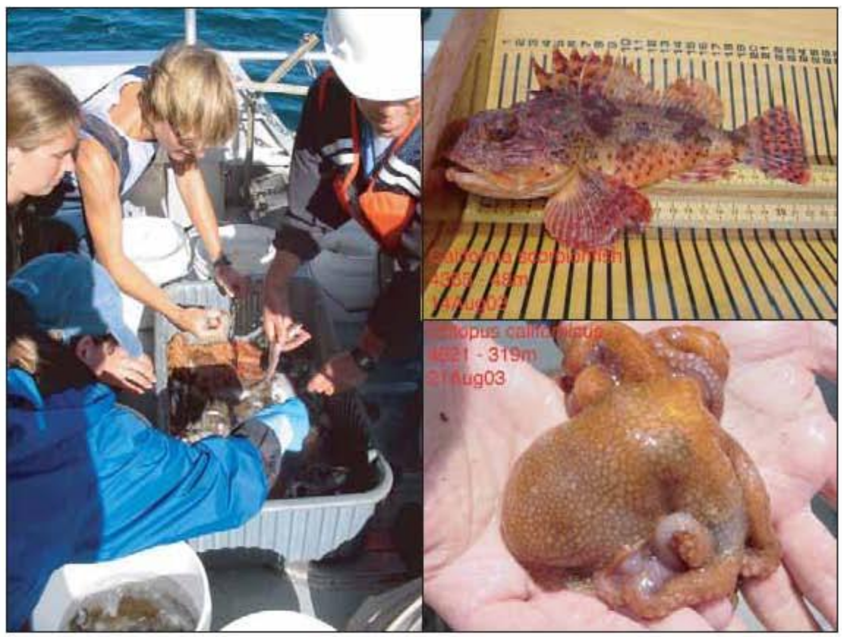
BIGHT'03

Demersal Fishes and Megabenthic Invertebrates



Southern California Bight
2003 Regional Monitoring
Program
Vol. IV

Southern California Bight 2003 Regional Monitoring Program:
IV. Demersal Fishes and Megabenthic Invertebrates

March 2007

M.J. Allen[1], T. Mikel [2], D. Cadien[3], J.E. Kalman[4], E.T. Jarvis[1], K.C. Schiff[1],
D.W. Diehl[1], S.L. Moore[1], S. Walther[3], G. Deets[5], C. Cash[5], S. Watts[6],
D.J. Pondella II[7], V. Raco-Rands[1], C. Thomas[4], R. Gartman[8], L. Sabin[1], W. Power[3],
A.K. Groce[8] and J.L. Armstrong[4]

[1]Southern California Coastal Water Research Project
[2]Aquatic Bioassay and Consulting Laboratory
[3]County Sanitation Districts of Los Angeles County
[4]Orange County Sanitation District
[5]City of Los Angeles, Environmental Monitoring Division
[6] Weston Solutions, Inc.
[7]Occidental College, Vantuna Research Group
[8]City of San Diego, Metropolitan Wastewater Department

THE BIGHT '03 TRAWL WORKING GROUP MEMBERS

Member	Affiliation
Chair - Dr. M. James Allen	Southern California Coastal Water Research Project
Co-Chair - Tim Mikel	Aquatic Bioassay and Consulting Laboratories
Dr. Jeff L. Armstrong	Orange County Sanitation District
Don Cadien	County Sanitation Districts of Los Angeles County
Curtis Cash	City of Los Angeles, Environmental Monitoring Division
Dr. Gregory Deets	City of Los Angeles, Environmental Monitoring Division
Dario W. Diehl	Southern California Coastal Water Research Project
Sarah Fangman	Channel Islands National Marine Sanctuary
Robin Gartman	City of San Diego, Metropolitan Wastewater Department
Ami K. Groce	City of San Diego, Metropolitan Wastewater Department
Erica T. Jarvis	Southern California Coastal Water Research Project
Dr. Julianne E. Kalman	Orange County Sanitation District/University of California, Los Angeles/ currently California State University, Long Beach
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
Dr. Lisa Sabin	Southern California Coastal Water Research Project
Kenneth C. Schiff	Southern California Coastal Water Research Project
Christina Thomas	Orange County Sanitation District
Shelly Walther	County Sanitation Districts of Los Angeles County
Susie Watts	Weston Solutions, Inc.

FOREWORD

The Southern California Bight 2003 Regional Monitoring Program (Bight '03) is part of an effort to provide an integrated assessment of the Southern California Bight through cooperative regional-scale monitoring. Bight '03 is a continuation of regional surveys conducted in 1994 (SCBPP Steering Committee 1998) and 1998 (Bight '98 Steering Committee 2003), and represents the joint efforts of 58 organizations. Bight '03 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 '03, 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 '03 guidance manuals, data, and reports are available for download at www.sccwrp.org.

The proper citation for this report is: 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. Southern California Coastal Water Research Project. Costa Mesa, CA.

ACKNOWLEDGEMENTS

The Southern California Bight 2003 Regional Monitoring Program (Bight '03) Trawl Report Group worked cooperatively to write this report. Dr. M. James Allen, (Southern California Coastal Water Research Project; SCCWRP) was Chair of the Committee and responsible for organizing and conducting committee meetings, organizing the report as whole, and giving presentations of progress to the B'03 Coastal Ecology Committee. Tim Mikel (Aquatic Bioassay and Consulting Laboratories; ABC) was Co-Chair of the Committee, helped to organize section teams for conducting report analyses, and provided back-up to the Chair in conducting committee responsibilities. Valerie Raco-Rands (SCCWRP) and Shelly Walther (County Sanitation Districts of Los Angeles County; CSDLAC) developed the analytical database for the project. The coauthors made essential contributions (e.g., writing and/or data analysis to specific sections of the report or to the report as a whole: Dr. Allen (SCCWRP), overall editing and writing of report as needed, with special emphasis on assemblage section (recurrent group analysis, functional organization of fish communities, biointegrity indices), introduction, discussion, and conclusions. Tim Mikel (ABC), fish populations section; Don Cadien (County Sanitation Districts of Los Angeles County; CSDLAC), invertebrate populations and quality assurance/quality control sections; Dr. Julianne E. Kalman (Orange County Sanitation Districts/University of California, Los Angeles; OCSD/UCLA/CSULB), ectoparasites of fishes section; Erica Jarvis (SCCWRP), bioaccumulation section (pelagic forage fish contamination); Kenneth C. Schiff (SCCWRP), bioaccumulation section (pelagic forage fish contamination); Dario Diehl (SCCWRP), materials/methods and quality assurance/quality control sections; Shelly Moore (SCCWRP), debris section; Shelly Walther (CSDLAC), invertebrate and debris sections; Dr. Greg Deets (CLAEMD) assemblage section (cladistics analyses); Curtis Cash (City of Los Angeles, Environmental Monitoring Division; CLAEMD) assemblage section (cladistics analyses); Susie Watts (Weston Solutions, Inc.), assemblage section (cluster analyses); Dr. Daniel J. Pondella (Occidental College, Vantuna Research Group), assemblage (multidimensional scaling) and fish populations (fisheries species) sections; Valerie Raco-Rands (SCCWRP), designed report cover, conducted data analysis for assemblage section (recurrent group analysis, functional organization of fish communities, biointegrity indices) and for other sections as needed; Christina Thomas (OCSD), data analysis for fish populations section; Robin Gartman (CSDMWWD), fish populations (size distribution); Dr. Lisa Sabin (SCCWRP), bioaccumulation section (contamination in pelagic forage fish and flatfishes); William Power (CSDLAC), material and methods section, quality assurance/quality control section; Ami K. Groce (City of San Diego, Metropolitan Wastewater Department; CSDMWWD), and Dr. Jeff L. Armstrong (Orange County Sanitation Districts), technical review of report. The committee as a whole participated in the planning of the report, development of recommendations, as well as review of draft and final reports.

The authors thank Kerry Ritter (SCCWRP) for statistical advice. The authors also thank the Bight '03 Coastal Ecology Committee for reviewing the draft reports. We are indebted to the Bight '03 Field Methods, Trawl Quality Assurance, and Analytical Chemistry Working Groups for ensuring high-quality data for this study. We thank workers at the following organizations for their assistance in field collection and data processing: ABC; Channel Islands National Marine Sanctuary; CLAEMD; CSDLAC; CSDMWWD; MBC Applied Environmental Sciences; Occidental College, Vantuna Research Group; OCSD; MEC Analytical Systems (now Weston Solutions, Inc.); and SCCWRP.

EXECUTIVE SUMMARY

Demersal fishes and megabenthic invertebrates are found on the soft-bottom habitat, the predominant habitat of the mainland shelf, and hence are widely distributed on the southern California shelf and slope. Populations of these sedentary fishes and invertebrates have been monitored extensively during the past three decades to assess impacts of treated wastewater discharge to the shelf. During this period, inputs of many anthropogenic contaminants (e.g., chlorinated hydrocarbons, trace metals) to the SCB decreased significantly, and discharge levels of these contaminants are presently low. Nevertheless, historical deposits of contaminants in the sediments may still affect populations of demersal fishes and invertebrates or organisms that feed on them. While demersal fish and megabenthic invertebrate populations in wastewater discharge areas have been well studied during the past 3-5 decades, less was known about their condition throughout southern California. Early reference or regional studies were limited in scope or based on compilations of data from studies conducted independently in local areas.

The first synoptic regional survey of the demersal fauna of the mainland shelf of southern California was conducted in 1994. This study provided baseline information on the relative abundance of fish and invertebrate populations, distribution of their assemblages; the extent of contamination in fish tissue (flatfish livers); and distribution of anthropogenic debris. It showed that DDTs and PCBs were the primary contaminants found in fish tissue, but that levels had decreased in reference areas since the 1970s. Similarly, fish anomalies associated with outfall conditions had decreased in prevalence during this period. Fish and invertebrate assemblages varied more by depth than by region, with generally distinct assemblages in three depth-related life zones (inner shelf, middle shelf, and outer shelf). Fish assemblages appeared relatively healthy compared to the 1970s and invertebrate assemblages on the mainland shelf were described for the first time. Although the study provided useful baseline information for the fauna of the mainland shelf, bays, and islands were not sampled. It also identified a need to assess effects with additional tools (e.g., wildlife-risk thresholds, biointegrity indices).

In addition to surveying the mainland shelf of the SCB, the second synoptic regional survey in 1998 surveyed the demersal fauna of bays and harbors and most of the islands of the SCB. As in 1994, fish and invertebrate assemblages varied more by depth than by region, but distinct assemblages occurred in bays and harbors, and to some extent at the islands. Recently developed biointegrity indices showed that fish and invertebrate assemblages were relatively normal, and the prevalence of fish anomalies continued to be low. DDT was prevalent in fish tissue throughout the SCB, with 70% of the area having sanddab-guild flatfishes with DDT levels above wildlife-risk screening values for birds and mammals. Some effects of the 1997-1998 El Niño were apparent in fish and invertebrate populations and assemblages, with invertebrate populations showing decreases in most population measures relative to 1994 (warm-regime) and 1957-1975 (generally cold regime). Many fish species were less widely distributed, often shifting to deeper water. Anthropogenic debris was found to be most common in bays and harbors, and at Santa Catalina Island, areas not assessed in 1994. Although the study expanded the baseline description of the fauna to bays and islands, a baseline survey of fish, invertebrates, and debris on the upper slope was needed. In addition, although the study showed that flatfishes with DDT above wildlife-risk guidelines occurred in 70% area, there was a need to assess contamination in pelagic fishes, which are more likely consumed by birds and mammals.

The third synoptic survey was conducted in 2003 and is the subject of this report. This survey collected trawl samples from 210 stations from Point Conception to the U.S.-Mexico Border at depths of 2-476 m from July to October 2003. In addition to the mainland shelf, bays and harbors, and Channel Islands sampled in 1998, this survey surveyed the demersal fish and invertebrate fauna of the upper slope (200-500 m). This study included many of the same assessments of the health of the fauna for comparison to previous surveys. However, it included a detailed study of ectoparasitism in fishes relative to POTW areas and an assessment of bioaccumulation in pelagic forage fish and squid to better assess potential health risks to seabird and marine mammal predators. The following is a description of the most important findings of this study.

Demersal fish and invertebrate populations and assemblages on the southern California shelf were healthy in 2003 compared to conditions in the 1970s. Biointegrity indices identified 96% of the southern California shelf as reference (i.e., normal) for fish, 92% for fish and invertebrates combined, and 84% for invertebrates. Nonreference (disrupted) assemblages occurred primarily on the inner shelf or bay/harbor areas, suggesting nearshore influences. Fish populations had background levels of anomalies and parasites. The prevalence of fish diseases and anomalies had decreased significantly from 5.0-0.9% from the 1970s-2003 but increased slightly from 0.5-0.9% between 1998 and 2003. There was no incidence of fin erosion, an important fish response to contaminated sediments in the past. A detailed baseline study of fish ectoparasites conducted regionally for the first time in the 2003 survey revealed many fish ectoparasites included flatworms, leeches, and crustaceans, with copepods comprising 88% of the parasites. Prevalence of ectoparasites on bigmouth sole (*Hippoglossina stomata*) were highest at large and small POTW areas and on hornyhead turbot (*Pleuronichthys verticalis*) at small POTW areas. The increase in prevalence of ectoparasites at small POTW areas may be due to the shallow depth and higher water temperature of these sites.

DDT was prevalent in pelagic forage fish tissue in the Southern California Bight. Contamination above Canadian screening values protective of wildlife (seabirds and marine mammals) consumers of fish was restricted primarily to DDT. Virtually none of the landings exceeded screening values for PCBs. Tissue concentrations of DDT were generally highest in the central SCB, the location with the highest sediment concentrations. An estimated 99% of northern anchovy (*Engraulis mordax*), 86% of Pacific sardine (*Sardinops sagax*), 33% of Pacific chub mackerel (*Scomber japonicus*), and 0% of California market squid (*Loligo opalescens*) composites exceeded Canadian wildlife screening values for total DDT. Northern anchovy had the greatest biomass-weighted mean concentrations (60 ng/g ww), followed by Pacific chub mackerel (41 ng/g), Pacific sardine (34 ng/g), and California market squid (0.8 ng/g). The Canadian wildlife-risk screening values used in this study identify tissue concentrations of DDT and PCB that may pose health-risk concerns to sensitive wildlife species. Although these screening values (based on responses of sensitive species) identify levels of potential concern, they may or may not be pertinent to seabirds or marine mammals of concern in the SCB. Additional study is necessary to determine what tissue concentrations in pelagic forage fishes are critical to local bird and mammal species of concern.

Anthropogenic debris (mostly plastic) was found in 25% of the southern California shelf. Debris was most common in the central region outer and middle shelf non-POTW areas. The percent area of plastic debris, metal cans, and glass bottles have decreased since the 1994 regional survey but fishing gear and other debris were highest in 2003.

Fish and invertebrate assemblages were generally associated with major depth zones on the shelf and upper slope, with distinct assemblages also in bay and harbor areas. Assemblages in the island region differed only slightly from those of the mainland region. Assemblages in San Diego Bay (a natural embayment) differed from those in Los Angeles/Long Beach Harbor (an artificially enclosed area of the open coast) by having distinctive inner bay species. The fish and invertebrate assemblages of the upper slope (depth 200-500 m), a new stratum for the survey in 2003, had distinctive deepwater species seldom found at shallower depths, but low species richness and abundance as is found on the inner shelf and bays.

Fish and invertebrate populations and assemblages have changed over time in response to the prevailing ocean climate during the survey (1994-warm regime; 1998-El Niño; and 2003-cold regime) and in an earlier (1972) cold-regime survey. Depth displacement patterns among dominant fish foraging guild species were most similar in cold regimes (1972, 2003), less in 1994 (warm), and least in the 1998 El Niño period. Displacement patterns were identical in both cold regime periods for the midshipman, sanddab, and combfish guilds, suggesting a characteristic cold regime pattern for the guilds. During the 1998 El Niño period, important community members in 13 guilds expanded or shifted their distributions to deeper parts of the shelf. For example, in the most widespread guilds, Pacific sanddab (*Citharichthys sordidus*) shifted its range deeper in the sanddab guild and Dover sole (*Microstomus pacificus*) and hornyhead turbot shifted deeper in the turbot guild. Both were replaced in shallow water by more southerly species (longfin sanddab, *Citharichthys xanthostigma*, and spotted turbot, *Pleuronichthys ritteri*) respectively) during the 1998 El Niño. Mean fish abundance and species richness per haul have increased with fish abundance in 2003 (cold regime) about two times greater than in any of the previous surveys. In contrast, mean invertebrate abundance was highest in 1994 (warm regime) but biomass was highest in 2003 (cold regime). These surveys have demonstrated that characteristics of the fish communities (abundance, biomass, and depth distribution of component species) vary by oceanic regime, with evidence that some fish foraging guilds return to similar patterns in at least one of these regimes (cold). The results demonstrate that assessments of anthropogenic effects on demersal fish communities must consider the oceanic regime of the assessment period to avoid confusing natural changes with anthropogenic effects.

TABLE OF CONTENTS

The Bight '03 Trawl Working Group Members i
Foreword ii
Acknowledgements iii
Executive Summary iv
Table of Contents vii
List of Tables x
List of Figures xv
I. Introduction 1
II. Methods 5
Sampling Design 5
Probability-based design 5
Subpopulations 5
Field Sampling 7
Sample Collection and Processing for Assemblage and Debris Studies 7
Collection of Fish Samples for Fish Ectoparasite Study 9
Collection of Fish and Squid Samples for Bioaccumulation in Pelagic Forage Fish Study 10
Laboratory Methods 12
Fish and Invertebrate Preservation for Voucher and Archival Collections 12
Fish Ectoparasite Preservation and Identification 12
Bioaccumulation Analysis 12
Information Management 14
Quality Assurance/Quality Control (QA/QC) Procedures 15
Trawl Assemblage Survey 15
Chemistry 16
Data Analyses 17
Description of Populations 17
Assemblage Analysis 20
Functional Organization of Fish Assemblage Analysis 28
Bioaccumulation Data Analysis 29
III. Quality Assurance 34
Introduction 34
Results 34
Assemblage Study 34
Bioaccumulation in Pelagic Forage Fish and Squid Study 42
Discussion 46
Beneficial Features of the Quality Assurance Program 46
Success at Meeting Measurement Quality Objectives 47
Problems Associated With Sampling 49

Pressure-Temperature Sensor 49
Improving Quality Assurance/Control in Future Multi-agency Surveys 50
IV. Demersal Fish Populations 51
Introduction 51
Results 51
Population Attributes 51
Species Composition 67
Species Size (Length) Distribution 74
Anomalies and Parasites 90
Discussion 95
Historical Surveys 95
Population Attributes 95
Species Composition 100
Commercial and Recreational Fishes 101
Effects of Oceanic Regime Changes 101
Anomalies and Parasites 103
V. Megabenthic Invertebrate Populations 106
Introduction 106
Results 106
Population Attributes 106
Species Composition 117
Anomalies and Parasites of Megabenthic Invertebrates 132
Discussion 133
Population Attributes 134
Species Composition in Regional Surveys 1994-2003 141
Effects of Oceanic Regime Changes on Regional Surveys 145
The Upper Slope Stratum 146
Important Megabenthic Species in Regional Trawling Surveys 147
VI. Assemblages and Biointegrity 149
Introduction 149
Results 150
Fish Assemblages 150
Invertebrate Assemblages 167
Combined Fish and Invertebrate Assemblages 177
Biointegrity Assessment 207
Discussion 211
Biointegrity Assessment 211
Assemblages in 2003 216
Historical Changes in the Functional Structure of Fish Communities 218
VII. Ectoparasitism of Fishes 231
Introduction 231

Results 233
Southern California Bight (SCB) 234
Discussion 245
Summary and Conclusion 267
VIII. Bioaccumulation 268
Introduction 268
Results 269
Sample Representation 269
Total DDT and Total PCB 270
Relationship to Lipid Content 270
Percent of Biomass Above Wildlife Risk Screening Values 277
Total Mass of Contaminants in SCB 277
Discussion 278
IX. Debris 284
Introduction 284
Results 284
Natural Debris 284
Anthropogenic Debris 285
Discussion 286
X. Discussion 297
Assessment of Human Impact 297
Assemblage Biointegrity 297
Populations 298
Diseases and Anomalies 298
Bioaccumulation 300
Debris 300
Assessment of Natural Effects 301
Depth Zonation of Assemblages 301
The Upper Slope Stratum 301
Cyclic Oceanographic Phenomena and Temporal Change 302
Responses of Assemblages to Changing Oceanic Regimes 303
The Broader Context of Regional Survey Observations 303
XI. Conclusions 304
XII. Recommendations 307
XIII.Literature Cited 312
APPENDIX A A-1
APPENDIX B B-1
APPENDIX C C-1
APPENDIX D D-1
APPENDIX E E-1
APPENDIX F F-1

LIST OF TABLES

Table II-1. Chlorinated hydrocarbons analyzed in pelagic forage fish bioaccumulation study, Southern California Bight 2003 Regional Survey. 14

Table II-2. Summary of congener-specific toxicity equivalent factors (TEFs) for mammals and birds used in the Southern California Bight 2003 Regional Survey. 32

Table III-1. Bight '03 bucket intercalibration results for trawl fish and invertebrate species identification. Results are from the primary practicum and a second test for agencies exceeding the measurement quality objective. 40

Table III-2. Error evaluation for trawl fish voucher and FID (requiring further identification) specimens submitted as part of the Southern California Bight 2003 Regional Survey quality assurance program. 41

Table III-3. Error evaluation for trawl invertebrate voucher and FID (requiring further identification) specimens submitted as part of the Southern California Bight 2003 Regional Survey quality assurance program. 42

Table III-4. Sampling success of southern California pelagic forage species targeted for whole fish composite contaminant analysis between July 2003 and February 2004. 43

Table III-5. Holding time results for fish tissue samples used in pelagic forage fish bioaccumulation study, July 2003-February 2004. 45

Table III-6. Quality control results for chlorinated hydrocarbon analyses of whole organism composites of pelagic forage fishes and squid in Southern California Bight 2003 Regional Survey. 46

Table IV-1. Demersal fish abundance by subpopulation at depths of 2-476 m on the shelf and upper slope of southern California, July-October 2003. 53

Table IV-2. Demersal fish abundance by region within shelf zone subpopulations at depths of 2-476 m on the southern California shelf and upper slope, July-October, 2003. 54

Table IV-3. Demersal fish biomass by subpopulation at depths of 2-476 m on the shelf and upper slope of southern California, July-October 2003. 57

Table IV-4. Demersal fish biomass by region within shelf zone subpopulations at depths of 2-476 m on the shelf and upper slope of southern California, July-October, 2003. 58

Table IV-5. Demersal fish species by subpopulation at depths of 2-476 m on the shelf and upper slope of southern California, July-October 2003. 59

Table IV-6. Demersal fish species by region within shelf zone subpopulations at depths of 2-476 m on the shelf and upper slope of southern California, July-October, 2003. 60

Table IV-7. Demersal fish diversity by subpopulation at depths of 2-476 m on the shelf and upper slope of southern California, July-September 2003. 64

Table IV-8. Demersal fish diversity by region within shelf zone subpopulations at depths 65

of 2-476 m on the shelf and upper slope of southern California, July-October, 2003. 65

Table IV-9. 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 5-202 m, July - October, 2003. 69

Table IV-10. Demersal fish species comprising 50% or more of the area by subpopulation on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003. 70

Table IV-11. Demersal fish species comprising 95% or more of the total fish abundance on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003. 71
Table IV-12. Demersal fish species comprising 80% or more of the fish abundance by subpopulation on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003. 72
Table IV-13. Demersal fish species comprising 95% or more of the total fish biomass on the southern California shelf and slope at depths of 2-476 m, July-October 2003....................... 75
Table IV-14. Demersal fish species comprising 80% or more of the fish biomass by subpopulation on the southern California shelf and slope at depths of 2-476 m, July-October 2003.. 76
Table IV-15. Demersal fish species with greatest and least lengths collected on the southern California shelf and upper slope at depths of 2 - 476 m, July-October 2003. 82
Table IV-16. Number of fish by species with different anomaly types collected at depths of 2-476 m on the southern California shelf, July-October 2003. 91
Table IV-17. Percent area by subpopulation of fish with different anomaly types collected on the southern California shelf and slope at depths of 2-476 m, July-October 2003....................... 92
Table IV-18. 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 1957-1975a, 1994, 1998, and 2003 regional survey data. 97
Table IV-19. Demersal fish abundance, biomass, species richness, and diversity at middle-shelf large publicly owned treatment work (LPOTW) and reference (non-LPOTW) subpopulations in 1994, 1998, and 2003. Data from 1994 reanalyzed using 1998 subpopulation boundaries. See Figure IV-15. 98
Table IV-20. Comparison of demersal fish species occurring in greater than 20% of the area on the mainland shelf of southern California in 1994, 1998, and 2003. 102
Table V-1. Megabenthic invertebrate abundance by subpopulation at depths of 2-476 m on the southern California shelf and upper slope, July-October 2003.. 108
Table V-2. Megabenthic invertebrate abundance by region within shelf zone subpopulations at depths of 2-476 m on the southern California shelf and upper slope, July-October, 2003. . 109
Table V-3. Megabenthic invertebrate biomass by subpopulation at depths of 2-476 m on the southern California shelf and upper slope, July-October 2003.. 110
Table V-4. Megabenthic invertebrate biomass by region within shelf zone subpopulations at depths of 2-476 m on the southern California shelf and upper slope, July-October, 2003. 113
Table V-5. Megabenthic invertebrate species by subpopulation at depths of 2-476 m on the southern California shelf and upper slope, July-October 2003.. 114
Table V-6. Megabenthic invertebrate species by region within shelf zone subpopulations at depths of 2-476 m on the southern California shelf and upper slope, July-October, 2003. . 115
Table V-7. Megabenthic invertebrate diversity by subpopulation at depths of 2-476 m on the southern California shelf and upper slope, July-October 2003.. 118
Table V-8. Megabenthic invertebrate diversity by region within shelf zone subpopulations at depths of 2-476 m on the southern California shelf and upper slope, July-October, 2003. 119
Table V-9. Megabenthic invertebrate species occurring in 20% or more of the area of the southern California shelf at depths of 2-476 m, July-October 2003.................................... 122

Table V-10. Megabenthic invertebrate species comprising 50% or more of the area by subpopulation on the southern California shelf at depths of 2-476 m, July-October 2003. . 123
Table V-11. Megabenthic invertebrate species comprising 95% or more of the total invertebrate abundance of the southern California shelf at depths of 2-476 m, July-October 2003. 124
Table V-12. Megabenthic invertebrate species comprising 80% or more of the invertebrate abundance by subpopulation on the southern California shelf at depths of 2-476 m, July-October 2003. 127
Table V-13. Megabenthic invertebrate species comprising 95% or more of the total invertebrate biomass of the southern California shelf at depths of 2-476 m, July-October 2003. 128
Table V-14. Megabenthic invertebrate species comprising 80% or more of the invertebrate biomass by subpopulation on the southern California shelf at depths of 2-476 m, July-October 2003. 129
Table V-15. Comparison of megabenthic invertebrate population attributes on mainland shelf by region and year(s) for the Southern California Bight (SCB) in 1971-1985, 1994, 1998, and 2003 regional survey data. 135
Table V-16. Megabenthic invertebrate abundance, biomass, species richness, and diversity at middle-shelf large publicly owned treatment work (LPOTW) and reference (non-LPOTW) subpopulations in 1994, 1998, and 2003. Data from 1994 reanalyzed using 1998 subpopulation boundaries. 136
Table V-17. Comparison of megabenthic invertebrate species occurring in greater than 20% of the area on the mainland shelf of southern California in 1994, 1998, and 2003. 143
Table V-18. Multiyear comparison of megabenthic species important because of abundance (A), biomass (B), or occurrence (Oc) in the Southern California Bight. Values reflect ranks in each survey, and average weighted importance rank by survey and overall. 144
Table VI-1. Mean and range of depth of demersal fish recurrent groups on the southern California shelf and upper slope in July-October 2003. 154
Table VI-2. Frequency of occurrence (number of stations) of demersal fish site clusters by region and subpopulation on the southern California shelf at depths of 2-476 m, July-October 2003. 155
Table VI-3. Frequency of occurrence (percent of stations) of demersal fish species occurring at 50% or more of the stations in at least one site cluster on the southern California shelf at depths of 2-476 m, July-October 2003. 164
Table VI-4. Mean and range of depth of megabenthic invertebrate recurrent groups on the southern California shelf and upper slope in July-October 2003. 171
Table VI-5. Frequency of occurrence (number of stations) of megabenthic invertebrate site clusters by region and subpopulation on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003. 178
Table VI-6. Frequency of occurrence (percent of stations) of megabenthic invertebrate species 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 2-476 m, July-October 2003. 181
Table VI-7. Mean and range of depth of combined demersal fish and megabenthic invertebrate recurrent groups on the southern California shelf and upper slope, July-October, 2003. 182

Table VI-8. Frequency of occurrence (number of stations) of combined demersal fish and megabenthic invertebrate site clusters by region and subpopulation on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003. 189
Table VI-9. Frequency of occurrence (percent of stations) of demersal fish and megabenthic invertebrate species 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 2-476 m, July-October 2003. (See Appendix D-D10 for complete Species Cluster B percent occurrences)............................. 194
Table VI-10. Percent occurrence of foraging guilds on the mainland shelf (10-200 m) in southern California in 1994, 1998, and 2003. 220
Table VII-1. Host fish taxa collected at depths of 22-198 m in the Southern California Bight, July-October 2003.. 236
Table VII-2. Classification and group totals of parasites on fishes collected at depths of 22-198 m in the Southern California Bight, July-October 2003. 237
Table VII-3. Total parasite prevalence and mean intensity for all host fish species collected from 79 stations at depths of 22-198 m in the Southern California Bight (SCB), July through October 2003, with host fishes ranked in order of highest to lowest prevalence. 238
Table VII-4. Host totals by region collected at depths of 22-198 m in the Southern California Bight, July-October 2003.. 239
Table VII-5. Number of stations each host was collected by Region in the Southern California Bight at depths of 22-198 m, July through October 2003.. 240
Table VII-6. Total parasite prevalence by Region collected at depths of 22-198 m in the Southern California Bight, July through October 2003. 241
Table VII-7. Total parasite mean intensity by Region collected at depths of 22-198 m in the Southern California Bight, July through October 2003. 242
Table VII-8. Host totals by Outfall Type collected at depths of 22-198 m in the Southern California Bight, July through October 2003. 243
Table VII-9. Number of stations each host was collected by Outfall Type in the Southern California Bight at depths of 22-198 m, July through October 2003. 253
Table VII-10. Total parasite prevalence by Outfall Type collected at depths of 22-198 m in the Southern California Bight, July through October 2003. 254
Table VII-11. Total parasite mean intensity by Outfall Type collected at depths of 22-198 m in the Southern California Bight, July through October 2003. 255
Table VII-12. Host totals by Large-Outfall collected at depths of 22-198 m in the Southern California Bight, July through October 2003. 256
Table VII-13. Number of stations each host was collected by Large-Outfall in the Southern California Bight at depths of 22-198 m, July-October 2003. 257
Table VII-14. Total parasite prevalence by Large-Outfall collected at depths of 22-198 m in the Southern California Bight, July through October 2003. 258
Table VII-15. Total parasite mean intensity by Large-Outfall collected at depths of 22-198 m in the Southern California Bight, July through October 2003. 259
Table VII-16. Frequency of occurrence of parasites on host fishes collected at depths of 22-198 m in the Southern California Bight, July through October 2003, hosts and parasites in phylogenetic order. For complete host and parasite scientific names refer to Tables 59 and 61, respectively. 260

Table VIII-1. Sampling success of southern California pelagic forage species targeted for whole fish composite contaminant analysis between July 2003 and February 2004. 271
Table VIII-2. Summary of total DDT (ug/kg) concentrations in southern California pelagic forage fish and squid composites by region within the southern California Bight............... 275
Table VIII-3. Summary of total PCB (ug/kg) concentrations in southern California pelagic forage fish and squid composites by region within the southern California Bight............... 276
Table VIII-4. Comparison of chlorinated hydrocarbons measured in pelagic forage fishes and squid of the southern California Bight in the early 1980s and this study, 2003-04.............. 283
Table Table IX-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 2003. 288
Table Table IX-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 2003. 292
Table Table IX-3. Total seasonal rainfall (precipitation) for Los Angeles Civic Center for year before and year of regional surveys (Taken from the Los Angeles Almanac (www.laalmanac.com/weather)). 296

LIST OF FIGURES

Figure II-1. Distribution of subpopulations (regions, shelf zones, and human influence areas) sampled by trawl in the Southern California Bight 2003 Regional Survey, July-October 2003. 6
Figure II-2. Population and assemblage study stations sampled by trawl on the southern California shelf at depths of 2-476 m in the Southern California Bight 2003 Regional Survey, July-October 2003........ 8
Figure II-3. Distribution of 79 fish ectoparasite study stations sampled by otter trawl at depths of 22-198 m in the Southern California Bight, July-October 2003........ 10
Figure II-4. Southern California coastal and island regions sampled from July 2003 to February 2004 for fish and squid samples in pelagic forage fish bioaccumulation study. 11
Figure II-5. Foraging guilds of soft-bottom fishes on the southern California shelf (from Allen 1982, 2006a). 29
Figure II-6. Functional structure and species composition of soft-bottom fish communities of the mainland shelf of southern California in 1972-1973 (modified from Allen 1982, 2006a)..... 30
Figure III-1. Successful and unsuccessful assemblage trawl stations during the Southern California Bight 2003 Regional Survey, July-October 2003........ 35
Figure III-2. Abandoned trawl stations during the Southern California Bight 2003 Regional Survey, July-October 2003. Symbols represent reasons given for station failure as presented in the database. Totals include number of failed trawls, which may be more than one at a station........ 36
Figure III-3. Trawl duration (time) versus distance towed results for assemblage trawls during the Southern California Bight 2003 Regional Survey. Five outliers were circled to illustrate potential transcription errors resulting from distance (circle) or time (square)........ 39
Figure III-4. Distribution of contaminant sample composites for a) northern anchovy, b) Pacific sardine, c) California market squid, and d) Pacific chub mackerel sampled from southern California commercial fishing markets and/or bait receivers during July 2003 – February 2004........ 44
Figure III-5. Total southern California commercial landings of pelagic forage fish and squid landings (metric tons) during the study period, July 2003 – February 2004 (CDFG data, unpublished). PS=Pacific sardine, PM=Pacific chub mackerel, NA=northern anchovy, MS=California market squid. 44
Figure IV-1. Distribution of fish abundance per haul at depths of 2-476m on the southern California shelf and upper slope, July-October 2003. 55
Figure IV-2. Distribution of fish biomass per haul at depths of 2-476m on the southern California shelf, July-October 2003........ 61
Figure IV-3. Distribution of number of fish species per haul at depths of 2-476 m on the southern California shelf and upper slope, July-October 2003........ 62
Figure IV-4. Distribution of fish diversity (Shannon-Wiener) per haul at depths of 2-476 m on the southern California shelf, July-October 2003........ 66
Figure IV-5. Equitability curves of fish occurrence, abundance, and biomass by species at depths of 2-476 m, Southern California Bight 2003 Regional Survey, July-October 2003. x=140th species........ 73

Figure IV-6. Length-Frequency distribution of all fish collected by trawl at depths of 2-476 m on the in the southern California shelf, July-September 2003. n=Number of fish measured; X=Largest fish (size class 105). 77
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 shelf zone and regional subpopulation on the southern California shelf, July-September 2003. 78
Figure IV-8. Length-frequency distribution (mean number of fish per size class) of all fish collected by trawl at southern California islands by Shelf zone and regional subpopulation on the southern California shelf, July - September 2003. NWI- Northwest Channel islands; SEI=Southeast Channel islands. No upper slope stations were sampled at SEI. 79
Figure IV-9. Length-frequency distributions of the 10 most abundant fish species collected by trawl at depths of 2-500 m on the southern California shelf, July-October 2003. n=Number of fish measured. 83
Figure IV-10. Length-frequency distributions of the 10 most abundant fish species collected by trawl within the Bays and Harbors on the southern California shelf, July-September 2003. n=Number of fish measured. 84
Figure IV-11. Length-frequency distributions of the 10 most abundant fish species collected by trawl on the mainland and Island shelf of southern California shelf, July-September 2003. Bays & Harbors are not included. n=Number of fish measured. 85
Figure IV-12. Length-frequency distributions for 2 species of fish collected by trawl on both the mainland shelf and within the bays and harbors of southern California shelf, July-September 2003. n=Number of fish measured. 86
Figure IV-13. Distribution of fish anomalies on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003. 93
Figure IV-14. Distribution of external parasites of fish on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003. 94
Figure IV-15. Median (and 95% confidence limits) of fish population attributes at large publicly owned treatment work (LPOTW) and reference (non-Large POTW) subpopulations on the southern California middle shelf in 1994, 1998, and 2003: a) abundance; b) biomass; c) species richness; and d) diversity. NOTE: LPOTW boundaries of 2003 were used for all years; non-large POTW areas consist of all mainland middle shelf stations that did not fall within the LPOTW boundaries. 99
Figure IV-16. Percent of area (with 95% confidence limits) of large publicly owned treatment works (LPOTW) subpopulations with fish population attributes above the reference (NLPOTW: mainland, middle shelf, non-large POTW) subpopulation medians in 1994, 1998, and 2003. NOTE: LPOTW boundaries of 2003 were used for all years; NLPOTW areas consist of all mainland middle shelf stations that did not fall within the LPOTW boundaries. 100
Figure V-1. Distribution of megabenthic invertebrate abundance per haul at depth of 2 to 476 m on the southern California shelf and upper slope, July-October 2003. 111
Figure V-2. Distribution of megabenthic invertebrate biomass per haul at depths of 2-476 m on the southern California shelf and upper slope, July-October 2003. 116
Figure V-3. Distribution of megabenthic invertebrate species per haul at depths of 2-476 m on the southern California shelf and upper slope, July-October 2003. 116

Figure V-4. Distribution of megabenthic invertebrate diversity (Shannon-Wiener) per haul at depths of 2-476 m on the southern California shelf and upper slope, July-October 2003. .. 120
Figure V-5. Equitability curves of megabenthic invertebrate occurrence, abundance, and biomass by species at depths of 2-476 m on the southern California shelf and upper slope, July-October 2003. x=308th species for area abundance curves; 300th species for the biomass curve (Eight species found only at stations 4028 and 4116 were not ranked because of questionable weights).. 125
Figure V-6. Median (and 95% confidence limits) megabenthic invertebrate population attributes at large publicly owned treatment work (LPOTW) subpopulations and reference (NLPOTW: mainland, middle shelf, non-large POTW) subpopulations in 1994, 1998, and 2003: a) abundance; b) biomass; c) species richness; and d) diversity. NOTE: LPOTW boundaries of 1998 were used in all years.. 137
Figure V-7. Percent of area (with 95% confidence limits) of large publicly owned treatment works (LPOTW) subpopulations of megabenthic invertebrate population attributes above the reference (NLPOTW: mainland, middle shelf, non-large POTW) subpopulation medians in 1994, 1998, and 2003. NOTE: LPOTW boundaries of 2003 were used for all years; NLPOTW areas consist of all mainland middle shelf stations that did not fall within the LPOTW boundaries. 139
Figure VI-1. Recurrent groups of demersal fishes on the southern California shelf at depths of 2-476 m, July-October 2003. 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. Lines show relationships between groups and associates, with values indicating proportion of possible pairs with I.A.=0.5 (0.495)... 153
Figure VI-2. Summary of demersal fish cluster analysis and relationships among site and species clusters on the southern California shelf at depths of 2-476 m, July-October 2003............ 156
Figure VI-3. Bathymetric distribution of demersal fish site clusters on the southern California shelf at depths of 2-476 m, July-October 2003.. 157
Figure VI-4. Distribution of fish site clusters on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003. 165
Figure VI-5. Multidimensional scaling plot of fish species assemblages (abundance by species) for 90 trawl stations sampled in Southern California Bight 2003 Regional Survey at depths of 2-476 m, July-October 2003. (Station name abbreviations: BH=Bays/Harbors; IS=Inner Shelf; MS=Middle Shelf; OS=Outer Shelf; US=Upper Slope)... 166
Figure VI-6. Functional organization of demersal fish communities on the shelf and upper slope of southern California in July-October 2003. Blocks enclose bathymetric zones where guild occurred in 20% or more of stations. Species in block is dominant species of guild in that zone.. 169
Figure VI-7. Recurrent groups of megabenthic invertebrates found at multiple sites on the southern California shelf at depths of 2-476 m, July-October 2003. Index of affinity (I.A.)=0.50 (0.495). Groups are numbered from shallow to deep. Species within a group are listed in order of abundance. Lines show relationships between groups and associates, with values indicating proportion of possible pairs with I.A.=0.5 (0.495)................................. 170
Figure VI-8. Summary of megabenthic invertebrate cluster analysis and relationships among site and species clusters on the southern California shelf at depths of 2-476 m, July- October 2003.. 179

Figure VI-9. Bathymetric distribution of megabenthic invertebrate site clusters on the southern California shelf at depths of 2-476 m, July-October 2003.. 180
Figure VI-10. Distribution of megabenthic invertebrate site cluster on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003. 183
Figure VI-11a. Recurrent groups of combined demersal fishes and megabenthic invertebrates occurring at multiple sites on the southern California shelf at depths of 2-476 m, July-October 2003. Index of affinity (I.A.)=0.50. Group depths 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. 190
Figure VI-11b. Recurrent groups of combined demersal fishes and megabenthic invertebrates occurring at multiple sites on the southern California shelf at depths of 2-476 m, July-October 2003. Index of affinity (I.A.)=0.50. Group depths 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. 191
Figure VI-12. Summary of combined demersal fish and megabenthic invertebrate cluster analysis and relationships among site and species clusters on the southern California shelf at depths of 2-476 m, July-October 2003. 192
Figure VI-13. Bathymetric distribution of demersal fish and megabenthic invertebrate site clusters on the southern California shelf at depths of 2-476 m, July-October 2003............ 193
Figure VI-14. Distribution of demersal fish and megabenthic invertebrate site cluster on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003. 197
Figure VI-15. Parsimony analysis of endemicity (PAE), or q-mode, cladogram showing the relationships of stations based on their taxa inventories on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003. Brackets on the left identify shelf zones. Brackets on the right identify sub-shelf zones. Larger font size represents majority membership of each bracket. Smaller font size represents minority membership of each bracket. Station Code=Station (xxxx), Region (a=letter), Shelf zone(a), depth(x-xxx), subshelf(a). Region: C=Central, E=Warm (Southeast channel islands), N=Northern, S=Southern, W=Cool (Northwest channel islands). Shelf zone: B=Bays and Harbors, I=Inner Shelf, M=Middle Shelf, O=Outer Shelf, U=Upper Slope. Subshelf: A=Marinas, I=Islands, L=Large POTWs, M=Mainland, N=Mainland non-POTW, P=Ports, S=Small POTWs. 199
Figure VI-16. Stress configurations for nonmetric multidimensional scaling results of site clades of fishes and invertebrates. 207
Figure VI-17. Percent of nonreference area by subpopulation on the southern California shelf and upper slope at depths of 2-476 m for the Fish Response Index (FRI), July-October 2003. . 208
Figure VI-18. Percent of nonreference area by shelf zone subpopulation on the southern California shelf and upper slope at depths of 2-476 m for the Fish Response Index (FRI), July-October 2003.. 209
Figure VI-19. Distribution of response levels for Fish Response Index (FRI) on the southern California shelf at depths of 2-476 m, July-October 2003.. 209
Figure VI-20. Percent of nonreference area by shelf zone subpopulation on the southern California shelf and upper slope at depths of 2-476 m for the Fish Foraging Guild Index (FFG), July-October 2003.. 210

Figure VI-21. Distribution of response levels for Fish Foraging Guild Index (FFG) on the southern California shelf at depths of 2-476 m, July-October 2003. 210
Figure VI-22. Percent of nonreference area by subpopulation on the southern California shelf and upper slope at depths of 2-476 m) for the Megabenthic Invertebrate Response Index (MIRI), July-October 2003. 212
Figure VI-23. Percent of nonreference area by shelf zone subpopulation on the southern California shelf and upper slope at depths of 2-476 m for the Megabenthic Invertebrate Response Index (MIRI), July-October 2003. 212
Figure VI-24. Distribution of response levels for Megabenthic Invertebrate Response Index (MIRI) on the southern California shelf at depths of 2-476 m, July-October 2003. 213
Figure VI-25. Percent of nonreference area by subpopulation on the southern California shelf and upper slope at depths of 2-476 m for the Trawl Response Index (TRI), July-October 2003. 213
Figure VI-26. Percent of nonreference area by shelf zone subpopulation on the southern California shelf and upper slope at depths of 2-476 m for the Trawl Response Index (TRI), July-October 2003. 214
Figure VI-27. Distribution of response levels for Trawl Response Index (TRI) on the southern California shelf at depths of 2-476 m, July-October 2003. 214
Figure VI-28a. Comparison of changes in depths of dominance of foraging guilds 1A1 to 1B2 of demersal fish communities on the southern California in 1972-1973 (Allen 1982), 1994 (Allen *et al.* 1998), Allen *et al.* (2002a), and 2003. 221
Figure VI-28b. Comparison of changes in depths of dominance of foraging guilds 1C1 to 2B of demersal fish communities on the southern California in 1972-1973 (Allen 1982), 1994 (Allen *et al.* 1998), Allen *et al.* (2002a), and 2003. 222
Figure VI-28c. Comparison of changes in depths of dominance of foraging guilds 2C1 to 2C2d demersal fish communities on the southern California in 1972-1973 (Allen 1982), 1994 (Allen *et al.* 1998), Allen *et al.* (2002a), and 2003. 223
Figure VI-28d. Comparison of changes in depths of dominance of foraging guilds 2D1a to 2D2 of demersal fish communities on the southern California in 1972-1973 (Allen 1982), 1994 (Allen *et al.* 1998), Allen *et al.* (2002a), and 2003. 224
Figure VII-1. Total parasite prevalence for all host fish species collected at depths of 22-198 m in the Southern California Bight, July through October 2003, host fishes in phylogenetic order. 261
Figure VII-2. Total parasite mean intensity for all host fish species collected at depths of 22-198 m in the Southern California Bight, July through October 2003, host fishes in phylogenetic order. 262
Figure VII-3. Individual parasite prevalence for California scorpionfish (*Scorpaena guttata*) collected at depths of 22-198 m in the Southern California Bight, July through October 2003, parasites in phylogenetic order. 263
Figure VII-4. Individual parasite mean intensity for California scorpionfish (Scorpaena guttata) collected at depths of 22-198 m in the Southern California Bight, July through October 2003, parasites in phylogenetic order. 264

Figure VII-5. Total parasite mean intensity for all host fish species collected at depths of 22-198 m in the Southern California Bight, July through October 2003, host fishes in order of increasing maximum standard length (mm). 265
Figure VIII-1. Distribution of contaminant sample composites for a) northern anchovy, b) Pacific sardine, c) California market squid, and d) Pacific chub mackerel sampled from southern California commercial fishing markets and/or bait receivers during July 2003 – February 2004..... 271
Figure VIII-2. Total southern California commercial landings of pelagic forage fish and squid landings (metric tons) during the study period, July 2003 – February 2004 (CDFG data, unpublished). PS=Pacific sardine, PM=Pacific chub mackerel, NA=northern anchovy, MS=California market squid. 272
Figure VIII-3. Representative samples by species and geographic stratum. Gray bars denote the relative percentage of total landings by species for each stratum. Black bars denote the fraction of total landings with a representative sample. 273
Figure VIII-4. Box plots of a) total DDT and b) total PCB in pelagic forage fish and squid whole fish composites sampled from southern California commercial fish markets and bait receivers during July 2003 – February 2004. (NA=northern anchovy (n=24); PS=Pacific sardine (n=34); MS=California market squid (n=28); PM=Pacific chub mackerel (n=13))..... 274
Figure VIII-5. Relationship between lipid content and total DDT concentrations in whole fish composites of pelagic forage fishes and squid sampled from southern California commercial fish markets and/or bait receivers during July 2003 – February 2004. Samples represent only those with detectable levels of total DDT (n=80). 277
Figure VIII-6. Percentage of pelagic forage fish and squid landings in the SCB estimated as having contaminant levels above wildlife risk screening values. (tDDT=Total DDT; PCB bTEQ=PCB Toxicity Quotient for birds; PCB mTEQ=PCB Toxicity Quotient for mammals). 281
Figure VIII-7. Southern California commercial landings (in metric tons) of a) Pacific sardine, b) Pacific chub mackerel, c) northern anchovy, and d) California market squid between 1983 and 2004 (CDFG data, unpublished). 282
Figure IX-1. Distribution of natural and anthropogenic debris on the mainland shelf and upper slope of southern California at depths of 2-476 m, July-October 2003. 289
Figure IX-2. Percent of area with natural and anthropogenic debris by region and depth on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003. 290
Figure IX-3. Percent of area with natural and anthropogenic debris by subpopulation within shelf zones on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003..... 291
Figure IX-4. Distribution of anthropogenic debris types on the southern California shelf at depths of 2-476 m, July-October 2003. 293
Figure IX-5. Percent of area of anthropogenic debris types on the mainland middle shelf (31-120 m) in publicly owned treatment work (POTW) and non-POTW subpopulations of southern California, July-October 2003. 294
Figure IX-6. Percent of area with anthropogenic debris by year and subpopulation within regions, depths, and large POTW areas on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003. 294

Figure IX-7. Percent of area of anthropogenic debris categories in large publicly owned treatment work (LPOTW) and non-LPOTW subpopulations on the mainland middle shelf (31-120 m) of southern California in 1994, 1998 and 2003. NOTE: 1994 data has been reclassified into 1998 and 2003 subpopulations and hence may differ from Allen *et al.* (1998) and Moore and Allen (2000)... 295
Figure IX-8. Percent of area with terrestrial debris by year and subpopulation within regions, depths, and large POTW areas on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003. 295

I. INTRODUCTION

The Southern California Bight (SCB) extends from Point Conception, California to Cabo Colnett, Baja California and is bounded seaward by the California Current (SCCWRP 1973). A large eddy is formed in the SCB above where the California Current impinges on the coast of Baja California (SCCWRP 1973; Dailey *et al.* 1993). The submarine topography in the SCB consists of a number of offshore islands and banks, and a narrow shelf and a number of offshore islands and basins. Surface water temperatures are generally warmer in the SCB than north of Point Conception or offshore in the California Current. The diverse topography, bathymetry, and substrates, and the juxtaposition of cold-temperate and warm-temperate waters result in a diverse fauna of fishes and invertebrates.

Demersal fishes (fish species living on or near the seafloor) and megabenthic invertebrates (large invertebrate species living on the seafloor) are widely distributed on the soft-bottom habitat of the southern California shelf. This fauna is diverse, consisting of more than 150 species of fish (Allen 1982; Allen *et al.* 1998, 2002a; Allen 2006a) and several hundred species of invertebrates (Moore and Mearns 1978; Allen *et al.* 1998, 2002a). Most are relatively sedentary, easily collected by trawl, respond to environmental stress, and are important indicators of human impacts on the soft-bottom habitat (Allen 2006b). Thus, populations of these organisms have been monitored extensively since 1969 to assess impacts resulting from wastewater discharge on the shelf.

Existing monitoring programs are focused near the outfalls of large municipal wastewater dischargers, also known as publicly owned treatment works (POTWs). These programs have conducted surveys for many years, with results reported annually by various agencies (e.g., CSDLAC 1990, 2006; CLAEMD 1994a,b; CSDMWWD 1995; CSDOC 1996). These monitoring programs are useful for assessing point-source impacts and historical trends near specific outfalls (Stull 1995, CSDOC 1996, Stull and Tang 1996). Although these programs have provided much information about the condition of demersal fishes and megabenthic invertebrates in local areas (e.g., Carlisle 1969a,b; SCCWRP 1973; Mearns *et al.* 1976; Allen 1977; Diehl 1992; Stull 1995; Stull and Tang 1996), less has been known about their spatial and temporal variability and condition throughout the SCB until the past decade. Some early regional assessments were made based on a compilation of trawl data collected at different times and places and for varied purposes (Allen and Voglin 1976, Allen 1982, Thompson *et al.* 1993a). Others were based on regional surveys of limited scope (generally focused in reference areas) (Allen and Mearns 1977; Word *et al.* 1977; Thompson *et al.* 1987, 1993b). As a result, it had been difficult to assess the Bight-wide extent of contamination in these organisms and the extent of anthropogenic alterations in their populations and assemblages. A baseline survey of the mainland shelf fauna of the SCB was needed to resolve this problem.

The first synoptic regional survey of the demersal fauna of the mainland shelf of southern California was conducted in 1994 (Allen *et al.* 1998). The purpose of this study was 1) to describe baseline variability in fish and invertebrate populations attributes for the SCB, geographic regions, bathymetric zones, and publicly owned treatment works (POTW) monitoring areas; 2) to describe baseline assemblages of demersal fishes and megabenthic invertebrates; 3) to assess the condition and extent of anthropogenic impact on fish and invertebrate populations and assemblages in the SCB based on spatial extent and distribution of the following: a) tissue contamination in flatfishes; b) health of fish and invertebrate populations; c) variation in population attributes in POTW and non-POTW areas; alterations in assemblages; d) indicators of impacted fish and invertebrate populations; and g) anthropogenic debris. The study concluded that 1) demersal fish and invertebrate populations and assemblages on the mainland shelf of southern California in 1994 appeared to be relatively healthy, with notable improvements since the early 1970s; 2) detectable DDT and PCB concentrations in flatfish livers were widely distributed but detectable levels of other chlorinated hydrocarbons were not found; 3) fish and invertebrate population attributes (i.e., abundance, biomass, number of species, and diversity per haul) were generally higher at POTW areas than in non-POTW areas; 4) anthropogenic debris (mostly bottles, cans, and fishing gear) was not widely distributed; debris was most common on the outer shelf and POTW areas, suggesting that marine vessel activity and fishing activities were primary sources; 5) the organization of fish and invertebrate assemblages was determined primarily by depth (over the depth range sampled) rather than by geographical area or sediment type. Recommendations were to 1) repeat demersal fish and megabenthic invertebrate surveys at periodic intervals; 2) select a new set of species for assessing bioaccumulation; 3) analyze whole fish rather than livers for bioaccumulation assessment; 4) limit chemical analysis to DDT and PCB in bioaccumulation assessment; 5) continue the Marine Monitoring Committee (which developed the Field Manual for the survey) for improving sampling methodology and protocol; 6) continue fish index development; 7) integrate data from continuing POTW and other monitoring programs with regional survey data for trends assessment; and 8) enhance the nearshore, bay, and harbor component of the sampling program.

The second synoptic regional survey in 1998 surveyed the demersal fauna of bays and harbors and most of the Channel Islands, in addition to surveying the mainland shelf of the SCB (Allen *et al.* 2002a). The general purpose of the survey was to assess the spatial variability and extent of human impact on demersal fish and megabenthic invertebrate populations on the mainland shelf, bays, and islands of the SCB. Specific objectives were to 1) describe patterns in fish and invertebrate attributes for the SCB, geographic regions (including islands), bathymetric zones (including bays and harbors), and point sources of contaminants (large and small POTW monitoring areas and river mouths); 2) describe assemblages of demersal fishes and megabenthic invertebrates based on the expanded study area; 3) assess the condition and extent of anthropogenic impact on fish and invertebrate populations and assemblages in the SCB based on the spatial extent and distribution of a) tissue contamination in flatfishes, b) health of fish and invertebrate populations (anomalies and sublethal effects), c) status of population attributes in potentially impacted and reference areas, d) assemblage biointegrity and organization, and e) debris. The study concluded that 1) demersal fish and invertebrate populations and assemblages on the southern California shelf were healthy in 1998; 2) DDT was prevalent in fish tissue on the southern California shelf; 3) fish and invertebrate assemblages were generally associated with major bathymetric zones on the shelf, with distinct assemblages also in bay and harbor areas; 4) anthropogenic debris (mostly plastic, metal, and cans) was found in 23% of the southern California shelf, being most common in areas frequented by boats (e.g., ports, marinas, and Santa Catalina Island); and 5) some effects of the 1997-1998 El Niños were apparent in fish and invertebrate populations and assemblages. Recommendations were to 1) determine the spatial extent of DDT above a predator-risk guideline in pelagic forage fishes; 2) define the route of DDT transport to sanddab-guild fishes in the Channel Islands National Marine Sanctuary; 3) apply the Fish Response Index to assess the biointegrity of demersal fish assemblages in other southern California monitoring surveys; 4) assess the regional extent of sublethal effects in southern California fishes; and 5) conduct periodic regional surveys of southern California demersal fishes and invertebrates to assess trends in human effects, populations, and baseline communities.

A third synoptic regional survey of the SCB was conducted in 2003, the results of which are presented herein. The Southern California Bight 2003 Regional Monitoring Program (Bight '03) involved 58 member organizations (Schiff *et al.* 2006). It was organized into three technical components: 1) Coastal Ecology, 2) Shoreline Microbiology, and 3) Water Quality. The Coastal Ecology component comprised three studies: a) Toxicology; b) Sediment Chemistry; c) Benthic Infauna; and d) Demersal Fishes and Megabenthic Invertebrates.

Eleven organizations participated in the B'03 regional trawl survey. In this study, the area extended in depth from 5-500 m, and included the mainland shelf (as in 1994 and 1998), Channel Islands and Bays and Harbors (as in 1998), and Upper Slope (200-500 m depth), a new stratum. The Upper Slope zone was added to address concerns that contaminant effects may extend deeper than 200 m. The objectives were the following:

1) to assess condition and health of fish and invertebrate assemblages of southern California bays and harbors, shelf, and upper slope;

2) to assess extent of contamination of concern in pelagic forage fishes and squid in the SCB;

3) to assess prevalence of ectoparasites in demersal fishes on middle shelf relative to POTW and reference areas;

4) to assess distribution of marine debris in bays/harbors and on the mainland shelf and upper slope;

5) to compare changes in fish and invertebrate populations and assemblages, anomalies, contaminant levels, and debris among the three regional surveys.

This report is organized into 13 major sections: I) Introduction; II) Methods; III) Quality Assurance; IV) Demersal Fish Populations; V) Megabenthic Invertebrate Populations; VI) Assemblages and Biointegrity; VII) Ectoparasites of Demersal Fishes; VIII) Bioaccumulation; IX) Debris; X) Discussion; XI) Conclusions; XII) Recommendations; and XIII) Literature Cited. The Introduction provides the background of the study, problems addressed, and study objectives. Methods describes field, laboratory, and analytical methods. Quality Assurance describes the logistical success of the survey and results of quality assurance protocol and quality control audits. The next six sections (Demersal Fish Populations through Debris) provide the results of the study. Each of these sections will internally include a short introduction, a description of 2003 survey results and a discussion of these results (including a comparison to the 1994 and 1998 surveys, if appropriate). The first three sections provide descriptions (some baseline) of populations and assemblages, and assessments of differences between potentially impacted (e.g., river mouths, POTW areas, ports) and reference areas. Demersal Fish Populations and Megabenthic Invertebrate Populations provide results for population attributes, species composition, population structure, and anomalies for fish and invertebrates. Assemblages and Biointegrity describes assemblages (recurrent groups, site and species clades, site and species clusters, multidimensional scaling) for fishes, invertebrates, and combined fishes and invertebrates; describes the functional organization of fish communities; and assesses the assemblage biointegrity. Ectoparasites of Demersal Fishes provides the first detailed assessment of ectoparasites of demersal fishes on the SCB shelf; host-parasite and parasite-host relationships; and the relative prevalence of fish parasitism at POTW and reference areas. The Bioaccumulation section assesses the extent of pelagic forage fish and squid contamination relative to wildlife-risk screening values. The Debris section describes the extent of anthropogenic debris in the study area. The Discussion section, Conclusions, Recommendations, and Literature Cited follow these sections. Appendices A through E provide additional data, and Appendix F provides a glossary defining the terms used in this document and alphabetical lists of fish and invertebrate species collected in this study by common name and scientific name is found at the end of this document.

II. METHODS

Sampling Design

Probability-based design

As in previous regional trawl surveys of the SCB (Allen *et al.* 1998, 2002a), the Bight '03 regional trawl survey was based on a stratified random sampling design detailed in Stevens (1997) and Bight '03 Coastal Ecology Committee (2003a). 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. Additional randomization details are found in Bight '03 Coastal Ecology Committee (2003a).

Subpopulations

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

- Regions – Mainland Shelf (Point Conception to United States-Mexico international border) and Island Shelf (San Miguel Island, Santa Rosa Island, Santa Cruz Island, Anacapa Island, and Santa Barbara Island). The mainland shelf was divided into three subregions: northern (Point Conception to Point Dume), central (Point Dume to Dana Point), and southern (Dana Point to United States-Mexico International Border)

- Shelf (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 (200-500 m)

    - Human Influence Areas – large POTW; small POTW; and non-POTW areas

The northern, central, and southern mainland subregions are the same in this study as in the 1994 and 1998 regional trawl surveys (Allen *et al.* 1998, 2002a) The island region is the same as in the 1998 regional survey (Allen *et al.* 2002a) except that Santa Catalina Island was not included in 2003. Although Bight '03 Coastal Ecology Committee (2003a), did not divide the Channel Islands into subregions, the present report analyzes data separately for two Channel Island subregions: cold-water (Northwest Channel Islands) and warm-water islands (Southeast Channel Islands). This was done to assess the cold-and warm-water fauna of the islands, as was done in 1998 (Allen *et al.* 2002a).

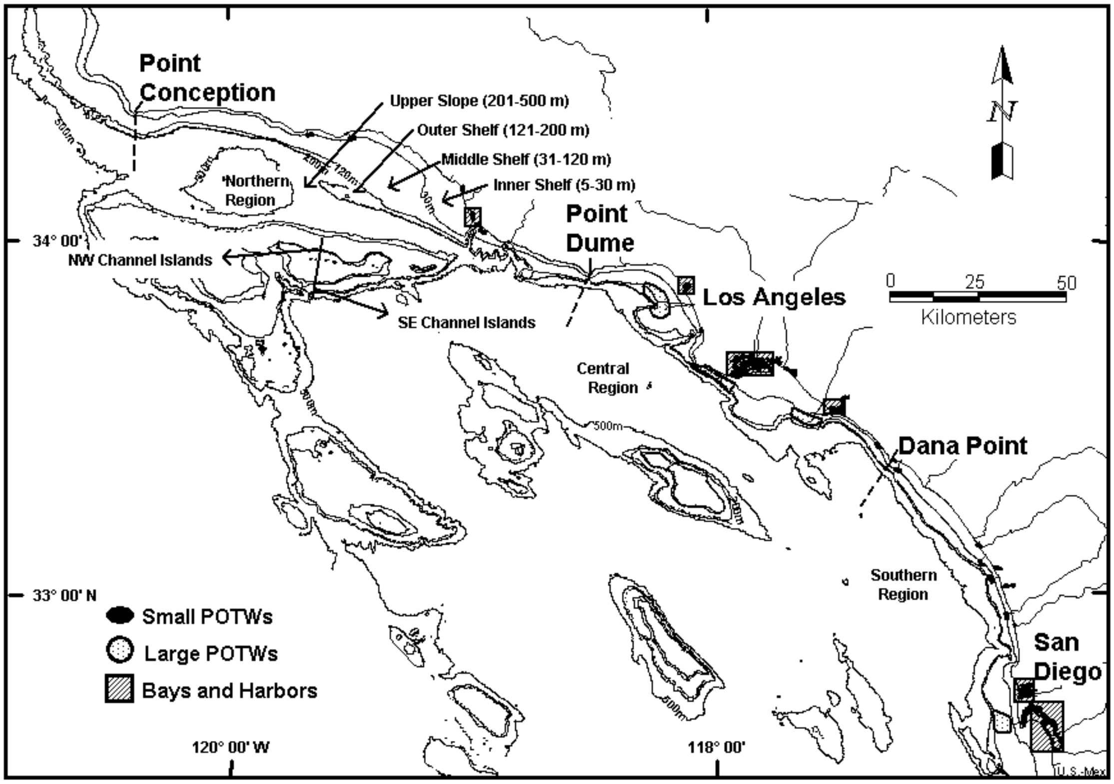


Figure II-1. Distribution of subpopulations (regions, shelf zones, and human influence areas) sampled by trawl in the Southern California Bight 2003 Regional Survey, July-October 2003.

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 and 1998 regional surveys (Allen *et al.* 1998, 2002a) as well as in the 2003 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). Depth ranges of the inner, middle, and outer shelf zones, respectively, were 10-25 m, 26-100 m, and 101-200 m in 1994 but were 5-30 m, 31-120 m, and 121-200 m in 1998 and 2003. Bays and harbors were added to the shelf zone/habitat subpopulations in 1998 and 2003; this subpopulation overlaps in depth with the inner shelf zone of the coast. In 2003 the upper (or mesobenthal) slope zone (200-500 m; Allen and Smith 1988, Allen 2006a) was added to the bathymetric subpopulations. Although the Islands Region was not divided into bathymetric subpopulations by the Bight '03 Coastal Ecology Committee (2003), the present report analyzed data from middle shelf, outer shelf, and upper slope zones for the islands separately. The island inner shelf zone was not included in the 2003 survey due to poor trawling success there in 1998.

Of the human influence subpopulations, the Large POTW areas delineate the monitoring areas around ocean outfalls of the four large POTWs (i.e., City of Los Angeles, Hyperion Treatment Plant; County Sanitation Districts of Los Angeles, Joint Water Pollution Control Plant; County Sanitation Districts of Orange County; and City of San Diego, Point Loma Wastewater Treatment Facility). The largest POTWs discharge at depths of 60 m near Los Angeles (Santa

Monica Bay, Palos Verdes Shelf, San Pedro Bay) or 100 m off San Diego. Nine small POTW outfall areas were sampled: Goleta; Santa Barbara; Oxnard; Terminal Island; Aliso; South East Regional Reclamation Authority (SERRA); Oceanside; Encina; and San Elijo wastewater treatment facilities. Discharge depths of these outfalls were generally about 30 m. Non-POTW areas were designated as those areas of a shelf zone that lay outside of the POTW areas.

Eight field-sampling organizations participated in this survey. Two hundred fifty-five sampling sites were originally distributed to these organizations based on resources available and the contribution of in-kind services. The distributed station list included a 10% overdraw in the offshore areas and 20% in the inshore areas. The overdraw sites were in recognition that agencies may not sample all the randomly selected sites because of improper substrate type, depth restrictions, or dredging activities. 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 210 trawl stations from Point Conception, California to the United States-Mexico international border, and around the Channel Islands between July 14 and October 13, 2003 (Figure II-2). Station coordinates, depths, and other characteristics provided for each sample are given in Appendix A-A1. The subpopulation classification of each station is provided in Appendix A-A2.

Trawl samples were collected according to standard methods described in a field manual written for the survey (Bight '03 Field Sampling & Logistics Committee 2003). 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). Due to expected untrawlable bottom at some island sites, island stations could be moved up 200 m from the nominal locations. 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 min (5-10 min in bays and harbors) at 0.8-1.0 m/sec (1.5-2 kn) as determined by DGPS. These tows covered an estimated distance of 300-600 m for 5 and 10 min trawls, respectively.

Agencies assigned with upper slope (200-500 m) stations used pressure-temperature sensors, attached to one of the otter trawl boards, to validate bottom time duration. Stations with bottom times less than 8 min or greater than 15 min were repeated. Since little information was available for upper slope habitats, all trawls were processed but only acceptable trawls were documented in the report.

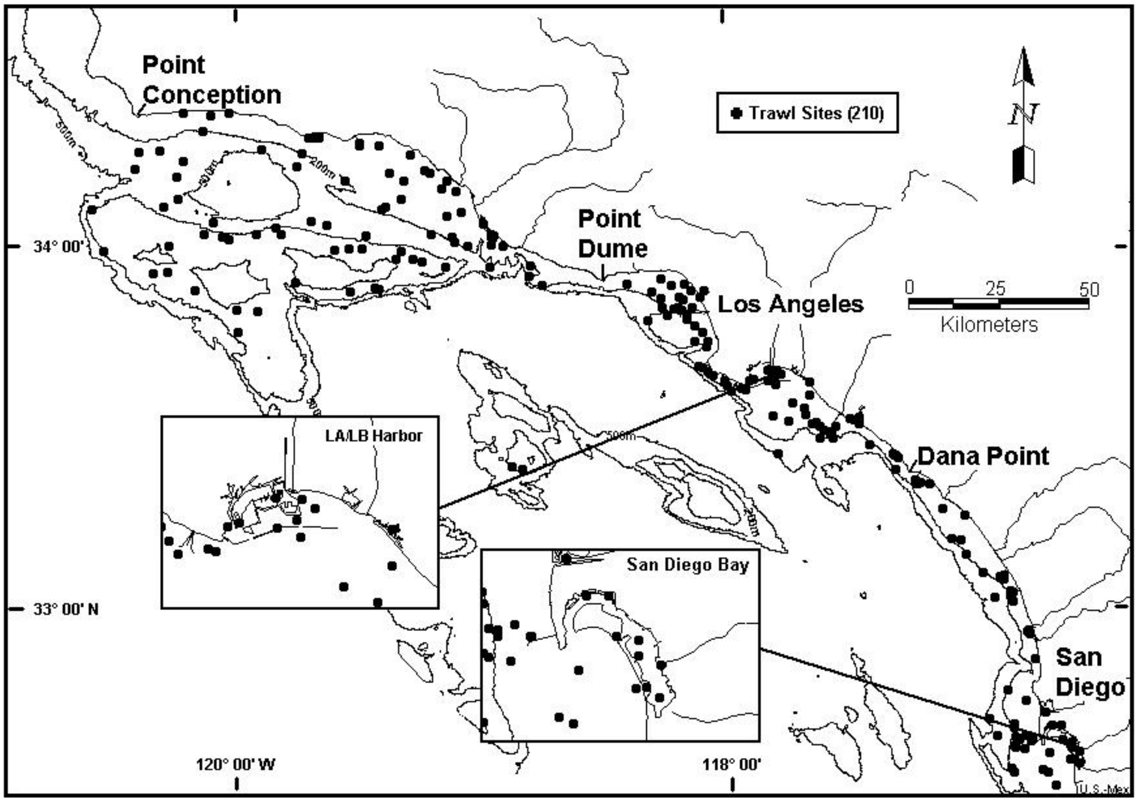


Figure II-2. Population and assemblage study stations sampled by trawl on the southern California shelf at depths of 2-476 m in the Southern California Bight 2003 Regional Survey, July-October 2003.

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 then 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 weighed to the nearest 0.1 kg (using spring scales). 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. Each organism was also examined for 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.

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).

Collection of Fish Samples for Fish Ectoparasite Study

Fishes for the fish ectoparasite study conducted by Dr. J. E. Kalman (UCLA) were collected in POTW on the mainland shelf and Non-POTW areas on the mainland shelf and northern Channel Islands from Point Conception, California, to the United States-Mexico International Border during the Bight '03 regional trawl survey in July-October 2003 (Kalman 2006). Samples were collected by otter trawl at 79 stations at 22-198 m (Figure II-3). Of these, 68 stations were B'03 stations and 11 were part of permit-required monitoring programs at three large POTW (Hyperion Treatment Plant, Orange County Sanitation District, Point Loma Wastewater Treatment Plant) and two small POTW (Oceanside and San Elijo) outfall and/or reference stations.

Fishes representing Scorpaeniformes (Scorpaenidae, Hexagrammidae, and Cottidae) and Pleuronectiformes (Paralichthyidae, Pleuronectidae, and Cynoglossidae) captured on the middle shelf were selected for the study. Immediately after the catch was brought on board, the fishes were separated into buckets by species. All conspecifics from the same haul were placed in a plastic bag and kept on ice in a cooler and subsequently frozen for a later examination in the laboratory.

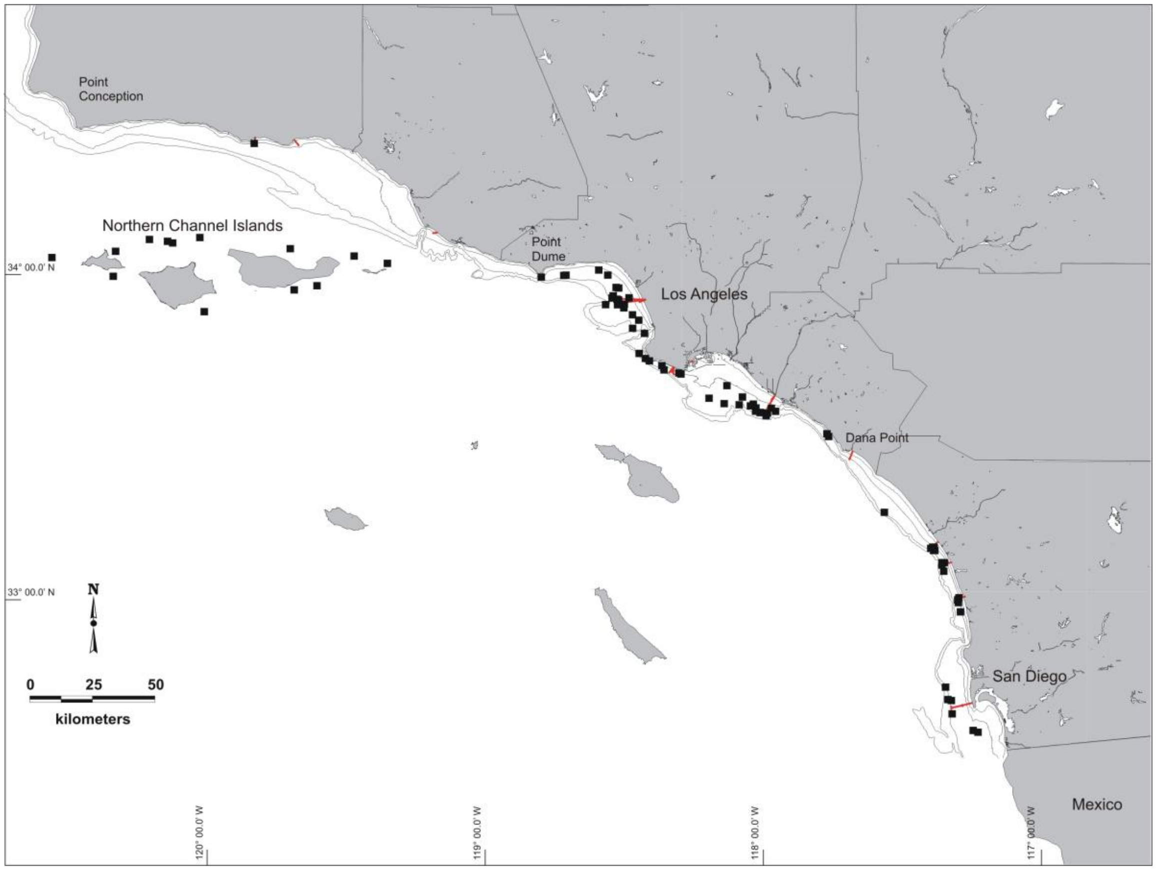


Figure II-3. Distribution of 79 fish ectoparasite study stations sampled by otter trawl at depths of 22-198 m in the Southern California Bight, July-October 2003.

Collection of Fish and Squid Samples for Bioaccumulation in Pelagic Forage Fish Study

General Approach

Pelagic forage fish and squid field composite samples were collected from January to February 2003 and July 2003 to February 2004. Due to the patchy spatial distribution of pelagic forage fishes species within the SCB, fish and squid composite samples were randomly collected at several local commercial fishing ports along the southern California coast in an attempt to quantify contaminant concentrations in pelagic forage fishes found within the northern, central, southern, and island regions of the SCB. Composite samples were collected from both commercial landing markets and bait receivers along the southern California coast from the following locations listed from north to south: Ventura Harbor, Port Hueneme, Marina Del Rey, King Harbor, Los Angeles/Long Beach (LA/LB) Harbor, Newport Harbor, Oceanside, and San Diego. Fishing location was determined from landing receipts or directly from fishing captain or bait receiver tender. Fishing location was typically provided as a California Department of Fish and Game (CDFG) fishing block, a number identifying a 10 mi x 10 mi (16 x 16 km) block encompassing a 100 mi^2 (260 km^2) square area within the SCB. Block numbers were designated for fishing location when only a geographic landmark was provided.

Field Sampling

Species selection was based on fish comprising the greatest biomass in the Bight SCB and also whether the species was a favored prey item by either marine birds or mammals. The species selected for contaminant analysis were northern anchovy (*Engraulis mordax*), Pacific sardine (*Sardinops sagax*), Pacific chub mackerel (*Scomber japonicus*), and the California market squid (*Loligo opalescens*). At the fish market, samplers systematically sampled fish from fish bins throughout an entire fishing vessel load during the offloading process. Samplers wrapped fish or squid in aluminum foil and placed them in a plastic zip-lock bag with a bag tag that included species name, date, fishing block or general location, and port. After sample collection, each field composite (consisting of 25 individuals) was returned to the laboratory, rinsed in deionized water, wrapped in foil, and frozen until sample processing.

Samples were collected from four predetermined strata (or regions) within the SCB that consisted of three coastal regions (north, central, south) and an islands region (Figure II-4).

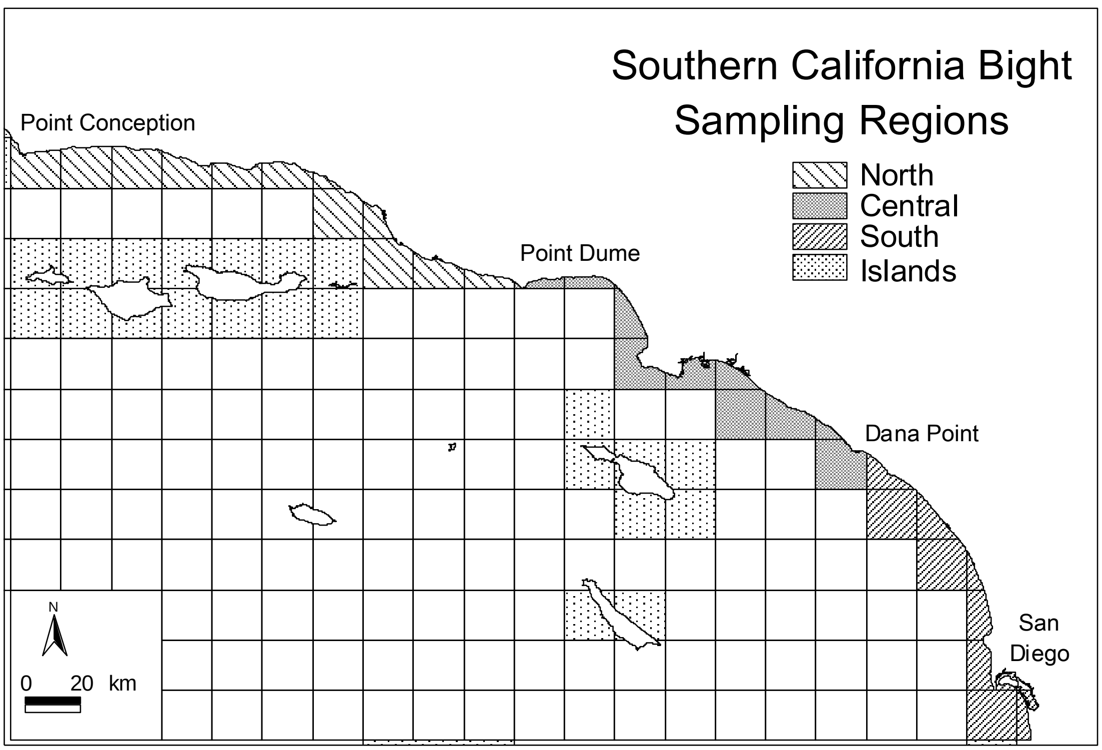


Figure II-4. Southern California coastal and island regions sampled from July 2003 to February 2004 for fish and squid samples in pelagic forage fish bioaccumulation study.

A power analysis was performed using data collected during a pilot study conducted in January–February 2003. Using results from this analysis, the objective was to collect 10 field composites per species per region (except for Pacific chub mackerel, with a target of three composites per region), for a total of 160 composites. For species targeted for 10 composites per region, samples were distributed as evenly as possible over the summer and nonsummer months of the sampling period.

Laboratory Methods

Fish and Invertebrate Preservation for Voucher and Archival Collections

Fish and invertebrate samples preserved in the field in 10% buffered formalin solution were kept in that solution for about a week. They were then transferred to water for 2-3 days (with water replacement during period) and then transferred to 50% isopropanol (fish) or 70% ethyl alcohol (invertebrates) 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).

Fish Ectoparasite Preservation and Identification

Individual fish were thawed and examined in the laboratory, and host standard length was measured to the nearest 0.1 mm. Ectoparasites were removed from the host using fine-tipped forceps and preserved in 70% ethyl alcohol (ETOH). Parasite attachment sites were recorded, and included the general body surface, eyes, fins (dorsal, pectoral, pelvic, anal, caudal), walls of gill cavity, gill filaments and arches, and walls of oral cavity (roof of mouth and tongue).

All monogenean and crustacean parasites were identified to species by Dr. J. E. Kalman (see Kalman 2006) using morphological characters and published information (Wilson 1905, 1912; Yamaguti 1963; Shiino 1965; Kabata 1967; Cressey 1969; Schultz 1969; Vervoort 1969; Ho 1970; Kabata 1970a; Ho 1971, 1972a, 1972b; Kabata 1973; Dojiri 1979; Dojiri and Perkins 1979; Brusca 1981; Dojiri 1981; Kabata 1984; Schell 1985; Castro and Baeza 1986; Kabata 1988; Dojiri and Brantley 1991; Ho and Kim, 1995 1996; Piasecki *et al.* 2000; Kalman 2003; Smit and Davies 2004). Leeches were identified at the Virginia Institute of Marine Science (VIMS) using molecular characters. Larval copepods and isopods were identified to larval stage (Kabata, 1972; Brusca, 1981; Smit and Davies, 2004), but were impossible to identify to species because no published literature exists. Monogeneans were fixed in AFA (ethyl alcohol-formalin-glacial acetic acid) and prepared according to Dailey (1996). Copepods were cleared in 85% lactic acid, and selected specimens were dissected and identified using the wooden slide technique of Humes and Gooding (1963). Classifications of parasites used in this manuscript follow Dailey (1996) for monogeneans and leeches, and Martin and Davis (2001) for crustaceans.

Bioaccumulation Analysis

<u>Processing of Fish and Squid Samples</u>

Composites to be processed for chemical analysis consisted of 10 individuals for northern anchovy, six for Pacific sardine and California market squid, and three for Pacific chub mackerel. After thawing frozen composites, individual fish in a composite were measured (cm SL for fish and cm mantle length (ML) for squid) and weighed. Individual weights were summed to give a composite weight in grams. Composite samples were homogenized in a blender, with 1.0 L glass containers with titanium blades and BUNA rubber gaskets with aluminum foil-lined lids. The composite fish and an equal weight of deionized water (to facilitate blending) were combined and blended for 2-5 min to obtain a smooth homogenate. Two equal-sized aliquots of homogenate were used to fill two wide-mouthed glass jars with Teflon-lined lids (and external labels) to three-fourths full or less; the remainder of the sample was saved and frozen as extra sample. Blenders were washed with nonionic soap and water, rinsed several times with deionized water, dried, and then rinsed with an appropriate solvent (e.g., methanol, ethanol, acetone) and dried. Samples were kept at –20^{o}C (±2^{o}C) for up to eight months.

Target Analytes

Homogenates of whole pelagic forage fish and squid were analyzed for chlorinated hydrocarbons. Chlorinated hydrocarbons were measured in pelagic forage fish due to their inherent bioaccumulation potential) (Gossett *et al.* 1982), historical importance in the SCB, and their potential risk to bird and mammal predators. DDT and polychlorinated biphenyls (PCBs) were the primary chlorinated hydrocarbons found in flatfishes on the mainland shelf of southern California in 1994 and 1998, and both were found in virtually all fish examined (Allen *et al.* 1998, Schiff and Allen 2000, Allen *et al.* 2002a, Allen *et al.* 2004b). Because of this, DDT and PCBs were chosen for analysis in this study.

Whole pelagic fish and squid samples were analyzed for two isomers of DDT and their four common metabolites, and 41 PCB congeners (Table II-1). Congener-specific analysis was performed because the transport, persistence, bioavailability, and toxicity varies substantially among different PCB congeners. Moreover, congener-specific data are more meaningful for use in biological impact assessments. The list of 41 PCB target analytes was developed based upon their presence in four common Aroclor mixtures (i.e., 1242, 1248, 1254, 1260); their occurrence in environmental samples; and their potential toxicity as identified by McFarland and Clarke (1989).

Chemical Analysis

Prior to analysis, sample aliquots were thawed and thoroughly mixed to ensure a uniform homogenate and then subsequently solvent extracted. Extraction methods included soxhlet extraction, accelerated solvent extraction (ASE), and homogenization solvent extraction. The extracts were subjected to appropriate clean-up procedures and analyzed by gas chromatography with either electron capture detection (GC ECD) or mass selective detection (GC-MS). Following analysis, the measured concentration was doubled to correct for the equal weight of water added to the sample during homogenization.

Table II-1. Chlorinated hydrocarbons analyzed in pelagic forage fish bioaccumulation study, Southern California Bight 2003 Regional Survey.

Pesticides	Polychlorinated Biphenyl (PCB) Congeners		
DDT and Metabolites	Predator-risk Congeners	Other PCB Congeners	
p,p'-DDT	PCB-77	PCB-18	PCB-138
p,p'-DDD	PCB-81	PCB-28	PCB-149
p,p'-DDE	PCB-105	PCB-37	PCB-151
o,p'-DDT	PCB-114	PCB-44	PCB-153
o,p'-DDD	PCB-118	PCB-49	PCB-158
o,p'-DDE	PCB-123	PCB-52	PCB-168
	PCB-126	PCB-66	PCB-170
	PCB-156	PCB-70	PCB-177
	PCB-157	PCB-74	PCB-180
	PCB-167	PCB-87	PCB-183
	PCB-169	PCB-99	PCB-187
	PCB-189	PCB-101	PCB-194
		PCB-110	PCB-201
		PCB-119	PCB-206
		PCB-128	

Information Management

Field Computer System

A field computer system was designed specifically for the Bight '03 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 had to use standard data forms found in the field operations manual and manually enter 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 errors 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 itself until the database accepted the data or only easily correctable errors were present. Final integrated across-agency data tables were provided to the Bight '03 Trawl Report Committee for review, further QC checks, and analysis.

Quality Assurance/Quality Control (QA/QC) Procedures

Trawl Assemblage Survey

Field Protocol

Special quality assurance/quality control (QA/QC) procedures were developed for the study (Bight '03 Coastal Ecology Committee 2003b), modeled after SCBPP (1994) and Bight '98 Steering Committee (2003), because 10 organizations were involved in the field survey. Field equipment and sampling protocol were described in the field operations manual (Bight '03 Field Sampling & Logistics Committee 2003), which was developed by representatives of these 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 '03 Field Sampling & Logistics Committee 2003) addressed the objectives of the Bight '03 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.

Presurvey audits were conducted on one new participating agency and an experienced agency with new personnel to ascertain their field sampling capabilities. The goal was to assess trawl methodologies and taxonomic competence for the regional survey. Presurvey audits consisted of checking equipment and sampling procedures utilized by each agency to determine consistency and needs 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 performed 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.

Postsurvey 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, postsurvey 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

Correct identification of organisms was vital for the biological assessment, which involved 10 organizations. All fish and most invertebrates were to be identified to species, using taxonomic keys and field guides as needed (Bight '03 Field Sampling & Logistics Committee 2003). Standard common and scientific names (Robins *et al.* 1991) were used for fish but scientific names alone were used for invertebrates. Some of these names were changed after the survey in 2004 to conform to Nelson *et al.* (2004) when this source became available. Because most fish and invertebrates were to be identified to species in the field, it was important that field identifications be done correctly. The importance of being conservative and bringing questionable species back to the laboratory for final identification was emphasized.

Prior to the survey, lists of recommended taxonomic identification aids and checklists of trawl-caught species for the SCB were distributed to participating agencies. Three presurvey information transfer meetings (one as a lecture and two in the field) were held to identify common and confusing species. All organizations participated in a presurvey 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 conducted random checks with each participating organization to assess accuracy of fishes and invertebrates identified. Voucher specimens for each species, difficult-to-identify species, and each species/anomaly combination were collected by each agency. These specimens were fixed in 10% buffered formalin-seawater solution, and returned to the laboratory for confirmation. Larger specimens were photographed and released. Fish and invertebrates preserved in buffered formalin solution were rinsed in water for 2-3 days and preserved in 70% ethanol for invertebrates and 50% isopropanol for fish as a final preservation. Detailed instructions are found in the Bight '03 Field Sampling & Logistics Committee (2003).

Post-survey field taxonomy checks were accomplished through submitted voucher specimens. Each agency submitted properly preserved species identified in the field, in addition to difficult-to-identify species and species/anomaly combinations. Each organization submitted a voucher specimen for each species it collected to predetermined taxonomic specialists. As correct identifications were completed, the appropriate changes were made to the original data sheets and database.

Data

Field data were checked and entered into a computer database by agency personnel. All computer data were checked against the original field data. After approval by the agencies and trawl QA/QC officer, the data were made available electronically to all agencies participating in the survey.

Chemistry

Whole fish samples were analyzed through the collaborative efforts of five participating laboratories. The quality assurance/quality control requirements for this study were performance based. The particular analytical methods used for the analysis were left to the discretion of the individual laboratory with the requirement that each demonstrate acceptable analyte recoveries and detection limits, and meet the general data quality objectives (DQOs) specified in Bight '03

Coastal Ecology Committee (2003b). All laboratories were required to evaluate and monitor their analytical performance through the use of method blanks, certified reference materials (CRMs), matrix spikes, and sample duplicate analyses. Method blanks were used to assess any laboratory contamination introduced during all stages of the sample preparation and analysis. Certified reference materials were used to assess the accuracy of the analytical results. The recommended CRM for the fish tissue analysis was the CARP-1, available from the Research Council of Canada. The CARP-1 CRM is a ground whole common carp (*Cyprinus carpio*) sample with certified values for 14 PCB congeners. Matrix spike samples were used to evaluate recoveries and analytical performance for low concentrations of target analytes. Note that in contrast to CRMs, blanks, and duplicates, there was no specific frequency or data quality objective stated for matrix spikes. Finally, duplicate analyses were performed on approximately 5% of the samples (i.e., one per batch) to estimate the precision of the analytical results. Reporting level objectives for chemistry results were 10 ng/g for DDTs and 20 ng/g for PCB congeners. No reporting level objective was defined for lipids.

Data Analyses

Description of Populations

Data Adjustments

As in the 1998 regional survey (Allen *et al.* 2002a), some stations in the 2003 regional survey were trawled for 5 min rather than 10 min because of inadequate space (e.g., in a bay or harbor). The following approach used in Allen *et al.* (2002a) was also used in the present study. To compare the 5-min and 10-min trawl data, the following two options were considered: 1) adjust catch information to catch per minute and then adjust catch by minutes of trawling, or 2) standardize the catch to a 10-min trawl and double the 5-min trawl catch. The following two points were considered: 1) the time that the net is actually on the bottom during a trawl is uncertain (Diener and Rimer 1993), and 2) the distribution of the fish and invertebrates in the trawl path varies by species, ranging from random to clumped. Thus, a per-minute adjustment of catch did not seem warranted, although it was clear that a 10-min trawl had a higher catch than a 5-min trawl. Trawls with durations of 4-6 min were lumped into a “5-min trawl” category and those of 9-12 min into a “10-min trawl” category. As the shorter trawls were in bays, we compared duplicate 5-min trawls at stations in Marina del Rey, California, (Allen *et al.* 2002a) to assess differences in catch. In this analysis, the catch of the first 5-min trawl at a site was compared to the combined catch of both 5-min trawls. Fish and invertebrate abundance in 10-min trawls was about twice the abundance in 5-min trawls. The number of fish and invertebrate species was about 1.4 for fish and invertebrates. It was assumed that biomass would behave similarly to abundance. Based on this, fish and invertebrate abundance and biomass values of 5-min trawls were adjusted to 10-min trawl values by doubling the 5-min trawl values. Numbers of fish and invertebrate species between 5-min and 10-min trawls were adjusted by multiplying species by 1.4. This latter adjustment was used for calculating subpopulation mean values. However, to determine the total species in a subpopulation, actual species (or taxa) were used rather than “virtual” species. This approach was also used to perform the diversity index calculations.

Population Attributes

The population attributes examined included abundance, biomass, number of species, and Shannon-Wiener diversity (Shannon and Weaver 1949), all expressed per haul. The Shannon-Wiener diversity index (H') is calculated using Equation 1.

$$H' = -\sum_{j=1}^{S} \frac{n_j}{N} ln \frac{n_j}{N}$$ **Equation 1**

where:

n_j	=	Number of individuals of the species *j* in sample.
S	=	Total number of species in sample.
N	=	Total number of individuals in sample.

Population Summary Statistics

Trawl data were expressed as values per standard trawl haul (i.e., "per haul"). In this survey, the area sampled in this trawl haul was approximately 3,014 m^2. Because a stratified random survey design was used, different weighting factors were assigned to stations in some subpopulations (Appendix A-A2). These weighting factors were used in percent of area calculations (including medians) and in adjustment of mean values, standard deviations, and confidence limits. If it is stated that *x* percent of the area had a particular attribute value, this should be interpreted as meaning that the value is likely to occur in a standard trawl haul from *x* percent of the area.

Population data were analyzed in two ways: 1) calculation of medians, means, and 95% confidence intervals for population attributes in the SCB and in various subpopulations; and 2) assessment of the percent of area within each subpopulation above the SCB median. Mean parameter values were calculated using a ratio estimator (Thompson 1992; Equation2).

$$m = \frac{\sum_{i=1}^{n} (p_i * w_i)}{\sum_{i=1}^{n} w_i}$$ **Equation 2**

where:

m	=	Mean parameter value for population *j*.
p_i	=	Parameter value at station *i*.
w_i	=	Weighting factor for station *i*, equal to the inverse of the inclusion probability for the site.
n	=	Number of stations sampled in population *j*

Weighting factors for each station are provided in Appendix A-A2. The ratio estimator was used in lieu of a stratified mean because an unknown fraction of each stratum could not be sampled (e.g., hard bottom). Thus, the estimated area was used as a divisor in place of the unknown true area. The standard deviation of the mean response was calculated as follows:

$$\text{Standard Deviation} = \sqrt{\frac{\sum_{i=1}^{n} (p_i - m)^2 * w_i}{\sum_{i=1}^{n} w_i}} \quad \textbf{Equation 3}$$

The standard error of the mean response was calculated as follows:

$$\text{Standard Error} = \sqrt{\frac{\sum_{i=1}^{n} ((p_i - m) * w_i)^2}{(\sum_{i=1}^{n} w_i)^2}} \quad \textbf{Equation 4}$$

The 95% confidence intervals were calculated as 1.96 times the standard error. The ratio estimator for the standard error approximates joint inclusion probabilities among samples and assumes a negligible spatial covariance, an assumption that appears warranted. However, the assumption is conservative because its violation would lead to overestimation of the confidence interval (Stevens and Kincaid 1997).

Percent of Area and Medians

As with the 1994 and 1998 surveys, the 2003 was specifically designed to address questions regarding the spatial distribution of the data. These issues included the determination of cumulative frequency distributions (CDFs) (Stevens and Olsen 1991). The CDFs provide graphical information on the percent of the survey area that lies below a given indicator value. A population attribute (e.g., abundance) value from a station has an associated weighting factor (Appendix A-A2). To calculate a CDF, indicator values were ranked from low to high. The weighting factors for stations with a given indicator value were then accumulated, giving a cumulative sum of weight at each ranked indicator value. Then each cumulative sum of weight was divided by the total area weight to give a cumulative frequency distribution (with proportions adding up to 1.0)**.** Medians can be determined from CDFs and compared among subpopulations and to those of the SCB as a whole. The median was the value of an attribute at which 50% of the area of a subpopulation lies above or below. This median thus differs from observation medians, defined as the value at which 50% of the observations lie above or below. Confidence limits of medians for population attribute data were determined by calculating 95% confidence limits of means on log-transformed data and back-transforming.

Comparisons Between 1994, 1998, and 2003 Results

Comparisons of population attribute values and percent of area between surveys were done when appropriate. For instance, comparisons of 2003 results to the 1994 survey (Allen *et al.* 1998) and the 1998 survey (Allen *et al.* 2002a) could only be made for the mainland shelf, as islands and bays/harbors were not sampled in 1994. To further complicate the comparison, some mainland subpopulation boundaries differed in 2003 and 1998 from those used in 1994. In particular, large POTW areas were much larger in 1994 than in later surveys, when they encompassed sites much nearer the discharge sites. In addition, there were slight modifications in depth zone subpopulation boundaries. The boundary of the inner shelf/middle shelf zone was at 25 m in 1994 and 30 m in later surveys, and the middle shelf/outer shelf boundary was at 100 m in 1994 compared to 120 m in 1998 and 2003. Thus, to make comparisons between the periods (and in particular for POTW subpopulations), the 1994 data were reclassified to 2003 subpopulation boundaries. The original 1994 area weights were maintained for 1994 stations used in the 2003 comparison. Hence, 1994 stations falling within the 2003 POTW subpopulation boundaries were compared to 2003 POTW stations. Medians were calculated for middle shelf non-POTW subpopulations (regarded as reference areas) in 1994, 1998, and 2003. The POTW results were compared to the median of the appropriate year to give percent of area of attributes of POTW areas above the non-POTW medians. Comparisons between the 1998 and 2003 surveys were straightforward.

Assemblage Analysis

Recurrent Group Analysis

Recurrent groups were determined independently for fish and invertebrates by first calculating the index of affinity of Fager (1963) and Fager and McGowan (1963) for all specie pairs. The index is based on the occurrence of each specie and co-occurrence of the two species being compared, and is defined by Equation 5.

$$I.A. = \frac{c}{\sqrt{ab}} - \frac{1}{2\sqrt{b}} \qquad \textbf{Equation 5}$$

where:

I.A.	=	Index of affinity.
a	=	Number of samples in which Species A occurred.
b	=	Number of samples in which Species B occurred.
c	=	Number of joint occurrences of Species A and B

In this equation, *b* is always greater than or equal to *a*. The first term is the ratio of joint occurrences of both species to the geometric mean of their individual occurrences. The second term is a correction factor to give weight to values of the first term based upon high occurrences of the more frequently occurring species.

The index was calculated for all pairs of species. Pairs of species with a predetermined level of affinity (e.g., I.A.=0.50) were grouped following rules described in Fager (1957). A recurrent group was required to satisfy the following criteria: 1) All species in a group must have positive affinities with all other members of the group; 2) the group must contain the largest possible number of species; 3) if several possible groups containing the same number of species can be formed, those that contain the largest number of groups without species in common are chosen; and 4) if two or more groups with the same number of species and with members in common can be formed, the group that occurs most frequently will be chosen.

Species were grouped at an index of affinity of 0.50 (i.e., 0.495 or greater). Associates were defined as species that had positive affinities with one or more members of a recurrent group but not with all members of the group. A connex value defines the level of relationship. This number is the proportion of possible positive affinities (e.g., I. A.=0.50 or greater) between members of two groups or between a group and an associate. The connex value is shown in recurrent group diagrams next to a line connecting different groups to each other or associate species to groups.

Cluster Analysis

Abundance-based site and species groups were defined using cluster analysis. Prior to conducting the cluster analysis, the data were screened to reduce the confounding effect of very rare species, which do not facilitate comparison between stations. The screening process had two criteria: 1) each taxa had to have an abundance of 10 or more individuals and these must have occurred in at least five or more stations; and 2) each station had to have at least five or more individuals to be included in the cluster analysis. A separate analysis was conducted for fish, invertebrates, and combined fish and invertebrate data.

After the selection criteria were met, the abundance data were square-root transformed and standardized. The square-root transformation is generally applied to count data to reduce the importance of the most abundant taxa (Sokal and Rohlf 1981, Clarke and Green 1988, Smith *et al.* 1988a). The data were standardized by dividing species abundance at a given otter trawl station by the mean abundance of that species over all stations. The benefit of standardization is that it has the effect of equalizing extreme abundance values and facilitates relative comparisons among species (Clarke 1993). The Bray-Curtis measure was used to convert the species composition and abundance data into a dissimilarity matrix (Bray and Curtis 1957, Clifford and Stephenson 1975). The clustering method (SAS PROC CLUSTER 1989) was an agglomerative, hierarchical, flexible sorting method (SAS Institute 1989). The sorting coefficient Beta was set at the standard value of -0.25 (Tetra Tech 1985).

Each cluster analysis on abundance data for fish, invertebrates, or combined fish and invertebrates involved two approaches. First, a cluster procedure was used to identify groups of stations that exhibit similar species abundance patterns. Second, a cluster procedure was conducted to identify groups of species that occur in similar habitats (stations). In each approach, the results of the cluster analysis were used to produce a dendrogram, a structured two-dimensional hierarchical display of similar station and species groups. Furthermore, the station and species clusters for each taxonomic group were used to produce a two-way coincidence table, a matrix of species-importance values which optimally displays the patterns identified in the cluster analyses by the dendrograms (Kikkawa 1968; Clifford and Stephenson 1975; CSDOC 1996; Allen *et al.* 1998, 2002a). The end result is a summary two-way table of observations, which corresponds to the order of similar station groups along one axis and similar species groups along the other axis. Major clusters were determined by evaluating the patterns and abundances that were summarized by the two-way table. This evaluation started with the most significant dendrogram separating dissimilar clusters. If the species abundance patterns showed that this separation was reflected in the two-way table, then this was considered a major cluster separation point. The evaluation continued to the next major separation point and the evaluation was continued until dendrogram separation points were not evident in the two-way table. All clusters not clearly evident as distinct in the two-way table were not considered as major cluster groupings and were not separated further into additional clusters.

The discussion for each cluster analysis begins with an overview of the analytical results, followed by a more detailed description of the site clusters, followed by the discussion of the species clusters, and finally followed by a comparison with the 1994 SCBPP regional cluster analysis. Throughout the discussion, whenever a number cluster is being discussed (i.e., Cluster 2), this is referring to the site clusters; and whenever a letter cluster is being discussed (i.e., Cluster F), this is referring to a species cluster.

Cladistic Analysis

Cladistic analysis is typically used to determine phylogenetic relationships among species. The relationship of species, linking those with shared characters, is described in a cladogram. Although typically used in taxonomic studies, it has also been used in describing assemblages of organisms. In this study, traditional biodiversity measures as well as abundance-based and binary (presence/absence) species data were used to develop cladograms of site groups using cladistic analysis.

Traditional Diversity Indices and Abundance. Community parameters including the benthic response index (BRI), biodiversity measures, and abundances (number of individuals), are calculated and presented. In previous reports, traditional biodiversity measures such as species richness [number of species (S)], Shannon-Wiener diversity index [H'(log_e)], Margalef''s diversity (d), Simpson's dominance (1-lamda), and Pielou's evenness (J'), were presented. Although we have retained species richness and Shannon-Wiener, we are now presenting a series of new biodiversity measures that more accurately reflect taxonomic, and ideally, phylogenetic relationships. These measures include taxonomic diversity (Δ), quantitative taxonomic distinctness (Δ*), average taxonomic distinctness (Δ+), variation in taxonomic distinctness (Λ+), total phylogenetic diversity ($S\Phi^+$), and average phylogenetic diversity (Φ^+). Most of these measures have gained immediate acceptance in much of the scientific community in recent years since inception due to their favorable features of being independent of sampling effort, relative to those indices previously employed, and their ability to utilize phylogenetic relationships. These concepts and calculations are presented in Clarke and Warwick (1999), Warwick and Clarke (1995), and Magurran (1988).

Assuming taxonomy reflects phylogeny, which recent systematists have striven to achieve with more confidence through advances in technology (i.e., molecular analyses) and cladistics, a sample having five species of the same genus is less biodiverse than another having five species of differing families. Accepting this to be true, indices integrating both taxonomic distances through a tree as well as abundances captures much more information than those indices which have been abandoned in this report, and yet most are more robust with respect to independence of samples size/effort.

- Taxonomic diversity (Δ) accomplishes these goals by calculating the expected path length between any two individuals chosen at random.

- Quantitative taxonomic distinctness (Δ*) still captures the phylogenetic relationships, but on the other hand, removes the influence of dominating abundances to produce an index more reflective of taxonomic hierarchy. This is achieved by dividing (Δ) by the Simpson index.

- Average taxonomic distinctness (Δ+) is merely the taxonomic breadth of a sample event based on presence/absence. This index is most appealing for data with highly variable or unknown sample size and effort.

- Variation in taxonomic distinctness (Λ+) can elicit differences among samples having the same Δ+ but different taxonomic or phylogenetic tree constructions by focus on the variance of the taxonomic distances between each pair of species about their Δ+ value.

- Total phylogenetic diversity ($S\Phi^{+}$) offers comparison of samples based on cumulative branch lengths of their full trees. This measure is incapable of discriminating samples of equal tree length but differential taxonomic distributions within.

- Average phylogenetic diversity (Φ^{+}), based on presence / absence data and being the quotient of $S\Phi^{+}/S$, is the contribution that each species makes on the total tree length. As species numbers increase, the later two indices values change noticeably rendering them sample-size/effort dependent.

The suite of taxonomic distinctness and phylogenetic diversity indices calculated in Primer v5.2.9, as well as all graphics derived from them, require the construction of an appropriate 'master species list' of which the given sampling events are compared. The master species list was composed of all fish and invertebrate species collected in the Bight '03 survey. The taxonomic hierarchy included species, genus, family, order, class, and phylum. Calculations of indices, based on comparison of a given sample data file with the respective master species list, were executed using 1000 repetitions and weighted by taxon richness.

Parsimony Analysis and Various Ordinations. Parsimony analyses of endemicity (PAE) or cladistic analyses were performed using the heuristic search, Tree-Bisection and Reconnection (TBR), algorithm with the computer program PAUP* Phylogenetic Analysis Using Parsimony (*and other methods) version 4.0b10 (Swofford 2000). Methods for calculating the measure-of-fit indices are presented in Kitching *et al.* (1998). The "new search strategy" developed by Quicke *et al.* (2001) was utilized, which is a new heuristic strategy designed to find optimal (parsimonious) trees for data sets with large numbers of taxa and characters. This new strategy uses an iterative searching process of branch swapping with equally weighted characters followed by swapping with re-weighted characters. This process increases the efficiency of the search because, after each round of swapping with re-weighted characters, the subsequent swapping with equal weights will start from a different group (island) of trees that are only slightly, if at all, less optimal. In contrast, conventional heuristic searching with constant equal weighting can become trapped on islands of suboptimal trees.

Deleting rare species can damage the sensitivity of community-based methods to detect ecological changes (Cao *et al.* 1998 and 2001), and since taxon autochthony may be more informative than their abundance, especially in parsimony analyses (Perochon *et al.* 2001), all species were used in the analysis regardless of abundance. Only supraspecific taxa were excluded from the analyses.

Multiple equally parsimonious cladograms, showing the relationships of the objects or stations (Q analysis) under study were generated using the heuristic search Tree-Bisection and Reconnection algorithm. Tree number 1 was randomly chosen to present. In addition, change lists and species diagnostic tables (calculating various fit indices for each species) were produced and not presented herein, but are available upon request. Mapping of species and independent variables onto the organism-derived cladogram was carried out in Mesquite version 1.05 (build g24) Maddison and Maddison (2004).

In addition to the PAE cladograms, showing the relationships of the objects or stations (Q analysis), cladograms of species groups, showing the association or co-occurrence of these descriptors or species with one another (R-analysis) (Legendre and Legendre 1998) were also produced for all trawl-caught organisms collected from all samples. This parsimony analysis of cooccuring species has been coined “PACOS” by Deets and Cash.

Specifically, the data was analyzed via a “generalized parsimony” or “step-matrix” approach (Sankoff and Rousseau 1975, Sankoff and Cedergen 1983, Swofford *et al.* 1996). Generalized parsimony is an efficient and highly adaptable approach for systematic analyses, as the parsimony criterion is easily applied to virtually any comparative (frequency, behavioral, stemmatic, cultural, ecological, etc.) data set Hillis (1998). This computationally intensive, “brute force” approach enumerates all possible combinations of character state assignments at every node, calculating partial costs (relative abundance of a given species) and converging on the most parsimonious tree.

Species (characters) abundance values were standardized to relative abundance equally weighting each species (character). The approach herein is very similar to the step-matrix approach utilized in MANOB (Manhattan Distance, Observed Frequency Arrays) introduced by Berlocher and Swofford (1997), but utilizes a two-column reductive coding approach guaranteeing the logical independence of a species’ absence from its presence, and the associated abundance states represented by a given step-matrix. This approach accommodates continuous data without resorting to coding strategies with problematical coding justifications, reduces impact of sampling error (e.g., the failure to detect or utilize rarely occurring or less abundant species), and utilizes potentially useful frequency or relative abundance data not conventionally used in presence/absence coding (see Berlocher and Swofford 1997).

Nonmetric multidimensional scaling (NMDS) is a highly recommended multivariate ordination method that works on any similarity or distance matrix (Quicke 1993, Warwick and Clarke 1995). Nonmetric MDS was applied to patristic distance (branch-length) matrices derived from the cladistic analyses (the cladogram). Patristic distances were chosen as it has been shown that pairwise similarity or distance is underestimated by the conventionally used phenetic distance methods (e.g., Bray-Curtis). Pairwise comparisons using cladistic, methods which include all changes (including homoplasy or lack-of-fit) along the branches is a better estimator or representation of the data (Smith 1994). Patristic distance matrices and pairwise homoplasy matrices (the incongruence, convergence, parallelism, or residual within the data) derived from the cladograms generated in PAUP*, were then imported into Primer v6 (Clarke and Gorley 2006) for the subsequent multivariate NMDS and BIO-ENV (the matching of biotic to environmental patterns) treatments. All NMDS analyses were carried out with 1,111 restarts in order to keep from being trapped in local sub-optimal minima.

Multidimensional Scaling

Multidimensional scaling (MDS) is an ordination analysis similar to factor analysis (StatSoft, Inc. 1984-2003). The method detects meaningful underlying dimensions that allow explanation of similarities or dissimilarities (distances) observed between variables. In factor analysis, the similarities between variables are expressed in a correlation matrix. With MDS any kind of similarity or dissimilarity matrix can be analyzed, as well as correlation matrices.

In the MDS analysis for this study, each station was assigned to one of five habitats: Bays and Harbors (BH), Inner shelf (IS), Middle shelf (MS), Outer shelf (OS) and Upper slope (US). Station numbers were recoded for the graphical representation by dropping the prefix 4 that was common to all stations and substituting it with the habitat acronym. The multivariate analyses were conducted in STATISTICA 7.0 (StatSoft Inc.). This program allows a maximum of 90 stations to be analyzed. A subset of the 210 total stations were selected at random (n=90) for multidimensional scaling analysis. To do this, each station was assigned to a habitat, and 18 stations from each habitat were chosen at random. Specifically, each station within a particular habitat was assigned a random number using the random number generator function in Excel. The random numbers were then ranked and the top 18 ranked sites were chosen for the MDS analysis. The abundance by species of fish was determined for each station (n=90) and a correlation matrix was constructed. The correlation matrix was used for the 2-dimensional MDS analysis.

Assemblage Biocriteria Analysis

The assessment of anthropogenic impact to fish and invertebrate assemblages requires that biocriteria be identified to describe reference (or normal) conditions to distinguish these from nonreference conditions. This assessment is enhanced if indicators are also identified that respond to impacted (or altered) conditions. While individual indicators are important in identifying anthropogenically altered habitats, a more valuable indicator of impacts to fish assemblages can be developed by combining these indicators into an index.

Since the 1994 regional survey (Allen *et al.* 1998), several biointegrity indices have been produced that can be applied to the data (Allen *et al.* 2001a, 2002a). These include a fish response index (FRI), invertebrate response index (IRI), trawl response index (TRI), and fish foraging guild (FFG) index. The name IRI of Allen *et al.* (2001a) is changed here to MIRI (megabenthic invertebrate index) to avoid confusion with the IRI (index of relative importance) of Pinkas *et al.* (1971). The first three are based on a multivariate-weighted-average approach, the same used to develop a successful benthic response index for the 1994 regional survey (Smith *et al.* 1998b). The FFG index was based on foraging guilds from Allen (1982) and the multimetric approach (Weisberg *et al.* 1997, Gibson *et al.* 2000). Detailed methods and testing of these indices are given in Allen *et al.* (2001a).

The multivariate weighted-average indices (FRI, MIRI, and TRI) were produced from an ordination analysis of calibrated (i.e., index development) species abundance data (Allen *et al.* 2001a). These ordination analyses determined a vector in ordination space that corresponded to the pollution gradient. Then all calibration observations were projected onto the pollution-effects gradient vector in the biological ordination space, rescaled, and species-tolerance scores (i.e., species positions along the gradient vector) were determined. From this, the index value for an observation (station-time) is the abundance-weighted-average pollution tolerance of all species in the observation. The index value is calculated using Equation 6.

$$I_s = \frac{\sum_{i=1}^{n} a_{si}^{f} p_i}{\sum_{i=1}^{n} a_{si}^{f}}$$ **Equation 6**

where :

I_s = The index value for observation s .

n = The number of species in the observation s.

p_i = The position for species i on the pollution gradient (an indicator of the pollution tolerance of the species).

a_{si} = The abundance of species i in observation s.

f = The exponent f allows for transformation of the abundance weights to prevent overemphasis on extreme abundances. FRI f values are as follows: 9-40 m: 0, 30-120 m: 0.25, 100-215 m: 0.50. If the observation (station) overlaps two of the above depth zones, I equals the mean of the two numerator portions of I (obtained by using the two corresponding f values) divided by the mean of the two denominators, this value differs from the average of the two overall I's calculated using the two corresponding f values. The MIRI and TRI f value=0.25.

The application of these indices requires that species be from a similar area and habitat (i.e., the mainland shelf of southern California) as those used in developing the index. The new species abundance values are multiplied by the p_i determined in the index development analysis. Appendix A-A3, A-A4, and A-A5 give p_i values by species for FRI, MIRI, and TRI indices.

With the multivariate approach producing the FFG index, 31 population and assemblage metrics were tested to determine metrics that differed significantly between reference and impact sites (Allen *et al.* 2001a). Combinations of responsive metrics were then scored and combined to form indices. Each index was the mean of the metric scores of the index (i.e., the sum of the scores of each component metric divided by the number of metrics in the index), calculated using Equation 7.

$$MI = \frac{\sum_{i=1}^{n} MS}{n} \qquad \textbf{Equation 7}$$

where:

MI	=	Multimetric index.
MS	=	Metric score.
n	=	Number of metrics in index.

The foraging guilds that, in combination, formed the best index for the middle shelf, were the bottom-living benthic extractors (turbot guild, 2D1a); bottom-living pelagobenthivores (sanddab guild, 2B); and bottom-living pelagivores (benthic ambushers guild, 2A). Guild designations were based on Allen (1982). The turbot guild included C-O sole (*Pleuronichthys coenosus*), curlfin sole (*Pleuronichthys decurrens*), diamond turbot (*Pleuronichthys guttulatus*), Dover sole (*Microstomus pacificus*), hornyhead turbot (*Pleuronichthys verticalis*), rock sole (*Lepidopsetta bilineata*), and spotted turbot (*Pleuronichthys ritteri*). The sanddab guild included Gulf sanddab (*Citharichthys fragilis*), longfin sanddab (*Citharichthys xanthostigma*), slender sole (*Lyopsetta exilis*), Pacific sanddab (*Citharichthys sordidus*), speckled sanddab (*Citharichthys stigmaeus*), and small (≤11 cm) California halibut (*Paralichthys californicus*) and petrale sole (*Eopsetta jordani*). The benthic ambushers guild included California lizardfish (*Synodus lucioceps*), bigmouth sole (*Hippoglossina stomata*), lingcod (*Ophiodon elongatus*), and large (>11 cm) California halibut and petrale sole.

The turbot guild had high abundance in impact areas and low abundance in reference areas, whereas the sanddab and benthic ambusher guilds were in low abundance at impact areas and high abundance in reference areas.

To apply this index, the guilds receive the following scores at different abundance levels in a 10-min trawl:

- Guild 2D1a – score 1 (>32 fish); score 3 (32-11 fish); score 5 (10-0 fish).

- Guild 2B – score 1 (0-15 fish); score 3 (16-29 fish); score 5 (>29 fish).

- Guild 2A – score 1 (0 fish); score 3 (1 fish); score 5 (> 1 fish).

This guild tested successfully for use on the middle shelf of southern California.

Allen *et al.* (2001a) noted that based on overall performance in this study, the FRI index appeared to be an effective fish index, particularly in the middle shelf zone. The FFG index may have value in interpreting the ecological meaning of the FRI index response. The FFG index measures the relative importance of benthic pelagivore, benthic pelagobenthivore, and benthic-extracting benthivore guilds along the pollution gradient, which in turn reflect changes in the relative abundance of polychaetes and pericarid crustaceans (mysids and gammaridean amphipods) along the gradient. Although the MIRI and TRI indices performed less well, they are the only attempt to produce indices for southern California using megabenthic invertebrates and fishes and invertebrates combined. Their performance was likely due to anomalous species abundances following the 1982-1983 El Niño.

