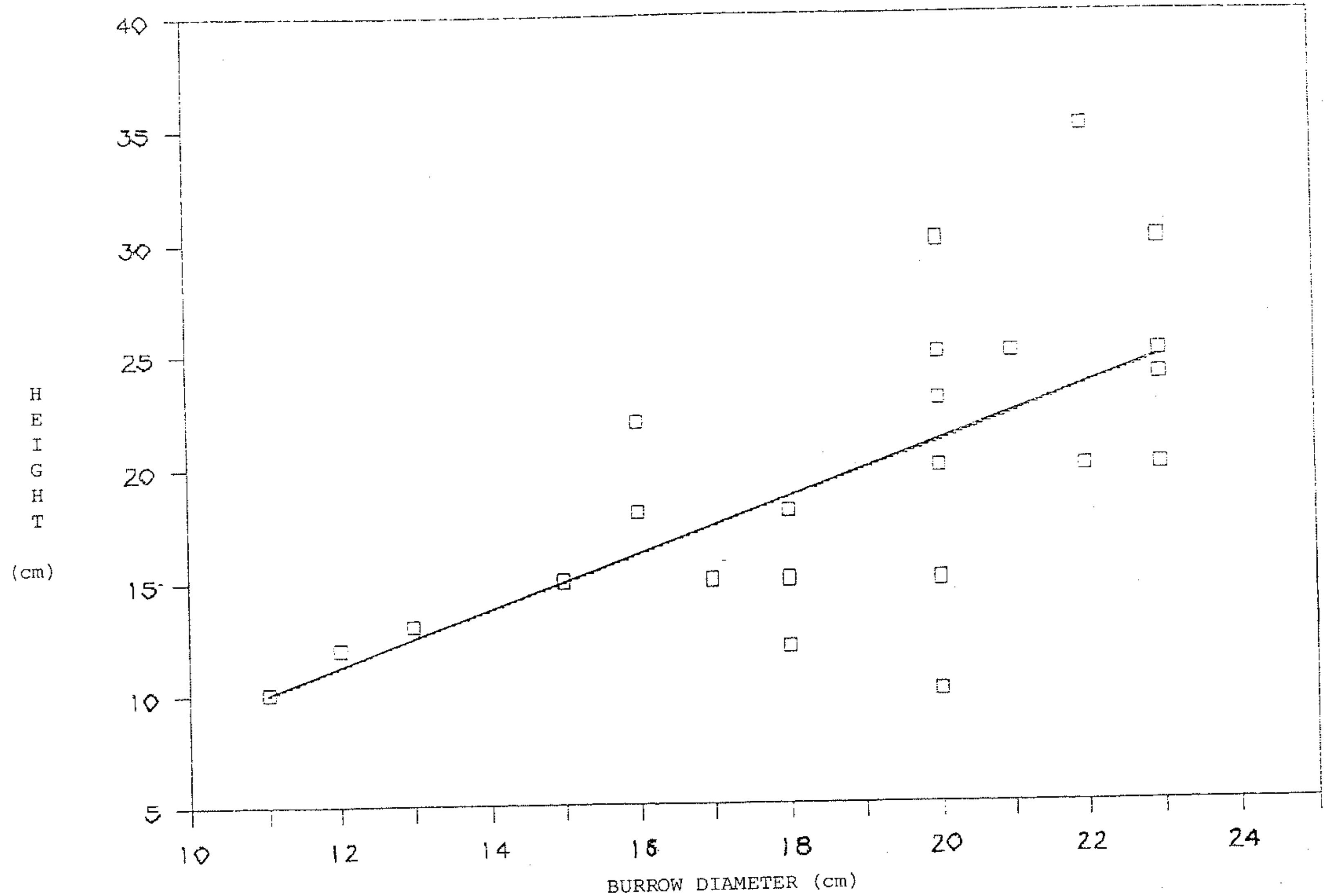


Fig. 5.9 Correlation between shell height and shell length of Jacknife Clams (*Tagelus californianus*) at Malibu Lagoon.

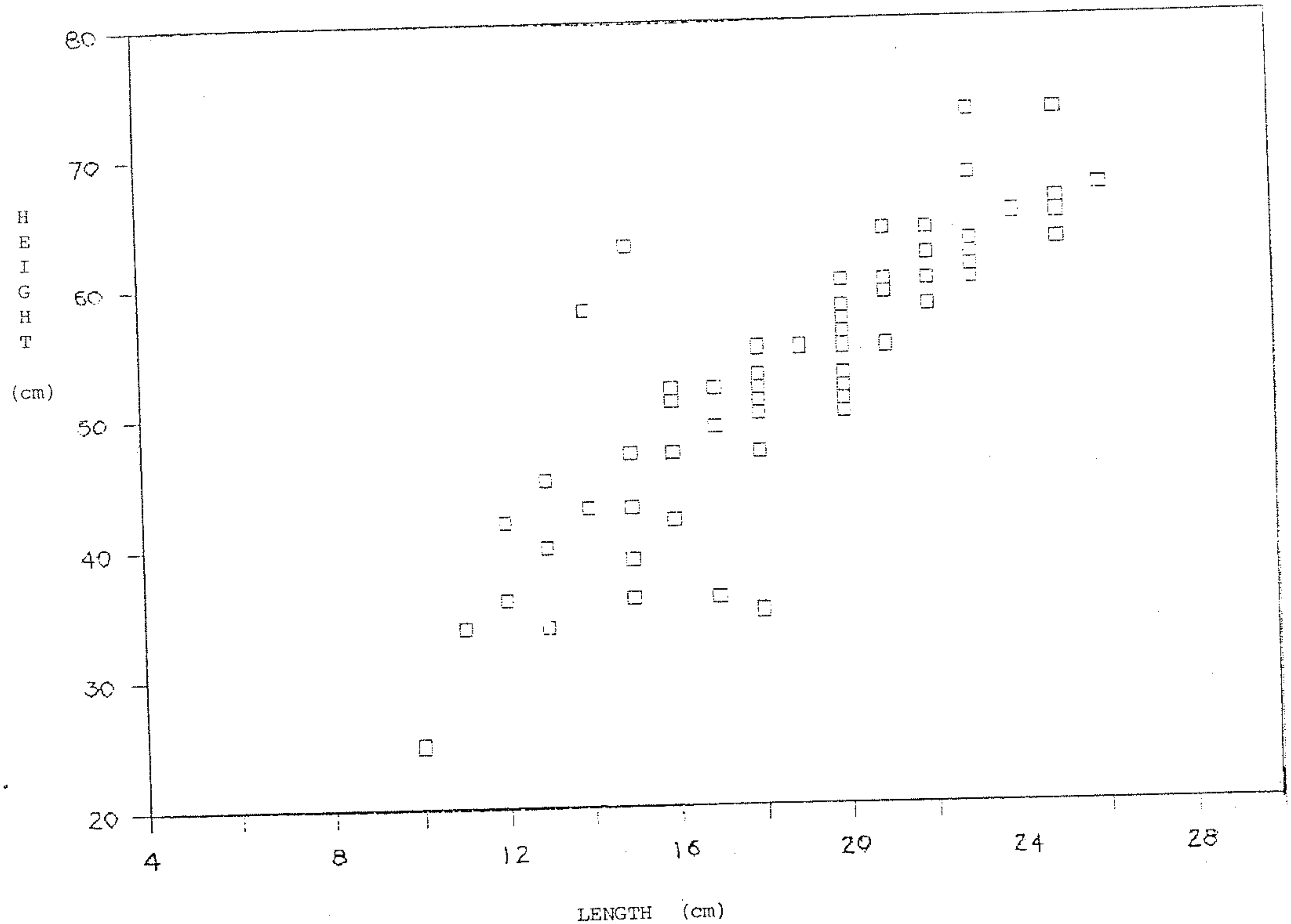
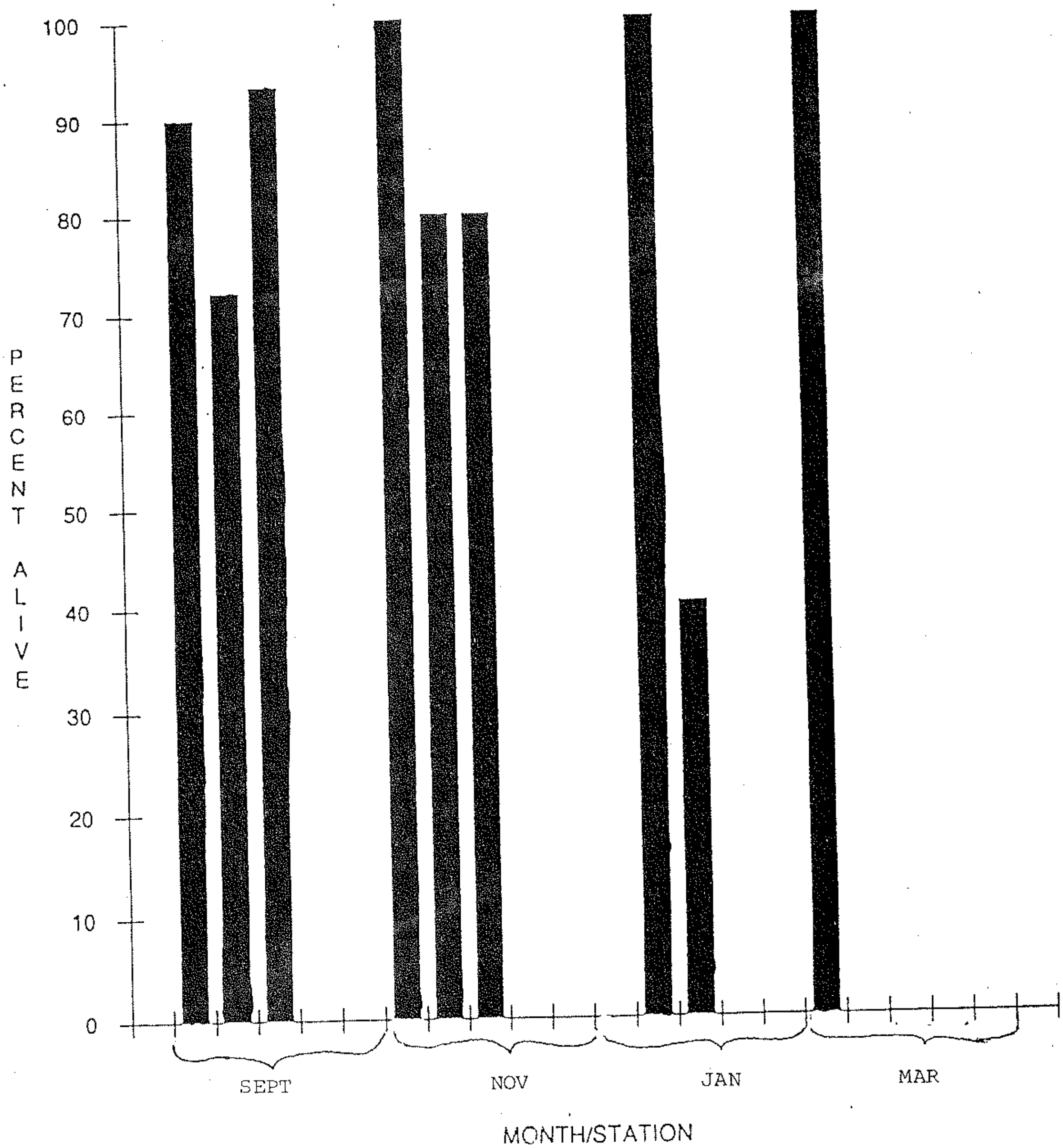


Fig. 5.10 Percent of live Jacknife Clams (Tagelus) californianus found at 5 stations at Malibu Lagoon.



impoundment, followed by an algal bloom. There was also another die-off in August 1987, following a sewage spill from the Pepperdine line connecting to Tapia.

5.5 DISCUSSION

This study provides an initial assessment of the benthic infauna of Malibu Lagoon. It took several months to revise the methodology so that greater accuracy could be assured, therefore only the last 4 samples were used in analyzing data. With further modifications, the sampling technique should better fit the specific needs of Malibu Lagoon, and thus provide more accurate information. An extension of this study for several years is needed in order to create a database sufficient for determining population trends.

Basic information concerning normal, seasonal population fluctuations of *Polydora nuchalis* is essential to the overall understanding of the role these organisms play in the Lagoon. How these animals respond to changes in water quality, especially extended periods of low salinity, fluctuations in water circulation, disturbance due to storms and predation, remain important questions that will provide essential pieces of the puzzle, allowing greater understanding of the role of these organisms in the overall food web of the Lagoon. It may be that the extended periods of non-seasonal fresh water inundation from the Tapia Water Reclamation Facility has prevented the expected colonization of other polychaete species which is characteristic of other estuaries (Nordby, pers. comm. to J. Dillingham).

Although some insight was gained into the distribution and population of Jacknife Clams (*Tagelus californianus*) it would still be of interest to determine: 1) at what season Malibu Lagoon serves as a nursery area, 2) the rate of growth at various locations within the Lagoon, as well as 3) basic information concerning their tolerance to changes in water quality. With the probability of non-point source pollutants entering the Lagoon in the channel near Malibu Colony, which is now somewhat restricted by the physiography of the inlets, this question is of great importance when considering the proposed connection of these fingers along a source of incoming pollution.

Malibu Lagoon has a limited diversity of benthic infauna which is consistent with other estuaries experiencing extended periods of brackish water conditions (Zedler, Koenigs and Magdych 1984). It has been 5 years since the restoration of the Lagoon, and the more usual development of a more diverse benthic infauna has yet to occur. *Polydora nuchalis* and *Tagelus californianus* may represent either an initial colonizing effort, re-establishment of a previous population, or could be a result of the physical and chemical parameters. Low salinity tolerances, and limiting factors such as temperature, pH, dissolved oxygen, turbidity and possible pollution may prevent the colonization by other, less flexible species. Continuation of this study, with a review of the impact of the sampling methodology, is recommended in order to determine which of the many variables outlined above may be the key to understanding the dynamics of these populations.

5.6 SUMMARY

1. Only two species of benthic infauna have been found in Malibu Lagoon, Polydora nuchalis and Tagelus californianus.

2. It is unusual to find a monoculture of Polydora nuchalis in an estuary. It may be that the influx of large volumes of fresh water coupled with inconsistent management of the ocean entrance are limiting factors. This warrants further investigation.

3. Both species prefer mud/silt organic sediments and disappear from areas inundated by sands.

4. Populations decreased overall during the survey. This could indicate disturbance due to sampling methodology, changes in water quality, the natural population cycle, or the influence of heavy predation by a large seasonal population of probing shorebirds.

5. It is not possible, based on current data, to determine how water quality factors such as salinity, large volume of fresh water, pH, turbidity, temperature and dissolved oxygen influence the population density and diversity of benthic infauna. Die-offs of Jacknife clams (Tagelus californianus) seem directly related to continued exposure to fresh water and possibly also to pollution (August 1987 Pepperdine spill). Continued study is needed to clarify these relationships.

6. Since benthic infauna are an important link in the food chain of Malibu Lagoon, further study is necessary to understand more fully the dynamics of the situation in order to foster continued growth and restoration of these populations.

5.7 LITERATURE CITED

Crippen, R. W. and Reish, D. J. 1969. An ecological study of the polychaetous annelids associated with fouling material in Los Angeles harbor with special reference to pollution. Bull. So. Calif. Acad. Sci. 68(3): 170-187.

Harris, L. 1988. USC. Allan Hancock Foundation. personal communication to Rosi Dagit and Jean Dillingham.

McConnaughey, B. 1985. Audubon Society Nature Guide: Pacific Coast. Alfred A. Knopf, Inc. pl. 65, pp. 340.

Morris, P.A. 1966. A Field Guide to Pacific Coast Shells: including Hawaii and the Gulf California. 2nd Ed. Houghton Mifflin Co. pl 25, pp. 37.

Peterson, C. H. 1977. Competitive organization of the soft-bottom macrobenthic communities of Southern California lagoons. Marine Biology 43: 343-359.

Reish, D. J. 1971. Seasonal settlement of polychaetous annelids on test panels in Los Angeles-Long Beach harbors 1950-1951. Journal of Fisheries Research Board, Canada. 28:1459-1467.

Reish, D.J. 1972. Marine Life of Southern California. pp. 68.

Ricketts, E. F., J. Calvin and J.W. Hedgepeth. 1985. Between Pacific Tides. 5th Ed. Stanford University Press. pp. 381-82, 520-21, 570.

Smith, R.I. and Carlton, J.T. 1975. Light's Manual: Intertidal Invertebrates of the Central California Coast. 3rd Ed. University of California Press. pp. 214-215, 565-566.

Wooden, S.A. 1974. Polychaete abundance patterns in a marine soft-sediment environment: the importance of biological interactions. Ecological Monographs 44:171-187.

Woodwick, K.H. 1953. Polydora nuchalis, a new species of polychaetous annelid from California. Journal of the Washington Academy of Science. Volume 43, No. 11. pp. 381-383.

Zedler, J.B. 1984. The Ecology of Southern California Salt Marshes: A Community Profile. US Fish and Wildlife Services FWS/obs-81/54. pp. 59-61.

Zedler, J.B. and Nordby, C. 1986. The Ecology of Tijuana Estuary, California: An Estuarine Profile. US Fish and Wildlife Service Biological Report 85 (7.5). pp. 35-44.

Zedler, J.B., Koenigs, R. and Magdych, W.P.. 1984. Freshwater Release and Southern California Wetlands. San Deigo Association of Governments. pp. 42.

6.0 INVERTEBRATE EPIFAUNA

6.1 INTRODUCTION

Five years after restoration, it was expected that a more diverse assemblage of invertebrates would have recolonized Malibu Lagoon. Initial surveys of invertebrates have instead shown that only two benthic species occur here. Species diversity and abundance of invertebrates can provide an important measure of the recovery cycle in the Lagoon. As a measure of this recovery, invertebrate epifauna were investigated at the sediment and water column interface, and include studies of the mud crab, oriental shrimp, and small epifauna (ostracods, copepods, water boatmen, amphipods, nematodes, flatworms). The most conspicuous of this epifauna is the mud-flat crab (*Hemigrapsus oregonensis*).

Abundance and diversity of invertebrates are probably related to factors limiting the recovery process at Malibu Lagoon. Mud crabs, shrimp and small epifauna may therefore assume greater importance as food resources than would be expected in a more productive estuary.

Malibu Lagoon is typical of other southern California estuaries receiving large quantities of fresh water from wastewater treatment facilities, where invertebrate species diversity is significantly reduced due to prolonged brackish water conditions (Zedler 1984). Since there are clearly large numbers of crabs at Malibu Lagoon, studies which might provide insight into the biology and behavior of this species may become a significant factor in understanding the "health" of this estuary in the future.

6.2 PROJECT OBJECTIVES

Prior to making changes in the physical and morphologic characteristics of Malibu Lagoon during phase II of the restoration process, it is important to identify species and determine relative abundance of epifaunal invertebrates along habitat gradients and over time in order to understand the interrelationships which exist in this ecosystem. Of particular interest is the mud-flat crab, which appears to be thriving in this ecosystem. Understanding the factors limiting the distribution of these organisms will aid in the development of a sound management plan in the future.

6.3 METHODOLOGY

6.3.1 MACROSCOPIC EPIFAUNA: MUD CRABS AND SHRIMP

Mud-flat crabs and oriental shrimp (Palaemon macrodactylus) are surveyed in conjunction with the daytime monthly fish surveys. Data was collected from June 1987 to August 1988 and on blocking net surveys in January and September 1988.

Both species were collected during each of three replicate passes of the seine net at five stations along habitat gradients in the Lagoon (see map A for exact locations). After each replicate of the 6.1 m X 1.8 m X 3.1 mm ace-type mesh net within each 10 meter study site, all organisms were collected, identified, and numbers counted. Voucher specimens of shrimp were sent to the Los Angeles County Museum of Natural History Crustacea Lab for positive identification.

In addition, surveys of crabs and shrimp were made during January and September 1988 fish surveys for the California Dept. of Parks and Recreation (DPR). Surveys for DPR followed the methodology used by Nordby and Covin (1988) in other southern California estuaries, where a 10 m length of inlet channel is blocked by using two 15 m by 3.1 m by 3.1 mm ace-type mesh seine net. The area is fished repeatedly until fish numbers approach zero. Then blocking nets are drawn together to capture the remaining fish, crabs and shrimp.

In both types of surveys, the carapace width of each mud crab is measured in mm at the second spine. Crabs are identified by sex and condition before being returned to the estuary. Crabs of other species are also identified, measured and counted.

Because of the fragile nature of this estuary, no attempt was made to excavate crabs from their burrows to determine crab populations, as did Willason (Zedler 1982) in his comparative studies of the mud crab and the lined shore crab (Pachygrapsus crassipes) at Goleta Slough.

6.3.2 SMALL EPIFAUNA: OSTRACODS, COPEPODS, WATER BOATMEN, NEMATODES, AND FLATWORMS

To identify small epifauna, random samples are collected at the interface between water and sediments by using a 13 cm by 15 cm fine aquarium dip net (1 mm mesh). Ten sweeps of the net are made within a meter square area during periods of low water in the Lagoon, where water depths are approximately 20 cm. The meter square area is marked with 1 m lengths of PVC pipe, which are joined at the corners with plastic elbows so that the meter square is floating in water. Epifauna collected in the aquarium net are then rinsed in the Lagoon to concentrate them in the bottom of the net. The net is

MAP A Study Stations at Malibu Lagoon

everted, and epifauna are added to a 5 cm diameter container holding 50 cc of surface water from the Lagoon. A 5 cc syringe with a 2 mm opening is used to collect a 2.5 cc subsample, which is placed in a 5 cm diameter watch glass.

Epifauna are identified and counted by using a 10-20 X widefield stereomicroscope. The relative abundance of each type of small epifauna are recorded by class, based on an average of the counts of three 10 X microscope fields. Individual organisms are first identified at 20 X magnification. Where classes overlap, a range is recorded.

RELATIVE ABUNDANCE BY CLASS:

Class 1:	fewer than 5	Class 3:	10-15
Class 2:	5-10	Class 4:	15 or above

AVERAGE NUMBER OF EPIFAUNA/ 10 X MICROSCOPE FIELD

This methodology was developed as a way of gaining needed information within the short time framework available for this study, and provides an idea of what organisms exist at Malibu Lagoon in this small size range.

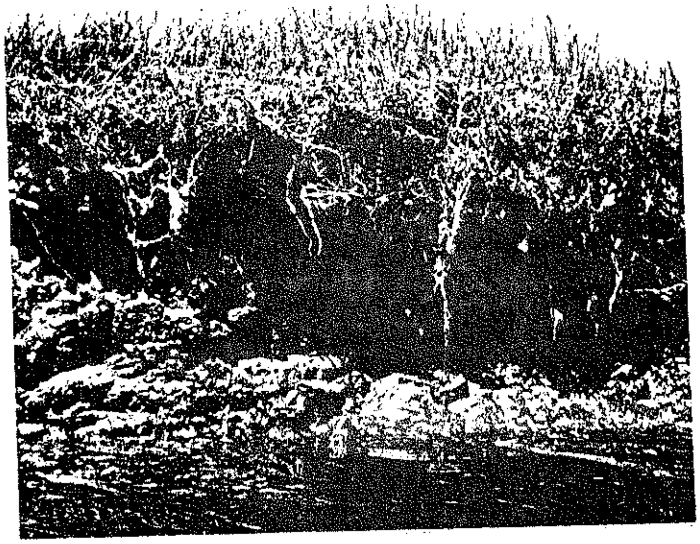
6.4 OBSERVATIONS

6.4.1 CRAB OBSERVATIONS

The mud(flat) or yellow shore crab (*Hemigrapsus oregonensis*) is the only crab regularly encountered in Malibu Lagoon. Mud crabs dig burrows along the banks of the Lagoon below the edges of vegetation to the 3-4 ft. tidal level (Fig. 6.1). Some burrows are encountered up to the level of the highest water in vegetated areas. Crabs often take advantage of the safety of cobble rocks occasionally found in the inlets, by establishing burrows beneath them. Holdfasts which drift into the Lagoon during extreme high tides and with storms also provide temporary habitat for these crabs. The mud crab is a major food resource for the western willet (Garth and Abbott, 1980), staghorn sculpins (Fitzgerald and Hasz 1983) and California killifish (Fritz 1975). At Malibu Lagoon, shorebirds are often seen feeding on or foraging for crabs.

Although many reference materials describe the mud crab as nocturnal in habit (Chace and Abbott 1980), (Ricketts and Calvin 1968), it is regularly observed in the daytime during fish surveys and programs for school groups at Malibu Lagoon. Although algae, mostly *Enteromorpha sp.*, appears to be the primary diet of the crabs, they are also observed feeding on dead razor clams, small organisms in the mud, probably diatoms (Garth and Abbott 1980) and an occasional dead fish. The

Fig. 6.1 Mudbank habitat of the mud(flat) or yellow shore crab (Hemigrapsus oregonensis). Photo by C. Nordby illustrations by J. DeWald (Zedler 1982).



