Demersal Fishes and Megabenthic Invertebrates

BIGHT'08

Southern California Bight
2008 Regional Monitoring
Program
Vol. IV

SOUTHERN CALIFORNIA BIGHT 2008 REGIONAL MONITORING PROGRAM: IV. DEMERSAL FISHES AND MEGABENTHIC INVERTEBRATES

December 2011

M.J. Allen[1], D. Cadien[2], D.W. Diehl[4], K. Ritter[4], S.L. Moore[4], C. Cash[5], D.J. Pondella II[6], V. Raco-Rands[4], C. Thomas[7], R. Gartman[8], W. Power[2], A.K. Latker[8], J. Williams[6], J.L. Armstrong[7], E. Miller[3], and K. Schiff[4]

[1]Ecorp Consulting, Inc.
[2]County Sanitation Districts of Los Angeles County
[3]MBC Applied Environmental Sciences
[4]Southern California Coastal Water Research Project
[5]City of Los Angeles, Environmental Monitoring Division
[6]Occidental College, Vantuna Research Group
[7]Orange County Sanitation District
[8]City of San Diego, Public Utilities Department

Southern California Coastal Water Research Project
3535 Harbor Blvd, Suite 110
Costa Mesa, CA 92626

Phone: (714) 755-3500
www.sccwrp.org

Bight '08 Trawl Technical Committee Members

Member	Affiliation
Chair - Dr. M. James Allen	Southern California Coastal Water Research Project
Co-Chair - Don Cadien	County Sanitation Districts of Los Angeles County
Dr. Jeff L. Armstrong	Orange County Sanitation District
Curtis Cash	City of Los Angeles, Environmental Monitoring Division
Dario W. Diehl	Southern California Coastal Water Research Project
Robin Gartman	City of San Diego, Metropolitan Wastewater Department
Ami K. Latker	City of San Diego, Metropolitan Wastewater Department
Eric Miller	MBC Applied Environmental Sciences
Shelly L. Moore	Southern California Coastal Water Research Project
Dr. Daniel J. Pondella, II	Occidental College, Vantuna Research Group
William Power	County Sanitation Districts of Los Angeles County
Valerie Raco-Rands	Southern California Coastal Water Research Project
Kenneth Schiff	Southern California Coastal Water Research Project
Fred Stern	County Sanitation Districts of Los Angeles County
Christina Thomas	Orange County Sanitation District
Shelly Walther	County Sanitation Districts of Los Angeles County
Jonathan P. Williams	Occidental College, Vantuna Research Group

Foreword

The Southern California Bight 2008 Regional Monitoring Program (Bight'08) is part of an effort to provide an integrated assessment of the Southern California Bight through cooperative regional-scale monitoring. Bight'08 is a continuation of regional surveys conducted in 1994 (Allen *et al.* 1998), 1998 (Allen *et al.* 2002a) and represents the joint efforts of more than 90 organizations. Bight '08 is organized into three technical components: 1) Coastal Ecology; (2) Shoreline Microbiology; and (3) Water Quality. This report presents the results of the Demersal Fishes and Megabenthic Invertebrate portion of Bight'08, which is part of the Coastal Ecology Component. Other Coastal Ecology components include sediment toxicology, sediment chemistry, and benthic Macrofauna. Copies of this and other Bight'08 guidance manuals, data, and reports are available for download at www.sccwrp.org.

The proper citation for this report is: Allen, M.J., D. Cadien, E. Miller, D.W. Diehl, K. Ritter, S.L. Moore, C. Cash, D.J. Pondella, V. Raco-Rands, C. Thomas, R. Gartman, W. Power, A.K. Latker, J. Williams, J. L. Armstrong, and K. Schiff. 2011. Southern California Bight 2008 Regional Monitoring Program: Volume IV. Demersal Fishes and Megabenthic Invertebrates. Southern California Coastal Water Research Project, Costa Mesa, CA.

Acknowledgements

The Southern California Bight 2008 Regional Monitoring Program (Bight'08) Technical Trawl Committee worked cooperatively to write this report. The authors thank Bruce Bealer and Marlene Merchain for developing the analytical database. The authors also thank Becky Schaffner for GIS support. M. James Allen and Valerie Raco-Rands authored the Demersal Fish Population and the Assemblages and Biointegrity chapter. Don Cadien authored the Megabenthic Invertebrate chapter. Don Cadien and Shelly Moore authored the marine debris chapter. Dario Diehl and William Power authored the Materials and Methods and Quality Assurance chapters. Additional data analysis was provided by Valerie Raco-Rands, Christina Thomas, Robin Gartman, Jonathan Williams, and Ami Latker. Eric Miller authored two appendices evaluating the use of fish density based on area swept by the trawl. Dario Diehl and M. James Allen authored an appendix on trawl method improvements. The authors thank Karlene Miller for technical editing and assistance with final report production. The authors also thank the Bight'08 Technical Trawl Committee, as well as the Bight'08 Coastal Ecology Planning Committee for reviewing the draft reports. We are indebted to the Bight'08 Field Method Committee for assuring high-quality data for this study. We thank workers at the following organizations for their tireless field collection and data processing: Aquatic Bioassay, and Consulting Laboratory (ABC); CLAEMD (City of Los Angeles Environmental Monitoring Division); CSDLAC (County Sanitation Districts of Los Angeles County); MBC Applied Environmental Sciences; Occidental College, Vantuna Research Group; Weston Solutions, Inc.; and SCCWRP.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Demersal fishes and benthic macroinvertebrates that live on soft-bottom habitat are an important part of the marine ecosystem. Soft-bottom habitat comprises the majority of the Southern California Bight (SCB) area and fish species number in the hundreds. Demersal fish and megabenthic invertebrates are regularly monitored in ocean outfall monitoring programs using otter trawls because these organisms have responded to wastewater inputs historically. However, previous monitoring has also demonstrated that demersal fish and megabenthic invertebrates respond to natural variations in the ocean including depth, latitude and water temperature cycles (i.e., El Niño Southern Oscillation, Pacific Decadal Oscillation). This naturally occurring variation affects large spatial scales and complicates interpretation of localized ocean outfall monitoring. The objective of the trawl component of 2008 Southern California Bight Regional Marine Monitoring Program (Bight'08) was to: 1) estimate the extent and magnitude of community changes at regional scales; and 2) determine the trends in these regional-scale changes. Environmental managers want to know how their site(s) compare to the natural variation of outlying areas within the SCB. Estimating the amount of area (i.e., number of acres, percentage of the total) that differs from these reference conditions directly address large-scale management concerns. Bight'08 is the fourth in a series of regional trawl monitoring surveys dating back to 1994. Comparisons in spatial extent of fish and megabenthic invertebrate communities among surveys form the basis of the trends evaluation.

Trawl samples were collected from 143 stations from Point Conception to the U.S.-Mexico Border at depths of 3-485 m from July to October 2008 using a stratified-random probability-based survey design. Stratification focused on known ecological zones including bays and harbors, three depths on the mainland continental shelf (5-30, 30-120, and 120-200m), and the upper continental slope (200-500m). For each trawl, organisms were identified to species, counted, weighed, fish length measured, checked for external anomalies or diseases, and then returned to the sea.

Quality assurance is an important component of the Bight'08 program. Overall, data quality was high and no data were censored due to quality related issues. However, several concerns were identified including presurvey evaluations and in-study field audits, ensuring representative on-bottom net times, and accuracy of voucher specimen identifications. While these deviations did not impact the conclusions of the study, future surveys should address these concerns.

Demersal fish and invertebrate communities of the SCB were relatively healthy in 2008 based on biointegrity assessment tools. Approximately 96% of the SCB had fish communities that were similar to reference conditions. In addition, approximately 84% of the SCB had megabenthic invertebrate communities that were similar to reference conditions. Nonreference conditions were found primarily on the inner continental shelf (<30m depth) and bay/harbor areas, suggesting nearshore influences. The biointegrity assessment tools used in Bight'08 do not address fisheries or standing stock assessments.

Fish populations had background levels of anomalies and diseases in the SCB during 2008. Anomalies identified in this study included parasites, tumors, ambicoloration, skeletal deformities, and albinism. The presence of anomalies was low, observed in only 0.5% of the more than 11,000 fish collected during the survey. Two fish were observed to have tumors.

Fish and invertebrate assemblages of the SCB were largely organized by depth with distinct bay assemblages during 2008. Natural bays had assemblages uniquely different from open coast or highly developed bays. In addition, the fauna observed from the upper slope (>200m) was distinctly different from the continental shelf (120-200m). These naturally occurring differences are an important reminder for those trying to assess the impacts from anthropogenic discharges as one crosses ecological gradients.

Most changes in regional fish species composition of the SCB since the early 1970s are likely related to cold and warm regimes of the Pacific Decadal Oscillation and the occurrence of two El Niños. Physical oceanographic conditions are known to influence biological condition in the SCB. Comparing the bathymetric distribution of species in fish foraging guilds illustrated the most similarity during cold regimes (1972, 2003, 2008), less similarity in 1994 (warm), and least similarity during the 1998 El Niño (very warm). These naturally occurring differences are an important reminder for those trying to assess the impacts from anthropogenic discharges as one crosses ecological gradients.

Debris was found throughout most (90%) of the SCB, but generally in trace amounts. Natural debris was observed three times as frequently as anthropogenic debris. Marine (seaweeds) and terrestrial (woody) debris were the most common natural debris. Plastics were the most common anthropogenic debris. Anthropogenic debris was found most frequently, and in greatest quantities, in the central SCB presumably due to its proximity to the urban center of Los Angeles and Orange Counties. The frequency and quantity of debris co-varied with rainfall quantity in the winter preceding each sampling campaign of the last four regional surveys.

A number of recommendations were identified for planning and implementing the next Bight regional survey. These recommendations included: 1) partnering with the Ocean Protection Council's Marine Monitoring Enterprise, the agency tasked with monitoring the effectiveness of pending Marine Protected Areas; 2) improved training of field teams to ensure continued QA; and 3) upgrading the tools used by trawl scientists for assessing impacts.

I. INTRODUCTION

The Southern California Bight (SCB) is an open embayment in the coast between Point Conception and Cape Colnett (south of Ensenada, Mexico). The most recent census data show that approximately 17 million people inhabit the five coastal counties that border the SCB (US Census Bureau 2010), a number that is projected to increase to over 20 million by 2020 (State of California 2001). Population growth generally results in conversion of open land into non-permeable surfaces. This "hardening of the coast" through development has increased stress to the coastal ocean environment. Urban and storm related runoff adds sediment, toxic chemicals, pathogens and nutrients to the ocean. Infrastructure to support urbanization has yielded fifteen municipal wastewater treatment facilities, eight power generating stations, 10 industrial treatment facilities, and 18 oil platforms, all discharging to the ocean. To comply with water quality standards associated with the California Ocean Plan and federal Clean Water Act, local, state and federal agencies spend in excess of $31 million a year (Schiff *et al.* 2002) to monitor potential impacts of their discharges to the coastal ocean. Historically, these point source monitoring agencies seldom ventured outside of their discharge area to evaluate their findings on a regional scale.

Marine community dynamics such as composition and abundance are often affected by a wide variety of natural and anthropogenic factors. Natural forces such as oceanographic variability, current patterns, habitat availability have historically shaped these communities (Dayton *et al.* 1998; Miller *et al.* in press). Anthropogenic factors such as fishing, pollution, habitat degradation, etc. have significantly contributed to the community structure now observed (Hidalgo *et al.* 2011; Mora *et al.* 2011). Disentangling these presently interacting forces affecting the current status of the SCB's marine communities is a daunting task that requires robust data on both large spatial and temporal scales (Scavia *et al.* 2002; Harley *et al.* 2006; Hsieh *et al.* 2008). While the core monitoring programs conducted by the various dischargers in the SCB have been conducted for decades, they are most often localized. Therefore, while they are capable of addressing the temporal patterns, the regional spatial scale is left under evaluated. The SCB Regional Marine Monitoring Program was begun to address this, specifically to examine the effects of anthropogenic discharges on the SCB's demersal marine community at a greater-than-local scale.

The Southern California Bight 2008 Regional Monitoring Project (Bight'08) was a continuation of earlier cooperative regional-scale monitoring studies conducted in 1994, 1998, and 2003. Each of these surveys built upon previous experiences and incorporated a multiple participant coalition to standardize procedures and techniques across the SCB. A complete list of Bight'08 participants can be found in Appendix E. The goal of the Regional Monitoring Programs has been, and continues to be, to provide a broad overview of the SCB's ecological communities to allow, among other things, dischargers the opportunity to place their site-specific monitoring results into a greater regional context. A greater-than-local perspective provides better opportunities to identify areas of potential environmental impact related to ocean discharge. This document focuses on the demersal fish and mega-invertebrates living on or near soft (mud) bottoms, or the ecosystems most commonly interacting with ocean discharges and their effluent.

Otter trawls are typically the preferred method to sample the soft-bottom demersal community. Rocky reef habitat is much more rare and fishing nets can be snagged or impaired while sampling. Trawlable soft-bottom substrates within the SCB are diverse, relating to a complex topography, with harbors, sandy nearshore areas, submarine canyons, offshore islands, ridges and basins (Dailey *et al.* 1993). The SCB also represents a transitional area influenced by cold northern currents, temperate ocean waters, and warm tropical waters from the south punctuated by oceanographic perturbations such as low-frequency oceanographic regime shifts and higher-frequency El Niño Southern Oscillation events (Hickey 1993; Bograd and Lynn 2003; McGowan *et al.* 2003; Horn *et al.* 2006). The mixing of currents, episodic events, and the multiple habitats allow for the coexistence of a broad spectrum of species, including more than

500 species of fish (Cross and Allen 1993) and thousands of invertebrate species (Thompson *et al.* 1993a). Many of these species separate themselves by depth, habitat, and feeding guilds to reduce food competition and allow multi-species coexistence (Allen 2006a; Allen *et al.* 1998, 2002, 2007). All these factors complicate data interpretation.

Since the SCB soft-bottom marine community is influenced by a variety of factors including both natural and anthropogenic influences, the objective of this report was to: 1) estimate the extent and magnitude of community changes; and 2) determine the trends in these changes over previous surveys. Consistent with Allen *et al.* (2007), many of the conclusions will be presented as estimated area (i.e., number of acres, percentage of the total) that differs from the reference conditions as described by various biointegrity indices that mathematically generate a numeric score to represent the communities condition in relation to a predetermined reference scale. More information on these indices can be found in Allen *et al.* (2001) and Smith *et al.* (2001). It should be noted that these indices reference the community along a pollution gradient and do not represent the status of these communities from a fisheries perspective. Such assessments were outside the scope of this investigation.

This report is organized into 9 chapters: I) Introduction; II) Methods; III) Quality Assurance; IV) Demersal Fish Populations; V) Megabenthic Invertebrate Populations; VI) Debris; VII) Assemblages and Biointegrity; VIII) Conclusions and Recommendations; and IX) References. The Introduction provides the background, and study objectives. Methods describe field, laboratory, and analytical procedures. Quality Assurance describes logistical success and quality assurance results. Demersal Fish Populations and Megabenthic Invertebrate Populations look at population attributes, species composition, population structure, and anomalies for fish and invertebrates. The Debris section describes the extent of natural and anthropogenic debris in the study area. Assemblages and Biointegrity describes assemblages (recurrent groups, site and species clusters) for fishes and invertebrates; functional organization of fish communities; and assesses the assemblage biointegrity. The Discussion, Conclusions and Recommendations, and References sections follow. Appendices provide additional information or data related to specific chapter context.

II. METHODS

Sampling Design

Probability-based design

As in previous regional trawl surveys of the SCB (Allen *et al.* 1998, 2002, 2007), the Bight'08 regional trawl survey was based on a stratified random sampling design detailed in Stevens (1997) and Bight'08 Coastal Ecology Committee (2008a). In summary, stratification consisted of identification of strata or subpopulations of interest. A sufficient number of sampling sites were allocated to each stratum to provide adequate precision. In general, 30 sites would yield a 90% confidence interval of 10% around estimates of areal extent (assuming a binomial probability distribution and p=0.2). Randomization of sites includes a systematic component to minimize clustering of sample sites. A tessellated hexagonal grid was randomly placed over a subpopulation map and hexagons were randomly chosen. A randomly selected site coordinate was obtained from each selected grid cell. If intensification of sampling in a stratum was desired, the size of the hexagons was reduced. Area-weighting factors were associated with the size structure of each hexagonal grid used in a subpopulation. In order to assess temporal trends, 50% of the Bight'08 samples were new sites while 25% of the sample sites were from Bight'98 and 25 % from Bight'03. Additional randomization details are found in the Bight'08 Coastal Ecology Committee Workplan (Bight'08 Coastal Ecology Committee 2008a).

Subpopulations

Subpopulations were defined for region and shelf zone/habitat categories (Figure II-1). The following subpopulation categories were defined within this area:

- Mainland Shelf – northern (Point Conception to Point Dume), central (Point Dume to Dana Point), and southern (Dana Point to United States-Mexico International Border);

- Depth Zones – Bays/Harbors (5-30 m); Inner Shelf (5-30 m); Middle Shelf (31-120 m); Outer Shelf (121-200 m); and Upper Slope (201-500 m).

The northern, central, and southern mainland sub-regions are the same in this study as in the 1994, 1998, and 2003 regional trawl surveys (Allen *et al.* 1998, 2002, 2007). Sub-regions not included in the present survey, but sampled during previous regional studies, were the island areas (Bight'98, Bight'03) and large/small POTWs (1994 Southern California Bight Pilot Program (SCBPP), Bight'98, Bight'03).

The shelf zones are bathymetric life zone divisions of the continental shelf and slope along the west coast of North America (Allen and Smith 1988, Allen 2006a). The inner, middle, and outer shelf zones were sampled in the 1994, 1998, and 2003 regional surveys (Allen *et al.* 1998, 2002, 2007) as well as in the 2008 survey. The depth ranges of these shelf life zone divisions have been slightly modified from Allen (1982), Allen and Smith (1988), and Allen *et al.* (1998). See Allen *et al.* 2007, for details on specific changes in depth. Bays and harbors were added to the shelf zone/habitat subpopulations in 1998, 2003, and 2008; this subpopulation overlaps in depth with the inner shelf zone of the coast. In 2003 and 2008 the upper (or mesobenthal) slope zone (201-500 m; Allen and Smith 1988, Allen 2006a) was added to the bathymetric subpopulations.

One hundred fifty sampling sites were originally distributed to participating organizations based on resources available and the contribution of in-kind services. The distributed station list included a percentage of overdraw sites for region and depth strata, as well as historical survey locations. The overdraw sites were in recognition that agencies may not sample all the randomly selected sites because of improper substrate type, depth restrictions, dredging activities, or other causes. Additional pre-selected sampling sites were available for each stratum if excess in-survey abandonment affected the statistical power.

Field Sampling

Sample Collection and Processing for Assemblage and Debris Studies

Trawling

Fish and invertebrate samples for population and assemblage analysis were collected from 143 trawl stations from Point Conception, California to the United States-Mexico international border between July 1 and September 30, 2008 (Figure II-2). Station coordinates, depths, and other characteristics provided for each sample are given in Appendix A-1. The subpopulation classification of each station was provided in Appendix A-2.

Trawl samples were collected according to standard methods described in a field manual written for the survey (Bight'08 Coastal Ecology Committee 2008c). Stations were located by differential global positioning system (DGPS). If a site could not be trawled or was too deep, stations could be moved up to 100 m from the nominal location (not to exceed 10% of the nominal site depth). Samples were collected with 7.6 m head-rope semi-balloon otter trawls with a 1.25-cm cod-end mesh. Trawls were towed along isobaths for 10 minutes (5-10 minutes in bays and harbors) at 0.8-1.0 m/sec (1.5-2 kts) as determined by DGPS. These tows covered an estimated distance of 300 and 600 m for 5- and 10-minute trawls, respectively.

Agencies were asked to use a pressure-temperature sensor, attached to one of the otter trawl boards, throughout the survey to provide net on-bottom data. Agencies assigned with upper slope (201-500 m) stations were asked to use the sensor as a learning tool and adjust their trawling method so that the sensor, net on-bottom, duration time fell between 8-15 minutes. If the station bottom time fell outside the window, agencies were expected to show progress in meeting the 8-15 minute window with either repeat trawls and/or method compensation at their next upper slope station.

Processing the Fish and Invertebrate Catch

All fish and megabenthic invertebrates from assemblage trawls were identified and processed. Megabenthic invertebrates were defined as epibenthic species with a minimum dimension of 1 cm; specimens less than 1 cm were excluded from the analysis. Other invertebrates excluded were pelagic, infauna, or small species that are better sampled by other methods. Infaunal, pelagic, and colonial species, as well as unattached fish parasites (e.g., leeches, cymothoid isopods), were noted but not processed.

Fish and invertebrates were identified to species, individuals were counted, and species were batch-weighed to the nearest 0.1 kg (using spring scales). Fish and invertebrates batch-weighs less than 0.1 kg were given a weight of 0.0 kg. Lengths of individual fish were measured to centimeter size class on measuring boards; total length (TL) was measured for cartilaginous fishes and board (or maximum) standard length (SL) was measured for bony fishes. In addition, wingspan was measured for round stingrays. Each organism was also examined for gross external anomalies. Targeted fish anomalies included fin erosion, tumors, external parasites, ambicoloration, albinism, diffuse pigmentation, skeletal deformities, and lesions. Targeted invertebrate anomalies included burnspot disease and external parasites.

Voucher specimens, incompletely identified fish and invertebrate specimens, and those with diseases that required further examination were returned to the laboratory. Depending on specimen size, animals were either fixed in the field with 10% buffered formalin-seawater solution, frozen, or photographed and returned to the laboratory for further identification or vouchering. Photographed voucher specimens were returned to the sea. At least one voucher specimen of each species processed was retained to confirm identifications.

Processing Debris

Debris collected in a trawl was classified into 11 type categories: rocks, terrestrial vegetation, marine vegetation, lumber, plastic, metal debris, cans, glass bottles, fishing gear, tires, and "other" anthropogenic debris. The amount of debris in each category was reported as abundance and weight classes. Abundance classes were Present (1 item), Low (2-10 items), Moderate (11-100 items), and High (>100 items). Weight classes included Trace (<0.1 kg), Low (>0.1-1.0 kg), Moderate (1.1-10.0 kg), and High (>10.0 kg).

Laboratory Methods

Fish and Invertebrate Preservation for Voucher and Archival Collections

Retained fish and invertebrate samples were preserved in the field with a 10% buffered formalin solution and kept in that solution for about a week. They were then transferred to water for 2-3 days (with water replacement during the period) and then transferred to either 50% isopropanol (fish) or 70% ethyl alcohol (invertebrates and fish) for storage. Glass or plastic jars or other containers with specimens included a label of waterproof paper, with collection information (date, location, station, and station depth) and identification information (scientific name of species, length (SL or TL as appropriate) range for fish, and identifier).

Information Management

Field Computer System

A field computer system was designed specifically for the Bight'08 regional survey. The use of the system was optional, but strongly recommended. The system facilitated the collection of all required station occupation and field sampling event information. It stored the data in a database application (MS Access 2000), received direct input from acceptable DGPS, provided data entry templates, employed drop down lists of acceptable values for many fields, produced fully completed hardcopy datasheets, and exported files (MS Excel) suitable for electronic submission to the project information manager. Those agencies not opting to use the system or those that experienced computer problems used standard data forms found in the field operations manual and manually entered the data at a later time.

Data Submittal Process

The submittal process began after data generation and entry into an electronic format. Field or laboratory personnel submitted electronic data to internal agency information managers for review and quality control (QC) checks. The checks included the proper format for standardized data transfer protocol (SDTP). The agencies then submitted the information electronically to a centralized database. The database automatically checked the data for proper SDTP format requirements. Noncompliant data generated error messages and did not load into the database. The errors were reported back to the agencies. Agencies corrected the errors and resubmitted the data. The process repeated until the database accepted the data or only easily correctable errors were present. Final integrated across-agency data tables were provided to the Bight'08 Trawl Report Committee for review, further QC checks, and analysis.

Quality Assurance/Quality Control Procedures

Trawl Assemblage Survey

Field Protocol

Special quality assurance/quality control (QA/QC) procedures were developed for the study (Bight'08 Coastal Ecology Committee 2008b), modeled after the SCBPP QA Plan (1994) and Bight'08 Workplan (Bight'08 Coastal Ecology Committee 2008a). Field equipment and sampling protocols were described in the field operations manual (Bight'08 Coastal Ecology Committee 2008c), which was developed by representatives of the participating organizations. Field crews were required to adhere to the specified standards and protocols for sampling methods, taxonomic identification, and QA/QC audits.

The field methods manual (Bight'08 Coastal Ecology Committee 2008c) addressed the objectives of the Bight'08 regional survey. This manual was distributed to all participating organizations during a protocol meeting with chief scientists and boat captains. Chief scientists were responsible for training all participating field personnel in the prescribed sampling methods for the regional survey.

Pre-survey audits were conducted on any new participating agency and agencies with new personnel to ascertain their field sampling capabilities. The goal was to assess trawl methodologies and taxonomic competence for the regional survey. Pre-survey audits consisted of checking equipment and sampling procedures utilized by each agency to determine consistency among the agencies, and making adjustments as needed prior to conducting the survey. Any discrepancies were corrected prior to the survey start date.

In-survey audits were attempted on all participating vessels in the trawl program. Field QA/QC auditors accompanied field teams to ensure compliance with sampling procedures and data quality. Auditors used checklists for equipment, trawling methods, and sample processing to assess compliance to field manual requirements. All auditors were taxonomic specialists assessing identification techniques for field personnel.

Post-survey field QA/QC involved checking station location data relative to survey design strata. The regional survey used stratified random survey design to select sites from a Geographical Information System (GIS) computer. Site locations were as accurate as the underlying maps on the computer. To verify that the actual sampling sites were still within their proper design strata, post-survey station occupation data was overlaid onto the stratification maps. Other data checks include sampling depth, distance from nominal site, trawl distance, and duration.

Taxonomic Identification

Prior to the survey, lists of recommended taxonomic identification aids and checklists of trawl-caught species for the SCB were distributed to participating agencies. Standard common and scientific names were to conform to Nelson *et al.* (2004) for fishes, SCAMIT (2008) for invertebrates. Three pre-survey information transfer meetings (one as a lecture and two in the field) were held to identify common and confusing species. All organizations were required to participate in a pre-survey intercalibration exercise, which involved identifying preserved species from a bucket (30 fish species and 30 invertebrate species). Organizations that had more than 5% misidentifications were required to repeat the exercise.

During the surveys, taxonomic QA/QC auditors were required to conduct random checks with each participating organization to assess accuracy of fishes and invertebrates identified. They were to ensure that survey teams followed protocols written in the field manual, observe identification procedures, and help correct potential data discrepancies. These included methodologies for vouching specimens for each species, difficult-to-identify species, and species/anomaly combination by each agency.

Post-survey field taxonomy checks were accomplished through a review of submitted voucher specimens by taxonomic specialists. The review process corroborated or corrected misidentifications and applied appropriate changes to the original data sheets and database.

Data Analyses

The data analysis methods are the same as, or similar to, those used in previous regional sampling reports (Allen *et al.* 1998, 2002, 2007). Details of data analytical methods are presented in Appendix A-6. Methods applied included: 1) descriptions of populations such as Shannon-Wiener Diversity (H'), population summary statistics such as means, medians, and standard deviations, and estimates of areal extent of population(s); 2) assemblage analysis including recurrent group analysis based on Fager's Index of Affinity or cluster analysis based on a Bray-Curtis dissimilarity; and 3) biointegrity analysis including the Fish Response Index (FRI), the Megainvertebrate Response Index (MIRI), the Trawl Response Index (TRI) incorporating both fish and invertebrates, and the Fish Feeding Guild (FFG) analysis.

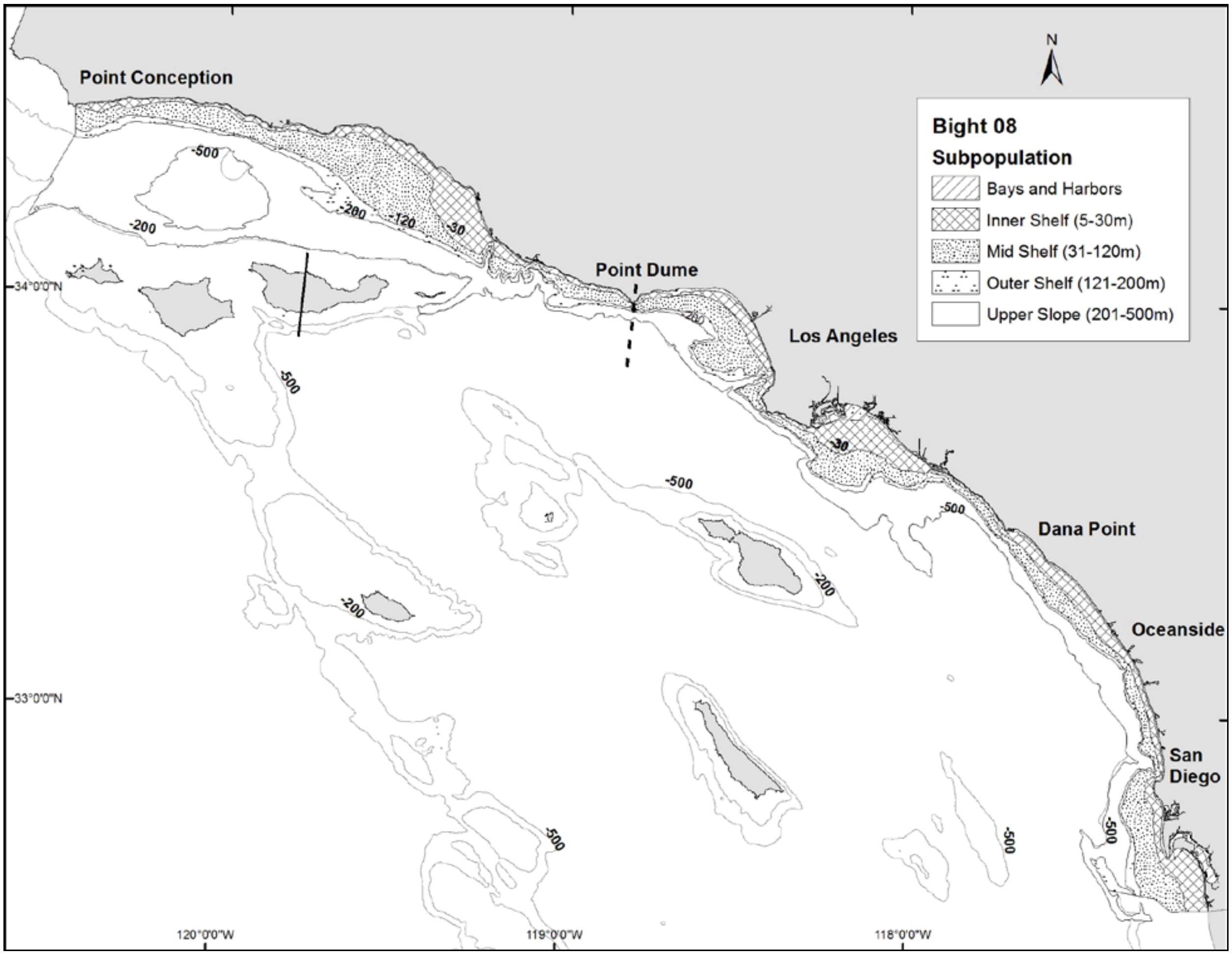

Figure II-1. Distribution of subpopulations sampled by trawl in previous Southern California Bight Regional Surveys.

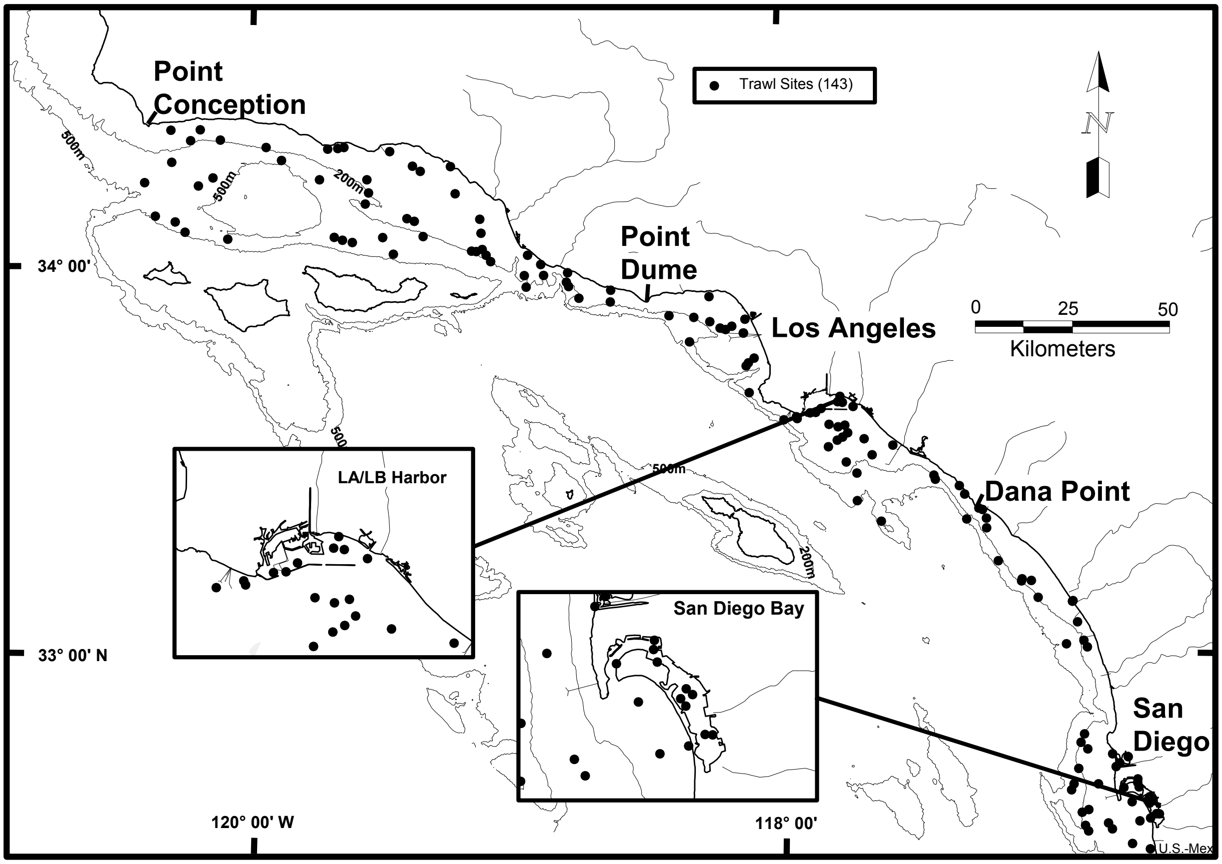

Figure II-2. Population and assemblage study stations sampled by trawl on the southern California shelf at depths of 3 - 485 m in the Southern California Bight 2008 Regional Survey, July-September 2008.

III. QUALITY ASSURANCE

Introduction

Prior to the Southern California Bight 2008 Regional Survey, a Quality Assurance (QA) Plan (Bight'08 Coastal Ecology Committee 2008b) was developed to ensure that data generated were of high quality and comparable among the participating organizations. Certain procedures addressed critical issues regarding data comparability. A common field manual provided standard sampling protocols among the group (Bight'08 Coastal Ecology Committee 2008c). Pre-survey training workshops allowed participants to become familiar with procedures to be used in the survey. Inter-agency taxonomic comparisons familiarized field crews with identification issues encountered in the SCB. In-survey audits and post-survey taxonomic checks assessed compliance and identification uniformity between agencies. The methods used to ensure QA were described in the Materials and Methods Chapter of this report.

The QA and quality control (QC) activities enacted cover a wide range of topics including biological data and information management consolidation. Assemblage data collected in the field required standard equipment, start and end points (time and GPS coordinates), uniform taxonomic identification, and uniform enumeration techniques. Information management consolidated individual agency data into a centralized database by establishing standard data transfer protocols (SDTP), implementing electronic submission procedures, and tracking post-submission error corrections. Many QA/QC protocols can be categorized as logistical activities, but all significantly improve data comparability among the various agencies.

The following section describes results of the QA/QC activities conducted during the study. The results of QC audits on submitted data were compared to criteria established in the Bight'08 Coastal Ecology Workplan (Bight'08 Coastal Ecology Committee 2008a), Quality Assurance Plan (Bight'08 Coastal Ecology Committee 2008b), and Field Operations Manual (Bight'08 Coastal Ecology Committee 2008c). These results were then evaluated relative to the measurement quality objectives (MQOs) described in the QA Plan. In addition, a post-survey performance review was included to facilitate improvement in data quality for future surveys.

Results

Assemblage Studies

Trawl Sampling Success

Trawl samples were collected from 143 (95%) stations selected in the stratified random design from Point Conception, California, to the United States-Mexico international border (Figure III-1). Sampling depths ranged from 3 to 485 m. Seven sites were re-assigned to different strata after the survey due to imperfect bathymetry GIS layers used for pre-survey site selection. Station 7741was changed from mid-shelf (31-120 m) to inner-shelf (2-30 m) subpopulation. Stations 7502, 7507, and 7544 were changed from outer shelf (121-200 m) to mid-shelf (31-120 m) subpopulation. Station 7528, 7678, and 7240 were changed from outer shelf (121-200 m) to upper slope (201-500 m) subpopulation. Ninety percent (90%) of the trawl tracks were completely within their assigned subpopulations. The other 10% of the trawls had a portion of the track within the proper subpopulation.

Trawl success was near 100% for most subpopulations except for outer shelf (77%) and embayment (63%). The embayment deviations resulted from in-survey changes (Table III-1). One agency requested relief (10 sites) from trawling due to resource constraints. Another sampling group dropped seven sites because of conflicts with another sampling program. The result of undersampling outer shelf and embayment subpopulations is a decrease in the confidence of areal extent estimates for these two subpopulations. For example, the 90% confidence interval for outer shelf changed from approximately ± 10% to ± 14% for estimates of areal extent.

Overall, 9% of stations resulted in station occupation failures (Figure III-1). The top six reasons for station occupation failures were improper distance/time, fouled net, rocky bottom, no contact with bottom, torn net, and kelp bed (Table III-1). Seventy-eight percent (78%) of the station occupation failures were from newly selected (i.e., previously unsampled) random sites. Only 8% of the successful stations were re-trawled (11 of 143) more than once, ranging from 2 – 6 attempts, in order to achieve station occupation success.

Trawl Event Criteria

Site Objectives. The QA/QC criterion for accepting a station for assemblage analysis required only that the station be within a subpopulation, but more precise field guidelines were implemented to ensure that sampling was conducted close to the assigned coordinates. The details are found in the Bight'08 Coastal Ecology Committee Field Operations Manual (Bight'08 Coastal Ecology Committee 2008c). The important specifications are as follows: 1) the trawl was to be taken within 100 m of the pre-assigned site, except at the Channel Islands where it was extended to 200 m; 2) the trawl depth was within 10% of the nominal depth; 3) trawls were to be towed for 10 minutes, 5 minutes in bay/harbor areas with distance restrictions, at a constant speed of 0.8-1.0 m/s (1.6-2.0 kts); and 4) trawls exceeding 200 m depth were required to use a pressure-temperature archival sensor to monitor and ensure proper "on bottom" times (8-15 minutes).

Distance from Nominal Site. For the survey, 99% of the trawls were within the proper 100 m radius of the nominal coordinates. One site, station 6325, in Dana Point Harbor was between 100-200 m. None of the biological data was excluded from any analysis because of its distance from the nominal coordinate. Since the implementation of post-survey QC reporting, the regional survey has seen a steady improvement of organizations achieving the 100/200 m radius criteria: in 1998 (69%), 2003 (95%).

Depth Change Criteria. Ninety-eight percent of the trawl tracks were within 10% of the average depth based on start and end depths. The four sites outside the 10% bracket were at depths less than 10 m. Minor changes at these shallow depths were considered insignificant, especially to the general assemblage population. No data were excluded due to depth change criteria.

Trawl Duration. Trawl times were evaluated for both 5- and 10-minute tows (Figure III-2). One hundred percent of the shallow water 5-minute tows were near the expected time. Ten minute tows shallower than 200 m ranged between 8-12 minutes with 86% near the expected time. Trawls over 200 m depth ranged between 6-23 minutes with a poor correlation to depth ($p=0.145$, Spearman Rank Order). See the pressure-sensor section for further investigation. All 5-minute trawls were normalized to a common 10-minute haul standard for data analysis (see Materials and Methods Chapter) comparability. None of the biological data was excluded from analysis because of excessive crew times.

Distance. Boat distances, start to end points, were evaluated for both 5- and 10- minute tows (Figure III-2). Based on the Field Operations Manual, the expected distance should range between 232-309 m for 5-minute and 464-618 m for 10-minute, trawls. None of the biological data was excluded from analysis because of distance.

Five minute tows ranged between 247-357 m with the average and median lengths of 313 m and 309 m, respectively. Forty-eight percent of the 5-minute tows were in the expected distance range. Station 7579 was the shortest, water depth 197 m, and may reflect transcription errors. The other short tows (4 sites) were close to the low expected range.

Ten minute tows (< 200 m depth) ranged between 290-887 m with the average and median lengths of 601 m and 569 m, respectively. Fifty-seven percent of the 10-minute tows were in the expected distance range. Seventeen sites were within 100 m of the upper expected range. The 15 sites (>718 m distance) were scattered among three sampling organizations.

Trawls over 200 m depth were problematic in terms of achieving standardized trawl distance. Tows at this depth ranged between 303-1346 m with the average and median lengths of 731 m and 701 m, respectively. The relationship between time and distance should positively correlate with increasing depth because the net takes longer to get to the bottom and lags on the bottom before coming off. Spearman Rank Order correlations show this positive (0.529, $p<0.010$) relationship. The expectations are that distances should exceed the upper limit of standard 10-minute trawls (618 m). Forty-two percent (14 sites) were below this expectation. No trawl > 200 m was adjusted for time.

Tow Speed. All trawls were evaluated based on recommended trawl speed, 0.8–1.0 m/sec (1.6-2.0 kts). For 5-minute tows, 43% were within range and no site was below the limit. Fifty-four percent of the 10-minute tows were within range and 33 sites were above the speed limit. For trawls deeper than 200m, 36% were within range and 19 sites were above the limit (58%). This general trend in boat speed generally faster, rather than slower, than the recommended speed was seen in previous surveys. Presuming nets are on-bottom, slower boat speeds are more problematic than faster since fish may swim out of the net. None of the biological data was excluded from analysis because of tow speed.

Pressure-Temperature (PT) Sensor. All organizations submitted PT data. No specific PT manufacture was required. Organizations experienced sensor failure (no downloadable data) in 33% of the trawls, ranging from 0 to 82% failures for each agency.

Information learned from PT data submitted from the 2003 survey, suggested that crews had to lengthen trawl times at depths greater than 200 m to compensate for travel time as the net descended to the bottom and lagged on initial retrieval. For instance, at a 500 m depth station, trawl times should approach 20 minutes to get an equivalent 10 minute on-bottom time for the net (Table III-6). The data also suggested that vessels have unique characteristics (i.e., winch speed, wire diameter, captains towing procedure) which must be monitored and adjusted to achieve near 10 minute net-on-bottom times while compensating for environmental factors (i.e., wind, swell, currents).

As shown in the 2008 PT data, 58% of the trawls were within the QA goals set prior to the start of the survey (Figure III-3). One organization with extremely long tow lengths were close to meeting the goal of 8-15 minute on-bottom net time. Eighteen percent of the data had bottom times greater than 20 minutes. Some short tow lengths were associated with long on-bottom times. Long bottom times were associated with 6-10 minute tows as reported by the crew (Figure III-4). Vessel or crew differences appear to cluster together (Figure III-3).

Field Audits

All but one organization were audited by Bight'08 designated taxonomists. The audited agencies used similar equipment and trawled the same way. Comparable community assessment data was collected by sorting, identifying, enumerating, and weighing organisms similarly among agencies. Species were identified correctly in the field, or appropriately returned for laboratory identification as FIDs (Further

Identifications). Each organization retained one specimen of each field-identified species as a voucher to substantiate identifications. All observed anomalies were noted correctly. The non-audited group participated in the previous 2003 regional survey, but new field personnel were present during the current survey.

Species Identification

Taxonomy QA/ QC was performed on two levels: pre-survey preparedness and post-survey voucher checks. Bucket practicum's (fish and invertebrates) were taken by most groups to verify taxonomic abilities. During a final post-survey voucher check, errors were corrected and database names were modified to reflect submitted specimens.

Pre-Survey Taxonomic Verification. Of the seven organizations participating in the bucket practicum, 43% achieved the Measurement Quality Objective (MQO) of ≥ 95% correct identifications for combined fish and invertebrates. The results were surprising since all groups had participated in the 2003 survey and passed the bucket test. Organizations had a higher number of further identifications (FIDs) with invertebrates as compared to fish (Table III-2). The goal of the test was to use common fish and invertebrate species expected in the survey. While number of species needing FID did not directly lower an agency's MQO, the effect was to lower the total number of identified organisms (<30) when calculating percentages. One agency did not participate in the invertebrate bucket pre-survey taxonomic verification and two agencies did not participate in either the invertebrate or fish bucket pre-survey taxonomic verification. These organizations did not participate due to logistical conflicts prior to the survey.

Post-Survey Voucher Checks - *Fishes*. Organizations listed 477 fish vouchers for validation of survey data submitted to the database. A taxonomic expert (M.J. Allen) reviewed the specimens and found 434 valid species. Twenty changes to the database, ranging from single entry to agency wide, were requested to match submitted vouchers. Data changes took the form of additional species, counts, and incorrect names. The details of errors are listed in Appendix C-1. Three organizations were above the targeted 5% error rate and 67% of all groups combined were in compliance with the accuracy MQO (Table III-3). Data corrections were a collaborative effort between the taxonomic expert, agency taxonomists, and data managers to produce consistent and comparable information across all organizations submitting data.

Voucher checks provide a feed-back mechanism to fish taxonomists for improvement. Vouchering compliance with the field manual was 99%, ranging from 100% to 96%. Overall, the fish identification error rate was 5.2 % for the Bight'08 trawl survey. Specimen preservation needed to improve. Some organizations did not use enough preservative or left them in the preservative too long hindering post-survey voucher checks due to specimen quality. Internal organizational voucher QC checks matching animals with labels also needed improvement. For example, clerical errors resulted in specimen mis-labeling and/or mis-identification. As a result, additional time was necessary to resolve clerical errors.

Post-Survey Voucher Checks - *Invertebrates*. Organizations listed 594 invertebrate vouchers for validation of survey data submitted to the database. Taxonomic experts (Don Cadien, Ron Velarde, John Ljubenkov, Megan Lilly, Lisa Haney, Tim Stebbins, and Steve LePage) reviewed the specimens and found 561 valid species. Eighty-two changes to the database, ranging from single entry to agency wide, were requested to match submitted vouchers. Data changes included additions or deletions of species, counts, and incorrect names. The details of the types of errors are listed in Appendix C-2. Five organizations were above the targeted 5% error rate and as a whole, 44% of the groups were in compliance with the surveys' planned accuracy MQO (Table III-4). Data corrections were a collaborative effort between the taxonomic expert, agency taxonomists, and data managers to produce consistent and comparable information across all organizations submitting data.

Voucher checks provide a feed-back mechanism to invertebrate taxonomists for future improvements during surveys. Vouchering compliance with the field manual was 98.8%, ranging from 100% to 94.9%. Overall, the invertebrate identification error was 6.4 % for the Bight'08 trawl survey. Voucher labeling was poor and in need of improvement. Taxonomists need to provide clear and complete labels listing organization, station, collection date, collection depth, status (voucher or FID), provisional identification, and specimen count. As a whole, organizations improved on voucher selection, preparation, number of animals submitted per lot (jar), and lowest taxa identification. In most cases, animals were appropriately identified as FIDs and further expertise was warranted. Organizational taxonomists should review the resulting, detailed, voucher breakdown provided by one of the QC taxonomists (Appendix C-3).