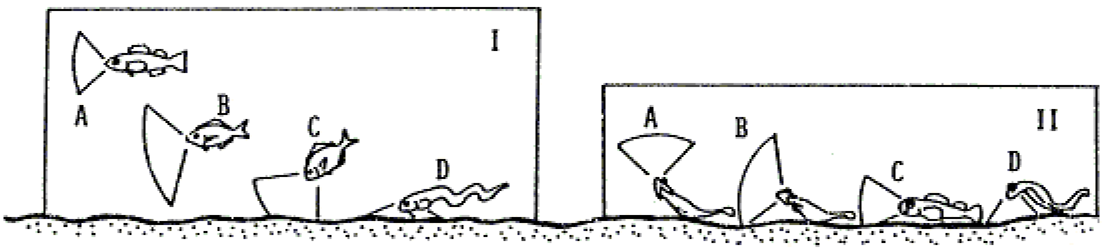
In this study, we focused on the FRI index as the primary index for assessing percent of area that was not reference because it could be applied across most of the study area and because it showed the best test results in the index development study (Allen *et al.* 2001a). The other indices give different perspectives of reference areas from the invertebrate, fish and invertebrate, and fish-foraging guild perspectives.

Functional Organization of Fish Assemblage Analysis

The functional organization of the demersal fish assemblages identified in the 1994 survey was based on the methods used in Allen (1982), which described the functional organization of demersal fish communities on the central portion of the southern California shelf at depths of 10-200 m in 1972-1973. This organization was based on 342 trawl samples collected in the same manner as those in the 1994 and 1998 regional surveys. It identified 15 basic foraging guilds of demersal fishes on the soft-bottom habitat of the mainland shelf, with one guild consisting of four size divisions (bringing the total possible guild categories to 18) (Figure II-5). Each guild consisted of two to four species, each dominant in a different depth zone. The functional structure of the community at a given depth is described in terms of the numbers and types of feeding guilds, whereas the species composition is described in terms of the dominant species of each guild (Figure II-6).

Species were sorted into 18 predefined foraging guilds. The guild classification of the most common species is defined in Allen (1982). The guild classification of other species was based on their known foraging behavior or on that inferred from their morphology and/or feeding habits. If more detailed information were available, some of the rarer species might be more appropriately classified into specialized guilds not defined in the above study. However, they are conservatively included here in the more general foraging orientation guilds.

The functional organization of the demersal fish assemblages in 2003 was described at 20-m depth intervals. This organization was compared to the model of functional organization for 1972-1973 (Allen 1982), 1994 (Allen *et al.* 1998), and 1998 (Allen *et al.* 2002a) to assess how the organization of the community has changed during three decades.



- I. Water-column Fishes
  - A. Pelagivores
    - 1. Schooling
    - 2. Bottom-refuge
      - a. Visual
      - b. Nonvisual
  - B. Pelagobenthivores
  - C. Benthopelagivores (Cruising)
    - 1. Diurnal
    - 2. Nocturnal
  - D. Benthivores (Cruising Nonvisual)
- II. Bottom-living Fishes
  - A. Pelagivores
  - B. Pelagobenthivores
  - C. Benthopelagivores
    - 1. Pursuing
    - 2. Ambushing
  - D. Benthivores
    - 1. Visual
      - a. Extracting
      - b. Excavating
    - 2. Nonvisual

Figure II-5. Foraging guilds of soft-bottom fishes on the southern California shelf (from Allen 1982, 2006a).

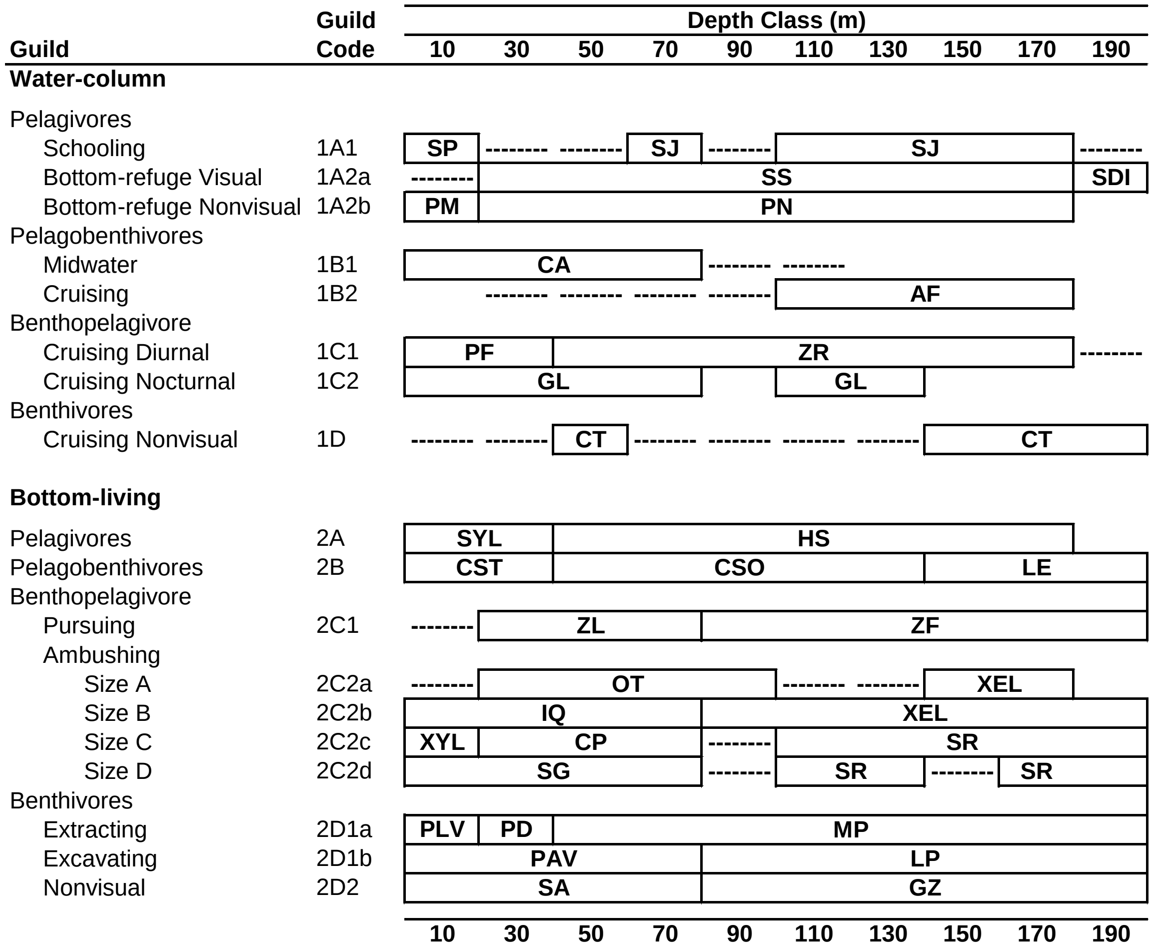
Bioaccumulation Data Analysis

Questions to be Answered

Five analyses were used to answer the following questions: 1) How representative are the samples relative to the appropriate geographic and temporal distributions of pelagic forage fishes commercially landed in southern California?; 2) What is the extent and magnitude of total DDT and PCB in pelagic forage fishes within the SCB?; 3) Are season, geographic region, and lipid content predictors of DDT and PCB concentrations found in pelagic forage fishes within the SCB?; 4) What is the percent of biomass for each pelagic forage fish species above the wildlife thresholds for DDT and PCB?; and 5) What is the total mass of total DDT and PCB contained within pelagic forage fishes in the SCB?

Sample Representation

Commercial landings of coastal pelagic species for the years 1983-2004 were obtained from CDFG and provided by species, CDFG block, and month. Each landing for the 2003/2004 fishing season was assigned to one of the four survey regions within the SCB according to block location, and total landings by species were summed by region/month. Because sampling only occurred between July 2003 and February 2004, landings for the rest of the season year were not included. To determine whether the appropriate species were selected the appropriate species for analysis, the relative proportion of landings by weight was calculated for the four coastal pelagic fish species (including jack mackerel, *Trachurus symmetricus*) and squid for the 2003/2004 commercial fishing season.



Size Classes (mouth length): A = 1-4 mm; B = 5-8 mm; C = 9-26 mm; and D ≥ 27 mm.

AF = *Anoplopoma fimbria*
CA = *Cymatogaster aggregata*
CP = *Chitonotus pugetensis*
CSO = *Citharichthys sordidus*
CST = *Citharichthys stigmaeus*
CT = *Chilara taylori*
GL = *Genyonemus lineatus*
GZ = *Glyptocephalus zachirus*
HS = *Hipposlossina stomata*
IQ = *Icelinus quadriseriatus*
LE = *Lyopsetta exilis*
LP = *Lycodes pacificus*
MP = *Microstomus pacificus*
OT = *Odontopyxis trispinosa*
PAV = *Parophrys vetulus*
PD = *Pleuronichthys decurrens*
PF = *Phanerodon furcatus*
PLV = *Pleuronichthys verticalis*
PM = *Porichthys myriaster*
PN = *Porichthys notatus*
SA = *Symphurus atricaudus*
SDI = *Sebastes diploproa*
SG = *Scorpaena guttata*
SJ = *Sebastes jordani*
SP = *Seriphus politus*
SR = *Sebastes rosenblatti*
SS = *Sebastes saxicola*
SYL = *Synodus lucioceps*
XEL = *Xeneretmus latifrons*
XYL = *Xystreurys liolepis*
ZF = *Zaniolepis frenata*
ZL = *Zaniolepis latipinnis*
ZR = *Zalembius rosaceus*

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 in guild is identified by abbreviations.

See Glossary G2 for common names of fish species.

Figure II-6. Functional structure and species composition of soft-bottom fish communities of the mainland shelf of southern California in 1972-1973 (modified from Allen 1982, 2006a).

Finally, the percent of landings with samples collected in each region were calculated by summing the total landing weight of the representative samples (i.e., matching block/month) within the region, dividing that landing weight by the weight of total landings within the region, and multiplying by 100. Bait samples were not accounted for in the calculation of percent representation because the fishing location of bait landings is not always reported and hence total bait landings by block/month could not always be determined. Therefore, the percent representation for northern anchovy and Pacific sardine in this study is likely conservative.

General Linear Model Analysis

A general linear models approach ("PROC GLM", SAS Version 9.1, SAS Institute, Cary, NC) was used to test whether species, season, and lipid content were predictors of the total DDT and total PCB concentrations found in pelagic forage fishes and squid within the SCB. As a result of unequal sampling across regions and season, sample region was not included in the analysis. Composites with nondetectable contaminant concentrations were removed prior to the analysis.

Percent Biomass Above Wildlife-Risk Screening Values

The thresholds of concern were predator-risk guidelines for wildlife consumers of aquatic and/or marine organisms from the Environment Canada (Caux and Roe 2000). The screening value for total DDT was 14.0 µg/kg ww (Ridgway *et al.* 2000) and that for PCB was 0.79 ng (TEQ)/kg (Roe *et al.* 2000). The PCB screening value was based on the toxicity equivalent quotient (TEQ) of the products of the summed PCB congeners and their toxicity equivalency factors (TEFs). These TEFs were used to estimate the relative toxicity of PCBs based on their similarity to dioxin. Specifically, the TEFs are assigned to the congeners based on their ability to produce a response in the cytochrome system relative to the most potent inducer, 2,3,7,8-TCDD [a dioxin; TCDD=tetrachlorodibenzo-p-dioxin]. Thus, the TEQ is the total TCDD toxic equivalents concentration and is calculated as

$$TEQ=S\ (PCBi \times TEFi)$$

where:
PCBi=Individual PCB congener.
TEFi=Toxicity of PCB congener relative to TCCD dioxin

The TEFs used in this study were those recommended by the World Health Organization (Van den Berg *et al.* 1998). The TEFs were available for 12 PCB congeners found in this study, with TEFs differing for mammals and birds (Table II-2).

Table II-2. Summary of congener-specific toxicity equivalent factors (TEFs) for mammals and birds used in the Southern California Bight 2003 Regional Survey.

	WHO Congener-specific TEFs[1]	
Congener	Mammals	Birds
PCB 77	0.00010	0.05000
PCB 81	0.00010	0.10000
PCB 105	0.00010	0.00010
PCB 114	0.00050	0.00010
PCB 118	0.00010	0.00001
PCB 123	0.00010	0.00001
PCB 126	0.10000	0.10000
PCB 156	0.00050	0.00010
PCB 157	0.00050	0.00010
PCB 167	0.00001	0.00001
PCB 169	0.01000	0.00100
PCB 189	0.00010	0.00001

WHO = World Health Organization.
[1] Van den Berg, *et al*. (1998).

Because fish for composite samples were not collected from each landing, a cumulative distribution curve (CDF) of fish tissue concentration versus percent biomass was calculated to estimate the percent of the total landings having tDDT and/or PCB TEQs above wildlife threshold. First, each region was assigned a scaling factor to yield an estimated biomass (landings weight) value associated with each composite. The scaling factor was calculated as one divided by the ratio of the total assigned landing weights of the representative composites in a region divided by the weight of all landings in that stratum. Next, the assigned landing weight of each composite was multiplied by the associated scaling factor to yield the estimated total biomass represented by each composite concentration value.

The CDFs provide graphical information on the percent of the landings that lie below a given indicator value. To calculate a CDF, composite concentration values were ranked from low to high. The estimated total biomass (landing weight) for each composite sample were then accumulated, giving a cumulative sum of weight at each ranked composite concentration value. Then each cumulative sum of weight was divided by the total biomass to give a cumulative frequency distribution (with proportions adding up to 1.0)**.**

Total Mass of Contaminants in SCB

The total mass of tDDT, tPCB, and PCB TEQs (for birds and mammals) contained within the pelagic forage fish and market squid compartment or reservoir within the SCB was calculated using Equation 8

$$X_a = \sum([\bar{x}]_i * L_i) \qquad \textbf{Equation 8}$$

where:

X_a =Total mass of constituent *x* in species *a*

$[\bar{x}]_i$ = Mean concentration of constituent *x* in region *i*

L_i =Landings in region *I*

Finally, the value of each X_a was summed across all species.

III. QUALITY ASSURANCE

Introduction

The goal of the Quality Assurance (QA) Plan was to ensure that data generated during the Southern California Bight 2003 Regional Survey (Bight '03 Coastal Ecology Committee 2003b) were of high quality and comparable among the participating agencies. Certain procedures addressed critical issues regarding data comparability. A common field manual (Bight '03 Field Sampling & Logistics Committee 2003) provided standard sampling protocols among the group. Presurvey training workshops allowed participants to become familiar with procedures to be used in the survey. Interagency 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 Section II (Methods) of this report.

The QA and quality control (QC) activities enacted cover a wide range of data types which include biological data, chemistry data, and information management consolidation. Assemblage data collected in the field required standard equipment, standard start and end points, uniform taxonomic identification, and uniform enumeration and measurement techniques. Chemistry data also included common field methods but added laboratory techniques to ensure accuracy and precision, such as standards, blanks, replicates, spiking, and reference materials. 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 significantly improve data comparability among participating organizations.

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 Field Manual (Bight '03 Field Sampling and Logistics Committee 2003) and QA Plan (Bight '03 Coastal Ecology Committee 2003b). 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 Study

Trawl Sampling Success

The original stratified random survey design identified 255 trawl sites, which allowed for 10% over sampling in each subpopulation in case of low trawling success. However, additional sites were added in-survey to compensate for untrawlable sites, bringing the total sites attempted to 295. Trawl samples were collected from 210 (71%) of the attempted stations (Figure III-1) from Point Conception, California, to the United States- Mexico International Border including San Miguel, Santa Rosa, Santa Cruz, Anacapa, and Santa Barbara Islands (all part of Channel Islands National Marine Sanctuary). Sampling depths ranged from 2-476 m (Appendix A-A1).

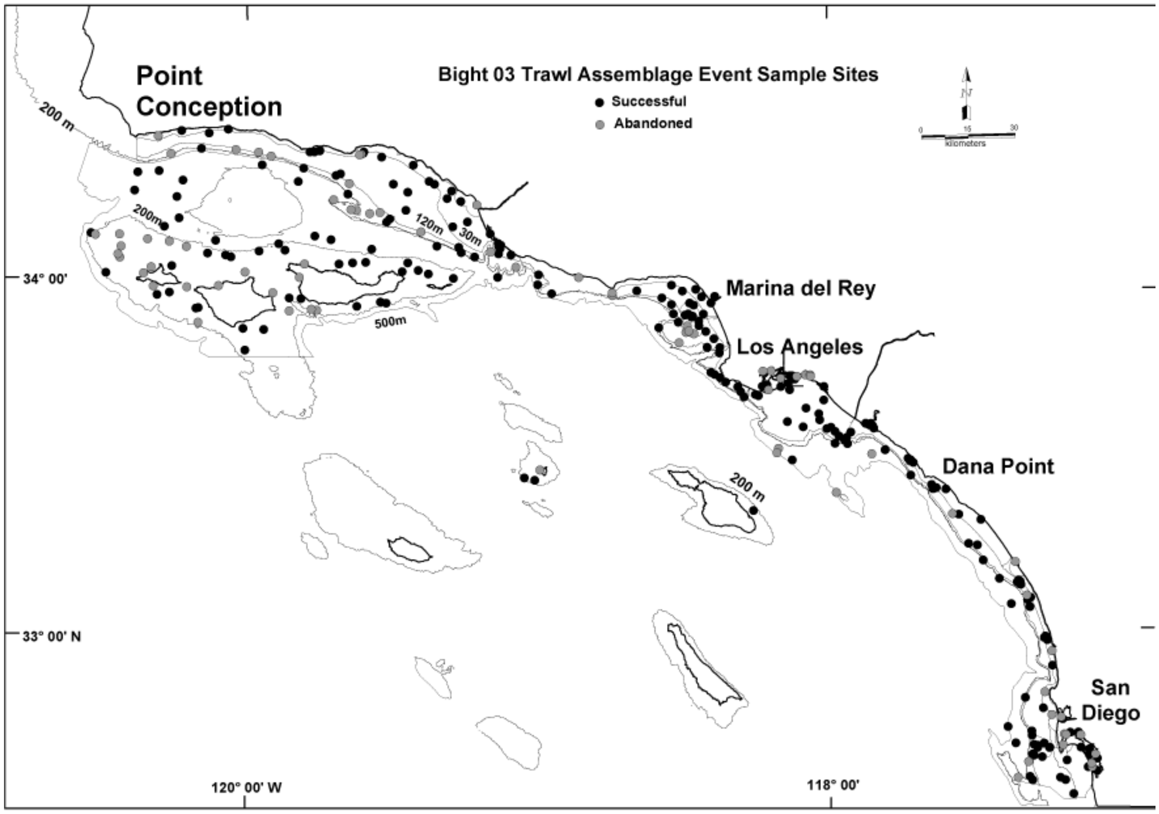


Figure III-1. Successful and unsuccessful assemblage trawl stations during the Southern California Bight 2003 Regional Survey, July-October 2003.

Trawl success varied by analytical subpopulation and was higher along the mainland shelf (76%) than at the islands (50%). Along the mainland shelf, trawl success was similar from north to south (73 to 77%, respectively). At the islands, the greatest success was on the northwest side (81%). Only two depth strata (middle shelf and outer shelf) were targeted at the islands with similar percentages (50-56%) and all sites falling in the 3-30 m range failed. By depth zone along the mainland shelf, trawl success ranged from 55 to 90%, with success being lowest on the outer shelf (120-200 m), and highest on the upper slope (201-500 m). In specific subpopulations such as bays/harbors and large/small POTWs, sampling success was 59% and 89%, respectively.

Of the failed stations, rocky bottom caused the highest percentage (39%) of abandonment (Figure III-2). A variety of reasons were given for abandonment including generalized categories such as the miscellaneous “other” category, 24%, obstructions, 12%, damaged gear, 11%, protocol violation, 8%, irregular bottom, 5%, and kelp bed, 2%. Failures in the “other” category required a comment, and were mostly navigation/safety related concerns.

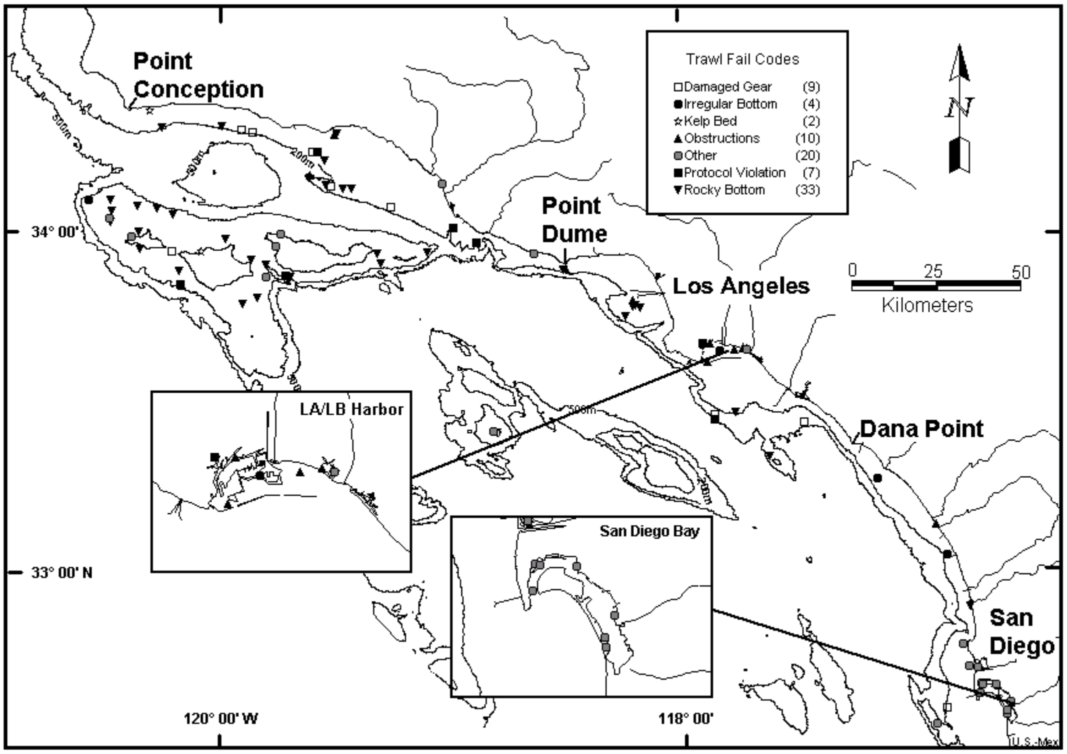


Figure III-2. Abandoned trawl stations during the Southern California Bight 2003 Regional Survey, July-October 2003. Symbols represent reasons given for station failure as presented in the database. Totals include number of failed trawls, which may be more than one at a station.

Review of Trawl Event Criteria

Site Location Criteria Objectives. Although the QA/QC criterion for accepting a station for assemblage analysis required only that the station be within the original subpopulation, more precise field criteria were implemented to ensure that sampling would be conducted close to the assigned coordinates. Bight '03 Field Sampling & Logistics Committee (2003) specified guidelines that field crews should meet in collecting a sample at a sampling site. The trawl was to be taken within 100 m of the pre-assigned site, except at the Channel Islands where it was extended to 200m, and within 10% of the nominal depth. Trawls were to be towed for 10 min at a constant speed of 0.8-1.0 m/s (1.6-2.0 kn). However, in bay/harbor areas with distance restrictions, they were towed for 5 min. Trawls used in the upper slope strata were required to use pressure-temperature sensor for stations deeper than 300m to ensure proper “on bottom” times (8-15 min). Post-survey quality control found that all 210 trawls had recorded adequate georeferences for GIS trawl analysis. These sites were used to evaluate distance from nominal site, depth change criteria, tow distance, and speed.

Distance from Nominal Site. For the survey, 95% of the trawls were within the proper radius (200 m for Channel Islands and 100 m for other subpopulations) of the original assigned (nominal) station coordinates. This was an improvement from the 1998 regional survey in which 69% of the trawls were within the proper radius (Allen *et al.* 2002a). The only difference from the previous survey was that a 200 m criterion was used for the Channel Islands in 2003. However, using the 100 m criterion would have only decreased the success rate by 3%. Ten trawls exceeded the criterion of which three had departure distances in the 100-200 m range. Of these, two were in the bay/harbor stratum, five in the 350-800 m departure range with one belonging to the upper slope stratum, and two in the 4,000-6,000 m departure range (stations 4323 and 4240). For the two sites missing the nominal coordinate by kilometers, transcription error caused one anomaly and an operational error probably caused the other (4323). One of the bay/harbor trawls altered the trawl course because of a sunken boat. The species composition of all sites exceeding the nominal distance rule was examined for unexpected species; all sites had species compositions expected for their particular depth strata. None of the biological data from any site were excluded from analysis because of the site's distance from the nominal coordinate, as all were in their preassigned subpopulations.

Depth Change Criterion. Demersal fish and invertebrate populations vary along depth gradients; hence, trawls were towed along isobaths. Lead scientists were asked to determine the nominal depth once the assigned station coordinates were occupied, and then trawled along the isobath within ±10% of this nominal depth. The depth criterion analysis used the mean from the start and end tow positions to bracket 10% changes because station occupation forms did not record the nominal station depth. All 210 sites recorded both the start and end position depths. For the survey, 94% of the trawls were within ±10% of the targeted depth. Of the 12 stations exceeding this criterion, 75% were on the inner shelf at depths of 2–27 m. Two were on the middle shelf at depths of 71-123 m. Station 4479 on the outer shelf barely exceeded the 10% mark. Because of the small range of depths at sites less than 10 m, some sites had higher percent departure from nominal. Ignoring these, the highest percent departure was at station 4408, which exceeded the depth criterion by 62% in a trawl starting at 18 m and ending at 4 m. Data entry error could not be ruled out. Another site with a large depth change was station 4173 which started at 86 m and ended at 123 m. The species composition of all sites exceeding the 10% depth criterion was examined for unexpected species; all sites had species compositions expected for their particular depth stratum.

Trawl Duration. Two categories of trawl duration times were observed in the data: 90% were 10-minute tows for normal coastal conditions; and 10% were 5-minute trawls for distance limited sites within bays/harbors. Most (94%) were within ±1 min of the target duration. Five sites exceeded ±2 minutes. Ten-minute tows ranged between 6-14 min. Twenty-two sites were 5-min trawls (range of 4-6 min). Station 4007 in the upper slope strata (452 m) was trawled for 4 min. Station 4421 (95 m) was trawled for 13 min. Stations 4123 (56 m), 4183 (34 m) and 4254 (454 m) trawled for 14 min. However, when the pressure-temperature sensor data was checked for 4254, the net had only been on the bottom for 10 min. In the 300-500 m range of the upper slope stratum, sites met the criteria if the tows were between 8 and 15 min. All 5-min trawls were normalized to 10 min for data analysis (see Section VII). None of the biological data from any site were excluded from any analysis because of differences in trawl duration.

Tow Speed and Distance. The variable tow speeds of 0.8-1.0 m/sec (1.6-2.0 kn) mentioned in the field manual (Bight '03 Field Sampling and Logistics Committee 2003) reflect suboptimal sea conditions normally encountered during fieldwork. Fifty-nine percent of the boats were able to stay within the prescribed speed. Bracketing the expected speed range by ±0.2 m/s increased compliance to 82%. In general, boats trawled faster rather than slower which may reflect the difficulty of maintaining slow speeds on one engine or during certain surface current and wind regimes. The two stations with the slowest tow rates were 4189 (0.02 m/s) and 4404 (0.98 m/s). The three fastest towed sites (4210, 4007, 4408) had speeds of 2.04, 2.52, and 3.79 m/s, respectively. Most of these outliers (Figure III-3) had distance anomalies that accounted for the unexpected speeds except station 4007 (time issue). Transcription errors could not be ruled out because speed was calculated from trawl duration and distance. The extremely slow tow speed calculated for station 4189 is due to a transcription error; the recorded start and stop coordinates are identical. None of the biological data from any site were excluded from any analysis because of tow speed.

Pressure-Temperature Sensor. A pressure-temperature sensor attached to the otter trawl doors recorded pressure and temperature at 2 sec intervals. This was checked after all trawls of greater than 300 m. If the trawl was outside the targeted bottom time range of 8-15 minutes, it was redone and the data submitted as an unofficial trawl. As few faunal data are available for the upper slope stratum, Bight '03 Field Sampling & Logistics Committee (2003) required submittal of all faunal data for these unofficial trawls. Pressure-temperature sensor data were submitted by four of the nine participating organizations and included nine sites at depths greater than 300 m. A total of 18 sites greater than 300 m were trawled during the survey. Two sites were retrawled because of excess bottom time. Analysis showed one repeated trawl was within the proper time range while the other, station 4201, was only 5 min long. Of the remaining eight sites, five trawls were within the 8-15 min range while three (4202, 4378, and 4297) had 19+ bottom times. Pressure-temperature sensor data were not available for all trawls greater than 300 m depth because several of the organizations experienced difficulty with the device.

Field Audits

All participating organizations complied with procedures described in the field operations manual (Bight '03 Field Sampling & Logistics Committee 2003). An auditor visited every organization during the survey. All organizations used similar equipment and trawled the same way. Fish and invertebrate community assessment data were collected similarly by sorting, identifying, enumerating, and weighing. Species were identified correctly in the field, or appropriately returned for laboratory identification for further identification (FID). Each organization retained at least one specimen of each field-identified species as a voucher to substantiate identifications. All observed anomalies were noted correctly.

Presurvey audits found agencies with completely new field personnel or new to the study competent for inclusion in the Bight '03 program.

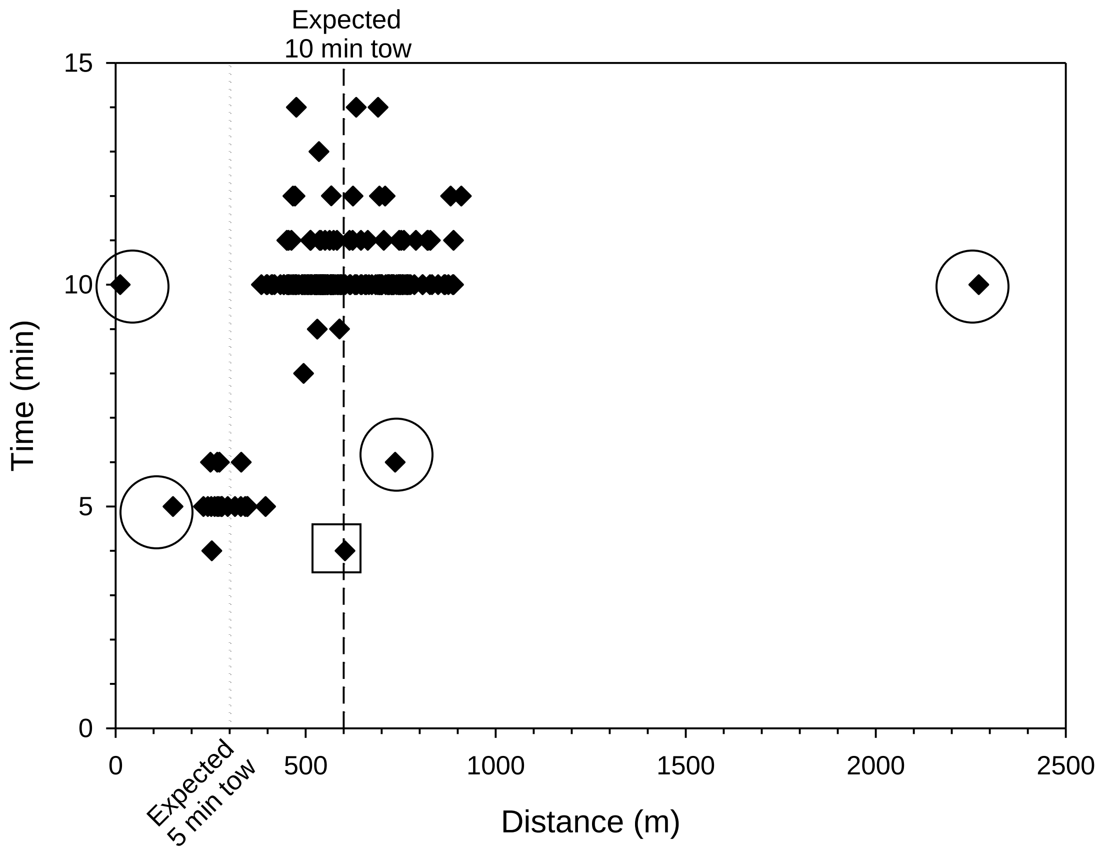


Figure III-3. Trawl duration (time) versus distance towed results for assemblage trawls during the Southern California Bight 2003 Regional Survey. Five outliers were circled to illustrate potential transcription errors resulting from distance (circle) or time (square).

Species Identification

Quality assurance and control of taxonomy was preformed on three levels: presurvey taxonomic preparedness for QA, in-survey QC field audits, and post-survey QC voucher checks. The presurvey process included an information transfer meeting with organization taxonomists, lead scientists, and boat captains. Expected and difficult species were discussed with the group and a list of recommended taxonomic aids was distributed. The Southern California Association of Marine Invertebrate Taxonomists (SCAMIT) held a number of meetings to expose participants to taxa expected in the upper slope stratum. Several hands-on training days brought taxonomists together to identify live animals and discuss differences in taxonomic approach and practice. Bucket tests for both fish and invertebrate species were given to all organizations participating in the trawl survey to verify taxonomic abilities. In-survey field audits ensured field personnel correctly processed and identified species. A final post-survey voucher check corrected taxonomic errors and modified field recorded data to reflect submitted vouchers.

Presurvey Taxonomic Verification. Of the nine agencies participating in the bucket practicum, 67% achieved the measurement quality objective (MQO) of ≤ 5% on the first try (Table III-1). The test involved common fish and invertebrate species expected in the survey.

Fish and invertebrates (30 each) were grouped into separate buckets to accommodate taxonomic specialization within organization staffs. Organizations not passing the first test were given a second set of buckets to identify with a different species composition. Three organizations were retested and passed the second bucket test. As a whole, invertebrates proved more difficult to identify than fishes.

Table III-1. Bight '03 **bucket intercalibration results for trawl fish and invertebrate species identification. Results are from the primary practicum and a second test for agencies exceeding the measurement quality objective.**

	Number Wrong			Percent Error		
Organization	Fish	Invertebrates	Total	Fish	Invertebrates	Total
First Test						
A	0	0	0	0	0	0
D	0	0	0	0	0	0
E	0	0	0	0	0	0
F	0	0	0	0	0	0
G	0	1	1	0	3	2
I	0	1	1	0	3	2
H	4	2	6	13	3	10
C	2	2	4	7	7	13
B	2	7	9	7	23	15
Second Test						
H	1	2	3	3	7	5
C	0	0	0	0	0	0
B	0	2	2	0	7	3

Measurement Quality Objective is ≤ 5% Error

Postsurvey Voucher Checks - ***Fishes.*** A total of 142 fish species were collected by trawl in 2003, one less than the 143 collected in the 1998 regional survey (Allen *et al.* 2002a). One or more specimens of each species collected by an organization were vouchered for confirmation of field identification. Not all fishes were caught by each of the nine organizations. The MQO goal for accuracy (i.e., the number of correctly identified vouchers divided by the total number of vouchers) was 95%. Four of the nine teams did not meet the MQO for accuracy (Table III-2). The overall accuracy error rate was 6%, slightly missing the goal of 5%. All agencies met the MQO for completeness (which was 90%) with 100% of fish collected identified.

The voucher and FID specimens were all checked or identified by the lead fish taxonomist from each organization and the survey quality assurance taxonomist (Dr. M. James Allen) after the sampling period was finished. Corrections to FID and voucher specimen identifications were changed in the database before final data analysis. In the case of voucher errors, the data managers along with the taxonomist determined what actions were needed to produce data comparable and consistent with that of other organizations.

Table III-2. Error evaluation for trawl fish voucher and FID (requiring further identification) specimens submitted as part of the Southern California Bight 2003 Regional Survey quality assurance program.

Data modification type	Error Type	Participating Agency									
		A	B	C	D	E	F	G	H	I	All
Trawl Fish Voucher Evaluation											
Total vouchers submitted		89	66	57	54	24	77	59	63	66	555
Old or misspelled names	-	3	1	0	0	1	4	5	2	2	18
Correct but incomplete IDs		0	0	0	0	0	0	0	0	0	0
Incorrect Identifications	Acc	9	3	0	1	2	6	8	2	4	35
Summary											
Total data Changes		12	4	0	1	3	10	13	4	6	53
% error in voucher identification accuracy	Acc	10	5	0	2	8	8	14	3	5	6
Compliance with Accuracy MQO *		N	Y	Y	Y	N	N	N	Y	Y	N
Trawl Fish FID Evaluation											
Total FIDs		1	9	0	0	0	8	5	8	0	31
Old or misspelled names	N/A	0	1	0	0	0	0	0	0	0	1
Correct but incomplete IDs	N/A	0	7	0	0	0	8	3	5	0	23
Incorrect identifications	N/A	0	1	0	0	0	0	0	3	0	4
No identification attempted	N/A	0	0	0	0	0	0	2	0	0	2

* Accuracy MQO compliance is the number of incorrect voucher identifications divided by total number of vouchers times 100. The goal was 95% correct identification.
Acc = Accuracy; FID = Further Identification; MQO = Measurement Quality Objectives; N/A = Not Applicable; QC = Quality control; N = No; Y = yes

Postsurvey Voucher Checks - *Invertebrates.* Each species-level taxon collected by each organization was vouchered for confirmation of field identification. In a few cases vouchers were forgotten, under-preserved or otherwise not useful, but compliance was nearly 100% for species vouchering. Additional vouchers were created during FID identification. Nine field teams were involved in the identifications (Table III-3). Five of the nine agencies met the MQO of 95% for accuracy. The overall accuracy error rate of 6% was slightly above the 5% MQO goal. Identifications listed as being correct but incomplete were specimens that could have been identified to a lower taxonomic level. All organizations were able to identify 95% of the invertebrate species to the lowest taxonomic level, with a survey mean of 99% (1% error).

Regional survey participants recognized that vouchering difficult or uncertain species provides a critical step in trawl data quality control. The resultant FID (further identification required) samples were processed by taxonomic specialists during voucher identification. Five quality-assurance taxonomists (Don Cadien, Ron Velarde, Lisa Haney, Megan Lilly, and John Ljubenkov) identified invertebrate vouchers and FID lots. Identifications were verified or corrected prior to final database acceptance. In cases of voucher error, the reviewing taxonomists worked with the organization data managers to determine what action was required to produce data comparable with that of other organizations. Once they reached agreement, the data was modified to reflect the corrections, and submitted to SCCWRP. The organizations that returned the largest number of FID lots will be targeted for added quality assurance efforts prior to subsequent regional surveys. Given the addition of the slope stratum and the high diversity of invertebrates taken, survey identification accuracy and precision results were very good.

Retention of the present MQO along with additional experience of field teams should result in continued improvement in performance in future surveys.

Table III-3. Error evaluation for trawl invertebrate voucher and FID (requiring further identification) specimens submitted as part of the Southern California Bight 2003 Regional Survey quality assurance program.

Data modification type	Error Type	A	B	C	D	E	F	G	H	I	All
		Participating Agency									
Trawl Invertebrate Voucher Evaluation											
Vouchers Submitted		85	110	55	81	29	117	66	117	115	775
Added by voucher lot splitting	Acc	0	1	0	0	0	1	2	0	0	4
Total Vouchers		85	111	55	81	29	118	68	117	115	779
Inappropriate Inclusions (out of habitat)	-	0	1	1	0	2	7	2	0	9	22
Old or misspelled names	-	1	6	6	4	2	12	7	0	10	48
Correct but incomplete IDs		0	0	0	0	0	5	2	4	0	11
Incorrect identifications	Acc	2	10	1	2	2	4	7	2	19	49
Summary											
Total Data Changes		3	18	8	6	6	28	18	6	38	121
% error in voucher identification accuracy	Acc	2	10	2	2	7	4	13	2	17	6
Compliance with Accuracy MQO *		Y	N	Y	Y	N	Y	N	Y	N	N
% correct but incomplete names		0	0	0	0	0	4	3	3	0	1
Trawl Invertebrate FID Evaluation											
Total FIDs (including split lots)		23	42	0	0	0	0	68	0	28	161
Lots created by splitting during QC		2	3	0	0	0	0	40	0	3	48
Inappropriate inclusions (out of habitat)	N/A	1	0	0	0	0	0	8	0	1	10
Old or misspelled names	N/A	0	0	0	0	0	0	0	0	0	0
Correct but incomplete IDs	N/A	2	22	0	0	0	0	22	0	22	68
Incorrect identifications	N/A	4	1	0	0	0	0	19	0	0	24
No identification attempted	N/A	0	0	0	0	0	0	1	0	0	1

* Accuracy MQO compliance is the number of incorrect voucher identifications divided by total number vouchers times 100. The goal was 95% correct identification.
Acc = Accuracy; FID = Further Identification; MQO = Measurement Quality Objectives; N/A = Not Applicable; QC = Quality control; N = No; Y = yes

Bioaccumulation in Pelagic Forage Fish and Squid Study

Sampling Success

A total of 99 composite samples, representing 1,460 individual fish or squid were collected for organic contaminant analysis (Table III-4; Figure III-4). Samples of all the four target species were collected from each of the four regions identified. Sample sizes ranged from 34 composites for Pacific sardine to 13 composites for Pacific chub mackerel. However, not all of the target samples were collected during the sampling campaign. For example, only 70% of the target samples were collected for northern anchovy. Low sample size was not due to low sampling effort or success. Rather, it was due to a lack of landings in specific regions, such as the Southern Coast and Channel Islands strata.

Table III-4. Sampling success of southern California pelagic forage species targeted for whole fish composite contaminant analysis between July 2003 and February 2004.

	Region					
	Mainland Coast					Percent
Species	North	Central	South	Islands	Total	Target
Northern anchovy	10	10	2	2	24	60
Pacific sardine	9	10	5	10	34	85
California market squid	10	8	0	10	28	70
Pacific chub mackerel	3	4	1	5	13	65
Total	32	32	8	27	99	71

Sample Representation

The representative sampling of pelagic forage fishes was assessed relative to the total amount of biomass landed (Figure III-5). California market squid and Pacific sardine had the greatest biomass (34×10^3 mt and 14×10^3 mt, respectively), and comprised over 90% of the total biomass landed in the SCB. These two species were sampled with the greatest success in the survey, comprised 6% (9×10^6 4×10^3 mt) of the total biomass landed during the study period. Northern anchovy (2×10^3 mt), the species sampled with the least success, comprised less than 3% of the total biomass landed during the study. Jack mackerel comprised only 1% of the total biomass landed during the study period.

While target sample sizes were not achieved for all species and strata, the sampling effort was representative of the appropriate geographic and temporal distributions of pelagic forage fishes and squid that were commercially landed in southern California (Figure III-5). For example, 71% of all Pacific sardine were landed in the Central stratum and this study representatively sampled 92% of these landings. Similarly, representative samples were collected for the majority of landings of California market squid. A very small proportion of the landings from the Islands stratum offset the lack of sampling success in the southern SCB. Representative sampling of northern anchovy landings was not achieved, as these were dominated by fisheries in the northern SCB. Approximately 50% of the Pacific chub mackerel were representatively sampled.

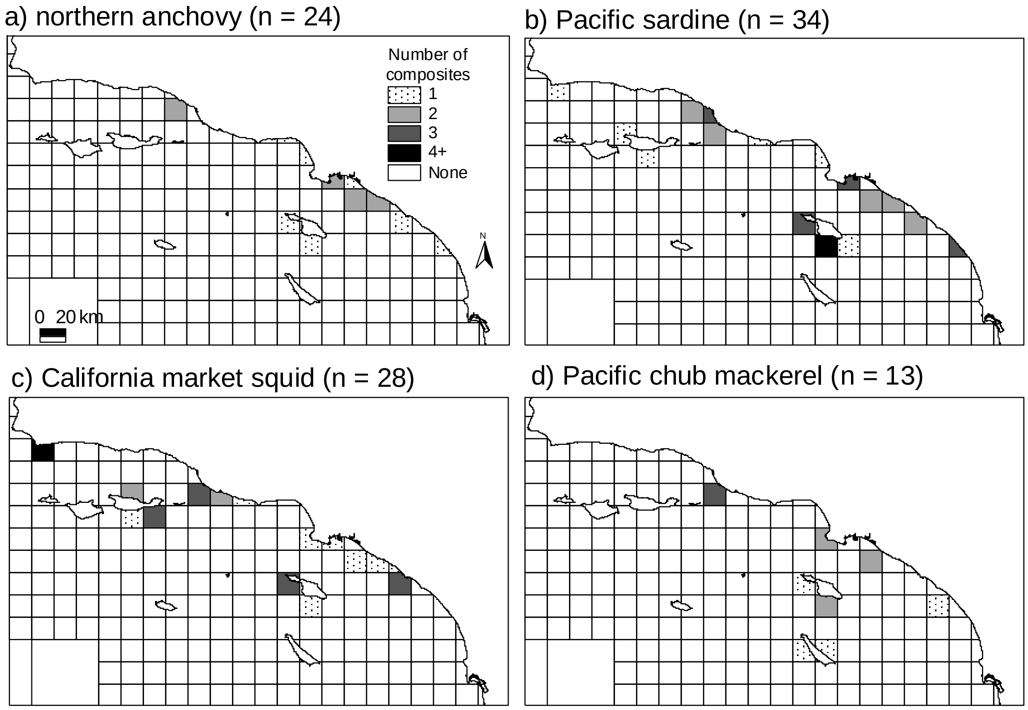


Figure III-4. Distribution of contaminant sample composites for a) northern anchovy, b) Pacific sardine, c) California market squid, and d) Pacific chub mackerel sampled from southern California commercial fishing markets and/or bait receivers during July 2003 – February 2004.

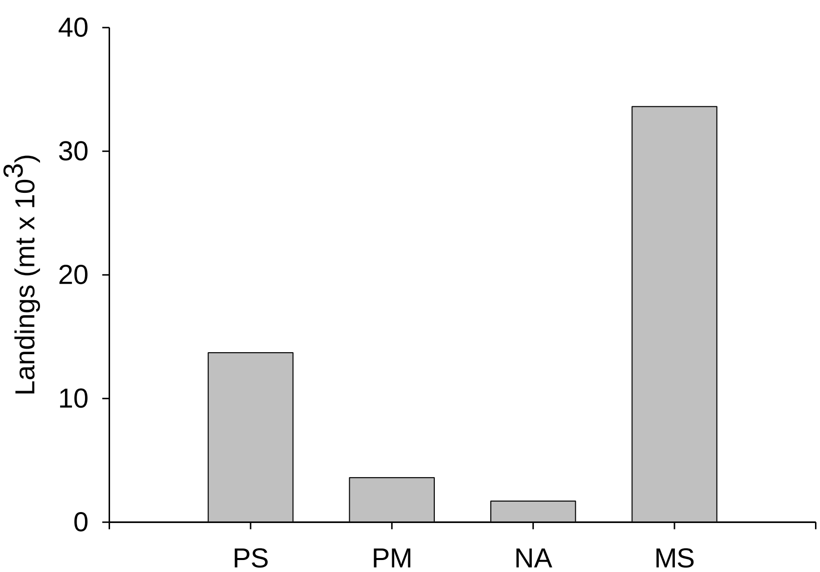


Figure III-5. Total southern California commercial landings of pelagic forage fish and squid landings (metric tons) during the study period, July 2003 – February 2004 (CDFG data, unpublished). PS=Pacific sardine, PM=Pacific chub mackerel, NA=northern anchovy, MS=California market squid.

Chemistry QC Results

Bight '03 Coastal Ecology Committee (2003b) defined quality assurance guidelines for chemical analysis of fish tissues. These included holding time recommendations and data analysis objectives for completeness, blanks, certified reference materials (CRM), matrix spikes (MS), and duplicates (DUPS). Holding time recommendations were one year for whole fish samples for organics analysis wrapped in aluminum foil in plastic bags and frozen at –20°C and one year for fish puree for organics analysis in 250 ml glass containers 80% full and frozen –20°C (Bight '03 Coastal Ecology Committee (2003b). All 99 (100%) of whole fish samples for organics analysis in this study were held (collecting to processing to puree) within the recommend one-year holding time (Table III-5). Similarly 99 samples (100%) of fish puree samples for organics analysis homogenized from the whole fish samples were processed within the recommended time frame. For these two phases combined (collecting to analysis), all were analyzed within 1.2 years (440 days) from collection, with a mean of 14 days more than a year for percent lipid and a mean of 24 days over for DDT and PCB samples. All samples analyzed were included in the data analysis for this report.

Common procedures such as completeness, blanks, certified reference materials (CRM), matrix spikes (MS), and duplicates (DUPS) all met the DQO of 100% (Table III-6).

Table III-5. Holding time results for fish tissue samples used in pelagic forage fish bioaccumulation study, July 2003-February 2004.

		Holding Time						
	No. of	Days		Days Exceeding		Samples Exceeding		% Samples
Holding Time Period	Samples	Mean	Max.	No.	Mean	No.	%	Within
Collecting to Processing	99	150	258	0	--	0	0	100
Processing to Analysis	99	143	223	0	--	0	0	100
% Lipid	83	167	223	0	--	0	0	100
% Moisture	54	11	15	0	--	0	0	100
DDTs	99	168	195	0	--	0	0	100
Lipid	15	149	150	0	--	0	0	100
PCBs	99	168	195	0	--	0	0	100
Collection to Analysis	99	291	440	0-75	41	41	12	59
% Lipid	83	317	393	1-28	14	10	12	88
% Moisture	54	149	252	--	--	0	0	100
DDTs	99	318	440	2-75	24	15	15	85
Lipid	15	305	387	22	22	1	7	93
PCBs	99	318	440	2-75	24	15	15	85

Boxes enclose values most pertinent to samples analyzed.

Table III-6. Quality control results for chlorinated hydrocarbon analyses of whole organism composites of pelagic forage fishes and squid in Southern California Bight 2003 Regional Survey.

Quality Control Parameter	Data Quality Objective	Success
Completeness	90%	100%
Blanks		
Frequency	1/batch	100%
Accuracy	<RL	100%
Certified Reference Material		
Frequency	1/batch	100%
Accuracy	Within ± 40% of certified value for 80% of analytes	100%
Matrix Spikes		
Frequency	Not Required	---
Accuracy	Not Required	---
Reporting Level Spikes		
Frequency	1/batch	60%
Accuracy	N/A[1]	---
Sample Duplicates		
Frequency	1/batch	100%
Accuracy	Relative Percent Difference<30%	100%

[1]N/A=no DQO established, data are for evaluation purposes only as part of ongoing QA/QC efforts

Discussion

The goal for of the QA/QC section was to evaluate how well the survey participants produced comparable data. Each organization produced data that was combined with other agency data to produce synoptic Bight-wide information. As long as the produced data were comparable among agencies, this synoptic database should be reliable. In general the participants did produce data of high comparability, suitable for construction of a synoptic Bight-wide data base.

Beneficial Features of the Quality Assurance Program

The strengths of the Bight '03 regional survey were the combined use of standard methods and performance based standards. Adherence to the requirements of the Field Operations Manual (Bight '03 Field Sampling & Logistics Committee 2003) was generally high, despite occasional lapses reverting to nonstandard practice. This was encouraged through early distribution of the Manual, and a presurvey information transfer meeting (including boat captains, chief scientists, and taxonomists) which stressed the need for uniformity. Availability and distribution of a Field

Computer program which captured standardized trawl event data was also useful. Field audits performed by Quality Control officers aboard each participating vessel documented compliant practice. Particular attention was paid to anticipated problems with addition of an upper slope stratum sampling sites at 200-500 m. The fauna was expected to differ there, and several different QA approaches to achieving taxonomic uniformity were implemented. Difficulties were also expected with staying within on-bottom trawl location and duration requirements in these deeper deployments. It was decided to provide concrete data for trawl on-bottom performance and vertical profile by using pressure-temperature sensor mounted on the trawl otter boards.

Performance based standards were used presurvey to determine the readiness of each participating field team to perform at-sea identifications (bucket practicum), and post-survey in voucher QC reidentifications. Standard chemical laboratory QC protocols were also observed in analysis of fish tissue samples. The group concluded that the data produced during the Bight '03 regional trawl survey were of high quality, and comparable among agencies. Overall, the trawl survey was successful in meeting most of its MQO goals.

Success at Meeting Measurement Quality Objectives

Trawling Sampling Success and Site Occupation Performance

The average trawl success rate for the regional survey was 71% with sites around islands, at 120-200 m depths, and within bays/harbors producing the lowest rates (50-60%). Trawl failures were generally a result of rocky bottom or related obstructions. Trawling restrictions regarding site criteria achieved 95% compliance for site occupation accuracy, 94% were within 10% of the nominal depth, and 94% were within ± 1 minute of the proper duration. Most outliers were probably the result of transcription rather than performance errors.

The B'03 station occupation success rate was intermediate between that of 1994 (81%) and 1998 (69%), and probably reflected the continued inclusion of sites in difficult to sample areas (islands, shelf break zone, bays/harbors) little sampled in 1994 (Allen *et al.* 1998, 2002a). The slight improvement over 1998 may actually document a decline in relative success, since 37% of the sites were in either island or bay subpopulations in 1998, and only 26% were in 2003. As these were the most difficult to trawl areas, with the highest proportion of failures in both surveys, the 3% improvement in trawl success between surveys does not seem proportionate to the 30% decline in the number of sites from hard-to-sample subpopulations.

Location of actual trawl sites relative to the nominal random sites was considerably better in 2003 than in 1998. This was due, in part, to the difficulty of site occupation experienced in the earlier survey. As a result of the low site locational success in 1998, the maximum allowable deviation from the nominal site was increased from 100 to 200 m within the island subpopulation. In 1998, 69% of the successful trawls were within the stipulated 100 m circle representing allowable site location variance (Allen *et al.* 2002a); in the present survey that value rose to 95% within the allowable variance circle (100 m or 200 m depending upon subpopulation). Equivalent data were not gathered in 1994 (Allen *et al.* 1998).

Once each trawling site was occupied, and prior to performing the trawl, the nominal depth of the site was determined from fathometer records by the captain or chief scientist. This established the basis for maintaining the trawl within ±10% of nominal depth while towing along an isobath, a performance criterion. In 1998, 85% of the successful trawls met the criterion (Allen *et al.* 2002a). In the present effort 94% of trawls were within these limits. Data on maintenance of isobath trawling was not gathered in 1994 (Allen *et al.* 1998).

The difficulty of performing 10-min trawls at randomly selected sites within bays and harbors led to a decision to use 5-min trawls where conditions did not permit a full 10 minute tow in Bight '98. This was continued in Bight '03. After normalizing the two trawl durations in 1998, 93% of the successful trawls had durations of 10 min ±0.5 min. In Bight '03, 94% of the successful trawls had durations of 10 min ±1.0 min. This is roughly equivalent performance, although the acceptable error bounds have been doubled for the current survey. These compliance statistics are based on surface GPS positioning as captured by the vessel navigational software from the GPS satellite signal and recorded by the Field Computer system during the trawl. Preliminary data from pressure-temperature sensors on the trawl doors in shallow water trawls, however, did not record the same on-bottom time calculated from surface GPS readings. The actual on-bottom durations so recorded are thus an approximation, and may vary between agency, and between individual trawls. Investigation of this issue should be on-going in an effort to further standardize trawl sampling procedures. No trawl duration statistics were gathered in the 1994 SCBPP except by stopwatch during field audits (Allen *et al.* 1998). The range of trawl durations in the 11 audits was 7-11 minutes, suggesting that overall performance has probably improved in terms of duration since 1994.

Trawling with the small net utilized throughout the SCB is as much an art as a science. Research vessels, either twin screw or single screw, have a difficult time moving slowly enough to maintain the trawl net on the bottom. Tow speed is not reliably provided by any standard vessel instrumentation, and has to be estimated based on the captain's experience of the relationship between forward motion and engine speed under variable wind and sea conditions. The GPS satellite position feed now provides information on vessel location that can be used to calculate distance traveled, and vessel speed can then be calculated based on distance traveled and trawl duration. Speeds were requested to remain between 0.8 and 1.0 m/sec prior to the survey, as in Bight '98. Performance in that survey showed an average trawl speed of 0.92 m/sec by back-calculation based on recorded trawl distance and duration, but only 50% of successful trawls fell within the requested speed limits. In the present survey that rose to 59%. Performance improvements are likely to be slow in coming, especially if the surface recorded trawl durations are not as accurate as at first believed. Field performance audits reported for the SCBPP (Allen *et al.* 1998) indicate that calculated trawling speeds ranged from 0.75-1.2 m/sec, roughly the range for 82% of the speeds calculated for successful Bight '03 trawls. Average speed and overall performance were not reported for that survey.

Efforts to increase the relative success of the trawling program in future should concentrate on modifying strict random selection and random draw to better reflect habitat complexities. Compliance with target fish acquisition for tissue analysis is also inherently at the mercy of the fish and not trawl practice. The 86% achievement of the desired fish composite number in 2003 must be regarded as very good, despite falling short of the 98% reached in 1998 (Allen *et al.* 2002a). While the MQO need not be lowered for such efforts, we need to interpret noncompliance correctly.

Taxonomic Goals

In-survey field audits showed all agencies followed the Field Manual (B'03 Field Sampling & Logistics Committee 2003) procedures. Presurvey taxonomic quality assurance prepared taxonomists for the survey as demonstrated by both the presurvey bucket testing, and the postsurvey taxonomic results. Postsurvey taxonomic quality control showed a 94% overall accuracy in field identifications of fish and invertebrate species, and nearly 100% precision. The application of the FID procedure, returning unrecognized specimens to the laboratory for identification, worked very well for fishes, but less well for invertebrates. Not all animals that should have been so treated were returned to the lab, leading to some inaccurate field voucher identifications. These difficulties stem not from the program design, but from the implementation. It is evident from the results (Table III-4) that some of the participating groups did not receive sufficient QA pretraining to allow full facility in identification of invertebrates in the field. Only one of the four teams failing to meet the accuracy MQO for invertebrate identification required two attempts to pass the QA practicum. This procedure, while a useful step, did not effectively guarantee subsequent field performance. Resolving this issue prior to the next regional survey should be a priority.

Fish Tissue Chemistry Goals

Chemistry QC showed that labs complied with the QA Plan (Table IV-2). QC measures were almost all within established performance limits.

Problems Associated With Sampling

Most of the MQOs which were not met involved field effort. These are contingent on the design and execution of the field portion of the survey. The basic design of randomized station selection based on an areal stratification of effort (Overton *et al.* 1990) is inherently of lower success in a habitat mosaic of hard and soft substrates such as that found in large areas of the SCB, particularly around the northern Channel Islands. This same problem was noted in the previous regional survey, which recommended that known untrawlable areas be excluded from the survey design (Allen *et al.* 2002a). This was not done in allocation of the selected sites for occupation during Bight '03. In consequence, the problems with achieving the MQO for trawling success experienced in 1998 recurred in 2003.

Pressure-Temperature Sensor

The pressure-temperature sensor was used experimentally to allow an agency trawling within the upper slope strata to evaluate their performance. Some agencies successfully used them and others did not. If field crews did not use the device, they followed the procedures outlined in the Field Manual. The limited data available indicates usefulness of the sensor in evaluating on-bottom times. The requirement for using this devise for sites deeper than 300m proved 50% successful with 56% being within proper bottom times. Where data was available on shallow stations, the on-bottom times often differed from shipboard times. This casts doubt on the reported 94% compliance with the duration of trawl MQO. The differences between surface based trawl duration and pressure-temperature sensor determined that on-bottom time must be further explored. These data can be used to adjust trawl protocols (e.g., wire scope based on wire diameter) for future surveys. The device used here and similar devices have great appeal due to their relative low cost, easy data download, and instant data graphic presentation by the software.

Problematic areas include manufacturing issues, field crew training/experience with the devices, and activation/downloading issues under at-sea conditions. In future surveys, there should be enough lead-time provided for agencies to acquire and gain experience with the devices prior to the start of the field effort.

Improving Quality Assurance/Control in Future Multi-agency Surveys

Presurvey

- Continue the current quality assurance procedures implemented during the Bight '03 regional trawl survey.

- Develop better within-agency training and taxonomic aids for FID animals. Target organizations with historically large FID collections and new agencies or field teams.

- Increase training on proper data recording. In particular, how to correctly fill out species datasheets. Any deviation from the Field Manual instructions needs to be documented on the datasheets.

In-survey

- Continue the field audit program using taxonomic QA experts in fish or invertebrate identification.

- A pressure-temperature sensor or similar device should be used in the next regional survey and its use should be expanded to include all depths. Field crews, if necessary, could redo trawls during the survey and adjust trawl protocols to match boat characteristics for similar depth stations. The survey may want to develop a QC program to validate on bottom times while in the field. The data structure in the database should be changed to allow easier postsurvey analysis.

Postsurvey

- Continue current QC laboratory procedures. Develop better QC tracking database tables to clearly follow samples from collection, processing (i.e., dissection, homogenization), extraction, and final instrument analysis. The QA Plan stresses following batches though the analysis process and checking that QC protocols were done on the batches. The QA Plan also stresses MDL and reporting limit (RL) protocols that were not clearly available in the database.

- Develop a block change protocol in the IM Plan. In many cases after an agency has submitted their data to the surveys database, QC procedures can find quite a few errors (blocks). The data submittal process could be streamlined to allow an EXCEL spreadsheet style format to serve as a block submittal.

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 mainland shelf (Emery 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 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 human effects on the southern California mainland shelf (Allen *et al.* 1998, 2002a; Allen 2006b).

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. Past regional studies compiled trawl data from various times and places (SCCWRP 1973, Mearns *et al.* 1976, Allen and Voglin 1976, Allen 1977, Allen 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 or the islands located offshore of the SCB. A second regional survey conducted in 1998 (Allen *et al.* 2002a) 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 (results presented here), 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 section 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 bays/harbors and islands), upper slope and predetermined geographic, bathymetric, and human influence subpopulations in 2003; 2) to assess temporal population changes 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 Fish Ectoparasites sections of this report (Sections VI and VII, respectively).

Results

Population Attributes

Abundance per Haul

A total of 61,687 fish were collected during the survey (Table IV-1). The number of fish collected per haul ranged from 8 to 1,569. The lowest individual value occurred at a station in the northern region of the upper slope, and the highest value occurred in the northwest (cool)

Channel Islands on the middle shelf (Table IV-1). The median for the SCB as a whole was 192 individuals per haul, with subpopulation medians ranging from 60 (bays and harbors) to 840 (upper slope of Channel Islands). Fish abundance (all depths combined) was higher in the island region (average 100% above the SCB median) than in the mainland region (average 40.7%) (Table IV-1; Appendix B-B1). Among the island subpopulations, the northwest (cool) islands had higher fish abundance than the southeast (warm) islands; median numbers of fish were 578 and 357, respectively. Among the mainland region subpopulations, both the central and southern regions had higher median number of fish (230 and 217, respectively) than the northern (79) region. When the different shelf zones were compared, the middle shelf had the highest median fish abundance, followed by the outer shelf, inner shelf, upper slope, and bays/harbors; median numbers of fish were 367, 309, 118, 72, and 60, respectively (Table IV-1).

Within the upper slope zone, the only sample from the island region was an order of magnitude higher than the median abundance of the mainland region (Table IV-1; Appendix B-B2). Medians within the outer shelf zone subpopulations were similar, although the island median (355) was higher than that of the mainland and large POTWs (287 and 259, respectively). Within the middle shelf zone, the large POTWs had the highest median abundance (434) and the small POTWs the lowest (185). Within the inner shelf zone subpopulations, the large POTW median (594) was considerably higher than those of other mainland areas (118) or small POTWs (60; Table IV-1).

Comparison of regions within shelf zones revealed that the highest median fish abundance (840) was found at the northwest Channel Islands on the upper slope, and the lowest was in the central region bays and harbors (44; Table IV-2; Appendix B-B3). Trawl stations were divided into four abundance groups (based upon the 10^{th}, median, and 90^{th} percentiles; Figure IV-1). Stations within the upper decile group (612 to 1569 individuals per haul) were primarily located in the middle and outer shelf (Figure IV-1; Tables IV-1 and IV-2).

Biomass per Haul

A total of 1,688.1 kg of fish were taken during the survey (Table IV-3). The biomass of fish per haul ranged from 0.3 to 118.4 kg. Values of 0.3 kg occurred in the northern mainland region within the upper slope zone. The highest biomass occurred in the central region within the bays and harbors. The median for the Bight as a whole was 6.5 kg per haul, with subpopulation medians ranging from 2.3 kg (inner shelf small POTWs) to 20.1 kg (upper slope islands subpopulation). Fish biomass was higher (more area above the Bight median) at the islands than in the mainland region (Table IV-3; Appendix B-B4). Among the island regions, the southeast (warm) island subpopulations had a median of 11.3 kg versus 9.0 kg for the northwest (cool) island subpopulations. Among the mainland regions, the central region had a higher median fish biomass (8.1 kg) than either the southern (5.9 kg) or northern regions (3.6 kg). Within major shelf zones, the outer shelf subpopulation had the highest median biomass (8.5 kg), followed by the upper slope (7.8 kg), middle shelf (6.3 kg), bays and harbors (5.2), and inner shelf zones (3.6 kg).

Table IV-1. Demersal fish abundance by subpopulation at depths of 2-476 m on the shelf and upper slope of southern California, July-October 2003.

Subpopulation	No. of Stations	Total Individuals	Abundance (Number of Individuals/Haul) Range Min.	Max.	Area-Weighted Values Median	Mean	SD	95% CL	Percent Above Bight Median
Region									
Mainland	**181**	**45,885**	**8**	**942**	**146**	**220**	**201**	**41**	**40.7**
Northern	54	10,289	8	942	79	136	158	45	15.3
Central	72	22,976	14	937	230	341	217	78	70.7
Southern	55	12,620	10	766	217	237	174	75	63.0
Island	**29**	**15,802**	**204**	**1,569**	**410**	**545**	**344**	**125**	**100.0**
Cool (NW Channel Islands)	16	10,534	204	1,569	578	658	407	199	100.0
Warm (SE Channel Islands)	13	5,268	220	757	357	405	159	86	100.0
Shelf Zone									
Bays and Harbors (2-30 m)	**26**	**2,918**	**10**	**526**	**60**	**112**	**124**	**48**	**18.4**
Inner Shelf (2-30 m)	**43**	**8,368**	**9**	**852**	**118**	**181**	**144**	**50**	**36.8**
Small POTWs	15	1,987	9	507	60	132	154	78	17.9
Large POTWs	3	2,041	386	852	594	680	209	237	100.0
Other Mainland	25	4,340	17	490	118	174	128	50	36.0
Middle Shelf (31-120 m)	**87**	**35,434**	**39**	**1,569**	**367**	**415**	**283**	**73**	**82.2**
Small POTWs	12	2,920	93	512	185	243	133	75	46.6
Large POTWs	25	10,536	57	813	434	421	164	64	92.4
Mainland non-POTW	26	8,912	39	937	302	343	201	77	71.2
Island	24	13,066	204	1,569	379	544	362	145	100.0
Outer Shelf (121-200 m)	**26**	**9,466**	**10**	**942**	**309**	**379**	**251**	**99**	**76.1**
Large POTWs	1	259	259	259	259	259	0	0	100.0
Mainland	21	7,311	10	942	287	342	257	104	66.1
Island	4	1,896	274	826	355	474	212	207	100.0
Upper Slope (201-500 m)	**28**	**5,501**	**8**	**840**	**72**	**146**	**176**	**59**	**17.6**
Mainland	27	4,661	8	766	71	136	157	57	16.5
Island	1	840	840	840	840	840	0	0	100.0
Total (all stations)	**210**	**61,687**	**8**	**1,569**	**192**	**271**	**259**	**45**	**50.0**

The average area sampled during a trawl tow was 3,014 m^2.
CL = Confidence limits (± value); Min. = Minimum; Max. = Maximum; No. = Number;
SD = Standard deviation.
POTW = Publicly owned treatment work monitoring areas.

Table IV-2. Demersal fish abundance by region within shelf zone subpopulations at depths of 2-476 m on the southern California shelf and upper slope, July-October, 2003.

			Abundance (No. Individuals/Haul)						Percent
					Area-Weighted Values				Above
	No. of	Total	Range					95%	Bight
Subpopulation	Stations	Individuals	Min.	Max.	Median	Mean	SD	CL	Median
Shelf Zone									
Bays and Harbors (2-30 m)	**26**	**2,918**	**10**	**526**	**60**	**112**	**124**	**48**	**18.4**
Northern Region	1	166	166	166	166.0	166.0	0.0	0.0	0.0
Central Region	16	2159	14	526	44.0	134.9	145.0	71.1	24.1
Southern Region	9	593	10	215	50.0	65.9	60.0	38.9	2.0
Inner Shelf (2-30 m)	**43**	**8,368**	**9**	**852**	**118**	**181**	**144**	**50**	**36.8**
Northern Region	21	4226	9	507	113.5	196.4	154.0	82.4	37.5
Central Region	11	3340	21	852	196.3	232.2	144.0	66.4	52.7
Southern Region	11	802	18	204	79.9	92.9	59.0	46.4	2.2
NW Channel Islands	0	--	--	--	--	--	--	--	--
SE Channel Islands	0	--	--	--	--	--	--	--	--
Middle Shelf (31-120 m)	**87**	**35,434**	**39**	**1,569**	**367**	**415**	**283**	**73**	**82.2**
Northern Region	6	1039	39	320	114.4	144.3	89.0	77.6	14.7
Central Region	33	13080	57	937	416.7	421.5	222.0	111.0	79.5
Southern Region	24	8249	93	623	369.4	342.3	93.0	51.0	86.6
NW Channel Islands	13	8594	204	1569	513.0	661.1	433.0	235.6	100.0
SE Channel Islands	11	4472	220	757	328.0	406.5	171.0	101.3	100.0
Outer Shelf (121-200 m)	**26**	**9,466**	**10**	**942**	**309**	**379**	**251**	**99**	**76.1**
Northern Region	8	2488	10	942	97.0	311.0	354.0	245.7	37.2
Central Region	8	3511	53	823	411.5	455.5	222.0	158.9	91.5
Southern Region	6	1571	131	474	278.5	273.4	92.0	62.8	73.2
NW Channel Islands	2	1100	274	826	274.0	550.0	276.0	382.5	100.0
SE Channel Islands	2	796	355	441	355.0	398.0	43.0	59.6	100.0
Upper Slope (201-500 m)	**28**	**5,501**	**8**	**840**	**72**	**146**	**176**	**59**	**17.6**
Northern Region	18	2370	8	663	65.9	105.3	131.0	57.7	6.6
Central Region	4	886	65	421	169.0	221.5	130.0	127.0	40.7
Southern Region	5	1405	31	766	52.4	181.4	223.0	190.9	20.3
NW Channel Islands	1	840	840	840	840.0	840.0	0.0	0.0	100.0
SE Channel Islands	0	--	--	--	--	--	--	--	--
Total (all stations)	**210**	**61,687**	**8**	**1,569**	**192**	**271**	**259**	**45**	**50.0**

The average area sampled during a trawl tow was 3,014 m^2.
CL = Confidence limits (± value); Min. = Minimum; Max. = Maximum; No. = Number;
SD = Standard deviation.
POTW = Publicly owned treatment work monitoring areas.

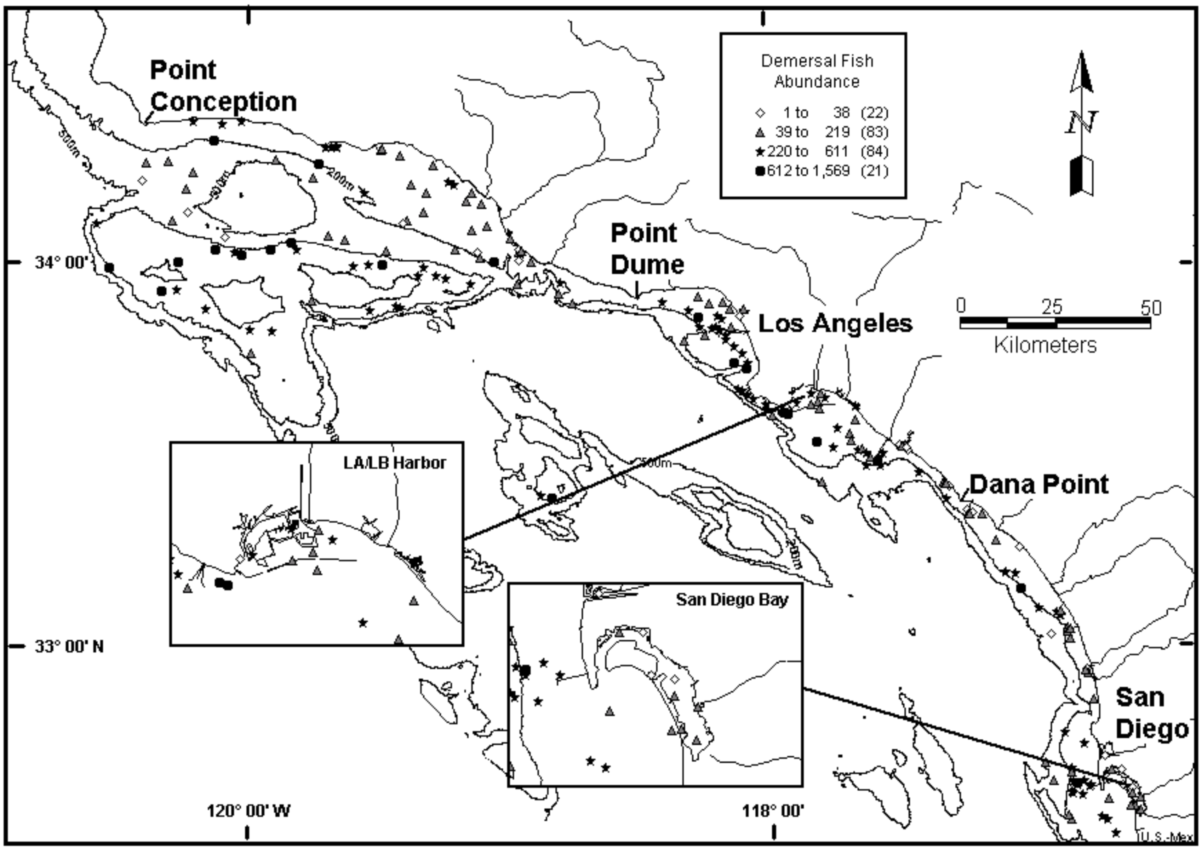


Figure IV-1. Distribution of fish abundance per haul at depths of 2-476m on the southern California shelf and upper slope, July-October 2003.

In the upper slope shelf zone (Table IV-3; Appendix B-B5), the island region had considerably higher fish biomass than the mainland region. In the outer shelf zone, the island region had higher biomass than the large POTW and other mainland regions. In the middle shelf zone, the island region had the highest biomass and the small POTW subpopulation had the lowest. In the inner shelf zone, large POTWs had a considerably greater median biomass than either small POTW or other mainland subpopulations.

Comparing regions within the shelf zones revealed that the highest median biomass (20.1 kg) was taken in the northwest Channel Islands within the upper slope subpopulation (Table IV-4; Appendix B-B6). Trawl stations were divided into four biomass groups (Figure IV-2). Stations within the highest biomass group (15.3 to 118.4 kg per haul) were primarily located in the outer shelf and upper slope (Figure IV-1; Tables IV-3 and IV-4).

Species Richness (Number of Species per Haul)

A total of 142 species of fish were taken during the survey (Table IV-5). The number of fish species per haul ranged from 3 to 25. The lowest value occurred in the southern region within bays and harbors and the highest number of species occurred in the southeast Channel Islands within the middle shelf zone. The median for the SCB as a whole was 12 species per haul, with subpopulation medians ranging from 8 (inner shelf small POTWs) to 18 (upper slope Channel Islands). More of the area with species richness above the Bight median occurred in the island region than in the mainland region (Table IV-5; Appendix B-B7). Among the islands, the southeast and northwest Channel Islands were identical (both with a median of 16 species). Among the mainland region subpopulations, only the southern region had a median (14) above that of the Bight median, while the northern region (9) was lower and central region (12) the same. Of the five major shelf zones, the middle shelf had the highest median number of species, followed by the outer shelf, upper slope, inner shelf, and bays and harbors; with medians of 16, 15, 9, 9, and 8, respectively. Within the upper slope zone (Table IV-5; Appendix B-B8), the island region had greater species richness than the mainland region. Within all shelf zones, the large POTWs had the highest median number of species.

Comparing the regions within the shelf zones (Table IV-6; Appendix B-B9) revealed that the median number of species (18) occurred at the northwest Channel Islands on both the outer shelf and upper slope. Trawl stations were divided into four richness groups (Figure IV-2). Stations within the highest richness group (20 to 26 species per haul) were primarily located in the middle and outer shelf (Figure IV-2; Tables IV-5 and IV-6).

Table IV-3. Demersal fish biomass by subpopulation at depths of 2-476 m on the shelf and upper slope of southern California, July-October 2003.

			Biomass (kg/haul)						Percent
					Area-Weighted Values				Above
	No. of		Range					95%	Bight
Subpopulation	Stations	Total (kg)	Min.	Max.	Median	Mean	SD	CL	Median
Region									
Mainland	**181**	**1,358.3**	**0.3**	**118.4**	**5.9**	**6.8**	**5.7**	**1.1**	**53.3**
Northern	54	299.7	0.3	40.9	3.6	5.8	5.7	1.8	34.3
Central	72	772.1	1.4	118.4	8.1	9.2	6.8	1.9	61.9
Southern	55	286.5	0.5	17.1	5.9	6.0	2.7	1.0	85.6
Island	**29**	**329.8**	**3.2**	**29.8**	**10.2**	**11.4**	**6.1**	**2.2**	**75.9**
Cool (NW Channel Islands)	16	172.3	3.5	25.3	9.0	10.8	6.0	2.9	67.3
Warm (SE Channel Islands)	13	157.5	3.2	29.8	11.3	12.1	6.2	3.4	84.6
Shelf Zone									
Bays and Harbors (2-30 m)	**26**	**318.1**	**1.0**	**118.4**	**5.2**	**12.2**	**22.3**	**8.6**	**47.5**
Inner Shelf (2-30 m)	**43**	**180.5**	**0.6**	**12.2**	**3.6**	**4.0**	**2.6**	**1.0**	**21.0**
Small POTWs	15	49.7	1.3	10.3	2.3	3.3	2.4	1.2	7.1
Large POTWs	3	33.1	10.2	12.2	10.5	11.0	0.8	1.0	100.0
Other Mainland	25	97.7	0.6	9.9	3.6	3.9	2.5	1.0	16.8
Middle Shelf (31-120 m)	**87**	**679.5**	**0.5**	**29.8**	**6.3**	**7.7**	**5.7**	**1.5**	**43.7**
Small POTWs	12	49.0	0.5	9.4	3.5	4.1	2.1	1.2	7.8
Large POTWs	25	221.8	1.8	22.6	7.4	8.9	5.4	2.1	60.6
Mainland non-POTW	26	156.2	0.9	20.2	4.9	6.0	4.7	1.8	26.9
Island	24	252.5	3.2	29.8	9.2	10.5	6.1	2.4	70.8
Outer Shelf (121-200 m)	**26**	**271.3**	**0.5**	**40.9**	**8.5**	**10.7**	**7.7**	**2.9**	**76.4**
Large POTWs	1	9.9	9.9	9.9	9.9	9.9	0.0	0.0	100.0
Mainland	21	204.2	0.5	40.9	6.6	9.3	8.4	3.5	66.5
Island	4	57.2	8.3	18.7	15.0	14.3	3.8	3.7	100.0
Upper Slope (201-500 m)	**28**	**238.7**	**0.3**	**22.9**	**7.8**	**8.0**	**5.3**	**2.0**	**53.2**
Mainland	27	218.6	0.3	22.9	7.5	7.8	5.2	2.0	52.6
Island	1	20.1	20.1	20.1	20.1	20.1	0.0	0.0	100.0
Total (all stations)	**210**	**1688.1**	**0.3**	**118.4**	**6.5**	**7.6**	**6.0**	**1.0**	**50.0**

The average area sampled during a trawl tow was 3,014 m^2.
CL = Confidence limits (± value); Min. = Minimum; Max. = Maximum; No. = Number;
SD = Standard deviation.
POTW = Publicly owned treatment work monitoring areas.

Table IV-4. Demersal fish biomass by region within shelf zone subpopulations at depths of 2-476 m on the shelf and upper slope of southern California, July-October, 2003.

			Biomass (kg/haul)						Percent
					Area-Weighted Values				Above
	No. of		Range					95%	Bight
Subpopulation	Stations	Total (kg)	Min.	Max.	Median	Mean	SD	CL	Median
Shelf Zone									
Bays and Harbors (2-30 m)	**26.0**	**318.1**	**1.0**	**118.4**	**5.2**	**12.2**	**22.3**	**8.6**	**47.5**
Northern Region	1.0	9.0	9.0	9.0	9.0	9.0	0.0	0.0	100.0
Central Region	16.0	253.8	1.6	118.4	7.2	15.9	27.5	13.5	52.2
Southern Region	9.0	55.3	1.0	17.0	3.1	6.1	5.7	3.7	26.5
Inner Shelf (2-30 m)	**43.0**	**180.5**	**0.6**	**12.2**	**3.6**	**4.0**	**2.6**	**1.0**	**21.0**
Northern Region	21.0	67.3	0.6	9.9	2.6	3.5	2.8	1.5	17.9
Central Region	11.0	73.3	2.2	12.2	3.7	5.0	2.7	1.8	23.6
Southern Region	11.0	39.9	1.1	6.6	4.2	4.0	1.4	1.1	0.0
NW Channel Islands	0.0	--	--	--	--	--	--	--	--
SE Channel Islands	0.0	--	--	--	--	--	--	--	--
Middle Shelf (31-120 m)	**87.0**	**679.5**	**0.5**	**29.8**	**6.3**	**7.7**	**5.7**	**1.5**	**43.7**
Northern Region	6.0	13.7	1.0	4.2	1.7	1.9	0.7	0.6	0.0
Central Region	33.0	309.3	1.8	22.6	6.5	8.5	5.4	2.6	49.4
Southern Region	24.0	104.0	0.5	8.0	5.1	4.8	2.0	1.3	12.7
NW Channel Islands	13.0	119.0	3.5	25.3	8.7	9.1	5.3	2.9	59.8
SE Channel Islands	11.0	134.0	3.2	29.8	11.3	12.2	6.6	3.9	81.8
Outer Shelf (121-200 m)	**26.0**	**271.3**	**0.5**	**40.9**	**8.5**	**10.7**	**7.7**	**2.9**	**76.4**
Northern Region	8.0	86.4	0.5	40.9	7.0	10.8	12.4	8.6	51.5
Central Region	8.0	89.1	1.4	23.9	10.1	11.3	6.5	4.7	72.7
Southern Region	6.0	38.6	3.4	10.2	5.3	6.5	2.1	1.4	24.6
NW Channel Islands	2.0	33.7	15.0	18.7	15.0	16.9	1.9	2.6	100.0
SE Channel Islands	2.0	23.5	8.3	15.2	8.3	11.8	3.5	4.8	100.0
Upper Slope (201-500 m)	**28.0**	**238.7**	**0.3**	**22.9**	**7.8**	**8.0**	**5.3**	**2.0**	**53.2**
Northern Region	18.0	123.3	0.3	22.9	5.0	6.8	5.4	2.6	41.5
Central Region	4.0	46.6	8.1	18.5	8.6	11.7	4.2	4.1	100.0
Southern Region	5.0	48.7	6.3	17.1	6.7	8.2	2.3	1.6	51.8
NW Channel Islands	1.0	20.1	20.1	20.1	20.1	20.1	0.0	0.0	100.0
SE Channel Islands	0.0	--	--	--	--	--	--	--	--
Total (all stations)	**210.0**	**1688.1**	**0.3**	**118.4**	**6.5**	**7.6**	**6.0**	**1.0**	**50.0**

The average area sampled during a trawl tow was 3,014 m^2.
CL = Confidence limits (± value); Min. = Minimum; Max. = Maximum; No. = Number;
SD = Standard deviation.
POTW = Publicly owned treatment work monitoring areas.

Table IV-5. Demersal fish species by subpopulation at depths of 2-476 m on the shelf and upper slope of southern California, July-October 2003.

Subpopulation	No. of Stations	Total Species	Number of Species /Haul) Range Min.	Max.	Area-Weighted Values Median	Mean	SD	95% CL	Percent Above Bight Median
Region									
Mainland	181	131	3	24	11	12	5	1	42.0
Northern	54	90	4	21	9	10	4	1	31.4
Central	72	91	4	24	12	13	5	2	45.3
Southern	55	94	3	22	14	13	4	2	59.4
Island	29	63	8	25	16	16	3	1	86.2
Cool (NW Channel Islands)	16	51	8	21	16	16	3	2	84.4
Warm (SE Channel Islands)	13	49	12	25	16	17	3	2	84.6
Shelf Zone									
Bays and Harbors (2-30 m)	26	38	3	21	8	8	4	2	13.2
Inner Shelf (2-30 m)	43	56	3	21	9	9	4	2	20.5
Small POTWs	15	40	4	14	8	8	3	2	6.7
Large POTWs	3	21	12	16	13	14	2	2	66.7
Other Mainland	25	44	3	21	9	9	4	2	20.0
Middle Shelf (31-120 m)	87	82	8	25	16	16	4	1	81.3
Small POTWs	12	44	8	20	15	15	4	2	75.0
Large POTWs	25	49	11	20	17	16	2	1	92.0
Mainland non-POTW	26	59	8	24	16	16	4	2	76.9
Island	24	58	8	25	16	16	3	1	87.5
Outer Shelf (121-202 m)	26	52	4	22	15	14	4	2	66.3
Large POTWs	1	16	16	16	16	16	0	0	100.0
Mainland	21	45	4	22	13	13	4	2	62.4
Island	4	33	12	19	15	16	3	2	75.0
Upper Slope (201-500 m)	28	48	4	18	9	10	3	1	25.4
Mainland	27	44	4	16	9	10	3	1	24.3
Island	1	18	18	18	18	18	0	0	100.0
Total (all stations)	**210**	**142**	**3**	**25**	**12**	**12**	**5**	**1**	**50.0**

* The average area sampled during a trawl tow was 3,014 m^2.
CL = Confidence limits (± value); Min. = Minimum; Max. = Maximum; No. = Number;
SD = Standard deviation.
POTW = Publicly owned treatment work monitoring areas.

Table IV-6. Demersal fish species by region within shelf zone subpopulations at depths of 2-476 m on the shelf and upper slope of southern California, July-October, 2003.

			Number of Species/Haul						Percent
					Area-Weighted Values				Above
	No. of	Total	Range					95%	Bight
Subpopulation	Stations	Species	Min.	Max.	Median	Mean	SD	CL	Median
Shelf Zone									
Bays and Harbors (2-30 m)	**26**	**38**	**3**	**21**	**8**	**8**	**4**	**2**	**13.2**
Northern Region	1	3	4	4	4	4	0	0	0.0
Central Region	16	34	4	21	9	10	4	2	21.4
Southern Region	9	17	3	11	6	6	3	2	0.0
Inner Shelf (2-30 m)	**43**	**56**	**3**	**21**	**9**	**9**	**4**	**2**	**20.5**
Northern Region	21	45	4	21	9	10	5	3	22.9
Central Region	11	29	6	16	9	10	2	2	19.6
Southern Region	11	31	3	13	6	8	3	3	16.3
NW Channel Islands	0	--	--	--	--	--	--	--	--
SE Channel Islands	0	--	--	--	--	--	--	--	--
Middle Shelf (31-120 m)	**87**	**82**	**8**	**25**	**16**	**16**	**4**	**1**	**81.3**
Northern Region	6	33	9	19	14	14	3	3	65.1
Central Region	33	54	8	24	16	16	5	2	71.3
Southern Region	24	54	8	22	16	16	3	2	88.0
NW Channel Islands	13	45	8	21	16	15	3	2	80.8
SE Channel Islands	11	45	12	25	17	17	3	2	90.9
Outer Shelf (121-200 m)	**26**	**52**	**4**	**22**	**15**	**14**	**4**	**2**	**66.3**
Northern Region	8	38	4	16	8	11	5	3	41.7
Central Region	8	33	8	22	13	14	4	3	63.6
Southern Region	6	28	11	18	14	15	3	3	66.4
NW Channel Islands	2	25	17	19	18	1	1	1	100.0
SE Channel Islands	2	21	12	16	14	2	2	3	100.0
Upper Slope (201-500 m)	**28**	**48**	**4**	**18**	**9**	**10**	**3**	**1**	**25.4**
Northern Region	18	37	4	16	9	10	3	2	24.2
Central Region	4	20	7	11	8	8	2	2	0.0
Southern Region	5	28	9	15	12	12	2	2	48.2
NW Channel Islands	1	18	18	18	18	18	0	0	100.0
SE Channel Islands	0	--	--	--	--	--	--	--	--
Total (all stations)	**210**	**142**	**3**	**25**	**12**	**12**	**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.
POTW = Publicly owned treatment work monitoring areas.

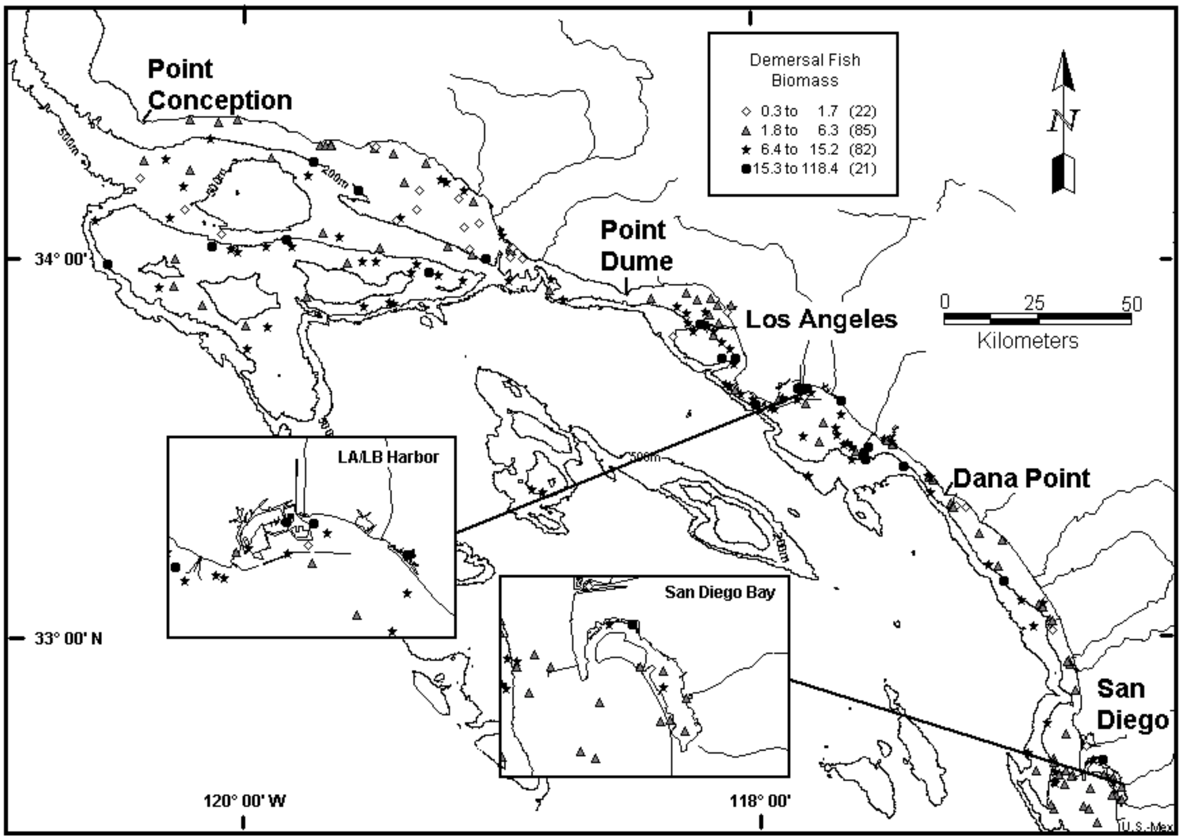


Figure IV-2. Distribution of fish biomass per haul at depths of 2-476 m on the southern California shelf, July-October 2003.

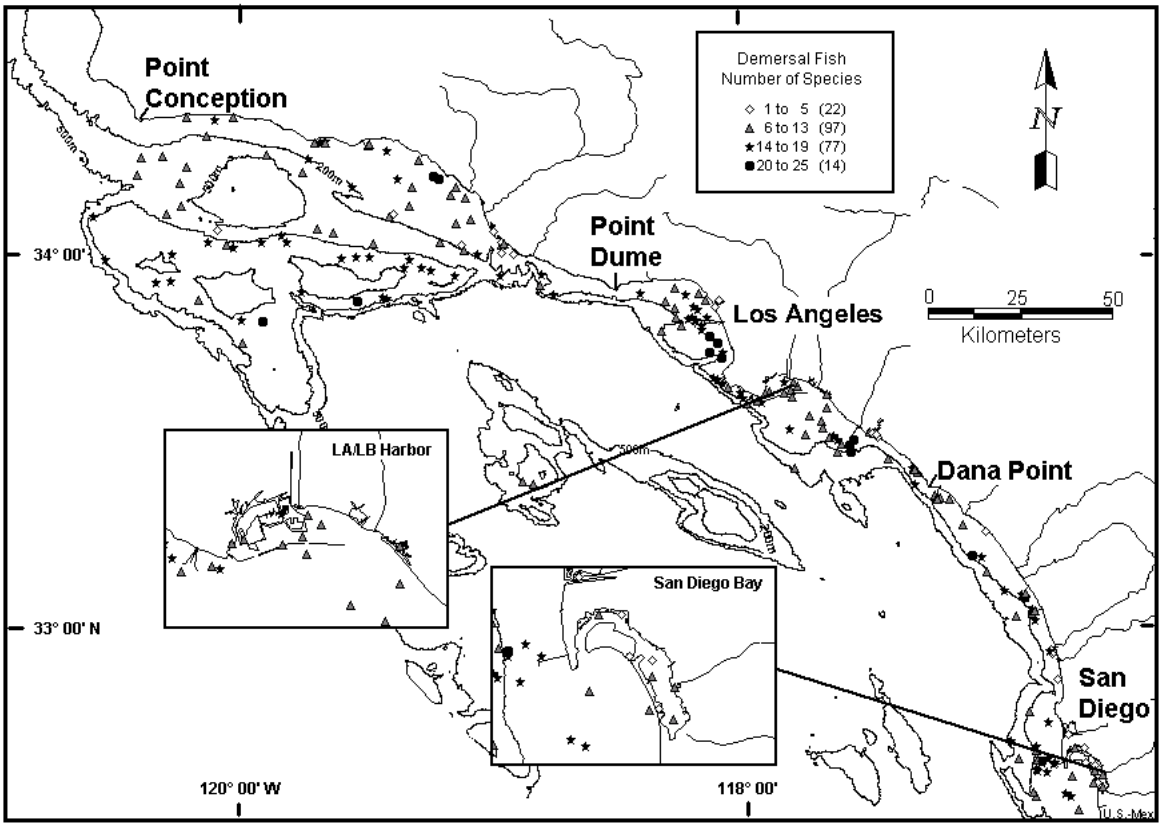


Figure IV-3. Distribution of number of fish species per haul at depths of 2-476 m on the southern California shelf and upper slope, July-October 2003.

Diversity per Haul

Fish diversity ranged from 0.18 to 2.29 bits/individual/haul (Table IV-7). The lowest value (0.18) occurred in the other (non-POTW) mainland subpopulation of the southern inner shelf. The highest value (2.29) occurred in the mainland region in the southern upper slope zone. The median for the Bight as a whole was 1.62, with subpopulation medians ranging from 0.66 (inner shelf, large POTWs) to 2.08 (islands, upper slope). Diversity was slightly higher (more area above the Bight median) in the mainland region than in the island region (Table IV-7; Appendix B-B10). Among the mainland region subpopulations, only the southern region had a median (1.77) above that of the Bight median, while the central (1.43) and southern regions (1.62) were slightly less. Among the islands, the northwest Channel Islands had greater diversity of fish (1.69) than the southeast Channel Islands (1.50; Table IV-7). Comparing among shelf zones, the middle shelf had the greatest median diversity, followed by the outer shelf, upper slope, inner shelf, and bays and harbors; with medians of 1.70, 1.68, 1.61, 0.99, and 0.91, respectively.

Within the upper slope subpopulation (Table IV-7; Appendix B-B11), the islands had higher diversity than the mainland. In the outer shelf zone, large POTWs had the highest diversity. Within both the middle and inner shelf zones, small POTWs had the highest diversity.

The regions within the shelf zones were also compared (Table IV-8; Appendix B-B12). This comparison revealed the greatest median diversity (2.08) was in the northwest Channel Islands within the upper slope zone. Trawl stations were divided into four diversity groups (Figure IV-4). Stations within the highest diversity group (2.04 to 2.29 per haul) were primarily located in the middle and outer shelf (Figure IV-4; Tables IV-7 and IV-8).

Table IV-7. Demersal fish diversity by subpopulation at depths of 2-476 m on the shelf and upper slope of southern California, July-September 2003.

		Shannon-Wiener Diversity (bits/individual/haul)						Percent
				Area-Weighted Values				Above
	No. of	Range					95%	Bight
Subpopulation	Stations	Min.	Max.	Median	Mean	SD	CL	Median
Region								
Mainland	**181**	**0.18**	**2.29**	**1.62**	**1.55**	**0.45**	**0.09**	**50.6**
Northern	54	0.26	2.26	1.62	1.58	0.40	0.12	49.3
Central	72	0.50	2.23	1.43	1.46	0.44	0.14	40.9
Southern	55	0.18	2.29	1.77	1.59	0.53	0.21	60.8
Island	**29**	**0.30**	**2.19**	**1.55**	**1.53**	**0.42**	**0.15**	**45.7**
Cool (NW Channel Islands)	16	0.79	2.19	1.69	1.58	0.42	0.21	52.8
Warm (SE Channel Islands)	13	0.30	2.03	1.50	1.48	0.42	0.23	32.6
Shelf Zone								
Bays and Harbors (2-30 m)	**26**	**0.35**	**2.09**	**0.91**	**1.11**	**0.49**	**0.19**	**19.5**
Inner Shelf (2-30 m)	43	0.18	2.04	0.99	1.12	0.47	0.18	17.3
Small POTWs	15	0.38	1.99	1.15	1.25	0.45	0.23	18.7
Large POTWs	3	0.63	1.12	0.66	0.81	0.22	0.25	0.0
Other Mainland	25	0.18	2.04	0.98	1.13	0.47	0.19	16.9
Middle Shelf (31-120 m)	**87**	**0.30**	**2.25**	**1.70**	**1.62**	**0.44**	**0.12**	**61.0**
Small POTWs	12	1.43	2.25	1.84	1.82	0.20	0.11	83.2
Large POTWs	25	1.00	2.09	1.77	1.72	0.29	0.11	67.7
Mainland non-POTW	26	0.68	2.25	1.76	1.67	0.45	0.17	66.1
Island	24	0.30	2.19	1.54	1.50	0.43	0.17	42.7
Outer Shelf (121-202 m)	**26**	**0.26**	**2.26**	**1.68**	**1.58**	**0.42**	**0.16**	**52.7**
Large POTWs	1	1.95	1.95	1.95	0.00	0.00	0.00	100.0
Mainland	21	0.26	2.26	1.68	1.57	0.46	0.20	53.1
Island	4	1.23	2.03	1.46	1.60	0.30	0.29	32.5
Upper Slope (201-500 m)	**28**	**0.89**	**2.29**	**1.61**	**1.63**	**0.33**	**0.13**	**48.6**
Mainland	27	0.89	2.29	1.61	1.62	0.32	0.13	47.9
Island	1	2.08	2.08	2.08	0.00	0.00	0.00	100.0
Total (all stations)	**210**	**0.18**	**2.29**	**1.62**	**1.54**	**0.44**	**0.1**	**50.0**

The average area sampled during a trawl tow was 3,014 m^2.
CL = Confidence limits (± value); Min. = Minimum; Max. = Maximum; No. = Number;
SD = Standard deviation.
POTW = Publicly owned treatment work monitoring areas.

Table IV-8. Demersal fish diversity by region within shelf zone subpopulations at depths of 2-476 m on the shelf and upper slope of southern California, July-October, 2003.

	Shannon-Wiener Diversity (bits/individual/haul)								Percent Above Bight Median
				Area-Weighted Values					
	No. of	Range					95%		
Subpopulation	Stations	Min.	Max.	Median	Mean	SD	CL		Median
Shelf Zone									
Bays and Harbors (2-30 m)	**26**	**0.35**	**2.09**	**0.91**	**1.11**	**0.49**	**0.19**		**19.5**
Northern Region	1	0.75	0.75	0.75	0.75	0.00	0.00		0.0
Central Region	16	0.50	2.09	1.36	1.33	0.47	0.23		31.7
Southern Region	9	0.35	1.41	0.70	0.75	0.28	0.19		0.0
Inner Shelf (2-30 m)	**43**	**0.18**	**2.04**	**0.99**	**1.12**	**0.47**	**0.18**		**17.3**
Northern Region	21	0.31	1.89	1.13	1.20	0.45	0.24		18.0
Central Region	11	0.56	1.57	0.86	0.89	0.20	0.15		0.0
Southern Region	11	0.18	2.04	1.04	1.20	0.62	0.48		33.4
NW Channel Islands	0	--	--	--	--	--	--		--
SE Channel Islands	0	--	--	--	--	--	--		--
Middle Shelf (31-120 m)	**87**	**0.30**	**2.25**	**1.70**	**1.62**	**0.44**	**0.12**		**61.0**
Northern Region	6	1.56	2.12	1.92	1.90	0.23	0.20		71.8
Central Region	33	0.95	2.23	1.77	1.69	0.39	0.20		67.5
Southern Region	24	0.68	2.25	1.63	1.53	0.54	0.35		61.6
NW Channel Islands	13	0.79	2.19	1.43	1.49	0.42	0.23		41.9
SE Channel Islands	11	0.30	2.03	1.54	1.51	0.45	0.26		38.5
Outer Shelf (121-200 m)	**26**	**0.26**	**2.26**	**1.68**	**1.58**	**0.42**	**0.16**		**52.7**
Northern Region	8	0.26	2.26	1.25	1.30	0.57	0.39		20.7
Central Region	8	0.85	2.13	1.66	1.64	0.45	0.32		56.0
Southern Region	6	1.60	2.04	1.78	1.78	0.12	0.08		76.3
NW Channel Islands	2	1.70	2.03	1.86	0.16	0.23	0.23		50.0
SE Channel Islands	2	1.23	1.43	1.33	0.10	0.14	0.14		0.0
Upper Slope (201-500 m)	**28**	**0.89**	**2.29**	**1.61**	**1.63**	**0.33**	**0.13**		**48.6**
Northern Region	18	0.89	2.25	1.64	1.65	0.29	0.14		53.2
Central Region	4	1.11	1.44	1.20	1.28	0.12	0.11		0.0
Southern Region	5	1.33	2.29	1.83	1.85	0.33	0.30		60.8
NW Channel Islands	1	2.08	2.08	2.08	2.08	0.00	0.00		100.0
SE Channel Islands	0	--	--	--	--	--	--		--
Total (all stations)	**210**	**0.18**	**2.29**	**1.62**	**1.54**	**0.44**	**0.08**		**50.0**

The average area sampled during a trawl tow was 3,014 m^2.
CL = Confidence limits (± value); Min. = Minimum; Max. = Maximum; No. = Number;
SD = Standard deviation.
POTW = Publicly owned treatment work monitoring areas.

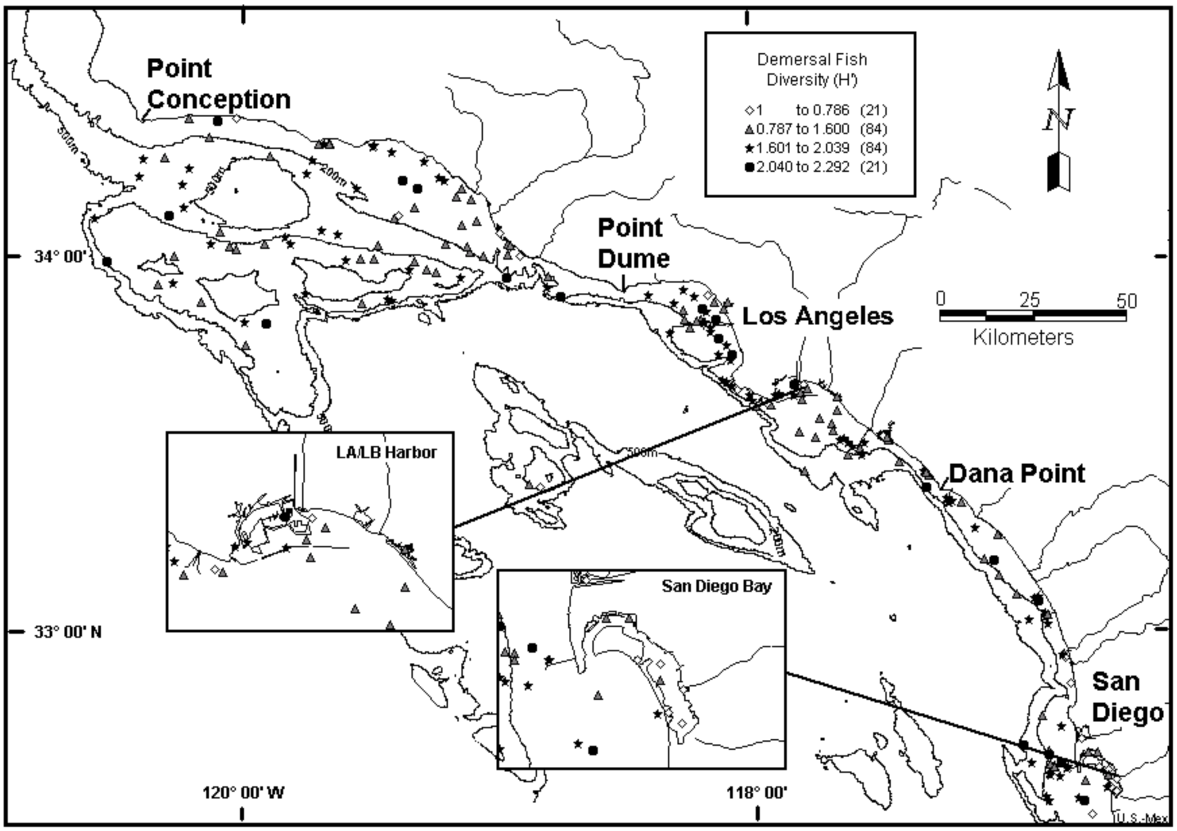


Figure IV-4. Distribution of fish diversity (Shannon-Wiener) per haul at depths of 2-476 m on the southern California shelf, July-October 2003.

Species Composition

Taxonomic Composition

A total of 142 species of fish, representing 3 classes and 52 families, were collected during the trawl survey (Appendix B-B13, Appendix F-F2, and Appendix F-F3). These consisted of 128 species of ray-finned fishes (Actinopterygii), 13 species of cartilaginous fishes (Chondrichthyes), and 1 species of hagfish (Myxini). The most diverse families were Scorpaenidae (rockfishes) with 25 species, Pleuronectidae (right-eye flounders) and Cottidae (sculpins) with 11 species each, Embiotocidae (surfperches) and Paralichthyidae (sand flounders) with 7 species each, and Agonidae (poachers) with 6 species. Two species, Colombian goby *(Bollmannia gomezi)* and whitetail tonguefish *(Symphurus oligomerus)* were taken for the first time in California during this survey.

Species Areal Occurrence

Of 142 species, relatively few occurred over a large proportion of the mainland shelf of the SCB. 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 (Figure IV-5; Appendix B-B14). Individually, 21 species (15% of all species) occurred in over 20% and only 2 (Dover sole, Pacific sanddab) in over 50% of the total area (Table IV-9). The 5 most widely distributed species were Dover sole, Pacific sanddab, English sole (*Parophrys vetulus*), slender sole, and stripetail rockfish (*Sebastes saxicola*). and a mean of 6 species occurred in more than 50% of the area of each shelf zone. Among the mainland and island regions, the southeast Channel Islands had the highest 5 most widely distributed species were Dover sole, Pacific sanddab, English sole (*Parophrys vetulus*), slender sole, and stripetail rockfish (*Sebastes saxicola*). and a mean of 6 species occurred in more than 50% of the area of each shelf zone. Among the mainland and island regions, the southeast Channel Islands had the highest Thirty species occurred in more than 50% of the area in at least one subpopulation (Table IV-10). A mean of 6 species occurred in more than 50% of the area of each subpopulation in the mainland and island regions, number of species (15) while the northern and southern mainland regions had the lowest (both with 2). Among the 5 shelf zones, the middle shelf had the highest number of species (13) occurring in 50% or more of the area and the bays and harbors had the least (1). Geographically, Dover sole was the most common species in the northern and southern mainland regions; hornyhead turbot was the most common species in the central region; Pacific sanddab was most common in the northwest Channel Islands; and Pacific sanddab, plainfin midshipman (*Porichthys notatus*), and shortspine combfish (*Zaniolepis frenata*) were most common in the southeast Channel Islands. Bathymetrically, Dover sole was the most common species in the upper slope zone, Dover sole and slender sole were most common in the outer shelf, Pacific sanddab was most common in the middle shelf, speckled sanddab in the inner shelf, and California halibut in the bays and harbors. The most widespread species, Dover sole, inhabited more than 50% of the area in all subpopulations except bays and harbors and inner shelf. The next most widespread species in this regard were Pacific sanddab (6 subpopulations), and English sole and stripetail rockfish (4 subpopulations). Sixteen species occurred in more than 50% of the area of only a single subpopulation (by region and depth). Regional or shelf zone specificity occurred in pygmy poacher (*Odontopyxis trispinosa*) and lingcod (northwest Channel Islands); spotted cusk-eel (*Chilara taylori*), curlfin sole, cowcod (*Sebastes levis*), chilipepper (*Sebastes goodei*), and spotfin sculpin (*Icelinus tenuis*) (southeast Channel Islands); California halibut (bays and harbors); speckled sanddab (inner shelf); roughback sculpin (*Chitonotus pugetensis*) (middle shelf); rex sole (*Glyptocephalus zachirus*), blacktip poacher (*Xeneretmus latifrons*), and blackbelly eelpout (*Lycodes pacificus*) (outer shelf); and splitnose rockfish (*Sebastes diploproa*), Pacific hake (*Merluccius productus*), and bigfin eelpout (*Lycodes cortezianus*) (upper slope).

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 15, with those ranking to the left sharply increasing in abundance and those to the right gradually decreasing (Figure IV-5; Appendix B-B15). The 36 most abundant species (25% of all species) together accounted for 95% of abundance in the survey (Table IV-11). Four species accounted for approximately 50% of the total fish abundance: Pacific sanddab, speckled sanddab, slender sole, and yellowchin sculpin (*Icelinus quadriseriatus*).

Combinations of 25 species comprised the top 80% of the abundance in each subpopulation (Table IV-12), with a mean of 9 species per subpopulation in the mainland and island regions. A mean of 7 species per subpopulation comprised 80% of the abundance in the shelf zones. On the mainland shelf, species comprising 80% of the abundance per region were similar among northern, central, and southern regions (12, 11, and 12, respectively), while northwest and southeast islands were much lower (6 and 5, respectively). Within the depth zones, the bays and harbors had the highest number of species (11), comprising 80% of the abundance. Fewer species made up this abundance on the shelf and slope zones (6-7 species). Pacific sanddab was the most abundant species in the central, southern, and island regions. Speckled sanddab was the most abundant species in the northern mainland region and within the inner shelf zone. Slender sole was the most abundant species within the outer shelf and upper slope zones. Longspine combfish (*Zaniolepis latipinnis*) was most abundant within the middle shelf, and white croaker (*Genyonemus lineatus*) was the most abundant species in bays and harbors.

Table IV-9. 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 5-202 m, July - October, 2003.

Scientific Name	Common Name	No. of Stations	Percent of Stations	Percent of Area*
Microstomus pacificus	Dover sole	110	52	69.6
Citharichthys sordidus	Pacific sanddab	131	62	56.1
Parophrys vetulus	English sole	97	46	48.5
Lyopsetta exilis	slender sole	56	27	45.4
Sebastes saxicola	stripetail rockfish	89	42	41.3
Pleuronichthys verticalis	hornyhead turbot	98	47	35.4
Porichthys notatus	plainfin midshipman	79	38	35.4
Zaniolepis latipinnis	longspine combfish	89	42	33.6
Zalembius rosaceus	pink seaperch	90	43	33.5
Icelinus quadriseriatus	yellowchin sculpin	87	41	33.0
Zaniolepis frenata	shortspine combfish	60	29	29.9
Sebastes diploproa	splitnose rockfish	28	13	29.4
Merluccius productus	Pacific hake	32	15	28.6
Citharichthys stigmaeus	speckled sanddab	79	38	27.8
Sebastes semicinctus	halfbanded rockfish	57	27	27.3
Lycodes cortezianus	bigfin eelpout	19	9	26.4
Hippoglossina stomata	bigmouth sole	68	32	25.9
Symphurus atricaudus	California tonguefish	65	31	23.1
Glyptocephalus zachirus	rex sole	31	15	21.8
Citharichthys xanthostigma	longfin sanddab	64	30	21.5
Chitonotus pugetensis	roughback sculpin	53	25	21.0

Total stations = 210
Total area = 6.917 km^2
*Based on area-weighted frequency of occurences.

Table IV-10. Demersal fish species comprising 50% or more of the area by subpopulation on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003.

	Percent of Area										
	Region										
	Mainland			Island		Shelf Zone					
Species*	N	C	S	NWC	SEC	B&H	IS	MS	OS	US	SCB
Dover sole	78	53	63	75	92	-	-	64	94	96	70
Pacific sanddab	-	62	58	100	100	-	-	100	91	-	56
English sole	-	55	-	-	62	-	75	71	-	-	-
slender sole	64	-	-	-	-	-	-	-	94	88	-
stripetail rockfish	-	-	-	81	85	-	-	76	84	-	-
hornyhead turbot	-	64	-	-	-	-	72	64	-	-	-
plainfin midshipman	-	-	-	81	100	-	-	70	-	-	-
longspine combfish	-	-	-	81	62	-	-	74	-	-	-
pink seaperch	-	-	-	-	85	-	-	71	-	-	-
yellowchin sculpin	-	50	-	63	-	-	-	74		-	-
shortspine combfish	-	-	-	69	100	-	-	-	88	-	-
splitnose rockfish	-	-	-	-	-	-	-	-	-	69	-
Pacific hake	-	-	-	-	-	-	-	-	-	65	-
speckled sanddab	-	-	-	-	-	-	96	-	-	-	-
halfbanded rockfish	-	-	-	56	77	-	-	65	-	-	-
bigfin eelpout	-	-	-	-	-	-	-		-	66	-
bigmouth sole	-	50	-	-	62	-	-	54	-	-	-
California tonguefish	-	50	-	-	-	-	-	51		-	-
rex sole	-	-	-	-	-	-	-	-	54	-	-
roughback sculpin	-	-	-	-	-	-	-	50	-	-	-
blacktip poacher	-	-	-	-	-	-	-	-	71	-	-
spotted cusk-eel	-	-	-	-	54	-	-	-	-	-	-
curlfin sole	-	-	-	-	69	-	-	-	-	-	-
pygmy poacher	-	-	-	50	-	-	-	-	-	-	-
lingcod	-	-	-	63	-	-	-	-	-	-	-
cowcod	-	-	-	-	69	-	-	-	-	-	-
blackbelly eelpout	-	-	-	-		-	-	-	54	-	-
chilipepper	-	-	-	-	54	-	-	-	-	-	-
spotfin sculpin	-	-	-	-	54	-	-	-	-	-	-
California halibut	-	-	-	-	-	81	-	-	-	-	-

* See Glossary G3 for scientific names of fish species. See Appendix B14 for list of areal occurrence of all species by subpopulation.
- Species not ocurring in at least 50% of the area or absent.

N = Northern; C = Central; S = Southern; NWC = Northwest Channel Islands; SEC = Southeast Channel Islands; B&H = Bays and Harbors; IS = Inner Shelf; MS = Middle Shelf; OS= Outer Shelf; US= Upper Slope; SCB = Southern California Bight

Total area (km^2) by subpopulation; N = 2,746; C = 1,710; S = 1,366; NWI = 604; SEI = 491; B&H = 65; IS = 982; MS = 2,635; OS = 529; US = 2,705; SCB = 6,916.

Table IV-11. Demersal fish species comprising 95% or more of the total fish abundance on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003.