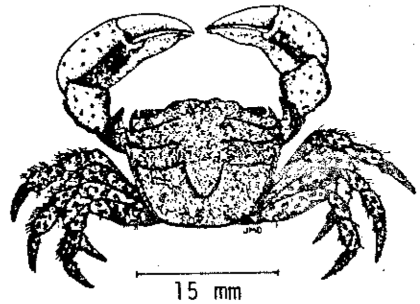
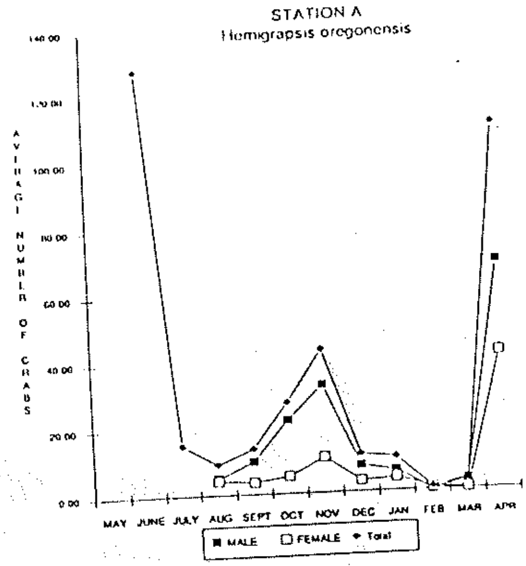
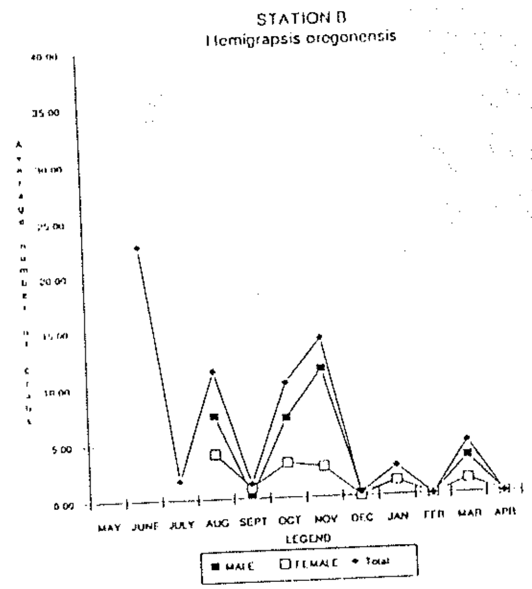
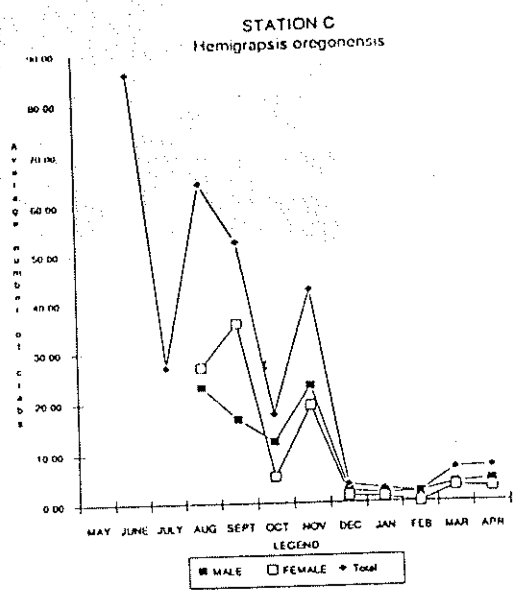
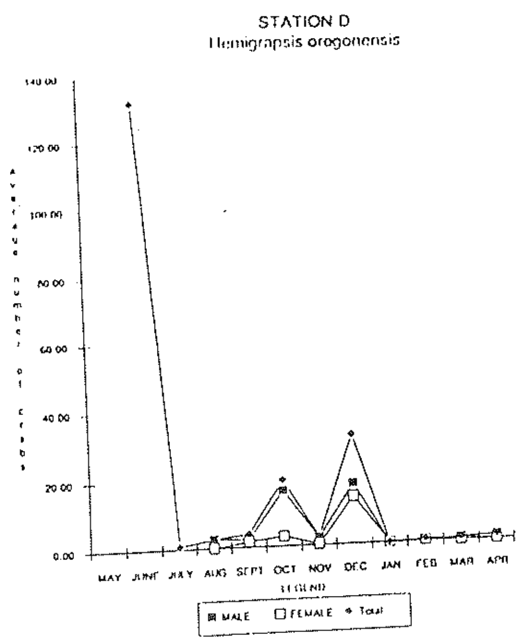


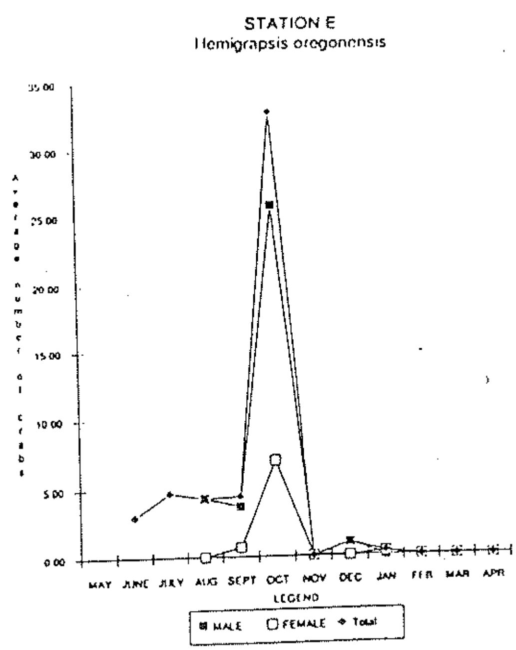
Fig. 6.2 Average number of mud crabs (*Hemigrapsus oregonensis*), including male and female crabs, observed at 5 stations along habitat gradients at Malibu Lagoon, June 1987 - April 1988.











algae mats upon which crabs feed first appear in March, predominate thoughout the inlets until late summer, and disappear completely by December when water temperatures drop.

The greatest numbers of mud crabs were observed at all stations (see map A for exact locations) during summer and fall months (Fig. 6.2). Beginning in December, crab numbers declined throughout the Lagoon, with the first real rise in numbers noted at station A in April. No increase at other stations was noted until the June 1988 survey. Observations made during student tours from bridges overlooking the inlets help confirm that mud crabs are active well into the day, and that this species is flourishing at Malibu Lagoon.

The relative abundance of crabs at each site was determined on the basis of the average density of crabs caught over the bottom substrate during fish surveys (Figure 6.3). The greatest numbers of crabs were observed in inlet channels where bank gradients are steep, and where there is a consolidated mud substrate for creating burrows. This type of channel configuration exists at stations A and C, where the greatest numbers of crabs were observed. Holdfasts, common temporary shelters for crabs, are often carried into both of these channels by tidal action, and crabs were found concentrated there. Crabs also appeared to be concentrated where burrows existed beneath cobble rock in these inlets.

During initial surveys, there were large numbers of mud crabs at station D. Beginning in November 1987 a sand bar filled in at this site, covering the original substrate of mixed fine sands and muds. Over time, with a shifting of substrate and changing water circulation patterns, numbers of crabs at this station have declined dramatically (Figure 6.2).

Two sites consistently have low densities of crabs. Station B is a mudflat area, where almost no bank exists next to the vegetation and where sediments are composed of fine, unconsolidated muds. Consolidated sediments where crab burrows might exist were not surveyed. Only once, when algae holdfasts were collected during a survey, were any numbers of crabs caught at station E, where sediments are composed mostly of unstable sand, with some cobble rock.

Little is known about mud crab reproduction in California waters, and no studies have been made south of Monterey Bay. At Malibu Lagoon, males predominate among the crabs collected on surveys. During late summer, from September to November, the ratio of males to females appears to increase dramatically (Figure 6.2). There are often two to three times as many males as females collected on surveys during this period. Only at station D, during August and September 1987, did the numbers of females exceed that of males. During the winter months, numbers of males are generally higher, but only slightly so. Gravid females were found from June through September, primarily at station C, but were also noted at stations B and D. Numbers of gravid females peaked in September 1987 at station C, where they represented 51% of females caught. The size range of gravid females includes those with carapace widths from 14 to 23 mm. The largest male caught had a carapace width of 30 mm.

Both crab numbers and activity in the Lagoon appear to be cyclical. Large crabs predominate in the summer months, when all crab numbers are highest. Small crabs predominate in the winter, when total numbers are lowest (Fig. 6.4). These shifts in sizes of crabs appear to take place in October and again in June. Further study is clearly needed in this area. Crabs with carapace widths as small as 3 mm have been collected on surveys. No large crabs were caught during February and March.

Physical conditions in Malibu Lagoon are extremely variable. Bottom salinities, where crabs are active, ranged from 2 ppt to 37 ppt, which is within the range tolerated by this species. The mud crab is a species that endures moderately polluted conditions in Los Angeles Harbor, and has the ability to tolerate wide ranges of salinities, including prolonged periods of both fresh water and hypersaline conditions (Garth and Abbott 1980). Crabs and other biota at Malibu Lagoon have had to withstand extended periods of unseasonal fresh water inundation. This is a result of tertiary-treated effluent discharged by the Tapia Water Reclamation Facility into Malibu Creek, which is often compounded by closure of the entrance for extended periods of time. Clearly, mud crabs show a measure of success in this brackish marsh.

Crabs were collected at water depths ranging from 10 to 100 cm, although fewer crabs were collected when water levels were high. Bottom temperatures, where crabs are active, ranged from 10 C to 27.5 C. Highest numbers were recorded when water temperatures were warmest. How these and other physical factors, such as pH and dissolved oxygen levels, affect crab populations can only be determined by further study.

Occasionally other species of crabs are encountered during seines after extreme high tides and when the ocean entrance to the Lagoon is maintained. Single specimens of kelp (*Pugettia producta*), cancer (*Cancer gracilis*), and lined shore crabs (*Pachygrapsus crassipes*) all have been collected in surveys. Although high school honors biology students who were involved in a research project at the Lagoon (April and May 1987) found burrows above the high tide mark and mud pellets typical of fiddler crab (*Uca crenulata*) activity, no crabs or molts have yet been found at the Lagoon. Additional research might yet reveal that these crabs are at Malibu Lagoon, making this estuary the northernmost extension of the species.

6.4.2 SHRIMP OBSERVATIONS

The oriental shrimp is a species which first appeared in San Francisco Bay (1954), apparently as a "stow-away" in the ballast of a ship returning from Korea, where these shrimp are native (Ricketts and Calvin 1962). This species has thrived where brackish water conditions predominate (Chace and Abbott 1980). The oriental shrimp were first noted during a fish survey at Malibu Lagoon in September 1987. Since this time, it has been absent from only three surveys. These shrimp appear periodically in the Lagoon and appear to be associated with coastal algae which has drifted in through the ocean entrance. The greatest numbers of shrimp have been encountered on surveys completed during fall and winter months (Figure 6.5).

6.4.3 SMALL EPIFAUNA OBSERVATIONS: OSTRACODS, COPEPODS, AMPHIPODS, WATER BOATMEN, NEMATODES, FLATWORMS

Surveys of small epifauna began in September 1987, after initial surveys indicated that invertebrate species diversity at Malibu Lagoon was extremely low. Since many of the over-wintering birds have been observed feeding on organisms in this size range, it was decided to initiate this limited study.

Four surveys of small epifauna which were made during September and November, 1987 and in January and April, 1988 indicate that there are five types of small invertebrates which are found at the interface between water and sediment layers at the Lagoon. Those observed include ostracods, copepods, non-segmented worms, amphipods, and a water-boatman (*Trichocorixia reticulata*) that lives in brackish water.

The area sampled on these surveys is extremely small and the studies made are very limited. To determine relative abundance of these organisms along gradients in the Lagoon, larger samples need to be taken. However, this methodology does provide a way of quantifying populations in the future, when further study over a greater area with finer nets and additional sampling would result in a more comprehensive analysis of populations of these small epifauna.

Ostracods are small crustaceans which are approximately 2 mm in size, with a body covered by a translucent bivalve carapace. Although reported to live among the interstitial spaces of coarser sediments (Abbott and Haderlie 1980), at

Malibu Lagoon, ostracods are found at the surface of fine, highly organic muds as well. School groups, which study epifauna and sediments as a part of their science programs at the Lagoon, regularly find large numbers of ostracods during these bi-weekly programs throughout the school year, and weekly programs during the summer. Although samples made during our surveys are extremely limited, distribution of ostracods appears to shift in the Lagoon during the year, from inlets with fine sediments in the summer and fall months, and where sediments are coarser during winter and spring months. At station A, where sediments are highly organic and anaerobic, ostracods are often coated with a white fuzzy material, resembling a long chain, sulfur-reducing bacteria, identified during studies of sulfurous hydrothermal vents at White's Point on the Palos Verdes peninsula (pers. comm. Paul Meister 1988).

Copepods are an important resource in marine food chains, and exist both in salt and fresh water habitats. At Malibu Lagoon, two types of copepods (harpactecoid and calanoid) have been observed. In our limited studies, greatest number of copepods were found at site B, where sediment composition includes a mixture of unconsolidated mud and organic material. Copepods exist in the Lagoon all year, with greatest numbers observed in autumn and winter months. During this time frame, many gravid females have been observed.

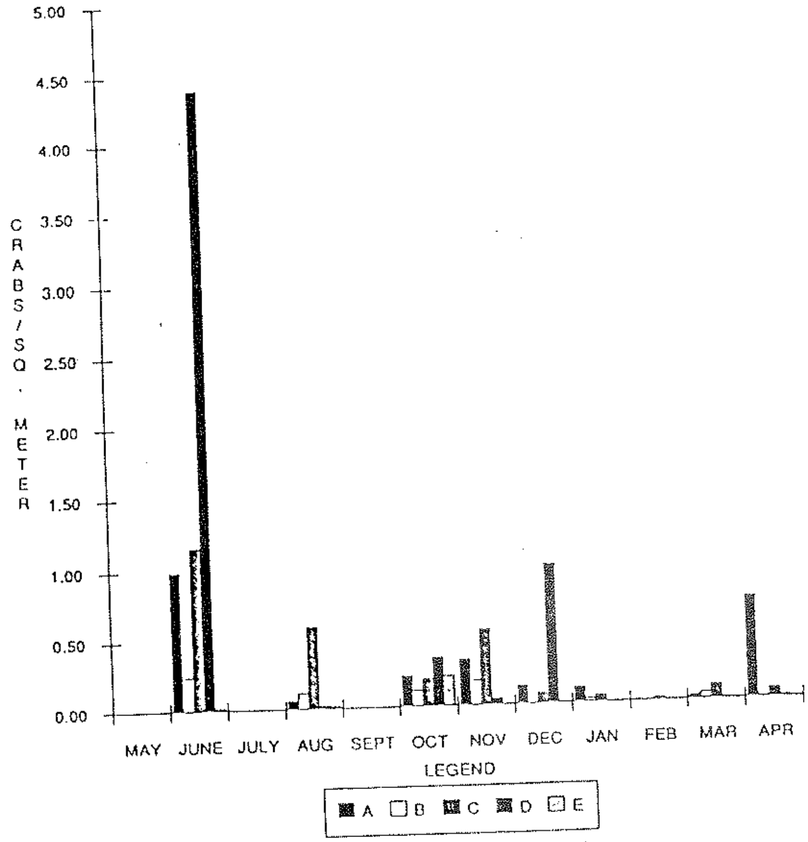
Non-segmented worms such as flatworms and nematodes appear throughout all surveys at the Lagoon, but in relatively small numbers. Flatworms live at the surface of the fine organic sediments at the Lagoon, and probably feed on copepods (Abbott and Haderlie, 1980). None have been observed at site E. Nematodes appear frequently in areas where sediments have a high organic content.

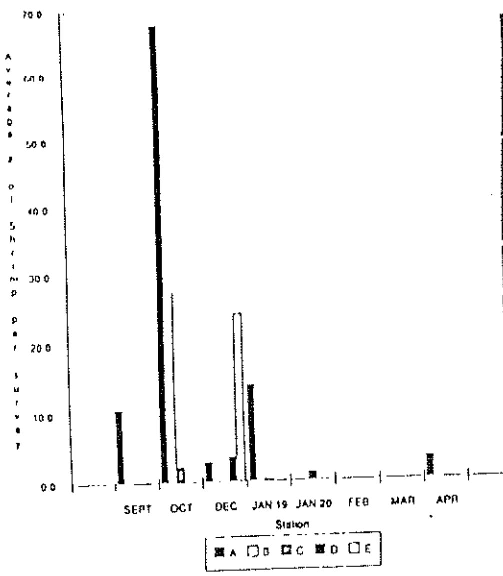
The brackish water boatman was observed in our studies and during student tours of the Lagoon throughout much of the year. This species of insect lives in fresh to brackish water and is a fierce predator. More water boatmen are observed while water temperatures are warm, and when algal mats are present.

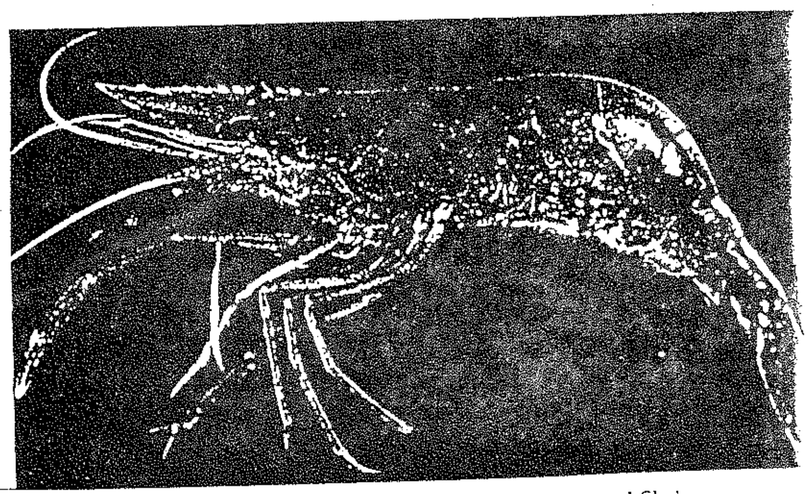
Amphipods (<u>Orchestia</u> sp.) are evident in the Lagoon particularly when storms and extremely high tides carry drift algae into the main Lagoon and inlets. These plant decomposers are also evident as algae mats begin to die-off in late summer.

The small epifaunal invertebrates found in Malibu Lagoon probably are an important food resource for some species of bottom-feeding fish, and for birds which utilize surface-picking or straining as feeding strategies. The fact that many of these organisms appear to be present in substantial

Fig. 6.3 Average density of mud crabs (Hemigrapsus oregonensis)/ m^2 at 5 study sites along habitat gradients at Malibu Lagoon, June 1987 - April 1988.



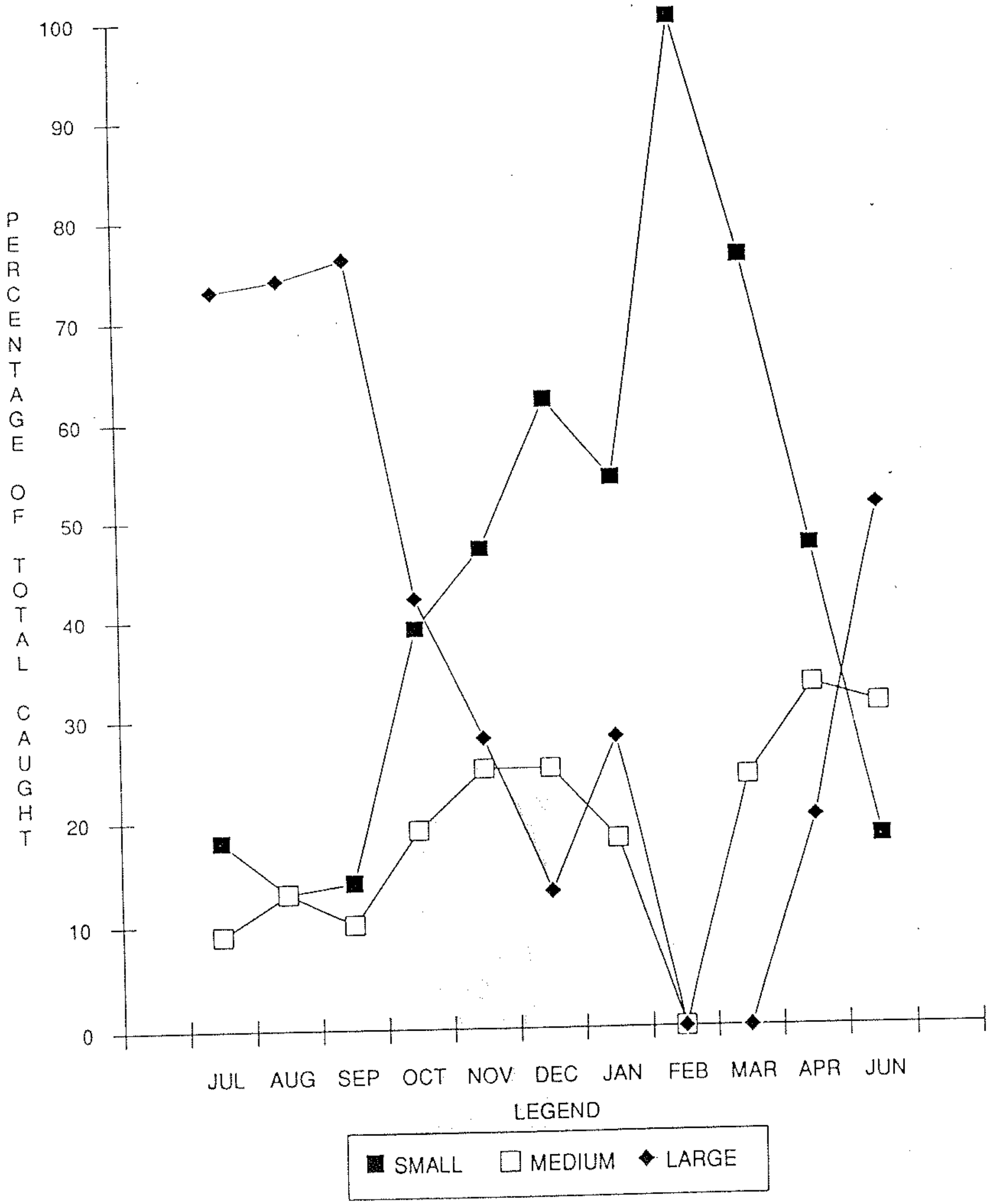




23.1 Palaemon (Palaemon) macrodactylus Rathbun. Oriental Shrimp. Female, 50 mm long. San Francisco Bay.

Fig. 6.5 Average numbers of oriental shrimp (Palaemon macrodactylus) during monthly fish surveys at 5 stations at Malibu Lagoon, May 1987 - April 1988

Fig. 6.4 Size classes of all mud crabs (Hemigrapsus oregonensis) observed at Malibu Lagoon, July 1987 - June 1988. small crabs: carapace width 9 mm or less; medium crabs: carapace width 10-13 mm; large crabs: carapace width 14-30 mm, includes size of smallest gravid female.



numbers when migratory birds are in residence at the Lagoon may indeed make them important as a food resource, since diversity and numbers of other invertebrate food resources are probably limited.

6.5 DISCUSSION

6.5.1 MUD-FLAT CRAB DISCUSSION

Seasonal population trends at Malibu Lagoon tend to reflect observations made of mud crabs in other areas along the Pacific Coast, although crab numbers remain higher here later in the year. This pattern possibly reflects the warmer water temperatures found in Southern California, and may be linked to the presence of algal mats as a food source and as cover from predators. Both sizes and numbers of crabs begin to increase in the spring, with peaks in summer and fall months following the period of greatest algae production. The observation that many crabs are present during the fall months when water temperatures might be expected to drop may be explained by a warm water inversion which is often present during this period of the year, and which may extend the period of algae production. Although the algae mats begin to die-off in late summer, an algal film covering the inlet bottoms and some coastal drift algae are usually present in most areas of the Lagoon to serve as a food source for the small crabs, whose numbers dominate winter surveys (Fig. 6.4). Further studies are indicated to determine if winter crab populations are diminished by cold water temperatures, the absence of algal mats, avian predation and/or sediment changes after storms. It may be during these periods that larger mud crabs remain dormant, and are in their burrows, where they are not collected during surveys.

Our methodology cannot be used to assess total crab numbers, since only crabs that are on the surface of the substrate can be captured with the seine net, with those residing in burrows evading capture. Since crabs were collected within similar physical and chemical parameters, the numbers observed at each study site probably give a good picture of the relative abundance of mud crabs along habitat gradients in the Lagoon.

Daytime seining may also affect our results, since other studies indicate that mud-flat crabs forage primarily on diatoms and green algae at night (Garth and Abbott 1980), and numbers of crabs caught during daytime may not relate to actual crab populations in the Lagoon.

Substrate appears to be important in the establishment of burrows. Not only does a susbstrate composed largely of consolidated muds seem to be preferred, a steep bank gradient also seems to be a factor in the distribution of crabs throughout the Lagoon. At stations A, C and D (map A), where banks are relatively steep, crab populations are highest. Although there is a mud substrate present at station B, inlet sediments are unconsolidated and no steep bank exists, and may explain why few crabs are collected on these surveys. It is possible that crabs also live in burrows underneath low-elevation vegetation at this site, where no surveys were conducted. Also, there are no cobble rocks and few holdfasts to serve as cover from predators at this site.

Gradual infilling of station D is a direct result of maintaining the present position of the Lagoon entrance by DPR. The covering of crab burrows with shifting sands probably explains why crab numbers have significantly dropped at this station.

Crabs appear to be more densely concentrated where there is additional protection from predators, such as under cobble rocks which exist above burrows, and in coastal algae holdfasts which are carried by tidal action into the Lagoon and inlet. The fluctuation in numbers which we noted on surveys during close periods of time probably reflect our survey techniques rather than any dramatic fluctuation in crab numbers. The fact that student tour groups regularly view large numbers of crabs from bridges over the Lagoon inlets from spring through fall months is probably a more visible measure of their success.

On all surveys conducted at the Lagoon, more males than females were present. Both small and large crabs exhibit these differences in sex ratios. During the summer reproductive period, two to three times as many males were collected on surveys as females. Possibly more males are produced during fertilization of eggs, or are the result after eggs are brooded and young are released. It has been noted in laboratory studies of crabs that several males may impregnate a single female (Garth and Abbott 1980). It is also possible that gravid females, with their increased vulnerability to predation, have retreated to burrows, where they are not collected during surveys. During blocking net surveys conducted for DPR, when the mud substrate was disturbed substantially during sampling, increased numbers of females were encountered during the final replicate seines (combined 6 and 7), but not in sufficient numbers to explain the great differences in numbers between male and female crabs.

Mud crabs at Malibu Lagoon show the resiliancy needed of a species which can survive here under constantly fluctuating physical conditions. In particular, these crabs seem to be able to adapt to a very wide ranges of salinities where other species cannot (Zedler and Nordby 1986), and to survive during extended periods where salinity levels remain low. The effects of fresh water discharge from the Tapia Water Reclamation Facility, which are compounded during periods when the entrance remains closed, clearly affects other biota in the Lagoon. Since mud crabs are highly tolerant of polluted conditions, present water quality in the Lagoon probably is not limiting. Factors relating to the success of this crab may aid in understanding how pollution and other physical factors may limit the success of other organisms in the Lagoon.

Both marine and fresh water crustaceans have been encountered on surveys, yet none have become established in the Lagoon. It is most likely that the long periods of brackish water conditions in the Lagoon prevent the lined shore crab (Pachygrapsus crassipes) from becoming established. Although it is a more aggressive species than the mud crab, it does not have the ability to osmoregulate over long periods of low salinities (Willason 1980). In contrast, the crayfish appears unable to tolerate brackish water conditions, and is found in the Lagoon only when salinity levels are very low.

6.5.2 ORIENTAL SHRIMP DISCUSSION

The presence of oriental shrimp in Malibu Lagoon appears to be associated primarily with the presence of coastal drift algae in the Lagoon, since the greatest numbers of shrimp were observed after algal mats had diminished in size, but not yet completely disappeared. The only factor consistent in the distribution of shrimp in the Lagoon appears to be the presence of drift algae, for shrimp may be present in large numbers at one site, and absent or in small numbers at others.

In the laboratory, these shrimp survive well at temperatures between 14-26 C, and tolerate wide ranges of salinities (Chace and Abbott 1980). At Malibu Lagoon, there appears to be no correlation between water temperature and the presence of shrimp. Shrimp appeared on surveys where temperatures extended well beyond this range, with temperatures varying from 10.5-27.5 C.

6.5.3 SMALL EPIFAUNA DISCUSSION

Observations made of the small epifauna only give a small indication of the potential of this resource, as samples were extremely small. Of particular interest is the little-described ostracod, which appears throughout the Lagoon in both fine and coarse sediments in relatively large numbers. Future studies might look into the changes in distribution patterns in the Lagoon, which appear to alter with season.

Copepods are an important resource at the beginning of the food chain. Sampling was so limited, that only the presence of this resource can be noted. Further study may confirm an observed trend of increased numbers during fall and winter months, when other food resources may be limiting. Many copepod females were observed carrying eggs during these surveys, and it is probable that they reproduce successfully here.

Although quantities of organic material are present in the Lagoon, unsegmented worm (nematodes and flatworms) numbers appear to be small during this study. Sampling techniques should have provided for ample collection of worms, as specimens were collected from the substrate of each study area. Worms are often used as indicators of pollution. Future studies in this area may assist in determining the "health" of the Lagoon.