Success at Meeting Measurement Quality Objectives

Overall, most MQOs were met and comparable data was produced (Table III-5). The identification error, accuracy and precision, were determined by taxonomic experts. The analytical database reflects near zero percent identification error because corrective actions were taken to rename misidentified species based on voucher collections. Internal organizational audits to estimate precision of counting, length, and biomass were sparse and needs to be addressed in future surveys. Of data submitted, counting errors were ±1 occurring in 14% of the species. Centimeter size class categories had average measurement errors of 4% in 57% of the species audited, but no corrective actions were applied since most errors were typically ±1cm due to rounding interpretations (nearest versus greatest centimeter). Organizations were aware of the QC requirement. For example, one group re-trawled a station because of poor length accuracy. The use of standard methods and post-survey performance analysis has helped to identify QC areas that need improvement in future surveys. The trawl committee concluded that the data produced during the regional survey was comparable among organizations.

Discussion

Overall, the Bight'08 trawl survey was a successful at quantifying QA and identifying QC issues. While some data were corrected or flagged, no data were eliminated or truncated due to QA deviations. This level of QA is comparable to previous Bight surveys.

The largest QA deviation was in sampling success. Two subpopulations did not meet targeted sample size requirements. For example, the number of successfully trawled stations in the bays/harbor subpopulation was 37% (19/30 sites) below targeted. This was due to a combination of reasons; 1) a resource conflict experienced by one of the organizations that could not be absorbed by the other participants; and 2) inappropriate site selection of redraw sites. While the inappropriate site selection can be addressed through training in future surveys, resource conflicts are more problematic. In this case, deviations in sampling success led to reduced confidence in areal estimates, but the reduced confidence was not so extreme as to invalidate the overall conclusions. In the case of the outer shelf subpopulation (121-200 m), which successfully trawled 23% fewer than expected sites, the deviation was a result of inaccurate base maps for site selection. Inaccurate bathymetry can only be resolved through additional contingency effort until new, more accurate, bathymetry maps can be ascertained. As a corrective action, these data were not discarded, but simply reassigned to the correct subpopulation associated with the sites actual depth.

The field manual QA/QC procedures continue to provide good data quality to the Bight'08 regional monitoring survey. The bucket practicum provides some proof that an organization's taxonomic ability is comparable to other participating agencies. The higher than expected misidentification during the bucket practicum may reflect staff changes between regional surveys for many organizations. The practice of vouchering species has also shown that taxonomic standards are comparable across all organizations. Vouchering serves as the last QC point to validate names entered into the survey's database. Field audits demonstrated that the field crews were following proper procedures. All organizations should guard against complacency by developing better internal QA/QC procedures. For instance, one organization that was not audited had high voucher errors and their net on-bottom times were too long. As shown in the QC analysis, there needs to be an improvement on maintaining trawl speeds throughout the process and using the pressure-temperature sensor to adjust on-bottom times. As a corrective action, the Trawl Working Group has developed new trawl monitoring tools such as those described in Appendix C-4.

The second attempt to sample the upper slope habitat (201-500 m) has shown some shortcomings with current trawling procedures. The trawl committee recommends clarifying which time gets recorded (crew time vs. PT sensor time) by adding new fields to the datasheet. Field crews should make several attempts at a station to adjust deck times for 8-15 minute on-bottom times. Better communication between field crews and the captain may prevent excessive bottom times in the future. The pressure-temperature sensor has been an excellent tool for field crews to immediately evaluate trawl performance. The sensor data submittal procedure provided the opportunity to cross-check field data and identify areas for improvement. Deep water trawling was difficult (65% did not meet the QC objective) and could incur extended ship/personnel expenses (Figure III-5) to achieve the objective. Asa corrective action, Table III-6 (see Appendix C-4 for details) is one tool developed to help participating organizations achieve 8-15 minute on-bottom times on the first attempt.

Changes to the survey trawling method are recommended based on the pressure-temperature sensor data. The trawling methodology should move away from a standard ship-based 10 minute tow to a variable time based on the on-bottom performance of the net (Table III-6) within a limited time bracket. This will standardize trawls to an acceptable level and reduce the inherent variability of the method. For organizations without PT sensors, the historical ship-based method works relatively well for depths up to 200 m though some organizations should review their internal QA/QC procedures (Figure III-6). The trawl committee recommends that organizations obtain reliable PT sensors and use them as a QC check. Each vessel has unique (i.e., engines, winch speed, wire, hydraulics) characteristics. Every station has unique environmental factors (i.e., wind, swell, currents). Crews need to make adjustments using a pressure sensor and re-trawl a station when necessary.

An approach detailed in Appendix F provides an alternative method, typically used in fisheries assessments, that standardizes to the area swept (net tow length x width of actively fishing net mouth x net capture efficiency). Utilizing densities has appealing qualities for minimizing field re-sampling effort and standardizing analytical units. However, underlying assumptions such as capture efficiency still need to be tested because theres is a paucity of supporting data on 25 ft net fishing characteristics. Most available fisheries data are based on larger, commercial nets with different characteristics and comparability to the survey's smaller nets remains a data gap.

The trawl committee should revisit the protocols on length measurements so that standardization of units (i.e., millimeter versus centimeter) for size class is achieved. Currently, errors in size class are in ±1 cm bins, but simply changing units may reduce the error to ±3 mm. Computers can easily tally millimeter measurements into centimeter size classes. It may mean crews will have to spend some extra time to measure large numbers of individual species. Length measurements provide size and age class cohort information on animals living at the site.

Taxonomic feed-back continues to provide training for all taxonomists participating in the regional survey QA/QC program. The process provides a good mechanism for standardization across organizations. While the overall identification error rate of 5 to 6% for fish and invertebrates seems reasonable low, the process has corrected organizational mis-identifications as high a 19%. This does not take into account the 3% and 12% FIDs for fish and invertebrates, respectively, needing expert identification. Missing and lost species were discussed among core taxonomists regarding validity and appropriate name for inclusion/removal from the database. Discussions about misidentification that affect single or multiple stations helped all organizations participating in the process. Post-survey workshops provided additional training and addressed large scale identification errors. The QA/QC process takes time and incurs cost, but this approach to corrective actions ultimately improves overall data quality on a continuing basis.

Fish Taxonomy feed-back:

1) Fish voucher compliance was good (99%), but some species were lost or missing.
2) The survey's fish identification accuracy (95%) goal was met by six of nine organizations; the others should strive to improve.
3) Identification precision error was 9% for all organizations. Precision targets common errors (i.e., spelling, old taxonomic names, etc). Taxonomists should challenge themselves to improve and develop internal QA/QC procedures.
4) Submitted FID samples declined 3% from the previous survey to 3% for Bight'08.
5) Organizational taxonomists need to continue improving their internal processing procedures, develop cross-check protocols, and identification of FID species (e.g., some specimens were poorly preserved, mislabeled voucher specimens, difficult taxonomic groups were rockfish, eelpouts, and pipefish).

Invertebrate Taxonomy feed-back:

1) Invertebrate voucher compliance was good, though some species were lost or missing.
2) The survey's identification accuracy (95%) goal was met by four organizations; the others should strive to improve.
3) Identification precision error was 7%. Taxonomists have reduced the average error by 3% and narrowed the range from 16% to 9% based upon the previous 2003 survey.
4) Submitted FID samples declined by 57% from the previous survey to 69 specimens.
5) Lot splitting (jars that require splitting into more than on species) declined 92% from the previous survey.
6) The number of improperly included taxa, correct but incomplete FIDs, and incorrect FIDs has declined from the previous two surveys.
7) A modest increase in the application of inappropriate nomenclature to FIDs and no identification attempt prior to FID submission was noticed.
8) Organizational taxonomists need to continue improving their internal processing and identification of FID species.

Quality Assurance/Quality Control Conclusions

- Trawls were conducted at 95% of the randomly selected stations from Point Conception to the United States-Mexico border.
- Two sub-populations (bay/harbor and outer shelf) in the survey design were under-sampled causing a 4% increase in the confidence interval around an estimate of areal extent.
- 99% of the trawl path passed within 100 m of their assigned coordinates.
- 98% of the trawl tracks were within 10% of the average depth.

- Crew trawl times were acceptable for five and ten minute tows in water less than or equal to 200 m. At greater depths, time did not meet expectations.
- The travel distances, start to end of trawl, were acceptable for many tows except those which were greater than 200 m deep. Of the 10 minute tows in water 200 m deep or less, 17% were 100m longer than expected.
- Boats generally trawled faster than the recommended speed at roughly half the sites.
- Sampling organizations continue to experienced pressure-temperature sensor equipment failure at many stations.
- From the available sensor data, field crews need to improve their trawl performance to optimize on-bottom net times to a recommended QA/QC range of 8-15 minutes.
- All field audited organizations showed compliance with the field manual.
- All organizations participating in the pre-survey taxonomic verification exercise showed acceptable accuracy in identifying fish and invertebrates.
- The post-survey QC voucher check process found errors, identified FIDs, and corrected the database mistakes to create a high quality taxonomic database comparable across organizations.

Improving Quality Assurance/Quality Control in Future Multi-Agency Surveys

Pre-survey

- Develop rules/protocols to retain survey design sub-populations sites near margins of GIS layers.
- Develop rules/protocols for substitute stations during resource conflicts with other surveys.
- Continue the current QA procedures implemented during the Bight'08 regional trawl survey.
- Improve application of the bucket practicum to ensure all agencies participate.
- Improve Field Manual (more detail) and pre-survey protocol meeting (training) on QA/QC.
- Continue training/taxonomic workshops to improve the skills of taxonomists including the Southern California Association of Ichthyological Taxonomists and Ecologists (SCAITE).
- Retain the identification precision MQO of 95% to focus attention on improvement.
- Revisit and refine failure codes regarding obstruction, rocky bottom, etc.
- Revisit centimeter versus millimeter size classing to improve organizational errors.
- Obtain reliable PT sensors for data submission.
- Add nominal station depth to the station occupation form to properly evaluate depth QA criteria.
- Add two data fields to the event datasheet to record PT sensor data (net on-bottom time, temperature).

In-survey

- Continue the field audit program using taxonomic QA experts in fish or invertebrates.
- Develop PT protocols to target 8-15 minute on-bottom net times
- Organizations with high PT failures should review their internal procedures to increase valid submissions, carry spare sensors, or switch manufacturers.
- Captains may have to change their retrieval procedures to mitigate excessive on-bottom times.
- Develop internal organization audit sheets for counts, measurement lengths, and weights.

Post-survey

- Develop protocols to integrate GPS data and crew event times from the field computer system with PT data files so that synchronizing and categorizing becomes relatively easy and straight forward.
- Utilize post-survey data normalization to area swept as a means to standardize organism density

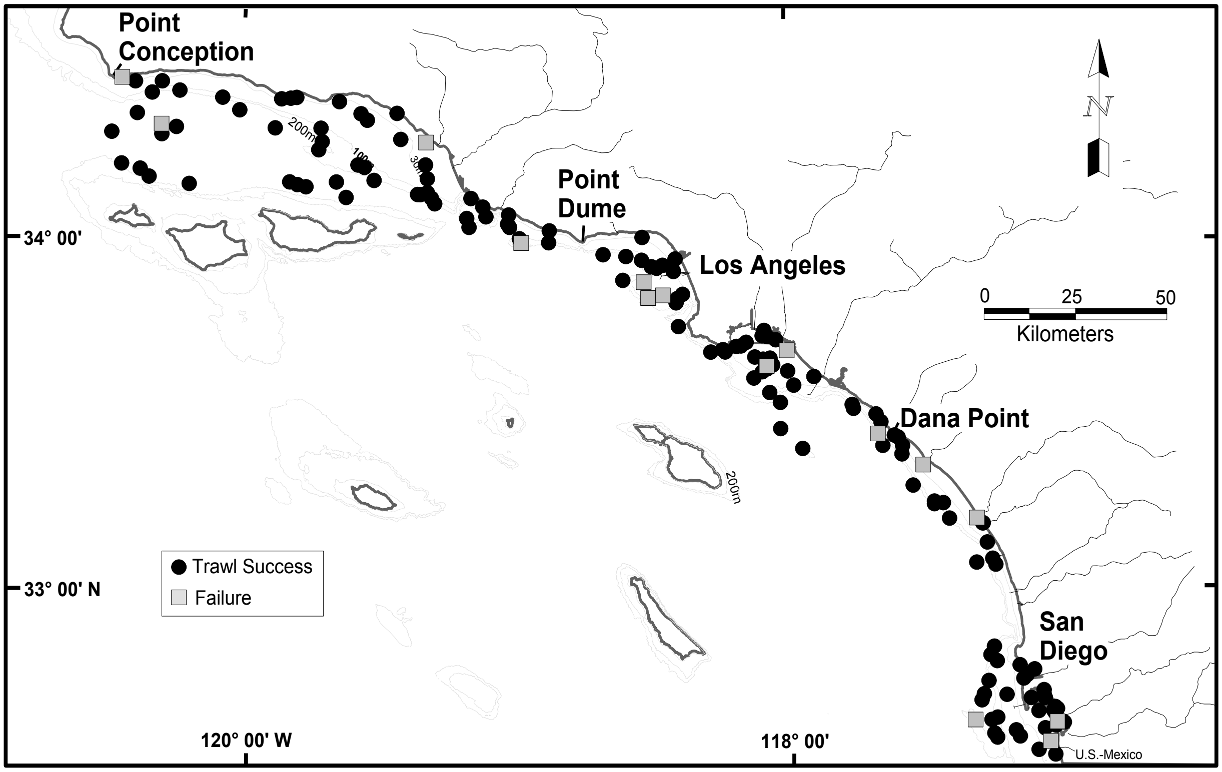

Figure III-1. Successful and unsuccessful assemblage event sample sites.

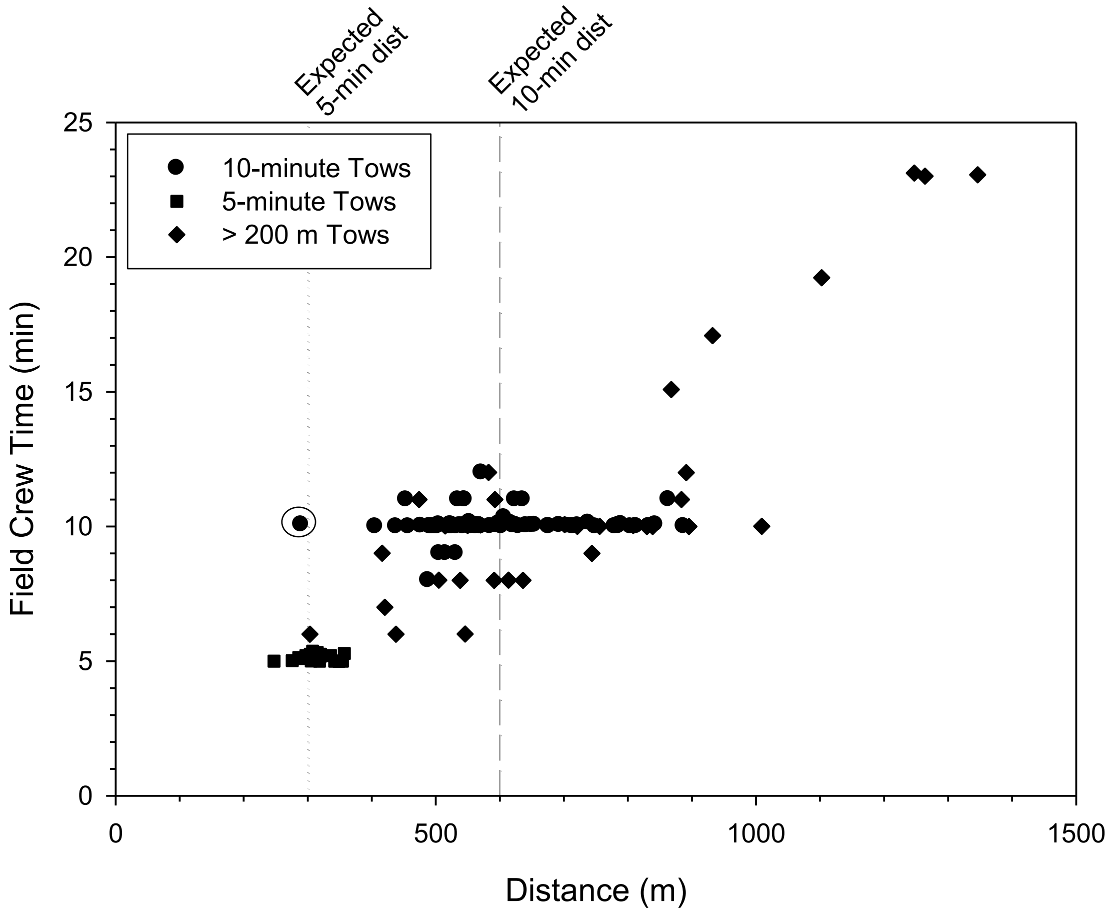

Figure III-2. Trawl distance versus boat time results for community data collected during the Bight'08 regional survey. The outlier was circled to illustrate potential transcription errors resulting in improper distance (circle).

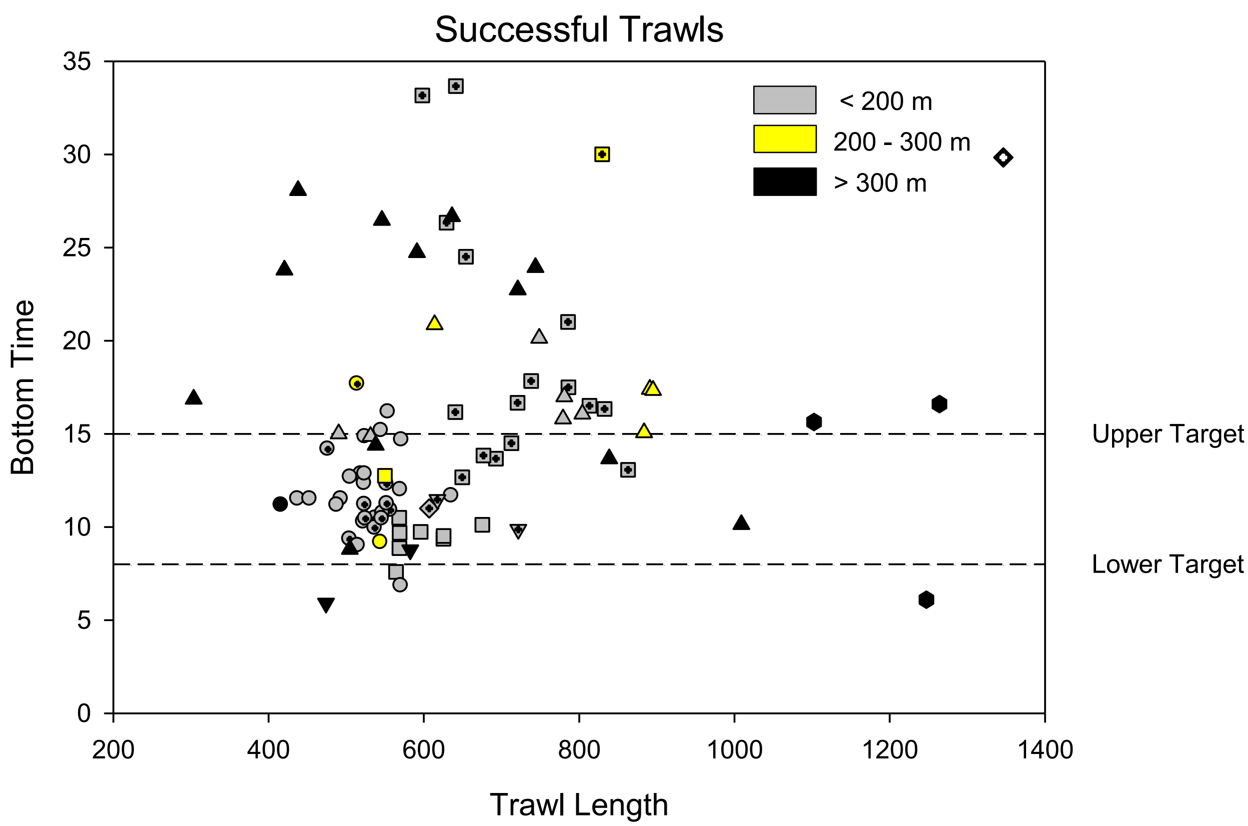

Figure III-3. Tow distance versus net on-bottom time (pressure-temperature sensor) for successful trawls during the Bight'08 regional survey. Colors represent depth. Symbols represent vessels and field crews. The upper and lower bounds were the quality assurance goals prior to the survey. Five-minute tows omitted from graph.

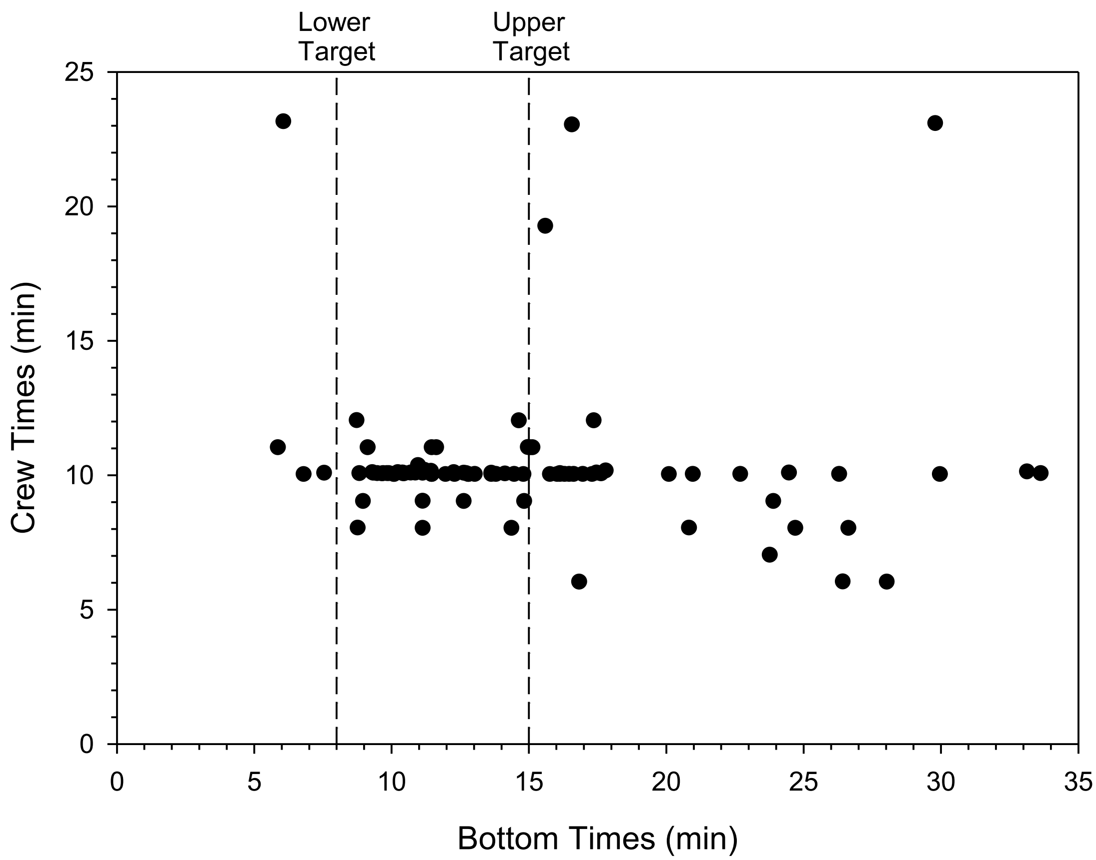

Figure III-4. Bottom time (pressure-temperature sensor) versus reported crew times during the Bight'08 regional survey. The upper and lower bounds were the quality assurance goals prior to the survey. Five-minute tows omitted from graph.

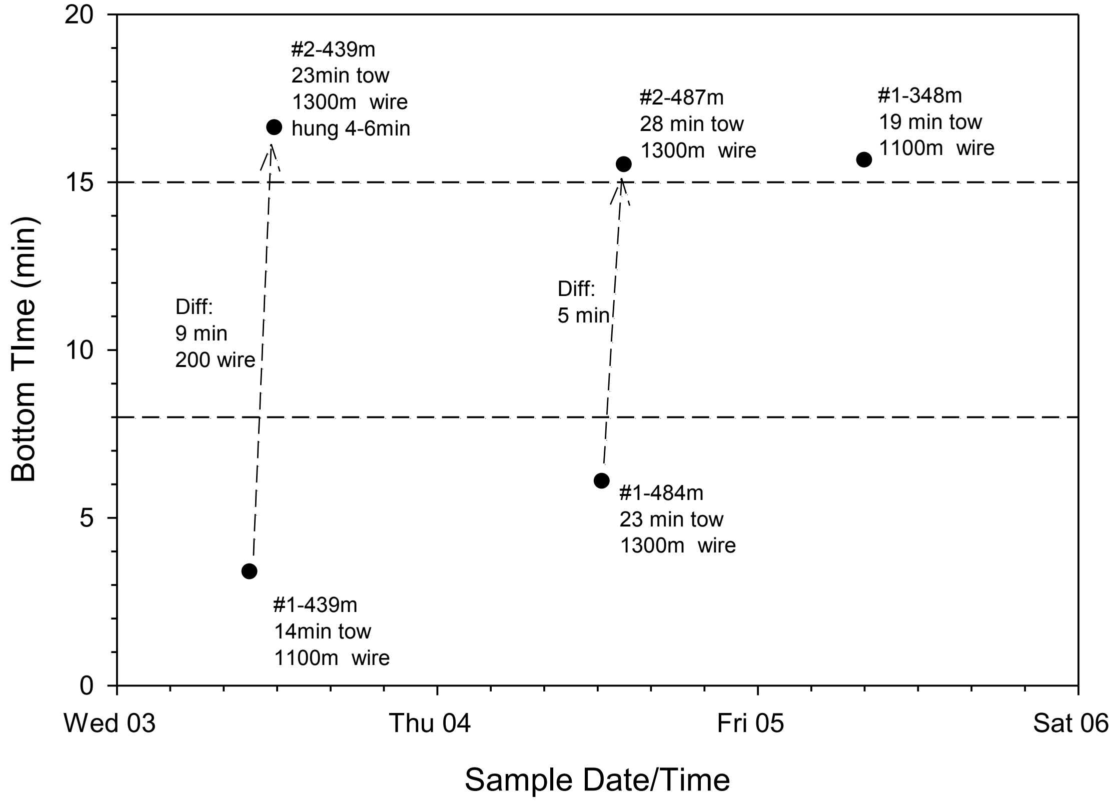

Figure III-5. Example of one organization's adjustments in wire out and trawl time at three consecutive deep water trawl sites using a pressure-temperature (PT) sensor. The vessel used 6.35 mm (1/4 inch) wire diameter. The "#1" and "#2" indicate the first and second attempt at a single station. The word "hung" means that upon net retrieval, the trawl doors snagged on a wall of a gully-like feature for several minutes (pulling the boat backwards) before breaking loose. The PT sensor was used as a learning tool to make tow adjustments on subsequent trawls in an attempt to achieve an 8- to 15-minute on-bottom time. The figure illustrates that the crew improved from #1 to #2 trawls until only a single trawl was necessary.

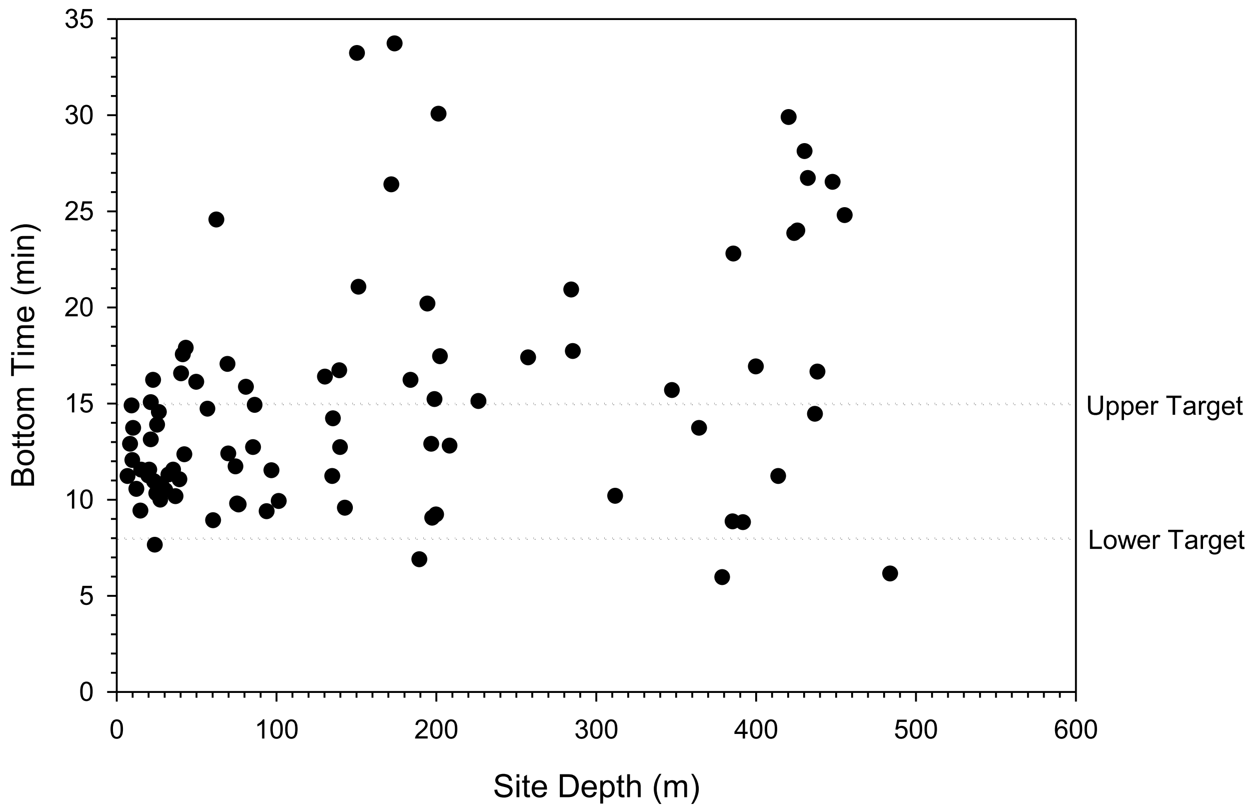

Figure III-6. Average station depth versus net on-bottom time (pressure-temperature sensor) for successful trawls during the Bight'08 regional survey. The upper and lower bounds were the quality control target times. Five-minute tows omitted from graph.

Table III-1. Trawl sample size design compared to actual survey results by subpopulation, plus failure reasons. Three successful marina sites were excluded due to inappropriate substitution.

Area	Strata	Expected	Success	Fail
Offshore	Inner shelf (5-30m)	30	32	7
Offshore	Mid-shelf (30-120m)	30	33	3
Offshore	Outer shelf (120-200m)	30	23	3
Offshore	Upper slope (200-500m)	30	33	1
Embayment	Bays/Harbors	30	19	1
Total		150	140	15

Reasons for Failure	Number
Kelp Bed	3
Obstructions	3
Rocky Bottom	3
Torn Net	2
Irregular Bottom	1
Exclusion Zone	1
< 6 m	1
Improper Distance/Time	1

Table III-2. Bight'08 bucket intercalibration results for trawl fish and invertebrate identification. Results are from the primary practicum.

	Num. In	Number of FIDs		Number Wrong		Percent Correct IDs	
Org.	Buckets	Fish	Invert.	Fish	Invert.	Fish	Invert.
1	30	1	ND	0	ND	100	ND
2	30	0	0	0	6	100	80
3	30	0	2	2	2	93	93
4	30	0	5	0	1	100	96
5	30	0	7	1	0	97	100
6	30	0	7	3	5	90	78
7	ND	ND	ND	ND	ND	ND	ND
8	ND	ND	ND	ND	ND	ND	ND
9	30	0	11	1	8	97	58

Measurement Quality Objective (MQO) was 95% correct. Org = organization; Num = number;
FID = further identification required; Invert = invertebrates; ID = identification; ND = could not be determined.

Table III-3. Summary of fish voucher validation for the Bight'08 regional trawl survey. The details can be found in Appendix C-2. FID means specimen need further expert identification. Measurement quality objective (MQO) was accuracy in species identification.

	Participating Organization									
	1	2	3	4	5	6	7	8	9	All
Voucher Summary										
Total submitted as vouchers/FID/lost	43	54	60	45	69	51	57	45	53	477
Total valid vouchers	42	47	57	44	67	40	47	45	45	434
Total data changes	4	1	4	3?	2	0	11	4	4	30
% error in voucher ID accuracy	9	2	5	0	3	0	15	4	6	5
Compliance with Accuracy MQO	N	Y	Y	Y	Y	Y	N	Y	N	67%

Table III-4. Summary of invertebrate voucher validation for the Bight'08 regional trawl survey. The details can be found in Appendix C-3. FID means specimen need further expert identification. Measurement quality objective (MQO) was accuracy in species identification.

	Participating Organization									
	1	2	3	4	5	6	7	8	9	All
Total submitted as vouchers/FID/lost	32	61	58	48	96	53	55	31	36	470
Total valid vouchers	33	72	83	48	98	69	73	46	39	561
Total data changes	5	11	7	4	23	14	8	2	8	82
% error in voucher ID accuracy	9	8	1	4	13	12	7	0	3	6
Compliance with Accuracy MQO	N	N	Y	Y	N	N	N	Y	Y	44%

Table III-5. Measurement quality objectives targeted during pre-survey quality assurance goals against post-survey information submitted by participating organizations during the Bight'08 regional trawl survey.

	Target			Actual		
MQO Category	Acc.	Prec.	Comp.	Acc.	Prec.	Comp.
Sample collection	NA	NA	90%	-	-	95%
Counting	NA	10%	90%	1.1%	14%	99%
Identification	5%	NA	90%	5.8%	8%	99%
Length	NA	10%	90%	4.3%	57%	100%
Biomass	NA	10%	90%	-	ND	99%
Gross Pathology	5%	NA	90%	ND	-	ND

Acc. = Accuracy; Prec. = Precision; Comp. = Completeness

ND = no data; field auditors communication and vouchers show compliance.

Table III-6. Suggested guide for boat/deck times toward achieving a 10 minute on-bottom net time. Negative values mean the net was on the bottom for a certain amount of minutes. Calculations were based on N = 99.

Station Depth (m)	Depth/Wire Scope[1]	Wire (m)	Winch[2] Time (min)	Wire[3] Depth (m)	Minutes To Bot Lag[4]	Minutes Off Bot Lag[5]	10 Min Trwl Est Deck Time (min)
50	5.0	252	6.12	50.7	-0.05	2.20	7.75
100	4.1	410	9.97	82.5	1.33	2.91	8.42
150	3.6	545	13.25	109.6	3.06	3.62	9.44
200	3.3	668	16.22	134.2	4.99	4.33	10.67
250	3.1	781	18.97	157.0	7.06	5.04	12.02
300	3.0	888	21.56	178.4	9.23	5.75	13.48
350	2.8	989	24.03	198.8	11.47	6.46	15.02
400	2.7	1,086	26.39	218.4	13.78	7.17	16.62
450	2.6	1,180	28.67	237.2	16.15	7.87	18.27
500	2.5	1,271	30.87	255.5	18.56	8.58	19.97

[1] Power function was 16.139219 * (Station Depth $^{-0.297449384}$) based on method protocol.

[2] Average agency winch rate was 41.16 m/min.

[3] Average descent rate was 8.3 m/min. Average lag on bottom decent rate changed +1.6 times.

[4] Used: (Station Depth – Wire Depth) / (Avg Descent Rate * Avg Change Rate Factor).

[5] Used: regression formula: 1.4903252151 + (0.0141874591*Station Depth)) based on Lag Off vs. Depth data.

IV. DEMERSAL FISH POPULATIONS

Introduction

Demersal fishes (i.e., fishes living on or near the sea floor) occupy the soft-bottom habitat, the most widespread benthic habitat on the southern California shelf (Emory 1960; Allen 1982, 2006a). The soft-bottom habitat has been the focus of historic trawl studies because it can be easily sampled by trawl and it is also where most wastewater and industrial outfalls are placed (Allen 2006a,b). Demersal fishes are relatively sedentary compared to pelagic species. Hence, they respond more readily to changes in the benthic environment and provide the best fish data for assessing the areal distribution of discharge effects on the southern California mainland shelf (Allen *et al.* 1998, 2002; Allen 2006b). However, assessment of these effects should also include alternative forces that may also affect the areal distribution of these species, such as overfishing by humans (E. Miller, MBC, personal communication), and shifts in oceanic conditions or oceanic regimes in the Southern California Bight (Allen *et al.* 2004, 2008).

Local demersal fish populations have been studied extensively for more than 45 years (e.g., Carlisle 1969b; SCCWRP 1973; Allen 1982; CSDLAC 1990; CLAEMD 1994a, b; CSDMWWD 1995; Stull 1995; CSDOC 1996; Stull and Tang 1996; Allen 2006a, b), but little was known about their spatial and temporal variability throughout the SCB (Southern California Bight). Past regional studies compiled trawl data from various times and places (SCCWRP 1973; Mearns *et al.* 1976; Allen and Voglin 1976; Allen 1977, 1982) or collected data in reference surveys of limited scope (Allen and Mearns 1977; Word *et al.* 1977; Love *et al.* 1986; Thompson *et al.* 1987, 1993b). The first synoptic regional survey of this fauna in southern California was conducted in 1994 (Allen *et al.* 1998). This study provided substantial background information on the fauna of the southern California mainland shelf (10-200 m depth) but did not assess fish populations in bays and harbors, the island shelf of islands located offshore in the SCB, or the upper slope (200-500 m depth) on the mainland and islands. A second regional survey conducted in 1998 (Allen *et al.* 2002) provided additional region-wide background information on the status and health of fish populations, as well as assessing fish populations on the mainland and island shelf and in bays and harbors. The 2003 survey (Allen *et al.* 2007) was conducted during the summer and fall of 2003. It surveyed bays and harbors as well as the shelf and the upper slope (201-500 m) on the mainland and previously surveyed islands (excluding Santa Catalina Island).

The objectives of this chapter are: 1) to describe the distribution, relative importance (areal coverage, abundance, and biomass), and health of the dominant fish species of the southern California mainland shelf (including bathymetric shelf zones (i.e., bays and harbors, inner shelf, middle shelf, outer shelf, and upper slope) and predetermined geographic regions (i.e., northern, central, and southern) in 2008; 2) to assess temporal changes in populations since 1998; and 3) to examine historical trends relative to earlier studies. This information will provide a context for understanding local population patterns in routine monitoring studies that assess human impact. Other aspects of this fauna are presented in the Assemblages and Biointegrity chapter of this report (Chapter 6).

Results

Population Attributes

Abundance per Haul

A total of 28,374 fish were collected during the survey (Table IV-1; Figure IV-1). The number of fish collected per haul ranged from 0 to 1,005. The lowest individual values (0) occurred on the inner shelf of the Southern region and the upper shelf of the Northern region. The highest number of fish per trawl (1,005) was collected on the middle shelf in the Central region. The median for the SCB as a whole was 132 individuals per haul, with subpopulation medians ranging from 53 (Bays and Harbors of the Southern region) to 329 (outer shelf of the Central region). Relative fish abundance was highest in the outer shelf of the Central and Southern regions (average 100% above the SCB median) and lowest (0% above the SCB median) in bays and harbors of the Southern region. Among the regional subpopulations, the Southern and Central regions had a higher median fish abundance (199 and 155 fish per haul, respectively) than did the Northern region, with a median number of fish per haul of 89. Comparison of the different shelf zones showed that the middle shelf and outer shelf zones had the highest median fish abundance (268 and 255, respectively), whereas the bays and harbors, upper slope, and inner shelf had lower median fish abundances (89, 86, and 71, respectively).

Within the upper slope zone, the median fish abundance from both the Central and Southern regions were higher (155 and 111, respectively) than the Northern region (71; Table IV-1). Within the outer shelf zone, median fish abundance was highest (329) in the Central region, followed by the Southern region (245) and Northern region (241). Within the middle shelf zone, median fish abundance was highest (291) in the Northern region, followed by the Southern region (257) and Central region (202). Within the inner shelf zone, median fish abundance was highest in the Northern region, followed by the Central, and Southern regions (70, 67, and 55, respectively). Within bays and harbors, median fish abundance was highest (279) in the Central region and lowest (53) in the Southern region. Comparing all regions within shelf zones revealed that the highest median fish abundance (329) was found in the Central region of the outer shelf, whereas the lowest median fish abundance (53) was in bays and harbors of the Southern region. Trawl stations were divided into four abundance groups (based upon the 10th, median, and 90th percentiles; Figure IV-1). Stations within the upper decile group of fish abundance (438 to 1,005 individuals per haul) were primarily located on the middle and outer shelf.

Biomass per Haul

A total of 1,073.8 kg of fish were taken during the survey (Table IV-2). The biomass of fish per haul ranged from 0 kg to 61.7 kg. Values of 0 kg occurred in the Northern and Southern regions. In the Southern region 0 kg catches occurred on the inner shelf and in the Northern region, 0 kg catches occurred on the upper slope. A value of 61.7 kg occurred on the outer shelf of the Northern region. The median biomass/haul for the SCB as a whole was 5.3 kg, with subpopulation medians ranging from 1.2 (inner shelf of Northern region) to 11.5 (upper slope of Central region). Among mainland regions of the SCB sampled, fish biomass was higher (% area above the Bight median) for the Southern region (59.7), than for the Central region (48.7) or Northern region (41.9). Within major shelf zones, the Outer Shelf had a higher median fish biomass (84.8), followed by Bays and Harbors (63.1), Upper Slope (60.9), Middle Shelf (39.2), and Inner Shelf (8.1).

Comparing regions within the shelf zones revealed that the highest median biomass (11.5 kg) was found in the Central region on the upper slope (Table IV-2). Trawl stations were divided into four biomass groups (Figure IV-2). Stations within the highest biomass group (15.8 to 61.74) were primarily located on middle shelf and upper slope.

Species Richness (Number of Species per Haul)

A total of 135 species of fish were taken during the 2008 regional trawl survey of the Southern California Bight (Table IV-3). The number of fish species collected per haul ranged from 0 to 22. The lowest value (0) occurred on the inner shelf of the Southern region and the upper slope of the Northern region. The highest value (22) occurred on the inner shelf of the Northern region and on the middle shelf of the Southern region. The median value for the SCB as a whole was 11 species per haul, with subpopulation medians ranging from 6 (inner shelf of Central region) to 17 (middle shelf of the Northern region). More of the area with species richness above the Bight median (11) occurred in the middle shelf of Northern and Southern regions, and outer shelf of the Northern and Southern regions (Figure IV-3). Among the mainland region subpopulations examined (Table IV-3), all (Northern, Central, Southern) had median numbers of species per haul of 11, the same as the Bight median. Of region/shelf zone populations, the middle shelf as a whole, and the Northern, Central, and Southern regions of the middle shelf had medians (14, 17, 11, and 15, respectively) equal to or greater than the Bight median of 11 species. Similarly, the outer shelf as a whole, and the Northern, Central, and Northern, Central, and Southern regions of the outer shelf had medians (15, 16, 11, and 15, respectively) greater or equal to the Bight median. The Central region of the upper slope had a median species richness (11), equal to that of the Bight. Of the five major shelf zones, the middle shelf of the Northern region had the highest median species richness (17). The Northern region had the highest species richness, especially in the inner shelf. In all the other regions, the middle shelf had the greatest richness.

Species Diversity per Haul

Fish diversity ranged from 0 to 2.37 bits/individual/haul (Table IV-4). The lowest value (0.0) occurred in Bays and Harbors and on the Inner Shelf of the Southern region. This lack of diversity was not found on the Middle Shelf or Outer Shelf. However, the lowest fish diversity on the Upper Shelf of the Northern region was 0.0. The highest fish diversity value (2.37) occurred on the Upper Slope of the Northern region, followed by 2.31 on the Inner Shelf of the Northern region. The median for the Bight as a whole was 1.60, with subpopulation medians ranging from 0.95 (Inner Shelf of the Southern region) to 1.83 (Middle Shelf of the Southern region and Outer Shelf of the Northern region). Among the mainland region subpopulations, the Southern and Northern regions had median diversities of 1.69 (Southern) and 1.62 (Northern), both greater than the Bight median of 1.60, whereas the Central region median was 1.52, lower than the Bight median. Among the shelf zones, the outer shelf had the highest median diversity, followed by the middle shelf and outer shelf (1.63 for both), inner shelf (1.13), and Bays and Harbors (1.08). Trawl stations were divided into five diversity groups (Figure IV-4). Stations with the highest diversity group (2.071 to 2.367) occurred mostly on the middle shelf. Comparing the diversity within the Bays and Harbor stratum to the other strata is complicated by sampling method. Trawls in Bays and Harbors were only half the distance of those in other zones (5 min vs. 10 min, see Chapter II). Since diversity is partly a function of species richness, which can be influenced by sampling effort, diversity index values from trawls within Bays and Harbors may be lower than those in the other zones due to sampling effort alone.

Species Composition

Taxonomic Composition

A total of 135 species of fish, representing 3 classes, 20 orders, and 47 families, were collected during the Bight 2008 trawl survey (Appendix B-4; alphabetical lists of species by common and scientific names are found in Appendices E-1 and E-2). These consisted of 121 species of ray-finned fishes (Actinopterygii), 13 species of cartilaginous fishes (Chondrichthyes), and 1 species of hagfish (Myxini). The most diverse families were rockfishes (Scorpaenidae), sculpins (Cottidae), and right-eye flounders (Pleuronectidae) with 25, 10, and 9 species, respectively. Surfperches (Embiotocidae) had seven species, whereas poachers (Agonidae), eelpouts (Zoarcidae), and sand flounders (Paralichthyidae) each had six species. Four species: slender barracudina (*Lestidiops ringens*), dogtooth lampfish (*Ceratoscopelus townsendi*), dusky sculpin (*Icelinus burchami*), and kelp clingfish (*Rimicola muscarum*) occurred for the first time in this survey, and have not been taken in any of the Bight regional trawl surveys. However, their geographic ranges have been previously reported to extend to or through southern California coastal waters (Love *et al.* 2005).

Species Areal Occurrence

Of the 135 species collected in the survey, relatively few occurred over a large proportion of the SCB (Figure IV-5; Appendix B-1). The equitability curve for areal occurrence was hyperbolic with a step-like appearance. The curve shows a relatively smooth change in slope with gradual decreasing percent of area to the right. Individually, 23 species, (17% of all species) occurred in 20% or more of the total area surveyed, and only Dover sole (*Microstomus pacificus*) and slender sole (*Lyopsetta exilis*) occurred in more than 50% of the total area (Tables IV-5 and IV-6). The five most widely distributed species were Dover sole, slender sole, Pacific sanddab (*Citharichthys sordidus*), English sole (*Parophrys vetulus*), and hornyhead turbot (*Pleuronichthys verticalis*).