Scientific Name	Common Name	Abundance	Total Percent	Cumulative Percent
Citharichthys sordidus	Pacific sanddab	17,058	27.7	27.7
Citharichthys stigmaeus	speckled sanddab	6,785	11.0	38.7
Lyopsetta exilis	slender sole	4,559	7.4	46.0
Icelinus quadriseriatus	yellowchin sculpin	3,962	6.4	52.5
Sebastes saxicola	stripetail rockfish	3,857	6.3	58.7
Zaniolepis latipinnis	longspine combfish	3,059	5.0	63.7
Sebastes semicinctus	halfbanded rockfish	2,692	4.4	68.0
Microstomus pacificus	Dover sole	2,236	3.6	71.7
Zalembius rosaceus	pink seaperch	1,292	2.1	73.8
Citharichthys xanthostigma	longfin sanddab	1,256	2.0	75.8
Sebastes diploproa	splitnose rockfish	1,249	2.0	77.8
Zaniolepis frenata	shortspine combfish	1,155	1.9	79.7
Genyonemus lineatus	white croaker	856	1.4	81.1
Parophrys vetulus	English sole	825	1.3	82.4
Porichthys notatus	plainfin midshipman	758	1.2	83.6
Lycodes pacificus	blackbelly eelpout	746	1.2	84.9
Symphurus atricaudus	California tonguefish	557	0.9	85.8
Chitonotus pugetensis	roughback sculpin	516	0.8	86.6
Glyptocephalus zachirus	rex sole	493	0.8	87.4
Pleuronichthys verticalis	hornyhead turbot	484	0.8	88.2
Lepidogobius lepidus	bay goby	456	0.7	88.9
Xeneretmus latifrons	blacktip poacher	386	0.6	89.5
Anchoa delicatissima	slough anchovy	362	0.6	90.1
Pleuronichthys decurrens	curlfin sole	361	0.6	90.7
Sebastes jordani	shortbelly rockfish	338	0.5	91.3
Seriphus politus	queenfish	267	0.4	91.7
Lyconema barbatum	bearded eelpout	262	0.4	92.1
Cymatogaster aggregata	shiner perch	257	0.4	92.5
Urobatis halleri	round stingray	252	0.4	92.9
Sebastes goodei	chilipepper	243	0.4	93.3
Merluccius productus	Pacific hake	231	0.4	93.7
Argentina sialis	Pacific argentine	201	0.3	94.0
Paralichthys californicus	California halibut	198	0.3	94.4
Chilara taylori	spotted cusk-eel	186	0.3	94.7
Porichthys myriaster	specklefin midshipman	184	0.3	95.0
Sebastolobus alascanus	shortspine thornyhead	178	0.3	95.3
Scorpaena guttata	California scorpionfish	168	0.3	95.5
Phanerodon furcatus	white seaperch	166	0.3	95.8

Total abundance = 61,687 fish.

Table IV-12. Demersal fish species comprising 80% or more of the fish abundance by subpopulation on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003.

	Percent Catch Abundance										
	Region										
	Mainland			Island		Shelf Zone					
Species *	N	C	S	NWC	SEC	B&H	IS	MS	OS	US	SCB
Pacific sanddab	11	23	30	37	64	-	4	2	22	-	28
speckled sanddab	22	14	6	4	-	6	60	6	-	-	11
slender sole	12	10	8	-	-	-	-	-	27	35	7
yellowchin sculpin	3	8	12	-	-	4	3	2	-	-	6
stripetail rockfish	6	4	3	15	3	-	-	6	15	6	6
longspine combfish	-	7	2	7	-	-	-	37	-	-	5
halfbanded rockfish	-	4	2	11	4	-	-	7	-	-	4
Dover sole	3	3	4	4	4	-	-	5	5	9	4
pink seaperch	6	-	2	-	-	-	7	-	-	-	2
longfin sanddab	-	3	5	-	-	-	-	-	-	-	2
splitnose rockfish	4	-	3	-	-	-	-	-	-	18	2
shortspine combfish	-	-	-	-	4	-	-	-	7	-	2
white croaker	2	3	-	-	-	21	3	-	-	-	-
English sole	4	-	-	-	-	-	3	-	-	-	-
California tonguefish	-	2	-	-	-	-	-	-	-	-	-
rex sole	3	-	-	-	-	-	-	-	-	5	-
slough anchovy	-	-	3	-	-	12	-	-	-	-	-
queenfish	-	-	-	-	-	8	-	-	-	-	-
round stingray	-	-	-	-	-	9	-	-	-	-	-
California halibut	-	-	-	-	-	5	-	-	-	-	-
specklefin midshipman	-	-	-	-	-	5	-	-	-	-	-
white seaperch	-	-	-	-	-	4	-	-	-	-	-
northern anchovy	-	-	-	-	-	4	-	-	-	-	-
barred sand bass	-	-	-	-	-	4	-	-	-	-	-
blackbelly eelpout	4	-	-	-	-	-	-	-	4	6	-

* See Glossary G3 for scientific names of fish species
"-" Species not ocurring in at least 80% of the invertebrate abundance or absent.

N = Northern; C = Central; S = Southern; NWC = Northwest Channel Islands; SEC = Southeast Channel Islands; 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 = 10,289; C = 22,976; S = 12,620; NWC = 10,534; SEC = 5,268; B&H = 2,918; IS = 8,368; MS = 35,434; OS = 9,466; US = 5,501; SCB = 61,687.

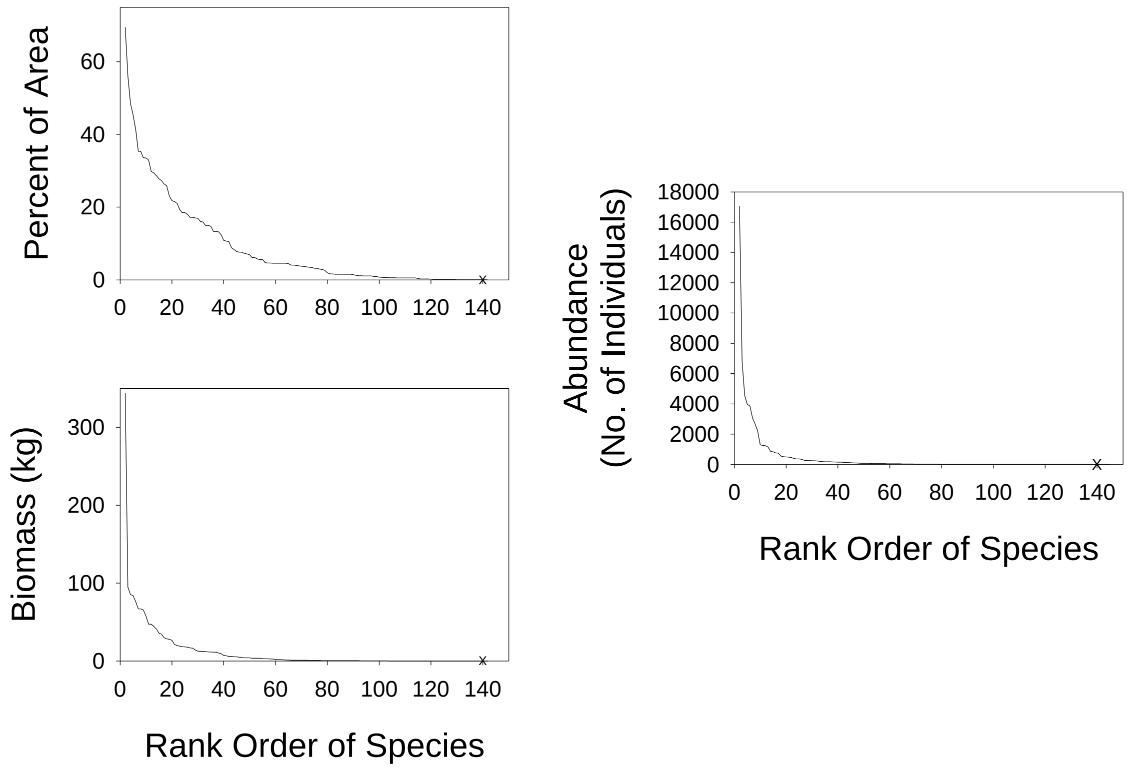


Figure IV-5. Equitability curves of fish occurrence, abundance, and biomass by species at depths of 2-476 m, Southern California Bight 2003 Regional Survey, July-October 2003. x=140th species.

Species Biomass

The equitability curve of species biomass approximated a tight hyperbola, similar to that for species abundance (Figure IV-5), although the curve for biomass was slightly less concave than the curve for species abundance. There was a sharp change of slope at about species 5, with those ranking to the left sharply increasing in biomass and those to the right gradually decreasing (Figure IV-5; Appendix B-B16). As with the abundance curve, relatively few species dominated the overall biomass. Forty-eight species (34 % of all species) accounted for the top 95% of biomass in the survey (Table IV-13). Seven species accounted for approximately 50% of the total fish biomass: Pacific sanddab, slender sole, California halibut, queenfish (*Seriphus politus*), Dover sole, English sole, and round stingray (*Urobatis halleri*).

Combinations of 35 species also made up the top 80% of the biomass in each subpopulation (Table IV-14), with a mean of 13 species per subpopulation in the mainland and island regions and a mean of 9 species in the shelf zones. More species comprised 80% of the biomass in the northern, central, and southern mainland regions (15, 17, and 17, respectively) than did the northwest and southeast Channel Islands (10 and 5, respectively). Among the shelf zones, inner and middle shelf zones had the highest number of species (both 12), while bays and harbors, outer shelf, and upper slope depths zones were less (7, 7, and 8, respectively). Geographically, Pacific sanddab was the biomass dominant in all mainland and island regions. Bathymetrically, biomass was dominated by queenfish in bays and harbors, by California halibut on the inner shelf, Pacific sanddab on the middle and outer shelf, and Dover sole on the upper slope.

Species Size (Length) Distribution

All Fish

Fish captured in this survey ranged in size from 1.5 cm (midpoint of size class 2) to 104.5 cm (midpoint of size class 105), with almost all below 30 cm in length (Figure IV-6). Most of the fish were small, ranging in length from 1.5-5.5 cm. The modal size class of the fish was 4.5 cm, comprising 16% of the catch. The length-frequency distribution was skewed to the right and strongly truncated to the left at 1.5 cm. Among major zones and regions, length-frequency distributions of all fish were most highly peaked in smaller size classes, with the highest modal abundance in the southern mainland region bays/harbors subpopulation (San Diego and Mission Bays). Length-frequency distributions showed relatively high peaks in the northern and central mainland region bays, the central mainland region inner shelf zone, the northern mainland region outer shelf zone, and the southern mainland upper slope (Figure IV-7). At the islands, the distributions were most peaked in the middle shelf and more peaked than at other regional depth subpopulations (Figures IV-7 and IV-8). In general, length-frequency distributions were similarly skewed to the right in all region/shelf zone subpopulations, 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 bays and harbors within the central and southern mainland region.

Table IV-13. Demersal fish species comprising 95% or more of the total fish biomass on the southern California shelf and slope at depths of 2-476 m, July-October 2003.

Scientific Name	Common Name	Biomass (kg)	Percent	Cumulative Percent
Citharichthys sordidus	Pacific sanddab	344.2	20.4	20.4
Lyopsetta exilis	slender sole	94.8	5.6	26.0
Paralichthys californicus	California halibut	85.2	5.0	31.1
Seriphus politus	queenfish	83.8	5.0	36.0
Microstomus pacificus	Dover sole	76.0	4.5	40.5
Parophrys vetulus	English sole	66.9	4.0	44.5
Urobatis halleri	round stingray	66.7	4.0	48.4
Sebastes saxicola	stripetail rockfish	65.4	3.9	52.3
Citharichthys xanthostigma	longfin sanddab	57.5	3.4	55.7
Pleuronichthys verticalis	hornyhead turbot	47.1	2.8	58.5
Scorpaena guttata	California scorpionfish	47.1	2.8	61.3
Citharichthys stigmaeus	speckled sanddab	44.4	2.6	63.9
Zaniolepis latipinnis	longspine combfish	41.0	2.4	66.4
Genyonemus lineatus	white croaker	35.5	2.1	68.5
Merluccius productus	Pacific hake	34.4	2.0	70.5
Porichthys notatus	plainfin midshipman	28.3	1.7	72.2
Zaniolepis frenata	shortspine combfish	27.9	1.7	73.8
Raja inornata	California skate	26.6	1.6	75.4
Myliobatis californica	bat ray	21.0	1.2	76.6
Hippoglossina stomata	bigmouth sole	19.9	1.2	77.8
Sebastes diploproa	splitnose rockfish	19.0	1.1	78.9
Sebastes semicinctus	halfbanded rockfish	18.3	1.1	80.0
Zalembius rosaceus	pink seaperch	18.0	1.1	81.1
Anoplopoma fimbria	sablefish	17.7	1.0	82.1
Paralabrax nebulifer	barred sand bass	16.7	1.0	83.1
Icelinus quadriseriatus	yellowchin sculpin	16.4	1.0	84.1
Raja rhina	longnose skate	14.0	0.8	84.9
Torpedo californica	Pacific electric ray	12.5	0.7	85.7
Symphurus atricaudus	California tonguefish	12.3	0.7	86.4
Glyptocephalus zachirus	rex sole	12.2	0.7	87.1
Rhinobatos productus	shovelnose guitarfish	12.0	0.7	87.8
Phanerodon furcatus	white seaperch	11.5	0.7	88.5
Lycodes pacificus	blackbelly eelpout	11.5	0.7	89.2
Pleuronichthys decurrens	curlfin sole	11.3	0.7	89.9
Sebastolobus alascanus	shortspine thornyhead	11.2	0.7	90.5
Porichthys myriaster	specklefin midshipman	10.3	0.6	91.1
Sebastes jordani	shortbelly rockfish	9.2	0.5	91.7
Xystreurys liolepis	fantail sole	7.0	0.4	92.1
Pleuronichthys guttulatus	diamond turbot	6.5	0.4	92.5
Synodus lucioceps	California lizardfish	5.9	0.3	92.8
Paralabrax maculatofasciatus	spotted sand bass	5.7	0.3	93.2
Lycodes cortezianus	bigfin eelpout	5.3	0.3	93.5
Ophiodon elongatus	lingcod	5.3	0.3	93.8
Pleuronichthys ritteri	spotted turbot	4.9	0.3	94.1
Citharichthys fragilis	Gulf sanddab	4.2	0.2	94.3
Chitonotus pugetensis	roughback sculpin	4.1	0.2	94.6
Sebastes rosenblatti	greenblotched rockfish	4.0	0.2	94.8
Sebastes chlorostictus	greenspotted rockfish	4.0	0.2	95.1

Total biomass = 1,688.1 kg.

Table IV-14. Demersal fish species comprising 80% or more of the fish biomass by subpopulation on the southern California shelf and slope at depths of 2-476 m, July-October 2003.

	Percent Catch Biomass										
	Region										
	Mainland			Island		Depth Zone					
Species	**N**	**C**	**S**	**NWC**	**SEC**	**B&H**	**IS**	**MS**	**OS**	**US**	**SCB**
Pacific sanddab	15	13	15	30	64	-	5	37	30	-	20
slender sole	8	6	8	3	-	-	-	-	19	18	6
California halibut	-	8	8	-	-	10	19	3	-	-	5
queenfish	-	11	-	-	-	26	-	-	-	-	5
Dover sole	8	3	6	4	-	-	-	3	4	19	5
English sole	6	4	-	3	4	-	6	6	5	-	4
round stingray	-	5	9	-	-	21	-	-	-	-	4
stripetail rockfish	4	3	3	12	-	-	-	2	14	5	4
longfin sanddab	-	4	8	-	-	-	5	7	-	-	3
hornyhead turbot	-	5	2	-	-	-	3	6	-	-	3
California scorpionfish	-	5	2	-	-	-	7	4	-	-	3
speckled sanddab	5	3	2	-	-	-	18	-	-	-	3
longspine combfish	-	2	2	9	-	-	2	5	-	-	2
white croaker	4	3	-	-	-	7	7	-	-	-	2
Pacific hake	8	-	2	-	-	-	-	-	-	14	2
plainfin midshipman	4	-	-	5	-	-	-	-	-	-	2
shortspine combfish	-	-	-	5	4	-	-	-	5	-	2
California skate	-	2	-	-	-	-	-	2	-	-	2
bat ray	-	-	6	-	-	5	3	-	-	-	1
bigmouth sole	-	2	-	-	-	-	2	-	-	-	1
splitnose rockfish	3	-	-	-	-	-	-	-	-	7	1
halfbanded rockfish	-	-	-	-	3	-	-	3	-	-	1
pink seaperch	2	-	-	-	-	-	4	-	-	-	1
sablefish	5	-	-	-	-	-	-	-	-	7	1
barred sand bass	-	2	1	-	-	5	-	-	-	-	1
yellowchin sculpin	-	-	2	-	-	-	-	2	-	-	1
longnose skate	3	-	-	3	-	-	-	-	-	-	1
Pacific electric ray	-	-	-	-	-	4	-	-	-	-	1
rex sole	-	-	2	-	-	-	-	-	-	4	1
blackbelly eelpout	2	-	-	-	-	-	-	-	3	-	1
white seaperch	3	-	-	-	-	-	-	-	-	-	1
curlfin sole	-	-	-	-	4	-	-	-	-	-	1
shortspine thornyhead	-	-	-	-	-	-	-	-	-	4	1
shortbelly rockfish	-	-	-	4	-	-	-	-	-	-	1
spotted sand bass	-	-	1	-	-	-	-	-	-	-	-

* See Glossary G3 for scientific names of fish species
"-" Species not ocurring in at least 80% of the fish abundance or absent.
N = Northern; C = Central; S = Southern; NWC = Northwest Channel Islands; SEC = Southeast Channel Islands; B&H = Bays and Harbors; IS = Inner Shelf; MS = Middle Shelf; OS= Outer Shelf; US= Upper Slope; SCB = Southern California Bight.
Total catch biomass (kg) by subpopulation; N = 299.7; C = 772.1; S = 286.5; NWC = 172.3; SEC = 157.5; B&H = 318.1; IS =180.5; MS = 679.5; OS = 271.3; US = 238.7; SCB =1688.1.

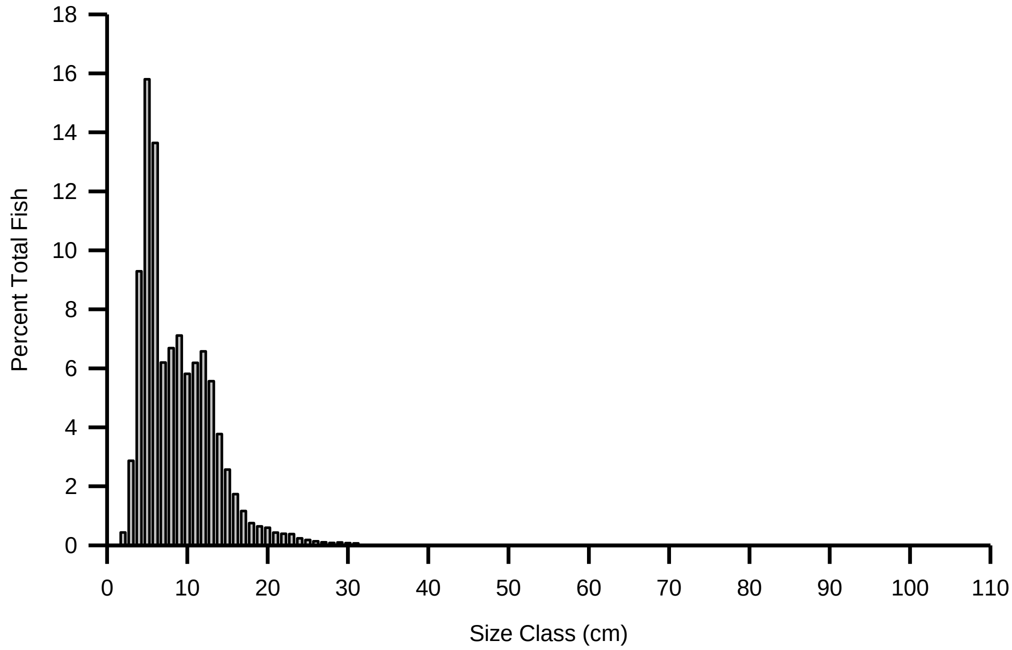


Figure IV-6. Length-Frequency distribution of all fish collected by trawl at depths of 2-476 m on the in the southern California shelf, July-September 2003. n=Number of fish measured; X=Largest fish (size class 105).

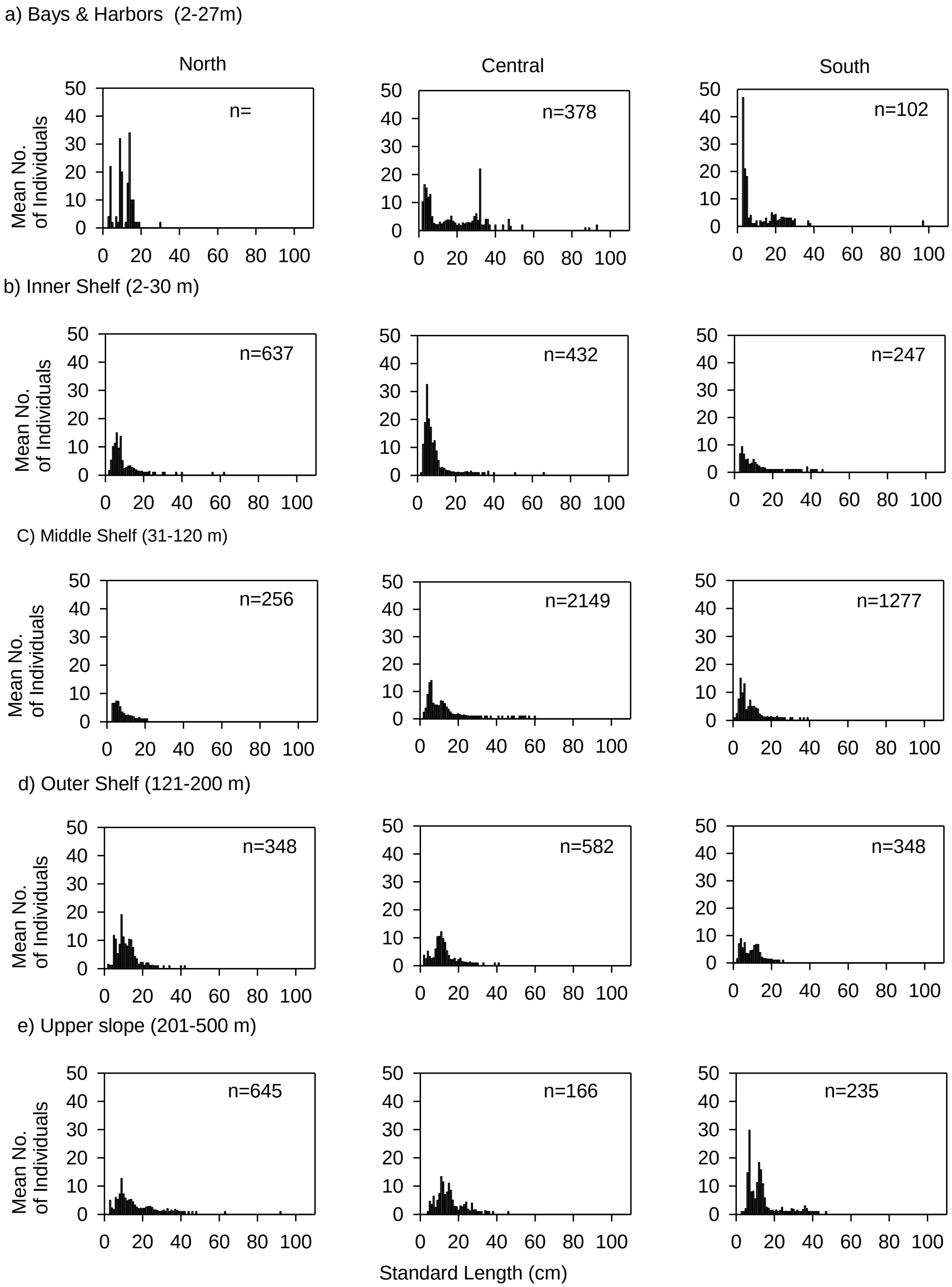


Figure IV-7. Length-frequency distribution (mean number of fish per size class) of all fish collected by trawl in the bays and harbors and on the mainland shelf by shelf zone and regional subpopulation on the southern California shelf, July-September 2003.

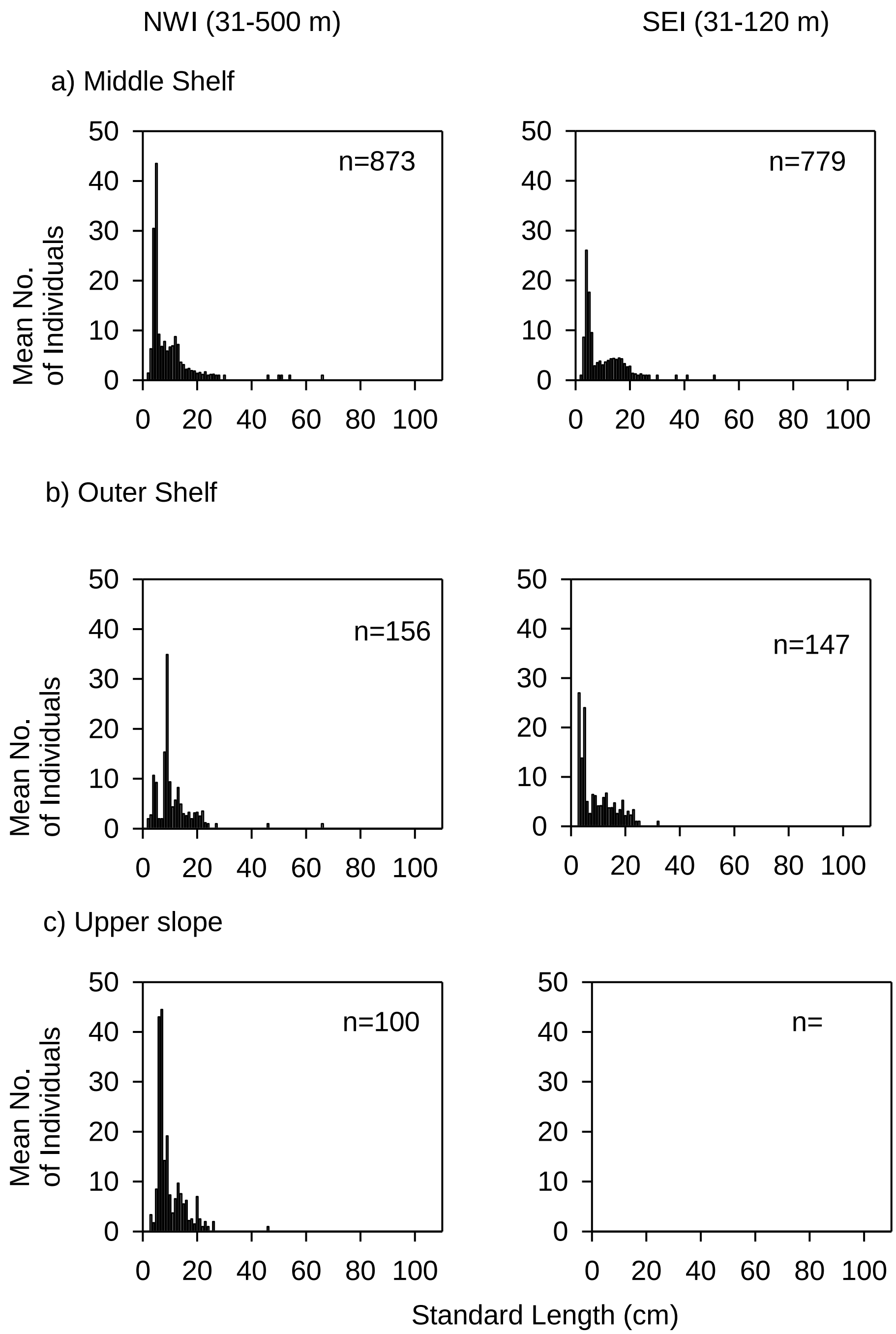


Figure IV-8. Length-frequency distribution (mean number of fish per size class) of all fish collected by trawl at southern California islands by Shelf zone and regional subpopulation on the southern California shelf, July - September 2003. NWI- Northwest Channel islands; SEI=Southeast Channel islands. No upper slope stations were sampled at SEI.

Individual Species

Fish caught in the survey ranged in length from 1-105 cm (Table IV-15). Six out of ten of the largest species by mean length were cartilaginous fishes, with the California halibut, wolf-eel (*Anarrhichthys ocellatus*), lingcod, and Pacific hake being the only ray-finned fish among the 10 largest species. In contrast, species with the shortest mean body length were all ray-finned fishes.

The species with the largest mean size were the bat ray *(Myliobatis californica)*, shovelnose guitarfish *(Rhinobatos productus)*, and Pacific electric ray *(Torpedo californica)*, with mean lengths of 81, 82, and 93 cm, respectively (Table IV-15). The largest individual fish was a bat ray of 105 cm total length (TL). Most of the large species were not represented by many individuals. Six or fewer individuals were collected for 6 of the 10 largest species. The species with the smallest mean size were bay goby *(Lepidogobius lepidus)*, queenfish, and cheekspot goby *(Ilypnus gilberti)*, with mean lengths of 7, 7, and 3 cm, respectively. The smallest individual fish was a California tonguefish *(Symphurus atricaudus)* with a length of 1 cm SL. Whereas most of 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 7 of the 10 smallest species, with Pacific sanddab numbering 17,058.

Population Structure

Overall length- frequency distributions of the 10 most abundant species in the survey varied in shape (Figure IV-9). Size distributions of longspine combfish, and stripetail rockfish were strongly bimodal; that of Pacific sanddab was slightly bimodal. Yellowchin sculpin, halfbanded rockfish (*Sebastes semicinctus*), pink seaperch, speckled sanddab, slender sole, Dover sole, and longfin sanddab had unimodal distributions. All of the 10 species had primary modes at lengths of 12.5 cm (size class 13) or less. The top 10 species had size distributions within the range of 1.5-29.5 cm. Only the size distribution of yellowchin sculpin was entirely below 10 cm. Recent recruitment of small juveniles (as indicated by fish length of 5.5 cm or less than) was apparent in all of the 10 most abundant species.

Size distributions of species differed by region and depth (Figures IV-12, IV-11, and IV-12; Appendix B-B17 through B-B37). Of the 10 most abundant species in bays and harbors (Figure IV-10), speckled sanddab, yellowchin sculpin, slough anchovy (*Anchoa delicatissima*), barred sand bass (*Paralabrax nebulifer*), and white seaperch (*Phanerodon furcatus*) showed unimodal distributions; whereas white croaker, round stingray, California halibut, speckled midshipman (*Porichthys myriaster*) and queenfish showed bimodal or indistinct distributions. All individuals of yellowchin sculpin and slough anchovy were below 10 cm in length; all individuals of barred sand bass and round stingray were above 10 cm in length. Note that bays and harbors include coastal harbors (e.g., LA/LB Harbor) and natural embayments (e.g., San Diego Bay), and that some species shown here often occur in one or the other but not both.

Shelf (mainland and island) populations (Figure IV-11) showed better-developed size distributions than those in bays and harbors (Figure IV-10). Most of the top 10 species had broader size ranges. Pacific sanddab, stripetail rockfish, and longspine combfish had bimodal distributions. All yellowchin sculpin were less than 10 cm; but no species were exclusively above 10 cm.

The two most abundant species did not vary greatly in their population structure in the bay/harbor zone and in the mainland region (Figure IV-12). Speckled sanddab was unimodal and nearly identical in size in both areas. Yellowchin sculpin was also unimodal in both populations and was also nearly identical in size distribution. Both are coastal species and were found in the bay/harbor zone in LA/LB Harbor (an enclosed coastal area) in the central region of this survey (Appendix B-B17).

Length-frequency distributions of the 10 most abundant species in bays/harbors by region showed differences in general abundance patterns as well as in population structure (Appendix B-B17). All 10 species were present in the central region harbors (e.g., LA/LB Harbor); however, only two were present in the northern region (California halibut and white seaperch) and six were present in the southern region (white croaker, slough anchovy, round stingray, speckled midshipman, California halibut, and barred sand bass). White croaker occurred far more frequently in the central region than in either the north or south (620, 0, and 4, respectively). Its distribution in the in the central region was somewhat bimodal. Slough anchovy was most abundant in the south (356) when compared to the north and central regions (0 and 6, respectively). The southern length distribution was unimodal and small. The speckled midshipman was only abundant in the central region. Its size distribution was wide and indistinct. California halibut, the only species present in all three regions, was abundant (124 individuals) and ranged widely in size in the central region. Only two moderately sized individuals were captured in the north, and 17 small to moderate sized individuals were found in the south. Barred sand bass was present in both central and southern regions. They were nearly 10 times more abundant in the central region, but the southern individuals tended to be larger. White seaperch were about three times more abundant in the north than in the central region, although both regions were similar in size distribution. White seaperch did not occur in the south. Queenfish, speckled sanddab, and yellowchin sculpin occurred only in the central region. Their distributions were generally small and unimodal.

The population structure (by region and major shelf zone) of the top 10 species in the mainland and island regions is shown in AppendiX B-B18 through B-B27 and Appendix B-B28 through B-B37, respectively. In general, the population structure was similar within a species by region and mainland shelf zone (Appendices B-B18 through B-B27), or between the two island regions (Appendix B-B28 through B-B37).

Table IV-15. Demersal fish species with greatest and least lengths collected on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003.

		Length (cm)			Total
Scientific Name	Common Name	Min.	Max.	Mean	Number
a) Largest Species					
Myliobatis californica	bat ray	40	105	81.2	6
Raja rhina	longnose skate	34	100	60.0	6
Rhinobatos productus	shovelnose guitarfish	41	97	81.8	5
Torpedo californica	Pacific electric ray	93	93	93.0	1
Paralichthys californicus	California halibut	2	67	25.2	198
Cephaloscyllium ventriosum	swell shark	66	66	66.0	1
Anarrhichthys ocellatus	wolf-eel	66	66	66.0	2[a]
Raja inornata	California skate	13	58	31.7	64
Ophiodon elongatus	lingcod	9	50	15.5	100
Merluccius productus	Pacific hake	8	48	24.2	231
b) Smallest Species					
Symphurus atricaudus	California tonguefish	1	18	13.5	557
Paralichthys californicus	California halibut	2	67	25.2	198
Ilypnus gilberti	cheekspot goby	2	4	2.7	58
Citharichthys sordidus	Pacific sanddab	2	28	9.3	17058
Porichthys notatus	plainfin midshipman	2	27	12.7	758
Seriphus politus	queenfish	2	21	7.1	267
Lepidogobius lepidus	bay goby	3	10	6.6	456
Cheilotrema saturnum	black croaker	3	21	15.0	6
Sebastes rosenblatti	greenblotched rockfish	3	24	11.4	83
Sebastes elongatus	greenstriped rockfish	3	25	7.9	120

Min.=Minimun; Max.=Maximum.

[a]Number of Fish not measured or not included: 1.

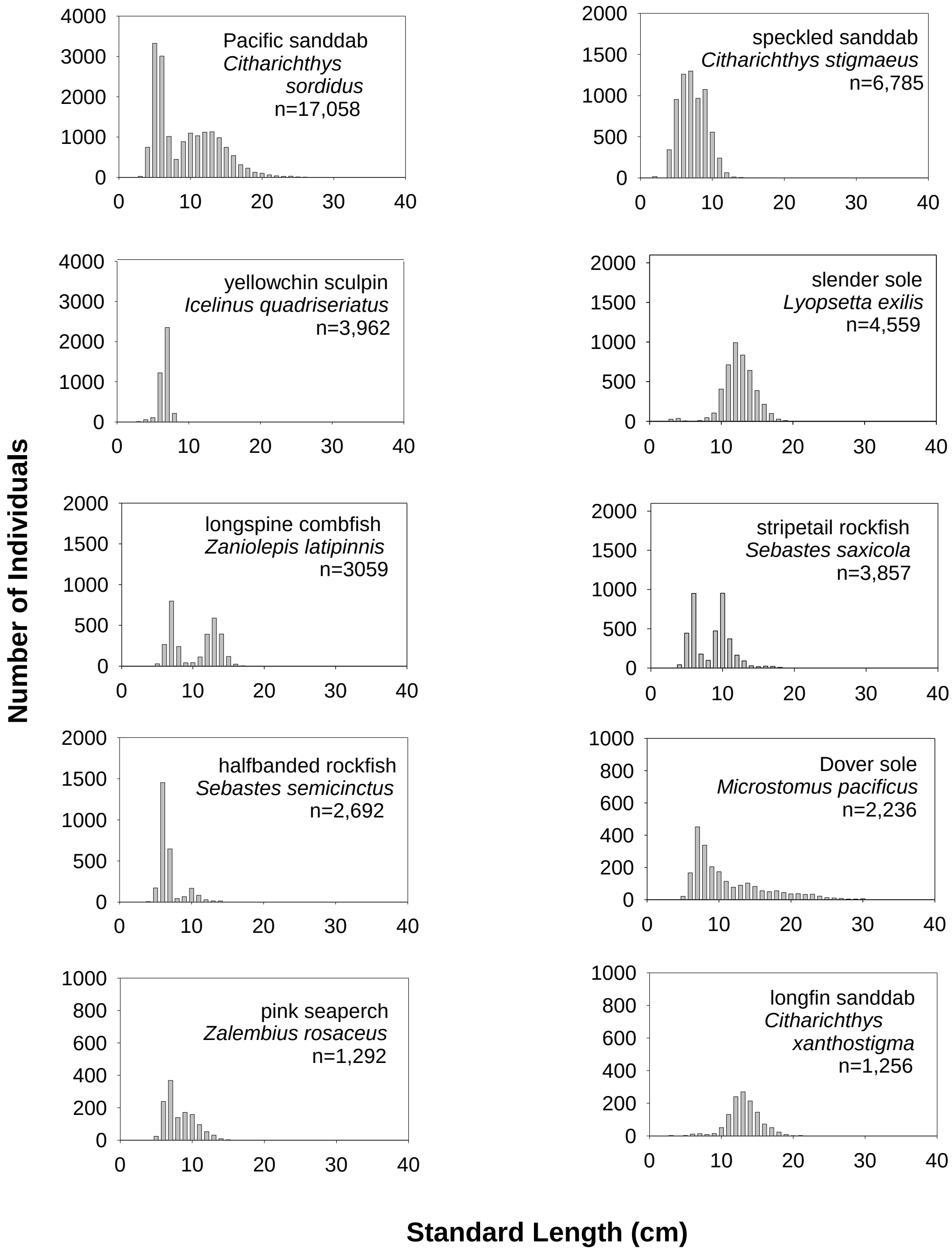


Figure IV-9. Length-frequency distributions of the 10 most abundant fish species collected by trawl at depths of 2-500 m on the southern California shelf, July-October 2003. n=Number of fish measured.

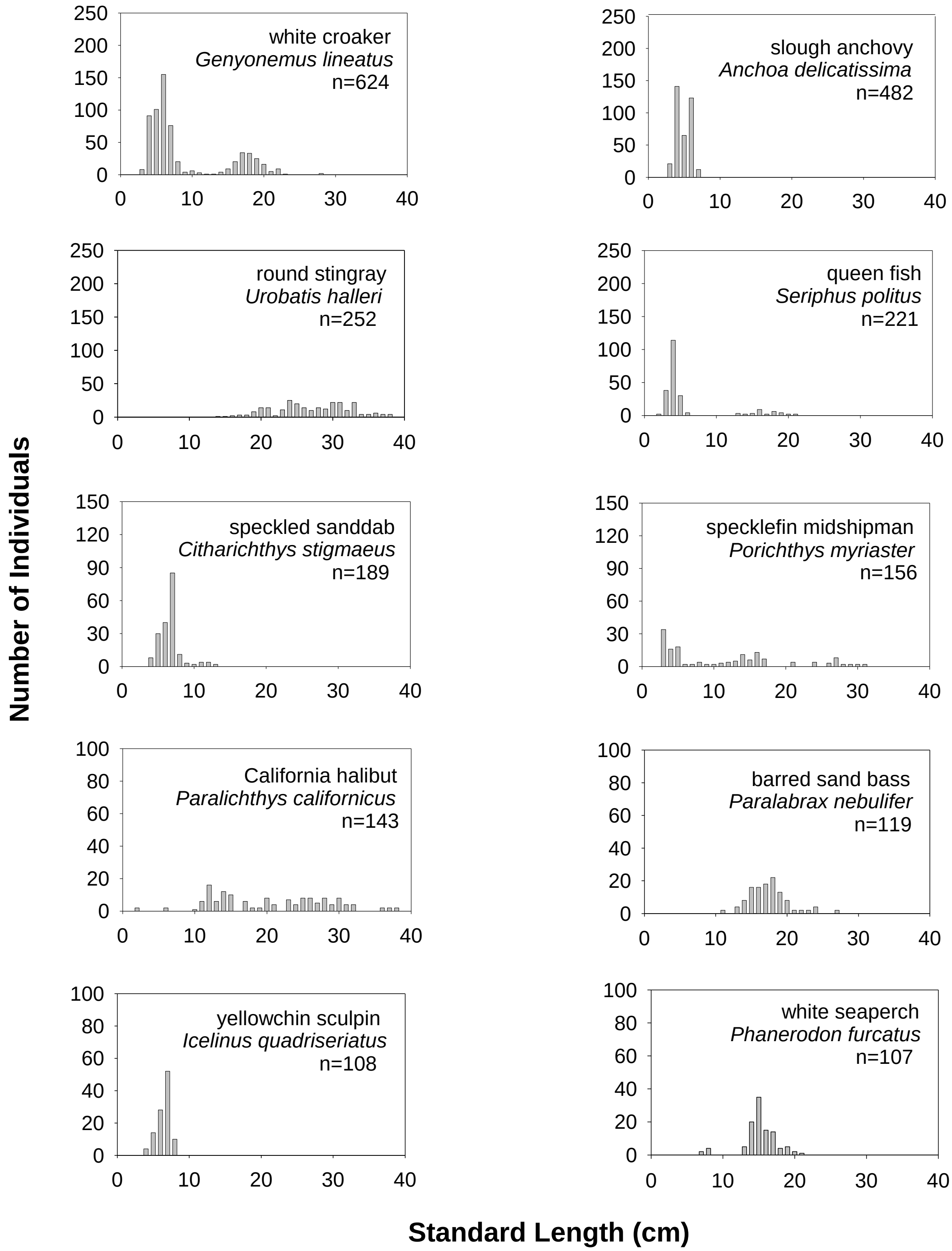


Figure IV-10. Length-frequency distributions of the 10 most abundant fish species collected by trawl within the Bays and Harbors on the southern California shelf, July-September 2003. n=Number of fish measured.

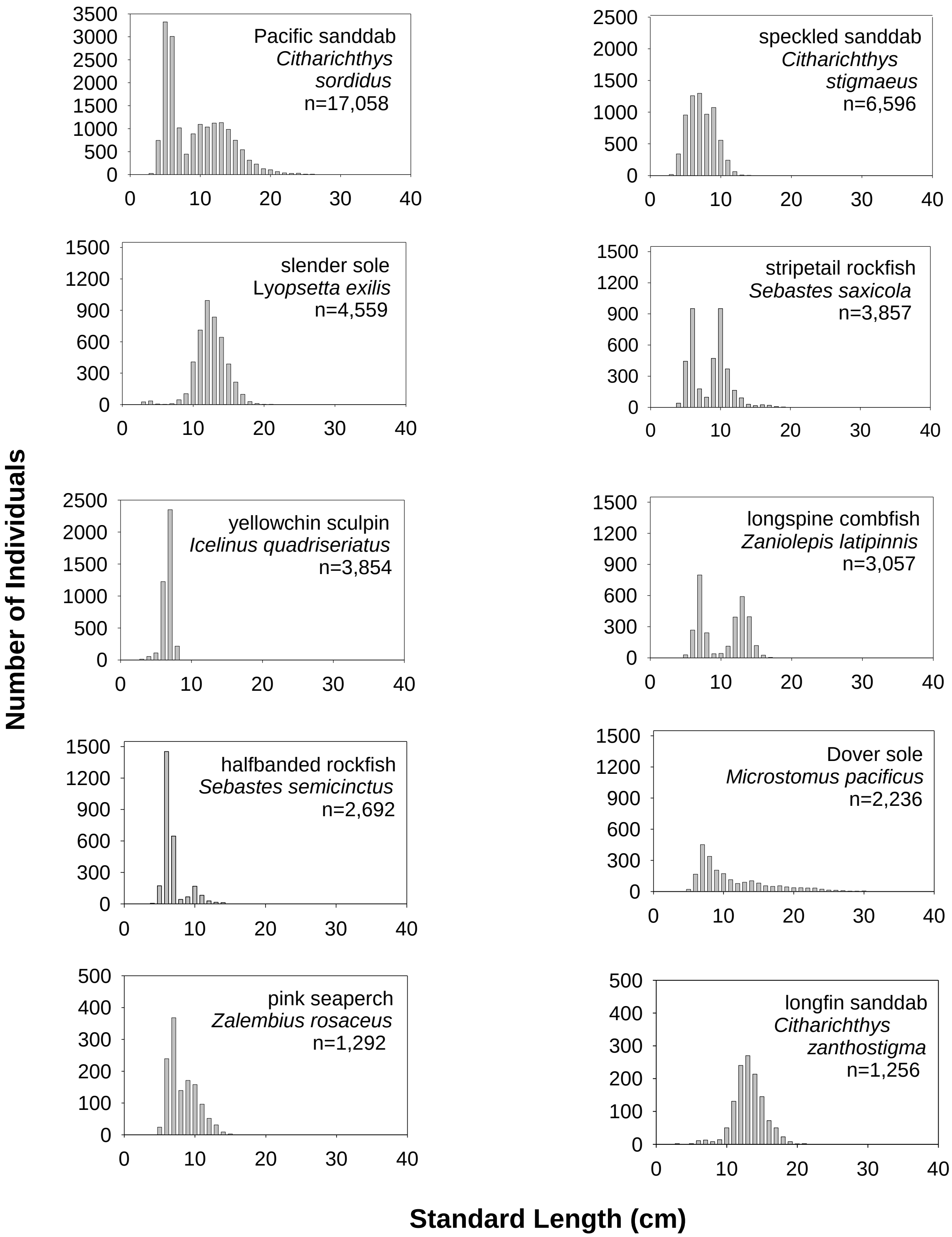


Figure IV-11. Length-frequency distributions of the 10 most abundant fish species collected by trawl on the mainland and Island shelf of southern California shelf, July-September 2003. Bays & Harbors are not included. n=Number of fish measured.

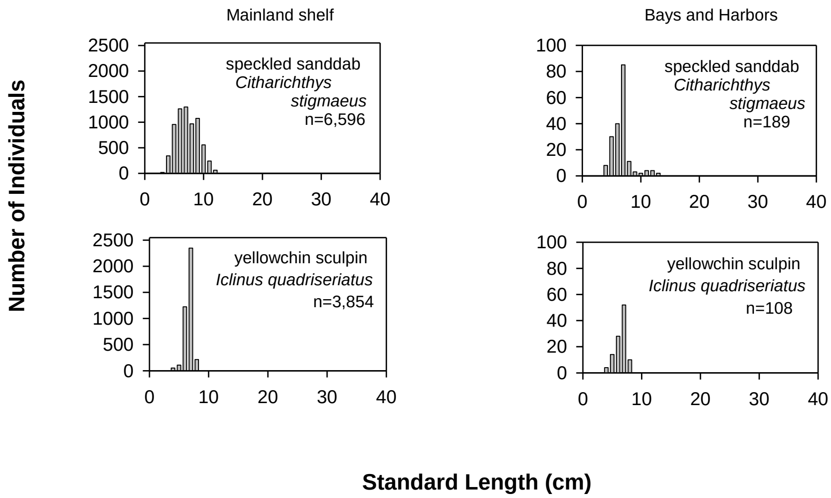


Figure IV-12. Length-frequency distributions for 2 species of fish collected by trawl on both the mainland shelf and within the bays and harbors of southern California shelf, July-September 2003. n=Number of fish measured.

Commercial and Recreational Fishes

A total of 23,785 individuals from 33 commercial and recreational species were captured during this sampling period (Appendix B-B38). By far the most abundant commercial species was the Pacific sanddab (n=17,058) followed by the Dover sole (n=2,236). Black perch (*Embiotoca jacksoni*), bocaccio (*Sebastes paucispinis*), brown rockfish (*Sebastes auriculatus*), kelp bass (*Paralabrax clathratus*) and California sheephead (*Semicossyphus pulcher*) are typically only found in rocky-reef habitats and their inclusion in this trawl survey must be viewed as incidental. A number of other rocky-reef fish appear to be accessible, albeit in low numbers, to this trawling program and primarily as juveniles. These fishes include calico rockfish (*Sebastes dallii*), copper rockfish (*Sebastes caurinus*), cowcod, and vermilion rockfish (*Sebastes miniatus*). Two coastal pelagic species, northern anchovy and Pacific pompano (*Peprilus simillimus*), were also captured incidentally. Two recreational species, barred sand bass and spotted sand bass (*Paralabrax maculatofasciatus*), were caught primarily in bays and estuaries. Barred sand bass are typically not accessible to trawling in open coast environments, while spotted sand bass are largely limited to bays and estuaries in southern California and only appear in offshore trawls off the coast of Mexico. The remaining fishes primarily represent two communities, a nearshore group represented by bay/harbor and surfzone species and a shelf complex. The nearshore group is not well represented, in part due to fewer trawls on the inner shelf and bays/harbors. Abundant surfzone species such as California corbina (*Menticirrhus undulatus*) and yellowfin croaker (*Umbrina roncador*) were virtually absent from this survey. Other important nearshore fishes such as white croaker, California halibut and queenfish were also low in abundance. As was expected, groundfish species on the shelf dominated this survey.

The abundance of fishes by size class for critical and abundant species is presented in Appendix B-B38 and these are plotted by shelf zone in Appendix B-B39 through B-B42. Pacific sanddab was primarily caught on the middle shelf where all size classes (3-24) were represented was dominated by a strong juvenile year class. Young Dover sole were distributed on the middle shelf to upper shelf, the distribution of larger fishes was found only on the upper slope. Shortbelly rockfish (*Sebastes jordani*) showed a bipartite distribution, with small individuals found on the inner shelf and larger individuals distributed on the outer shelf and upper slope. The distribution of rex sole had a few small individuals on the middle shelf but most fish were found on the outer shelf and upper slope, with the largest individuals on the upper slope. English sole were distributed widely from the inner shelf to the upper slope. California scorpionfish (*Scorpaena guttata*) were found at all size classes on the inner and middle shelf regions, with most fishes captured on the middle shelf. Juvenile cowcod were primarily caught on the middle shelf, while juvenile copper rockfish on the inner shelf. This shelf assemblage had either a pattern of younger individuals found in shallow reaches of their distribution with larger fishes found in the deeper habitats (e.g., chilipepper), or all sizes distributed across their depth range.

A similar pattern was found for the nearshore species. California halibut exhibited the well studied pattern of juveniles in bays and harbors, with the adults offshore. Small and larger white croaker were caught in the bays and harbors, with generally larger individuals captured on the inner shelf.

Widespread and Dominant Species

The distribution and population structure of 10 fish species with high occurrence, abundance, and/or biomass (i.e., ranking in top 10 of at least one of these attributes) in the survey are described below. The numbers following each species' name are the occurrence, abundance, and biomass ranks, respectively.

Pacific Sanddab (*Citharichthys sordidus*) (2,1,1). Pacific sanddab was second in frequency of occurrence in the survey but was the dominant species in abundance and biomass. It is primarily a middle shelf and outer shelf species (Table IV-10) that occurred in 56% of the area and represented 28% of the fish abundance and 20% of the biomass (Tables IV-9, IV-11, and IV-13). Pacific sanddab was the numerical dominant at the islands and central and southern mainland shelf zones (Table IV-12) and was the top biomass contributor in all regions (Table IV-14). It accounted for 64% of both the abundance and biomass at the southeast Channel Islands (Tables IV-12 and IV-14). Pacific sanddab ranged in size from 2 to 28 cm SL (Appendix B-B38). It had a bimodal size class distribution over the entire shelf, with the primary mode at 5 cm SL and a secondary mode at 13 cm SL (Figure IV-9). Pacific sanddab has a pelagic larval stage lasting several months (Moser and Sumida 1996) and matures around 19 cm TL (Hart 1973; i.e., about 16 cm SL). Thus, most (91%) of the sanddab catch consisted of juveniles (Figure IV-9; Chamberlain 1979, Love 1996). As with the adults, most juveniles were caught on the middle shelf zone (88%, Appendix B-B18, B-B38, and B-B41), while 40% were caught at island sites (Appendix B-B28) and 30% near large POTWs.

Slender Sole (*Lyopsetta exilis*) (4,3,2). Slender sole is primarily an outer shelf and upper slope species (Table IV-10) that occurred in 45% of the area and represented 7% of the total abundance and 6% of the total biomass (Tables IV-9, IV-11, and IV-13). Slender sole was abundant in all mainland regions, and was the numerical dominant within outer shelf and upper slope zones (Table IV-12). It was also an important contributor of biomass in all mainland regions, northwest Channel Islands, and in the outer shelf and upper slope zones (Table IV-14).

Slender sole ranged from 3 to 21 cm SL. It had a unimodal distribution over the entire shelf, with the mode at 12 cm SL (Figures IV-9 and IV-11). Slender sole has a pelagic larval stage, settling after several months. It matures between 14-16 cm TL (Hart 1973; i.e., about 12-14 cm SL). Juveniles comprised only 30% of slender sole catch (Figure IV-9). Of the juveniles, 94% were located on the mainland and 70% were located on the outer shelf (Appendix B-B20).

Dover Sole (*Microstomus pacificus*) (1,8,5). Dover sole is primarily a middle shelf to upper slope species (Table IV-10) that occurred in 70% of the area and contributed 4% of the total abundance and 4% of the biomass (Tables IV-9, IV-11, and IV-13). Dover sole was the biomass dominant on the upper slope zone and was a moderate contributor in the middle and outer shelf zones of both abundance and biomass (Tables IV-12 and IV-14). It contributed small to moderate abundance throughout all Bight regions. Dover sole ranged from 4 to 36 cm SL (Appendix B-B38). It had a bimodal distribution over the entire shelf, with the primary mode at 7 cm SL and a secondary mode at 14 cm SL (Figures IV-9 and IV-11). The species has a prolonged pelagic larval stage, which may last as long as 18 months to 2 years before it settles (Markle *et al.* 1992, Toole *et al.* 1993). It matures at around 33 cm TL (i.e., about 28 cm SL) and about 5 years (Fitch and Lavenberg 1971). Thus, juveniles comprised 99% of Dover sole catch (Figure IV-9; Appendix B-B38), 66% of which were on the mainland and 58% of which were on the middle shelf (Appendix B-B24 and B-B32).

Stripetail Rockfish (*Sebastes saxicola*) (5,5,8). Stripetail rockfish is a primarily a middle shelf to outer shelf species (Table IV-10) that occurred in 41% of the area and represented 6% of the total abundance and 4% of the biomass (Tables IV-9, IV-11, and IV-13). This species did not dominate a region or shelf zone by either abundance or biomass but was present in small to moderate numbers throughout all Bight regions (Tables IV-12 and IV-14). Stripetail rockfish ranged in size from 3 to 19 cm SL. It had a bimodal distribution over the entire shelf, with modes at 6 cm and 10 cm SL (Figures IV-9 and IV-11). This species has a pelagic larval stage and matures as small as 9 cm TL (i.e., about 7.5 cm SL) and 2 years off southern California (Love *et al.* 2002). Thus, juveniles comprised only 12% of stripetail rockfish catch (Figures IV-9 and IV-11). Of these juveniles, 91% were found on the middle shelf and 61% were found at Channel Island sites (Appendix B-B23 and B-B29). Stripetail rockfish can live to at least 38 years (Love *et al.* 2002).

English Sole (*Parophrys vetulus*) (3,14,6). English sole in the SCB is predominantly an inner shelf to middle shelf species (Table IV-10) that occurred in 48% of the area and contributed only 1% of the total abundance but 4% of the biomass (Tables IV-9, IV-11, and IV-13). It was most common on the inner shelf and middle shelf (75 and 71% of the area, respectively; Table IV-10). English was not a numerical dominant of abundance or biomass in any region or shelf zone (Tables IV-12 and IV-14) but was common in the central region and southeast Channel Islands (Table IV-10). English sole ranged in size from 5 to 34 cm SL (Appendix B-B38). It had a unimodal distribution over the shelf and upper slope with the mode at 14 cm SL (Appendices B-B40). Many mature between the total lengths of 26 cm (males) and 29.5 cm (females; Hart 1973). Thus, juveniles comprised 96% of English sole catch (AppendiX B-B38 and B-B40). Of these, 89% were caught on the mainland shelf, and 50% were caught in the northern region.

Longspine Combfish (*Zaniolepis latipinnis*) (8,6,13). Longspine combfish is primarily a middle shelf species (Table IV-10) that occurred in 34% of the area and represented 5% of the total abundance and 2% of the biomass (Tables IV-9, IV-11, and IV-13). This species was the numerical dominant in the middle shelf zone and numerically important in the central, southern, and northwest Channel Islands regions (Table IV-10) where it contributed relatively small amounts of biomass (Table IV-14). Longspine combfish ranged in size from 4 to 18 cm SL. It had a bimodal distribution over the entire shelf, with the primary mode at 7 cm and a secondary mode at 13 cm (Figures IV-9 and IV-11). Females are oviparous with demersal eggs (Love 1996). Longspine combfish mature at 11-16 cm SL (Johnson and Adams 1970, Goldberg 1979). To date, little has been published about their average size at sexual maturity, but by using a life history calculator (http://www.fishbase.org accessed on 01/28/07), based on 30 cm TL (i.e., about 26 cm SL) as the maximum length (Love 1996), it was estimated that average maturity can be reached when fish reach 16 cm SL. Using this metric, 99% of longspine combfish in this survey were juveniles. Of these, 70% were found on the mainland and 95% were caught on the mid shelf (Appendix B-B22).

Speckled Sanddab (*Citharichthys stigmaeus*) (14,2,12). Speckled sanddab is primarily an inner shelf species (Table IV-10). It occurred in 28% of the area and contributed 11% of the total abundance but only 3% of the biomass (Tables IV-9, IV-11, and IV-13). Speckled sanddab was the numerical dominant in both the northern mainland region and the inner shelf zone (Table IV-12) and was the second-most dominant biomass contributor in the inner shelf (Table IV-14). Speckled sanddab ranged in size from 3 to 15 cm SL. It had a unimodal distribution over the entire shelf, with the modes at 7 cm (Figures IV-9 and IV-11). This species has a pelagic larval stage lasting several months. Juveniles settle at 2.5-3.8 cm TL. They mature at around 7 cm TL (i.e., about 6 cm SL) (Ford 1965, Chamberlain 1979, Love 1996). Thus, juveniles comprised only 19% of speckled sanddab catch (Figures IV-9 and IV-11). Of these juveniles, 77% were found on the inner shelf and almost all (>99%) were found on the mainland (Appendix B-B19 and B-B34).

Yellowchin Sculpin (*Icelinus quadriseriatus*) (10,4,26). Yellowchin sculpin is primarily a middle shelf species (Table IV-10). It occurred in 33% of the area and comprised 6% of the total abundance but only 1% of the biomass (Tables IV-9, IV-11, and IV-13). The yellowchin sculpin was the second most abundant species collected in the southern region (Table IV-12), but it contributed very little biomass to any region or depth zone (Table IV-14). Yellowchin sculpin ranged in size from 3 to 8 cm SL. It had a unimodal distribution over the shelf with the mode at 7 cm SL (Figures IV-9 and IV-11). The smallest mature female recorded in the literature was 6 cm TL (Love 1996; i.e., about , which equates to approximately 5 cm SL, (http://www.fishbase.org; accessed 1/30/07). Using this metric, almost all yellowchin sculpin caught during this survey were adults (98%). This species solely occurred on the mainland. Of the juveniles caught, 82% were taken from middle shelf depths and 66% were found in the central region (Appendix B-B21).

California Halibut (*Paralichthys californicus*) (44,33,3). California halibut is predominantly a bay and harbor species (Table IV-10) that occurred in 8% of the area (Appendix B-B14) It accounted for 0.3% of the total abundance (Appendix B-B15) but 5% of the abundance in bays and harbors (Table IV-12). It accounted for 31% of the total biomass for the survey (Table IV-13) and was the biomass dominant on the inner shelf, second-most in bays and harbors, and an important contributor to demersal fish biomass in the central and southern regions (Tables IV-14). California halibut were caught in a broad range of sizes from 2 to 67 cm SL (Appendix B-B38). Due to the large diversity in size classes caught, distribution differed depending on habitat. Juveniles were only found in bays and harbors and there was a small primary mode among the juveniles at 12 cm, while larger size classes were evenly distributed with no modes (Figure IV-10; Appendix B-B38). California halibut matures at 20-23 cm SL for males (2-3 years old) and 38-43 cm SL for females (4-5 years old; Allen 1990). Thus, 42% of the halibut catch consisted of juveniles. Although juveniles were limited to bays and harbors, adults were found on the inner shelf (38%) and the middle shelf (10%) although they were mostly located in bays and harbors (52%) (Appendix B-B38).

Queenfish (*Seriphus politus*) (56,26,4). Queenfish is primarily an inner shelf and bay and harbor species found in 5% of the total area surveyed (Appendix B-B14) and represented 0.4% of the total abundance but 5% of the biomass (Appendix B-B15; Table IV-13). This species occurred primarily in bays in harbors in relatively small numbers (Table IV-12) but was the bay and harbor biomass dominant (Table IV-14). Queenfish ranged in sized from 2 to 21 cm SL. It had a bimodal distribution with the primary mode at 4 cm and a smaller secondary mode at 12 cm (Figure IV-10; Appendix B-B17). Queenfish females are oviparous and mature at around 12.7 cm TL (i.e., about 10 cm SL; Love 1996). Thus, 70% of this species catch consisted of juveniles. All juveniles were caught in bays and harbors in the central mainland region.

Anomalies and Parasites

The prevalence of fish anomalies and parasites was low and incidences were scattered throughout the SCB. A total of 557 (0.9%) of 61,687 fish had anomalies or parasites (Table IV-16). Anomalies were found in 22 (16%) of the 140 species. Anomalies and parasites identified in the study included parasites, tumors, lesions, fin erosion, ambicoloration, pigmentation, deformities, and deformities /lesions. Most (88%) of these were parasites. Of the remaining anomalies, tumors were the most abundant, followed closely by lesions, then ambicoloration, deformities, fin erosion, pigmentation, and deformities/lesions. In the survey, 454 (93%) of the 489 fish that had parasites were Pacific sanddab. Similarly, most (88%) of the fish with tumors (26) were Dover sole (23), and most (85%) fish with lesions (20) were speckled sanddab (17). Although all kelp bass collected had parasites, this only represented two individuals (Table IV-16). Similarly, only 1 of 6 black eelpouts (*Lycodes diapterus*) had parasites, but it was enough to rate this species second highest in percent of anomalies (17%). Otherwise, among fish species with total catches greater than 10, percent anomalies ranged from 0.03-3.1% to. Among these, California skate (*Raja inornata*;3.1%) had 2 parasitized fish out of 64, California halibut (3.0%) had 5 parasitized and 1 ambicolored fish out of 198, and Pacific sanddab (2.7%) had 454 parasitized fish, 4 ambicolored fish, 2 fish with deformities, and 1 individual characterized with a deformity or lesion.

Table IV-16. Number of fish by species with different anomaly types collected at depths of 2-476 m on the southern California shelf, July-October 2003.

						Pigment.				Total		
Scientific Name	Common Name	Par	Tu	Le	Fe	Am	Gr	De	D/L	OvAn	OvTotFi	%An
Citharichthys fragilis	Gulf sanddab	1	-	-	-	-	-	-	-	1	77	1.3
Citharichthys sordidus	Pacific sanddab	454	-	-	-	4	-	2	1	461	17,058	2.7
Citharichthys stigmaeus	speckled sanddab	3	-	17	1	-	-	-	-	21	6,785	0.3
Citharichthys xanthostigma	longfin sanddab	1	-	-	-	-	-	-	-	1	1,256	0.1
Glyptocephalus zachirus	rex sole	-	-	1	-	-	-	-	-	1	493	0.2
Hippoglossina stomata	bigmouth sole	3	-	-	-	1	-	-	-	4	156	2.6
Lepidogobius lepidus	bay goby	2	-	-	-	-	-	-	-	2	456	0.4
Lycodes diapterus	black eelpout	1	-	-	-	-	-	-	-	1	6	16.7
Lyopsetta exilis	slender sole	-	-	-	-	1	-	-	-	1	4,559	0.0
Microstomus pacificus	Dover sole	1	23	-	-	-	-	2	-	26	2,236	1.2
Paralabrax clathratus	kelp bass	2	-	-	-	-	-	-	-	2	2	100.0
Paralichthys californicus	California halibut	5	-	-	-	1	-	-	-	6	198	3.0
Parophrys vetulus	English sole	1	-	-	-	-	-	-	-	1	825	0.1
Pleuronichthys decurrens	curlfin sole	3	-	-	-	-	-	-	-	3	361	0.8
Pleuronichthys verticalis	hornyhead turbot	6	-	-	-	4	-	-	-	10	484	2.1
Raja inornata	California skate	2	-	-	-	-	-	-	-	2	64	3.1
Scorpaena guttata	California scorpionfish	3	-	-	-	-	-	-	-	3	168	1.8
Sebastes eos	pink rockfish	1	-	1	-	-	-	-	-	2	63	3.2
Sebastes rosenblatti	greenblotched rockfish	-	2	-	-	-	-	-	-	2	83	2.4
Symphurus atricaudus	California tonguefish	-	-	-	-	4	1	-	-	5	557	0.9
Zalembius rosaceus	pink seaperch	-	1	-	-	-	-	-	-	1	1,292	0.1
Zaniolepis latipinnis	longspine combfish	-	-	1	-	-	-	-	-	1	3,059	0.0
Total		489	26	20	1	15	1	4	1	557[a]	61,687[b]	0.9

[a] Total reflects number of fish with anomalies.
[b] Total of all fish in survey.
Pigment. = Pigmentation
Par = Parasite; Tu = Tumor; Le = Lesion; Fe = Fin erosion; Am = Ambicoloration; Gr = Green pigmentation on ventral side; De = Deformities; D/L = Deformity/Lesion; OvAn = Overall anomalous; OvTotFis = Overall total fish; %An = Percent anomalous.

Anomalies occurred in 38.2% of the area of the mainland shelf of southern California (Table IV-17). Among regions, they were most prevalent at cool and warm island regions (81.3 and 84.6%, respectively), followed by the central and southern mainland regions (52.8 and 41.2%, Parasites occurred in 32.0% of the area, followed by ambicoloration (6.5%), tumors (3.6%), lesions (2.0%), deformities (1.7 %), pigmentation (0.9%), deformities/lesions (0.9%), and fin erosion (0.5%). Parasites were the most widespread anomaly at inner and outer shelf large POTWs (both 100%), middle shelf islands (83.3%), and middle shelf large POTWs (64.0%). Tumors were most prevalent in middle shelf small POTWs (25.0%), middle shelf islands (16.7%), and middle shelf large POTWs (12.0%; Table IV-17; Figure IV-13). Ambicoloration was most widespread (33.2%) at inner shelf large POTWs (66.7%), outer shelf islands (25.0%), and the mainland middle shelf (15.4%; Table IV-17; Figure IV-14).

Table IV-17. Percent area by subpopulation of fish with different anomaly types collected on the southern California shelf and slope at depths of 2-476 m, July-October 2003.

Subpopulation	No. of Stations	Par	Tu	Le	Fe	Amb	Gr	De	D/L	Overall
Region										
Mainland	181									
Northern	54	7.6	0.0	---	---	---	2.2	---	---	9.8
Central	72	36.7	4.5	---	---	23.9	---	6.8	3.6	52.8
Southern	55	40.0	1.3	4.5	---	---	---	0.4	---	41.2
Island	29									
Cool (NW Channel Island	16	68.8	18.8	12.5	6.3	---	---	---	---	81.3
Warm (SE Channel Islanc	13	84.6	7.7	---	---	7.7	---	---	---	84.6
Shelf Zone										
Bays and Harbors (2-30 m)	26	7.7	---	---	---	---	---	---	---	7.7
Inner Shelf (2-30 m)	43									
Small POTWs	15	20.0	---	---	---	---	---	---	---	20.0
Large POTWs	3	100.0	---	---	---	66.7	---	---	---	100.0
Other Mainland	25	24.0	---	---	---	4.0	---	---	---	28.0
Middle Shelf (31-120 m)	87									
Small POTWs	12	41.7	25.0	---	---	---	---	---	---	50.0
Large POTWs	25	64.0	12.0	---	---	8.0	---	12.0	---	72.0
Mainland non-POTW	26	50.0	3.8	3.8	---	15.4	3.8	---	3.8	61.5
Island	24	83.3	16.7	4.2	4.2	---	---	---	---	87.5
Outer Shelf (121-202 m)	26									
Large POTWs	1	100.0	---	---	---	---	---	---	---	100.0
Mainland	21	37.3	4.2	---	---	---	---	---	---	41.5
Island	4	50.0	---	25.0	---	25.0	---	---	---	75.0
Upper Slope (201-500 m)	28									
Mainland	27	4.0	---	---	---	4.0	---	4.0	---	7.9
Island	1	---	---	---	---	---	---	---	---	0.0
Total all stations	210	32.0	3.6	2.0	0.5	6.5	0.9	1.7	0.9	38.2

Par = Parasite; Tu = Tumor; Le = Lesion; Fe = Fin erosion; Amb = Ambicoloration; Gr = Green pigmentation o ventral side; De = Deformities; D/L = Deformity/Lesion.

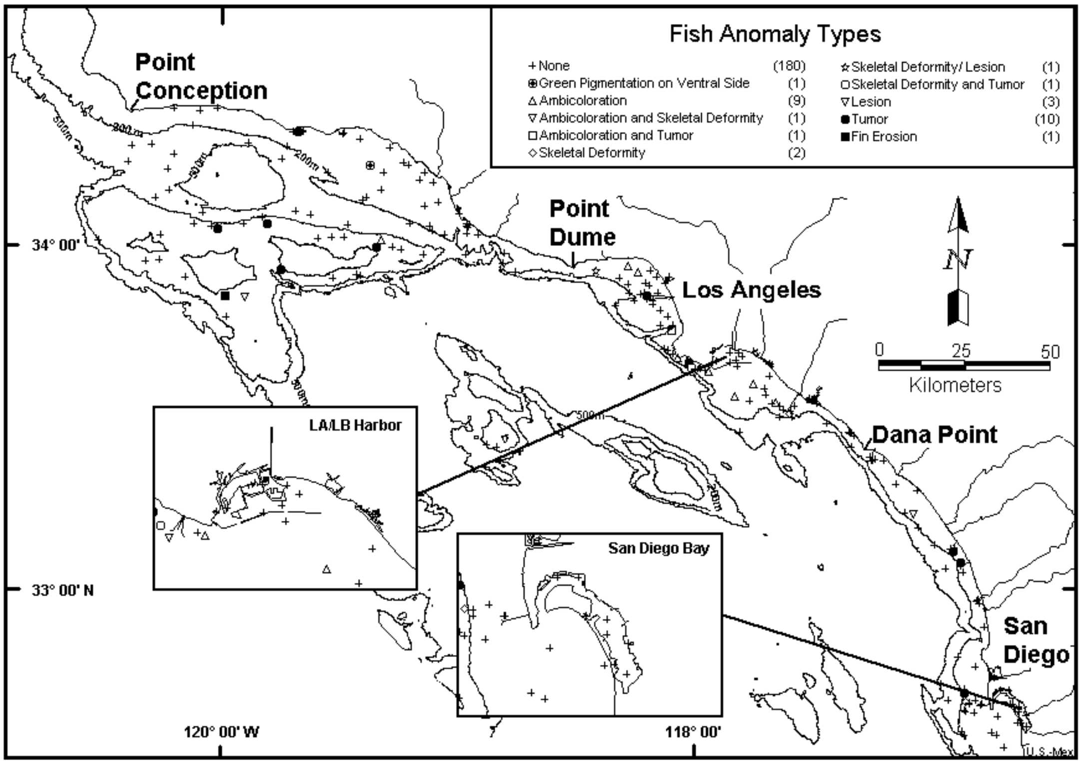


Figure IV-13. Distribution of fish anomalies on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003.

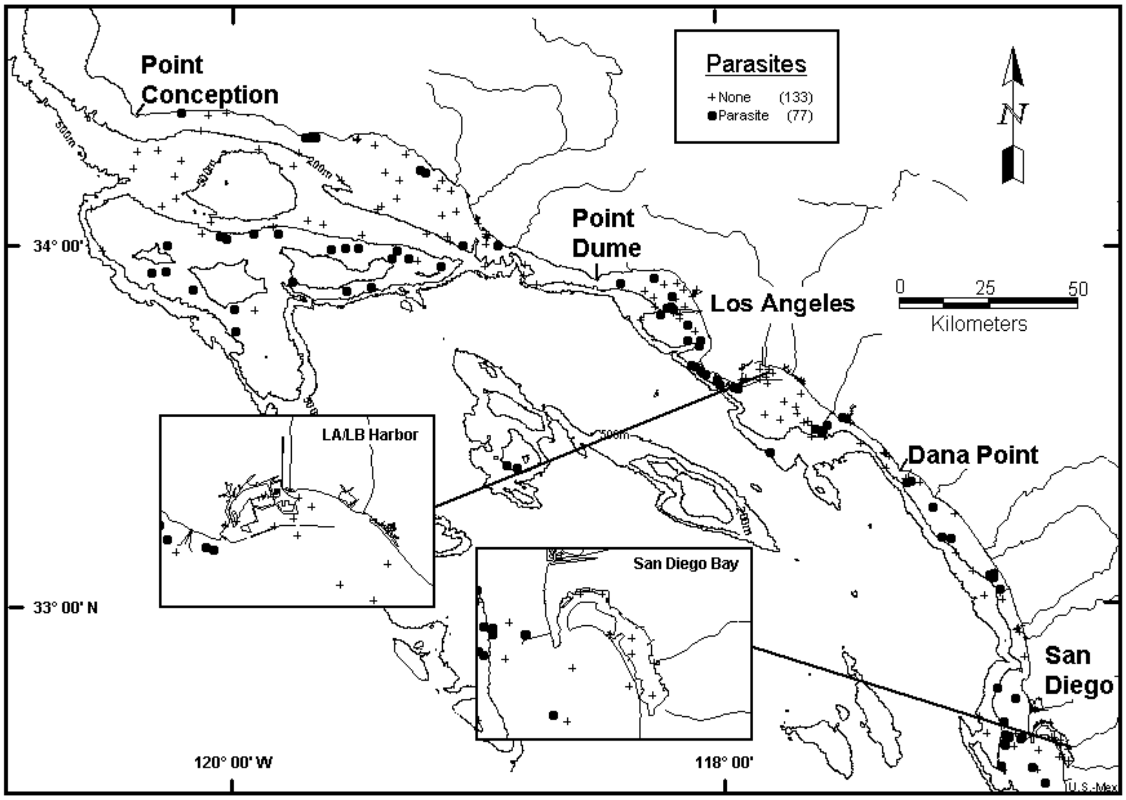


Figure IV-14. Distribution of external parasites of fish on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003.

Discussion

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 trawl gear used in present-day surveys. As with Carlisle (1969b), the primary focus of these studies (e.g., CLAEMD 1994a,b; CSDMWWD 1995; Stull 1995; CSDOC 1996; Stull and Tang 1996; CSDLAC 2006) has been the assessment of 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, Allen 1982). Later, a need arose to conduct synoptic surveys 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.* 1987, 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. The 1994 regional survey (Allen *et al.* 1998) collected 114 trawl samples from 9-215 m, all on the mainland shelf. A second regional survey was conducted in 1998 (Allen *et al.* 2002a) to provide additional region-wide background information on the status and health of fish populations, as well as to assess fish populations not only on the mainland shelf but also in bays and harbors and the offshore islands. The 1998 survey collected samples from 314 stations, of which 197 were from the mainland shelf (depths of 10-200 m). The present regional survey, which was conducted during the summer and fall of 2003, surveyed all of the areas monitored in 1998, but a deep-water component of the upper slope (201-500 m) was added. The present regional survey collected 210 samples, 128 of which were collected from the mainland shelf (10-200 m).

Population Attributes

Fish population attribute mean values for the SCB were generally similar on the mainland shelf (10-200 m) between the four time periods -- 1957-1975 (Allen and Voglin 1976), 1994 (Allen *et al.* 1998), 1998 (Allen *et al.* 2002a), and 2003 (present study; Table IV-18). However, although mean fish abundance (individuals/haul) was similar (156 to 173) in the first three periods, it was nearly double (294) that in 2003. During the four periods, mean biomass (kg/haul) ranged from 4.9 to 7.1; species richness (species/haul) from 10 to 14; and diversity (bits/individual/haul) from 1.28 to 1.59. It should be noted that the number of samples used in the analysis was much larger in 1957-1975 than in the three recent surveys. However, in the latter three surveys, the samples were collected synoptically within the same year using a stratified randomized design whereas in 1957-1975, samples collected over a 29-year period were compiled from surveys of varying designs.

Whereas regional population attribute means often showed remarkable similarity to 1957-1975 values (given as ranges of means within regions), 2003 means were noticeably greater for fish abundance in the northern and southern regions (Table IV-18). In the southern region, mean biomass was lower and species richness higher than in 2003 than in previous surveys.

As in 1994 and 1998 (Allen *et al.* 1998, 2002a) median fish abundance, species richness, and diversity were lowest in the inner shelf zone relative to the middle shelf and outer shelf zones, and median biomass was higher in the outer shelf zone (Tables IV-1, IV-3, IV-5, and IV-7). Bays and harbors were also surveyed in 1998 and 2003. In 1998, these areas had higher medians than the inner shelf zone for all population attributes but in 2003 these areas were lower than the inner shelf for all except biomass. Median population attribute values for the upper slope zone (added in 2003) was lower than the medians of abundance and species richness in all zones except bays and harbors. Median diversity on the upper slope was higher than bays and harbors and the inner shelf.

Fish population attribute median values for the SCB (subdivided into LPOTWs and non-LPOTWs) were somewhat similar among the three regional surveys (Table IV-19; Figure IV-15): fish abundance was 141-434 individuals/haul, biomass 3.1-7.4 kg/haul, species richness 11-16 species/haul, and diversity was 1.62-1.77 bits/individual/haul. In all three surveys, median LPOTW fish counts exceeded non-LPOTW counts, most dramatically in 2003. Median counts for both LPOTWs and non-LPOTWs in 1994 (164 and 146 individuals/haul, respectively) and in 1998 (169 and 141) were only about half those collected in 2003 (434 and 302). Similar to abundance, median biomass tended to be higher near LPOTWs than at non-LPOTW sites during all three surveys (Table IV-19; Figure IV-15). Also, 2003 LPOTW and non-LPOTW biomass measurements (7.4 and 4.9 kg/haul, respectively) were higher than those of 1994 (5.5 and 3.1) and 1998 (4.0 and 3.4), although to a lesser degree than for individuals. Unlike individual counts and biomass, median species richness tended to be nearly the same between LPOTWs and non-LPOTWs during the three surveys (Table IV-19; Figure IV-15). In 2003 LPOTW and non-LPOTW species richness measurements (both 16 species/haul) were higher than those collected in 1994 (both 13) and 1998 (11 and 12). Median diversity measurements among the three surveys were very similar between LPOTWs and non-LPOTWs (Table IV-19; Figure IV-15). 2003 LPOTW and non-LPOTW diversity measurements (1.77 and 1.76 bits/individual/haul, respectively) were only very slightly higher than those collected in 1994 (1.74 and 1.70) and 1998 (1.62 and 1.75).

Among the three surveys and four population attributes (Figure IV-16), LPOTW medians were mostly above 50% of their non-LPOTW counterparts. Only species richness (38%) and diversity (45%) in 1998 were below 50%. When compared to the medians of the Bight as a whole (Table IV-19), LPOTW medians were similarly above 50%, with the exception of species richness in 1998 when it was 44%.

The survey design of the 1998 regional survey reduced the size of the area included in the LPOTW area to the area where outfall effects on fish and invertebrate populations had been observed. In comparing outfall effects between the two periods, the 1998 POTW boundaries were applied to the 1994 station map, and 1994 stations were reapportioned into the new LPOTW and non-LPOTW subpopulation boundaries of 1998; the 1994 stations retained their area-weights from that year. Area-weights for the 2003 survey were the same as for the 1998.

Table IV-18. 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 1957-1975a, 1994, 1998, and 2003 regional survey data.

		Mean/haul[b]			
Southern California Bight Database	No. samples	Abundance (no. of individuals)	Biomass (kg)	No. of Species	Diversity[c] (bits/individual)
Northern Region					
1957-1975[d]	149	64-147	3.5	8-12	0.91-1.50
1994	45	137	3.6	12	1.72
1998[e]	65	136	4.6	9	1.45
2003[f]	35	195	4.0	12	1.45
Central Region					
1957-1975[d]	1511	139-420	7.6-13.4	10-16	1.23-1.64
1994	41	159	6.7	11	1.45
1998[e]	78	158	7.0	10	1.54
2003[f]	52	387	8.1	15	1.53
Southern Region					
1957-1975[d]	577	97-192	5.0-6.2	10-12	1.28-1.50
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
All Mainland Shelf Regions[f]					
1957-1975[d]	2237	173	7.1	11	1.28
1994	114	157	4.9	12	1.59
1998[e]	197	156	5.8	10	1.57
2003[f]	128	294	5.9	14	1.49

[a]Twenty-seven (1%) of 2,237samples are from Santa Catalina Island.
[b]The 1994, 1998, and 2003 mean values are weighted in accordance with the sampling design.
[c]1957-1975 are Brillouin diversities; 1994, 1998, and 2003 values are Shannon-Wiener diversities.
[d]1957-1975 data from Allen and Voglin (1976).
[e]Data from Islands (except 1957-1975) and Bays/Harbors are excluded from analysis.
[f]Data from Islands (except 1957-1975), Bays/Harbors, and Upper Slope (201-500 m) are excluded from analysis.
[g]SCB as a whole.

Table IV-19. Demersal fish abundance, biomass, species richness, and diversity at middle-shelf large publicly owned treatment work (LPOTW) and reference (non-LPOTW) subpopulations in 1994, 1998, and 2003. Data from 1994 reanalyzed using 1998 subpopulation boundaries. See Figure IV-15.

Category	No. of Stations	Total	Range Min.	Range Max.	Stratified Values Md	95% CL LL	95% CL UL	Mn	SD	Percent Above Bight Median
Abundance (no. of individuals/haul)										
1994 LPOTW	9	2,304	43	726	164	92	351	257	211	53
1998 LPOTW	32	6,997	23	775	169	113	209	219	182	56
2003 LPOTW	25	10,536	57	813	434	290	508	421	164	92
1994 non-LPOTW	49	8,452	23	394	146	108	160	162	93	52
1998 non-LPOTW	61	8,987	6	371	141	107	157	160	87	59
2003 non-LPOTW	38	11,832	39	937	302	188	400	342	200	71
Biomass (kg/haul)										
1994 LPOTW	9	53.9	1.5	19.3	5.5	2.8	8.2	8.0	5.3	63
1998 LPOTW	32	208.7	0.8	24.5	4.0	3.2	6.0	6.5	6.0	53
2003 LPOTW	25	221.8	1.8	22.6	7.4	5.5	9.3	8.9	5.4	61
1994 non-LPOTW	49	213.5	0.6	15.2	3.1	2.6	3.9	4.2	3.3	32
1998 non-LPOTW	61	247.8	0.1	26.3	3.4	2.3	3.8	4.2	4.5	38
2003 non-LPOTW	38	205.2	0.5	20.2	4.9	3.0	6.5	6.0	4.7	27
Number of Species (no. of Species/haul)										
1994 LPOTW	9	37	8	21	13	10	16	14	4	56
1998 LPOTW	32	51	5	26	11	10	13	12	5	44
2003 LPOTW	25	49	11	20	16	15	17	16	2	92
1994 non-LPOTW	49	60	7	23	13	11	13	13	3	66
1998 non-LPOTW	61	63	3	23	12	11	13	13	4	62
2003 non-LPOTW	38	64	8	24	16	13	17	16	4	77
Shannon-Wiener Diversity (bits/individual/haul)										
1994 LPOTW	9		1.00	2.46	1.74	1.29	1.99	1.66	0.44	60
1998 LPOTW	32		0.61	2.43	1.62	1.43	1.74	1.63	0.39	65
2003 LPOTW	25		1.00	2.09	1.77	1.58	1.93	1.72	0.30	68
1994 non-LPOTW	49		0.67	2.37	1.70	1.46	1.72	1.65	0.42	62
1998 non-LPOTW	61		0.46	2.30	1.75	1.59	1.81	1.74	0.37	71
2003 non-LPOTW	38		0.68	2.25	1.76	1.56	1.90	1.67	0.40	68

CL = Confidence limits (LL = Lower Limit; UL = Upper Limit); Min. = Minimum; Max. = Maximum; No. = Number; SD = Standard deviation; Md = Median; Mn = Mean.

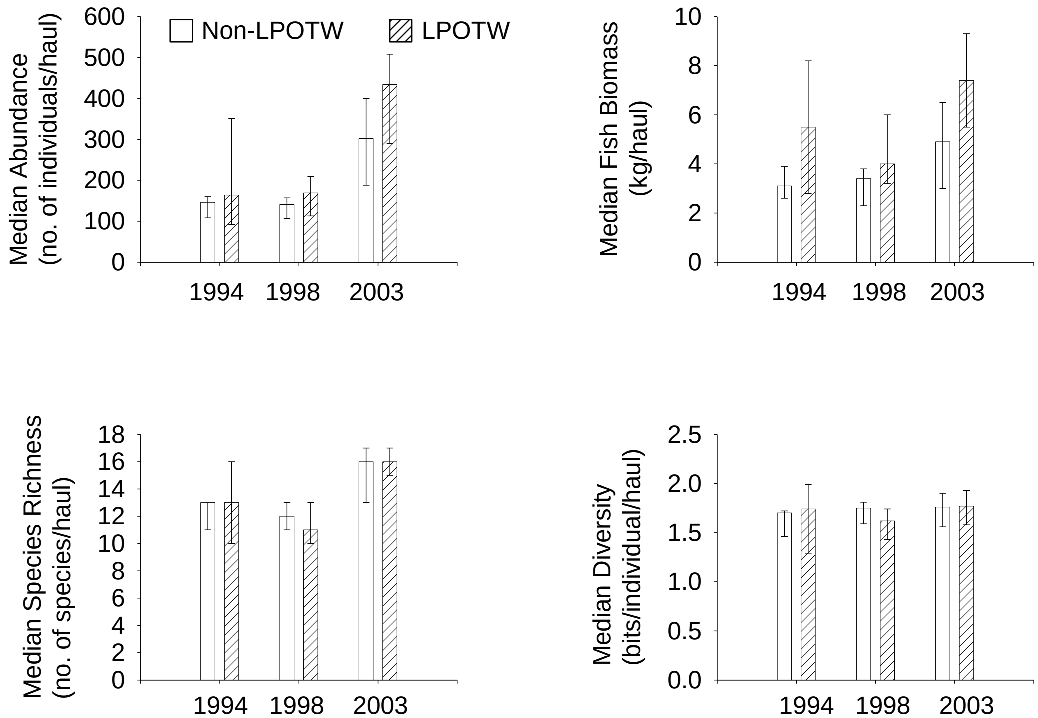


Figure IV-15. Median (and 95% confidence limits) of fish population attributes at large publicly owned treatment work (LPOTW) and reference (non-Large POTW) subpopulations on the southern California middle shelf in 1994, 1998, and 2003: a) abundance; b) biomass; c) species richness; and d) diversity. NOTE: LPOTW boundaries of 2003 were used for all years; non-large POTW areas consist of all mainland middle shelf stations that did not fall within the LPOTW boundaries.

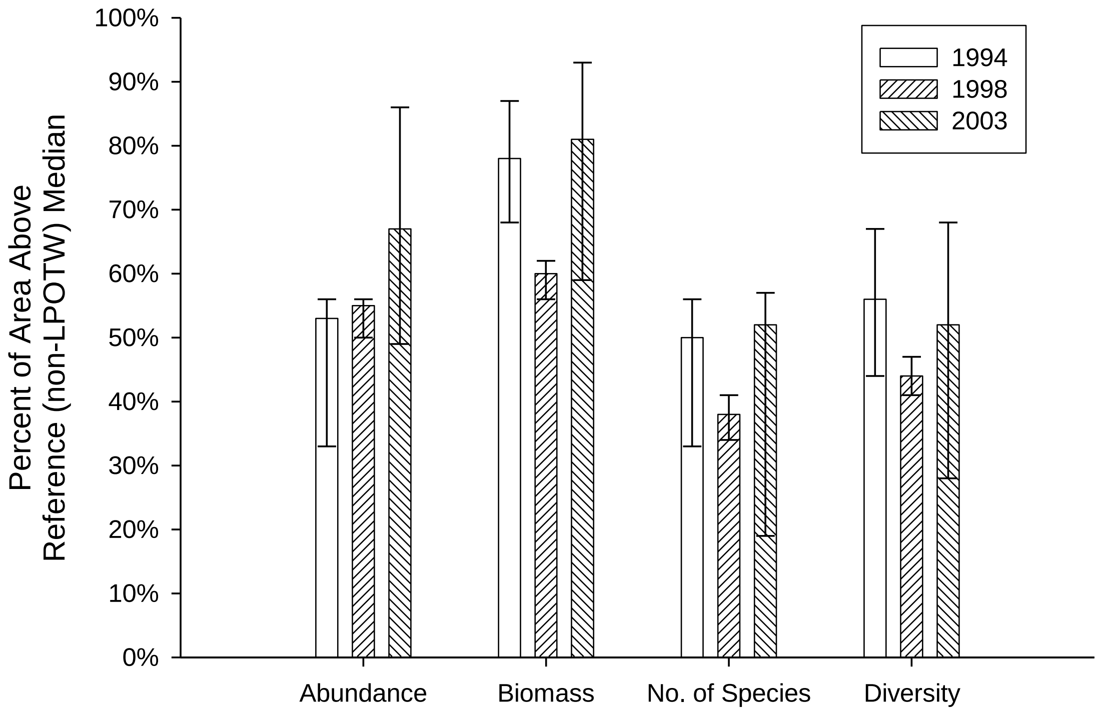


Figure IV-16. Percent of area (with 95% confidence limits) of large publicly owned treatment works (LPOTW) subpopulations with fish population attributes above the reference (NLPOTW: mainland, middle shelf, non-large POTW) subpopulation medians in 1994, 1998, and 2003. NOTE: LPOTW boundaries of 2003 were used for all years; NLPOTW areas consist of all mainland middle shelf stations that did not fall within the LPOTW boundaries.

Species Composition

Some important changes in species composition occurred between 1994, 1998, and 2003. The distribution of species among higher taxa was nearly the same as in 1994 (Allen *et al.* 1998, 2001b, 2002a), although the number of species collected were 87 in 1994, 143 in 1998 and 142 in 2003. Scorpaenidae (=Sebastidae, in part), Pleuronectidae, and Paralichthyidae were the most diverse families in 1994 and 1998, whereas Scorpaenidae, Pleuronectidae, and Cottidae were the most diverse families in 2003. Five to six species occurred in 50% of the area of the mainland shelf in all three years. In 1994, these were Pacific sanddab, Dover sole, plainfin midshipman, California lizardfish, hornyhead turbot, and yellowchin sculpin (Table IV-20); in 1998, California lizardfish, hornyhead turbot, longfin sanddab, yellowchin sculpin, and bigmouth sole; and in 2003, Pacific sanddab, hornyhead turbot, yellowchin sculpin, pink seaperch, stripetail rockfish, and speckled sanddab. Two species, hornyhead turbot and yellowchin sculpin, occurred in 50% of the area in all three years. Two species occurred in this amount of area in two years: Pacific sanddab in 1994 and 2003, and California lizardfish in 1994 and 1998.

Pacific sanddab was the most abundant species and California halibut contributed the most biomass in 1994; white croaker was most abundant species and contributed the most biomass in 1998; and Pacific sanddab was most abundant and had the most biomass in 2003. In 1994, white croaker occurred in 4% of the area, and contributed 3% of the total abundance and 8% of the biomass. In 1998, white croaker occurred in 17% of the area and represented 28% of the total abundance and 26% of the total biomass . The increased abundance of white croaker in 1998 was largely due to the addition of LA/LB Harbor to the study scope (Allen *et al.* 2002a). White croaker was very abundant in this harbor, and in 1979-1980, it was the most abundant species in Los Angeles Harbor in trawl surveys (Allen *et al.* 1983).

Commercial and Recreational Fishes

During this sampling program, economic important species of groundfish in the SCB were well represented on the inner, middle, and outer shelf. These included Pacific sanddab (17,058), Dover sole (2236), English sole (825), rex sole (493), and California scorpionfish (168 individuals; Appendix B-B38). A general distribution pattern for some groundfish species (e.g., Dover sole, rex sole) consisted of larger individuals occurring on the upper slope with smaller individuals on the shelf. Nearshore species such as the croakers (e.g., queenfish, white croaker, California corbina, yellowfin croaker, etc.) were conspicuously low in abundance despite of the inclusion of bays and harbors in the sampling program.

Effects of Oceanic Regime Changes

The three regional surveys occurred during three different oceanic regimes: 1994 – warm regime; 1998 –El Niño (very warm); and 2003 – cold regime (Chavez *et al.* 2003, Allen *et al.* 2004, Goericke *et al.* 2005). The older database (1957-1975; Allen and Voglin 1976) consisted of two periods –El Niño (1957-1959) and cool regime (1960-1963, 1969-1975); about 10% of the 2,237 stations sampled during that period were from the El Niño period and 90% from the subsequent cool regime period. Hence, the database was dominated by cold-regime data and will be regarded as primarily representing a cold regime. Fish population attributes showed some patterns associated with these regimes. For the SCB mainland shelf (islands and bays excluded), fish abundance and species richness were highest in 2003 (cold) and lowest in 1998 (El Niño). Both fish abundance and biomass were higher during the two cold periods and lower during the two warm periods.

Eight species showed strong affinities (50% or more areal coverage) with one or more of these oceanic periods in the three recent regional surveys (Table IV-20). As noted above, hornyhead turbot and yellowchin sculpin (both warm temperate species) were widespread in 1994 (warm), 1998 (El Niño), and 2003 (cold). Pacific sanddab (temperate) was common in warm and cold regimes, but decreased in occurrence during the El Niño. California lizardfish (warm temperate) was most widespread during the El Niño, followed by the preceding warm regime. Dover sole and plainfin midshipman (both temperate) were most common during the warm regime; longfin sanddab and bigmouth sole (both warm temperate) during the El Niño; and pink seaperch, stripetail rockfish, and speckled sanddab (all temperate) during the cold regime. Several species occurring in at least 20% of the area but not in 50% of the area in any year were much less common in the warm regime and El Niño than in the cold regime; these included halfbanded rockfish (warm temperate) and roughback sculpin and pygmy poacher (both temperate). In terms of areal occurrence, Pacific sanddab showed the strongest positive warm regime and cold regime responses; California lizardfish showed the strongest positive El Niño response.

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

		No. of Stations			Percent of Stations			Percent of Area*		
Scientific Name	Common Name	1994	1998[a]	2003[b]	1994	1998[a]	2003[b]	1994	1998[a]	2003[b]
Citharichthys sordidus (1,7)	Pacific sanddab	75	76	98	66	39	77	**68.3**	47.0	**79.5**
Pleuronichthys verticalis (5,3)	hornyhead turbot	60	93	83	53	47	65	**51.3**	**54.4**	**67.7**
Icelinus quadriseriatus (6,5)	yellowchin sculpin	51	75	68	45	38	53	**50.9**	**52.5**	**54.0**
Zalembius rosaceus	pink seaperch	44	54	72	39	27	56	43.8	40.7	**53.1**
Sebastes saxicola	stripetail rockfish	50	46	60	44	23	47	46.9	35.7	**52.0**
Citharichthys stigmaeus	speckled sanddab	47	70	65	41	36	51	36.1	39.1	**51.9**
Zaniolepis latipinnis	longspine combfish	44	51	67	39	26	52	46.1	44.0	49.4
Citharichthys xanthostigma (8,4)	longfin sanddab	55	101	64	48	51	50	48.7	**53.6**	48.1
Hippoglossina stomata	bigmouth sole	56	87	57	49	44	45	48.7	**49.8**	44.6
Microstomus pacificus (2,16)	Dover sole	65	40	60	57	20	47	**57.4**	27.2	43.5
Porichthys notatus (3,12)	plainfin midshipman	57	52	49	50	26	38	**54.3**	37.2	43.4
Sebastes semicinctus	halfbanded rockfish	15	7	38	13	4	30	13.2	4.5	37.9
Chitonotus pugetensis	roughback sculpin	13	10	45	11	5	35	9.8	7.2	37.3
Lepidogobius lepidus	bay goby	36	19	42	32	10	33	36.5	14.3	35.2
Synodus lucioceps (4,1)	California lizardfish	58	135	38	51	69	30	**51.6**	**74.1**	31.9
Scorpaena guttata	California scorpionfish	26	39	42	23	20	33	19.5	19.6	27.0
Raja inornata	California skate	25	31	25	22	16	20	23.3	13.4	23.5
Zaniolepis frenata	shortspine combfish	32	22	30	28	11	23	24.8	14.8	23.0
Odontopyxis trispinosa	pygmy poacher	6	15	28	5	8	22	4.7	14.0	22.3
Total (all stations)		114	197	128				3,075[d]	3,344[d]	3,089[d]

*Percent of area based on area-weighted frequency of occurrences.
[a]Mainland shelf only (10-200 m); stations in island and bay/harbor subpopulations were excluded from the 1998 and 2003 analyses.
[b]Mainland shelf only (10-200 m); stations in island, bay/harbor, and upper slope subpopulations were excluded from the 1998 and 2003 analyses.
[c]Numbers in parentheses represent rank of species by percent of areal occurrence in 1994 and in 1998 (species occurred in greater than 50% of the area in any one of the years).
[d]Total area in km^2.
Areal occurrences of 50% or greater are shaded in gray.

The regime shifts are part of the Pacific Decadal Oscillation, a multidecadal cycle of alternating cold and warm regimes (Chavez *et al.* 2003). During warm regime, temperatures are not only warmer but the California Current is weaker and upwelling and productivity are less. A weakened California Current probably also results in reduced transport of eggs and larvae of temperate species spawning north of the SCB. In addition, to reduced recruitment of coldwater species, there is an increased occurrence of warmwater species (Allen *et al.* 2004). In general, fish abundance and biomass decreased between the earlier cold regime and the warm regime period. The decrease in areal occurrence of the coldwater species was due in part to decreased occurrence in the SCB, and due to a shift in distribution from the middle shelf zone to the outer shelf zone. As the middle shelf zone comprises about 50% of the area of the southern California mainland shelf (Allen 1982), a species shift in distribution from the middle shelf to the outer shelf would also decrease the overall areal distribution of the species.

The reduced areal occurrence of the coldwater species and the increased occurrence of warmwater species in 1998 suggest a response to the 1997-1998 El Niño (Allen *et al.* 2002a). During an El Niño, there is a deepening of the thermocline. Thus it is likely that some coldwater species seek refuge on the outer shelf to avoid the increase in water temperature on the middle shelf. Of the three most widespread coldwater species in 1994 (e.g., Pacific sanddab, Dover sole, plainfin midshipman) showed a decrease in areal occurrence in the middle shelf zone in 1998 (Allen *et al.* 1998, 2002a). In contrast, of the three species that became more widespread in 1998, California tonguefish and longfin sanddab expanded their occurrence northward (the former becoming more widespread in the northern region and the latter in the central region); whereas the bigmouth sole simply became more widespread in the central region (Allen *et al.* 1998, 2002a). In addition, two new species (and families) from southern Baja California were caught for the first time in California: blacklip dragonet (*Synchiropus atrilabiatus*; Callionymidae) and speckledtail flounder (*Engyophrys sanctilaurentii*; Bothidae), were taken for the first time in California during this survey (Allen and Groce 2001b, Groce *et al.* 2001a). Thus, the coldwater species appeared to have shifted its range deeper to the outer shelf zone (comprising less area), whereas the warmwater species increased its occurrence in the middle shelf zone.

During a cold regime period in 2003 (beginning in 1999; Goericke *et al.* 2005), there was an increased areal occurrence of many temperate (coldwater) and some warm temperate species from 1998. This may be the result of a variety of environmental changes, including cooler water temperatures, shallower thermocline, increased strength of the California Current, increased upwelling and productivity off central California, and the transport of this productivity and fish larvae to the SCB, resulting in increased recruitment of many coldwater species (Figures IV-9, IV-10, and IV-15). This coldwater period began in 1999, immediately after the 1998 El Niño (Allen *et al.* 2004). Thus, there was about four years of this cold regime prior to the 2003 survey, allowing for several years of recruitment of coldwater species to the SCB. As recruitment of coldwater species increased, that of warmwater species decreased. For example, Pacific sanddab and speckled sanddab (both coldwater species) populations consisted largely of new recruits (<10 cm), whereas the longfin sanddab (a warmwater species) population showed almost no recruitment preceding the 2003 survey (Figures IV-9 and IV-10). The occurrence of more deepwater fish (e.g., juvenile Dover sole) at shallower depths suggests a shallower thermocline than in 1998, as well as the influence of the California Current in the SCB (particularly in the Santa Barbara Channel region. Perhaps due to the increased recruitment and the transport of productivity to the SCB, fish abundance and biomass had increased by 2003 relative to 1998. Two new species from southern Baja California were also caught for the first time in California in this survey: Colombia goby and whitetail tonguefish. Since these are warmwater species from the south, it probable that their larvae arrived in California during the 1998 El Niño or from unreported populations off Baja California. Hence their occurrence in 2003 may not be directly related to the cold regime during which they were caught.

Anomalies and Parasites

The prevalence of anomalies in demersal fish from the mainland shelf of southern California was higher in 2003 (0.9%) than in 1998 (0.5%; Allen *et al.* 2002a) but lower than in 1994 (1.0%; Allen *et al.* 1998). As in 1994 and 1998, the prevalence of anomalies in 1998 was similar to background anomaly rates in mid-Atlantic (0.5%) and Gulf Coast (0.7%) estuaries (Fournie *et al.*

1996). In contrast, the prevalence of anomalies on the mainland shelf of the SCB from 1969-1976 was much higher (5.0%; Mearns and Sherwood 1977).

Fin erosion was observed in only one fish in 61,687 fish in the survey was reported with fin erosion in 2003 (Table IV-16). It was reported in a speckled sanddab at the Channel Islands from the middle shelf of the northwest Channel Islands off the south side of Santa Rosa Island (Table IV-17; Figure IV-13). Fin erosion was not observed in any fish in 1998 (Allen *et al.* 2002a), and was observed in one Dover sole with a tumor near Santa Barbara in 1994 (Allen *et al.* 1998). Fin erosion was the most frequently observed anomaly in 1972 and 1976 (Mearns and Sherwood 1977). It was found in 33 species of fish on the shelf, with 60% of the species being flatfishes (Pleuronectidae, Paralichthyidae [= Bothidae, in part], and Cynoglossidae) and rockfishes. The disease was very prevalent on the Palos Verdes Shelf but was found at a low frequency in Santa Monica Bay, San Pedro Bay, and Dana Point. Approximately 39% of the Dover sole from the Palos Verdes Shelf had fin erosion in 1972 and 1976. Bight-wide (including the Palos Verdes Shelf), 30% of Dover sole had fin erosion. Fin erosion in Dover sole decreased as sediment contamination levels decreased between the early 1970s and the mid-1980s and was virtually absent on the Palos Verdes Shelf by 1990 (Stull 1995, Allen 2006b). Only 1 fish of 18,912 fish had fin erosion in 1994 (Allen *et al.* 1998, 2001b). The fin erosion in this specimen off Santa Barbara did not have the dark edges found in fin erosion on the Palos Verdes Shelf in the 1970s. It is also unlikely that the fin erosion in the speckled sanddab in 2003 was the same as that found on the Palos Verdes Shelf in the 1970s. Speckled sanddab from the Palos Verdes Shelf in that period did not have fin erosion although the disease was widespread in other species (Mearns and Sherwood 1977).

In the 2003 survey, epidermal tumors occurred in 26 of 61,687 fish (Table IV-16) and 3.6% of the area of the mainland shelf of the SCB (Table IV-16). Although found at Channel Islands, mainland shelf (including Palos Verdes Shelf), their greatest areal occurrence (25%) was in the SPOTW area. Of the occurrences, 23 were found in Dover sole (1.2% of 2,236 fish); 2 in greenblotched rockfish (*Sebastes rosenblatti*; 2.4% of 83 fish); and 1 in pink seaperch (0.1% of 1,292 fish). In the 1998 regional survey, epidermal tumors occurred in 12 of 1,635 (0.7%) Dover sole collected (Allen *et al.* 2002a); Dover sole with tumors occurred on the Palos Verdes Shelf and at the southeast Channel Islands. In 1994, epidermal tumors were found in 10 (1%) of 961 Dover sole, occurring from Santa Barbara to Mission Bay (Allen *et al.* 1998, 2001b). This rate of occurrence probably represents the background prevalence for this disease in the SCB. In 1972-1975, epidermal tumors occurred in 126 (1.4%) of 8,733 Dover sole collected from Santa Monica Bay to Point Loma, California (Mearns and Sherwood 1977). Most of the individuals with this anomaly were less than 12 cm in length. The prevalence of epidermal tumors in Dover sole on the Palos Verdes Shelf decreased with increasing distance from the White Point outfall and also with time from 1971-1983 (Cross 1988). Epidermal tumors in Dover sole are not found only at outfall areas. Sherwood and Mearns (1976) found epidermal tumors in Dover sole from Point Arguello, California, to off Cedros Island, Baja California Sur, Mexico. Epidermal tumors are x-cell lesions thought to be caused by an amebic parasite (Dawe *et al.* 1979).

Ambicoloration has been found in a number of southern California flatfish species over the years, including bigmouth sole, California halibut, diamond turbot, Dover sole, English sole, curlfin sole, hornyhead turbot, and California tonguefish (Haaker and Lane 1973, Mearns and

Sherwood 1977). In 1994, this anomaly was found in California halibut, California tonguefish, spotted turbot, Dover sole, hornyhead turbot, rex sole, and fantail sole (*Xystreurys liolepis*) (Allen *et al.* 1998). In the 1998 regional survey, ambicoloration was found mostly in hornyhead turbot, but also in California tonguefish, bigmouth sole, spotted turbot, California halibut, and speckled sanddab (Allen *et al.* 2002a). In 2003 it was found in Pacific sanddab, slender sole, bigmouth sole, California halibut, hornyhead turbot, and California tonguefish. It was most widespread near LPOTWs where it occurred in 67% of the area.

As in 1994 and 1998, parasites were the most commonly occurring anomaly of fishes in 2003, and Pacific sanddab was the most affected species (Table IV-16). The most noticeable external parasite that infests Pacific sanddab is the eye copepod (*Phrixocephalus cincinnatus*). It was the most common external parasite on demersal fish collected from 1969-1976 (Mearns and Sherwood 1977) and in 1994 and 1998 (Allen *et al.* 1998, 2002a). Although Mearns and Sherwood (1977) found a lower prevalence of this infestation on the Palos Verdes Shelf in the early 1970s (when that area was highly contaminated), the prevalence was relatively high at this location in fish collected from 1979-1994 (Perkins and Gartman 1997). Although it was the larger and more obvious parasites that were reported in this survey, additional species of parasitic copepods were identified from the fins and bodies of flatfishes and rockfishes (Kalman 2006). Results of this more detailed study of fish ectoparasites during the 2003 survey are described in Section VII of this report.

V. MEGABENTHIC INVERTEBRATE POPULATIONS

Introduction

Invertebrates living on or in the surface sediment and large enough to be retained by a trawl net are termed megabenthos. Hundreds of megabenthic invertebrate species occur within the southern California Bight (SCB; Moore and Mearns 1978, Allen *et al.* 1998, Stull *et al.* 2001, Allen *et al.* 2002a). Because these species are relatively sedentary and respond to changes in the benthic environment, their populations have been used for decades to assess impacts resulting from human activities. Most information on the megabenthic invertebrate fauna of the southern California shelf has resulted from regular trawl surveys conducted near ocean outfalls to assess effects of wastewater discharge (e.g., Carlisle 1969a,b; Mearns and Greene 1974; CLAEMD 1994a,b; CSDMWWD 1995; Stull 1995; CSDOC 1996; CSDLAC 2000). While local areas have been well-studied for temporal and small-scale spatial variability, earlier regional assessments compiled trawl data gathered for various purposes (Allen and Voglin 1976, Thompson *et al.* 1993a), collected data in reference surveys of limited scope (Word *et al.* 1977, Thompson *et al.* 1987b, Thompson *et al.* 1993b), or provided composite assessment in wastewater discharge areas (Mearns and Greene 1974). A synoptic regional assessment was not conducted until 1994 (Allen *et al.* 1998, Stull *et al.* 2001). Although this study provided substantial information on the fauna of 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.* 2002a) to provide additional region-wide information on the status of invertebrate populations. This study included bays, harbors, and offshore island habitats.

The objectives of this section are 1) to describe the distribution, relative importance (areal coverage, abundance, and biomass) and health of the dominant invertebrates of the SCB in bays, at islands, on the shelf and slope, and in select geographic, depth, and human influence subpopulations in 2003; 2) to assess population changes between 1994, 1998, and 2003; and 3) to examine historical trends based on earlier studies. This information will provide context for local population patterns observed in monitoring studies. Other aspects of this fauna are presented in the Section VI – Assemblages and Biointegrity.

Results

Population Attributes

Abundance per Haul

A total of 157,326 invertebrates were collected during the survey (Table V-1). The number per haul ranged from 0 to 10,986. The lowest individual values occurred in the mainland region on the outer shelf and in bays, and the highest in the northern mainland region on the upper slope. The median for the Bight as a whole was 389 individuals per haul, with subpopulation medians ranging from 12 (inner shelf, small POTWs) to 1,701 (mainland upper slope). Abundance was higher (more area above the Bight median) on the mainland, although the southeast islands were higher than the southern mainland. Both island medians were below the Bight median. The warm islands had much higher numbers of invertebrates than did the cool islands, with median numbers of 268 and 84, respectively. On the mainland, the median abundance was highest in the north (683), followed by the central (486) and southern (151) regions. By depth zone, the upper slope had the highest median number, followed by the outer and middle shelf, bays/harbors, and lastly, the inner shelf; medians were 1,653, 174, 154, 94, and 18, respectively. On the upper slope, mainland catches were higher than at islands. On the outer shelf, large POTWs had the highest median abundances and other mainland sites had the lowest. On the middle shelf, median abundance was highest (196) at mainland non-POTW sites and lowest at small POTWs (37). Median abundance declined with decreasing depth from the upper slope to the inner shelf, but increased in 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-2).

More than 1,979 invertebrates per haul were caught at 21 stations (Figure V-1). All of these high abundance sites were on the outer shelf or upper slope. Most were located on either the mainland or island sides of the Santa Barbara Channel. The highest invertebrate catch of 10,986 individuals occurred at an upper slope site on the mainland side. Most (83) stations had invertebrate catches of 107 to 1,978 individuals, with nearly half the sites having more than 106 invertebrates in the catch.

Biomass per Haul

A total of 2214.3 kg of invertebrates were taken during the survey (Table V-3). The biomass of invertebrates per haul ranged from 0 to 186.7 kg. Lowest individual values occurred in all mainland regions at all shelf zones, although not in the upper slope zone or in all human influence subpopulations. The highest individual biomass occurred on the central region outer shelf. The Bight-wide median was 4.8 kg/haul, with subpopulation medians ranging from 0.2 kg (island upper slope, and inner shelf small POTW and "other mainland" sites) to 38.2 kg at the single outer shelf large POTW site. Invertebrate biomass was higher (more sites above the Bight median) at northern and central mainland regions than at either the northwest or southeast islands (Table V-3). All regions except the northern and central mainland had median biomass below that of the Bight as a whole, as did all subpopulations except outer shelf large POTWs, mainland non-POTWs, islands, and upper slope mainland. Island subpopulations had similar median biomass values, and both the cool and warm islands were lower than the median for mainland regions. This was a result of the almost complete lack of upper slope samples from the islands (only 1 upper slope station in the Island subpopulation). Among the mainland regions the northern region had a significantly higher median (42%) than the central region, which in turn had a higher median biomass (79%) than the southern mainland subpopulation. On the inner shelf small POTW sites had the same median biomass as other mainland non-POTW sites, while the median at large POTW sites was four times higher. On the middle shelf this relationship did not hold, with the island median being the highest, followed by mainland non-POTW, large POTW, and small POTW medians.

By depth zone the inner shelf supported the lowest median biomass (0.2 kg/haul) and upper slope the highest (21.0 kg/haul; Table V-3). Inner shelf sites followed a regional trend with northern region > central region > southern region medians. Bay and harbor sites had double the median biomass/haul of the inner shelf, but were far lower than other shelf zones.

Table V-1. Megabenthic invertebrate abundance by subpopulation at depths of 2-476 m on the southern California shelf and upper slope, July-October 2003.

		Abundance (no. individuals/haul)*								Percent
					Area-Weighted Values					Above
	No. of		Range					95%		Bight
Subpopulation	Stations	Total	Min.	Max.	Median	Mean	SD	CL		Median
Region										
Mainland	**181**	**134,778**	**0**	**10,986**	**448**	**1,622**	**2,644**	**663**		**54.0**
Northern	54	74,533	0	10,986	683	2,485	3,502	1,280		58.5
Central	72	39,902	2	4,711	486	988	991	386		59.9
Southern	55	20,343	0	3,722	151	679	1,016	463		27.9
Island	**29**	**22,548**	**28**	**5,618**	**136**	**778**	**1,436**	**523**		**24.1**
Cool (NW Channel Islands)	16	3,715	28	1,351	84	232	375	184		11.6
Warm (SE Channel Islands)	13	18,833	73	5,618	268	1,449	1,900	1,033		38.5
Shelf Zone										
Bays and Harbors (2-30 m)	**26**	**7,151**	**0**	**1,960**	**94**	**275**	**518**	**199**		**14.1**
Inner Shelf (2-30 m)	**43**	**1,670**	**2**	**323**	**18**	**34**	**39**	**14**		**0.0**
Small POTWs	15	624	3	323	12	42	77	39		0.0
Large POTWs	3	225	17	189	18	75	81	91		0.0
Other Mainland	25	821	2	177	18	33	37	14		0.0
Middle Shelf (31-120 m)	**87**	**47,002**	**21**	**5,618**	**154**	**681**	**1,133**	**290**		**36.7**
Small POTWs	12	695	23	151	37	58	39	22		0.0
Large POTWs	25	9,523	21	2,340	106	381	588	231		21.6
Mainland non-POTW	26	15,196	27	3,722	196	584	828	318		41.9
Island	24	21,588	28	5,618	123	900	1,550	620		28.7
Outer Shelf (121-202 m)	**26**	**21,963**	**0**	**4,712**	**174**	**671**	**1,189**	**426**		**27.5**
Large POTWs	1	1,206	1,206	1,206	1,206	1,206	0	0		100.0
Mainland	21	19,842	0	4,712	150	843	1,373	586		34.9
Island	4	915	73	389	178	229	119	116		0.0
Upper Slope (201-500 m)	**28**	**79,540**	**28**	**10,986**	**1,653**	**2,991**	**3,281**	**1,264**		**83.1**
Mainland	27	79,495	28	10,986	1,701	3,033	3,285	1,279		84.2
Island	1	45	45	45	45	45	0	0		0.0
Total (all stations)	**210**	**157,326**	**0**	**10,986**	**389**	**1488**	**2511**	**571**		**50.0**

The average area sampled during a trawl tow was 3,014 m^2.
CL = Confidence limits (± value); Min. = Minimum; Max. = Maximum; No. = Number;
SD = Standard deviation.
POTW = Publicly owned treatment work monitoring areas.

Table V-2. Megabenthic invertebrate abundance by region within shelf zone subpopulations at depths of 2-476 m on the southern California shelf and upper slope, July-October, 2003.

		Abundance (no. of individuals/haul)*								Percent
					Area-Weighted Values					Above
	No. of		Range					95%		Bight
Subpopulation	Stations	Total	Min.	Max.	Median	Mean	SD	CL		Median
Shelf Zone										
Bays and Harbors (2-30 m)	26	**7,151**	**0**	**1,960**	**94**	**275**	**518**	**199**		**14.1**
Northern Region	1	12	12	12	12	12	0	0		0.0
Central Region	16	4,191	2	1,960	110	262	474	232		10.9
Southern Region	9	2,948	0	1,950	36	327	605	395		17.5
Inner Shelf (2-30 m)	43	**1,670**	**2**	**323**	**18**	**34**	**39**	**14**		**0.0**
Northern Region	21	393	2	80	14	24	23	12		0.0
Central Region	11	564	13	189	18	48	61	44		0.0
Southern Region	11	713	5	323	34	39	32	21		0.0
NW Channel Islands	0	--	--	--	--	--	--	--		--
SE Channel Islands	0	--	--	--	--	--	--	--		--
Middle Shelf (31-120 m)	87	**47,002**	**21**	**5,618**	**154**	**681**	**1,133**	**290**		**36.7**
Northern Region	6	941	25	636	70	183	227	199		9.2
Central Region	33	15,262	21	1,966	438	642	606	298		57.9
Southern Region	24	9,211	23	3,722	82	661	1,182	772		23.3
NW Channel Islands	13	3,217	28	1,351	84	247	412	224		13.2
SE Channel Islands	11	18,371	79	5,618	268	1,670	1,986	1,174		44.8
Outer Shelf (121-200 m)	26	**21,963**	**0**	**4,712**	**174**	**671**	**1,189**	**426**		**27.5**
Northern Region	8	8,576	0	4,712	73	1,072	1,709	1,184		27.4
Central Region	8	10,990	30	4,711	829	1,389	1,442	1,044		65.4
Southern Region	6	1,482	60	720	109	204	190	141		7.9
NW Channel Islands	2	453	170	283	170	227	57	78		0.0
SE Channel Islands	2	462	73	389	73	231	158	219		0.0
Upper Slope (201-500 m)	28	**79,540**	**28**	**10,986**	**1,653**	**2,991**	**3,281**	**1,264**		**83.1**
Northern Region	18	64,611	28	10,986	1,030	3,663	3,781	1,788		82.8
Central Region	4	8,895	1,567	2,737	2,101	2,224	483	474		100.0
Southern Region	5	5,989	151	2,475	764	1,211	955	919		52.1
NW Channel Islands	1	45	45	45	45	45	0	0		0.0
SE Channel Islands	0	--	--	--	--	--	--	--		--
Total (all stations)	**210**	**157,326**	**0**	**10,986**	**389**	**1,488**	**2,511**	**571**		**50.0**

The average area sampled during a trawl tow was 3,014 m^2.
CL = Confidence limits (± value); Min. = Minimum; Max. = Maximum; No. = Number;
SD = Standard deviation.
POTW = Publicly owned treatment work monitoring areas.