The speed and the relatively large size of the brackish water boatmen made subsampling of this species difficult. These fast swimmers were almost always present during student surveys, and during these limited studies. In the future, counts will need to be made of this population on the basis of the entire sample if the relative abundance of water boatmen is to be understood. This extremely visible insect may be an important food resource for birds and fish, and warrants further study.

Never studied, but also of possible importance as a food resource are the large numbers of amphipods (*Orchestoidea sp.*) which appear in the Lagoon when coastal drift algae is present and when algal mats decompose in late summer.

6.6 SUMMARY

1. Mud crabs appear to be able to withstand the long periods of unseasonal fresh water inundation which occurs throughout much of the year at Malibu Lagoon as a result of discharge of wastewater from the Tapia Water Reclamation Facility. Infrequent opening of the Lagoon entrance by DPR and a natural closure of the entrance from April until the first major winter storms extends the effects of this additional fresh water.

2. Crab burrows are most numerous where bank gradients are steep, and sediments are composed of consolidated muds. Where sediments are unstable, few crabs are found. The presence of drift coastal algae holdfasts and cobble rock appears to provide temporary cover from predation for crabs along the bottoms of inlet channels.

3. Mud crabs clearly utilize algae mats as a major food resource, and are also observed feeding on organisms in the mud. In turn, shorebirds such as willets, whimbrels, and snowy egrets are often seen feeding upon the crabs. Mud crabs are also an important food resource of the staghorn sculpin and California killifish.

4. Greatest numbers of mud crabs (Fig. 6.2) have been observed during summer and fall months, when water temperatures are warm and algae mats are present. Large sized crabs (carapace width greater than 14 mm.) dominate in the summer and fall months, and small crabs (carapace width less than 12 mm) predominate in winter and spring. Almost no large crabs are found during winter months. The smallest gravid female collected during the survey had a carapace width of 14 mm.

5. Of particular interest is the ratio of males to females during this survey. Throughout the year, males are more numerous than females, with a hugh increase in the number of males caught at all sites during summer and fall months. The numbers of males are often two to three times that of females during this period, with the greatest difference being noted in October 1987. The ratios observed may be biased by our sampling methods.

6. Oriental shrimp most likely have entered Malibu Laoon on drift coastal algae as a result of shipping along the coast, and have appeared periodically throughout the Lagoon during these studies. Additional studies might add more insight into the role this shrimp plays in the Lagoon ecosystem.

7. The small epifauna probably represent a greater potential food resource than this small study indicates, since ostracods, copepods, brackish water boatmen, amphipods, nematodes, and flatworms are present in the Lagoon throughout the year. Clearly, more needs to be learned about these small organisms and their distribution patterns in the surface sediments and throughout the seasons. Future studies should also include the plankton.

8. Two other crustaceans found on surveys of the Lagoon serve as indicators of the extremes in the salinities noted throughout these studies. Freshwater crayfish were found on one fish survey, where salinities were very low. The lined shore crab, and other marine crabs, have been collected on other surveys. Neither fresh water nor marine species have become established in the brackish waters at Malibu Lagoon.

9. It is important to continue studies of the mud crab, for it appears to be thriving in the Lagoon, where only a few other species of invertebrates have colonized five years after restoration. Clearly the mud crab is extremely tolerant of the changing physical conditions noted during these studies at Malibu Lagoon. A continued monitoring of crab populations and water quality may give further insight into factors affecting the "health" of this estuary.

LITERATURE CITED

Abbott, D.J. and E.C. Haderlie. 1980. Crustacea and other arthropods, pp. 499-502. In R.H. Morris, D.P. Abbott and E.C.Haderlie eds., Intertidal Invertebrates of California. Stanford University Press. pp.690.

Chace, F.A. Jr. and D.P. Abbott. 1980. Caridea: The shrimps, pp 567- 576. In R. H.Morris, D.P. Abbott and E.C. Haderlie eds., Intertidal Invertebrates of California. Stanford University Press. pp.690.

Fitzgerald, C. and L. Hasz. 1983. Water Quality and Fish Sampling Results at Malibu Lagoon: Pre-restoration Period. CSUN. Unpublished. pp.15.

Fritz, E.S. 1975. The life history of the California killifish, *Fundulus parvipinnis* Girard in Anaheim Bay, California, pp 91- 105. In E.D. Lane and C.W. Hill eds., The marine resources of Anaheim Bay, California Department of Fish and Game, Fish Bulletin 165.

Garth, J.S. and D.P. Abbott. 1980. Brachyura: The true crabs, pp. 594-630, In R.H.Morris, D.P. Abbott and E.C. Haderlie eds., Intertidal Invertebrates of California. Stanford University Press. pp.690.

Meister, Paul., pers. comm. 1988. L.A. Oceanic Society, underwater coastal monitoring program.

Nordby, C. and J. Covin 1988. Physical-Chemical and Biological Monitoring of Los Penisquitos Lagoon. Los Penasquitos Foundation. Unpublished.

Ricketts, E.F. and J. Calvin as revised by J.W. Hedgpeth. 1968., Between Pacific Tides, p. 311. Stanford University Press, 4th edition. pp.614

Willason, S.W. 1980. Factors influencing the biology and coexistence of Grapsid crabs, *Pachygrapsus crassipes* Randall and *Hemigrapsis oregonensis* (Dana) in a California salt marsh. M.A. Thesis, University of California, Santa Barbara.

Zedler, J.B. 1982. The ecology of southern California coastal salt marshes: a community profile, pp 61-64. U.S. Fish Wild. Serv. FW/OBS-81/54. pp.110.

Zedler, J.B., R. Koenigs, and W.P. Magdych 1984. Freshwater release and Southern California Coastal wetlands: Technical reports San Diego Association of Governments. pp.39-44.

Zedler, J.B. and C.S. Nordby. 1986, pp. 35-44. The ecology of Tijuana Estuary, California: an estuarine profile. U.S. Fish Wild.and Serv. Biol. Rep. 85 (7.5). 104 pages.

7.0 THE FISHES OF MALIBU LAGOON

7.1 INTRODUCTION

Estuarine saltmarshes, such as Malibu Lagoon, have long been recognized as an important natural resource in the marine environment. They are among the most productive environments on earth. The estuary has been identified as a nursery ground for the juveniles of several species of marine fish, one of which is the California halibut. In fact, five of our six most important commercial fish species are dependent in some way on estuaries (Haedrich and Hall 1976).

An estuary simply defined is the transitional area between freshwater and saltwater environments (Moyle and Cech 1982). An estuary is typically a very stressful environment in which to live. The fishes found in this transitional environment are presented with some very real problems. Many physical factors are constantly changing in the estuarine environment, such as salinity, temperature, and dissolved oxygen. The fishes here have evolved either metabolically or behaviorally to deal with these changing situations.

Once the problems have been overcome, the estuarine environment offers a great many seasonal advantages to the fishes living here. In the summer and fall, the fishes find lots of food, warmer temperatures, and reduced competition and predation from other fishes that have not adapted to the estuarine environment. The seasonal availability of these resources are reflected in the seasonal changes of the fish communities. There are relatively few resident fishes in the estuarine community (Moyle and Cech 1982).

Malibu Lagoon is typical of a very small saltmarsh. The Lagoon is now a semi-natural marsh, due to the great degree of reclamation that has gone on here (Long and Mason 1983). Malibu Lagoon, historically, was typical of other small coastal lagoons found in southern California in that during the summer and fall months when rainfall is scarce the influx of freshwater into the Lagoon was virtually nonexistent (Soltz 1979; Swift and Frantz 1982). The lack of rainfall would allow a sand bar to build up at the mouth of the Lagoon and isolate the Lagoon from the ocean. When the Lagoon is cut off, the waters can become very brackish. These brackish conditions would persist until the winter rains came and washed the sand bar away. These natural conditions do not generally persist in Malibu Lagoon today. The mouth of the Lagoon is opened whenever it closes for any length of time.

In the past, the Lagoon has been dependent on the drainage of Malibu Creek to add freshwater to the system. The Malibu drainage has always been subject to periods of drought, where little or no freshwater has flowed into the Lagoon system via Malibu Creek. Now, with the development of

Malibu Canyon and the year-round runoff from man's activities via the Tapia Water Reclamation Facility, the Lagoon may, for the first time, have a year-round influx of freshwater into the Lagoon system.

Malibu Lagoon is an important and functioning estuarine saltmarsh. There are fishes here that are very dependent on the Lagoon for their survival, and the survival of any coastal wetland or estuary is of great importance to all of us both economically and ecologically.

7.2 OBJECTIVES

The purpose of this study is to develop a post-restoration baseline survey of the fishes found in the various habitats of the Lagoon. A species list reflecting relative abundance will be produced, along with estimations of the diversity of the fish communities in Malibu Lagoon. This study will establish some post-restoration baseline data on the fish populations of Malibu Lagoon.

7.3 DESCRIPTION OF STUDY AREA

It is of great importance to look at the study sites (stations) in relation to their ability to support fish communities. There are several different types of fishes found in this lagoon system that use very different habitats. The arrow goby and the Pacific staghorn sculpin use the bottom for their homes and burrows. California killifish, topsmelt, and striped mullet are found in the water column.

Many important factors, besides the physical and chemical characteristics of the water, determine where a species of fish can live. Two of these are: 1) the type of bottom, i.e. sandy, silty, or muddy and 2) the presence or absence of rocks, cobbles, plants, or algae that provide shelter or food resources. Refer to the map (figure 7.1) in order to see the physical locations of the various stations. Refer to temperature, and salinity, respectively.

Station A - This station was located in one of the channels of the developed Lagoon. It is most like station D in its proximity to the main body of the Lagoon, but is very different because of its distance from the mouth of the Lagoon. It has a very soft bottom composed of fine silts. Many organic materials are apparently being broken down in the anaerobic mud, due to the overpowering odors of hydrogen sulfide gas. The mean sediment depth has been measured to be 40 cm. This station also had the largest bloom of the algae _Ulva sp._ and _Enteromorpha sp._. The water was typically very still and did not reveal any real currents or flows throughout the sampling period. This station was always deep enough to have standing water and never went dry.

Station B - This station is located on one of the innermost arms of the restored Lagoon. It is most like station C in its proximity to the main Lagoon body, but differs in that it is furthest from the Lagoon mouth. It has a soft, silty bottom type without the odor of hydrogen sulfide gas. The mean sediment depth here was measured to be 43 cm. This station would exhibit wide fluctuations in water depth and water currents. During one sampling period, the station was drained of free-standing water by the outgoing tide. This left only the mud bottom. This station does have a seasonal algal mat (Ulva sp./Enteromorpha sp.), but it is not as thick as that at station A.

Station C - This station is located in one of the back channels of the developed Lagoon. It is most like station B in its proximity to the main body of the Lagoon, but is different due to the shorter distance to the Lagoon mouth. It is more ocean-influenced than station B. It generally has a much firmer bottom than A or B. The mean sediment depth here was measured to be 36 cm. There appeared to be a current moving through this station most of the time, however slight. This station was not as subject to the algal mats (Ulva sp./Enteromorpha sp.) as were the other stations. The presence of drift coastal algae was noted here as a regular occurrence, i.e. Macrocystis sp. holdfasts, Eisenia sp. (the whole plants), and various assorted red and brown algae with the occasional occurrence of the flowering plant Phyllospadix sp..

Station D - This station is located fairly close to both the main body of the Lagoon and the mouth of the Lagoon. The bottom here is very sandy, with small pockets of silts. It has the most spatially heterogeneous bottom of all the stations. The sediment depth here ranged from 18 to 33 cm. There was an infilling of the channel with sand as a result of winter storms and also its proximity to the managed entrance channel. It generally had drift materials: algae, flotsam, and trash. It also had many pockets of rocks/ cobbles that represent the major differences between the stations. At times of water influx or outflux this station had very rapid water movement whenever water covered the sandbar. This station did not have algal mats of Ulva sp./Enteromorpha sp..

Station E - This station was located along the shore of the Lagoon proper. It has a very sandy bottom with little or no silt. It is always subjected to the inflow and outflow of the main Lagoon system. There were no algal mats produced by Ulva sp./Enteromorpha sp. at this station. The only algae found here were those that had been brought in by the tidal influx. This tidal influx did leave many larger-sized

Macrocystis sp. holdfasts. There were many other types of drift algae observed at this station, i.e. *Corallina sp.*, *Colpomela sp.*, *Sargassum sp.*, *Elsenia sp.*.

7.4 MATERIALS AND METHODS

The Lagoon was sampled at five stations every month. A seine, measuring 6.1 x 1.8 meters of 3.1 mm mesh ace style netting, was used for this survey. Three seine hauls were made at each station.

The fishes caught were measured to the nearest millimeter (mm) standard length (S.L.). When the catches were large and the measurement of all individuals could not be done because of time constraints, sub-sampling was employed. A sub-sample of the most numerous species would be measured and all individuals would be counted for each replicate. The fishes were then returned to the area between replicate hauls (sampling with replacement). Most fishes were returned alive, but topsmelt (*Atherinops affinis*) did suffer a high degree of mortality.

In order to visualize what size class of a certain species of fish is using the Lagoon at any one time, the standard length of the four most numerous fish was broken into 10 mm size classes and graphed.

Representatives of the different species of fishes were compared to Miller and Lea (1972) for their proper identification.

The volumes of water fished were calculated from the measurements of: 1) channel depth, 2) channel width, and 3) the width of the net.

Gear efficiency was measured by blocking off a section of the Lagoon with blocking nets. The blocked-off section was made to resemble the typical fishing conditions of our study areas. The blocking nets were set far enough apart (10 meters) to allow for escape around the sides of the nets, again modeling typical conditions. The area between the nets was then fished. One seine haul was made and the number and S.L. of the fish were recorded. The blocked-off area was then fished several more times until the number of fish caught approached 0. The blocking nets were then drawn together and brought up on shore, capturing the rest of the fish. A comparison between the first net haul catch and the total number of fish caught could then be performed.

The calculations for Shannon-Weiner and Simpson diversity indices, Simpson dominance, and community similarity were performed by software by J. Eckblad (1984).

7.5 RESULTS

Gear efficiency for the seine haul method was determined to be 17.27%. Volume of water fished (cubic meters) has been calculated and graphed in figure 7.2.

Mean monthly temperatures (Celsius) were calculated and graphed in figure 7.3.

Mean monthly salinities (parts/thousand) were calculated and graphed in figure 7.4.

Table 7.1 A species list of the fish caught and their relative abundance over the entire Lagoon during the one-year period is as follows:

SPECIES	NUMBER
California killifish (*Fundulus parvipinnis*)	5864
Topsmelt (*Atherinops affinis*)	2271
Arrow goby (*Clevelandia ios*)	1034
Staghorn sculpin (*Leptocottus armatus*)	370
Opaleye (*Girella nigricans*)	44
Striped mullet (*Mugil cephalus*)	25
Long-jaw mudsucker (*Gillichthys mirabilis*)	17
Mosquito fish (*Gambusia affinis*)	16
Spotted turbot (*Pleuronichthys ritteri*)	2
California halibut (*Paralichthys californicus*)	2
Northern anchovy (*Engraulis mordax*)	1
Crevice kelpfish (*Gibbonsia monterivensis*)	1
Serranid juv. (*Paralabrax sp.*)	1
TOTAL	9648

Table 7.2 Percent of total catch of all species found in the Lagoon during the one-year sampling period.

SPECIES	% CATCH
California killifish (*Fundulus parvipinnis*)	60.78
Topsmelt (*Atherinops affinis*)	23.54
Arrow goby (*Clevelandia ios*)	10.72
Staghorn sculpin (*Leptocottus armatus*)	3.83
Opaleye (*Girella nigricans*)	.46
Striped mullet (*Mugil cephalus*)	.23
Long-jaw mudsucker (*Gillichthys mirabilis*)	.18
Mosquito fish (*Gambusia affinis*)	.17
Spotted turbot (*Pleuronichthys ritteri*)	.02
California halibut (*Paralichthys californicus*)	.02
Northern anchovy (*Engraulis mordax*)	.01
Crevice kelpfish (*Gibbonsia monterivensis*)	.01
Serranid juv. (*Paralabrax sp.*)	.01
TOTAL	99.98

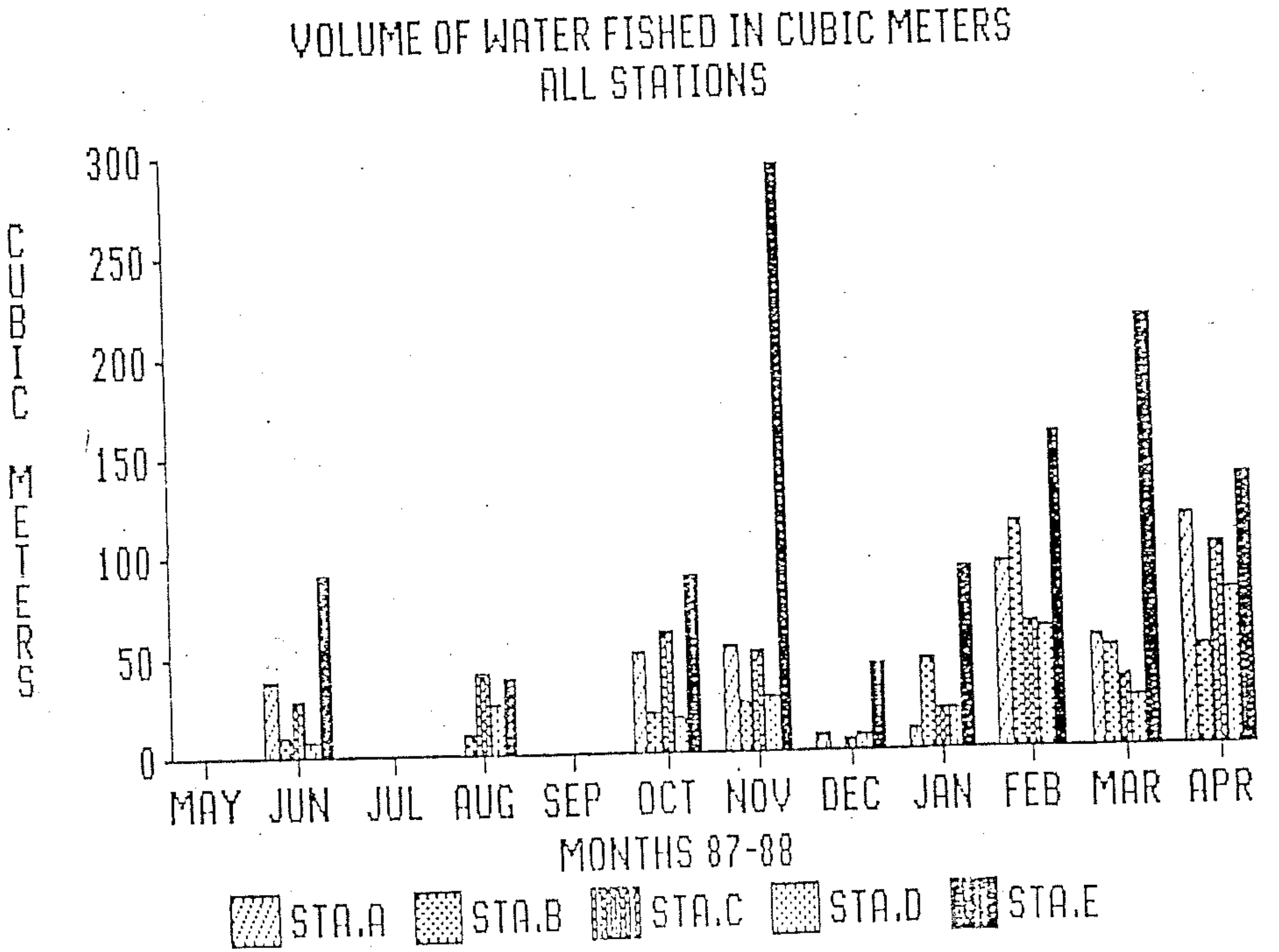


Figure 7.2 The volumes of water fished at each station per month, over the one year study period. (* Note missing data for the months of May, July, and September 1987).

Table 7.3 A species list and total numbers of each species per station. Ranked in order of most abundant.

SPECIES	STATION A	B	C	D	E
Fundulus parvipinnis	1541	1927	1515	300	581
Atherinops affinis	850	104	290	371	656
Clevelandia ios	63	148	382	341	100
Leptocottus armatus	73	0	15	38	90
Girella nigricans	10	11	11	10	2
Mugil cephalus	4	0	10	11	0
Gillichthys mirabilis	1	1	15	0	0
Gambusia affinis	8	2	6	0	0
Pleuronichthys ritteri	0	0	0	0	2
Paralichthys californicus	0	1	0	0	1
Engraulis mordax	0	0	1	0	0
Gibbonsia monterivensis	0	0	0	0	1
Paralabrax sp.	0	0	0	1	0
	2550	2194	2399	1072	1433

Table 7.4 The percentage of the total catch per station

STATION	# Individuals	% CATCH
A	2550	26.43 %
B	2194	22.74 %
C	2399	24.87 %
D	1072	11.11 %
E	1433	14.85 %
TOTAL	9648	100.00 %

Table 7.5 Percent (%) similarity of the various stations in regards to the fish fauna over the year. This is a measure of how similar the various stations are with one another.

STATIONS	B	C	D	E
A	68%	78%	67%	79%
B	*	75%	40%	52%
C	*	*	60%	66%
D	*	*	*	73%

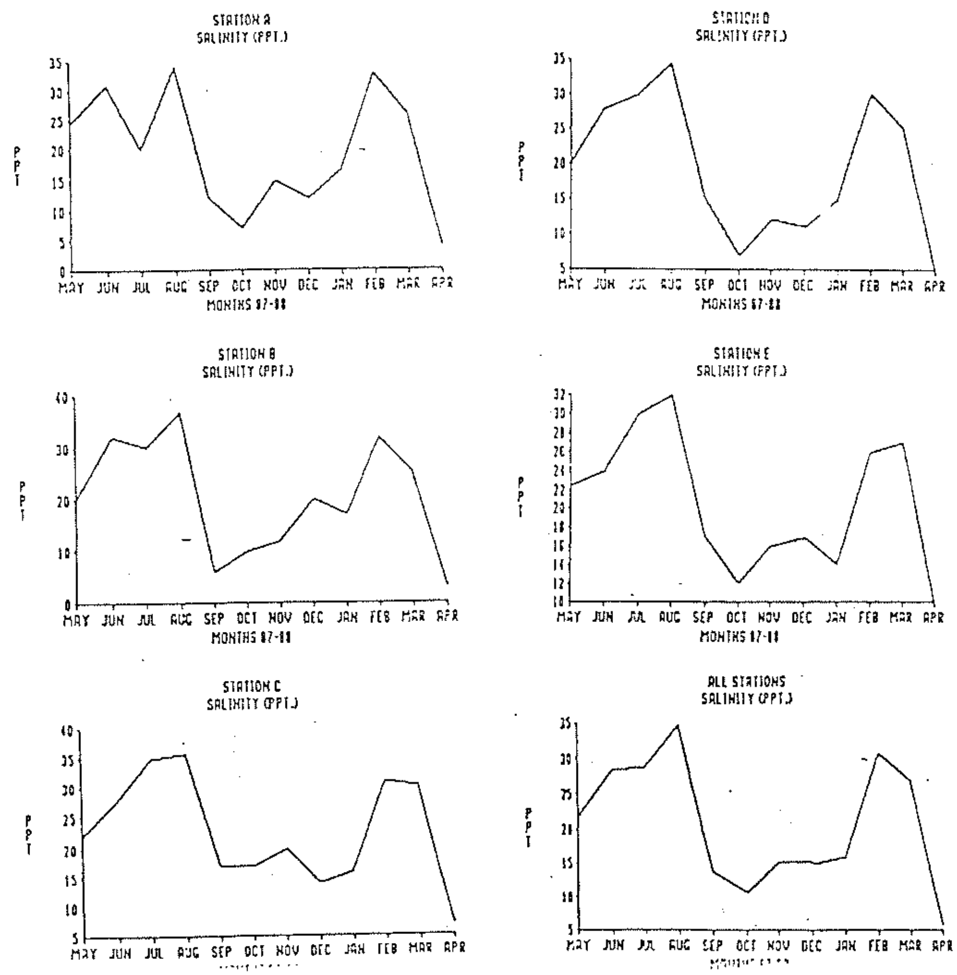


Figure 7.4 Water salinity measurements (ppt) at each station by month and mean salinity profile, of the lagoon, for all stations, over the one year study period.

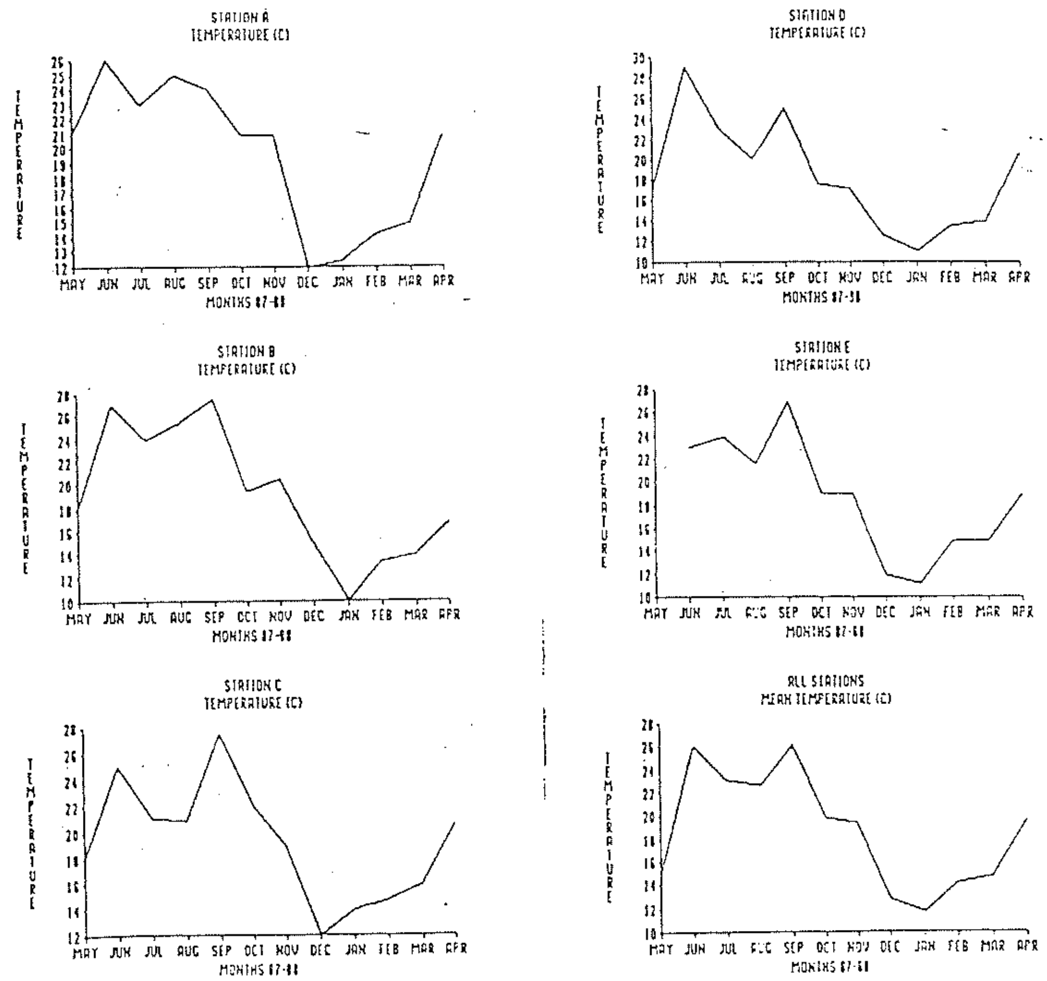


Figure 7.3 Water temperature (C) at each station by month and mean temperature profile, of the lagoon, for all stations, over the one year study period.