Twenty-six species occurred in 50% or more of the area of at least one of the subpopulations (Table IV-6). Among the five shelf zones, the outer shelf had the highest number of species (14) occurring in 50% or more of the area, and followed by the middle shelf (12). The Bays and Harbors, Inner Shelf, and Upper Slope, each had only 3 species that occurred in 50% or more of the area of these subpopulations. Geographically, Dover sole was the most common species of the Northern and Southern regions (72% and 80% of the area, respectively), with hornyhead turbot the most common species (56% of the area) of the Central region. By shelf zone, California halibut (*Paralichthys californicus*) and barred sand bass (*Paralabrax nebulifer*) were the most common species (66% and 65% of the area) of Bays and Harbors, followed by California tonguefish (*Symphurus atricaudus*; 50% of the area). On the Inner Shelf, speckled sanddab (*Citharichthys stigmaeus*) was most common (94% of the area), followed by hornyhead turbot (68%), and California lizardfish (*Synodus lucioceps*), (55%). The most common species on the middle shelf were Pacific sanddab (91%) and yellowchin sculpin (*Icelinus quadriseriatus*; 91%), followed by hornyhead turbot (82%). The outer shelf had three species (Dover sole, slender sole, and Pacific sanddab) occupying the highest percent area (100%) of any subpopulations. On the upper slope, Dover sole and slender sole occurred in 91% of the area, followed by Pacific hake (*Merluccius productus*; 55% of the area). Dover sole, the most widespread species, inhabited 50% or more of the three deeper shelf zone subpopulations (middle shelf, outer shelf, upper slope) but did not occur in the shallow shelf zone subpopulations (Bays and Harbors, and the Inner Shelf). The next most widespread species occupied 50% of the area of two shelf zone subpopulations. Of these, slender sole occurred in 100% of the area of the outer shelf, and 91% of that of the upper slope, whereas the Pacific sanddab occupied 100% of the outer shelf area and 91% of the middle shelf. Other species with their highest area of occurrence in two shelf zone subpopulations include English sole (65% of middle shelf and 70% of outer shelf areas, respectively), hornyhead turbot (82% middle shelf, 68% inner shelf), plainfin midshipman (*Porichthys notatus*; 70% middle shelf, 61% outer shelf); pink seaperch (*Zalembius rosaceus*; 67% middle shelf, 61% outer shelf); and California tonguefish (67% middle shelf, 50% bays and harbors).

Additional species with high areas of occurrence (e.g., 50% or greater) in single shelf zone subpopulations include the following middle shelf species (Table IV-6): longspine combfish (*Zaniolepis latipinnis*; 70%); bigmouth sole (*Hippoglossina stomata*; 64%); longfin sanddab (*Citharichthys xanthostigma*; 61%); roughback sculpin (*Chitonotus pugetensis*; 55%). Also included are the following outer shelf species: stripetail rockfish (*Sebastes saxicola*; 87%); shortspine combfish (*Zaniolepis frenata*; 96%); blacktip poacher (*Xeneretmus latifrons*; 87%); blackbelly eelpout (*Lycodes pacificus*; 61%); pink rockfish (*Sebastes eos*; 52%); halfbanded rockfish (*Sebastes semicinctus*; 52%); spotted cusk-eel (*Chilara taylori*; 52%); and greenstriped rockfish (*Sebastes elongatus*) (65%).

Species Abundance

The equitability curve of species abundance approximated a tight hyperbola (Figure IV-5), indicating that relatively few species dominated the overall abundance. There was a sharp change of slope at about species 20, with those ranking to the left sharply increasing in abundance and those to the right gradually decreasing. Species 20 was California tonguefish (*Symphurus atricaudus*) with 313 fish. The 41 most abundant species (30% of all species) together accounted for 95% of fish abundance in the survey (Table IV-7). Five species accounted for approximately 50% of the total fish abundance: Pacific sanddab, slender sole, speckled sanddab, yellowchin sculpin, and Dover sole.

Combinations of 28 species comprised the top 80% of the abundance in each subpopulation (Table IV-8), with a mean of 10 species per subpopulation. A mean of 6 species per subpopulation comprised 80% of the fish abundance in the shelf zones. On the mainland shelf, the number of species comprising 80% of the abundance per region was similar (18, 12, 18) for the northern, Central, and southern region, respectively. Within the shelf zones, the middle shelf and upper slope had the highest number of species (8), which in combination comprised 80% of the abundance. Fewer species (5-6) made up this abundance in the remaining shelf zones. Pacific sanddab (18, 12, 18), and slender sole (14, 12, 16) had the highest percent abundance of the northern, Central and southern regions, respectively. White croaker (*Genyonemus lineatus*) comprised the greatest percent abundance (37) in Bays and Harbors, speckled sanddab (59) on the inner shelf, Pacific sanddab (24) on the middle shelf, Pacific sanddab and slender sole (27 each) on the outer shelf, and slender sole (42%) on the upper slope.

Species Biomass

The equitability curve of species biomass (Figure IV-5) approximated a tight hyperbola, similar to that for species abundance, although the curve for biomass was slightly more concave than the curve for species abundance at about species 10, with those ranking to the left sharply increasing in biomass and those to the right, gradually decreasing. As with the abundance curve, relatively few species dominated the overall biomass. Forty-six species (34% of all species) accounted for the top 95% of fish biomass in the survey (Table IV-9). Five species accounted for approximately 50% of the total fish biomass: Pacific sanddab, Dover sole, slender sole, English sole, and white croaker.

Combinations of 34 species (25% of all species) also made up the top 80% of the biomass in each subpopulation (Table IV-10), with a mean of 15 species per mainland region and 9.5 species per depth zone. Among the shelf (depth) zones, inner shelf and middle shelf zones had the highest number of fish species (9 for each zone) comprising 80% of the biomass per zone, whereas the upper slope, bays and harbors, and outer shelf had fewer comprising 80% per zone (7, 6, and 5, respectively). Geographically, Pacific sanddab was the biomass dominant at all regional mainland zones. Bathymetrically, white croaker was dominant in bays and harbors, speckled sanddab on the inner shelf, Pacific sanddab on the middle shelf and outer shelf, and Dover sole on the Upper Slope.

Species Size (Length) Distribution

All Fish

Fish captured in this survey ranged from 2 cm to 101 cm, with almost all below 30 cm in length (Figure IV-6). Kelp clingfish (*Rimicola muscarum*) and a juvenile greenblotched rockfish (*Sebastes rosenblatti*) were the smallest sized (2 cm) fish (Table IV-11). Spiny dogfish (*Squalus acanthias*) was the largest (101 cm). The modal size of the fish was 11 cm. Fish of this size comprised about 9.3% of the total catch. The length-frequency distribution was skewed to the right and was strongly truncated to the left at 4 cm. Among the major shelf zones and regions, length-frequency distributions of all fish were most highly peaked in smaller size classes, with the highest modal abundance in Central and southern region bays and harbors and in the Central region Middle Shelf zone (Figure IV-7). In general, length-frequency distributions were similarly skewed to the right in all region/shelf zone populations, and the lengths of the smallest fish captured did not usually differ greatly between regions or by depth. A few large fish were found in many subpopulations, with the largest fish in the survey collected from the upper slope of the northern and southern regions.

Individual Species

Fish caught in the survey ranged in length from 2 to 101 cm (Table IV-11). Note that the lengths of bony fish were standard lengths (anterior tip of head to end of caudal peduncle at the posterior border of the hypural plate). Lengths for cartilaginous fishes were total lengths, from the anterior end of the head to the posterior end of the tail. Six of the 10 largest fishes are cartilaginous fishes (Chondrichthyes): spiny dogfish had the largest maximum length (101 cm) in this survey, followed by longnose skate (*Raja rhina*; 91 cm), shovelnose guitarfish (*Rhinobatos productus*; 79 cm), California skate (*Raja inornata*; 58 cm), brown smoothhound (*Mustelus henlei*; 51 cm), and spotted ratfish (*Hydrolagus colliei*; 43 cm). Sablefish (*Anoplopoma fimbria*; 56 cm), California halibut (42 cm), and Pacific hake (41 cm) are ray-finned fishes (Actinopterygii).

Besides cartilaginous and ray-finned fishes, Pacific hagfish (*Eptatretus stoutii*; 41 cm), a myxinid, had long length measurements. Ray-finned species had the smallest lengths in this survey. Two (kelp clingfish) and a juvenile greenblotched rockfish were 2 cm in length. The remaining small fishes: slough anchovy (*Anchoa delicatissima*), tropical (=silver) hatchetfish (*Argyropelecus lychnus*), lowcrest hatchetfish (*Argyropelecus sladeni*); Pacific sanddab; speckled sanddab; spotted kelpfish (*Gibbonsia elegans*); yellowchin sculpin; and cheekspot goby (*Ilypnus gilberti*), had minimum lengths of 3 cm in this survey (Table IV-11). Whereas the larger species were represented by few individuals, most of the smaller species were represented by many individuals. More than 100 individuals were collected for four of the 10 smallest species, with slough anchovy with 124, Pacific sanddab having 4,406, speckled sanddab with 2,659, yellowchin sculpin with 1,989.

Population Structure

The overall length-frequency distributions of the 10 most abundant species in the survey varied in shape (Figure IV-8). Size distributions of Dover sole (*Microstomus pacificus*), white croaker (*Genyonemus lineatus*), English sole (*Parophrys vetulus*), pink seaperch (*Zalembius rosaceus*) and Pacific sanddab (*Citharichthys sordidus*) were slightly biomodal, or multimodal. Slender sole (*Lyopsetta exilis*), speckled sanddab (*Citharichthys stigmaeus*), yellowchin sculpin (*Icelinus quadriseriatus*), halfbanded rockfish (*Sebastes semicinctus*), and stripetail rockfish (*Sebastes saxicola*) were primarily unimodal. Five of the top 10 species: Pacific sanddab, speckled sanddab, yellowchin sculpin, stripetail rockfish, and pink seaperch all had primary modes at 10 cm or less. The top 10 species had size distributions within the range of 3 to 41 cm. Only the size distribution of yellowchin sculpin was entirely below 10 cm. Recent recruitment of small juveniles (as indicated by fish lengths of 5 cm or less) was apparent in 9 of the top 10 species (Pacific sanddab, slender sole, speckled sanddab, yellowchin sculpin, Dover sole, white croaker, stripetail rockfish, English sole, and pink seaperch. Only in halfbanded rockfish were all fish collected above 5 cm in length. The length-frequency distributions for each of the top ten most abundant species by geographic zone can be found in Appendix B-5.

Anomalies and Parasites

The prevalence of fish anomalies was low and incidences were scattered throughout the SCB. Anomalies identified in the study included parasites, tumors, ambicoloration, skeletal deformities, and albinism (Table IV-12). Fifty-five fish, a total of 0.5% of 11,149 fish collected in the survey were anomalous. Anomalies were found in 12 (8.8%) of 135 species collected in the survey. Most (71%) of these were parasites (Table IV-12). Of the remaining anomalies, ambicoloration was most abundant, followed by skeletal deformities, tumors, and albinism. In this study, 22 (73%) of the fish with parasites were Pacific sanddab. All two (100%) occurrences of tumors were on Dover sole. Eight fish had ambicoloration, four of which (50%) were California halibut. Of the five fish with skeletal deformities, two (40%) were white croaker. Hornyhead turbot was the only species collected with albinism.

Overall fish anomalies occurred in 16.3% of the area of the southern California shelf and upper slope (Table IV-13). Geographically, fish anomalies were most prevalent (22.3%) in the Southern region, followed by 16.3% in the Central region, and by 13.3% in the Northern region. Bathymetrically, fish anomalies were most prevalent (32.3%) on the Inner Shelf, followed by 29.5% in Bays and Harbors, 27.3% on the Middle Shelf, 17.4% on the Outer Shelf, and 3.0% on the Upper Slope.

Of 140 stations sampled, no anomalies were found at 113 (81%) stations (Figure IV-9). Fish with parasites were found at 19 (6.7%) stations (mostly on the northern and southern mainland shelf (Figure IV-9). Fish with ambicoloration and deformities occurred at four (1.4%) of the stations each, with ambicoloration occurring on the northern and central mainland shelves, and deformities on the central mainland shelf. Tumors occurred at one site near Mugu Submarine Canyon. A combination of parasites and tumor also occurred at one site on the Palos Verdes Shelf off Palos Verdes Point, and combination of ambicoloration, albinism, and parasitism occurred at one site on the Palos Verdes shelf off Point Fermin.

Historical Surveys

Many surveys of soft-bottom fishes have been conducted in southern California since Carlisle (1969b) conducted the first environmental assessment trawl survey of Santa Monica Bay from 1957-1963, using the same gear used in present-day surveys. As with Carlisle (1969b), these studies (e.g., CLAEMD 1994 a, b; CSDMWWD 1995; Stull 1995; CSDOC 1996; Stull and Tang 1996; CSDLAC 2006) focused on the effects of wastewater discharge on fish populations. Most are focused on local areas (primarily large POTW areas) rather than the SCB as a whole. Many of the routine monitoring surveys near wastewater outfalls began between 1969 and 1972, and shortly after, the effort was made to put outfall conditions into a Bight-wide perspective by compiling existing data (SCCWRP 1973; Mearns 1974; Mearns *et al.* 1976; Allen and Voglin 1976; Allen 1977, 1982).

Later synoptic surveys were conducted at various regional scales to get better temporal coherence and similarity of spatial coverage (Mearns and Green 1974; Allen and Mearns 1977; Word *et al.* 1977; Love *et al.* 1986; Thompson *et al.* 1987b, 1993b). The first synoptic regional trawl survey in 1994 (Allen *et al.* 1998) provided a region-wide assessment of demersal fish population conditions for the mainland shelf of southern California and provided perspective to later regional surveys. In addition, Allen and Voglin (1976) compiled information on demersal fish populations from surveys conducted throughout southern California from 1957-1975. In all, information on population attributes was collected from 2,237 samples during that period.

Population Attributes

Fish population attribute mean values for the SCB were generally similar on the mainland shelf (10-200 m) among time periods1957–1975 (Allen and Voglin 1976), 1994 (Allen *et al.* 1998), 1998 (Allen *et al.* 2002), 2003 (Allen *et al.* 2007), and 2008 (present study; Table IV-14). Among all mainland shelf regions, mean fish abundance ranged from 154 in 1994 to 267 in 2003, it was next highest in the present survey (2008) with a mean of 230 fish per haul (Table IV-14). Among all shelf regions, mean fish biomass (kg/haul) ranged from 4.8 in 1994 to 7.1 kg/haul in 1957-1975 (Table IV-14). Among all shelf regions, mean numbers of fish species per haul ranged from 10 in 1998 to 14 in 2003 (Table IV-14). Among all shelf regions, mean fish diversity ranged from 1.28 in 1957-1975 to 1.59 in 1994. Overall, in 2008, mean values of abundance (244) over all shelf regions were second in abundance only to 2003 mean values (294). For biomass, the 2008 mean value over all shelf regions (6.2 kg/haul) was second only to the 1957-1975 mean biomass (7.1 kg/haul). Overall, in 2008, the mean number of species (13 species) was second only to 2003 (14 species per haul). In contrast, the overall mean fish diversity across all shelf regions was 1.51 in 2008, which was third relative to the mean diversity in 1994 (1.59) and in 1998 (1.57), but was higher than that of 2003 (1.49; Table IV-14). Details of areal percentage, abundance, and biomass for demersal fish by subpopulations are available in Appendices B-1, B-2, and B-3, respectively.

Species Composition

Some important changes in species composition occurred between 1994, 1998, 2003, and 2008. The distribution of species among higher taxa was nearly the same as in 1994 (Allen *et al.* 1998, 2002, 2007), although the number of species collected were variable with 87 in 1994, 143 in 1998, 142 in 2003, and 135 in 2008. Scorpaenidae, Pleuronectidae, and Cottidae were the most diverse families in 2003. In 2008, Scorpaenidae, Cottidae, Pleuronectidae were the most diverse families. Five to eight species occurred in 50% of the area of the mainland shelf in each of the four regional surveys (1994, 1998, 2003, 2008; Table IV-15). In 1994, these were Pacific sanddab, hornyhead turbot, yellowchin sculpin, plainfin midshipman, Dover sole, California lizardfish, bigmouth sole, and longfin sanddab. In 1998, these were hornyhead turbot, yellowchin sculpin, California tonguefish, California lizardfish, and longfin sanddab. In 2003, Pacific sanddab, hornyhead turbot, English sole, yellowchin sculpin, pink seaperch, California tonguefish, speckled sanddab, and stripetail rockfish each occurred in 50% or more of the shelf in the survey. In 2008, species occurring that frequently were Pacific sanddab, hornyhead turbot, English sole, yellowchin sculpin, plainfin midshipman, and pink seaperch. Hornyhead turbot and yellowchin sculpin occurred in 50% or more of the area in all four years. Pacific sanddab occurred in 50% or more of the area in 3 years (1994, 2003, 2008). English sole, plainfin midshipman, pink seaperch, California tonguefish, California lizardfish, and longfin sanddab each occurred in 50% of the area in two years. Dover sole, speckled sanddab, bigmouth sole, and stripetail rockfish occurred in at least 50% of the area in one year each.

Discussion

The Bight'08 program identified the relative importance and distribution of the dominant fish species in the SCB. During Bight'08, fish were captured in all but two of the 143 trawls. The total number of fish captured numbered over 28,000 encompassing 135 species and cumulatively weighing over one metric ton. The top five species (in order) included Pacific sanddab, slender sole, speckled sanddab, yellowchin sculpin, and Dover sole. Altogether, these five species accounted for approximately half the fish abundance in the SCB. The distribution of these five species was dissimilar. Dover sole and slender sole were most abundant in deeper water such as the outer shelf and upper slope, but were completely absent in the shallow water of the inner shelf and bays/harbors. In contrast, speckled sanddab was most abundant in shallow water such as the inner shelf, but was completely absent in the deeper water of the outer shelf and slope. Pacific sanddab and yellowchin sculpin were most abundant at mid-depths such as the middle shelf, decreasing in abundance as one moves either shallower or deeper.

These five species are known to be important fishes in the SCB. For example, at least four of these five species have been used as indicator species for monitoring the effects of treated wastewater discharges (Stull and Tang 1996). Dover sole first gained notoriety due to physiological impacts such as fin erosion and epidermal tumors in the 1970's (Mearns and Sherwood 1974; McDermott-Ehrlich *et al.* 1977). Dover sole has also been used to examine recovery of SCB benthic ecosystems after cessation of sludge discharge (SCCWRP 1993) as well as the influence of new chemicals of emerging concern (Steve Bay, personal communication). Pacific sanddab, owing to its wide distribution, has been used in a number of bioaccumulation studies (Schiff and Allen 2000, Allen *et al.* 1998). Nearly every sample of Pacific sanddab from the SCB had some measureable quantity of total DDT in its tissues. Pacific sanddab and Dover sole are also commercially fished species. In 2008, Dover sole was the fifth most landed groundfish species in California at over 3,000 metric tons and an estimated value of $2.5 million (PacFin 2010).

The areal extent of these five dominant species has only moderately changed since the first Bight survey in 1994. For example, the extent of yellowchin sculpin has ranged between 52 and 57% of the SCB area over the four regional surveys between 1994 and 2008. Similar consistency was observed for slender sole (19 to 28% of area) and speckled sanddab (37 to 52% of area). More variation was observed in the inter-survey extent of Pacific sanddab (47 to 80% of the SCB area) and Dover sole (27 to 56% of the SCB area), with the smallest extent occurring in 1998. Oceanographic shifts in water temperature were suggested as the primary reason for the decline in 1998 (Allen *et al.* 2002). The extent of Dover sole distribution has increased to 74% of the SCB area in 2008 with length-frequency distributions indicating healthy recruitment of young individuals.

The frequency of fish anomalies and parasites was low in 2008. Approximately 0.5% of all the fish collected during Bight'08 exhibited parasitism, tumors, skeletal deformities, ambicoloration and/or albinism. External parasites were the most common anomaly and no fin erosion was observed. This pattern of infection and relative abundance is similar to results observed during Bight'03 (Allen *et al.* 2007).

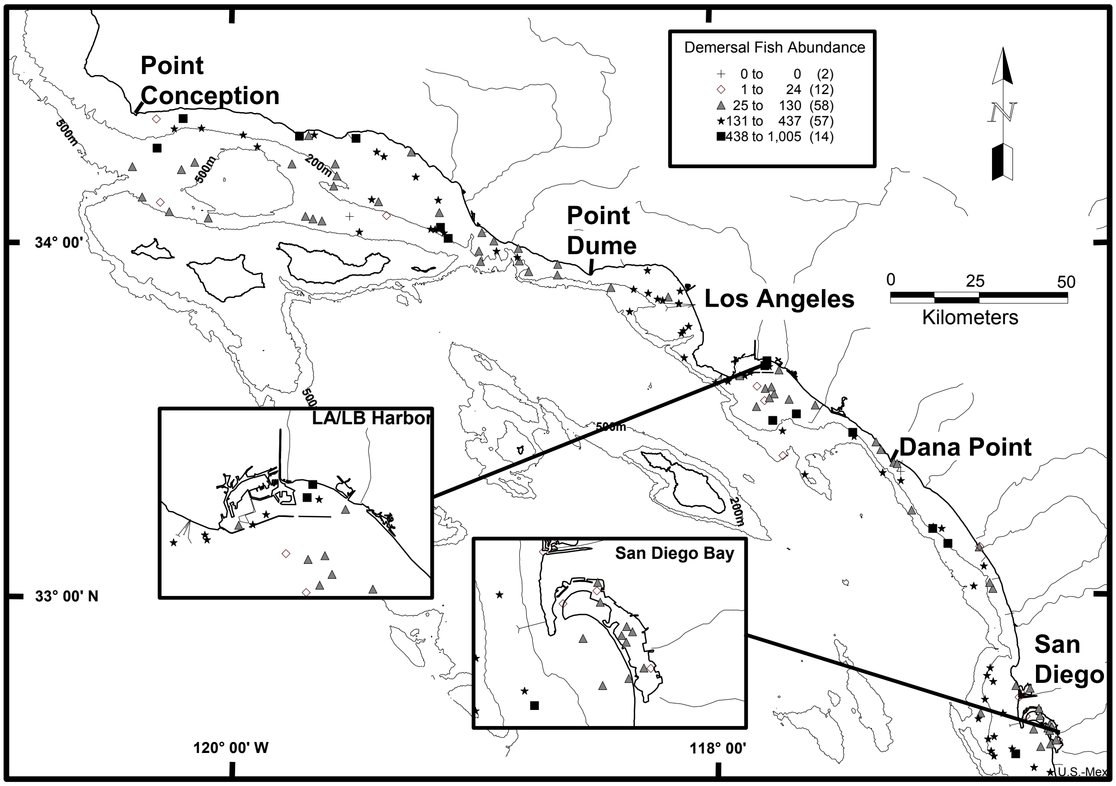

Figure IV-1. Distribution of fish abundance per haul at depths of 3-485 m on the southern California shelf and upper slope, July-September 2008.

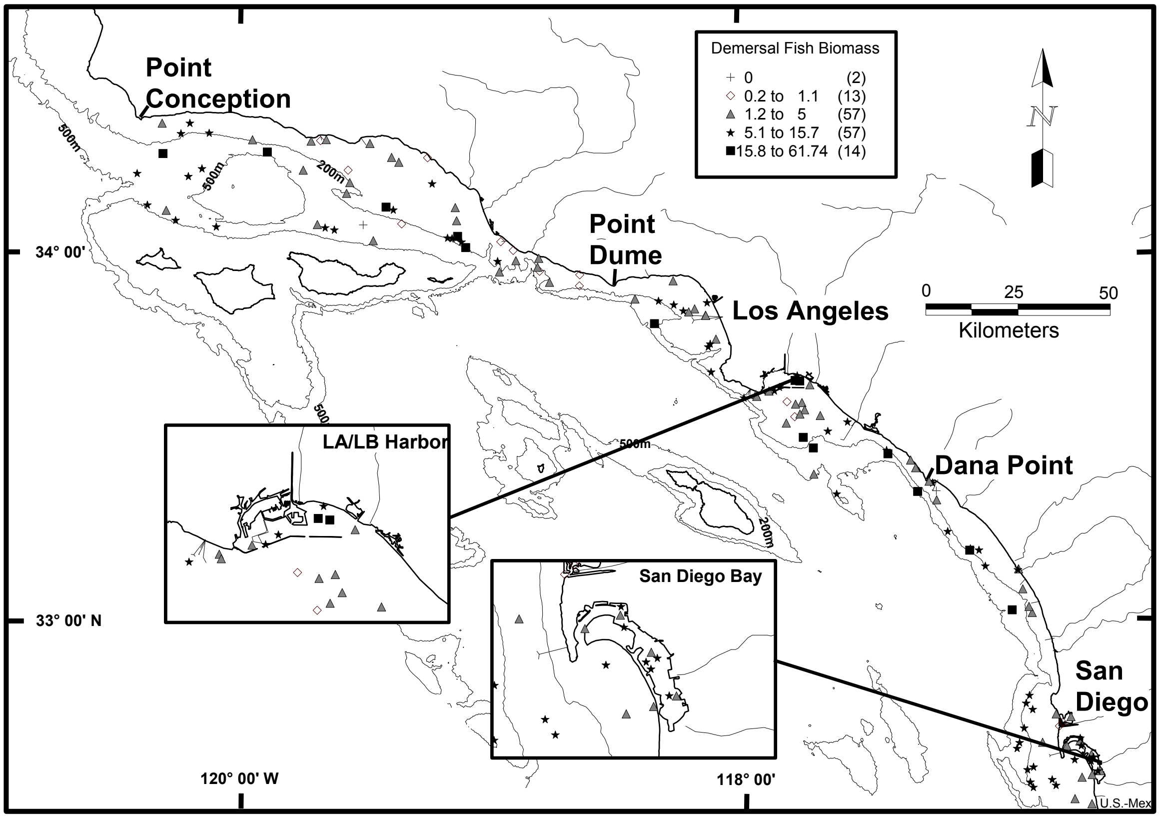

Figure IV-2. Distribution of fish biomass (kg) per haul at depths of 2-484 m on the southern California shelf and upper slope, July-September 2008.

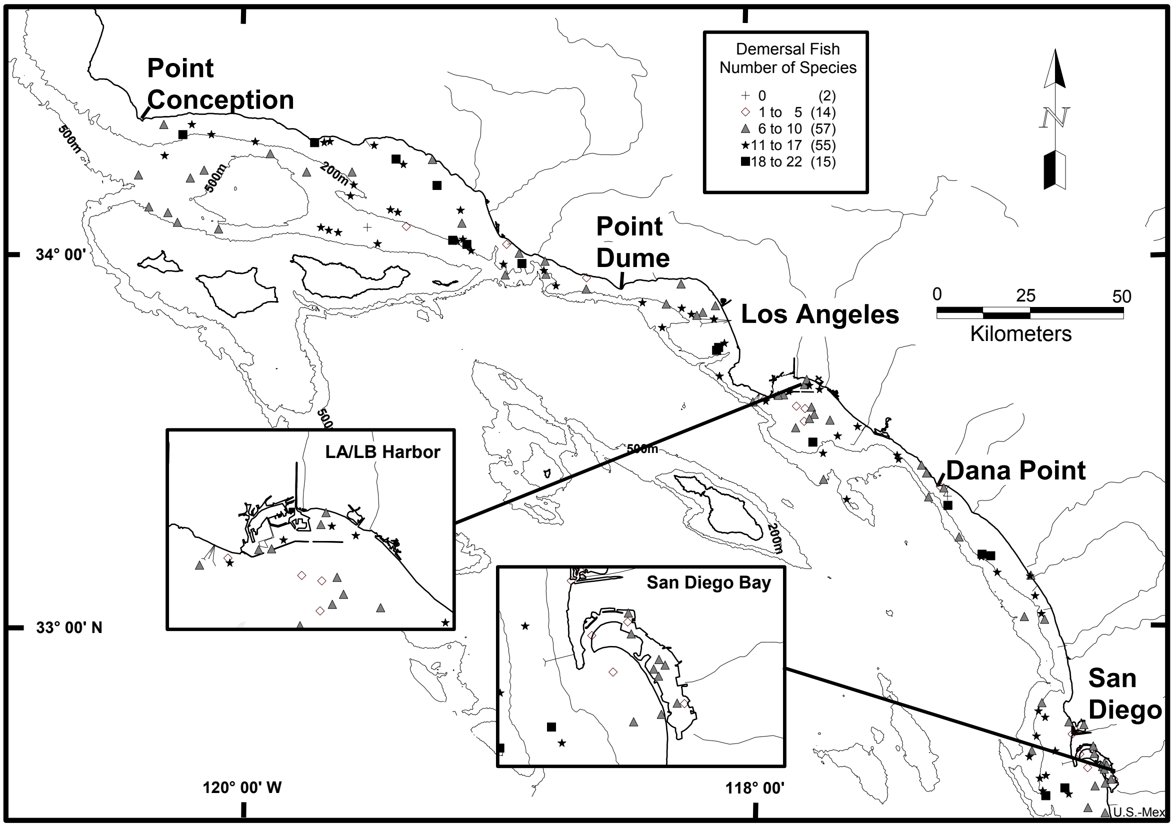

Figure IV-3. Distribution of species richness (number of fish species per haul) at depths of 2-484 m on the southern California shelf, July-September 2008.

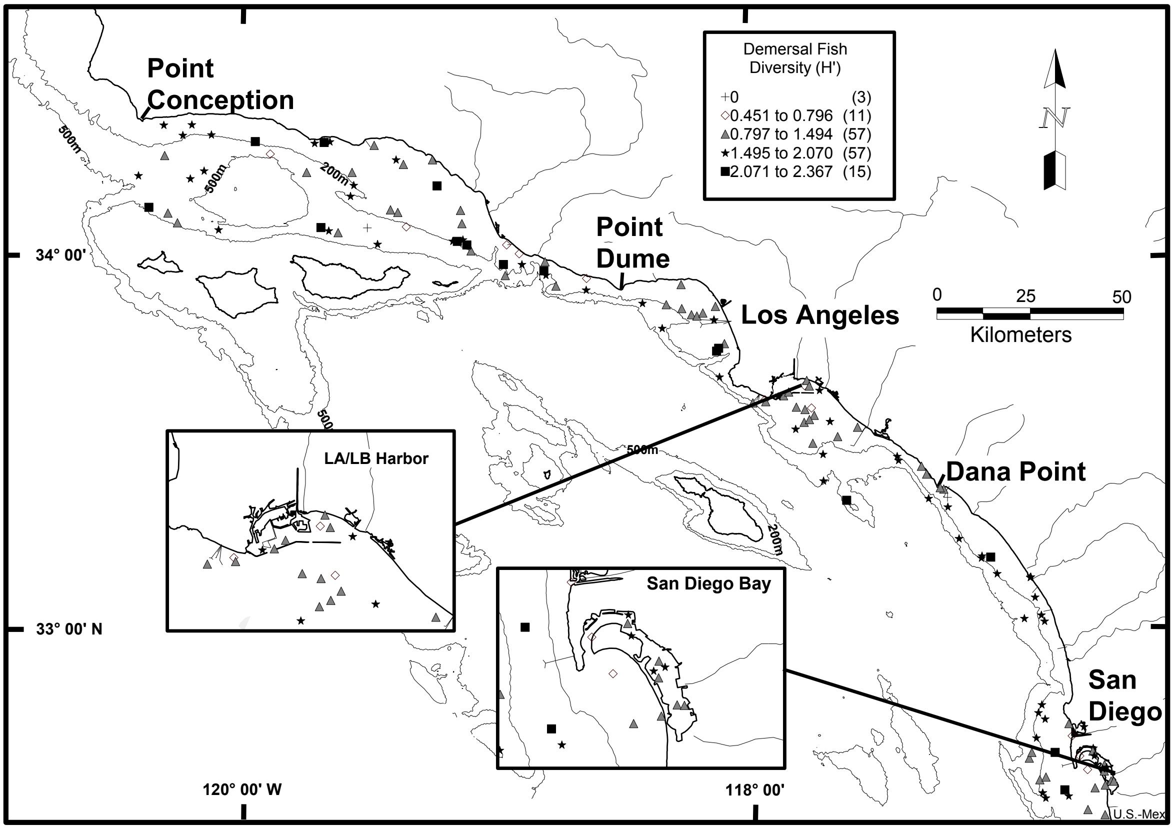

Figure IV-4. Distribution of fish diversity (Shannon-Wiener) per haul at depths of 2-484 m on the southern California shelf, July-September 2008.

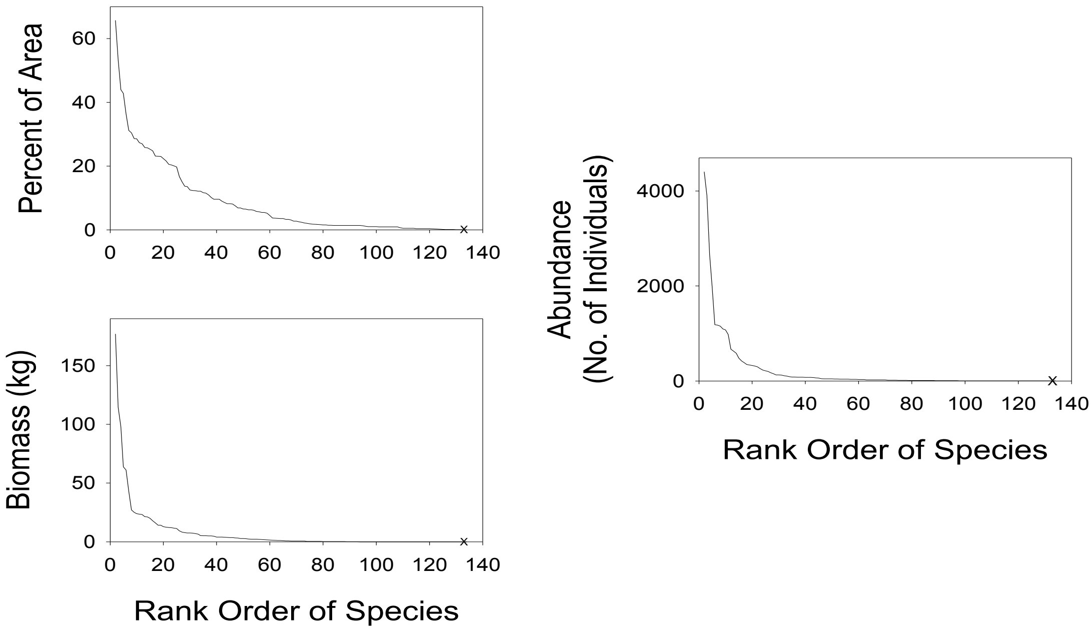

Figure IV-5. Equitability curves of fish occurrence, abundance, and biomass by species at depths of 2-484 m, Southern California Bight 2008 Regional Survey, July-September 2008, x = 135th species.

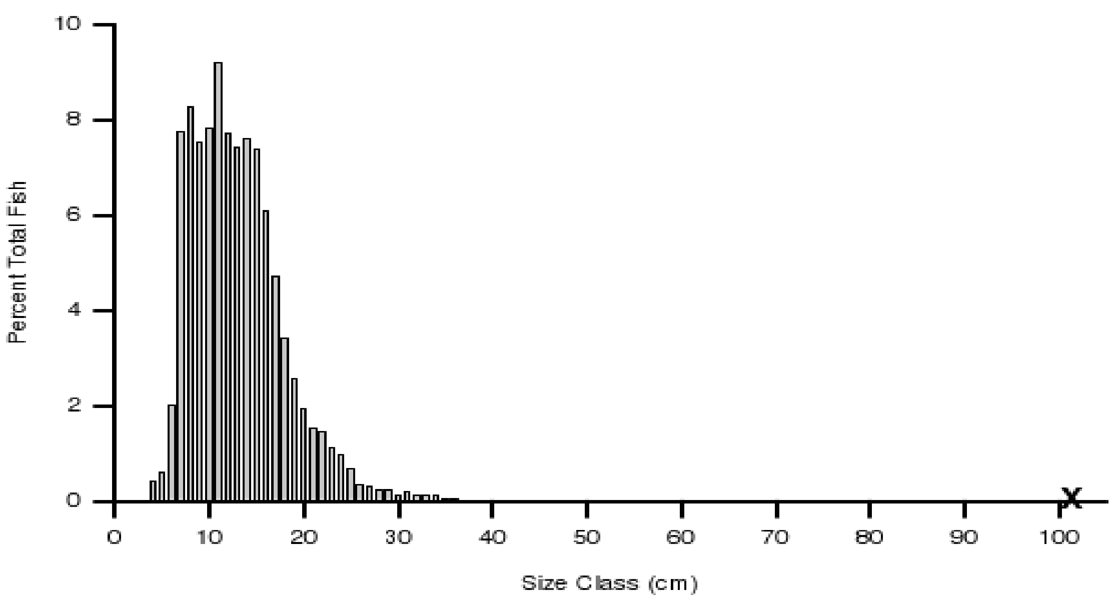

Figure IV-6. Length-frequency distribution of all fish collected by trawl at depths of 2 to 484m on the southern California shelf and upper shelf, July-September 2008. X = largest fish (size class 101 cm). N = 28,374 fish.

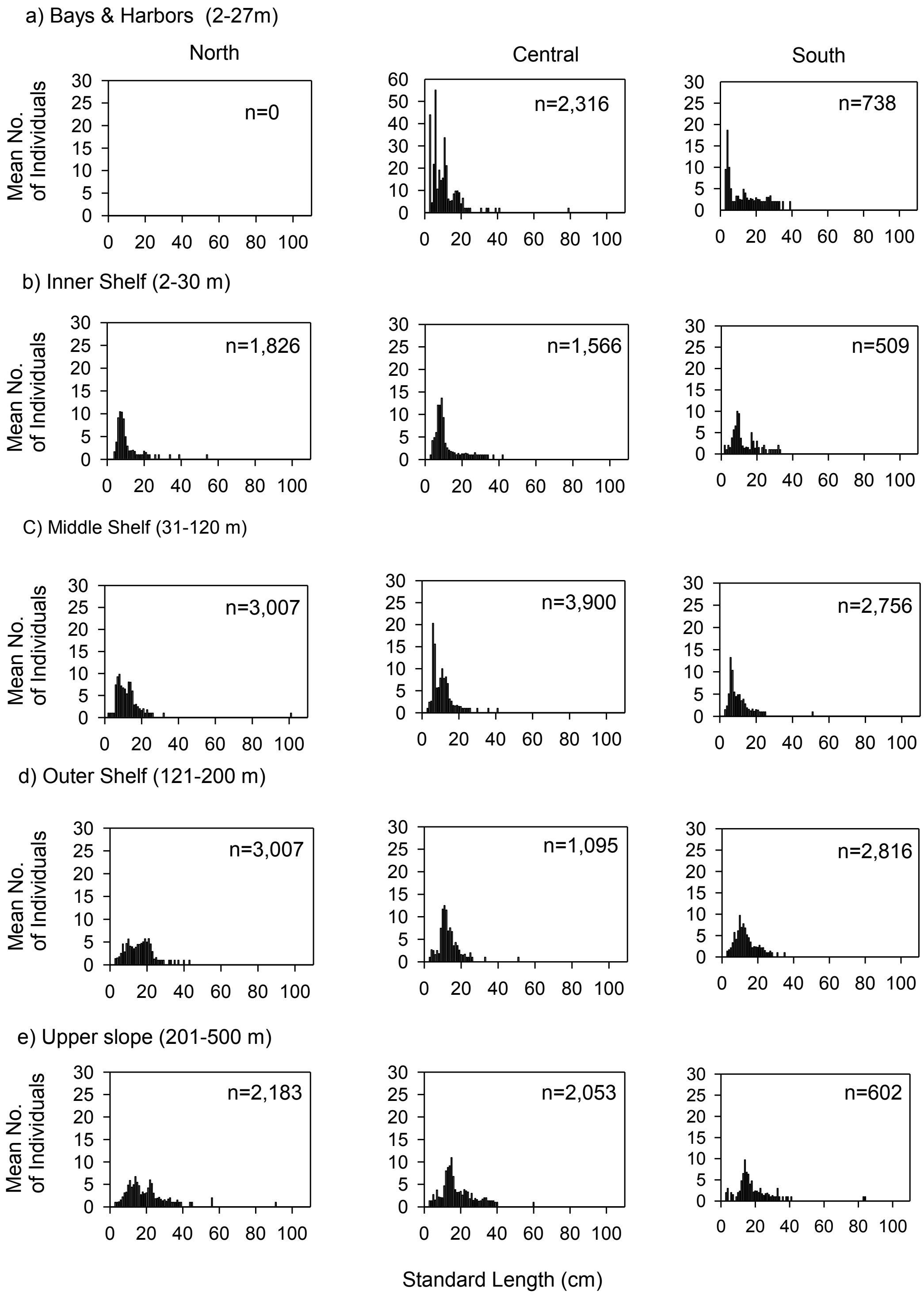

Figure IV-7. Length-frequency distribution (mean number of fish per size class) of all fish collected by trawl in the bays and harbors and on the mainland shelf by zone and regional subpopulation on the southern California shelf at depths of 2-484 m, July-September 2008.

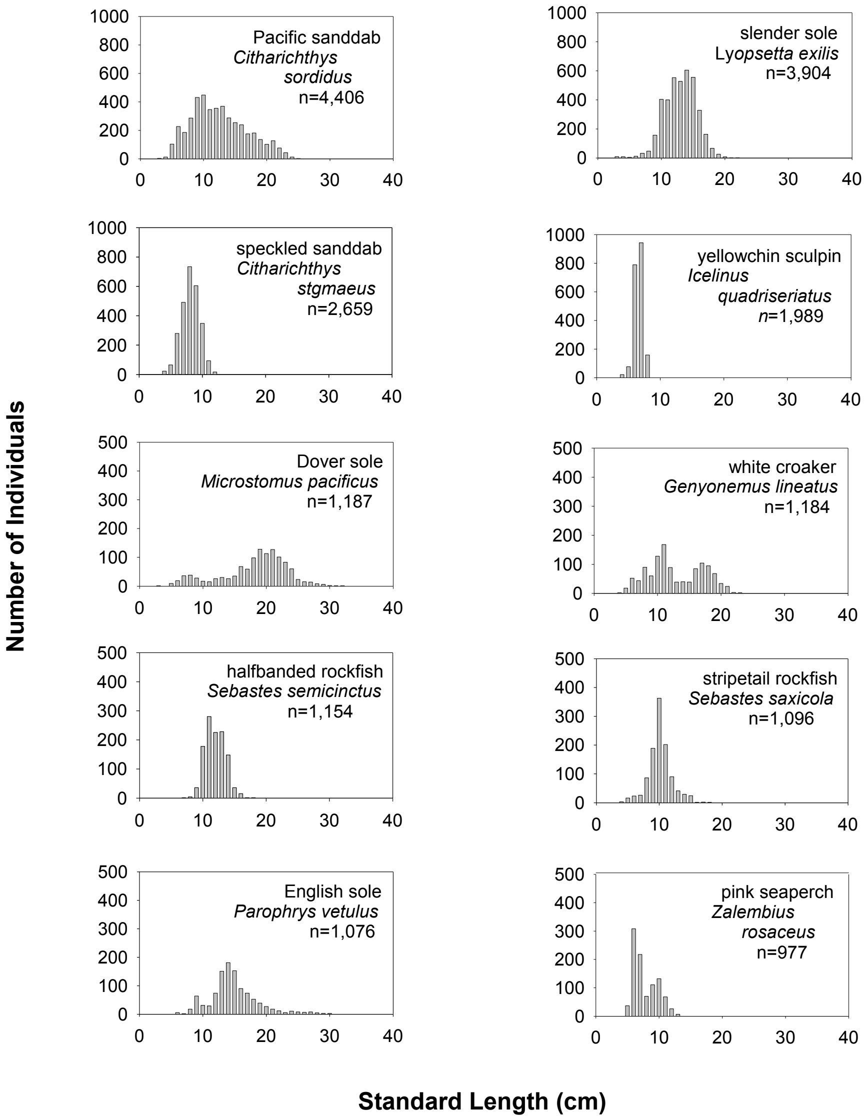

Figure IV-8. Overall length frequency distributions for the 10 most abundant demersal fish species in the Bight'08 Regional Survey at depths of 2-484 m from July to September 2008.

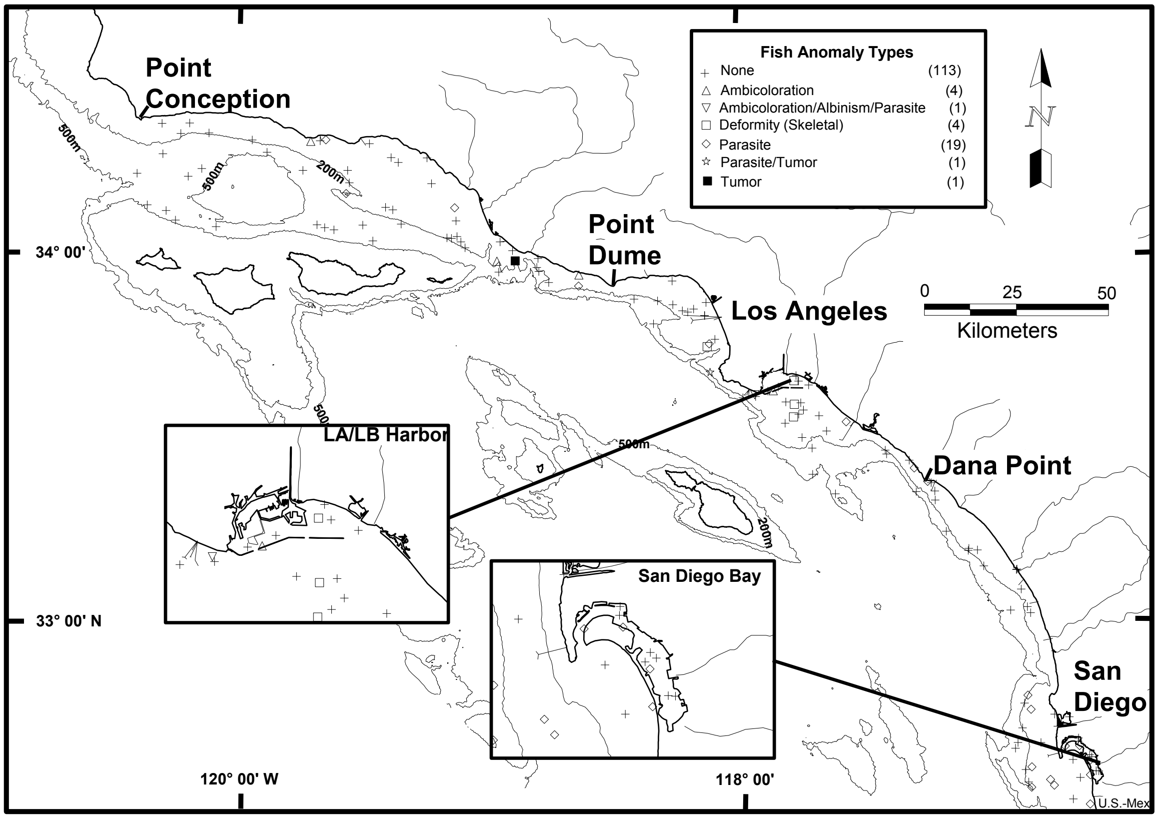

Figure IV-9. Distribution of fish anomalies on the southern California shelf and slope at depths of 2-484 m on the southern California shelf, July-September 2008.

Table IV-1. Demersal fish abundance by region and depth zone at depths of 3-485 m on the southern California shelf, July-September 2008.