Table V-3. Megabenthic invertebrate biomass by subpopulation at depths of 2-476 m on the southern California shelf and upper slope, July-October 2003.

Subpopulation	No. of Stations	Biomass (kg/haul)* Total	Range Min.	Range Max.	Area-Weighted Values Median	Mean	SD	95% CL	Percent Above Bight Median
Region									
Mainland	**181**	**2,009.3**	**0.0**	**186.7**	**5.3**	**19.4**	**28.7**	**6.6**	**51.0**
Northern	54	897.5	0.0	132.2	8.4	24.2	33.5	11.8	54.7
Central	72	823.7	0.0	186.7	5.9	19.3	25.7	8.5	57.0
Southern	55	288.1	0.0	61.5	2.6	9.9	16.9	8.7	35.1
Island	**29**	**205.0**	**0.2**	**32.2**	**3.6**	**7.1**	**8.6**	**3.1**	**37.1**
Cool (NW Channel Islands)	16	75.3	0.2	17.5	3.6	4.7	4.4	2.2	29.7
Warm (SE Channel Islands)	13	129.7	0.8	32.2	3.9	10.0	11.2	6.1	43.6
Shelf Zone									
Bays and Harbors (2-30 m)	**26**	**62.3**	**0.0**	**20.6**	**0.4**	**2.4**	**5.1**	**2.0**	**10.8**
Inner Shelf (2-30 m)	**43**	**20.6**	**0.0**	**2.6**	**0.2**	**0.4**	**0.6**	**0.2**	**0.0**
Small POTWs	15	7.0	0.0	2.1	0.2	0.5	0.6	0.3	0.0
Large POTWs	3	4.1	0.3	2.5	0.8	1.4	0.9	1.0	0.0
Other Mainland	25	9.5	0.0	2.6	0.2	0.4	0.5	0.2	0.0
Middle Shelf (31-120 m)	**87**	**448.9**	**0.0**	**50.2**	**3.5**	**6.4**	**9.5**	**2.7**	**36.0**
Small POTWs	12	17.9	0.1	4.8	1.6	1.5	1.3	0.8	0.0
Large POTWs	25	109.6	0.0	31.1	2.9	4.4	6.1	2.4	25.1
Mainland non-POTW	26	179.9	0.1	50.2	3.2	6.9	10.7	4.1	37.2
Island	24	141.5	0.6	32.2	3.5	5.9	7.4	3.0	32.3
Outer Shelf (121-202 m)	**26**	**741.2**	**0.0**	**186.7**	**10.7**	**24.3**	**37.8**	**13.5**	**73.1**
Large POTWs	1	38.2	38.2	38.2	38.2	38.2	0.0	0.0	100.0
Mainland	21	639.7	0.0	186.7	6.6	27.6	44.0	18.6	71.9
Island	4	63.3	3.2	31.5	10.4	15.8	10.4	10.2	69.3
Upper Slope (201-500 m)	**28**	**941.3**	**0.2**	**113.9**	**21.0**	**33.4**	**31.4**	**12.1**	**74.2**
Mainland	27	941.1	0.2	113.9	21.5	33.9	31.4	12.2	75.2
Island	1	0.2	0.2	0.2	0.2	0.2	0.0	0.0	0.0
Total (all stations)	**210**	**2214.3**	**0.0**	**186.7**	**4.8**	**17.4**	**26.9**	**5.7**	**50.0**

The average area sampled during a trawl tow was 3,014 m^2.
CL = Confidence limits (± value); Min. = Minimum; Max. = Maximum; No. = Number;
SD = Standard deviation.
POTW = Publicly owned treatment work monitoring areas.

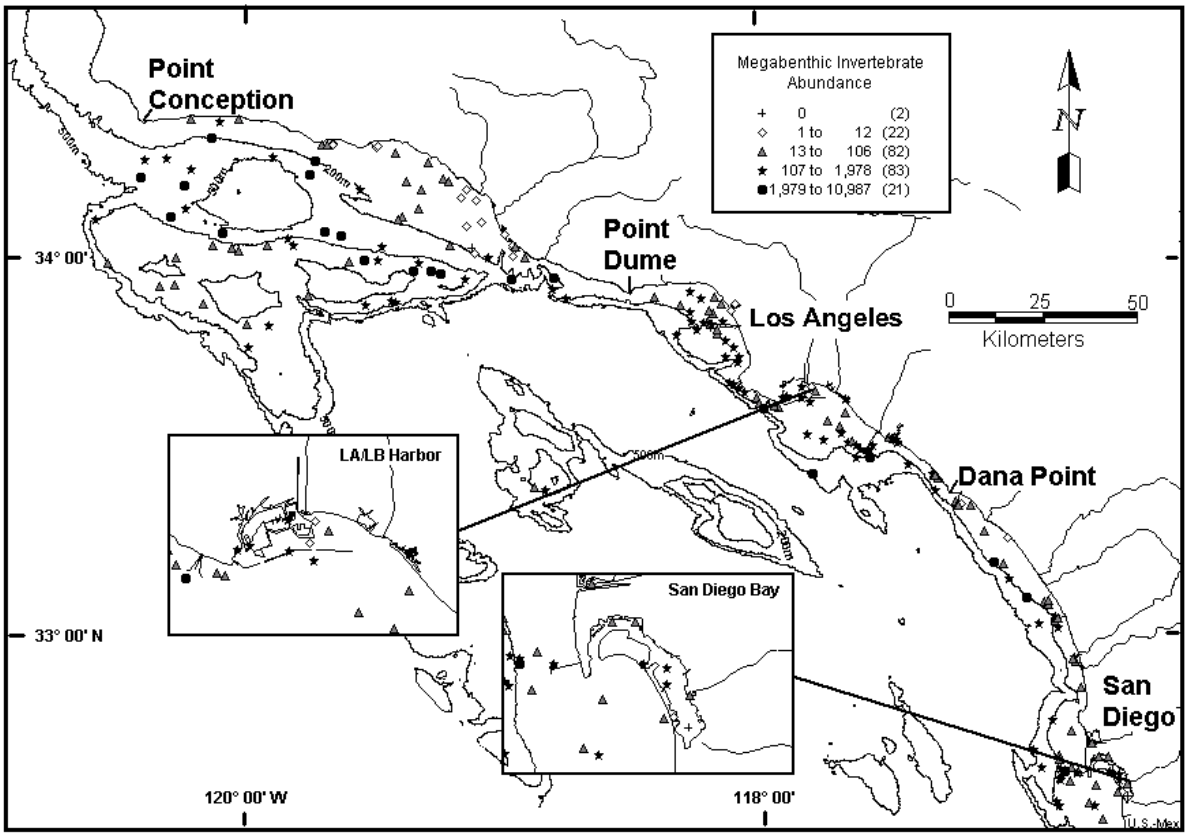


Figure V-1. Distribution of megabenthic invertebrate abundance per haul at depth of 2-476 m on the southern California shelf and upper slope, July-October 2003.

Median biomass values increased with depth beyond the inner shelf; from 3.5 kg on the middle shelf, to 10.7 kg on the outer shelf, and 21 kg on the upper slope (Table V-4). Twenty-one stations, 11 of which were in the Santa Barbara Channel, had catches over 31.1 kg (Figure V-2). Of the remaining 10 high biomass sites, 9 were located on the central region mainland shelf, and one on the southern region shelf. Most stations (82) had biomass between 2.2 and 31 kg/haul, while 32 sites had invertebrate biomass of 0.1 kg or less.

Species Richness (Number of Species) per Haul

A total of 308 species of invertebrates were collected during the survey (Table V-5). The number of species per haul ranged from 0 to 37. No invertebrates were caught in at least one station in the north and south mainland regions, in bays, and on the mainland outer shelf. The single highest number of species (37) was caught in the northwest island region on the middle shelf.

The median for the Bight as a whole was 12 species per haul, with subpopulation medians ranging from 4 (inner shelf, small POTWs) to 16 (Islands region and northwest and southeast islands subpopulations). The number of invertebrate species was higher (more area above the Bight median) on the islands than the mainland regions. All island subpopulations had median numbers of species above the Bight median (Table V-5), and varied little amongst themselves. Mainland region medians were similar, although the central region median was about 30% higher (13 species/haul). By depth, the middle and outer shelf zones had the same medians, with the upper slope slightly lower (Table V-5). Bays (7 species) and the inner shelf (5 species) had considerably lower medians.

Within the outer shelf zone, the median number of species was highest at the islands, followed by the mainland non-POTW subpopulation, with the single large POTW site on the outer shelf being lower than the latter median (Table V-5). Within the middle shelf, islands had the highest median, followed by the large POTWs and mainland non-POTW areas, with small POTWs having the lowest median. Overall, the inner shelf had low species richness medians, and the islands had the highest. Comparing regions within shelf zones, the highest medians in the middle and outer shelf zones were at the northwest islands (Table V-6). Overall, 20 stations had more than 19 species, with 7 of these occurring around islands (Figure V-3). The remaining high richness sites were nearly evenly distributed between the northern, central and southern mainland regions. Most (86) stations had 4 to 11 species, with 46% of the sites having 12 or more invertebrate species. Two sites, one in southern San Diego Bay and one off Ventura, had no invertebrates in the haul.

Table V-4. Megabenthic invertebrate biomass by region within shelf zone subpopulations at depths of 2-476 m on the southern California shelf and upper slope, July-October, 2003.

		Biomass (kg/haul)*								Percent
					Area-Weighted Values					Above
	No. of		Range					95%		Bight
Subpopulation	Stations	Total	Min.	Max.	Median	Mean	SD	CL		Median
Shelf Zone										
Bays and Harbors (2-30 m)	**26**	**62.3**	**0.0**	**20.6**	**0.4**	**2.4**	**5.1**	**2.0**		**10.8**
Northern Region	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0
Central Region	16	23.3	0.0	8.2	0.5	1.5	2.2	1.1		5.0
Southern Region	9	39.0	0.0	20.6	0.1	4.3	7.7	5.1		19.3
Inner Shelf (2-30 m)	**43**	**20.6**	**0.0**	**2.6**	**0.2**	**0.4**	**0.6**	**0.2**		**0.0**
Northern Region	21	9.1	0.0	2.6	0.3	0.5	0.7	0.4		0.0
Central Region	11	6.9	0.1	2.5	0.2	0.4	0.5	0.3		0.0
Southern Region	11	4.6	0.0	2.1	0.1	0.1	0.2	0.1		0.0
NW Channel Islands	0	--	--	--	--	--	--	--		--
SE Channel Islands	0	--	--	--	--	--	--	--		--
Middle Shelf (31-120 m)	**87**	**448.9**	**0.0**	**50.2**	**3.5**	**6.4**	**9.5**	**2.7**		**36.0**
Northern Region	6	14.7	0.2	6.8	0.9	2.5	2.5	2.2		11.2
Central Region	33	217.2	0.0	50.2	5.2	9.8	13.1	6.6		50.8
Southern Region	24	75.5	0.1	17.8	2.5	4.0	5.5	3.6		22.8
NW Channel Islands	13	46.5	0.6	8.2	3.5	3.6	2.3	1.2		21.2
SE Channel Islands	11	95.0	0.8	32.2	3.7	8.6	10.0	5.9		42.4
Outer Shelf (121-200 m)	**26**	**741.2**	**0.0**	**186.7**	**10.7**	**24.3**	**37.8**	**13.5**		**73.1**
Northern Region	8	220.3	0.0	132.2	3.9	27.5	42.7	29.6		44.3
Central Region	8	403.8	1.6	186.7	25.8	51.6	57.3	41.5		83.1
Southern Region	6	53.8	4.5	20.6	6.5	8.2	4.7	3.3		80.8
NW Channel Islands	2	28.6	11.1	17.5	11.1	14.3	3.2	4.4		100.0
SE Channel Islands	2	34.7	3.2	31.5	3.2	17.4	14.2	19.6		46.8
Upper Slope (201-500 m)	**28**	**941.3**	**0.2**	**113.9**	**21.0**	**33.4**	**31.4**	**12.1**		**74.2**
Northern Region	18	653.4	0.2	113.9	14.4	34.3	35.2	16.6		75.1
Central Region	4	172.5	24.4	56.6	36.1	43.1	11.8	11.5		100.0
Southern Region	5	115.2	1.4	61.5	12.8	23.1	24.0	23.1		51.4
NW Channel Islands	1	0.2	0.2	0.2	0.2	0.2	0.0	0.0		0.0
SE Channel Islands	0	--	--	--	--	--	--	--		--
Total (all stations)	**210**	**2,214.3**	**0.0**	**186.7**	**4.8**	**17.4**	**26.9**	**5.7**		**50.0**

* The average area sampled during a trawl tow was 3,014 m^2.

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

POTW = Publicly owned treatment work monitoring areas.

Table V-5. Megabenthic invertebrate species by subpopulation at depths of 2-476 m on the southern California shelf and upper slope, July-October 2003.

		Species Richness (no. of species/haul)							Percent
					Area-Weighted Values				Above
	No. of		Range					95%	Bight
Subpopulation	Stations	Total	Min.	Max.	Median	Mean	SD	CL	Median
Region									
Mainland	**181**	**269**	**0**	**28**	**11**	**12**	**6**	**1**	**43.9**
Northern	54	106	0	22	9	10	6	2	33.6
Central	72	183	1	28	13	12	5	2	58.2
Southern	55	165	0	28	10	13	6	3	46.8
Island	**29**	**136**	**10**	**37**	**16**	**18**	**7**	**2**	**79.3**
Cool (NW Channel Islands)	16	110	11	37	16	18	7	3	87.5
Warm (SE Channel Islands)	13	86	10	36	16	18	7	4	69.2
Shelf Zone									
Bays and Harbors (2-30 m)	**26**	**78**	**0**	**18**	**7**	**7**	**5**	**2**	**15.4**
Inner Shelf (2-30 m)	**43**	**70**	**1**	**13**	**5**	**5**	**3**	**1**	**0.3**
Small POTWs	15	35	1	11	4	5	3	1	0.0
Large POTWs	3	21	6	13	7	9	3	3	6.7
Other Mainland	25	44	1	10	5	5	3	1	0.0
Middle Shelf (31-120 m)	**87**	**198**	**3**	**37**	**14**	**15**	**7**	**2**	**67.4**
Small POTWs	12	57	3	20	11	11	5	3	33.3
Large POTWs	25	71	4	28	13	13	5	2	60.0
Mainland non-POTW	26	113	5	28	13	14	6	2	59.0
Island	24	120	10	37	15	18	7	3	79.2
Outer Shelf (121-200 m)	**26**	**114**	**0**	**21**	**14**	**13**	**6**	**2**	**56.6**
Large POTWs	1	10	10	10	10	10	0	0	0.0
Mainland	21	68	0	21	12	12	6	3	49.9
Island	4	39	12	18	15	16	2	2	75.0
Upper Slope (201-500 m)	**28**	**89**	**5**	**20**	**12**	**12**	**4**	**2**	**49.3**
Mainland	27	74	5	20	12	12	4	2	48.6
Island	1	15	15	15	15	15	0	0	0.0
Total (all stations)	**210**	**308**	**0**	**37**	**12**	**13**	**6**	**1**	**50.0**

The average area sampled during a trawl tow was 3,014 m^2.
CL = Confidence limits (± value); Min. = Minimum; Max. = Maximum; No. = Number; SD = Standard deviation.
POTW = Publicly owned treatment work monitoring areas.

Table V-6. Megabenthic invertebrate species by region within shelf zone subpopulations at depths of 2-476 m on the southern California shelf and upper slope, July-October, 2003.

		Species Richness (no. of species/haul)							Percent
					Area-Weighted Values				Above
	No. of		Range					95%	Bight
Subpopulation	Stations	Total	Min.	Max.	Median	Mean	SD	CL	Median
Shelf Zone									
Bays and Harbors (2-30 m)	**26**	**78**	**0**	**18**	**7**	**7**	**5**	**2**	**15.4**
Northern Region	1	3	3	3	3	3	0	0	0.0
Central Region	16	64	1	18	9	9	5	2	18.8
Southern Region	9	29	0	14	5	6	4	3	4.4
Inner Shelf (2-30 m)	**43**	**70**	**1**	**13**	**5**	**5**	**3**	**1**	**0.3**
Northern Region	21	25	1	8	3	4	2	1	0.0
Central Region	11	49	4	13	7	7	2	2	1.0
Southern Region	11	31	2	9	4	5	3	2	0.0
NW Channel Islands	0	--	--	--	--	--	--	--	--
SE Channel Islands	0	--	--	--	--	--	--	--	--
Middle Shelf (31-120 m)	**87**	**198**	**3**	**37**	**14**	**15**	**7**	**2**	**67.4**
Northern Region	6	32	5	22	9	11	6	5	26.6
Central Region	33	103	4	28	14	14	6	3	67.6
Southern Region	24	93	3	28	13	15	7	4	62.5
NW Channel Islands	13	93	11	37	16	19	7	4	88.5
SE Channel Islands	11	78	10	36	15	18	7	4	63.6
Outer Shelf (121-200 m)	**26**	**114**	**0**	**21**	**14**	**13**	**6**	**2**	**56.6**
Northern Region	8	46	0	21	4	9	8	6	29.2
Central Region	8	45	7	18	11	13	4	3	47.8
Southern Region	6	35	8	17	12	13	4	4	55.2
NW Channel Islands	2	24	12	18	18	15	3	4	50.0
SE Channel Islands	2	29	16	17	17	17	1	1	100.0
Upper Slope (201-500 m)	**28**	**89**	**5**	**20**	**12**	**12**	**4**	**2**	**49.3**
Northern Region	18	54	5	20	12	12	4	2	41.7
Central Region	4	34	7	14	11	12	3	3	54.2
Southern Region	5	35	9	19	12	14	4	4	50.0
NW Channel Islands	1	15	15	15	15	15	0	0	0.0
SE Channel Islands	0	--	--	--	--	--	--	--	--
Total (all stations)	**210**	**308**	**0**	**37**	**12**	**13**	**6**	**1**	**50.0**

The average area sampled during a trawl tow was 3,014 m^2.
CL = Confidence limits (± value); Min. = Minimum; Max. = Maximum; No. = Number;
SD = Standard deviation.
POTW = Publicly owned treatment work monitoring areas.

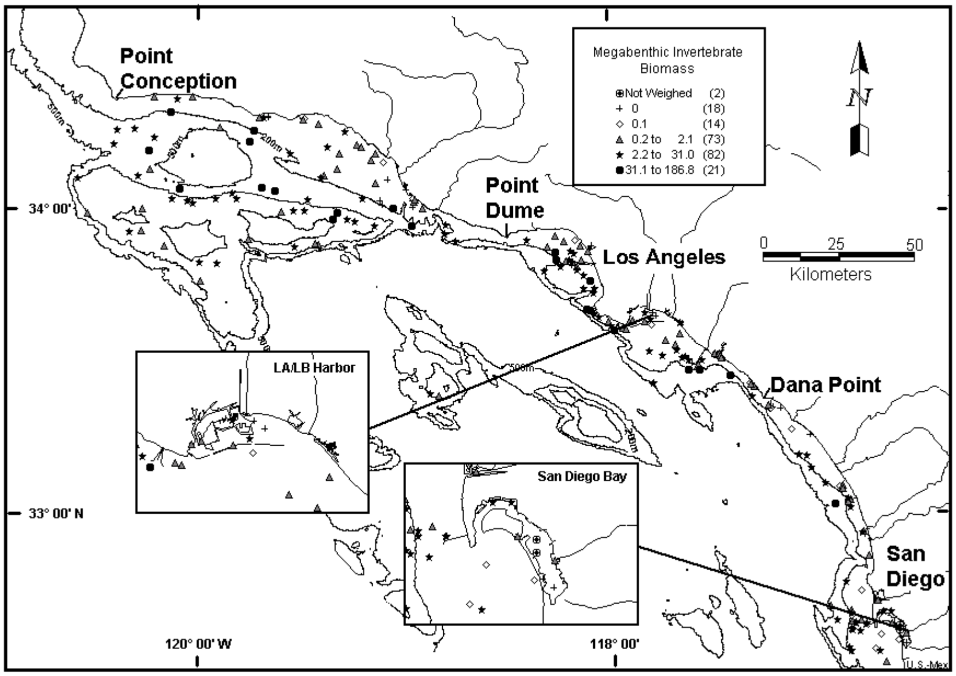


Figure V-2. Distribution of megabenthic invertebrate biomass per haul at depths of 2-476 m on the southern California shelf and upper slope, July-October 2003.

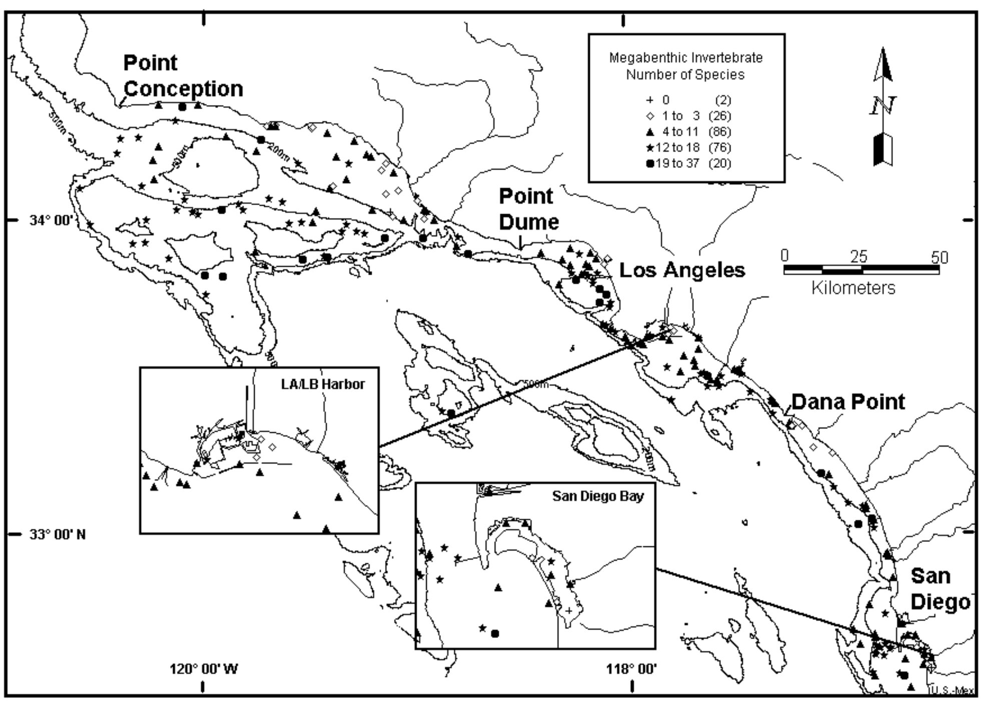


Figure V-3. Distribution of megabenthic invertebrate species per haul at depths of 2-476 m on the southern California shelf and upper slope, July-October 2003.

Diversity per Haul

Invertebrate diversity ranged from 0.0 to 2.77 bits/individual/haul (Table V-7). Values of zero occurred at all three mainland regions, and in inner and outer shelf zones. The highest diversity occurred in the northwest island middle shelf. The median for the Bight as a whole was 1.10 bit/individual/haul, with subpopulation medians ranging from 0.10 (outer shelf, large POTW) to 2.35 (island upper slope). Invertebrate diversity was higher (more area above the Bight median) at the islands than at the mainland: medians were 1.71 and 0.96, respectively (Table V-7). Among the islands, the cool northwest islands had a greater median diversity (2.15) than the warm southeast islands (1.22). Along the mainland, the southern region had a higher median diversity (1.20) than the Bight and northern (0.95) and central mainland regions (0.90).

Among depth zones the middle shelf had the highest diversity, followed by the outer shelf, bays, upper slope, and inner shelf; medians were 1.17, 1.15, 1.10. 0.96. and 0.90, respectively. On the outer shelf, islands had a higher median diversity than mainland areas. On the middle shelf, only mainland non-POTW sites did not exceed the Bight median (Table V-7). Comparing regions within the shelf zones, the highest diversity medians occurred at northwest islands in the middle shelf, outer shelf, and upper slope zones; in the northern region, the highest median was in bays (Table V-8). Invertebrate diversities exceeding 2.05 occurred at 21 stations distributed throughout the SCB. One- third of these occurred at the islands, and one in San Diego Bay (Figure V-4). The remainder were located on the mainland shelf in the central (4) and southern (6) regions. Most (85) stations had diversity values ranging from 1.14 to 2.05.

Species Composition

Taxonomic Composition

Megabenthic invertebrates collected in the trawl survey represented 10 phyla, 23 classes, and 127 families (Appendix C-C1, Appendix F-F4, and Appendix F-F5). A total of 325 taxa were collected, which included 308 identified species and 17 identified only to a higher taxa due to damage during collection, and. Of the 308 species, there were 88 mollusks, 76 arthropods, 57 echinoderms, 31 cnidarians, 19 chordates, 10 sponges, 9 ectoprocts, 4 annelids, 4 brachiopods, and 2 echiurans. The most diverse classes were Malacostraca, with 71 species, Gastropoda with 69 species, and Anthozoa with 26 species. The most diverse families were Majidae (spider crabs; 13 species), Trochidae (top snails, 9 species), and both Hippolytidae and Crangonidae (shrimps), with 7 species each. A number of the species encountered had not previously been taken in either routine POTW monitoring or regional synoptic monitoring efforts. Several of the species given provisional names appear to be new species both to the SCB fauna, and to science.

Table V-7. Megabenthic invertebrate diversity by subpopulation at depths of 2-476 m on the southern California shelf and upper slope, July-October 2003.

		Shannon-Wiener Diversity (bits/individual/haul)						Percent
				Area-Weighted Values				Above
	No. of	Range					95%	Bight
Subpopulation	Stations	Min.	Max.	Median	Mean	SD	CL	Median
Region								
Mainland	**181**	**0.00**	**2.42**	**0.96**	**1.04**	**0.55**	**0.11**	**45.4**
Northern	54	0.00	1.82	0.95	0.97	0.41	0.13	42.3
Central	72	0.00	2.36	0.90	1.00	0.67	0.25	40.9
Southern	55	0.00	2.42	1.20	1.22	0.59	0.22	57.0
Island	**29**	**0.07**	**2.77**	**1.71**	**1.59**	**0.81**	**0.29**	**73.4**
Cool (NW Channel Islands)	16	0.28	2.77	2.15	2.00	0.64	0.31	85.1
Warm (SE Channel Islands)	13	0.07	2.24	1.22	1.09	0.70	0.38	55.5
Shelf Zone								
Bays and Harbors (2-30 m)	**26**	**0.00**	**2.42**	**1.10**	**1.13**	**0.66**	**0.25**	**53.8**
Inner Shelf (2-30 m)	**43**	**0.00**	**2.02**	**0.90**	**1.01**	**0.60**	**0.23**	**44.7**
Small POTWs	15	0.00	2.02	0.95	0.93	0.51	0.26	30.3
Large POTWs	3	1.13	1.72	1.26	1.42	0.24	0.27	100.0
Other Mainland	25	0.00	2.00	0.90	1.01	0.60	0.24	44.0
Middle Shelf (31-120 m)	**87**	**0.07**	**2.77**	**1.17**	**1.29**	**0.75**	**0.20**	**51.3**
Small POTWs	12	0.40	2.39	1.66	1.62	0.59	0.33	77.6
Large POTWs	25	0.15	2.33	1.51	1.44	0.61	0.24	69.0
Mainland non-POTW	26	0.10	2.28	0.97	1.13	0.65	0.25	38.3
Island	24	0.07	2.77	1.68	1.54	0.86	0.34	67.8
Outer Shelf (121-200 m)	**26**	**0.00**	**2.24**	**1.15**	**1.13**	**0.59**	**0.25**	**53.9**
Large POTWs	1	0.10	0.10	0.10	0.10	0.00	0.00	0.0
Mainland	21	0.00	1.68	1.00	0.92	0.51	0.26	36.0
Island	4	1.37	2.24	1.55	1.70	0.34	0.34	100.0
Upper Slope (201-500 m)	**28**	**0.10**	**2.35**	**0.96**	**1.00**	**0.46**	**0.17**	**45.1**
Mainland	27	0.10	1.66	0.96	0.98	0.44	0.17	44.3
Island	1	2.35	2.35	2.35	2.35	0.00	0.00	100.0
Total (all stations)	**210**	**0.00**	**2.77**	**1.10**	**1.13**	**0.63**	**0.11**	**50.0**

The average area sampled during a trawl tow was 3,014 m^2.
CL = Confidence limits (± value); Min. = Minimum; Max. = Maximum; No. = Number;
SD = Standard deviation.
POTW = Publicly owned treatment work monitoring areas.

Table V-8. Megabenthic invertebrate diversity by region within shelf zone subpopulations at depths of 2-476 m on the southern California shelf and upper slope, July-October, 2003.

		Shannon-Wiener Diversity (bits/individual/haul)						Percent
				Area-Weighted Values				Above
	No. of	Range					95%	Bight
Subpopulation	Stations	Min.	Max.	Median	Mean	SD	CL	Median
Shelf Zone								
Bays and Harbors (2-30 m)	**26**	**0.00**	**2.42**	**1.10**	**1.13**	**0.66**	**0.25**	**53.8**
Northern Region	1	1.10	1.10	1.10	1.10	0.00	0.00	0.0
Central Region	16	0.00	2.36	1.02	1.17	0.59	0.29	43.8
Southern Region	9	0.00	2.42	1.22	1.06	0.80	0.52	55.9
Inner Shelf (2-30 m)	**43**	**0.00**	**2.02**	**0.90**	**1.01**	**0.60**	**0.23**	**44.7**
Northern Region	21	0.00	1.69	1.05	0.96	0.46	0.25	46.0
Central Region	11	0.18	2.02	1.62	1.42	0.64	0.49	67.2
Southern Region	11	0.17	1.99	0.50	0.70	0.59	0.47	16.5
NW Channel Islands	0	--	--	--	--	--	--	--
SE Channel Islands	0	--	--	--	--	--	--	--
Middle Shelf (31-120 m)	**87**	**0.07**	**2.77**	**1.17**	**1.29**	**0.75**	**0.20**	**51.3**
Northern Region	6	0.70	1.82	1.03	1.18	0.38	0.33	39.2
Central Region	33	0.13	2.22	0.86	1.00	0.66	0.32	28.4
Southern Region	24	0.10	2.39	1.72	1.42	0.67	0.43	62.4
NW Channel Islands	13	0.28	2.77	2.17	2.04	0.68	0.37	82.9
SE Channel Islands	11	0.07	1.95	1.00	0.95	0.66	0.39	47.5
Outer Shelf (121-200 m)	**26**	**0.00**	**2.24**	**1.15**	**1.13**	**0.59**	**0.25**	**53.9**
Northern Region	8	0.00	1.65	0.64	0.70	0.51	0.35	12.2
Central Region	8	0.10	1.68	0.60	0.84	0.56	0.39	29.0
Southern Region	6	0.37	1.49	1.10	1.14	0.37	0.35	50.8
NW Channel Islands	2	1.43	1.73	1.43	1.58	0.15	0.21	100.0
SE Channel Islands	2	1.37	2.24	1.37	1.81	0.44	0.60	100.0
Upper Slope (201-500 m)	**28**	**0.10**	**2.35**	**0.96**	**1.00**	**0.46**	**0.17**	**45.1**
Northern Region	18	0.32	1.66	0.88	0.96	0.38	0.18	37.1
Central Region	4	0.10	1.61	0.60	0.77	0.61	0.60	25.2
Southern Region	5	0.62	1.59	1.19	1.28	0.27	0.23	58.6
NW Channel Islands	1	2.35	2.35	2.35	2.35	0.00	0.00	100.0
SE Channel Islands	0	--	--	--	--	--	--	--
Total (all stations)	**210**	**0.00**	**2.77**	**1.10**	**1.13**	**0.63**	**0.11**	**50.0**

The average area sampled during a trawl tow was 3,014 m^2.
CL = Confidence limits (± value); Min. = Minimum; Max. = Maximum; No. = Number;
SD = Standard deviation.
POTW = Publicly owned treatment work monitoring areas.

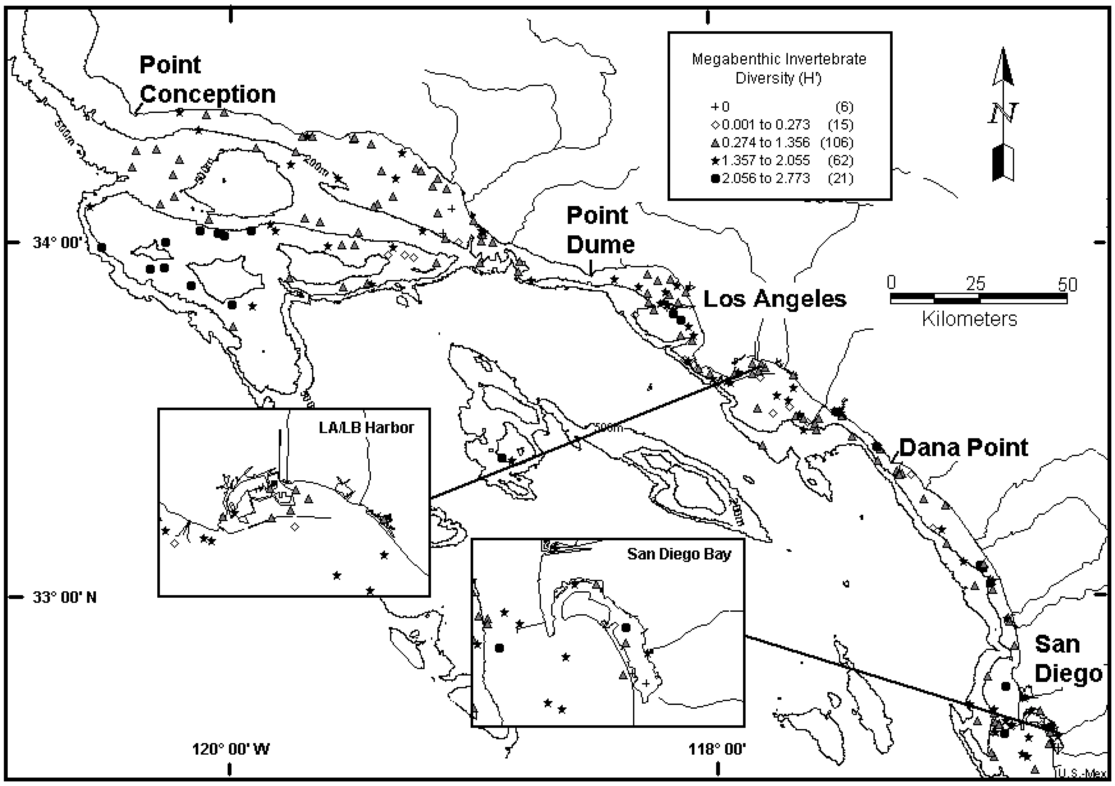


Figure V-4. Distribution of megabenthic invertebrate diversity (Shannon-Wiener) per haul at depths of 2-476 m on the southern California shelf and upper slope, July-October 2003.

Species Areal Occurrence

Of the 308 species, few occurred widely over the mainland shelf and slope in the SCB. No species occurred at more than 44% of the stations, or in over 37% of the sampled area (Table V-9). The equitability curve for areal occurrence was hyperbolic, with a change in slope at 18 species and 18% of the area (Figure V-5; Appendix C-C2). Species ranking to the left of the 18th species rapidly increased in areal occurrence and those to the right decreased in occurrence more gradually. Seventeen species (5.5% of all species) occurred in over 20% and five in 33% or more of the total area (Table V-9). These five most widely distributed species were the red octopus (*Octopus rubescens*), fragile sea urchin (*Allocentrotus fragilis*), California sea slug (*Pleurobranchaea californica*), northern heart urchin (*Brisaster latifrons*), and California sand star (*Astropecten verrilli*). Eighteen species occurred in more than 50% of the area in at least one subpopulation (Table V-10; Appendix C-C2). A mean of 4 species occurred in more than half the area of each subpopulation in the Mainland and island regions, and a mean of 3 species occurred in more than half the area of each shelf zone.

By regions, both island regions had eight species which occurred in over 50% of the area; on the mainland, the northern region had three, and the central and southern regions one each. Among the five shelf zones, the middle shelf had the highest number of species occurring in 50% or more of the area (six), while the inner shelf and bays each had only one. Geographically, the California sand star was the most frequently encountered species in the central and southern regions, and the orange bigeye octopus (*Octopus californicus*) was the most widespread species in the northern region. The white sea urchin (*Lytechinus pictus*) and trailtip sea pen (*Acanthoptilum* spp.) each occurred at nearly all southeast island sites, while the red sea star (*Mediaster aequalis*) was the most widely occurring species at the northwestern islands. Bathymetrically, the California aglaja (*Navanax inermis*) was the only species occurring in 50% of the area of bays and harbors. The most commonly encountered species at open coast sites were the yellow sea twig (*Thesea* spp. B) on the inner shelf; the white sea urchin on the middle shelf, the fragile sea urchin on the outer shelf, and the northern heart urchin on the upper slope. No species occurred in over 50% of the area in more than three regions, or in more than two of the depth zones. Only one species, the California sand star, occurred in over 50% of the area of both mainland and island regions. Six species occurred in over 50% of only a single subpopulation (Table V-10).

Species Abundance

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 3 species and 57% of the catch (Table V-11), with abundance increasing in species ranked to the left of the third species (fragile sea urchin), and decreasing more gradually to the right. The 32 most abundant species (10% of all species) accounted for 95% of abundance in the survey (Table V-11). The northern heart urchin was the most abundant species accounting for 23% of the total invertebrate abundance (36,074 individuals). The next most abundant were the white sea urchin accounting for 21% (33,028 individuals), and the fragile sea urchin accounting for 13% (20,917 individuals) of the total abundance.

Table V-9. Megabenthic invertebrate species occurring in 20% or more of the area of the southern California shelf at depths of 2-476 m, July-October 2003.

Scientific Name	Common Name	No. of Stations	Percent of Stations	Percent of Area*
Octopus rubescens	red octopus	89	42.4	36.8
Allocentrotus fragilis	fragile sea urchin	50	23.8	36.1
Pleurobranchaea californica	California sea slug	49	23.3	35.9
Brisaster latifrons	northern heart urchin	29	13.8	34.8
Astropecten verrilli	California sand star	92	43.8	34.2
Lytechinus pictus	white sea urchin	71	33.8	32.1
Acanthoptilum sp	trailtip sea pen	69	32.9	31.1
Octopus californicus	orange bigeye octopus	26	12.4	29.9
Mediaster aequalis	red sea star	36	17.1	29.2
Luidia foliolata	gray sand star	62	29.5	28.3
Rossia pacifica	eastern Pacific bobtail	52	24.8	28.0
Ophiura luetkenii	"brittle star"	65	31.0	28.0
Spirontocaris sica	offshore blade shrimp	20	9.5	26.6
Spatangus californicus	California heart urchin	26	12.4	25.0
Sicyonia ingentis	ridgeback rock shrimp	50	23.8	22.0
Brissopsis pacifica	Pacific heart urchin	25	11.9	21.9
Parastichopus californicus	California sea cucumber	56	26.7	20.8

Total stations = 210

Total area = 6,916 km^2

* Based on area-weighted frequency of occurrences.

Table V-10. Megabenthic invertebrate species comprising 50% or more of the area by subpopulation on the southern California shelf at depths of 2-476 m, July-October 2003.

		Percent of Area										
		Region										
		Mainland			Island		Shelf Zone					
Scientific Name	Common Name	N	C	S	NWI	SEI	B&H	IS	MS	OS	US	SCB
Octopus rubescens	red octopus	-	-	-	81	77	-	-	64	62	-	-
Allocentrotus fragilis	fragile sea urchin	-	-	-	-	-	-	-	-	77	69	-
Pleurobranchaea californica	California sea slug	-	-	-	56	-	-	-	-	-	-	-
Brisaster latifrons	northern heart urchin	55	-	-	-	-	-	-	-	-	83	-
Astropecten verrilli	California sand star	-	58	52	-	54	-	-	71	-	-	-
Lytechinus pictus	white sea urchin	-	-	-	56	92	-	-	76	-	-	-
Acanthoptilum sp	trailtip sea pen	-	-	-	69	92	-	-	63	-	-	-
Octopus californicus	orange bigeye octopus	58	-	-	-	-	-	-	-	-	71	-
Mediaster aequalis	red sea star	-	-	-	81	62	-	-	-	-	-	-
Luidia foliolata	gray sand star	-	-	-	75	62	-	-	57	-	-	-
Ophiura luetkenii	"brittle star"	-	-	-	63	77	-	-	65	-	-	-
Spirontocaris sica	offshore blade shrimp	52	-	-	-	-	-	-	-	-	67	-
Spatangus californicus	California heart urchin	-	-	-	-	-	-	-	-	-	56	-
Sicyonia ingentis	ridgeback rock shrimp	-	-	-	-	-	-	-	-	62	-	-
Thesea sp B	yellow sea twig	-	-	-	-	69	-	-	-	-	-	-
Crangon nigromaculata	blackspotted bay shrimp	-	-	-	-	-	-	71	-	-	-	-
Pycnopodia helianthoides	sunflower star	-	-	-	56	-	-	-	-	-	-	-
Navanax inermis	California aglaja	-	-	-	-	-	50	-	-	-	-	-

"-" Species not ocurring in at least 50% of the area or absent.

N = Northern; C = Central; S = Southern; NWI = Northwest Channel Islands; SEI = Southeast Channel Islands; B&H = Bays and Harbors; IS = Inner Shelf; MS = Middle Shelf; OS= Outer Shelf; US= Upper Slope; SCB =

Total area (km2) by subpopulation; N = 2,746; C = 1,710; S = 1,366; NWI = 604; SEI = 491; B&H = 65; IS = 982; MS = 2,635; OS = 529; US = 2,705; SCB = 6,916.

Table V-11. Megabenthic invertebrate species comprising 95% or more of the total invertebrate abundance of the southern California shelf at depths of 2-476 m, July-October 2003.

Scientific Name	Common Name	Abundance	Percent	Cumulative Percent
Brisaster latifrons	northern heart urchin	36074	22.9	22.9
Lytechinus pictus	white sea urchin	33028	21.0	43.9
Allocentrotus fragilis	fragile sea urchin	20917	13.3	57.2
Myxoderma platyacanthum	"sea star"	10571	6.7	63.9
Asteronyx longifissus	"ophiuroid"	9172	5.8	69.8
Brissopsis pacifica	Pacific heart urchin	8568	5.4	75.2
Sicyonia ingentis	ridgeback rock shrimp	4175	2.7	77.9
Acanthoptilum sp	trailtip sea pen	3673	2.3	80.2
Spatangus californicus	California heart urchin	3617	2.3	82.5
Crangon nigromaculata	blackspotted bay shrimp	1930	1.2	83.7
Astropecten verrilli	California sand star	1766	1.1	84.8
Ophionereis eurybrachiplax	"brittlestar"	1656	1.1	85.9
Porifera	"sponge"	1630	1.0	86.9
Thesea sp B	yellow sea twig	1577	1.0	87.9
Ophiothrix spiculata	Pacific spiny brittlestar	1448	0.9	88.9
Spirontocaris holmesi	slender blade shrimp	1008	0.6	89.5
Philine auriformis	New Zealand paperbubble	881	0.6	90.1
Pandalus jordani	ocean shrimp	810	0.5	90.6
Stachyptilum superbum	"sea pen"	719	0.5	91.0
Styela plicata	cobblestone sea squirt	598	0.4	91.4
Neocrangon zacae	moustache bay shrimp	596	0.4	91.8
Bulla gouldiana	California bubble	584	0.4	92.2
Parastichopus californicus	California sea cucumber	570	0.4	92.5
Pannychia moseleyi	"holothuroid"	541	0.3	92.9
Spirontocaris sica	offshore blade shrimp	509	0.3	93.2
Musculista senhousia	mat mussel	508	0.3	93.5
Ophiura luetkenii	"brittle star"	485	0.3	93.8
Molgula verrucifera	warty tunicate	442	0.3	94.1
Neocrangon communis	gray shrimp	433	0.3	94.4
Octopus rubescens	red octopus	425	0.3	94.7
Dromalia alexandri	sea dandelion	419	0.3	94.9
Mediaster aequalis	red sea star	412	0.3	95.2

Total abundance = 157,326 invertebrates

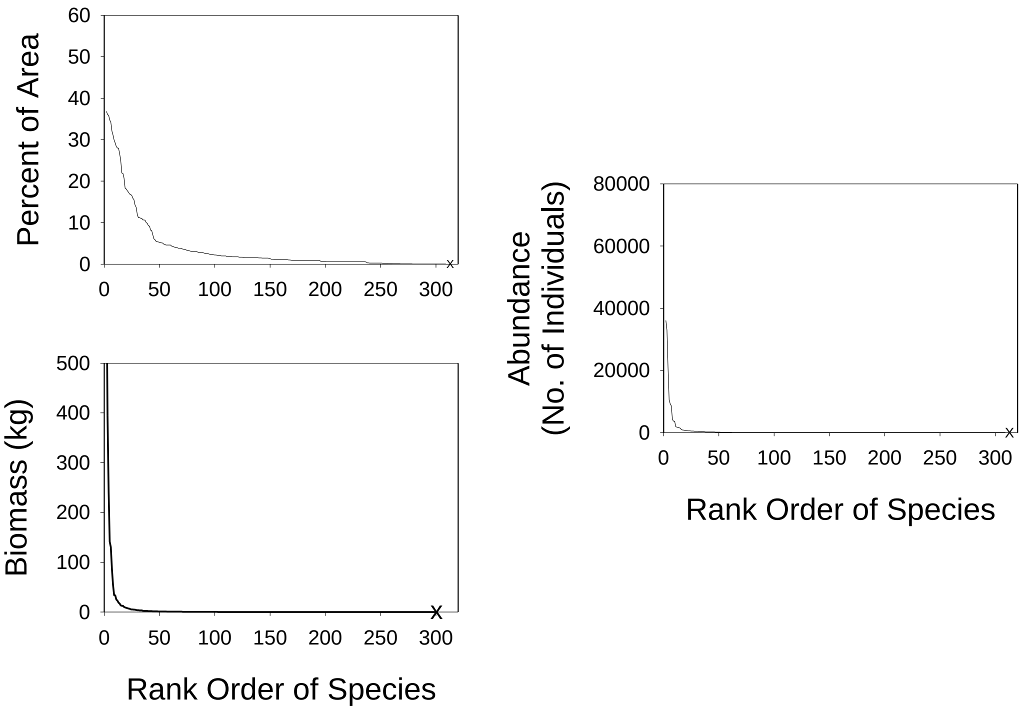


Figure V-5. Equitability curves of megabenthic invertebrate occurrence, abundance, and biomass by species at depths of 2-476 m on the southern California shelf and upper slope, July-October 2003. x=308th species for area abundance curves; 300th species for the biomass curve (Eight species found only at stations 4028 and 4116 were not ranked because of questionable weights).

Combinations of 28 species comprised the top 80% of abundance in each subpopulation (Table V-12; Appendix C-C3), with a mean of 7 species per subpopulation in the mainland and island regions. A mean of 6 species per subpopulation comprised 80% of the abundance in the shelf zones. On the mainland and island shelf regions, 11 and 9 species comprised 80% of abundance on the southern mainland shelf and northwest island regions, respectively. One species, the white sea urchin, accounted for 90% of abundance at southeast island sites. More species (12) comprised 80% of abundance in bays and harbors. Fewer species (3) comprised this abundance on the middle and outer shelf, with intermediate species numbers (5) in both inner shelf and upper slope zones. The white sea urchin was the most abundant species in both island regions, and at southern mainland sites. By depth it was most abundant in the middle shelf zone. The northern heart urchin was the most abundant in the northern region and on the upper slope. The fragile sea urchin was the most abundant in the central region and on the outer shelf, the California sand star on the inner shelf, and the blackspotted bay shrimp (*Crangon nigromaculata*) in bays and harbors.

Species Biomass

The equitability curve of species biomass, similar to that for abundance, approximated a smooth hyperbola (Figure V-3), indicating that a few species dominated the overall biomass. A sharp change in slope occurred at species 8 (ridgeback rock shrimp, *Sicyonia ingentis*) and 2.5% (Table

V-13), with biomass steeply increasing to the left and decreasing gradually to the right. Twenty-seven species (8.3 % of all species) accounted for 95% of the survey biomass. Fragile sea-urchin had the largest biomass (744.5 kg; 33.6 %), followed by the northern heart urchin with 393.7 kg (17.8%), and the California sea cucumber (*Parastichopus californicus*) with 240.4 kg (10.9%). Combinations of 33 species comprised the top 80% of the biomass in the subpopulations (Table V-14; Appendix CC4), with a mean of 5 species per subpopulation for the mainland and island regions, and a mean of 7 species per subpopulation for the shelf zones. More species (9) were required to account for 80% of the biomass in the northwest island region than in any other. Only four species were required to account for 80% of the biomass in all other regions except the southern region. By shelf zone only three species provided more than 80% of the biomass on the outer shelf, while four were required on the upper slope, six on the middle shelf and in bays and harbors, and 17 on the inner shelf.

Geographically, the fragile sea urchin ranked highest for biomass in the Bight as a whole, occurred in substantial biomass in all five regions, and was the dominant biomass contributor in the northwest islands, and in the central and southern mainland regions. The northern heart urchin was the greatest biomass contributor at northern mainland sites, and the white sea urchin dominated at southeast island sites (Table V-14). On the upper slope the northern heart urchin dominated biomass, as did the fragile sea-urchin on the outer shelf, the California sea cucumber on the middle shelf, the shortspined sea star on the inner shelf, and unidentified sponges in the bays and harbors.

Species Distributions

The distributions, habitat preferences, and habits of 10 species with high occurrence, abundance, and/or biomass are described below. The numbers following each species name are the abundance rank, biomass rank, and occurrence rank, respectively. The ordering of these 10 was based on a weighted average rank which devalued biomass. Occurrence rank was not area-weighted, but based on percentage of sampled sites where it was taken.

White Sea Urchin (*Lytechinus pictus*) (2,6,3). The white sea urchin is a predominantly middle shelf species that occurred in 32.1% of the entire survey area, and was most common at the islands and southern mainland sites (Tables V-9 and V-12). It was the second most abundant species caught (32,028 individuals) and accounted for 21% of the total Bight invertebrate catch (Table V-11). It ranked sixth among species in biomass, accounting for 3.9% of the total biomass taken (Table V-13). The white sea urchin was the numerical dominant in the southern mainland region, both island subpopulations, and the middle shelf zone (Table V-12). Catches greater than 5,200 individuals were taken at two sites on the southeast Island shelf (Appendix C-C3). The species ranges from Monterey south to Ecuador, and from the intertidal to about 300m (Maluf 1988). While characterized here as predominantly middle shelf in occurrence, it is also well known as an eelgrass bed species in bays (Durham *et al.* 1980).The animal feeds primarily on plants, either attached algae or diatoms, or drift, but can also be carnivorous (Walther 2005), “mobbing” and devouring larger urchins.

Table V-12. Megabenthic invertebrate species comprising 80% or more of the invertebrate abundance by subpopulation on the southern California shelf at depths of 2-476 m, July-October 2003.

		Percent of Catch Abundance										
		Region										
		Mainland			Island		Shelf Zone					
Scientific Name	Common Name	N	C	S	NWI	SEI	B&H	IS	MS	OS	US	SCB
Brisaster latifrons	northern heart urchin	48	-	-	-	-	-	-	-	19	40	23
Lytechinus pictus	white sea urchin	-	19	34	43	90	-	14	70	-	-	21
Allocentrotus fragilis	fragile sea urchin	7	31	15	4	-	-	-	-	51	12	13
Myxoderma platyacanthum	"sea star"	13	-	6	-	-	-	-	-	-	13	7
Asteronyx longifissus	"ophiuroid"	12	-	-	-	-	-	-	-	-	12	6
Brissopsis pacifica	Pacific heart urchin	-	10	8	-	-	-	-	-	-	10	5
Sicyonia ingentis	ridgeback rock shrimp	-	4	-	2	-	-	-	-	17	-	3
Acanthoptilum sp	trailtip sea pen	-	5	5	6	-	5	5	6	-	-	2
Crangon nigromaculata	blackspotted bay shrimp	-	4	-	-	-	22	21	-	-	-	-
Astropecten verrilli	California sand star	-	-	4	-	-	-	36	-	-	-	-
Ophionereis eurybrachiplax	"brittlestar"	-	4	-	-	-	-	-	4	-	-	-
Thesea sp B	yellow sea twig	-	4	-	-	-	-	-	-	-	-	-
Ophiothrix spiculata	Pacific spiny brittlestar	-	-	-	12	-	-	-	-	-	-	-
Philine auriformis	New Zealand papperbubble	-	-	-	-	-	6	-	-	-	-	-
Styela plicata	cobblestone sea squirt	-	-	2	-	-	8	-	-	-	-	-
Neocrangon zacae	moustache bay shrimp	-	-	-	5	-	-	-	-	-	-	-
Bulla gouldiana	California bubble	-	-	-	-	-	8	-	-	-	-	-
Musculista senhousia	mat mussel	-	-	2	-	-	7	-	-	-	-	-
Molgula verrucifera	warty tunicate	-	-	2	-	-	6	-	-	-	-	-
Octopus rubescens	red octopus	-	-	-	2	-	-	4	-	-	-	-
Mediaster aequalis	red sea star	-	-	-	3	-	-	-	-	-	-	-
Loligo opalescens	California market squid	-	-	2	-	-	-	-	-	-	-	-
Ciona intestinalis	yellow-green sea squirt	-	-	2	-	-	5	-	-	-	-	-
Ascidiacea sp SD3	"tunicate"	-	-	-	-	-	3	-	-	-	-	-
Ascidiacea sp SD2	"tunicate"	-	-	-	-	-	3	-	-	-	-	-
Ascidiacea sp SD4	"tunicate"	-	-	-	-	-	3	-	-	-	-	-
Ascidiacea sp SD5	"tunicate"	-	-	-	-	-	3	-	-	-	-	-
Chlamys hastata	spiny scallop	-	-	-	2	-	-	-	-	-	-	-

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

N = Northern; C = Central; S = Southern; NWI = Northwest Channel Islands; SEI = Southeast Channel Islands; B&H = Bays and Harbors; IS = Inner Shelf; MS = Middle Shelf; OS= Outer Shelf; US= Upper Slope; SCB = Southern

Total catch abundance (no. of individuals) by subpopulation; N = 74,533; C = 39,902; S = 20,343; NWI = 3,715; SEI = 18,833; B&H = 7,151; IS = 1,670; MS = 47,002; OS = 21,963; US = 79,540; SCB = 157,326.

Table V-13. Megabenthic invertebrate species comprising 95% or more of the total invertebrate biomass of the southern California shelf at depths of 2-476 m, July-October 2003.

Scientific Name	Common Name	Biomass (kg)	Percent	Cumulative Percent
Allocentrotus fragilis	fragile sea urchin	744.5	33.6	33.6
Brisaster latifrons	northern heart urchin	393.7	17.8	51.4
Parastichopus californicus	California sea cucumber	240.4	10.9	62.3
Spatangus californicus	California heart urchin	141.3	6.4	68.6
Brissopsis pacifica	Pacific heart urchin	130.3	5.9	74.5
Lytechinus pictus	white sea urchin	85.8	3.9	78.4
Porifera	"sponge"	55.9	2.5	80.9
Sicyonia ingentis	ridgeback rock shrimp	54.7	2.5	83.4
Porifera sp SD4	"sponge"	33.8	1.5	84.9
Metridium farcimen	gigantic anemone	33.3	1.5	86.4
Asteronyx longifissus	"ophiuroid"	24.9	1.1	87.5
Myxoderma platyacanthum	"sea star"	22.8	1.0	88.6
Pycnopodia helianthoides	sunflower star	18.5	0.8	89.4
Dromalia alexandri	sea dandelion	16.8	0.8	90.2
Luidia foliolata	gray sand star	13.2	0.6	90.8
Pisaster brevispinus	shortspined sea star	12.3	0.6	91.3
Loxorhynchus grandis	sheep crab	12.2	0.6	91.9
Pleurobranchaea californica	California sea slug	10.1	0.5	92.3
Lopholithodes foraminatus	brown box crab	9.1	0.4	92.7
Ophionereis eurybrachiplax	"brittlestar"	8.3	0.4	93.1
Octopus californicus	orange bigeye octopus	7.7	0.3	93.5
Pannychia moseleyi	"holothuroid"	6.7	0.3	93.8
Pandalus jordani	ocean shrimp	6.6	0.3	94.1
Gorgonocephalus eucnemis	basket star	5.4	0.2	94.3
Pandalus platyceros	spot shrimp	5.1	0.2	94.5
Paralithodes californiensis	California king crab	5.0	0.2	94.8
Platymera gaudichaudii	armed box crab	4.8	0.2	95.0

Total biomass = 2,214.3 kg

Table V-14. Megabenthic invertebrate species comprising 80% or more of the invertebrate biomass by subpopulation on the southern California shelf at depths of 2-476 m, July-October 2003.

		Percent of Catch Biomass											
		Region											
		Mainland			Island		Shelf Zone						
Scientific Name	Common Name	N	C	S	NWI	SEI	B&H	IS	MS	OS	US	SCB
Allocentrotus fragilis	fragile sea urchin	21	52	27	26	21	-	-	-	68	26	34
Brisaster latifrons	northern heart urchin	43	-	-	-	-	-	-	-	8	36	18
Parastichopus californicus	California sea cucumber	-	19	14	4	22	-	6	52	-	-	11
Spatangus californicus	California heart urchin	14	-	-	-	-	-	-	-	7	9	6
Brissopsis pacifica	Pacific heart urchin	-	6	20	-	-	-	-	-	-	13	6
Lytechinus pictus	white sea urchin	-	-	5	3	36	-	2	19	-	-	4
Porifera	"sponge"	6	-	-	-	-	-	-	-	-	-	3
Sicyonia ingentis	ridgeback rock shrimp	-	4	-	3	4	-	-	2	-	-	-
Porifera sp SD4	"sponge"	-	-	12	-	-	54	-	-	-	-	-
Metridium farcimen	gigantic anemone	-	-	3	3	-	-	-	-	-	-	-
Pycnopodia helianthoides	sunflower star	-	-	-	22	-	-	-	4	-	-	-
Luidia foliolata	gray sand star	-	-	-	5	-	-	-	-	-	-	-
Pisaster brevispinus	shortspined sea star	-	-	-	-	-	10	26	-	-	-	-
Loxorhynchus grandis	sheep crab	-	-	-	-	-	-	9	2	-	-	-
Pleurobranchaea californica	California sea slug	-	-	-	7	-	-	-	-	-	-	-
Lopholithodes foraminatus	brown box crab	-	-	-	8	-	-	-	-	-	-	-
Ophionereis eurybrachiplax	"brittlestar"	-	-	-	-	-	-	-	2	-	-	-
Platymera gaudichaudii	armed box crab	-	-	-	-	-	-	2	-	-	-	-
Octopus rubescens	red octopus	-	-	-	-	-	-	4	-	-	-	-
Bulla gouldiana	California bubble	-	-	-	-	-	6	-	-	-	-	-
Panulirus interruptus	California spiny lobster	-	-	-	-	-	5	-	-	-	-	-
Cancer anthonyi	yellow rock crab	-	-	-	-	-	-	5	-	-	-	-
Parastichopus parvimensis	warty sea cucumber	-	-	-	-	-	3	-	-	-	-	-
Cancer antennarius	Pacific rock crab	-	-	-	-	-	2	1	-	-	-	-
Astropecten verrilli	California sand star	-	-	-	-	-	-	3	-	-	-	-
Eugorgia rubens	purple gorgonian	-	-	-	-	-	-	8	-	-	-	-
Crangon nigromaculata	blackspotted bay shrimp	-	-	-	-	-	-	3	-	-	-	-
Kelletia kelletii	Kellet whelk	-	-	-	-	-	-	2	-	-	-	-
Cancer gracilis	graceful rock crab	-	-	-	-	-	-	4	-	-	-	-
Hemisquilla californiensis	blueleg mantis shrimp	-	-	-	-	-	-	1	-	-	-	-
Euspira lewisii	Lewis moonsnail	-	-	-	-	-	-	2	-	-	-	-
Aplysia californica	purple sea hare	-	-	-	-	-	-	1	-	-	-	-
Astropecten armatus	spiny sand star	-	-	-	-	-	-	1	-	-	-	-

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

Fragile Sea Urchin (*Allocentrotus fragilis*) (3,1,8). The fragile sea urchin, a middle shelf to upper slope species, occurred in 36% of the area and in all regions (Appendix C-C2). It accounted for 13.3% of the total Bight invertebrate abundance and 33.6% of the biomass (Tables V-11 and V-13). This species was a numerical dominant in the central region, and in the outer shelf zone, ranking third in the Bight as a whole (Table V-12). In terms of biomass, the fragile sea urchin was dominant in the central and southern regions, at the northwest islands, and on the upper slope zone (Table V-14). It ranges from British Columbia to Baja California, and from 50-1200m depths (Maluf 1988). The animal is a detritivore and opportunistic scavenger (Lissner and Hart 1996), favoring bottoms with organic carbon levels between 0.3 and 2.7% (Walther 2005). It ingests bottom sediments, grazing on them in herds (Salazar 1970, Alton 1972, Thompson *et al.* 1993a). It has been historically considered one of the dominant echinoderms on coastal slopes (Thompson *et al.* 1987a), consistent with its occurrences in 2003.

Northern Heart Urchin (*Brisaster latifrons*) (1,2,18). This is an outer shelf and upper slope species. It was taken in 83% of upper slope stations, most prominently in the northern region (Table V-10). With a catch of 35,074 it represented 22.9% of the Bight total (Table V-11) and was the most abundant trawl invertebrate. It was also a major biomass contributor, ranking second overall (394 kg, 17.8% of total biomass; Table V-13).

Occurrences were limited to 13.8% of sampled sites, although on an area-weighted basis the species was taken in 34.8% of the study area (Table V-9). There is some evidence that two species of heart urchins are confused under this name; *B. latifrons*, and southern heart urchin (*Brisaster townsendi*; Hood and Mooi 1996), with a species replacement taking place in the central region of the study area (R. Mooi, California Academy of Sciences, personal communication). Since the population characterized here occurred most abundantly in the northern region, only a small portion of the population in the southern region is suspected to belong to the second species, *B. townsendi*. Historical distribution trends are described in Thompson *et al.* (1987a). Maluf (1988) lists the range of *B. latifrons* as Bering Sea to Galapagos, but it should be restricted to Bering Sea to Santa Monica Bay, with *B. townsendi* ranging from Santa Monica Bay to the Galapagos. All records of these species in the SCB suffer from the same confusion, which stems from treatment of *B. townsendi* as a synonym of *B. latifrons* by Clark (1948).

Ridgeback Rock Shrimp (*Sicyonia ingentis*) (7,7,11). The ridgeback rock shrimp is a middle and outer shelf species that occurred in 22% of the area,but occurred frequently only in the outer shelf zone (Tables V-14 and V-15). It was the seventh most abundant invertebrate caught (4175 individuals), accounting for 16.0% of the total Bight invertebrate abundance and 2.5% of the biomass (Tables V-11 and V-13). This species was the third most abundant species in the outer shelf zone (Table V-12). The ridgeback rock shrimp ranked fourth in biomass in the central region, but was less important in terms of biomass for the other subpopulations (Table V-13). Although it ranges north to Monterey (Sunada *et al.* 2001), the SCB has the most area of suitable habitat for the species (Clark *et al.* 2005). The abundance of the species in the SCB supports a fishery during periods of warm southern influence (Sunada 1984). Reproduction is limited under cooler regimes, and the population density declines these periods. It feeds as a selective deposit feeder on organic aggregates in surface sediments (Walther 2005).

California Sand Star (*Astropecten verrilli*) (11,38,1). The California sand star is a predominantly middle shelf species that occurred in 34.2% of the survey area (43.8% of the sites), and was most common on the central and southern mainland shelf, and at the warm southeast islands (Tables V-9 and V-10). It accounted for 1.1% of the total Bight invertebrate abundance (Table V-11), and 0.07% of the biomass. This species was a numerical and biomass dominant at island sites (Tables V-12 and V-14), ranking first in abundance and eighth in biomass in that subpopulation. Biomass values for the California sand star were mainly low (<0.1 kg), with a total biomass of only 1.7 kg from its 92 stations of occurrence. The species occupies bottoms ranging from silty sands inshore, to muddy habitat offshore. It is reported from Point Arena in northern California to Nicaragua (Maluf 1988), tolerating a broad range of oceanographic conditions. A microcarnivore (Walther 2005) like others in the genus (Christensen 1970, Wurzian 1984), it seeks out and devours small mollusks, crustaceans, and worms in the surface sediments.

California Sea Cucumber (*Parastichopus californicus*) (23,3,7). The California sea cucumber, a middle and outer shelf species, occurred in 20.8% of the survey area, and did not occur in more than half the area of any subpopulation (Tables V-9 and V-10). It accounted for 0.4% of the total Bight invertebrate abundance (Table V-11). This species was not a numerical dominant in any of the subpopulations (Table V-12); however, it contributed 11% of the biomass taken in the survey, mainly from sites in the midshelf zone (Table V-14). Further, the California sea cucumber ranked second in biomass contribution to sites in the central region, and at the southeast islands. The size distribution of this species in the Bight was discussed in Allen *et al.* (2002a). The species ranges from Alaska to Baja California (Lambert 1997), so it is able to tolerate both cool and warm oceanographic regimes. While listed in some references as being restricted to waters under 100m depth, it is often taken at over 300m in the SCB. It is long-lived, not reaching sexual maturity until four years old (Lambert 1997). There has been a fishery in the SCB for this species (Rogers-Bennett and Ono 2001), as well as in northern waters (Lambert 1997). The resource has apparently been overutilized, and is in general decline. It is a nonselective detritivore, sweeping surface particulates and organic aggregates from both rocky and soft substrate. Habitats throughout the SCB are highly suitable for this species, particularly between 40-90m (Clark *et al.* 2005).

California Heart Urchin (*Spatangus californicus*) (9,4,21). Although occurring in 25% of study area using area-weighting, the species was found at only 12.4% of sampled sites (Table V-9). Catch was concentrated on the upper slope, where the species occurred with several other abundant echinoderms (Table V-10). These sediment swallowers tend to be heavy and ranked fourth in biomass, although only ninth in abundance (Tables V-11 and V-13). The species was not among the top species in abundance in any area or subpopulation, and its most significant biomass medians were in the northern mainland region, on the outer shelf and upper slope (Table V-14). Over 33% of the total catch of this species was from a single site at 390 m on the upper slope in the northern Santa Barbara Channel. The species ranges from central California to Mazatlan (Maluf 1988), and is near its northern range endpoint in the SCB. It is a burrowing detritivore which swallows and extracts organic nutrients from bottom sediments ranging in organic content from 0.3 to 2.3% (Thompson *et al.* 1987a).

Pacific Heart Urchin (*Brissopsis pacifica*) (6,5,24). The Pacific heart urchin, a slope species, occurred in 21.9% of the area and in all regions (Table V-9; Appendix C-C2). It accounted for 5.4% of the total Bight invertebrate abundance and 5.9% of the biomass (Tables V-11 and V-13). This species was a numerical dominant in the central region, and in the outer shelf zone (10% of the specimens in each), and was the sixth most abundant species in the Bight as a whole (Table V-12). In terms of biomass, the Pacific heart urchin ranked fifth in the Bight, and was a major contributor in the southern region (ranking second), in the central region (ranking third), and on the upper slope zone (also ranking third) subpopulations (Table V-14). The species ranges from the SCB south to Ecuador (Maluf 1988), and is thus a predominantly southern species. While it occurs between 9 and 3,270 m (Maluf 1988), Thompson *et al.* (1987a) found greatest density of this species at depths between 400 and 500m. It has not been important in previous regional samplings as a consequence. Like other irregular echinoids, it is likely to be a nonselective deposit feeder (Lawrence 1987), and has been taken on bottoms with organic carbon content of between 0.5 and 4.6% (Thompson *et al.* 1987a).

Yellow Sea Twig (*Thesea* sp B) (14,41,13). Known for many years, this gangly prostrate sea-fan remains undescribed. It was most characteristic of the warm southeastern islands, where it was found at 69% of subpopulation sites (Table V-10). It accounted for 1% of the Bight catch (Table V-11) but only 1.4 kg (Appendix C-C4), 0.06% of total biomass. Although proportionately more often taken on the warm island shelf, the species was found at 19.5% of sampled sites. Most of the catch of this species was concentrated at midshelf sites in the central mainland region (Appendix C-C3), while only a single individual was taken at each of nine sites in the southeast islands. Nearly a third of the total catch was from a single 30m central mainland region site near a large POTW. This colonial animal feeds both on surface deposited detritus and organic particulates carried in the benthic boundary layer. While seemingly free on the bottom, it is actually attached at one or more points to small pieces of shell debris, or to small stones.

Red Octopus (*Octopus rubescens*) (32,28,2). The red octopus was widely distributed within the study area, although not at high density. It ranked first in areal occurrence (Table V-9, Appendix C-C2), but second in terms of occupied stations (Table V-9). Red octopus did not occur in more than half of the sites in any mainland region (Table V-10), although it occurred at most northwest (81%) and southeast island sites (77%). Most occurrences were at middle and outer shelf sites (64% and 62%, respectively). Its abundance was only 0.3% of the Bight total (Table V-11), and it was most abundant (2% of catch) in the northwest island subpopulation. It represented 4% of the catch in the inner shelf zone (Table V-12). It was not a significant contributor to biomass (Tables V-13 and V-14). The species is known to range from Alaska to the Gulf of California and from the intertidal zone to at least 200m (Hochberg and Fields 1980). Red octopus are active predators living usually in self-excavated shallow depressions or appropriated burrows constructed by other animals. They may occur on rock bottoms, but are typically found on soft substrate. Their primary prey is probably crustaceans, although it also includes mollusks and fishes (Hochberg and Fields 1980). Individuals of this species live only 12-18 months (Hochberg 1998).

Anomalies and Parasites of Megabenthic Invertebrates

Megabenthic invertebrate health appeared quite good, with no anomalies or disease and only a few external parasites recorded. Among 157,326 invertebrates caught, there were 9 with parasites (0.01% incidence) found at 4 sites. Parasites were found on 4 (1.2%) of the 308 species. All parasites were taken on the mainland shelf and slope, five at sites in the northern, and four in the southern region. No parasites were associated with invertebrates around POTWs, or from island, central region, or bay/harbor subpopulations. Some ectoparasites are easily dislodged from the host during trawl sampling, and our reported incidences are undoubtedly lower than those actually occurring in the field.

Eulimid snail parasites, found on 0.02% of the fragile sea urchin, were the most common parasite found (44% of occurrences). The family Eulimidae contains around 1,250 described species (McLean 1996), all known to parasitize echinoderms for at least part of their life history. The urchin snail (*Polygireulima rutila*) is the species most likely found on fragile sea urchins during this survey, but specimens were not returned for laboratory identification and a second eulimid (echinoderm snail, *Balcis oldroydae*) is also reported from this host (Barwick and Douglas 2003). This species is also known as a frequent ectoparasite of both the California sea cucumber and the shortspined sea star (*Pisaster brevispinus*), but none were reported from these potential hosts in 2003 samples.

Isopod gill parasites were reported at prevalences of 0.5% of gray shrimp (*Neocrangon communis*) and 0.1% of blackspotted bay shrimp, and were the second most common parasite found (3 occurrences). The shrimp isopod (*Argeia pugettensis*) is the only isopod reported as a gill parasite of crangonid shrimp in the NEP (Butler 1980), and is the parasite presumed to be involved. Specimens were not, however, returned for verification of identity in the laboratory.

The crab barnacle (*Briarosaccus callosus*; Sacculinidae) was found on two California king crabs (*Paralithodes californiensis*; 25% prevalence). This parasite is common on crabs in this genus and the record here is unlikely to be a full representation of the incidence in *Paralithodes* captured during the survey. The hyperparasitic crab amphipod (*Myzotarsa anaxiphilius*), which usually occurs on crabs bearing this barnacle in the SCB (Cadien and Martin 1999), was not reported from these two occurrences. There were no reported cases of crustacean burn-spot disease or echinoderm wasting disease, both known to have occurred in the SCB during previous warm water El Niño Southern Oscillation (ENSO) episodes (Stull *et al.* 2001).

Discussion

Many trawl studies have been conducted in southern California during the past 40 years. Most are focused on local areas rather than the SCB as a whole. However, three studies, Thompson *et al.* (1993a) and the 1994 and 1998 regional surveys (Allen *et al.* 1998; Stull *et al.* 2001; Allen *et al.* 2002a), provide population attribute data for the SCB as a whole and provide perspective to the 2003 data. Thompson *et al.* (1993a) summarized information on megabenthic invertebrates from 1,203 trawl samples taken in southern California from 1971 to 1985 over a depth range of 10-915 m. Of these, 658 were collected over the mainland shelf (10-137 m). The 1994 survey collected 114 trawl samples from 9-215 m, all on the mainland shelf. The 1998 survey collected samples from 314 stations, of which 197 were from the mainland shelf (depths of 10-202 m). These efforts compare with the current data from 210 sites, of which 156 were from the mainland shelf (depths of 2-202 m), with a total depth coverage of 2-476 m. Effort allocations between sampled subpopulations differed in each of these four surveys, but the efforts were strongly overlapping in coverage overall.

Population Attributes

Invertebrate population attribute mean values for the SCB were varied in similarity on the mainland shelf (10-200 m) between the four time periods -- 1971-1985 (Thompson *et al.* 1993a), 1994 (Allen *et al.* 1998), 1998 (Allen *et al.* 2002a), and 2003 (present study; Table V-15). Mean invertebrate abundance (individuals/haul) was highest in 1994 (631) and lowest in 1998 (302). The earlier periods 1971-1985 and 1994 were periods of higher abundance and the two later periods had lower abundance. Mean biomass was similar (6.6-7.3) 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 the other periods, with the earlier periods being higher (13) than 2003 (11). Diversity values were not available for 1971-1985 but this measure was more similar in the three recent surveys (although still lowest in 1998). It should be noted that the number of samples used in the analysis was much larger in 1971-1985 than in the three later surveys. However, in the latter three surveys, the samples were collected synoptically within the same year using a stratified randomized design whereas in 1971-1985, samples collected over a 15-year period were compiled from surveys of varying designs.

In the three recent surveys, regional population attribute means often differ in temporal patterns (Table V-15). In the northern mainland region, mean abundance, biomass, and species richness was highest in 1994 and lowest in 2003. For abundance, 1994 was 2.5 and 3.7 times higher than the means of 1998 and 2003, respectively. For biomass and species richness, 1994 values were about 1.5 times higher than in the later years. In contrast, in the central region, means were highest for abundance and biomass in 2003, and lowest in 1998. For species richness, means were highest in both 1994 and 2003 and lowest in 1998. In the southern region, abundance biomass, and species richness were all highest in 1994 and lowest in 1998, with 2003 being intermediate. Diversity values varied less in time or space.

As in 1994 and 1998 (Allen *et al.* 1998, 2002a) median invertebrate abundance, biomass, and species richness in 2003 were lowest on the inner shelf and highest on the outer shelf (Tables V-2, V-4, and V-6). In 1998 and 2003, means in bays and harbors were low, but higher than the inner shelf. Median diversity did not show a consistent depth zone pattern among the three survey periods. Median abundance and biomass values for the upper slope zone (added in 2003) was higher than those for the other depth zones in any of the three years. However, median species richness was moderate and diversity was similarly as low as those of the inner shelf in 1998 and 2003.

Invertebrate population attribute median values at LPOTW areas and non-LPOTWs varied by attribute among the three regional surveys (Figure V-6; Table V-16). Median invertebrate abundance was much higher at non-LPOTW areas than in LPOTW areas in 1994, but was higher at LPOTW areas in 1998, with 2003 having lower values at the LPOTWs. Biomass was similar in both areas for 1994 and 2003, but was slightly higher at LPOTWs in 1998. Species richness was similar in both areas in all three years although lowest in 1994. Diversity was higher at LPOTWs in 1994 and 2003 but lower then non-LPOTWs in 1998.

Table V-15. Comparison of megabenthic invertebrate population attributes on mainland shelf by region and year(s) for the Southern California Bight (SCB) in 1971-1985, 1994, 1998, and 2003 regional survey data.

		Mean/haul[a]			
Southern California Bight Database	No. samples	Abundance (no. of individuals)	Biomass (kg)	No. of Species	Diversity[c] (bits/individual)
Northern Region					
1994	45	805	7.4	12	1.03
1998[c]	65	318	5.7	8	0.85
2003[d]	35	216	4.8	7	1.00
Central Region					
1994	41	384	7.0	13	1.36
1998[c]	78	267	3.4	8	1.09
2003[d]	52	593	11.8	13	1.07
Southern Region					
1994	28	530	6.2	13	0.81
1998[c]	54	336	3.5	8	1.13
2003[d]	41	431	3.7	12	1.19
All Mainland Shelf Regions[e]					
1971-1985[b]	658	577	6.6	13	--
1994	114	631	7.0	13	1.09
1998[c]	197	302	3.6	8	0.99
2003[d]	128	431	7.3	11	1.08

[a]The 1994, 1998, and 2003 mean values are weighted in accordance with the sampling design.
[b]1971-1985 data from Thompson *et al.* (1993a).
[c]Data from Bays/Harbors and Islands are excluded from 1998 analysis.
[d]Data from Bays/Harbors, Islands, and Upper Slope (201-500 m) are excluded from 2003 analysis.
[e]SCB as a whole.

Table V-16. Megabenthic invertebrate abundance, biomass, species richness, and diversity at middle-shelf large publicly owned treatment work (LPOTW) and reference (non-LPOTW) subpopulations in 1994, 1998, and 2003. Data from 1994 reanalyzed using 1998 subpopulation boundaries.

					Stratified Values					Percent
	No. of		Range			95% CL				Above Bight
Category	Stations	Total	Min.	Max.	Md	LL	UL	Mn	SD	Median
Abundance (no. of individuals/haul)										
1994 LPOTW	9	5,745	16	2,831	97	54	536	637	950	50
1998 LPOTW	32	25,091	56	4,712	235	41	265	784	1,136	75
2003 LPOTW	25	9,523	21	2,340	106	63	289	381	588	22
1994 non-LPOTW	49	44,446	16	11,616	439	200	468	903	1,948	68
1998 non-LPOTW	61	14,225	1	2,039	95	77	179	379	582	49
2003 non-LPOTW	38	15,891	23	3,722	208	78	496	581	826	42
Biomass (kg/haul)										
1994 LPOTW	9	73.3	0.0	29.0	3.9	1.3	12.3	8.7	9.2	59
1998 LPOTW	32	153.3	0.2	20.2	2.0	1.6	3.8	4.8	5.3	52
2003 LPOTW	25	109.6	0.0	31.1	2.9	1.0	4.5	4.4	6.1	26
1994 non-LPOTW	49	374.8	0.0	31.8	3.8	2.0	4.9	6.7	7.1	65
1998 non-LPOTW	61	140.6	0.0	16.3	1.0	0.6	1.8	3.8	5.2	41
2003 non-LPOTW	38	197.8	0.1	50.2	3.1	0.6	5.9	6.9	10.6	38
Species Richness (no. of species/haul)										
1994 LPOTW	9	68	5	35	13	9	21	16	8	67
1998 LPOTW	32	89	6	34	15	14	18	17	6	50
2003 LPOTW	25	70	4	28	13	9	15	13	5	60
1994 non-LPOTW	49	155	6	40	12	11	13	13	6	52
1998 non-LPOTW	61	100	1	28	15	11	16	13	6	66
2003 non-LPOTW	38	126	3	28	13	8	18	14	6	61
Shannon-Wiener Diversity (bits/individual/haul)										
1994 LPOTW	9		0.23	2.34	1.26	0.56	1.80	1.26	0.69	58
1998 LPOTW	32		0.09	2.15	0.73	0.45	0.93	0.99	0.74	45
2003 LPOTW	25		0.15	2.33	1.51	0.96	1.91	1.44	0.61	69
1994 non-LPOTW	49		0.03	2.42	0.77	0.59	0.96	0.99	0.62	41
1998 non-LPOTW	61		0.00	2.34	1.02	0.84	1.26	1.05	0.61	44
2003 non-LPOTW	38		0.10	2.39	0.96	0.71	1.79	1.14	0.65	39

CL = Confidence limits (LL = Lower Limit; UL = Upper Limit); Min. = Minimum; Max. = Maximum; No. = Number; SD = Standard deviation; Md = Median; Mn = Mean.

POTW = Publicly owned treatment work monitoring areas.

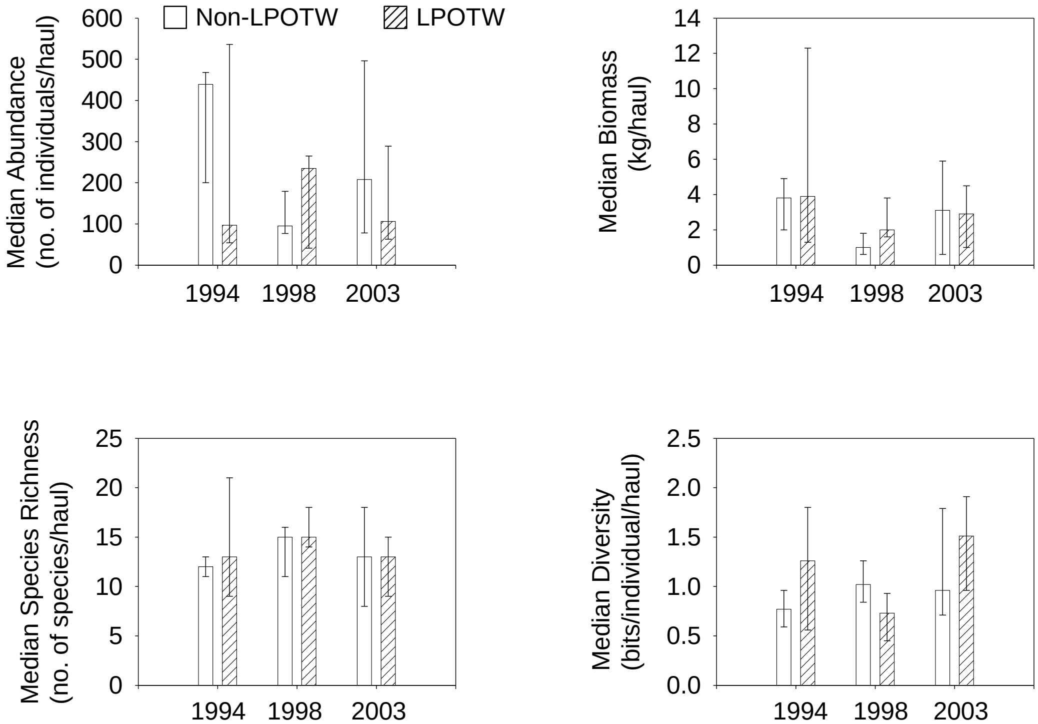


Figure V-6. Median (and 95% confidence limits) megabenthic invertebrate population attributes at large publicly owned treatment work (LPOTW) subpopulations and reference (NLPOTW: mainland, middle shelf, non-large POTW) subpopulations in 1994, 1998, and 2003: a) abundance; b) biomass; c) species richness; and d) diversity. NOTE: LPOTW boundaries of 1998 were used in all years.

Among the three surveys and four population attributes (Figure V-7), LPOTW medians were above 50% of their non-LPOTW counterparts for abundance and biomass only in 1998, but were above this level at non-LPOTW areas for species in 1994 and for diversity in 1994 and 2003. The least area at LPOTWs above non-LPOTW areas were for abundance in 1994 and 2003 (Figure V-7).

The survey design of the 1998 and 2003 regional surveys reduced the size of the area included in the LPOTW area from that in 1994 to the area where outfall effects on fish and invertebrate populations had been observed. In comparing outfall effects between the three periods, the 1998 and 2003 POTW boundaries were applied to the 1994 station map, and 1994 stations were reapportioned into the new LPOTW and non-LPOTW subpopulation boundaries of 1998; the 1994 stations retained their area-weights from that year. Area-weights for the 2003 survey were the same as for the 1998.

Invertebrate Abundance over Time

Effort differences between surveys were minimized by selecting a subset of the sites sampled and comparing means between regional surveys (Table V-15). Only sites from mainland inner shelf, middle shelf, and outer shelf in each of the three surveys are included in calculation of means, with bay/harbor and slope strata excluded. In the SCB as a whole, invertebrate abundance was highest in 1994, about a decade after a strong El Niño (1982-1984) and during a warm regime period of the Pacific Decadal Oscillation (PDO). Mean abundance was 52% lower in 1998 (another strong El Niño), but had increased by 43% in 2003 during the PDO cold regime, which was in place at least from 1999 to 2005 (Goericke *et al.* 2005). The 2003 trawl mean invertebrate abundance was 32% below that recorded in 1994. The 2003 abundance is also lower than the long-term mean of 577 (Thompson *et al.* 1993a) by 25%. Given the observed differences in means between regional surveys, this is not a particularly noteworthy decline. Rather than a reflection of declining ecosystem condition, this decline reflects the nature of population fluctuations over time under the variable thermal and current structures in the waters of the SCB. This is evident in the wide error bounds around the mean values, where the standard deviation is always greater than the mean (Table V-16). It may be that the 1971-1985 mean is somewhat inflated by inclusion of predominantly POTW based data. Trawl abundance was higher in large POTW areas than in non-POTW areas during the 1998 El Niño survey (e.g., Allen *et al.* 2002a) but was higher in non-POTW areas in the warm and cold-regime surveys (Table V-16). The much higher abundances in large POTW areas seen in 1998 were not seen in either 1994 or 2003, where large POTW areas had abundance means lower than at sites outside large POTW influence (Figure V-6; Table V-16).

The pattern of change over time in mean trawl invertebrate abundance has not been uniform throughout the SCB. In the northern region, where no large POTWs are located, mean abundance has declined consistently since 1994; by 60% between 1994 and 1998, and by a further 32% between 1998 and 2003 for a net decline of 73% over the decade. In the central region, where 3 large POTW discharges are located, an initial 30% decline from 1994 to 1998 was more than offset by a 122% increase between 1998 and 2003, yielding a net increase of 54% over the decade. In the southern region (with one large POTW discharge), this decline between 1994 and 1998 and increase between 1998 and 2003 was also seen, but yielded a net decline of 19% in mean abundance between 1994 and 2003 (Table V-15).

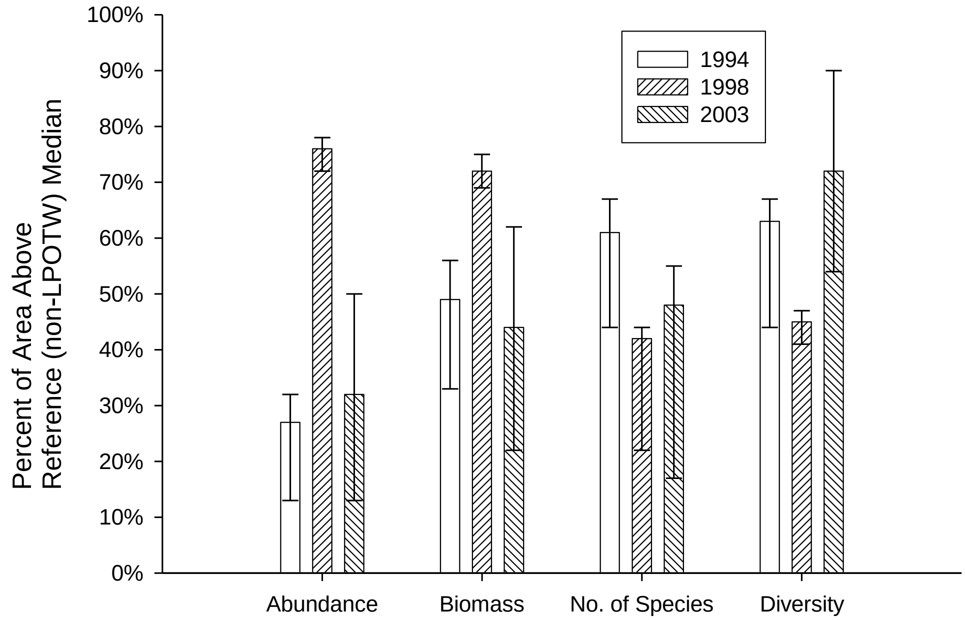


Figure V-7. Percent of area (with 95% confidence limits) of large publicly owned treatment works (LPOTW) subpopulations of megabenthic invertebrate population attributes above the reference (NLPOTW: mainland, middle shelf, non-large POTW) subpopulation medians in 1994, 1998, and 2003. NOTE: LPOTW boundaries of 2003 were used for all years; NLPOTW areas consist of all mainland middle shelf stations that did not fall within the LPOTW boundaries.

Invertebrate Biomass over Time

Like mean abundance, mean biomass has fluctuated over time in a pattern of alternating increases and decreases (Table V-15). The 1994 mean was 6% greater than that reported by Thompson *et al.* (1993a) from the 1971-1985 period. Following a 49% decline in mean biomass between 1994 and 1998, a 103% increase between 1998 and 2003 yielded a +4% net change in mean from the multi-year mean. The magnitude of the standard deviations in mean biomass in both POTW and non-POTW areas in regional surveys (Table V-16) again suggests that the observed changes, while sizeable, are not statistically significant.

The regional pattern of mean biomass per trawl is similar to that for mean abundance per trawl, with declines between each survey in the northern region, decline followed by strong recovery in the central region, and decline followed by moderate recovery in the southern region (Table V-15). Large POTW mean biomass was greater than that of non-POTW areas in both 1994 and 1998, but lower than in non-POTW areas in 2003 (Figure V-7; Table V-16). The difference may reflect the change in definition of POTW areas between surveys, with some of the area considered as POTW in earlier surveys considered as non-POTW in 2003 (see Methods section for definition of subpopulations). There was a consistent decline in mean biomass between regional surveys in large POTW areas, but the high variability around these means indicate that the declines are not statistically significant. In non-POTW areas the pattern of decline followed by recovery is also unlikely to have statistical significance given the variability of catch data.

Invertebrate Species Richness over Time

Invertebrate species richness (number of species/haul) in 1994 was the same as the 1971-1985 mean of 13 species/haul (Thompson *et al.* 1993a, Allen and Moore 1996). Between 1994 and 1998 this declined by 38%, but then increased (by 38%) by 2003 to a mean of 11 species/haul (Table V-15; Allen *et al.* 2002a). While the depression in mean species/haul in 1998 seems large, it remains within the standard deviation of the long term mean reported for the mainland shelf by Thompson *et al.* (1993a).

The pattern of change over time in mean species/haul in the SCB overall was also seen in the central and southern regions of the SCB (Table V-15). In the northern region, however, the increase in species following the 1998 survey did not occur, with the 2003 mean 13% below that in 1998. As in 1994 and 1998 (Allen and Moore 1996; Allen *et al.* 1998, 2002a), species richness was very low on the inner shelf, relative to the middle and outer shelf zones (Table V-5). In all three regional surveys and in Thompson *et al.* (1987b) there was a distinct pattern of increase in invertebrate biomass with depth but the latter study found fewer individuals on the middle shelf and more species on the inner shelf. Allen *et al.* (1998) suggested that the low population attributes in the inner shelf zone might be related to a more variable environment (e.g., of temperature, salinity, turbulence, and food availability). The higher daytime light levels in this zone may also select for more cryptic invertebrate species and facilitate net avoidance by fish.

Comparing only middle shelf large POTW and non-POTW areas (Table V-16), there was little difference in mean invertebrate species richness between subpopulations, or between years within each subpopulation (Figure V-7; Table V-16). All the means for both areas were within one standard deviation of the others (Table V-16), so their differences are not statistically significant.

Invertebrate Species Diversity over Time

Shannon-Wiener species diversity (H') is a measure of the information content of the catch, which synthesizes elements of both abundance and species richness. Diversity values provided in Thompson *et al.* (1993a) in their synopsis of earlier survey data, were presented as Brillouin diversity, and are not directly comparable. No values for diversity are listed for the 1957-75 period due to this discrepancy (Table V-15). Diversity has been quite stable over the decade spanning the three regional surveys, declining by a net of 1% over the 1994-2003 period. This measure, like mean abundance and mean biomass exhibited a pattern of decrease from 1994 to 1998 followed by increase from 1998 to 2003.

The regional pattern of change in species diversity over time is almost a mirror image of the pattern in mean abundance per trawl, with decreases replaced by increase or vice-versa in both the central and southern regions (Table V-15). In the northern region a major decline in abundance over the three surveys (73%) was reflected in a minor decline (3%) in species diversity. Thus, the northern region exhibited a pattern of change very similar to that in the SCB overall, while the pattern in the central and southern regions differed from that in the SCB. In the central region, the 21% decline in species diversity was driven by a strong increase in mean abundance with no change in species richness. In the southern region, a slight decline in species richness and a 33% decline in mean abundance produced an increase in species diversity. This suggests that the abundance was more evenly divided between the various species in the southern region in 2003. The error bounds of the mean values for both large POTW and non-POTW areas in the three surveys (Figure V-7; Table V-15), while less than the means, are still large enough to indicate that the observed differences between surveys are not statistically significant. In non-POTW areas there has been consistent increase in mean diversity between the three surveys, while in large POTW areas a decline between 1994 and 1998 was more than offset by a large increase between 1998 and 2003. Mean species diversity in large POTW areas was greater than that in non-POTW areas in both 1998 and 2004 (while lower in 1994), with most sites above the bight-wide median in both those years (Figure V-7).

Species Composition in Regional Surveys 1994-2003

Differences in scope and effort allocation between surveys make comparison of megabenthic species composition over time difficult. In the crudest sense, there has been an increase over time from 204 species in 1994 to higher numbers (313 in 1998, 308 in 2003) which has been parallel to the increase in effort and in habitat coverage. The greatest increase in different species taken was associated with the addition of the bay/harbor/marina and island strata in the 1998 survey. Sampling of these continued in 2003, but at lower intensity. The addition of the upper slope stratum in 2003 added only a limited number of species not encountered elsewhere (8% of the encountered species occurred only at slope stratum sites). Despite this the number of taxa occurring at non-slope sites in 2003 (283) remained high relative to the effort expended compared to 1998. In 1998, 314 non-slope sites were occupied, yielding 313 different taxa; approximately one additional species for each site occupied. In 2003, the 182 non-slope sites yielded 283 species, approximately 1.6 additional species for each site occupied. Using this crude summary estimator it does not appear that the biota of the SCB is becoming less varied over time. It is likely that the relatively low level of species addition per unit effort in 1998 reflects the strength of the El Niño conditions in force at the time, which excluded a number of cool water forms normally found in the SCB.

Phyletic Diversity in Regional Surveys 1994-2003

A slow accretion of megabenthic invertebrate phyletic diversity has occurred over time, as measured in the diversity of higher taxonomic categories represented. These are simple count measures and not the derived phyletic diversity measures proposed and discussed by others (i.e., Clarke and Warwick 1998, Warwick and Clarke 1998, Clarke and Warwick 2001, Salas *et al.* 2006). Per unit of sampling effort, the greatest phyletic diversity was in the 1994 survey. Accumulation of such diversity is, however, far from linear. The curve of taxa accumulation at the species or any higher level rises nearly vertically initially, with the slope rapidly decreasing to an asymptote. As the heirarchical position of the considered taxon becomes higher, the asymptote is increasingly close to the origin. With number of phyla, for instance, only one additional phylum was added in the 1998 and 2003 surveys, despite significant increases in the number of different habitats sampled, and in overall sampling effort. The number of classes encountered in each regional survey has gradually increased from 20 to 23 between 1994 and 2003, while family diversity peaked at 132 in 1998 (110 in 1994 and 127 in 2003). None of these differences indicate a trend of either increasing or decreasing phyletic diversity within the SCB that might trigger concern.

Population Areal Occurrence Changes between Surveys

In both the 1994 and 1998 surveys, California sand star and ridgeback rock shrimp occurred over more than 50% of the area of the mainland shelf of southern California. In 2003 California sand star and red octopus occurred in more than 50% of the area (Table V-17; Allen *et al.* 1998, Stull *et al.* 2001, Allen *et al.* 2002a). Although California sand star occurred in over 50% of the shelf area in 2003, it has become less widely distributed in each successive regional survey (Table V-17). Ridgeback rock shrimp, which had occupied nearly the same portion of the shelf in both 1994 and 1998, dropped in shelf area occupied by 50% between 1998 and 2003. Two species, New Zealand paperbubble (*Philine auriformis*) and California blade barnacle (*Hamatoscalpellum californicum*), which showed dramatic increases in areal occurrence from 1994 to 1998, became much less abundant and less widely distributed in 2003 (Appendix C-C2) and were not among the dominant species in abundance, biomass, or occurrence.

The reason for the decline in the California blade barnacle population between 1998 and 2003 (to 36th in abundance, and occurring in 11% of the sampled area) is not known, especially since the yellow sea twig, to which it is frequently attached, was found in 26% of the SCB shelf area in 2003 (Table V-17). The two species were grouped together in recurrent group analysis of 1998 data (Allen *et al.* 2002), but not in analysis of either 1994 data (Allen and Moore 1997b) or in the present study (Table V-15). The decline in the population density and distribution of the New Zealand paperbubble was more predictable. It is an exotic species which has recently invaded the offshore and bay waters of the SCB (Cadien and Ranasinghe 2003). After being initially detected at very low density in 1994, this invader had explosive population growth, utilizing available resources and escaping predation, so that it was the seventh most abundant megabenthic invertebrate by 1998. The species attracted predators and became better integrated in the community by 2003, dropping in rank to 17th in abundance and 8th in areal occurrence (Table V-18). This represented occurrence in only 17% of the shelf area in 2003, and did not place it among the occurrence dominants in the multisurvey comparison (Table V-17).

As these populations have been in decline, shrinking in density and distribution, those of the red octopus and blackspotted bay shrimp have been expanding (Table V-17). Red octopus, which was found at the same proportion of shelf sites in 1994 and 1998, increased in distribution by over 172% between 1998 and 2003; no other widely distributed species showed such an aggressive expansion over the shelf. While also becoming higher in relative abundance (Table V-18), the population density slightly increased and the distribution broadened very significantly. The species is distributed mainly to the north but also occurs in the Gulf of California. It may have benefited from the PDO regime shift from warm to cool which took place just after the 1998 regional survey. The same may be true of the blackspotted bay shrimp, which has nearly quadrupled it's distribution on the shelf since the 1994 regional survey (Table V-17).This species has also increased in relative abundance rank from 28th in 1994 to 12th in 1998, and 10th 2003 (Table V-18). Species noted as being forced into deeper waters by the strong warm water influence over the shelf in 1998 (Allen *et al.* 2002a) have returned to their normal shelf zonal distribution in 2003 data.

Table V-17. Comparison of megabenthic invertebrate species occurring in greater than 20% of the area on the mainland shelf of southern California in 1994, 1998, and 2003.

		No. of Stations			Percent of Stations			Percent of Area*		
Scientific Name	Common Name	1994	1998[a]	2003[b]	1994	1998[a]	2003[b]	1994	1998[a]	2003[b]
Astropecten verrilli (1,1)	California sand star	80	119	80	70	60	63	71.8	65.4	61.8
Octopus rubescens	red octopus	21	28	65	18	14	51	18.6	18.7	51.0
Lytechinus pictus	white sea urchin	55	65	49	48	33	38	47.9	43.8	46.0
Acanthoptilum sp	trailtip sea pen	25	30	42	22	15	33	24.0	20.5	37.9
Parastichopus californicus	California sea cucumber	53	57	46	46	29	36	45.9	37.4	36.6
Luidia foliolata	gray sand star	54	39	37	47	20	29	48.1	31.1	31.1
Sicyonia ingentis (2,2)	ridgeback rock shrimp	67	89	38	59	45	30	61.4	61.3	30.8
Thesea sp B	yellow sea twig	29	45	30	25	23	23	18.9	33.5	26.2
Rossia pacifica	eastern Pacific bobtail	23	19	35	20	10	27	17.9	11.3	25.8
Crangon nigromaculata	blackspotted bay shrimp	10	33	27	9	17	21	7.7	14.5	24.6
Loligo opalescens	California market squid	28	26	24	25	13	19	25.6	17.5	22.8
Pleurobranchaea californica	California sea slug	44	28	22	39	14	17	46.0	22.7	21.7
Total (all stations)		114	197	128				3,075[d]	3,344[d]	3,089[d]

* Percent of area based on area-weighted frequency of occurrences.
[a]Mainland shelf only (9 - 200 m); stations in island and bay/harbor subpopulations were excluded from the 1998 analysis.
[b]Mainland shelf only (5 - 200 m); stations in island, bay/harbor, and upper slope subpopulations were excluded from the 2003 analysis.
[c]Numbers in parentheses represent rank of species occurring in greater than 50% of the area in 1994.
[d]Total area in km^2.
Areal occurrences of 50% or greater are underlined.

Table V-18. Multiyear comparison of megabenthic species important because of abundance (A), biomass (B), or occurrence (Oc) in the Southern California Bight. Values reflect ranks in each survey, and average weighted importance rank by survey and overall.

	Rank												
	1994			1998			2003			Weighted Rank			
Species	A	B	Oc	A	B	Oc	A	B	Oc	1994	1998	2003	94-03
Lytechinus pictus	1	5	3	1	5	1	2	6	3	2.6	1.8	3.2	2.5
Sicyonia ingentis	3	4	2	2	4	3	7	7	11	2.8	2.8	8.6	4.7
Allocentrotus fragilis	4	2	8	4	2	14	3	1	8	5.2	7.6	4.6	5.8
Parastichopus californicus	10	1	4	11	1	7	23	3	7	5.8	7.4	12.6	8.6
Astropecten verrilli	9	16	1	5	32	2	11	38	1	7.2	9.2	12.4	9.6
Luidia foliolata	11	9	5	23	13	4	35	15	6	7.2	13.4	19.4	13.3
Brisaster latifrons	7	6	19	29	43	28	1	2	18	11.6	31.4	8.0	17.0
Spatangus californicus	5	3	28	24	16	38	9	4	21	13.8	28.0	12.8	18.2
Ophiothrix spiculata	12	32	10	8	51	12	15	48	15	15.2	18.2	21.6	18.3
Pleurobranchaea californica	17	12	6	32	30	6	52	18	12	11.6	21.2	29.2	20.7
Ophiura luetkenii	2	8	6	22	104	11	27	109	5	4.8	34.0	34.6	24.5
Thesea sp B	32	32	9	25	104	8	14	41	13	22.8	34.0	19.0	25.3
Octopus rubescens	36	32	15	48	56	12	32	28	2	26.8	35.2	19.2	27.1
Crangon nigromaculata	28	32	31	12	104	22	10	42	16	30.0	34.4	18.8	27.7
Neocrangon zacae	8	32	13	17	88	28	21	92	18	14.8	35.6	34.0	28.1
Pyromaia tuberculata	24	32	15	6	48	23	46	92	30	22.0	21.2	48.8	30.7
Loligo opalescens	14	32	10	50	104	17	33	64	20	16.0	47.6	34.0	32.5
Metridium farcimen	35	7	26	52	8	20	66	10	40	25.8	30.4	44.4	33.5
Hamatoscalpellum californicum	41	32	15	15	104	6	36	109	17	28.8	29.2	43.0	33.7
Mediaster aequalis	68	32	45	31	49	10	31	33	14	51.6	26.2	24.6	34.1
Luidia armata	21	16	18	40	54	15	81	71	44	18.8	32.8	64.2	38.6
Brissopsis pacifica	13	13	25	100	78	94	6	5	24	17.8	93.2	13.0	41.3
Stylatula elongata	22	32	19	35	88	20	75	109	27	22.8	39.6	62.6	41.7
Megasurcula carpenteriana	30	32	19	46	72	29	114	109	50	26.0	44.4	87.4	52.6
Luidia asthenosoma	60	32	39	57	104	15	89	92	30	46.0	49.6	66.0	53.9
Platymera gaudichaudii	96	32	56	86	44	23	67	27	27	67.2	52.4	43.0	54.2
Paguristes turgidus	31	32	39	47	18	19	126	109	71	34.4	30.0	100.6	55.0
Philine auriformis	146	32	124	7	104	5	17	80	8	114.4	25.6	26.0	55.3
Spirontocaris holmesi	15	32	94	62	104	114	16	49	36	50.0	91.2	30.6	57.3
Dromalia alexandri	32	16	51	72	51	176	30	14	35	36.4	109.4	28.8	58.2
Pandalus platyceros	81	32	124	65	67	56	37	25	24	88.4	61.8	29.4	59.9
Pandalus jordani	-	-	-	63	88	114	18	23	92	-	88.4	48.6	68.5
Florometra serratissima	106	32	94	49	78	114	38	54	50	86.4	80.8	46.0	71.1
Bulla gouldiana	-	-	-	16	40	176	22	30	126	-	84.8	65.2	75.0
Ciona intestinalis	-	-	-	26	32	176	34	71	92	-	87.2	64.6	75.9
Musculista senhousia	-	-	-	10	88	176	26	109	71	-	92.0	60.6	76.3
Molgula verrucifera	-	-	-	27	76	176	28	109	92	-	96.4	69.8	83.1
Ophionereis eurybrachiplax	91	32	94	171	104	56	12	20	126	80.4	111.6	59.2	83.7
Styela plicata	-	-	-	65	104	176	20	80	71	-	117.2	52.4	84.8
Neocrangon communis	36	32	94	224	104	176	29	64	71	58.4	180.8	52.8	97.3
Spirontocaris sica	96	32	94	224	104	176	25	92	30	82.4	180.8	40.4	101.2
Ptilosarcus gurneyi	46	16	45	69	54	23	260	109	260	39.6	47.6	229.8	105.7
Stachyptilum superbum	-	-	-	224	104	176	19	64	126	-	180.8	70.8	125.8
Pannychia moseleyi	-	-	-	-	-	-	24	22	44	-	-	31.6	N/A

Weighted Rank = (2*A +B+2*Oc)/3
"-" = absent
NA = not applicable (only one survey)

Macroscalar patterns are visible in the comparison of 1993, 1998, and 2003 regional data. Comparisons are complicated by differing effort levels and stratum coverage over time. Examination in trends of invertebrate species "importance" (Table V-18), species were ranked by abundance, biomass, and percent occurrence at sampled sites in each survey. Weighted ranks were generated for each survey and for the three survey set (abundance and occurrence were weighted twice as heavily as biomass). Data from Thompson *et al.* (1993a) was not included, as they were strongly associated with POTWs, and were not collected using the same area-weighted random allocation strategy. However, they remain useful as a benchmark of temporal changes in data predating the recent Bight-wide regional studies. Some of the data used by Thompson *et al.* (1993a) was also included in analyses summarized in Walther (2005), which extended the examination of invertebrate catch around the POTW discharge on Palos Verdes through 2004. While the data are influenced by POTW discharge (but with much lower particulate and toxicant loads than the data used by Thompson *et al.* 1993a), it provides both a long period of examination, and the ability to compare trends in a single area before and during the period covered by regional synoptic surveys.

Effects of Oceanic Regime Changes on Regional Surveys

The three 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 ended culminating in the 1997-1998 El Niño, and a cool period began. The regime shift resulted in a swing of 9ºC, from 6º above the seasonal mean sea-surface temperature to 3º below it (Schwing *et al.* 2000). This decadal scale trend is independent of the shorter cycle El Niño Southern Oscillation (ENSO; Wolter 1987), which 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 three standardized regional surveys (1994, 1998, 2003), ocean conditions 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 in a cool regime. The California Current has remained in this cool regime from 1999 to 2005 (Goericke *et al.* 2005). Such oceanographic changes are reflected in the composition of the megabenthic invertebrate (and demersal fish) fauna, although most such animals live for several years, and respond after a time-lag. Each species will have a somewhat different response lag.

Interactions of the PDO and ENSO cycles produce a complex temporal mosaic of oceanographic conditions, primarily associated with temperature, but also influenced by associated changes in current transport of larvae, and upwelling driven by both oceanic and atmospheric circulation states, which affect the availability of nutrients in waters over the continental margin. Examination for temporal changes in the SCB must be performed with the above complexity in mind. 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 the 123 fish species examined lacked strong correlations to the oceanographic variables examined. A similar analysis has not been performed for trawl megabenthic invertebrates, and the present database is not yet long enough to permit one. However, it is expected that the patterns reported for fishes by Allen *et al.* (2004) will be repeated in the invertebrates.

Some apparent relationships to oceanic cycles in invertebrate populations examined here can be observed in overall population attributes, species occurrence, or importance (Tables V-14, V-17, and V-18). For example, invertebrate abundance, species richness, and diversity were higher in 1994 (warm regime) but biomass was higher in 2003 (cold regime). Invertebrate abundance, biomass, species richness, and diversity were all lowest in 1998 (El Niño, warm; Table V-14). In 1994, the difference in median invertebrate abundance between non-LPOTW and LPOTW areas on the middle shelf were particularly apparent, much lower at LPOTW areas (Figure V-6). With regard to species areal occurrence, ridgeback rock shrimp was most widespread in warmer periods (1994 and 1998) and least in the cooler 2003 (Table V-17). In contrast, red octopus was most widespread in the cooler period. California sea slug was more than twice as widespread in 1994 (warm) as in 1998 or 2003. With regard to importance (Table V-18), some species (brokenspine brittlestar, *Ophiura luetkenii*; moustache bay shrimp, *Neocrangon zacae*) did best in the warm regime but New Zealand paperbubble did worst (partly due to being recently introduced). A number of species were strongly negatively affected by the 1998 El Niño (e.g., northern heart urchin; California heart urchin; Pacific heart urchin; sea dandelion, *Dromalia alexandri*; gray shrimp; 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 regime in 2003.

The Upper Slope Stratum

The Bight '03 survey was the first of the regional surveys to venture off the continental shelf and onto the slope. Worldwide, the boundary dividing the shelf and slope is conventionally set at 200m, although the geological boundary between the flat shelf and the steeper slope lies shallower (80-130 m) in southern California (Emery 1960, Curray 1966, Allen 2006a). The upper slope region between 200-500m depths is a distinct life zone, the Mesobenthal Slope, which connects the shelf with the Bathybenthal Slope (500-1,000 m), which extends into the southern California basins (Hedgpeth 1957, Allen 2006a). The complex continental borderland is located between the shelf and the true continental slope seaward at the Patton Escarpment (Uchupi and Emery 1963). The geological demarcation between the shelf and this slope is subtle and variable in depth. It is usually marked by a relatively abrupt change in the angle of the sea floor relative to the sea surface. The shelf usually slopes down only 1° to 2°, while the slope slopes downward at 4° or greater. This change is often accompanied by changes in current velocity, which tend to remove fine particulates from the edge of the shelf, exposing underlying bedrock. Fish communities occupying both shelf and slope bathymetric zones were treated by Allen (2006a).

The megabenthic invertebrates which occupy this mesobenthal slope (Hedgpeth 1957, Allen 2006a) or upper bathyal or archibenthal transition zone (Menzies *et al.* 1973) are usually also found either shallower on the shelf, or deeper on the slope. Thompson *et al.* (1993a) showed deeper slope sites clustering together, while uppermost slope sites grouped with outer shelf depth sites. This is an area of biotic transition, where many shelf populations reach their maximum depths, and many deeper living forms find their shallow limits. These slopes tend to bear uniform silty sand or sandy silt sediments with occasional rocky outcrops. They are sufficiently close to shore that terrestrially derived nutrients are in plentiful supply, and nutrient limitation does not shape the fauna as it does in deeper waters further from land (Dickinson and Carey 1981). The bottom of the zone is still above the Northeastern Pacific oxygen minimum layer (Cimberg *et al.* 1993; Allen 2006a), and waters on these slopes, while dysoxic, do not seriously limit biotic diversity or abundance.

Echinoderms dominate the trawl invertebrate catches in the upper slope zone. The fragile sea-urchin, northern heart urchin, California heart urchin, Pacific heart urchin, sea-stars, and brittle-stars are all major contributors, forming the majority of both catch abundance and catch biomass. The four urchin species mentioned above, for instance, contribute 63.7% of biomass in the Bight as a whole, while accounting for 84.4% of biomass at upper slope stations (Table V-14). They contributed 43.9% of the Bight invertebrate catch, and 65.7% of the slope depth catch. In the multisurvey importance ranking (Table V-18) echinoderms also dominated the list of important species in 1994, when only shelf depth stations were sampled. Their relative dominance is increased by inclusion of the slope stratum. Most of the species taken in 2003 (Appendix C-C2) did not occur on the slope (78%), while 27 (8%) occurred only there. Distribution of 14% of species taken was common to sites in the outer shelf and upper slope strata. In a longer database from 305m sampling on the upper slope (Walther 2005, Table 4.14; quarterly trawls at four sites from 1991-2004) echinoderms also dominated both abundance and biomass. In this 2003 trawl dataset fragile sea-urchin and northern heart urchin combined for 97% of both trawl abundance and trawl biomass.

Important Megabenthic Species in Regional Trawling Surveys

Various importance measures are used to compare megabenthic populations. Those that are particularly abundant may be small and have little biomass. Some that occur widely in the study area may be at very low density, and some that have large abundances and biomass may be restricted to a particular depth zone or subpopulation. Their relative importance in each year can be determined based on abundance, biomass, or occurrence in the three regional surveys (Table V-18). Since effort and coverage have varied in all three, the comparison is based on rank within survey for each of the parameters considered. The three importance measures were not considered equal, with biomass having only half the importance of the other two. Using this weighting, weighted average importance was calculated for each regional survey, and for the three survey set.

While the list of important species is longer for the combined data than it would be in any given survey, the same species recur throughout the three regional surveys. The greatest differences in important species resulted from inclusion of the slope stratum in the 2003 survey, and the bay/harbor stratum in both 1998 and 2003. Several species of importance were absent in either the 1994 shelf only dataset, or in both 1994 and 1998 (Table V-18). Most of the species examined are found in earlier lists of dominant SCB megabenthic invertebrates (Carlisle 1969a,b; Stull 1995; Thompson *et al.* 1993a). The major point one may derive from the multisurvey comparison is the validity of the old adage "*Plus ça change, plus c'est la meme chose*" (The more things change, the more they remain the same). The composition and relative balance of the important species populations within the SCB are in constant flux, tracking changes in oceanographic conditions. As these conditions are modified by the complex interaction of the PDO cycle, the ENSO cycle, and the second-order changes resulting in current, wind, and upwelling shifts, the animals follow suit. Although trends in individual populations may be significant over time, reflecting fitness (or lack of fitness) to the oceanographic regime in force, the megabenthic invertebrate population attributes measured in the SCB do not seem to be following a significant trend of either increase or decrease since regional monitoring efforts began. This appears to be true both in areas around large POTWs, and in areas outside apparent POTW influence.

VI. ASSEMBLAGES AND BIOINTEGRITY

Introduction

The demersal fish and invertebrate fauna of southern California have been the focus of environmental assessment studies for more than 35 years. Most studies have been local in nature and assessed the effects of wastewater discharge on fish and invertebrate populations (e.g., Carlisle 1969a,b; CSDLAC 1990; CLAEMD 1994a,b; CSDMWWD 1995; CSDOC 1996; CLAEMD 2003a,b; CSDLAC 2006). While these studies focused on populations, some used 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 or away from outfalls. Others (e.g., Allen 1985) used cluster analysis to define soft-bottom fish assemblages relative to hard-bottom assemblages. Some studies have described demersal fish communities for southern California at depths of 10-200 m using recurrent group analysis (defining species groups based on species co-occurrence; SCCWRP 1973, Mearns 1974, Allen 1982), and later in Allen and Moore (1997a) and Allen *et al.* (1998, 2002a). Recurrent groups of invertebrates have been described in Allen and Moore (1997b) and Allen *et al.* (1998, 2002a). The functional organization (based on foraging guilds) of soft-bottom fish communities of the southern California shelf (10-200 m) was originally described for 1972-1973 in Allen (1982), and again based on regional survey data from 1994 and 1998 (Allen *et al.* 1998, 2002a). This description was expanded to the entire coast of California and Pacific Baja California at depths from 5-500 m in Allen (2006a). On a regional scale, fish assemblages (site and species groups) were described by cluster analysis in southern California in Allen *et al.* (1998, 1999a, 2002a) and NCCOS (2005). Invertebrate assemblages have been described regionally using cluster analysis by Thompson *et al.* (1993a), Allen *et al.* (1998, 1999b, 2002a), and NCCOS (2005). Assemblages based on combined fish and invertebrate data have been described in Allen *et al.* (2002a) using recurrent group, cluster, and cladistic analyses.

Regardless of method, the regional assemblage analyses all identified depth (from 5-200 m) as the primary factor around which the communities were organized. Allen (2006a) described the functional structure of the major soft-bottom fish community on the upper slope for California. Thompson *et al.* (1993a) was the only study that described invertebrate assemblages for depths greater than 200 m. It used cluster analysis to describe invertebrate site and species assemblages based upon species-abundance data accumulated from 1971-1985 from the southern California mainland shelf, slope, and basins as well as from highly contaminated sites and different (warm and cool) oceanic regimes. These data focused on the central part of the SCB and identified depth-related species groups for the southern California shelf. Allen *et al.* (2002a) described changes in assemblages between 1994 and 1998, and in functional structure of fish communities from 1972 to 1998.