Figure 7.5 Mean Shannon-Weiner diversity values (logs to the base 2) per month over the one year study period.

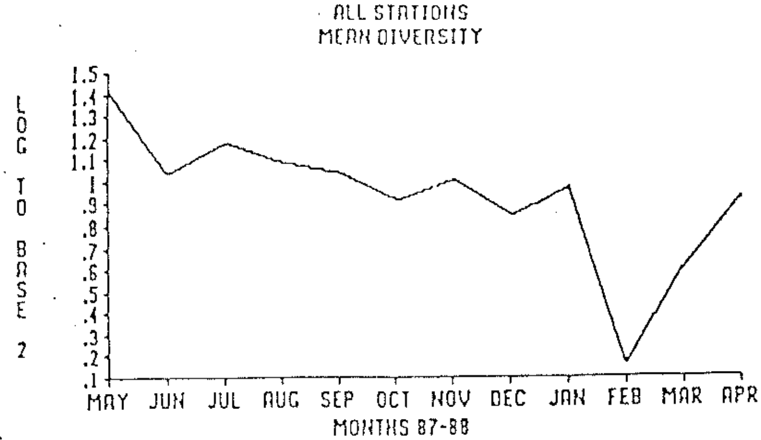


Figure 7.6 Shannon-Weiner diversity values (logs to the base 2) by station per month for the one year study period.

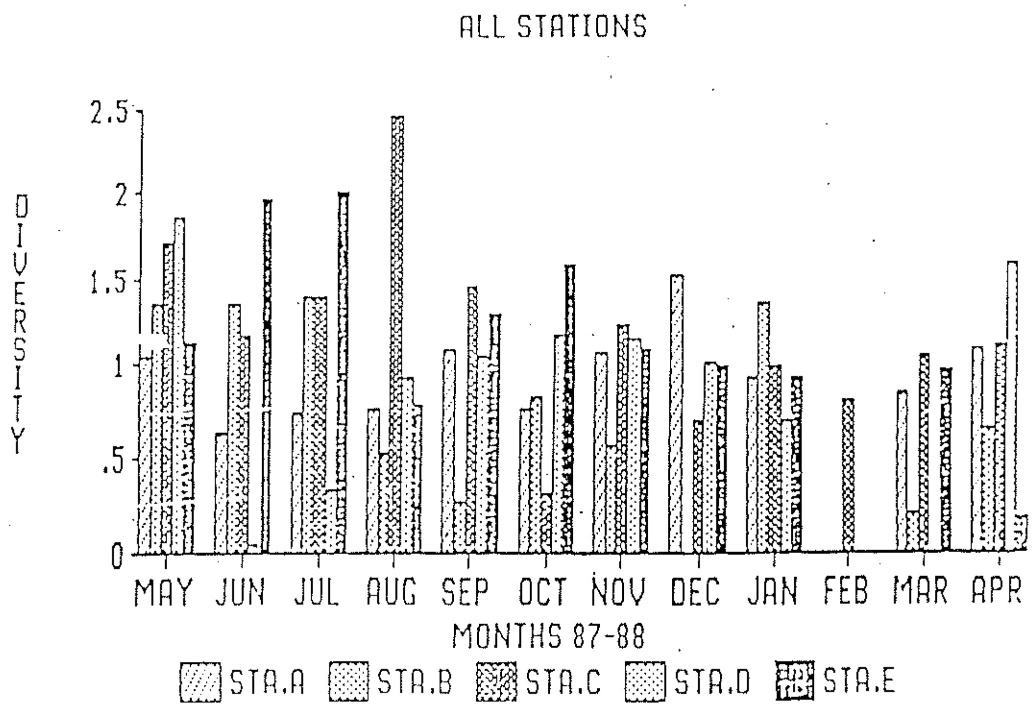


Table 7.6 A measure of diversity and dominance of the the total catch of all stations over the one-year period (Simpson and Shannon indices, *logs to base 2).

STATION	SIMPSON DIVERSITY	SIMPSON DOMINANCE	SHANNON DIVERSITY
A	.522	.478	1.322*
B	.221	.779	.692*
C	.556	.444	1.619*
D	.699	.301	1.880*
E	.617	.383	1.604*

Mean monthly Shannon-Weiner diversity values for all stations over the one-year period were calculated and graphed in figure 7.5. It should be noted that the high of 1.416 was in May and the low of .1582 was in February.

Shannon-Weiner diversity values for each station are graphed over a one-year period in figure 7.6. The number of species (S) has been graphed for each station over the one-year period in figure 7.7.

The monthly Shannon-Weiner diversity values for each station over a one-year period were calculated and graphed in figure 7.8.

The total of all fishes caught per month is graphed in figure 7.9. The mean monthly abundance of the four most numerous species has been graphed in figure 7.10.

Standard lengths of the four most abundant fishes were sorted into 10mm size classes and graphed. Figure 7.11 California killifish (*Fundulus parvipinnis*), figure 7.12 Topsmelt (*Atherinops affinis*), figure 7.13 Arrow goby (*Clevelandia ios*), figure 7.14 Pacific staghorn sculpin (*Leptocottus armatus*).

7.6 OBSERVATIONS

The surface areas of both the Malibu Lagoon State Beach and its waters have been measured to be 14.7 hectares (36.1 acres) and 5.2 hectares (13 acres) respectively. Malibu Lagoon is a very small coastal wetland that supports a fish population that is characterized by low diversity and fairly low productivity, which is typical for a lagoon of this size. The Lagoon is subject to sedimentation. It does not have any established *Zostera sp.* as do many other bay and estuarine systems in California (Onuf 1987). Due to the lack of plants and the effects of sedimentation, the Lagoon does not have much spatial heterogeneity, which may allow for more diversity.

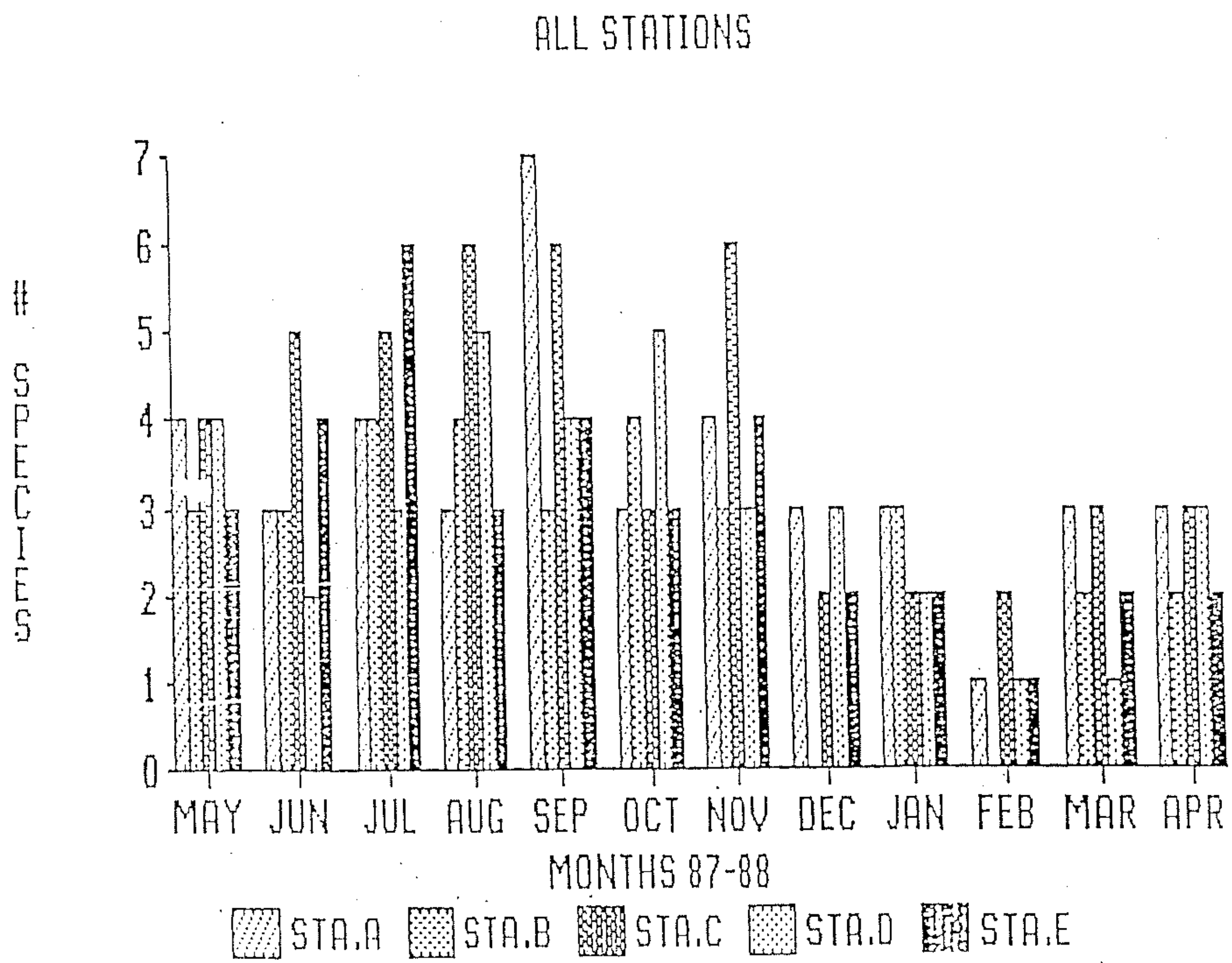


Figure 7.7 Number of species (S) present at Station per month, over the one year study period.

Figure 7.8 Shannon-Weiner diversity values (logs to the base 2) per month, and by station, over the one year study period.

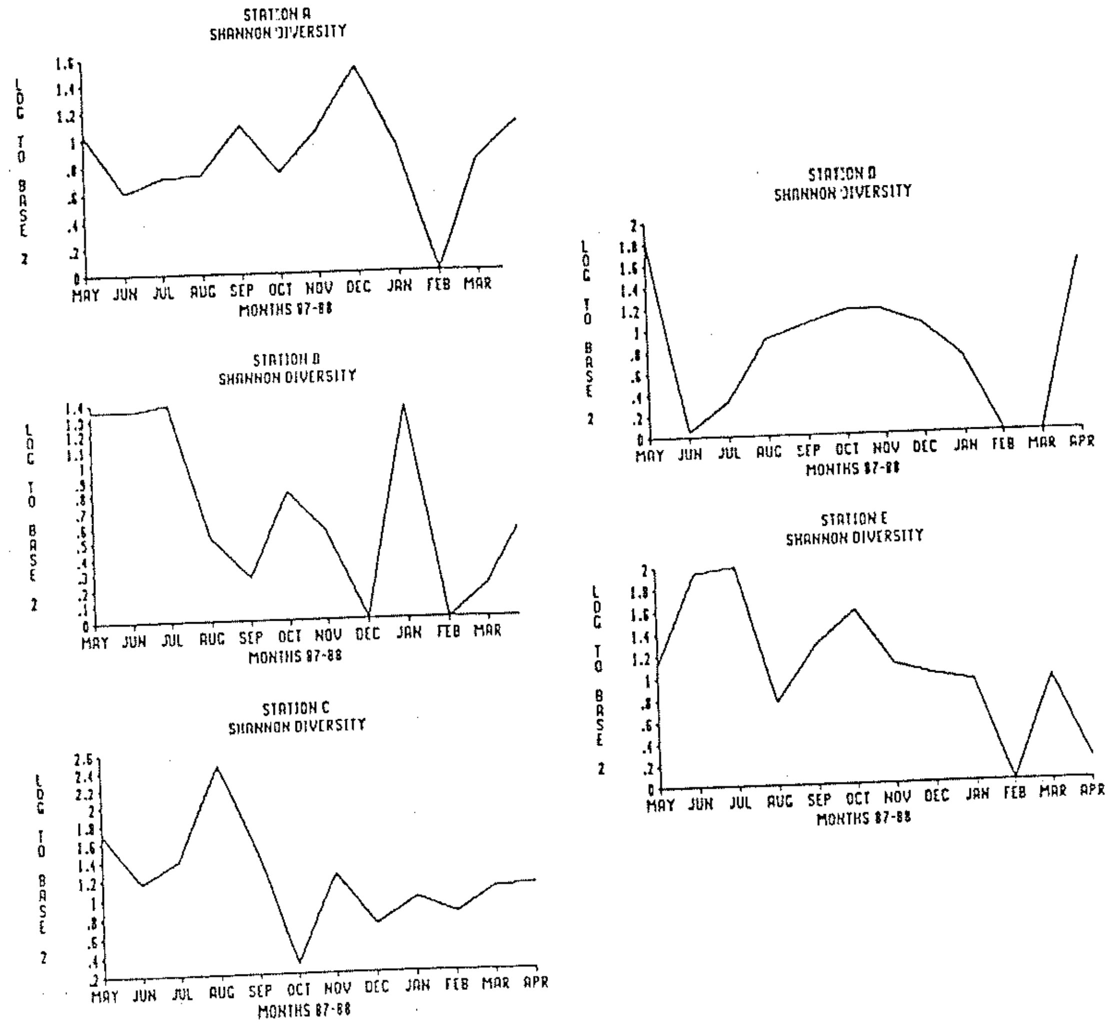


Figure 7.9 Total numbers of fish caught, per month, at all stations throughout the one year study period.

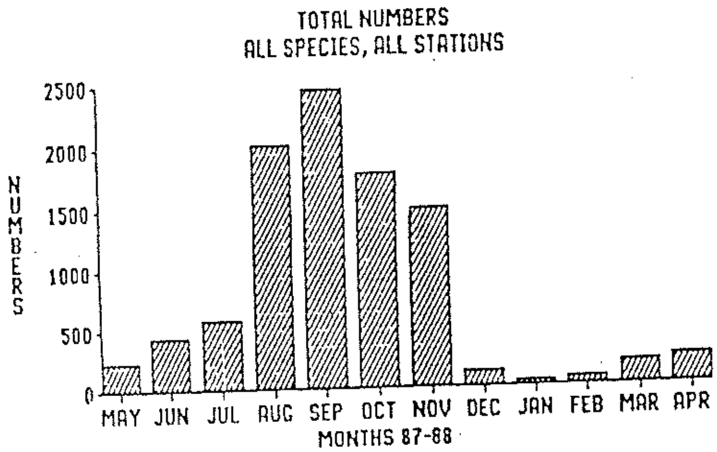
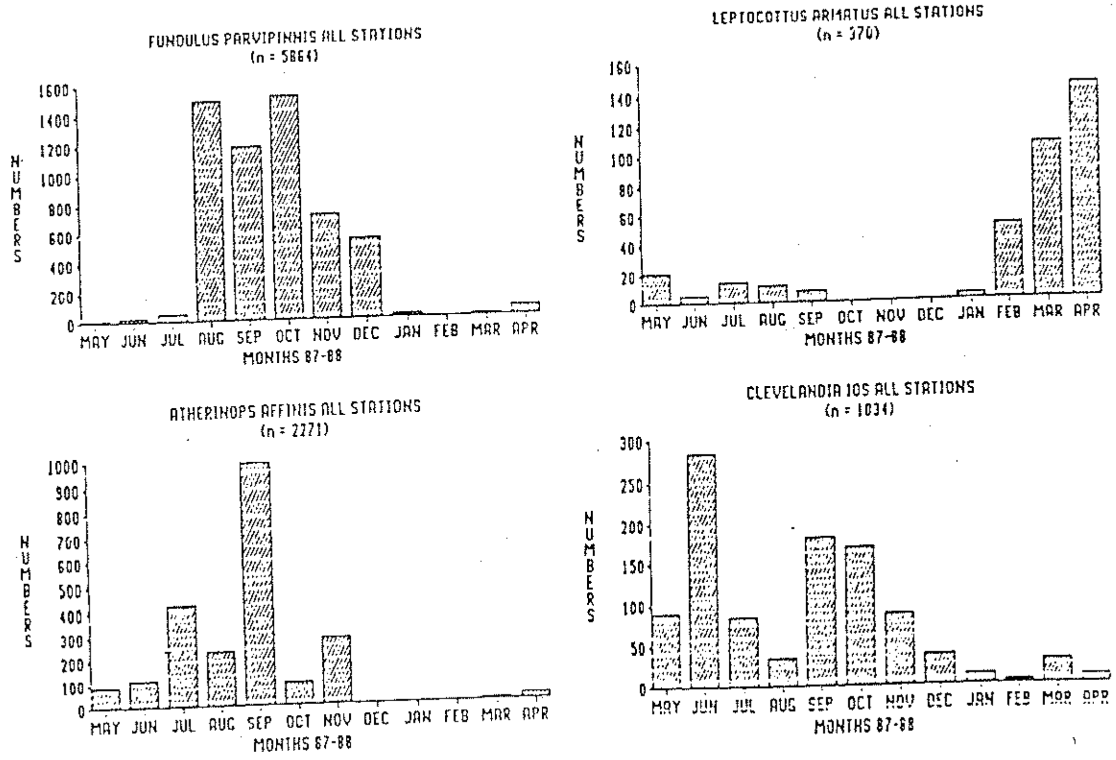


Figure 7.10 Relative abundances per month of the four most numerous species over the one year study period.



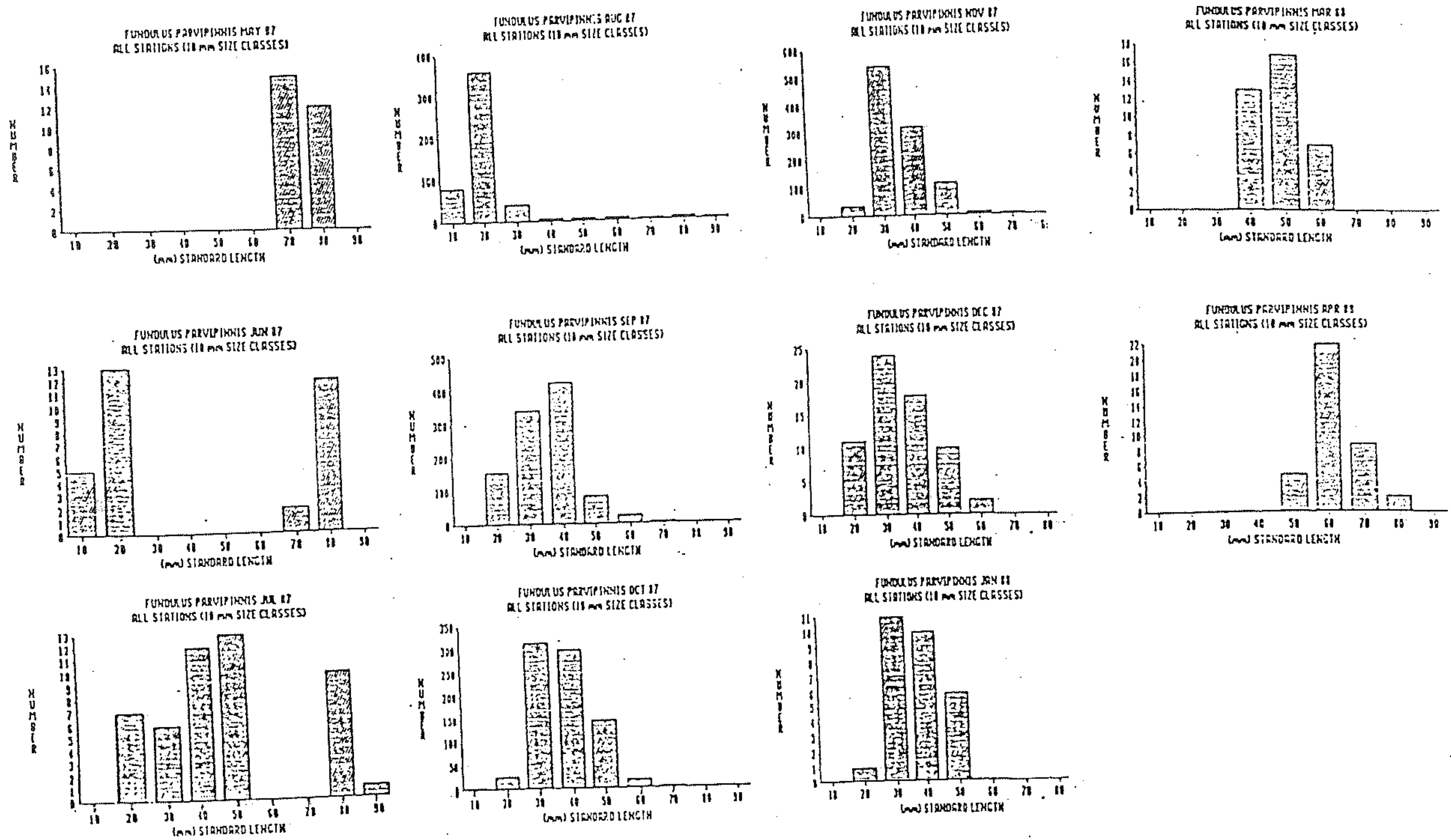


Figure 7.11 Standard length, in 10 mm groupings, of California killifish (Fundulus parvipinnis) found at all stations, per month, in the lagoon over the one year study period.

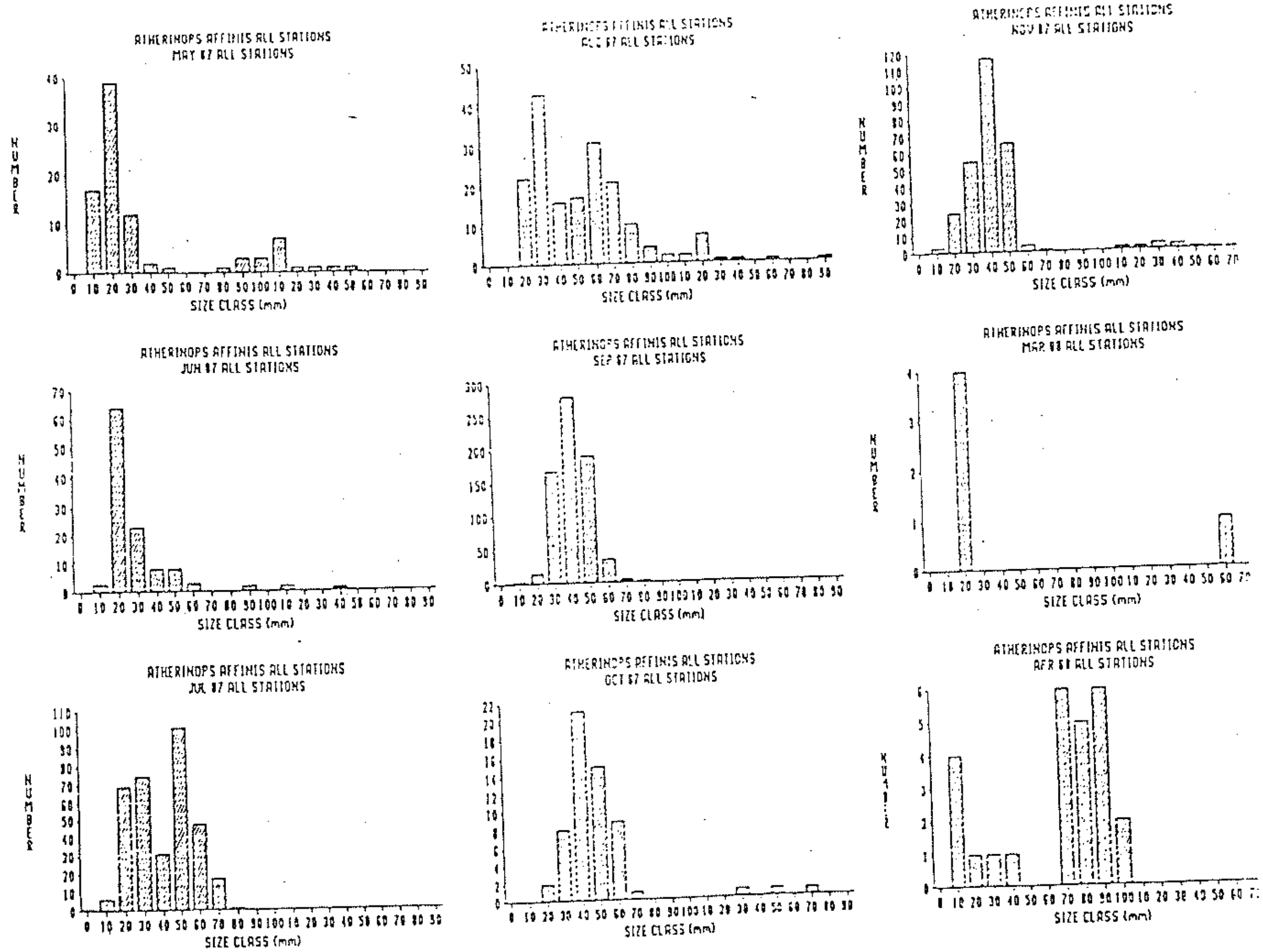


Figure 7.12 Standard length, in 10 mm groupings, of topsmelt (Atherinops affinis) found at all stations, per month, in the lagoon over the one year study period.

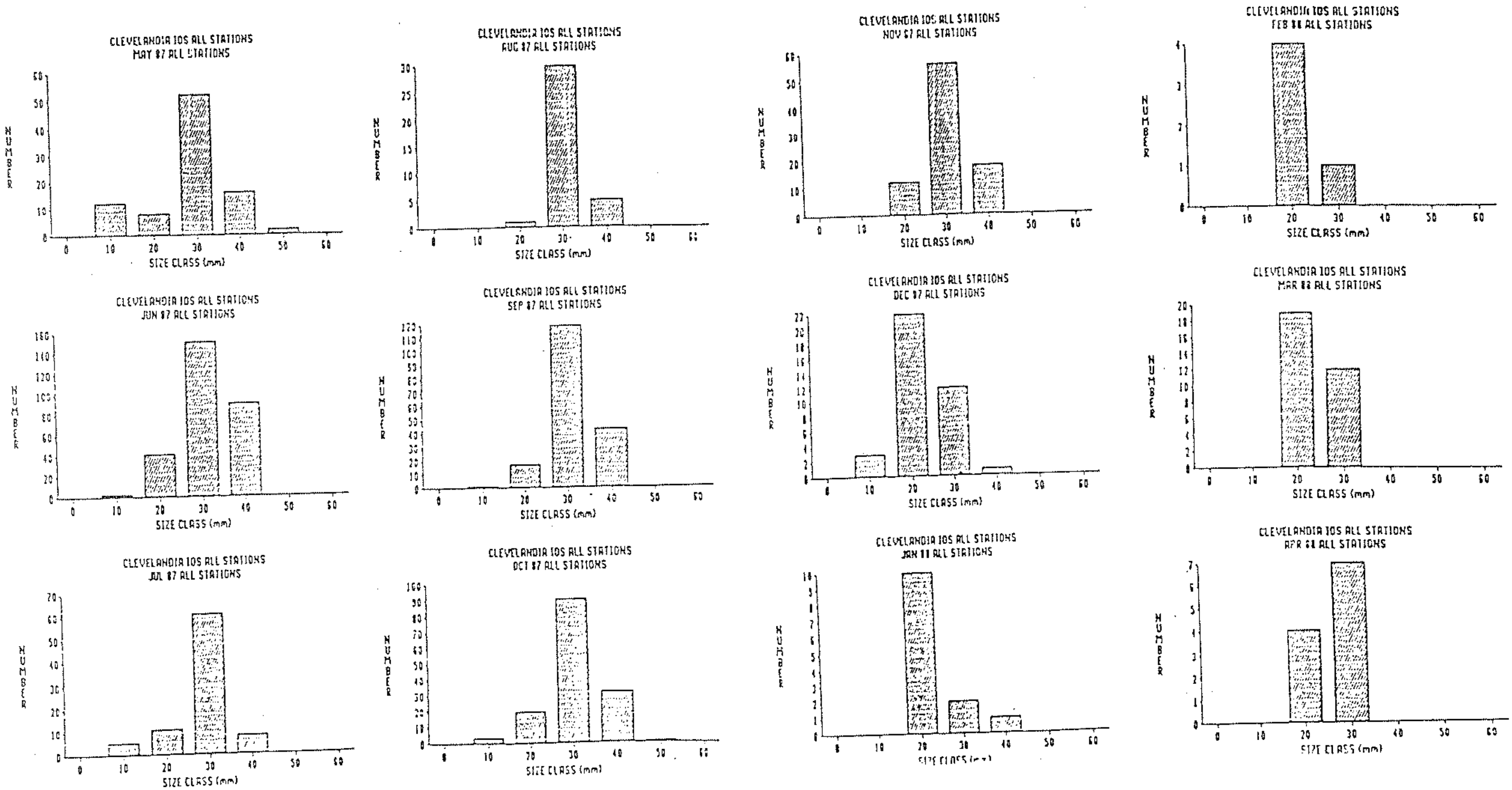


Figure 7.13 Standard length, in 10 mm groupings, of arrow goby (Clevelandia ios) found at all stations, per month, in the lagoon over the one year study period.