Subpopulation	No. of Stations	Total	Range Min.	Range Max.	Area-Weighted Values Median	Area-Weighted Values Mean	Area-Weighted Values SD	Area-Weighted Values 95% CL	Percent Above Bight Median
Abundance (no. of individuals/haul)*									
Region									
Northern	52	10,023	0	901	80	169	191	55	32.3
Central	44	10,930	4	1005	155	239	206	68	65.7
Southern	47	7,421	0	506	199	206	124	44	62.9
Shelf Zone									
Bays & Harbors(2-30m)	**22**	**2,904**	**2**	**738**	**89**	**210**	**241**	**127**	**37.2**
Central Region	6	2,316	90	738	279	386	255	204	68.8
Southern Region	13	588	2	130	53	55	35	20	0.0
Southern Region *	3	150 *	22	96	*	*	*	*	*
Inner Shelf (2-30m)	**32**	**3,901**	**0**	**467**	**71**	**124**	**123**	**43**	**27.6**
Northern Region	12	1,826	24	467	70	152	151	86	30.4
Central Region	13	1,566	4	377	67	120	109	59	27.4
Southern Region	7	509	0	165	55	74	53	43	11.0
Middle Shelf (31-120m)	**33**	**9,663**	**18**	**1005**	**268**	**293**	**222**	**76**	**71.5**
Northern Region	9	3,007	26	901	291	334	255	166	65.8
Central Region	13	3,900	18	1005	202	300	259	141	64.4
Southern Region	11	2,756	57	471	257	251	111	66	77.2
Outer Shelf (121-200m)	**23**	**6,918**	**34**	**621**	**255**	**301**	**132**	**54**	**90.8**
Northern Region	11	3,007	34	621	241	273	146	86	80.7
Central Region	3	1,095	234	437	329	365	93	105	100.0
Southern Region	9	2,816	195	506	245	313	113	74	100.0
Upper Slope (201-500m)	**33**	**4,838**	**0**	**629**	**86**	**147**	**149**	**51**	**35.0**
Northern Region	20	2,183	0	629	71	109	141	62	14.5
Central Region	9	2,053	20	458	155	228	158	103	67.9
Southern Region	4	602	88	272	111	151	72	71	27.1
Total (all stations)	**143**	**28,374**	**0**	**1,005**	**132**	**200**	**186**	**36**	**50.0**

* Stations that were not assigned area-weights as they were not in the appropriate survey strata.
In Bays and Harbors, trawls were towed for 5 minutes and sampled an average of 1,527m.^{2}
See methods secion for description of doubling the abundance and biomass of stations taken in 5-min trawls conducted primarily in bays and harbors.
In the other shelf zones, trawls were towed for 10 min., an average area of 2,933 m.^{2}
CL = Confidence limits (± value); Min. = Minimum; Max. = Maximum; No. = Number;
SD = Standard Deviation.

Table IV-2. Demersal fish biomass (kg) by region and depth zones at depths of 3-485 m on the southern California shelf, July-September 2008.

Subpopulation	No. of Stations	Total (kg)	Biomass (kg/haul) Range Min.	Max.	Area-Weighted Values Median	Mean	SD	95% CL	Percent Above Bight Median
Biomass (kg/haul)*									
Region									
Northern	52	396.0	0.0	61.7	4.3	7.6	9.9	2.9	41.9
Central	44	381.0	0.7	41.7	5.0	9.3	9.5	3.4	48.7
Southern	47	296.8	0.0	22.4	5.8	6.8	4.8	1.9	59.7
Shelf Zone									
Bays and Harbors (2-30 m)	**19**	**159.0**	**0.2**	**30.1**	**6.4**	**10.1**	**8.5**	**4.4**	**63.1**
Central Region	6	86.0	1.6	30.1	11.0	14.3	9.9	7.9	70.1
Southern Region	13	73.0	0.2	15.6	4.7	6.4	4.3	2.5	45.4
Southern Region	3	11.8	2.4	5.6	*	*	*	*	*
Inner Shelf (2-30 m)	**32**	**88.0**	**0.0**	**9.0**	**2.2**	**2.6**	**1.7**	**0.6**	**8.1**
Northern Region	12	22.0	0.7	4.7	1.2	1.8	1.3	0.7	0.0
Central Region	13	41.0	0.9	6.5	2.5	3.1	1.7	0.9	10.6
Southern Region	7	26.0	0.0	9.0	2.6	2.8	1.7	1.4	3.8
Middle Shelf (31-120 m)	**33**	**214.0**	**0.7**	**41.7**	**3.6**	**6.5**	**8.1**	**2.8**	**39.2**
Northern Region	9	70.0	0.7	29.1	3.5	7.8	8.3	5.4	34.2
Central Region	13	93.0	0.7	41.7	3.6	7.1	10.3	5.6	30.2
Southern Region	11	51.0	1.2	12.3	3.8	4.6	2.9	1.7	36.9
Outer Shelf (121-200 m)	**23**	**268.0**	**0.5**	**61.7**	**9.2**	**11.7**	**11.5**	**4.7**	**84.8**
Northern Region	11	144.0	0.5	61.7	7.4	13.1	16.0	9.5	68.2
Central Region	3	33.0	8.9	12.1	10.4	11.0	1.5	1.6	100.0
Southern Region	9	92.0	6.3	22.4	9.2	10.2	4.6	3.0	100.0
Upper Slope (201-500 m)	**33**	**331.0**	**0.0**	**44.4**	**6.9**	**10.0**	**9.4**	**3.2**	**60.9**
Northern Region	20	160.0	0.0	44.4	4.7	8.0	9.6	4.2	45.5
Central Region	9	128.0	3.0	31.1	11.5	14.3	8.9	5.8	75.1
Southern Region	4	43.0	7.0	19.1	7.7	10.7	4.9	4.8	100.0
Total (all stations)	**143**	**1073.8**	**0.0**	**61.7**	**5.3**	**8.0**	**8.9**	**1.8**	**50.0**

* Stations that were not assigned area-weights as they were not in the appropriate survey strata.
Bay and Harbor stations were 5 min. tows with a mean area towed of 1,527 m^2.
*Stations in other subpopulations were 10 min. tows with a mean area towed of 2,933 m2.
CL = Confidence limits (± value); Min. = Minimum; Max. = Maximum; No. = Number;
SD = Standard deviation.

Table IV-3. Demersal fish species richness by region and depth zones at depths of 3-485 m on the southern California shelf, July-September 2008.

			Number of Species per Haul							Percent
					Area-Weighted Values					Above
	No. of	**Total	Range					95%		Bight
Subpopulation	Stations	Species	Min.	Max.	Median	Mean	SD	CL		Median
Species richness (no. of species/haul)*										
Region										
Northern	52	95	0	22	11	11	5	1		41.3
Central	44	85	4	19	11	11	4	1		35.3
Southern	44	89	0	22	11	12	5	2		48.0
Shelf Zone										
Bays and Harbors (2-30 m)	**19**	37	1	15	10	10	3	1		20.8
Central Region	6	21	7	15	10	11	3	2		33.3
Southern Region	13	29	1	13	10	9	2	1		9.8
Inner Shelf (2-30 m)	**32**	52	0	22	8	8	4	1		12.9
Northern Region	12	41	5	22	7	10	5	3		33.3
Central Region	13	25	4	11	6	8	3	1		0.0
Southern Region	7	26	0	10	9	7	4	3		0.0
Middle Shelf (31-120 m)	**33**	58	4	22	14	14	4	2		66.7
Northern Region	9	48	9	21	17	16	4	3		77.8
Central Region	13	38	4	19	11	13	4	2		46.2
Southern Region	11	37	8	22	15	15	4	2		77.3
Outer Shelf (121-200 m)	**23**	45	7	21	15	15	3	1		78.3
Northern Region	11	34	7	21	16	15	4	2		83.6
Central Region	3	22	10	17	11	13	3	4		33.3
Southern Region	9	35	9	19	15	14	3	2		77.8
Upper Slope (201-500 m)	**33**	52	0	17	10	10	3	1		27.3
Northern Region	20	39	0	13	10	9	3	2		25.0
Central Region	9	38	6	17	11	12	3	2		44.4
Southern Region	4	14	7	11	9	10	2	1		0.0
*** **Total (all stations)**	**140**	**135**	**0**	**22**	**11**	**11**	**5**	**1**		**50.0**

* In Bays and Harbors, trawls were towed for 5 minutes and sampled an average area of 1,527 m^2.

* On the Inner, Middle, and Outer Shelf, and Upper slope, trawls were towed for 10 min, an average area of 2,933 m^2.

CL = Confidence limits (± value); Min. = Minimum; Max. = Maximum; No. = Number;
SD = Standard deviation.

** Total species = total species in each subpopulation

*** Total species (all stations) = total fish species in entire survey, not sum of total species by subpopulation.

Table IV-4. Demersal fish diversity by region and depth zones at depths of 2-484 m on the shelf and upper slope of southern California, July-September 2008.

Subpopulation	No. of Stations	Shannon-Wiener Diversity (bits/individuals/haul) Area-Weighted Values: Range Min.	Max.	Median	Mean	SD	95% CL	Percent Above Bight Median
Region								
Northern	52	0	2.37	1.62	1.53	0.52	0.16	51.85
Central	44	0.64	2.2	1.52	1.45	0.41	0.13	35.2
Southern	44	0	2.25	1.69	1.58	0.45	0.16	57.74
Shelf Zone								
Bays and Harbors (2-30 m)	**19**	**0**	**1.85**	**1.08**	**1.28**	**0.39**	**0.19**	**28.65**
Central Region	6	0.69	1.82	1.05	1.12	0.34	0.27	4.89
Southern Region	13	0	1.85	1.49	1.42	0.38	0.21	39.19
Inner Shelf (2-30 m)	**32**	**0**	**2.31**	**1.13**	**1.17**	**0.49**	**0.17**	**16.58**
Northern Region	12	0.5	2.31	1.16	1.31	0.55	0.31	28.85
Central Region	13	0.64	2.06	1.06	1.17	0.38	0.21	8.76
Southern Region	7	0	1.32	0.95	0.88	0.44	0.35	0
Middle Shelf (31-120 m)	**33**	**0.88**	**2.26**	**1.63**	**1.64**	**0.41**	**0.14**	**52.78**
Northern Region	9	1.37	2.26	1.6	1.73	0.3	0.2	49.08
Central Region	13	0.88	2.14	1.31	1.39	0.41	0.22	19.97
Southern Region	11	1.18	2.25	1.83	1.88	0.3	0.18	83.18
Outer Shelf (121-200 m)	**23**	**1.12**	**2.18**	**1.7**	**1.68**	**0.36**	**0.15**	**61.26**
Northern Region	11	1.16	2.18	1.83	1.76	0.4	0.24	58.35
Central Region	3	1.18	2.05	1.24	1.51	0.39	0.44	19.67
Southern Region	9	1.12	1.98	1.68	1.65	0.27	0.17	67.15
Upper Slope (201-500 m)	**33**	**0**	**2.37**	**1.63**	**1.53**	**0.46**	**0.16**	**52.69**
Northern Region	20	0	2.37	1.64	1.48	0.54	0.24	51.05
Central Region	9	1.09	2.2	1.64	1.67	0.28	0.18	58.07
Southern Region	4	1.21	1.73	1.39	1.43	0.23	0.22	19.82
Total (all stations)	**143**	**0.00**	**2.37**	**1.60**	**1.52**	**0.47**	**0.09**	**50.00**

* Bay and Harbor stations were 5 min. tows with a mean area towed of 1,527 m^2.
* Stations in other subpopulations were 10 min. tows with a mean area towed of 2,933 m^2.
CL = Confidence limits (± value); Min. = Minimum; Max. = Maximum; No. = Number;
SD = Standard deviation.

Table IV-5. Demersal fish species occurring in 20% or more of the area in the regional survey of the mainland shelf and slope of southern California at depths of 2-484 m, July-September 2008.

Common Name	Scientific Name	No. of Stations	Percent of Stations	Percent of Area*
Dover sole	*Microstomus pacificus*	71	51	65.7
slender sole	*Lyopsetta exilis*	57	41	53.4
Pacific sanddab	*Citharichthys sordidus*	65	46	44.0
English sole	*Parophrys vetulus*	59	42	42.8
hornyhead turbot	*Pleuronichthys verticalis*	55	39	36.4
yellowchin sculpin	*Icelinus quadriseriatus*	40	29	31.2
plainfin midshipman	*Porichthys notatus*	43	31	30.4
stripetail rockfish	*Sebastes saxicola*	41	29	28.6
Pacific hake	*Merluccius productus*	27	19	28.6
pink seaperch	*Zalembius rosaceus*	41	29	27.3
California tonguefish	*Symphurus atricaudus*	43	31	27.0
shortspine combfish	*Zaniolepis frenata*	39	28	25.8
rex sole	*Glyptocephalus zachirus*	26	19	25.7
blacktip poacher	*Xeneretmus latifrons*	34	24	25.3
speckled sanddab	*Citharichthys stigmaeus*	43	31	24.8
longspine combfish	*Zaniolepis latipinnis*	30	21	23.1
California lizardfish	*Synodus lucioceps*	36	26	23.1
blackbelly eelpout	*Lycodes pacificus*	28	20	23.0
bigmouth sole	*Hippoglossina stomata*	30	21	22.4
longfin sanddab	*Citharichthys xanthostigma*	28	20	21.6
shortspine thornyhead	*Sebastolobus alascanus*	15	11	20.5
bigfin eelpout	*Lycodes cortezianus*	17	12	20.3
roughback sculpin	*Chitonotus pugetensis*	26	19	20.0
splitnose rockfish	*Sebastes diploproa*	18	13	19.7

Table IV-6. Demersal fish species comprising 50% or more of the area by region and shelf zone on the southern California shelf and upper slope at depths of 2-484 m, July-September 2008.

		Percent of Area								
		Region			Shelf Zone					
Species	Common Name	N	C	S	B&H	IS	MS	OS	US	SCB
Microstomus pacificus	Dover Sole	72	-	80	-	-	55	100	91	66
Lyopsetta exilis	slender sole	67	-	-	-	-	-	100	91	53
Citharichthys sordidus	Pacific sanddab	-	-	55	-	-	91	100	-	-
Parophrys vetulus	English sole	-	51	-	-	-	64	70	-	-
Pleuronichthys verticalis	hornyhead turbot	-	56	-	-	68	82	-	-	-
Icelinus quadriseriatus	yellowchin sculpin				-	-	91	-	-	-
Porichthys notatus	plainfin midshipman	-	-	-	-	-	70	61	-	-
Sebastes saxicola	stripetail rockfish	-	-	-	-	-	-	87	-	-
Merluccius productus	Pacific hake	-	-	-	-	-	-	-	55	-
Zalembius rosaceus	pink seaperch	-	-	-	-	-	67	61	-	-
Symphurus atricaudus	California tonguefish	-	-	-	50	-	67	-	-	-
Zaniolepis frenata	shortspine combfish	-	-	-	-	-	-	96	-	-
Xeneretmus latifrons	blacktip poacher	-	-	-	-	-	-	87	-	-
Citharichthys stigmaeus	speckled sanddab	-	-	-		94	-	-	-	-
Zaniolepis latipinnis	longspine combfish	-	-	-	-	-	70	-	-	-
Synodus lucioceps	California lizardfish	-	-	-	-	55	-	-	-	-
Lycodes pacificus	blackbelly eelpout	-	-	-	-	-	-	61	-	-
Hippoglossina stomata	bigmouth sole	-	-	-	-	-	64	-	-	-
Citharichthys xanthostigma	longfin sanddab	-	-	-	-	-	61	-	-	-
Chitonotus pugetensis	roughback sculpin	-	-	-	-	-	55	-	-	-
Sebastes eos	pink rockfish	-	-	-	-	-	-	52	-	-
Sebastes semicinctus	halfbanded rockfish	-	-	-	-	-	-	52	-	-
Chilara taylori	spotted cusk-eel	-	-	-	-	-	-	52	-	-
Sebastes elongatus	greenstriped rockfish	-	-	-	-	-	-	65	-	-
Paralichthys californicus	California halibut	-	-	-	66	-	-	-	-	-
Paralabrax nebulifer	barred sand bass	-	-	-	65	-	-	-	-	-

N = Northern; C = Central; S = Southern; B&H = Bays and harbors; IS = Inner shelf; MS = Middle shelf; OS = Outer shelf; SCB = Southern California Bight

Table IV-7. Demersal fish species comprising 95% or more of the total fish abundance on the southern California shelf and upper slope at depths of 2-484 m, July to September 2008.

Scientific Name	Common Name	Abundance	Total Percent	Cumulative Percent
Citharichthys sordidus	Pacific sanddab	4,406	15.5	15.5
Lyopsetta exilis	slender sole	3,904	13.8	29.3
Citharichthys stigmaeus	speckled sanddab	2,659	9.4	38.7
Icelinus quadriseriatus	yellowchin sculpin	1,989	7.0	45.7
Microstomus pacificus	Dover sole	1,187	4.2	49.9
Genyonemus lineatus	white croaker	1,184	4.2	54.0
Sebastes semicinctus	halfbanded rockfish	1,154	4.1	58.1
Sebastes saxicola	stripetail rockfish	1,096	3.9	62.0
Parophrys vetulus	English sole	1,076	3.8	65.7
Zalembius rosaceus	pink seaperch	977	3.4	69.2
Zaniolepis frenata	shortspine combfish	667	2.4	71.5
Zaniolepis latipinnis	longspine combfish	626	2.2	73.7
Engraulis mordax	northern anchovy	596	2.1	75.8
Lycodes pacificus	blackbelly eelpout	480	1.7	77.5
Porichthys notatus	plainfin midshipman	423	1.5	79.0
Sebastes diploproa	splitnose rockfish	383	1.3	80.4
Seriphus politus	queenfish	381	1.3	81.7
Chitonotus pugetensis	roughback sculpin	345	1.2	82.9
Citharichthys xanthostigma	longfin sanddab	323	1.1	84.1
Symphurus atricaudus	California tonguefish	313	1.1	85.2
Pleuronichthys verticalis	hornyhead turbot	297	1.0	86.2
Xeneretmus latifrons	blacktip poacher	260	0.9	87.1
Sebastolobus alascanus	shortspine thornyhead	226	0.8	87.9
Cymatogaster aggregata	shiner perch	216	0.8	88.7
Glyptocephalus zachirus	rex sole	201	0.7	89.4
Synodus lucioceps	California lizardfish	172	0.6	90.0
Sebastes jordani	shortbelly rockfish	151	0.5	90.5
Lyconema barbatum	bearded eelpout	128	0.5	91.0
Merluccius productus	Pacific hake	125	0.4	91.4
Anchoa delicatissima	slough anchovy	124	0.4	91.9
Paralabrax nebulifer	barred sand bass	120	0.4	92.3
Umbrina roncador	yellowfin croaker	104	0.4	92.7
Phanerodon furcatus	white seaperch	91	0.3	93.0
Sebastes dallii	calico rockfish	89	0.3	93.3
Paralichthys californicus	California halibut	87	0.3	93.6
Sebastes elongatus	greenstriped rockfish	83	0.3	93.9
Physiculus rastrelliger	hundred-fathom codling	79	0.3	94.2
Urobatis halleri	round stingray	78	0.3	94.5
Hippoglossina stomata	bigmouth sole	75	0.3	94.7
Odontopyxis trispinosa	pygmy poacher	75	0.3	95.0
Lycodes cortezianus	bigfin eelpout	74	0.3	95.2

Combined total abundance of fish species listed in this table = 27,024.
Total abundance of fish collected in the Bight'08 trawl survey = 28,374.
Total number of stations = 143.

Table IV-8. Demersal fish species comprising 77% or more of the fish abundance by region and depth zone on the southern California shelf and upper slope at depths of 2-484 m, July-September 2008.

		Region			Shelf Zone					
Species*	Common Name	N	C	S	B&H	IS	MS	OS	US	SCB
Citharichthys sordidus	Pacific sanddab	18	12	18	-	6	24	27	-	16
Lyopsetta exilis	slender sole	14	12	16	-	-	-	27	42	14
Citharichthys stigmaeus	speckled sanddab	10	11	6	-	59	-	-	-	9
Icelinus quadriseriatus	yellowchin sculpin	3	10	7	-	5	19	-	-	7
Microstomus pacificus	Dover sole	6	3	3	-	-	-	-	16	4
Genyonemus lineatus	white croaker	-	11	-	37	-	-	-	-	4
Sebastes semicinctus	halfbanded rockfish	-	7	3	-	-	10	-	-	4
Sebastes saxicola	stripetail rockfish	4	2	6	-	-	-	11	-	4
Parophrys vetulus	English sole	8	2		-	4	7	-	-	4
Zalembius rosaceus	pink seaperch	6	-	4	-	-	8	-	-	3
Zaniolepis frenata	shortspine combfish	3	-	4	-	-	-	8	-	2
Zaniolepis latipinnis	longspine combfish	3	-	2	-	-	6	-	-	2
Engraulis mordax	northern anchovy	-	4	-	16	-	-	-	-	2
Lycodes pacificus	blackbelly eelpout	4	-	-	-	-	-	5	2	2
Porichthys notatus	plainfin midshipman	-	-	2	-	-	-	-	-	1
Sebastes diploproa	splitnose rockfish	-	-	-	-	-	-	-	6	1
Anchoa delicatissima	slough anchovy	-	-	2	4	-	-	-	-	-
Chitonotus pugetensis	roughback sculpin	-	2	2	-	-	3	-	-	-
Citharichthys xanthostigma	longfin sanddab	-	-	3	-	-	3	-	-	-
Cymatogaster aggregata	shiner perch	-	-	-	4	-	-	-	-	-
Glyptocephalus zachirus	rex sole	-	-	-	-	-	-	-	3	-
Lyconema barbatum	bearded eelpout	-	-	-	-	-	-	-	3	-
Paralabrax nebulifer	barred sand bass	-	-	2	4	-	-	-	-	-
Pleuronichthys verticalis	hornyhead turbot	-	-	-	-	4	-	-	-	-
Sebastes jordani	shortbelly rockfish	-	-	-	-	-	-	-	3	-
Sebastolobus alascanus	shortspine thornyhead	-	-	-	-	-	-	-	5	-
Seriphus politus	queenfish	-	3	-	12	-	-	-	-	-
Umbrina roncador	yellowfin croaker	-	-	1	-	-	-	-	-	-
percent abundance		79	80	80	79	78	79	77	80	80
no. species comprising ~ 80% of abundance		11	12	16	6	5	8	5	8	16

"-" Species not ocurring in at least 80% of the fish abundance or absent.

N = Northern; C = Central; S = Southern; B&H = Bays and Harbors; IS = Inner Shelf; MS = Middle Shelf; OS = Outer Shelf; US = Upper Slope; SCB = Southern California Bight.

Total catch abundance (no. of individuals by subpopulation; N = 10,023; C = 10,930; S = 7,421; B&H = 3,054; IS = 3,901; MS = 9,663; OS = 6,918; US = 4,838; SCB = 28,374.

Table IV-9. Demersal fish species comprising 95% or more of the total fish biomass on the southern California shelf and upper slope at depths of 2-484 m, July to September 2008.

Scientific Name	Common Name	Biomass (kg)	Percent	Cumulative Percent
Citharichthys sordidus	Pacific sanddab	177.0	16.8	16.8
Microstomus pacificus	Dover sole	114.6	10.9	27.7
Lyopsetta exilis	slender sole	98.0	9.3	36.9
Parophrys vetulus	English sole	63.7	6.0	43.0
Genyonemus lineatus	white croaker	62.5	5.9	48.9
Sebastes semicinctus	halfbanded rockfish	43.1	4.1	53.0
Sebastes saxicola	stripetail rockfish	27.2	2.6	55.6
Pleuronichthys verticalis	hornyhead turbot	25.1	2.4	58.0
Citharichthys stigmaeus	speckled sanddab	24.0	2.3	60.2
Merluccius productus	Pacific hake	23.5	2.2	62.5
Urobatis halleri	round stingray	23.2	2.2	64.7
Paralichthys californicus	California halibut	21.6	2.0	66.7
Raja rhina	longnose skate	21.4	2.0	68.7
Glyptocephalus zachirus	rex sole	21.1	2.0	70.7
Sebastolobus alascanus	shortspine thornyhead	18.0	1.7	72.4
Paralabrax maculatofasciatus	spotted sand bass	16.0	1.5	74.0
Lycodes pacificus	blackbelly eelpout	14.1	1.3	75.3
Sebastes diploproa	splitnose rockfish	14.1	1.3	76.6
Zaniolepis frenata	shortspine combfish	12.8	1.2	77.9
Zalembius rosaceus	pink seaperch	12.4	1.2	79.0
Citharichthys xanthostigma	longfin sanddab	12.2	1.2	80.2
Umbrina roncador	yellowfin croaker	12.0	1.1	81.3
Zaniolepis latipinnis	longspine combfish	11.6	1.1	82.4
Porichthys notatus	plainfin midshipman	11.2	1.1	83.5
Seriphus politus	queenfish	9.7	0.9	84.4
Cheilotrema saturnum	black croaker	8.2	0.8	85.2
Sebastes jordani	shortbelly rockfish	7.8	0.7	85.9
Paralabrax nebulifer	barred sand bass	7.7	0.7	86.7
Sebastes aurora	aurora rockfish	7.5	0.7	87.4
Scorpaena guttata	California scorpionfish	7.5	0.7	88.1
Icelinus quadriseriatus	yellowchin sculpin	7.4	0.7	88.8
Anoplopoma fimbria	sablefish	6.6	0.6	89.4
Phanerodon furcatus	white seaperch	6.3	0.6	90.0
Synodus lucioceps	California lizardfish	5.1	0.5	90.5
Lycodes cortezianus	bigfin eelpout	5.1	0.5	91.0
Raja inornata	California skate	5.0	0.5	91.5
Myliobatis californica	bat ray	5.0	0.5	91.9
Xystreurys liolepis	fantail sole	5.0	0.5	92.4
Roncador stearnsii	spotfin croaker	4.8	0.5	92.9
Hippoglossina stomata	bigmouth sole	4.8	0.5	93.3
Symphurus atricaudus	California tonguefish	4.1	0.4	93.7
Sebastes melanostomus	blackgill rockfish	4.0	0.4	94.1
Squalus acanthias	spiny dogfish	4.0	0.4	94.5
Pleuronichthys ritteri	spotted turbot	3.9	0.4	94.8
Rhinobatos productus	shovelnose guitarfish	3.7	0.4	95.2
Sebastes elongatus	greenstriped rockfish	3.6	0.3	95.5

Total biomass = 1688.1 kg

Table IV-10. Demersal fish species comprising 80% or more of the fish biomass by subpopulation on the southern California shelf and slope at depths of 2-484 m, July-September 2008.

		Percent Catch Biomass								
		Region Mainland			Depth Zone					
Species		N	C	S	B&H	IS	MS	OS	US	SCB
Citharichthys sordidus	Pacific sanddab	25	10	15	-	5	21	49	-	17
Microstomus pacificus	Dover sole	17	8	6	-	-	-	4	31	11
Lyopsetta exilis	slender sole	9	10	9	-	-	-	13	19	9
Parophrys vetulus	English sole	10	5	2	-	6	16	6	-	6
Genyonemus lineatus	white croaker	-	15	-	35	4	-	-	-	6
Sebastes semicinctus	halfbanded rockfish	-	9	3	-	-	18	-	-	4
Sebastes saxicola	stripetail rockfish	3	-	4	-	-	-	7	-	3
Pleuronichthys verticalis	hornyhead turbot	-	5	-	-	13	6	-	-	2
Citharichthys stigmaeus	speckled sanddab	2	3	2	-	25	-	-	-	2
Merluccius productus	Pacific hake	2	3	-	-	0	-	-	7	2
Urobatis halleri	round stingray	-	-	8	14	0	-	-	-	2
Paralichthys californicus	California halibut	-	3	3	6	14	-	-	-	2
Raja rhina	longnose skate	3	-	2	-	-	-	-	6	2
Glyptocephalus zachirus	rex sole	-	4	2	-	-	-	-	6	2
Sebastolobus alascanus	shortspine thornyhead	-	-	2	-	-	-	-	6	2
Paralabrax maculatofasciatus	spotted sand bass	-	-	6	9	-	-	-	-	2
Lycodes pacificus	blackbelly eelpout	3	-	-	-	-	-	-	-	1
Sebastes diploproa	splitnose rockfish	-	3	-	-	-	-	-	4	1
Zaniolepis frenata	shortspine combfish	-	-	2	-	-	-	-	-	1
Zalembius rosaceus	pink seaperch	-	-	-	-	-	4	-	-	1
Citharichthys xanthostigma	longfin sanddab	-	-	3	-	-	5	-	-	1
Cheilotrema saturnum	black croaker	-	-	3	-	-	-	-	-	-
Icelinus quadriseriatus	yellowchin sculpin	-	-	-	-	-	3	-	-	-
Myliobatis californica	bat ray	-	-	2	-	-	-	-	-	-
Paralabrax nebulifer	barred sand bass	-	-	2	-	-	-	-	-	-
Phanerodon furcatus	white seaperch	-	-	2	-	5	-	-	-	-
Porichthys notatus	plainfin midshipman	2	-	-	-	-	-	-	-	-
Scorpaena guttata	California scorpionfish	-	-	-	-	-	2	-	-	-
Sebastes jordani	shortbelly rockfish	2	-	-	-	-	-	-	-	-
Seriphus politus	queenfish	-	2	-	6	-	-	-	-	-
Synodus lucioceps	California lizardfish	-	-	-	-	3	-	-	-	-
Umbrina roncador	yellowfin croaker	-	-	4	7	-	-	-	-	-
Xystreurys liolepis	fantail sole	-	-	-	-	3	-	-	-	-
Zaniolepis latipinnis	longspine combfish	2	-	-	-	-	5	-	-	-

"-" Species not ocurring in at least 80% of the fish biomass or absent.

N = Northern; C = Central; S = Southern; B&H = Bays and Harbors; IS = Inner Shelf; MS = Middle Shelf; OS = Outer Shelf; US = Upper Slope; SCB = Southern California Bight.

Total catch abundance (no. of individuals by subpopulation; N = 388.4; C = 376.3; S = 289.6; B&H = 168.9; IS = 85.4; MS = 208.6; OS = 265.2; US = 326.1; SCB = 1,054.3.

Table IV-11. Demersal fish species with greatest and least lengths collected on the southern California shelf and upper slope at depths of 2-484 m, July-September 2008. (Min. = minimum; Max. = maximum).

		Length (CM)			Total
Speceis Name	Common Name	Min	Max	Mean	Number
a) largest Species					
spiny dog fish	*Squalus acanthias*	101	101	101	1
longnose skate	*Raja rhina*	24	91	51	11
shovelnose guitarfish	*Rhinobatos productus*	23	79	39	8
California skate	*Raja inornata*	12	58	29	21
sablefish	*Anoplopoma fimbria*	37	56	50	3
brown smoothhound	*Mustelus henlei*	51	51	51	1
Pacific hagfish	*Eptatretus stoutii*	26	44	35	7
spotted ratfish	*Hydrolagus colliei*	33	43	39	7
California halibut	*Paralichthys californicus*	11	42	22	87
Pacific hake	*Merluccius productus*	11	41	27	125
b) Smallest Species					
kelp clingfish	*Rimicola muscarum*	2	2	2	2
greenblotched rockfish	*Sebastes rosenblatti*	2	19	11	24
slough anchovy	*Anchoa delicatissima*	3	8	5	124
tropical (=silver) hachetfish	*Argyropelecus lychnus*	3	4	4	5
lowcrest hatchetfish	*Argyropelecus sladeni*	3	3	3	2
Pacific sanddab	*Citharichthys sordidus*	3	26	12	4406
speckled sanddab	*Citharichthys stigmaeus*	3	13	8	2659
spotted kelpfish	*Gibbonsia elegans*	3	3	3	2
yellowchin sculpin	*Icelinus quadriseriatus*	3	9	7	1989
cheekspot goby	*Ilypnus gilberti*	3	3	3	4

Table IV-12. Number of fish by species with different anomaly types collected at depths of 2-484 m on the southern California shelf and slope, July-September 2008.

			Pigmentation					Total	
Scientific Name	**Common Name**	**Par**	**Tu**	**Am**	**De**	**AB**	**OvAn**	**OvTotFi**	**%An**
Cheilotrema saturnum	black croaker	2	-	-	-	-	2	42	4.8
Citharichthys sordidus	Pacific sanddab	22	-	-	1	-	23	4,406	0.5
Citharichthys stigmaeus	speckled sanddab	3	-	-	1	-	4	2,659	0.2
Genyonemus lineatus	white croaker	-	-	-	2	-	2	1,184	0.2
Microstomus pacificus	Dover sole	-	2	-	-	-	2	1,187	0.2
Myliobatis californica	bat ray	2	-	-	-	-	2	8	25.0
Paralichthys californicus	California halibut	2	-	4	-	-	6	87	6.9
Parophrys vetulus	English sole	1	-		-	-	1	1,076	0.1
Phanerodon furcatus	white seaperch	2	-		-	-	2	91	2.2
Pleuronichthys guttulatus	diamond turbot	-	-	1	-	-	1	8	12.5
Pleuronichthys verticalis	hornyhead turbot	3	-	3	1	1	8	297	2.7
Umbrina roncador	yellowfin croaker	2	-	-	-	-	2	104	1.9
Total		39	2	8	5	1	55[a]	11,149[b]	0.5

[a] Total reflects number of fish with anomalies.

[b] Total of all fish in survey.

Par=Parasite; Tu=Tumor; Am=Ambicoloration; AB=Ambicoloration/Albinism; De=Deformity (Skeletal); OvAn=Overall anomalous; OvTotFi=Overall total fish; %An=Percent anomalous.

Table IV-13. Percent area by region and depth zone subpopulations of fish with different anomaly types collected at depths of 2-484 m on the southern California shelf and slope, July-September 2008. Number of stations are only those with area weights. Three stations do not have area weights.

Subpopulation	No. of Stations	Percent of Area with Anomaly					
		Par	Tu	Am	De	A/B	Overall*
Region							
North	52	7.2	1.9	4.2			13.3
Central	44	8.7	1.2	1.8	7.4	1.6	16.3
South	44	22.3					22.3
Shelf zone							
Bays and Harbors	19	13.9		7.8	7.8		29.5
Inner Shelf	32	22.6		9.7	3.2	3.2	32.3
Middle shelf	33	15.2	3.0	3.0	6.1		27.3
Outer shelf	23	17.4	4.3				17.4
Upper Slope	33	3.0					3.0
Total all stations	140	11.0	1.3	2.5	2.4	0.5	16.3

Par=Parasite; Tu=Tumor; Am=Ambicoloration; AB=Ambicoloration/Albinism; De=Deformity (Skeletal)

* "Overall" column values only count anomalies as one per station even if there are multiple anomaly types at the same station to prevent summing the same area weights more than once. Therefore in these cases, "Overall" column values will be less than the sum of all the anomaly types for the same subpopulation.

Table IV-14. Comparison of demersal fish population attributes on the mainland shelf (10-200 m) by region and year(s) for the Southern California Bight (SCB) in 1957-1975[a], 1994, 1998, 2003, and 2008 regional survey data.

		Mean/haul[a]			
Southern California Bight Database	No. samples	Abundance (no. of individuals)	Biomass (kg)	No. of Species	Diversity[b] (bits/individual)
Northern Region					
1957-1975[c]	14-74	64-147	3.5	8-12	0.91-1.50
1994[d]	43	136	3.5	12	1.71
1998[e]	65	136	4.6	9	1.45
2003[f]	35	195	4.0	12	1.45
2008[g]	32	259	7.0	14	1.60
Central Region					
1957-1975[c]	296-853	139-420	7.6-13.4	10-16	1.23-1.64
1994[d]	39	150	6.6	11	1.48
1998[e]	78	158	7.0	10	1.54
2003[f]	52	387	8.1	15	1.53
2008[g]	29	242	6.0	11	1.32
Southern Region					
1957-1975[c]	17-347	97-192	5-6.2	10-12	1.27-1.5
1994	28	197	5.7	11	1.47
1998[e]	54	174	5.5	11	1.66
2003[f]	41	267	4.8	14	1.48
2008[g]	27	230	5.5	13	1.64
All Mainland Shelf Regions[h]					
1957-1975[c]	2210	64-420	3.5-13.4	8.1-16.1	0.91-1.64
1994[d]	110	154	4.8	12	1.59
1998[e]	197	156	5.8	10	1.57
2003[f]	128	294	5.9	14	1.49
2008[g]	88	244	6.2	13	1.51

[a]The 1994, 1998, 2003, and 2008 mean values are weighted in accordance with the sampling design.
[b]1957-1975 are Brillouin diversities; 1994, 1998, 2003, and 2008 values are Shannon-Wiener diversities.
[c]1957-1975 data from Allen and Voglin (1976).
[d]Values have been revised because original values included mainland stations down to 215 m.
[e]Data from Islands (except 1957-1975) and Bays/Harbors are excluded from 1998 analysis.
[f]Data from Islands (except 1957-1975), Bays/Harbors, and Upper Slope (201-500 m) are excluded from 2003 analysis.
[g]Data from Bays/Harbors, and Upper Slope (201-500 m) are excluded from 2008 analyses.
[h]SCB as a whole.

Table IV-15. Comparison of demersal fish species occurring in greater than 20% of the area of the mainland shelf of southern California in 1994, 1998, 2003, and 2008.

		No. of Stations				Percent of Stations				Percent of Area*			
Scientific Name	Common Name	'94	'98[a]	'03[b]	'08[c]	'94	'98[a]	'03[b]	'08[c]	'94	'98[a]	'03[b]	'08[c]
Citharichthys sordidus (1, 7, 1)	Pacific sanddab	73	76	98	62	66	39	77	70	68.9	47.0	79.5	74.1
Pleuronichthys verticalis (5, 3, 3)	hornyhead turbot	60	93	83	52	55	47	65	59	53.0	54.4	67.7	67.2
Parophrys vetulus (10, 9, 2)	English sole	48	62	78	51	44	31	61	58	47.1	40.8	74.5	59.1
Icelinus quadriseriatus (6, 5, 4)	yellowchin sculpin	51	75	68	39	46	38	53	44	52.5	52.5	54.0	57.9
Porichthys notatus (3, 12, 13)	plainfin midshipman	57	52	49	41	52	26	38	47	56.0	37.2	43.4	51.5
Zalembius rosaceus (12, 10, 4)	pink seaperch	44	54	72	41	40	27	56	47	45.2	40.7	53.1	50.8
Symphurus atricaudus (11, 2, 7))	California tonguefish	48	112	59	36	44	57	46	41	45.7	66.4	51.2	49.2
Microstomus pacificus (2, 16, 12)	Dover sole	61	40	60	41	55	20	47	47	56.1	27.2	43.5	45.8
Citharichthys stigmaeus (15,11, 6)	speckled sanddab	47	70	65	40	43	36	51	45	37.3	39.1	51.9	45.7
Zaniolepis latipinnis	longspine combfish	44	51	67	30	40	26	52	34	47.6	44.0	49.4	43.0
Synodus lucioceps (4, 1, 17)	California lizardfish	58	135	38	33	53	69	30	38	53.2	74.1	31.9	42.5
Hippoglossina stomata (7, 6, 11)	bigmouth sole	56	87	57	30	51	44	45	34	50.3	49.8	44.6	41.6
Sebastes saxicola (13, 13, 5)	stripetail rockfish	46	46	60	36	42	23	47	41	45.2	35.7	52.0	40.4
Citharichthys xanthostigma (8, 4, 10)	longfin sanddab	55	101	64	28	50	51	50	32	50.2	53.6	48.1	40.2
Chitonotus pugetensis	roughback sculpin	13	10	45	26	12	5	35	30	10.2	7.2	37.3	37.2
Zaniolepis frenata	shortspine combfish	29	22	30	34	26	11	23	39	23.2	14.8	23.0	35.3
Odontopyxis trispinosa	pygmy poacher	6	15	28	21	5	8	22	24	4.9	14.0	22.3	31.1
Sebastes semicinctus	halfbanded rockfish	15	7	38	21	14	4	30	24	13.6	4.5	37.9	23.3
Scorpaena guttata	California scorpionfish	26	39	42	17	24	20	33	19	20.2	19.6	27.0	22.9
Lyopsetta exilis	slender sole	33	30	27	27	30	15	21	31	28.0	18.7	19.5	22.8
Raja inornata	California skate	25	31	25	15	23	16	20	17	24.0	13.4	23.5	21.4
Total (all stations)		110	197	128	88					2980[e]	3,344[e]	3,089[e]	3723[e]

*Percent of area based on area-weighted frequency of occurrences.
[a]Mainland shelf only (5-200 m); stations in island and bay/harbor subpopulations were excluded from the 1998 analyses.
[b]Mainland shelf only (5-200 m); stations in island, bay/harbor, and upper slope subpopulations were excluded from the 2003 analyses.
[c]Mainland shelf only (5-200 m); stations in bay/harbor and upper slope subpopulations excluded from the 2008 analyses.
[d]Numbers in parentheses represent rank of species by percent of areal occurrence in 1994, 1998, and 2003 (species occurred in greater than 50% of the area in any one of the years).
[e]Total area in km^2.
Areal occurrences of 50% or greater are shaded in gray.

V. MEGABENTHIC INVERTEBRATE POPULATIONS

Introduction

Invertebrates living on the seafloor and large enough to be retained by a trawl net are termed megabenthos. Hundreds of megabenthic invertebrate species reside within the Southern California Bight (SCB; Allen *et al.* 2002). Because these species are relatively sedentary and respond to changes in the benthic environment, their populations have been used for decades to assess the impact of human activities. Most information on the megabenthic invertebrate fauna of the southern California shelf comes from regular trawl surveys conducted near ocean outfalls. While local areas have been well-studied for temporal and small-scale spatial variability, no synoptic regional assessment was conducted until 1994 (Allen *et al.* 1998, Stull *et al.* 2001). Although that study provided substantial information on the mainland shelf (10-200 m depth), it did not cover bays and harbors, islands, or the slope of the SCB. A second regional survey was conducted in 1998 (Allen *et al.* 2002) which included bays, harbors, and island habitats. Another iteration in 2003 (Allen *et al.* 2007) covered bays, harbors, islands, and upper slopes along with the mainland shelf.

Objectives of this chapter are 1) to describe the distribution, relative importance (areal coverage, abundance, and biomass) and health of the dominant invertebrates of the SCB in bays, on the shelf and slope, and in select geographic and depth subpopulations in 2008; 2) to assess population changes between 1994, 1998, 2003, and 2008; and 3) to examine historical trends based on earlier studies. This information will provide context for local patterns observed in monitoring studies. Since this was only the second survey to sample on the upper continental slope, a discussion of that stratum is provided in Appendix D-5. Other analyses of this fauna are presented in Chapter VII.

Results: Bight Megabenthic Invertebrate Populations in 2008

Abundance

A total of 201,677 invertebrates were collected during the survey (TableV-1). The number per trawl ranged from 0 to 22,182. Lowest abundance values occurred on the upper slope in the Northern Region, on the inner shelf in all regions, and in bays in the Southern Region. Greatest catches occurred on the middle shelf in the Central Region, and on the upper slope in the Northern and Southern Regions. The median for the Bight as a whole was 395 individuals per haul, with subpopulation medians ranging from 10 (Southern Region bays/harbors) to 5,595 (Southern Region upper slope). The highest average abundance (more area above than below the Bight median) occurred at stations on the Southern Region upper slope (100% above Bight median). The lowest average abundance occurred on the inner shelf (none above Bight median). Median abundance declined with decreasing depth from the upper slope to bays. Slope median abundance was an order of magnitude greater than the outer shelf median, and two orders of magnitude higher than inner shelf median (Table V-1). Over 75% of the total catch came from stations in the upper slope subpopulaton.

Over 2,287 invertebrates per haul were caught at 16 stations (Figure V-1). These high abundance sites were typically on the upper slope, with a few at middle or outer shelf depths. Most were located in the Santa Barbara Channel. The highest invertebrate catch of 22,182 individuals occurred at a middle shelf site in Santa Monica Bay (Central Region). This represented more than 10% of the survey aggregate catch, and contained two orders of magnitude more invertebrates than the survey median. More than half the sites had more than 131 invertebrates in the catch. One upper slope site in the Santa Barbara Channel had no invertebrates. A second site in the bay/harbor subpopulation near Oceanside also lacked megabenthic invertebrates (Figure V-1).

Biomass

A total of 2126 kg of invertebrates were taken during the survey (Table V-2). The biomass of invertebrates per haul ranged from 0 to 367.1 kg. Low values occurred in all three regions and at all bathymetric zones other than the outer shelf. The highest haul biomass occurred on the northern region upper slope. The Bight-wide median was 6.4 kg/haul, with subpopulation medians ranging from 0.3 kg (bays/harbors and inner shelf) to 26.9 at upper slope sites. Invertebrate biomass was highest (more sites above the bight median) at Southern Region upper slope sites (all above the median, Table V-2). Only the Southern Region outer shelf sites, and upper slope sites from all three regions were above the Bight median biomass.

Median biomass increased from 0.3 kg/haul at bay/harbor and inner shelf depths, to 26.9 kg/haul at upper slope depths. These increases ranged from three fold (middle to outer shelf sites) to an order of magnitude (inner to middle shelf sites and outer shelf to upper slope sites).

Thirteen stations, 9 in the Santa Barbara Channel, had catches over 46.9 kg (Figure V-2). Of the remaining 4 high biomass sites, 3 were located on the mainland shelf off San Diego, and one in San Diego Bay. Most stations (58) had biomass between 0.1and 3 kg/haul, and 57 had catches between 3.1 and 46.8kg, while 15 sites had invertebrate biomass of less than 0.1kg

Species Richness

The 2008 regional monitoring effort collected 215 species of invertebrates (Table V-3). Species richness (expressed as number of species) per haul ranged from 0 to 27. Invertebrates were caught at all sites except one on the upper slope in the Northern Region, and one in bays/harbors near Oceanside. The highest number of species/haul (27) was taken on the Central Region upper slope. Median richness was very similar in all three regions, increasing slightly from south to north.

Median richness was very similar in bathymetric subpopulations from middle shelf through upper slope depths; roughly twice that seen in inner shelf and bay/harbor sites. Richness was above the Bightwide median at middle shelf, outer shelf, and upper slope sites, and below the median at shallower stations. Closer examinaton of that pattern shows it varied with coastal region, with only Central Region middle shelf sites and Northern Region upper slope sites above the median. At outer shelf depths, Central Region sites were below the Bightwide median of 11 species per haul, while those of the other regions exceeded the median value. Fourteen stations had more than 17 species, with six of these in the Santa Barbara Channel (Figure V-3). The remaining high richness sites were found in Santa Monica Bay, on the San Pedro Seashelf, off San Diego, and off Oceanside at declining frequency. The majority of sites (75) had more than 10 species of invertebrates/haul. About 13% of the sites had 3 or less species/haul.

Diversity

Invertebrate diversity ranged from 0.0 to 2.39 bits/individual/haul (Table V-4). Values of zero occurred in all except the central region; on the inner shelf in the Southern Region, and on the upper slope in the Northern Region. The highest diversity occurred inshore along the southern Orange County and northern San Diego County portions of the Central Region. The median for the Bight as a whole was 1.15

bits/individual/haul, with subpopulation medians ranging from 0.92 in bays/harbors to 1.49 on the outer shelf. Invertebrate diversity was higher (more area above the Bight median) at outer shelf sites, where values exceeded the median in both the Central and Northern Regions (Table V-4). Both Northern and Southern Region inner shelf sites also exceeded the Bight median, as did upper slope sites in the Northern Region. Diversity was quite low in the four Southern Region upper slope sites, with none above the Bight median

Lowest diversity sites were scattered, with sites showing zero diversity in the middle of the Santa Barbara Channel in the Northern Region, and on the inner shelf off Dana Point and in Oceanside Harbor in the Southern Region. No null diversity sites were located in the Central Region.

The 15 sites falling in the highest diversity category (Figure V-4) were scattered among all three geographic regions, and from the inner shelf to the upper slope. Nearly half of these sites were located in the Northern Region, with 5 inner shelf and two outer shelf sites on the mainland side of the Santa Barbara Channel. Three inner shelf, one outer shelf and one upper slope site with high diversity occurred in the Central Region. Three high diversity sites were sampled in the Southern Region; two on the inner shelf and one on the outer shelf. Most sites (114 in two diversity categories) had values ranging between 0.797 and 2.070 bits/individual/haul (Figure V-4).

Anomalies and Parasites

Megabenthic invertebrate health appeared excellent, with no anomalies or disease, and only one type of parasite recorded. There were no reported cases of crustacean burn-spot disease or echinoderm wasting disease in 2008, both known to have occurred in the SCB during previous warm water El Niño Southern Oscillation (ENSO) episodes (Stull *et al.* 2001). Recent evidence suggests that these disease outbreaks are controlled by temperature, and should be rare or absent during the cooler phase of the PDO. The causative agent is present, but infections at low ambient temperatures seldom progress to death of the animal (Bates *et al.* 2009).