Site clusters and clades (which provide assemblage information for all sites) provided a basis for assessing publicly owned treatment work (POTW) effects in space, and no effects were observed in the assemblages in 1994 and 1998 (Allen *et al.* 1998, 2002a). Biointegrity indices for fish, invertebrate, and combined fish and invertebrate assemblages (Allen *et al.* 2001a) were used to assess spatial extent of nonreference (altered or disturbed) assemblages on the mainland and island shelf in 1998 (Allen *et al.* 2002a). These indices identified 85-97% of the southern California shelf area as having reference (normal) assemblages. The few nonreference sites were clustered near river mouths (especially at the Santa Clara River), suggesting runoff effects.

The objectives of the assemblage analyses in the present study were 1) to determine how assemblages on the upper slope (201-500 m depth) compare to shelf assemblages (5-200 m); 2) to assess condition and health of fish and invertebrate assemblages of southern California bays and harbors, shelf, and upper slope; and 3) to compare changes in fish and invertebrate assemblages among the three regional surveys, which coincidentally were conducted in three distinct oceanic periods.

Recurrent group analysis was used to describe species groups based on presence/absence data and species co-occurrence, cladistic analysis was used to describe site and species clades based on presence/absence and abundance data, and cluster analysis was used to describe species and site clusters based on species abundances. Multidimensional scaling was used to examine relationship of site assemblages to physical gradients. The areal extent of altered communities was determined using biointegrity indices from Allen *et al.* (2001a). A model of the functional organization of the fish communities (Allen 1982) was used to examine effects of cold and warm regimes, and the 1998 El Niño event on fish community organization.

Results

Fish Assemblages

Fish Recurrent Groups

Recurrent group analysis at the 0.50 level of affinity identified 11 recurrent groups of fishes consisting of 2-9 species per group with 10 associate species (Figure VI-1). In all, the groups and associates included 44 (31%) of the 140 species collected in the survey. The groups generally differed in depth distribution, with most occurring in one or two of the four predetermined shelf zones except for Group 7, which spanned three shelf zones: middle (31-120 m), outer (121-200 m), and a little of the upper slope zone (201-500 m; Table VI-1). Groups were found at 1-32 stations, with 5 groups occurring at more than 10 stations.

Group 1 (Inner Shelf Algae Group). Group 1 consisted of two species, crevice kelpfish (*Gibbonsia montereyensis*) and barcheek pipefish (*Syngnathus exilis*; Figure VI-1). The group occurred at one station (4367) on the mainland inner shelf at a depth of 16 m west of Santa Barbara (Table VI-1). Group 1 did not have affinities with other recurrent groups. Crevice kelpfish is predominantly a hard bottom species associated with subtidal algae. Both may also be associated with drift algae found on the soft-bottom in shallow water.

Group 2 (Harbor/Inner-Shelf Croaker Group). Group 2 consisted of two schooling sciaenid species, white croaker and queenfish (Figure VI-1). This group occurred at 12 stations on the soft bottom inner shelf ranging in depth from 8-30 m with a mean depth of 17 m (Table VI-1). It was found in the LA/LB Harbor (5 stations), near the Santa Clara and Ventura river mouths (4 stations), as well as in the San Diego County region (3 stations). It was not found on the islands. Group 2 did not have affinities with other recurrent groups.

Group 3 (Inner Shelf Hard-bottom Group). Group 3 consisted of two inner shelf hard-bottom species: blacksmith (*Chromis punctipinnis*) and roughcheek sculpin (*Ruscarius creaseri*; Figure

VI-1). This group occurred at one site (Station 4094) in north San Diego County, on the mainland shelf at 20 m (Table VI-1). It was not associated with any of the other groups.

Group 4 (Inner/Middle Shelf Mainland Group). Group 4 consisted of nine species: Pacific sanddab, yellowchin sculpin, longspine combfish, pink seaperch, longfin sanddab, roughback sculpin, California tonguefish, hornyhead turbot and bigmouth sole (Figure VI-1). The group occurred at 18 sites in the inner and middle shelf zones, ranging in depth from 24-81 m and with a mean depth of 49 m (Table VI-1). It occurred on soft bottom throughout the mainland middle shelf zone, but was not found at the islands. Speckled sanddab, pygmy poacher, lingcod, English sole, California scorpionfish, California lizardfish, bay goby, and Groups 5 and 7 were associates of this group (Figure VI-1).

Group 5 (Middle/Outer Shelf Group). Group 5 consisted of four species: stripetail rockfish, halfbanded rockfish, Dover sole, and plainfin midshipman (Figure VI-1). The species are found on soft bottoms, with halfbanded rockfish also found near rocks. The group was found at 32 sites at depths of 40-192 m on the middle shelf (primarily) and outer shelf of the mainland and islands with a mean depth of 86 m (Table VI-1). On the mainland middle shelf it occurred at some LPOTW and SPOTW areas, but mostly at non-POTW areas. It was associated with bay goby, greenstriped rockfish (*Sebastes elongatus*), and Groups 4 and 7 (Figure VI-1).

Group 6 (Middle Shelf Hard-bottom Group). Group 6 consisted of two species: greenspotted rockfish (*Sebastes chlorostictus*) and bluebanded ronquil (*Rathbunella hypoplecta*; Figure VI-1). The group was found at 3 sites at depths of 80-104 m (mean depth 88 m; Table VI-1) at the southeast Channel Islands, Santa Monica Bay, and north San Diego shelf. The species are typically found on hard bottom, including low-relief hard bottom areas. The group did not have any associate species or groups.

Group 7 (Outer Shelf Group). Group 7 consisted of four species: slender sole, blackbelly eelpout, shortspine combfish, and blacktip poacher (Figure VI-1). The group was found at 20 sites on the outer shelf at depths of 90-204 m (mean depth 163 m; Table VI-1) on soft bottom at the northwest Channel Islands and mainland. The species are soft-bottom species. Associate species of the group included greenstriped rockfish, bluebarred prickleback (*Plectobranchus evides*), and rex sole, and it was associated with Groups 4, 5, and 8 (Figure VI-1).

Group 8 (Outer Shelf-Upper Slope Group). Group 8 consisted of two species: splitnose rockfish and Pacific hake (Figure VI-1). The group was found at 23 sites on the outer shelf and upper slope at depths of 155-433 m (mean depth 272 m; Table VI-1) on soft bottom on the mainland and at one northwest Channel Islands site. It was associated with rex sole and Group 7 (Figure VI-1).

Group 9 (Upper Slope Benthic Group). Group 9 consisted of two species: shortspine thornyhead (*Sebastolobus alascanus*) and bigfin eelpout (Figure VI-1). The group was found at 10 sites on the upper slope at depths of 197-463 m (mean depth 373 m; Table VI-1) on soft bottom along the mainland. It did not have associate species or groups (Figure VI-1).

Group 10 (Mesopelagic-Upper Slope Group). Group 10 consisted of two species: dogface witch eel (*Facciolella equatorialis*) and California grenadier (*Nezumia stelgidolepis*; Figure VI-1). The group was found at 3 sites on the upper slope at depths of 456-469 m (mean depth 463 m; Table VI-1) along the mainland upper slope. Dogface witch eel is mesopelagic and California grenadier is found near the bottom on the upper slope. This group did not have associate species or groups (Figure VI-1).

Group 11 (Mesopelagic Group). Group 11 consisted of three species: slender hatchetfish (*Argyropelecus affinis*), blackbelly dragonfish (*Stomias atriventer*), and bulldog lightfish (*Ichthyococcus irregularis*; Figure VI-1). The group was found at 1 site on the upper slope at 463 m (Table VI-1) on the south San Diego shelf. All three species are mesopelagic fishes (Figure VI-1).

Fish Site and Species Clusters

Selection of Species. The trawl survey sampled 210 stations and collected 61,687 fish representing 142 species. Based upon the screening criteria, 209 stations representing 61,103 fish and 70 species were included in the cluster analysis. The cluster analysis delineated eight major site clusters (station clusters), denoting habitats, and seven major species clusters, denoting species assemblages or communities (Figure VI-2; Appendix D-D1 through D-D3). Each site and species cluster was unique, based on the relative proportion of species of different species clusters comprising a site cluster and the relative proportion of species of each species cluster in different site clusters (Figure VI-2).

Site Clusters. The site clusters varied by region, depth, and subpopulation (Table VI-2; Figures VI-2 and VI-3). Each site cluster consisted of 1-3 species clusters, with 1-2 of these being dominant (Figure VI-2). Each species group was primarily dominant in a single site cluster; the only site cluster without a species group specific to the cluster was the inner shelf cluster (Figure VI-2).

Site Cluster 1 (Upper Slope) included 18 stations at depths of 258-476 m (Table VI-2; Figures VI-3 through VI-4). This site group represents an upper slope habitat occurring at 8 mainland upper slope sites. By subregion, this cluster included 13 northern, 2 central, and 3 southern mainland sites (Table VI-2). Sites in this cluster showed a strong latitudinal gradient from north to south associated with this upper shelf fish site cluster. Eight species occurred in more than 50% of the stations in Site Cluster 1 (Table VI-3; Appendix D-D1 and D-D2). All four species of Species Cluster D, three species of Species Cluster C, and one from Species Cluster B occurred in more than 50% of the stations within Site Cluster 1 (Table VI-3). The most frequently occurring species were Dover sole (100%) and slender sole (94%), followed by splitnose rockfish, Pacific hake, and bigfin eelpout (all at 72%). The most abundant species were slender sole (457), Dover sole (240), and Pacific hake (240; Appendix D-D3).

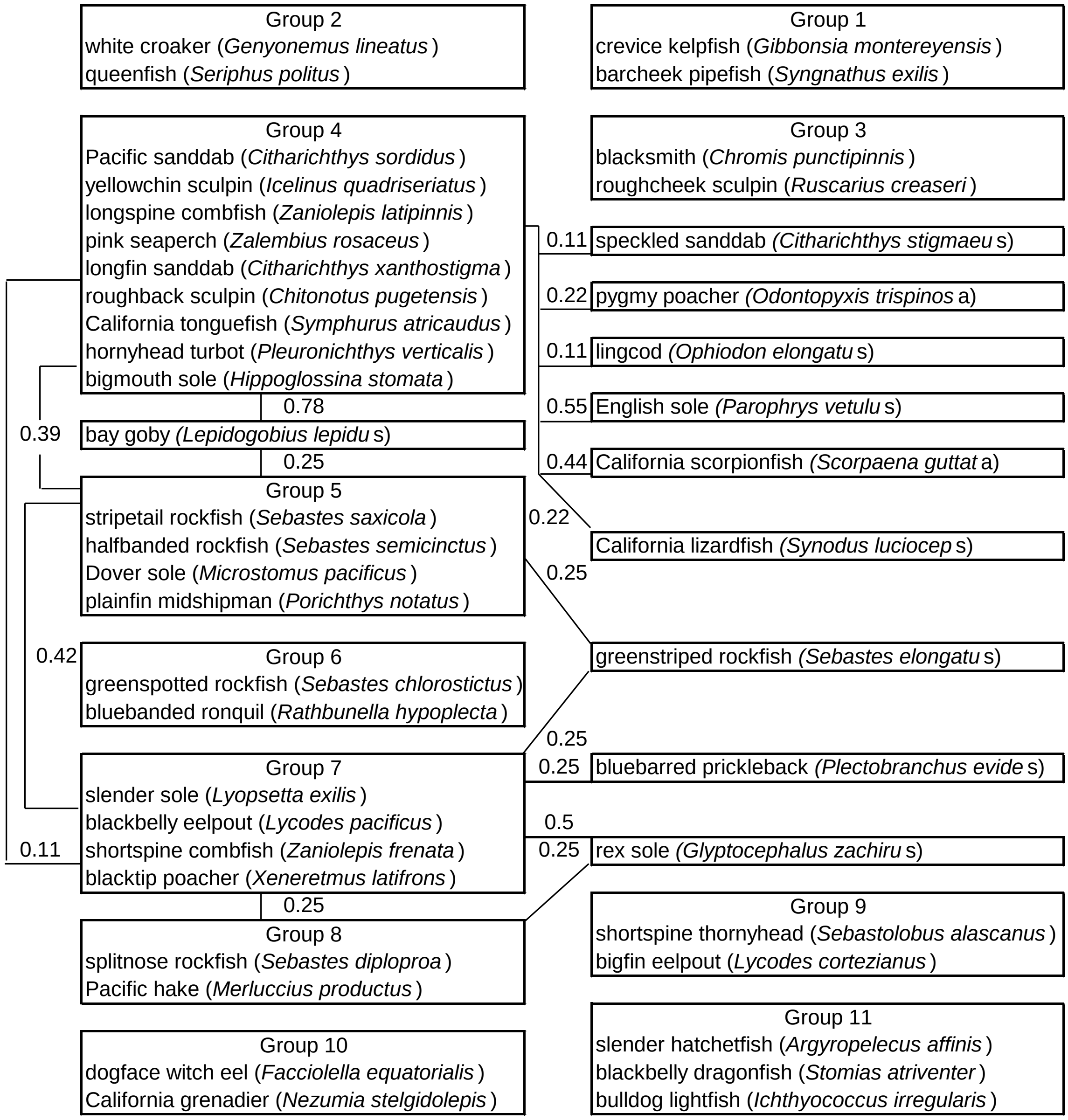


Figure VI-1. Recurrent groups of demersal fishes on the southern California shelf at depths of 2-476 m, July-October 2003. Index of affinity (I.A.)=0.5 (0.495). Groups are numbered from shallow to deep. Species within a group are listed in order of abundance. Lines show relationships between groups and associates, with values indicating proportion of possible pairs with I.A.=0.5 (0.495).

Table VI-1. Mean and range of depth of demersal fish recurrent groups on the southern California shelf and upper slope in July-October 2003.

Recurrent Group	No. of Stations	Mean Depth (m)	Depth Range (m)
1	1	16	16
2	12	17	8-30
3	1	20	20
4	18	49	24-81
5	32	86	40-192
6	3	88	80-104
7	20	163	90-204
8	23	272	155-433
9	10	373	197-463
10	3	463	456-469
11	1	463	463-463

Table VI-2. Frequency of occurrence (number of stations) of demersal fish site clusters by region and subpopulation on the southern California shelf at depths of 2-476 m, July-October 2003.

	Site Cluster								
	1	2	7	8	6	5	4	3	
	Upper Slope	Upper Slope/ Outer Shelf	Outer/ Middle Shelf	Middle Shelf	Middle/ Inner Shelf	Inner Shelf	Inner Shelf B&H N/C	B&H C/S	
Number of Stations	18	18	49	32	20	35	20	17	Grand
Depth Range (m)	258-476	138-264	72-144	25-86	16-87	12-47	8-36	2-12	Total
Subpopulation									
Region									
Mainland									
Northern	13	4	13	--	7	6	10	--	53
Central	2	8	8	19	3	17	6	9	72
Southern	3	4	10	13	1	12	4	8	55
Island									
Cool (NW Channel Islands)	--	2	9	--	5	--	--	--	16
Warm (SE Channel Islands)	--	--	9	--	4	--	--	--	13
Shelf Zone									
Bays and Harbors	--	--	--	--	--	2	7	17	26
Inner shelf									
Small POTWs	--	--	1	--	2	9	3	--	15
Large POTWs	--	--	--	2	--	1	--	--	3
Other Mainland	--	--	1	--	3	12	9	--	25
Middle Shelf (31-120 m)									
Small POTWs	--	--	1	5	1	5	--	--	12
Large POTWs	--	--	6	14	2	3	--	--	25
Mainland non-POTW	--	--	8	11	3	3	1	--	26
Island	--	--	15	--	9	--	--	--	24
Outer Shelf (121-200 m)									
Large POTWs	--	--	1	--	--	--	--	--	1
Mainland	--	10	11	--	--	--	--	--	21
Island	--	1	3	--	--	--	--	--	4
Upper slope (200-500 m)									
Mainland	18	6	2	--	--	--	--	--	26
Island	--	1	--	--	--	--	--	--	1
Total (all stations)	18	18	49	32	20	35	20	17	209

C = Central; N = Northern; S = Southern; B&H = Bays/Harbors; POTW = Publicly owned treatment work monitoring area.

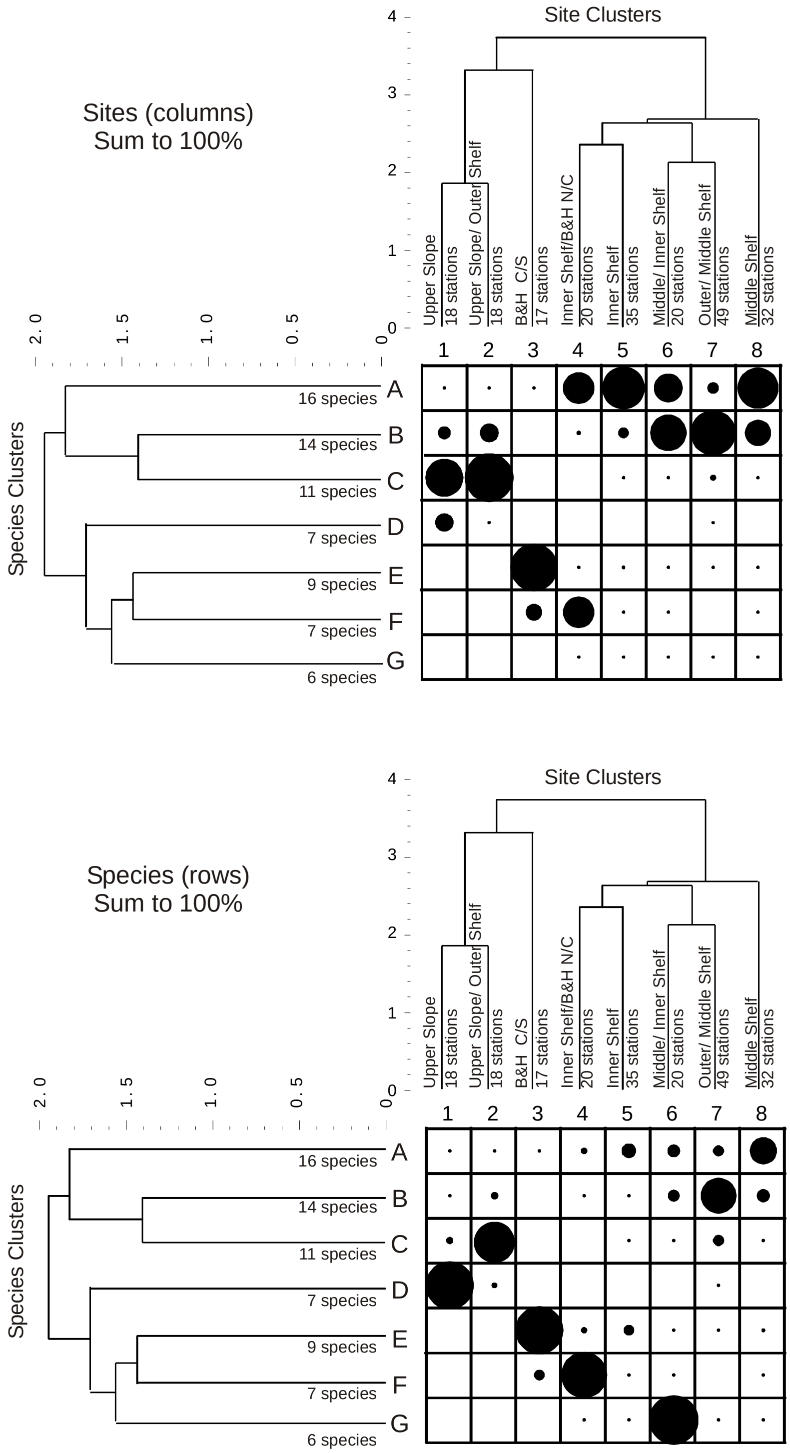


Figure VI-2. Summary of demersal fish cluster analysis and relationships among site and species clusters on the southern California shelf at depths of 2-476 m, July-October 2003.

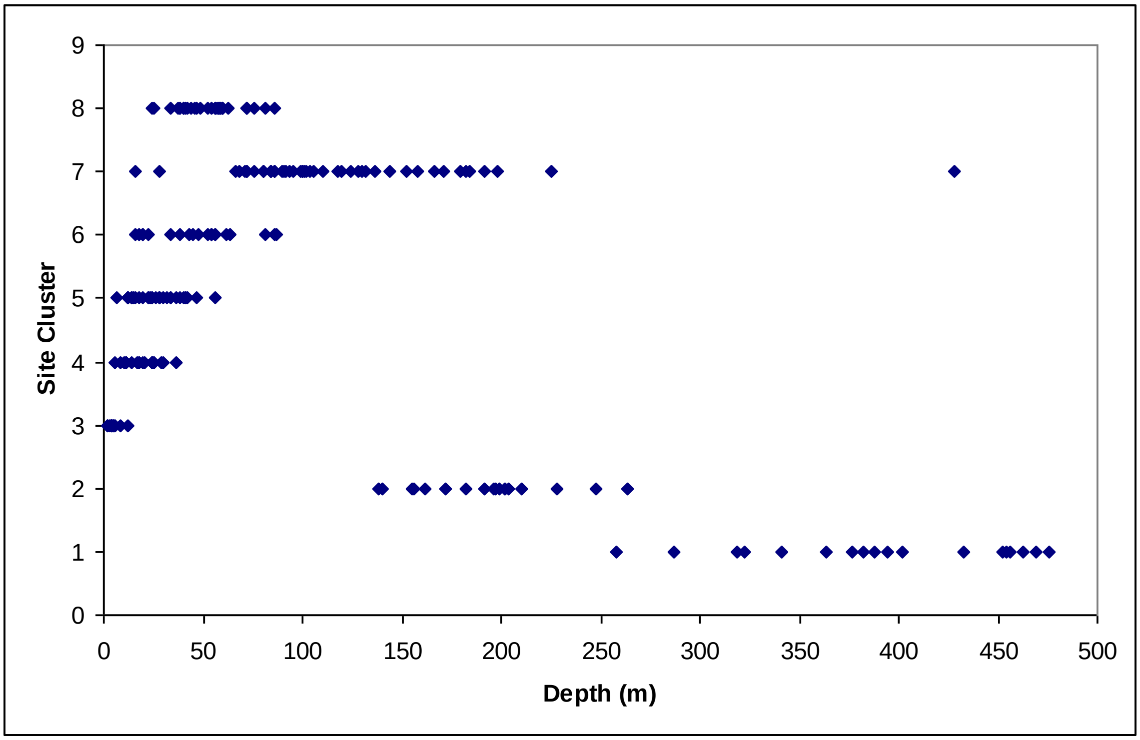


Figure VI-3. Bathymetric distribution of demersal fish site clusters on the southern California shelf at depths of 2-476 m, July-October 2003.

Site Cluster 2 (Upper Slope/Outer Shelf), included 18 stations ranging in depth from 138-264 m (Table VI-2; Figures VI-2 through VI-4). It represents a generalized outer shelf/upper slope habitat of 11 outer shelf and 7 upper slope stations at mainland and island sites (Table VI-2). By region, the cluster was most frequent (8 sites) of the stations were in the central mainland area. Eleven species occurred in more than 50% of the stations in Site Cluster 2 (Table VI-3, Appendix D-D1 and D-D2). All eight species of Species Cluster C and three species of Species Cluster B occurred at more than 50% of the sites (Table VI-3). The most frequently occurring species were Dover sole and slender sole (both 100%), and stripetail rockfish (94%). The most abundant species were slender sole (3,751), stripetail rockfish (1,538), and splitnose rockfish (1,150; Appendix D-D3).

Site Cluster 7 (Outer/Middle Shelf) included 49 stations at depths of 72-144 m (Table VI-2; Figures VI-2 through VI-4). It represents a generalized outer shelf/middle shelf habitat characterized by 30 middle shelf, 15 outer shelf, 2 upper slope, and 2 inner shelf stations (Table VI-2). Of these, 31 were mainland and 18 island sites. Nine species occurred in more than 50% of the stations in Site Cluster 7 (Table VI-3; Appendix D-D1 and D-D2). All five species of Species Cluster B, three species of Species Cluster A, and one from Species Cluster C occurred in more than 50% of the stations within Site Cluster 1 (Table VI-3). The most frequently occurring species were Pacific sanddab (94%), Dover sole (88%), and shortspine combfish (76%). The most abundant species were Pacific sanddab (10,192), stripetail rockfish (1,597), and longspine combfish (1,363; Appendix D-D3).

Site Cluster 8 (Middle Shelf) included 32 stations at depths of 25-86 m (Table VI-2; Figures VI-2 through VI-4). It represents a generalized middle shelf habitat characterized by 30 middle shelf and 2 inner shelf stations (Table VI-2). All 32 were mainland stations, with 19 in the central region and 13 in the southern region. Fourteen sites (44% of total for this cluster occurred at middle shelf large POTW areas (Table VI-2). Fourteen species occurred in more than 50% of the stations in Site Cluster 8 (Table VI-3; Appendix D-D1 and D-D2). Ten of these species were from Species Cluster A and four from Species Cluster B. The most frequently occurring species were Pacific sanddab (100%) and yellowchin sculpin and longspine combfish (97% each). The most abundant species were Pacific sanddab (4,068), yellowchin sculpin (2,559), and speckled sanddab (1,551; Appendix D-D3).

Site Cluster 6 (Middle/Inner Shelf) included 20 stations at depths of 16-87 m (Table VI-2; Figures VI-2 through VI-4). It represents a generalized middle and inner shelf habitat found at 15 middle and 5 inner shelf stations (Table VI-2). Of these, 11 were mainland and 9 were island. Twelve species occurred in more than 50% of the stations in Site Cluster 6 (Table VI-3; Appendix D-D1 and D-D2). Nine of these species were from Species Cluster A and three from Species Cluster B. The most frequently occurring species were Pacific sanddab (100%), English sole (80%), and speckled sanddab (75%). The most abundant species were halfbanded rockfish (2,145), speckled sanddab (2,143), and Pacific sanddab (1,711; Appendix D-D3).

Site Cluster 5 (Inner Shelf) included 35 stations at depths of 12-47 m (Table VI-2; Figures VI-2 through VI-4). It represents a generalized inner shelf habitat characterized by 2 bay/harbor, 22 inner shelf, and 11 middle shelf stations (Table VI-2). All 35 stations were along the mainland, with most (17) in the central region and least (6) in the southern region. Five species occurred in more than 50% of the stations in Site Cluster 6 (Table VI-3; Appendix D-D1 and D-D2); four were from Species Cluster A and one from Species Cluster E. The most frequently occurring species were speckled sanddab (91%), hornyhead turbot (71%), and California lizardfish and longfin sanddab (54% each). The most abundant species were speckled sanddab (2,646), Pacific sanddab (711), and longfin sanddab (45; Appendix D-D3).

Site Cluster 4 (Inner Shelf-Bays/Harbors North-Central) included 20 stations at depths of 8-36 m (Table VI-2; Figures VI-2 through VI-4). It represents a generalized inner shelf and bays/harbors habitat best developed in the northern and central regions. It is characterized by 7 stations in bays/harbors, 12 on the inner shelf, and one on the middle shelf (Table VI-2). All 20 stations were mainland, with 10 in the northern, 6 in the central, and 4 in the southern regions. Seven species occurred in more than 50% of the stations in Site Cluster 4 (Table VI-3; Appendix D-D1 and D-D2). Five of these of these species were from Species Cluster F and two from Species Cluster A. The most frequently occurring species were hornyhead turbot (75%), speckled sanddab (70%), and white croaker and queenfish (65% each). The most abundant species were white croaker (809), pink seaperch (557), and yellowchin sculpin (285; Appendix D-D3).

Site Cluster 3 (Bays/Harbors Central-South) included 17 stations at depths of 2-12 m (Table VI-2; Figures VI-2 through VI-4). All 17 stations were from the bay/harbor habitat, with 9 from the central mainland and 8 from the southern mainland (Table VI-2). Four species occurred in more than 50% of the stations in Site Cluster 3; all were from Species Cluster E (Table VI-3; Appendix D-D1 and D-D2). By frequency of occurrence, these were California halibut (88%), barred sand bass (65%), round stingray (59%), and diamond turbot (53%). The most abundant species were slough anchovy (362), round stingray (252), and barred sand bass (118; Appendix D-D3).

Species Clusters. Seven major species clusters were delineated by the analysis (Figure VI-2). The species clusters occupied successively deeper depth zones, each most abundant in one specific zone. The relationship of the site clusters with depth results from the depth distribution patterns of fish species found in the species clusters. All site clusters included representatives of two or more species groups. Species Cluster D was most dominant in Site Cluster 1; Species Cluster C in Site Cluster 2; Species Cluster E in Site Cluster 3; Species Cluster F in Site Cluster 4; Species Cluster G in Site Cluster 6; Species Cluster B in Site Cluster 7; and Species Cluster A in Site Cluster 8.

Species Cluster A included 16 species found primarily in Site Cluster 8 (Middle Shelf), but also at varying levels in other Site Clusters (Figure VI-2; Appendix D-D1 through D-D3). The most frequently occurring species of this group in the analysis was hornyhead turbot (98 sites; 47% of total), followed by English sole (97; 46%), and pink seaperch (90; 43%; Appendix D-D1). Fourteen species occurred in 50% or more of the stations in at least one site cluster (Table VI-3). Of these, the most widespread species of importance was English sole, occurring at greater than 50% of stations in four site groups on the outer/middle shelf, middle shelf, middle/inner shelf, and inner shelf (Site Clusters 7, 8, 6, 5; Table VI-3). The species of this cluster occurring most frequently in a site cluster were yellowchin sculpin and longspine combfish (both 97%) and longfin sanddab and California tonguefish (both 94%) in Site Cluster 8 (Middle Shelf). The most abundant were speckled sanddab (6,785), yellowchin sculpin (3,962), and pink seaperch (3,059; Appendix D-D3). The most abundant species of this species cluster in a site cluster were speckled sanddab (2,646; inner shelf), yellowchin sculpin (2,559; middle shelf), and speckled sanddab (2,143; middle shelf/inner shelf) in site groups 5, 8, and 6, respectively (Appendix D-D3).

Species Cluster B included 14 species found primarily in Site Cluster 7 (Outer/Middle Shelf), but also at varying levels in the other Site Clusters (Figure VI-2; Appendix D-D1 through D-D3). The most frequently occurring species of this group in the analysis was Pacific sanddab (131 sites; 63% of total), followed by Dover sole (110; 53%), and stripetail rockfish (89; 43%) (Appendix D-D1). Five species of this group occurred in 50% or more of the stations in at least one site cluster (Table VI-3). Of these, the most widespread species of importance were these three species, with Pacific sanddab and stripetail rockfish occurring at 50% of the stations in four site groups on the outer shelf, outer /middle shelf, middle shelf, and middle/inner shelf (Site Clusters 2, 7, 8, 6; Table VI-3). Dover sole occurred at this frequency on the upper slope, upper slope/outer shelf, outer/middle shelf, and middle shelf (Site Clusters 1, 2, 7, 8). The species of this species cluster occurring most frequently in a site cluster were Pacific sanddab and Dover sole (both 100%). Pacific sanddab occurred at all sites in the middle shelf and middle/shelf clusters (Site Clusters 8, 6), and Dover sole at this all sites in the upper slope and upper slope/outer shelf clusters (Site Clusters 1, 2; Table VI-3). The most abundant species of this species cluster were Pacific sanddab (17,058), stripetail rockfish (3,857), and halfbanded rockfish (2,692; Appendix D-D3). The most abundant species of this species cluster in a site cluster were Pacific sanddab (10,192, outer/middle shelf; 4,068, middle shelf); and halfbanded rockfish (2,145; middle/inner shelf) in site groups 7, 8, and 6, respectively (Appendix D-D3).

Species Cluster C included 11 species primarily found in Site Cluster 2 (Upper Slope/Outer Shelf), but also at varying levels in other Site Clusters (Figure VI-2; Appendix D-D1 through D-D3). The most frequently occurring species of this group in the analysis was shortspine combfish (60 sites; 29% of total), followed by slender sole (56; 27%), and blacktip poacher (33; 16%; Appendix D-D1). Eight species of this group occurred in 50% or more of the stations in at least one site cluster (Table VI-3). Of these, the most widespread species of importance were shortspine combfish, splitnose rockfish, slender sole, and Pacific hake, occurring at 50% of the stations in two site groups on the upper slope, upper slope/outer shelf, or outer shelf (Site Clusters 1, 2, 7; Table VI-3). Shortspine combfish occurred at this frequency on the upper slope/outer shelf and outer shelf (Site Clusters 2, 7), and the others on the upper slope and upper slope/outer shelf. The species of this cluster occurring most frequently in a site cluster were slender sole (100% in Upper Slope/Outer Shelf and 94% in Upper Slope) and shortspine combfish, rex sole, and blackbelly eelpout (89% in Upper Slope/Outer Shelf). The most abundant species of this cluster were slender sole (3,751), splitnose rockfish (1,249), and shortspine combfish (1,155; Appendix D-D3). The most abundant species of this species cluster in a site cluster were slender sole (3,751) and splitnose rockfish (1,150) in the upper slope/outer shelf (site cluster 2), and shortspine combfish (695) in the outer shelf (site cluster 7; Appendix D-D3).

Species Cluster D included 7 species primarily in Site Cluster 1 (Upper Slope) and at lesser levels in Site Cluster 2 and 7 (Figure VI-2; Appendix D-D1 through D-D3). The most frequently occurring species of this group in the analysis was bigfin eelpout (18 sites; 9% of total), followed by sablefish (13; 6%), and shortspine thornyhead and northern lampfish (12; 9%; Appendix D-

D1). Four species of this group occurred in 50% of sites in Site Cluster 1 only (Table VI-3). The species of this species cluster occurring most frequently in the upper slope site cluster were bigfin eelpout (72%), northern lampfish (61%), sablefish (56%), and shortspine thornyhead (50%). The most abundant species were shortspine thornyhead (176 overall; 163 in Site Cluster 1), bigfin eelpout (72, 61), and northern lampfish (*Stenobrachius leucopsarus;* 56, 55; Appendix D-D3).

Species Cluster E included 9 species found primarily in Site Cluster 3 (Bays/Harbors-Central/South) and also in Site Cluster 4 (Inner Shelf) and others at varying levels (Figure VI-2; Appendix D-D1 through D-D3). The most frequently occurring species of this group in the analysis was California halibut (45 sites; 22% of total), followed by California lizardfish (43; 21%), and fantail sole (20; 10%; Appendix D-D1). Five species of this group occurred in 50% or more of the stations in at least one site cluster (Table VI-3). Four of these (California halibut, barred sand bass, round stingray, and diamond turbot occurred at this level or above in Site Cluster 3 and California lizardfish at this level in Site Cluster 5. The species of this cluster occurring most frequently in a site cluster were California halibut (88%), barred sand bass (65%), and round stingray (59%), all in Site Cluster 3. The most abundant species of this species cluster were slough anchovy (362), round stingray (252), and California halibut (198; Appendix D-D3). These three species were also most abundant species in Site Cluster 3, with abundances of 362, 252, and 101, respectively (Appendix D-D3).

Species Cluster F included 7 species which were found primarily in Site Cluster 4 (Bays/Harbors-North/South) and also in others at varying levels (Figure VI-2; Appendix D-D1 through D-D3). The most frequently occurring species of this group in the analysis was specklefin midshipman (24 sites; 11% of total), followed by white croaker (21; 10%), and shiner perch (20; 10%; Appendix D-D1). Five species of this group occurred in 50% or more of the stations at Site Cluster 4 only (Table VI-3). The species of this species cluster occurring most frequently in that site cluster were white croaker and queenfish (both 65%), and specklefin midshipman (60%). The most abundant species of this species cluster were white croaker (809), queenfish (267), and shiner perch (257; Appendix D-D3). These three species were also most abundant species in Site Cluster 4, with abundances of 809 (white croaker), 224 (shiner perch), and 186 (queenfish; Appendix D-D3).

Species Cluster G included 6 species found primarily in Site Cluster 6 (Middle Shelf/Inner Shelf) and also in others at varying levels (Figure VI-2; Appendices D1 through D3). The most frequently occurring species of this group in the analysis were copper rockfish and vermilion rockfish (10 sites each; 5% of total), followed by southern spearnose poacher (*Agonopsis sterletus*) and bull sculpin (*Enophrys taurina*; 8 sites each; 4%; Appendix D-D1). None of the species in this group occurred at 50% or more of the stations in a site group and hence the group is not shown in Table VI-3. The species of this species cluster occurring most frequently in site cluster 6 were bull sculpin (40%), copper rockfish, and vermilion rockfish (10 sites each; 35%). The most abundant species of this cluster were copper rockfish (67), blackeye goby (*Rhinogobiops nicholsii*; 55), and bull sculpin (50; Appendix D-D3). These three species were also most abundant species in Site Cluster 6, with abundances of 63, 52, and 50, respectively (Appendix D-D3). This cluster consists of species associated with hard bottom.

Fish – Multidimensional Scaling of Sites

Multidimensional scaling results provided information on underlying similarities and dissimilarities among the fish catch data (abundance by species) by station for 90 trawl samples. The samples were selected at random from five habitat (e.g., bathymetric zones) subpopulations used in the survey. Correlations of catches from these stations relative to two ordination axes showed a distinct two-dimensional pattern (Figure VI-5). The distribution of the sites relative to Dimension 1 follows the depth-related habitat pattern of the preassigned site classifications, ranging from Bays/Harbor and Inner Shelf stations at the right, to Middle Shelf stations in the middle, and Outer Shelf and Upper Slope stations to the left. In one dimension, these would be aligned linearly. Dimension 2 appears to sort the stations by abundance, species richness, and diversity. Bays/harbors and upper slope fish catches were similar in having lower median abundance, species richness, and diversity than middle shelf and outer shelf sites (Tables III-3, IV-3, and IV-4). Hence, the gradient for Dimension 2 shows decreasing abundance, species richness, and diversity up the axis (Figure VI-5). This produces in a U-shaped pattern of fish trawl samples, reflecting the depth gradient and the abundance/diversity gradient.

Fish Functional Organization

Overview of Community Organization. Fishes collected in this survey represented at least 18 foraging guilds (Figures II-5 and II-6; based on Allen 1982; Figure VI-6). The depiction of the functional structure of the fish communities in 2003 (Figure VI-6) differs somewhat from that shown in Figure II-6 in that blocks represent regions where the guild and dominant species occurred in 20% of the samples for the bathymetric zone rather than at 20% of samples from 20-m depth classes. This is due to fewer (10) 20-m depth classes on the shelf (three zones combined) and more (15) 20-m depth classes in the single upper slope zone. Further, 182 trawl samples were collected from the shelf and 28 from the upper slope, resulting in fewer samples per 20-m depth classes in the upper slope zone than in the shelf zones. A detailed comparison of guild patterns by 20-m depth classes relative to that in previous surveys is given in the Discussion section of this section.

More bottom-living guilds were widespread across the depth range (2-500 m) of the shelf and upper slope than water-column guilds. However, only five guilds occurred with a frequency of 20% or more within the bathymetric life zones across the entire shelf and upper slope. These were all the bottom-living guilds, and included pelagobenthivores (sanddab guild), ambushing benthopelagivores size D (scorpionfish guild), extracting benthivores (turbot guild), excavating benthivores (eelpout guild), and nonvisual benthivores (tonguefish guild; Figure VI-6). Three guilds occurred at 20% of samples in a single zone: midwater pelagobenthivores (shiner perch guild), cruising pelagobenthivores (sablefish guild), and cruising nonvisual benthivores (cusk-eel guild). Numbers of guilds per bathymetric zones were 12 (inner shelf), 13 (middle shelf and outer shelf), and 11 (upper slope). The greatest number of water-column guilds (5) occurred on the inner shelf and outer shelf, and the least (3) on the middle shelf. The highest number of bottom-living guilds (10) occurred on the middle shelf, whereas the least number (7) occurred on the inner shelf and upper slope.

Dominant Species in Guilds by Depth. Dominant members of the guilds by depth generally were the characteristic species of the bathymetric zones, although some guilds were represented by more species. Eight water-column and 10 bottom-living guilds were represented (Figure VI-6).

Water column guilds included pelagivores, pelagobenthivores, benthopelagivores, and benthivores, with most of these having subdivisions. Of the schooling pelagivores, queenfish was the dominant on the inner shelf and Pacific hake on the outer shelf and upper slope (Figure VI-6). However, this guild occurred rarely on the middle shelf. The bottom-refuge visual pelagivores were rare on the inner shelf, but stripetail rockfish was dominant on the middle and outer shelf, and splitnose rockfish on the upper slope. Among the bottom-refuge nonvisual pelagivores, specklefin midshipman was dominant on the inner shelf and plainfin midshipman on the middle and outer shelf; the guild was virtually absent on the upper slope. Of the midwater pelagobenthivores, shiner perch was dominant on the inner shelf, and the guild occurred rarely on the middle shelf; the guild was absent on the outer shelf and upper slope. Cruising pelagobenthivores were important only on the upper slope, with sablefish the dominant species. The guild was absent on the inner, middle, and outer shelf.

Of the cruising diurnal benthopelagivores, white seaperch was dominant on the inner shelf and pink seaperch on the middle and outer shelf. The guild was absent on the upper slope. White croaker was the dominant member of the cruising nocturnal benthopelagivore guild on the inner shelf and filetail catshark (*Parmaturus xaniurus*) on the upper slope. The guild occurred rarely on the middle shelf and was virtually absent on the outer shelf. Among cruising nonvisual benthivores, spotted cusk-eel (*Chilara taylori*) was dominant on the outer shelf; the guild was rare on the inner and middle shelf, and upper slope.

Bottom-living guilds also included pelagivores, pelagobenthivores, benthopelagivores, and benthivores, with most of these having subdivisions. Of the bottom-living pelagivores (halibut guild), California halibut was the guild dominant on the inner shelf, and bigmouth sole on the middle and outer shelf; the guild was virtually absent on the upper slope (Figure VI-6). Of the bottom-living pelagobenthivores (sanddab-guild), the speckled sanddab was dominant on the inner shelf, Pacific sanddab on the middle shelf, and slender sole on the outer shelf and upper slope.

Bottom-living pursuing benthopelagivores (combfish guild) were represented by longspine combfish on the middle shelf and shortspine combfish on the outer shelf and upper slope; the guild was absent on the inner shelf (Figure VI-6). Ambushing benthopelagivores size A were represented by pygmy poacher on the middle shelf; the guild was rare on the inner shelf, virtually absent on the outer shelf, and absent on the upper slope. Ambushing benthopelagivores size B were represented by yellowchin sculpin on the middle shelf and blacktip poacher on the outer shelf and upper slope; the guild was rare on the inner shelf. Ambushing benthopelagivores size C were represented by fantail sole on the inner shelf and roughback sculpin on the middle shelf; the guild was rare on the outer shelf and absent on the upper slope. Of the ambushing benthopelagivores size D, barred sand bass was dominant on the inner shelf, California scorpionfish on the middle shelf, greenblotched rockfish on the outer shelf, and shortspine thornyhead on the upper slope.

Bottom-living benthivore guilds were common at all depths. Of the extracting benthivores, hornyhead turbot was dominant on the inner and middle shelf and Dover sole on the middle and outer shelf (Figure VI-6). Excavating benthivores were dominated by the English sole on the inner and middle shelf, blackbelly eelpout on the outer shelf, and bigfin eelpout on the upper slope. Of the nonvisual benthivores, round stingray was dominant on the inner shelf, California tonguefish on the middle shelf, and rex sole on the outer shelf and upper slope.

Table VI-3. Frequency of occurrence (percent of stations) of demersal fish species occurring at 50% or more of the stations in at least one site cluster on the southern California shelf at depths of 2-476 m, July-October 2003.

			Site Cluster							
			1	2	7	8	6	5	4	3
			Upper Slope	Upper Slope/ Outer Shelf	Outer/ Middle Shelf	Middle Shelf	Middle/ Inner Shelf	Inner Shelf	Inner Shelf B&H N/C	B&H C/S
		Number of Stations	18	18	49	32	20	35	20	17
		Depth Range (m)	258-476	138-264	72-144	25-86	16-87	12-47	8-36	2-12
Species Cluster	Common Name	Scientific Name								
E	California halibut	*Paralichthys californicus*	--	--	2	9	10	49	35	88
	barred sand bass	*Paralabrax nebulifer*	--	--	--	3	--	3	5	65
	round stingray	*Urobatis halleri*	--	--	--	--	--	--	--	59
	diamond turbot	*Pleuronichthys guttulatus*	--	--	--	--	--	6	--	53
	California lizardfish	*Synodus lucioceps*	--	--	6	47	5	54	25	--
F	white croaker	*Genyonemus lineatus*	--	--	--	6	5	9	65	12
	queenfish	*Seriphus politus*	--	--	--	--	--	3	65	6
	specklefin midshipman	*Porichthys myriaster*	--	--	--	13	5	6	60	29
	white seaperch	*Phanerodon furcatus*	--	--	--	--	20	6	55	--
	shiner perch	*Cymatogaster aggregata*	--	--	--	--	10	14	50	18
A	speckled sanddab	*Citharichthys stigmaeus*	--	--	10	38	75	91	70	6
	hornyhead turbot	*Pleuronichthys verticalis*	--	6	33	88	65	71	75	--
	longfin sanddab	*Citharichthys xanthostigma*	--	--	12	94	30	54	15	--
	English sole	*Parophrys vetulus*	17	22	59	59	80	51	40	--
	lingcod	*Ophiodon elongatus*	--	11	20	28	70	3	15	--
	curlfin sole	*Pleuronichthys decurrens*	--	--	24	3	65	26	10	--
	yellowchin sculpin	*Icelinus quadriseriatus*	--	--	41	97	70	43	35	--
	longspine combfish	*Chitonotus pugetensis*	--	--	8	84	60	29	--	--
	pink seaperch	*Zalembius rosaceus*	--	11	55	84	60	40	40	--
	longspine combfish	*Zaniolepis latipinnis*	--	6	57	97	60	26	40	--
	California tonguefish	*Symphurus atricaudus*	--	--	16	94	30	37	35	6
	bigmouth sole	*Hippoglossina stomata*	--	17	35	78	35	40	10	--
	bay goby	*Lepidogobius lepidus*	--	--	20	75	15	14	25	--
	California scorpionfish	*Scorpaena guttata*	--	6	12	53	25	49	5	--
B	Pacific sanddab	*Citharichthys sordidus*	6	67	94	100	100	49	15	--
	stripetail rockfish	*Sebastes saxicola*	--	94	73	59	60	6	15	--
	halfbanded rockfish	*Sebastes semicinctus*	--	17	53	44	60	6	--	--
	plainfin midshipman	*Porichthys notatus*	--	44	65	63	40	11	35	--
	Dover sole	*Microstomus pacificus*	100	100	88	63	40	3	10	--
C	shortspine combfish	*Zaniolepis frenata*	--	89	76	6	25	--	--	--
	rex sole	*Glyptocephalus zachirus*	39	89	14	3	--	--	--	--
	splitnose rockfish	*Sebastes diploproa*	72	78	--	3	--	--	--	--
	blackbelly eelpout	*Lycodes pacificus*	6	89	29	--	--	--	--	--
	bluebarred prickleback	*Plectobranchus evides*	--	50	12	--	--	--	--	--
	blacktip poacher	*Xeneretmus latifrons*	22	78	31	--	--	--	--	--
	slender sole	*Lyopsetta exilis*	94	100	43	--	--	--	--	--
	Pacific hake	*Merluccius productus*	72	83	8	--	--	--	--	--
D	bigfin eelpout	*Lycodes cortezianus*	72	17	4	--	--	--	--	--
	northern lampfish	*Stenobrachius leucopsarus*	61	6	--	--	--	--	--	--
	sablefish	*Anoplopoma fimbria*	56	11	2	--	--	--	--	--
	shortspine thornyhead	*Sebastolobus alascanus*	50	17	--	--	--	--	--	--

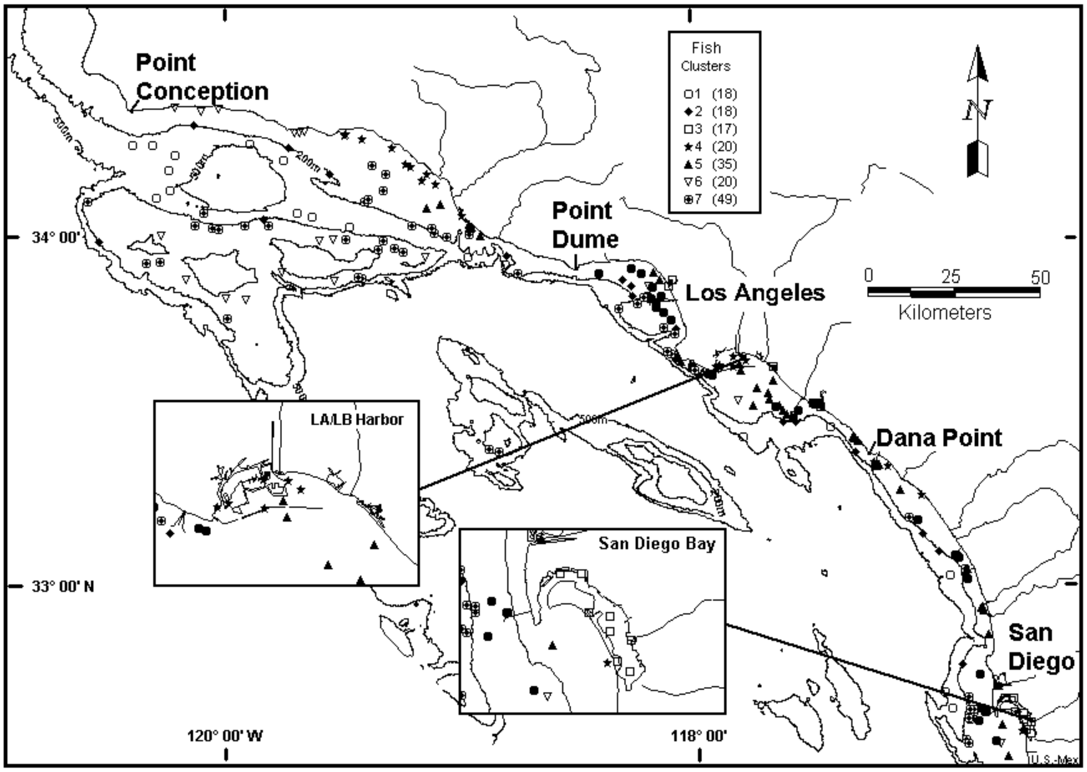


Figure VI-4. Distribution of fish site clusters on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003.

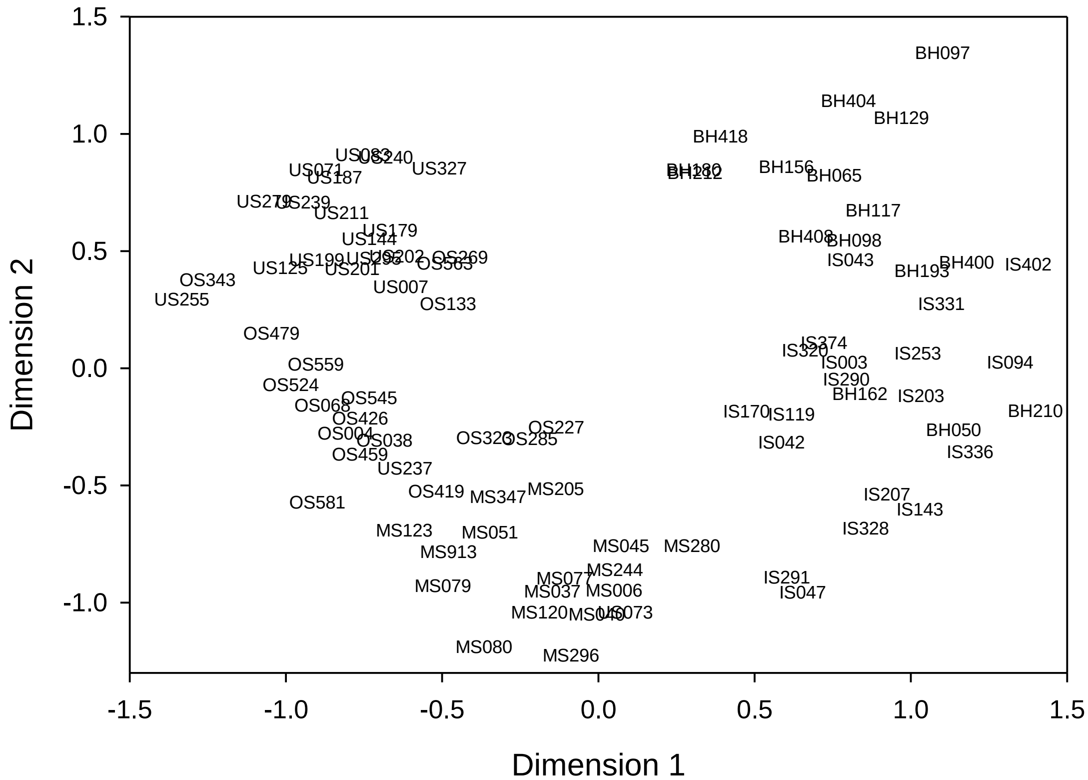


Figure VI-5. Multidimensional scaling plot of fish species assemblages (abundance by species) for 90 trawl stations sampled in Southern California Bight 2003 Regional Survey at depths of 2-476 m, July-October 2003. (Station name abbreviations: BH=Bays/Harbors; IS=Inner Shelf; MS=Middle Shelf; OS=Outer Shelf; US=Upper Slope).

Invertebrate Assemblages

Invertebrate Recurrent Groups

Recurrent group analysis at the 0.50 level of affinity identified 40 recurrent groups of invertebrates consisting of 2-6 species per group with 11 associate species (Figure VI-7; Appendix D-D4). In all, the groups and associates included 87 (28%) of the 308 species collected in the survey. Recurrent groups were found at 1-38 stations**;** 26 of the 40 groups occurred at only 1 site, with 14 occurring at 2-38 sites (Table VI-4). These 14 major groups generally differed in depth distribution, with most occurring in one or two of the four predetermined shelf zones (Table VI-4). Recurrent groups occurring at 5 or more stations will be discussed in detail below.

Group 23 (Middle Shelf Group). Group 23 consisted of four species: white sea urchin, yellow sea twig, California sea cucumber, and California sand star (Figure VI-7). It occurred at 20 stations at depths of 38-106 m (mean 66 m; Table VI-4) on the middle shelf of Santa Monica Bay, and the San Pedro, San Diego, and Islands shelves. The group was associated with Group 26 and with the Pacific spiny brittlestar (*Ophiothrix spiculata*; Figure VI-7).

Group 26 (Middle/Outer Shelf Seapen/Echinoderm Group). Group 26 consisted of three species, the trailtip sea pen, brokenspine brittle star (*Ophiura luetkenii*), and gray sand star (*Luidia foliolata*; Figure VI-7). It occurred at 29 stations at depths of 38-166 m (mean 83 m) (Table VI-4) at the Channel Islands, west and east Santa Barbara Channel, Santa Monica Bay, and San Pedro, and San Diego shelves. The group was associated with Groups 23 and 30 (Figure VI-7).

Group 30 (Middle/Outer Shelf Shrimp/Octopus Group). Group 30 consisted of two species: ridgeback rock shrimp and red octopus (Figure VI-6). It occurred at 38 stations at depths of 29-204 m (mean 106 m; Table VI-4) on the middle and outer shelf of the Channel Islands and mainland. The group was associated with Group 26 (Figure VI-7).

Group 35 (Outer Shelf-Upper Slope Group). Group 35 consisted of fragile sea urchin and moustache bay shrimp (Figure VI-6). It occurred at 25 stations at depths of 58-377 m (mean 190 m; Table VI-4), primarily on the outer shelf and upper slope of the mainland and Channel Islands. The group was associated with Group 36 and flagnose bay shrimp (*Neocrangon resima*; Figure VI-7).

Group 36 (Upper Slope Heart Urchin Group). Group 36 consisted of northern heart urchin, California heart urchin, offshore blade shrimp (*Spirontocaris sica*), and orange bigeye octopus (Figure VI-7). It occurred at 13 stations at depths of 192-426 m (mean 300 m; Table VI-4), primarily on the upper slope of the mainland of the Santa Barbara Channel. The group was associated with Groups 35 and 37, and with sea dandelion, Pacific heart urchin (*Brissopsis pacifica*), and slender blade shrimp (*Spirontocaris holmesi*; Figure VI-7).

Group 37 (Upper Slope Sea Star/Holothurian Group). Group 37 consisted of two species, a sea star *Myxoderma platyacanthum* and a holothuroid *Pannychia moseleyi* (Figure VI-7). It occurred at 8 stations at depths of 248-469 m (mean=397 m; Table VI-4), on the upper slope of the mainland from the Santa Barbara Channel to San Diego. The group was associated with Group 36 and another sea star *Pseudarchaster pusillus* (Figure VI-7).

Invertebrate Site and Species Clusters

Selection of Species. The trawl survey sampled 210 stations and collected 157,326 invertebrates representing 308 species. Based upon the screening criteria, 195 stations representing 151,554 individuals of 97 species were included in the cluster analysis (Appendix D-D5 through D-D7). The cluster analysis delineated nine major site clusters (station clusters), denoting habitats, and nine major species clusters, denoting species assemblages or communities (Figure VI-7; Appendix D-D5 through D-D7). Each site and species cluster was unique, based on the relative proportion of different species clusters within a site cluster and the relative proportion of each species cluster in different site clusters (Figure VI-8). Some pairs or sets of site clusters might alternatively have been lumped to form a single site cluster.

<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>Anoplopoma fimbria</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>Phanerodon furcatus</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>--------------------------------</td><td>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>Citharichthys sordidus</td><td colspan="2">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 colspan="2">Zaniolepis frenata</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>--------------------------------</td><td>Odontopyxis trispinosa</td><td>--</td><td></td></tr>
<tr><td>Size B</td><td>2C2b</td><td>--------------------------------</td><td>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 rosenblatti</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="2">Parophrys vetulus</td><td>Lycodes pacificus</td><td>Lycodes cortezianus</td></tr>
<tr><td>Nonvisual</td><td>2D2</td><td>Urobatis halleri</td><td>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 VI-6. Functional organization of demersal fish communities on the shelf and upper slope of southern California in July-October 2003. Blocks enclose bathymetric zones where guild occurred in 20% or more of stations. Species in block is dominant species of guild in that zone.

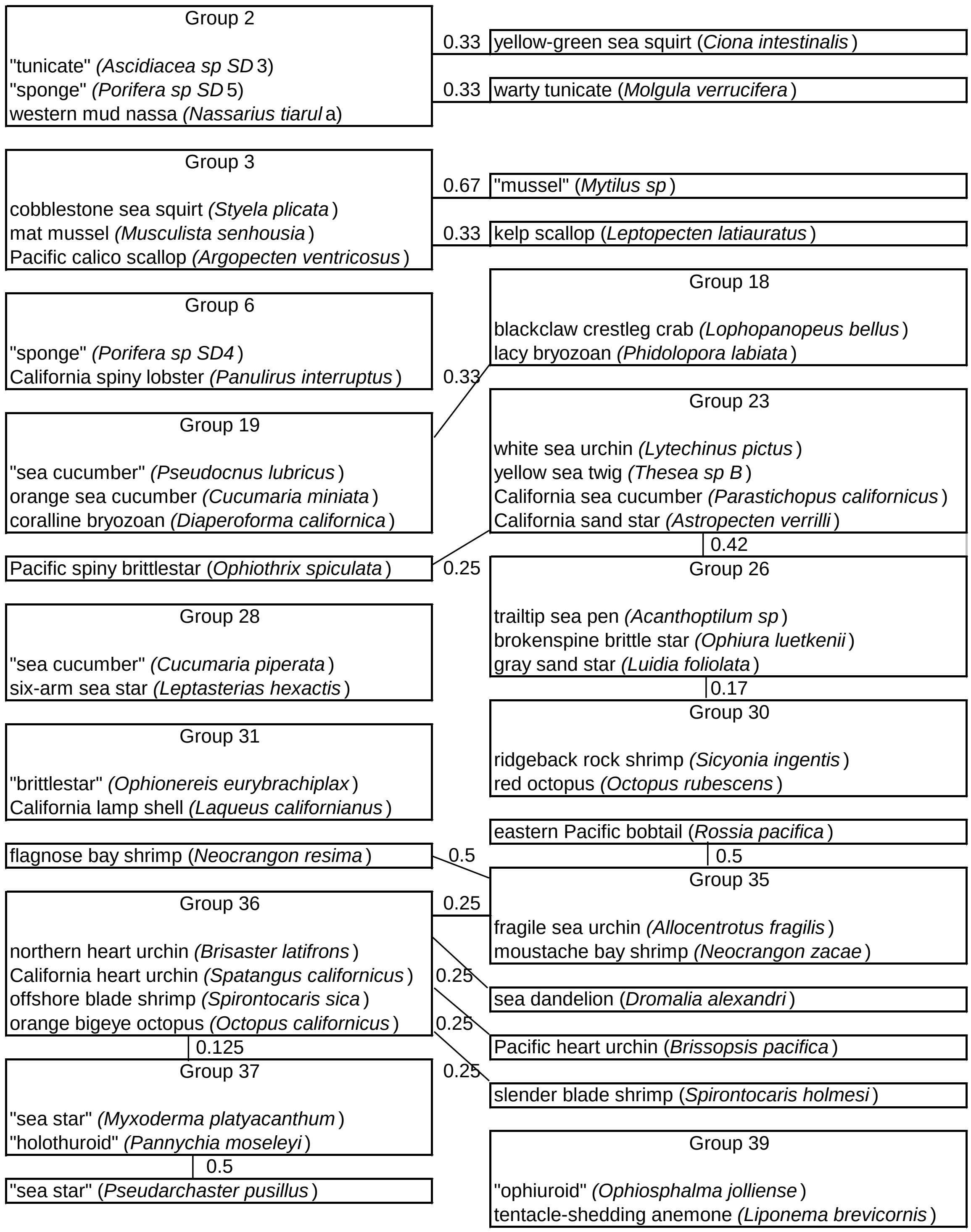


Figure VI-7. Recurrent groups of megabenthic invertebrates found at multiple sites on the southern California shelf at depths of 2-476 m, July-October 2003. Index of affinity (I.A.)=0.50 (0.495). Groups are numbered from shallow to deep. Species within a group are listed in order of abundance. Lines show relationships between groups and associates, with values indicating proportion of possible pairs with I.A.=0.5 (0.495).

Table VI-4. Mean and range of depth of megabenthic invertebrate recurrent groups on the southern California shelf and upper slope in July-October 2003.

Recurrent Group	No. of Stations	Mean Depth (m)	Depth Range (m)	Recurrent Group	No. of Stations	Mean Depth (m)	Depth Range (m)
1	1	4	4	21	1	56	56
2	2	4	4	22	1	64	64
3	4	4	2-5	23	20	66	38-106
4	1	4	4	24	1	80	80
5	1	5	5	25	1	81	81
6	2	6	4-8	26	29	83	38-166
7	1	12	12	27	1	95	95
8	1	12	12	28	3	97	81-106
9	1	14	14	29	1	104	104
10	1	16	16	30	38	106	29-204
11	1	28	28	31	2	142	104-179
12	1	37	37	32	1	166	166
13	1	38	38	33	1	171	171
14	1	38	38	34	1	179	179
15	1	41	41	35	25	190	58-377
16	1	42	42	36	13	300	192-426
17	1	45	45	37	8	397	248-469
18	2	46	38-54	38	1	454	454
19	2	50	45-54	39	2	462	454-469
20	1	54	54	40	1	469	469

Site Clusters. The site clusters varied by region, depth, and subpopulation (Table VI-5; Figures VI-7 through VI-9). Each site cluster includes 1-4 important (based on abundance) species clusters, with 1-2 of these being dominant (Figure VI-8, top). Viewed from the perspective of what species clusters were most important in a site cluster, Each species group was primarily dominant in a single site cluster, species cluster C was most important in three site clusters (3,4,9) and species cluster K in two site clusters (1,6). Species cluster A was especially important in site cluster 7 (Figure VI-8).

Site Cluster 2 (Upper Slope) included 15 stations at depths of 225-476 m (Table VI-5; Figures VI-8 through VI-10). This site group is characterized by 15 mainland upper slope sites, including 12 northern (mostly Santa Barbara Channel), 1 central, and 2 southern sites (Table VI-5, Figure VI-9). Seven species occurred in more than 50% of the stations in Site Cluster 2 (Table VI-6, Appendix D-D5 and D-D6). All four species of Species Cluster I and three species of Species Cluster J occurred in more than 50% of the stations within Site Cluster 2 (Table VI-5). The most frequently occurring species were northern heart urchin and a holothuroid *Pannychia moseleyi* (73% each), and orange bigeye octopus, offshore blade shrimp, and a sea star *Myxoderma platyacanthum* (67% each; Table VI-6). The most abundant species were northern heart urchin (28,750), *Myxoderma platyacanthum* (9,460), and an ophiuroid *Asteronyx longifissus* (9,169; Appendix D7).

Site Cluster 1 (Upper Slope/Outer Shelf) included 13 stations at depths of 192-377 m (Table VI-5; Figures VI-8 through VI-10). This site group represents an upper slope and outer shelf habitat sampled at 13 mainland sites, 11 on the upper slope and 2 barely on the outer shelf (Table VI-5). By subregion, this cluster included 7 northern, 3 central, and 3 southern mainland sites. Eleven species occurred in more than 50% of the stations in Site Cluster 1 (Table VI-6; Appendix D-D5 and D-D6). Six species of Species Cluster K, all four species of Species Cluster J, and one from Species Cluster C occurred in more than 50% of the stations within Site Cluster 1 (Table VI-6). The most frequently occurring species were fragile sea urchin and California heart urchin (100% each), and northern heart urchin and orange bigeye octopus (92% each). The most abundant species were fragile sea urchin (9,553), northern heart urchin (6,511), and California heart urchin (1,382; Appendix D-D7).

Site Cluster 5 (Outer Shelf) included 22 stations at depths of 120-202 m (Table VI-5; Figures VI-8 through VI-10). This site cluster included 16 outer shelf sites, 4 barely middle shelf sites, and 2 barely upper slope sites (Table VI-5). By subregion, this cluster included 13 mainland sites (3 northern, 8 central, 6 southern) and 5 islands (3 northwest, 2 southeast). Five species occurred in more than 50% of the stations in Site Cluster 5 (Table VI-6; Appendix D-D5 and D-D6); four from Species Cluster K and 1 from Species Cluster C (Table VI-6). The most frequently occurring species were fragile sea urchin (82%), moustache bay shrimp (68%), and red octopus and ridgeback rock shrimp (64% each). The most abundant species were fragile sea urchin (7,275), ridgeback rock shrimp (3,726), and white sea urchin (2,873; Appendix D-D7).

Site Cluster 9 (Middle Shelf) included 48 stations at depths of 28-138 m (Table VI-5; Figures VI-8 through VI-10). This site cluster included 45 middle shelf sites, 2 outer shelf sites, and 1 barely inner shelf site (Table VI-5). By subregion, this cluster included 43 mainland sites (4 northern, 20 central, 19 southern) and 5 islands (1 northwest, 4 southeast). Nine species occurred in more than 50% of the stations in Site Cluster 9 (Table VI-6; Appendix D-D5 and D-D5). Seven species of Species Cluster C and 1 species each of Site Clusters D and G occurred in more than 50% of the stations within Site Cluster 9 (Table VI-6). The most frequently occurring species were California sand star (85%), California sea cucumber (73%), and brokenspine brittlestar (71%). The most abundant species were white sea urchin (16,071), trailtip seapen (2,149), and California sand star (828; Appendix D-D7).

Site Cluster 4 (Channel Islands Middle Shelf) included 22 stations at depths of 52-132 m (Table VI-5; Figures VI-8 through VI-10). This site cluster included 19 middle shelf sites, 2 outer shelf sites, and 1 bays/harbor site (Table VI-5). By subregion, this cluster included 4 mainland sites (3 central, 1 southern) and 18 islands (11 northwest, 7 southeast). Seven species occurred in more than 50% of the stations in Site Cluster 9 (Table VI-6, Appendix D-D5 and D-D6). Five species of Species Cluster C and 2 species of Site Cluster E occurred in more than 50% of the stations within Site Cluster 9 (Table VI-6). The most frequently occurring species were red octopus (91%), red sea star (86%), and white sea urchin (82%). The most abundant species were white sea urchin (10,371), fragile sea urchin (1,371), and Pacific spiny brittlestar (569; Appendix D-D7).

Site Cluster 8 (Inner/Middle Shelf) included 46 stations at depths of 25-86 m (Table VI-5; Figures VI-8 through VI-10). This site cluster included 23 inner shelf sites, 17 middle shelf sites, 4 bays/harbors site, and 2 outer shelf sites (Table VI-5). By subregion, all 46 stations of this site cluster were mainland sites (10 northern, 24 central, 12 southern). California sand star, occurring in 63% of the stations, was the only species in Site Cluster 8 to occur in more than 50% of the stations (Table VI-6; Appendix D-D5 and D-D6); it was a member of Species Cluster C. The most abundant species were white sea urchin (3,289), blackspotted bay shrimp (1,769), and yellow sea twig (1,242; Appendix D-D7).

Site Cluster 3 (Inner Shelf) included 14 stations at depths of 12-28 m (Table VI-5; Figures VI-8 through VI-10). This site cluster included 13 inner shelf sites and 1 middle shelf site (Table VI-5). All 14 sites were in the mainland region (11 northern, 1 central, 2 southern). Five species occurred in more than 50% of the stations in Site Cluster 3 (Table VI-6; Appendix D-D5 and D-D6); 3 were of Species Cluster G and 2 of Species Cluster C. The most frequently occurring species were red octopus (71%), and blackspotted bay shrimp and shortspined sea star (57% each). The most abundant species were white sea urchin (420), California sand star (129), and blackspotted bay shrimp (96; Appendix D-D7).

Site Cluster 6 (Bays/Harbors Central) consisted of 9 stations at a depth of 9 m in Bays/Harbors of the central mainland region (Table VI-5; Figures VI-8 through VI-10). Seven species occurred in more than 50% of the stations in Site Cluster 6 (Table VI-6; Appendix D-D5 and D-D6); 3 each were of Species Clusters A and B, and 1 of Species Cluster G. The most frequently occurring species were tuberculate pear crab (89%) and California aglaja and Pacific calico scallop (*Argopecten ventricosus*; 78% each). The most abundant species were trailtip seapen (370), cobblestone sea squirt (*Styela plicata*; 198), and New Zealand papperbubble (166; Appendix D-D7).

Site Cluster 7 (Bays/Harbors South) consisted of 6 stations at a depth of 4-12 m in Bays/Harbors of the southern mainland region (Table VI-5; Figures VI-8 through VI-10). Three species occurred in more than 50% of the stations in Site Cluster 7 (Table VI-6; Appendix D-D5 and D-D6); all 3 were of Species Clusters A. The most frequently occurring species were yellow-green sea squirt (*Ciona intestinalis*; 83%), California aglaja (67%) and warty tunicate (*Molgula verrucifera*; 50%). The most abundant species were warty tunicate (420), and cobblestone sea squirt and mat mussel (*Musculista senhousia*; 400 each; Appendix D-D7).

Species Clusters. Eleven major species clusters were delineated by the analysis (Figure VI-8). The species clusters generally occupied different depth zones or combinations of these, each most abundant in one or more zone. The relationship of the site clusters with depth results from the depth distribution patterns of invertebrate species found in the species clusters. All site clusters included representatives of two or more species groups. Species Cluster A was dominant in Site Cluster 7; Species Cluster B in Site Cluster 6; Species Cluster C in Site Cluster 9; Species Cluster D in Site Cluster 8; Species Cluster E in Site Cluster 4; Species Cluster F was most dominant in Site Cluster 1; Species Clusters G and H in Site Cluster 8; Species Clusters I and J in Site Cluster 2; and Species Cluster K was dominant in Site Clusters 1 and 4 (Figure VI-7).

Species Cluster A included 5 species found primarily in Site Cluster 8 (Bays/Harbors South), but also to a lesser extent in Site Cluster 6 (Bays/Harbors Central; Figure VI-7; Appendix D-D5 through D-D7). The most frequently occurring species in this group overall were California aglaja (11 sites; 6%), and mat mussel and cobblestone sea squirt (7; 4%). All 5 species in the group occurred in 50% or more of the stations in at least one site cluster (Table VI-6). Of these, the most widespread species of importance was California aglaja, occurring at greater than 50% of stations in bays and harbors in the central and southern region (Site Clusters 6, 7; Table VI-6). The most frequently occurring species of this group at a site cluster was yellow-green seasquirt (5 sites; 83% of total) in Site Cluster 7, followed by California aglaja (7 sites, 78% in Site Cluster 6 and 4 sites, 67% in Site Cluster 7; Appendix D-D5). The most abundant species in the group overall were cobblestone seasquirt (598), mat mussel (508), and warty tunicate (420; Appendix D-D7). The most abundant species at a site cluster were warty tunicate (420), and cobblestone sea squirt and mat mussel (400 each) all in Site Cluster 7 (Appendix D-D7).

Species Cluster B included 4 species found primarily in Site Cluster 6 (Bays/Harbors Central), but also to a lesser extent in Site Cluster 7 (Bays/Harbors Central) and Site Cluster 8 (Inner/Middle Shelf; Figure VI-8; Appendix D-D5 through D-D7). The most frequently occurring species of this group overall were kelp scallop (*Leptopecten latiauratus*; 8 sites; 4%), Pacific calico scallop (7 sites; 4%), and unidentified mussel (*Mytilus* spp.; 6 sites; 3%). Three of the species occurred in 50% or more of the stations in at least one site cluster, which was Site Cluster 6 (Table VI-6). Of these, the most frequently occurring species were Pacific calico scallop (7; 78%), kelp scallop (6; 67%), and unidentified mussel (5; 56%) in Site Cluster 6 (Table VI-6; Appendix D-D5). The most abundant of the group overall were kelp scallop (88), Pacific calico scallop (66), and unidentified mussel (52). The most abundant species at a site cluster were kelp scallop (74), Pacific calico scallop (66), and the mussel (46) in Site Cluster 6 (Appendix D7).

Species Cluster C included 8 species found primarily in Site Cluster 9 (Middle Shelf), followed by Site Cluster 4 (Islands Middle Shelf), to a lesser extent in six more clusters, but was absent in Site Cluster 7 (Southern Bays/Harbors; Figure VI-8; Appendix D-D5 through D-D7). The most frequently occurring species overall were California sand star (90; 46%), red octopus (88; 45%), and white sea urchin (71; 36%; Appendix D-D5). All eight species in the cluster occurred in 50% or more of the stations in at least one site cluster (Table VI-6). Six of the species occurred at this percent occurrence or higher in 2 or more site clusters. Of these, the most widespread species of importance was red octopus, occurring at greater than 50% of stations in four site clusters: the outer shelf, middle shelf, Channel Islands middle shelf, and inner shelf (Site Clusters 5, 9, 4, and 3, respectively; Table VI-6). California sand star was the next most widespread species of importance, occurring in 50% or more of sites in three site clusters: middle shelf, inner/middle shelf, and inner shelf (Site Clusters 9, 8, and 3; Table VI-6). Four species (trailtip seapen; white sea urchin; brokenspine brittlestar; gray sand star) occurred at 50% or more of the sites in the middle shelf and Islands middle shelf site clusters (Site Clusters 9 and 4). The most frequently occurring species of this group at a site cluster was red octopus (20 sites; 91%) in Site Cluster 4, followed by California sand star (48; 85%) in Site Cluster 9; and white sea urchin (18; 82%) at Site Cluster 4 (Appendix D-D5 and D-D6; Table VI-6). The most abundant species overall were white sea urchin (33,028), trailtip seapen (3,673), and California sand star (1,764; Appendix D-D7). The most abundant species in a site cluster was white sea urchin: 16,071 (Site Cluster 9); 10,371 (Site Cluster 4); and 3,289 (Site Cluster 8).

Species Cluster D included 9 species sparsely dispersed through a number of site clusters across the shelf (Figure VI-8; Appendix D-D5 through D-D7). The most frequently occurring species in the cluster overall were yellow sea twig (41 sites; 21%), California blade barnacle (15; 21%), and Alaska bay shrimp (*Crangon alaskensis*; 23; 12%; Appendix D-D5). However, only one species occurred at 50% or more of the sites in a site cluster: yellow sea twig, at 26 sites (54%) in Site Cluster 9 (Middle Shelf; Table VI-6; Appendix D-D5 and D-D6). The most abundant species overall were yellow sea twig (1,577), California blade barnacle (309), and Alaska bay shrimp (117; Appendix D-D7). Yellow sea twig was also the most abundant species of the group at site cluster: 1,242 at Site Cluster 8 (Inner/Middle Shelf) and 318 at Site Cluster 9 (Middle Shelf), followed by California blade barnacle with 195 at Site Cluster 9.

Species Cluster E included 25 species occurred at a number of site clusters across the shelf (Figure VI-8; Appendix D-D5 through D-D7). The most frequently occurring species overall were red sea star and Pacific spiny brittlestar (36 sites each; 18% each), and California market squid (26 sites, 13%; Appendix D5). However, only two species occurred at 50% or more of the sites in a site cluster: red sea star (86%) and rosy tritonia (*Tritonia diomedea*; 50%), both at Site Cluster 4 (Channel Islands middle shelf; Table VI-6; Appendix D-D5 and D-D6). The most abundant species overall were Pacific spiny brittlestar (1,448), red sea star (412), and California market squid (384; Appendix D-D7). The most abundant species in a site cluster were Pacific spiny brittlestar with 796 at Site Cluster 8 (Inner/Middle Shelf) and 569 at Site Cluster 4 (Channel Islands Middle Shelf), followed by California market squid at 348 at Site Cluster 9 (Middle Shelf).

Species Cluster F included 11 species occurring at site clusters on the middle and outer shelf, but mostly on the upper slope (Figure VI-8; Appendix D-D5 through D-D7). The most frequently occurring species in the cluster overall were armed box crab (*Platymera gaudichaudii*; 21 sites; 11%), southern spinyhead (*Metacrangon spinosissima*; 13; 7%), and orange sand star (*Astropecten ornatissimus*; 11; 6%; Appendix D-D5). None of the species occurred at 50% or more of the sites within a site cluster (Appendix D-D5); hence the species cluster is not shown in Table VI-6. The most frequently occurring species at a site cluster was armed box crab (32%) in Site Cluster 5 (Outer Shelf; Appendix D-D5). The most abundant species overall were ocean shrimp (*Pandalus jordani*; 810), gray shrimp (433), and orange sand star (126; Appendix D-D7). The most abundant species in the group at a site cluster were ocean shrimp with 803 at Site Cluster 1 (Upper Slope/Outer Shelf), gray shrimp with 433 (Site Cluster 1), and orange sand star with 116 at Site Cluster 5 (Outer Shelf).

Species Cluster G included 8 species sparsely dispersed through site clusters on the inner or middle shelf, but primarily in Site Cluster 8 (inner/middle shelf; Figure VI-8; Appendix D-D5 through D-D7). The most frequently occurring species in the cluster overall were New Zealand paperbubble (52 sites; 27%), blackspotted bay shrimp (28; 14%), and tuberculate pear crab (20; 10%; Appendix D-D5). Five species in the species cluster occurred in 50% or more of the sites in a site cluster. The most frequently occurring species at a site cluster were tuberculate pear crab with 89% in Site Cluster 6 (Bays/Harbors Central), and blackspotted bay shrimp and shortspined sea star with 57% for each in Site Cluster 3 (Inner Shelf; Table VI-6). The most abundant species overall were blackspotted bay shrimp (1,919), New Zealand paperbubble (881), and tuberculate pear crab (183; Appendix D-D7). The most abundant species of the species cluster at a site cluster were blackspotted bay shrimp with 1,769 at Site Cluster 8 (Inner/Middle Shelf), and New Zealand paperbubble with 495 (Site Cluster 8) and 166 at Site Cluster 6 (Bays/Harbors Central).

Species Cluster H included 6 species which occurred at site clusters on the inner and middle shelf, and primarily in Site Cluster 8 (inner/middle shelf; Figure VI-8; Appendix D-D5 through D-D7). The most frequently occurring species in the cluster overall were sandflat elbow crab (*Heterocrypta occidentalis*; 10 sites; 5%), and Spanish shawl (*Flabellina iodinea*) and northern kelp crab (*Pugettia producta*) at 9 sites (5%) each (Appendix D-D5). No species in the species cluster occurred in 50% or more of the sites in a site cluster (Appendix D-D6); hence the group is not shown in Table VI-6. The most frequently occurring species at a site cluster was Spanish shawl, occurring at 9 sites (20%) of Site Cluster 8 (Inner/Middle Shelf; Appendix D-D5, D6). The most abundant species overall were northern kelp crab (46), Pacific acorn barnacle (*Paraconcavus pacificus*; 29), and Spanish shawl (25; Appendix D-D7). The most abundant species of the species cluster at a site cluster were northern kelp crab with 38, Pacific acorn barnacle with 29, and Spanish shawl with 25 at Site Cluster 8 (Inner/Middle Shelf).

Species Cluster I included 8 species which were found in site clusters on the upper slope and outer shelf, primarily in Site Clusters 2 (Upper Slope; Figure VI-8; Appendix D-D5 through D-D7). Overall, the most frequently occurring species in the cluster were unidentified sponges (Porifera unid.; 26 sites; 13%), unidentified sea mouse (*Aphrodita* spp.; 14; 7%), and the holothurian *Pannychia moseleyi* (12; 6%; Appendix D-D5). No species in the species cluster occurred in 50% or more of the sites in a site cluster (Appendix D-D6); hence the group is not shown in Table VI-6. Four species occurred at 50% of more of the sites within a site cluster (all in Site Cluster 2, Upper Slope); these were the holothurian *Pannychia moseleyi* (73%), the sea star *Myxoderma platyacanthum* (67%), and unidentified sea mouse and the ophiuroid *Asteronyx* *longifissus* (53% each; Table VI-6). The most abundant species overall were *Myxoderma platyacanthum* (10,571), *Asteronyx longifissus* (9,172), and unidentified sponges (1,630; Appendix D-D7). The most abundant species of the species cluster at a site cluster (all in Site Cluster 2) were *Myxoderma platyacanthum* (9,460), *Asteronyx longifissus* (9,169) and unidentified sponges (1,558).

Species Cluster J consisted of 4 species found in site clusters on the upper slope and outer shelf (primarily in Site Clusters 1 and 2; Figure VI-8; Appendix D-D5 through D-D7). Overall, the most frequently occurring species in the species cluster were northern heart urchin (29 sites; 15%); orange bigeye octopus and California heart urchin (26 sites; 13% each); and offshore blade shrimp (20 sites; 10%; Appendix D-D5). All four of these species occurred in 50% or more of the sites in one or more site clusters (Table VI-6; Appendix D-D6). Northern heart urchin, orange bigeye octopus, and offshore blade shrimp occurred at this percent or higher in both Site Clusters 1 and 2, but California heart urchin was at this level only in Site Cluster 1. The most frequently occurring species were California heart urchin (100%; Site Cluster 1, Upper Slope/Outer Shelf), and northern heart urchin and orange bigeye octopus (92% each in Site Cluster 1; Table VI-6). The most abundant species overall were northern heart urchin (36,074), California heart urchin (3,617), and offshore blade shrimp (509; Appendix D-D7). The most abundant species of the species cluster at a site cluster (all in Site Cluster 1) were northern heart urchin (28,750), California heart urchin (2,166), and offshore blade shrimp (178).

Species Cluster K included 9 species found mainly in site clusters on the upper slope and outer shelf (Site Clusters 1, 2, and 5; Figure VI-8; Appendix D-D5 through D-D7). Overall, the most frequently occurring species in the species cluster were Eastern Pacific bobtail (*Rossia pacifica*; 52 sites; 27%), and fragile urchin and ridgeback rock shrimp (50 sites, 26% each; Appendix D-D5). Six of the species in this species cluster occurred in 50% or more of the sites in one or more site clusters (Table VI-6; Appendix D-D6). Of these, three (fragile urchin, moustache bay shrimp, eastern Pacific bobtail) occurred at this level in two site clusters (1 and 5). The most frequently occurring species were fragile sea urchin (100%; Site Cluster 1, Upper Slope/Outer Shelf, and 82%; Site Cluster 5, Outer Shelf), and Pacific heart urchin (77%; Site Cluster 1; Table VI-6). The most abundant species overall were fragile sea urchin (20,917), Pacific heart urchin (8,568), and ridgeback rock shrimp (4,175; Appendix D-D7). The most abundant species of this species cluster at a site cluster were fragile sea urchin (9,553 at Site Cluster 1, and 7,275 at Site Cluster 5) and Pacific heart urchin (6,859 at Site Cluster 2).

Combined Fish and Invertebrate Assemblages

Combined Fish and Invertebrate Recurrent Groups

Recurrent group analysis at the 0.50 level of affinity identified 60 recurrent groups of combined fishes and invertebrates consisting of 2-10 species per group with 11 associate species (Figure VI-11a; Table VI-7; Appendix D-D8). In all, the groups and associates included 87 (19%) of the 450 species collected in the survey. Recurrent groups were found at 1-36 stations; 34 of the 60 groups occurred at only 1 site (Appendix D-D8), with 17 at 2-10 sites, and 9 at 11-36 sites (Figures VI-11a and VI-11b; Table VI-7). The major recurrent groups generally differed in depth distribution, with most occurring in one or two of the four predetermined shelf zones (Table VI-4). The more widespread groups are likely to represent important assemblages. While groups occurring with low frequency may provide some useful biological information on species associations, some may be due to chance. The most widespread recurrent groups occurring at more than 10 stations will be discussed in detail below.

Table VI-5. Frequency of occurrence (number of stations) of megabenthic invertebrate site clusters by region and subpopulation on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003.

	Site Cluster								
	2	1	5	9	4	8	3	6	7
Invertebrates	Upper Slope	Upper Slope/ Outer Shelf	Outer Shelf	Middle Shelf	Channel Islands/ Middle Shelf	Inner/ Middle Shelf	Inner Shelf	B&H C	B&H S
Number of Stations	15	13	22	48	22	46	14	9	6
Depth Range (m)	225-476	192-377	120-202	28-138	52-132	25-86	12-28	2-25	4-12
Subpopulation									
Region									
Mainland									
Northern	12	7	3	4	--	10	11	--	--
Central	1	3	8	20	3	24	1	9	--
Southern	2	3	6	19	1	12	2	--	6
Island									
Cool (NW Channel Islands)			3	1	11				
Warm (SE Channel Islands)	--	--	2	4	7	--	--	--	--
Shelf Zone									
Bays and Harbors	--	--	--	--	1	4	--	9	6
Inner shelf									
Small POTWs	--	--	--	--	--	8	5	--	--
Large POTWs	--	--	--	1	--	2	--	--	--
Other Mainland	--	--	--	--	--	13	8	--	--
Middle Shelf (31-120 m)									
Small POTWs	--	--	--	9	--	3	--	--	--
Large POTWs	--	--	1	19	--	5	--	--	--
Mainland non-POTW	--	--	1	5	17	--	--	--	--
Island	--	--	2	12	2	9	1	--	--
Outer Shelf (121-200 m)									
Large POTWs	--	--	--	--	1	--	--	--	--
Mainland	--	2	13	2	--	2	--	--	--
Island	--	--	3	--	1	--	--	--	--
Upper slope (200-500 m)									
Mainland	15	11	1	--	--	--	--	--	--
Island	--	--	1	--	--	--	--	--	--
Total (all stations)	15	13	22	48	22	46	14	9	6

C = Central; N = Northern; S = Southern; B&H = Bays/Harbors; POTW = Publicly owned treatment work monitoring area.

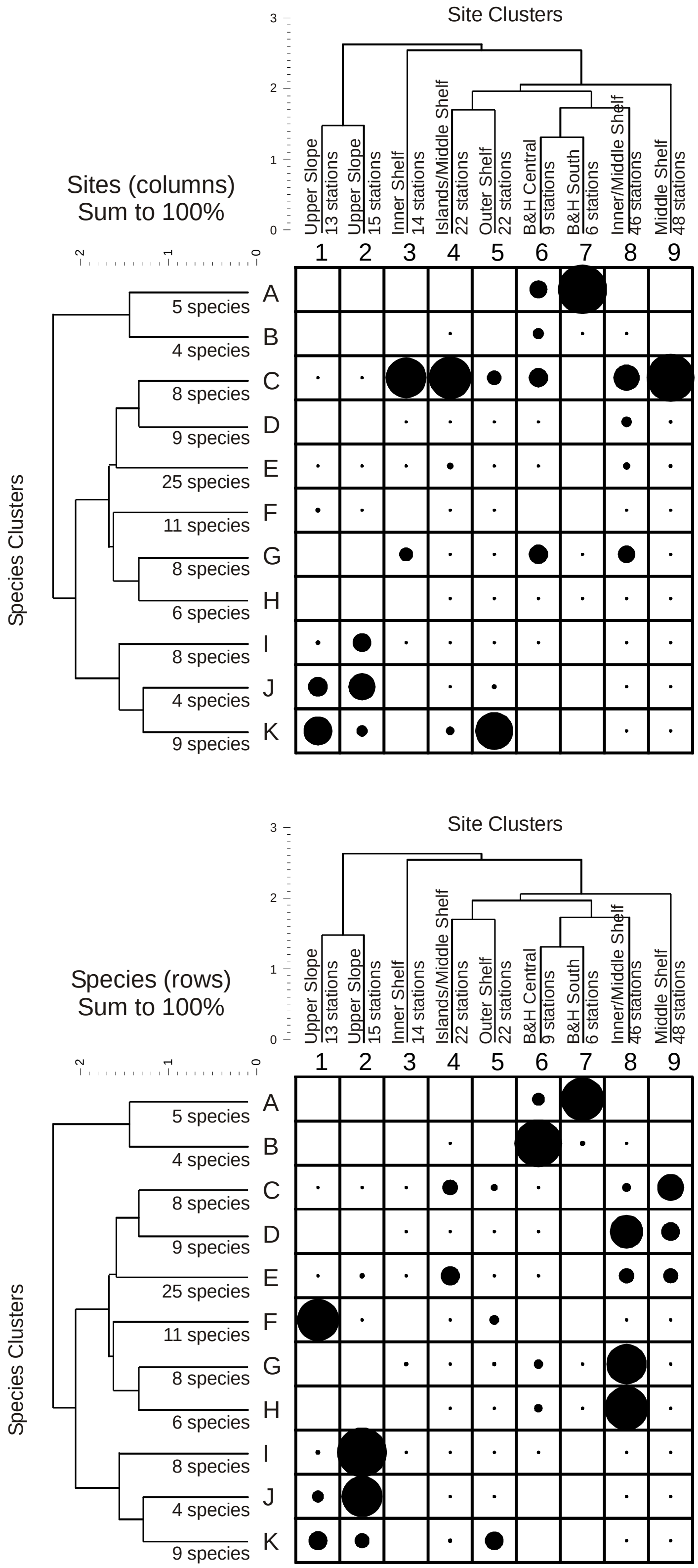


Figure VI-8. Summary of megabenthic invertebrate cluster analysis and relationships among site and species clusters on the southern California shelf at depths of 2-476 m, July- October 2003.

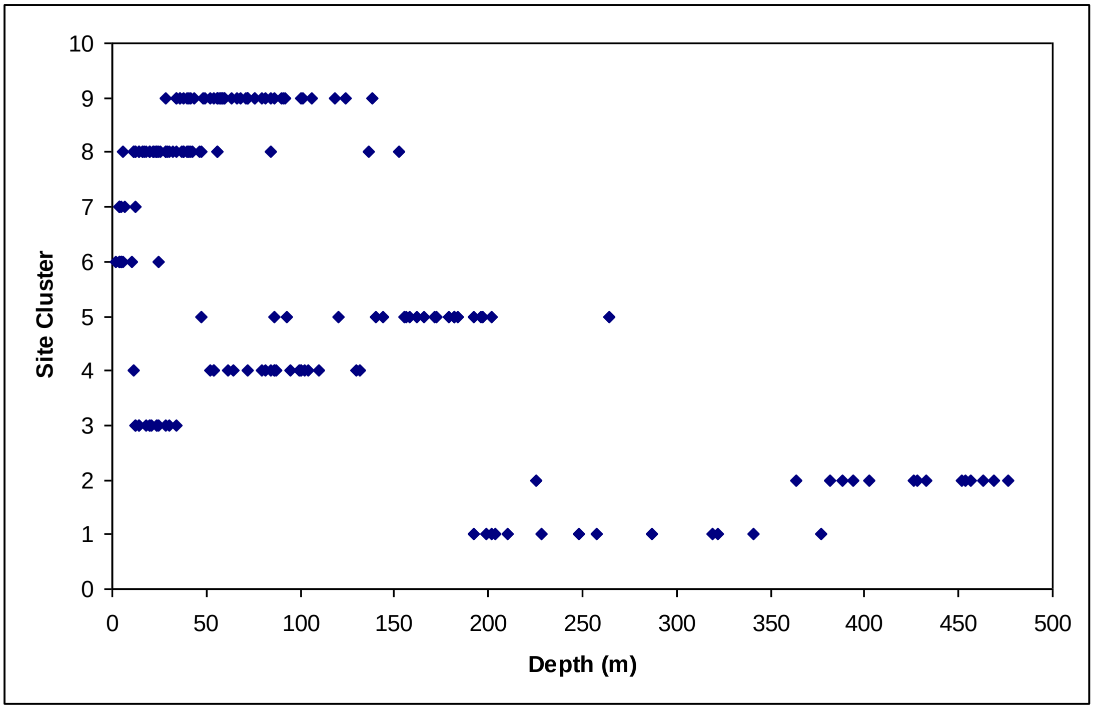


Figure VI-9. Bathymetric distribution of megabenthic invertebrate site clusters on the southern California shelf at depths of 2-476 m, July-October 2003.

Table VI-6. Frequency of occurrence (percent of stations) of megabenthic invertebrate species 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 2-476 m, July-October 2003.

		Species with 50% or more occurrence at site group	Site Cluster								
			2	1	5	9	4	8	3	6	7
	Invertebrates		Upper Slope	Upper Slope/ Outer Shelf	Outer Shelf	Middle Shelf	Channel Islands/ Middle Shelf	Inner/ Middle Shelf	Inner Shelf	B&H Central	B&H South
		Number of Stations	15	13	22	48	22	46	14	9	6
		Depth Range (m)	225-476	192-377	120-202	28-138	52-132	25-86	12-28	2-25	4-12
Species Cluster	Common Name	Scientific Name									
A	yellow-green sea squirt	*Ciona intestinalis*	--	--	--	--	--	--	--	--	83
A	warty tunicate	*Molgula verrucifera*	--	--	--	--	--	--	--	11	50
A	California aglaja	*Navanax inermis*	--	--	--	--	--	--	--	78	67
A	mat mussel	*Musculista senhousia*	--	--	--	--	--	--	--	56	33
A	cobblestone sea squirt	*Styela plicata*	--	--	--	--	--	--	--	56	33
B	Pacific calico scallop	*Argopecten ventricosus*	--	--	--	--	--	--	--	78	--
B	kelp scallop	*Leptopecten latiauratus*	--	--	--	--	--	--	--	67	33
B	mussel	*Mytilus sp*	--	--	--	--	--	2	--	56	--
G	tuberculate pear crab	*Pyromaia tuberculata*	--	--	--	4	--	15	21	89	--
G	graceful rock crab	*Cancer gracilis*	--	--	--	--	--	7	50	11	--
G	blackspotted bay shrimp	*Crangon nigromaculata*	--	--	--	--	--	39	57	22	--
G	shortspined sea star	*Pisaster brevispinus*	--	--	--	--	--	7	57	--	--
G	New Zealand papperbubble	*Philine auriformis*	--	--	36	52	14	24	7	33	17
C	California sand star	*Astropecten verrilli*	--	--	27	85	32	63	50	--	--
C	red octopus	*Octopus rubescens*	--	15	64	58	91	30	71	--	--
C	trailtip sea pen	*Acanthoptilum sp*	7	--	23	58	77	30	7	33	--
C	white sea urchin	*Lytechinus pictus*	--	--	18	60	82	39	7	11	--
C	brokenspine brittle star	*Ophiura luetkenii*	--	--	36	71	68	17	--	--	--
C	gray sand star	*Luidia foliolata*	7	38	32	50	73	17	--	11	--
C	California sea cucumber	*Parastichopus californicus*	--	8	18	73	27	15	7	22	--
C	California sea slug	*Pleurobranchaea californica*	40	69	27	29	45	9	--	--	--
E	rosy tritonia	*Tritonia diomedea*	--	--	14	10	50	4	--	--	--
E	red sea star	*Mediaster aequalis*	40	15	14	10	86	2	--	--	--
D	yellow sea twig	*Thesea sp b*	--	--	14	54	23	15	--	--	--
K	fragile sea urchin	*Allocentrotus fragilis*	47	100	82	6	32	4	--	--	--
K	Pacific heart urchin	*Brissopsis pacifica*	33	77	27	--	18	--	--	--	--
K	sea dandelion	*Dromalia alexandri*	27	69	18	--	--	--	--	--	--
K	flagnose bay shrimp	*Neocrangon resima*	--	46	41	--	9	--	--	--	--
K	moustache bay shrimp	*Neocrangon zacae*	--	69	68	4	9	2	--	--	--
K	spot shrimp	*Pandalus platyceros*	13	38	9	13	14	13	--	--	--
K	eastern Pacific bobtail	*Rossia pacifica*	20	62	50	44	18	11	--	--	--
K	ridgeback rock shrimp	*Sicyonia ingentis*	--	31	64	42	36	9	--	--	--
K	slender blade shrimp	*Spirontocaris holmesi*	20	54	27	--	--	--	--	--	--
J	northern heart urchin	*Brisaster latifrons*	73	92	18	--	9	--	--	--	--
J	orange bigeye octopus	*Octopus californicus*	67	92	14	2	--	--	--	--	--
J	California heart urchin	*Spatangus californicus*	33	100	23	--	9	2	--	--	--
J	offshore blade shrimp	*Spirontocaris sica*	67	69	5	--	--	--	--	--	--
I	sea mouse	*Aphrodita sp*	53	15	--	2	9	2	--	--	--
I	ophiuroid	*Asteronyx longifissus*	53	8	--	--	--	--	--	--	--
I	sea star	*Myxoderma platyacanthum*	67	8	--	--	--	--	--	--	--
I	holothuroid	*Pannychia moseleyi*	73	8	--	--	--	--	--	--	--

Table VI-7. Mean and range of depth of combined demersal fish and megabenthic invertebrate recurrent groups on the southern California shelf and upper slope, July-October, 2003.

Recurrent Group	No. of Stations	Mean Depth (m)	Depth Range (m)	Recurrent Group	No. of Stations	Mean Depth (m)	Depth Range (m)
1	1	4	4	31	1	80	80
2	1	4	4	32	1	81	81
3	2	4	4	33	1	86	86
4	5	4	2-5	34	3	88	80-104
5	1	4	4	35	13	88	56-110
6	6	5	2-6	36	1	95	95
7	1	5	5	37	3	97	81-106
8	2	6	4-8	38	1	100	100
9	1	12	12	39	1	104	104
10	1	12	12	40	1	106	106
11	1	14	14	41	36	110	42-204
12	1	16	16	42	2	112	106-118
13	12	17	8-30	43	25	125	76-202
14	29	19	11-30	44	2	142	104-179
15	1	20	20	45	1	166	166
16	1	28	28	46	1	171	171
17	1	37	37	47	11	176	120-322
18	1	38	38	48	1	179	179
19	1	38	38	49	1	210	210
20	1	41	41	50	24	233	132-469
21	1	42	42	51	10	288	192-388
22	1	45	45	52	10	373	197-463
23	2	46	38-54	53	7	399	248-469
24	2	50	45-54	54	8	437	382-476
25	16	51	34-81	55	1	454	454
26	2	53	52-54	56	2	462	454-469
27	1	54	54	57	3	463	456-469
28	1	56	56	58	1	463	463
29	31	59	25-92	59	1	469	469
30	1	64	64	60	1	476	476

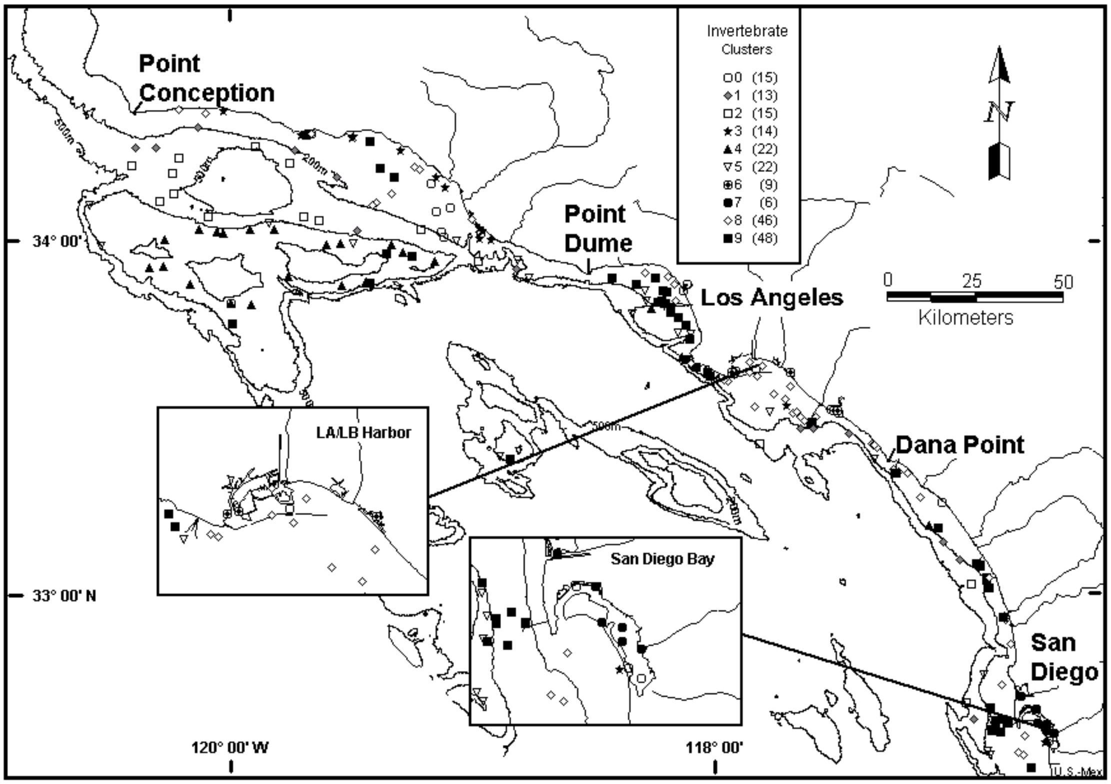


Figure VI-10. Distribution of megabenthic invertebrate site cluster on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003.

Group 13–Harbor/Inner Shelf Croaker Group. This group is the same as Group 2 in the fish recurrent group results above (Figure VI-1). It consisted of two schooling sciaenid species, white croaker and queenfish (Figures VI-1 and VI-11b). This group occurred at 12 stations on the soft bottom inner shelf at depths of 8-30 m (mean=17 m; Table VI-7). It was found in the LA/LB Harbor (5 stations), near the Santa Clara and Ventura river mouths (4 stations), as well as in the San Diego County region (3 stations). It was not found on the islands. Although in the fish recurrent group analysis, Group 2 did not have affinities with other recurrent groups, Group 13 in combined fish and invertebrates was associated with Group 14 (Figure VI-11b). It was not associated at the affinity level used in the analysis with any invertebrate species.

Group 14–Inner Shelf Shrimp/Sanddab Group. This group consisted of two species, speckled sanddab and blackspotted shrimp (Figure VI-10). It occurred at 29 stations on the soft bottom inner shelf at depths of 11-30 m (mean=19 m; Table VI-7). It was found on the mainland inner shelf from north to south and in LA/LB Harbor (4 stations). Group 14 was associated with Groups 13 and 25 (Figure VI-11b).

Group 25–Middle Shelf Fish/Sand Star Group. This group consisted of 10 species, 9 fishes (Pacific sanddab, yellowchin sculpin, longspine combfish, longfin sanddab, pink seaperch, roughback sculpin, California tonguefish, hornyhead turbot, and bigmouth sole) and 1 invertebrate (California sand star; Figure VI-11b). The fish portion of the group was the same as Group 4 in the fish recurrent group analysis (Figure VI-1). It occurred at 16 stations on the middle shelf at depths of 34-81 m (mean=51 m; Table VI-7). It was found on the mainland middle shelf, primarily in the central region, at LPOTW and Non-LPOTW areas. Group 25 had 9 associate species, (California blade barnacle, New Zealand papperbubble, yellow sea twig, pygmy poacher, lingcod, English sole, California scorpionfish, California lizardfish, and halfbanded rockfish) and was associated with Groups 14, 29, 41, and 43 (Figure VI-10).

Group 29–Middle Shelf Sea Cucumber/Goby Group. This group consisted of 2 species: California sea cucumber and bay goby (Figure VI-11b). It occurred at 31 stations on the middle shelf at depths of 25-92 m (mean=59 m; Table VI-7). It was found on the mainland middle shelf, primarily in the central and southern regions, at SPOTW, LPOTW, and Non-POTW areas. Group 29 had 2 associate species (yellow sea twig and halfbanded rockfish) and was associated with Group 25 (Figure VI-11b).

Group 35–Middle Shelf Fish/Sea Pen/Echinoderm Group. This group consisted of 6 species, 4 invertebrates (white sea urchin, trailtip sea pen, brokenspine brittlestar, gray sand star), and 2 fishes (stripetail rockfish, plainfin midshipman; Figure VI-11b) It occurred at 13 stations on the middle shelf at depths of 56-110 m (mean=88 m; Table VI-7). It was found on the mainland (9 stations) and islands (4 stations). Group 35 had 4 associate species (yellow sea twig, halfbanded rockfish, Pacific spiny brittlestar, eastern Pacific bobtail) and was associated with Groups 25, 29, 41, 43, and 47 (Figure VI-11b).

Group 41–Middle Shelf/Outer Shelf Shrimp/Dover Sole /Octopus Group. This group consisted of 3 species, 2 invertebrates (ridgeback rock shrimp, red octopus), and 1 fish (Dover sole; Figure VI-11b) It was the most widespread recurrent group, occurring at 36 stations on the middle shelf and outer shelf at depths of 42-204 m (mean=110 m; Table VI-7). It was found on the mainland (all regions, POTW, and non-POTW areas) and islands. Group 41 had associate species (pygmy poacher, English sole, halfbanded rockfish, eastern Pacific bobtail) and was associated with Groups 25, 43, and 50 (Figure VI-11b).

Group 43–Middle Shelf/Outer Shelf Combfish/Rockfish Group. This group consisted of 2 species: shortspine combfish and greenstriped rockfish (Figure VI-11b) In the fish recurrent group analysis, shortspine combfish was a member of Group 7 and greenstriped rockfish was an associate to Groups 5 and 7 (Figure VI-1). Group 43 occurred at 25 stations on the middle shelf and outer shelf at depths of 76-202 m (mean=125 m; Table VI-7). It was found on the mainland and at islands. Group 43 was associated with Groups 25, 41, 47, and 50 (Figure VI-11b).

Group 47–Outer Shelf/Upper Slope Shrimp/Poacher/Eelpout Group. This group consisted of 4 species, 2 invertebrates (moustache bay shrimp, flagnose bay shrimp) and 2 fishes (blacktip poacher, blackbelly eelpout) (Figure VI-10). Group 47 occurred at 11 stations on the outer shelf and upper slope at depths of 120-322 m (mean=176 m; Table VI-7). It was found on the mainland (all regions) and at the northwest Channel Islands. Group 47 had an associate species (eastern Pacific bobtail) and was associated with Groups 35 and 43 (Figure VI-11b).

Group 50–Outer Shelf/Upper Slope Flatfish/Sea Urchin Group. This group consisted of 3 species, 1 invertebrate (fragile sea urchin) and 2 fishes (slender sole, rex sole; Figure VI-11b). Group 50 occurred at 24 stations on the outer shelf and upper slope at depths of 132-469 m (mean=233 m; Table VI-7). It was found on the mainland (all regions) and at the northwest Channel Islands. Group 50 had an associate species (bluebarred prickleback) and was associated with Groups 43 and 51 (Figure VI-11b).

Combined Fish and Invertebrate Site and Species Clusters

Selection of Species. The trawl survey sampled 210 stations and collected 61,687 fish and 157,326 invertebrates, or 219,013 fish and invertebrates combined. These represented 142 species of fish and 308 species of invertebrates, or 450 fish and invertebrate species combined. Based upon the screening criteria, all 210 stations representing 212,628 individuals and 167 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 VI-12; Appendix D-D8 through D-D10). Each site and species cluster was unique, based on the relative proportion of different species clusters within a site cluster and the relative proportion of each species cluster in different site clusters (Figure VI-12).

Site Clusters. The site clusters varied by region, depth, and subpopulation (Table VI-8; Figures VI-12 through VI-14). Each site cluster consisted of 1-2 dominant species clusters (Figure VI-12, top). Viewed from the perspective of what species clusters were most important in a site cluster, four species groups were primarily dominant in a single site cluster, but Species Cluster A was dominant in five site clusters (5, 6, 7, 8, 9). The dominant species cluster in Site Cluster 1 was Species Cluster E; in Site Cluster 2, Species Cluster B; in Site Cluster 3, Species Cluster C; and in Site Cluster 4, Species Cluster F (Figure VI-12, top).

Site Cluster 2 (Upper Slope) included 18 stations at depths of 225-476 m (Table VI-8; Figures VI-12 through VI-14). This site group is characterized by 18 mainland upper slope sites (Table VI-8, Figure VI-14). Fourteen species occurred in more than 50% of the stations in Site Cluster 2, including 9 species of Species Cluster B, 4 species of Species Cluster E, and 1 species of Species Cluster A (Table VI-9, Appendix D-D10). The most frequently occurring species were Dover sole (94%), northern heart urchin (78%), and bigfin eelpout and offshore blade shrimp (72%; Table VI-9). The most abundant species were northern urchin (28, 938), sea star *Myxoderma platyacanthum* (9,460), and brittlestar *Asteronyx longifissus* (4,038; Appendix D-D11).

Site Cluster 1 (Upper Slope/Outer Shelf) included 25 stations at depths of 132-322 m (Table VI-8; Figures VI-12 through VI-14). This site group contained 23 mainland upper slope sites and 2 island sites (Table VI-8; Figure VI-14). Nineteen species occurred in more than 50% of the stations in Site Cluster 2 (Table VI-9; Appendix D-D10). All 11 species of Species Cluster E, 4 species of Species Cluster A, 2 species of Species Cluster B, and 1 species of Species Cluster D occurred in more than 50% of the stations within Site Cluster 2 (Table VI-9). The most frequently occurring species were slender sole (100%), Dover sole (96%), and fragile sea urchin (92%; Table VI-9). The most abundant species were fragile sea urchin (15,897), northern heart urchin (7,132), and slender sole (4,038; Appendix D-D11).

Site Cluster 7 (Outer Shelf) included 16 stations at depths of 80-192 m (Table VI-8; Figures VI-12 through VI-14). This site group consisted of 10 mainland and 6 island sites (Table VI-8; Figure VI-14). Thirteen species occurred in more than 50% of the stations in Site Cluster 7, including 6 species of Species Cluster A, 3 species of Species Cluster D, and 2 species each of Species Clusters B and E (Table VI-9; Appendix D-D10). The most frequently occurring species were Pacific sanddab (94%), Dover sole (88%), and shortspine combfish (81%; Table VI-9). The most abundant species were white sea urchin (5,132), Pacific sanddab (3,204), and fragile sea urchin (897; Appendix D-D11).

Site Cluster 6 (Channel Islands Middle Shelf) included 21 stations at depths of 45-130 m (Table VI-8; Figures VI-12 through VI-14). This site group contained 20 island sites and 1 mainland site (Table VI-8; Figure VI-14). Twenty-one species occurred in more than 50% of the stations in Site Cluster 7, including 18 species of Species Cluster A, 3 species of Species Cluster D, and 1 species of Species Cluster G (Table VI-9; Appendix D-D10). The most frequently occurring species were Pacific sanddab (100%), and red sea star and red octopus (90%; Table VI-9; Appendix D-D10). The most abundant species were white sea urchin (17,465), Pacific sanddab (4,375), and halfbanded rockfish (1,536; Appendix D-D11).

Site Cluster 8 (Mainland Middle Shelf) included 16 stations at depths of 57-101 m (Table VI-8; Figures VI-12 through VI-14). This site group formed by 16 mainland middle shelf sites (Table VI-8; Figure VI-14). Twenty-four species occurred in more than 50% of the stations in Site Cluster 8, including 20 species of Species Cluster A, and 2 species each of Species Clusters E and G (Table VI-9; Appendix D-D10). Three species (Pacific sanddab, Dover sole, and longspine combfish) occurred at 100% of the sites (Table VI-9; Appendix D-D10). The most abundant species were white sea urchin (4,710), Pacific sanddab (2,961), and yellowchin sculpin (873; Appendix D-D11).

Site Cluster 9 (Middle Shelf/Inner Shelf) included 48 stations at depths of 15-86 m (Table VI-8; Figures VI-12 through VI-14). This site group contains 47 mainland sites and 1 island site (Table VI-8; Figure VI-14). Eighteen species occurred in more than 50% of the stations in Site Cluster 8, including 17 species of Species Cluster A, and 1 species of Species Cluster F (Table VI-9; Appendix D-D10). The most frequently occurring species were Pacific sanddab D10). The most abundant species were white sea urchin (5,617), Pacific sanddab (5,012), and speckled sanddab (2,927; Appendix D-D11).

Site Cluster 4 (Inner Shelf/Bays/Harbors) included 20 stations at depths of 4-71 m (Table VI-8; Figures VI-12 through VI-14). This site group consisted of 20 mainland sites with 8 in bays and harbors, 9 on the inner shelf, and 3 on the middle shelf (Table VI-8; Figure VI-14). Six species occurred in more than 50% of the stations in Site Cluster 4, including 4 species of Species Cluster F, and 2 species of Species Cluster A (Table VI-9; Appendix D-D10). The most frequently occurring species were white croaker and hornyhead turbot (70% each) and queenfish (65%) (Table VI-9; Appendix D-D10). The most abundant species were blackspotted bay shrimp (1,701), white croaker (839), and pink seaperch (500; Appendix D-D11).

Site Cluster 5 (Inner Shelf) included 30 stations at depths of 7-34 m (Table VI-8; Figures VI-12 through VI-14). This site group contains 30 mainland sites with 28 on the inner shelf, and 1 each in bays/harbors and on the middle shelf (Table VI-8; Figure VI-14). Five species (all of Species Cluster A) occurred in more than 50% of the stations in Site Cluster 5 (Table VI-9; Appendix D-D10). The most frequently occurring species were speckled sanddab (93%), English sole (70%), and California sand star (60%; Table VI-9; Appendix D-D10). The most abundant species were speckled sanddab (3,283), California sand star (514), and Pacific sanddab (198; Appendix D-D11).

Site Cluster 3 (Bays/Harbors/Central/South) included 16 stations at depths of 2-12 m (Table VI-8; Figures VI-12 through VI-14). This site group is formed by 16 mainland bay sites (Table VI-8; Figure VI-14). Five species occurred in more than 50% of the stations in Site Cluster 3, 4 of Species Cluster C and 1 of Species Cluster F (Table VI-9; Appendix D-D10). The most frequently occurring species were California halibut (88%), barred sand bass (69%), and round stingray and diamond turbot (56% each; Table VI-9, Appendix D10). The most abundant species were cobblestone seasquirt (598), mat mussel (508), and warty tunicate (198; Appendix D-D11).

Species Clusters. Seven major species clusters were delineated by the analysis (Figure 12). The species clusters generally occupied different depth zones or combinations of these, each most abundant in one or more zone. The relationship of the site clusters with depth results from the depth distribution patterns of fish and invertebrate species found in the species clusters. All site clusters included representatives of two or more species groups. Species Cluster A was dominant in Site Clusters 6 and 9; Species Cluster B in Site Cluster 2; Species Cluster C in Site Cluster 3; Species Cluster D in Site Cluster 7; Species Cluster E in Site Cluster 1; Species Cluster F was most dominant in Site Cluster 4; and Species Clusters G in Site Cluster 9 (Figure VI-12).

Species Cluster A included 31 species found primarily in Site Clusters 6 (Channel Islands Middle Shelf) and 9 Inner Shelf/Middle Shelf (Bays/Harbors South), but also to a lesser extent in other site clusters (Figure VI-12; Appendix D-D9 through D-D11). The most frequently occurring species in this group overall were Pacific sanddab (131 sites; 62% of 210), Dover sole (110; 52%), and hornyhead turbot (98; 47%) (Appendix D-D9). Twenty-nine species in the group occurred in 50% or more of the stations in at least one site cluster, with species occurring at this frequency in 1-5 site clusters (Table VI-9). Of these, the most widespread species of importance were Pacific sanddab and Dover sole, occurring at greater than 50% of stations in 5 site clusters (Site Clusters 1, 7, 6, 8, 9 for Pacific sanddab; Site Clusters 2, 1, 7, 6, 8 for Dover sole; Table VI-9). The most frequently occurring species of this group in a site cluster were Pacific sanddab (100% in Site Clusters 6, 8; Channel Islands Middle Shelf and Middle Shelf, respectively), and longspine combfish and Dover sole (100% each in Site Cluster 8, Middle Shelf). The most abundant species in the group overall were white sea urchin (33,028), Pacific sanddab (17,058), and speckled sanddab (6,785; Appendix D-D11). The most abundant species in a site cluster was white sea urchin with 17,465 in Site Cluster 6; 5,617 in Site Cluster 9; and 5,132 in Site Cluster 7 (Appendix D-D11).