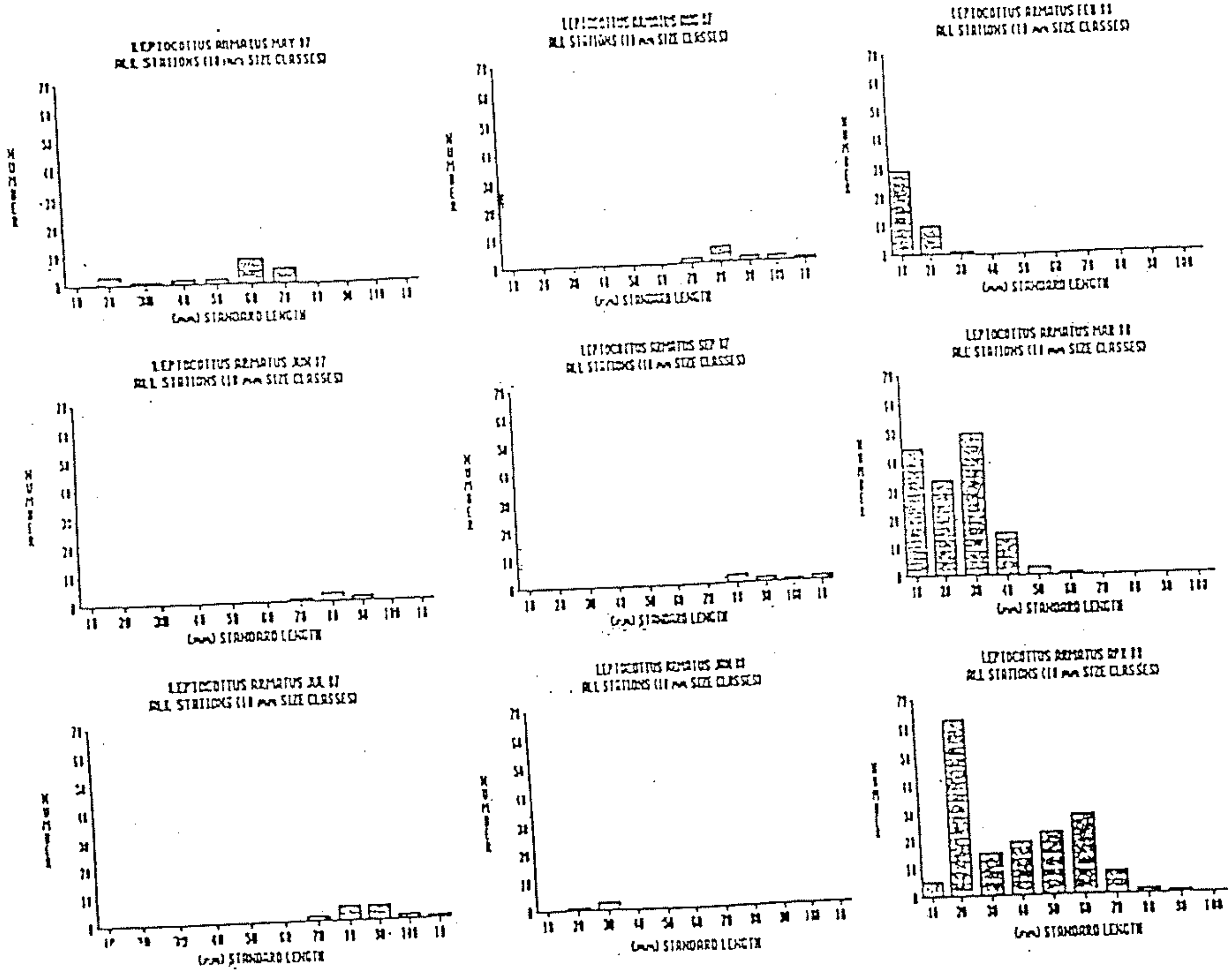


Figure 7.14 Standard length, in 10 mm groupings, of Pacific staghorn sculpin (*Leptocottus armatus*) found at all stations, per month, in the lagoon over the one year study period.

In terms of the sampling gear employed for this study, it has long been recognized that obtaining good samples of the fish populations requires much effort and expense (Haedrich and Hall 1976). In the present study a haul seine was used because it was inexpensive and fairly efficient (17.27%). Haul seines have been employed in many areas where, due to the nature of the waters being sampled, it was the best alternative (Calliet, et. al. 1986). The areas that were sampled were generally shallow - 1 meter. It would have been very difficult to use casting nets, otter trawls, or drop nets in the channel arms of the Lagoon. The use of a bag seine may have given us a better estimate of the fish communities in the Lagoon.

The haul seine, by itself, cannot effectively sample all the different fish species of Malibu Lagoon. Fast swimming fish, such as adult striped mullet and topsmelt, may be able to escape this net and therefore are not consistently surveyed. Blocking nets were used to gauge the fishing efficiency of the haul seine, but they are very labor intensive and time consuming to use. For these reasons, the blocking nets could not be used in the monthly samplings, and thus, the size and structure of the fish populations may not have been as effectively sampled as by other means.

The volumes of water fished, figure 7.2, were quite variable, both month to month, and station to station. This is an important factor to keep in mind as the data from these stations is reviewed. The causes of the variations in water volume are a combination of several factors, such as tidal height and the degree of Lagoon mouth closure. Station E, located on the main Lagoon body, consistently had the most volume of water fished.

A total of thirteen species of fish were collected from the five stations of the Lagoon (see table 7.1.). (Ed. note: A 14th species, a bay pipefish (Syngathus sp.) was collected during a September 1988 survey). A previous study performed on Malibu Lagoon, Fitzgerald and Hasz (1982), revealed eleven species of fish over a two-year period. A species list assembled by Swift (1982) shows that, from historical accounts and more recent studies, there is a total of twenty-five species recorded for the Lagoon. This study can add several fishes to this listing. They are the: California halibut (Paralichthys californicus), spotted turbot (Pleuronichthys ritteri), crevice kelpfish (Gibbonsia montereyensis), and a juvenile serranid (Paralabrax sp.).

A similar study was done on Los Penasquitos Lagoon (Nordby and Covin 1988), another small estuarine saltmarsh, where they found eleven species of fish during their one-year survey. The Malibu Lagoon species list is quite different in that fourteen species of fish were found in Malibu Lagoon. The two lagoon systems are different from one another. Los Penasquitos Lagoon has been measured to have 13 hectares (33 acres) of channel habitat which is about 2.5 times that of Malibu Lagoon, which has 5.2 hectares (13 acres) of similar habitat. Los Penasquitos Lagoon is also located in a more southern region of California than is Malibu Lagoon.

When comparing the total number of fishes present in the Lagoon (figure 7.9) throughout the year, it can be seen that there are more individuals present during the months of August through November. This has been recognized as a general pattern in the studies of temperate estuarine fish populations (Allen 1982). This is partially due to the young of the year (YOY) of California killifish, topsmelt, and arrow goby being present at this time. These months are very important to the survival of these species in the Lagoon system. It is during this time that the Lagoon waters are generally warmer (figure 7.3), and there is an abundance of food available to the YOY of these species.

Four species of fish accounted for 98.87% of the total catch (see table 7.2). THe most numerous species found in the Lagoon was the California killifish (figure 7.10). It accounted for 60.78% of the total catch. It is the large amount of YOY killifish found in the months of August through November (figure 7.11) that account for this percentage. This species was found in the Lagoon in all samples except February's. It appears that the California killifish are year-round residents of the Lagoon, and that during the winter and early spring the population consists of mainly adults. The California killifish has been considered to be a resident of other similar lagoon systems (Allen and Horn 1975).

Other year-round residents of the Lagoon appear to be the arrow goby and the staghorn sculpin. The most consistent of these being the arrow goby (figure 7.10), which was caught at some point on all sampling dates. The topsmelt was frequently found in the Lagoon, but was absent from all samples in the months of December, January, and February. This, in part, may be due to the schooling nature of these fishes, and the fact that our sampling method seemed to catch the juvenile topsmelt much more readily than the adults, with the fast-swimming adults (greater than 100 mm) escaping the net. The topsmelt is probably a year-round resident of the Malibu Lagoon system, when compared to other lagoon and estuarine systems (Allen and Horn 1975; Klingbeil, et. al. 1975), just not caught by our sampling methods.

Topsmelt were found the most abundant in the months of July, August, September, and November with the heaviest use in September (figure 7.10). Arrow goby were found in the largest numbers in the months of June, September, and October (figure 7.10).

The staghorn sculpin (figure 7.10) has a different pattern of temporal use. It is present in the Lagoon from January to September. No staghorn sculpins were found in the Lagoon in the months of October, November, and December. It is found in the most abundant numbers in the months of February, March, and April. This is when the YOY sculpin are present (figure 7.14). This pattern is in agreement with that found by Tasto (1975). Tasto (1975) also found that staghorn sculpin eat the juvenile arrow goby, which is abundant during these months.

There were no staghorn sculpins caught at station B throughout the year-long survey, although it was caught at all other stations. The fact that station B was drained during periods of low tide, and that staghorns have been observed to exhibit little movement (Tasto 1975) suggest that the YOY staghorns would not settle at this station and would not move into the station as adults at a later date.

Patterns of Lagoon use by the YOY of the four most abundant species can be seen in the following figures: California killifish (7.11), topsmelt (7.12), arrow goby (7.13), and Pacific staghorn sculpin (7.14). These figures, consisting of standard length data broken into 10 mm size classes, can be used to follow the growth of the YOY fishes from month to month in the Lagoon system. The 10 mm size class grouping did not resolve any distinct patterns in arrow gobies because of their small size. It should be noted that adult-sized topsmelt and staghorn sculpin were not taken in the Lagoon. The adult topsmelt has been taken in Anaheim Bay (Klingbeil et. al. 1975). The adult staghorn sculpin may move out of the Lagoon to spawn offshore (Tasto 1975).

Simpson and Shannon-Weiner diversity indices have been included in this report, although it seems that indices of this type should be de-emphasized (Green 1979). Green (1979) now feels that a simple index like S (the number of species) are biologically more meaningful as indicators of change in the environment. Future studies may be better able to use a measure of S, as opposed to the calculated diversity indices, in order to see changes in fish populations. It is for this reason that S has been presented in figure 7.7.

Station B (figure 7.6) has the least diversity of all stations. It also had the highest measure of dominance, that is, where one organism is found in much greater numbers. Station B is interesting in that the fishes found here could not be residents of this station. This is due to the fact the station B would be drained of standing water at low tide. The fishes caught here must move in and out of this station with the incoming or outgoing tides. This type of movement has been observed in the California killifish found at this station, which turns out to be over 87% of the total catch at this station.

It can be seen in figure 7.5 that the mean monthly values of the Shannon-Weiner diversity index is highest (1.416) in May 1987 and lowest (.158) in February 1988. The pattern of high and low diversity found here is somewhat different from that found in Colorado Lagoon by Allen and Horn (1975). They obtained their highest values (1.11) in April and June and their lowest value (0.03) in September.

The Shannon-Weiner diversity index value calculated for Malibu Lagoon was 1.423. When this is compared to the annual Shannon-Weiner diversity index values calculated for various estuarine areas (Moore 1978), six values above and six values below the calculated diversity index for Malibu Lagoon are found. It can be concluded that the calculated mean diversity value is similar to other estuarine areas.

All of the stations that were sampled are in effect little microhabitats in the Lagoon system. The physical proximity of these stations to each other and to the main body of the Lagoon may determine what fish communities are found there. The fish communities of each station were compared and contrasted in order to see if there may be a microhabitat difference. Table 7.5 shows that the most dissimilar stations from each other are B&D, B&E. This is probably due to the close proximity of stations D and E to the Lagoon mouth. Station B is the farthest of all stations (see figure 7.1) from the Lagoon mouth and the potential influx of ocean water. Station B is also the most variable station with respect to water height and volume.

7.7 DISCUSSION

There are many ecological reasons to promote the preservation and wise management of these small estuarine saltmarsh habitats (Horn 1980). Malibu Lagoon does serve as a breeding and nursery ground for various coastal fishes. The California killifish and the arrow goby, although not important commercial fishes, may provide forage for economically more important higher-level consumers in the ecosystem.

It is now quite important that threats to the normal functioning of Malibu Lagoon be taken into account. One of the major problems facing the Lagoon will be the influx of treated or untreated water. There have been major housing developments placed at the headwaters of the Malibu Creek drainage system. These contribute influxes of waste water from washing cars, watering lawns, etc., into the Creek system that could possibly influence the Lagoon.

The proposed expansion of the Tapia Water Reclamation Facility will increase the influx of treated effluent into Malibu Creek. This will be an increase to approximately 15 million gallons per day (MGD), up from the current 8-10

MGD. In combination with a proposed satellite plant, the total discharge of treated effluent may rise to 25 MGD.

There will be ecological problems associated with the release of this treated water into the Lagoon. Historically the Lagoon has had little or no freshwater influx during the summer and fall months. This, along with the natural closing of the Lagoon mouth, would cause very brackish conditions in the Lagoon. Now, with the constant release of treated water into the Lagoon, the Lagoon will experience reduced salinities and increased nutrient concentrations (Zedler 1986). This will have an effect on the fishes found in the Lagoon system. If the water is released on a very even schedule, bringing with it lowered salinities and increasing nutrient concentrations, it may predispose the Lagoon system to favor one species over another, thereby adversely affecting the normal patterns of selection in this system.

There should be some emphasis placed on releasing the water in such a manner as to reflect natural seasonal streamflow patterns of freshwater influx into the Lagoon system. As Zedler (1984) suggests, a system of impounding the treated effluent and the release of it with the outgoing tide may help in minimizing the effects of this freshwater influx. The release of the treated water may also be staggered so that the Lagoon may return to semi-natural conditions between discharges.

If this water is to be stored in percolation/retention ponds or a similar structure, an effort should be made to monitor the physical/chemical characteristics of this water mass prior to its release. The water mass may develop physically/chemically distinct qualities that again may influence the natural system of the Lagoon with respect to the flora and fauna. This influence may affect the recruitment patterns of coastal fishes that may use the Lagoon as a nursery ground (Boehlert and Mundy 1988). Percolation/retention ponds may exert a significant influence upon the rejuvenation of the steelhead fishery in this watershed.

The editors note that surveys for steelhead trout (Oncorhynchus mykiss) during the expected migration period and the tidewater goby (Eucyclogobius newberryi), two species historic to Malibu Lagoon, were unsuccessful. On Feb. 14, 1988, a single adult female steelhead trout was recorded in Malibu Creek (California Trout, Inc., Izaak Walton League of America records, 1988).

The anadromous steelhead trout (Oncorhynchus mykiss) is an example of a fish whose historic numbers in Malibu Creek and Lagoon have dramatically decreased over time to extremely low levels. Malibu Creek is presently the southernmost range extension of this highly regarded fish species, which enters Malibu Lagoon to spawn in Malibu Creek.

The Rindge Dam has been a substantial geographic barrier to migration of steelhead since the 1920s. The creek segment upstream from the dam is believed to be the optimum spawning habitat for steelhead along Malibu Creek (Tippets 1988 pers. comm.).

Malibu Lagoon is a critical habitat component in the life cycle of local steelhead trout. (pers. comm. Camm Swift 1989) Opening the Lagoon entrance artificially, as is currently done, will likely have a continual destructive impact upon the steelhead fishery in Malibu Creek. A coastal lagoon may hold the entire year's crop of juvenile steelhead, and sudden non-natural exposure to the sea may fatally affect them all (Clark 1988). Management must continually adjust to the myriad of variables which themselves are in a state of flux.

The subject of steelhead management is beyond the scope and intent of the present study, yet it is of great interest and importance and merits further research.

7.8 SUMMARY

Thirteen species of fish were caught in Malibu Lagoon over a one-year sampling period. The California killifish (Fundulus parvipinnis) made up 68.78% of the total catch. The top four species of fish accounted for 98.87% of the total catch. Patterns of Lagoon use by young-of-year fishes were established and can by considered typical of a west coast temperate estuary. Calculated diversity indices show that the Lagoon is not a very diverse system, which is typical of estuarine saltmarshes. Malibu Lagoon appears to be a functioning estuary, even though it is relatively small in size.

7.9 LITERATURE CITED

Allen, L.G. and M.H. Horn. 1975. Abundance, diversity and seasonality of fishes in Colorado lagoon, Alamitos bay, California. Estuarine and coastal marine science 3:371-380.

Allen, L.G. 1982. Seasonal abundance, composition, and productivity of the littoral fish assemblage in upper Newport Bay. Fishery Bulletin: Vol. 80(4):769-790.

Boehlert, G.W. and B.C. Mundy. 1988. Roles of behavioral and physical factors in larval and juvenile fish recruitment to estuarine nursery areas. American Fisheries Society Symposium 3:51-67.

Caillet, G.M., Love, M.S., and Ebeling, A.W. 1986. Fishes: a field and laboratory manual on their structure, identification, and natural history. Wadsworth Inc. pp. 194.

Eckblad, J. 1984. Ecological analysis programs plus. Oakleaf Systems.

Fitzgerald, C. and L. Hasz. 1983. Water quality and fish sampling results from Malibu Lagoon: prerestoration period. Unpublished report? pp. 15.

Fritz, E.S. 1975. The life history of the California killifish *Fundulus parvipinnis* Girard, in Anaheim Bay, California. pp. 91-106. In E.D. Lane and C.W. Hill (Editors), The Marine Resources of Anaheim Bay, California Department of Fish and Game, Fish Bulletin 165.

Green, R.H. 1979. Sampling Design and Statistical Methods for Environmental Biologists. John Wiley and Sons Inc. pp. 257.

Haedrich, R.L., and C.A.S. Hall. 1976. Fishes and Estuaries. Oceanus (Fall, 1976) 19(5):55-63.

Horn, M.H. 1980. Diversity and ecological roles of noncommercial fishes in the California marine habitats. CalCOFI Rep., Vol. XXI:37-47.

Klingbeil, R.A., Sandell, R.D., and Wells, A.W. 1975. An annotated checklist of the elasmobranchs and teleosts of Anaheim Bay, pp. 79-90. In E.D. Lane and C.W. Hill (Editors), The Marine Resources of Anaheim Bay, California Department of Fish and Game, Fish Bulletin 165.

Long, S.P., and C.F. Mason. 1983. Saltmarsh ecology. Chapman and Hall distributors. pp. 160.

Miller, D.J. and Lee, R.N. 1972. Guide to the coastal marine fishes of California. California Department of Fish and Game, Fish Bulletin 157. pp. 1-249.

Moore, R.H. 1978. Variations in the diversity of summer estuarine fish populations in Aransas bay, Texas, 1966-1973. Estuarine and coastal marine science 6:495-501.

Moyle, P.B. and J.J. Cech, Jr. 1982. *Fishes: an introduction to ichthyology.* Prentice-Hall, Inc. Englewood Cliffs, N.J. 07632. pp. 593.

Nordby, C. and Covin, J. 1988. Physical-chemical and biological monitoring of Los Penasquitos lagoon. Unpublished report from the Los Penasquitos Lagoon Foundation, P.O. Box 866, Cardiff, CA 92007. pp. 45.

Onuf, C.P. 1987. The ecology of Mugu lagoon, California: an estuarine profile. U.S. Fish and Wildlife Service Biol. Rep. 85(7.15). pp. 122.

Swift, C. 1982. A list of the fishes of Malibu creek and lagoon with a brief description of their habitat requirements and seasonal movements. Unpublished report? pp. 12.

Tasto R.N. 1975. Aspects of the biology of Pacific staghorn sculpin, *Leptocottus armatus* Girard, in Anaheim Bay, pp.123-135. In E.D. Lane and C.W. Hill (Editors), the Marine Resources of Anaheim Bay, California Department of Fish and Game, Fish Bulletin 165.

Zedler, J.B. and C.S. Nordby. 1986. The ecology of Tijuana Estuary, California: an estuarine profile. U.S. Fish and Wildlife Service Biol. Rep. 85(7.5). pp. 104.

8.0 BIRDS OF MALIBU LAGOON

8.1 INTRODUCTION

Malibu Lagoon contains a high diversity of bird species and relatively high numbers of birds for its small size (Kiff and Nakamura 1979). Most of the birds appear in the Lagoon between October and March, with minimum numbers occuring between May and August (Figure 8.1), coinciding with migration times along the Pacific Flyway.

The Lagoon is used by both landbirds and waterbirds as resting, bathing, feeding, mating and nesting habitat. Although some species observed at the Lagoon use it for all of these purposes, most species do not. Some species such as the snowy plover (*Charadrius alexandrinus*) and bald eagle (*Haliaeetus leucocephalus*) formerly nested in and around Malibu Lagoon, but no longer do so because of habitat destruction and increased human activity (Kiff and Nakamura 1979).

8.2 OBJECTIVES

The goal of this survey is to gather accurate baseline data on seasonal population trends, habitat use, current local status of rare and endangered species, and to compile an overall list of bird species utilizing Malibu Lagoon. Birds are important indicators of environmental problems within an ecosystem, for example, thinning of pelican eggshells caused by DDT (Anderson and Gress 1983). Therefore, baseline information becomes a valuable tool in documenting and comparing future change in environmental conditions within this estuarine system, and will yield important data, enhancing the long-term management potential of Malibu Lagoon.

8.3 MATERIALS AND METHODS

The birds of Malibu Lagoon were observed and counted for a total of 51 surveys, averaging 1.5 hours per survey from April 1987 to March 1988. Counts were made using a 20X spotting scope and 7X35 binoculars from several locations (Map 8.A) around the inlets of the Lagoon (1,2,3) and three locations around the main Lagoon (4,6,7). The beach and the ocean were surveyed from two locations, one (4) near the Lagoon and one on the beach (5). The upper Lagoon, bounded North by the storm drain from Malibu Civic Center and South by the Pacific Coast Highway Bridge, was surveyed from several locations (8,9,10,11). This was necessary because of tall thick vegetation along the edges of the upper Lagoon.

Map 8.A. Aerial Photograph of Malibu Lagoon. 1986. Entrance closed. Locations of bird observation stations. Inlets (1,2,3), Main Lagoon (4,6,7), Beach and Ocean (4,5), and Upper Lagoon (8,9,10 11). Location of Adamson Property (A).

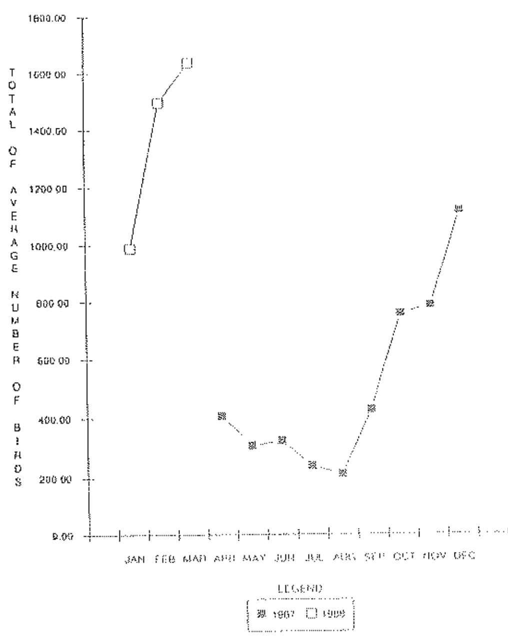


Figure 8.1. Monthly Averages for All Species of Waterbirds at 11 Census Sites. April 1987 - March 1988.

In the main Lagoon, the survey was conducted by counting the individuals of one species before moving on to the next species. This was necessary because of interference from humans and dogs disturbing the birds. The inlets of the Lagoon were easier to survey because fewer birds utilized them. Several species could be counted at one time because of the low numbers there.

The beach and ocean survey was conducted in the same manner as the main Lagoon survey. This was complicated by heavy usage of the beach by people and dogs. Most of the birds congregated on or around the floating rafts in the ocean. The survey of the upper Lagoon was done by continually moving upstream from site to site and counting the birds. Most surveys were conducted by two individuals and independent identification was performed as a measure of accuracy. This insured that any misidentification could be corrected before species were recorded. Several birds that appeared rarely were confirmed on The Audubon Society recorded tape for that time period.

When counting birds, several problems can potentially bias the totals and identification of birds. Disturbances which cause the birds to take flight and then re-settle, make it extremely difficult to get an accurate count, especially when numbers encountered for a species may exceed 300. To avoid a serious miscount, when a mass movement to a new area occurred, those species whose counts had not been completed were recounted. Otherwise only the areas not previously counted were surveyed.

Species identification was sometimes complicated because of distance from the observation points, especially with small shorebirds. This problem was overcome by counting after moving to a better vantage point where the birds could be properly identified.

Habitat usage and sightings of bird species were further confirmed using data collected by students involved in marine science school programs. These programs were conducted by the Topanga-Las Virgenes Resource Conservation District, with students being assisted by leaders trained in bird identification. Information was collected twice weekly during the school year (October to June) and once weekly during summer programs.

8.4 OBSERVATIONS

There were a total of 151 bird species sighted in Malibu Lagoon, 78 waterbird species and 73 landbird species, from April 1987 to March 1988. Numbers of birds dropped in the late spring and remained low through the summer. Numbers began climbing in late summer, continued climbing through winter and peaked in March, then dropped again in late spring (Figure 8.1).

8.4.1 SITE OBSERVATIONS

UPPER LAGOON

The upper Lagoon is primarily fresh water with rocky shores. Dumpsters behind the supermarket attract scavengers and human feeding of birds sustains a population of feral ducks. The rocky shoreline provides food for surface feeding shorebirds, while the channelized creek provides food for wading fishers (fish eating birds), surface divers, coots and dabbling ducks. It is also used for bathing and mating by dabbling ducks, and for bathing by a few gulls. It is here that most of the over-wintering ducks are observed.