Among 201,677 invertebrates caught, 3 were parasitized (0.0015% incidence). These parasites were the barnacle *Briarosaccus callosus* on the California king crab (*Paralithodes californicus*). Only three crabs of this species were taken in 2008 (Santa Barbara Channel, 197 m). Rathbun's king crab (*Paralithodes rathbuni*) is also a potential host for this parasite (Cadien and Martin 1999). Four of the latter were taken in 2008, but none were reported parasitized. Parasite prevalence in potential host species was 43% based on the population sample obtained. In 2003, two parasites were found, equaling a 25% prevalence in the crab population (Allen *et al.* 2007). Sample size is too small for meaningful comparison of the parasite prevalence in the two surveys. This parasite has a ramified growth form with tendrils of parasite tissue throughout the crab. Its reproductive body (a fusiform egg sack) is externally visible, protruding ventrally through the crab abdomen. A hyperparasite of *Briarosaccus*, the amphipod *Myzotarsa anaxiphilius* (Cadien and Martin 1999), was not reported from parasitized crabs in this instance, or in 2003.

Eulimid mollusk parasites of echinoderms, and bopyrid isopod gill parasites of shrimp, both reported in 2003 (Allen *et al.* 2007), were not reported from the 2008 regional effort. Both are reasonably visible during catch processing, and should have been reported if observed. The eulimids are known from sea urchin, sea cucumber, and sea star species taken during the 2008 trawls (Barwick and Douglas 2003). The bopyrids are recorded from a variety of pandalid, crangonid and hippolytid shrimp (Butler 1980), several of which were taken in 2008 (Appendix D-3). Despite the presence of available hosts, neither type of invertebrate parasite was observed in 2008 regional trawls.

Taxonomic Composition

Invertebrates representing 9 phyla, 20 classes, and 134 families were caught during the trawl survey (Appendix D-1; alphabetical lists of species by scientific and common name are given in Appendix G). A total of 215 taxa were taken, which included 4 identified only to high levels due to immaturity, and 211 identified species. Of these, 59 were arthropods, 52 mollusks, 47 echinoderms, 31 cnidarians, 7 sponges, 6 ectoprocts, 4 annelids, 3 chordates, and 2 brachiopods.

The most diverse classes were Malacostraca, with 57 species, Gastropoda with 47 species, and Asteroidea with 19 species. The most diverse families were shrimp Crangonidae (; 7 species), with Asteriidae (sea stars), Muricidae (murexes and trophon snails), Paguridae (hermit crabs), and Cancridae (rock crabs) all represented by 5 species. Several of the species encountered had not previously been taken in either routine Publically Owned Treatment Works (POTWs) monitoring or regional monitoring efforts. Several given provisional names appear to be new both to the SCB fauna, and to science.

The most diverse groups were usually not among either the abundance (Table V-7) or biomass (Table V-6) leaders. Of the twelve taxa making up 95% of the catch, 10 (83%) were echinoderms, and half were in the class Echinodea (sea urchins). Two members of the class Asteroidea (sea stars), and one from Classes Ophiuroidea (brittle stars) and Holothuroidea (sea cucumbers) were also included. Two members of the diverse class Malacostraca (both shrimp) were included among the species with highest abundance in 2008. These same groups were also prominent among the 19 species comprising 95% of the biomass. Sea urchins occupied the three top positions on this list (Table V-6), accounting for nearly 63% of total biomass. Two more sea urchins were among the top species, and added another 3.8% of aggregate catch biomass. The other echinoderm classes (except Crinoidea) were also represented, with sea stars, sea cucumbers and brittle stars each accounting for between 4 and 6.6% of total biomass. Other groups (sponges, cephalopod mollusks, sea anemones, brachiopods) were represented with lower proportional biomass contributions.

Despite the broad diversity of arthropods and mollusks, the 2008 catch on the SCB shelf and upper slope should be considered dominated by echinoderms, particularly sea urchins. This was true for subpopulations ranging from the middle shelf to the upper slope depths, but not for bays/harbors. On the inner shelf sea urchins were overshadowed in abundance and biomass by asteroids, and a variety of taxa from many groups were among the major contributors. In bays/harbors echinoderms were poorly represented, with biomass dominated by sponges (Table V-6), and abundance by sea pens and crabs (Table V-6).

Frequency of Occurrence

Of the 211 species, few occurred widely over the mainland shelf and slope in the SCB. No species occurred at more than 43% of the stations, or in over 54% of the sampled area (Table V-5). The equitability curve for areal occurrence was hyperbolic, with a step in the slope between 12 and 19 species, followed by a somewhat slower decline in percent area for additional species (Figure V-5; Appendix D-2). Species ranking to the left of the 12th species rapidly increased in areal occurrence and those to the right of the 19th decreased in occurrence more gradually. Twelve species (5.7% of all species) occurred in over 20% and six in 35% or more of the total area (Table V-5). These six most widely distributed species were the California sea slug (*Pleurobranchaea californica*), fragile sea urchin (*Strongylocentrotus fragilis*), California sand star (*Astropecten verrilli*), orange big eye octopus (*Octopus californicus*), and grey sand star (*Luidia foliolata*).

Species Abundance and Biomass

The equitability curve of species abundance approximated a smooth hyperbola but was more concave than that for areal occurrence (Figure V-5), indicating fewer species dominated abundance than were areal dominants. A change in slope occurred at 4 species and 73% of the catch (Table V-6), with abundance increasing in species ranked to the left of the fourth species (white sea urchin), and decreasing more gradually to the right. The 12 most abundant species (5.6% of all species) accounted for 95% of abundance in the survey (Table V-6). Southern heart urchin was the most abundant species accounting for 21% of the total invertebrate abundance (42,967 individuals). Slimy mud star (*Myxoderma platyacanthum*) was almost as abundant, representing 20.9 % of the catch. Pacific heart urchin (32,205 individuals), and white sea urchin (29,514 individuals) added an additional 30.6 percent of catch (Table V-7).

The equitability curve of species biomass, similar to that for abundance, approximated a smooth hyperbola (Figure V-5); few species dominated the overall biomass. Slope of the curve lessened between species 1 and 2, and again between species 3 and 4 (Table V-7). Four of the total species (1.9%) represented nearly 70% of total biomass. Nineteen species (9 % of all species) accounted for 95% of the survey biomass. Southern heart urchins had the largest biomass (673.4 kg; 31.6 %), followed by fragile sea urchin with 381.7 kg(17.9%), and Pacific heart urchin with 284.2 kg (13.4%).

Multiannual Trends: 1957 to 2008

Important Species

Species judged important in the community of invertebrates based on abundance, biomass, or frequency of occurrence in the Bight are discussed in Appendix D-4, both for 2008, and for previous regional samplings. Information on the biology of those species most important in 2008 is provided. The spatial distribution of such important species in 2008 is also presented in the appendix.

The distribution of selected important species populations over the four regional surveys is shown in Table V-9. Populations which occurred in over 50% of the sampled area are highlighted.

Temporal Distribution 1957-2008

Invertebrate population attribute mean values for the SCB varied on the shelf (10-200 m) between the five time periods -- 1971-1984 (Thompson *et al.* 1993a), 1994 (Allen *et al.* 1998), 1998 (Allen *et al.* 2002), 2003 (Allen *et al.* 2007), and 2008 (the present study; Table V-8). While the results of these surveys are generally comparable, differences in their design may have affected the results. The earlier data were collected over a period of 13 years, and without specific station allocation criteria. Much of the data (87%) came from POTW monitoring sites, and is thus biased towards conditions around wastewater discharges. POTW adjacent samples were also collected in 1994, 1998, and 2003, but were not taken in 2008, when no subpopulation of POTW impact was established. If effort differences between surveys are minimized by selection of a subset of the sites sampled, means can be informatively compared between regional surveys (Table V-8). Only sites from mainland inner shelf, middle shelf, and outer shelf in each of the four surveys are included in calculation of means, with bay/harbor and slope data excluded.

Mean invertebrate abundance was highest in 2008 (655), exceeding slightly the mean in 1994 (631). Mean abundance was lowest in 1998 (302), less than half that seen in either 1994 or 2008. There is some indication of cyclic change in invertebrate abundance, with values increasing from 1971-1994, decreasing from 1994-1998, then again increasing through 2008. Mean biomass was similar in all periods except 1998, when it was much lower (3.6 kg/haul). Mean species richness was also much lower (8) in 1998, than in other periods, with the earlier periods being higher (13) than 2003 and 2008 (11). Diversity values were not available for 1971-1985 and have increased at an accelerating rate since 1994-98 when they were essentially the same.

In the four recent surveys, regional population attribute means often followed different temporal patterns (Table V-8). In the Northern Region, mean abundance, biomass, and species richness were highest in 1994 and lowest in 2003, rebounding somewhat between 2003 and 2008. For abundance, 1994 was 2.5 and 3.7 times higher than the means of 1998 and 2003/2008, respectively. Biomass means in 1994 were about 1.5 times higher than in later years. This was also true of species richness between 1994 and 1998 and 2003, but it increased back to the 1994 value in 2008. Northern Region mean diversity was slightly depressed in 1998, and markedly higher in 2008 than in either 1994 or 2003.

Central Region mean abundance declined between 1994 and 1998, then increased strongly, reaching 3.5 times the 1994 value by 2008. In contrast biomass means alternately declined and increased between 1994 and 2008, peaking in 2003. Species richness was virtually the same for all surveys except 1998, when it was about 1/3 lower than in other surveys. Species diversity in the central region was greatest in 1994, and roughly the same in the other 3 regional surveys.

In the Southern Region, mean abundance was virtually the same in 2003 and 2008, both higher than in 1998, and lower than in 1994. Mean biomass per trawl was much higher in 1994 and 2008 than in either 1998 or 2003, with 2008 biomass the highest in the series. As in the Central Region, species richness was virtually the same in all surveys except 1998, when it was depressed by roughly 30%. Species diversity mean values have remained within 10% of one another except in 1994, when they were depressed by about 30% (Table V-8).

As in previous regional surveys (Allen *et al.* 1998, 2002, 2007) median invertebrate abundance, biomass, and species richness in 2008 were lowest on the inner shelf and highest on the outer shelf (Tables V-1, V-2, V-3). In 1998, 2003, and 2008 means in bays and harbors were low but higher than the inner shelf (except for richness, which was nearly the same in both subpopulations). Median diversity did not show a consistent depth zone pattern among the four survey periods. Median abundance and biomass values for the upper slope zone (added in 2003) were again higher in 2008 than those for the other depth zones in any of the four surveys. However, mean species richness was virtually the same at middle shelf to upper slope depths. Upper slope mean diversity was more similar to that of the inner shelf or bays/harbors, than to that of the middle and outer shelf subpopulations in 2008 (Table V-4) as in 2003.

Relationships to oceanic cycles in invertebrate populations are suggested by their population attributes, species occurrence, or importance (Tables V-8, V-9, V-10~~, V-13~~). For example, invertebrate abundance, and species richness were higher in 1994 (warm regime), but biomass was higher in 2003 and diversity in 2008 (both cold regime periods). Invertebrate abundance, biomass, species richness, and diversity were all lowest in 1998 (El Niño, warm; Table V-8). In terms of population areal occurrence, ridgeback rock shrimp was most widespread in warmer periods (1994 and 1998) and less in the cooler 2003 and 2008 periods (Table V-9). In contrast, red octopus was most widespread in the cooler periods of 2003 and 2008. California sea slug was twice as widespread in 1994 (warm) as in 1998 or 2003, although returning to nearly as broad a distribution in 2008's cool waters. Factors other than regime state are clearly involved in such distributional changes.

Based on weighted importance (Table V-10), many of the top ranked species did better in the warm regime: white sea urchin, ridgeback rock shrimp, California sea cucumber, and California sand star Some species appeared strongly negatively affected by the 1998 El Niño (e.g., northern heart urchin; California heart urchin (*Spatangus californicus*); Pacific heart urchin (*Brissopsis pacifica*); sea dandelion (*Dromalia alexandri)*; offshore blade shrimp (*Spirontocaris sica*)). Besides ridgeback rock shrimp, tuberculate pear crab (*Pyromaia tuberculata*) and slenderclaw hermit (*Paguristes turgidus*) appeared to be negatively affected by the cool regimes in 2003 and 2008. Once a longer dataset can be amassed, it is expected that these observed preliminary patterns of temperature response could be assigned to the influences of PDO, ENSO, or some combination of the two.

Discussion

Potential Causative Factors

Anthropogenic Point Sources

Man's influence has, in the past, been most clearly manifest in the injury caused by point sources. These represent typically discharges of POTWs (publicly owned treatment works), industrial sources (refineries, power plants, etc.), and ocean dumping of solids (dredge spoil, etc.). Such inputs were for long implicated in degradation of water quality and biota around the inputs, and sometimes also down current. Their cumulative impact to the Bight has been considerable over the years. Regulatory agencies have focused on this problem over the last 30 years, resulting in reductions in discharge volume, and dramatic improvements in discharge quality (i.e., Stein and Cadien 2009). In early regional studies strata for both large and small POTW discharges were included, allowing evaluation of these sources relative to the Bight as a whole. By the start of B'08 it was evident that this no longer served a purpose, as these areas could no longer be reliably distinguished from others at the same depths. Consequently the POTW strata were not applied in the B'08 design. While some evidence of discharge can still be seen in POTW monitoring programs, it is slight, and can no-longer be considered a significant contributor to the structure of the Bight megabenthic invertebrate communities.

Anthropogenic Non-Point Sources

While regulator attention was brought to bear on point-source impacts, yielding much reduction in anthropogenic impact, non-point sources continued to discharge into the waters of the SCB without equivalent evaluation.

Human presence alone may be a source of diffuse impact. This involves many aspects of the natural environment from distortion of the behavior of marine mammals (either attractive or repulsive changes), distortion of bird communities through disturbance of breeding grounds or alteration of feeding, through trampling of intertidal biota by visitors. Boat traffic can have major impacts through non-point source discharge of oil and other waste, through collision with wildlife, and through upset of normal behaviors by light , motion or noise. As the population continues to grow adjacent to the sea, so do such impacts on marine organisms.

Terrestrial Run-off

For most potentially harmful materials, both toxic and nutrient, the major means of introduction to the waters of the SCB is through runoff. The surface of the land adjacent to the sea in Southern California has been largely covered by structure, leaving most of the infrequent rain volume to run-off into rivers and storm drains rather than sink into the soil. Increased hardening of the surface and continued population growth has led to increasing levels of run-off reaching the sea. While it is difficult to capture the true nature of these inputs, increasing attempts to do so have been undertaken. A recent summary of the relative inputs of toxic materials to the SCB (Schiff *et al.* 2000) found that such terrestrial sources have surpassed in importance the contributions of point sources as human impacts to the waters of the SCB. While these inputs are highly episodic, when the rivers are swollen with rainfall they discharge huge amounts of flow into the SCB. Mass balance calculations routinely now find that these constitute the major source of input for nearly all pollutants.

Atmospheric Inputs

Some materials (both metals and organics) have as a major input source dust which usually reaches the sea via aerial resuspension and transport, followed by deposition from the atmosphere to the surface layer of the sea. Inputs of this nature are impossible to discern in analysis of the pattern of distribution of these materials following their introduction, so evidence of them is restricted to specialized sampling of the ocean surface layer (i.e., Cross *et al.* 1987)

Global Changes

In recent years it has become apparent that man is changing his environment on a global scale, yielding the dual problems of ocean warming and ocean acidification (Feeley *et al.* 2009, Kleypas *et al.* 2006). While research on these issues is still accumulating at a rapid pace, it is evident that changes are well underway in most parts of the world ocean. Like atmospheric inputs, such changes do not provide a distributional footprint in even regional scale investigations such as this. They are important, however, despite our current inability to determine just how much impact they are having on local communities.

Extractive Uses

We also alter the natural environment through utilization of its resources. This includes both commercial and recreational fishing, and mining for mineral resources (off-shore oil extraction, and sand harvesting). In some areas sea-water itself may be harvested for desalination and human consumption (at least in the future).While statistics on these uses are often available, they are usually difficult to scale to survey results for analysis.

Natural Variability in Physical Oceanographic Conditions

The four regional surveys cover a period of phase shift in oceanographic regime associated with the Pacific Decadal Oscillation (PDO; Francis *et al.* 1998). This shift occurred just after the Bight-wide sampling in 1998, when the previous multidecadal warm period culminated in the 1997-1998 El Niño, and a cool period began. The regime shift resulted in a swing of 9º C, from 6º C above the seasonal mean sea-surface temperature to 3º below it (Schwing and Moore 2000). This decadal scale trend is independent of the shorter cycle El Niño Southern Oscillation (ENSO; Wolter 1987) that moves between warm (El Niño) and cool (La Niña) states at the Equator every 1-2 years, although individual states may rarely persist for up to 7 years. El Niño states at the Equator do not always have a significant effect in the Southern California Bight. During the period covered by the four standardized regional surveys (1994, 1998, 2003, and 2008) we went from warm regime to El Niño (extreme warm event) to a cold regime (or La Niña) state. The 1994 survey was performed in the middle of a prolonged and intense warm regime; the 1998 survey during the 1997-1998 El Niño (very warm), and the 2003 survey at the end of a cold La Niña. The California Current remained in this cool regime from 1999 to 2005 (Goericke *et al.* 2005), and has continued cooler than normal except for the late summer and early fall of 2007. Conditions in 2003 and 2008, while both reflecting a prevailing La Niña state, differed in detail. In 2003 the sampling period occurred during a period of below average sea-surface temperature that followed a slightly warmed winter and spring. In 2008, sea surface temperatures remained cool, following a persistent cooler trend since 2005, although directly following several months of warmer temperatures. Such oceanographic changes are reflected in the composition of the megabenthic invertebrate fauna, although most such animals live for several years, and respond after a time-lag (see Allen *et al.* 2004 for a discussion of time lag in fish population response).

Interactions of the PDO and ENSO cycles produce a complex temporal mosaic of oceanographic conditions, primarily associated with temperature, but also influenced by changes in larval transport, and upwelling driven by both oceanic and atmospheric circulation states, which affects the availability of nutrients. Examination of temporal changes in the SCB must consider such complexity. The correlations of these environmental variables with fishes within the SCB were evaluated in Allen *et al.* (2004) and Jarvis *et al.* (2004). They tested time-lags of 1, 2, and 3 years, finding different species exhibited different apparent lags. In Allen *et al.* (2004) the PDO proved to be the most influential environmental variable, followed by upwelling intensity within the SCB, upwelling intensity off Baja California, off-shore water temperature, and ENSO variations. They also found that 45% of fish species lacked strong correlations to these oceanographic variables. A similar analysis remains to be performed for trawl megabenthic invertebrates, and the present database is not yet long enough to permit one. However, it is expected that the general patterns reported for fishes by Allen *et al.* (2004) will also be seen in invertebrates. Walther (2010) plotted long-term monitoring data on megabenthic invertebrate catches off Palos Verdes against PDO, NPDO, and ENSO, finding suggestive connections between fluctuations in the populations and one or more of these potential influences. More rigorous demonstration of these connections is still required, but current data suggests they will be found.

The Upper Slope Stratum

Data gathered in 2008 provided a point of comparison with 2003 data on the status of the communities on the upper slope at depths of 200-500 m within the SCB. Initial examination found only slight changes within this stratum. Since current evidence suggests that this is at least a temporary accumulation area for toxins, it is of interest and should continue to be monitored. Final deposition is in the coastal basins, but anthropogenic inputs may have long residence on the slopes. The nature of this habitat and its biota is discussed in Appendix D-5.

Conclusions – Status of Bight Macroinvertebrates in 2008

Having described the results of the 2008 regional trawl survey, and compared its results to those of previous efforts, we can now summarize the current status of megainvertebrate populations in the Bight.

The abundance of these organisms at shelf depths, adjusted for unit effort, was greater in 2008 than in any of the previous surveys, including that based on 1971-1985 data. The catch weight was lower in 2008 than in previous surveys, exceeding only that of the strong El Niño year of 1998. This suggests that many of the organisms sampled were smaller in size than those taken previously. Particularly good recruitment of juveniles prior to this survey, increased full adult mortality, or declining productivity in the system could contribute to such a result. Given the strong variability in biomass values in space and time, however, it is as likely to be an accidental result of sample site selection. Establishment of a trend of declining biomass in future surveys would be worrisome, but concern is as yet premature.

Species richness, as measured by the number of invertebrate species per trawl stayed the same between 2003 and 2008, slightly below the levels seen in 1971-1994, but well above those during the 1998 El Niño. Species diversity was greater in 2008 invertebrate trawl catches, than in those of any previous regional survey. There thus appears to be no trend of declining megainvertebrate richness or diversity in the regional data. The number of species encountered in 2008 after adjustment for differences in effort, was greater than that of the 1998 or 2003, and nearly that of the 1994 survey. Several of these forms appear to be new to regional surveys, and to science. The same suite of species important in number, biomass, or breadth of distribution was found in 2008 as in previous surveys. While individual populations waxed or waned in response to changing conditions, the community as a whole remained stable in the period of regional analysis. No evidence of disease and a very low prevalence of external parasites were found in 2008, suggesting that trawl invertebrates remain in good health throughout the Bight.

Invertebrate populations in bays and harbors are less diverse and less abundant than those of most other areas of the Bight. Benthic condition has been characterized as poorer in this subpopulation than in any other (Ranasinghe *et al.* 2010), a situation seemingly reflected in trawl invertebrate populations as well. The upper slope invertebrate community remained similar in 2008 to that found in 2003, with high invertebrate abundance and biomass, and dominance by sea urchins, sea stars, and brittle stars.

Megainvertebrate populations in 2008 seemed in fine condition throughout the SCB. The biointegrity analysis of megainvertebrates is presented with that of fishes in Chapter VII. Those in bays and harbors reflect the generally poorer condition in such embayments, but are not worsening from previous periods. Invertebrates are quite healthy, maintain broad distributions in appropriate habitats in the Bight, and are numerous and diverse. Lower biomass in 2008 populations did not detract from this, but should be monitored in future regional efforts. As noted previously, changes in oceanographic conditions (temperature, currents, nutrients) are reflected in the megabenthic invertebrates caught. As these conditions continue their cyclic fluctuation, so will composition and density of the megabenthic invertebrates in the Bight.

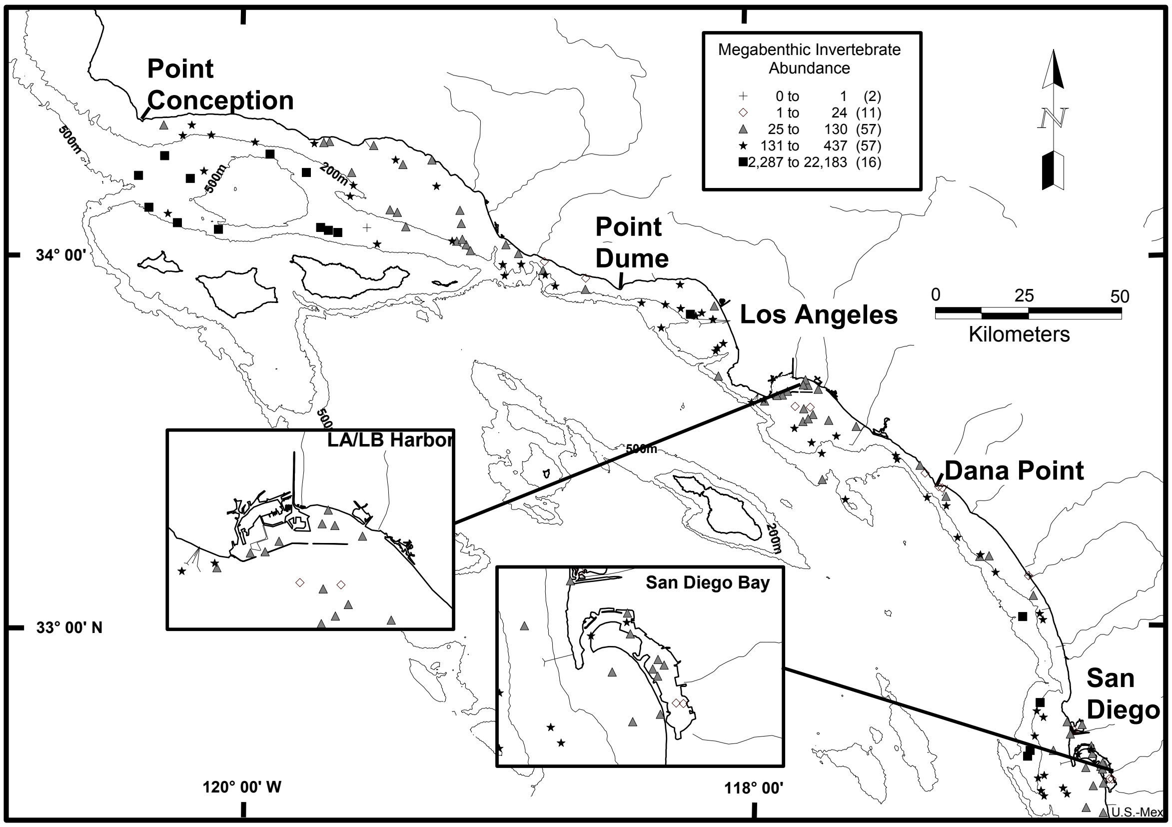

Figure V-1. Megabenthic Invertebrate Abundance map.

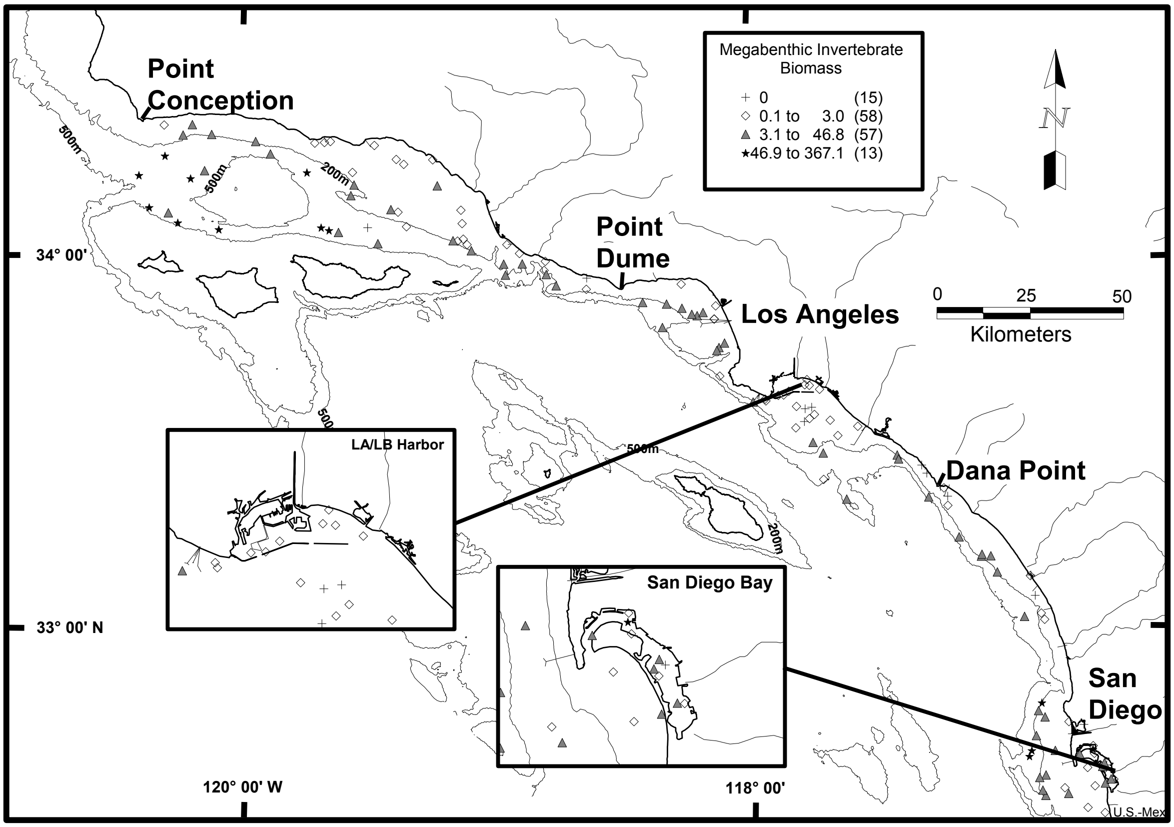

Figure V-2. Megabenthic Invertebrate Biomass map.

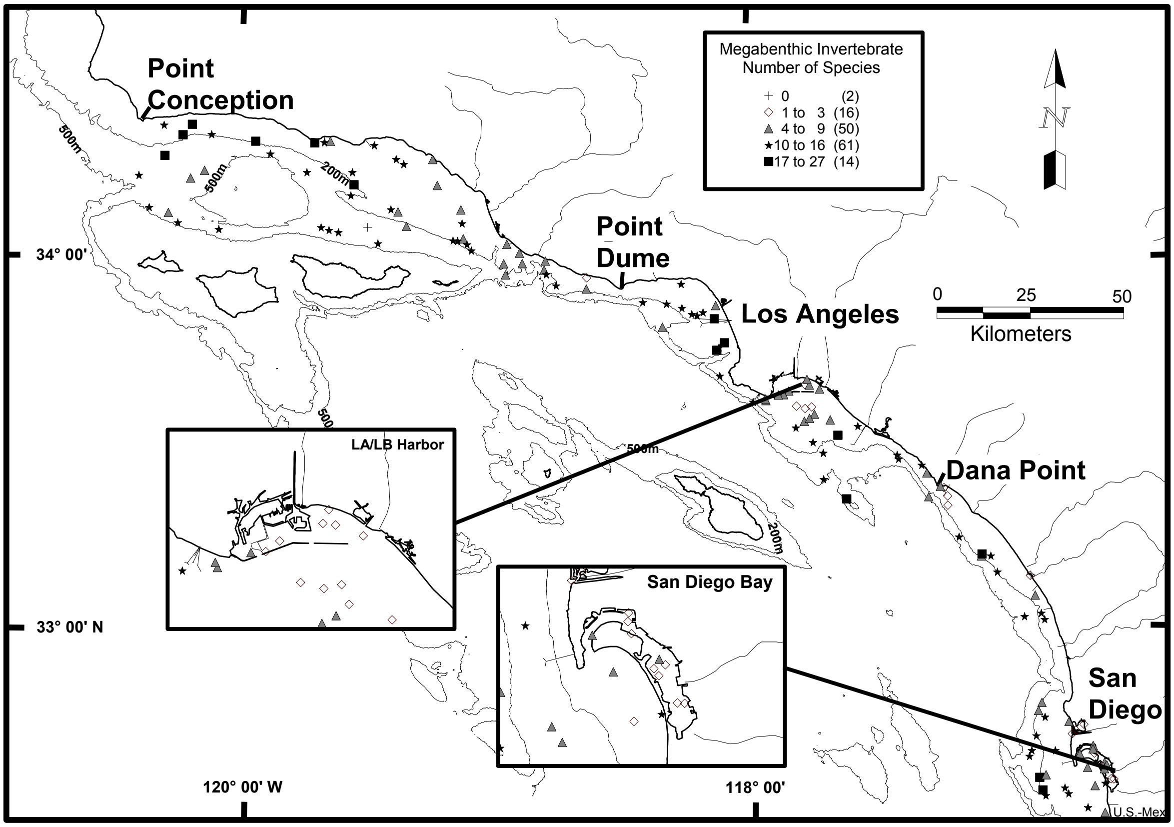

Figure V-3. Megabenthic Invertebrate Number of Species map.

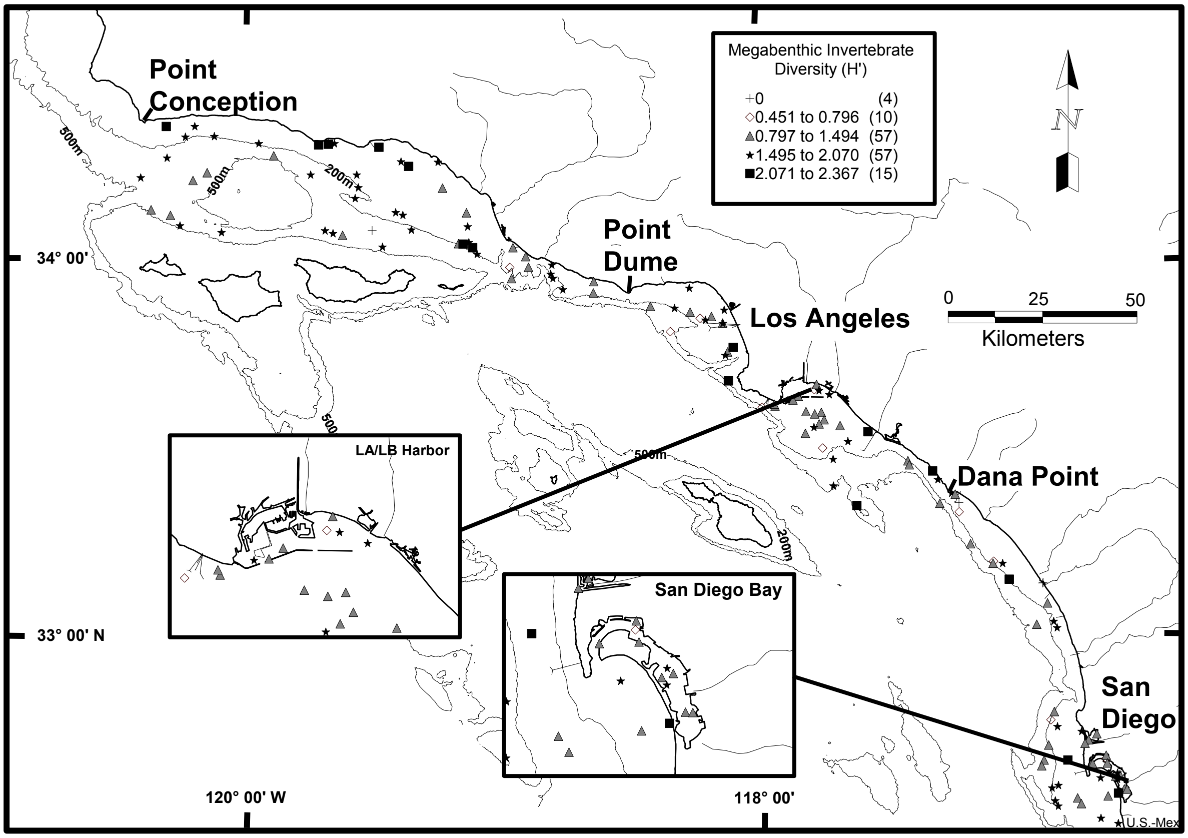

Figure V-4. Megabenthic Invertebrate Diversity map.

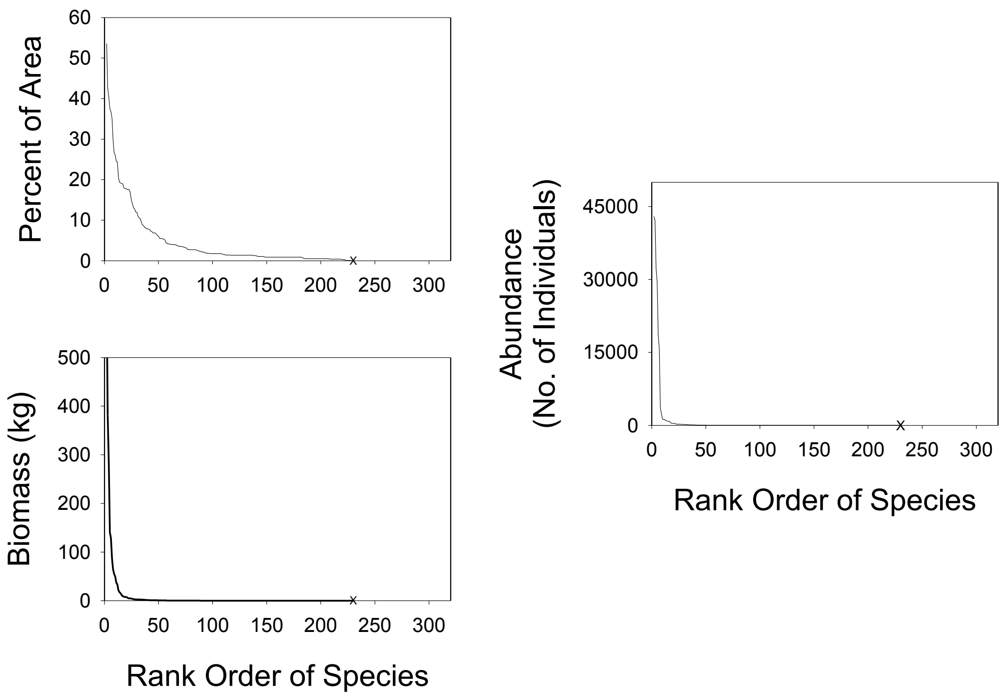

Figure V-5. Equitability curves of invertebrate occurrence, abundance, and biomass by species at depths of 2-484 m, Southern California Bight 2008 Regional Survey, July-October 2008. x = 230th species.

Table V-1. Megabenthic invertebrate abundance by region and depth zones at depths of 2-484 m on the southern California shelf, July-September 2008.

Subpopulation	No. of Stations	Total	Range Min.	Range Max.	Area-Weighted Values Median	Mean	SD	95% CL	Percent Above Bight Median
Abundance (no. of individuals/haul)*									
Region									
Northern	52	120,979	0	20,038	580	3,533	5,253	1,704	56.8
Central	44	34,848	4	22,182	304	1,032	3,591	1,166	41.9
Southern	44	45,850	4	18,618	315	2,362	4,744	2,226	43.7
Shelf Zone									
Bays and Harbors (2-30 m)	**19**	**1,220**	**4**	**468**	**15**	**54**	**96**	**37**	**1.6**
Central Region	6	260	10	70	36	43	24	19	0.0
Southern Region	13	960	4	468	10	64	129	67	3.0
Inner Shelf (2-30 m)	**32**	**1,184**	**3**	**168**	**25**	**38**	**40**	**14**	**0.0**
Northern Region	12	497	3	135	24	41	39	22	0.0
Central Region	13	502	4	168	21	39	48	26	0.0
Southern Region	7	185	6	44	27	30	11	9	0.0
Middle Shelf (31-120 m)	**33**	**35,005**	**26**	**22,182**	**199**	**1,061**	**3,766**	**1,285**	**33.0**
Northern Region	9	3,256	56	791	208	362	278	182	35.1
Central Region	13	26,780	26	22,182	222	2,060	5,824	3,166	30.6
Southern Region	11	4,969	37	2,286	131	452	658	389	23.8
Outer Shelf (121-200 m)	**23**	**9,716**	**37**	**2,535**	**287**	**422**	**545**	**223**	**36.5**
Northern Region	11	2,360	37	599	72	215	209	124	20.9
Central Region	3	851	53	409	221	284	163	185	23.2
Southern Region	9	6,505	118	2,535	359	723	739	483	45.0
Upper Slope (201-500 m)	**33**	**154,552**	**0**	**20,038**	**1,450**	**4,683**	**5,685**	**1,940**	**79.5**
Northern Region	20	114,866	0	20,038	4,004	5,743	5,810	2,546	78.6
Central Region	9	6,455	92	1,472	444	717	489	320	69.3
Southern Region	4	33,231	1,874	18,618	5,595	8,308	6,568	6,437	100.0
Total (all stations)	**140**	**201,677**	**0**	**22,182**	**395**	**2,470**	**4,789**	**1,034**	**50.0**

* The average area sampled during a trawl tow was x,xxx m^2.

CL = Confidence limits (± value); Min. = Minimum; Max. = Maximum; No. = Number; SD = Standard deviation.

Table V-2. Megabenthic invertebrate biomass (kg) by region and depth zones at depths of 2-484 m on the southern California shelf, July-September 2008.

Subpopulation	No. of Stations	Total (kg)	Range Min.	Range Max.	Area-Weighted Values Median	Area-Weighted Values Mean	Area-Weighted Values SD	Area-Weighted Values 95% CL	Percent Above Bight Median
Abundance (no. of individuals/haul)*									
Region									
Northern	52	1209.0	0.0	367.1	8.7	33.7	65.9	21.9	55.4
Central	44	271.0	0.0	46.8	4.2	9.6	12.8	4.7	40.5
Southern	44	647.0	0.0	101.6	5.7	22.1	31.7	14.4	47.4
Shelf Zone									
Bays and Harbors (2-30 m)	**19**	**145.0**	**0.0**	**93.4**	**0.3**	**5.3**	**17.3**	**6.5**	**9.9**
Central Region	6	2.0	0.1	0.7	0.2	0.3	0.2	0.2	0.0
Southern Region	13	143.0	0.0	93.4	1.4	9.7	22.8	11.8	18.6
Inner Shelf (2-30 m)	**32**	**18.0**	**0.0**	**3.5**	**0.3**	**0.6**	**0.8**	**0.3**	**0.0**
Northern Region	12	10.0	0.0	3.0	0.4	0.8	0.9	0.5	0.0
Central Region	13	3.0	0.0	1.1	0.1	0.2	0.3	0.2	0.0
Southern Region	7	6.0	0.0	3.5	0.4	0.9	1.2	1.0	0.0
Middle Shelf (31-120 m)	**33**	**200.0**	**0.0**	**36.7**	**3.1**	**6.1**	**7.9**	**2.7**	**28.6**
Northern Region	9	64.0	0.4	19.4	3.1	7.1	6.8	4.4	30.4
Central Region	13	93.0	0.0	36.7	2.6	7.2	10.2	5.6	26.3
Southern Region	11	43.0	0.0	14.8	1.1	3.9	4.4	2.6	19.8
Outer Shelf (121-200 m)	**23**	**270.0**	**1.1**	**57.5**	**9.0**	**11.7**	**12.5**	**5.1**	**62.1**
Northern Region	11	77.0	1.1	20.0	4.3	7.0	6.1	3.6	46.7
Central Region	3	14.0	2.7	7.7	3.3	4.8	2.1	2.4	11.5
Southern Region	9	179.0	4.3	57.5	11.6	19.9	15.5	10.2	84.4
Upper Slope (201-500 m)	**33**	**1493.0**	**0.0**	**367.1**	**26.9**	**45.3**	**65.4**	**22.3**	**78.2**
Northern Region	20	1059.0	0.0	367.1	30.3	52.9	79.3	34.8	74.3
Central Region	9	159.0	1.5	46.8	11.7	17.7	14.2	9.3	67.7
Southern Region	4	276.0	38.0	101.6	65.2	68.9	28.4	27.8	100.0
Total (all stations)	**140**	**2126.0**	**0.0**	**367.1**	**6.4**	**23.4**	**48.7**	**10.9**	**50.0**

* The average area sampled during a trawl tow was x,xxx m^2.
CL = Confidence limits (± value); Min. = Minimum; Max. = Maximum; No. = Number; SD = Standard deviation.

Table V-3. Megabenthic invertebrate species by region and subpopulation within depth zone subpopulations at depths of 2-476 m on the southern California shelf, July-September 2008.

Subpopulation	No. of Stations	Total (kg)	Range Min.	Range Max.	Area-Weighted Values Median	Mean	SD	95% CL	Percent Above Bight Median
Abundance (no. of individuals/haul)*									
Region									
Northern	52	120	0	26	12	12	5	1	57.9
Central	44	121	2	27	11	12	6	2	48.9
Southern	44	125	1	21	10	11	4	2	35.2
Shelf Zone									
Bays and Harbors (2-30 m)	**19**	**31**	**3**	**13**	**6**	**6**	**3**	**1**	**4.5**
Central Region	6	15	3	13	6	7	3	2	4.8
Southern Region	13	20	3	10	4	5	2	1	0.0
Inner Shelf (2-30 m)	**32**	**82**	**1**	**20**	**6**	**7**	**5**	**2**	**22.6**
Northern Region	12	48	2	20	6	8	5	3	29.2
Central Region	13	39	2	14	5	6	4	2	15.4
Southern Region	7	23	1	12	7	7	3	3	4.2
Middle Shelf (31-120 m)	**33**	**105**	**3**	**23**	**13**	**12**	**5**	**2**	**54.6**
Northern Region	9	47	6	17	9	11	4	2	40.0
Central Region	13	58	7	23	14	14	5	3	69.2
Southern Region	11	55	3	21	11	11	5	3	45.5
Outer Shelf (121-200 m)	**23**	**71**	**5**	**26**	**13**	**13**	**5**	**2**	**63.0**
Northern Region	11	49	6	26	13	14	6	3	68.2
Central Region	3	26	12	14	13	13	1	1	100.0
Southern Region	9	45	5	20	10	12	5	3	42.6
Upper Slope (201-500 m)	**33**	**73**	**0**	**27**	**12**	**12**	**5**	**2**	**54.6**
Northern Region	9	49	0	19	13	12	5	2	65.0
Central Region	20	47	4	27	11	12	6	4	44.4
Southern Region	4	21	10	13	11	11	1	1	25.0
Total (all stations)	**140**	**215**	**0**	**27**	**11**	**11**	**5**	**1**	**50.0**

* The average area sampled during a trawl tow was x,xxx m^2.
CL = Confidence limits (± value); Min. = Minimum; Max. = Maximum; No. = Number; SD = Standard deviation.

Table V-4. Megabenthic invertebrate diversity by region and depth zones at depths of 2-484 m on the southern California shelf, July-September 2008.

Subpopulation	No. of Stations	Range Min.	Range Max.	Area-Weighted Values Median	Area-Weighted Values Mean	Area-Weighted Values SD	Area-Weighted Values 95% CL	Percent Above Bight Median
Abundance (no. of individuals/haul)*								
Region								
Northern	52	0.00	2.30	1.20	1.19	0.59	0.17	59.6
Central	44	0.04	2.39	1.06	1.08	0.62	0.21	41.8
Southern	44	0.00	2.11	0.79	0.97	0.64	0.23	38.3
Shelf Zone								
Bays and Harbors (2-30 m)	**19**	**0.08**	**1.83**	**0.92**	**0.93**	**0.44**	**0.22**	**24.3**
Central Region	6	0.18	1.83	0.89	0.96	0.54	0.43	33.3
Southern Region	13	0.08	1.40	0.92	0.90	0.33	0.18	13.4
Inner Shelf (2-30 m)	**32**	**0.00**	**2.39**	**1.42**	**1.36**	**0.64**	**0.23**	**56.5**
Northern Region	12	0.64	2.30	1.51	1.54	0.61	0.34	61.8
Central Region	13	0.27	2.39	0.99	1.21	0.60	0.33	43.1
Southern Region	7	0.00	2.11	1.52	1.31	0.71	0.57	58.4
Middle Shelf (31-120 m)	**33**	**0.04**	**2.30**	**1.13**	**1.07**	**0.70**	**0.24**	**48.8**
Northern Region	9	0.17	2.30	1.15	1.16	0.75	0.49	49.7
Central Region	13	0.04	2.05	1.09	1.02	0.65	0.35	43.3
Southern Region	11	0.12	2.00	0.83	1.05	0.70	0.41	45.5
Outer Shelf (121-200 m)	**23**	**0.23**	**2.18**	**1.49**	**1.40**	**0.61**	**0.25**	**70.5**
Northern Region	11	0.90	2.18	1.73	1.68	0.34	0.20	85.5
Central Region	3	0.72	2.09	1.22	1.51	0.58	0.66	52.2
Southern Region	9	0.23	2.05	0.85	1.01	0.67	0.44	45.4
Upper Slope (201-500 m)	**33**	**0.00**	**2.03**	**0.98**	**0.99**	**0.50**	**0.17**	**42.1**
Northern Region	20	0.00	1.90	1.16	1.04	0.48	0.21	54.5
Central Region	9	0.19	2.03	0.96	1.03	0.57	0.37	32.2
Southern Region	4	0.43	0.83	0.60	0.62	0.17	0.17	0.0
Total (all stations)	**140**	**0.00**	**2.39**	**1.15**	**1.10**	**0.62**	**0.11**	**50.0**

* The average area sampled during a trawl tow was x,xxx

CL = Confidence limits (± value); Min. = Minimum; Max. = Maximum; No. = Number; SD = Standard deviation.

Table V-5. Megabenthic invertebrate species occurring in 20% or more of the area in the regional survey of the mainland shelf of southern California at depths of 2-484 m, July-September 2008.