Table VI-8. Frequency of occurrence (number of stations) of combined demersal fish and megabenthic invertebrate site clusters by region and subpopulation on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003.

	Site Cluster								
	2	1	7	6	8	9	4	5	3
	Upper Slope	Upper Slope/ Outer Shelf	Islands/ Outer Shelf	Channel Islands	Middle Shelf	Middle/ Inner Shelf	Inner Shelf/B&H N/C	Inner Shelf	B&H C/S
Number of Stations	18	25	16	21	16	48	20	30	16
Depth Range (m)	225-476	132-322	80-192	45-130	57-101	15-86	4-71	7-34	2-12
Subpopulation									
Region									
Mainland									
Northern	13	8	5	--	--	3	9	16	--
Central	2	9	1	1	4	32	8	7	8
Southern	3	6	4	--	12	12	3	7	8
Island									
Cool (NW Channel Islands)	--	2	3	11	--	--	--	--	--
Warm (SE Channel Islands)	--	--	3	9	--	1	--	--	--
Shelf Zone									
Bays and Harbors	--	--	--	--	--	1	8	1	16
Inner shelf									
Small POTWs	--	--	--	--	--	2	--	13	--
Large POTWs	--	--	--	--	--	3	--	--	--
Other Mainland	--	--	--	--	--	1	9	15	--
Middle Shelf (31-120 m)									
Small POTWs	--	--	--	--	5	6	--	1	--
Large POTWs	--	--	1	--	5	18	1	--	--
Mainland non-POTW	--	--	1	1	6	16	2	--	--
Island	--	--	4	19	--	1	--	--	--
Outer Shelf (121-200 m)									
Large POTWs	--	1	--	--	--	--	--	--	--
Mainland	--	13	8	--	--	--	--	--	--
Island	--	1	2	1	--	--	--	--	--
Upper slope (200-500 m)									
Mainland	18	9	--	--	--	--	--	--	--
Island	--	1	--	--	--	--	--	--	--
Total (all stations)	18	25	16	21	16	48	20	30	16

C = Central; N = Northern; S = Southern; B&H = Bays/Harbors; POTW = Publicly owned treatment work monitoring area.

Group 3

"tunicate" *(Ascidiacea sp SD3)*
"sponge" *(Porifera sp SD5)*

0.33 black croaker *(Cheilotrema saturnum)*
0.33 warty tunicate *(Molgula verrucifera)*
0.33 yellow-green sea squirt *(Ciona intestinalis)*

Group 4

cobblestone sea squirt *(Styela plicata)*
Pacific calico scallop *(Argopecten ventricosus)*
"mussel" *(Mytilus sp)*

0.33 kelp scallop *(Leptopecten latiauratus)*

0.5

Group 6

mat mussel *(Musculista senhousia)*
diamond turbot *(Pleuronichthys guttulatus)*

Group 8

"sponge" *(Porifera sp SD4)*
California spiny lobster *(Panulirus interruptus)*

Group 23

blackclaw crestleg crab *(Lophopanopeus bellus)*
lacy bryozoan *(Phidolopora labiata)*

0.38

Group 24

pit-head sculpin *(Icelinus cavifrons)*
"sea cucumber" *(Pseudocnus lubricus)*
orange sea cucumber *(Cucumaria miniata)*
coralline bryozoan *(Diaperoforma californica)*

Group 26

furrowed rock crab *(Cancer branneri)*
painted greenling *(Oxylebius pictus)*

Group 34

greenspotted rockfish *(Sebastes chlorostictus)*
bluebanded ronquil *(Rathbunella hypoplecta)*

Group 37

"sea cucumber" *(Cucumaria piperata)*
six-arm sea star *(Leptasterias hexactis)*

Group 42

slim sculpin *(Radulinus asprellus)*
variegate topsnail *(Calliostoma variegatum)*

Group 44

"brittlestar" *(Ophionereis eurybrachiplax)*
California lamp shell *(Laqueus californianus)*

Group 56

"ophiuroid" (Ophiosphalma jolliense)
tentacle-shedding anemone *(Liponema brevicornis)*

Group 57

dogface witch eel *(Facciolella equatorialis)*
California grenadier *(Nezumia stelgidolepis)*

signet ring anemone *(Stephanauge annularis)* 0.5

Figure VI-11a. Recurrent groups of combined demersal fishes and megabenthic invertebrates occurring at multiple sites on the southern California shelf at depths of 2-476 m, July-October 2003. Index of affinity (I.A.)=0.50. Group depths 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.

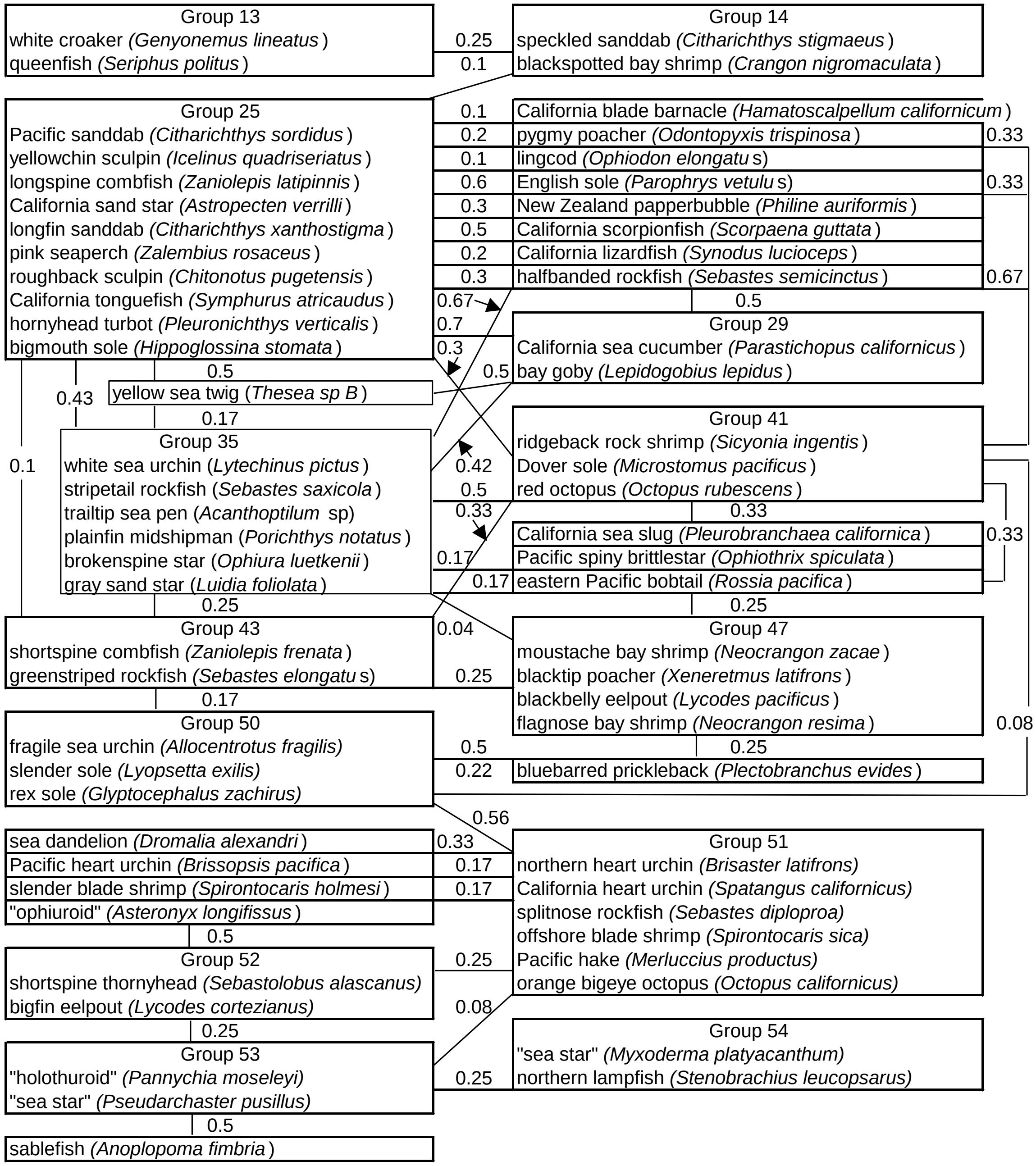


Figure VI-11b. Recurrent groups of combined demersal fishes and megabenthic invertebrates occurring at multiple sites on the southern California shelf at depths of 2-476 m, July-October 2003. Index of affinity (I.A.)=0.50. Group depths are numbered in order of depth. Species within a group are listed in order of abundance. Lines show relationships between groups and associates, with values indicating the proportion of possible pairs with I.A.=0.50.

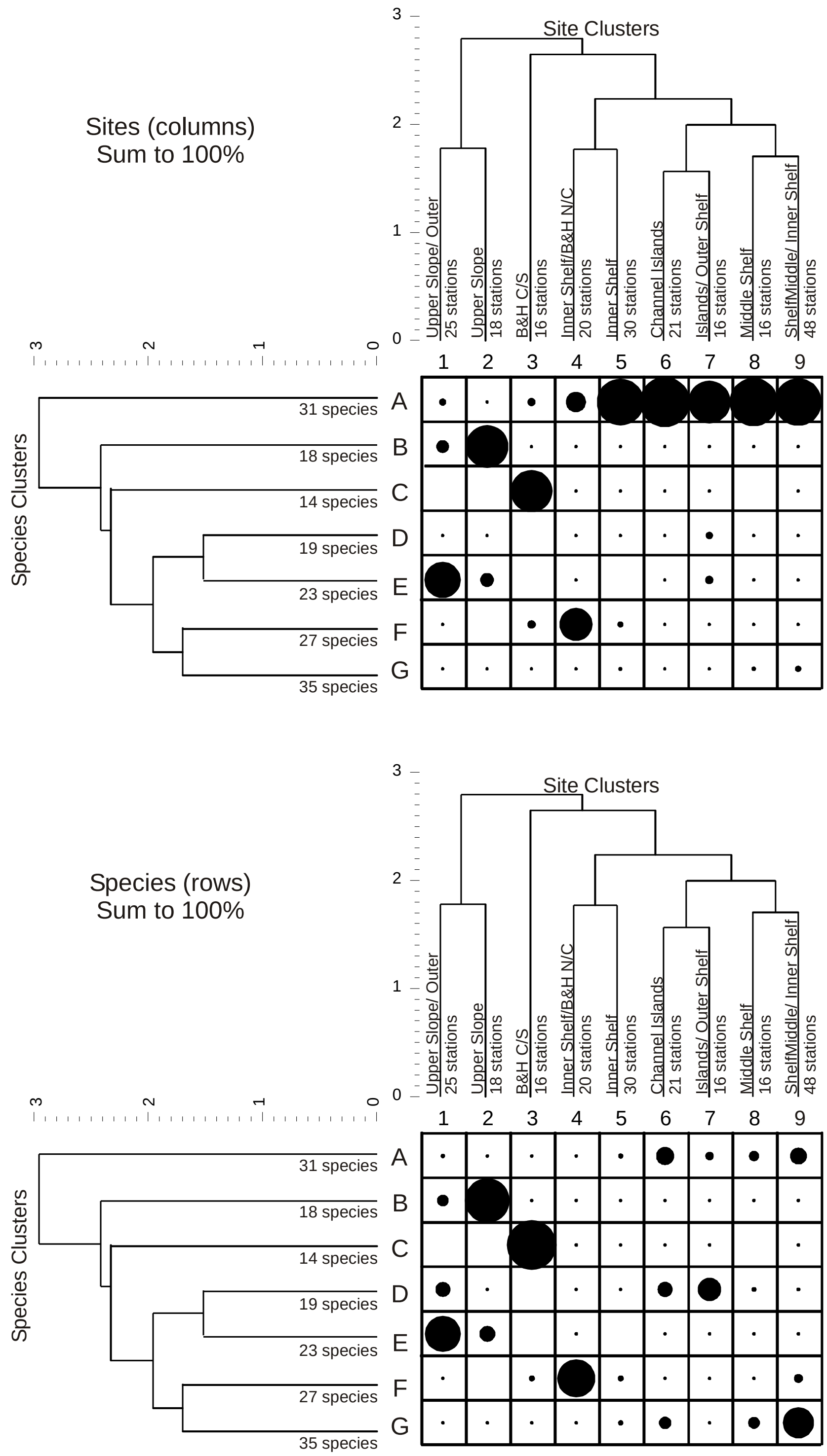


Figure VI-12. Summary of combined demersal fish and megabenthic invertebrate cluster analysis and relationships among site and species clusters on the southern California shelf at depths of 2-476 m, July-October 2003.

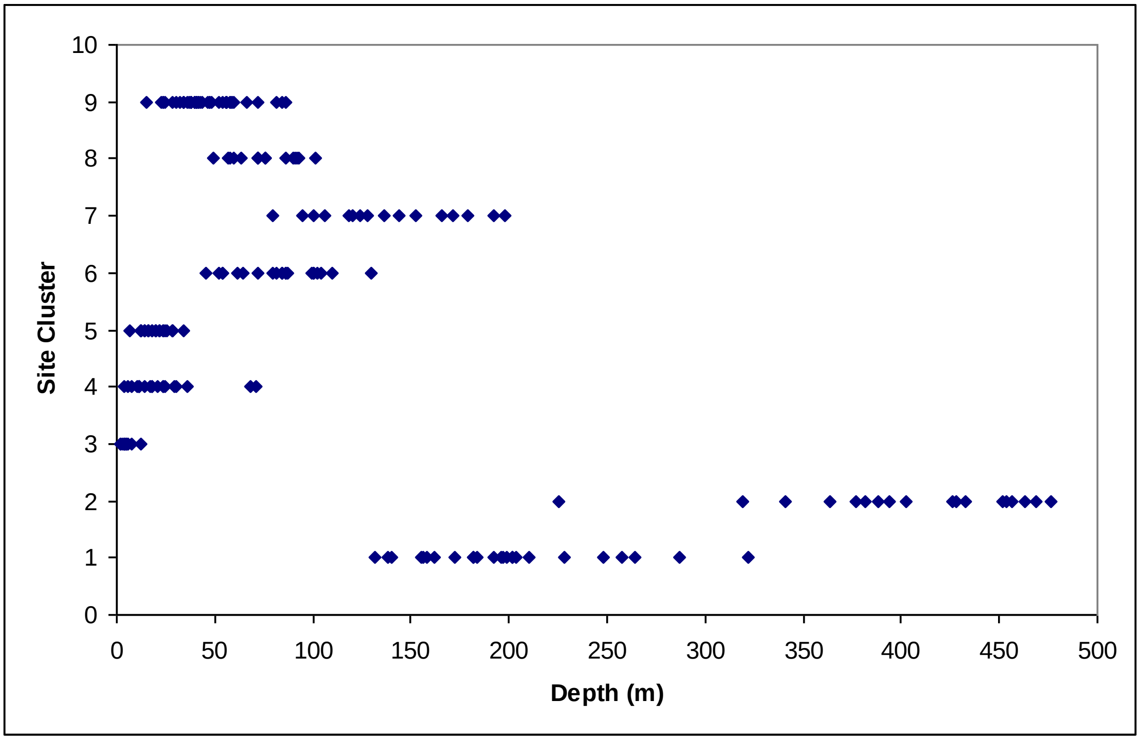


Figure VI-13. Bathymetric distribution of demersal fish and megabenthic invertebrate site clusters on the southern California shelf at depths of 2-476 m, July-October 2003.

Table VI-9. Frequency of occurrence (percent of stations) of demersal fish and megabenthic invertebrate species 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 2-476 m, July-October 2003. (See Appendix D-D10 for complete Species Cluster B percent occurrences).

Species at 50% or greater in site group		Site Cluster								
		2	1	7	6	8	9	4	5	3
		Upper Slope	Outer Shelf	Channel Islands/ Outer Shelf	Channel Islands/ Middle Shelf	Middle Shelf	Middle/ Inner Shelf	Inner Shelf/B&H N/C	Inner Shelf	B&H C/S
	Number of Stations	18	25	16	21	16	48	20	30	16
	Depth Range (m)	225-476	132-322	80-192	45-130	57-101	15-86	4-71	7-34	2-12

Species Cluster	Common Name	Scientific Name	2	1	7	6	8	9	4	5	3
C	diamond turbot	Pleuronichthys guttulatus	--	--	--	--	--	--	--	7	56
	round stingray	Urobatis halleri	--	--	--	--	--	--	5	--	56
	California aglaja	Navanax inermis	--	--	--	--	--	--	10	3	50
	barred sand bass	Paralabrax nebulifer	--	--	--	--	--	2	5	3	69
F	California halibut	Paralichthys californicus	--	--	--	--	--	21	40	43	88
	queenfish	Seriphus politus	--	--	--	--	--	--	65	3	6
	specklefin midshipman	Porichthys myriaster	--	--	--	--	--	10	50	13	31
	white croaker	Genyonemus lineatus	--	--	--	--	--	13	70	--	6
	blackspotted bay shrimp	Crangon nigromaculata	--	--	--	--	--	10	60	37	--
	New Zealand papperbubble	Philine auriformis	--	24	13	10	63	52	20	7	6
A	speckled sanddab	Citharichthys stigmaeus	--	4	--	38	6	58	60	93	6
	hornyhead turbot	Pleuronichthys verticalis	--	8	6	48	63	92	70	57	--
	California sand star	Astropecten verrilli	--	4	44	33	94	85	5	60	--
	English sole	Parophrys vetulus	17	28	38	67	56	58	45	70	--
	curlfin sole	Pleuronichthys decurrens	--	--	25	62	--	10	--	50	--
	roughback sculpin	Chitonotus pugetensis	--	--	--	38	38	73	--	13	--
	California scorpionfish	Scorpaena guttata	--	4	--	24	13	67	10	17	--
	California tonguefish	Symphurus atricaudus	--	--	--	--	69	85	45	10	6
	California sea cucumber	Parastichopus californicus	--	8	25	33	88	50	10	7	6
	longfin sanddab	Citharichthys xanthostigma	--	8	6	--	69	79	10	33	--
	bigmouth sole	Hippoglossina stomata	--	20	19	38	50	75	10	20	--
	bay goby	Lepidogobius lepidus	--	--	6	5	88	50	35	--	--
	white sea urchin	Lytechinus pictus	--	8	44	81	63	65	--	10	6
	yellowchin sculpin	Icelinus quadriseriatus	--	--	6	67	94	90	35	23	--
	pink seaperch	Zalembius rosaceus	--	12	38	81	88	73	30	30	--
	longspine combfish	Zaniolepis latipinnis	--	12	31	81	100	75	40	13	--
	brokenspine brittle star	Ophiura luetkenii	--	12	56	62	81	52	10	--	--
	Pacific sanddab	Citharichthys sordidus	11	64	94	100	100	94	25	37	--
	halfbanded rockfish	Sebastes semicinctus	--	16	38	76	75	35	10	--	--
	trailtip sea pen	Acanthoptilum sp	6	12	63	81	50	44	25	3	19
	plainfin midshipman	Porichthys notatus	--	32	50	81	94	44	45	3	--
	stripetail rockfish	Sebastes saxicola	--	84	69	81	81	44	20	7	--
	red octopus	Octopus rubescens	--	52	44	90	75	48	25	30	--
	Dover sole	Microstomus pacificus	94	96	88	76	100	38	20	3	--
	pygmy poacher	Odontopyxis trispinosa	--	4	13	52	31	33	10	13	--
	lingcod	Ophiodon elongatus	--	8	--	52	19	29	20	17	--
	gray sand star	Luidia foliolata	11	36	44	71	44	40	10	3	--
	red sea star	Mediaster aequalis	33	16	19	90	6	6	--	--	--
	California sea slug	Pleurobranchaea californica	39	52	31	43	31	17	5	3	--
G	Pacific argentine	Argentina sialis	--	12	13	--	63	8	--	--	--
	yellow sea twig	Thesea sp b	--	4	25	33	50	42	--	3	--
	rosy tritonia	Tritonia diomedea	--	4	6	52	19	8	5	--	--
E	ridgeback rock shrimp	Sicyonia ingentis	--	64	19	33	69	19	20	--	--
	eastern Pacific bobtail	Rossia pacifica	22	64	25	14	75	25	5	--	--
	slender sole	Lyopsetta exilis	83	100	56	5	31	2	--	--	--
	fragile sea urchin	Allocentrotus fragilis	56	92	50	29	13	2	--	--	--
	moustache bay shrimp	Neocrangon zacae	6	76	19	5	13	6	--	--	--
	blackbelly eelpout	Lycodes pacificus	--	80	19	14	31	--	--	--	--
	blacktip poacher	Xeneretmus latifrons	11	84	38	5	19	--	--	--	--
	rex sole	Glyptocephalus zachirus	39	76	25	--	6	--	--	--	--
	orange bigeye octopus	Octopus californicus	67	52	--	--	--	--	5	--	--
	splitnose rockfish	Sebastes diploproa	56	68	--	--	6	--	--	--	--
	Pacific hake	Merluccius productus	56	76	19	--	--	--	--	--	--
D	shortspine combfish	Zaniolepis frenata	6	80	81	76	38	8	--	--	--
	spotted cusk-eel	Chilara taylori	6	24	50	33	13	13	--	3	--
	spotfin sculpin	Icelinus tenuis	--	--	63	29	6	2	--	--	--
	bluespotted poacher	Xeneretmus triacanthus	--	4	50	24	13	--	--	--	--
B	California heart urchin	Spatangus californicus	44	56	19	5	--	--	--	--	--
	northern heart urchin	Brisaster latifrons	78	52	--	10	--	--	--	--	--
	sea mouse	Aphrodita sp	50	4	--	10	6	2	--	--	--
	sablefish	Anoplopoma fimbria	56	12	--	--	--	--	--	--	--
	bigfin eelpout	Lycodes cortezianus	72	20	--	--	--	--	--	--	--

Species Cluster B included 18 species primarily from Site Cluster 2 sites (Upper Slope; Figure VI-12; Appendices Appendix D-D9 through D-D11). The most frequently occurring species in this group overall were northern heart urchin (29 sites; 14% of 210), and California heart urchin and unidentified sponge (26 sites; 12%, each; Appendix D-D9). Ten species in the group occurred in 50% or more of the stations in at least one site cluster, with species occurring at this frequency in 1-2 site clusters (Appendix D-D10). Of these, the most widespread species of importance was northern heart urchin, occurring at greater than 50% of stations in 2 site clusters (Site Clusters 2 and 1; Table VI-9; Appendix D-D10). The most frequently occurring species of this group in a site cluster were northern heart urchin (78% in Site Cluster 2), and bigfin eelpout and offshore blade shrimp (72% each in Site Cluster 2). The most abundant species in the group overall were northern heart urchin (36,074), the sea star *Myxoderma platyacanthum* (10,571), and the brittle star *Asteronyx longifissus* (9,172; Appendix D-D11). These three species were also the most abundant species in a site cluster (Site Cluster 2) with 28,938; 9,460; and 9,169, respectively (Appendix D-D11).

Species Cluster C included 14 species found primarily in Site Cluster 3 (Bays/Harbors Central/South; Figure VI-12; Appendix D-D9 through D-D11). The most frequently occurring species in this group overall were barred sand bass (14 sites; 7% of 210), and diamond turbot and California aglaja (11 sites; 5% each; Appendix D-D9). Four species occurred in 50% or more of the stations in at least one site cluster, (Table VI-9; Appendix D-D10). The most frequently occurring species of this group in a site cluster were barred sand bass (69%), diamond turbot and round stingray (56% each), and California aglaja (50%), all in Site Cluster 3. The most abundant species in the group overall were cobblestone sea squirt (598), mat mussel (508), and warty tunicate (440; Appendix D-D11). These three species were also the most abundant species in Site Cluster 3 with the same respective abundances (Appendix D-D11).

Species Cluster D included 19 species primarily dominant in Site Cluster 7 (Outer Shelf; Figure VI-12; Appendix D-D9 through D-D11). The most frequently occurring species in this group overall were spotted cusk-eel (31 sites; 15% of 210), greenstriped rockfish (29 sites; 14%), and armed box crab (21 sites; 10%; Appendix D-D9). Four species occurred in 50% or more of the stations in at least one site cluster (Table VI-9; Appendix D-D10). Shortspine combfish occurred at this level in 3 site clusters (1, 7, 6). Shortspine combfish was also the most frequently occurring species of this group in a site cluster (81% in Site Cluster 7, 80% in Site Cluster 1, and 76% in Site Cluster 6; Table VI-9). The most abundant species in the group overall were shortspine combfish (1,155), feather star (*Florometra serratissima*; 224), and white paperbubble (*Philine alba*; 188; Appendix D-D11). The most abundant species in a site cluster were shortspine combfish (432, Site Cluster 1; 412, Site Cluster 7), and feather star (202, Site Cluster 7; Appendix D-D11).

Species Cluster E included 23 species which were dominant in Site Cluster 1 (Upper Slope/Outer Shelf; Figure VI-12; Appendix D-D9 through D-D11). The most frequently occurring species in this group overall were slender sole (56 sites; 27% of 210), eastern Pacific bobtail (52 sites; 25%), and fragile sea urchin and ridgeback rock shrimp (24 sites; 24% each; Appendix D-D9). Eleven species in the group occurred in 50% or more of the stations in at least one site cluster (Table VI-9; Appendix D-D10). Fragile sea urchin was most widespread, occurred at this level in 3 site clusters (1, 2, 7; Table VI-9). Slender sole was the most frequently occurring species of this group in a site cluster (100% in Site Cluster 1), followed by fragile sea urchin 92% and blacktip poacher (84%) also in Site Cluster 1 (Table VI-9). The most abundant species in the group overall were fragile sea urchin (20,917), northern heart urchin (8,568), and slender sole (4,559; Appendix D-D11). These were also the most abundant species in a site clusters, with fragile sea urchin 15,897 in Site Cluster 1, northern heart urchin 8,568 in Site Cluster 2, and slender sole (4,038 at Site Cluster 1; Appendix D-D11).

Species Cluster F included 27 species which were most dominant in Site Cluster 4 (Inner Shelf/Bays/Harbors; Figure VI-12; Appendix D-D9 through D-D11). The most frequently occurring species in this group overall were New Zealand paperbubble (52 sites; 25% of 210), California halibut (45 sites; 21%), and California lizardfish (43 sites; 20%; Appendix D-D9). Six species in the group occurred in 50% or more of the stations in at least one site cluster (Table VI-9; Appendix D-D10). California halibut was the most frequently occurring species of this group in a site cluster (88% in Site Cluster 3, Bays/Harbors Central/South), followed by white croaker and queenfish (70 and 65%, respectively, in Site Cluster 4; Table VI-9). The most abundant species in the group overall were blackspotted bay shrimp (1,919), New Zealand paperbubble (881), and white croaker (856; Appendix D-D11). These were also the most abundant species in a site cluster (Site Cluster 4 in all casers), with blackspotted bay shrimp being 1,701, white croaker (839), and New Zealand paperbubble (438; Appendix D-D11).

Species Cluster G included 35 species which were most dominant in Site Cluster 9 (Inner Shelf/Middle Shelf; Figure VI-12; Appendix D-D9 through D-D11). The most frequently occurring species in this group overall were yellow sea twig (41 sites; 20% of 210), California blade barnacle (30 sites; 14%), and California market squid (26 sites; 12%; Appendix D-D9). Three species in the group occurred in 50% or more of the stations in at least one site cluster (Table VI-9; Appendix D-D10). Pacific argentine (*Argentina sialis*) was the most frequently occurring species of this group in a site cluster (63% in Site Cluster 8, Middle Shelf), followed by rosy tritonia (52% in Site Cluster 6, Channel Islands Middle Shelf), and yellow sea twig (50$, Site Cluster 8; Table VI-9). The most abundant species in the group overall were yellow sea twig (1,577), California market squid (384), and shortbelly rockfish (338; Appendix D-D11). These were also the most abundant species in a site cluster, with yellow sea twig being 1,539 in Site Cluster 9, California market squid with 339 in Site Cluster 8, and shortbelly rockfish being 290 in Site Cluster 6 (Appendix D-D11).

Parsimony analysis of Combined Fish and invertebrate Clades

Diversity Analyses. With such a large data set, patterns in matrices of diversity analyses were difficult to discern or summarize (Appendix D-D12). However, Mesquite (a recently developed and sophisticated software; Maddison and Maddison 2004) software allowed employment of mapping modules that literally illuminate these continuous values over and through the cladogram. Species richness or the total number of species or taxa represented by (S) was captured both via inspection of the length of the branches on the cladogram and by mapping. The highest number of taxa or species richness values were found at the stations with the longest branches, namely Stations 4235 and 4029, followed by 4256, 4258, and 4096.

In general, the shallower stations possessed fewer numbers of species than the remaining groups. No real patterns emerge regarding abundance values with the exception of extremely high values found at deep outer shelf Stations 4179 (364 m) and 4091 (428 m) due to very high collections of northern heart urchin and northern heart urchin plus the sea star *Myxoderma platyacanthum*, respectively. The pattern of Margalef's index "d" generally mirrored that seen with the total number of species (S). Pielou's evenness (J') showed highest values in the shallow bays and harbors subclade composed of mainly marina samples bordered by stations 4065 and 4204 on the cladogram (Figure VI-15). The Shannon-Wiener index of diversity (H') tended to produce higher values in the two clades located on the middle shelf containing many of the large POTW stations. Simpson's dominance (1-lambda) showed rather high scores throughout the samples with the general pattern mirroring Pielou's evenness (d').

Although conventional biodiversity indices are presented in Appendix D-D12, the series of new biodiversity measures presented here more accurately reflect taxonomic, and ideally, phylogenetic relationships. The suite of taxonomic distinctness and phylogenetic diversity indices were calculated in Primer v5.2.9. These measures include taxonomic diversity (Δ), quantitative taxonomic distinctness (Δ*), average taxonomic distinctness (Δ+), variation in taxonomic distinctness (Λ+), total phylogenetic diversity ($S\Phi^+$), and average phylogenetic diversity (Φ^+). .Most of these measures have gained immediate acceptance in much of the scientific community in recent years since inception due to their favorable features of being independent of sampling effort, relative to those indices previously employed, and their ability to utilize phylogenetic relationships. These concepts and calculations are presented in Clarke and Warwick (1999), Warwick and Clarke (1995), and Magurran (1988).

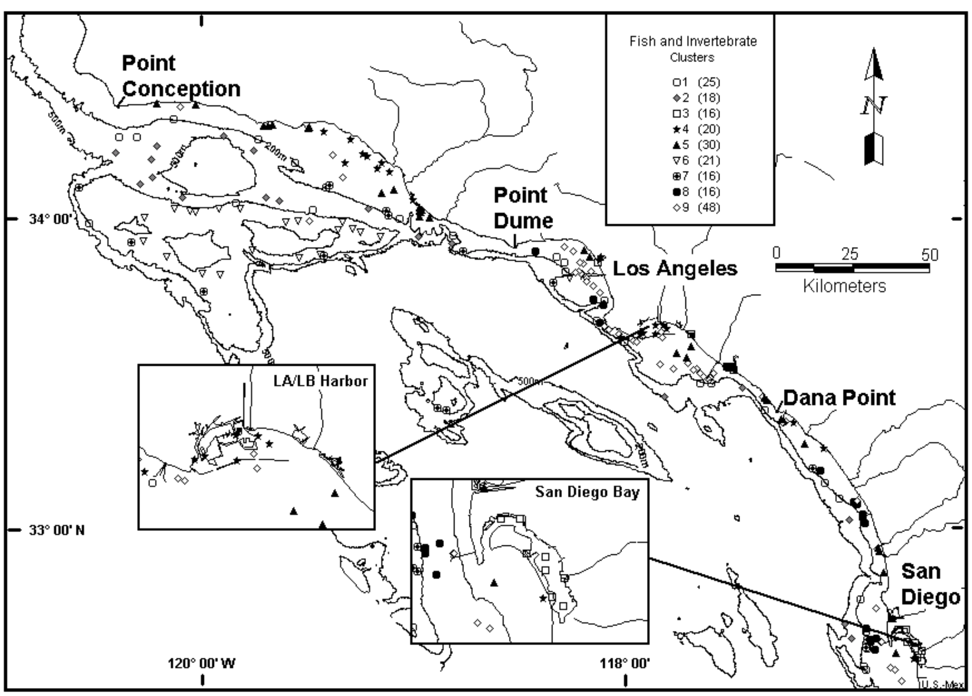


Figure VI-14. Distribution of demersal fish and megabenthic invertebrate site cluster on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003.

Assuming taxonomy reflects phylogeny, which recent systematists have striven to achieve with more confidence through advances in technology (i.e., molecular analyses) and cladistics, a sample having five species of the same genus is less biodiverse than another having five species of differing families. Accepting this to be true, indices integrating both taxonomic distances through a tree as well as abundances captures much more information than those traditional indices, and yet most are more robust with respect to independence of samples size/effort. Taxonomic diversity (Δ) accomplishes these goals by calculating the expected path length between any two individuals chosen at random. Quantitative taxonomic distinctness (Δ^*) still captures the phylogenetic relationships, but on the other hand, removes the influence of dominating abundances to produce an index more reflective of taxonomic hierarchy. This is achieved by dividing (Δ) by the Simpson index. Average taxonomic distinctness (Δ+) is merely the taxonomic breadth of a sample event based on presence/absence. This index is most appealing for data with highly variable or unknown sample size and effort. Total taxonomic distinctness (SΔ+) utilizing presence/absence data is the average taxonomic distance from species to species, and is a useful measure of the total taxonomic breadth of an assemblage; hence an assemblage of 20 closely-related species would be calculated to be less diverse than an assemblage of 10 distantly-related species. Variation in taxonomic distinctness (Λ+) can elicit differences among samples having the same Δ+ but different taxonomic or phylogenetic tree constructions by focus on the variance of the taxonomic distances between each pair of species about their Δ+ value. Total phylogenetic diversity ($S\Phi^+$) offers comparison of samples based on cumulative branch lengths of their full trees. This measure is incapable of discriminating samples of equal tree length but differential taxonomic distributions within. Average phylogenetic diversity (Φ^+), based on presence/absence data and being the quotient of $S\Phi^+/S$, is the contribution that each species makes on the total tree length. As species numbers increase, the later two indices values change noticeably rendering them sample-size/effort dependent.

Mapping the aforementioned phylodiversity indices back onto the cladogram (not shown herein, but available from CLAEMD upon request) showed that the general pattern for both total phylogenetic diversity and total taxonomic distinctness mirror the pattern seen with the total number of species (S) very closely. Higher average phylogenetic diversity values were seen in the 2-7 m marina clade and the upper slope clade (Figure VI-15). Average taxonomic distinctness values were generally higher in the 2-7 m marina clade and in the deeper upper slope clade and Channel Island clade; lower values in the variation in taxonomic distinctness also occurred in these three aforementioned clades.

Station Groupings. The most parsimonious reconstruction of the combined fish and invertebrate data resulted in a cladogram with a tree length of 2233, a consistency index of 0.225 (maximal value 1.0), and a retention index, which is a measure of branch support, of 0.4417 (maximal value 1.0). The topology of the cladogram (Figure VI-15) reveals several readily identifiable groups or station clades distinguished by depth as well as by predetermined shelf and subshelf zones (strata). In addition, since cladograms are additive trees, branch lengths are indicative of species diversity or the number of species found in a given sample. Thus, providing an additional dimension of information not available in the conventionally used ultrametric trees derived from overall similarity measures in phenetic approaches.

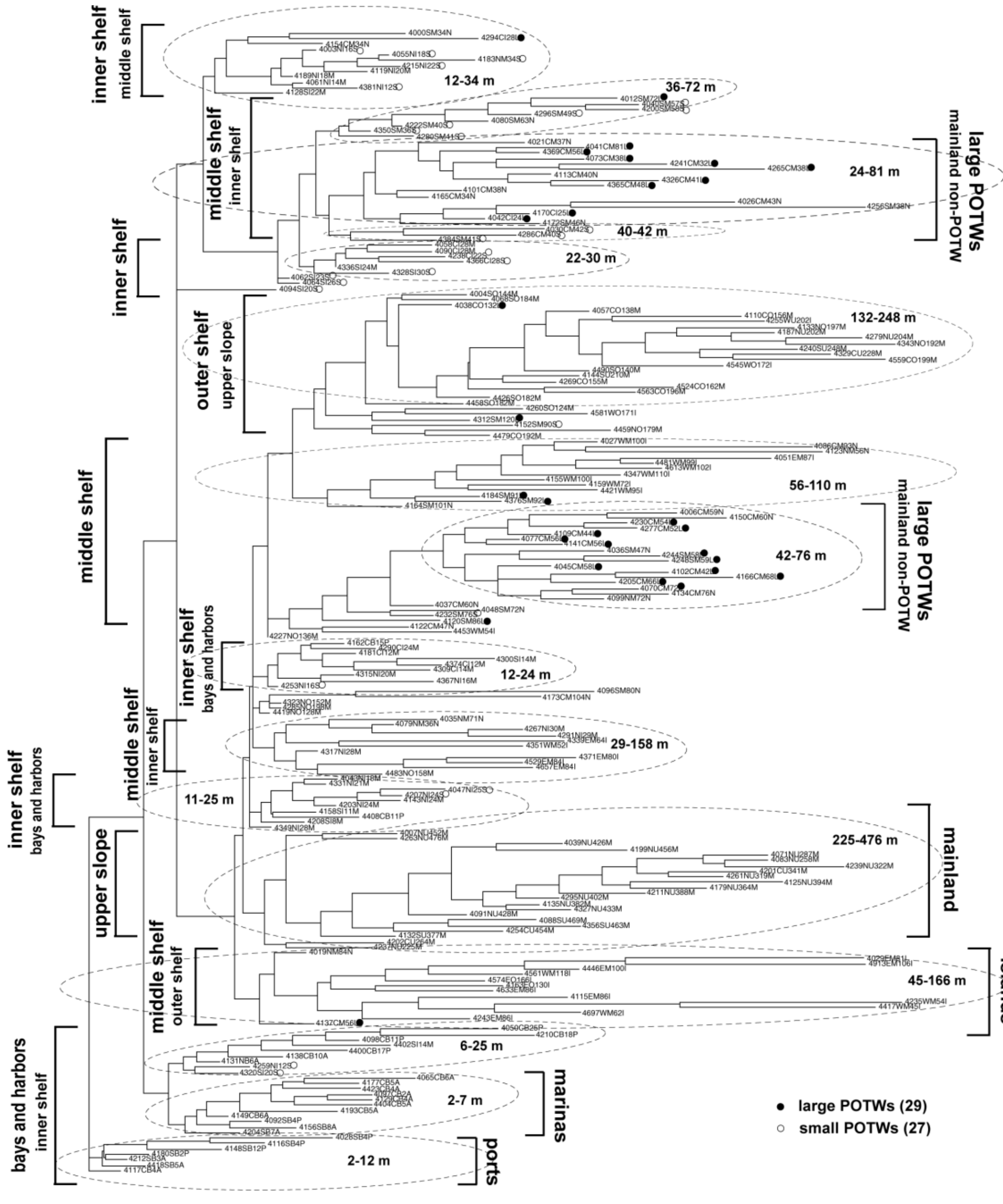


Figure VI-15. Parsimony analysis of endemicity (PAE), or q-mode, cladogram showing the relationships of stations based on their taxa inventories on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003. Brackets on the left identify shelf zones. Brackets on the right identify sub-shelf zones. Larger font size represents majority membership of each bracket. Smaller font size represents minority membership of each bracket. Station Code=Station (xxxx), Region (a=letter), Shelf zone(a), depth(x-xxx), subshelf(a). Region: C=Central, E=Warm (Southeast channel islands), N=Northern, S=Southern, W=Cool (Northwest channel islands). Shelf zone: B=Bays and Harbors, I=Inner Shelf, M=Middle Shelf, O=Outer Shelf, U=Upper Slope. Subshelf: A=Marinas, I=Islands, L=Large POTWs, M=Mainland, N=Mainland non-POTW, P=Ports, S=Small POTWs.

When mapping depth back on to the tree (Figure VI-15) a very clear pattern of assemblages grouping by depth is evident. The basal clades are entirely composed of stations from very shallow depths and generally from bays and harbors. The first 2-12 meter clade is mostly a grouping of samples from San Diego Bay, followed by a 2-7 m clade of primarily Newport Harbor samples with a few San Diego bay samples and a single Marina Del Rey sample. The sister clade “I” is a 6-25 m grouping of a single San Diego sample, followed by shallow Ventura County samples, and the remaining collected from Los Angeles and Long Beach Harbors. The next group or clade, located at the “top” of the cladogram, is also a relatively shallow grouping of samples from 12-34 m with basal components from off San Diego, Long Beach, and the majority collected from the Oxnard and Santa Barbara nearshore areas. The adjacent stations 4094, 4062, and 4064 range from 20-26 m and located off northern and central San Diego County. The next clade is composed of stations from 24-30 m found from San Diego, southern Orange County, and off Long Beach. The sister clade to these stations group slightly deeper stations from southern Orange County to San Diego County in a 36-72 m subclade, with five of seven stations representing small POTWs. The subclade sister to this group is comprised of samples from a similar depth regime, 32-81 m, with smaller groupings exhibiting extreme site or location fidelity, with small sets of stations all from off Newport Beach, Santa Monica bay, and Palos Verdes. This middle-shelf group also contains many large and small POTWs sites. In fact, 43% of these stations are designated as such. The remaining “middle” portion of the cladogram is composed primarily of middle shelf stations. The most-basal sister clade is composed primarily of all “island” stations, with the only exceptions being the two basal stations, 4137 (a 56 m large POTW station located off Newport Beach) and 4019 (located in the Santa Barbara Channel in 84 m). The remaining stations represent a grouping of Channel Island stations that have a tendency for island specific samples to group together. The next clade is a distinct upper slope grouping with station samples ranging from 225-476 m. Once again, not only is there great fidelity with these deep stations grouping together, but many of the sub-groupings, or subclades, are composed of stations all from similar areas. For example, all stations near San Miguel island, stations in the Santa Barbara channel near Point Conception, as well as those deep, more southern stations off San Diego, and the San Pedro Channel group accordingly into their own respective subclades, indicating regional groupings or subdivisions within the more general shelf zone groups.

The next group on the cladogram bordered by stations 4349 and 4043, is a shallow inner shelf group composed mainly of stations off Santa Barbara County, with the three basal stations 4208, 4408, and 4158 located in San Diego County, Los Angeles Harbor, and southern Orange County, respectively. This shallow clade is followed by another shallow 12-24 m clade with stations located from as far south as San Diego County to almost Point Conception. The next group has stations located from 29-84 m with a single basal sample (Station 4483) collected at 158 m. This group is composed of stations located off deep northern waters from this survey, as in the case of Station 4483, and then a general grouping of northern middle to inner shelf stations off the Santa Barbara coast as well as a few stations located near San Miguel and Santa Cruz Islands. A small, relatively unresolved (on the cladogram) set of stations, 4323 (152 m), 4285 (198 m), and 4419 (128 m) are all located near each other in the eastern edge of the Santa Barbara Channel. A lone station, 4227 (136 m), is also found in the same area as these three stations in the next clade at a node removed.

The next major clade is bordered by stations 4453 and 4006. This is a middle shelf group occurring at depths from 42-86 m. The most apical clade is composed mainly of stations located near large POTWs from 42-76 m. The most apical subclade bordered by stations 4006 to 4141, are all stations in the Santa Monica Bay, proximal to the Hyperion's 5-Mile Outfall. The base of the next sister clade is composed of stations with large POTW designations, all of which are located off Mission Bay (Station 4036) and Point Loma (Stations 4244 and 4248). The remaining stations are composed of stations located in the Santa Monica Bay or off the Palos Verdes Peninsula, with a single station from off Santa Barbara (Station 4099). The remaining grade of stations, bordered by 4037 and 4453, range from off Malibu (Station 4037) to large and small POTWs off San Diego County (Stations 4120 and 4232), with the 54 m Station 4453 located near Santa Rosa Island.

The final large clade of the analysis is composed of a deep (56-110 m) middle shelf group bordered by stations 4027 and 4164, the sister clade or group to the slightly deeper (132-248 m) outer shelf group bordered by Stations 4479 and 4004. The 56-110 m middle shelf group is composed of three basal stations (4164, 4376, and 4184) off Point Loma. With the exception of Station 4086 near the Redondo Canyon, the rest of the clade is composed of stations located in the Santa Barbara Channel near San Miguel, Santa Rosa, and Santa Cruz Islands.

The final clade to be discussed is the 132-248 m upper slope clade, the sister group to the 56-100 m middle shelf clade. This group has members located throughout the entire spatial sampling regime from off Point Loma, small subclades of Santa Monica Bay stations, offshore Newport Beach Stations, and a large terminal group of mainly Santa Barbara Channel and Channel Island Stations.

Abiotic Variable Mapping. Mapping discrete variables back onto the cladogram in Mesquite 1.05 (Maddison and Maddison 2004) was also conducted to look for geographical patterns relating to regions, shelf, and subshelf zones.

Five regions, mainland central, warm southeast Channel Islands, mainland northern, mainland southern, and cool northwest Channel Islands were mapped (but not shown herein due to constraints on color graphics in this report) onto the cladogram (Figure VI-15) as discrete variables. In general, regions were quite distinct within a given clade (stratum or substratum). The bays and harbors clade at the base of the tree broke down into distinct southern versus central subclades. The island clade or stratum was composed of a cool northwest subclade and a warm southeast Channel Island subclade. The very deep (225-476 m) upper slope clade was composed of some southern and central stations in the basal portion of the clade, with all but one station or terminus composed of northern station samples. The 42-76 m middle shelf large POTW clade was composed primarily of central region stations with a southern subclade embedded within. The relatively deep (132-248 m) outer shelf-upper slope clade had many southern components at the base of the clade, followed by many mainland central components, with a terminal clade composed of four mainland northern station samples. Finally, the 24-81 m large POTW clade near the top of the cladogram is mostly composed of mainland central stations with its 36-72 m sister clade composed of all mainland southern stations. The most apical 12-34 m clade has southern and central basal components with the remaining cohorts all composed of mainland northern stations.

Five shelf zones, bays and harbors, inner shelf, middle shelf (31-120 m), outer shelf (121-200 m), and upper slope (201-500 m) were mapped onto the cladogram. Very distinct and congruent character mapping clearly distinguished the clades. The basal clades were composed primarily of samples belonging to the bays and harbors shelf zones with two inner shelf stations. The next clade located at the top of the cladogram was composed primarily of inner shelf terminating in middle shelf station samples, with one bay and harbor station. The next clade which is the sister clade to the rest of the cladogram is a middle shelf clade with two outer shelf stations. This is followed by a grade of more middle shelf stations with inner shelf components. The next group is entirely a middle shelf clade which is the sister clade to the shallower 132-248 m outer shelf/upper slope clade. Finally, the deepest upper slope clade, with station depths ranging from 225-476 m, stands alone as the sister clade to the three aforementioned shelf groups.

Six subshelf zones, bays and harbors, islands, mainland, mainland non-POTWs, small POTWs, and large-POTWs were mapped onto the cladogram as discrete character states. Again, there is a large degree of subshelf character state distribution and clade fidelity. The bottom grade of stations are primarily bays and harbors with two shallow (12 and 20 m) small POTW stations. The top clades of the cladogram show relatively nested subsets of small POTWs, large POTWs, and non-POTW stations within that group of clades. The rest of the cladogram shows similar patterns of some clades being primarily composed of island stations, mainland stations, and various nested groups of large POTWs, mainland non-POTW, small POTW, and mainland stations. In fact, 65% of the stations found in the most apical set of clades bordered by stations 4094 to 4000 are categorized as either small POTWs or large POTWs, while the other middle shelf group (42-86 m) bordered by stations 4120 and 4006 possesses 67% of the stations categorized mainly as large POTWs. [Note: Portable document format (PDF) files of all mapped variables are available from parsimony analysis section authors Dr. Greg Deets and Curtis Cash (both CLAEMD) at request].

Species Mapping. All 475 taxa were used in the analysis and all taxa were subsequently mapped back onto the cladogram. Character based cladistic methods create testable hypotheses of station relationships in this context, which also yield a highly informative summary of species distributions. Thus, it is the only method in systematics that functions as a general reference classification in biology. In other words, the various species that distinguish certain clades determine the groupings or relationships between the sample stations or strata. Although it is impractical to describe the specific distributions from the character mapping procedure of all of the species, a description of some of the more parsimony-informative distributions follow.

The various bay and harbor subclades were held together (minimum of two occurrences) by barred sand bass, California halibut, spotted sand bass, diamond turbot, specklefin midshipman, the sponge Porifera spp. SD4, tuberculate pear crab, shovelnose guitarfish, longstalk sea squirt (*Styela montereyensis*), cobblestone sea squirt, yellowfin croaker, round stingray, slough anchovy, Pacific calico scallop, black croaker (*Cheilotrema saturnum*), yellow-green sea squirt, yellow shore crab (*Hemigrapsus oregonensis*), kelp scallop, Hemphill fileclam (*Limaria hemphilli*), scaly tunicate (*Microcosmus squamiger*), warty tunicate, mat mussel, unidentified mussel *Mytilus* spp., western mud nassa (*Nassarius tiarula*), California aglaja, unidentified oyster *Ostrea* spp., California spiny lobster (*Panulirus interruptus*), and Pacific acorn barnacle.

The two aforementioned clades, composed of the many small and large POTW stations, convergently (as they are not sister clades) shared higher occurrences and abundances of California scorpionfish, California tonguefish, brown spiny doris (*Acanthodoris brunnea*), Pacific argentine, California sand star, roughback sculpin, longfin sanddab, yellowchin sculpin, and gray sand star.

The Channel Islands clade and its many smaller subclades are held together by the shared occurrences and increased abundances of red sea urchin (*Strongylocentrotus franciscanus*), variegate topsnail (*Calliostoma variegatum*), furrowed rock crab (*Cancer branneri*), the sea cucumbers *Cucumaria piperata* and *Havelockia benti*, blood star (*Henricia leviuscula*), spotfin sculpin, rock sole, the heart urchin *Nacospatangus laevis*, spinypalm hermit (*Parapagurodes laurentae*),slim sculpin (*Radulinus asprellus*), and banded sea star (*Sclerasterias heteropaes*).

As mentioned above, the deep outer shelf/upper slope station samples grouped into two distinct and somewhat removed clades. A rather deep upper slope clade with station depths ranging from 225-476 m and a shallower outer shelf subclade composed of stations found at depths from 132-248 m. This shallower outer shelf 132-248 m subclade bordered by stations 4004 and 4479 on the cladogram is the sister clade to a 56-110 m middle shelf subclade. It should be noted that of the 27 stations included in this 132-248 m subclade, only two stations, 4329 (228 m) and 4240 (248 m), are significantly deeper than 200 m. The majority of the stations are near 200 m and shallower. Thus, this should be considered an outer shelf clade. This combined middle shelf/outer shelf clade bordered by stations 4004 and 4164 on the cladogram groups together due to the shared occurrences and/or higher abundances of roughdisk brittlestar (*Amphichondrius granulatus*), the brittlestar *Amphiura arcystata*, spindle topsnail (*Calliostoma turbinum*), spotted cusk-eel, Pacific sanddab, moss crab (*Loxorhynchus crispatus*), gray sand star, moustache bay shrimp, plainfin midshipman, greenstriped rockfish, stripetail rockfish, and shortspine combfish.

The stations in the deep 225-476 m upper slope clade, bordered by stations 4039 and 4237 in the cladogram, were grouped together by many species unique or much more abundant in this environment: the anemone *Actinostola* spp. A, two-tone Amphissa (*Amphissa bicolor*), sablefish, the turrid *Antiplanes thalea*, the echiuran *Arhynchite californicus*, the ophiuroid *Asteronyx longifissus*, bigeye poacher (*Bathyagonus pentacanthus*), northern heart urchin, blacktail snailfish (*Careproctus melanurus*), longhorn decorator crab (*Chorilia longipes*), Pacific hagfish (*Eptatretus stoutii*), dogface witch eel, boreopacific armhook squid (*Gonatopsis borealis*), the seapen *Halipteris californica*, California smoothtongue (*Leuroglossus stilbius*), tentacle-shedding anemone (*Liponema brevicornis*), bigfin eelpout, black eelpout, Pacific hake, the sea star *Myxoderma platyacanthum*, the echiuran *Nellobia eusoma*, California grenadier, the ophiuroid *Ophiosphalma jolliense*, the holothuroid *Pannychia moseley*i, filetail catshark, the sea pen *Pennatula californica*, the sea star *Pseudarchaster pusillus*, aurora rockfish (*Sebastes aurora*), shortspine thornyhead, longspine thornyhead (*Sebastolobus altivelis*), northern lampfish, and signet ring anemone (*Stephanauge annularis*). These were responsible for this nested topology.

Species with relatively restricted (albeit imperfect) distributions or elevated abundances to the outer shelf clade include rex sole, basket star (*Gorgonocephalus eucnemis*), spotted ratfish (*Hydrolagus colliei*), threadfin sculpin (*Icelinus filamentosus*), blackbelly eelpout, slender sole, southern spinyhead, gigantic anemone (*Metridium farcimen*), smooth western nassa (*Nassarius insculptus*), gray shrimp, flagnose bay shrimp, bluebarred prickleback, Eastern Pacific bobtail, splitnose rockfish, greenblotched rockfish, blacktip poacher, and shortspine combfish. Incidentally, shortspine combfish was collected in higher numbers and frequency in the Channel Island clade.

Species Groupings. The parsimony analysis of co-occurring species (PACOS) resulted in several very similar equally parsimonious trees. Tree number 1 (Appendix D-D13a-d) was randomly chosen to present.

In general, species groups derived from the PACOS analysis were amazingly congruent with that found in the recurrent groups analysis, but with larger suites of species as no species are excluded in the analysis and there is not a secondary rationale for species exclusion as determined by the index of affinity in recurrent group analyses. Additionally, PACOS cladograms offer information regarding how widely occurring or how often the various species co-occurred and do so by the relative length of the branches in the cladogram. Being a cladogram, relationships of species groups to other species groups are easily determined via inspection. However, many groups are composed of very unique and somewhat rarely occurring species; hence these will have unresolved relationships (nodes emerging directly from lower levels with neighboring groups. Their apparent closeness on the cladogram should not be confused or interpreted as being closely associated or related in an ecological context.

Examining the PACOS cladogram (Appendix D-D13a-d) is probably the easiest way to visualize the fidelity of groupings between this method and recurrent group analysis. Appendix D-D13a and b represents the top half of the cladogram divided up into various subclades of species groupings. Subclade A (Appendix D-D13a) in the upper left hand corner contains recurrent groups 30, 34 and 37; subclade B (Appendix D-13a) contains recurrent groups 25, 35, with Dover sole from recurrent group 41, and California sea cucumber from recurrent group 29. Subclade C (Appendix D-D13b) contains members from recurrent groups 7, 10, 22, 23, 24, 27, 39, 44, 46, and gray sand star from recurrent group 35, and California sea slug from recurrent group 41. Subclade D (Appendix D-D13b) is composed of species from recurrent groups 19, 28, 41, 43, 47, 50, 53, and 54. Subclade F (Appendix D-D13c) contains recurrent groups 3, 4, 6, 9, 16, 51, 52, 55, 57, 58, and 59. Recurrent groups 1, 2, 18, 21, 26, 32, 33, 40, 42, 45, 48 are found in subclade G (Appendix D-D13c). Subclade H (Appendix D-D13d) holds recurrent groups 13, 14, 15, 17, 20, 31, 38, and 60. Finally, subclade I (Appendix D-D13d) consists of many species from recurrent groups 5, 8, 11, 12, 25, 36, and 49.

Both the PACOS analysis and recurrent group analysis revealed several subclades of species groups diagnostic of specific ecological strata. Notable examples include subclade B (Appendix D-D13a) with brokenspine brittlestar, plainfin midshipman, stripetail rockfish, a trailtip seapen *Acanthoptilum* sp, white sea urchin, all from recurrent group 35 and Dover sole a member from recurrent group 41. At the base of this group are several members of recurrent group 25, namely, California blade barnacle, California scorpionfish, bigmouth sole, roughback sculpin, yellow sea twig, and halfbanded rockfish. Other members include Pacific spiny brittlestar (from recurrent group 41), and California sea cucumber (from recurrent group 29). The remaining species, Loebeck's simnia (*Neosimnia loebbeckeana*) grouping with its specific food source, California sea pen (*Virgularia californica*), along with mosaic sand star (*Luidia armata*), fantail sole, and brown spiny doris did not earn recurrent group membership, but enjoy membership in subclade B. The species composing this clade are generally middle and outer shelf inhabitants, but fantail sole is characteristic of the inner shelf.

Closely akin to subclade B is subclade E (Appendix D-D13b), represented by California sand star, longfin sanddab, English sole, hornyhead turbot, Pacific sanddab, pink seaperch, longspine combfish, yellowchin sculpin, California tonguefish, New Zealand paperbubble, California lizardfish, and pygmy poacher all belonging to recurrent group 25. Bay goby from recurrent group 29, speckled sanddab from recurrent group 14, and red octopus from recurrent group 41 are also found nested in this clade. Finally, the other species that did not earn recurrent group membership include Pacific argentine, spindle topsnail, pink rockfish (*Sebastes eos*), Alaska bay shrimp, and California market squid. The aforementioned species found in subclade E are generally common middle shelf inhabitants.

The apical portion of subclade D (Appendix D-D13b) contains fragile sea urchin, slender sole, slender blade shrimp, and rex sole all from recurrent group 50; blacktip poacher, moustache bay shrimp, blackbelly eelpout, flagnose bay shrimp, and bluebarred prickleback from recurrent group 47, shortspine combfish from recurrent group 43, and Eastern Pacific bobtail and ridgeback rock shrimp both from recurrent group 41. The remaining species that were not included in any recurrent group membership consist of California king crab, fish-eating star (*Stylasterias forreri*), gigantic anemone, greenblotched rockfish, southern spinyhead, and bearded eelpout (*Lyconema barbatum*). All of the species in this clade are known to be members of the outer shelf to upper slope ecosystem.

Subclade F (Appendix D-D13c) contains an interesting group composed of offshore blade shrimp, northern heart urchin, orange bigeye octopus, splitnose rockfish, Pacific hake, California heart urchin, sea dandelion, Pacific heart urchin all from recurrent group 51, shortspine thornyhead and bigfin eelpout both from recurrent group 52, dogface witch-eel and California grenadier both from recurrent group 57, and blackbelly dragonfish, bulldog lightfish, and slender hatchetfish all from recurrent group 58. The remaining species not associated with any recurrent groups were aurora rockfish, longhorn decorator crab, the sea pen *Halipteris californica*, and the wide depth ranging porcelainclaw hermit (*Phimochirus californiensis*). This group of species represents primarily an upper slope community with some “bleeding” into the outer shelf.

The PACOS analysis further identified interesting species subgroups not recognized in the recurrent group effort. For example, subclade G (Appendix D-D13c) contains a small group of species containing a nudibranch *Armina* sp A, rock sole, the heart urchin *Nacospatangus laevis*, Santa Barbara spindle (*Fusinus barbarensis*), spinypalm hermit, fringed sand star (*Luidia athenosoma*), spotfin sculpin, feather star, curlfin sole, spotted cusk-eel, and orange sand star, which when mapped backed onto the cladogram show a striking propensity to be associated with the Channel Island clade of station samples.

Subclade H (Appendix D-D13d) has an interesting group composed of graceful rock crab (*Cancer gracilis*), purple sea pansy (*Renilla koellikeri*), Pacific staghorn sculpin (*Leptocottus armatus*), shiner perch, white seaperch, and Pacific pompano. These co-occurring species represent community members often associated with exposed (high-energy) inner shelf environments.

Finally, Subclade I (Appendix D-D13d) with the small group composed of bat ray, channeled nassa (*Nassarius fossatus*), spotted turbot, and Pacific electric ray, seem to represent another group from shallow mainland areas and the mouths of bays and harbors (albeit the association of bat ray and Pacific electric ray most likely represent an artifactual relationship, due to their wide-ranging and highly mobile life histories).

Nonmetric Multidimensional Scaling. Arguably, one of the better ordination techniques is the method of nonmetric multidimensional scaling (NMDS). NMDS was carried out on the patristic distance (branch-length) matrix derived from the cladistic analysis (PAE cladogram). Stress values for the 2-D and the two 3-D (Figure VI-16) configurations were 0.24 and 0.18, respectively. The lower the stress value, the better the correspondence between the NMDS map or plot and the rank order of dissimilarities amongst the samples.

Subshelf zones were treated as factors in both of the 2-D and 3-D configurations. In general, like zones grouped together, albeit imperfectly, and the NMDS was able to clearly distinguish the 2 pairs of the highly species rich island stations, represented by the 2 pairs of distant dots on the 2-D NMDS configuration (Figure VI-16).

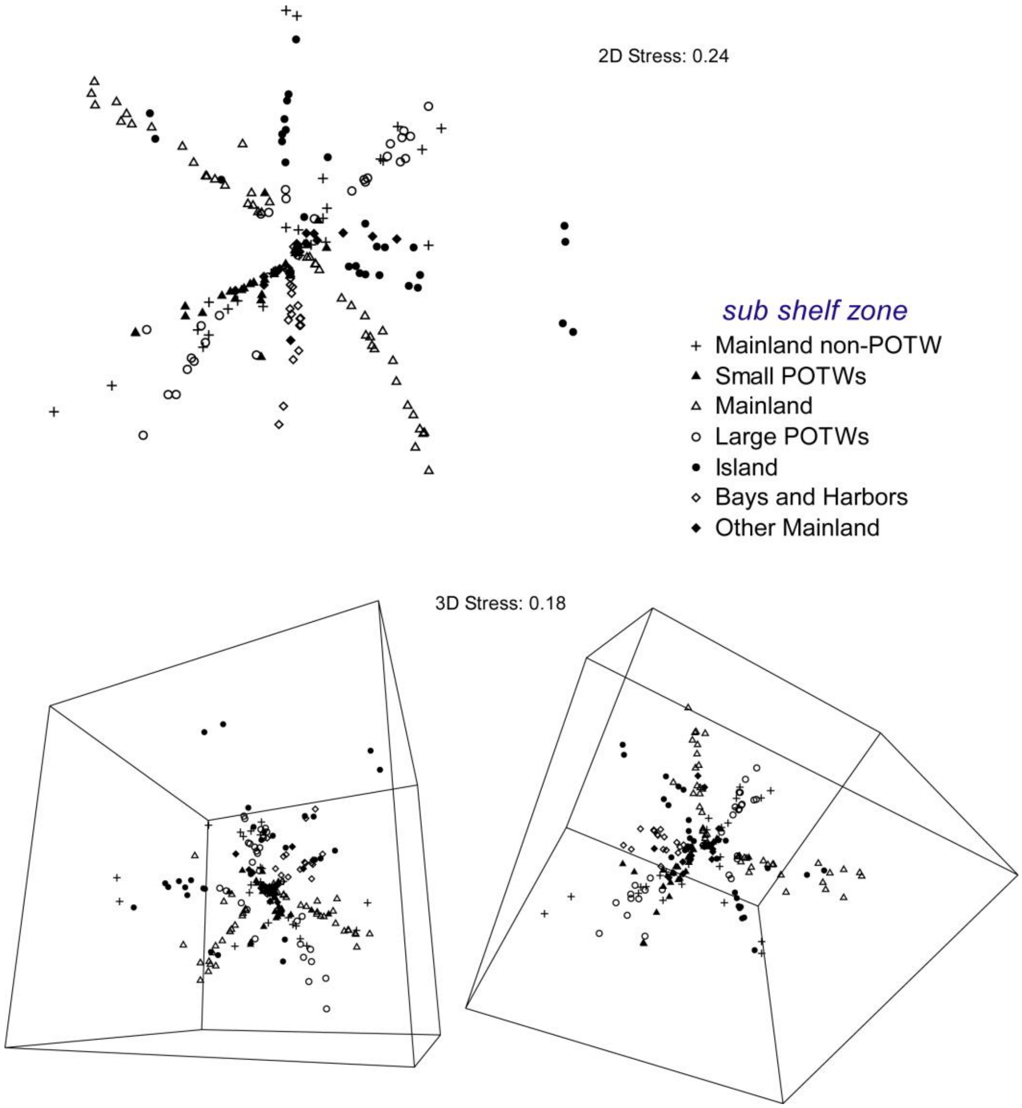


Figure VI-16. Stress configurations for nonmetric multidimensional scaling results of site clades of fishes and invertebrates.

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. Two fish indices, the fish response index (FRI) and fish foraging guild (FFG) index were used to assess alterations in fish assemblages. The FRI was applied to the entire survey area whereas the FFG was applied only to the middle shelf area. The megabenthic invertebrate response index (MIRI) was used for invertebrate effects and the trawl response index (TRI) was used for combined fish and invertebrate effects. Index values by station are given in Appendix D-D14.

Based on the FRI, 96% of the area of the SCB (165 stations) was classified as reference (normal) and 4% (25 stations) as nonreference (abnormal or disturbed); no index could be calculated for 1 station in San Diego Bay and 24 on the upper slope due to being shallower or deeper, respectively, than the range of 10-200 m depth range from which the index was developed (Figures VI-17 through VI-19). The highest percent of nonreference area in a subpopulation for fish assemblages was on the inner shelf (24%), followed by bays and harbors (15%); none of the middle shelf sites were classified as nonreference and only a few outer shelf stations were nonreference (Figures VI-17 and VI-18). Inner shelf small POTWs had the highest percent of nonreference area in the inner shelf zone (47%), followed by other mainland inner shelf areas (24%; Figure VI-18). Some of the nonreference inner-shelf POTW areas had high abundance of speckled sanddab and curlfin sole; the latter species was typical of the Palos Verdes Shelf in 1970s but not so in the 1980s and 1990s.

The FFG index indicated that 81% of the middle shelf zone was classified as reference and 19% classified as nonreference for fish assemblages (Figure VI-20). In the middle shelf zone where the index was applied, the Channel Islands had the highest percent of nonreference area for a region (41%). Of two subpopulations in this region (NW Channel Islands and Southwest Channel Islands), 46% of the NW Channel Islands and 36% of the SW Channel Islands were nonreference (Figures VI-20 and VI-21)**.**

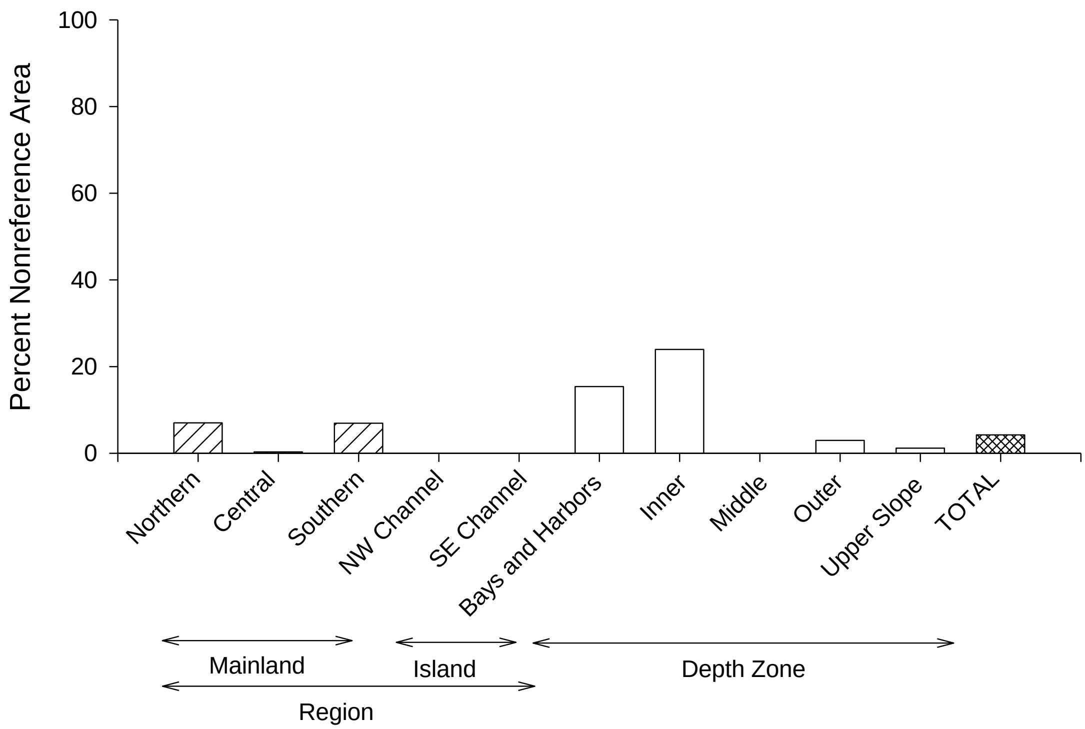


Figure VI-17. Percent of nonreference area by subpopulation on the southern California shelf and upper slope at depths of 2-476 m for the Fish Response Index (FRI), July-October 2003.

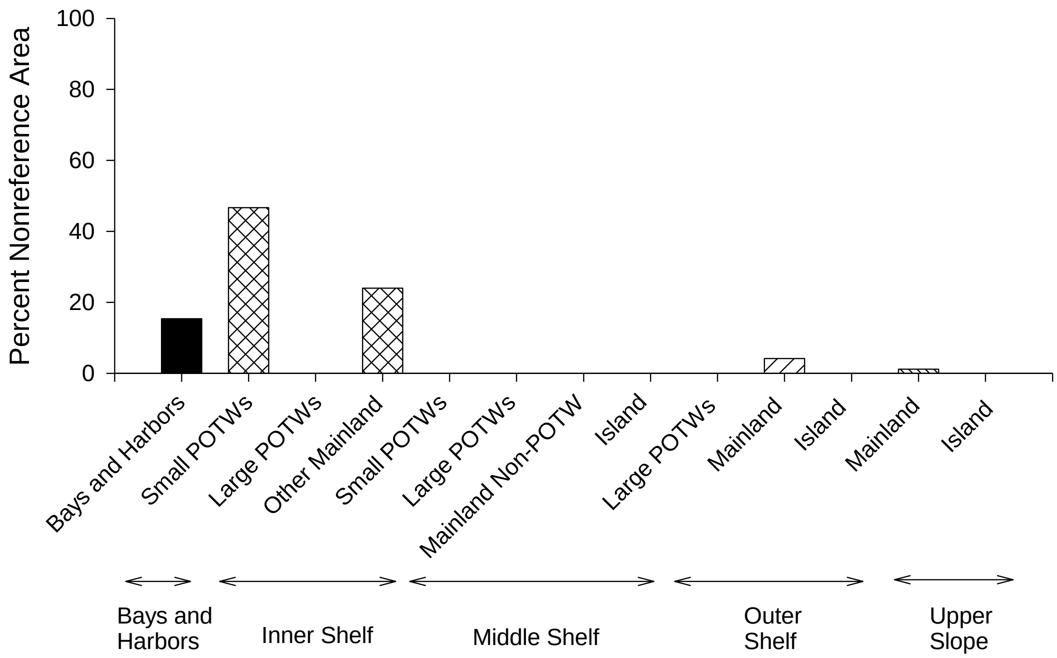


Figure VI-18. Percent of nonreference area by shelf zone subpopulation on the southern California shelf and upper slope at depths of 2-476 m for the Fish Response Index (FRI), July-October 2003.

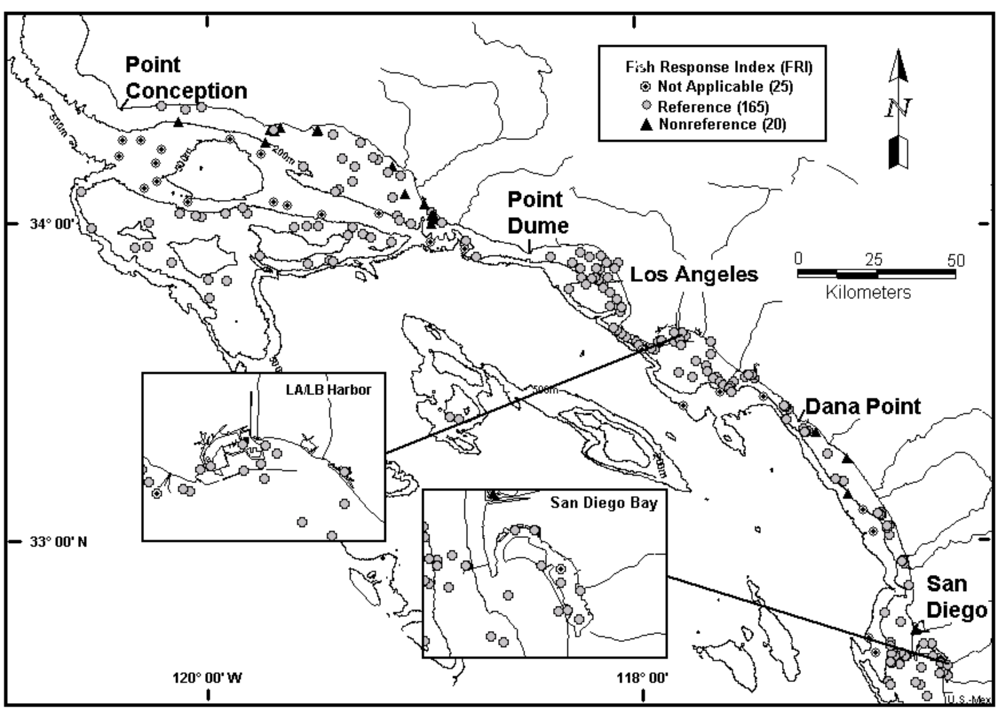


Figure VI-19. Distribution of response levels for Fish Response Index (FRI) on the southern California shelf at depths of 2-476 m, July-October 2003.

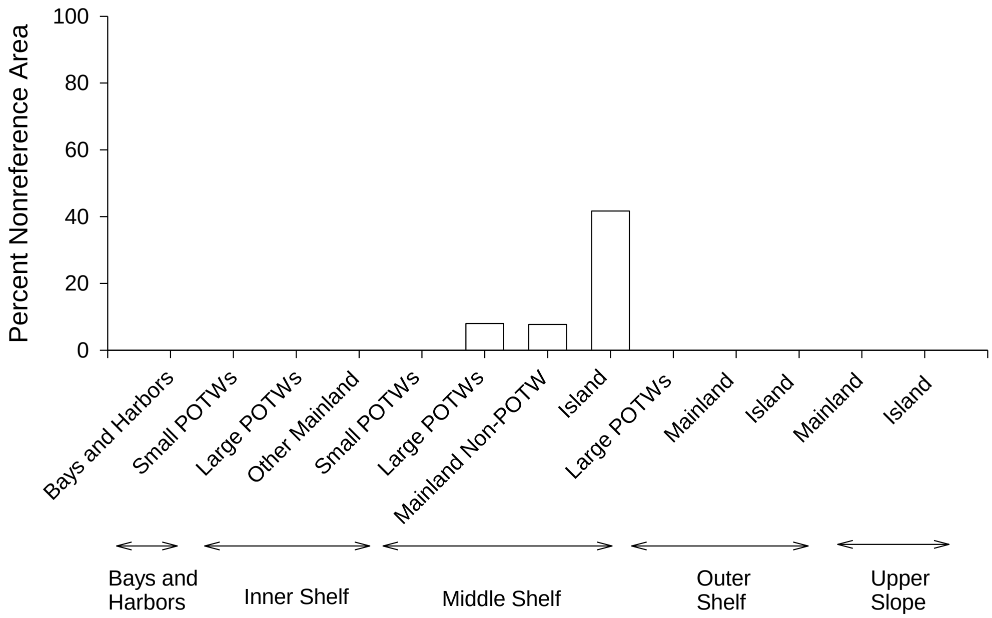


Figure VI-20. Percent of nonreference area by shelf zone subpopulation on the southern California shelf and upper slope at depths of 2-476 m for the Fish Foraging Guild Index (FFG), July-October 2003.

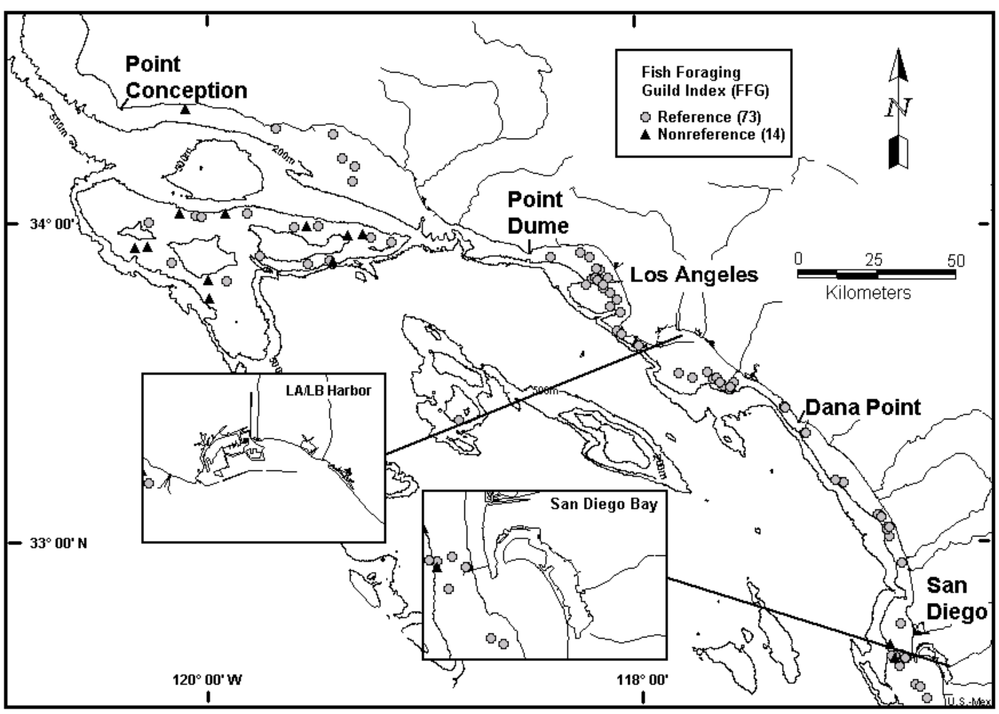


Figure VI-21. Distribution of response levels for Fish Foraging Guild Index (FFG) on the southern California shelf at depths of 2-476 m, July-October 2003.

For the MIRI index, 84% of the area of the SCB was classified as reference and 16% as nonreference; an index could not be calculated for 30 stations in the area, mostly on the upper slope and in San Diego Bay. By shelf zone, the highest percent of nonreference area for invertebrate assemblages was in bays and harbors (53%), followed by the inner shelf zone (32%) (Figure VI-22). By human-influence subpopulation, all bay/harbor subpopulations were relatively high in nonreference areas, with the other mainland subpopulation being the highest (64%; Figure VI-23). Similarly, all mainland region inner shelf populations were relatively high in nonreference areas, with the other mainland subpopulation (usually near river mouths) being the highest (64%). In the bay/harbor subpopulation, nonreference sites were most common in LA/LB Harbor (Figure VI-24). The index could not be calculated for a relatively high number of sites in San Diego Bay and the upper slope due to insufficient numbers of appropriate species for calculating the index.

Using the TRI, 92% of the area of the SCB was classified as reference and 8% as nonreference. The TRI had the highest percent of nonreference area in the bays and harbors (35%), followed by the inner shelf zone (31%; Figure VI-25). Of subpopulations within the inner shelf subpopulation, percent nonreference was 32% for other mainland and 27% for SPOTWs (Figure VI-26). In the inner shelf zone, nonreference areas were generally found near river mouth areas (Figure VI-27).

Discussion

Biointegrity Assessment

The biointegrity indices that were applied to the SCB as a whole (i.e., FRI, MIRI, and TRI) showed that 81-96% of the SCB area was classified as reference (normal) with 4-19% being nonreference (abnormal or disturbed). These indices could not be calculated in 0-14% of the stations. For the middle shelf zone, the FFG index indicated that 41% of the area (primarily on the Channel Island Shelf) was classified as nonreference. For the SCB-wide indices, the highest percent of nonreference area were found in the bay/harbor and in the inner shelf river mouth subpopulation (particularly near the Santa Clara River mouth). Most of the sites where the MIRI could not be calculated were in San Diego Bay, with others in LA/LB Harbor and river mouth areas (Figure VI-23). These areas had insufficient index species because species richness was greatly reduced (e.g., river mouth areas) or the fauna was dramatically different from the coastal fauna upon which the indices are based (e.g., San Diego Bay). All of the response indices (FRI, MIRI, and TRI) were developed from fish data collected on the mainland shelf from 10-200 m from 1973 to 1994 (Allen *et al.* 2001a). Since the bay fauna differs from the coast, the indices become less effective in this region. However, nonreference assemblages also occurred in LA/LB Harbor, and on the Santa Barbara Shelf, suggesting that other explanations are needed.

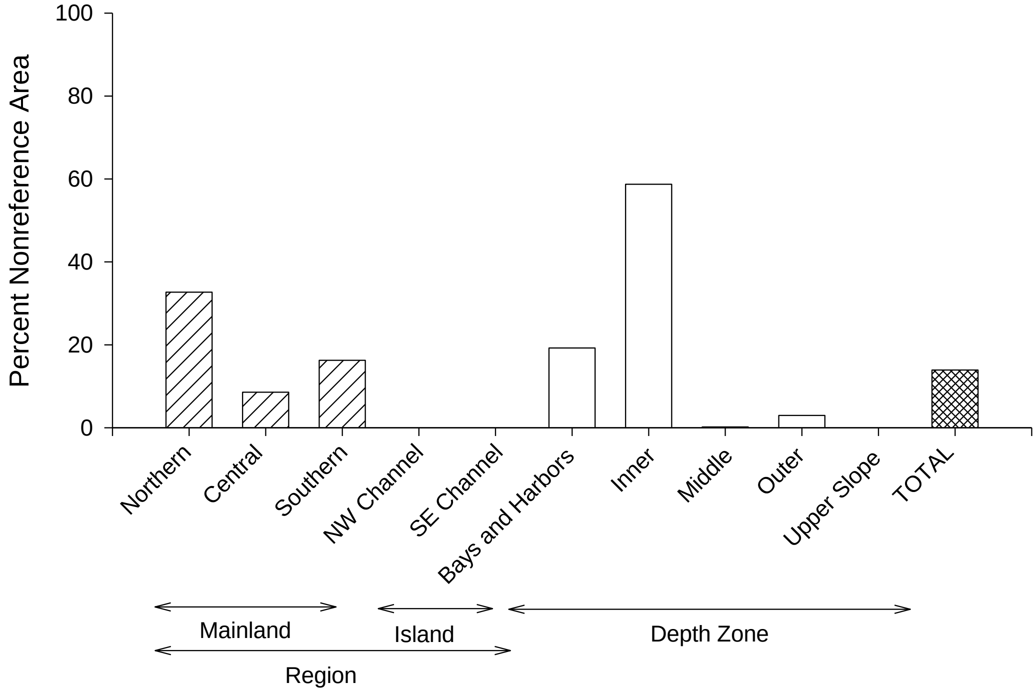


Figure VI-22. Percent of nonreference area by subpopulation on the southern California shelf and upper slope at depths of 2-476 m) for the Megabenthic Invertebrate Response Index (MIRI), July-October 2003.

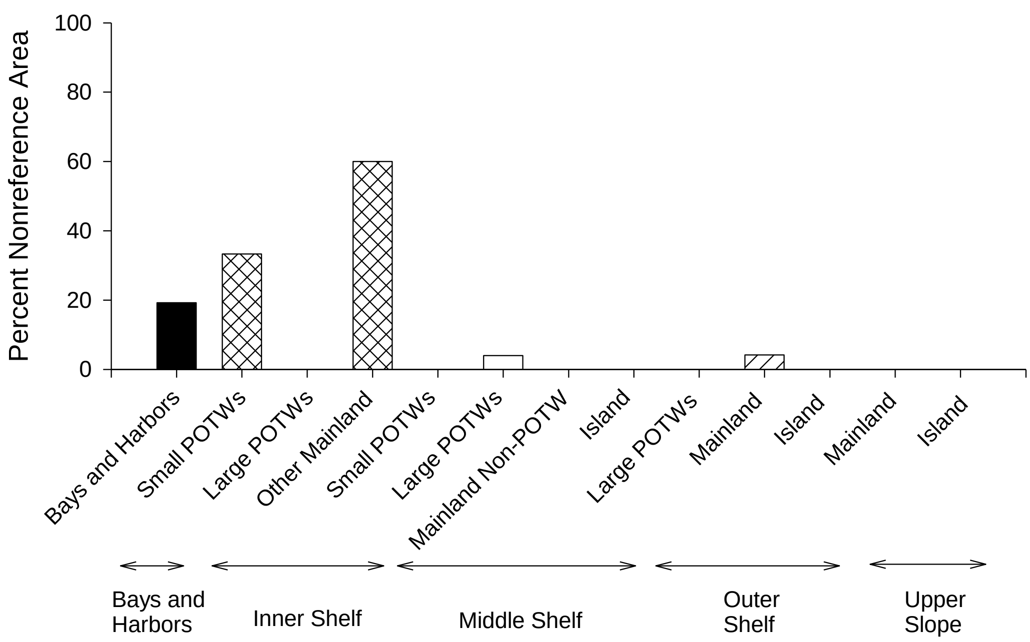


Figure VI-23. Percent of nonreference area by shelf zone subpopulation on the southern California shelf and upper slope at depths of 2-476 m for the Megabenthic Invertebrate Response Index (MIRI), July-October 2003.

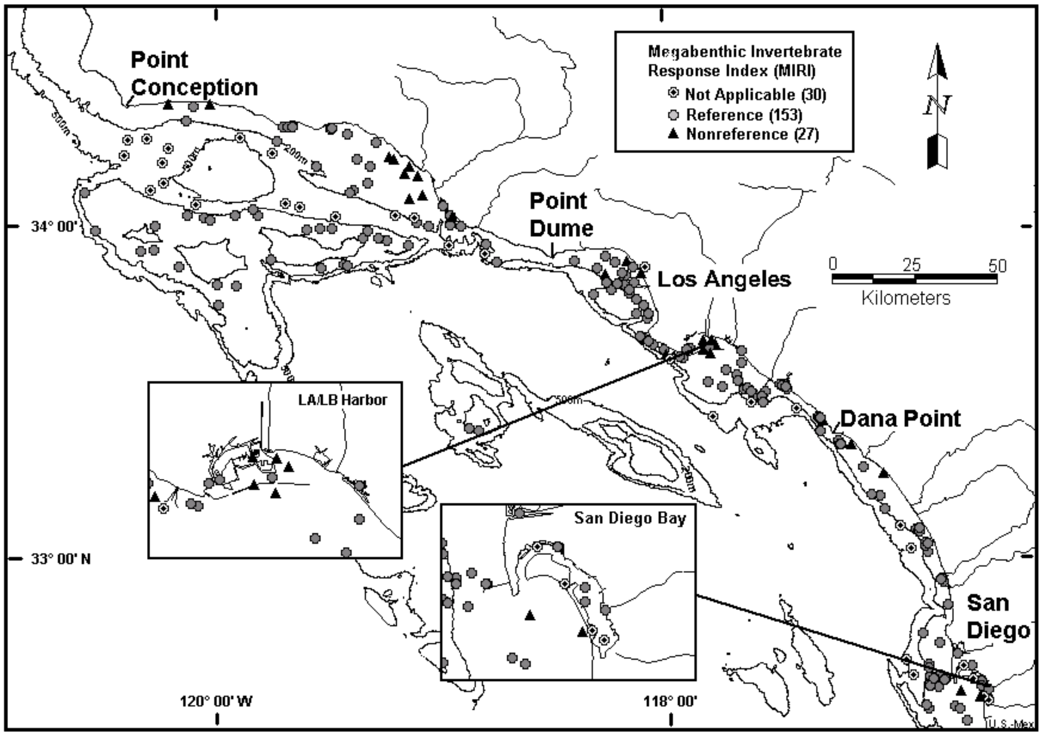


Figure VI-24. Distribution of response levels for Megabenthic Invertebrate Response Index (MIRI) on the southern California shelf at depths of 2-476 m, July-October 2003.

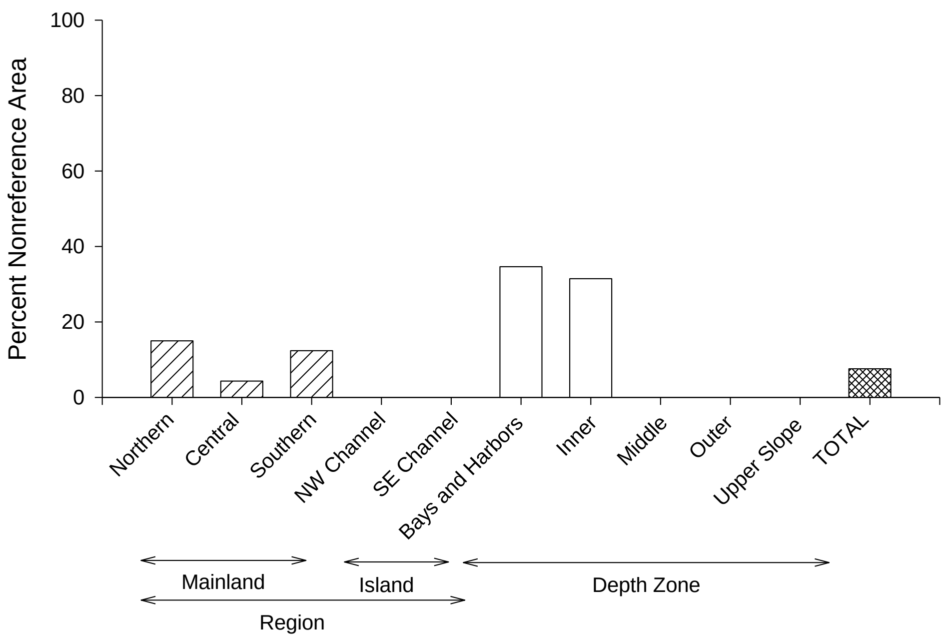


Figure VI-25. Percent of nonreference area by subpopulation on the southern California shelf and upper slope at depths of 2-476 m for the Trawl Response Index (TRI), July-October 2003.

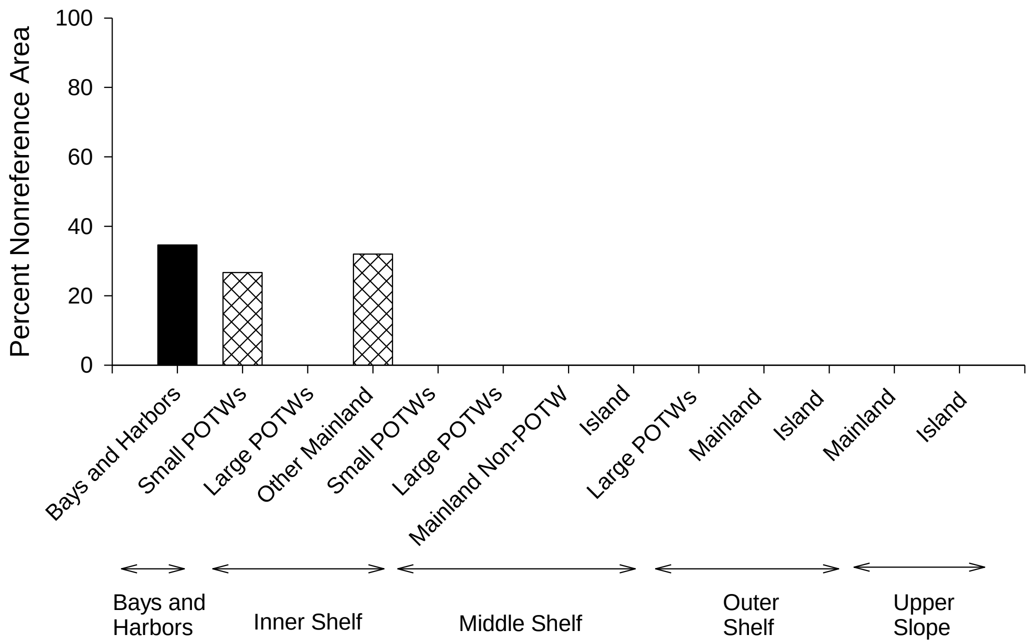


Figure VI-26. Percent of nonreference area by shelf zone subpopulation on the southern California shelf and upper slope at depths of 2-476 m for the Trawl Response Index (TRI), July-October 2003.

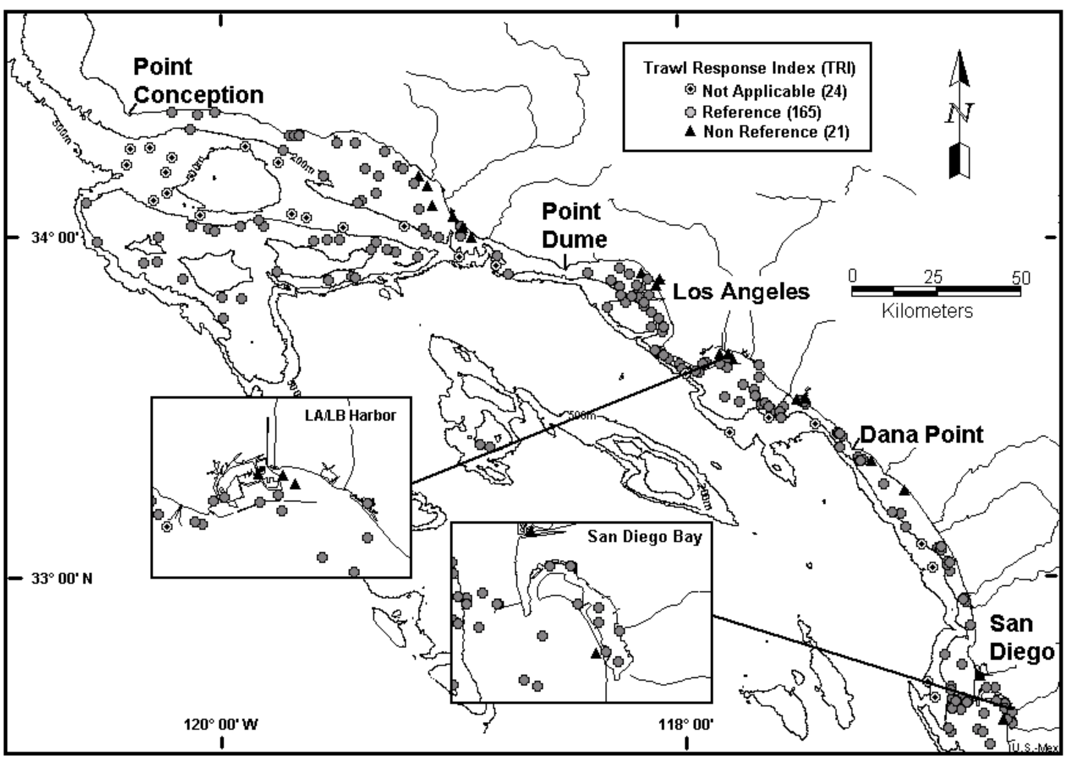


Figure VI-27. Distribution of response levels for Trawl Response Index (TRI) on the southern California shelf at depths of 2-476 m, July-October 2003.

Although in 1998, the MIRI showed many nonreference shelf sites in the Santa Barbara Channel and the FRI and TRI did not (Allen *et al.* 2002a), all three indices identified nonreference areas in this area in 2003 (Figures VI-19, VI-24, and VI-27). Similar to the MIRI, the TRI showed nonreference areas in bays/harbors whereas the FRI did not. River mouths (particularly the Santa Clara River area) had relatively high numbers of nonreference sites for all three indices.

Whereas the response indices are based on the relative distribution of many species to a pollution gradient regardless of their biology, the FFG index is based on relative abundances of three foraging guilds. These are the generalists (benthic pelagobenthivores, sanddab guild), polychaete feeders (benthic extracting benthivores, turbot guild), and nekton ambushers (benthic pelagivores, lizardfish guild; Allen *et al.* 2001a). Typically, turbot guild species are abundant near wastewater discharge sites and sanddab and lizardfish guild species are not. Thus, the index addresses ecological conditions in polluted areas, such as food type availability and sediment type (as this often determines food type availability). Nonreference areas (e.g., near outfalls discharging particulates) are typically those with higher organic sediments, more polychaetes, and fewer epibenthic pericarid crustacea; Cross *et al.* 1985) whereas reference areas have sediments with lower organic content and higher crustacean abundance. Whereas both sanddab guild and turbot guild species are widespread on the shelf, lizardfish guild species (e.g., California lizardfish, bigmouth sole, California halibut) were less common and abundant in 1994, equally common in 1998, and less common in 2003. In this survey, nonreference areas for this index were primarily on the middle shelf of the Channel Islands, perhaps related to increased organic fallout to sediments from cold-regime upwelling in the California Current, perhaps resulting in a benthic polychaete fauna suitable for turbot-guild species (Figures VI-20 and VI-21).

These indices were developed using (in part) nearly three decades of trawl data from the Palos Verdes Shelf in the early 1970s (Allen *et al.* 2001a), the most contaminated sites along the southern California coast (Mearns *et al.* 1976). Heavily impacted sites occurred in this area, particularly in the middle shelf zone, but also in the outer shelf zone. However, sites of similar high impact were not identified in the inner shelf zone (or subsequently for bays and harbors, where fish assemblage sampling was done along with sediment chemistry sampling). These indices, while not perfect, performed nearly as well as the BRI (Smith *et al.* 1998) in following improving conditions over time on the Palos Verdes Shelf. Their real value is likely to become apparent when applied to historical data with clearly defined impact sites (CSDLAC 2002; Montagne 2002a,b; Allen 2006b). Although impact levels were not defined for the response indices, such a level was defined for the FFG index (Allen *et al.* 2001a). It should be noted that no site in the middle shelf zone was classified as impacted for the FFG index in 1998. Overall, the condition of the fish and invertebrate assemblages on the southern California shelf in 2003 was generally good, except perhaps in river mouth areas (particularly near the Santa Clara River) and LA/LB Harbor.

The four indices were based on the most contaminated site (Palos Verdes Shelf) in the early 1970s and all four indices showed that site to have abnormal or disrupted (i.e., nonreference) assemblages of fishes, invertebrates, combined fishes and invertebrates, and fish foraging guilds relative to those typical of the southern California shelf. This was apparent in gradients of species or guild abundances relative to the outfall area (Allen *et al.* 2001a). Although these gradients existed, the cause of each gradient is not known. Certainly concentrations of contaminants (e.g., DDT, PCBs, other organochlorines, and trace metals) were higher there than elsewhere on the shelf. In addition, there were also high levels of total organics, anaerobiosis, and different infaunal assemblages in the sediments near the outfall than further away. All or some of these may have influenced the species gradients there. However, the MIRI and TRI have there own value in identifying abnormal megabenthic invertebrate assemblages and combined fish and invertebrate assemblages. The FFG index has value in showing the distribution of alternative natural soft-bottom habitat states (low organics, high epibenthic crustacea, lower polychaete abundance; high organics, low epibenthic crustacea, and high polychaete abundance) independent of contaminant concentrations, and has value in ecological studies of the demersal fish fauna of the shelf. The cause of the high organic sediment state may be due to natural phenonema (e.g., upwelling, depositional conditions) or anthropogenic activity (e.g., discharge of organic particulates).

Based on its relative performance along historical spatial and temporal gradients in contamination, Allen *et al.* (2001a) recommended the FRI as the best index for use in assessing effects on fish assemblages. Based on that index, 97% of the area of the southern California shelf had relatively normal fish assemblages in 1998 (Allen *et al.* 2002a) and 96% in 2003.

Assemblages in 2003

Evaluation of Methods

Four different methods were used for describing assemblages: recurrent group analysis, cluster analysis, cladistic analysis, and multidimensional scaling. Species groups were described using recurrent group, cladistic, and cluster analyses. Site groups were defined using cluster analyses, cladistic analyses, and multidimensional scaling. Recurrent group analysis uses binary (presence/absence) data and describes groups of species that frequently co-occur. Cladistic analysis uses abundance data for describing site clades and binary data for describing species clades. Cluster analysis uses species abundance data for site and species clusters. Multidimensional scaling uses abundance data by species at sites to determine similarity or dissimilarity of sites. It uses sample dissimilarity matrices, or distance matrices – not on the original data array.

The MDS map on the 90 trawl-station subset (Figure VI-5) that was composed of a subset of fish species was also a function of the dissimilarity index used, in this case the Bray-Curtis similarity index. The recurrent group analysis and cladistic analysis also used all species whereas cluster analysis eliminated species and stations with low abundance and multidimensional scaling limited the number of sites analyzed. NMDS from the total evidence data set utilizing all taxa in the fish and invertebrate data set and all stations was applied to the patristic distance (similar to branch length) matrix derived from the cladogram. As a result of using all species data, recurrent group analysis showed many single-site groups, which may or may not be meaningful. Also, because it describes species groups based on a predetermined index value, it only describes groups at the determined level and does not provide detailed relationships of species in the database. However, it may get to the core species in a community more directly because it does not provide detailed relationships. Cladistic and cluster analyses show more detailed relationships of sites and species in the assemblages in cladograms (former) and dendrograms (latter). Cluster analysis provided depictions of abundance and frequency of occurrence of the subset of species utilized within the site and species clusters were graphically displayed in a table. Cladistic analysis showed explicit relationships of all species, depth zones, subpopulations, and sites. The following represents a brief summary of the similarities and differences of the assemblages defined by these different approaches.

All methods used showed that demersal assemblages in the SCB are largely organized around depth, although cluster analysis also showed influence of sediment type on some assemblages. Most analyses identified unique species or site assemblages in San Diego Bay; shelf assemblages that generally included inner shelf/bay and harbor assemblages; inner shelf assemblages, outer shelf assemblages, and various forms of middle shelf assemblages (e.g., inner/middle shelf, middle shelf, and/or middle/outer shelf); and upper slope and outer shelf/upper slope assemblages.

General Results Across Methods

Fish, invertebrate, and combined fish/invertebrate assemblages were generally associated with a distinct bathymetric zone, or overlapped two bathymetric zones (Figures VI-15, VI-18, and VI-21). However some species groups (particularly Cluster A in combined fishes and invertebrates; Figure VI-21) were widespread over inner and middle shelf zones. Distinct upper slope assemblages occurred among fishes, invertebrates, and combined fishes and invertebrates. Islands did not show distinct assemblages for fishes (Figure VI-1) but middle shelf island assemblages did differ from mainland middle shelf assemblages for invertebrates and combined fishes/invertebrates (Figures VI-18 and VI-21). Outfall associated assemblages and Channel Island associated assemblages of combined fishes and invertebrates were revealed in the site cladogram and NMDS (Figures VI-15 and VI-16).

Fishes, invertebrates, and combined fishes and invertebrate analyses showed distinctly different recurrent groups and site clusters in bays/harbors areas of the Central Region (primarily LA/LB Harbor) and San Diego Bay (Figures VI-15, VI-18, and VI-21). Both LA/LB Harbor and San Diego Bay were combined into a bays and harbors subpopulation in the survey design, due to their similarities in human activities (e.g., shipping and recreational boating). However, the distinct assemblages emphasize the ecological differences in the two regions. San Diego Bay is a large natural bay with a bay fauna similar to that of other natural embayments (e.g., lagoons) along the southern California coast. LA/LB Harbor is an artificially enclosed part of the inner shelf zone, and hence has a typical inner shelf fauna with enhanced abundance of some schooling species (e.g., white croaker, queenfish). Future regional surveys should consider the ecological differences between the two embayments. Multidimensional scaling of fish assemblages results (Figure VI-5) and fish cluster analysis results (Figure VI-1) showed that the fish assemblages of bays and harbors and the upper slope are similar: both have lower species richness and species abundance than middle shelf and outer shelf areas.

Among fishes, flatfishes and scorpaeniform fishes were important in assemblages across the shelf and slope. Among invertebrates, echinoderms (particularly urchins) were widespread over the shelf and upper slope, with different species dominant in different bathymetric zones. For instance, white sea urchin was dominant on the inner shelf and middle shelf, fragile sea urchin on the outer shelf, and northern heart urchin on the upper slope.

Assemblage composition changed somewhat between regional surveys. Among fishes, a distinct inner shelf recurrent group consisting of flatfishes did not appear in 2003 (Figure VI-1) although it was present in 1972, 1994, and 1998 (Allen 1982; Allen *et al.* 1998, 2002a). This appeared to be in part due to an inshore expansion of deeper coldwater species toward shore in 2003, a cold-regime period. Historical changes will be discussed below in detail with changes in the functional structure of fish communities.

Historical Changes in the Functional Structure of Fish Communities

Allen (1982) described the functional organization of soft-bottom fish communities on the southern California shelf based on the ecological segregation of the most common species. Examination of fish recurrent groups from 1972-1973 showed that in general, species occurring together in recurrent groups are ecologically and morphologically different, whereas species that were most similar in their foraging morphology were found in different recurrent groups at different depths. Species with similar foraging behavior were grouped into foraging guilds (Figure II-5). Species comprising a guild generally displaced each other by depth across the southern California shelf from 10-200 m. The functional organization was described as the number and type of guilds found at a given depth and the composition of the communities as the dominant species of each guild found at that depth (Figure II-6). The model of the functional structure of the demersal fish communities of southern California were reassessed based on regional survey data collected in 1994 and 1998 (Allen *et al.* 1998, 2002). Although there were some changes in depth displacement pattern of guild members or occasional shifts in dominant species in these surveys, the general pattern remained the same. Allen (2006a) extended this approach using data from other sources to describe the functional structure of demersal fish communities off California and Baja California from the California-Oregon Border to Cabo San Lucas, Baja California Sur. This was done for the inner shelf, middle shelf, outer shelf, and upper slope. Due to limited data, this could not be described for the upper slope of Baja California.

Frequency of Occurrence of Foraging Guilds

Allen (1982) described the functional structure of soft-bottom fish communities of the southern California shelf based on 342 trawl samples at depths of 10-342 m in 1972-1973. Although this study provides detailed information on the guild members and guilds from that time, it does not give information on the percent occurrence of the guilds on the southern California shelf. The synoptic regional surveys of the past decade (1994, 1998, 2003; Allen *et al.* 1998, 2002a; present study) provide this information, providing an assessment of extent of occurrence by guilds, and changes in this occurrence over time (Table VI-10). Occurrence varies by guild with some being widespread and others with limited distributions. The most widespread guilds were the benthic pelagobenthivore (sanddab) and benthic extracting benthivore (turbot) guilds, both occurring in more than 90% of the samples on the mainland shelf in all three surveys, as well as upper slope and island shelf in 2003. Hence, these two guilds provide the core members of the soft-bottom fish community of the southern California shelf. These were the only two guilds occurring in greater than 75% of the samples in all three years. The benthic pelagivore (lizardfish) guild and benthic nonvisual benthivore (tonguefish) guild occurred at greater than 75% in 1994 and 1998, but not in 2003. In addition to the sanddab, turbot, lizardfish, and tonguefish guilds, two additional guilds occurred in more than 50% of the samples during all three years: small benthic ambushing benthopelagivore (sculpin/poacher) guild and benthic pursuing benthopelagivore (combfish) guilds. Three guilds occurred in greater than 50% of samples in two years: benthic excavating benthivore (eelpout) guild and water-column bottom-refuge pelagivore (rockfish) guild, and water-column bottom-refuge nonvisual pelagivore (midshipman) guild. The eelpout and rockfish guilds occurred at this level in 1994 and 2003, but not in 1998. The midshipman guild occurred at this level in 1994 and 1998, but not in 2003. Three guilds occurred in greater than 50% occurrence in a single year: water-column diurnal benthopelagivore (seaperch) guild, benthic large ambushing benthopelagivore (scorpionfish) guild, and benthic medium ambushing benthopelagivore (sculpin) guild. The seaperch and scorpionfish guilds were most widespread in 2003 and the sculpin guild in 1994. The remaining six guilds occurred in less than 50% of the samples in all years.

The three surveys represent different oceanic periods: 1994 (warm regime), 1998 (El Niño, very warm), and 2003 (cold regime; Allen *et al.* 2004). Hence, the occurrence pattern of the guilds provides insight into what oceanic periods are best or worst for the guilds in southern California. Seven guilds show a pattern of being most frequent in 2003, less in 1994, and least in 1998. These include the sanddab, turbot, sculpin/poacher, eelpout, combfish, rockfish, and cusk-eel guilds. These guilds were most common in the cold regime, intermediate in the warm regime, and least common in the very warm El Niño period. Three guilds (lizardfish, tonguefish, and midshipman guilds) showed the opposite pattern, being most frequent during the El Niño period, intermediate in the warm regime, and least frequent in the cold regime. Three guilds (seaperch, scorpionfish, and shiner perch guilds) were most frequent in the cold regime, intermediate during the El Niño period, and least common in the warm regime. Among remaining guilds, the sculpin and queenfish guilds were most common in the warm regime and least common in the El Niño period. The croaker guild was most common during the El Niño period and the sablefish guild in the cold regime. More detailed reasons for these patterns (recruitment success, adult movements, biogeographic adaptions, etc.) require further study.

Changes in Functional Organization of the Communities Relative to Oceanic Regimes

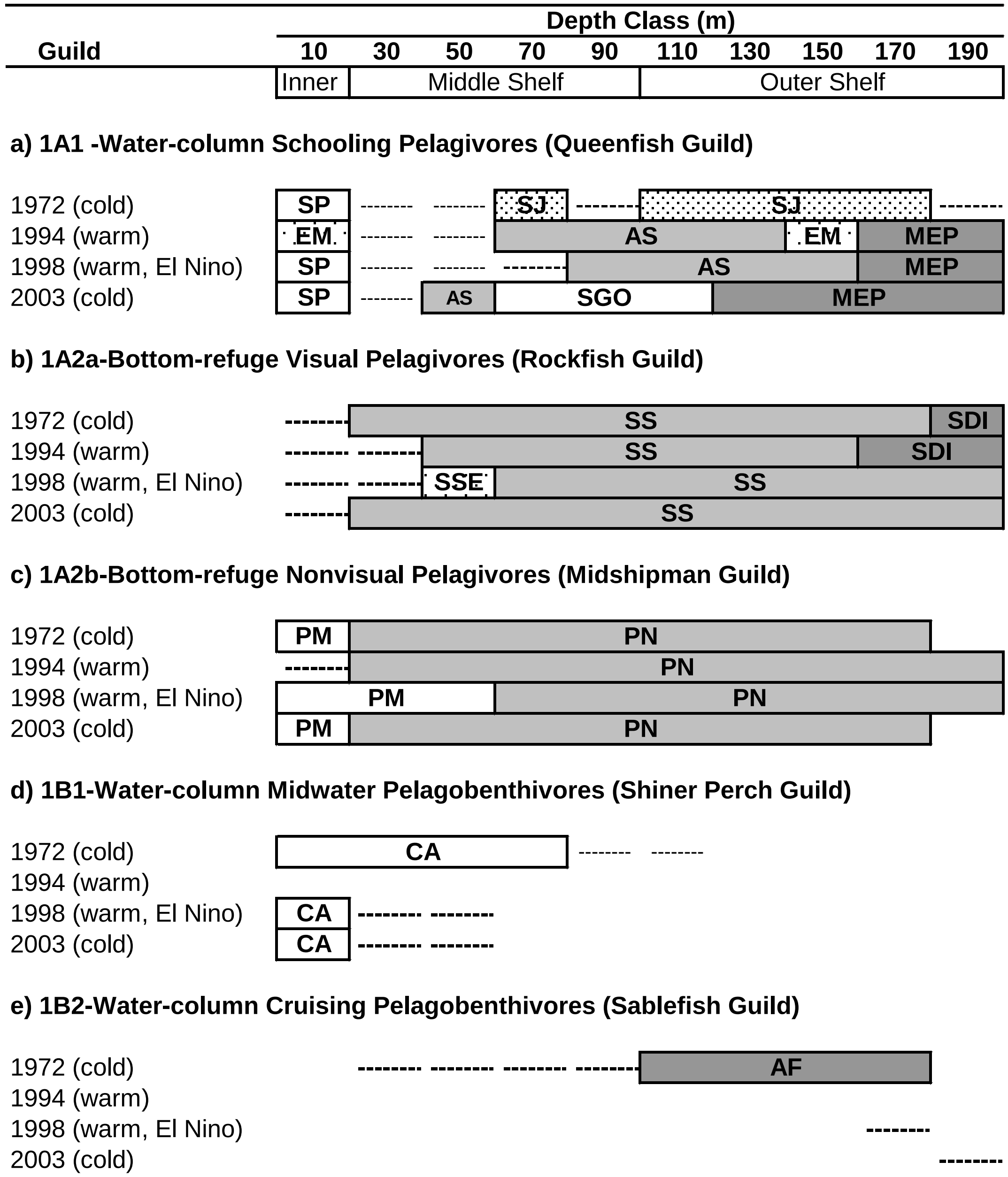
The description of the functional organization of soft-bottom fish communities on the southern California shelf by Allen (1982) was based on data collected in 1972-1973, a cool regime period. Although the oceanic climate had warmed since the 1980s and then cooled following the 1998 El Niño (Chavez *et al.* 2003, Allen *et al.* 2004, Goericke *et al.* 2005), the model provides a framework for examining changes in the functional organization of the communities with changing ocean regimes. Thus, the organization of the soft-bottom fish communities of the southern California shelf can be compared in four different oceanic periods: 1972-1973 (cool regime; Allen 1982); 1994 (warm regime; Allen *et al.* 1998); 1998 (El Niño period; Allen *et al.* 2002a); and 2003 (cold regime; this study; Figures VI-28a through VI-28d).

Table VI-10. Percent occurrence of foraging guilds on the mainland shelf (10-200 m) in southern California in 1994, 1998, and 2003.

Guild No.	Guild Name (Allen 1982)	Identifier	% FO* SC Bight 2003 (n=210)	Mainland Shelf 1994 (n = 114)	Mainland Shelf 1998 (n = 185)	Mainland Shelf 2003 (n=127)
2B	Benthic Pelagobenthivores (1, 1)	sanddab	90	96	93	99
2D1a	Benthic Extracting Benthivores (2, 3)	turbot	91	92	80	94
2C2b	Benthic Ambushing Benthivores, Small (6, 5)	sculpin/poacher	65	65	62	73
2D1b	Benthic Excavating Benthivores (9, 9)	eelpout	62	54	46	71
2A	Benthic Pelagivores (3, 2)	lizardfish	61	75	87	67
2C1	Benthic Pursuing Benthivores (5, 7)	combfish	60	66	51	67
2D2	Benthic Nonvisual Benthivores (4, 4)	tonguefish	64	72	80	65
1C1	Water-Column Diurnal Benthopelagivores (11, 8)	seaperch	49	42	48	63
1A2a	Bottom-refuge Visual Pelagivores (7, 12)	rockfish	59	57	40	61
2C2d	Benthic Ambushing Benthoplagivores, Large (13, 10)	scorpionfish	57	29	43	60
2C2c	Benthic Ambushing Benthivopelagivores, Med. (10, 11)	sculpin	34	53	41	45
1A2b	Bottom-refuge Nonvisual Pelagivores (8, 6)	midshipman	45	56	57	44
1A1	Water-Column Schooling Pelagivores	queenfish	50	38	32	37
2C2a	Benthic Ambushing Benthoplagivores, Tiny	pygmy poacher	20	7	15	22
1D	Water-Column Cruising Benthivores	cusk-eel	20	16	7	19
1C2	Water-Column Nocturnal Benthopelagivores	croaker	20	6	25	12
1B1	Water-Column Schooling Pelagobenthivores	shiner perch	10	0	4	11
1B2	Water-Column Cruising Pelagobenthivores	sablefish	6	0**	0**	1

Occurred in 75% or more of area (dark shading)
Occurred in 50% or more of area (light shading)

*FO = Frequency of Occurrence;
** Barred sand bass, included in this guild in 1994 and 1998, was moved to guild 2C2d in 2003, reducing the guild occurrence to 0.
SC Bight = Southern California shelf (2-476 m): Includes mainland shelf, islands, bays/harbors, and upper slope.
Numbers in parentheses are top 10 rank of guilds in 1994 and in 1998, respectively (rank is listed if it is in the top 10 in either 1994 or 1998).