MAIN LAGOON

A combination of sand and cobble rock shoreline and tidally exposed cobble rock in the main lagoon provides feeding habitat for every group of birds. Several species were observed mating within the Lagoon. The fresh water from Malibu Creek is used by plunge divers, gulls, surface divers and dabbling ducks for bathing and drinking. Shorelines and tidally exposed areas are used by most groups for roosting.

INLETS

Inlet substrates varied depending on location within the Lagoon. In areas close to the Lagoon and ocean, there is sand with some mud, while the substrate near the back of the inlets is muddy. At high tide or when the Lagoon entrance is closed, the inlets are used by the fishing birds, and occasionally by dabbling ducks. At low tide, when the lagoon entrance is open, mudflats are exposed and shorebirds, dabblers, and coots feed on the algae and invertebrates. Channelized sections of the inlets where amounts of sedimentation are relatively low are usually covered with water, providing fishing habitat for wading fishers even at low tide.

BEACH AND OCEAN

During the summer months (June-September) the beach is heavily used by people and very few birds other than scavengers are found at this time. Most birds are found on two man-made wooden rafts anchored approximately 200 yards offshore and on the Eastern edge of the lagoon by the Adamson house, where human activity is low. During the winter months when human use of the beach is lower, surface-feeding and probing shorebirds, gulls, and wading fishers use the area for roosting and feeding. The plunge divers also use the beach for roosting. Offshore, plunge divers, surface divers and diving ducks occur throughout the year.

8.4.2 WATERBIRD POPULATIONS

Waterbird populations are divided into groups based on feeding strategy. The groups are:

Gulls	Dabbling Ducks and Geese	Surface Divers
Coots	Surface-feeding Shorebirds	Diving Ducks
Plunge Divers	Probing Shorebirds	Wading Fishers

Landbird populations are divided taxonomically:

Birds of Prey	Swifts and Swallows	Flycatchers
Waxwings	Thrushes and Mimic Thrushes	Warblers
Hummingbirds	Blackbirds and Orioles	Weavers
Woodpeckers	Pigeons and Doves	Wrens
Jays and Crows	Wrentits, Titmice and Bushtits	
Finches	Grosbeaks, Buntings and Sparrows	
Starlings	Pipits and Wagtails	

Some species of birds are "Blue listed" which refers to the National Audubon Society's listing of bird populations that have declined significantly in recent years. Species of Special Concern are those that have declined slightly but not significantly (Tate 1986). Note: Since 3-5 surveys were taken per month, totals were averaged for both numbers seen per month and area usage.

GULLS

Gulls were the most populous group of all with an average of 347 birds seen per survey . Within this group are five of the eleven most commonly occuring species in the Lagoon (Figure 8.2). Gull populations follow a seasonal pattern with low numbers during spring and summer, rising through fall and winter and peaking in March (Figure 8.3).

Gulls use the main Lagoon for roosting, feeding and bathing. They were often seen immediately below the Highway bridge washing in the fresh water from Malibu Creek. Gulls roosted and fed upon the rocky tidal island located in the main lagoon, on the beach and on the ocean. Heermann's Gulls (Larus heermanni) often attempted to steal food from Brown Pelicans (Pelecanus occidentalis). Gulls also scavenged from trash left by humans on the beach in the picnic area, and from dumpsters behind the supermarket near Malibu Creek (Map 8.1).

Of the gull species occuring at Malibu Lagoon, the Heermann's Gull and the California Gull (Larus californicus) are experiencing significant population threats. These

Figure 8.2. Waterbird species abundance and catagory ranking; overall species abundance ranked in decreasing order. Mean number of birds seen per census, averaged for all seasons for 11 census sites. Landbird occurance. April 1987 - March 1988.

Category	Rank in Abundance	Species	Number seen per census
1		GULLS	347.51
	1	California Gull (*Larus californicus*)	142.59
	2	Bonaparte's Gull (*Larus philadelphia*)	107.16
	4	Western Gull (*Larus occidentalis*)	69.41
	10	Ring-billed Gull (*Larus delawarensis*)	14.37
	11	Heermanns Gull (*Larus heermanni*)	13.88
	*	Mew Gull (*Larus canus*)	0.04
		Herring Gull (*Larus argentatus*)	0.02
		Franklin's Gull (*Larus pipixcan*)	0.02
		Thayer's Gull (*Larus thayeri*)	0.02
		Black-legged Kittiwake (*Rissa tridactyla*)	0.02
	***	Glaucous-winged Gull (*Larus glaucescens*)	
	***	Pomarine Jaeger (*Stercorarius pomarinus*)	
2		DABBLING DUCKS AND GEESE	94.33
	5	Mallard (*Anas platyrhynchos*)	69.02
	12	American Wigeon (*Anas americana*)	13.71
	15	Green-winged Teal (*Anas crecca*)	5.41
	17	Gadwall (*Anas strepera*)	5.10
	38	Cinnamon Teal (*Anas cyanoptera*)	0.65
	52.5	Canada Goose (*Branta canadensis ssp.*)	0.13
	52.5	Canada Goose (*Branta canadensis minima*)	0.13
	54	Northern Shoveler (*Anas clypeata*)	0.10
	*	Brant (*Branta bernicla*)	
9		DIVING DUCKS	1.59
	37	Bufflehead (*Bucephala albeola*)	0.71
	41	Ruddy Duck (*Oxyura jamacensis*)	0.49
	44	Surf Scoter (*Melanitta perspicillata*)	0.37
	*	Lesser Scaup (*Aythya affinis*)	0.02
3		COOTS	86.24
	3	Coot (*Fulica americana*)	
		SHOREBIRDS	
4		SURFACE-FEEDING SHOREBIRDS	77.59
	6	Sanderling (*Calidris alba*)	30.86
	8	Black-bellied Plover (*Pluvialis squatarola*)	15.00
	13	Snowy Plover (*Charadrius alexandrinus*)	11.59
	21	Killdeer (*Charadrius vociferus*)	4.31
	22	Ruddy Turnstone (*Arenaria interpres*)	3.86
	23	American Avocet (*Recurvirostra americana*)	3.76
	24.5	Western Sandpiper (*Calidris mauri*)	3.41
	28	Black Turnstone (*Arenaria melanocephala*)	2.25
	34	Least Sandpiper (*Calidris minutilla*)	1.18
	35	Spotted Sandpiper (*Actitis macularia*)	0.86
	40	Semipalmated Plover (*Charadrius semipalmatus*)	0.51
	*	Wilson's Phalarope (*Phalaropus tricolor*)	
	***	Baird's Sandpiper (*Calidris bairdii*)	

Figure 8.2. (cont).

Category	Rank in Abundance	Species	Number seen per census
6		PROBING SHOREBIRDS	19.05
	16	Dowitcher (*Limnodromus sp.*)	5.26
	18	Willet (*Catoptrophorus semipalmatius*)	5.06
	20	Marbled Godwit (*Limosa fedoa*)	4.94
	27	Whimbrel (*Numenius phaeopus*)	2.90
	39	Dunlin (*Calidris alpina*)	0.63
	49.5	Greater Yellowlegs (*Tringa melanoleuca*)	0.20
	*	Black-necked Stilt (*Himantopus mexicanus*)	0.04
		Long-billed Curlew (*Numenius americanus*)	0.02
	***	Common Snipe (*Gallinago gallinago*)	
8		WADING FISHERS	10.33
	19	Snowy Egret (*Egretta thula*)	5.04
	29	Green-backed Heron (*Butorides striatus*)	1.82
	31	Black-crowned Night-Heron (*Nycticorax nycticorax*)	1.47
	32	Great Blue Heron (*Ardea herodias*)	1.33
	42	Great Egret (*Casmerodius albus*)	0.47
	49.5	Cattle Egret (*Bubulus ibis*)	0.20
7		SURFACE DIVERS	16.86
	14	Double-crested Cormorant (*Phalacrocorax auritus*)	8.45
	24.5	Western Grebe (*Aechmophorus occidentalis*)	3.41
	26	Pied-billed Grebe (*Podilymbus podiceps*)	2.98
	30	Red-breasted Merganser (*Mergus serrator*)	1.59
	46	Common Merganser (*Mergus merganser*)	0.25
	*	Red-throated Loon (*Gavia stellata*)	0.08
		Common Loon (*Gavia immer*)	0.02
		Hooded Merganser (*Lophodytes cucullatus*)	0.02
		Pacific Loon (*Gavia pacifica*)	0.02
		Pelagic Cormorant (*Phalacrocorax pelagicus*)	0.02
	***	Horned Grebe (*Podiceps auritus*)	
	***	Eared Grebe (*Podiceps nigricollis*)	
	***	Clark's Grebe (*Aechmophorus clarkii*)	
	***	Brandt's Cormorant (*Phalacrocorax penicillatus*)	
5		PLUNGE DIVERS	36.95
	7	Forster's Tern (*Sterna forsteri*)	19.24
	9	Brown Pelican (*Pelecanus occidentalis*)	14.75
	33	Caspian Tern (*Sterna caspia*)	1.29
	36	Elegant Tern (*Sterna elegans*)	0.75
	43	Belted Kingfisher (*Ceryle alcyon*)	0.41
	45	Least Tern (*Sterna antillarum*)	0.33
	51	Royal Tern (*Sterna maxima*)	0.14
	*	Black Skimmer (*Rhynchops niger*)	0.04
	***	Common Tern (*Sterna hirundo*)	
10		RAILS	
		Sora (*Porzana carolina*)	0.02

TOTAL WATERBIRD SPECIES: 78

LAND BIRDS

BIRDS OF PREY

**	Red-shouldered Hawk (*Buteo lineatus*)	
	Red-tailed Hawk (*Buteo jamaicensis*)	
	Osprey (*Pandion haliaetus*)	
	Northern Harier (*Circus cyaneus*)	
	American Kestrel (*Falco sparverius*)	
	Loggerhead Shrike (*Lanius ludovicianus*)	
	Turkey Vulture (*Cathartes aura*)	

Figure 8.2. (cont).

PIGEONS AND DOVES
Rock Dove (*Columba livia*)
Mourning Dove (*Zenaida macroura*)
*** Spotted Dove (*Streptopelia chinensis*)

SWIFTS AND SWALLOWS
White-throated Swift (*Aeronautes saxatalis*)
Cliff Swallow (*Hirundo pyrrhonota*)
Barn Swallow (*Hirundo rustica*)
Violet-green Swallow (*Tachycineta thalassina*)
*** Tree Swallow (*Tachycineta bicolor*)
*** Northern Rough-winged Swallow (*Stelgidopteryx serripennis*)

HUMMINGBIRDS
Anna's Hummingbird (*Calypte anna*)
*** Allen's Hummingbird (*Selasphorus sasin*)
*** Black-chinned Hummingbird (*Archilochus alexandri*)

WOODPECKERS
*** Nuttall's Woodpecker (*Picoides nuttallii*)
*** Downy Woodpecker (*Picoides pubscens*)

FLYCATCHERS
Black Phoebe (*Sayornis nigricans*)
Say's Phoebe (*Sayornis saya*)
*** Ash-throated Flycatcher (*Myiarchus cinerascens*)
*** Western Kingbird (*Tyrannus verticalis*)
*** Cassin's Kingbird (*Tyrannus vociferans*)
*** Western Flycatcher (*Empidonax difficilis*)

WAXWINGS
*** Cedar waxwing (*Bombycilla cedrorum*)
*** Phainopepla (*Phainopepla nitens*)

JAYS AND CROWS
Scrub Jay (*Aphelocoma coerulescens*)
American Crow (*Corvus brachyrhyncos*)
Common Raven (*Corvus corax*)

WRENTITS, TITMICE, AND BUSHTITS
*** Wrentit (*Chamaea fasciata*)
*** Plain Titmouse (*Parus inornatus*)
Bushtit (*Psaltriparus minimus*)

WRENS
Bewick's Wren (*Thyromanes bewickii*)
*** House Wren (*Troglodytes aedon*)
*** Marsh Wren (*Cistothorus palustris*)

THRUSHES AND MIMIC THRUSHES
Northern Mockingbird (*Mimus polyglottos*)
California Thrasher (*Toxostoma redivivum*)
*** Ruby-crowned Kinglet (*Regulus calendula*)
*** American Robin (*Turdus migratorius*)

PIPITS AND WAGTAILS
*** Water Pipit (*Anthus spinoletta*)

STARLINGS
European Starling (*Sturnus vulgaris*)

Figure 8.2. (cont).

WARBLERS
Yellow-rumped Warbler (Dendroica coronata)
Common Yellowthroat (Geothylpis trichas)
*** Orange-crowned Warbler (Vermivora celata)
*** Yellow Warbler (Dendroica petechia)
*** Wilson's Warbler (Wilsonia pusilla)
*** Yellow-breasted Chat (Icteria virens)

GROSBEAKS, BUNTINGS, AND SPARROWS
Brown Towhee (Pipilo fuscus)
Song Sparrow (Melospiza melodia)
White-crowned Sparrow (Zonotrichia leucophrys)
*** Black-headed Grosbeak (Pheucticus melanocephalus)
*** Lazuli Bunting (Passerina amoena)
*** Rufous-sided Towhee (Pipilo erythrophthalmus)
*** Savannah Sparrow (Passerculus sandwichensis)

BLACKBIRDS AND ORIOLES
Brewer's Blackbird (Euphagus cyanocephalus)
Red-winged Blackbird (Agelaius phoeniceus)
Tricolored Blackbird (Agelaius tricolor)
Yellow-headed Blackbird (Xanthocephalus xanthocephalus)
Rusty Blackbird (Euphagus carolinus)
Western Meadowlark (Sturnella neglecta)
Brown-headed Cowbird (Molothrus ater)
*** Northern Oriole (Icterus galbula)
*** Hooded Oriole (Icterus cucullatus)
*** Western Tanager (Piranga ludoviciana)

FINCHES
American Goldfinch (Carduelis tristis)
House Finch (Carpodacus mexicanus)
*** Purple Finch (Carpodacus purpureus)
*** Lesser Goldfinch (Carduelis psaltria)
*** Pine Siskin (Carduelis pinus)

WEAVERS
House Sparrow (Passer domesticus)

TOTAL LANDBIRD SPECIES: 73
TOTAL NUMBER OF SPECIES: 151

* Those species seen less than 0.10 per census not ranked.
** Landbirds not ranked
*** From Kimball Garrett, Personal Communication.
Natural History Museum of Los Angeles County
Section of Birds and Mammals

problems stem from the gulls having restricted breeding areas, as Raza Island in the Gulf of California holds 96 percent of the breeding population of Heermann's Gulls. Human impact on the island from fishermen, boaters and natural history tours has lead to lower productivity among the gulls. Presently several private organizations are providing funding for wardens on the island (Anderson and Keith 1980, Hand 1980, Croxall et al. 1984). The California Gull is on the California Fish and Game "Species of Special Concern" list due to threats to certain inland colonies such as Mono Lake (K. Garrett, Pers. comm. 1988). As water is diverted from Mono Lake, islands that the California Gulls nest on are becoming connected to the mainland and the colonies are being abandoned as predators invade them (Gaines 1987).

DABBLING DUCKS AND GEESE

Dabbling duck and goose numbers are fairly constant because of a large resident population of feral mallards (Anas platyrhynchos) (Figure 8.4). This was augmented by a transient population of wild mallards, as well as other species of ducks and geese to make them the group with the second highest numbers, averaging 95 birds per survey. The feral mallards were quite successful in nesting in 1987-1988, with at least 10 females raising young. There was evidently some mortality among the young mallards as one female started with thirteen young and ended up with only nine. This was the first of the clutches to hatch and so was easy to monitor. Mallards were observed several times mating in the upper Lagoon, where four to five males would mate with the same female.

Two Canada Geese (Branta canadensis moffetti and B.c. minima) and a Greater White-fronted Goose (Anser albifrons) also appeared in the Lagoon and were almost certainly of wild origin (K. Garrett, Pers. comm. 1988). Black Brant (Branta bernicla) stop to forage at the Lagoon even though it lacks the eelgrass beds that normally attract them (Small 1974). The brant usually stay about two months in the spring and have been observed feeding on green algae (Enteromorpha sp.) mats. The dabbling ducks and geese preferred the upper Lagoon but also used the main Lagoon for feeding and resting. Some utilization of the inlets occured at low water when Cinnamon (Anas cyanoptera) and Green-winged (Anas crecca) Teal would feed on the algal scum growing on the mud (Figure 8.5).

DIVING DUCKS

Diving ducks occured in low numbers in the Lagoon (only 1.1 birds per survey). Bufflehead (Bucephala albeola) feed on shrimp, small fish and bivalve mollusks (Small 1974; Palmer 1976). The bufflehead stayed for a longer period of time and appeared in the main Lagoon in flocks of six to fifteen birds (Figure 8.5). Surf scoters (Melanitta perspicillata) did not come into the Lagoon but were seen offshore around the anchored rafts and near the entrance to the Lagoon. The diving ducks disappeared during July and August (Figure 8.6).

COOTS

Coots were often the most numerous birds to be counted on surveys but on average were only the third most numerous, averaging 86.2 birds per survey (Figure 8.2). Because coots only breed in freshwater marshes (Small 1974) they disappear from May through August from the lagoon, except for a few oversummering individuals. These few individuals utilize large algae mats which grow during this time, until the rest of the coots return in time to forage on this resource before the winter rains wash the mats out to sea. The population peaks in October and remains high until March dropping in April to almost zero in May again (Figure 8.7). At low tide the coots graze on the delicate green algae growing on the surface of the mud. When water levels are high, they feed on pickleweed (Salicornia virginica) in upland areas of the inlets. Coots were also observed feeding on jacknife clams during a December die-off of the clams. Coots were most often observed in the main and upper Lagoon (Figure 8.8) but also came into the inlets to feed.

SHOREBIRDS

Shorebirds were divided into two categories, surface-feeding and probing shorebirds. During the spring and summer the population average moves up and down (Figure 8.10), likely because the shorebird migration occurs during this period (Garrett and Dunn 1981).

SURFACE-FEEDING SHOREBIRDS

Surface-feeding shorebirds are short-billed shorebirds which feed either on the surface or immediately below the surface of the sediments. These comprised the group with the fourth greatest numbers, having on average 77.6 birds per survey. Most of these shorebirds fed within the main Lagoon, although they also foraged along the shore of the upper Lagoon, on the mud flats of the inlets and on the beach (Figure 8.9).

Territoriality was observed in the semipalmated plover (Charadrius semipalmatus) on the mudflats in the inlets where one plover would chase other plovers which came within approximately six feet of where the first one was feeding. The only shorebird that mated and nested was the killdeer (Charadrius vociferus). It was hoped that the snowy plovers (Charadrius alexandrinus) would nest in a sandy area along the beach, since they are known to have nested in the past.

Figures 8.3 - 8.6. All data from April 1987 - March 1988 from 11 census sites.

Figure 8.3. Average number of Gulls per month.

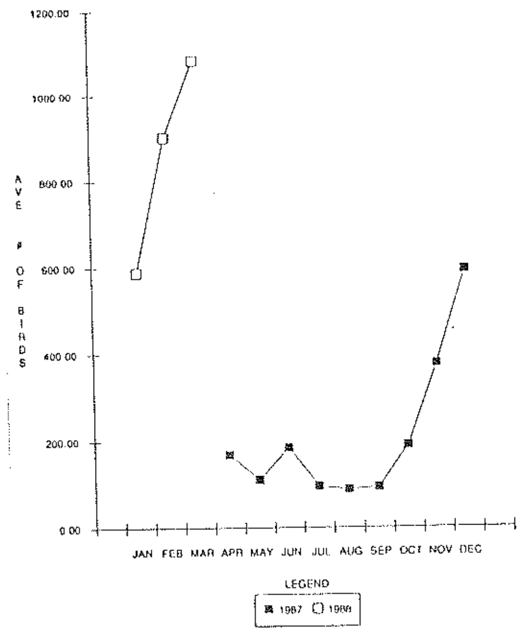


Figure 8.4. Average number of Dabbling Ducks and Geese per month.

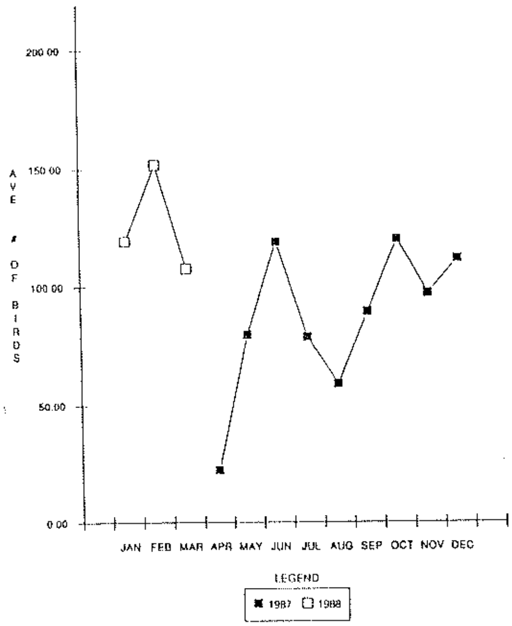


Figure 8.5. Area use for Dabbling Ducks and Diving Ducks.

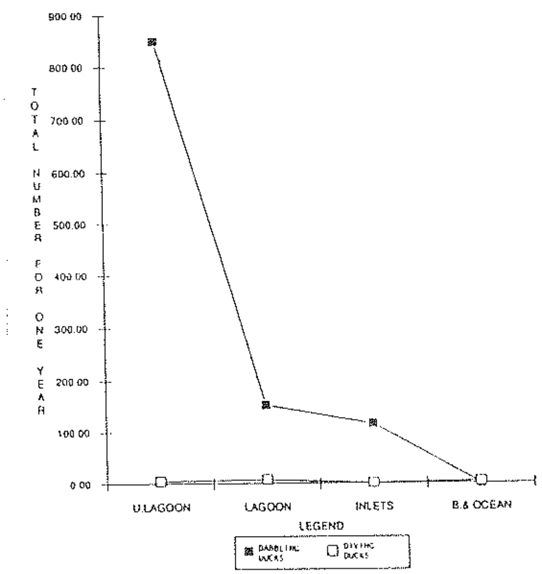
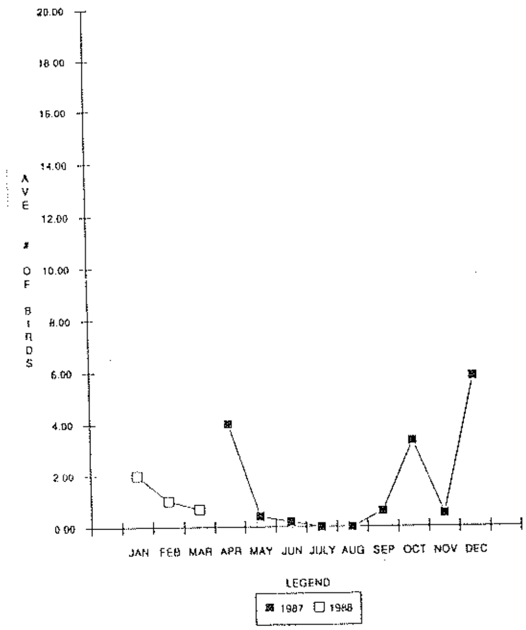


Figure 8.6. Average number of Diving Ducks per month.



Figures 8.7 - 8.9. All data from April 1987 - March 1988 from 11 census sites.

Figure 8.7. Average number of Coots per month.

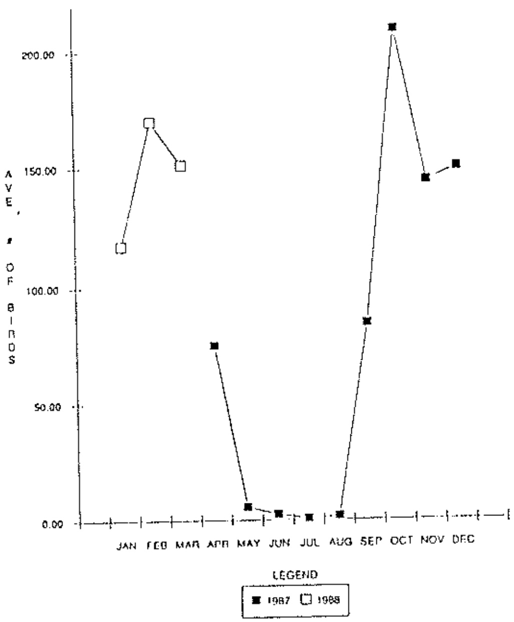


Figure 8.8. Area use by Gulls and Coots.

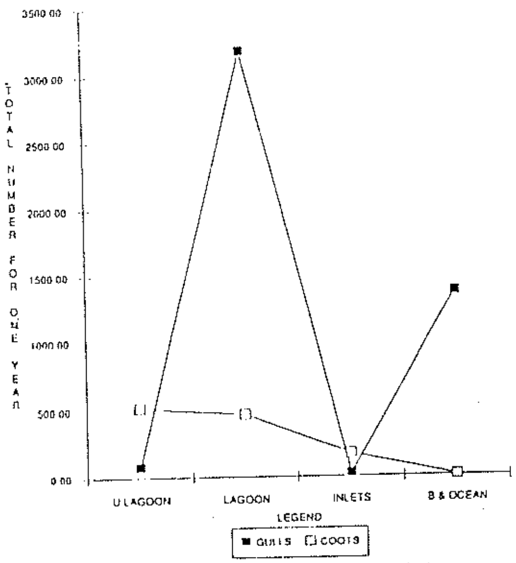
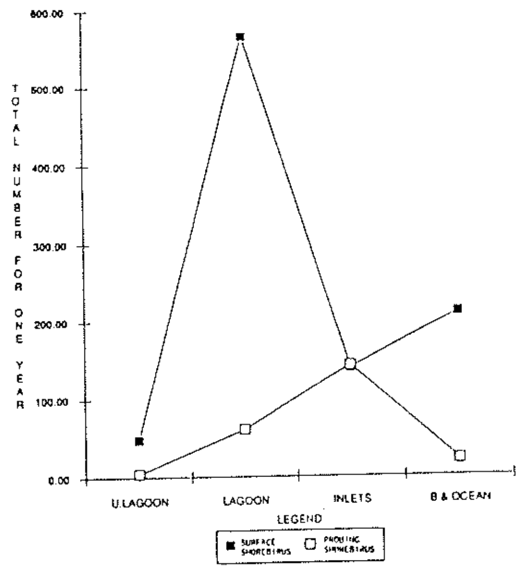


Figure 8.9. Area use by Surface-feeding and Probing Shorebirds.



Unfortunately the heavy human intrusion starting in the 1950s have eliminated the plovers as breeding residents (Kiff and Nakamura 1979). Volley ball nets were recently erected near the plovers roosting area on the eastern edge of the Lagoon. This is also used as a turn around point for joggers. Plovers were formerly seen roosting in wind cups in the sand or in among the washed up kelp but numbers of birds decreased as numbers of humans increased. However, since many plovers migrate to the interior to breed at the time of the decrease, humans are not necessarily the cause (K. Garrett. Pers. comm. 1988).

The snowy plover was Blue listed from 1972 to 1982 and was of Special Concern in 1986 (Tate 1986). This plover has been of historic concern on the West Coast as shown by the Blue list (Tate 1986).