Scientific Name	Common Name	No. of Stations	Percent of Stations	Percent of Area*
Pleurobranchaea californica	California sea slug	60	43	53.5
Strongylocentrotus fragilis	fragile sea urchin	46	33	42.7
Astropecten verrilli	California sand star	59	42	40.4
Octopus californicus	orange bigeye octopus	31	22	37.5
Luidia foliolata	gray sand star	46	33	36.8
Brissopsis pacifica	Pacific heart urchin	34	24	35.2
Brisaster townsendi	southern heart urchin	24	17	29.9
Sicyonia ingentis	ridgeback rock shrimp	42	30	26.6
Lytechinus pictus	white sea urchin	37	26	26.0
Octopus rubescens	red octopus	37	26	24.5
Philine auriformis	New Zealand paperbubble	31	22	24.3
Myxoderma platyacanthum	slimy mud star	15	11	20.5

Total stations = 140
Total area = 6,922 km^2
*Based on area-weighted frequency of occurences.

Table V-6. Megabenthic invertebrate species comprising 95% or more of the invertebrate biomass on the southern California shelf and upper slope at depths of 2-484 m, July-September 2008.

Scientific Name	Common Name	Biomass (kg)	Percent	Cumulative Percent
Brisaster townsendi	southern heart urchin	673.4	31.6	31.6
Strongylocentrotus fragilis	fragile sea urchin	381.7	17.9	49.6
Brissopsis pacifica	Pacific heart urchin	284.2	13.4	62.9
Suberites latus	hermitcrab sponge	140.2	6.6	69.5
Myxoderma platyacanthum	slimy mud star	128.8	6.1	75.6
Parastichopus californicus	California sea cucumber	86.7	4.1	79.7
Sicyonia ingentis	ridgeback rock shrimp	64.5	3.0	82.7
Asteronyx longifissus	brittlestar	54.9	2.6	85.3
Lytechinus pictus	white sea urchin	49.2	2.3	87.6
Pannychia moseleyi	pedicelled sea cucumber	37.3	1.8	89.3
Spatangus californicus	California heart urchin	32.9	1.5	90.9
Octopus californicus	orange bigeye octopus	21.1	1.0	91.9
Tetilla sp.	burgandy bay sponge	17.2	0.8	92.7
Metridium farcimen	gigantic anemone	14.8	0.7	93.4
Luidia foliolata	gray sand star	11.5	0.5	93.9
Pleurobranchaea californica	California sea slug	9.1	0.4	94.3
Gorgonocephalus eucnemis	basket star	8.2	0.4	94.7
Pandalus platyceros	spot shrimp	7.7	0.4	95.1
Laqueus californianus	California lamp shell	7.6	0.4	95.4

Total biomass = 2,128.0 kg

Table V-7. Megabenthic invertebrate species comprising 95% or more of the total invertebrate abundance on the southern California shelf and upper slope at depths of 2-484 m, July-September 2008.

Scientific Name	Common Name	Abundance	Total Percent	Cumulative Percent
Brisaster townsendi	southern heart urchin	42967	21.3	21.3
Myxoderma platyacanthum	slimy mud star	42205	20.9	42.2
Brissopsis pacifica	Pacific heart urchin	32205	16.0	58.2
Lytechinus pictus	white sea urchin	29514	14.6	72.8
Asteronyx longifissus	brittlestar	18447	9.1	82.0
Strongylocentrotus fragilis	fragile sea urchin	15931	7.9	89.9
Sicyonia ingentis	ridgeback rock shrimp	3568	1.8	91.6
Pannychia moseleyi	pedicelled sea cucumber	2300	1.1	92.8
Goniasteridae	sea star	1274	0.6	93.4
Spirontocaris holmesi	slender blade shrimp	1212	0.6	94.0
Brisaster sp	heart urchin	1186	0.6	94.6
Brisaster latifrons	northern heart urchin	984	0.5	95.1

Total abundance = 201,686
Total No. Stations = 143

Table V-8. Comparison of megabenthic invertebrate population attributes on mainland shelf by region and year(s) for the Southern California Bight (SCB) in 1957-1975, 1994, 1998, 2003, and 2008 regional survey data.

Southern California Bight Database	No. samples	Abundance (no. of individuals)	Biomass (kg)	No. of Species	Diversity[b] (bits/individual)
Northern Region					
1994[c]	43	817	7.0	11	0.99
1998[d]	65	318	5.7	8	0.85
2003[e]	35	216	4.8	7	1.00
2008[f]	32	220	5.0	11	1.41
Central Region					
1994[c]	39	356	6.0	12	1.26
1998[d]	78	267	3.4	8	1.09
2003[e]	52	593	11.8	13	1.07
2008[f]	29	1257	4.6	12	1.11
Southern Region					
1994	28	530	6.2	12[c]	0.78[c]
1998[d]	54	336	3.5	8	1.13
2003[e]	41	431	3.7	12	1.19
2008[f]	27	429	6.7	11	1.09
All Mainland Shelf Regions[g]					
1957-1975[h]	658	577	6.6	13	--
1994[c]	110	631	6.6	12	1.01
1998[d]	197	302	3.6	8	0.99
2003[e]	128	431	7.3	11	1.08
2008[f]	88	655	5.4	11	1.21

[a]The 1994, 1998, 2003, and 2008 mean values are weighted in accordance with the sampling design.
[b]1957-1975 are Brillouin diversities; 1994, 1998, 2003, and 2008 values are Shannon-Wiener diversities.
[c]Value(s) have been revised.
[d]Data from Bays/Harbors and Islands are excluded from 1998 analysis.
[e]Data from Bays/Harbors, Islands, and Upper Slope (201-500 m) are excluded from 2003 analysis.
[f]Data from Bays/Harbors, and Upper Slope (201-500 m) are excluded from 2008 analyses.
[g]SCB as a whole.
[h]1957-1975 data from Thompson *et al.* (1993a).

Table V-9. Comparison of megabenthic invertebrate species occurring in greater than 20% of the area on the mainland shelf of southern California in 1994, 1998, 2003, and 2008.

Scientific Name	Common Name	No. of Stations				Percent of Stations				Percent of Area*			
		'94	'98[a]	'03[b]	'08[c]	'94	'98[a]	'03[b]	'08[c]	'94	'98[a]	'03[b]	'08[c]
Astropecten verrilli (1, 1, 1)	California sand star	80	119	80	58	73	60	63	66	74.1	65.4	61.8	65.9
Sicyonia ingentis (2, 2, 8)	ridgeback rock shrimp	65	89	38	39	59	45	30	44	61.7	61.3	30.8	44.3
Luidia foliolata	gray sand star	52	39	37	39	47	20	29	44	48.0	31.1	31.1	44.3
Pleurobranchaea californica	California sea slug	44	28	22	38	40	14	17	43	47.5	22.7	21.7	43.2
Lytechinus pictus	white sea urchin	55	65	49	36	50	33	38	41	49.4	43.8	46.0	40.9
Octopus rubescens	red octopus	19	28	65	35	17	14	51	40	17.6	18.7	51.0	39.8
Parastichopus californicus	California sea cucumber	53	57	46	24	48	29	36	27	47.4	37.4	36.6	27.3
Philine auriformis	New Zealand paperbubble	-	54	41	23	-	27	32	26	-	30.9	30.1	26.1
Acanthoptilum sp	trailtip sea pen	24	30	42	23	22	15	33	26	24.0	20.5	37.9	26.1
Strongylocentrotus fragilis	fragile sea urchin	27	15	22	21	25	8	17	24	20.8	7.6	10.7	23.9
Ophiura luetkenii	brokenspine brittlestar	44	23	45	21	40	12	35	24	40.1	22.7	38.1	23.9
Ophiothrix spiculata	Pacific spiny brittlestar	33	28	24	19	30	14	19	22	32.1	20.9	17.7	21.6
Crangon nigromaculata	blackspotted bay shrimp	10	33	27	19	9	17	21	22	7.9	14.5	24.6	21.6
Thesea sp B	yellow sea twig	29	45	30	18	26	23	23	20	19.5	33.5	26.2	20.5
Total (all stations)		110	197	128	88					2980[e]	3,344[e]	3,089[e]	3723[e]

*Percent of area based on area-weighted frequency of occurrences.
[a]Mainland shelf only (5-200 m); stations in island and bay/harbor subpopulations were excluded from the 1998 analyses.
[b]Mainland shelf only (5-200 m); stations in island, bay/harbor, and upper slope subpopulations were excluded from the 2003 analyses.
[c]Mainland shelf only (5-200 m); stations in bay/harbor and upper slope subpopulations excluded from the 2008 analyses.
[d]Numbers in parentheses represent rank of species by percent of areal occurrence in 1994, 1998, and 2003 (species occurred in greater than 50% of the area in any one of the years).
[e]Total area in km^2.
Areal occurrences of 50% or greater are shaded in gray.

Table V-10. Multiyear comparison of megabenthic species important because of abundance (A), biomass (B), or wide distribution (OCC) in the Southern California Bight. Values reflect ranks in each survey, and average weighted importance rank by survey and overall.

	Rank												Weighted Rank				
	2008			2003			1998			1994			2008	2003	1998	1994	94-08
Species	A	B	OCC	A	B	OCC	A	B	OCC	A	B	OCC	WR = (2A +B+2OCC)/3				
Lytechinus pictus	4	9	9	2	6	3	1	5	1	1	5	3	7.0	3.2	1.8	2.6	3.65
Strongylocentrotus fragilis	6	2	2	3	1	8	4	2	14	4	2	8	3.6	4.6	7.6	5.2	5.25
Sicyonia ingentis	7	7	8	7	7	11	2	4	3	3	4	2	7.4	8.6	2.8	2.8	5.40
Astropecten verrilli	12	28	3	11	38	1	5	32	2	9	16	1	11.6	12.4	9.2	7.2	10.10
Parastichopus californicus	25	6	13	23	3	7	11	1	7	10	1	4	16.4	12.6	7.4	5.8	10.55
Brisaster latifrons	1	1	3	1	2	18	29	43	28	7	6	19	1.8	8	31.4	11.6	13.20
Luidia foliolata	20	15	5	35	15	6	23	13	4	11	9	5	13.0	19.4	13.4	7.2	13.25
Myxoderma platyacanthum	2	6	12	4	12	24	-	-	-	-	-	-	11.3	22.7	-	-	17.00
Spatangus californicus	17	11	17	9	4	21	24	16	38	5	3	28	15.8	12.8	28	13.8	17.60
Pleurobranchaea californica	18	16	1	52	18	12	32	30	6	17	12	6	10.8	29.2	21.2	11.6	18.20
Pannychia moseleyi	8	10	17	24	22	44	-	-	-	-	-	-	12.0	31.6	-	-	21.80
Ophiothrix spiculata	37	85	25	15	48	15	8	51	12	12	32	10	41.8	21.6	18.2	15.2	24.20
Ophiura luetkenii	14	61	17	27	109	5	22	104	11	2	8	6	24.6	34.6	34	4.8	24.50
Octopus rubescens	33	24	10	32	28	2	48	56	12	36	32	15	22.0	19.2	35.2	26.8	25.80
Neocrangon zacae	11	50	13	21	92	18	17	88	28	8	32	13	19.6	34	35.6	14.8	26.00
Crangon nigromaculata	24	61	30	10	42	16	12	104	22	28	32	31	33.8	18.8	34.4	30	29.25
Thesea sp B	40	85	24	14	41	13	25	104	8	32	32	9	42.5	19	34	22.8	29.58
Brissopsis pacifica	3	3	6	6	5	24	100	78	94	13	13	25	4.2	13	93.2	17.8	32.05
Pyromaia tuberculata	19	85	36	46	92	30	6	48	23	24	32	15	39.0	48.8	21.2	22	32.75
Hamatoscalpellum californicum	32	85	26	36	109	17	15	104	6	41	32	15	40.2	43	29.2	28.8	35.30
Metridium farcimen	60	14	56	66	10	40	52	8	20	35	7	26	49.2	44.4	30.4	25.8	37.45
Doryteuthis opalescens	53	85	51	33	64	20	50	104	17	14	32	10	58.6	34	47.6	16	39.05
Stylatula elongata	36	85	32	75	109	27	35	88	20	22	32	19	44.2	62.6	39.6	22.8	42.30
Luidia armata	60	55	71	81	71	44	40	54	15	21	16	18	63.4	64.2	32.8	18.8	44.80
Mediaster aequalis	95	85	56	31	33	14	31	49	10	68	32	45	77.4	24.6	26.2	51.6	44.95
Philine auriformis	16	55	11	17	80	8	7	104	5	146	32	124	21.8	26	25.6	114.4	46.95
Dromalia alexandri	28	23	13	30	14	35	72	51	176	32	16	51	19.0	28.8	109.4	36.4	48.40
Spirontocaris holmesi	10	61	17	16	49	36	62	104	114	15	32	94	23.0	30.6	91.2	50	48.70
Pandalus platyceros	35	18	28	37	25	24	65	67	56	81	32	124	28.8	29.4	61.8	88.4	52.10
Luidia asthenosoma	85	85	51	89	92	30	57	104	15	60	32	39	71.4	66	49.6	46	58.25
Megasurcula carpenteriana	114	85	56	114	109	50	46	72	29	30	32	19	85.0	87.4	44.4	26	60.70
Paguristes turgidus	98	85	56	126	109	71	47	18	19	31	32	39	78.6	101	30	34.4	60.90
Platymera gaudichaudii	105	61	86	67	27	27	86	44	23	96	32	56	88.6	43	52.4	67.2	62.80
Florometra serratissima	51	61	56	38	54	50	49	78	114	106	32	94	55.0	46	80.8	86.4	67.05
Ciona intestinalis	-	-	-	34	71	92	26	32	176	-	-	-	-	64.6	87.2	-	75.90
Pandalus jordani	127	85	88	18	23	92	63	88	114	-	-	-	103.0	48.6	88.4	-	80.00
Bulla gouldiana	44	85	155	22	30	126	16	40	176	-	-	-	96.6	65.2	84.8	-	82.20
Molgula verrucifera	-	-	-	28	109	92	27	76	176	-	-	-	-	69.8	96.4	-	83.10
Spirontocaris sica	21	85	13	25	92	30	224	104	176	96	32	94	30.6	40.4	180.8	82.4	83.55
Ophionereis eurybrachiplax	-	-	-	12	20	126	171	104	56	91	32	94 -		59.2	111.6	80.4	83.73
Styela plicata	-	-	-	20	80	71	65	104	176	-	-	-	-	52.4	117.2	-	84.80
Musculista senhousia	145	85	155	26	109	71	10	88	176	-	-	-	137.0	60.6	92	-	96.53
Ptilosarcus gurneyi	145	85	111	260	109	260	69	54	23	46	16	45	119.4	230	47.6	39.6	109.10
Neocrangon communis	174	85	155	29	64	71	224	104	176	36	32	94	148.6	52.8	180.8	58.4	110.15
Stachyptilum superbum	174	85	71	19	64	126	224	104	176	-	-	-	115.0	70.8	180.8	-	122.20

VI. DEBRIS

Introduction

Many studies have documented the types and amounts of marine debris that aesthetically impair coastal recreation areas and threaten marine organisms through ingestion and entanglement (Fowler 1987, Ryan 1987, Bjorndal *et al.* 1994, Moore and Allen 2000). Several organizations have collected and analyzed debris data to inform the public of this growing worldwide problem (Ribic *et al.* 1997). Although marine debris is of increasing concern, most studies have focused only on the types and amounts of large debris found on coastal beaches (MBC 1988, Ribic *et al.* 1997). In southern California, the Los Angeles Regional Water Control Board has set a total maximum daily load of zero trash for several area watersheds based on the amounts of trash flowing from rivers and storm drains. However, few studies have documented the amount of trash that remains in the ocean versus that transported to beaches. A recent study (Moore *et al.* 2003) documented a density of 8 pieces of plastic per cubic meter in the neuston while three regional studies conducted in 1994, 1998 and 2003 documented the types and amounts of benthic debris in the Southern California Bight (SCB; Allen *et al.* 1998, Moore and Allen 2000, Allen *et al.* 2007).

This chapter presents the fourth regional study of debris on the seafloor of the SCB. The objectives of this chapter are: 1) to assess the distribution, type, and amount of anthropogenic and natural marine debris on the seafloor of the mainland shelf and upper slope of the SCB in 2008, and 2) to compare these findings to those of previous regional surveys.

Results

Debris (natural and/or anthropogenic) was found in 71% of the SCB area (Table VI-1; Figure VI-1). Natural debris had much greater extent than anthropogenic debris. Natural debris occurred in 64% of the SCB. Anthropogenic debris occurred in 21% of the SCB. The greatest amount of total debris was found in the inner shelf (90% of area). Debris extended across 69% of the bay and harbor stratum. No stratum had debris in less than 57% of its area. Anthropogenic debris was primarily found off highly populated areas while natural debris was found in the south and no debris in the north.

Natural Debris

Natural debris consists of either terrestrial or marine vegetation, rocks, or other marine debris of natural origin. The extent of natural debris varied by geography (Table VI-1; Figure VI-1). The extent of natural debris was greatest in the northern SCB (77% of area) and decreased to 69% and 42% of the area in the southern and central SCB, respectively. The inner shelf stratum had the greatest extent of natural debris (90% of area). Roughly two-thirds of the bay and harbor (69%) or middle shelf (70%) strata had natural debris. The least extent of natural debris occurred in the outer shelf (48%) and upper slope (53%) strata.

Marine vegetation was the most commonly occurring natural debris, followed by terrestrial vegetation, rocks, and other benthic debris (Tables VI-1 and VI-2). All types of natural debris were most commonly found in trace numerical abundance (1 item per haul) and moderate weight (1-10 kg) categories. The greatest extent of marine and terrestrial vegetation was found in the low abundance (2-10 items) and low weight (0.2-1 kg) categories.

Different types of natural debris also varied by stratum (Table VI-1). While the areal extent of marine vegetation decreased with depth, terrestrial vegetation increased with depth. The areal extent of marine vegetation ranged from 58 to 87% in bay and harbor, inner shelf, and middle shelf strata, then decreased to 22 to 26% of the area in the outer shelf and upper slope strata. In contrast, the areal extent of terrestrial debris ranged from 22 to 38% in the outer shelf and upper slope strata, then decreased to 0 to 19% in the bay and harbor, inner shelf, and middle shelf strata. The areal extent of rocks and other benthic debris were relatively consistent and among strata. The areal extent of other benthic debris ranged from six to nine percent in each of the survey strata. Rocks were rarely observed and were absent in all but the deepest stratum (3% of the upper slope).

Anthropogenic Debris

Anthropogenic debris consists of either plastic, metal, lumber, fishing gear, tires, or glass and bottles. The extent of anthropogenic debris varied by geography (Table VI-1; Figure VI-1). The extent of anthropogenic debris was the opposite of natural debris; anthropogenic debris was observed more frequently in the central SCB (30% of area) compared to the northern of southern SCB (18% and 14% of area, respectively). The outer shelf stratum had the greatest extent of natural debris (30% of area). Roughly one-fifth of the middle shelf (21%) and upper slope (22%) strata had anthropogenic debris. The least extent of anthropogenic debris occurred in the bay and harbor (8%) or middle shelf (13%) strata.

Plastic was the most commonly occurring anthropogenic debris, followed by cans, lumber, fishing gear, metal, and glass/bottles (Table sVI-1 and VI-2; Figure VI-2). Other anthropogenic debris such as clothing, or tires also comprised a substantial portion of the anthropogenic debris extent. All types of anthropogenic debris were most commonly found in trace numerical abundance (1 item per haul) and trace weight (0.0-0.1 kg) categories. Plastic was exclusively found in the trace and low abundance (up to 10 items) categories and dominated by the trace and low weight (up to1 kg) categories.

Different types of anthropogenic debris also varied by stratum (Table VI-1). Four types of anthropogenic debris all had maximum extent in the outer shelf stratum including plastic, bottles, metal, lumber, and tires. The areal extent of cans and fishing gear peaked in the middle shelf stratum. The areal extent for seven of eight anthropogenic debris categories was greater in deeper water (30-500 m) than in shallow water (< 30 m). For example, plastic was not found in bays and harbors, but steadily increased to 13% of the area in the outer shelf (120-200 m depth). Other anthropogenic debris was the only category with abundance in every stratum.

Discussion

Natural and anthropogenic debris were found throughout the SCB, but were generally found in trace amounts at any given site. While debris was found in 90% of the SCB, natural debris was observed three times as frequently as anthropogenic debris. Marine vegetation such as kelp and other seaweeds were the most common occurrence although terrestrial debris was a common occurrence. Of the anthropogenic debris, plastics were most frequently found.

Anthropogenic debris was highest in the central SCB, likely due to the proximity of large population centers such as the Los Angeles metropolitan area. Anthropogenic debris was found in all strata, but was most common with increasing depth. We assume this is because anthropogenic debris generally moves down-shelf with time due to wave and tide action (i.e., plastic and lumber) or perhaps because it was dumped further offshore (i.e., cans and fishing gear). The high occurrence of anthropogenic debris in bays and harbors is likely from land-based and marine vessel sources.

The areal extent of debris in the SCB has ranged from 50 to 89% over the last 15 years without monotonic trend over time (Figures VI-3 and VI-4). The greatest extent of debris occurred in the summer of 1998 and the least in summer of 2003. Part of this may be due to timing of rainfall preceding the four regional surveys. The winter of 1997-98 had the greatest rainfall relative to the least rainfall in 2002-03 (205% vs. 109% of long-term annual rainfall, respectively). Interestingly, the aerial extent of anthropogenic debris remained relatively constant compared to the extent of natural debris. The aerial extent of anthropogenic debris ranged from 14 to 25% of the SCB between the four regional surveys. In comparison, the aerial extent of natural debris ranged from 40 to 88% of the SCB between the four surveys. It was this large range in natural debris, with a maximum in 1998 and a minimum in 2003 that was responsible for the overall extent estimates in the SCB.

There were several similarities among the four regional surveys that appear to be trends of consistency. First, debris most frequently occurred in trace to low abundance and weight. Second, the aerial extent of natural debris was always greater than the extent anthropogenic debris regardless of survey. Third, the greatest extent of anthropogenic debris always occurred in the central and southern regions where the greatest most population centers are located. Finally, plastic was always the category of anthropogenic debris with the greatest aerial extent.

Table VI-1. Percent of area by subpopulation of debris types on the southern California shelf and upper slope at depths of 2-476 m, July-October 2008.

	Natural Debris					Anthropogenic Debris									
Category	M.Veg	T.Veg	Ben.D	Rocks	Total	Plast	Metal	Cans	Other	Lumb	FshGr	GlaBo	Tires	Total	Overall
Region															
Northern	41.4	50.8	0.0	9.9	76.7	10.1	0.8	0.8	3.8	2.8	0.0	0.0	0.0	17.5	80.6
Central	35.8	5.5	0.0	4.5	41.5	14.1	0.0	12.5	6.1	5.9	0.0	1.2	0.0	30.0	58.3
Southern	60.9	4.2	6.6	1.8	69.3	5.5	1.8	0.0	4.2	1.8	4.2	0.0	1.8	13.9	71.1
Depth Zone															
Bays and Harbors (2-30 m	61.0	0.0	0.0	7.8	68.8	0.0	0.0	0.0	7.8	0.0	0.0	0.0	0.0	7.8	68.8
Inner Shelf (2-30 m)	87.1	19.4	0.0	6.5	90.3	6.5	0.0	0.0	3.2	3.2	0.0	0.0	0.0	12.9	90.3
Middle Shelf (31-120 m)	57.6	15.2	0.0	6.1	69.7	9.1	0.0	9.1	3.0	3.0	3.0	0.0	0.0	21.2	78.8
Outer Shelf (121-200 m)	26.1	21.7	0.0	8.7	47.8	13.0	8.7	4.3	4.3	8.7	0.0	4.3	4.3	30.4	56.5
Upper Slope (201-500 m)	21.9	37.5	3.1	6.3	53.1	12.5	0.0	3.1	6.3	3.1	0.0	0.0	0.0	21.9	62.5
Total	43.7	26.2	1.4	6.5	63.7	10.4	0.8	4.5	4.7	3.6	0.9	0.4	0.4	20.9	71.3

M.Veg = Marine vegetation; T.Veg = Terrestrial vegetation; Ben.D = Benthic debris; Plast = Plastic;
Metal = Metal debris; Lumb = Lumber; FshGr = Fishing gear; GlaBo = Glass & Bottles.

Table VI-2. Percent of area of quantification categories of debris types collected on the southern California shelf and upper slope at depths of 2-476 m, July-October 2008.

DebrisType	No. of Stations	Abundance[a] T	Abundance[a] L	Abundance[a] M	Abundance[a] H	Weight[b] T	Weight[b] L	Weight[b] M	Weight[b] H	Total
Natural Debris										
Marine Vegetation	74	12.6	20.7	9.2	1.2	14.9	18.9	7.9	2.1	43.7
Terrestrial Vegetation	28	3.5	19.0	3.7	-	7.1	13.1	6.0	-	26.2
Rocks	9	1.7	3.4	1.4	-	3.6	1.4	1.4	0.1	6.5
Benthic Debris	1	1.4	-	-	-	-	-	1.4	-	1.4
Total	112	19.2	43.1	14.3	1.2	25.6	33.4	16.6	2.1	63.7
Anthropogenic Debris										
Plastic	13	5.5	5.0	-	-	6.4	3.2	0.9	-	10.4
Other	6	3.2	0.0	0.1	1.4	2.3	0.9	1.4	0.1	4.7
Lumber	5	1.8	1.8	-	-	2.8	0.4	0.4	-	3.6
Fishing Gear	1	0.9	-	-	-	-	-	0.9	-	0.9
Metal Debris	2	0.8	-	-	-	0.4	-	0.4	-	0.8
Glass Bottles	1	0.4	-	-	-	-	0.4	-	-	0.4
Cans	5	4.5	-	-	-	4.5	-	-	-	4.5
Tires	1	0.4	-	-	-	0.4	-	-	-	0.4
Total	34	17.4	6.7	0.1	1.4	16.7	4.8	4.0	0.1	20.9
Overall	139	30.9	42.0	14	2.6	33.9	32.6	20.1	2.1	71.3

[a]T = Trace (1 item)
L = Low (2-10 items)
M = Moderate (11-100 items)
H = High (>100 items)

[b]T = Trace (0.0-0.1 kg)
L = Low (0.2-1.0 kg)
M = Moderate (1.1-10.0 kg)
H = High (>10.0 kg)

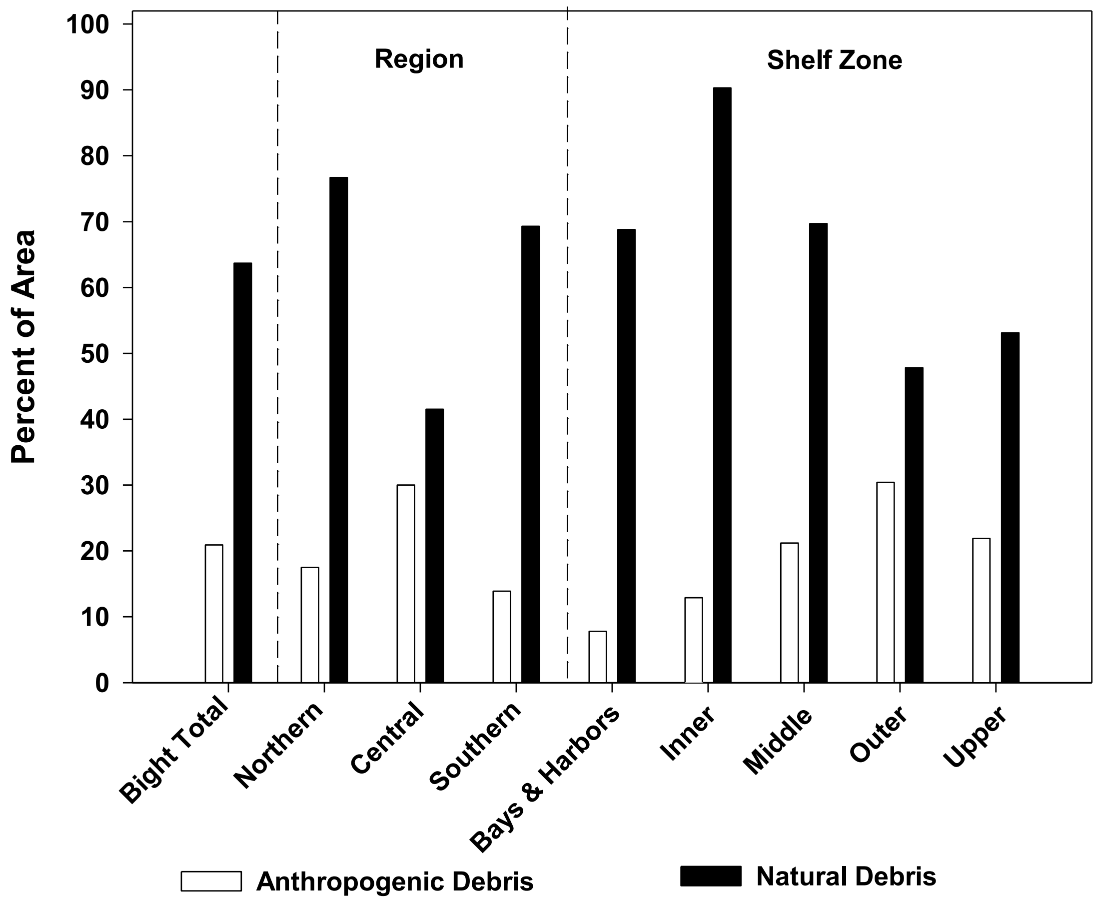

Figure VI-1. Extent of either anthropogenic or natural debris in the southern California Bight in 2008.

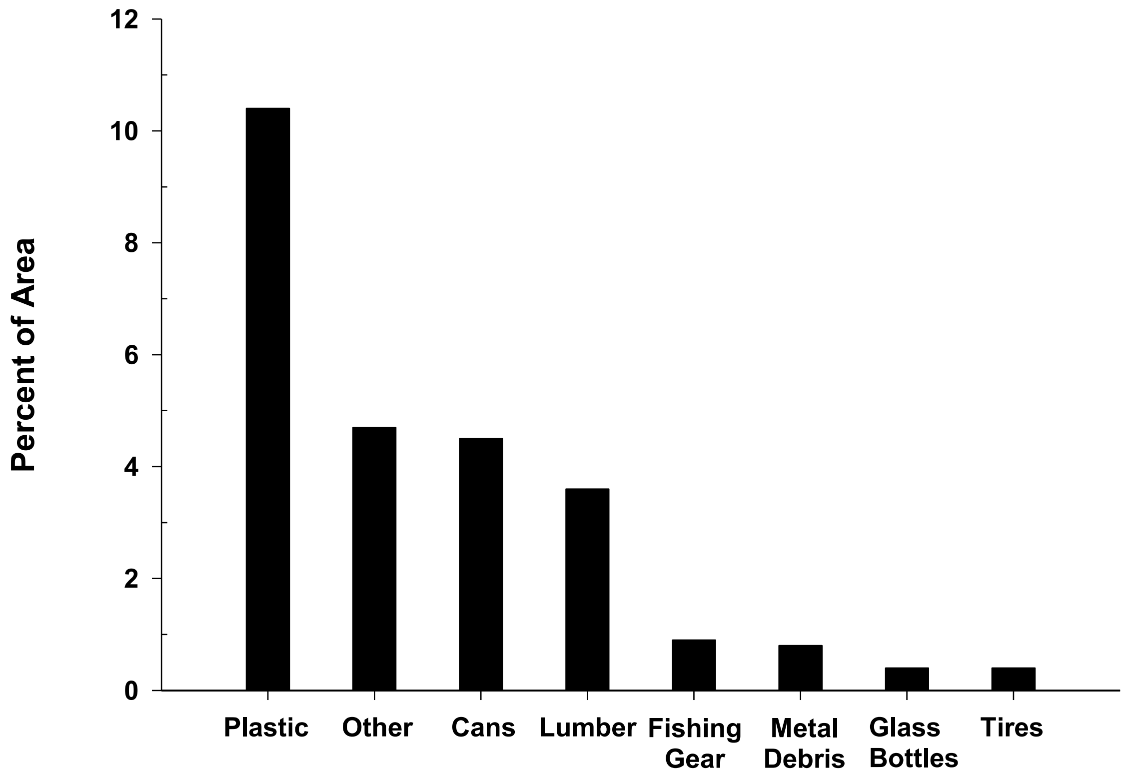

Figure VI-2. Extent of anthropogenic debris in the southern California Bight by debris type from the 2008 Regional Marine Monitoring Program surveys.

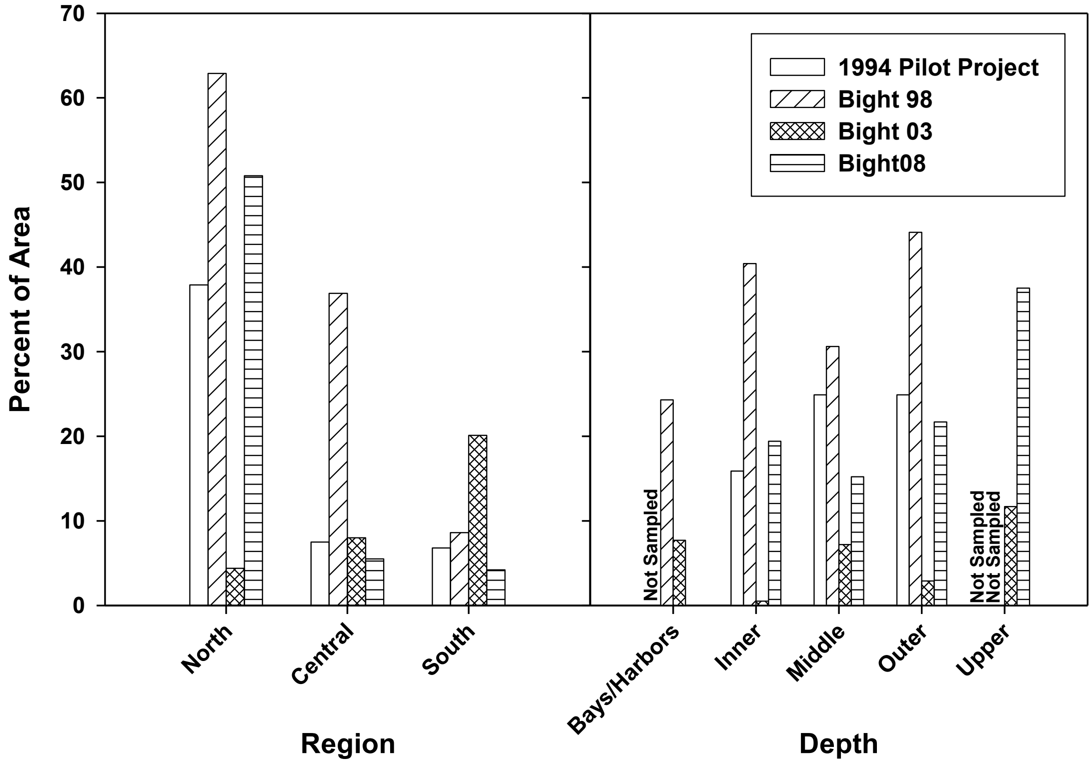

Figure VI-3. Extent of natural debris in the southern California Bight from 1994, 1998, 2003, and 2008 Regional Marine Monitoring Program surveys.

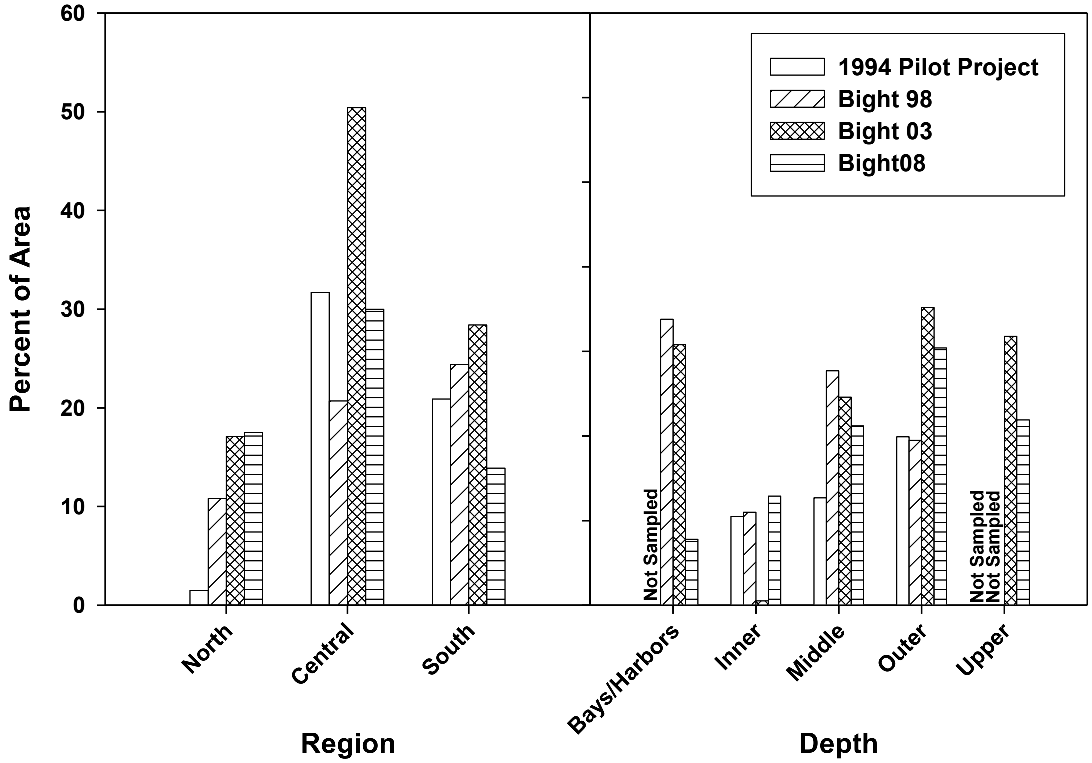

Figure VI-4. Extent of anthropogenic debris in the southern California Bight from 1994, 1998, 2003, and 2008 Regional Marine Monitoring Program surveys.

VII. ASSEMBLAGES AND BIOINTEGRITY

Introduction

The demersal fish and invertebrate fauna of southern California have been monitored for more than 41 years with most of the early studies (1969 to 1993) focusing on effects of wastewater discharge on these fauna (e.g., Carlisle 1969a,b; CSDLAC 1990; CLAEMD 1994a,b; CSDMWWD 1995; CSDOC 1996; CLAEMD 2003a,b; CSDLAC 2006). Recent studies incorporated cluster analysis to describe species and site assemblages (e.g., CSDOC 1996) or cladistic analysis to describe site and species clades (Deets *et al.* 2003a,b) near and away from outfalls. Classification analyses such as clustering and recurrent group analyses have also been used to define soft-bottom fish assemblages with respect to depth, foraging guild, functional organization, etc. (Allen 1985; SCCWRP 1973; Mearns 1974; Allen 1982; Allen *et al.* 1998, 2002, 2007). These techniques were extended to evaluate the invertebrate by Thompson *et al.* (1993a), Allen *et al.* (1998, 1999b, 2002), and NCCOS (2005) and a combination of both fish and invertebrates by Allen *et al.* (2002, 2007). These classifications consistently stratified, initially, by depth followed by additional factors such as foraging base. More recent classification analyses found no segregation based on proximity to wastewater discharge sites reaffirming no effect on the demersal communities resulting from wastewater discharge at that time (Allen *et al.* 1998, 2002).

Allen *et al.* (2001) derived biointegrity indices for fish, invertebrates, and the two taxa combined to assess the spatial extent of altered or disturbed assemblages. These indices were based on the species composition observed along a pollution gradient extending away from a wastewater discharge. These indices have been applied across the SCB continental shelf as general indices of disturbance (Allen *et al.* 2002). Such general application is supported by earlier results which identified disturbed areas off river mouths distant from wastewater discharge.

The objectives of the analyses in this chapter were to: 1) characterize the assemblages of demersal fish and megabenthic invertebrates on the upper continental slope (201-500 m depth), continental shelf (5-200 m), and bay/harbor habitats in the SCB; 2) assess the areal extent of disturbance to SCB demersal communities in the SCB during 2008 using a suite of biointegrity indices; and 3) compare the areal extent of disturbance to SCB demersal communities across the four Bight regional surveys (1994, 1998, 2003, and 2008).

Results

Fish Assemblages

Fish Recurrent Groups

Recurrent group analysis at the 0.50 level of affinity identified 12 recurrent groups of fishes consisting of 2-6 species per group with 11 associate species (Figure VII-1). Group-specific information is presented in Appendix H-1 including the roster of species in each group and their generic habitat affinities and collection sites during the 2008 trawl survey. The groups and associates included 44 (33%) of the 135 species collected in the survey. Depth accounted for most of the identified differences among groups (Table VII-1), which was consistent with their known species-specific distributions. A less well-known group, Group 12, was unique to the Upper Slope Zone (200-500 m).

Fish Site and Species Clusters

Detailed species and site cluster descriptions are presented in Appendix H-2.

Selection of Species
Using the *a priori* screening criteria for abundance and occurrence (see Appendix A6), data collected from 139 stations on 63 species were included in the cluster analysis. The cluster analysis delineated nine major site clusters (station clusters), denoting habitats, and seven major species clusters, denoting species assemblages or communities (Figure VII-2). Each site and species cluster was unique, based on the relative proportion of species within different species clusters comprising a site cluster.

Site Clusters
The site clusters were defined by their similar species assemblages and varied primarily by depth and secondarily by region (Table VII-2). Each site cluster consisted of 2 to 5 species clusters, with 1or 2 of these species being dominant. Each species group was primarily dominant in one or two site groups (Table VII-2). The species distribution among the sites was consistent with known ecological affinities of the dominant species comprising each group (Allen *et al.* 2007).

Fish Functional Organization

Overview of Community Organization.
Fishes collected in this survey represented at least 18 foraging guilds (Figure VII-3). As would be expected in a demersal otter trawl survey, more bottom-living guilds (6) were widespread across the depth range (2-500 m) of the shelf and upper slope than water-column guilds (3). Only the six bottom-living guilds occurred with a frequency of ≥20% of sites within the bathymetric life zones across the entire shelf and upper slope: 1) pelagobenthovores (sanddab guild), 2) ambushing benthopelagivores size B (sculpin-poacher guild), 3) ambushing benthopelagivores size D (sandbass-benthic rockfish guild), 4) extracting benthivores (turbot-sole guild), 5) excavating benthivores (sole-eelpout guild), and 6) nonvisual benthivores (tonguefish-rex sole guild). One guild occurred at ≥20% of sites in a single zone: midwater pelagobenthivores (shiner perch guild –Inner Shelf). Ten bottom-living guilds were commonly encountered (≥20% of sites) along the middle shelf while guilds became less common with depth at the remaining shelf depths.

Dominant Species in Guilds by Depth.
Dominant members of the guilds by depth were typical of the bathymetric zones and included 10 bottom-living guilds (Figure VII-3). Bottom-living guilds included pelagivores, pelagobenthivores, benthopelagivores, and benthivores, with most of these having subdivisions. Of the bottom-living pelagivores, California halibut was dominant on the inner shelf, and bigmouth sole on the middle shelf and outer shelf in this survey, and the guild was virtually absent on the upper slope. The bottom-living pelagobenthivores occurred in ≥20% of the samples in all offshore depth zones (inner shelf, middle shelf, outer shelf, and upper slope). Of the dominant species in this guild, the speckled sanddab was dominant on the inner shelf, the Pacific sanddab on the middle and outer shelf zones, and the slender sole on the upper slope in this survey.

The bottom-living pursuing benthopelagivore guild was absent on the inner shelf, but was represented by longspine and shortspine combfish on the middle shelf, and blacktail snailfish on the upper slope (Figure VII-3). Ambushing benthopelagivores were divided by mouth sizes per Allen (1982) ranging from A (smallest) to D (largest). In this survey, ambushing benthopelagivores size class A were dominated on the inner and middle shelf zones by pygmy poacher. Ambushing benthopelagivores class B were dominated by yellowchin sculpin on the inner and middle shelf zones and blacktip poacher on the outer shelf and upper slope. Fantail sole was the most common class C ambushing benthopelagivore on the inner shelf in this survey, replaced by roughback sculpin on the middle shelf. The guild was rare on the outer shelf and virtually absent on the upper slope. The ambushing benthopelagivores class D stratified by increasing depth of the shelf zone from the inner shelf to the upper slope. Species were dominated by, in order of increasing depth, barred sand bass, California scorpionfish, pink rockfish, and shortspine thornyhead.

The bottom-living benthivore guild included three subdivisions: extracting, excavating, and nonvisual (Figure VII-3). Of the bottom-living extracting benthivore guild, hornyhead turbot dominated the inner and middle shelf zones while Dover sole dominated the outer shelf and upper slope zones. English sole was the dominant excavating benthivores on the continental shelf whereas bigfin eelpout dominated the upper slope zone. Nonvisual benthivores were dominated by California tonguefish on the inner and middle shelf and rex sole the outer shelf and upper slope zones.

Invertebrate Assemblages

Invertebrate Recurrent Groups

Recurrent groups at the 0.50 level of affinity identified 7 recurrent groups consisting of consisting of 2 to 4 species per group, with 7 associate species (Figure VII-4; Appendix H-3). In all, the groups and associates included 23 (10%) of the 229 species of invertebrates collected in the survey. Recurrent group frequency of occurrence ranged from six stations (Recurrent Group 1) to 27 stations (Recurrent Groups 3 and 4; Table VII-3). The seven major recurrent groups segregated mostly by depth, consistent with their ecological distribution and dominant species composition. Group 6 associated with Groups 5 and 7 with all three including species common to the upper slope. No association was detected between Groups 5 and 7 as Group 7 was comprised exclusively of species taken on the upper slope (i.e., sea star, sea cucumber) while Group 5 included outer shelf species (i.e., moustache bay shrimp, flagnose bay shrimp). Group 2 was the only remaining group that was solely comprised of species taken in one shelf depth zone (i.e., blackspotted bay shrimp, tuberculate pear crab). Detailed assemblage descriptions are available in Appendix H-3.

Combined Fish and Invertebrate Assemblages

Combined Fish and Invertebrate Recurrent Groups

Recurrent group analysis at the 0.50 level of affinity identified 20 recurrent groups of combined fishes and invertebrates, consisting of 2 to 7 species per group with 21 associate species (Figures VII-5 and VII-6; Table VII-4). In all, the groups and associates included 93 (26%) of the 365 fish and invertebrate species, combined, collected. These included 51 (38%) of the 135 species of fish and 42 (18%) of the 229 invertebrate species collected (Figures VII-5 and VII-6). Recurrent groups were found at 3 to 32 stations (Table VII-4). Of these 20 groups, seven were replicates of either a Fish or Invertebrate Recurrent Group with 13 representing a regular co-occurrence of fish and invertebrate species. The combined assemblages primarily stratified by depth as was described for the individual fish and invertebrate assemblages. Occurrences were consistent with known ecological distributions for each species examined and generally represent overlap of the fish and invertebrate assemblages at similar depth ranges. In many cases, the Fish/Invertebrate group was the same as a prior fish or invertebrate group in the taxa-specific analysis. Few groups incorporated separate fish and invertebrates into one combined fish/invertebrate group. See Appendix H-4 for a detailed narrative of each assemblage.