IA1: SP = *Seriphus politus;* SJ = *Sebastes jordani* ; EM = *Engraulis mordax* ; AS = *Argentina sialis*
MEP = *Merluccius productus* ; SGO = *Sebastes goodei*

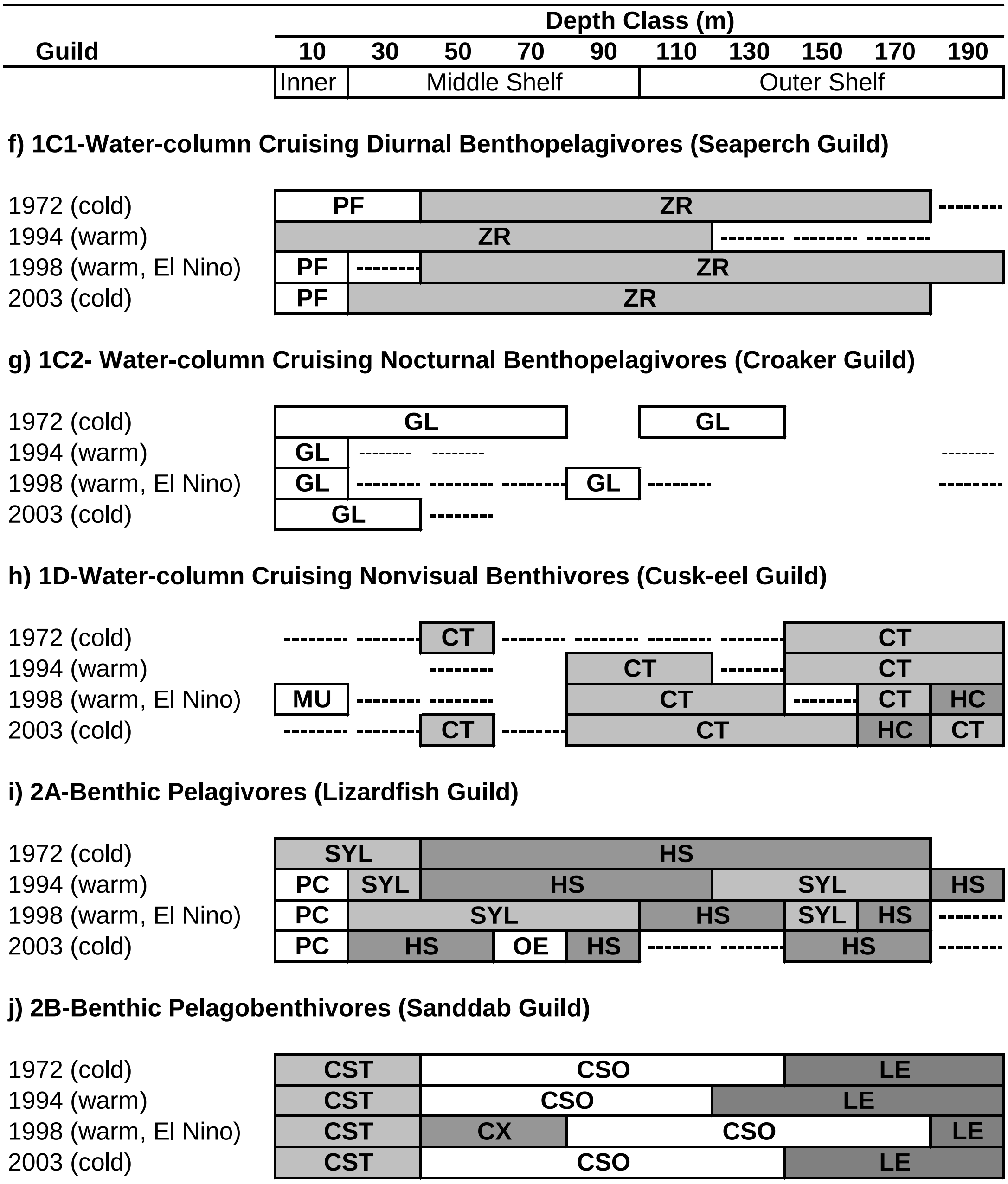
IA2a: SS = *Sebastes saxicola* ; SDI = *Sebastes diploproa* ; SSE = *Sebastes semicinctus*

IA2b: PM = *Porichthys myriaster* ; PN = *Porichthys notatus*

IB1: CA = *Cymatogaster aggregata*

IB2: IB2 = *Anoplopoma fimbria*

Figure VI-28a. Comparison of changes in depths of dominance of foraging guilds 1A1 to 1B2 of demersal fish communities on the southern California in 1972-1973 (Allen 1982), 1994 (Allen *et al.* 1998), Allen *et al.* (2002a), and 2003.



IC1: PF = *Phanerodon furcatus;* ZR = *Zalembius rosaceus*

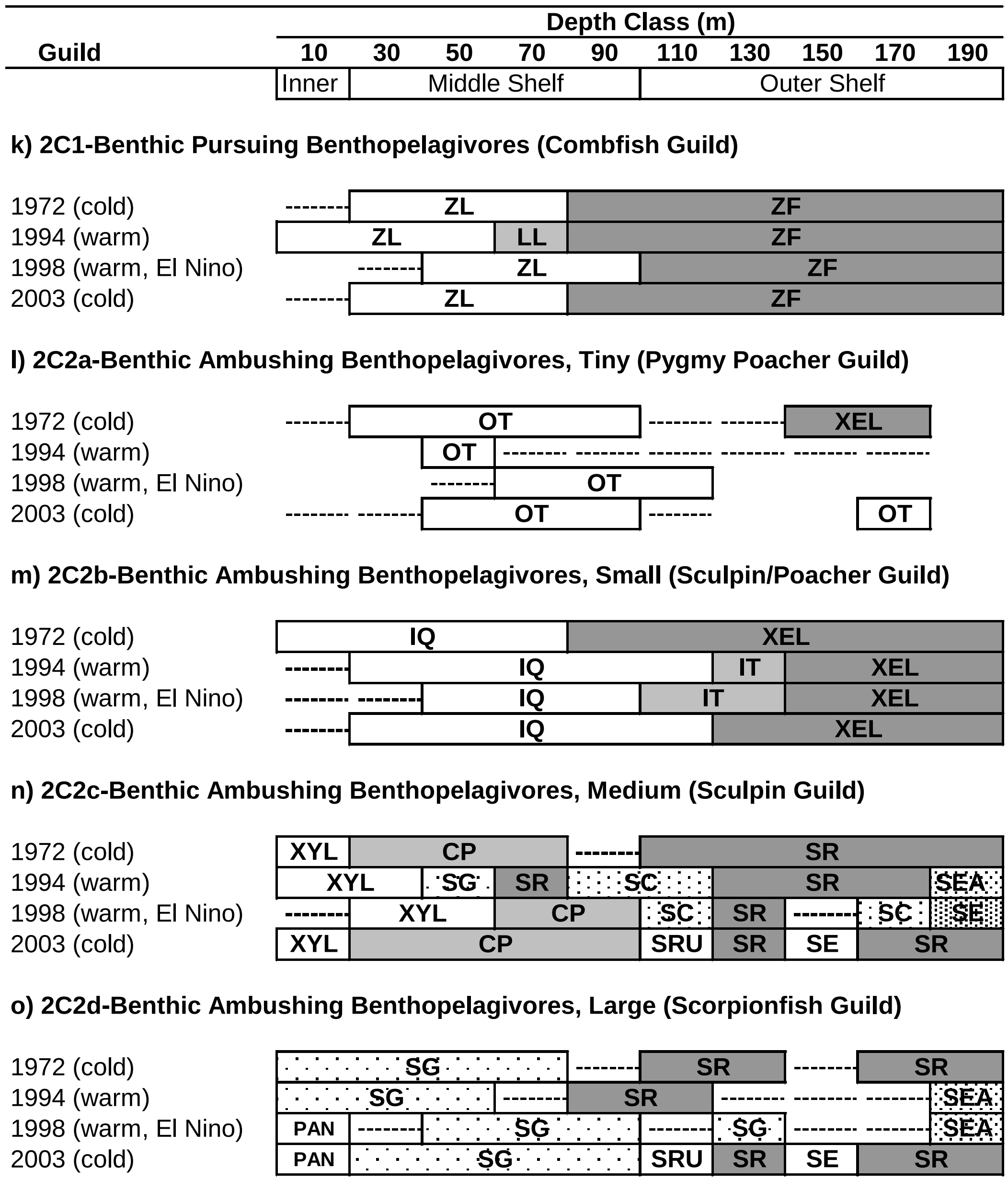
IC2: GL = *Genyonemus lineatus*

ID: CT = *Chilara taylori* ; MU = *Menticirrhus undulatus* ; HC = *Hydrolagus colliei*

2A: SYL = *Synodus lucioceps* ; HS = *Hippoglossina stomata* ; PC = *Paralichthys californicus;*
OE = *Ophiodon elongatus*

2B: CST = *Citharichthys stigmaeus* ; CSO = *Citharichthys sordidus* ; LE = *Lyopsetta exilis;*
CX = *Citharichthys xanthostigma*

Figure VI-28b. Comparison of changes in depths of dominance of foraging guilds 1C1 to 2B of demersal fish communities on the southern California in 1972-1973 (Allen 1982), 1994 (Allen *et al.* 1998), Allen *et al.* (2002a), and 2003.



2C1: ZL = *Zaniolepis latipinnis;* ZF = *Zaniolepis frenat;* LL = *Lepidolepidus lepidus*

2C2a: OT = *Odontopyxis trispinosa*; XEL = *Xeneretmus latifrons* (S = small)

2C2b: IQ = *Icelinus quadriseriatus*; XEL = *Xeneretmus latifrons* (L = large); IT = *Icelinus tenuis*

2C2c: XYL = *Xystreurys liolepis*; CP = *Chitonotus pugetensis*; SR = *Sebastes rosenblatti* (S);
SG = *Scorpaena guttata* (S); SC = *Sebastes chlorostictus*; SEA = *Sebastolobus alascanus* (S)
SE = *Sebastes eos* (S); SRU = *Sebastes rubrivinctus* (S)

2C2d: SG = *Scorpaena guttata* (L); SR = *Sebastes rosenblatti* (L); SEA = *Sebastolobus alascanus* (S);
PAN = *Paralabrax nebulifer;* SRU = *Sebastes rubrivinctus* (L); SE = *Sebastes eos* (L)

Figure VI-28c. Comparison of changes in depths of dominance of foraging guilds 2C1 to 2C2d demersal fish communities on the southern California in 1972-1973 (Allen 1982), 1994 (Allen *et al.* 1998), Allen *et al.* (2002a), and 2003.

<table>
<tr><th rowspan="2">Guild</th><th colspan="10">Depth Class (m)</th></tr>
<tr><th>10</th><th>30</th><th>50</th><th>70</th><th>90</th><th>110</th><th>130</th><th>150</th><th>170</th><th>190</th></tr>
<tr><td></td><td>Inner</td><td colspan="4">Middle Shelf</td><td colspan="5">Outer Shelf</td></tr>
<tr><td colspan="11">p) 2D1a-Benthic Extracting Benthivores (Turbot Guild)</td></tr>
<tr><td>1972 (cold)</td><td>PLV</td><td>PD</td><td colspan="8">MP</td></tr>
<tr><td>1994 (warm)</td><td colspan="2">PLV</td><td colspan="8">MP</td></tr>
<tr><td>1998 (warm, El Nino)</td><td>PLR</td><td colspan="2">PLV</td><td colspan="7">MP</td></tr>
<tr><td>2003 (cold)</td><td colspan="3">PLV</td><td colspan="7">MP</td></tr>
<tr><td colspan="11">q) 2D1b-Benthic Excavating Benthivores (Eelpout Guild)</td></tr>
<tr><td>1972 (cold)</td><td colspan="4">PAV</td><td colspan="6">LP</td></tr>
<tr><td>1994 (warm)</td><td colspan="6">PAV</td><td colspan="4">LP</td></tr>
<tr><td>1998 (warm, El Nino)</td><td>--------</td><td colspan="5">PAV</td><td>LP</td><td colspan="2">PAV</td><td>LP</td></tr>
<tr><td>2003 (cold)</td><td colspan="7">PAV</td><td colspan="3">LP</td></tr>
<tr><td colspan="11">r) 2D2-Benthic Nonvisual Benthivores (Tonguefish Guild)</td></tr>
<tr><td>1972 (cold)</td><td colspan="4">SA</td><td colspan="6">GZ</td></tr>
<tr><td>1994 (warm)</td><td colspan="6">SA</td><td colspan="4">GZ</td></tr>
<tr><td>1998 (warm, El Nino)</td><td colspan="5">SA</td><td colspan="2">RS</td><td>--------</td><td colspan="2">GZ</td></tr>
<tr><td>2003 (cold)</td><td>UH</td><td colspan="3">SA</td><td>RI</td><td>--------</td><td colspan="4">GZ</td></tr>
</table>

2D1a: PLV = *Pleuronichthys verticalis* ; PD = *Pleuronichthys decurrens* ; MP = *Microstomus pacificus* ;
PLR = *Pleuronichthys ritteri*

2D1b: PAV = *Parophrys vetulus* ; LP = *Lycodes pacificus*

2D2: SA = *Symphurus atricaudus* ; GZ = *Glyptocephalus zachirus* ; RS = *Raja stellutata* (S);
UH = *Urobatis halleri* ; RI = *Raja inornata*

Figure VI-28d. Comparison of changes in depths of dominance of foraging guilds 2D1a to 2D2 of demersal fish communities on the southern California in 1972-1973 (Allen 1982), 1994 (Allen *et al.* 1998), Allen *et al.* (2002a), and 2003.

The extent of distribution of the guilds across the shelf (10-200 m) and the depth displacement pattern within guilds varied by guild. Some guilds occurred across the entire area or most of it in all years. Others had distinct breaks, where a guild was rare, in all years. Some showed such gaps primarily during the El Niño period, suggesting a retreat from some depths. In general, the depth displacement sequence of species within a guild did not change from that described in Allen (1982) but in some cases, another guild member became dominant at a depth. Some of these showed evidence of invasion from the south or north during an oceanic period.

In Guild 1A1-Water Column Schooling Pelagivores (Figure VI-28a through VI-28d), the guild distribution pattern showed stable occurrence on the inner part of the inner shelf (5-20 m), with the neritic queenfish being dominant (except in 1994 when northern anchovy, a coastal pelagic species, being more common and abundant; Allen *et al.* 1998). The guild was rare (<20% occurrence) in all years at 30 m (20-40 m), but relatively common at greater depths, although the dominant species varied. In 1972-1973, shortbelly rockfish was dominant on the middle and outer shelf. In 1994, 1998, and 2003, Pacific hake was the dominant species on the outer shelf. Pacific argentine was dominant on the middle shelf in 1994 and 1998, and to some extent on the outer shelf in 1998. In 2003, juvenile chilipepper were most common and abundant on the middle shelf. Hence, Pacific argentine was the middle shelf dominant on the middle shelf in warmer periods (1994, 1998) and rockfishes in the colder period (shortbelly rockfish in 1972-1973 and chilipepper in 2003). Except on the inner shelf, the guild appeared to retreat to deeper water in 1998 during the El Niño period.

In Guild 1A2a–Bottom-refuge Visual Pelagivores (Figure VI-28a), the guild was dominated by planktivorous rockfishes on the middle and outer shelf, but was rare on the inner shelf. The dominant guild member on the middle shelf in all years was the stripetail rockfish. On the outer shelf, this species was also dominant in 1998 and 2003, but splitnose rockfish was dominant there in 1972-1973 and 1994. Stripetail rockfish appeared to retreat to deeper water on the shallow side of its occurrence in the warm years of 1994 and 1998, but particularly during 1998.

In Guild 1A2b–Bottom refuge Nonvisual Pelagivores (Figure VI-28a), the guild was dominated by midshipmen in all years, with specklefin midshipman dominant on the inner shelf (rare in 1994) and plainfin midshipman throughout the middle and outer shelf. The depth displacement pattern was identical in the two cold regime periods (1972, 2003). Specklefin midshipman extended its inshore dominance deepest in 1998

In Guild 1B1–Water-column Midwater Pelagobenthivores (Figure VI-28a), shiner perch was the only dominant species. This species was dominant on the inner and middle shelf in 1972-1973, was absent in 1994, and was dominant only on the inner shelf in 1998 and 2003, occurring rarely on the middle shelf.

In Guild 1B2–Water-column Cruising Pelagobenthivores (Figure VI-28a), sablefish was the only dominant species. This species was dominant on the middle and outer shelf in 1972-1973, was absent in 1994, and occurred rarely on the outer shelf in 1998 and 2003. It was the guild dominant on the upper slope in 2003 (Figure VI-4).

In Guild 1C1–Water-column Cruising Diurnal Benthopelagivores (Figure VI-28b), white seaperch was dominant on the inner shelf in 1972-1973, 1998, and 2003, but was rare there in 1994. Pink seaperch was dominant on the middle shelf in all years, and also on the outer shelf in 1972-1973, 1998, and 2003. It replaced white seaperch as dominant on the inner shelf in 1994. In that year it appeared to shift its range shoreward, being dominant on the inner and middle shelf, but rare on the outer shelf. Although white seaperch was dominant on the inner shelf in 1998, pink seaperch appeared to retreat from the inner shelf (occurring only rarely at 30 m) during this El Niño period.

In Guild 1C2–Water-column Cruising Nocturnal Benthopelagivores (Figure VI-28b), white croaker was the dominant in all years. As with the shiner perch in Guild 1B1, it was dominant on the inner and middle shelf in 1972-1973, but was generally (with an exception in 1998) only dominant on the inner shelf in 1994, 1998, and 2003. It occurred rarely on the middle shelf during these years, and rarely on the outer shelf in 1994 and 1998.

In Guild 1D–Water-column Cruising Nonvisual Benthivores (Figure VI-28b), spotted cusk-eel was the dominant species on much of the area of the middle and outer shelf in 1994, 1998, and 2003. However, in 1972-1973 it occurred only rarely on the middle shelf, but was dominant on the outer shelf. Because this guild is primarily a cusk-eel guild, some of the low occurrence on the inner and middle shelf may be artifact related to daytime trawling in the surveys. Cusk-eels typically bury in sediments during the day in shallow water and only are out foraging at night. Night trawls may find that this species and its shallow replacement (basketweave cusk-eel, Ophidion scrippsae) may be common and abundant at shallow depths. In deeper water where light levels are minimal, spotted cusk-eel actively forages during the day (Allen 1982, 2006a). California corbina made a brief appearance as a dominant on the inner shelf in 1998 and spotted ratfish as a dominant at locations on the outer shelf in 1998 and 2003.

Guild 2A–Benthic Pelagivores (Figure VI-28b) was widespread in occurrence in 1972, 1994, and 1998, but was less so in 2003. The dominant species on the inner shelf in 1972 was California lizardfish, but was California halibut in 1994, 1998, and 2003. Bigmouth sole was dominant over the middle and outer shelf in 1972, and on the middle shelf in 1994, but it was frequently replaced as dominant on the middle shelf and outer shelf in 1994 and 1998. Allen (2006a) split this guild into two guilds foraging in the same way, but differing in body type – flatfishes and roundfishes. Among the flatfishes, the typical pattern is California halibut the dominant on the inner shelf and bigmouth sole on the middle and outer shelf. This would be the case if California lizardfish (a roundfish) were removed from the comparison (although bigmouth sole clearly had areas of low occurrence on the outer shelf in 2003. California lizardfish appears to have been an invader during 1972, spreading to deeper water 1994 and 1998, before becoming less common and abundant in 2003 (when California halibut and bigmouth sole outranked it in dominance). Juvenile lingcod (Ophiodon elongatus), a roundfish northern replacement of California lizardfish (Allen 2006a), were abundant in a limited area of the middle shelf in 2003. The disjunct regions of California lizardfish dominance on the outer shelf raises concern that these may be spotted lizardfish (Synodus evermanni) from southern Baja California. However, that species is only the dominant member of the benthic roundfish pelagivores guild on the outer shelf south of Magdalena Bay, Baja California Sur, whereas California lizardfish is the dominant member of that guild on the outer shelf from Point Conception to Magdalena Bay (Allen 2006a).

Guild 2B–Benthic Pelagobenthivores (Figure VI-28b) was common and abundant at all depths in all four time periods. Speckled sanddab was the dominant species on the inner shelf in all four years (1972, 1994, 1998, and 2003). Pacific sanddab was the dominant member of the entire middle shelf in 1972, 1998, and 2003, but was replaced on the inner side of this zone in 1998 by longfin sanddab. The depth range of dominance for Pacific sanddab remained about the same in 1998 as other areas, but it shifted seaward and well on to the outer shelf. Slender sole was the dominant on the outer shelf in 1972, 1994, and 2003, but was replaced by Pacific sanddab as dominant at depths between 120 and 180 m. The sudden dominance of longfin sanddab and retreat of Pacific sanddab and slender sole to deeper water in 1998 appears to be a strong El Niño response.

In Guild 2C1–Benthic Pursuing Benthopelagivores (Combfish Guild; Figure VI-28c), the primary pattern was longspine combfish dominant on the middle shelf and shortspine combfish on the outer part of the outer shelf as well as on the outer shelf. The guild was rare or absent on the inner shelf in all years except 1994, when longspine combfish extended shallow. This species also retreated to deeper water, occurring rarely at 30 m in 1998. This pattern of extending as dominant on the inner shelf in 1994 and retreating to deeper than 40 m in 1998 also occurred in Guild 1C1 with pink seaperch. Both species feed primarily on gammaridean amphipods along the bottom, suggesting that perhaps a shift in abundance of prey and/or a change in temperature may have affected their distributions in these years.

Guild 2C2a–Benthic Ambushing Benthopelagivores Size A (Tiny; Figure VI-28c) was dominated by pygmy poacher on the middle shelf and juvenile blacktip poacher on the outer shelf in 1972. In 1998 and 2003, pygmy poacher was the dominant on the middle shelf, but occurred rarely on much of the middle shelf in 1994. It was a dominant in a small region of the outer shelf in 2003.

Guild 2C2b–Benthic Ambushing Benthopelagivores Size B (Small; Figure VI-28c) was largely dominated by yellowchin sculpin on the middle shelf and blacktip poacher on the outer shelf. In 1972, yellowchin sculpin were also dominant on the inner shelf dominant and blacktip poacher also shifted shoreward, replacing yellowchin sculpin on the outer part of the middle shelf. The shallow edge of the region of common occurrence of yellowchin sculpin shifted deeper from 1972 to 1998, but returned to the 1994 depth in 2003. Spotfin sculpin was dominant at shelf break depths in 1994 and 1998, but not during the cold regime periods of 1994 and 2003.

In Guild 2C2c–Benthic Ambushing Benthopelagivores, Size C (Medium; Figure VI-28c), the guild distribution pattern was most similar in 1972 and 2003 (both cold regimes) and least in 1994 and 1998 (warmer periods). In 1972, fantail sole was dominant on the inner shelf, roughback sculpin on the middle shelf, and juvenile greenblotched rockfish on the outer shelf. This pattern was similar in 2003 except that at some depths on the outer shelf, juvenile greenblotched rockfish was replaced by other rockfishes. Fantail sole was the dominant species of this guild on the inner shelf in 1972, 1994, and 2003, but the guild was rare there in 1998. Fantail sole shifted as a dominant deeper onto the middle shelf in 1998, displacing roughback sculpin as dominant in that area. Although roughback sculpin was generally the dominant on the middle shelf, in 1994 it was rare there, being replaced by juveniles of a number of rockfishes of this guild. In general, the typical pattern of this guild was disrupted in all years at the shelf break with the guild either being rare (as in 1972) or replaced by juveniles of hard bottom rockfishes in 1994, 1998, and 2003. Juvenile greenblotched rockfishes declined dramatically in distribution on the outer shelf during the period, being widespread in 1972, less so in 1994, dominant at a limited depth (120-140 m) in 1998, and increasing in dominance in 2003.

Guild 2C2d–Benthic Ambushing Benthopelagivores, Size D (Large; Figure VI-28c) showed a relatively consistent pattern on the middle shelf, but a similar pattern to Guild 2C2c on the outer shelf. California scorpionfish was the dominant member of this guild on the inner shelf in 1972 and 1994, but barred sand bass was dominant in 1998 and 2003. California scorpionfish was dominant on the middle shelf in all years, although it shifted shallower in 1994 and deeper in 1998. Adult greenblotched rockfish was dominant on the outer shelf in 1972, but was more restricted to the shelf break in 1994, but returning to broad distribution on the outer shelf in 2002. The guild was rare, usually represented by incidental hard-bottom rockfishes of this guild in 1994 and 1998. The distribution of greenblotched rockfish in 1994 and 1998 among both adults (this guild) and its juveniles (Guild 2C2), indicate a strong negative response to the warm regime and El Niño, perhaps due to poor recruitment of juveniles and movement of adults to deeper water.

Guild 2D1a–Benthic Extracting Benthivores (Figure VI-28d) occurred consistently in all depth zones in all years. Dover sole was the consistent dominant on the middle and outer shelf in all years. Hornyhead turbot was generally the dominant on the inner shelf and inner part of the middle shelf. It was dominant on the inner shelf in 1972, 1994, and 2003, but was replaced there by spotted turbot, a shallow species, in 1998. Hornyhead turbot was also dominant on the inner part of the middle shelf in 1998 and 2003, but was replaced by curlfin sole there in 1972. Curlfin sole replaces hornyhead turbot on the inner shelf north of Point Conception and spotted turbot replaces hornyhead turbot on the inner shelf and middle shelf in Baja California Sur (Allen 2006a).

Guild 2D1b–Benthic Excavating Benthivores (Figure VI-28d) showed a relatively consistent pattern in all years. English sole was typically dominant on the inner and middle shelf and blackbelly eelpout on the outer shelf. English sole was dominant on the inner shelf in 1972, 1994, and 1998, but the guild was rare on the inner shelf in 1998, with English sole retreating to deeper water during the El Niño period. The depth on the middle or outer shelf where it was replaced by blackbelly eelpout increased over the four years, being about 80 m in 1972, 120 m in 1994 and 1998, and 140 m in 2003. English sole replaced blackbelly eelpout along parts of the mainland outer shelf in 1998.

Guild 2D2–Benthic Nonvisual Benthivores (Figure VI-28d) showed a relatively consistent pattern over the years. California tonguefish was typically dominant on the inner and middle shelf and rex sole on the outer shelf. California tonguefish was dominant on the inner shelf in 1972, 1994, and 1998, but was replaced by round stingray in 2003. The depth range of dominance for this species expanded to the inner part of the outer shelf in 1994, but returned to the middle shelf in 1998 and 2003. Rex sole replaced California tonguefish at 80m in 1972, but this occurred at 120 m in 1994 and 2003. Rex sole retreated as dominant to 160 m or deeper on the outer shelf in 1998. The guild was rare or replaced by juvenile skates (starry skate, Raja stellulata) in 1998 and California skate in 2003 at limited depths near the shelf break.

In general, the distribution of the 18 foraging guilds across the depth range of 10-200 m was most complete in 1972-1973, with some guilds showing large gaps in occurrence during the four periods. Among guilds foraging from the water column, these gaps occurred among schooling pelagivores (Guild 1A1), midwater and cruising pelagobenthivores (Guilds 1B1 and 1B2), cruising nocturnal benthopelagivores (1C2), cruising benthivores (1D). Among guilds foraging from the bottom, large gaps of presence occurred among benthic ambushing benthopelagivores sizes A (pygmy poacher guild; 2C2a) and D (scorpionfish guild; 2C2d). The organization is generally stable if a single dominant guild member occupies a broad depth range on the shelf. However, if an expected dominant from Allen (1982) is missing, there may be no good replacement (Allen *et al.* 2002a). This is particularly apparent in the outer shelf representative of the sculpin (2C2c) and scorpionfish guild (2C2d). Whereas the greenblotched rockfish (SR) was dominant on the outer shelf in these guilds in 1972-1973, larger members of this species (2C2d) were rare in 1994, and were very rare in 1998, with many closely related species (green spotted rockfish, pink rockfish) and some less closely related species (shortspine thornyhead; California scorpionfish) being caught within the outer shelf. This suggests that the best-adapted species of this guild for the outer shelf soft-bottom habitat of southern California is the greenblotched rockfish.

Thus, responses of different foraging guilds to changing ocean conditions varied between different oceanic periods. In some cases, these suggest a response to the oceanic cycles during the past 30 years (Chavez *et al.* 2003, Allen *et al.* 2004, Goericke *et al.* 2005. During the warm regime, ocean temperatures increased, upwelling in the California Current decreased, and zooplankton abundance decreased (Roemmich and McGowan 1995, Smith 1995, Chavez *et al.* 2003). In most cases (Figures VI-28a through VI-28d) there appears to be an El Niño effect in 1998 that is greater than the differences between 1972-1973 and 1994. These responses occur primarily on the inner shelf and shallow middle shelf, but in some guilds, responses occurred at the interface of the middle shelf and outer shelf. During an El Niño, the thermocline deepens and bottom water temperatures are warmer on the shelf (Dark and Wilkins 1994, Hayward 2000), perhaps causing species to expand or contract their bathymetric or geographic ranges. Some changes occurring during this period may be related to zooplankton abundance or decreased transport of larvae in the California Current from the north, whereas others may be due to movement of juveniles and adults to more desirable conditions. In addition, several guilds showed a resilient return in 2003 to 1972 patterns. In guilds 1A2b (midshipman guild), 2B (sanddab guild), and 2C1 (combfish guilds) the patterns in the two cold regime periods (1972 and 2003) were exactly the same. In guild 1A2a (rockfish) and 1C1 (seaperch), the guilds were almost exactly the same. In general the patterns of these two periods were more similar than either was to 1994 or 1998. Knowledge of the oceanic regime at the time of a survey may allow prediction of expected community structure at a given depth.

These regional surveys have demonstrated that characteristics of the fish communities (abundance, biomass, and depth distribution of component species) vary by oceanic regime, with evidence that some fish foraging guilds return to similar patterns in at least one of these regimes (cold). The results demonstrate that assessments of anthropogenic effects on demersal fish communities must consider the oceanic regime of the assessment period to avoid confusing natural changes with anthropogenic effects.

VII. ECTOPARASITISM OF FISHES

Introduction

Effluent pollution, generally organic material, has the potential to adversely affect fishes and invertebrates through effects such as oxygen depletion (Tsai 1973). Exposure to pollution may result in stress, which could potentially decrease the immune response in fishes and increase their susceptibility to diseases and parasites (Ellis 1981, Adams 1990). A variety of organisms have been evaluated as potential biological indicators of pollution in the aquatic environment, such as polychaetes, mollusks, and fishes (Wolfe 1992 Doherty *et al.* 1993, Wilson 1994, George-Nascimento *et al.* 2000). However, due to the range of contaminants, concentrations, and exposure time that marine organisms experience, it is unclear which organisms and which anomalies are best used as indicators. Many of these studies measured the amount of toxins, such as heavy metals, accumulated in the tissues of the indicator species (Doherty *et al.* 1993, Cross *et al.* 2001). Cross *et al.* (2001) found that the quality of the larval stage of a parasitic marine trematode (the cercariae), in terms of horizontal swimming rate and longevity, was reduced when development occurred within a metal-accumulating host. They speculated that the cercarial tegument, which is specialized for absorption in the endoparasitic environment, was responsible for quick metal accumulation and thus suggested that cercariae may be excellent indicator organisms for heavy metal pollution. Others have used low reproductive output (k) factors, anemia, and low blood hemoglobin and lymphocyte levels as indicators of stress in fish (Barker *et al.* 1994, George-Nascimento *et al.* 2000). Perkins (1995) illustrated effects of wastewater on three target species of marine fishes: bigmouth sole, hornyhead turbot, and white croaker. The fishes collected close to the outfall suffered severe liver neoplasms compared to those collected further away from the outfall. In addition, fin erosion in some flatfishes appears to be directly associated with discharge of municipal effluent (Mearns and Sherwood, 1977). Many studies have used fin erosion, tumors, and lesions as indicators of environmental stress (Mearns and Sherwood 1977, Siddall *et al.* 1994, Sures *et al.* 1997; Landsberg *et al.* 1998, George-Nascimento *et al.* 2000). George-Nascimento *et al.* (2000) found lesions and impaired blood values, such as low hemoglobin, total plasma protein, and lymphocytes, in flounder (*Paralichthys* spp.) at heavily polluted sites. The historical decrease in abundance or complete absence of a species, such red brittlestar, has also been used as an indicator of sediment contamination (OCSD, 2006).

Conversely, the presence and consistent abundance of specific organisms in routine monitoring indicate stable habitat quality (OCSD, 2006). More than a hundred papers have established a correlation between parasitism and pollution in marine fishes (Khan and Thulin, 1991). Williams and MacKenzie (2003) discuss eight major reviews and give a literature update for the period 1995-2001 on the use of marine parasites as potential indicators of pollution. They proposed 10 criteria for selecting parasites as indicator/monitoring species, as follows: 1) the ecology of the study areas should be well known from research over a long period, 2) both host and parasite should be readily available for study throughout the year and over a number of years using cost-effective methods, 3) host and parasite should be readily identifiable without the aid of time-consuming methods, 4) problems regarding possible sampling of different host and parasite populations should be taken into consideration, 5) the ecology and life-cycles of both host and parasite should be well known, 6) there should be consistency in the use of ecological terms, for example those in Bush *et al.* (1997), 7) the pollutant(s) should be identifiable and their possible effects on both host and parasite considered relative to those of almost 30 biotic and abiotic factors, 8) selection should focus on host/parasite systems with large geographical and ecological ranges, but also where populations might be restricted in their migrations within this range, and sampling should occur where conditions are thought to be optimal for host and parasite as well as near the limits of the parasite's geographical range, 9) wherever possible the indicator parasite(s) should be used in conjunction with one or more of about 50 other techniques used for monitoring the biological effects of pollution, and 10) host/parasite systems for which it might be possible to investigate the complex interactions between pollutant, immune response and parasites when interpreting results should be selected (Williams and MacKenzie 2003).

Few have used host organisms and ectoparasites as indicators of effluent pollution in southern California (Mearns and Sherwood 1977; Perkins and Gartman 1997; Kalman 2001, 2006a,b; Hogue and Paris 2002; Hogue and Peng 2003). Parasites are potentially good candidates for indicator species in the marine environment because 1) there are more parasitic than free-living species, 2) many have complex life cycles with multiple stages, each with potential as an indicator, and 3) there is likely varying species resistance to pollution (MacKenzie 1999). A change in parasite levels of infection may serve as an early warning of deteriorating environmental conditions before a large number of species are seriously affected (MacKenzie 1999).

Many biotic and abiotic factors influence the prevalence and mean intensity of fish parasites. Field and laboratory research indicates that the incidence and intensity of infestation of ectoparasites are enhanced by exposure to environmental pollution (Mearns and Sherwood, 1977, Siddall *et al.* 1994, Perkins and Gartman 1997, Landsberg *et al.* 1998, MacKenzie 1999). However, many of these studies were conducted on a small scale in terms of location (i.e., restricted to a single location or area) or targeted a single host and/or parasite species. Perkins and Gartman (1997) determined the prevalence (percentage of fishes parasitized) of the eye copepod (*Phrixocephalus cincinnatus*), on the Pacific sanddab in southern California to be highest at areas nearest to effluent discharge. However, Mearns and Sherwood (1977) found the prevalence of the eye copepod on Pacific sanddab to be lowest in more polluted areas (Santa Monica Bay to San Pedro Bay) and highest in cleaner areas to the north and south. They speculated that because the parasite feeds on the vascular supply of choroid tissue of the eye of the fish host, the elevated levels of chlorinated hydrocarbons in the tissues of the host may have been related to the absence of parasitized individuals in more polluted areas. Landsberg *et al.* (1998) showed that ecto- and endoparasites of the silver perch (*Bairdiella chrysoura*) respond differently to different environmental stressors. They found that responses of specific parasite groups vary according to different environmental stressors; monogeneans with temperature, nematodes with contaminants, protists with low dissolved oxygen, and crustaceans with salinity and metal contaminants (Landsberg *et al.* 1998). They suggested that parasites of fishes are useful biomarkers because the parasites themselves appeared to be more sensitive to environmental stressors than did the fishes. MacKenzie (1999) concluded that as a general rule, endoparasites, with complex indirect life cycles, tend to decrease with increasing levels of pollution, whereas ectoparasites, with direct single-host life cycles, tend to increase with increasing levels of pollution.

The present study evaluates the conditions around wastewater outfalls in terms of infestation of ectoparasites on fishes and examines whether specific parasite and/or host species can be used as bioindicators of environmental stress. The Southern California Bight (SCB) provides an ideal area in which to examine the impact of effluent pollution on fishes and their corresponding parasites. While it is widely known that the southern California marine environment has been subjected to numerous inputs of pollution, such as wastewater effluent, storm runoff, Dichloro-diphenyl-trichloroethane (DDT), and Polychlorinated Biphenyls (PCBs; Dorsey *et al.* 1995, Stull 1995, Schiff 2000, Schiff *et al.* 2000, Allen 2006b), little is known about the effects of pollution on parasites of marine fishes in the SCB. In addition, it is unclear to what degree parasites cause stress to their host and what long-term damage occurs to host physiological responses. Chronic stress can inhibit an organism's normal physiological response to the environment. Thus, fishes may be subjected to two major forms of environmental stress in the SCB: parasites and poor water quality. A detailed investigation of the parasite community in outfall areas may provide important knowledge about the influence of environmental variables on parasite-host relationships.

Because of the importance of the soft-bottom fish fauna to fisheries and to environmental assessments of human activities on the continental shelf, the biology and ecology of soft-bottom fishes have been relatively well studied (Allen 2006a). In addition, studies have shown flatfishes and scorpionfishes to be infested with monogeneans, leeches, copepods, and isopods (Causey 1960; Cressey 1969; Ho 1972a, 1972b; Mearns and Sherwood, 1977; Dojiri, 1979, 1981; Dojiri and Brantley 1991; Allen *et al.* 1998; Kalman 2001, 2003, 2006a,b). In 2003 (July through September), through a joint project with University of California Los Angeles (UCLA), the Orange County Sanitation District-Ocean Monitoring Program, and SCCWRP, fishes collected during Bight '03 and the permit-required monitoring programs of the four major sanitation districts (HY, LA, OC, and SD) were examined for ectoparasites. The goals of this project were to assess the parasite community 1) in the SCB, 2) regionally, 3) by outfall type (large, small, and nonoutfall), and 4) across the four large-outfalls. Furthermore, the use of specific parasite and host species as bioindicators of environmental stress in the SCB was investigated. Additional detail on the results given below can be found in Kalman (2006b).

Results

Otter trawl sampling occurred at 79 stations at depths of 22-198 m in the SCB. Nominal coordinates and start depth for each station were reported in Appendix E-E1. Sampling encompassed the mainland shelf and northern Channel Islands from Point Conception, California, to the United States-Mexico International Border (Figure II-3). A total of 15,848 individual fish representing 34 species (including six families, 17 genera) were examined (Table VII-1). Host vouchers were deposited in the Natural History Museum of Los Angeles County (LACM 56324-1 through 56348-2).

A total of 14,620 parasites composed of monogeneans (681 individuals), leeches (97 individuals), branchiurans (six individuals), copepods (12,795 individuals), and isopods (1,041 individuals) infected the host fishes (Table VII-2). The parasites consisted of three species of monogeneans (representing two orders, three families, three genera), four species of leeches (representing one order, one family, one genus), one species of branchiuran (Argulidae), 26 species of adult copepods (representing two orders, six families, 12 genera), one larval copepod (chalimus) representing a single family (Caligidae), two species of adult isopods (representing one order, one family, one genus), and two larval isopods (aegathoid and praniza) representing two families (Cymothoidae and Gnathiidae, respectively; Appendix E-E2). Host-parasite and parasite-host tables are presented in Appendix E-E3 and E-E4, respectively. Parasite vouchers were deposited at the U.S. National Parasite Collection (monogeneans; USNPC 97856 through 97858), the Smithsonian National Museum of Natural History (leeches; USNM 1086228 through 1086230), and the Natural History Museum of Los Angeles County (crustaceans; LACM CR 2003-018.1 through 2003-041.1).

Southern California Bight (SCB)

Total parasitization was calculated for individual host fishes collected at 79 stations throughout the SCB and ranked in order of highest to lowest prevalence (Table VII-3). The prevalence ranged from 0% to 100% and the mean intensity ranged from 0.0 to 48.2. Of fishes with parasites, longspine combfish had the lowest prevalence (0.2%) and fantail sole had the highest prevalence (100%); C-O sole, Gulf sanddab, and rex sole had the lowest mean intensity (1.0) and California scorpionfish had the highest mean intensity (48.2). No parasites were found on 11 host species. However, other species, such as Pacific sanddab, bigmouth sole, and California halibut, carried as many as 11 species of parasites (Appendix E-E3). Three new species of leeches (*Austrobdella* spp. 1-3) and one new species of parasitic copepod (*Parabrachiella* spp. 1) were found in this study. In addition, 56 new host records are reported (Appendix E-E3 and E-E4).

Region

Host species totals were separated by four regions within the SCB (Northern Channel Islands, Northern Mainland Shelf, Central Mainland Shelf, and Southern Mainland Shelf; Table VII-4). Six of 34 species of hosts were collected in all four Regions: longspine combfish, Pacific sanddab, speckled sanddab, Dover sole, English sole, and curlfin sole. Northern Channel Islands consisted of 13 stations, Northern Mainland Shelf consisted of one station, Central Mainland Shelf consisted of 44 stations, and Southern Mainland Shelf consisted of 21 stations (Figure II-3). The total number of stations in which each host was collected was calculated for each Region (Table VII-5).

Total parasite prevalence and mean intensity were calculated for each host species for each Region in which it was collected (Tables VII-6 and VII-7, respectively). There was a significant difference in median prevalence for three host species by Region ($p \leq 0.05$: Pacific sanddab, p=0.0281; speckled sanddab, p=0.0293; hornyhead turbot, p=0.0002), and there was a significant difference in median mean intensity for three host species by Region ($p \leq 0.05$: Pacific sanddab, p=0.0051; bigmouth sole, p=0.0296; English sole, p=0.0449). The total prevalence and mean intensity for Pacific sanddab in all four Regions was 12.7% and 1.4 (n=497, 3 stations) on the Northern Channel Islands, 19.4% and 1.1 (n=36, 1 station) on the Northern Mainland Shelf, 5.5% and 1.1 (n=4,132, 43 station) on the Central Mainland Shelf, and 5.0% and 1.2 (n=1,437, 18 stations) on the Southern Mainland Shelf (Tables VII-5 to VII-7). The total prevalence for speckled sanddab in all four Regions was 18.2% (n=55, 1 station) on the Northern Channel Islands, 10.9% (n=165, 1 station) on the Northern Mainland Shelf, 44.2% (n=443, 17 stations) on the Central Mainland Shelf, and 28.7% (n=522, 10 stations) on the Southern Mainland Shelf (Tables VII-4 through VII-6). The total mean intensity for bigmouth sole in the two Regions in which it was collected was 2.6 (n=101, 33 stations) on the Central Mainland Shelf, and 4.6 (n=32, 11 stations) on the Southern Mainland Shelf (Tables VII-5, VII-6, and VII-8). The total mean intensity for English sole in all four regions was 2.6 (n=24, 4 stations) on the Northern Channel Islands, 1.2 (n=19, 1 station) on the Northern Mainland Shelf, 2.2 (n=396, 32 stations) on the Central Mainland Shelf, and 1.4 (n=124, 7 stations) on the Southern Mainland Shelf. The total prevalence for hornyhead turbot in the two Regions in which it was collected was 64.5% (n=313, 41 stations) on the Central Mainland Shelf and 97.1% (n=35, 12 stations) on the Southern Mainland Shelf (Tables VII-5 through VII-7).

Host-parasite prevalence and mean intensity were calculated for each Region (Appendix E-E5 and E-E6, respectively). There was a significant difference in median prevalence for three parasite species by Region ($p \leq 0.05$: the copepod *Clavella parva* on stripetail rockfish, p=0.0453; the copepod *Holobomolochus prolixus* on speckled sanddab, p=0.0497; the leech *Austrobdella* spp. 2 on hornyhead turbot, p=0.0272). The Kruskal-Wallis test showed a significant difference in median mean intensity for five parasite species by Region ($p \leq 0.05$: the copepod *Naobranchia scorpaenae* on California scorpionfish, p=0.0009; the eye copepod (*Phrixocephalus cincinnatus*) on Pacific sanddab, p=0.0006, the monogenetic trematode *Neoheterobothrium hippoglossini* on bigmouth sole, p=0.0260; gnathiid isopod praniza on bigmouth sole, p=0.0374; the copepod *Taeniacanthodes haakeri* on hornyhead turbot, p=0.0285).

Table VII-1. Host fish taxa collected at depths of 22-198 m in the Southern California Bight, July-October 2003.

Taxon/Species	Common Name
SCORPAENIFORMES	
Scorpaenidae	
Scorpaena guttata Girard, 1854	California scorpionfish
Sebastes caurinus Richardson, 1844	copper rockfish
Sebastes chlorostictus (Jordan and Gilbert, 1880)	greenspotted rockfish
Sebastes dallii (Eigenmann and Beeson, 1894)	calico rockfish
Sebastes elongatus Ayres, 1859	greenstriped rockfish
Sebastes goodei (Eigenmann and Eigenmann, 1890)	chilipepper
Sebastes jordani (Gilbert, 1896)	shortbelly rockfish
Sebastes miniatus (Jordan and Gilbert, 1880)	vermilion rockfish
Sebastes paucispinis Ayres, 1854	boccacio
Sebastes rubrivinctus (Jordan and Gilbert, 1880)	flag rockfish
Sebastes saxicola (Gilbert, 1890)	stripetail rockfish
Sebastes semicinctus (Gilbert, 1897)	halfbanded rockfish
Hexagrammidae	
Ophiodon elongatus Girard, 1854	lingcod
Zaniolepis frenata Eigenmann and Eigenmann, 1889	shortspine combfish
Zaniolepis latipinnis Girard, 1858	longspine combfish
Cottidae	
Chitonotus pugetensis (Steindachner, 1876)	roughback sculpin
Icelinus quadriseriatus (Lockington, 1880)	yellowchin sculpin
Icelinus tenuis Gilbert, 1890	spotfin sculpin
PLEURONECTIFORMES	
Paralichthyidae	
Citharichthys fragilis Gilbert, 1890	Gulf sanddab
Citharichthys sordidus (Girard, 1854)	Pacific sanddab
Citharichthys stigmaeus Jordan and Gilbert, 1882	speckled sanddab
Citharichthys xanthostigma Gilbert, 1890	longfin sanddab
Hippoglossina stomata Eigenmann and Eigenmann, 1890	bigmouth sole
Paralichthys californicus (Ayres, 1859)	California halibut
Xystreurys liolepis Jordan and Gilbert, 1880	fantail sole
Pleuronectidae	
Glyptocephalus zachirus Lockington, 1879	rex sole
Lepidopsetta bilineata (Ayres, 1855)	rock sole
Lyopsetta exilis (Jordan and Gilbert, 1880)	slender sole
Microstomus pacificus (Lockington, 1879)	Dover sole
Parophrys vetulus (Girard, 1854)	English sole
Pleuronichthys coenosus Girard, 1854	C-O sole
Pleuronichthys decurrens Jordan and Gilbert, 1881	curlfin sole
Pleuronichthys verticalis Jordan and Gilbert, 1880	hornyhead turbot
Cynoglossidae	
Symphurus atricaudus (Jordan and Gilbert, 1880)	California tonguefish

Table VII-2. Classification and group totals of parasites on fishes collected at depths of 22-198 m in the Southern California Bight, July-October 2003.

PLATYHELMINTHES	681		
Monogenea		681	
Monopisthocotylea			
Capsalidae			79
Polyopisthocotylea			
Diclidophoridae			105
Microcotylidae			497
ANNELIDA	97		
Clitellata			
Hirudinida		97	
Rhynchobdellida			
Piscicolidae			97
ARTHROPODA	13,842		
Crustacea			
Maxillopoda			
Branchiura		6	
Arguloida			
Argulidae			6
Copepoda		12,795	
Poecilostomatoida			
Bomolochidae			742
Chondracanthidae			345
Taeniacanthidae			136
Siphonostomatoida			
Caligidae			1,372
Lernaeopodidae			9,927
Pennellidae			273
Malacostraca			
Eumalacostraca			
Isopoda		1,041	
Cymothoidae			82
Gnathiidae			959
TOTAL =	14,620		

Table VII-3. Total parasite prevalence and mean intensity for all host fish species collected from 79 stations at depths of 22-198 m in the Southern California Bight (SCB), July through October 2003, with host fishes ranked in order of highest to lowest prevalence.

SCB					
Host			Parasite		
Species	Sampled	Infected	n	Prevalence (%)	Mean Intensity
Xystreurys liolepis	26	26	171	100.0	6.6
Scorpaena guttata	216	210	10,132	97.2	48.2
Paralichthys californicus	27	26	234	96.3	9.0
Sebastes miniatus	26	20	96	76.9	4.8
Pleuronichthys verticalis	348	236	839	67.8	3.6
Hippoglossina stomata	133	89	270	66.9	3.0
Sebastes chlorostictus	22	10	37	45.5	3.7
Parophrys vetulus	563	241	520	42.8	2.2
Pleuronichthys decurrens	56	22	45	39.3	2.0
Pleuronichthys coenosus	3	1	1	33.3	1.0
Citharichthys stigmaeus	1,185	374	537	31.6	1.4
Sebastes saxicola	546	174	647	31.9	3.7
Citharichthys xanthostigma	1,101	257	440	23.3	1.7
Lepidopsetta bilineata	5	1	2	20.0	2.0
Ophiodon elongatus	88	10	12	11.4	1.2
Citharichthys fragilis	11	1	1	9.1	1.0
Citharichthys sordidus	6,102	369	424	6.0	1.1
Microstomus pacificus	571	30	95	5.3	3.2
Sebastes semicinctus	581	28	38	4.8	1.4
Glyptocephalus zachirus	23	1	1	4.3	1.0
Icelinus quadriseriatus	1,615	64	68	4.0	1.1
Chitonotus pugetensis	416	4	5	1.0	1.3
Zaniolepis latipinnis	1,411	3	5	0.2	1.7
Symphurus atricaudus	522	0	-----	0.0	0.0
Zaniolepis frenata	98	0	-----	0.0	0.0
Lyopsetta exilis	91	0	-----	0.0	0.0
Icelinus tenuis	21	0	-----	0.0	0.0
Sebastes elongatus	17	0	-----	0.0	0.0
Sebastes dallii	12	0	-----	0.0	0.0
Sebastes caurinus	5	0	-----	0.0	0.0
Sebastes goodei	2	0	-----	0.0	0.0
Sebastes paucispinis	2	0	-----	0.0	0.0
Sebastes rubrivinctus	2	0	-----	0.0	0.0
Sebastes jordani	1	0	-----	0.0	0.0
TOTAL =	15,848	2,197	14,620		
MEAN =				13.9	6.7

Table VII-4. Host totals by region collected at depths of 22-198 m in the Southern California Bight, July-October 2003.

Host		TOTAL HOSTS SCB*	NCI	NMS	CMS	SMS
	Total # of stations:	79	13	1	44	21
SCORPAENIFORMES						
Scorpaenidae						
Scorpaena guttata	California scorpionfish	216	1	0	153	62
Sebastes caurinus	copper rockfish	5	0	0	5	0
Sebastes chlorostictus	greenspotted rockfish	22	0	0	22	0
Sebastes dallii	calico rockfish	12	0	0	12	0
Sebastes elongatus	greenstriped rockfish	17	0	0	7	10
Sebastes goodei	chilipepper	2	0	0	2	0
Sebastes jordani	shortbelly rockfish	1	0	0	0	1
Sebastes miniatus	vermilion rockfish	26	0	0	25	1
Sebastes paucispinis	boccacio	2	0	0	2	0
Sebastes rubrivinctus	flag rockfish	2	0	0	0	2
Sebastes saxicola	stripetail rockfish	546	75	0	321	150
Sebastes semicinctus	halfbanded rockfish	581	54	0	338	189
Hexagrammidae						
Ophiodon elongatus	lingcod	88	0	0	87	1
Zaniolepis frenata	shortspine combfish	98	0	0	42	56
Zaniolepis latipinnis	longspine combfish	1411	155	6	1,100	150
Cottidae						
Chitonotus pugetensis	roughback sculpin	416	17	0	363	36
Icelinus quadriseriatus	yellowchin sculpin	1615	0	20	1,358	237
Icelinus tenuis	spotfin sculpin	21	13	0	2	6
PLEURONECTIFORMES						
Paralichthyidae						
Citharichthys fragilis	Gulf sanddab	11	0	0	9	2
Citharichthys sordidus	Pacific sanddab	6102	497	36	4,132	1,437
Citharichthys stigmaeus	speckled sanddab	1185	55	165	443	522
Citharichthys xanthostigma	longfin sanddab	1101	0	0	666	435
Hippoglossina stomata	bigmouth sole	133	0	0	101	32
Paralichthys californicus	California halibut	27	0	0	14	13
Xystreurys liolepis	fantail sole	26	0	2	22	2
Pleuronectidae						
Glyptocephalus zachirus	rex sole	23	22	0	0	1
Lepidopsetta bilineata	rock sole	5	5	0	0	0
Lyopsetta exilis	slender sole	91	38	0	16	37
Microstomus pacificus	Dover sole	571	82	21	258	210
Parophrys vetulus	English sole	563	24	19	396	124
Pleuronichthys coenosus	C-O sole	3	0	0	3	0
Pleuronichthys decurrens	curlfin sole	56	42	8	5	1
Pleuronichthys verticalis	hornyhead turbot	348	0	0	313	35
Cynoglossidae						
Symphurus atricaudus	California tonguefish	522	0	1	402	119
	TOTAL =	15,848	1,080	278	10,619	3,871

*SCB = Southern California Bight; NCI = Northern Channel Islands (San Miguel, Santa Rosa, Santa Cruz, and Anacapa); NMS = Northern Mainland Shelf (Point Conception to Point Dume); CMS = Central Mainland Shelf (Point Dume to Dana Point); SMS = Southern Mainland Shelf (Dana Point to United States-Mexico border)

Table VII-5. Number of stations each host was collected by Region in the Southern California Bight at depths of 22-198 m, July through October 2003.

Host		TOTAL STATIONS SCB*	NCI	NMS	CMS	SMS
Total No.of stations:		79	13	1	44	21
SCORPAENIFORMES						
Scorpaenidae						
Scorpaena guttata	California scorpionfish	43	1	0	34	8
Sebastes caurinus	copper rockfish	1	0	0	1	0
Sebastes chlorostictus	greenspotted rockfish	1	0	0	1	0
Sebastes dallii	calico rockfish	2	0	0	2	0
Sebastes elongatus	greenstriped rockfish	4	0	0	2	2
Sebastes goodei	chilipepper	1	0	0	1	0
Sebastes jordani	shortbelly rockfish	1	0	0	0	1
Sebastes miniatus	vermilion rockfish	3	0	0	2	1
Sebastes paucispinis	boccacio	1	0	0	1	0
Sebastes rubrivinctus	flag rockfish	1	0	0	0	1
Sebastes saxicola	stripetail rockfish	31	2	0	17	12
Sebastes semicinctus	halfbanded rockfish	31	1	0	21	9
Hexagrammidae						
Ophiodon elongatus	lingcod	14	0	0	13	1
Zaniolepis frenata	shortspine combfish	10	0	0	5	5
Zaniolepis latipinnis	longspine combfish	52	3	1	37	11
Cottidae						
Chitonotus pugetensis	roughback sculpin	40	1	0	33	6
Icelinus quadriseriatus	yellowchin sculpin	54	0	1	39	14
Icelinus tenuis	spotfin sculpin	3	1	0	1	1
PLEURONECTIFORMES						
Paralichthyidae						
Citharichthys fragilis	Gulf sanddab	3	0	0	1	2
Citharichthys sordidus	Pacific sanddab	65	3	1	43	18
Citharichthys stigmaeus	speckled sanddab	29	1	1	17	10
Citharichthys xanthostigma	longfin sanddab	47	0	0	31	16
Hippoglossina stomata	bigmouth sole	44	0	0	33	11
Paralichthys californicus	California halibut	16	0	0	9	7
Xystreurys liolepis	fantail sole	11	0	1	8	2
Pleuronectidae						
Glyptocephalus zachirus	rex sole	2	1	0	0	1
Lepidopsetta bilineata	rock sole	1	1	0	0	0
Lyopsetta exilis	slender sole	5	1	0	2	2
Microstomus pacificus	Dover sole	35	2	1	21	11
Parophrys vetulus	English sole	44	4	1	32	7
Pleuronichthys coenosus	C-O sole	1	0	0	1	0
Pleuronichthys decurrens	curlfin sole	7	3	1	2	1
Pleuronichthys verticalis	hornyhead turbot	53	0	0	41	12
Cynoglossidae						
Symphurus atricaudus	California tonguefish	51	0	1	37	13

*SCB = Southern California Bight; NCI = Northern Channel Islands (San Miguel, Santa Rosa, Santa Cruz, and Anacapa); NMS = Northern Mainland Shelf (Point Conception to Point Dume); CMS = Central Mainland Shelf (Point Dume to Dana Point); SMS = Southern Mainland Shelf (Dana Point to United States-Mexico border)

Table VII-6. Total parasite prevalence by Region collected at depths of 22-198 m in the Southern California Bight, July through October 2003.

Host		PREVALENCE (%) SCB*	NCI	NMS	CMS	SMS
SCORPAENIFORMES						
Scorpaenidae						
Scorpaena guttata	California scorpionfish	97.2	100	-----	98.0	95.2
Sebastes caurinus	copper rockfish	0.0	-----	-----	0.0	-----
Sebastes chlorostictus	greenspotted rockfish	45.5	-----	-----	45.5	-----
Sebastes dallii	calico rockfish	0.0	-----	-----	0.0	-----
Sebastes elongatus	greenstriped rockfish	0.0	-----	-----	0.0	0.0
Sebastes goodei	chilipepper	0.0	-----	-----	0.0	-----
Sebastes jordani	shortbelly rockfish	0.0	-----	-----	-----	0.0
Sebastes miniatus	vermilion rockfish	76.9	-----	-----	80.0	0.0
Sebastes paucispinis	boccacio	0.0	-----	-----	0.0	-----
Sebastes rubrivinctus	flag rockfish	0.0	-----	-----	-----	0.0
Sebastes saxicola	stripetail rockfish	31.9	0.0	-----	48.6	12.0
Sebastes semicinctus	halfbanded rockfish	4.8	3.7	-----	5.6	3.7
Hexagrammidae						
Ophiodon elongatus	lingcod	11.4	-----	-----	11.5	0.0
Zaniolepis frenata	shortspine combfish	0.0	-----	-----	0.0	0.0
Zaniolepis latipinnis	longspine combfish	0.2	0.0	0.0	0.3	0.0
Cottidae						
Chitonotus pugetensis	roughback sculpin	1.0	0.0	-----	1.1	0.0
Icelinus quadriseriatus	yellowchin sculpin	4.0	-----	0.0	4.6	0.8
Icelinus tenuis	spotfin sculpin	0.0	0.0	-----	0.0	0.0
PLEURONECTIFORMES						
Paralichthyidae						
Citharichthys fragilis	Gulf sanddab	9.1	-----	-----	11.1	0.0
Citharichthys sordidus	Pacific sanddab	6.0	12.7	19.4	5.5	5.0
Citharichthys stigmaeus	speckled sanddab	31.6	18.2	10.9	44.2	28.7
Citharichthys xanthostigma	longfin sanddab	23.3	-----	-----	23.4	23.2
Hippoglossina stomata	bigmouth sole	66.9	-----	-----	67.3	65.6
Paralichthys californicus	California halibut	96.3	-----	-----	92.9	100
Xystreurys liolepis	fantail sole	100.0	-----	100	100	100
Pleuronectidae						
Glyptocephalus zachirus	rex sole	4.3	4.5	-----	-----	0.0
Lepidopsetta bilineata	rock sole	20.0	20.0	-----	-----	-----
Lyopsetta exilis	slender sole	0.0	0.0	-----	0.0	0.0
Microstomus pacificus	Dover sole	5.3	1.2	4.8	7.4	4.3
Parophrys vetulus	English sole	42.8	70.8	47.4	50.5	12.1
Pleuronichthys coenosus	C-O sole	33.3	-----	-----	33.3	-----
Pleuronichthys decurrens	curlfin sole	39.3	40.5	37.5	40.0	0.0
Pleuronichthys verticalis	hornyhead turbot	67.8	-----	-----	64.5	97.1
Cynoglossidae						
Symphurus atricaudus	California tonguefish	0.0	-----	0.0	0.0	0.0

*SCB = Southern California Bight; NCI = Northern Channel Islands (San Miguel, Santa Rosa, Santa Cruz, and Anacapa); NMS = Northern Mainland Shelf (Point Conception to Point Dume); CMS = Central Mainland Shelf (Point Dume to Dana Point); SMS = Southern Mainland Shelf (Dana Point to United States-Mexico border)

Table VII-7. Total parasite mean intensity by Region collected at depths of 22-198 m in the Southern California Bight, July through October 2003.

		MEAN INTENSITY				
Host		SCB*	NCI	NMS	CMS	SMS
SCORPAENIFORMES						
Scorpaenidae						
Scorpaena guttata	California scorpionfish	48.2	33.0	-----	61.8	14.2
Sebastes caurinus	copper rockfish	0.0	-----	-----	0.0	-----
Sebastes chlorostictus	greenspotted rockfish	3.7	-----	-----	3.7	-----
Sebastes dallii	calico rockfish	0.0	-----	-----	0.0	-----
Sebastes elongatus	greenstriped rockfish	0.0	-----	-----	0.0	0.0
Sebastes goodei	chilipepper	0.0	-----	-----	0.0	-----
Sebastes jordani	shortbelly rockfish	0.0	-----	-----	-----	0.0
Sebastes miniatus	vermilion rockfish	4.8	-----	-----	4.8	0.0
Sebastes paucispinis	boccacio	0.0	-----	-----	0.0	-----
Sebastes rubrivinctus	flag rockfish	0.0	-----	-----	-----	0.0
Sebastes saxicola	stripetail rockfish	3.7	0.0	-----	3.9	1.9
Sebastes semicinctus	halfbanded rockfish	1.4	1.5	-----	1.3	1.6
Hexagrammidae						
Ophiodon elongatus	lingcod	1.2	-----	-----	1.2	0.0
Zaniolepis frenata	shortspine combfish	0.0	-----	-----	0.0	0.0
Zaniolepis latipinnis	longspine combfish	1.7	0.0	0.0	1.7	0.0
Cottidae						
Chitonotus pugetensis	roughback sculpin	1.3	0.0	-----	1.3	0.0
Icelinus quadriseriatus	yellowchin sculpin	1.1	-----	0.0	1.1	1.0
Icelinus tenuis	spotfin sculpin	0.0	0.0	-----	0.0	0.0
PLEURONECTIFORMES						
Paralichthyidae						
Citharichthys fragilis	Gulf sanddab	1.0	-----	-----	1.0	0.0
Citharichthys sordidus	Pacific sanddab	1.1	1.4	1.1	1.1	1.2
Citharichthys stigmaeus	speckled sanddab	1.4	1.1	1.1	1.5	1.4
Citharichthys xanthostigma	longfin sanddab	1.7	-----	-----	1.7	1.8
Hippoglossina stomata	bigmouth sole	3.0	-----	-----	2.6	4.6
Paralichthys californicus	California halibut	9.0	-----	-----	10.9	7.1
Xystreurys liolepis	fantail sole	6.6	-----	2.0	6.4	13.5
Pleuronectidae						
Glyptocephalus zachirus	rex sole	1.0	1.0	-----	-----	0.0
Lepidopsetta bilineata	rock sole	2.0	2.0	-----	-----	-----
Lyopsetta exilis	slender sole	0.0	0.0	-----	0.0	0.0
Microstomus pacificus	Dover sole	3.2	1.0	1.0	3.9	2.0
Parophrys vetulus	English sole	2.2	2.6	1.2	2.2	1.4
Pleuronichthys coenosus	C-O sole	1.0	-----	-----	1.0	-----
Pleuronichthys decurrens	curlfin sole	2.0	1.5	3.3	4.5	0.0
Pleuronichthys verticalis	hornyhead turbot	3.6	-----	-----	3.6	3.4
Cynoglossidae						
Symphurus atricaudus	California tonguefish	0.0	-----	0.0	0.0	0.0

*SCB = Southern California Bight; NCI = Northern Channel Islands (San Miguel, Santa Rosa, Santa Cruz, and Anacapa); NMS = Northern Mainland Shelf (Point Conception to Point Dume); CMS = Central Mainland Shelf (Point Dume to Dana Point); SMS = Southern Mainland Shelf (Dana Point to United States-Mexico border)

Table VII-8. Host totals by Outfall Type collected at depths of 22-198 m in the Southern California Bight, July through October 2003.

Host		TOTAL HOSTS SCB*	Large	Small	Non
	Total number of stations:	79	27	15	24
SCORPAENIFORMES					
Scorpaenidae					
Scorpaena guttata	California scorpionfish	216	132	47	36
Sebastes caurinus	copper rockfish	5	0	0	5
Sebastes chlorostictus	greenspotted rockfish	22	0	0	22
Sebastes dallii	calico rockfish	12	12	0	0
Sebastes elongatus	greenstriped rockfish	17	7	0	10
Sebastes goodei	chilipepper	2	0	0	2
Sebastes jordani	shortbelly rockfish	1	1	0	0
Sebastes miniatus	vermilion rockfish	26	6	1	19
Sebastes paucispinis	boccacio	2	2	0	0
Sebastes rubrivinctus	flag rockfish	2	2	0	0
Sebastes saxicola	stripetail rockfish	546	227	65	179
Sebastes semicinctus	halfbanded rockfish	581	232	69	226
Hexagrammidae					
Ophiodon elongatus	lingcod	88	43	0	45
Zaniolepis frenata	shortspine combfish	98	60	8	30
Zaniolepis latipinnis	longspine combfish	1,411	740	67	449
Cottidae					
Chitonotus pugetensis	roughback sculpin	416	169	2	228
Icelinus quadriseriatus	yellowchin sculpin	1,615	721	157	737
Icelinus tenuis	spotfin sculpin	21	2	0	6
PLEURONECTIFORMES					
Paralichthyidae					
Citharichthys fragilis	Gulf sanddab	11	10	0	1
Citharichthys sordidus	Pacific sanddab	6,102	3,258	684	1,663
Citharichthys stigmaeus	speckled sanddab	1,185	237	510	383
Citharichthys xanthostigma	longfin sanddab	1,101	256	507	338
Hippoglossina stomata	bigmouth sole	133	69	24	40
Paralichthys californicus	California halibut	27	10	9	8
Xystreurys liolepis	fantail sole	26	7	3	16
Pleuronectidae					
Glyptocephalus zachirus	rex sole	23	1	0	0
Lepidopsetta bilineata	rock sole	5	0	0	0
Lyopsetta exilis	slender sole	91	34	0	19
Microstomus pacificus	Dover sole	571	304	82	103
Parophrys vetulus	English sole	563	305	21	213
Pleuronichthys coenosus	C-O sole	3	3	0	0
Pleuronichthys decurrens	curlfin sole	56	4	8	2
Pleuronichthys verticalis	hornyhead turbot	348	217	28	103
Cynoglossidae					
Symphurus atricaudus	California tonguefish	522	264	95	163
	TOTAL =	15,848	7,335	2,387	5,046

*SCB = Southern California Bight; Large-Outfall = City of Los Angeles Bureau of Sanitation-Hyperion, Los Angeles County Sanitation District, Orange County Sanitation District, and City of San Diego Metropolitan Wastewater Department-Point Loma; Small-Outfall = Goleta, South Orange County, Oceanside, Encina, and San Elijo; Non-Outfall = SCB mainland shelf only

POTW Outfall Areas

Host species totals were calculated for each POTW Outfall Type (Large-Outfall, Small-Outfall, and Non-Outfall; Table VII-8). Nineteen of 34 species of hosts were collected at all three Outfall Types. Large-Outfall areas consisted of 27 stations, Small-Outfall areas consisted of 15 stations, and Non-Outfall areas consisted of 24 stations (Figure II-3). The total number of stations in which each host was collected was calculated for each Outfall Type (Table VII-9).

Total parasite prevalence and mean intensity were calculated for each host species for each Outfall Type in which it was collected (Tables VII-10 and VII-11, respectively). The Kruskal-Wallis test showed a significant difference in median prevalence for two host species by Outfall Type ($p \leq 0.05$: bigmouth sole, p=0.0227; hornyhead turbot, p=0.0113) and there was a significant difference in median mean intensity for one host species by Outfall Type ($p \leq 0.05$: bigmouth sole, p=0.0119). The total prevalence and mean intensity for bigmouth sole across the three Outfall Types was 73.9% and 2.4 (n=69, 21 stations) in the Large-Outfall areas, 79.2% and 5.1 (n=24, 9 stations) in the Small-Outfall areas, and 47.5% and 2.7 (n=40, 14 stations) in the Non-Outfall areas (Tables VII-9 through VII-12). The total prevalence for hornyhead turbot across the three Outfall Types was 72.4% (n=217, 24 stations) in the Large-Outfall areas, 96.4% (n=28, 9 stations) in the Small-Outfall areas, and 50.5% (n=103, 20 stations) in the Non-Outfall areas (Tables VII-9 through VII-11).

Host-parasite prevalence and mean intensity were calculated for each Outfall Type (Appendix E-E7 and E-E8, respectively). There was no significant difference in median prevalence for any parasite species by Outfall Type ($p \leq 0.05$), but there was a significant difference in median mean intensity for three parasite species by Outfall Type ($p \leq 0.05$: copepod chalimus larvae on *H. stomata*, p=0.0498; the copepod *Acanthochondria fraseri* on hornyhead turbot, p=0.0244; and gnathiid isopod praniza on *P. verticalis*, p=0.0342).

Large-POTW Outfall Areas

Host species totals were calculated for the four Large-POTW Outfall zones in the SCB (HY, LA, OC, SD; Table VII-12). Thirteen of 34 species of hosts were collected at all four Large-Outfalls zones. HY consisted of nine stations, LA consisted of seven stations, OC consisted of eight stations, and SD consisted of three stations (Figure II-3). The total number of stations in which each host was collected was calculated for each Large-Outfall area (Table VII-13).

Total parasite prevalence and mean intensity were calculated for each host species for each Large-Outfall zone in which it was collected (Tables VII-14 and VII-15, respectively). There was no significant difference in median prevalence or median mean intensity for any host species by Large-Outfall ($p \leq 0.05$).

Host-parasite prevalence and mean intensity were calculated for each Large-Outfall zone (Appendix E-E9 and E-E10, respectively). The Kruskal-Wallis test showed a significant difference in median prevalence for two parasite species by Large-Outfall ($p \leq 0.05$: the leech *Austrobdella* spp. 1 on California scorpionfish, p=0.0194; the copepod *Acanthochondria fraseri* on hornyhead turbot, p=0.0280), and there was a significant difference in median mean intensity for one parasite species by Large-Outfall ($p \leq 0.05$: the copepod *Naobranchia scorpaenae* on California scorpionfish, p=0.0335).

Discussion

The purpose of this study was to assess the ectoparasitic fauna on marine fishes in the Southern California Bight (SCB) and determine if specific species of marine fishes and their ectoparasites can be used as bioindicators of environmental stress. To assess parasitic infections throughout the Bight, the prevalence and mean intensity of parasites was determined. Marine fishes representing Scorpaeniformes (Scorpaenidae, Hexagrammidae, and Cottidae) and Pleuronectiformes (Paralichthyidae, Pleuronectidae, and Cynoglossidae) living in the SCB were collected. Results show that ectoparasite prevalence and intensity vary considerably according to host species (Figures VII-1 and VII-2). In addition, parasite species abundances (Appendix E-E4) and host-parasite specificity varied according to parasite species (Table VII-16).

The prevalence of ectoparasites ranged from 0% to 100%, with the mean intensity ranging from zero to 48.2 (Table VII-3). Twenty-three of the 34 host species collected were parasitized. The 11 host species not found to be parasitized varied in sample size. California tonguefish, shortspine combfish, slender sole, spotfin sculpin, greenstriped rockfish, and calico rockfish had a sample size ranging from 12 to 522 individuals. However, only five individuals or fewer of copper rockfish, chilipepper, bocaccio, flag rockfish (*Sebastes rubrivinctus*), and shortbelly rockfish were collected. Therefore, it is possible that some of the hosts with a low sample size and 0% prevalence are sometimes infected with ectoparasites, but not enough individuals were sampled in this study to detect them. However, the large sample size and 0% prevalence for slender sole, shortspine combfish, and California tonguefish (91, 98, and 522 individuals, respectively) suggests that these host species may be more resistant to parasitization or have evolutionarily lost their parasites. Other studies have found similar results with California tonguefish (Dojiri, 1977; Kalman 2001, 2006 a,b). Dojiri (1977) inspected 326 individuals of California tonguefish and only found seven parasites representing three species; three individuals of *Holobomolochus prolixus* (Copepoda), three individuals of *Taeniacanthodes haakeri* (Copepoda), and one praniza larva (Isopoda). Because of the low prevalence and intensity of each of these parasite species, these occurences were attributed to fortuitous transfer. Kalman (2006a) inspected 385 individuals of California tonguefish and found no parasites. Thus, it is likely that California tonguefish does not harbor parasites. It is possible that this fish avoids the planktonic infective stage of many ectoparasites by burrowing in the sediment. In addition, California tonguefish is the only flatfish in this study with imbricating (overlapping) scales (Allen 1982), which may prohibit attachment of an ectoparasite. In contrast, most other species of flatfishes examined in this study, all without imbricating scales, had a high prevalence of ectoparasites; 10 of 16 species of flatfishes had prevalences greater than 20%. California halibut and fantail sole had a prevalence of 96.3% and 100%, respectively. Kalman (2006a) also found a relatively high prevalence on these two species of flatfishes (71% and 75%, respectively). Although it was typical that most flatfish species with a large sample size had a high prevalence of ectoparasites, there were a few species that did not, such as Pacific sanddab (6.0%, n=6,102) and Dover sole (5.3%, n=571). It is possible that some of these fishes have some means of defense against parasitism. Dover sole produces a thick mucous layer over its entire body (Kramer *et al.* 1995). Perhaps the mucous prevents parasites from firmly attaching to the host or, if attachment is successful, the mucous inhibits ability of the parasite to respire. Shields and Goode (1978) described a defense mechanism by the goldfish (*Carassius auratus*) against the parasitic copepod *Lernaea cyprinacea*. An immune reaction of the host tissues resulted in a rejection of the parasitic copepods embedded in the tissues. Kabata (1970b) described a reaction of blue skate (*Raja batis*) that also eventually resulted in rejection of a parasite. A portion of soft tissue on the gills of the host in which a parasitic copepod had attached was eventually sloughed off, along with the parasite. Thus, perhaps some host species have more efficient defense mechanisms against parasitism than other species and these evolutionary differences are reflected in the variable prevalence among the different host species in this study.

California scorpionfish had the second highest prevalence in this study (97.2%), and thus it is clear that this species of fish is a preferred host of all types of parasites (Table VII-3). The overall mean intensity was 48.2, far greater than for any other host in this study (Figure VII-2). This host harbored as many as eight species of parasites ranging in prevalence from 0.5% for California fish louse (*Elthusa californica*) to 88.4% the copepod (*Lepeophtheirus rotundipes*) (Figure VII-3). The mean intensity of individual parasite species on California scorpionfish ranged from 1.0 for the copepod *Holobomolochus spinulus*, California fish louse, and Pacific fish louse (*Elthusa vulgaris*) to 54.3 for the copepod *Naobranchia scorpaenae* (Figure VII-4). The range of intensity of the parasitic copepod *N. scorpaenae*, from 0 to 321 individuals on a single fish, was the most conspicuous. It was not uncommon to find individual fish with more than 100 individuals of this copepod parasitizing the gill filaments. The prevalence of *N. scorpaenae* at 78.2% was equally prominent. *Naobranchia scorpaenae* is a lernaeopodid copepod that is highly adapted to attach to the host's gill filaments using its modified maxilla (Kabata, 1979). Most of the individuals recovered in this study had visible blood in the gut, presumably from feeding on the host's gill tissue. Kalman (2006a) also found a relatively high intensity of *N. scorpaenae* on California scorpionfish collected in Santa Monica Bay; 26 of 75 hosts sampled were parasitized by this copepod (prevalence=35%, mean intensity=26). California scorpionfish may be parasitized more often than other fishes because the maximum standard length is larger than most other species sampled in this study, thus providing a larger attachment area upon which a planktonic larval parasite may settle. Studies have shown accumulation of contaminants and parasites with age, concluding that larger individuals of a given species, therefore older individuals, tend to have higher contaminant levels and often more parasites (Boxshall 1974, Nagasawa *et al.* 1993, Phillips *et al.* 1997, Kalman 2006a). Phillips *et al.* (1997) found that larger (presumably older) barred sand bass had significantly higher muscle and liver concentrations of mercury. Boxshall (1974) found the age of the host influenced the frequency distribution of the parasitic copepod *Bomolochus confusus.* The difference between the frequency distributions of the parasite on the different size classes of hosts suggested there was a gradual accumulation of parasites with increasing size, and therefore likely age, of host fishes. Nagasawa *et al.* (1993) found increasing infection levels of the parasitic copepod *Lepeophtheirus salmonis* with host age and size. Regression analyses have been used to indicate a positive correlation between fish size (standard length) and intensity of infestation (e.g., larger fishes have more parasites) (Kalman, 2001). The current study shows that the fish species with a large maximum standard length tend to have more parasites (Figure VII-5). For example, some of the fishes in this study with a high mean intensity of parasites, such as bigmouth sole, California scorpionfish, and California halibut all had a maximum standard length of 288 mm or longer. Conversely, the fishes with no parasites or a low mean intensity, such as yellowchin sculpin and California tonguefish, had a maximum standard length of 72 and 153 mm, respectively. Therefore, it seems that fishes gradually accumulate parasites with age. However, it is important to consider phylogenetic differences between the two groups of fishes sampled in this study, in addition to the potential differences in age of the fishes. Most rockfishes sampled in this study were juveniles (from 30-70 mm). Some rockfishes are thought to be among the longest-lived fishes on earth, living up to 205 years (Love *et al.* 2002). Conversely, other species of rockfishes, such as calico rockfish, live to be about 11 years old. In addition, trends of longevity with size and longevity with temperature show that the species that grow the largest generally live the longest, and the species that live in colder water generally have longer life spans (Love *et al.* 2002). Therefore, it is important to consider age of a host, rather than solely standard length, to infer accumulation of parasites over time.

In addition to size differences with other fish species sampled in this study, California scorpionfish is demersal (living on or near the bottom), does not bury in the sediment like many flatfishes, and has larger oral and gill cavities compared to most flatfishes. With a larger available surface area for a parasite to attach, California scorpionfish may be more accessible to ectoparasites compared to the other fishes in this study. Furthermore, it is likely California scorpionfish is infected with the copepod *N. scorpaenae* while resting on the bottom and actively pumping the buccal cavity for respiration. As water is drawn into the mouth and over the gill filaments for oxygen exchange, the infective stage of *N. scorpaenae* is also drawn into the mouth and is pushed over the gills. The copepod opportunistically then attaches and completes its life cycle on the gill filaments of California scorpionfish. It is interesting to note that another species of parasitic copepod also belonging to the genus *Naobranchia* was collected in this study, *Naobranchia occidentalis.* This copepod parasitizes the gill filaments of sanddabs (Pacific sanddab and longfin sanddab; Appendix E-E4). However, the prevalence and intensity of *N. occidentalis* (0.9%, 1.2 and 12.0%, 2.0 for Pacific sanddab and longfin sanddab, respectively) is nowhere near as high as *N. scorpaenae*. This profound variation in prevalence and mean intensity of two closely related copepods deserves further study.

The use of fishes as indicator species can present problems due to their mobility. However, I chose to examine scorpaeniform and pleuronectiform fishes because these fishes tend to be sedentary relative to pelagic species. In addition, soft-bottom fishes are commonly used to assess the impacts of treated wastewater discharge to the southern California mainland shelf (Mearns and Sherwood 1977, Allen *et al.* 1998, Allen *et al.* 2002a). These groups of fishes are easily sampled in large numbers by otter trawl, are known to show responses to outfall conditions, respond more readily to changes in the benthic habitat, and are known to be heavily parasitized (Mearns and Sherwood 1977, Dojiri 1979, Allen *et al.* 1998, Allen *et al.* 2002a, Kalman 2006a,b). The use of parasites as bioindicators of environmental stress may be a useful tool for monitoring programs in the SCB. Sedentary fishes typically use the branchiostegal apparatus to actively pump water over the gills for respiration compared to more pelagic species that irrigate the gills by holding the mouth open as they swim (Bond 1996). By actively drawing water into the mouth and over the gills, it is likely that the fishes are unknowingly assisting the infective stage of an ectoparasitic, such as a copepodid.

Host movement among collection sites in addition to the loss of parasites and fortuitous transfer due to collection methods must be considered. Even though a fish may be sedentary, there maybe various factors driving a fish to move, such as lack of food or mates, or the presence of predators (Lowe and Bray 2006). Little is known about the home range and migration patterns of flatfishes in the SCB (Lowe and Bray 2006). Robinson (1982) concluded that the population of parasitic isopods on fishes collected by an otter trawl might not truly reflect the actual population that was parasitizing the sampled fishes. Many of the parasitic isopods were dislodged from the host during otter trawl sampling (Robinson 1982). A comparison of the percent of fishes infested with parasitic isopods revealed a significant disparity between the two sampling methods: otter trawl and scuba divers, both at 16 m. In the otter trawl method, 37.5% of the hosts were infested as opposed to 73.9% of the hosts that were collected by the divers (Robinson 1982). In addition, Brusca (1981) concluded that reports of adult cymothoids (Isopoda) found free-living are probably erroneous, representing cases of isopods that have abandoned their dying or stressed hosts. Therefore, because the fishes in the present study also were collected by otter trawl, loss of parasites and accidental transfer may have occurred. Thus, the population of the cymothoid isopods, California fish louse (*Elthusa californica*) and Pacific fish louse (*Elthusa vulgaris*) in the SCB may not be accurately represented. However, this aspect is less relevant to the overall results of the study because the majority of parasites collected were copepods (27 of 39 species, 12,795 individuals), which tend to attach more firmly and permanently to the host than do parasitic isopods (4 of 39 species, 1,041 individuals; Kabata 1970b; Table VII-2). However, it is possible there were so many individual copepods collected because copepods may be more successful in remaining attached to their hosts. Thus, it is likely copepods were not dislodged from the hosts while in the net and during handling, while other groups of parasites, such as monogeneans, leeches, and isopods, were lost. Copepods are undoubtedly the largest group of Crustacea parasitic on fishes and have various levels of modifications for attachment and overall morphological adaptation (Kabata 1970b). At one end of the adaptive range are the groups of parasitic copepods whose morphology has not yet been greatly affected by their association with the host, such as the Caligidae. The caligids are freely mobile, able to swim and to exchange one fish for another, in this respect resembling the Branchiura and Isopoda (Kabata 1970b). At the other end of the range are highly modified copepods, such as the Lernaeopodidae and Pennellidae, sometimes with greatly reduced appendages, oval sac-like bodies, and often evolutionary loss of legs and thus the loss of the ability to swim (Kabata 1970b). The lernaeopodids were by far the most abundant group of ectoparasites collected in this study (9,927 individuals). It is likely this group of copepods is indeed the most abundant occurring naturally, but many lernaeopodid species are highly modified for attachment within the gill cavity, so were therefore protected from loss while in the net and during handling. In addition, *N. scorpaenae*, mentioned previously from California scorpionfish, is among this extremely abundant group.

Many ectoparasites showed a high degree of host-specificity (21 of 39 species appeared to be specific for a single host species; Table VII-16). In addition, when a parasite occurred on only two species of hosts, typically the hosts are closely related, belonging to the same genus (the branchiuran *Argulus* spp. on Gulf sanddab and Pacific sanddab; the copepod *Acanthochondria fraseri* on curlfin sole and hornyhead turbot; the copepods *Naobranchia occidentalis* and *Parabrachiella* spp.1, and the eye copepod, *Phrixocephalus cincinnatus*, on Pacific sanddab and longfin sanddab). Boxshall (1974) found the majority of copepod species (24 out of 39) were strictly specific for a single host species. Another study of metazoan parasites associated with flatfishes indicated that, among the highly host-specific parasites, copepods ranked first (Bijukumar 1996). Of the ten species of parasitic copepods found, nine species were found to attach to a single host species. In the current study, 16 of 26 species of adult copepods were specific for a single host species. However, all four species of leeches were also specific for a single host species. The monogenean trematode *Microcotyle sebastis* was also extremely host specific at the genus level, occurring only on rockfishes (greenspotted rockfish, stripetail rockfish, and halfbanded rockfish).

In contrast, the adult isopods, California fish louse (*Elthusa californica*) and Pacific fish louse (*Elthusa vulgaris*), seem to be generalists, occurring on seven and nine different species of hosts, respectively. Brusca (1978) concluded that the host preference in Pacific fish louse (reported as *Lironeca vulgaris*) is largely a function of ecological preference, rather than taxonomic preference. In addition, the three parasitic larvae found in this study, chalimus (Copepoda: Caligidae), aegathoid (Isopoda: Cymothoidae), and praniza (Isopoda: Gnathiidae), were removed from 14, 4, and 16 different fish species, respectively. Caligids and cymothoids remain parasitic, or at least symbiotic, throughout their life cycle (Kabata 1979, Brusca 1981). Gnathiids, on the other hand, become free-living as adults (Grutter *et al.* 2000, Smit and Davies 2004). In the current study, eight species of adult caligids and two species of adult cymothoids were found parasitizing the fishes. In addition, there are at least eight described species of adult gnathiid isopods living in the SCB (Wetzer and Brusca 1996). Thus, the chalimus, aegathoid, and praniza larvae probably represent these different species of adult copepods and isopods, respectively. Grutter *et al.* (2000) discussed the emergence of gnathiid larval stages from the benthos and found that they spend only minutes or hours on a host before dropping off back into the benthos. Thus, it appears gnathiids spend most of their time in the benthos to digest the blood meal and to moult and reproduce. Grutter *et al.* (2000) also concluded that gnathiids emerge both during the day and night, unlike many other fish parasites, so they replace themselves on hosts much quicker than other types of parasites, such as copepods. Therefore, it is likely that many of the praniza reported in this study are not only multiple species, but were collected mid-meal and were somewhat temporary. Due to the large sample size of this study (15,848 fishes and 14,620 parasites), it can be inferred that the parasite-host species records occurring in large numbers are valid host records. In addition, it is likely that the parasites occurring on a single host species are especially host specific. Therefore, the high parasite-host specificity of monogeneans, leeches, and copepods supports the notion that fortuitous transfer of parasites among hosts while in the net was probably uncommon.

Results show there was a significant difference in total median prevalence for three host species by Region (Pacific sanddab, speckled sanddab, and hornyhead turbot). In addition, there was a significant difference in total median mean intensity for three host species by Region (Pacific sanddab, bigmouth sole, and English sole). Median prevalence of California scorpionfish was marginally insignificant (p=0.0529) but could, however, be ecologically significant. It is likely that the prevalence is significantly higher for Pacific sanddab on the Northern Mainland Shelf because only one station was sampled and noticeably less fishes were collected in this Region (n=36 vs. 497, 4,132, and 1,437 for NCI, CMS, and SMS, respectively; Tables VII-5 and VII-6). Of the 11 species of parasites found on Pacific sanddab, the eye copepod (*Phrixocephalus cincinnatus*; Penellidae), was clearly the parasite species responsible for driving the significant difference in prevalence in the Regions in which this host was collected (Appendix E-E5). The prevalence of the eye copepod on Pacific sanddab was marginally insignificant at p=0.0651; however it is possible that this could be ecologically significant and the high prevalence of this copepod on the Northern Channel Islands and Northern Mainland Shelf (9.7 and 8.3%, respectively) should be investigated . It is interesting to note that five individuals of eye copepod infected the left eye of a single host individual of Pacific sanddab collected on the San Diego

Shelf. This is atypical of this parasitic copepod, which typically has a mean intensity of 1.1 (Appendix E-E6). The total prevalence for speckled sanddab was significantly higher on the Central Mainland Shelf (44.2%) even though more individuals were sampled on the Southern Mainland Shelf (Tables VII-5 through VII-7). The bomolochid copepod *Holobomolochus prolixus* was clearly the parasite species driving the significant difference in total prevalence across the four Regions (p=0.0497) (Appendix E-E5). Although speckled sanddab carried as many as 10 species of parasites, the prevalence for *H. prolixus* throughout the SCB was 29.6% and was 42.2% on the Central Mainland Shelf alone. In addition, the overall prevalence for hornyhead turbot was significantly higher on the Southern Mainland Shelf (97.1%) than on the Central Mainland Shelf (64.5%) even though more individuals were sampled on the Central Mainland Shelf (Tables VII-5 through VII-7). Six of the ten species of parasites that were reported on hornyhead turbot occurred in both regions in which this host was sampled (Appendix E-E5). Many of these parasite species had a high intensity in both regions; however the intensity was always higher on the Southern Mainland Shelf. The leech *Austrobdella* spp. 2 was the only species that was statistically significant; Southern Mainland Shelf (25.7%), Central Mainland Shelf (1.9%; p=0.0272) . The prevalence of the copepod *Naobranchia scorpaenae* on California scorpionfish was marginally insignificant by Region (p=0.0563); however the mean intensity was significantly different by Region (p=0.0009). This lernaeopodid copepod was relatively common throughout the Bight, but had the highest intensity on the Central Mainland Shelf (67.5; Appendix E-E5 and E-E6). This likely was because more than half of the total number of specimens of this host species collected throughout the study were collected on the Central Mainland Shelf (Table VII-4).

The overall sampling on the Central Mainland Shelf, 10,619 individuals from 44 stations, was considerably higher than in the other three Regions; Northern Channel Islands: 1,080 individuals, 13 stations; Northern Mainland Shelf: 278 individuals, 1 station; Southern Mainland Shelf: 3,871 individuals, 21 stations (Table VII-4). An analogous survey of the SCB (Bight '98) showed similar results for the mainland shelf regions (Allen *et al.* 2002). Allen *et al.* (2002) found the highest abundance of fishes living on the Central Mainland Shelf (28,532 individuals from 114 stations) compared to the Northern and Southern Mainland Shelves (10,321 individuals from 68 stations and 11,848 individuals from 75 stations, respectively). It is likely that there are more individual fishes living on the Central Mainland Shelf compared to Northern and Southern Shelves because the continental shelf is larger from Point Dume to Dana Point, thus there is more available surface area for habitat (Hickey 1993). However, on the Palos Verdes Shelf, and from Newport Canyon south to Dana Point, the continental shelf is quite narrow (Figure II-3). In addition to shelf size, the three areas have differing temperature regimes. The circulation in the SCB is dominated by a poleward-flowing Southern California Countercurrent, which is a large scale eddy of the California Current (Hickey 1993). The Northern Mainland Shelf is influenced by cold currents from north of Point Conception, and the Southern Mainland Shelf is influenced by warm currents from Mexico. The Central Mainland Shelf between them is affected by both temperature regimes (Hickey 1993). Temperature could account for the different host abundances seen in the four regions, and hence influence parasite prevalence. In addition, the difference in prevalence by Region could be due to the geographical range of the parasite. Some species of parasites may not naturally occur in certain areas, and this again could be driven by different temperature regimes or some other abiotic factor. For example, the chondracanthid copepod *Auchenochondria lobosa* was collected only on the San Pedro and Oceanside Shelves.

Dojiri and Perkins (1979) also originally collected this copepod from the Oceanside Shelf. This copepod is extremely host specific, occurring only on California halibut. Kalman (2006a) inspected 36 individuals of this host from Santa Monica Bay, and no fish were infected with *A. lobosa*. Therefore, although this is a rare copepod (only four individuals were collected in this study), it seems the range of this parasite is restricted to the area around Dana Point.

In addition to region, results show there was a significant difference by outfall type in median prevalence for two host species (bigmouth sole and hornyhead turbot) and median mean intensity for one host species (bigmouth sole). Total prevalence for speckled sanddab and total mean intensity for hornyhead turbot were marginally statistically insignificant (p=0.0551 and 0.0526, respectively) but could be ecologically significant, and thus are included here. The total prevalence was significantly higher for speckled sanddab at the Large-Outfall areas (45.6%) than in the Small-Outfall (28.6%) and Non-Outfall (28.7%) areas (p=0.0551; Table VII-10). Although there was no significant difference in prevalence of individual parasite species, the bomolochid copepod *Holobomolochus prolixus* was clearly the species responsible for the difference seen in total prevalence at Large-Outfall areas (p=0.0648; Appendix E-E7). Of the 10 species of parasites occurring on speckled sanddab, this was the most common parasite species found on this host. This parasitic copepod was found on 10 species of flatfishes ranging in prevalence from 0.1% on Pacific sanddab to 74.1% on California halibut. Although the overall prevalence of *H. prolixus* on speckled sanddab throughout the SCB was only 29.6%, this is a prominent parasite on a small host species. Most other flatfishes with a high prevalence of this copepod are larger species, such as California halibut (74.1%) and fantail sole (61.5%). *Holobomolochus prolixus* parasitized the gill cavity of many species of flatfishes. Mean intensity is typically low, from 1.0 to 3.7, usually with a single copepod on the inner side of each opercula of the host (Appendix E-E8).

In contrast, total prevalence was significantly higher for bigmouth sole and hornyhead turbot at the Small-Outfall areas (79.2% p=0.0227 and 96.4%, p=0.0113, respectively; Table VII-10). In addition, the total mean intensity was significantly higher for bigmouth sole and hornyhead turbot at the Small-Outfall areas (5.1, p=0.0119 and 4.0, p=0.0526, respectively; Table VII-11). Of the six species of parasites occurring on bigmouth sole in all three Outfall Types, four species had a higher prevalence at the Small-Outfall areas (Appendix E-E7). The other two species, chalimus and praniza, were both higher at the Large-Outfall areas. Of the six species of parasites occurring on hornyhead turbot in all three Outfall Types, five species had a higher prevalence at the Small-Outfall areas. The copepod chalimus larva was the only species higher at the Large-Outfall areas. Thus, in all cases of significant differences seen in the three Outfall Types, the prevalence and mean intensity is always higher at outfall areas. Increased ectoparasitic infestations have been reported from fishes collected from areas with increased environmental pollution (Skinner 1982, Perkins and Gartman 1997). Studies show stress resulting from pollutant exposure can affect the immune response in fishes and increase their susceptibility to diseases and parasites (Ellis 1981). Perkins and Gartman (1997) found that the prevalence of the parasitic eye copepod (*Phrixocephalus cincinnatus*), occurring on Pacific sanddab collected in Santa Monica Bay, was highest at stations closest to the Hyperion Treatment Plant 5-Mile outfall. Roy *et al.* (2003) found elevated levels of vitellogenin, a precursor egg yolk protein, in male hornyhead turbot collected near the Orange County Sanitation District's wastewater outfall.

In addition, Rempel *et al.* (2006) found a correlation with plasma estradiol and sperm DNA damage in hornyhead turbot, indicating the potential for negative reproductive affects.

In addition to outfall effluent, the marine environment in the SCB is influenced by many other factors, such as freshwater runoff from various creeks, oil and gas pollution from marinas, numerous storm drains, currents, and historical contaminants, such as DDT in the sediment (MBC 1988, Stull 1995, Allen *et al.* 1998, Schiff 2000). Historically wastewater outfalls accounted for a majority of pollution impacts in the SCB; however, with increased technology and higher treatment standards, the current impact of wastewater to the environment is thought to be low (Anderson *et al.* 1993). Perkins (1995) illustrated histopathological effects of wastewater on three target species of marine fishes; however, more recently OCSD (2004) found this relationship to be driven by size, thus age, of the fishes. In addition, the Large-Outfall areas were all between 60-90 m and the Small-Outfall areas were all around 30 m, due to the depth of the diffusers on the outfalls. The Non-Outfall areas ranged from 22-198 m. Therefore, it is possible that differences in prevalence of ectoparasites are due to depth, and thus possibly temperature, rather than outfall affects. In any case, speckled sanddab, bigmouth sole, and hornyhead turbot present interesting questions relative to parasites and stress and deserve further study.

No significant differences in median prevalence and mean intensity for any host species were found among the three Large-Outfall areas ($p \leq 0.05$). However, the prevalence was routinely higher at the LA Large-Outfall area. For example, the copepod *Homobomolochus. prolixus* on speckled sanddab across the three Large-Outfall areas was statistically insignificant, but it was highest at the LA Large-Outfall area; 40.0% (HY), 48.5% (LA), and 32.6% (OC; Appendix E-E9). The prevalence of the monogenean trematode *Microcotyle sebastis* and the lernaeopodid copepod *Clavella parva,b*oth parasitic on stripetail rockfish, was higher at LA (40.4% and 43.1%, respectively). The prevalence of the chondracanthid copepod *Acanthochondria fraseri* parasitic on hornyhead turbot, was significantly higher at LA (27.5%). In addition, although there was no significant difference in the total prevalence of hornyhead turbot across the Large-Outfall areas, the total prevalence at the LA outfall area was notably higher (88.4%; Table VII-14). It is likely that the single individual with 100% prevalence collected at SD influenced the results. The prevalence of the larval copepod chalimus was high at LA compared to HY and OC (47.8% compared to 14.5% and 26.7%, respectively; Appendix E-E9). In addition, the mean intensity of the chalimus stage was also highest at LA (6.1), an occurrence commonly noticed in the field, as compared to HY (4.8), OC (1.8), and SD (2.0; Appendix E-E10).

Table VII-9. Number of stations each host was collected by Outfall Type in the Southern California Bight at depths of 22-198 m, July through October 2003.

Host		TOTAL STATIONS SCB*	Large	Small	Non
	Total number of stations:	79	27	15	24
SCORPAENIFORMES					
Scorpaenidae					
Scorpaena guttata	California scorpionfish	43	21	8	13
Sebastes caurinus	copper rockfish	1	0	0	1
Sebastes chlorostictus	greenspotted rockfish	1	0	0	1
Sebastes dallii	calico rockfish	2	2	0	0
Sebastes elongatus	greenstriped rockfish	4	1	0	3
Sebastes goodei	chilipepper	1	0	0	1
Sebastes jordani	shortbelly rockfish	1	1	0	0
Sebastes miniatus	vermilion rockfish	3	1	1	1
Sebastes paucispinis	boccacio	1	1	0	0
Sebastes rubrivinctus	flag rockfish	1	1	0	0
Sebastes saxicola	stripetail rockfish	31	13	5	11
Sebastes semicinctus	halfbanded rockfish	31	13	4	13
Hexagrammidae					
Ophiodon elongatus	lingcod	14	9	0	5
Zaniolepis frenata	shortspine combfish	10	5	1	4
Zaniolepis latipinnis	longspine combfish	52	25	9	15
Cottidae					
Chitonotus pugetensis	roughback sculpin	40	20	2	17
Icelinus quadriseriatus	yellowchin sculpin	54	23	11	20
Icelinus tenuis	spotfin sculpin	3	1	0	1
PLEURONECTIFORMES					
Paralichthyidae					
Citharichthys fragilis	Gulf sanddab	3	2	0	1
Citharichthys sordidus	Pacific sanddab	65	26	13	23
Citharichthys stigmaeus	speckled sanddab	29	8	10	10
Citharichthys xanthostigma	longfin sanddab	47	19	12	16
Hippoglossina stomata	bigmouth sole	44	21	9	14
Paralichthys californicus	California halibut	16	6	6	4
Xystreurys liolepis	fantail sole	11	3	2	6
Pleuronectidae					
Glyptocephalus zachirus	rex sole	2	1	0	0
Lepidopsetta bilineata	rock sole	1	0	0	0
Lyopsetta exilis	slender sole	5	1	0	3
Microstomus pacificus	Dover sole	35	17	6	10
Parophrys vetulus	English sole	44	19	2	19
Pleuronichthys coenosus	C-O sole	1	1	0	0
Pleuronichthys decurrens	curlfin sole	7	1	1	2
Pleuronichthys verticalis	hornyhead turbot	53	24	9	20
Cynoglossidae					
Symphurus atricaudus	California tonguefish	51	22	11	18

*SCB = Southern California Bight; Large-Outfall = City of Los Angeles Bureau of Sanitation-Hyperion, Los Angeles County Sanitation District, Orange County Sanitation District, and City of San Diego Metropolitan Wastewater Department-Point Loma; Small-Outfall = Goleta, South Orange County, Oceanside, Encina, and San Elijo; Non-Outfall = SCB mainland shelf only

Table VII-10. Total parasite prevalence by Outfall Type collected at depths of 22-198 m in the Southern California Bight, July through October 2003.

Host		PREVALENCE (%)			
		SCB*	Large	Small	Non
SCORPAENIFORMES					
Scorpaenidae					
Scorpaena guttata	California scorpionfish	97.2	97.7	93.6	100
Sebastes caurinus	copper rockfish	0.0	-----	-----	0.0
Sebastes chlorostictus	greenspotted rockfish	45.5	-----	-----	45.5
Sebastes dallii	calico rockfish	0.0	0.0	-----	-----
Sebastes elongatus	greenstriped rockfish	0.0	0.0	-----	0.0
Sebastes goodei	chilipepper	0.0	-----	-----	0.0
Sebastes jordani	shortbelly rockfish	0.0	0.0	-----	-----
Sebastes miniatus	vermilion rockfish	76.9	33.3	0.0	94.7
Sebastes paucispinis	boccacio	0.0	0.0	-----	-----
Sebastes rubrivinctus	flag rockfish	0.0	0.0	-----	-----
Sebastes saxicola	stripetail rockfish	31.9	38.3	20.0	41.3
Sebastes semicinctus	halfbanded rockfish	4.8	6.5	4.3	3.5
Hexagrammidae					
Ophiodon elongatus	lingcod	11.4	11.6	-----	11.1
Zaniolepis frenata	shortspine combfish	0.0	0.0	0.0	0.0
Zaniolepis latipinnis	longspine combfish	0.2	0.1	0.0	0.4
Cottidae					
Chitonotus pugetensis	roughback sculpin	1.0	1.8	0.0	0.4
Icelinus quadriseriatus	yellowchin sculpin	4.0	4.6	0.6	4.1
Icelinus tenuis	spotfin sculpin	0.0	0.0	-----	0.0
PLEURONECTIFORMES					
Paralichthyidae					
Citharichthys fragilis	Gulf sanddab	9.1	10.0	-----	0.0
Citharichthys sordidus	Pacific sanddab	6.0	4.9	3.1	7.6
Citharichthys stigmaeus	speckled sanddab	31.6	45.6	28.6	28.7
Citharichthys xanthostigma	longfin sanddab	23.3	21.5	20.5	29.0
Hippoglossina stomata	bigmouth sole	66.9	73.9	79.2	47.5
Paralichthys californicus	California halibut	96.3	90.0	100	100
Xystreurys liolepis	fantail sole	100	100	100	100
Pleuronectidae					
Glyptocephalus zachirus	rex sole	4.3	0.0	-----	-----
Lepidopsetta bilineata	rock sole	20.0	-----	-----	-----
Lyopsetta exilis	slender sole	0.0	0.0	-----	0.0
Microstomus pacificus	Dover sole	5.3	6.6	6.1	3.9
Parophrys vetulus	English sole	42.8	37.4	47.6	46.9
Pleuronichthys coenosus	C-O sole	33.3	33.3	-----	-----
Pleuronichthys decurrens	curlfin sole	39.3	25.0	37.5	50.0
Pleuronichthys verticalis	hornyhead turbot	67.8	72.4	96.4	50.5
Cynoglossidae					
Symphurus atricaudus	California tonguefish	0.0	0.0	0.0	0.0

*SCB = Southern California Bight; Large-Outfall = City of Los Angeles Bureau of Sanitation-Hyperion, Los Angeles County Sanitation District, Orange County Sanitation District, and City of San Diego Metropolitan Wastewater Department-Point Loma; Small-Outfall = Goleta, South Orange County, Oceanside, Encina, and San Elijo; Non-Outfall = SCB mainland shelf only

Table VII-11. Total parasite mean intensity by Outfall Type collected at depths of 22-198 m in the Southern California Bight, July through October 2003.

		MEAN INTENSITY			
Host		SCB*	Large	Small	Non
SCORPAENIFORMES					
Scorpaenidae					
Scorpaena guttata	California scorpionfish	48.2	58.7	17.8	48.4
Sebastes caurinus	copper rockfish	0.0	-----	-----	0.0
Sebastes chlorostictus	greenspotted rockfish	3.7	-----	-----	3.7
Sebastes dallii	calico rockfish	0.0	0.0	-----	-----
Sebastes elongatus	greenstriped rockfish	0.0	0.0	-----	0.0
Sebastes goodei	chilipepper	0.0	-----	-----	0.0
Sebastes jordani	shortbelly rockfish	0.0	0.0	-----	-----
Sebastes miniatus	vermilion rockfish	4.8	1.0	0.0	5.2
Sebastes paucispinis	boccacio	0.0	0.0	-----	-----
Sebastes rubrivinctus	flag rockfish	0.0	0.0	-----	-----
Sebastes saxicola	stripetail rockfish	3.7	4.0	1.5	3.7
Sebastes semicinctus	halfbanded rockfish	1.4	1.1	2.0	1.5
Hexagrammidae					
Ophiodon elongatus	lingcod	1.2	1.4	-----	1.0
Zaniolepis frenata	shortspine combfish	0.0	0.0	0.0	0.0
Zaniolepis latipinnis	longspine combfish	1.7	1.0	0.0	2.0
Cottidae					
Chitonotus pugetensis	roughback sculpin	1.3	1.3	0.0	1.0
Icelinus quadriseriatus	yellowchin sculpin	1.1	1.1	2.0	1.0
Icelinus tenuis	spotfin sculpin	0.0	0.0	-----	0.0
PLEURONECTIFORMES					
Paralichthyidae					
Citharichthys fragilis	Gulf sanddab	1.0	1	-----	0.0
Citharichthys sordidus	Pacific sanddab	1.1	1.1	1.1	1.1
Citharichthys stigmaeus	speckled sanddab	1.4	1.5	1.5	1.4
Citharichthys xanthostigma	longfin sanddab	1.7	1.5	1.7	1.9
Hippoglossina stomata	bigmouth sole	3.0	2.4	5.1	2.7
Paralichthys californicus	California halibut	9.0	7.6	14.0	5.0
Xystreurys liolepis	fantail sole	6.6	4.1	6.3	7.7
Pleuronectidae					
Glyptocephalus zachirus	rex sole	1.0	0.0	-----	-----
Lepidopsetta bilineata	rock sole	2.0	-----	-----	-----
Lyopsetta exilis	slender sole	0.0	0.0	-----	0.0
Microstomus pacificus	Dover sole	3.2	3.7	1.2	3.8
Parophrys vetulus	English sole	2.2	2.3	1.2	2.0
Pleuronichthys coenosus	C-O sole	1.0	1.0	-----	-----
Pleuronichthys decurrens	curlfin sole	2.0	5.0	3.3	4.0
Pleuronichthys verticalis	hornyhead turbot	3.6	3.8	4.0	2.5
Cynoglossidae					
Symphurus atricaudus	California tonguefish	0.0	0.0	0.0	0.0

*SCB = Southern California Bight; Large-Outfall = City of Los Angeles Bureau of Hyperion, Los Angeles County Sanitation District, Orange County Sanitation District, and City of San Diego Metropolitan Wastewater Department-Point Loma; Small-Outfall = Goleta, South Orange County, Oceanside, Encina, and San Elijo; Non-Outfall = SCB mainland shelf only

Table VII-12. Host totals by Large-Outfall collected at depths of 22-198 m in the Southern California Bight, July through October 2003.

Host		TOTAL HOSTS SCB*	HY	LA	OC	SD
	Total number of stations:	79	9	7	8	3
SCORPAENIFORMES						
Scorpaenidae						
Scorpaena guttata	California scorpionfish	216	35	40	40	17
Sebastes caurinus	copper rockfish	5	0	0	0	0
Sebastes chlorostictus	greenspotted rockfish	22	0	0	0	0
Sebastes dallii	calico rockfish	12	10	0	2	0
Sebastes elongatus	greenstriped rockfish	17	0	0	0	7
Sebastes goodei	chilipepper	2	0	0	0	0
Sebastes jordani	shortbelly rockfish	1	0	0	0	1
Sebastes miniatus	vermilion rockfish	26	6	0	0	0
Sebastes paucispinis	boccacio	2	2	0	0	0
Sebastes rubrivinctus	flag rockfish	2	0	0	0	2
Sebastes saxicola	stripetail rockfish	546	65	109	3	50
Sebastes semicinctus	halfbanded rockfish	581	4	9	125	94
Hexagrammidae						
Ophiodon elongatus	lingcod	88	12	0	31	0
Zaniolepis frenata	shortspine combfish	98	14	0	1	45
Zaniolepis latipinnis	longspine combfish	1,411	315	94	244	87
Cottidae						
Chitonotus pugetensis	roughback sculpin	416	52	22	94	1
Icelinus quadriseriatus	yellowchin sculpin	1,615	297	69	311	44
Icelinus tenuis	spotfin sculpin	21	2	0	0	0
PLEURONECTIFORMES						
Paralichthyidae						
Citharichthys fragilis	Gulf sanddab	11	0	0	9	1
Citharichthys sordidus	Pacific sanddab	6,102	1,421	421	783	633
Citharichthys stigmaeus	speckled sanddab	1,185	25	169	43	0
Citharichthys xanthostigma	longfin sanddab	1,101	53	27	171	5
Hippoglossina stomata	bigmouth sole	133	15	20	24	10
Paralichthys californicus	California halibut	27	2	6	2	0
Xystreurys liolepis	fantail sole	26	2	0	5	0
Pleuronectidae						
Glyptocephalus zachirus	rex sole	23	0	0	0	1
Lepidopsetta bilineata	rock sole	5	0	0	0	0
Lyopsetta exilis	slender sole	91	0	0	0	34
Microstomus pacificus	Dover sole	571	37	90	64	113
Parophrys vetulus	English sole	563	88	88	20	109
Pleuronichthys coenosus	C-O sole	3	0	3	0	0
Pleuronichthys decurrens	curlfin sole	56	0	4	0	0
Pleuronichthys verticalis	hornyhead turbot	348	117	69	30	1
Cynoglossidae						
Symphurus atricaudus	California tonguefish	522	112	65	69	18
	TOTAL =	15,848	2,686	1,305	2,071	1,273

*SCB = Southern California Bight; HY = City of Los Angeles Bureau of Sanitation-Hyperion;
LA = Los Angeles County Sanitation District; OC = Orange County Sanitation District;
SD = City of San Diego Metropolitan Wastewater Department-Point Loma

Table VII-13. Number of stations each host was collected by Large-Outfall in the Southern California Bight at depths of 22-198 m, July-October 2003.

Host		TOTAL STATIONS				
		SCB*	HY	LA	OC	SD
	Total # of stations:	79	9	7	8	3
SCORPAENIFORMES						
Scorpaenidae						
Scorpaena guttata	California scorpionfish	43	7	6	7	1
Sebastes caurinus	copper rockfish	1	0	0	0	0
Sebastes chlorostictus	greenspotted rockfish	1	0	0	0	0
Sebastes dallii	calico rockfish	2	1	0	1	0
Sebastes elongatus	greenstriped rockfish	4	0	0	0	1
Sebastes goodei	chilipepper	1	0	0	0	0
Sebastes jordani	shortbelly rockfish	1	0	0	0	1
Sebastes miniatus	vermilion rockfish	3	1	0	0	0
Sebastes paucispinis	boccacio	1	1	0	0	0
Sebastes rubrivinctus	flag rockfish	1	0	0	0	1
Sebastes saxicola	stripetail rockfish	31	6	2	2	3
Sebastes semicinctus	halfbanded rockfish	31	4	3	4	2
Hexagrammidae						
Ophiodon elongatus	lingcod	14	5	0	4	0
Zaniolepis frenata	shortspine combfish	10	1	0	1	3
Zaniolepis latipinnis	longspine combfish	52	9	5	8	3
Cottidae						
Chitonotus pugetensis	roughback sculpin	40	8	3	8	1
Icelinus quadriseriatus	yellowchin sculpin	54	9	4	8	2
Icelinus tenuis	spotfin sculpin	3	1	0	0	0
PLEURONECTIFORMES						
Paralichthyidae						
Citharichthys fragilis	Gulf sanddab	3	0	0	1	1
Citharichthys sordidus	Pacific sanddab	65	9	6	8	3
Citharichthys stigmaeus	speckled sanddab	29	3	4	1	0
Citharichthys xanthostigma	longfin sanddab	47	6	3	8	2
Hippoglossina stomata	bigmouth sole	44	8	5	6	2
Paralichthys californicus	California halibut	16	1	3	2	0
Xystreurys liolepis	fantail sole	11	2	0	1	0
Pleuronectidae						
Glyptocephalus zachirus	rex sole	2	0	0	0	1
Lepidopsetta bilineata	rock sole	1	0	0	0	0
Lyopsetta exilis	slender sole	5	0	0	0	1
Microstomus pacificus	Dover sole	35	5	4	5	3
Parophrys vetulus	English sole	44	8	6	3	2
Pleuronichthys coenosus	C-O sole	1	0	1	0	0
Pleuronichthys decurrens	curlfin sole	7	0	1	0	0
Pleuronichthys verticalis	hornyhead turbot	53	9	7	7	1
Cynoglossidae						
Symphurus atricaudus	California tonguefish	51	9	5	7	1

*SCB = Southern California Bight; HY = City of Los Angeles Bureau of Sanitation-Hyperion;
LA = Los Angeles County Sanitation District; OC = Orange County Sanitation District;
SD = City of San Diego Metropolitan Wastewater Department-Point Loma

Table VII-14. Total parasite prevalence by Large-Outfall collected at depths of 22-198 m in the Southern California Bight, July through October 2003.

Host		PREVALENCE (%)				
		SCB*	HY	LA	OC	SD
SCORPAENIFORMES						
Scorpaenidae						
Scorpaena guttata	California scorpionfish	97.2	100	92.5	100	100
Sebastes caurinus	copper rockfish	0.0	-----	-----	-----	-----
Sebastes chlorostictus	greenspotted rockfish	45.5	-----	-----	-----	-----
Sebastes dallii	calico rockfish	0.0	0.0	-----	0.0	-----
Sebastes elongatus	greenstriped rockfish	0.0	-----	-----	-----	0.0
Sebastes goodei	chilipepper	0.0	-----	-----	-----	-----
Sebastes jordani	shortbelly rockfish	0.0	-----	-----	-----	0.0
Sebastes miniatus	vermilion rockfish	76.9	33.3	-----	-----	-----
Sebastes paucispinis	boccacio	0.0	0.0	-----	-----	-----
Sebastes rubrivinctus	flag rockfish	0.0	-----	-----	-----	0.0
Sebastes saxicola	stripetail rockfish	31.9	20.0	67.0	0.0	2.0
Sebastes semicinctus	halfbanded rockfish	4.8	25.0	0.0	8.0	4.3
Hexagrammidae						
Ophiodon elongatus	lingcod	11.4	0.0	-----	16.1	-----
Zaniolepis frenata	shortspine combfish	0.0	0.0	-----	0.0	0.0
Zaniolepis latipinnis	longspine combfish	0.2	0.0	0.0	0.4	0.0
Cottidae						
Chitonotus pugetensis	roughback sculpin	1.0	0.0	0.0	3.2	0.0
Icelinus quadriseriatus	yellowchin sculpin	4.0	3.0	2.9	7.1	0.0
Icelinus tenuis	spotfin sculpin	0.0	0.0	-----	-----	-----
PLEURONECTIFORMES						
Paralichthyidae						
Citharichthys fragilis	Gulf sanddab	9.1	-----	-----	11.1	0.0
Citharichthys sordidus	Pacific sanddab	6.0	4.2	6.2	3.8	7.0
Citharichthys stigmaeus	speckled sanddab	31.6	44.0	49.1	32.6	-----
Citharichthys xanthostigma	longfin sanddab	23.3	22.6	18.5	21.6	20.0
Hippoglossina stomata	bigmouth sole	66.9	73.3	80.0	79.2	50.0
Paralichthys californicus	California halibut	96.3	100	83.3	100	-----
Xystreurys liolepis	fantail sole	100.0	100	-----	100	-----
Pleuronectidae						
Glyptocephalus zachirus	rex sole	4.3	-----	-----	-----	0.0
Lepidopsetta bilineata	rock sole	20.0	-----	-----	-----	-----
Lyopsetta exilis	slender sole	0.0	-----	-----	-----	0.0
Microstomus pacificus	Dover sole	5.3	10.8	4.4	12.5	3.5
Parophrys vetulus	English sole	42.8	58.0	40.9	85.0	9.2
Pleuronichthys coenosus	C-O sole	33.3	-----	33.3	-----	-----
Pleuronichthys decurrens	curlfin sole	39.3	-----	25.0	-----	-----
Pleuronichthys verticalis	hornyhead turbot	67.8	63.2	88.4	70.0	100
Cynoglossidae						
Symphurus atricaudus	California tonguefish	0.0	0.0	0.0	0.0	0.0

*SCB = Southern California Bight; HY = City of Los Angeles Bureau of Sanitation-Hyperion;
LA = Los Angeles County Sanitation District; OC = Orange County Sanitation District;
SD = City of San Diego Metropolitan Wastewater Department-Point Loma

Table VII-15. Total parasite mean intensity by Large-Outfall collected at depths of 22-198 m in the Southern California Bight, July through October 2003.