PROBING SHOREBIRDS

Probing Shorebirds are those shorebirds with medium to long bills used for delving deeply into soft sediments for invertebrates, such as mollusks and crustaceans. This group has the sixth greatest numbers averaging 19.1 birds per survey. They are highly seasonal, mainly appearing between September and March (Figure 8.11). They utilize the main Lagoon mostly for roosting although they will search the cobble for food. They also feed on the beach, searching the cobble and probing in the sand. Most of the feeding occurs on the mudflats in the inlets (Figure 8.9), where they probe deeply into the sediments. They have been observed feeding on jacknife clams (Tagelus californianus) but since there was a large die-off of these clams it is unclear whether the birds capture them on their own or only when a die-off occurs. Whimbrels (Numenius phaeopus) were observed chasing other whimbrels and willets (Cataptrophorus semipalmatius) during feeding but both species flocked together when at rest. This suggests that the aggressive behavior observed is related to feeding territories. Long-billed curlews (Numenius americanus) were rarely seen in the Lagoon because of limited habitat (i.e. tidal mudflats), not because of a declining population (K. Garrett. Pers. comm. 1988). Curlews were Blue listed in 1981 and of Special Concern in 1986 (Tate 1986).

WADING FISHERS

Wading fishers rank eighth in number seen per census, averaging 10.3 birds per survey. The population peaked during the winter months much like all other bird groups, with the highest numbers occuring in December (Figure 8.12). This is consistent with other southern California coastal wetland population fluctuations.

These birds spend most of their time foraging along the edges of the Lagoon and inlets, although snowy egrets (Egretta thula) and green-backed herons (Butorides striatus)

Figures 8.10 - 8.12. All data from April 1987 - March 1988 from 11 census sites.

Figure 8.10. Average number of Surface-feeding Shorebirds per month.

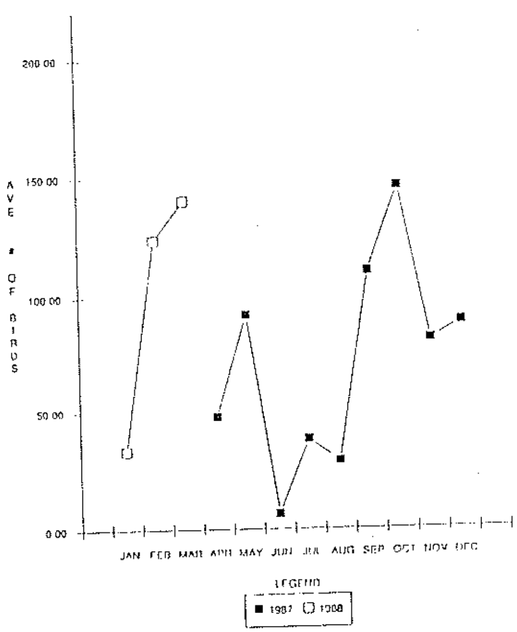


Figure 8.11. Average number of Probing Shorebirds per month.

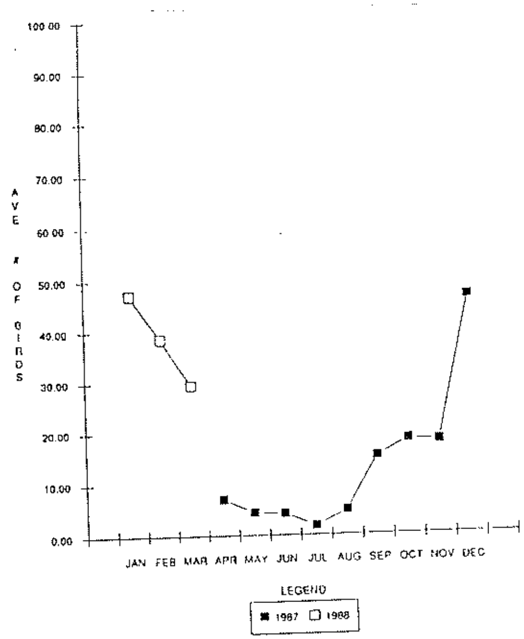
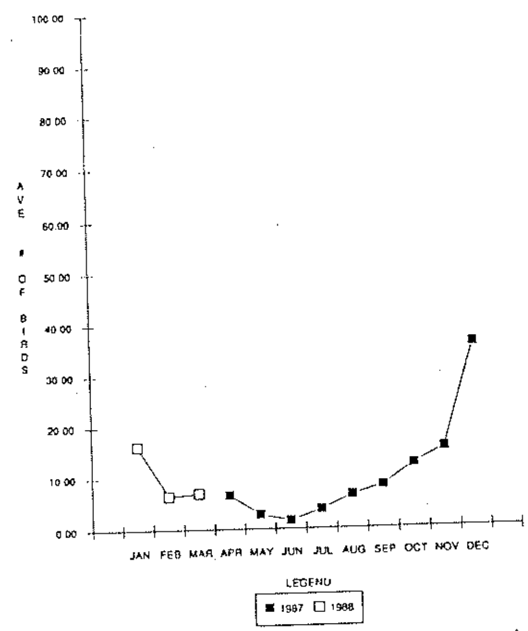


Figure 8.12. Average number of Wading Fishers per month.



were also observed feeding on lizards caught on raised areas of land between the inlets (Figure 8.13). Great blue herons (Ardea herodias) used the raised areas for roosting but seemed to prefer three large trees near the southwest edge of the Lagoon for most of their roosting.

Snowy egrets were also observed foraging among the exposed cobble both in the Lagoon and on the beach at low tide. This only occurred during periods when the beach was not being used by humans. These egrets usually roosted on the side of the Lagoon near the Adamson House in an area mostly undisturbed by human activity. They were seen following a group of red-breasted mergansers (Mergus serrator) that were feeding in the Lagoon along the shoreline. The egrets were apparently catching the fish that were escaping from the mergansers. This behavior was seen on several surveys and has been previously described (Christman 1957).

Within this group, great blue herons and black-crowned night-herons (Nycticorax nycticorax) were Blue listed 1980-1981 and 1972-1981 respectively. Both were classified as being of special concern in 1982 and under local concern in 1986 (Tate 1986).

SURFACE DIVERS

Surface Divers are fish eating birds which dive from the surface of the water and chase fish by swimming after them. These birds were seen at the average rate of 16.8 birds per survey (Figure 8.2). They leave during the spring and summer and gradually return during the fall, with peak numbers observed in winter (Figure 8.14). During the winter of 1987-1988, fish populations dropped off significantly in the Lagoon, coinciding with winter rain flows through the Lagoon. The surface diver population moved at this time from the upper Lagoon and main Lagoon to the ocean. Double-crested cormorants (Phalacrocorax lauritus) after fishing within the Lagoon are often observed spreading their wings in order to dry the feathers. The tidal island in the Lagoon and the strip of beach between the Lagoon and the ocean were the most commonly used areas by the cormorants for this purpose. The man-made raft and a rocky reef offshore were used by the cormorants for roosting.

The double-crested cormorant, formerly Blue listed, has been making a slight recovery over the last decade. Western grebes (Aechmophorus occidentalis) were on the Blue list from 1973 to 1982 and of special concern in 1984 (Tate 1986). These grebes are present from September to March both in the Lagoon and offshore but are absent during the breeding season when they travel to inland lakes and marshes to nest, rest and feed (Small 1974).

PLUNGE DIVERS

Plunge divers are those that plunge from flight to capture fish. They are ranked fifth with an average rate of 37 birds per survey (Figure 8.2). These populations drop during the summer and rise during the fall to peak in late winter/early spring (Figure 8.15).

Pelicans were seen most often on two man-made wooden rafts anchored approximately 200 yards offshore and also within the main Lagoon (Figure 8.13). Brown pelicans (Pelecanus occidentalis) were often seen feeding upon the many fish within the Lagoon, flapping a few times to gain altitude then plunging into the water. They were also observed bathing in the fresh surface water. These birds often left the main Lagoon when they were disturbed by helicopters, traffic noise from the highway or from heavy human usage on that strip of beach. Often when startled, they would fly out to the anchored rafts offshore. This is where the majority of sightings occurred. During the summer months, one of the rafts is used as a covered boat dock which makes it unavailable for the birds. They were also observed feeding in the ocean. Brown pelicans, still classified as an endangered species on the west coast, have recovered since DDT was banned in 1972. They now have populations of between 75,000 and 90,000 birds occurring in fall off the west coast (Jehl 1984).

In late summer, many juvenile pelicans are in the Lagoon learning to fish, first scooping fish from the surface, then low altitude plunging. Adult un-mated males assist in training the young (K. Garrett. Pers. comm).

Terns utilize the sandy areas around the Lagoon and the tidal island for roosting and for mating (Fig. 8.13). Two pair of elegant terns (Sterna elegans) were observed mating several times on the tidal island, although this species does not nest here. All species of terns would stand in the Lagoon water but were not observed bathing. All species of terns foraged within the Lagoon and inlets, plunging into the water for food. Elegant and royal (S. maxima) terns have exhibited lowered productivity in the Gulf of Mexico because of both direct and indirect human disturbance (Anderson and Keith 1980; Hand 1980; Jehl 1984). Again this disturbance is on Raza Island. Malibu Lagoon has late summer peaks of elegant terns but in 1987, numbers were low (Figure 8.15). However, in 1988, 700 to 1500 elegant terns appeared in the lagoon (K. Garrett. Pers. comm. 1988). Least terns (S. antillarum) are listed as a declining species (Jehl 1984) and also are on the U.S. Fish and Wildlife Service endangered species list (Tate 1984) The California Least Tern (S.a. browni) is considered endangered in California because the open sandy or gravelly shores near fishing areas have experienced heavy human disturbance (Garrett and Dunn 1981).

Figures 8.13 - 8.15. All data from April 1987 - March 1988 from 11 census sites.

Figure 8.13. Area use by Plunge Divers, Surface Divers and Wading Fishers.

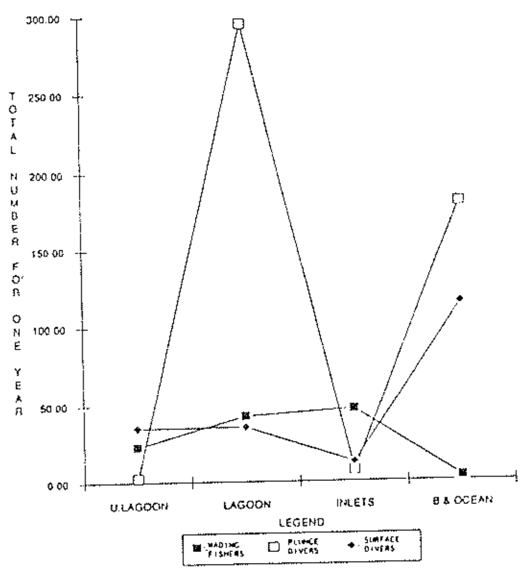


Figure 8.14. Average number of Surface Divers.

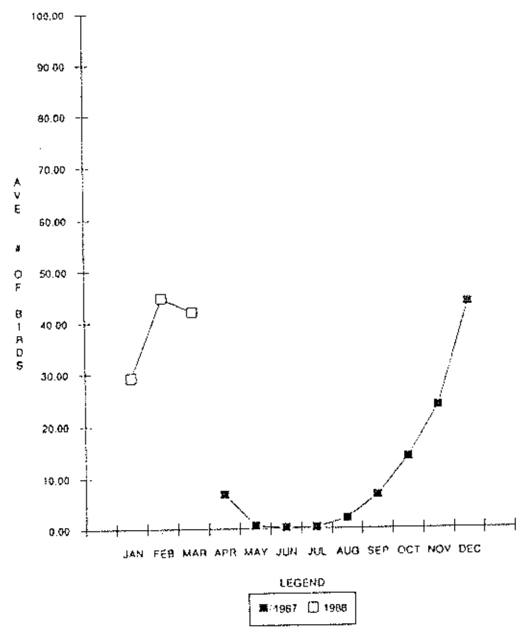
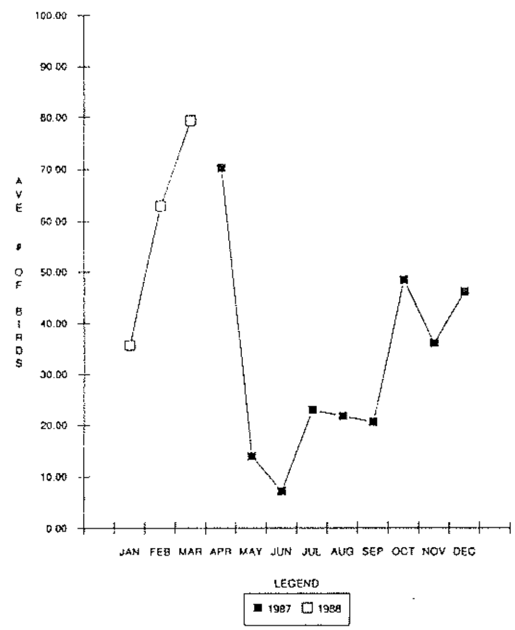


Figure 8.15. Average number of Plunge Divers.



8.5 DISCUSSION

Malibu Lagoon displays a high diversity of bird species considering the amount of disturbance from human activity, and its relatively small size compared to many other wetlands along the coast. However, there is still much that could be done to improve the habitat for birds. Using this species list for Malibu Lagoon, it might be possible to manage the habitat for those species that are having difficulty not only in the Lagoon, but also in other areas.

Since the total area of the Lagoon is limited, it might be advisable to create foraging and resting areas for as many species as possible, rather than creating breeding areas for only rare or endangered species. This is because most of the birds that utilize the Lagoon breed in other areas and only use the Lagoon for foraging and resting. The snowy plover has not decreased in numbers as has the least tern, since the plovers have a more extensive breeding range, from Mexico to Oregon (Small 1974) and because they also nest commonly at interior localities in the West (Garrett and Dunn 1981). Snowy plovers often nest on the more secluded northern beaches (Small 1974). Another reason snowy plover population has not declined as severely as least terns is their willingness to nest in areas close to human activity (Small 1974).

Least terns are colony nesters which are easily disturbed by a single intruder which will put the entire colony into flight. Snowy plovers are not colony nesters and are therefore more tolerant of human intrusion (Small 1974). This tolerance of human activity should not be tested too severely however. Fencing off areas suitable for snowy plovers and least terns would solve both the domestic predator (i.e. cats and dogs) and the human intrusion problem. Snowy plovers are currently absent from the beach which seperates Malibu Lagoon from the ocean. As mentioned earlier, this could either be from human intrusion into the roosting area or migration to other less disturbed nesting areas. Snowy plovers formerly nested at Malibu Lagoon but disappeared as a breeding resident when heavy human use began in the 1950s (Kiff and Nakamura 1979).

If a species is not currently rare or endangered but is Blue listed as a declining population, habitat could be set aside as additional breeding grounds. It is possible that a small population of snowy plovers and least terns could be established at Malibu Lagoon with the provision of suitable habitat, free from human intrusion and predation.

Should the Lagoon be altered for breeding grounds, several measures would have to be taken. First of all, the domestic predators should be either removed or totally restricted from entering the breeding areas. This could be accomplished by fencing off areas as breeding preserves, creating islands which will separate the breeding areas from these predators, strict enforcement of existing pet laws, or a combination of these.

Some species that would usually be present in this estuarine environment are not because of the unusual topography and size of the Lagoon. Most estuaries have very little change in elevation throughout. Malibu Lagoon has fairly extensive elevational changes so that soil conditions (e.g. salinity) vary greatly. Plant distribution is therefore limited and areas that might be usable by birds, based on vegetation preference, might not be extensive enough. Additional habitat can be created by managing for more extensive and productive mudflats in inlet areas for feeding and roosting, and reducing the height of land above the highest high water mark to reduce some of the upland areas into pickleweed marshes.

Malibu Lagoon is an example of how an extremely disturbed area can still have a high diversity and abundance of birds as long as there is some separation from contact with humans. The greater the separation, the greater the chance of success in all aspects of the animals' life history. It also exemplifies an environment which has future potential for a greater successful use as a bird habitat where complete life cycles of some birds can succeed. Foremost among this is management of nesting areas, especially for threatened and endangered species, and minimizing human intrusion which disrupts the daily life and foraging success.

Public access to the coast is an ongoing conflict between homeowners and the public. The beaches are a public resource and there are many users who are looking for the quickest way to the shore. Malibu Lagoon State Beach is one such resource which is becoming more heavily used as access routes from inland areas to the coast are improved. A recent plan for public access includes a path along the eastern edge of the Lagoon by the Adamson House. This is a roosting and feeding area for birds that have escaped the areas heavily used by humans. Among the birds that use this area are hawks, kingfishers, ducks, geese, gulls, terns, pelicans, sandpipers, and plovers. The birds mainly use the strip of land right next to the Lagoon, extending from the beach into the upper Lagoon and creek area. Public access is available both through the Lagoon and on the eastern edge of the Adamson property. Additional access is not necessary for humans and undisturbed areas for birds to roost and feed are important. If public access is permitted into these areas, it should be on guided walkways located back from the edge of the Lagoon with vegetative screens to prevent the loss of undisturbed areas available for birds.

8.6 SUMMARY

1. Malibu Lagoon displays a high diversity of bird species relative to the amount of human disturbance, and its small size. A total of 151 bird species, 78 waterbird and 73 landbird, were sighted from April 1987 to March 1988.

2. Migrating birds use the Lagoon as a rest stop and a source of fresh water as well as an over-wintering area. Several species breed and nest including killdeer, mallard, black phoebe, kingfisher, red-winged blackbird, house finch, cliff and barn swallows and black-crowned night heron.

3. Snowy plovers, Blue listed by the Audubon Society, formerly nested at the Lagoon. A small breeding population of these plovers could be re-established by creating suitable habitat.

4. Other Blue listed bird species seen at the Lagoon include long-billed curlew, great blue heron, black-crowned night heron, double-crested cormorant and western grebe. Of special concern is the California gull.

5. The brown pelican, the least tern, and the California least tern are endangered species that use the Lagoon.

8.7 LITERATURE CITED

Anderson, D.W. and Gress, F. 1983. Status of a Northern Population of California Brown Pelicans. The Condor. 85:79-88.

Christman, G.M. 1957. Some interspecific relations in the feeding of estuarine birds. The Condor. 59:343

Gaines, D. 1987. The NAS Study: A Critical Review. In The Mono Lake Newsletter. Mono Lake Committee. Vol. 10 No. 2. pp. 5-6.

Garrett, K. 1988. Personal Communication. Natural History Museum of Los Angeles County. Section of Birds and Mammals.

Garrett, K. and Dunn, J. 1981. Birds of Southern California: Status and Distribution. Los Angeles Audubon Society. pp. 407.

Jehl, J.R. Jr. 1984. Conservation Problems of Seabirds in Baja California and the Pacific Northwest. In Croxall et al, eds. Status and Conservation of the Worlds Seabirds. pp. 41-48.

Kiff, L. and Nakamura K. 1979. The Birds of Malibu Lagoon. Audubon Imprint. 4(2):1-13.

McClave, J.T. and Dietrich, F.H., II. 1982. Statistics. San Francisco and Santa Clara, California. Dellen Publishing Company. pp. 766.

National Geographic Society. 1983. Field Guide to the Birds of North America. Washington. National Geographic Society. pp. 464.

Onuf, C. 1975. The Ecology of Mugu Lagoon, California: An Estuarine Profile. Biological Report 85(7.15). pp. 59-69.

Palmer, R.S. 1976. Handbook of North American Birds v. 3 (Waterfowl). Yale University Press, New Haven and London. pp. 560.

Small, A. 1974. The Birds of California. New York. Winchester Press. pp. 35-177.

Tate, J. Jr. 1986. The Blue List for 1986. In American Birds. Volume 40 No. 2. National Audubon Society. pp. 227-235.

Tomkins, I.R. 1959. Life History Notes of the Least Tern. The Wilson Bulletin. Vol. 71 No. 4. pp. 313-322.

Vermeer, K. and Rankin, L. 1984. Influence of Habitat Destruction. In Status and Conservation of the Worlds Seabirds. Croxall et al. pp. 724-735.

Zedler, J. 1982. The Ecology of Southern California Coastal Salt Marshes: A Community Profile. FWS/OBS-81/54. pp. 76-82.

Zedler, J. and Nordby, C.S. 1986. The Ecology of Tijuana Estuary: An Estuarine Profile. Biological Report 85(7.5). pp. 48-59.

9.0 MANAGEMENT CONSIDERATIONS FOR THE MALIBU CREEK WATERSHED AND MALIBU LAGOON

9.1 INTRODUCTION

The Malibu Creek-Malibu Lagoon area is a unique ecological, recreational, educational, and research resource harboring significant value for present and future generations. Species compositions patterns can reveal the relative health of an ecosystem, provide an early warning system, or demonstrate the relative intensity of pollution problems. Biotic community analysis can often identify types of pollution and other potential problems affecting the habitat. Impacts from almost everything that occurs in a watershed system show up in streams and affect the faunal and floral community composition (Mangum 1986).

Human understanding of estuaries is still rudimentary, and comprehensive baseline data and monitoring programs are lacking. Therefore, vigilant and flexible management programs need to be adopted and implemented. Zedler (1986) believes adoption of a management program for southern California's Tijuana Estuary should emphasize "experimentation, evaluation, and progressively improved treatments...". This type of flexible approach would also be a valuable framework for managing Malibu Creek and Lagoon.

Human-generated disturbances continue to have a significant cumulative impact on the Malibu Creek-Malibu Lagoon ecosystem complex. Because of the ecological pressure exerted by humans on the natural resources of this area, active resource management is necessary for long-term maintenance of the native biota (plants and animals). Active management, in this report, is considered to refer to the stringent control and regulation of human impacts upon the ecosystem, and to the ecological restoration and maintenance of the physical and biotic environment.

Cooperative interagency resource management and community involvement are essential for the native biota of Malibu Creek and Malibu Lagoon to survive. The long-term viability of this watershed is tied to the implementation of comprehensive natural resource management plans that address the enhancement of habitat conditions for all native faunal and floral groups.

These two ecosystems (creek and lagoon) are intimately linked by virtue of their shared aqueous environment. Because these ecosystems are contiguous, management of the whole watershed is necessary in order to conserve them in perpetuity. Additionally, for managemement to be successful, further research focusing on Malibu Creek and Malibu Lagoon as a single interacting ecosystem complex is vital. Therefore, in addition to considerations based on the summary data, the following problems concerning Malibu Creek, which flows into Malibu Lagoon, warrants examination.

9.1.1 STREAMFLOW MODIFICATION

Excessive freshwater input into creeks connected to coastal wetlands is detrimental to these biotic ecosystems and results in a reduced diversity of estuarine species (Zedler 1982). Under normal conditions the native estuarine flora and fauna naturally recover from periodic winter storm flooding. However, they cannot recover from freshwater flooding on a more frequent or daily basis, as is presently occuring. For example, according to Zedler (1984), comparative studies indicate that prolonged periods of unnatural freshwater influence in a coastal wetland environment would greatly reduce or extirpate many native species. For instance, diversity of fish species will be lowered from a potential high of about forty species to a low of approximately fourteen fish species. In addition, most species of estuarine invertebrates are eliminated with prolonged periods of freshwater innundation. Plant species undergo significant shifts in boundaries (see 9.2.2) when innundated by prolonged or unseasonal freshwater. In general, many native faunal and floral groups are likely to experience detrimental changes in species composition when natural streamflow patterns are altered.

Malibu Creek and Malibu Lagoon are currently experiencing a human-generated input of imported freshwater which results in a non-natural streamflow pattern. The natural hydrologic regime in this watershed of periodic winter storm flooding has been artificially extended by the addition of large amounts of tertiary-treated wastewater. The additional water flows directly into Malibu Creek and ultimately into Malibu Lagoon. This alteration of the hydrologic regime exerts a negative cumulative impact on many species of flora and fauna.

Recent historical documentation, for example, indicates 25 recorded species of fish inhabiting Malibu Lagoon. Our study has documented a current total of fourteen fish species. Native species utilizing Malibu Creek which may be affected by altered streamflow cycles and ultimate change in species composition are the arroyo chub (*Gila orcutti*), Pacific sea lamprey (*Entosphenus tridentatus*), and steelhead trout (*Salmo gairdnerii*). Native species of Malibu Lagoon which could be affected are listed in Table 7.1 of chapter 7. Introduced non-native fish species in Malibu Creek may be in the process of usurping the ecological niches of some native fish species, partly due to altered streamflow patterns. Those non-native species include, but are not limited to, the black bullhead (*Ictalurus melas*), green sunfish (*Lepomis cyanellus*), and largemouth bass (*Micropterus salmoides*) (Swift 1982).

Presently, the major contributor of additional non-natural streamflow in Malibu Creek is the Tapia Water Reclamation Facility. Tapia is a tertiary treatment facility which discharges up to 8-10 MGD from October through June. The water from Tapia is of exceptionally high quality, thus providing a significant opportunity for Creek and Lagoon restoration and re-establishment of a more natural seasonal streamflow cycle.

The primary building blocks in wetland ecosystem restoration are the existence of clean water and natural streamflow cycles. Thus the potential for successful management and wetland restoration exists for the contiguous Malibu Creek-Malibu Lagoon ecosystems. For this potential to be actualized, we strongly recommend a cooperative-adaptive management strategy by those agencies and communities affecting the watershed. The primary recommended goal is to restore and maintain the natural seasonal streamflow cycle within the Malibu Creek watershed, and to regulate pollution entering this aquatic ecosystem.

An important management consideration and potential benefit to Malibu Creek and Malibu Lagoon include the refinement of existing percolation ponds near the Tapia treatment plant. This may be an effective method for controlling streamflow in Malibu Creek. Specific potential benefits of refined wetland percolation/retention ponds are:

1. Maintenance of a streamflow pattern which mimics natural seasonal conditions.

2. Controlling excessive algae-promoting nutrients.

3. Controlling water temperatures in the Creek in order to mimic natural temperature conditions for native biotic elements that lack "ecological plasticity" (i.e. the ability to adapt to varying environmental conditions).

4. Controlling excessive freshwater influence on Malibu Lagoon and its associated biota (plants and animals).

5. The ponds could become additional habitat for wildlife, especially birds migrating along the Pacific Flyway.

The maintance of natural seasonal streamflow patterns in Malibu Creek is essential for many native fishes using Malibu Creek and Lagoon. The total amount of freshwater entering the Creek at any one time, and the length of time (temporal component) the non-natural water source continues to flow into the Creek are the two critical components of the local streamflow pattern.

The percolation/retention pond concept could be a significant strategy in regulating the excessive human influence on the Malibu Creek watershed. With the current prolonged and non-seasonal streamflow pattern, the Creek and Lagoon ecosystems may be predisposed, by altered physical and chemical parameters, to favor one fish species over another, thus changing the overall species composition in these habitats. Ponds designed for a controlled release of water would be likely to successfully mitigate any potential detrimental change in fish species composition. Other faunal and floral assemblages could also experience changes in species composition. These changes are a critical subject area that merits future examination. If the percolation/ retention pond concept proves unworkable, it will be important to consider other alternatives that would restore the natural streamflow pattern.

9.2.0 SUMMARY OF LAGOON STATUS

9.2.1 WATER QUALITY

1. As in many estuaries, salinities, dissolved oxygen, and pH at Malibu Lagoon fluctuate widely. At the Lagoon, these fluctuations often occur within a short time frame. These fluctuations are associated with tidal change, the unseasonal addition of large volumes of freshwater from the Tapia Water Reclamation Facility and problems associated with the management of the Lagoon entrance by the California Department of Parks and Recreation (DPR). Often this relatively freshwater remains ponded in the Lagoon for several days, even after Lagoon water levels have reached the mandated opening level of 3.5 feet.