Biointegrity Assessment

Biointegrity indices for fish, invertebrates, and combined fishes and invertebrates (Allen *et al.* 2001a) were used to assess the extent of altered assemblages on the southern California shelf. These indices were developed to assess conditions in relation to wastewater outfalls on a gradient ranging away from the discharge. They are used here as representative of generalized disturbance gradients. The purpose of these indices are not, however, meant to be indicative of fluctuations in the total standing stock of the fish species as this can be influenced by, among other things, fishing, habitat degradation, oceanographic conditions, etc. in addition to pollution. Two fish indices, the Fish Response Index (FRI) and Fish Foraging Guild Index (FFG) were used to assess alterations in fish assemblages in response to a pollution gradient from an offshore treated wastewater outfall. The FRI was applied to nearly the entire survey area whereas the FFG was applied only to the middle shelf area. The Megabenthic Invertebrate Response Index (MIRI) was used to assess alterations in invertebrate assemblages and the Trawl Response Index (TRI) was used for combined fish and invertebrate effects. Fish and invertebrate pollution gradient position values (*pi*) by species by depth zone for biointegrity indices FRI, MIRI, and TRI, are given in Appendices A-3 through A-5. Species and depth-specific pollution gradient values are not used in calculating FFG index values (Allen *et al.* 2001).

Fish Response Index (FRI) and Fish Foraging Guild Index

Based on the FRI, 62% of the area of the SCB was classified as normal (reference) or undisturbed and 4% as abnormal or disturbed (nonreference; Figure VII-7). The remaining 34% of the SCB was in areas too deep for application of the FRI. The Inner shelf had the highest percent disturbed area by depth zone (16%) followed by the Bays and Harbors (8%; Table VII-5; Figures VII-8 and VII-9). None of the Middle Shelf, or Outer Shelf areas were classified as disturbed based on the FRI index (Table VII-5). The northern region had the most area considered as disturbed by this index (12%), followed by the central (<1%) and southern (<1%) regions (Table VII-5; Figure VII-8). The FFG index indicated that 18% of the middle shelf zone was classified as disturbed (nonreference) (Figures VII-10 and VII-11).

Comparison of FRI and FFG by Depth Zone and Survey Year

The Inner Shelf and Bays and Harbors consistently rank the highest in terms of disturbed areas as derived by the FRI in each of the last three Bight Regional Surveys (Figure VII-9). Bays and Harbors FRI results have been generally similar between the surveys with less variability than was observed along the Inner Shelf. Conditions on the Middle Shelf were consistent with past surveys while the Outer Shelf conditions were consistent with those recorded during the 1998 survey and better than was observed during the 2003 survey when a small percentage of disturbed areas were identified. In general, the 2008 survey recorded little difference from prior surveys. Percent disturbed areas based on FFG for the middle shelf was highest in 2003 followed by 2008. The lowest percent disturbed area was observed in 1998.

Trawl (Combined Fish and Invertebrate) Response Index (TRI)

Using the TRI, disturbed (nonreference) areas in the SCB regions accounted for about 8% of the area and undisturbed (reference) areas accounted for 59% of the area sampled by trawl in the SCB during the 2008 trawl survey (Figure VII-12). The remaining 34% of the SCB was in areas too deep for application of the TRI. By region, disturbed areas accounted for 12% of the Northern Region, 2% of the Central Region, and 7% of the Southern Region (Table VII-5; Figures VII-13 and VII-14). By depth zones, disturbed areas accounted for 56% of the Bays and Harbors (primarily in the Central Region), and 23% of the Inner Shelf (primarily in the Northern and Southern Regions; Table VII-5; Figures VII-13 and VII-14). Middle Shelf and Outer Shelf stations were predominantly undisturbed (Figure VII-12). The TRI was not applicable in the Upper Slope stratum.

Comparison of TRI by Depth Zone and Survey Year.

The Trawl Response Index (TRI) indicated the greatest area of disturbed (nonreference) area in the Bays and Harbors during the 2008 survey (85%). The TRI indicated the greatest area of disturbed (nonreference) area in the Inner Shelf during the 2003 survey (28%). Middle Shelf and Outer Shelf results have consistently indicated undisturbed areas in all three surveys.

Megabenthic Invertebrate Response Index (MIRI)

Using the MIRI index, about 57% of the area of the SCB sampled by trawl in the Bight'08 regional survey was classified as undisturbed (reference) area, and about 11% was classified as disturbed (nonreference) area (Figure VII-15). By region, disturbed areas for MIRI accounted for 16% of the Northern Region, 9% of the Central Region, and 10% of the Southern Region (Table VII-5). By depth zone, disturbed areas for MIRI accounted for 70% of Bays and Harbors area, 36% of the Inner Shelf, and 3% of the Middle Shelf (Table VII-5). However, the MIRI index was not applicable to outer shelf and upper slope areas (Figures VII-15 and VII-16). Nonreference areas for Bays and Harbors were primarily in Los Angeles and Long Beach Harbors (Figures VII-15 and VII-16).

Comparison of MIRI by Depth Zone and Survey Year

The percent disturbed area for the MIRI was very low for all three years (1998, 2003, and 2008; Figure VII-17). In Bays and Harbors and along the Inner Shelf, the percent disturbed area for this index was by greatest in the 2008 survey (74%). The two prior surveys recorded comparatively similar percentages of disturbed areas (51%).

Comparison of FRI, MIRI and TRI by Survey Year

The three indices varied similarly in relative magnitude of disturbed area over time (Figure VII-18). Regardless of survey year, for the SCB as a whole, none of the indices differed dramatically or in a monotonic direction between 1998 and 2008. Overall, the percent of disturbed area in the SCB was low, between 3% and 18% depending upon the index used. Regardless of index or survey year, the greatest relative area in disturbed (non-reference) condition almost always the Bay and Harbor stratum. Similarly, all three indices indicated that nearly all of the Middle and Outer Shelf strata were in undisturbed (reference) condition.

Discussion

Assemblage analyses described a demersal community that segregated principally by depth. Regardless of the analytical approach utilized (recurrent groups, cluster analysis, fish functional groups), dominant species stratified on depth similar to the depth stratifications employed during this survey (3-30 m, 30-120 m, 120-200 m, 200-500 m). These patterns are well-known and have been described elsewhere (Carlisle 1969a, Fauchald and Jones 1979, Allen and Voglin 1976, Allen 1985, Allen 2006a), so choosing these stratifications was not happenstance. Recurrent group analysis and cluster analysis defined similar site and species groupings in all four Bight regional surveys (Allen *et al.* 1998, 2002, 2007). The consistency in these groupings persisted within fish assemblages, megabenthic invertebrate assemblages, or combined fish and invertebrate assemblages.

Perhaps a unique component of the Bight'08 program was the assemblage associated with the Upper Slope stratum. This stratum is not monitored routinely and has a life zone dominated by many species not typically encountered at the routinely monitored depths of the continental shelf. Some fish species were well-known such as Dover sole, slender sole, and Pacific hake. Other fishes, however, such as the shortspine thornyhead and dogface witch eel, are relatively unstudied and the effects of anthropogenic impacts on these species are unknown. Similarly, Upper Slope invertebrates such as the brittlestar *Asteronyx* are also relatively unstudied. The lack of understanding between anthropogenic inputs and responses from these unique deepwater taxa takes on more relevance now that we know sediments at these depths contain some of the highest concentrations in the SCB for several anthropogenic trace metals and organic contaminants (Maruya and Schiff 2009).

Regardless of which biointegrity index was applied, a large extent of fish and megabenthic invertebrate communities appeared to be in undisturbed reference condition. Whether the FRI, FFG, MIRI, or TRI was utilized, the vast majority of the SCB was deemed in undisturbed reference condition. Similarly, all available indices indicated that where disturbed communities did exist, it was exclusively found in Bay and Harbor or Inner Shelf strata. The extent of Middle and Outer Shelf nonreference condition was largely nonexistent. This may indicate that there are nearshore sources of impacts to fish and megabenthic invertebrate community assemblages, and that offshore sources are no longer a large-scale threat to the ecosystem as had been observed historically (Carlisle 1969b, Stull 1995).

The widespread extent of undisturbed reference condition based on our biointegrity tools such as the FRI, MIRI, or TRI has been relatively consistent across previous regional surveys. Nonreference condition defined by the FRI has changed little, varying from 6 to 8% of the SCB between 1998 and 2008. Similarly, the Bays and Harbor stratum has consistently been the stratum with the greatest extent of disturbed (nonreference) condition over the last decade. Between 36 and 85% of the Bays and Harbor stratum has been defined as disturbed by the TRI, with the greatest relative extent occurring during 2008. Whether this increase in trend of disturbed area of the Bays and Harbors continues is unknown.

Three structural (FRI, MIRI, TRI) biointegrity indices and one functional (FFG) biointegrity index were used to assess the condition of the demersal communities in Bight '08. The FRI, TRI, and MIRI were calibrated and validated on the relative distribution of species along a pollution gradient (Allen *et al.* 2001). For the structural indices, the polluted end of the gradient was largely based on early 1970's surveys offshore of the Palos Verdes Peninsula, an area considered among the most polluted in the SCB at that time (Mearns *et al.* 1976). The alternate end of the gradient was established using data from many locations over many years where anthropogenic pollutant impacts to demersal, soft-bottom habitat were reduced or undetectable. All three structural biointegrity tools included inner, middle, and outer shelf strata, but did not include data from the continental slope. Similarly, the FFG index was developed from middle continental shelf communities and its application is limited to this depth (Allen 1982). Therefore, all four assessment tools are limited in their application in two ways. First, their application in slope habitats has not been calibrated or validated. Therefore, an assessment of this habitat was not attempted for this report. Second, the assessment tools are focused on pollutant-mediated impacts. We know that other anthropogenic stressors (i.e., fishing) can also disrupt demersal fish and megabenthic invertebrate communities, but the existing tools were not designed to specifically measure non-pollutant impacts.

Table VII-1. Mean and range of depths of demersal fish recurrent groups on the southern California shelf and slopes at depths of 2-484 m in July-September 2008.

Recurrent Group	No. of Stations	Mean Depth (m)	Depth Range (m)
1	9	4	2-6
2	4	4	4-4
3	3	6	5-6
4	7	12	6-24
5	9	19	6-44
6	3	27	22-30
7	10	28	13-42
8	24	48	13-86
9	15	100	40-152
10	15	150	77-200
11	13	166	94-225
12	9	401	348-484

Table VII-2. Frequency of occurrence (percent of stations) of demersal fish species of specific species clusters with shading identifying those occurring at 50% or more of the stations in at least one site cluster on the southern California shelf and upper slope at depths of 2-484 m, July-September 2008.

			Site Cluster								
			1	2	3	4	5	6	7	8	9
			Upper slope	Upper slope	Upper Slope-Outer/Middle Shelf	Outer/Middle Shelf	Middle/Inner Shelf	Middle/Inner Shelf	Inner Shelf	Inner Shelf/B&H	B&H
		Number of Stations	15	11	21	15	25	18	8	15	11
		Depth Range (m)	365-484	209-421	70-285	77-198	26-86	15-48	8-16	5-24	2-12
Species Cluster	Common Name	Scientific Name									
A	black croaker	*Cheilotrema saturnum*									45
A	spotted sand bass	*Paralabrax maculatofasciatus*								7	82
A	barred sand bass	*Paralabrax nebulifer*						6		40	91
A	yellowfin croaker	*Umbrina roncador*									55
A	round stingray	*Urobatis halleri*								7	55
B	slough anchovy	*Anchoa delicatissima*								7	36
B	northern anchovy	*Engraulis mordax*			19		8			33	
B	white croaker	*Genyonemus lineatus*				7	4		25	60	
B	bay goby	*Lepidogobius lepidus*					28			7	
B	California halibut	*Paralichthys californicus*						28	50	47	73
B	specklefin midshipman	*Porichthys myriaster*					12	22	25	33	9
B	California skate	*Raja inornata*			10	7	44	6		13	
B	queenfish	*Seriphus politus*							13	40	
C	shiner perch	*Cymatogaster aggregata*					12		38	53	
C	giant kelpfish	*Heterostichus rostratus*							13	27	18
C	Pacific staghorn sculpin	*Leptocottus armatus*							88		
C	white seaperch	*Phanerodon furcatus*					12		13	47	
C	spotted turbot	*Pleuronichthys ritteri*					8	33	25	7	9
C	vermilion rockfish	*Sebastes miniatus*					20				
C	barcheek pipefish	*Syngnathus exilis*					8		38	7	
C	fantail sole	*Xystreurys liolepis*					24	22	63	13	
D	roughback sculpin	*Chitonotus pugetensis*				7	68	39	13		
D	Pacific sanddab	*Citharichthys sordidus*		9	81	100	100	33		7	
D	speckled sanddab	*Citharichthys stigmaeus*					44	94	100	47	
D	longfin sanddab	*Citharichthys xanthostigma*			10	13	56	44	13	7	
D	bigmouth sole	*Hippoglossina stomata*			10	47	64	28			
D	yellowchin sculpin	*Icelinus quadriseriatus*			19	7	100	44	13	7	
D	pygmy poacher	*Odontopyxis trispinosa*			10		64	11		7	
D	lingcod	*Ophiodon elongatus*			10		20				
D	English sole	*Parophrys vetulus*		45	52	87	68	44	25	13	
D	hornyhead turbot	*Pleuronichthys verticalis*				47	88	94	63	20	
D	plainfin midshipman	*Porichthys notatus*			52	67	76	6	13	7	
D	calico rockfish	*Sebastes dallii*			5		36				
D	California tonguefish	*Symphurus atricaudus*			5		84	61	38	40	9
D	California lizardfish	*Synodus lucioceps*				13	60	50	50	40	
D	pink seaperch	*Zalembius rosaceus*			43	73	76	6		7	
D	longspine combfish	*Zaniolepis latipinnis*			19	47	72	6			
E	spotted cusk-eel	*Chilara taylori*			19	67	24				
E	California scorpionfish	*Scorpaena guttata*			14	7	16	44		7	
E	greenspotted rockfish	*Sebastes chlorostictus*			29	20					
E	greenstriped rockfish	*Sebastes elongatus*			38	80	4				
E	pink rockfish	*Sebastes eos*		18	48	47	4				
E	greenblotched rockfish	*Sebastes rosenblatti*		18	10	40	8				
E	stripetail rockfish	*Sebastes saxicola*		18	71	87	40	6			
E	halfbanded rockfish	*Sebastes semicinctus*			19	80	20				
E	bluespotted poacher	*Xeneretmus triacanthus*				47					
E	shortspine combfish	*Zaniolepis frenata*		9	76	100	28				
F	blacktail snailfish	*Careproctus melanurus*	53	9	5						
F	black eelpout	*Lycodes diapterus*	33	9	5						
F	California grenadier	*Nezumia stelgidolepis*	47								
F	filetail cat shark	*Parmaturus xaniurus*	47	9							
F	longnose skate	*Raja rhina*	27	18	10						
F	aurora rockfish	*Sebastes aurora*	60	18							
F	longspine thornyhead	*Sebastolobus altivelis*	33								
F	northern lampfish	*Stenobrachius leucopsarus*	33	18							
G	bigeye poacher	*Bathyagonus pentacanthus*		45							
G	dogface witch eel	*Facciolella equatorialis*	20	55							
G	rex sole	*Glyptocephalus zachirus*	40	73	48	13					
G	bigfin eelpout	*Lycodes cortezianus*	33	73	10	13					
G	blackbelly eelpout	*Lycodes pacificus*	27	18	76	40					
G	slender sole	*Lyopsetta exilis*	87	100	86	93	4				
G	Pacific hake	*Merluccius productus*	53	91	14	40					
G	Dover sole	*Microstomus pacificus*	100	100	90	100	44				

Table VII-3. Mean and range of depth of megabenthic invertebrate recurrent groups on the southern California shelf and upper slope at depths of 2-484 m in July-September 2008.

Recurrent Group	No. of Stations	Mean Depth (m)	Depth Range (m)
1	6	4	2-4
2	13	16	6-34
3	27	57	20-174
4	27	101	35-195
5	14	223	140-414
6	15	337	172-439
7	9	417	365-439

Table VII-4. Mean and range of depths of combined demersal fish and megabenthic invertebrate recurrent groups on the southern California shelf and upper slope in July-September 2008.

Recurrent Group	No. of Stations	Mean Depth (m)	Depth Range (m)
1	7	4	2-4
2	4	4	4-4
3	4	4	4-4
4	3	6	5-6
5	7	12	6-24
6	13	16	6-34
7	9	19	6-44
8	3	27	22-30
9	10	28	13-42
10	24	48	13-86
11	6	69	41-172
12	14	78	38-136
13	32	114	26-209
14	12	165	94-225
15	27	205	94-407
16	14	223	140-414
17	13	342	172-439
18	6	395	365-426
19	9	401	348-484
20	6	418	386-433

Table VII-5. Percent nonreference area for SCB regions and depth zones by integrity index for Bight 2008 trawl survey of demersal fishes and invertebrates.

	BIOINTEGRITY INDEX			
BIGHT ZONE	**FRI**	**FFG**	**TRI**	**MIRI**
Region				
North	**12.2**	**22.2**	**12.2**	**16.4**
Central	**0.37**	**15.4**	**2.2**	**9.1**
South	**0.01**	**18.2**	**6.6**	**9.9**
Depth				
Bays/Harbors	**7.8**	____	**55.5**	**70.1**
Inner Shelf	**16.7**	____	**22.6**	**35.5**
Middle Shelf	____	**18.2**	____	**3**
Outer Shelf	____	____	____	____
Upper Slope	____	____	____	____

Indices: FRI = Fish Response Index. FFG = Fish Foraging Guild Index.
TRI = Trawl Response Index (combined fishes and invertebrates).
MIRI = Megabenthic Invertebrate Response Index.

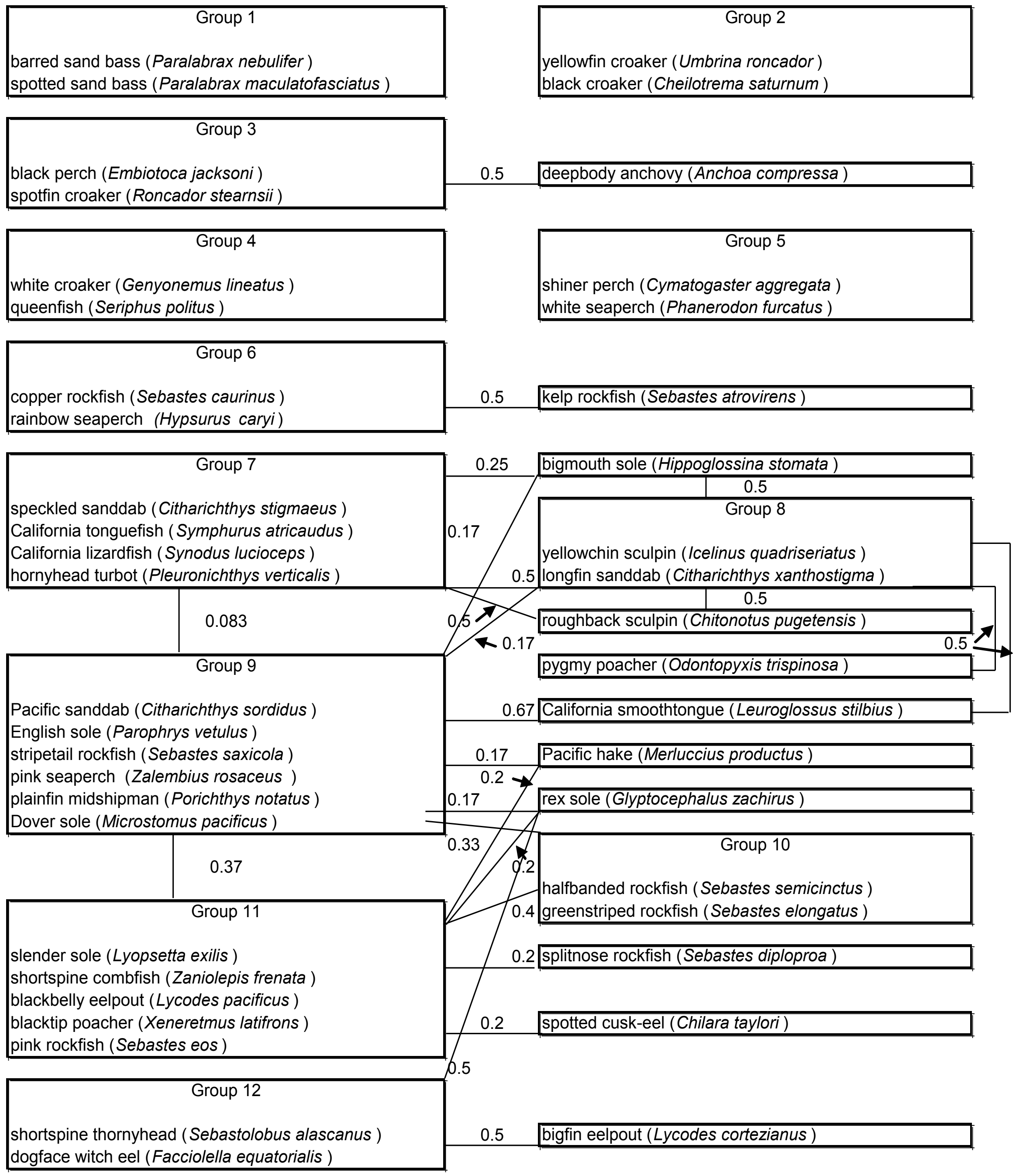

Figure VII-1. Recurrent groups of demersal fishes on the southern California shelf at depths of 2-484 m, July-September 2008. Index of affinity (I.A. = 0.5 (0.495)). Groups are numbered from shallow to deep. Species within a group are listed in order of abundance. Connex lines show relationships between groups and associates, with values indicating the proportion of possible pairs with IA = 0.5 (0.495).

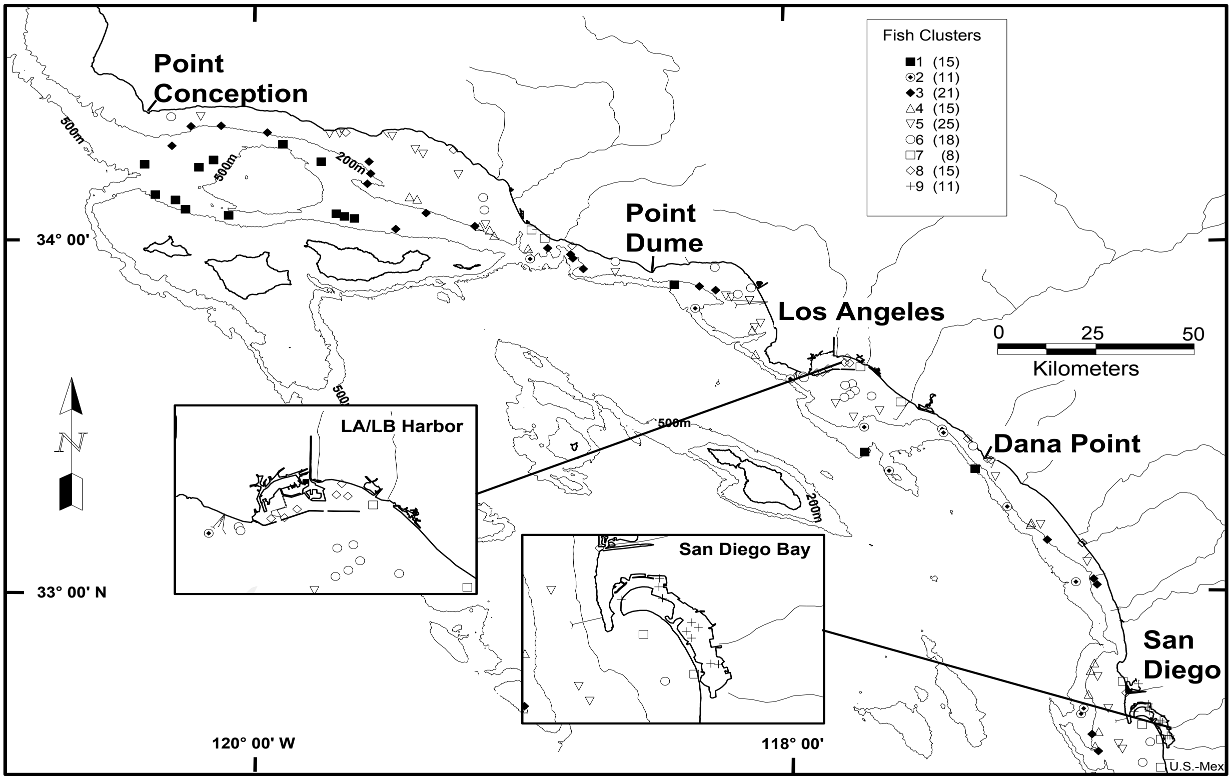

Figure VII-2. Distribution of fish site clusters on the southern California shelf and upper slope at depths of 2-484 m, July-September 2008.

<table>
<tr><th>Guild</th><th>Guild Code</th><th>Inner Shelf 2-30 m</th><th>Middle Shelf 31-120 m</th><th>Outer Shelf 121-200 m</th><th>Upper Slope 201-500 m</th></tr>
<tr><td>Water-column</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Pelagivores</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Schooling</td><td>1A1</td><td>Seriphus politus</td><td>--------</td><td colspan="2">Merluccius productus</td></tr>
<tr><td>Bottom-refuge Visual</td><td>1A2a</td><td>--------</td><td colspan="2">Sebates saxicola</td><td>Sebastes diploproa</td></tr>
<tr><td>Bottom-refuge Nonvisual</td><td>1A2b</td><td>Porichthys myriaster</td><td colspan="2">Porichthys notatus</td><td>--</td></tr>
<tr><td>Pelagobenthivores</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Midwater</td><td>1B1</td><td>Cymatogaster aggregata</td><td>--------</td><td></td><td></td></tr>
<tr><td>Cruising</td><td>1B2</td><td></td><td></td><td></td><td>--------</td></tr>
<tr><td>Benthopelagivore</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Cruising Diurnal</td><td>1C1</td><td>--------</td><td colspan="2">Zalembius rosaceus</td><td></td></tr>
<tr><td>Cruising Nocturnal</td><td>1C2</td><td>Genyonemus lineatus</td><td>--------</td><td>------</td><td>Parmaturus xaniurus</td></tr>
<tr><td>Benthivores</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Cruising Nonvisual</td><td>1D</td><td>--------</td><td colspan="2">Chilara taylori</td><td>--------</td></tr>
<tr><td>Bottom-living</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Pelagivores</td><td>2A</td><td>Paralichthys californicus</td><td colspan="2">Hippoglossina stomata</td><td>--</td></tr>
<tr><td>Pelagobenthivores</td><td>2B</td><td>Citharichthys stigmaeus</td><td colspan="2">Citharichthys sordidus</td><td>Lyopsetta exilis</td></tr>
<tr><td>Benthopelagivore</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Pursuing</td><td>2C1</td><td></td><td>Zaniolepis latipinnis</td><td>Zaniolepis frenata</td><td>Careproctus melanurus</td></tr>
<tr><td>Ambushing</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Size A</td><td>2C2a</td><td colspan="2">Odontopyxis trispinosa</td><td>--</td><td></td></tr>
<tr><td>Size B</td><td>2C2b</td><td colspan="2">Icelinus quadriseriatus</td><td colspan="2">Xeneretmus latifrons</td></tr>
<tr><td>Size C</td><td>2C2c</td><td>Xystreurys liolepis</td><td>Chitonotus pugetensis</td><td>--------</td><td>--</td></tr>
<tr><td>Size D</td><td>2C2d</td><td>Paralabrax nebulifer</td><td>Scorpaena guttata</td><td>Sebastes eos</td><td>Sebastolobus alascanus</td></tr>
<tr><td>Benthivores</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Extracting</td><td>2D1a</td><td colspan="2">Pleuronichthys verticalis</td><td colspan="2">Microstomus pacificus</td></tr>
<tr><td>Excavating</td><td>2D1b</td><td colspan="3">Parophrys vetulus</td><td>Lycodes cortezianus</td></tr>
<tr><td>Nonvisual</td><td>2D2</td><td colspan="2">Symphurus atricaudus</td><td colspan="2">Glyptocephalus zachirus</td></tr>
</table>

Concept and methods from Allen (1982, 2006a)
Boxes indicate where guild occurred in 20% or more of stations in depth class.
Dotted lines define areas where guild occurred in less than 20% of stations in depth class.
Dominant species of each guild are shown by depth zone.
See Glossary G2 for common names of fish species.

Figure VII-3. Functional organization of demersal fish communities on the shelf and slope of southern California in July-September 2008. Blocks enclose bathymetric zones where guild occurred in 20% or more of stations. Species in block is dominant species of guild in that zone.

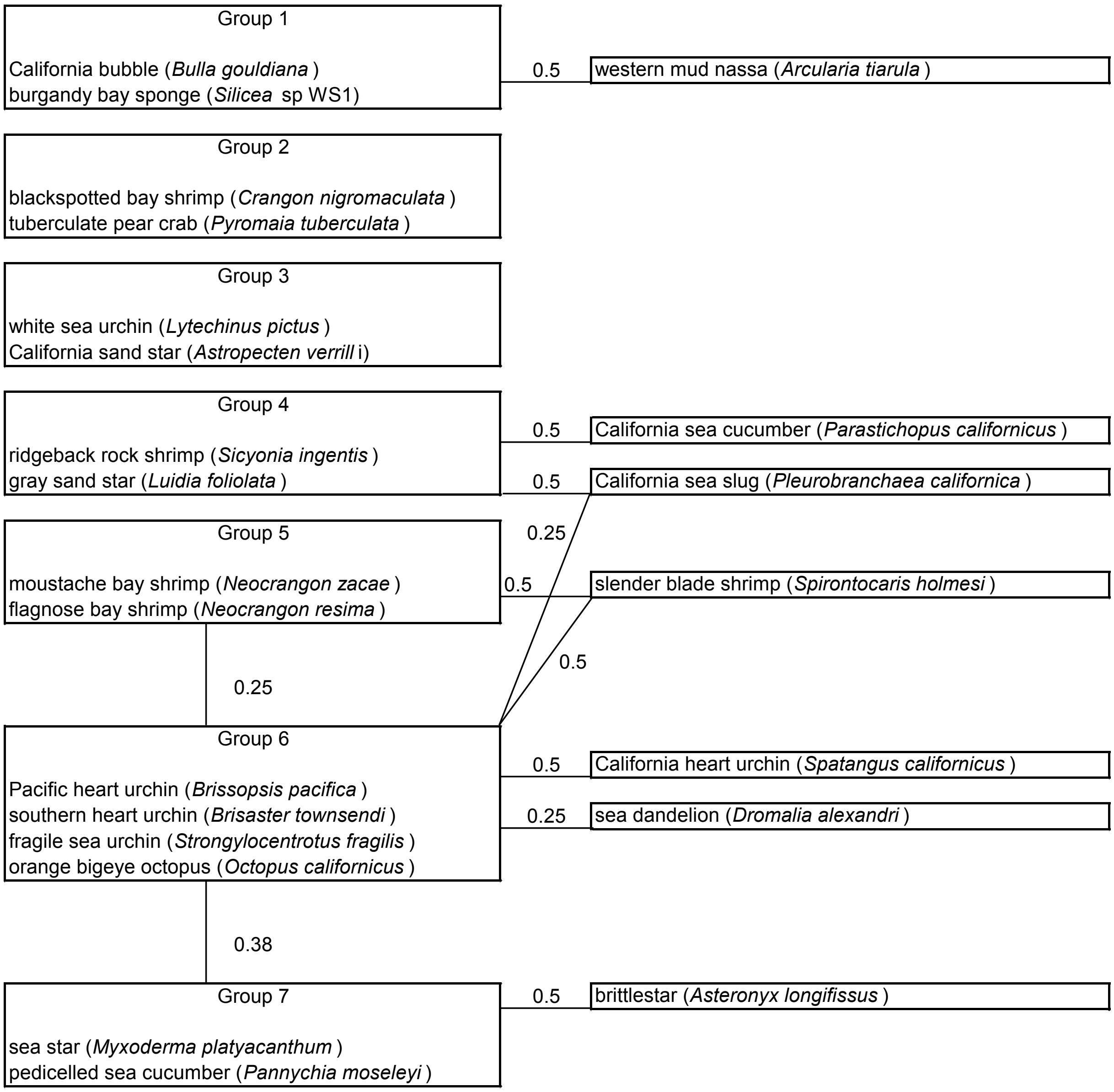

Figure VII-4. Recurrent groups of megabenthic invertebrates found at multiple sites on the southern California shelf at depths of 2-484 m, July-September 2008. Index of affinity (I.A. = 0.5 (0.495)). Groups are numbered from shallow to deep. Species within a group are listed in order of abundance. Connex lines show relationships between groups and associates, with values indicating the proportion of possible pairs with IA = 0.5 (0.495).

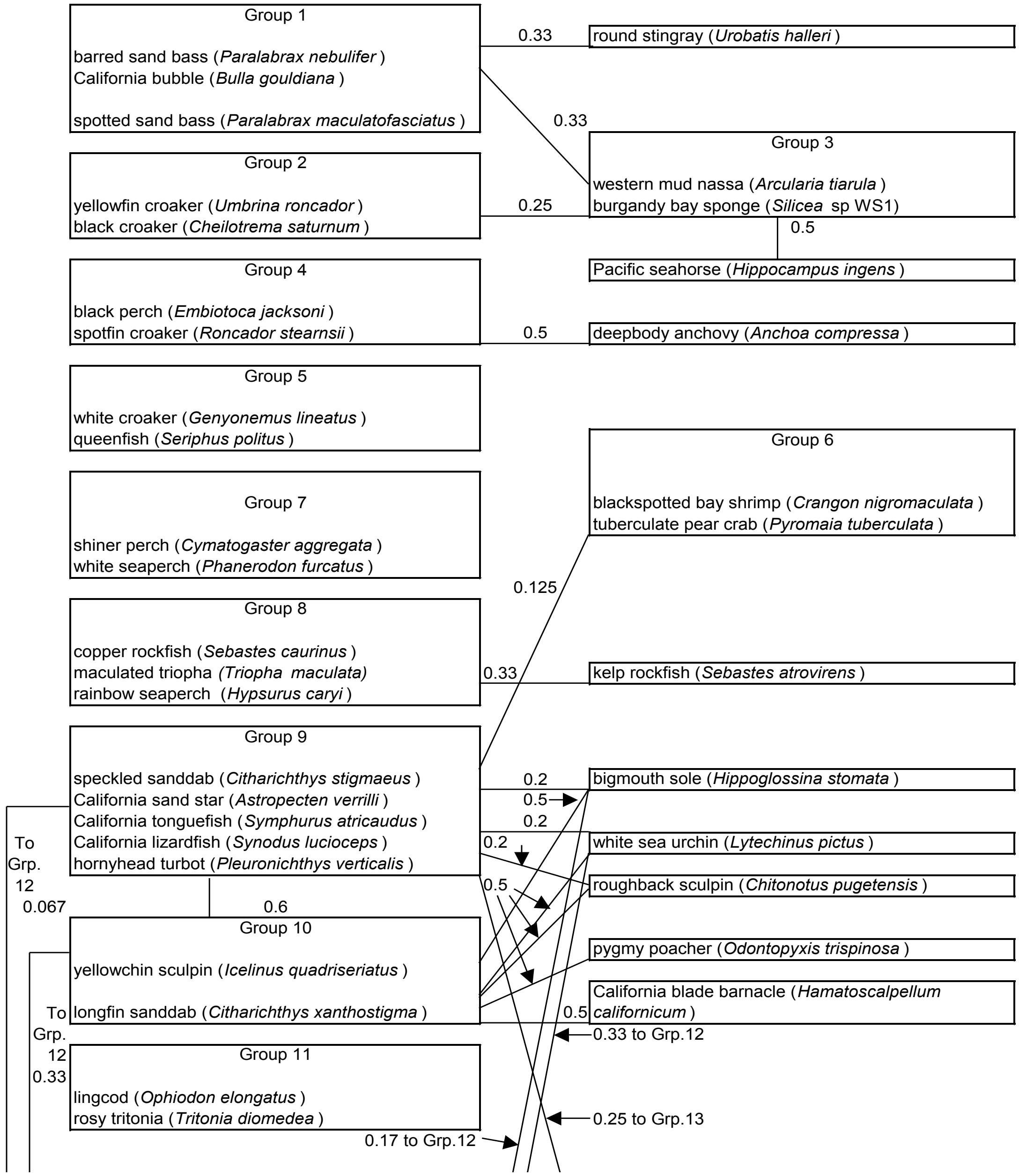

Figure VII-5. Recurrent groups of combined demersal fishes and megabenthic invertebrates occurring at multiple sites on the southern California shelf and slope at depths of 2-484 m, July-September 2008. Index of affinity (I.A.) = 0.50. Groups are numbered in order of depth. Species within a group are listed in order of abundance. Lines show relationships between groups and associates. Values are the proportion of possible pairs with I.A. = 0.50.

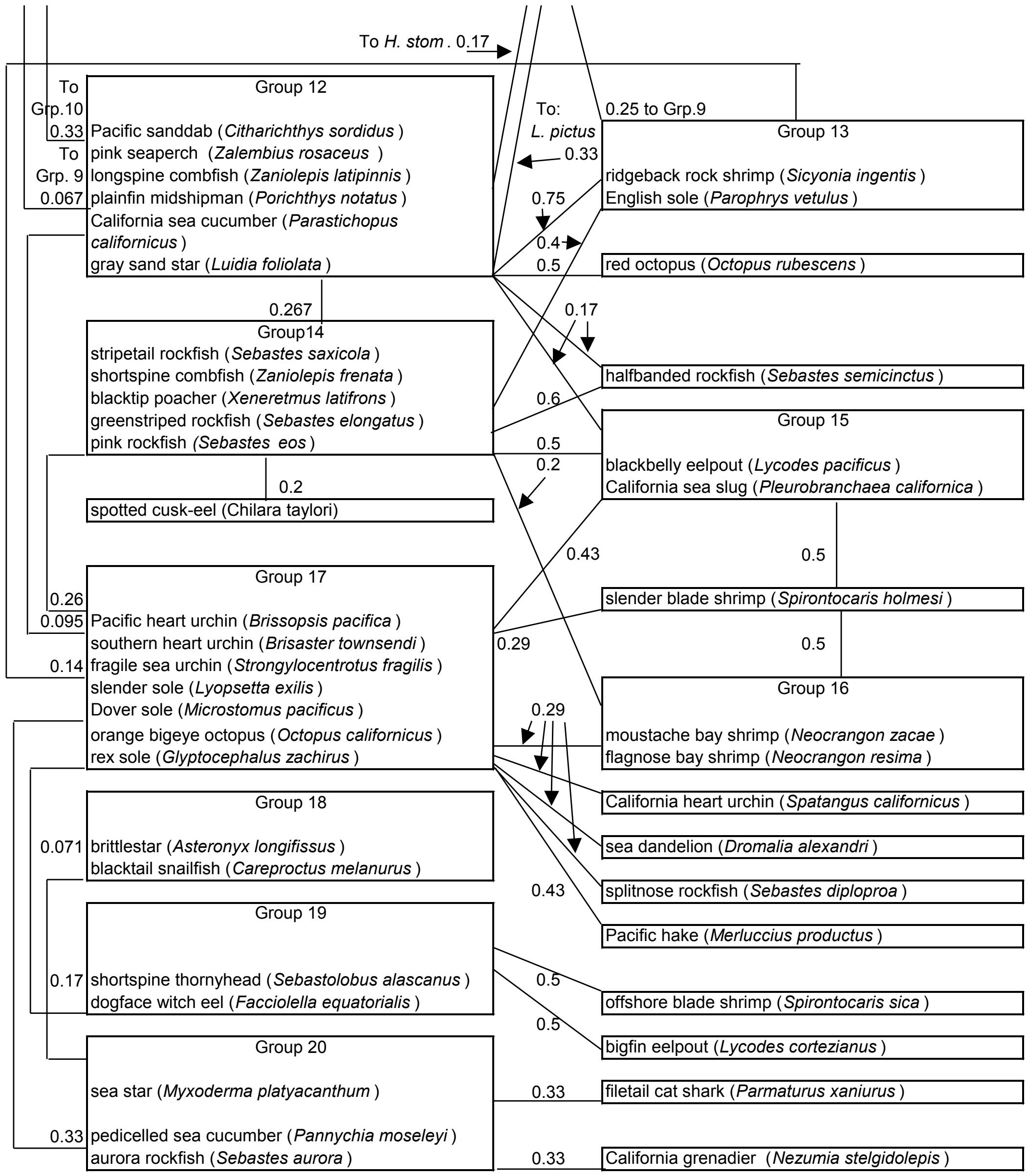

Figure VII-6. Continuation of Figure VII-5 for recurrent groups of combined demersal fishes and megabenthic invertebrates occurring at multiple sites on the southern California shelf and slope at depths of 2-484 m, July-September 2008. Index of affinity (I.A.) = 0.50. Groups are numbered in order of depth. Species within a group are listed in order of abundance. Lines show relationships between groups and associates, with values indicating the proportion of possible pairs with I.A. = 0.50.

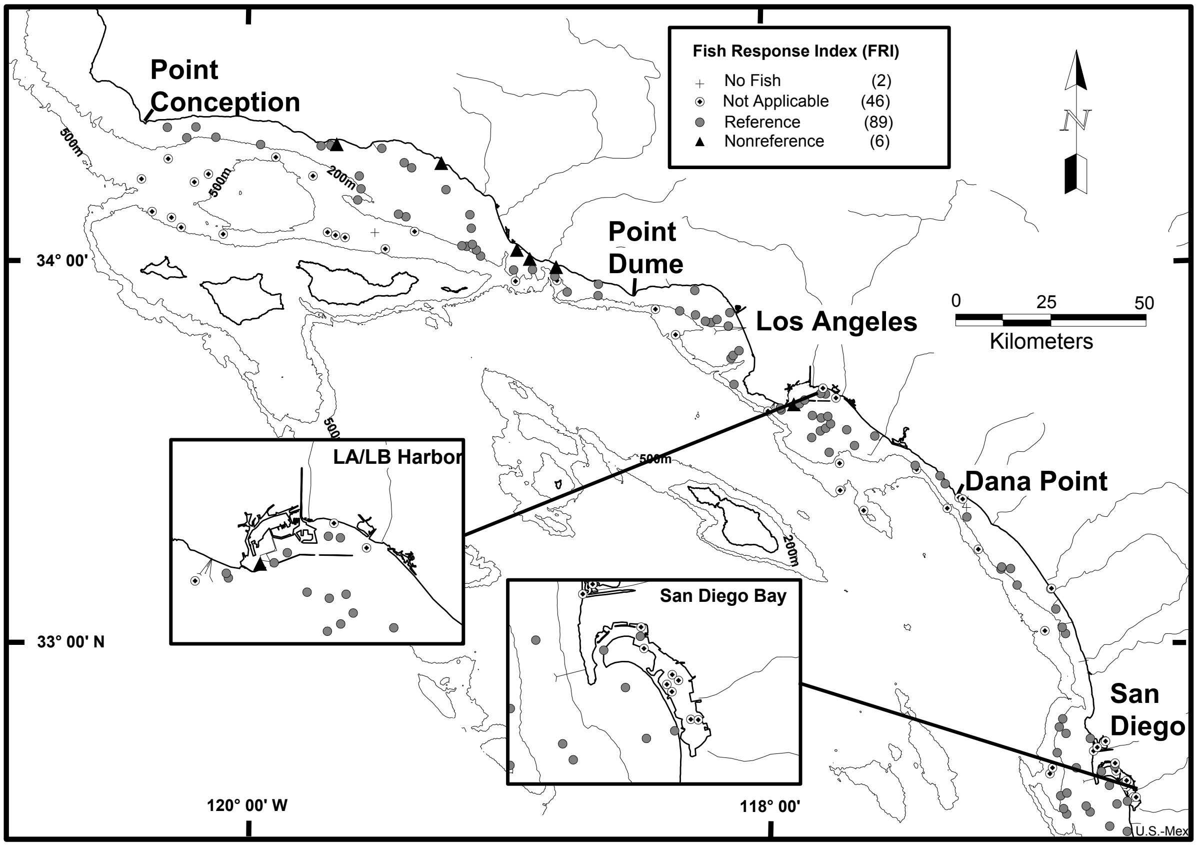

Figure VII-7. Distribution of nonreference area of Fish Response Index (FRI) categories by region and depth zone in Bight'08 regional trawl survey of 2008.

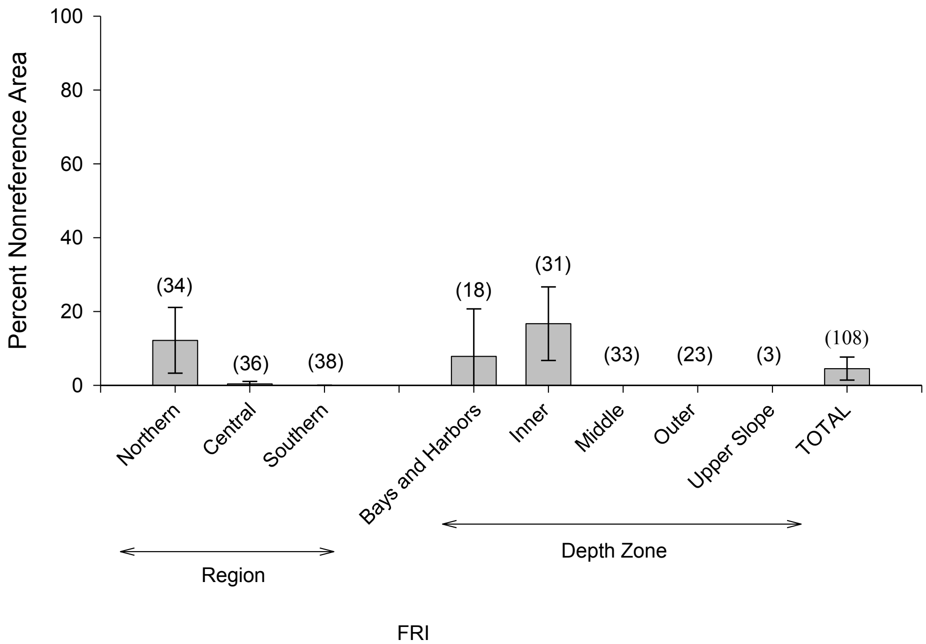

Figure VII-8. Percent nonreference area of fish response index (FRI) by subpopulation of regions and depth zones at depths of 2-484 m in Bight'08 regional trawl survey in 2008. Numbers in parentheses are the total number of stations with an FRI value. The size of each bar is the percent nonreference area

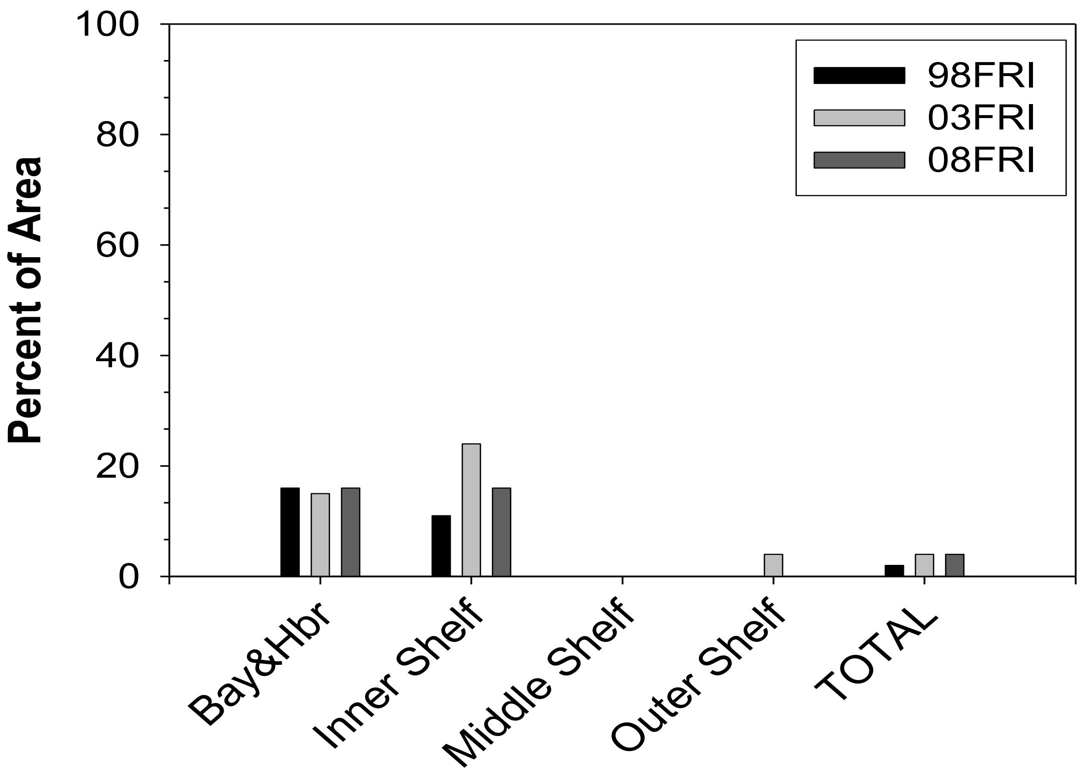

Figure VII-9. Percent nonreference area of Southern California Bight for Fish Response Index (FRI) by Shelf Zone in Bight'98, Bight'03, and Bight'08 regional trawl surveys.