2. Water samples at 5 stations in the Lagoon (Map 9a) were taken to the U.C.L.A. Biomedical and Environmental Studies Lab for analysis. The results indicate that no elements appear to be at toxic levels, although manganese, cobalt, lithium and vanadium are often below the lower limits set for maintaining healthy growth of organisms.

3. Data provided by the Las Virgenes Municipal Water District (LVMWD), plus our own observations, indicate that the Tapia facility is well operated, and the water discharged is of high quality. The high volume of freshwater released directly into Malibu Creek has probably slowed the ecologic recovery process at Malibu Lagoon after the 1983 restoration by limiting the colonization of species that are less tolerant of fresh water.

4. The tertiary-treated water discharged from the Tapia facility has received national acclaim for its quality. Yet, biological pollution does occur in the Lagoon. Data provided by the LVMWD and the L.A. County Dept. of Health indicates that total coliform levels in the Lagoon and in

Malibu Creek, above as well as below the Tapia Plant, are often above the standard considered healthy for bodily contact. This indicates that other sources of pollution exist and need to be identified. (see chapter 2.4). Total coliform levels are presently used as an indicator of the potential for the presence of disease-causing pathogens, rather than a measure of actual pathogens.

Coliform levels are highest when water levels are high in the Lagoon, either due to closure of the entrance, extremely high tides, or storms. The source (or sources) of this pollution has not yet been determined, although studies prior to the 1983 restoration have indicated non-point source pollution causes, and that aging or poorly maintained septic systems in nearby Malibu Colony are one potential source. Often, when water levels in the Lagoon exceed 3 feet, foam, bubbles, and floating scum are observed, especially in channel C (Map 9b) bordering Malibu Colony. The large drain at the western end of C channel seems to be a main source of suds observed occasionally at the Lagoon, and which account for high pH levels.

5. Wide fluctuations of all physical and chemical parameters have been observed during this study.

9.2.2 SEDIMENTATION AND WATER FLOW

1. Sedimentation after the 1983 restoration has followed a predictable pattern, with coarser sediments being deposited in the main Lagoon, and finer silts and muds finding their way to the back reaches of the channels, where water movement is slowest. The large volumes of freshwater have probably accelerated this process. The schedule of managing the Lagoon entrance has resulted in an increase in sedimentation of beach sands near the entrance, which has affected water flow patterns in the Lagoon.

2. Water levels sometimes reach above 5 ft. prior to scheduled opening of the entrance, causing a dramatic exit of large volumes of water from the Lagoon over a two hour period, after which the Lagoon stabilizes at the 2 ft. level. This rapid outflow of water causes sediments and benthic organisms residing in them to be removed.

9.2.3 EMERGENT VEGETATION

1. Of the 18 marsh species normally encountered in estuaries in Southern California, only 7 have been observed during vegetative surveys at Malibu Lagoon, out of a potential total of 133 species in southern California.

2. Vegetation patterns at Malibu Lagoon do not follow patterns observed at other estuaries, due to steeper than normal (0.7%) banks. After the 1983 restoration, substantial areas of disturbed soils were left as upland habitat. Initial distribution of plants was the result of hydroseeding of soil and re-planting of stockpiled marsh vegetation which had been removed from the Lagoon prior to restoration, with species boundaries being determined by fresh water influx.

3. The dominant plant at the Lagoon is (Jaumea carnosa) rather than the usual marsh dominant, pickleweed (Salicornia virginica). This reflects the extended "windows" of fresh water available to foster growth and dominance. Although pickleweed vegetation extends throughout the Lagoon, it is usually found upland of Jaumea. One exception occurs at station D (Map 9a), where substantial infilling of sand occurred, and where there is a predominant saltwater influence.

4. The upland areas are dominated by salt-tolerant perennials and exotic vegetation which have proliferated, due to disturbed soil conditions. Areas where soil salinities are lowest have typical upland marsh vegetation. Additional plantings of California native species by DPR have not been successful.

5. Where soil salinities are high, salt pannes exist which are almost devoid of vegetation. None of the salt panne annuals associated with nearby salt marshes have yet been found at Malibu Lagoon. Predictably, after winter rains, soil salinities are lowered.

6. Only channel A (Map 9b) is being filled in with California bulrush (Scirpus californicus). Management is needed in order to maintain this species and an open channel.

9.2.4 BENTHIC INFAUNA

1. Only two species of benthic invertebrates have been encountered on surveys at Malibu Lagoon. These include a spionid polychaete worm (Polydora nuchalis) and the jacknife clam (Tagelus californianus). In all probability, the extended periods of low salinities found at Malibu Lagoon have prevented the establishment of other more marine species usually associated with estuaries in Southern California. This reduction in diversity is much more pronounced in Malibu Lagoon than in other Southern California estuaries.

2. A polychaete worm (Polydora nuchalis), associated with early colonization of estuaries and which is highly tolerant of low salinities, has been found as a monoculture. In no other Southern California estuary has only one species of polychaete worm been observed. Worms are found in greatest

concentrations near the centers of those inlets where sediments are composed of organic muds and silt. Largest concentrations of worms were found in the mudflat area, station B (Map 9a), which regularly drains at low tidal levels.

3. Over the course of this survey, numbers of polychaete worms decreased in the Lagoon, perhaps reflecting a seasonal reduction in numbers, disturbance from repeated surveys, or changes in water quality within a limited area.

4. Jacknife clams regularly die-off when water conditions in the Lagoon become relatively fresh for a sustained length of time. Numbers of clams have decreased dramatically during the course of this survey.

9.2.5 EPIFAUNA: CRABS, SHRIMP, MICROSCOPIC ORGANISMS

1. Mud crabs (Hemigrapsus oregonensis) are clearly thriving in the brackish water conditions at Malibu Lagoon, and appear to withstand the wide fluctuations in salinities which exist there. They appear to be reproducing successfully, as both gravid females and young crabs have been collected during surveys.

2. Mud crab burrows are most numerous where bank gradients are steep and where sediments are composed of consolidated muds. Crabs are also numerous in inlet channels where cobble rocks and drift coastal algae holdfasts are present.

3. Greatest numbers of crabs occur during summer and fall months when water temperatures are warm and algae mats are present. Large sized crabs (carapace width greater than 14mm) dominate in summer and fall months, and small crabs (carapace width less than 9 mm) predominate during the winter and spring.

4. Throughout the year males are more numerous than females. During summer and fall months males may outnumber females by a factor of two or three to one.

5. The oriental shrimp (Palaemon macrodactylus) is a species which has appeared periodically during fish surveys, and was most likely introduced into Malibu Lagoon on drift coastal algae as a result of coastal shipping.

6. Microscopic epifauna which live at the interface region between the sediments and water column represent a greater potential resource than this small study indicates. Ostracods, copepods, brackish water boatmen, amphipods, nematodes, and flatworms are present in the Lagoon throughout the year. As Malibu Lagoon has exhibited a low diversity of invertebrate species, these organisms may be more important as food resources here than in other estuaries in Southern California.

9.2.6 THE FISHES

1. Malibu Lagoon supports a fish population that is characterized by low diversity and fairly low productivity, which may be typical for a lagoon of this size. In the 12 surveys conducted this year at 5 stations reflecting habitat gradients within the Lagoon, 14 fish species have been encountered, with four species regularly being present. The decreased diversity in fish species observed here is consistent with other estuaries which have received large influxes of freshwater from sewage treatment plants.

2. Fish numbers peak in the summer and early fall months, and decline to relatively small numbers during the winter. Year round residents include the California killifish (Fundulus parvipinnis), topsmelt (Atherinops affinis), arrow goby (Clevlandia ios), and staghorn sculpin (Leptocottus armatus).

3. Malibu Lagoon appears to be an important nursery area for several species of fish. Growth of topsmelt, arrow goby, California killifish, striped mullet (Mugil cephalus), and staghorn sculpin have been followed as increasing size classes in the Lagoon. Eggs of topsmelt have been observed attached to algae mats in the late spring and early summer. Young of year (YOY) of several marine species have been encountered, with large numbers of YOY opaleye perch (Girella nigricans) being caught. The period from August through November, when Lagoon waters are warm and much food is available, appears to be most critical for the developing YOY.

9.2.7 THE BIRDS

1. For an estuary of such small size, Malibu Lagoon shows a high diversity of bird species. A total of 151 species have been sighted at the Lagoon, including 78 species of waterbirds and 73 landbird species. Greatest numbers of birds are observed during the winter months and during migration periods, when birds use the Lagoon primarily as a feeding, freshwater source, bathing and resting area.

2. The most populous species at the Lagoon are the gulls. Two species which over-winter at the Lagoon are experiencing population threats. California gull (Larus californicus) numbers are tied to the continued health of Mono Lake while numbers of Heermann's gulls (Larus heermanni) are being reduced, due to the commercial development of their island breeding site off the coast of Baja California.

3. Numbers of over-wintering wild ducks observed at the Lagoon are quite low. This may be the result of the relatively small area of the Lagoon or the loss of wetlands

where these ducks breed. Most ducks have been observed in the upper Lagoon where water is fresh and there is less disturbance by humans.

4. Most birds utilize the Lagoon when water levels are low, exposing more area for feeding. The mudflat area at channel B is most heavily used by probing shorebirds. The west end of channel C (Map 9b), nearest Malibu Colony, is the least used.

5. The Lagoon is utilized by a few species of shorebirds as a breeding and nesting area. Two threatened species, the snowy plover (*Charadrius alexandrinus*) and the least tern (*Sterna antillarum*), and the endangered bald eagle (*Haliaeetus leucocephalus*) historically nested at the Lagoon. As a result of habitat destruction, increased human activities, and the presence of unleashed dogs and cats, these species no longer nest here. The bald eagle no longer is a Lagoon visitant. Only the snowy plover has demonstrated an ability to co-exist with beach-goers, and a small breeding colony might be re-established at the Lagoon with the availability of suitable habitat.

6. Malibu Lagoon is an important resource for the brown pelican (*Pelicanus occidentalis*), which nests on Anacapa Island. Young brown pelicans, trained by non-breeding adult males, use the Lagoon as a learning area for catching fish.

7. Riparian areas near Malibu Creek and Malibu Lagoon, with relatively little human disturbance and a diversity of riparian vegetation, serve as a breeding area for several species of water and landbirds.

8. Birds respond to human disturbances and unleashed pets at the Lagoon by moving to areas where they are not threatened. The main roosting area when large numbers of beach-goers are present is the east side of the Lagoon, which presently is subject to light recreational use. Offshore rafts are also used as roosts.

9.2.8 OTHER ANIMALS

1. Relatively few wildlife corridors, such as ones existing in the Malibu watershed, remain in the Santa Monica Mountains. These corridors are important to the success of many species.

2. Although not studied, several vertebrate species have been observed in the upper and main Lagoon areas. Mule deer (*Odocoileus hemionus*) have been observed at the upper Lagoon, and tracks of deer and raccoon (*Procyon lotor*) have been seen in both the main Lagoon and inlets.

3. Vegetated upland habitat hosts a number of vertebrates Audubon's cottontail (Sylvilagus audubonii) is a common resident where there is sufficient cover. Sightings of the long-tailed weasel (Mustela frenata) were made at both the main and upper Lagoon. Vole (Microtus sp.) trails are evident throughout the saltgrass vegetation. Pocket gophers (Thomomys bottae) exist throughout upland areas, with large numbers being observed in the managed lawn near the interpretive area. In the upper Lagoon, many Beechy ground squirrels (Citellus beecheyi) exist along the creek bank.

4. Western fence lizards (Sceloporus occidentalis), the San Diego gopher snake (Pituophis melanoleucus annectens) and the striped racer (Masticophis lateralis) are the reptiles sighted at the Lagoon. Pacific rattlesnakes (Crotalus viridis helleri) have been sighted adjacent tothe upper Lagoon.

9.3 MANAGEMENT CONSIDERATIONS PROPOSED FOR MALIBU LAGOON

9.3.1 WATER QUALITY

The two major influences on the water quality at Malibu Lagoon are the large and unseasonal volumes of fresh water released from the Tapia Water Reclamation Facility of the Las Virgenes Municipal Water District and the frequent closure of the Lagoon entrance.

Until recently (see 9.3.2), all waste water has been pumped from the Tapia facility directly into Malibu Creek during "off peak" hours. The increased flow rate generated by this practice has most likely increased the rate of erosion in the Creek, with increased sedimentation downstream. In the future, these effects need to be measured. A reduction in the amount of non-seasonal fresh water which reaches Malibu Lagoon, with management for lower Lagoon water levels would greatly benefit this ecosystem.

In providing a management plan that would be acceptable to nearby Malibu Colony residents and to the recreational users of Surfrider State Beach, the natural regime of the Malibu Lagoon ecosystem was compromised. Prior to restoration, the entrance of the Lagoon was opened by the first winter storms each year. During periods of high water flow in Malibu Creek, the entrance remained open, with a gradual eastward drift. Usually by mid-April the entrance closes, to be opened again by storm cycles of the following year. Post restoration, a mandated opening of the Lagoon entrance at a location just east of Malibu Colony was required by the California Department of Parks and Recreation (DPR) when water levels reach 3.5 ft. Maintaining the entrance at its present location has probably preserved the longshore break for surfing at Surfrider State Beach. However, with only one bulldozer to serve all parks in this area, this management plan is not functioning well.

Impoundment of brackish water due to infrequent opening of the Lagoon entrance provides the potential for biological pollution. Coliform bacteria multiply rapidly under the brackish water conditions which exist in the Lagoon, and are killed by salt water. Management for lower Lagoon water levels would greatly benefit this ecosystem. The high coliform counts noted when Lagoon water levels are high, (recorded by LVMWD and L.A. County Dept. of Health) need to be reduced and sources of biological pollutants determined. In particular, septic systems and road run-off need to be controlled.

9.3.2 FRESHWATER RELEASE

Excessive amounts of freshwater released directly into Malibu Creek increase the rate of streambed scouring and downstream sedimentation in Malibu Lagoon. The recent use of existing percolation ponds adjacent to the Tapia facility has somewhat modified the effects of the release of large volumes of freshwater. However, the present percolation ponds are inadequate for the large volumes of water presently being released.

A preferred management scheme would be one which would more fully restore the natural hydrologic regime. For this to occur, the additional freshwater generated from the Tapia facility must not impact the biota of the Lagoon. These options may be considered:

1. Establish an overflow pipe in the Lagoon to siphon off the less dense surface freshwater when water levels reach a pre-determined height for the best functioning of this ecosystem. This overflow pipe would have to be eastward of any storm-erosive forces, and directed far enough seaward to prevent plugging by sand carried by the longshore current. The Lagoon entrance to the sea would be determined by natural events. Studies are needed to determine if this is a feasible alternative.

2. Minimize the impact of fresh water by establishing additional and refined percolation/retention ponds for a more gradual, controlled release of reclaimed water. Additional percolation/retention ponds can benefit wildlife and may serve as recreational facilities in an area experiencing extensive development. Returning to a natural hydrologic regime will restore the historic brackish marsh, reduce the amount of sedimentation in Malibu Lagoon and possibly enhance re-establishment of a permanent steelhead fishery.

9.4 SITE SPECIFIC MANAGEMENT CONSIDERATIONS

Based on our observations at Malibu Lagoon, management considerations for planned and future restoration efforts are being made by location. Map 9b identifies peninsulas, bridges, and channels. It is our hope that some of these suggestions, for which funds are not yet allocated, may be considered for the future.

9.4.1 BIRD PENINSULA (A' on the map)

1. Maintain upland habitat between the parking area and the PCH bridge, with areas of continuous vegetative cover for upland bird species and mammals such as rabbits.

2. During future restoration efforts, reduce the elevation of the presently unvegetated portions of this peninsula to encourage the formation of a more naturally zonated marsh. At this time, elevated boardwalks and viewing decks could be established for birdwatching, and to keep human impact to a minimum. Even if this area is not altered, the addition of guided pathways and viewing decks might result in natural re-vegetation of this relatively barren peninsula.

3. Improve water circulation to the A' channel by connecting this small inlet to the main Lagoon. Hydrologic studies are necessary to determine if this suggestion is feasible. This would make the bird peninsula an island, which would assist in controlling predation and damage by domestic dogs and cats.

9.4.2 "A" CHANNEL AND PENINSULA

1. Retain and manage existing but invasive California bulrushes (*Scirpus californicus*) as habitat for sensitive bird species such as sora rails (*Porzana carolina*) seen nesting there this spring.

2. Retain some upland habitat for mammals, reptiles, and birds.

9.4.3 "B" CHANNEL

1. Maintain this channel "as is". Use this channel as a model for the re-design of other designated mudflat areas to foster populations of benthic infauna and to provide more feeding areas for migratory and resident birds.

9.4.4 "B" AND "C" PENINSULAS, WEST OF BRIDGES

1. There is some concern regarding the effects in the connection of these two channels, while visible pollutants such as suds, foam and oil are still entering C channel from open drains of nearby houses and roads.

2. Removal of soil during the lowering of the peninsulas should occur prior to connection to intertidal areas, to minimize the effects of sedimentation during the restoration process.

9.4.5 "C" PENINSULA (EAST OF PATHWAY)

1. Create an island from this peninsula where it naturally narrows just east of the pathway, to provide the potential for snowy plover (Charadrius alexandrinus) breeding and nesting habitat. The many cat and dog tracks observed here demonstrate the critical need for protection of nesting birds and nestlings from predation.

2. Maintain the habitat for nesting of killdeer (Charadrius mongolus).

3. Add more sand, to encourage nesting of these species.

9.4.6 "C" CHANNEL

1. The entrance to this channel has been heavily filled-in by the deposition of beach sands since the present entrance to the Lagoon has been maintained. A sand bar has now formed at station D (Map 9a), which has severely altered water circulation patterns into this channel.

2. Re-establish a permanent channel at station D by removing the accumulated sand. To prevent the rapid recurrence of infilling, move the entrance opening eastward or allow the natural eastward drift of the entrance to occur as part of the natural hydrologic regime.

3. Use the sand which would be removed from channel D to provide snowy plover and killdeer nesting habitat at the end of the C peninsula, and for the planned dune community near Malibu Colony.

9.4.7 "COLONY" PENINSULA, ADJACENT TO BEACH

1. To improve water quality in the Lagoon, close all drainage pipes from nearby homes into the C channel.

2. Locate and eliminate the source(s) of pollutants entering the Lagoon from the large drain at the back of the C channel. This drain appears to be a main source of non-point source pollutants, such as suds and oils observed at the Lagoon.

9.4.8 PROPOSED SAND DUNE COMMUNITY

1. Vegetate the dune with native plants (based on historic records) for this estuary.

2. Provide interpretive exhibits so that the public can gain a better understanding of dunes historic to this area. Provide post and cable fencing, similar to that already in the Lagoon, to guide visitors away from sensitive areas of the dune community. Post an interpretive sign to let visitors know that this is a sensitive area, with reasons why they should stay out. A DO NOT ENTER sign alone often has the opposite effect.

3. Provide a wide-mesh fence next to the dune, which will permit the drift of sand and keep predators out, and help to maintain dune stability.

9.4.9 EAST SIDE OF MALIBU LAGOON, ADJACENT TO THE BEACH

1. This area presently has little public access, and is an important semi-secluded area where shorebirds retreat when human visitation at the Lagoon is high.

2. Future trails should have guided fencing leading toward the beach, similar to that on the west side of the Lagoon, with vegetative screening established between the trail and areas where birds roost. Any establishment of a trail system on this side of the Lagoon should be away from the Creek and the Lagoon. The area along the east shore contains sensitive nesting habitat and is the only area where water birds can currently roost when public visitation at the Lagoon is high. The potential exists here for establishing a fenced least tern (<u>Sterna antillarum</u>) breeding area to the east of a proposed trail, in the area at the back of the beach which has little public visitation. Similar breeding areas have been established for this endangered species at McGrath and Venice beaches.

9.4.10 ENTRANCE TO MALIBU LAGOON:

1. The Lagoon entrance to the sea is a keystone management area within the Malibu Creek watershed. Our recommended management strategy is to allow the entrance condition to be determined by natural events rather than by

humans. Non-natural Lagoon conditions generated by human manipulation of the environment (i.e. additional freshwater flow from Tapia, artificial opening) is likely to affect species composition patterns in this estuary and needs to be controlled.

2. Opening the entrance of the Lagoon should be a priority in the management of this resource only until other management methods are implemented. The high water levels which remain in the Lagoon for many days after water levels reach the mandated 3.5 feet are associated with high levels of coliform bacteria and surface pollution. Maintenance of the entrance at a lower water level (approximately 3 ft.) may prevent overflow from nearby septic systems leaching into the Lagoon.

3. An additional management alternative would be to have the entrance determined by natural events and establish the overflow pipe referred to in section 9.3.2. Impounded water from the current management scheme poses a problem of biological pollution, since coliform counts are highest when water levels in the Lagoon are high.

9.5 SUMMARY

1. The importance of total watershed management cannot be overstated. Only when entire watersheds and landscapes are conserved and managed responsibly, will conservation of biodiversity, including humans, be successful in perpetuity.

2. Malibu Creek is a significant riparian wildlife corridor within the Santa Monica Mountains.

3. Our recommended management strategy is to mimic the natural streamflow cycle for the Malibu Creek watershed. The non-seasonal (extended season) and excessive seasonal influxes of freshwater originating from domestic sources needs to be controlled and regulated. Water levels in the Lagoon need to be effectively managed for native species.

4. This data base provides a preliminary understanding of the local aquatic ecology and some of the human disturbance factors impacting the Malibu Creek and Malibu Lagoon ecosystems. Continued ecological studies are needed in conjunction with pollution studies for our understanding of this system to reach a point where we can effectively and efficiently manage these two contiguous ecosystems.

5. Since the 1983 restoration Malibu Lagoon has made progress towards physical and ecological recovery. However, generally low diversity at the species level is a major concern which requires knowledge to lead the way to solutions.

6. Regulation of human disturbances and their consequent cumulative impact on this creek and lagoon ecosystem is paramount. Continued ecological restoration and monitoring efforts are recommended in order to meet the management goal of long-term maintenance of biodiversity within this ecosystem complex.

LITERATURE CITED

Mangum, F. 1986. Macroinvertebrates. In Inventory Monitoring and Wildlife Habitat. Eds. A.T. Cooperrider, R.J. Boyd, and H.R. Stuart. U.S. Dept.Inter. Bur. Land Manage. Service Center. Denver, Colorado. pp. 858.

Swift, C. 1982. A List of The Fishes of Malibu Creek and Malibu Lagoon, with a Brief Description of Their Habitat Requirements and Seasonal Movements. Natural History Museum of L.A. County, Los Angeles, CA.

Tippets, W. 1988. Associate Resource Ecologist. State of California, Department of Parks and Recreation.

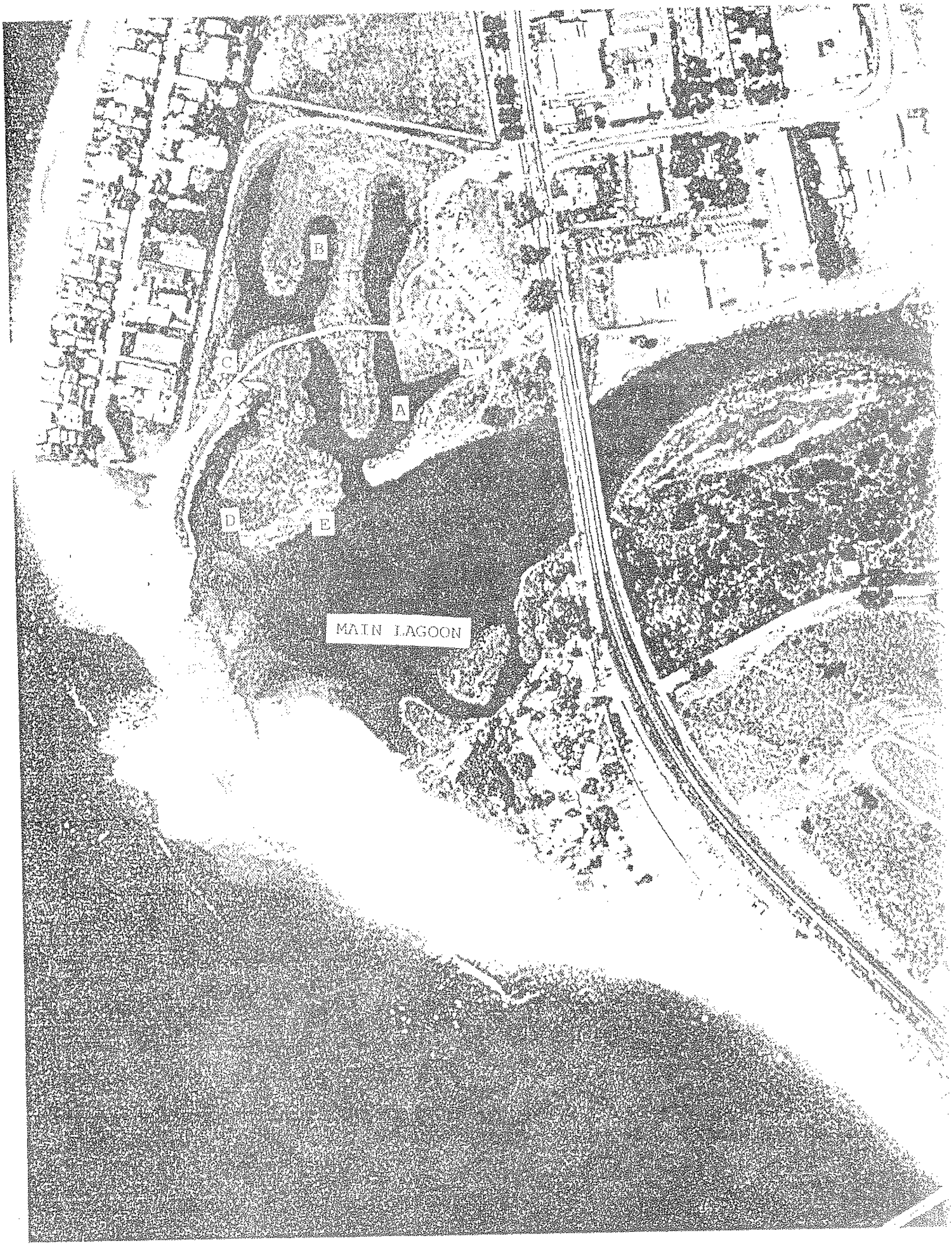
Zedler, J.B. 1982. The Ecology of Southern California Coastal Salt Marshes: A Community Profile. U.S. Fish and Wildlife Service: FWS/OBS-81/54. pp.110 (second printing with corrections 1984).

Zedler, J.B., Koenigs. R. and Magdych. W.P. 1984. Freshwater Release and Southern California Coastal Wetlands. San Diego Association of Governments, San Diego, CA. Report no.2. pp.51.

Zedler, J.B. and Nordby, C.S. 1986. The Ecology of Tijuana Estuary: An Estuarine Profile. U.S. Fish and Wildlife Service Biol. Report. 85 (7.5). pp.104.

MAP 9A

Study Stations at Malibu Lagoon



MAP 9b

SPECIFIC SITES AT MALIBU LAGOON FOR MANAGEMENT CONSIDERATIONS