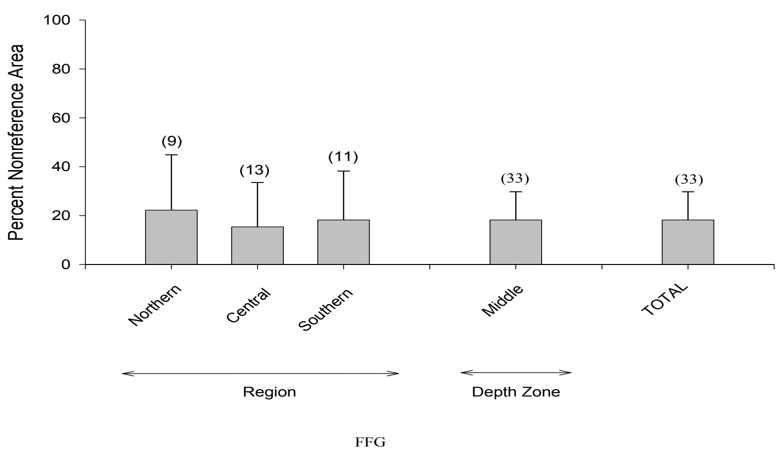

Figure VII-10. Percent nonreference area of Fish Foraging Guild Index (FFG) by subpopulation of regions and depth zones at depths of 2-484 m in Bight'08 regional trawl survey in 2008. Numbers in parentheses are the total number of stations in the subpopulation with an FFG value. The size of each bar is the percent nonreference area.

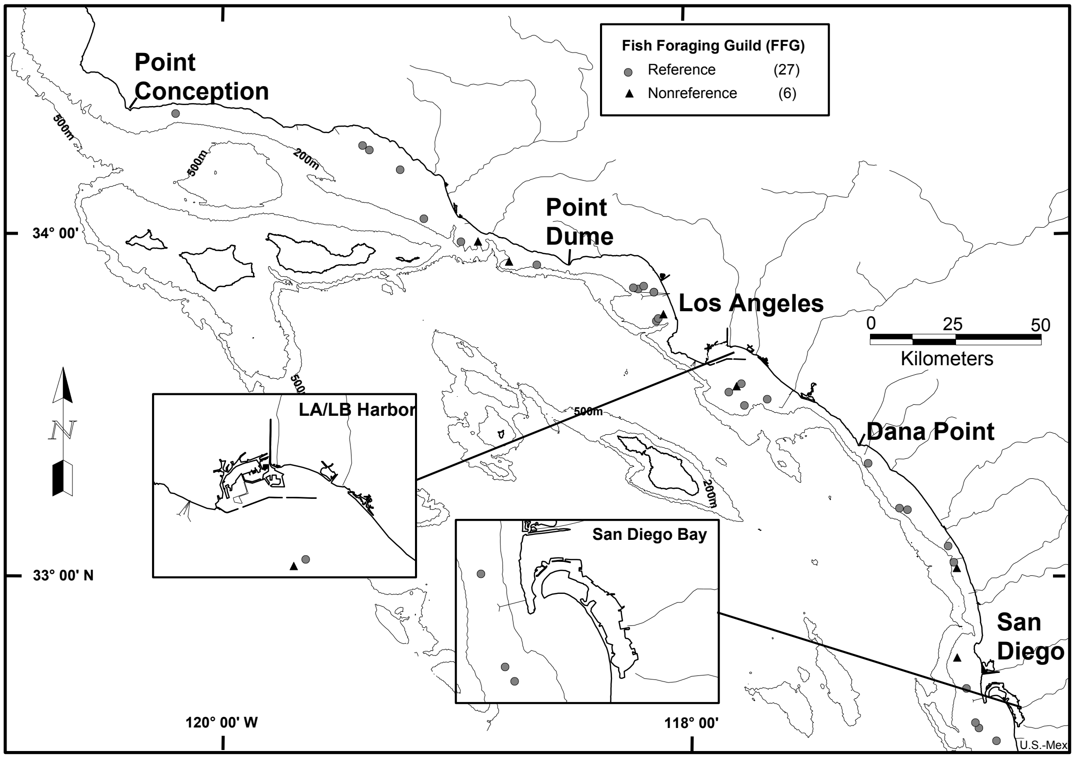

Figure VII-11. Distribution of nonreference area of Fish Foraging Guild Index (FFG) categories by region and depth zone in Bight'08 regional trawl survey.

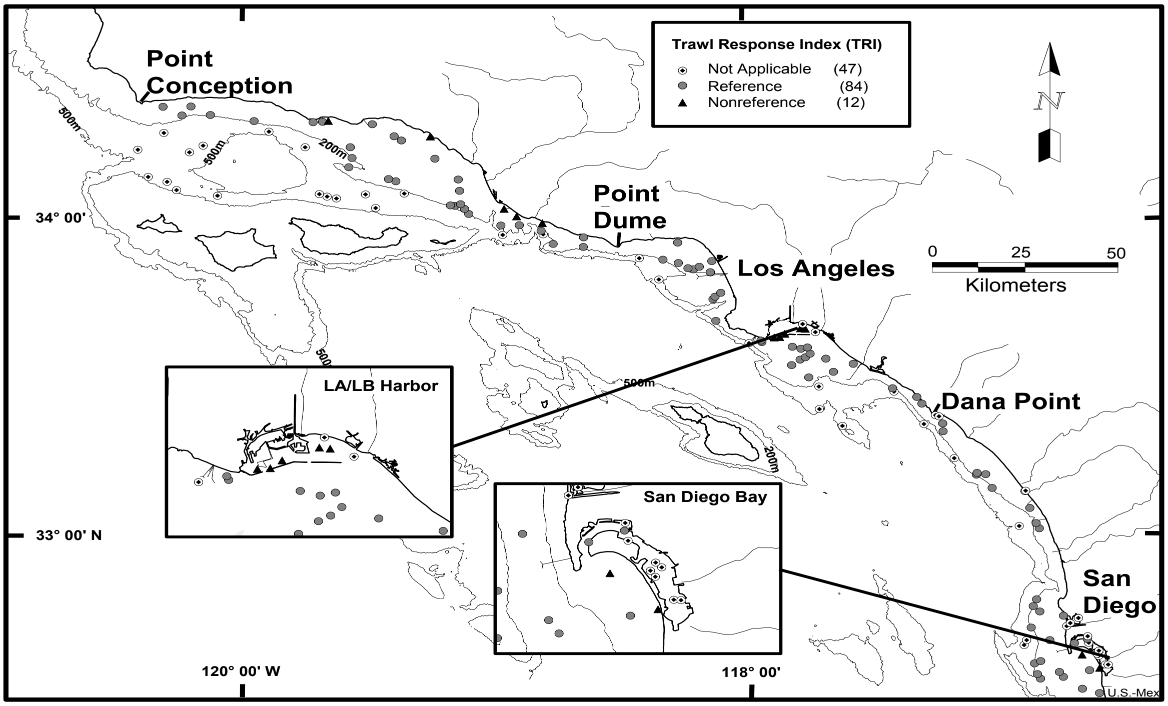

Figure VII-12. Map of distribution of trawl (combined fish and invertebrate response index (TRI) categories by region and depth zone in Bight'08 regional trawl survey. Numbers in parentheses are number of trawl stations in subpopulation on which the biointegrity index could be calculated and hence on which percentages are based.

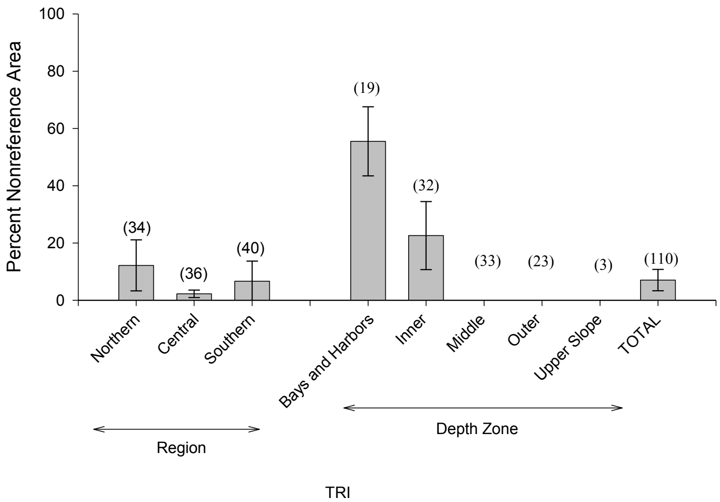

Figure VII-13. Percent nonreference area of trawl (combined fish and invertebrate) response index (TRI) by region and depth zone in Bight'08 regional trawl survey. Numbers in parentheses are number of trawl stations in subpopulation on which the biointegrity index could be calculated The size of each bar is the percent nonreference area. "Total" is the total number of stations with a TRI value.

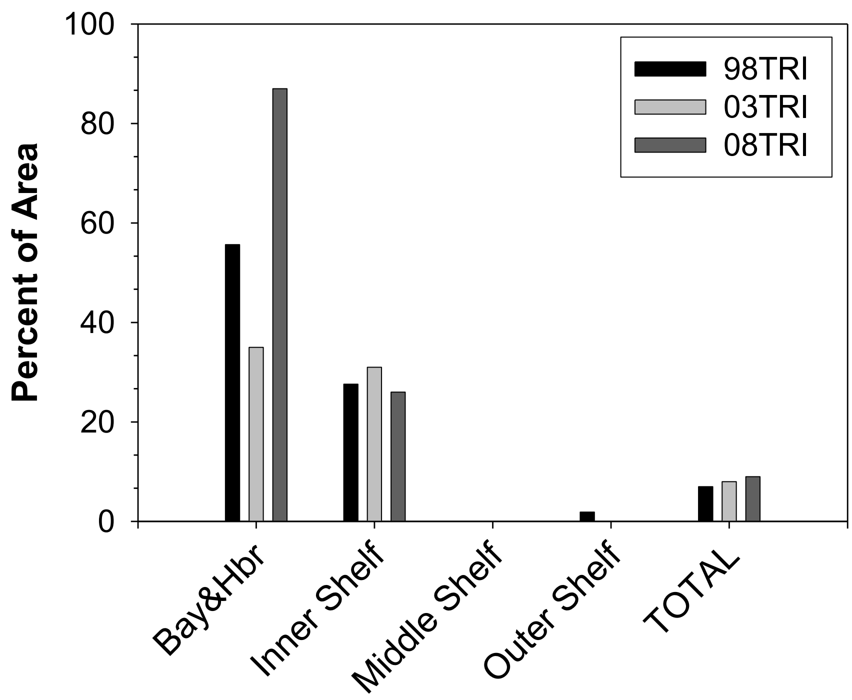

Figure VII-14. Trends in percent nonreference area of Southern California Bight for Trawl Response Index (TRI) by Shelf Zone in Bight'98, Bight'03, and Bight'08 regional trawl surveys.

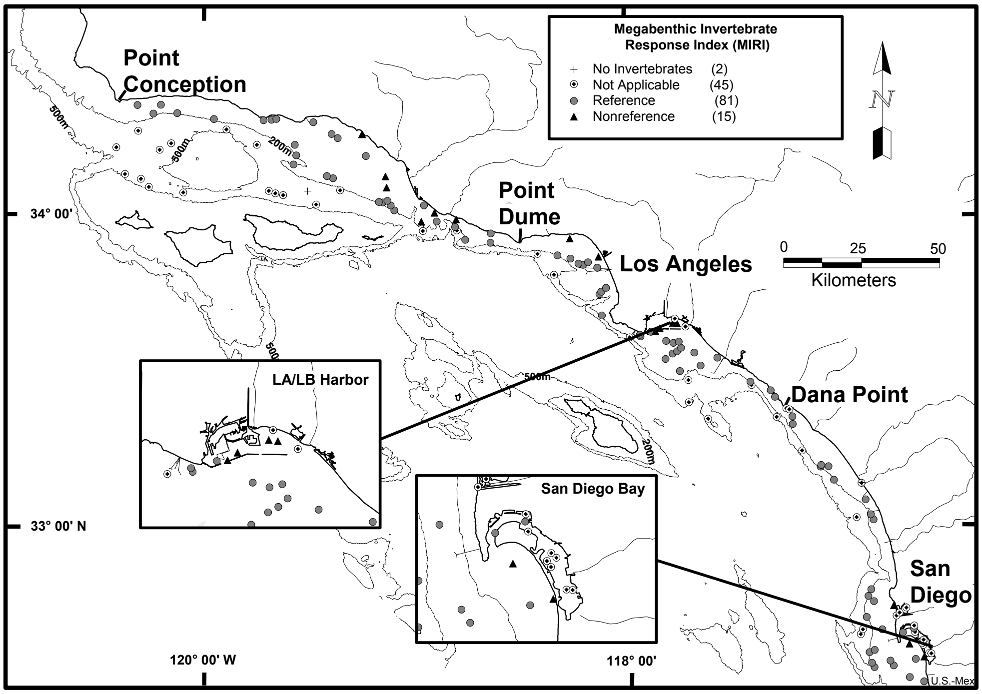

Figure VII-15. Map of distribution of megabenthic invertebrate response index (MIRI) categories by region and depth zone in Bight'08 regional trawl survey.

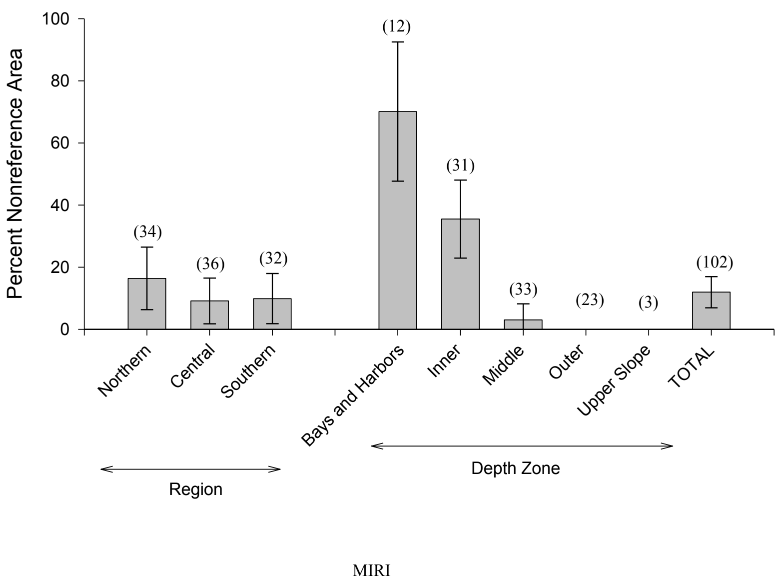

Figure VII-16. Percent nonreference area of megabenthic invertebrate response index (MIRI) by region and depth zone in Bight'08 regional trawl survey. Numbers in parentheses are number of trawl stations in subpopulation on which the biointegrity index could be calculated and hence on which percentages are based. "Total" is the total number of stations with a MRI value.

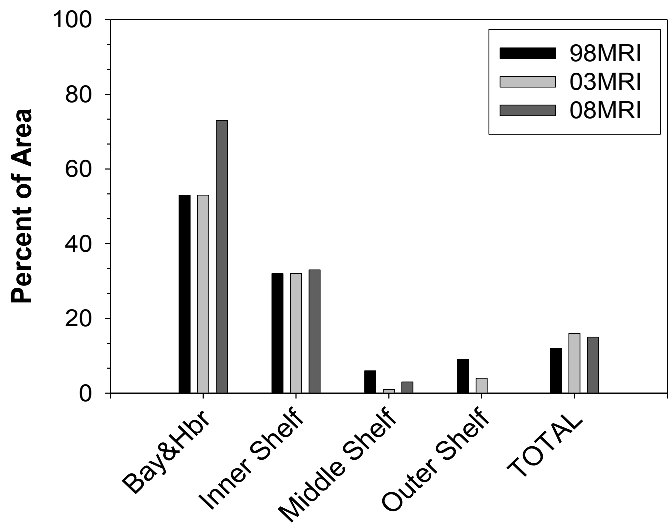

Figure VII-17. Trends in percent nonreference area in Southern California Bight for Megabenthic Invertebrate Response Index (MIRI) by shelf zone in Bight'98, Bight'03, and Bight'08 regional trawl surveys.

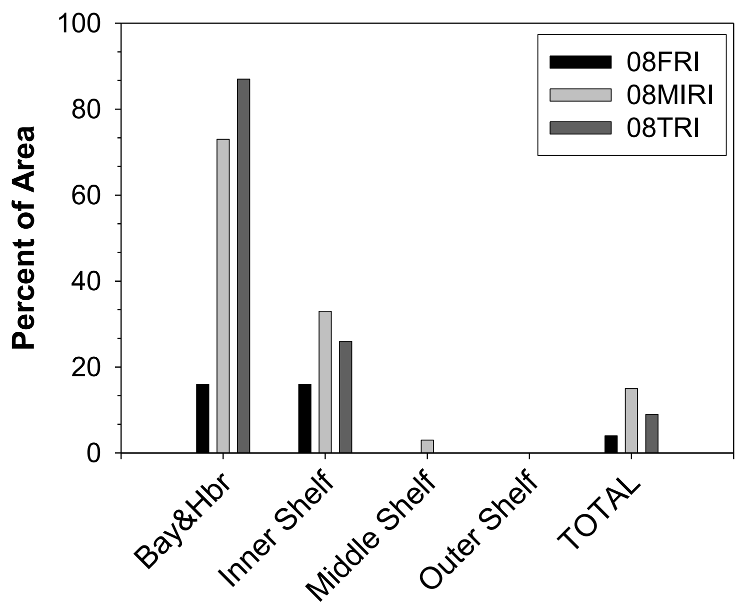

Figure VII-18. Percent nonreference area of Southern California Bight for Trawl Response Index (TRI), Megabenthic Invertebrate Response Index (MIRI), and Trawl Response Index (TRI) by Shelf Zone in the Bight'08 regional trawl survey.

VIII. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

- **Demersal fish of the SCB were relatively undisturbed in 2008 according to our biointegrity tools**

  Approximately 96% of the SCB had fish communities that were similar to reference conditions based on biointegrity assessment tools that include the fish response index (FRI). Nonreference conditions were found primarily on the Inner Shelf (<30 m depth) and Bay/Harbor areas, suggesting nearshore influences. The Trawl response index (TRI) and Fish Foraging Guild (FFG), two other biointegrity tools for fish, showed similar results. None of these three biointegrity tools address fisheries or standing stock assessments.

- **Macrobenthic invertebrate populations showed a wider area of impact than demersal fish**

  Using the MIRI (the megabenthic invertebrate response index) as a biointegrity tool, 84% of the Bight at depths less than 200m had invertebrates in similar to reference or reference condition. Non-reference areas were predominantly observed on the Inner Shelf (<30 m depth) and Bay/Harbor areas, again implicating nearshore influences.

- **Fish populations had background levels of anomalies and diseases.**

  Anomalies identified in this study included parasites, tumors, ambicoloration, skeletal deformities, and albinism. The presence of anomalies was low, observed in only 0.5% of the more than 11,000 fish collected during the survey. Only two fish were observed to have tumors.

- **The extent of disturbance in either fish or megabenthic invertebrate assemblages has changed little since 1998**

  The extent of undisturbed reference condition based upon the Fish Response Index (FRI) has ranged from 3% to 4% across the three different Bight Regional Surveys. In addition, the greatest relative extent of disturbed, non-reference fish communities has consistently been in the Inner Shelf and Bay/Harbor strata.

- **Natural and anthropogenic debris were found throughout the SCB in 2008, but generally in trace amounts at any given site**

  While debris was found in 90% of the SCB, natural debris was observed three times as frequently as anthropogenic debris. Marine (seaweeds) and terrestrial (woody) debris were the most common natural debris. Plastics were the most common anthropogenic debris. Anthropogenic debris was found most frequently, and in greatest quantities, in the central SCB presumably due to its proximity to the urban center of Los Angeles and Orange Counties. The frequency and quantity of debris co-varied with rainfall quantity in the winter preceding each sampling campaign of the last four regional surveys.

Recommendations

- **Identify synergistic interactions with the newly developed Marine Protected Areas**

  California is in the midst of developing Marine Protected Areas (MPAs), which limits the harvest of marine organisms. A proposed network of MPAs, encompassing 187 square miles, has been developed for the SCB and submitted to the Department of Fish and Game for approval (http://www.dfg.ca.gov/mlpa/southcoast.asp). The MPA Monitoring Enterprise is tasked with creating, implementing and reporting on the changes that occur following promulgation of MPAs. Because of the similarities in spatial scale, and the potential overlap in monitoring questions dealing with ecosystem health, the Bight program should explore ways to partner with the MPA Monitoring Enterprise. These partnerships can range from information transfer to full study design integration for one or more elements of the Bight program.

- **Continue regional trawl surveys to assess temporal trends**

  The Bight'08 survey did not detect any large-scale changes in fish or invertebrate communities over the last 15 years due to anthropogenic inputs. The Bight survey has identified large-scale changes due to changes in oceanographic conditions. Maintaining periodic regional surveys will be important as regional scale oceanography responds to global climate change and ocean acidification. The regional scale responses will be masked if only local routine trawl monitoring is conducted.

- **Improve training of field personnel**

  The quality of the data used in assessment of demersal fishes and megabenthic invertebrates is dependent on the quality of field identification and the consistency with which field protocols are executed. 'Three areas of improvement were found during the Bight' survey. The first is pre-survey training and QA exercises. All participating agencies should be tested prior to their first collection. One way to enhance this training is through the newly formed Southern California Association of Ichthyological Taxonomists and Ecologists (SCAITE). The mission of this *ad hoc* group is to enhance fish taxonomy through education and interaction as the Southern California Association of Marine Invertebrate Taxonomists (SCAMIT) has done for years. A second area of improvement is quality assurance (QA) audits. Not every survey crew received a field audit and these individuals had the poorest QA results for post-survey voucher specimens. Many of these problematic taxonomic issues could have been resolved through the audit QA mechanism. A third area of improvement is through the use of trawl measuring tools. Utilizing updated deployment procedures and depth/time data loggers, survey teams can improve their performance in achieving targeted net on-bottom times and trawl distances.

- **Continue development of biointegrity tools**

  Biointegrity tools are used to assess the status and health of fish and invertebrate assemblages collected in the regional surveys. The Bight'08 survey used four different biointegrity tools to assess reference or non-reference conditions. There are two applications that could be expanded upon in future surveys for further evaluation of community assemblages: 1) improved calibration and validation for all habitats of interest including Bays/Harbors, Inner Shelf, and Upper Slope strata; and 2) integrate more ecological function components.

IX. REFERENCES

Allen, L.G. 1985. A habitat analysis of the nearshore marine fishes from southern California. *Bulletin of the Southern California Academy of Sciences* 84:133-155.

Allen, M.J. 1977. Pollution-related alterations of demersal fish communities. *American Fisheries Society, Cal-Neva Wildlife Transactions* 1977:103-107.

Allen, M.J. 1982. Functional structure of soft-bottom fish communities of the southern California shelf. Ph.D. Dissertation, University of California, San Diego. La Jolla, CA.

Allen, M.J. 2006a. Continental shelf and upper slope. pp. 167-202 *in*: L.G. Allen, M.H. Horn, and D.J. Pondella, II (eds.), Ecology of Marine Fishes: California and Adjacent Areas. University of California Press. Berkeley, CA.

Allen, M.J. 2006b. Pollution. pp. 595-695 *in*: L.G. Allen, M.H. Horn and D.J. Pondella, II (eds.), Ecology of Marine Fishes: California and Adjacent Areas. University of California Press. Berkeley, CA.

Allen, MJ. 2008. Bathymetric responses in functional structure of southern California demersal fish communities to Pacific Decadal Oscillation regimes and an El Niño. pp. 211-228 *in*: S.B. Weisberg and K. Miller (eds.), Southern California Coastal Water Research Project 2008 Annual Report. Southern California Coastal Water Research. Costa Mesa, CA.

Allen, M.J., A.K. Groce, D. Diener, J. Brown, S.A. Steinert, G. Deets, J.A. Noblet, S.L. Moore, D. Diehl, E.T. Jarvis, V. Raco-Rands, C. Thomas, Y. Ralph, R. Gartman, D. Cadien, S.B. Weisberg and T. Mikel. 2002. Southern California Bight 1998 Regional Monitoring Program: V. Demersal fishes and megabenthic invertebrates. Technical Report 380. Southern California Coastal Water Research Project. Westminster, CA.

Allen, M.J. and A.J. Mearns. 1977. Bottom fish populations below 200 meters. pp. 109-115 *in*: Southern California Coastal Water Research Project. Annual Report 1976-1977. Southern California Coastal Water Research Project. El Segundo, CA.

Allen, M.J., T. Mikel, D. Cadien, J.E. Kalman, E.T. Jarvis, K.C. Schiff, D.W. Diehl, S.L. Moore, S. Walther, G. Deets, C. Cash, S. Watts, D.J. Pondella II, V. Raco-Rands, C. Thomas, R. Gartman, L. Sabin, W. Power, A.K. Groce and J.L. Armstrong. 2007. Southern California Bight 2003 Regional Monitoring Program: IV. Demersal fishes and megabenthic invertebrates. Technical Report 505. Southern California Coastal Water Research Project. Costa Mesa, CA.

Allen, M.J., S.L. Moore, K.C. Schiff, S.B. Weisberg, D. Diener, J.K. Stull, A. Groce, J. Mubarak, C.L. Tang and R. Gartman. 1998. Southern California Bight 1994 Pilot Project: V. Demersal fishes and megabenthic invertebrates. Technical Report 308. Southern California Coastal Water Research Project. Westminster, CA.

Allen, M.J. and G.B. Smith. 1988. Atlas and zoogeography of common fishes in the Bering Sea and northeastern Pacific. NOAA Technical Report NMFS 66. MBC Applied Environmental Sciences and Northwest Images. Costa Mesa, CA.

Allen, M.J., R.W. Smith, E.T. Jarvis, V. Raco-Rands, B. Bernstein and K. Herbinson. 2004. Temporal trends in southern California coastal fish populations relative to 30-year trends in oceanic conditions. pp.

264-285 *in*: S.B. Weisberg and D. Elmore (eds.), Southern California Coastal Water Research Project Biennial Report 2003-2004. Southern California Coastal Water Research Project. Westminster, CA.

Allen, M.J., R.W. Smith and V. Raco-Rands. 2001. Development of biointegrity indices for marine demersal fish and megabenthic invertebrate assemblages of southern California. EPA grant X-989186-01-0. Prepared for United States Environmental Protection Agency, Office of Science and Technology, Washington, DC. Southern California Coastal Water Research Project. Westminster, CA.

Allen, M.J. and R. Voglin. 1976. Regional and local variability of bottom fish and invertebrate populations. pp. 217-221 *in*: Southern California Coastal Water Research Project Annual Report 1975-1976. Southern California Coastal Water Research Project. El Segundo, CA.

Barwick, K. and S. Douglas. 2003. A review of the Eulimidae (Mollusca: Gastropoda) reported by major benthic monitoring programs in the Southern California Bight. *SCAMIT Newsletter* 22: 3-6.

Bates, A.E., B.J. Hilton, and C.D.G. Harley. 2009. Effects of temperature, season and locality on wasting disease in the keystone predatory sea star *Pisaster ochraceus*. Diseases of Aquatic Organisms 86:245-251.

Bight'08 Coastal Ecology Committee. 2008a. Southern California Bight 2008 Regional Monitoring Survey (Bight'08): Coastal Ecology Workplan. Southern California Coastal Water Research Project. Costa Mesa, CA.

Bight'08 Coastal Ecology Committee. 2008b. Southern California Bight 2008 Regional Monitoring Survey (Bight'08): Quality Assurance Plan. Southern California Coastal Water Research Project. Costa Mesa, CA.

Bight'08 Coastal Ecology Committee. 2008c. Southern California Bight 2008 Regional Marine Monitoring Survey (Bight'08): Coastal Ecology Field Operations Manual. Southern California Coastal Water Research Project. Costa Mesa, CA.

Bjorndal, K.A., A.B. Bolton and C.J. Lagueux. 1994. Ingestion of marine debris by juvenile sea turtles in coastal Florida habitats. *Marine Pollution Bulletin* 28:154-158.

Bograd, S.J. and R.J. Lynn. 2003. Long-term variability in the southern California Current System. *Deep Sea Research Part II: Topical Studies in Oceanography* 50:2355-2370.

Butler, T.H. 1980. Shrimps of the Pacific coast of Canada. *Canadian Bulletin of Fisheries and Aquatic Sciences* 202:1-280.

Cadien, D.B. and J.W. Martin. 1999. *Myzotarsa anaxiphilius*, new genus, new species, an atylopsine amphipod (Gammaridea: Pleustidae) commensal with lithodid crabs in California. *Journal of Crustacean Biology* 19:693-711.

Carlisle, J.G. 1969a. Invertebrates taken in a six year trawl study in Santa Monica Bay. *Veliger* 11:237-242.

Carlisle, J.G. 1969b. Results of a six-year trawl study in an area of heavy waste discharge: Santa Monica Bay, California. *California Fish and Game* 55:26-46.

City of Los Angeles, Environmental Monitoring Division (CLAEMD). 1994a. Marine Monitoring in the Los Angeles Harbor: Annual Assessment Report for the Period March, 1993 through December, 1993. Prepared for United States Environmental Protections Agency and Regional Water Quality Control Board, Los Angeles Region. City of Los Angeles, Department of Public Works, Bureau of Sanitation, Terminal Island Treatment Plant. San Pedro, CA.

City of Los Angeles, Environmental Monitoring Division CLAEMD). 1994b. Santa Monica Bay, Annual Assessment Report 1994. City of Los Angeles, Department of Public Works, Bureau of Sanitation, Environmental Monitoring Division. Los Angeles, CA.

City of San Diego, Metropolitan Wastewater Department (CSDMWWD). 1995. Receiving Waters Monitoring Report 1994. City of San Diego, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division. San Diego, CA.

County Sanitation Districts of Orange County (CSDOC). 1996. CSDOC Marine Monitoring Annual Report 1995; including a ten-year synthesis: 1985-1995. County Sanitation Districts of Orange County. Fountain Valley, CA.

County Sanitation Districts of Los Angeles County (CSDLAC). 1990. Palos Verdes Ocean Monitoring Annual Report, 1989, Chapter 4: Trawls. County Sanitation Districts of Los Angeles County. Whittier, CA.

Cross, J.N. and L.G. Allen. 1993. Fishes. pp. 459-540 *in*: M.D. Murray, D.J. Reish and J.W. Anderson (eds.), The Ecology of the Southern California Bight: A Synthesis and Interpretation. University of California Press. Berkeley, CA.

Cross, JN, JT Hardy, JE Hose, GP Hershelman, LD Antrim, RW Gossett, and EA Crecelius. 1987. Contaminant concentrations and toxicity of sea-surface microlayer near Los Angeles, California. *Marine Environmental Research* 23:307-323.

Dailey, M.D., J.W. Anderson, D.J. Reish and D.S. Gorsline. 1993. The Southern California Bight: background and setting. pp. 1-18 *in*: M.D. Murray, D.J. Reish and J.W. Anderson (eds.), The Ecology of the Southern California Bight: A Synthesis and Interpretation. University of California Press. Berkeley, CA.

Dayton, P., M. Tegner, P. Edwards and K. Riser. 1998. Sliding baselines, ghosts, and reduced expectations in kelp forest communities. *Ecological Applications* 8:309-322.

Deets, G.B., C.L. Cash, J.M. Rounds and J.D. Roney. 2003a. Trawl-caught fish and macroinvertebrates. pp. 7-1 to 7-42 *in*: City of Los Angeles, Environmental Monitoring Division. Marine monitoring in Santa Monica Bay, Biennial assessment report, January 2001 through December 2002. City of Los Angeles, Department of Public Works, Bureau of Sanitation, Environmental Monitoring Division. Los Angeles, CA.

Deets, G.B., J.D. Roney, J.M. Rounds and C.L. Cash. 2003b. Fish and macroinvertebrates. pp. 7-1 to 7-22 *in*: City of Los Angeles, Environmental Monitoring Division. Marine monitoring in the Los Angeles Harbor, Annual assessment report, January 2002 through December 2002. City of Los Angeles, Department of Public Works, Bureau of Sanitation, Environmental Monitoring Division. Los Angeles, CA.

Emery, K.O. 1960. The Sea Off Southern California. John Wiley & Sons. New York, NY.

Fauchald, K. and G.F. Jones. 1979. Variation in community structure of shelf, slope and basin macrofaunal communities of the Southern California Bight. *in*: Southern California outer continental shelf baseline study 1978/1977 (second year) Benthic Program, Vol. II, Rept. 17, National Technical Information Service PB 80-166101. Washington, DC.

Feeley RA, SC Doney and SR Cooley. 2009. Ocean acidification - present conditions and future changes in a high-CO2 world. *Oceanography* 22:36-47.

Fowler, C.W. 1987. Marine debris and northern fur seals: A case study. *Marine Pollution Bulletin* 18:326-335.

Francis, R.C., S.R. Hare, A.B. Hollowed and W.S. Wooster. 1998. Effects of interdecadal climate variability on the oceanic ecosystems of the NE Pacific. *Fisheries and Oceanography* 7:1-21.

Goericke, R., E. Venrick, A. Mantyla, S.J. Bograd, F.B. Schwing, A. Huyer, R.L. Smith, P.A. Wheeler, R. Hooff, W. T. Peterson, F. Chavez, C. Collins, B. Marinovic, N. Lo, G. Gaxiola-Castro, R. Durazo, K.D. Hyrenbach and W.J. Sydeman. 2005. The state of the California Current, 2004-2005: still cool? *California Cooperative Oceanic Fisheries Investigations* 46:32-71.

Harley, C.D.G., A. Randall Hughes, K.M. Hultgren, B.G. Miner, C.J.B. Sorte, C.S. Thornber, L.F. Rodriguez, L. Tomanek and S.L. Williams. 2006. The impacts of climate change in coastal marine systems. *Ecological Letters* 9:228-241.

Hickey, B.M. 1993. Physical oceanography. pp. 19-70 *in*: M.D. Murray, D.J. Reish and J.W. Anderson (eds.), The Ecology of the Southern California Bight: A Synthesis and Interpretation. University of California Press. Berkeley, CA.

Hidalgo, M., T. Rouyer, J.C. Molinero, E. Massutí, J. Moranta, B. Guijarro and N.C. Stenseth. 2011. Synergistic effects of fishing-induced demographic changes and climate variation on fish population dynamics. *Marine Ecology Progress Series* 426:1-12.

Horn, M.H., L.G. Allen and R.N. Lea. 2006. Biogeography. pp. 3-25 *in*: L.G. Allen, M.H. Horn and D.J. Pondella, II (eds.), Ecology of Marine Fishes: California and Adjacent Areas. University of California Press. Berkeley, CA.

Hsieh, C., Reiss, C.S., Hewitt, R.P., Sugihara, G., 2008. Spatial analysis shows that fishing enhances the climatic sensitivity of marine fishes. *Canadian Journal of Fisheries and Aquatic Sciences* 65, 947-961.

Jarvis, E.T., M.J. Allen and R.W. Smith. 2004. Comparison of recreational fish catch trends to environment-species relationships and fishery-independent data in the Southern California Bight. *California Cooperative Oceanic Fisheries Investigations Reports* 45:167-179.

Kleypas JA, RA Feely, VJ Fabry, C Langdon, CL Sabine, and LL Robbins. 2006. Impacts of ocean acidification on coral reefs and other marine calcifiers: a guide for future research, report of a workshop held 18-20 April 2005, St. Petersburg, Florida, sponsored by NSF, NOAA, and the U.S. Geological Survey. http://www.ucar.edu/communications/Final_acidification.pdf

Koslow, A.J., R. Goericke, A. Lara-Lopez and W. Watson. 2011. Impact of declining intermediate-water oxygen on deepwater fishes in the California Current. *Marine Ecological Progress Series* 436: 207–218.

Love, M.S., J.S. Stephens, Jr., P.A. Morris, M.S. Singer, M. Sandhu and T.C. Sciarrotta. 1986. Inshore soft substrata fishes in the Southern California Bight: an overview. *California Cooperative Oceanic Fisheries Investigations Reports* 27:84-106.

Maruya, K.A. and K. Schiff. 2009. The extent and magnitude of sediment contamination in the Southern California Bight. *The Geological Society of America Special Paper 454:399-412.*

MBC Applied Environmental Sciences. 1988. The state of Santa Monica Bay, Part one: Assessment of conditions and pollution impacts. Prepared for Southern California Association of Governments, Los Angeles, CA. MBC Applied Environmental Sciences. Costa Mesa, CA.

McDermott-Ehrlich, D.J., M.J. Sherwood, T.C. Heesen, D.R. Young and A.J. Mearns. 1977. Chlorinated hydrocarbons in dover sole, *Microstomus pacificus*: Local migrations and fin erosion. *Fishery Bulletin* 75:513-527

McGowan, J.A., Bograd, S.J., Lynn, R.J., Miller, A.J., 2003. The biological response to the 1977 regime shift in the California Current. *Deep Sea Research Part II: Topical Studies in Oceanography* 50, 2567-2582.

Mearns, A.J. 1974. Southern California's inshore demersal fishes: diversity, distribution, and disease as responses to water quality. *California Cooperative Oceanic Fisheries Investigations Reports* 18:141-148.

Mearns, A.J., M.J. Allen, L.S. Word, J.Q. Word, C.S. Greene, M.J. Sherwood and B. Myers. 1976. Quantitative responses of demersal fish and benthic invertebrate communities to coastal municipal wastewater discharges. Grant R801152. Prepared for United States Environmental Protection Agency, National Marine Water Quality Laboratory, Corvallis, OR. Southern California Coastal Water Research Project. El Segundo, CA.

Mearns, A.J. and C.S. Greene (eds.). 1974. A comparative trawl survey of three areas of heavy waste discharge. Southern California Water Research Project. El Segundo, CA.

Mearns, A.J. and M. Sherwood. 1974. Environmental aspects of fin erosion and tumors in southern California Dover Sole. *Transactions of the American Fisheries Society* 103:799-310.

Miller, E.F., Pondella II, D., Beck, D.S., Herbinson, K., in press. Decadal-scale changes in southern California sciaenids under differing harvest pressure. *ICES Journal of Marine Science: Journal du Conseil*.

Miller, E.F., Williams, J.P., Pondella, D.J., Herbinson, K.T., 2009. Life history, ecology, and long-term demographics of queenfish. *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science* 1, 187-199.

Moore, S.L. and M.J. Allen. 2000. Distribution of anthropogenic and natural debris on the mainland shelf of the Southern California Bight. *Marine Pollution Bulletin* 40:83-88.

Moore, C.J., S.L. Moore, S.B. Weisberg, G.L. Lattin and A.F. Zellers. 2003. A comparison of neustonic plastic and zooplankton abundance in southern California's coastal waters. pp. 72-76 *in*: S.B. Weisberg and D. Elmore (eds.), Southern California Coastal Water Research Biennial Report 2001-2002. Westminster, CA.

Mora, C., Aburto-Oropeza, O., Bocos, A.A., Ayotte, P.M., Banks, S., Bauman, A.G., Beger, M., Bessudo, S., Booth, D.J., Brokovich, E., 2011. Global Human Footprint on the Linkage between Biodiversity and Ecosystem Functioning in Reef Fishes. *PLoS Biology* 9, e1000606.

Nelson, J.S., E.J. Crossman, H. Espinosa-Perez, L.T. Findley, C.R. Gilbert, R.N. Lea and J.D. Williams. 2004. Common and Scientific Names of Fishes from the United States, Canada, and Mexico. American Fisheries Society, Special Publication 29. Bethesda, MD.

NOAA National Centers for Coastal Ocean Science (NCCOS). 2005. A biogeographic assessment of the Channel Islands National Marine Sanctuary: A review of boundary expansion concepts for NOAA's National Marine Sanctuary Program. R. Clark, J. Christensen, C. Caldow, [M.] J. Allen, M. Murrary, and S. MacWilliams (eds.). NOAA Technical Memorandum NOS NCCOS 21. Prepared by NCCOS's Biogeography Team in Cooperation with the National Marine Sanctuary Program. Silver Spring, MD.

Pacific Fisheries Information Network (PacFIN) report #308, dated Feb 17, 2010, Pacific States Marine Fisheries Commission, Portland, Oregon (www.psmfc.org)

Ranasinghe JA, KC Schiff, DE Montagne, TK Mikel, DB Cadien, RG Velarde, CA Brantley. 2010. Benthic macrofaunal community condition in the Southern California Bight, 1994-2003. *Marine Pollution Bulletin* 60:827-833

Ribic, C.A., S.W. Johnson and C.A. Cole. 1997. Distribution, type, accumulation, and source of marine debris in the United States, 1989-1993. pp. 35-47 *in*: J.M. Coe and D.B. Rogers (eds.), Marine Debris: Sources, Impacts, and Solutions. Springer-Verlag. New York, NY.

Ryan, P.G. 1987. The effects of ingested plastic on seabirds: Correlations between plastic load and body condition. *Environmental Pollution* 46:119-125.

SCAMIT. 2008. A taxonomic listing of micro- and megainvertebrates from infaunal and epibenthic monitoring programs in the Southern California Bight. The Southern California Association of Marine Invertebrate Taxonomists, Natural History Museum of Los Angeles County Research & Collections. Los Angeles, CA http://scamit.org/

Scavia, D., Field, J.C., Boesch, D.F., Buddemeier, R.W., Burkett, V., Cayan, D.R., Fogarty, M., Harwell, M.A., Howarth, R.W., Mason, C., 2002. Climate change impacts on US coastal and marine ecosystems. *Estuaries and Coasts* 25, 149-164.

Schiff, K. and M.J. Allen. 2000. Chlorinated hydrocarbons in flatfishes from the Southern California, USA, Bight. *Environmental Toxicology and Chemistry* 9:1559-1565.

Schiff, KC, MJ Allen, EY Zeng, SM Bay. 2000. Southern California. *Marine Pollution Bulletin* 41:76-93

Schiff, K.C., S.B. Weisberg and V. Raco-Rands. 2002. Inventory of ocean monitoring in the Southern California Bight. *Environmental Management* 6:871-876.

Schwing, F.B. and C.S. Moore. 2000. A year without summer for California, or a harbinger of a climate shift? *EOS, Transactions, American Geophysical Union* 81:304-305.

Smith, R.W., M. Bergen, S.B. Weisberg, D. Cadien, A. Dalkey, D. Montagne, J.K. Stull and R.G. Velarde. 2001. Benthic response index for assessing infaunal communities on the southern California mainland. *Ecological Applications* 11:1073-1087.

Southern California Bight Pilot Project (SCBPP). 1994. Quality assurance project plan for the Southern California Bight Pilot Project. Southern California Coastal Water Research Project. Westminster, CA.

Southern California Coastal Water Research Project (SCCWRP). 1973. The ecology of the Southern California Bight: Implications for water quality management. Technical Report 104. Southern California Coastal Water Research Project. El Segundo, CA.

SCCWRP. 1993. Response of Dover sole to termination of sludge discharge in Santa Monica Bay. pp. 78-80 *in*: J.N. Cross and C. Francisco (eds.), Southern California Coastal Water Research Project 1990-91 and 1991-92 Annual Report. Long Beach, CA.

State of California. 2001. Interim County Population Projections. Demographic Research Unit. Sacramento, CA.

Stein, ED and DB Cadien 2009. Ecosystem response to regulatory and management actions: The southern California experience in long-term monitoring.. *Marine Pollution Bulletin* 59:91-100.

Stevens, Jr., D.L. 1997. Variable density grid-based sampling designs for continuous spatial populations. *Environmetrics* 8:167-195.

Stull, J. 1995. Two decades of marine biological monitoring, Palos Verdes, California, 1972 to 1992. *Bulletin of the Southern California Academy of Sciences* 94:21-45.
Stull, J.K. and C.-L. Tang. 1996. Demersal fish trawls off Palos Verdes, southern California, 1973-1993. *California Cooperative Oceanic Fisheries Investigations Reports* 37:211-240.

Stull, J.K., M.J. Allen, S.L. Moore and C.L. Tang. 2001. Relative abundance and health of megabenthic invertebrate species on the southern California shelf in 1994. pp. 189-209 *in*: S.B. Weisberg and D. Hallock (eds.), Southern California Coastal Water Research Annual Report 1999-2000. Westminster, CA.

Thompson, B.E., J.D. Laughlin and D.T. Tsukada. 1987. 1985 reference site survey. Technical Report 221. Southern California Coastal Water Research Project. Long Beach, CA.

Thompson, B., D. Tsukada and J. Laughlin. 1993a. Megabenthic assemblages of coastal shelves, slopes, and basins off southern California. *Bulletin of the Southern California Academy of Sciences* 92:25-42.

Thompson, B., D. Tsukada and D. O'Donohue. 1993b. 1990 reference site survey. Technical Report 269. Southern California Coastal Water Research Project. Westminster, CA.

Walther, S. 2010. Invertebrate and fish trawls, *in*: Los Angeles County Sanitation Districts Palos Verdes Ocean Monitoring, 2009 Annual Report. County Sanitation Districts. Whittier, CA.
US Census Bureau. 2010. 2010 Census Data. http://2010.census.gov/2010census/data/

Wolter, K. 1987. The Southern Oscillation in surface circulation and climate over the tropical Atlantic, Eastern Pacific, and Indian Oceans as captured by cluster analysis. *Journal of Climate and Applied Meteorology* 26:540-558.

Word, J.Q., A.J. Mearns and M.J. Allen. 1977. Better control stations: the 60-meter survey. pp. 89-97 *in:* Southern California Coastal Water Research Project Annual Report 1976-1977. El Segundo, CA.

APPENDIX A: MATERIALS AND METHODS

ftp://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/655_B08Trawl_Appendix_A.pdf

APPENDIX B: FISH POPULATION ATTRITUBUTES

ftp://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/655_B08Trawl_Appendix_B.pdf

APPENDIX C: QUALITY ASSURANCE

ftp://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/655_B08Trawl_Appendix_C.pdf

APPENDIX D: INVERTEBRATE POPULATION ATTRIBUTES

ftp://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/655_B08Trawl_Appendix_D.pdf

APPENDIX E: PARTICIPANTS IN THE BIGHT'08 REGIONAL MONITORING PROGRAM

ftp://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/655_B08Trawl_Appendix_E.pdf

APPENDIX F: ALTERNATIVE ANALYSES

ftp://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/655_B08Trawl_Appendix_F.pdf

Appendix F-1. Getting the most utility out of your trawl data: Catch per trawl or density?

Appendix F-2. Spatial distribution of Southern California Bight demersal fishes in 2008

APPENDIX G: GLOSSARY

ftp://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/655_B08Trawl_Appendix_G.pdf

Appendix G-1. Demersal Fish Species Alphabetized by Species Name

Appendix G-2. Demersal Fish Species Alphabetized by Common Name

Appendix G-3. Invertebrate Species Alphabetized by Species Name

Appendix G-4. Invertebrate Species Alphabetized by Common Name

APPENDIX H: FISH AND MEGABENTHIC INVERTEBRATE ASSEMBLAGES

ftp://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/655_B08Trawl_Appendix_H.pdf