Host		MEAN INTENSITY				
		SCB*	HY	LA	OC	SD
SCORPAENIFORMES						
Scorpaenidae						
Scorpaena guttata	California scorpionfish	48.2	80.9	25.5	88.3	15.8
Sebastes caurinus	copper rockfish	0.0	-----	-----	-----	-----
Sebastes chlorostictus	greenspotted rockfish	3.7	-----	-----	-----	-----
Sebastes dallii	calico rockfish	0.0	0.0	-----	0.0	-----
Sebastes elongatus	greenstriped rockfish	0.0	-----	-----	-----	0.0
Sebastes goodei	chilipepper	0.0	-----	-----	-----	-----
Sebastes jordani	shortbelly rockfish	0.0	-----	-----	-----	0.0
Sebastes miniatus	vermilion rockfish	4.8	1.0	-----	-----	-----
Sebastes paucispinis	boccacio	0.0	0.0	-----	-----	-----
Sebastes rubrivinctus	flag rockfish	0.0	-----	-----	-----	0.0
Sebastes saxicola	stripetail rockfish	3.7	1.2	4.5	0.0	6.0
Sebastes semicinctus	halfbanded rockfish	1.4	1.0	0.0	1.1	1.3
Hexagrammidae						
Ophiodon elongatus	lingcod	1.2	0.0	-----	1.4	-----
Zaniolepis frenata	shortspine combfish	0.0	0.0	-----	0.0	0.0
Zaniolepis latipinnis	longspine combfish	1.7	0.0	0.0	1.0	0.0
Cottidae						
Chitonotus pugetensis	roughback sculpin	1.3	0.0	0.0	1.3	0.0
Icelinus quadriseriatus	yellowchin sculpin	1.1	1.1	1.0	1.0	0.0
Icelinus tenuis	spotfin sculpin	0.0	0.0	-----	-----	-----
PLEURONECTIFORMES						
Paralichthyidae						
Citharichthys fragilis	Gulf sanddab	1.0	-----	-----	1.0	0.0
Citharichthys sordidus	Pacific sanddab	1.1	1.1	1.2	1.0	1.2
Citharichthys stigmaeus	speckled sanddab	1.4	1.3	1.5	1.4	-----
Citharichthys xanthostigma	longfin sanddab	1.7	1.3	1.8	1.4	8.0
Hippoglossina stomata	bigmouth sole	3.0	3.5	1.9	2.4	1.6
Paralichthys californicus	California halibut	9.0	21.5	4.0	2.5	-----
Xystreurys liolepis	fantail sole	6.6	4.0	-----	4.2	-----
Pleuronectidae						
Glyptocephalus zachirus	rex sole	1.0	-----	-----	-----	0.0
Lepidopsetta bilineata	rock sole	2.0	-----	-----	-----	-----
Lyopsetta exilis	slender sole	0.0	-----	-----	-----	0.0
Microstomus pacificus	Dover sole	3.2	1.8	1.0	7.1	1.3
Parophrys vetulus	English sole	2.2	3.0	1.5	2.5	1.5
Pleuronichthys coenosus	C-O sole	1.0	-----	1.0	-----	-----
Pleuronichthys decurrens	curlfin sole	2.0	-----	5.0	-----	-----
Pleuronichthys verticalis	hornyhead turbot	3.6	3.1	5.2	2.4	3.0
Cynoglossidae						
Symphurus atricaudus	California tonguefish	0.0	0.0	0.0	0.0	0.0

*SCB = Southern California Bight; HY = City of Los Angeles Bureau of Sanitation-Hyperion; LA = Los Angeles County Sanitation District; OC = Orange County Sanitation District; SD = City of San Diego Metropolitan Wastewater Department-Point Loma

Table VII-16. Frequency of occurrence of parasites on host fishes collected at depths of 22-198 m in the Southern California Bight, July through October 2003, hosts and parasites in phylogenetic order. For complete host and parasite scientific names refer to Tables 59 and 61, respectively.

PARASITES	HOSTS: *S. guttata*	*S. chlorostictus*	*S. miniatus*	*S. saxicola*	*S. semicinctus*	*O. elongatus*	*Z. latipinnis*	*C. pugetensis*	*I. quadriseriatus*	*C. fragilis*	*C. sordidus*	*C. stigmaeus*	*C. xanthostigma*	*H. stomata*	*P. californicus*	*X. liolepis*	*G. zachirus*	*L. bilineata*	*M. pacificus*	*P. vetulus*	*P. coenosus*	*P. decurrens*	*P. verticalis*	No. of species	% Total
E. hippoglossi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	1	4
N. hippoglossini	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	x	-	-	-	-	-	-	-	2	9
M. sebastis	-	x	-	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	13
A. californiana	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	1	4
A. sp. 1	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4
A. sp. 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	1	4
A. sp. 3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	1	4
A. sp.	-	-	-	-	-	-	-	-	-	x	x	-	-	-	-	-	-	-	-	-	-	-	-	2	9
H. prolixus	-	-	-	-	-	-	-	x	-	-	x	x	x	x	x	x	-	-	-	x	x	x	-	10	43
H. spinulus	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4
A. cyclopsetta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	1	4
A. dojiri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	1	4
A. fraseri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x	2	9
A. hoi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	1	4
A. margolisi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	1	4
A. lobosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	1	4
P. longicauda	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	1	4
P. scorpaenus	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4
T. haakeri	-	-	-	-	-	-	-	-	-	-	-	x	-	x	x	x	-	-	-	-	-	x	x	6	26
C. pectinatus	-	-	-	x	-	-	-	-	-	-	-	x	-	x	x	-	-	-	-	-	-	-	-	4	17
C. sp. 1	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	1	4
L. bifurcatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	1	4
L. pravipes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	x	2	9
L. remiopsis	-	-	-	-	-	-	-	-	-	-	x	x	x	x	x	-	-	-	-	x	-	-	-	6	26
L. rotundipes	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4
L. spatha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	1	4
L. sp. 1	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	1	4
chalimus	-	-	-	x	x	x	x	x	x	-	x	x	-	x	x	x	-	-	-	x	-	x	x	14	61
C. parva	-	-	-	x	x	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	3	13
N. occidentalis	-	-	-	-	-	-	-	-	-	-	x	-	x	-	-	-	-	-	-	-	-	-	-	2	9
N. scorpaenae	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4
P. paralichthyos	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	1	4
P. robusta	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4
P. sp. 1	-	-	-	-	-	-	-	-	-	-	x	-	x	-	-	-	-	-	-	-	-	-	-	2	9
P. cincinnatus	-	-	-	-	-	-	-	-	-	-	x	-	x	-	-	-	-	-	-	-	-	-	-	2	9
E. californica	x	-	-	-	-	-	-	x	-	-	x	x	x	x	-	-	-	-	-	-	-	-	x	7	30
E. vulgaris	x	-	-	-	-	x	-	-	-	-	x	x	x	-	-	-	-	x	-	x	-	x	x	9	39
aegathoid	-	-	-	-	-	-	-	-	-	-	x	x	-	-	x	-	-	-	-	-	-	-	x	4	17
praniza	x	-	x	x	x	x	x	-	x	-	x	x	x	x	x	-	-	-	x	x	-	x	x	16	70
No. of species	8	1	2	5	4	3	2	3	2	1	11	10	9	11	11	8	1	1	2	5	1	6	10		
% Total	21	3	5	13	10	8	5	8	5	3	28	26	23	28	28	21	3	3	5	13	3	15	26		

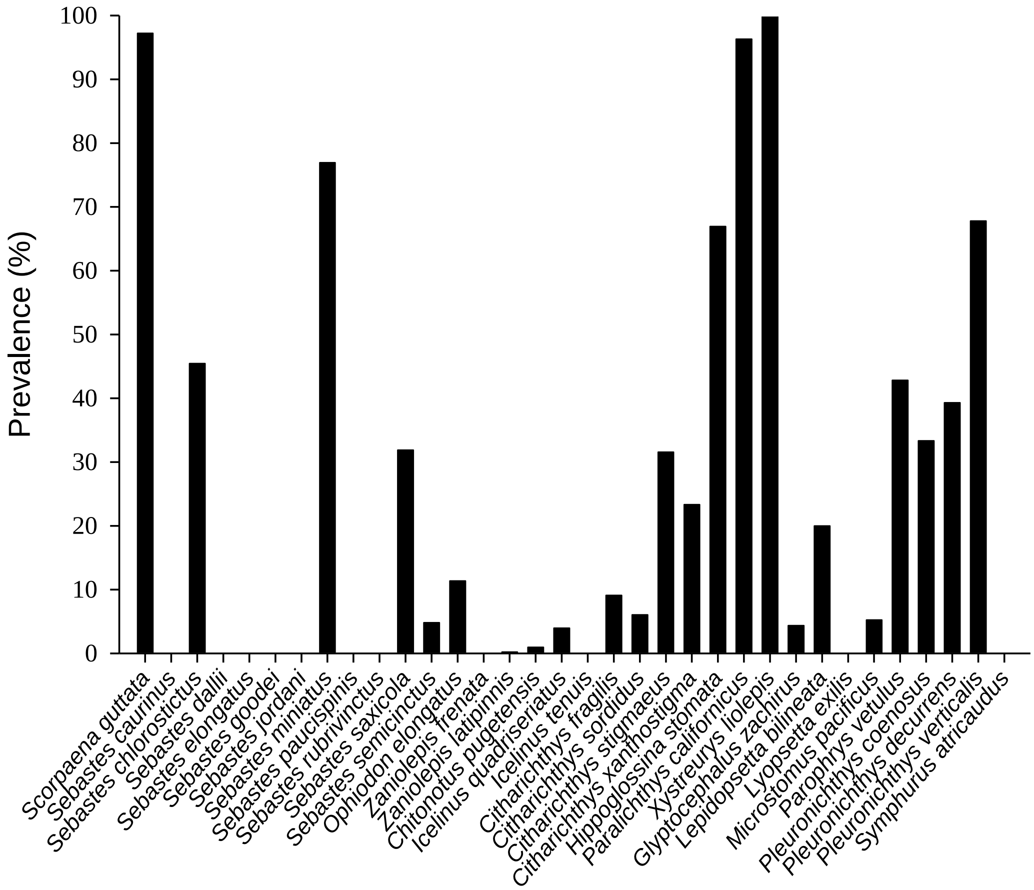


Figure VII-1. Total parasite prevalence for all host fish species collected at depths of 22-198 m in the Southern California Bight, July through October 2003, host fishes in phylogenetic order.

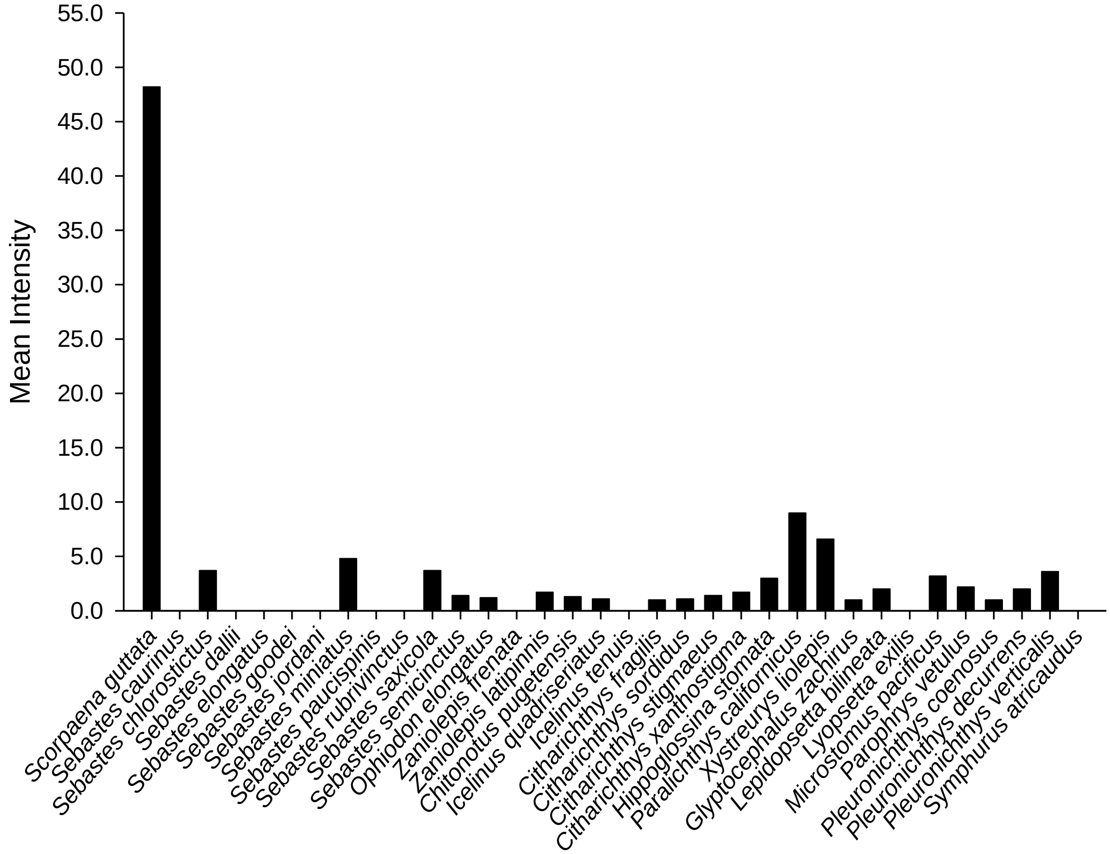


Figure VII-2. Total parasite mean intensity for all host fish species collected at depths of 22-198 m in the Southern California Bight, July through October 2003, host fishes in phylogenetic order.

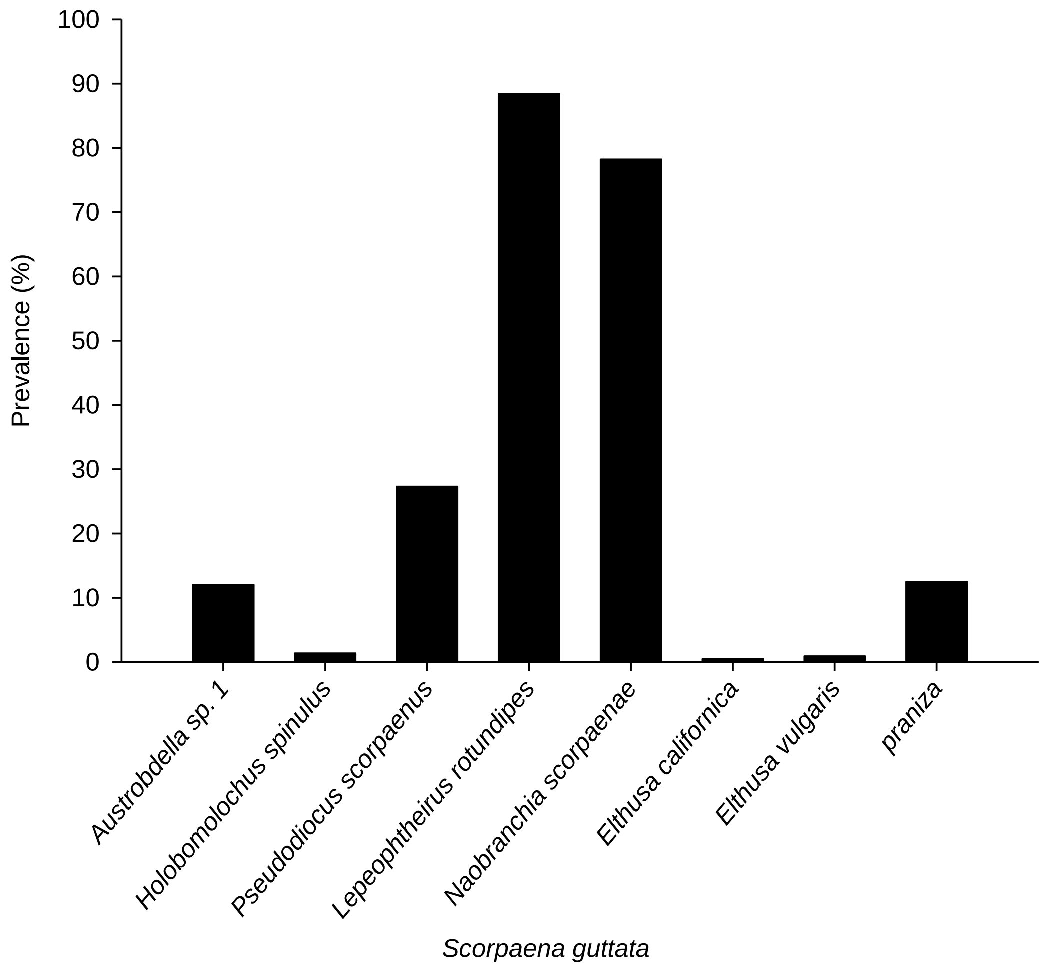


Figure VII-3. Individual parasite prevalence for California scorpionfish (*Scorpaena guttata*) collected at depths of 22-198 m in the Southern California Bight, July through October 2003, parasites in phylogenetic order.

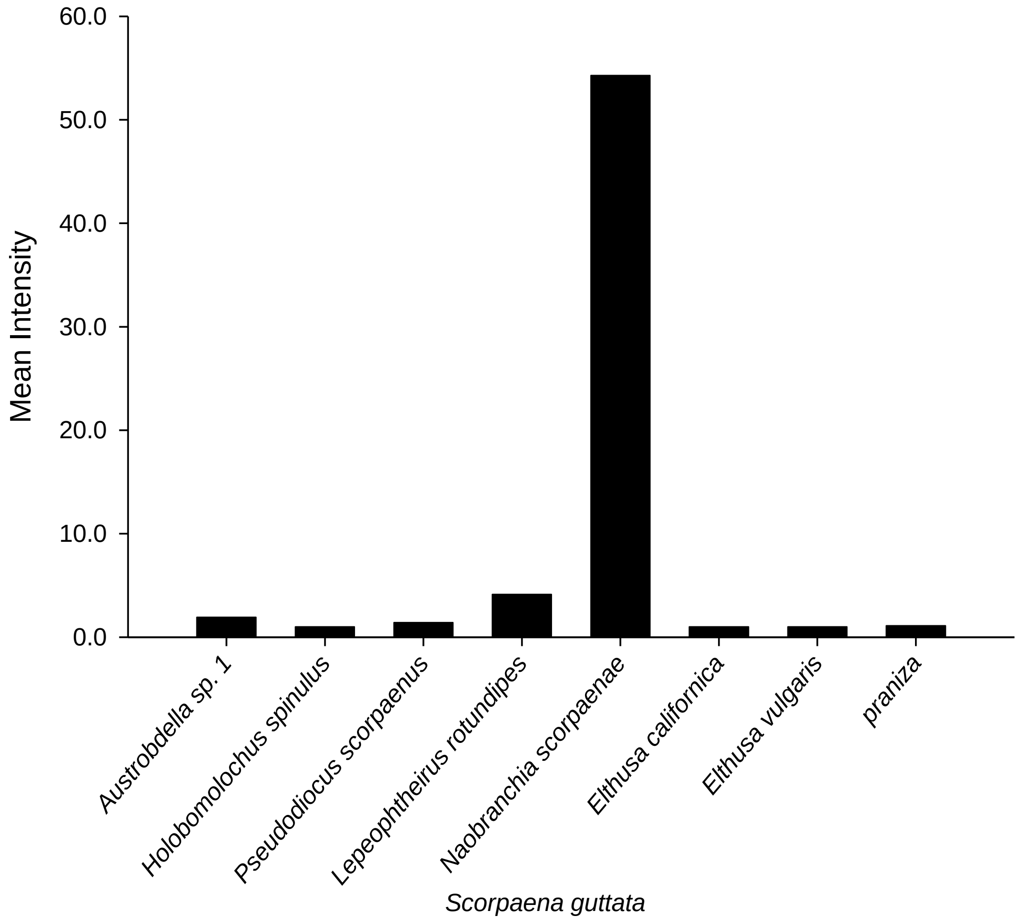


Figure VII-4. Individual parasite mean intensity for California scorpionfish (Scorpaena guttata) collected at depths of 22-198 m in the Southern California Bight, July through October 2003, parasites in phylogenetic order.

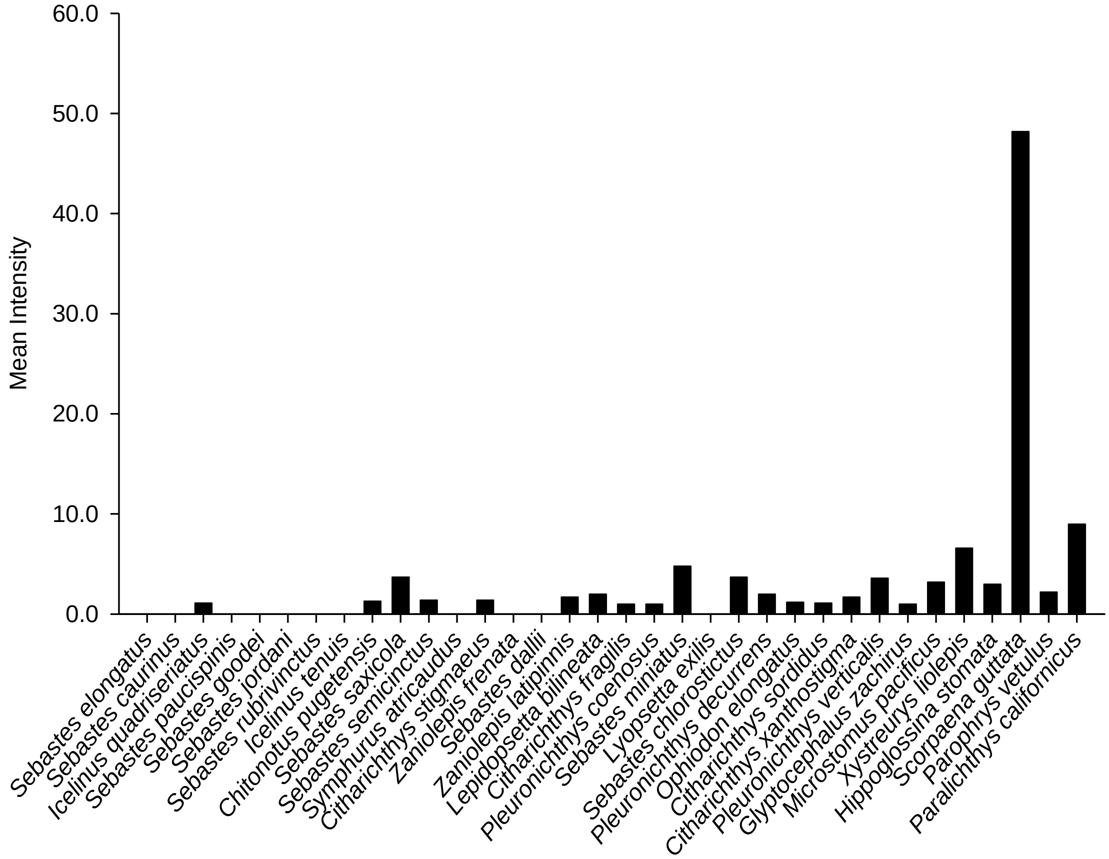


Figure VII-5. Total parasite mean intensity for all host fish species collected at depths of 22-198 m in the Southern California Bight, July through October 2003, host fishes in order of increasing maximum standard length (mm).

Historically the LA Large-Outfall area has had a large influx of contaminants, such as DDT and PCBs, most of which still remain in the sediment (Stull 1995, Schiff 2000). Schiff and Allen (1996) found high levels of total DDT and total PCB in livers of three species of flatfish, Pacific sanddab, longfin sanddab, and Dover sole, collected on the Palos Verdes Shelf near the outfall. They attributed the accumulation to the niche of each of these fish species, an intimate association with the sediment, historical contamination on the Palos Verdes Shelf, and feeding upon resident infaunal invertebrates. In contrast, the prevalence of the piscicolid leech *Austrobdella* spp. 1 parasitic on California scorpionfish was significantly higher at OC (48.5 %) compared to HY (5.7 %), LA (0%), and SD (0%; p=0.0194; Appendix E-E9). This is a new species of leech, thus little is known of its life history and geographical range. It is possible that the range of this leech is restricted to the San Pedro Shelf and Santa Monica Bay. In addition, the lernaeopodid copepod *N. scorpaenae*, also parasitic on California scorpionfish, had a significantly higher mean intensity at HY and OC (79.8 and 89.1) than at LA and SD (32.0 and 15.7; p=0.0335; Appendix E-E10). The HY and OC areas are distant, separated by the LA area (Figures VII-3 through VII-5). Love *et al.* (1987) found California scorpionfish formed large offshore spawning aggregations in waters deeper than their off-season habitat. Tagging results indicated that fish return to the same spawning area annually. However, little is known of the alongshore movements of California scorpionfish in the SCB. Because both HY and OC areas have large, broad continental shelves, it is possible that when the fish move back onshore, they go to either shelf. Therefore, it is possible the similar prevalence and mean intensity of California scorpionfish at HY and OC is because the same population, thus the same assemblage of parasites, was sampled from these two areas. Kabata (1963) was among the first to demonstrate that parasites could be used to delineate fish stocks for management purposes and was instrumental in pioneering the use of parasites as biological tags for fisheries management. Since then, various parasites have been used as potential biological tags for fish stock and habitat identification (Leaman and Kabata 1987, Stanley *et al.* 1992, Oliva *et al.* 2004). Thus, the use of ectoparasites of California scorpionfish as biomarkers could potentially give some insight to the movement patterns of this host.

It is interesting to note, even with the numerous studies and monitoring of benthic fishes in southern California, three new species of leeches, one new species of copepod, and 56 new host records were found in this study. This is likely due to the nature of marine monitoring sampling in the SCB. The protocol of many studies and monitoring programs does not include inspection for small parasitic organisms occurring on the sampled fishes, and only the larger parasites, such as the eye copepod (*Phrixocephalus cincinnatus*) and the gill isopod Pacific fish louse(*E. vulgaris*) are reported (Allen *et al.* 1998, Allen *et al.* 2002a, CSDMWWD 2004, CLAEMD 2005, CSDLAC 2005, OCSD 2006). It is recommended that if these programs plan to continue to include sampling of ectoparasites, the routine monitoring methods should be modified. For example, a subsample of target host species from outfall and nonoutfall areas, such as California scorpionfish, speckled sanddab, bigmouth sole, and hornyhead turbot, could be frozen and brought back to the laboratory for a thorough inspection and identification of ectoparasites. The presence/absence and prevalence of the various ectoparasites could then be determined and used as a monitoring tool.

In conclusion, this study may serve not only as a basis of the species composition of the host-parasite fauna in the SCB, but also as an indication that certain host species and their ectoparasites can be a useful tool for identifying different areas subjected to environmental stress, such as effluent and sediment contamination. This study was the first of its kind attempted throughout the SCB. The outcome of the study suggests a reduction of the number of potential species of demersal fishes and their corresponding ectoparasites as bioindicators, from 34 species down to three. Results indicate that the prevalence of the copepod *Holobomolochus prolixus* on speckled sanddab, and total parasitization on bigmouth sole and hornyhead turbot, can be used as bioindicators of environmental stress in the SCB. In addition, the mean intensity of the parasitic larval stage chalimus on bigmouth sole and both the copepod *Acanthochondria fraseri* and the gnathiid praniza larvae on hornyhead turbot, also can be used as an indication of environmental stress. Many of the fishes that were evaluated in this study are of commercial importance (e.g., California scorpionfish and California halibut) and thus information about the parasite infestations on these hosts may be important to consumers and fisheries managers.

Furthermore, the parasite-host relationships of California scorpionfish are complex and should be investigated further. The prevalence of the leech *Austrobdella* spp. 1 on California scorpionfish at OC was higher than at the other three Large-Outfall areas, indicating a narrow parasite range.

In addition, the median mean intensity of the copepod *Naobranchia scorpaenae* on California scorpionfish was high at HY and OC, two areas distant from each other, implying host movement. Although the sample sizes of this study were large and covered a widespread geographical area, the results from this study are from a single survey within one year. Routine sampling of ectoparasites is needed to see if these trends persist. It is apparent that additional information on both taxonomic and ecological aspects of fish parasites in the SCB are greatly needed.

Summary and Conclusion

1. Parasite infestation varies according to host species. Some hosts, such as fantail sole, California scorpionfish, and California halibut, appear to be more susceptible to parasites than other hosts, such as California tonguefish and slender sole.
2. Prevalence varies according to parasite species. The parasitic copepods *Lepeophtheirus rotundipes* and *Naobranchia scorpaenae*, found exclusively on California halibut, were conspicuously the most prevalent parasite species collected in the SCB (88.4% and 78.2%, respectively).
3. California scorpionfish had the highest mean intensity of ectoparasites of any fish species examined to date.
4. Many ectoparasites are host species and/or host genus specific (26 of 39 species appear to be specific for a single host species or host genus).
5. Copepods are by far the most abundant group of ectoparasites on fishes living in the SCB (12,795 out of 14,620 individuals).
6. The following parasite-host combinations are of bioindicator utility in the SCB:
   - caligid copepod chalimus larvae on bigmouth sole
   - the copepod *Acanthochondria fraseri* on hornyhead turbot
   - gnathiid isopod praniza larvae on hornyhead turbot
   - the copepod *Holobomolochus prolixus* on speckled sanddab
7. The total prevalence of ectoparasites on bigmouth sole was significantly highest at Large- and Small-Outfall areas.
8. The total prevalence of ectoparasites on hornyhead turbot was significantly highest at Small-Outfall areas.
9. The higher prevalence of ectoparasites on hornyhead turbot and bigmouth sole at the shallow Small-Outfall areas rather than the deeper Large-Outfall areas may be due to higher temperatures at the shallow depths rather than outfall effects.
10. The host-ectoparasite relationships of California scorpionfish, speckled sanddab, bigmouth sole, and hornyhead turbot are complex and deserve further study.
11. Three new species of leeches and one new species of parasitic copepod were found in this study.
12. Fifty-six new host records were reported.

VIII. BIOACCUMULATION

Introduction

Large quantities of the chlorinated hydrocarbons dichlorodiphenyltrichloroethane (DDT) and polychlorinated biphenyls (PCB) have been historically discharged to the southern California Bight (SCB). An estimated 41.5 metric tons (mt) of DDT and 55.5 mt of PCB have been discharged to the SCB since 1971 (Schiff *et al.* 2000, Raco-Rands and Steinberger 2001). The DDT emanated from the Montrose Chemical Corporation, formerly the worlds largest manufacturer of chlorinated pesticide, and was discharged through the Los Angeles County sanitary sewer system ocean outfall (Stull 1995). Sources of PCBs included ocean dumping, wastewater discharges, vessel coating, surface runoff and other nonpoint sources (Mearns *et al.* 1991). Since 1970 when the use of DDT was banned and Montrose halted production, discharges from the ocean outfalls in the SCB have dramatically decreased and DDT emissions are generally nondetectable. Municipal waste discharge of PCBs (as well as other sources) have decreased dramatically as well (Mearns *et al.* 1991). However, the legacy of this contamination is still observed in the SCB. For example, the highest sediment total DDT concentrations in the SCB are found on the Palos Verdes Shelf on the Los Angeles margin, and it is thought that an estimated 100 mt may still reside in these marine sediments (Lee and Wiberg 2002). DDT and PCB contamination remains widespread, with more than 82% of the ocean floor in the SCB has sediments with measurable DDT and/or PCB (Schiff 2000).

The historical inputs of DDT and PCBs have also resulted in exposure and impacts to biota. As in sediments, contamination of biological organisms has been widespread. Marine bivalves had detectable concentrations of DDT along the entire 350 km coastline of the SCB (Mearns 1993). An estimated 96% of the Pacific sanddab population, the most common flatfish on the shelf, is contaminated with total DDT and/or total PCB (Schiff and Allen 2000) and 99% of the sanddab guild (the most widespread foraging guild on the shelf) had detectable levels of DDT in 1998 (Allen *et al.* 2002a, 2004b). Reproductive impairment due to DDT and/or PCB was observed in white croaker in the 1980s (Cross and Hose 1988, Hose *et al.*. 1989). Health-risk advisories to warn anglers still exist along many kilometers of the southern California coastline for several species, including white croaker (OEHHA 2006). Historically, reproductive success was impaired in pinnipeds, such as the California sea lion (*Zalophus californianus*) that suffered from premature pupping (Delong *et al.* 1973) or seabirds, such as the brown pelican (*Pelecanus occidentalis*) that suffered from eggshell thinning (Gress 1994). While these reproductive failures have reversed themselves, other high level predators continue to struggle. For instance, transplanted bald eagles (*Haliaeetus leucocephalus*) hatched their first two chicks on the California Channel Islands in more than 30 years (D. Witting, NOAA, NMFS, Southwest Regional Office, Long Beach, CA, personal communication May 13, 2006). Concentrations of total DDT and total PCB still average 150 ug/kg in the blubber of marine mammals such as California sea lions in 2000 (LeBouf *et al.* 2002).

While contaminant pathways to sediment associated biota are well documented, contaminant pathways to higher-level predators are still uncertain. For example, tissue concentrations of flatfish are highest on the Palos Verdes Shelf where sediment concentration maxima are located (Mearns *et al.* 1991; Allen *et al.* 2002a, 2004b). Bightwide relationships between sediment contaminant concentrations and flatfish tissue concentrations were highly correlated for both total DDT and total PCB (Schiff and Allen 2000; Allen *et al.* 2002a,b, 2004b). Moreover, different flatfish species within the same foraging guild and having similar lifestyles accumulated similar quantities of total DDT and total PCB with exposure to the same contaminated sediments (Allen *et al.* 2002b). In contrast, little data exists in pelagic forage fishes and squid that might serve as pathways to mammals and seabirds. Both northern anchovy and California market squid are primary prey items for the California sea lion in the SCB (Antonelis *et al.* 1980, Lowry *et al.* 1991, Lowry and Carreta 1999). Brown pelican was reported to feed consistently on northern anchovy and its breeding status in the SCB has been strongly linked to anchovy abundance and availability (Anderson *et al.* 1980). Pacific whiteside dolphin (*Lagenorhynchus obliquidens*) also commonly forages on small pelagic fishes and squid, while the harbor seal (*Phoca vitulina*), short-beaked common dolphin (*Delphinus delphis*), and bottlenose dolphin (*Tursiops truncatus*) forage mainly on other types of fish (Pauly *et al.* 1998). Additional wildlife predators of pelagic forage species such as northern anchovy, California market squid, Pacific sardine, and Pacific chub mackerel include larger pelagic fishes of the SCB such as Pacific barracuda (*Sphyraena argentea*), Pacific bonito (*Sarda chiliensis*), tunas (*Thunnus* spp.), and yellowtail jack (*Seriolis lalandi*; Leet *et al.* 2001).

The primary objective of this study was to assess the extent and magnitude of total DDT and total PCB in pelagic forage fishes and squid within the SCB. This goal will be addressed by answering two basic questions: 1) What percentage of the pelagic forage fish and squid biomass exceeds wildlife risk screening values?; 2) Are there geographic patterns in the concentration of total DDT, total PCB, or the percentage of biomass that exceeds thresholds of concern? These data can then be used for determining potential pathways to higher predators such as marine mammals and birds.

Results

A total of 99 composite samples, representing 1,460 individual fish or squid were collected for organic contaminant analysis (Table VIII-1; Figure VIII-1). Samples of the four target species were collected from each of the four regions identified. Sample sizes ranged from 34 composites for Pacific sardine to 13 composites for Pacific chub mackerel. Bait and landing composites were treated equally throughout the data analysis process. Concentrations of total DDT and total PCB in bait receiver and commercial landing composites for both northern anchovy and Pacific sardine were not significantly different ($p > 0.05$). Despite combining composites from commercial landings and bait receivers, not all of the sampling targets were achieved for each species. For example, only 70% of the target samples were collected for northern anchovy.

Sample Representation

California market squid (34×10^3 mt) and Pacific sardine (14×10^3 mt) comprised over 90% of the total biomass landed in the SCB during this study (Figure VIII-2). These two species were sampled with the greatest success in the survey. Pacific chub mackerel (4×10^3 mt), the species that was sampled with intermediate success, comprised 6% of the total biomass landed during the study period. Northern anchovy (2×10^3 mt), the species sampled with the least success, comprised less than 3% of the total biomass landed during the study. Jack mackerel, which was not sampled, comprised only 1% of the total biomass landed during the study period.

While target sample sizes were not achieved for all species and strata, the sampling effort was representative of the appropriate geographic distributions of pelagic forage fishes and squid that were commercially landed in southern California (Figure VIII-3). For example, 71% of all Pacific sardine were landed in the central stratum and this study representatively sampled 92% of these landings. Similarly, representative samples were collected for the majority of landings of California market squid. A very small proportion of the landings from the islands stratum offset the lack of sampling success in the southern SCB. Representative sampling of the majority of the northern anchovy landings was not achieved as these were dominated by fisheries in the northern SCB. Approximately 50% of the Pacific chub mackerel were representatively sampled.

Total DDT and Total PCB

Tissue concentrations differed among species (Figure VIII-4; Table VIII-2). Northern anchovy had the highest biomass-weighted average concentrations of total DDT (61 ±38 SD ug/kg ww). All but one of the northern anchovy samples had detectable quantities of total DDT and these concentrations ranged from 3 to 135 SD ug/kg ww. California market squid had the lowest biomass-weighted average concentration of total DDT (0.8 ±1.2 SD ug/kg ww). Fifty percent of California market squid samples had nondetectable concentrations. Pacific sardine and Pacific chub mackerel had intermediate biomass-weighted average concentrations of total DDT (34 ±29 SD and 41 ±40 SD ug/kg ww, respectively). Both species also ranged in total DDT concentration from 3 to >100 ug/kg ww with only a single nondetectable sample (for Pacific sardine). Pacific chub mackerel had the maximum total DDT concentration of all three species (141 ug/kg ww). The distribution of total PCB concentrations between species followed the pattern of total DDT concentrations, but was lower by approximately one order of magnitude (Figure VIII-4). For example, the biomass-weighted average total PCB concentration in northern anchovy was 3 ±5 SD ug/kg ww.

Despite within-strata variability, the central stratum generally had the highest mean concentrations of detectable total DDT and total PCB (Table VIII-2 and VIII-3). Detectable concentrations of total DDT were higher in the central stratum for three of the four species. Interestingly, the islands stratum contained the highest average total DDT concentration for northern anchovy. The highest average total PCB concentrations were also observed from the central stratum for three of the four species. Only the southern stratum had greater detectable total PCB concentrations than the central stratum, and this was in Pacific chub mackerel.

Relationship to Lipid Content

Regardless of species or season, concentrations of total DDT appeared to be a function of lipid content (Figure VIII-5). Lipid content and total DDT concentration were significantly correlated for northern anchovy and Pacific sardine ($p < 0.05$). Lipid content explained 43% and 34% of the variability in total DDT concentrations for Pacific sardine and northern anchovy, respectively. Percent lipid content was highest in Pacific sardine (5.0 % ±0.91 SE), followed by northern anchovy (4.1 % ±0.78 SE) and Pacific chub mackerel (2.9 % ±0.34 SE). California market squid had the lowest percent lipid content (1.1 % ±0.16 SE).

Table VIII-1. Sampling success of southern California pelagic forage species targeted for whole fish composite contaminant analysis between July 2003 and February 2004.

	Region					
	Mainland Coast					Percent
Species	North	Central	South	Islands	Total	Target
Northern anchovy	10	10	2	2	24	60
Pacific sardine	9	10	5	10	34	85
California market squid	10	8	0	10	28	70
Pacific chub mackerel	3	4	1	5	13	65
Total	32	32	8	27	99	71

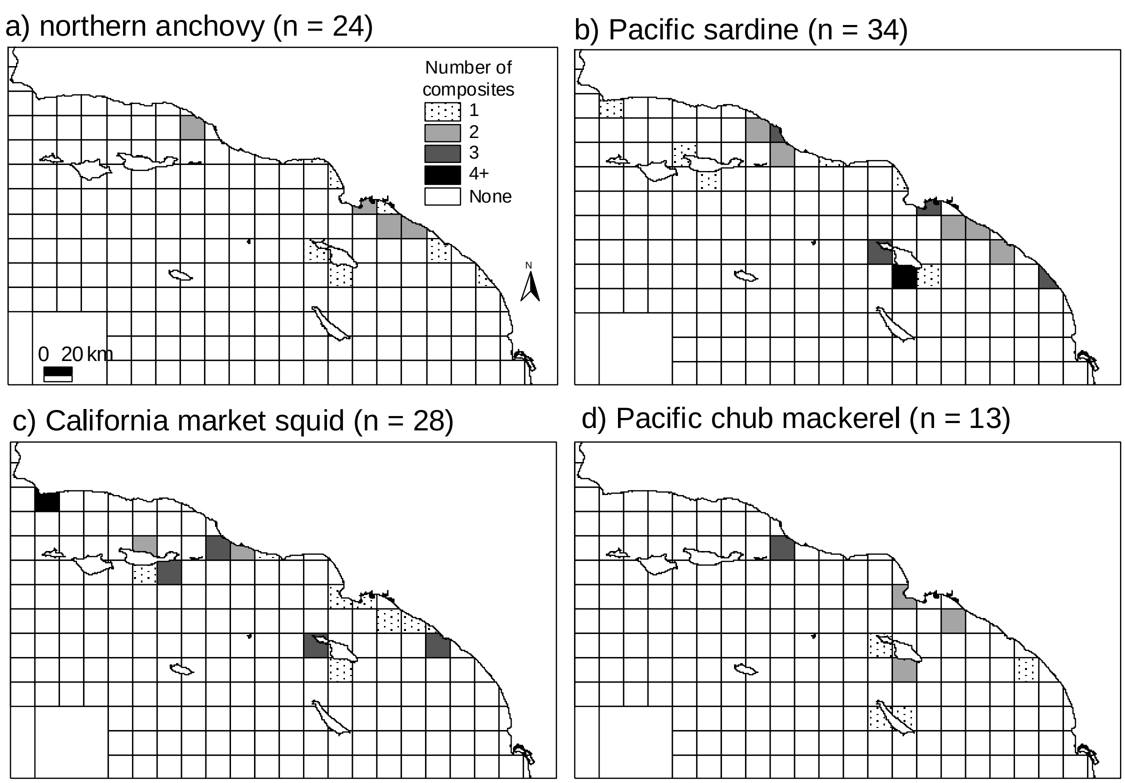


Figure VIII-1. Distribution of contaminant sample composites for a) northern anchovy, b) Pacific sardine, c) California market squid, and d) Pacific chub mackerel sampled from southern California commercial fishing markets and/or bait receivers during July 2003 – February 2004.

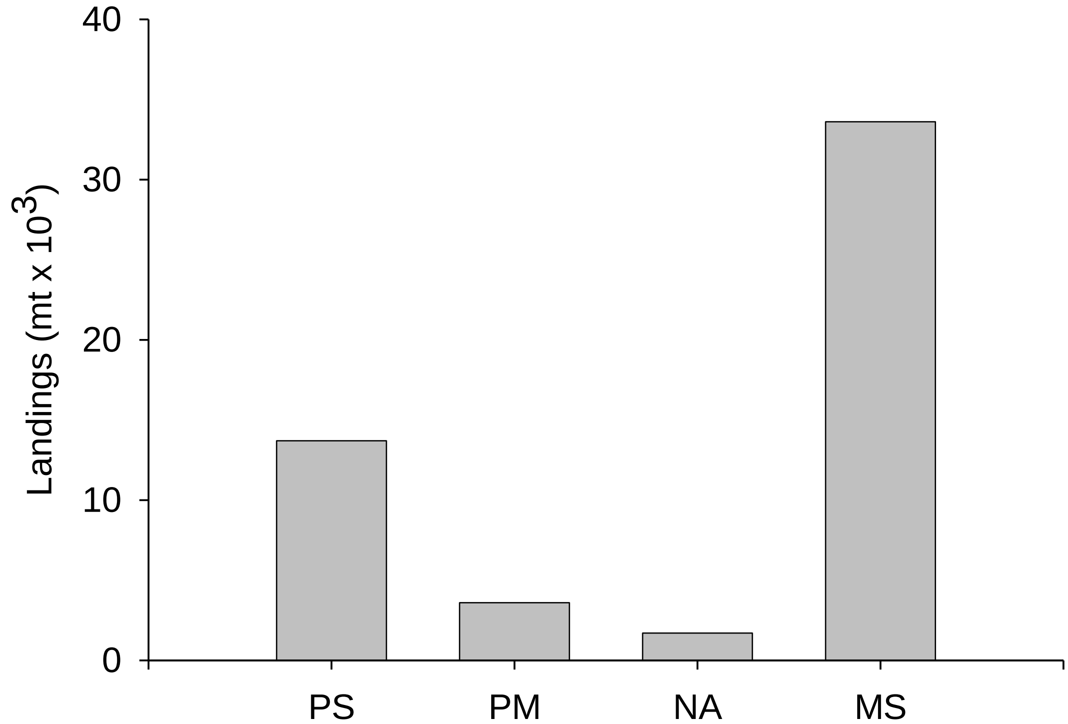


Figure VIII-2. Total southern California commercial landings of pelagic forage fish and squid landings (metric tons) during the study period, July 2003 – February 2004 (CDFG data, unpublished). PS=Pacific sardine, PM=Pacific chub mackerel, NA=northern anchovy, MS=California market squid.

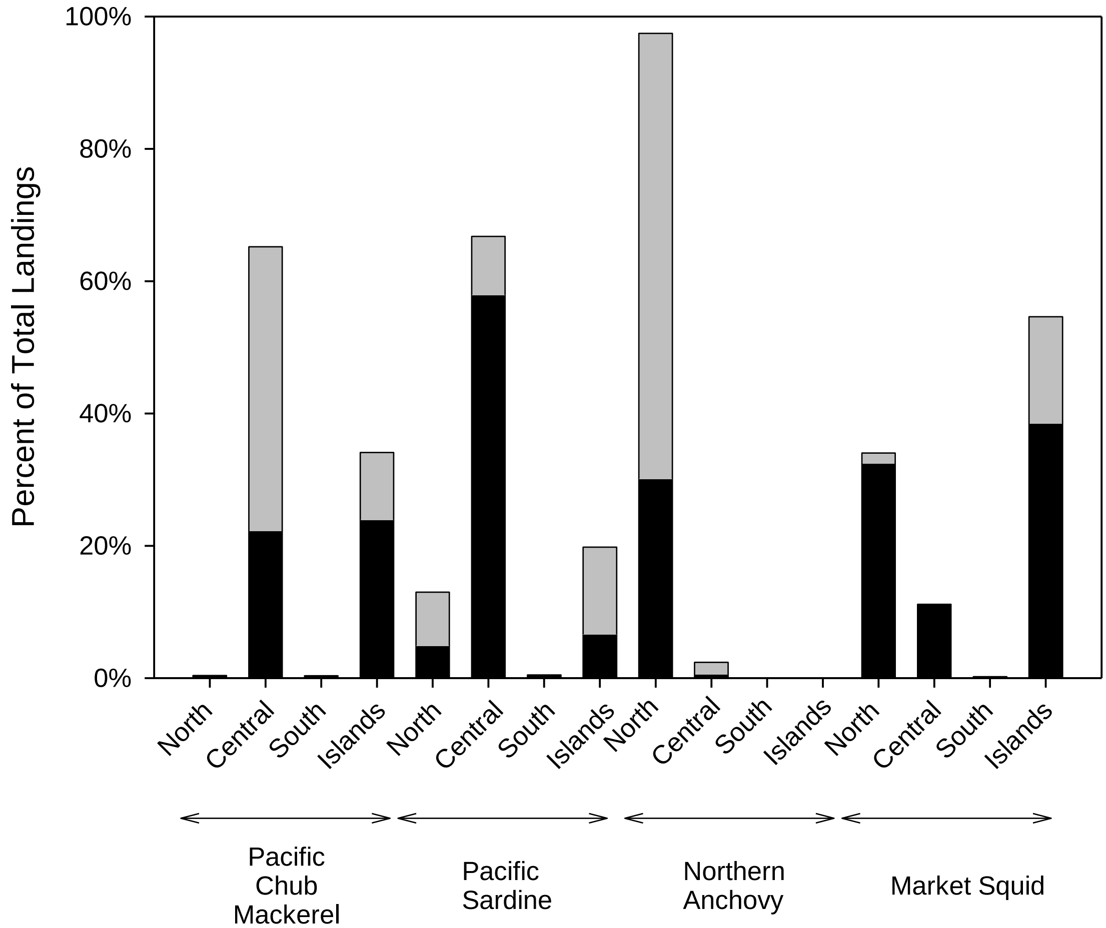


Figure VIII-3. Representative samples by species and geographic stratum. Gray bars denote the relative percentage of total landings by species for each stratum. Black bars denote the fraction of total landings with a representative sample.

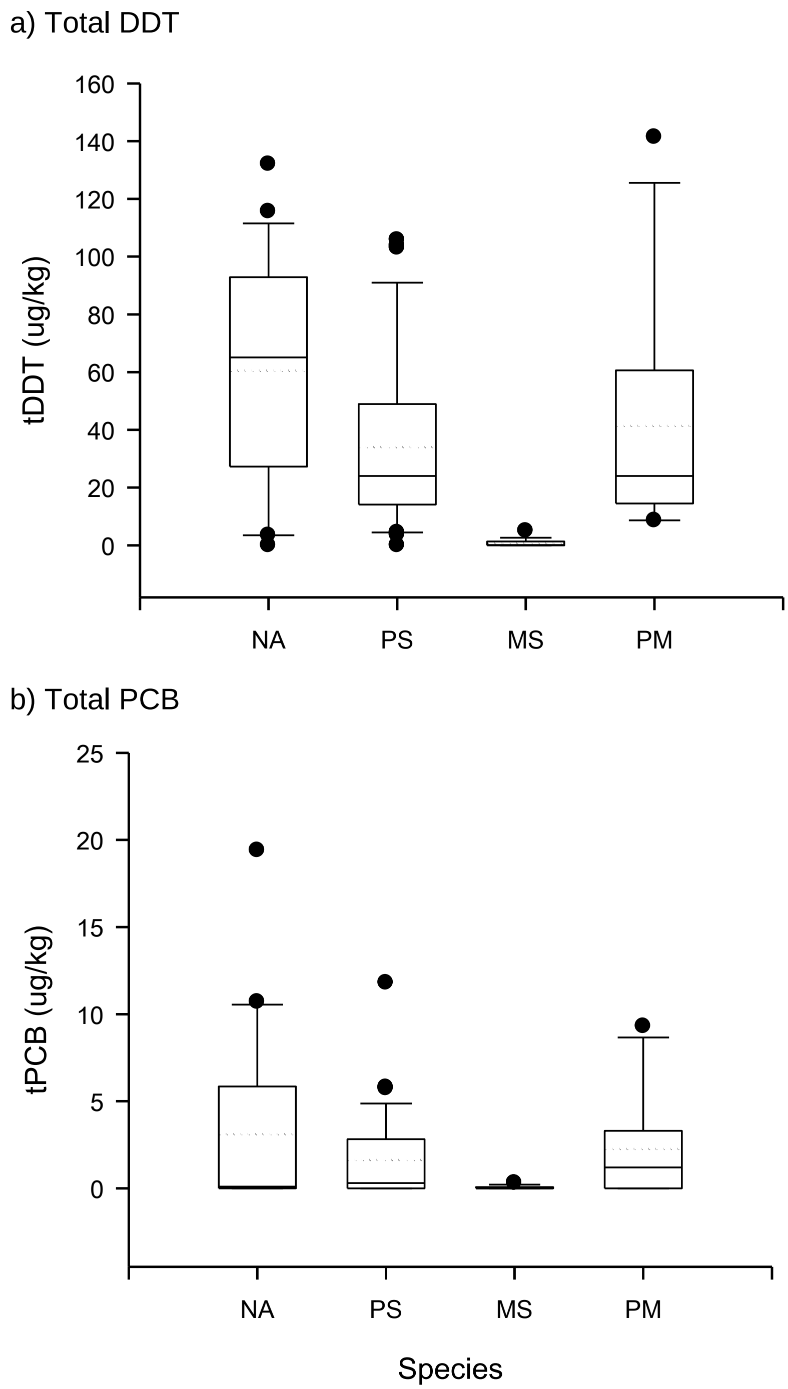


Figure VIII-4. Box plots of a) total DDT and b) total PCB in pelagic forage fish and squid whole fish composites sampled from southern California commercial fish markets and bait receivers during July 2003 – February 2004. (NA=northern anchovy (n=24); PS=Pacific sardine (n=34); MS=California market squid (n=28); PM=Pacific chub mackerel (n=13)).

Table VIII-2. Summary of total DDT (ug/kg) concentrations in southern California pelagic forage fish and squid composites by region within the southern California Bight.

		Composites with Detectable Concentrations				All Composites	
Total DDT (ug/kg ww)	**% ND**	**Median**	**Mean**	**95% CI**	**N**	**Min**	**Max**
Pacific chub mackerel							
Mainland coast							
North	0	23.80	21.80	3.08	3	17.60	24.00
Central	0	56.70	65.90	0.96	4	8.80	141.40
South	0	31.20	31.20	--	1	31.20	31.20
Islands	0	17.40	40.87	2.39	5	8.60	57.40
California market squid							
Mainland coast							
North	60	1.50	1.55	13.41	4	0.00	2.60
Central	38	2.40	2.72	8.45	5	0.00	4.98
South	--	--	--	--	--	--	--
Islands	60	0.70	0.65	8.48	4	0.00	1.00
northern anchovy							
Mainland coast							
North	0	75.20	71.49	3.42	10	24.80	132.00
Central	10	68.80	63.14	2.85	9	0.00	115.60
South	0	13.60	13.60	1.03	2	3.40	23.80
Islands	0	72.29	72.29	0.56	2	37.20	107.38
Pacific sardine							
Mainland coast							
North	0	23.20	33.57	3.28	9	14.60	105.74
Central	0	43.10	52.76	3.45	10	12.60	103.80
South	0	10.00	13.07	3.46	5	4.80	23.60
Islands	10	36.00	29.36	3.79	9	0.00	57.60

Table VIII-3. Summary of total PCB (ug/kg) concentrations in southern California pelagic forage fish and squid composites by region within the southern California Bight.

		Composites with Detectable Concentrations				All Composites	
Total PCB (ug/kg ww)	**% ND**	**Median**	**Mean**	**95% CI**	**N**	**Min**	**Max**
Pacific chub mackerel							
Mainland coast							
North	67	2.30	2.30	--	1	0.00	2.30
Central	50	1.20	5.25	5.73	2	0.00	9.30
South	100	4.30	4.30	--	1	4.30	4.30
Islands	60	1.80	4.75	4.17	2	1.80	7.70
California market squid							
Mainland coast							
North	80	0.15	0.15	0.07	2	0.00	0.20
Central	80	0.25	0.25	0.07	2	0.00	0.30
South	--	--	--	--	0	--	--
Islands	90	0.10	0.10		1	0.00	0.10
northern anchovy							
Mainland coast							
North	70	9.20	6.93	3.95	3	0.00	9.60
Central	60	10.40	11.75	5.45	4	0.00	19.40
South	50	3.65	3.90	--	1	0.20	3.90
Islands	50	2.30	2.30	--	1	0.00	2.30
Pacific sardine							
Mainland coast							
North	44	17.60	2.13	0.80	5	0.00	3.30
Central	50	28.00	5.23	3.90	5	0.00	11.80
South	60	6.20	2.25	1.48	2	0.00	3.30
Islands	70	5.80	4.23	1.46	3	0.00	5.80

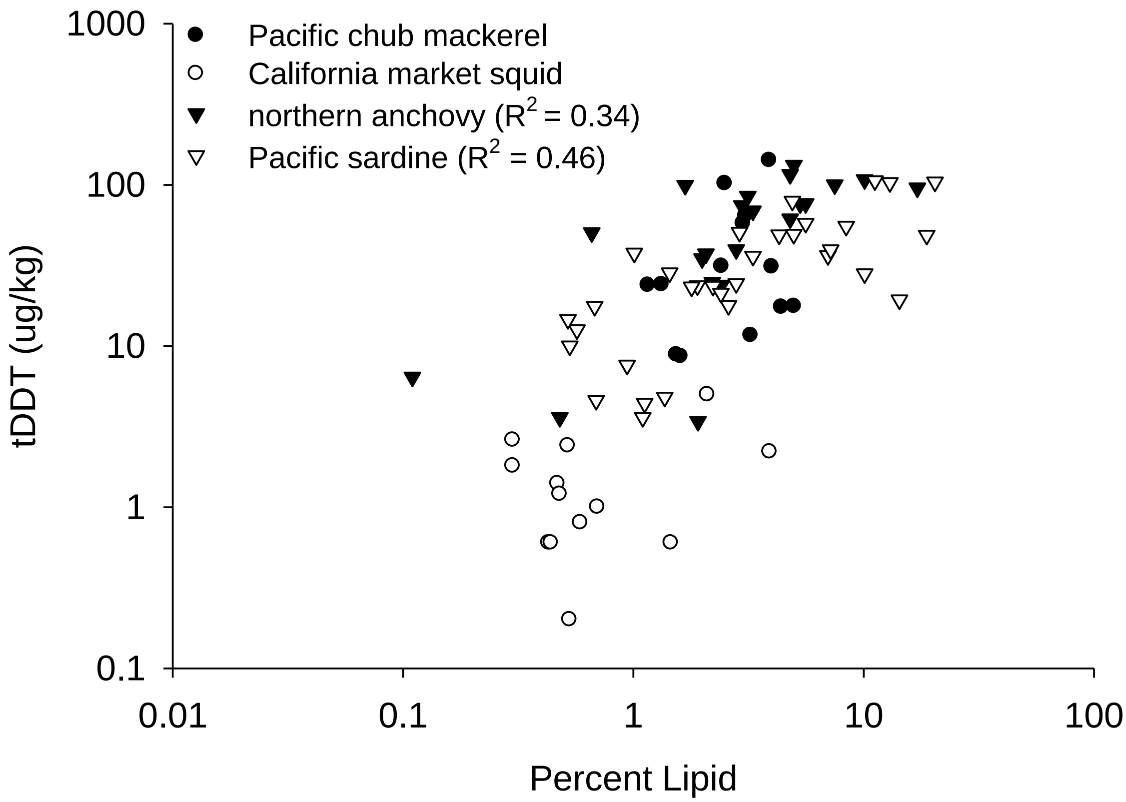


Figure VIII-5. Relationship between lipid content and total DDT concentrations in whole fish composites of pelagic forage fishes and squid sampled from southern California commercial fish markets and/or bait receivers during July 2003 – February 2004. Samples represent only those with detectable levels of total DDT (n=80).

Percent of Biomass Above Wildlife Risk Screening Values

Approximately 99% of all commercial landings of northern anchovy in the SCB exceeded wildlife-risk screening values for total DDT during this study (Figure VIII-6). Approximately 86% of the Pacific sardine and 33% of the Pacific chub mackerel commercial landings also exceeded the total DDT screening values during this study. None of the California market squid landings exceeded the wildlife risk screening value for total DDT. The extent of total PCB exceedence of wildlife risk screening values (as TEQs) was much less. Less than 1% of the commercial landings for Pacific sardine exceeded wildlife-risk screening values for birds during this study. None of the other species exceeded the PCB risk screening values for either birds or mammals.

Total Mass of Contaminants in SCB

Based on the total biomass of commercial landings, an estimated 1.3 kg (±95% CI=0.6 kg) of total DDT was contained within the four pelagic fish species examined during this study. Total PCB contained within the four pelagic fish species was 0.06 kg (±95% CI=0.06 kg). Most of the DDT (71%) resides within the landings for Pacific sardine. Pacific sardine had the second highest average concentrations of total DDT and it was the species with the second highest biomass. In contrast, California market squid contained less than 2% of the total DDT mass found in pelagic forage species tissues. While California market squid had the highest landing biomass, it also had extremely low levels of total DDT. Like the total DDT mass estimates, Pacific sardine had the highest quantity of total PCB of all species examined (83%).

Discussion

Despite the reduction in the discharge of total DDT and total PCB in the SCB over the last 35 years (Schiff *et al.* 2000, Raco-Rands and Steinberger 2001), a large fraction of pelagic biomass appears to be affected by DDT. Bioaccumulation examined in this study was widespread with multiple species; sardines, anchovies, and mackerel accumulated measurable total DDT and total PCB throughout virtually all of the landings in the SCB. Moreover, the accumulation of total DDT, based upon wildlife risk screening values (Ridgway *et al.* 2000), was at levels that represented a potential risk to higher order predators such as marine birds and mammals.

There are at least three factors that could possibly control the bioaccumulation of total DDT and total PCB in pelagic forage species of the SCB. One factor could be equilibrium partitioning between the concentrations in the water column and lipid reservoirs in the fish (Zeng *et al.* 2005). A strong correlation was observed between tissue concentrations and fish lipid content during the present study. Species with the greatest lipid content contained the highest contaminant concentrations. Highest concentrations of organochlorines in fish are typically found in the liver associated with lipids (primarily triacylglycerides), and often related to the consumption of lipid-rich prey (Groce 2002). Moreover, the geographic patterns in tissue total DDT concentrations from this study mirrored geographic patterns in total DDT concentrations observed in both sediment (Schiff and Gossett 1998, Schiff *et al.* 2006) and the water column (Zeng *et. al.* 2005) of the SCB. All three studies found the greatest concentrations of total DDT in the central region of the SCB.

Life history strategy including diet and age could also control tissue concentrations of pelagic forage species of the SCB. California market squid, the species with the lowest contaminant concentrations, forages primarily on crustacean zooplankton (Loukashkin 1976, Yaremko 2001) and has a relatively short life span of approximately 6-9 months (Butler *et al.* 1999, Zeidberg *et al.* 2006). The low total DDT concentrations found in California market squid in this study could be due, in part, to its short life span and lower trophic level diet. Northern anchovy generally live to approximately 3-4 years and feed by filtering or engulfing crustacean zooplankton and ichthyoplankton (Miller 1955, Baxter 1967, Bergen and Jacobson 2001). Most Pacific sardine live to 3-7 years and feed by filtering crustacean zooplankton and ichthyoplankton (Wolf *et al.* 2001, DFO 2004). Northern anchovy and Pacific sardine had greater tissue contaminant concentrations, perhaps due to their longer life span and amended diet. Pacific chub mackerel feed primarily on small fishes, ichthyoplankton, squid, and crustacean zooplankton; most that are caught in the commercial fishery are less than 4 years (Konno *et al.* 2001). The average tissue contaminant concentrations in Pacific chub mackerel were higher than squid, but less than anchovy and sardine.

A third factor that could control tissue concentrations of pelagic forage species is fish mobility that, in turn, would affect exposure. The central subpopulation of northern anchovy in the SCB is known to migrate southward and offshore for winter spawning (Mais 1974). Pacific chub mackerel subadults and adults move northward along the coast during the summer and also exhibit inshore-offshore migration off California, moving inshore from July through November and offshore from December through May (Mais 1974, Konno *et al.* 2001). Although affected by oceanographic factors, Pacific sardine migrations typically are northward during the early summer and southward beginning in the fall (DFO 2004). Despite population mobility, average concentrations of total DDT and total PCB in this study were generally higher from the central coastal region of the SCB.

The assessment of widespread risk to wildlife in this study is derived from the use of wildlife risk screening values. While there are a number of human health risk screening values for human consumers of fish (e.g., USEPA 2000; OEHHA 2001, 2006), there are no widely accepted screening thresholds for wildlife consumption. Environment Canada has published values specifically for marine birds and mammals, some of which are found in the SCB (Environment Canada 1997, 1998; Ridgway *et al.* 2000; Roe *et al.* 2000). To assess potential bias associated with different screening values, other unpublished screening values used in California were examined. Regardless of the screening value, little change in the assessment of widespread risk given here was observed. Screening values and guidelines usually focus on effects to the most sensitive species examined. Hence, they identify levels below which there is not likely to be a health risk and thus provide only a general warning. The actual risk to consumers is a function of prey selection, prey concentration, predator consumption rates, physiological target organs, and genetic predisposition of a species and hence may vary by species or individuals within a species. Although a screening value provides a general warning, further studies may be needed to determine what tissue concentrations are critical for local bird and mammal species of concern. After these critical levels are identified, an assessment can be made to determine if species or populations of concern are actually at risk.

The estimate of the extent and magnitude of contamination presented here was dependent on fishing success in a number of cases. First, the ability to extrapolate to Bightwide biomass was a function of sampling success (i.e., landings representation). For example, sampling success was robust for Pacific sardine and California market squid, but appeared limited for northern anchovy and Pacific chub mackerel. Although sample representation was relatively low for these two species, relatively low quantities of biomass were actually fished for northern anchovy and Pacific chub mackerel. Cumulatively, northern anchovy and Pacific chub mackerel constituted less than 9% of the total biomass landed during the study period.

A second source of potential bias due to fishing success was the ability to extrapolate to geographic regions of the SCB. While extrapolating data collected from commercial landings are well-grounded in fisheries assessments, landings data are prone to inaccurate and imprecise spatial representation. For example, catch in fishing blocks (270 km^2) are self-reported by the fishermen, and there is no mechanism for ground-truthing reported fishing locations. Perhaps a more important concern, however, was bias associated with unequal sample size among regional strata of the SCB used in this study. One again, this bias was minimized by the low quantity of biomass landed in these regions. Small sample sizes were due to regional differences in catch and not poor sampling. For example, the smallest sample sizes routinely occurred in the southern SCB, but only 1% of the commercial landings occurred in the southern SCB for all four species.

Fish availability and fishing effort arising from temporal variability is a third source of potential bias. Sampling minimized intra-annual variability across seasons. However, inter-annual variability may be a factor. Based on the past 20 years of landings data, this study year (2004) was above the median for three of the four species (Figure VIII-7). Fishing was relatively good during this study period for northern anchovy, Pacific sardine, and California market squid compared to annual landings between 1983 and 2004. In contrast, Pacific chub mackerel had a poor year in 2004 relative to previous years. These data show that the extrapolated estimates of biomass provided herein will likely vary over time based on fishing success for each species.

Finally, an obvious potential source of bias in estimating biomass is the difference associated with commercial landings versus standing stock. Standing stock may be substantially larger than the landed biomass and this would represent an enormous underestimate, particularly for our estimate of total DDT and total PCB mass in pelagic species of the SCB. The Pacific Fishery Management Council sets landings limits for the species examined in this study based upon estimates of stock biomass (Conser *et al.* 2003, CDFG 2004). Based on available estimates of standing stock for Pacific sardine and Pacific chub mackerel for the SCB, the mass of total DDT in pelagic species targeted in this study would increase from 1.3 to at least 26 kg. While the estimate of total DDT mass in pelagic species increases by an order of magnitude, this quantity is still far short of the 100 mt estimated to reside in sediments on the Palos Verdes shelf (Lee and Wiborg 2002).

While no previous studies of wildlife risk to consumers of pelagic forage fish have been conducted, total DDT and total PCB levels in edible muscle tissue of pelagic forage fish and California market squid of the SCB were conducted in the early 1980s (Mearns and Young 1980, Gosset *et al.* 1982, Schafer *et al.* 1982). The total DDT muscle tissue values reported in these studies are in general of the same order of magnitude or slightly higher than the whole fish contaminant values reported in this study (Table VIII-4). While there is not a quantified relationship between edible muscle and whole fish total DDT concentrations in these species, whole fish tissue concentrations of total DDT in other fishes are generally an order of magnitude greater than muscle tissue concentrations (D. Witting, NMFS, Long Beach, CA, pers. comm. Sep. 2006). Assuming this relationship holds true for pelagic forage fishes and squid, total DDT concentrations in pelagic forage fishes and squid in the SCB have decreased over the past 25 years. Similarly, total PCB concentrations have also decreased for the species examined herein. For both total DDT and total PCB, Pacific sardine showed the most dramatic difference between muscle tissue concentration in the early 1980s (484 ug total DDT/kg ww; Mearns and Young 1980) and whole fish concentrations in 2003-04 (34 ug total DDT/kg ww; this study).

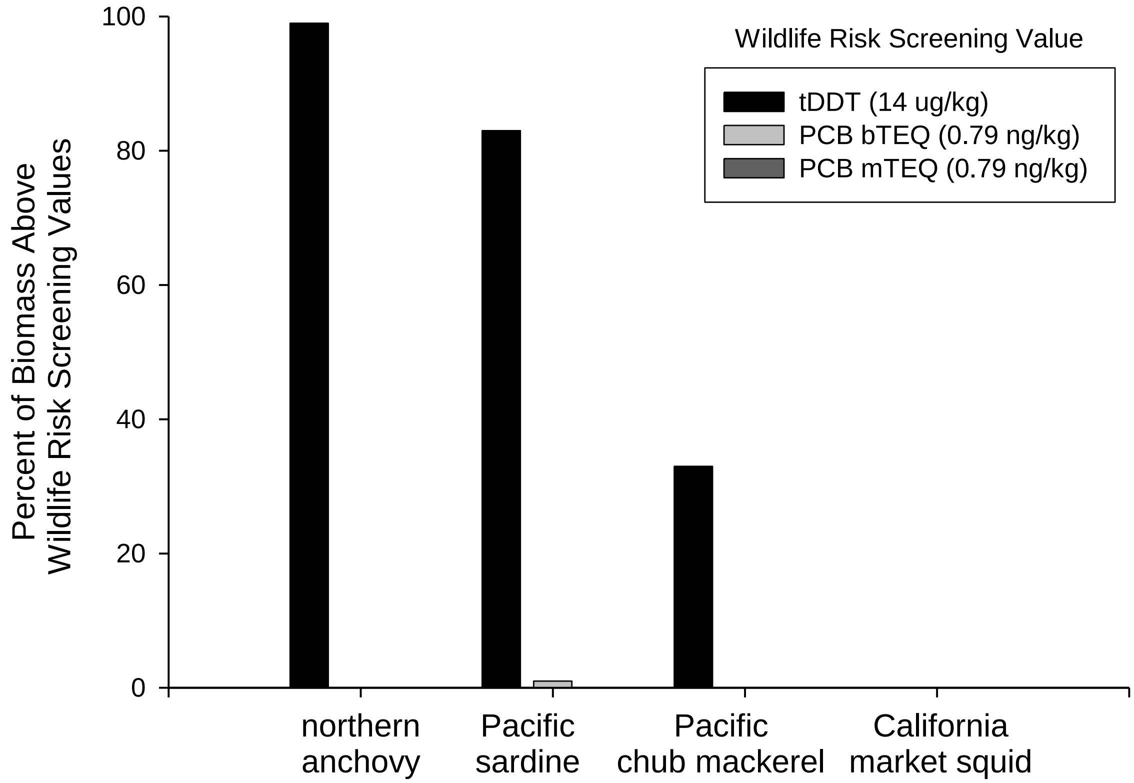


Figure VIII-6. Percentage of pelagic forage fish and squid landings in the SCB estimated as having contaminant levels above wildlife risk screening values. (tDDT=Total DDT; PCB bTEQ=PCB Toxicity Quotient for birds; PCB mTEQ=PCB Toxicity Quotient for mammals).

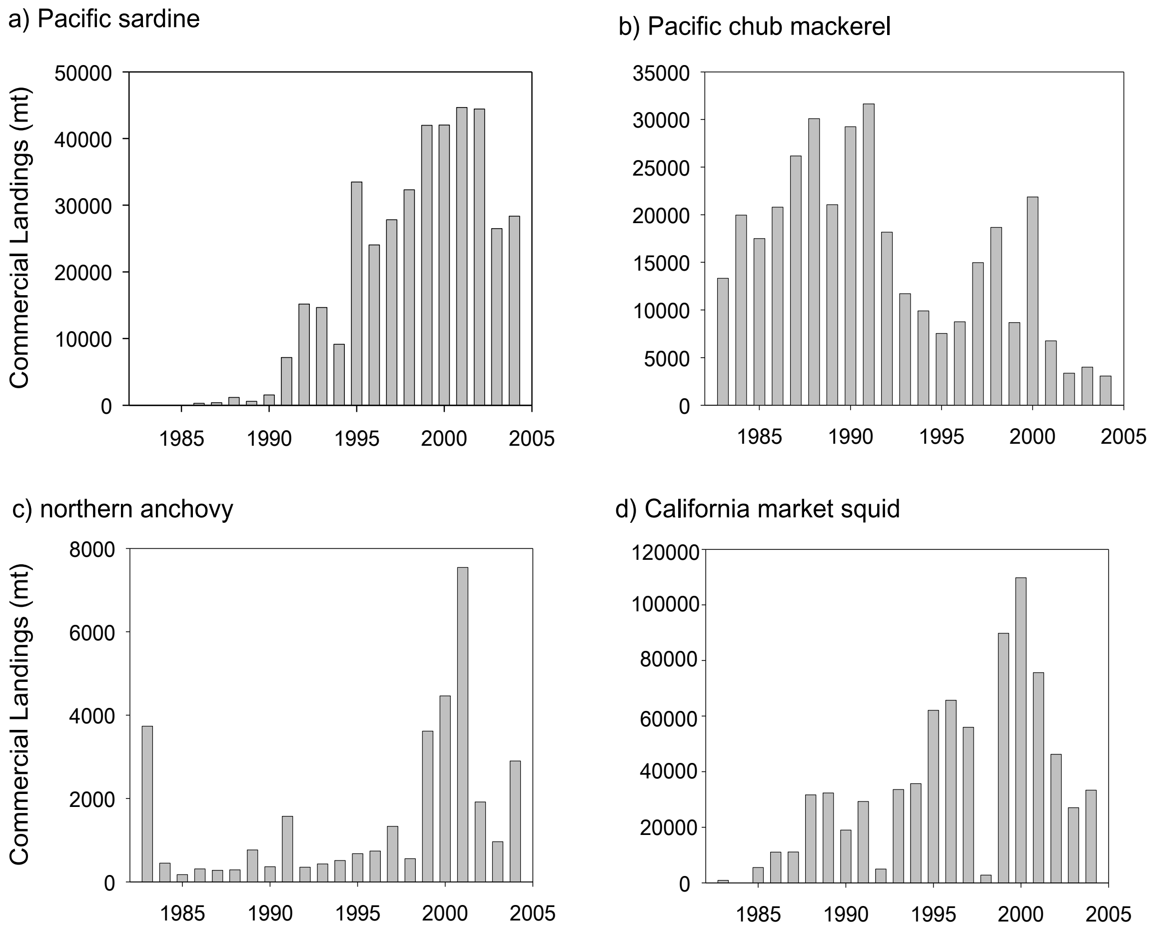


Figure VIII-7. Southern California commercial landings (in metric tons) of a) Pacific sardine, b) Pacific chub mackerel, c) northern anchovy, and d) California market squid between 1983 and 2004 (CDFG data, unpublished).

Table VIII-4. Comparison of chlorinated hydrocarbons measured in pelagic forage fishes and squid of the southern California Bight in the early 1980s and this study, 2003-04.

Species Location	Year	Tissue Composite	No. of Samples	Total DDT (ug/kg ww) Mean	Total DDT (ug/kg ww) SD	Total PCB (ug/kg ww) Mean	Total PCB (ug/kg ww) SD
California market squid							
Coastal	1980-81[a]	mantle	3	10	10	10	9
SCB	2003-04[b]	whole	28	0.8	1.2	0.0	0.1
northern anchovy							
Coastal	1980-81[a]	muscle	5	47	33	8	9
LA/LB Harbor	1980[c]	muscle	5	121	31	98	21
SCB	2003-04[b]	whole	24	60.6	38.3	3.1	5.1
Pacific chub mackerel							
Coastal	1980-81[a]	muscle	6	130	145	26	22
Santa Monica Bay	1981[d]	muscle	5	57	37	15	7
Palos Verdes	1981[d]	muscle	5	44	--	12	12
Laguna Beach	1981[d]	muscle	1	129	86	34	22
SCB	2003-04[b]	whole	13	41.4	40.2	2.3	3.1
Pacific sardine							
Coastal	1980-81[a]	muscle	5	484	112	105	40
SCB	2003-04[b]	whole	34	34.1	28.7	1.6	2.5

SCB = Southern California Bight

[a]Schafer et al. 1982

[b]Current study

[c]Mearns and Young 1980

[d]Gossett et al. 1982

IX. 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 *et al.* 2003). Several organizations have been and are currently collecting and analyzing debris data to inform the public of this growing worldwide problem (Ribic *et al.* 1997). Although marine debris is increasingly of 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 Quality 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 eight pieces of plastic per cubic meter in the neuston while two regional studies conducted in 1994 and 1998 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.* 2002a).

This section presents the third regional study of debris on the seafloor of the SCB. The objectives of this section are 1) to assess the distribution, type, and amount of anthropogenic and natural marine debris on the seafloor of the mainland shelf of the SCB in 2003; and 2) to compare these findings to those of a 1994 regional baseline survey (Allen *et al.* 1998) and a 1998 regional survey of the southern California Bight (Allen *et al.* 2002a).

Results

Debris (natural and/or anthropogenic) was found in 122 of 210 (58%) trawl stations representing an area of 3,439 km^2 (39% of the area) on the southern California shelf and upper slope. Natural debris occurred in 40% of the area of the shelf and upper slope, whereas anthropogenic debris occurred in 25% of the area (Table IX-1). Anthropogenic debris was primarily found off of highly populated areas while natural debris was typically found in the southern region (Figure IX-1).

Natural Debris

Natural debris varied in areal coverage by subpopulation (Figures IX-2 and IX-3). Regionally, the percent of areal coverage of natural debris increased from the northern (30%) and central (41%) to southern (76%) regions (Table IX-1). The areal coverage for island subpopulations showed a similar pattern where the percent of areal coverage of natural debris increased from the cool northwest channel islands (13%) to warm southeast channel islands (23%). Bathymetrically, natural debris had the highest percent of area on the inner shelf (53%), followed by bays and harbors (50%), upper slope (40%), middle shelf (37%), and outer shelf (26%). Within the middle shelf, small POTWs had the highest percent of area of natural debris (92%) followed by non-POTW (46%), large POTWs (40%), and the islands (21%; Figure IX-3; Table IX-1). Inner shelf natural debris occurred in the highest percent of area in the large and small POTWs (100%), followed by the mainland (52%). On the outer shelf, the percent of area of natural debris was highest in the mainland area (37%) and lowest in the large POTWs (0%) and island (0%) areas. The percent of area for natural debris in the upper slope was highest in the mainland (40%) area and lowest in the island (0%) area.

On the mainland shelf of southern California, marine vegetation was the most commonly occurring natural debris, followed by terrestrial vegetation, rocks, and benthic debris (Table IX-1). Natural debris was most commonly found in trace numerical densities (one item per haul) and trace weight densities (0.0-0.1 kg; Table IX-2).

Different types of natural debris also varied by subpopulation (Table IX-1). Marine vegetation was most widely distributed in inner shelf small POTWs (53%) and least distributed in the outer shelf large POTWs and outer shelf and upper slope island areas (0%). Terrestrial vegetation occurred most commonly in large POTWs (33%) and was absent in island areas, inner shelf small POTW and mainland areas, and outer shelf large POTWs areas. Benthic debris was the least common type of natural debris in the SCB with the highest areal coverage found in the outer shelf mainland and middle shelf island areas (8%). Rocks were also uncommon on the soft bottom of the SCB, with the highest areal coverage occurring in outer shelf mainland (29%) areas.

Anthropogenic Debris

Anthropogenic debris also varied by subpopulation (Figures IX-2 and IX-3). Regionally, inner shelf large and small POTWs (100%) had the highest areal coverage of anthropogenic debris and the outer shelf POTWs and outer shelf and upper slope island areas the lowest (0%; Table IX-1). Along the mainland, anthropogenic debris had the highest aerial coverage in the central (50%) region followed by the southern (28%) and northern (17%) regions. Unlike in previous surveys, anthropogenic debris was not found at the Channel Islands. Bathymetrically, anthropogenic debris occurred most commonly in the outer shelf (35%), followed by the upper slope (32%), bays and harbors (31%), middle shelf (25%) and inner shelf (1%) zones. The only occurrence (33%) of anthropogenic debris on the inner shelf occurred at large POTWs. On the middle shelf, non-POTW areas had the highest areal coverage (39%) of anthropogenic debris, whereas middle shelf small POTWs had the least (8%). On the outer shelf, mainland areas had the highest occurrence (50%) and large POTWs and island areas the least (0%).

Anthropogenic debris consisted of cans, glass bottles, fishing gear, metal, paper, plastic, lumber, tires, and “other” debris. On the mainland shelf of the SCB, plastic occurred most commonly and paper the least. Anthropogenic debris occurred primarily at trace abundance and weights (Table IX-2). However, metal and fishing gear occurred most commonly at low numerical densities and metal and glass bottles at low weight densities. Anthropogenic debris types were found to vary by location and subpopulation along the southern California shelf (Figure VI-4, Table IX-1). Regionally, all types of anthropogenic debris occurred in the central region, with plastic occurring most commonly (28%) and paper the least (1%). In the southern region, “other”, fishing gear, metal, and plastic occurred most commonly (10%, 9%, 9%, and 5% respectively) and all other types of anthropogenic debris were absent. In the northern region only plastic, lumber, and cans were present (9%, 8%, and 1% respectively). Cans were the only form of anthropogenic debris found on the inner shelf and only in large POTWs areas. On the middle shelf, plastic occurred with equal frequency in large POTWs (12%) and non-POTW (12%) areas.

Plastic, cans, metal, tires, and "other" debris occurred nearly equally in both middle shelf large POTW and non-POTW subpopulations; fishing gear and glass bottles occurred only in middle shelf non-POTW subpopulations (Figure IX-5). On the outer shelf, metal (21%) and cans (13%) occurred most commonly on the mainland shelf (Table IX-1). On the upper slope plastic (20%) and lumber (12%) and "other" (8%) debris were the only anthropogenic debris that occurred and were found only in mainland areas.

Discussion

Anthropogenic and natural debris were found throughout the mainland shelf of southern California (Figure IX-1), generally in trace amounts. Anthropogenic debris was highest in the central region due to the proximity of large populations to these areas (near Los Angeles metropolitan areas). Anthropogenic debris was found in similar numbers for all shelf zones (about 30%) except for the inner shelf zone (1%). The high occurrence of anthropogenic debris in bays and harbors is likely from land-based and marine vessel sources. The next highest occurrence of anthropogenic debris on the middle shelf, outer shelf, and upper slope is likely from a combination of recreational fishing and boating sources, and from historical runoff events. The lack of anthropogenic debris in the inner shelf may be due to wave and tide transport of sand and debris downcoast to submarine canyons and the lack of recent storms prior to the 2003 survey season (Table IX-3). Plastic was the most commonly occurring debris item in all subpopulations, except for the outer shelf island areas, where metal and cans were the most common.

Terrestrial debris, a component of natural debris and a potential indicator for the path of anthropogenic debris from land-based sources, increased in areal extent from north to south. Bathymetrically, terrestrial debris was most common in the deeper waters of the upper slope, followed by the middle and outer shelf zones, and while it occurred in bays and harbors, it was almost absent in the inner shelf. The lack of terrestrial debris on the inner shelf was similar to that of anthropogenic debris and may be due to the lack of wave and tide action and lack of recent storms as well. On the middle shelf, terrestrial debris was most common in small POTW areas followed by non-POTW areas, and finally large POTW areas. Terrestrial debris, similar to anthropogenic debris, was absent in island areas which are narrower compared to those on the mainland.

The present study (2003) was part of the third region-wide monitoring effort of the SCB. The first study, in 1994 (Allen *et al.* 1998, Moore and Allen 2000), provided a baseline for comparing the amounts of debris to those found in 1998 and 2003. In 1994 about 14% of the SCB had anthropogenic debris, whereas in 1998 this number increased to 23%, and in 2003 was about the same at 25%. This is largely due to the fact that more extensive surveys were done in 1998 and 2003 (314 stations in 1998 and 210 in 2003 compared to 114 for 1994) and to the inclusion of bays, harbors, and islands.

Trends for all three (1994, 1998, and 2003) studies were similar in that most of the debris occurred in small amounts and small biomass; however, trends for occurrence varied. The higher occurrence of anthropogenic debris in the central and southern regions (the most populated) was similar to that found in 1994 and 1998 (Figure IX-6). For 1994 and 1998, plastic, metal debris, and glass bottles occurred over a much larger area at large POTW areas and were thought to be most likely from recreational boat uses; however, in 2003 most items were distributed evenly among the large POTW areas with the exception of fishing gear and glass bottles which were found only in non-POTW areas (Figure IX-7). Overall, anthropogenic debris had higher areal extent in all subpopulations for 2003 versus the previous surveys, with the exception of the inner shelf and POTW subpopulations. This higher areal coverage in 2003 is thought to be due to boating and shipping activities as well as to debris left by historical runoff events.

Terrestrial debris had higher areal extent in the northern region for the 1994 and 1998 surveys but was higher in the southern region for the 2003 survey (Figure IX-8). The higher areal extent in the northern region for the previous surveys was thought to be due to large rain events prior to the surveys (Table IX-3). In 2003 no such rain events occurred, and the rain for this season was not only less but the previous year was a drought year. Overall, terrestrial debris occurred over less of the area in all subpopulations in 2003 versus 1994 and 1998, with the exception of the southern region.

In conclusion, while anthropogenic debris occurred in about 25% of the SCB, it was not present in large quantities. Anthropogenic debris had higher areal coverage for this survey compared to previous surveys, whereas terrestrial debris had less coverage, suggesting a possible relationship to seasonal rain totals. As marine debris becomes of greater concern to the public, not only for aesthetic reasons, but also in regard to marine organism health, regional monitoring studies such as this one, done at regular intervals, will provide valuable information on the types, amounts, and location of debris in the marine benthic habitat. Hence, it is recommended that this survey be continued as part of future regional surveys of the SCB.

Table Table IX-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 2003.

	Natural Debris					Anthropogenic Debris										
Category	M.Veg	T.Veg	Ben.D	Rocks	Total	Plast	Metal	Cans	Other	Lumb	FshGr	GlaBo	Paper	Tires	Total	Overall
Region																
Mainland	37.3	9.1	2.5	4.0	44.0	13.4	2.5	2.1	6.5	5.4	2.5	2.4	0.3	1.1	29.5	55.8
Northern	28.6	4.4	0.6	0.6	29.8	8.8	0.0	0.6	0.0	7.7	0.0	0.0	0.0	0.0	17.1	42.5
Central	29.8	8.0	7.5	9.1	41.1	27.7	1.2	6.1	13.9	6.2	1.4	8.2	0.9	3.9	50.4	60.1
Southern	64.0	20.1	0.0	4.5	76.2	4.9	9.0	0.0	10.1	0.0	9.0	0.0	0.0	0.0	28.4	77.4
Island	13.8	0.0	6.9	0.0	17.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.2
Cool (NW Channel Isl.)	12.5	0.0	6.3	0.0	12.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.5
Warm (SE Channel Isl.)	15.4	0.0	7.7	0.0	23.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.1
Depth Zone																
Bays and Harbors (2-30 m	50.0	7.7	3.8	3.8	50.0	11.5	0.0	3.8	0.0	0.0	11.5	3.8	0.0	0.0	30.8	73.1
Inner Shelf (2-30 m)	52.8	0.5	0.1	0.0	53.4	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	53.4
Small POTWs	93.3	0.0	6.7	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
Large POTWs	66.7	33.3	0.0	0.0	100.0	0.0	0.0	33.3	0.0	0.0	0.0	0.0	0.0	0.0	33.3	100.0
Mainland	52.0	0.0	0.0	0.0	52.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.0
Middle Shelf (31-120 m)	31.0	7.2	3.1	4.6	37.3	7.6	2.5	2.5	5.1	0.0	4.6	4.6	0.0	2.5	24.6	42.8
Small POTWs	83.3	16.7	0.0	0.0	91.7	8.3	0.0	0.0	8.3	0.0	0.0	0.0	0.0	0.0	8.3	91.7
Large POTWs	36.0	4.0	4.0	0.0	40.0	12.0	4.0	4.0	8.0	0.0	0.0	0.0	0.0	4.0	28.0	56.0
Non-POTW	38.5	11.5	0.0	7.7	46.2	11.5	3.8	3.8	7.7	0.0	7.7	7.7	0.0	3.8	38.5	53.8
Island	16.7	0.0	8.3	0.0	20.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2	20.8
Outer Shelf (121-200 m)	17.5	2.9	5.9	20.4	26.3	5.9	14.5	8.8	5.9	0.0	2.9	2.9	2.9	0.0	35.2	44.0
Large POTWs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mainland	24.8	4.2	8.4	28.9	37.3	8.4	20.6	12.5	8.4	0.0	4.2	4.2	4.2	0.0	49.8	62.4
Island	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Upper Slope (201-500 m)	31.8	11.7	3.9	0.0	39.6	20.1	0.0	0.0	7.8	11.7	0.0	0.0	0.0	0.0	31.8	55.7
Upper Mainland	32.2	11.9	4.0	0.0	40.1	20.4	0.0	0.0	7.9	11.9	0.0	0.0	0.0	0.0	32.2	56.5
Island	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	33.6	7.7	3.2	3.4	39.8	11.3	2.1	1.7	5.4	4.6	2.1	2.0	0.2	1.0	24.8	49.7

POTW = Publicly owned treatment work monitoring areas.

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.

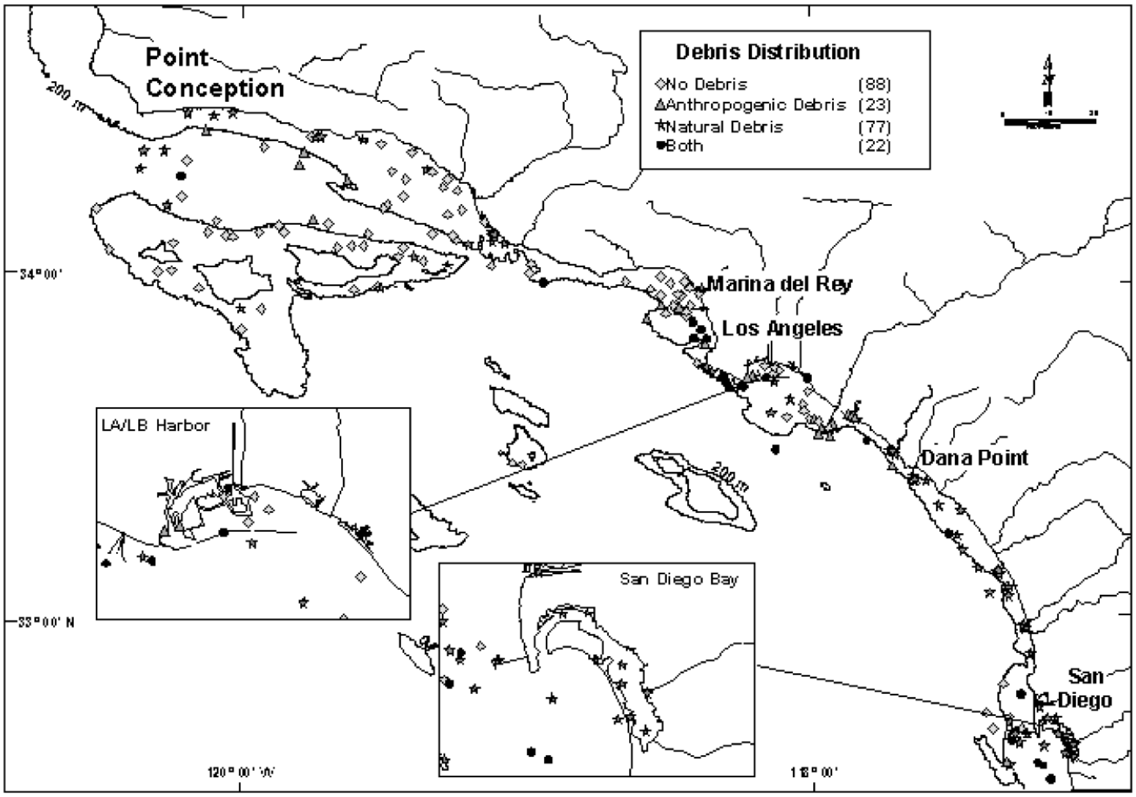


Figure IX-1. Distribution of natural and anthropogenic debris on the mainland shelf and upper slope of southern California at depths of 2-476 m, July-October 2003.

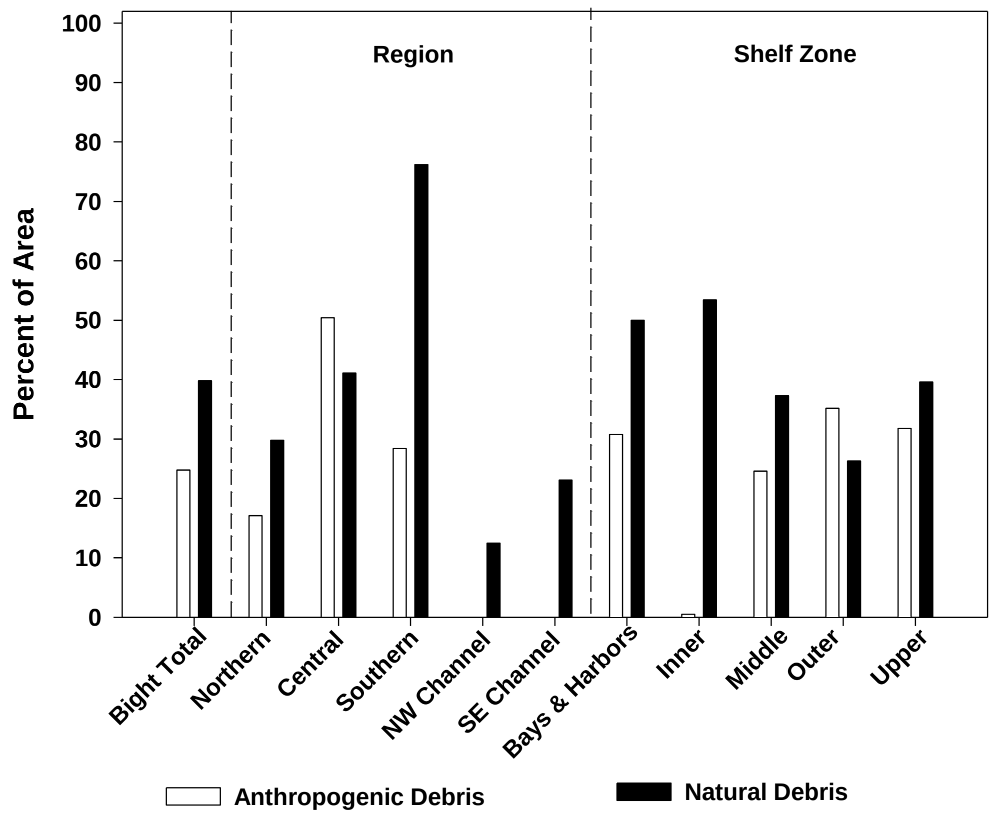


Figure IX-2. Percent of area with natural and anthropogenic debris by region and depth on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003.

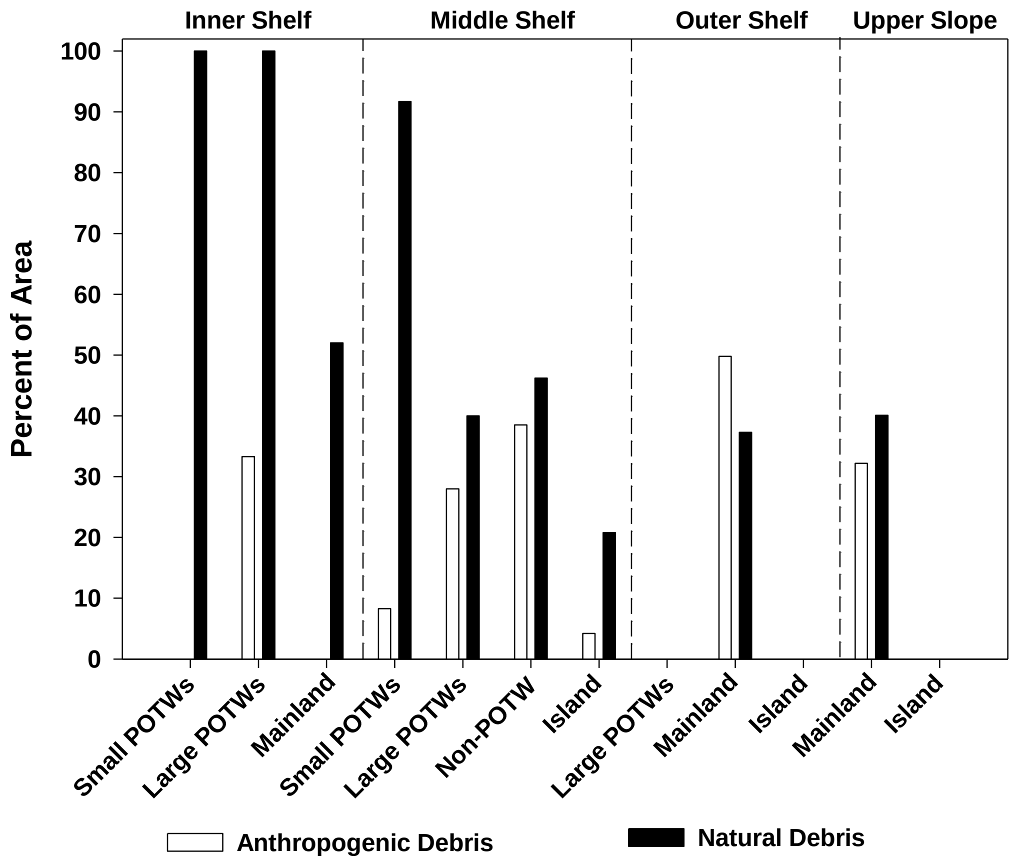


Figure IX-3. Percent of area with natural and anthropogenic debris by subpopulation within shelf zones on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003.

Table Table IX-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 2003.

DebrisType	No. of Stations	Abundance[a] T	L	M	H	Weight[b] T	L	M	H	Total
Natural Debris										
Marine Vegetation	89	15.1	11.2	5.7	1.6	19.5	7.5	4.5	2.1	33.6
Terrestrial Vegetation	13	4.3	3.4	0.1	-	4.9	2.7	0.1	-	7.7
Rocks	7	2.0	1.1	0.2	-	-	2.0	1.1	0.2	3.4
Benthic Debris	8	1.8	0.0	0.6	0.8	1.8	0.0	1.1	0.2	3.2
Total	99	19.6	14.5	5.85	2.3	24.7	10.3	5.1	2.3	39.8
Anthropogenic Debris										
Plastic	19	9.7	1.6	-	-	8.8	2.5	-	-	11.3
Other	10	3.8	0.1	1.5	-	2.6	1.0	0.1	1.7	5.4
Lumber	3	4.6	-	-	-	3.0	1.5	-	-	4.6
Fishing Gear	6	1.0	1.1	-	-	1.2	0.9	-	-	2.1
Metal Debris	4	0.3	1.8	-	-	0.1	1.1	0.9	-	2.1
Glass Bottles	4	2.0	-	-	-	-	2.0	-	-	2.0
Cans	7	1.7	-	-	-	1.7	-	-	-	1.7
Tires	2	1.0	-	-	-	1.0	-	-	-	1.0
Paper	1	0.2	-	-	-	0.2	-	-	-	0.2
Total	46	22.6	5.7	2.3	-	16.0	10.0	2.6	2.0	24.8
Overall	210	47.5	20.2	8.15	2.3	44.8	21.4	7.7	4.3	49.7

[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)

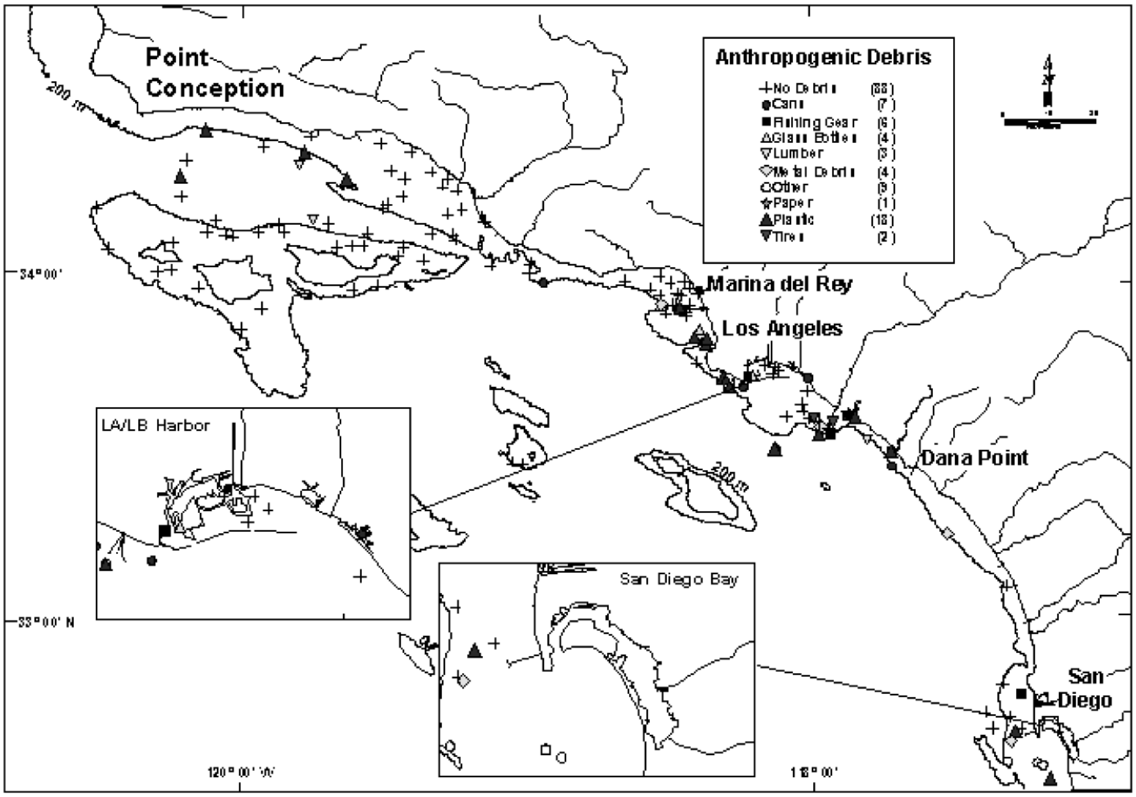


Figure IX-4. Distribution of anthropogenic debris types on the southern California shelf at depths of 2-476 m, July-October 2003.

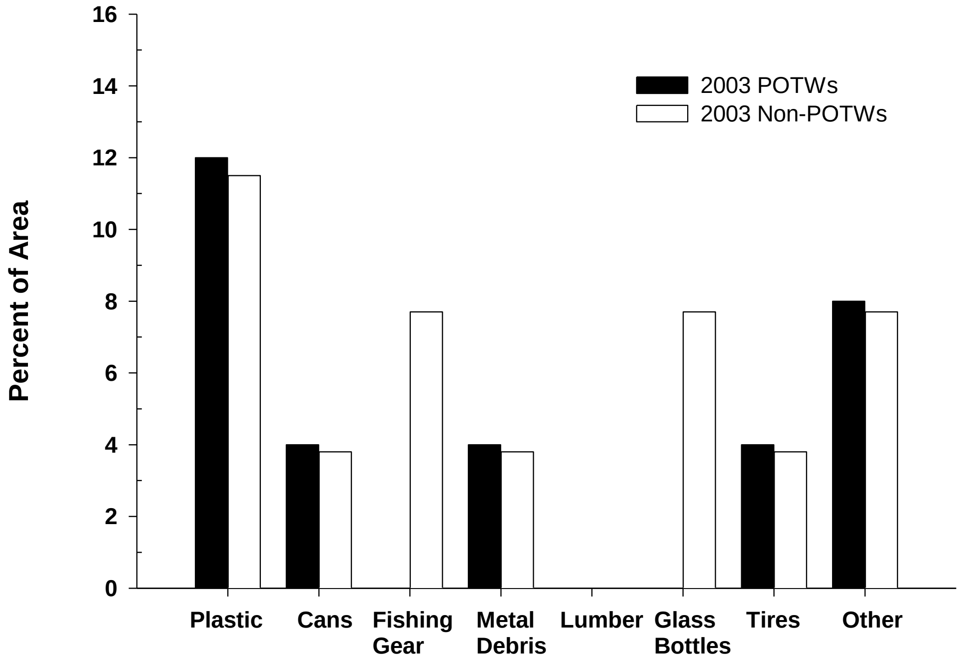


Figure IX-5. Percent of area of anthropogenic debris types on the mainland middle shelf (31-120 m) in publicly owned treatment work (POTW) and non-POTW subpopulations of southern California, July-October 2003.

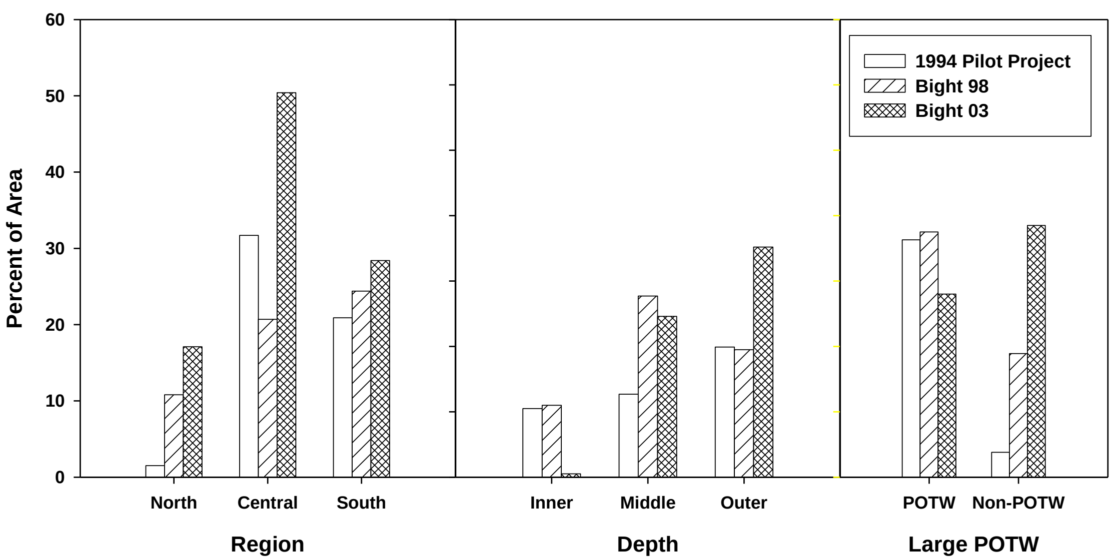


Figure IX-6. Percent of area with anthropogenic debris by year and subpopulation within regions, depths, and large POTW areas on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003.

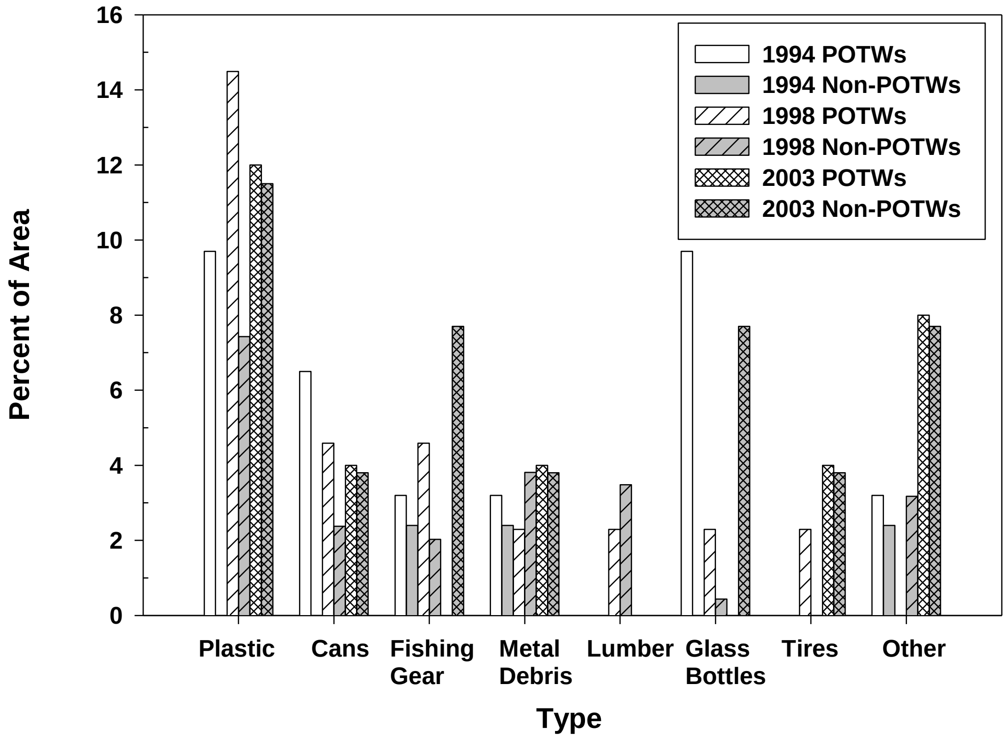


Figure IX-7. Percent of area of anthropogenic debris categories in large publicly owned treatment work (LPOTW) and non-LPOTW subpopulations on the mainland middle shelf (31-120 m) of southern California in 1994, 1998 and 2003. NOTE: 1994 data has been reclassified into 1998 and 2003 subpopulations and hence may differ from Allen *et al.* (1998) and Moore and Allen (2000).

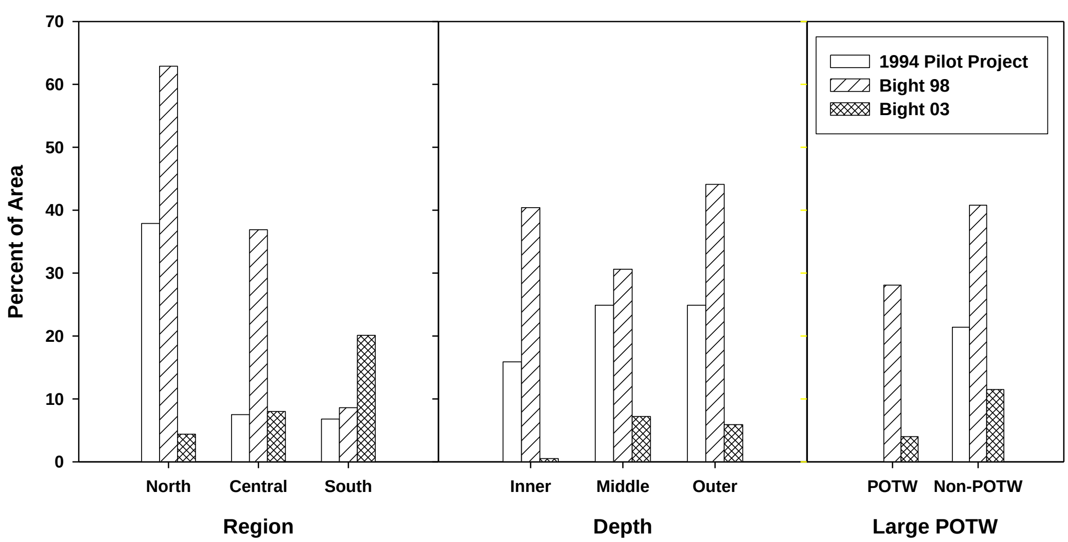


Figure IX-8. Percent of area with terrestrial debris by year and subpopulation within regions, depths, and large POTW areas on the southern California shelf and upper slope at depths of 2-476 m, July-October 2003.

Table Table IX-3. Total seasonal rainfall (precipitation) for Los Angeles Civic Center for year before and year of regional surveys (Taken from the Los Angeles Almanac (www.laalmanac.com/weather)).

Season (July 1-June 30)	Total Inches	Inches Above/Below(-) 128 Year Average
1991-1992	21.0	5.9
1992-1993	27.4	12.3
1996-1997	12.4	-2.7
1997-1998	31.0	15.9
2001-2002	4.4	-10.7
2002-2003	16.4	1.3

X. DISCUSSION

Assessment of Human Impact

Assemblage Biointegrity

Demersal fish and invertebrate populations and assemblages on the southern California shelf were healthy in 2003. Biointegrity indices identified 96% of the southern California shelf as reference for fish, 92% for fish and invertebrates combined, 84% for invertebrates, and 81% for fish foraging guilds. Nonreference occurred primarily on the inner shelf or bay/harbor areas for the first three indices, suggesting nearshore influences. However for the fish foraging guild index, these were mostly at the Channel Islands, perhaps related to natural conditions.

Demersal fish and invertebrate populations and assemblages on the southern California shelf were healthy in 2003. A fish biointegrity index (fish response index, FRI; Allen *et al.* 2001a) identified 96% of the area of the southern California shelf as reference (normal), with 4% nonreference sites in inner shelf and bay/harbor areas, with nonreference (abnormal or disturbed) areas primarily at small POTW and mainland non-POTW areas of the inner shelf (Figure VI-17 through VI-19). In 1998 (the first application of a biointegrity index to regional trawl data), about the same percent area of reference (97%) and nonreference areas (3%) occurred, with the latter occurring primarily in bays/harbor areas and river mouth areas of the inner shelf (Allen *et al.* 2002a). Whereas none of the nonreference sites were located near any POTW areas in 1998, 47% of the inner-shelf small POTW area was nonreference in 2003. The percent nonreference area was 8% for a combined fish and invertebrate index (trawl response index, TRI), 16% for a megabenthic invertebrate response index (MIRI), and 19% for fish foraging guild index (FFG). Whereas most of the nonreference area for the response indices was in inner shelf and bays/harbor areas, most of the nonreference area for the FFG index was on the middle shelf of the Channel Islands.

The findings of the 2003 survey, as well as those of the 1994 and 1998 regional surveys (Allen *et al.* 1998, 2002a), differed dramatically from conditions in the 1970s, when populations and assemblages were clearly altered in the most contaminated areas (SCCWRP 1973; Mearns *et al.* 1976; Allen 1977, 1982; Cross *et al.* 1985; Stull 1995; Stull and Tang 1996; Allen 2006b). The biointegrity indices used here have identified nonreference (disturbed) conditions in historical data from the Palos Verdes Shelf, the only area with substantial effects, and showed that index values there shifted from nonreference in the 1970s to reference in the 1980s (Allen *et al.* 2001a; Montagne 2002a,b; Allen 2006b). As these indices are based on the relative abundance of fish species along a pollution gradient, they are expected to be most responsive to contaminated conditions.

Detailed analyses of abnormal assemblages at sites will provide insight regarding potential reasons for the altered state (e.g., what species are high or low at the site that were also high or low on the Palos Verdes Shelf in the 1970s). This in turn, may lead to hypothesized causes that might be tested. Such follow-up studies of assemblages at nonreference sites in a survey will ultimately provide better understanding of the nature of the alterations and may result in management actions to improve the conditions.

Based on its relative performance along historical spatial and temporal gradients in contamination, Allen *et al.* (2001a) recommended the FRI as the best index for use in assessing effects on fish assemblages. Based on that index, 97% of the area of the southern California shelf had relatively normal fish assemblages in 1998 (Allen *et al.* 2002a) and 96% in 2003.

Populations

Fish population attributes (abundance, biomass, species richness, and diversity) varied by region and depth. By subpopulation, median fish abundance, biomass, species richness, and diversity were highest on the island upper slope. Lowest medians were generally found in bays/harbors (abundance and species richness) and inner shelf POTW areas (abundance and biomass at small POTWs and diversity at large POTWs). By shelf zone, the lowest values were found on the upper slope for fish abundance and biomass, in bay/harbors for species richness, and on the inner shelf for diversity. However, highest values were found on the middle shelf for abundance and species richness, on the outer shelf for biomass, and on the upper slope for diversity. Fish abundance was significantly higher in large POTW areas in 2003 than in 1998, but not so relative to 1994. However, fish abundance in non-POTW areas of the middle shelf was significantly higher in 2003 than in 1994 and 1998.

Invertebrate population attributes (abundance, biomass, species richness, and diversity) varied by region and depth. By subpopulation, median invertebrate abundance was highest on the mainland upper slope, biomass at outer shelf POTWs, species richness at the Channel Islands, and diversity on the upper slope of the Channel Islands. Median invertebrate abundance, biomass, and species richness were lowest at inner shelf small POTW areas, and diversity at outer shelf large POTW areas. By shelf (depth) zones, median abundance and biomass were highest on the upper slope, species richness on the middle shelf and outer shelf, and diversity on the middle shelf. Medians of abundance, biomass, species richness, and diversity were lowest on the inner shelf. Invertebrate population attributes at large POTW areas and non-large POTW areas were generally similar between 1994 and 2003

Current wastewater discharge does not appear to adversely affect the demersal fish and invertebrate assemblages and populations. Some minor population and assemblage differences were found between POTW and non-POTW areas. In 2003, fish abundance and biomass were generally higher in large POTW areas. Compared to previous regional surveys (Allen *et al.* 1998, 2002a), fish abundance at large POTW areas was highest in 2003 and fish biomass, species richness, and diversity were lowest in 1998. In contrast, fish invertebrate abundance and biomass at large POTW areas were highest in 1998, with species richness and diversity lowest in that year; fish diversity there was highest in 2003. These differences appear to be related to the El Niño of 1998 and the cold regime of 2003. In general, wastewater discharge appears to have had little obvious population or assemblage level effect on local demersal fish and invertebrate assemblages since the early 1990s.

Diseases and Anomalies

Fish populations had background levels of anomalies and routinely monitored parasites. The prevalence of anomalies in 2003 had decreased significantly from 5.0 to 0.9% since the 1970s (Mearns and Sherwood 1977) but increased slightly from 0.5 to 0.9% since 1998 (Allen *et al.*

2002a). These rates were similar to background anomaly rates in mid-Atlantic (0.5%) and Gulf Coast (0.7%) estuaries (Fournie *et al.* 1996).

Fin erosion, an important fish response to contaminated sediments in the past was virtually absent (observed in one speckled sanddab) in 2003. From 1972-1976, fin erosion was the most frequently observed anomaly of southern California demersal fishes, being found in 33 species, with most being flatfishes (Mearns and Sherwood 1977). It occurred primarily on the Palos Verdes Shelf, but occasionally at other outfall areas. In the 1970s, 39% of the Dover sole on the Palos Verdes Shelf had fin erosion. However, fin erosion decreased on the Palos Verdes Shelf as sediment contamination decreased between the early 1970s and the mid-1980s, when it was virtually absent (Stull 1995; Allen *et al.* 2001a; Montagne 2002a,b; Allen 2006b). Although the disease appeared to be related to sediment contamination, its cause was never determined. Fin erosion likely results from chemical stress and low dissolved oxygen concentrations and possibly enhanced hydrogen sulfide, and in some cases secondary bacterial infection (Sindermann 1979, Allen 2006b).

Epidermal tumors were another common disease in the 1970s. In 1972-1975, epidermal tumors were found in 1.4% of the Dover sole (Mearns and Sherwood 1977), and this decreased to 1% in 1994 (Allen *et al.* 1998), 0.7% in 1998, and up to 1% in 2003. This rate of occurrence probably represents the background prevalence for this disease in the SCB. Epidermal tumors occur predominantly in Dover sole less than 12 cm in length (Mearns and Sherwood 1977). Although the tumors occurred frequently on the Palos Verdes Shelf in the 1970s, they were also found in Dover sole from other areas throughout the SCB, from Point Arguello, California, to Cedros Island, Baja California Sur, Mexico (Mearns and Sherwood 1976). The prevalence of epidermal tumors in Dover sole on the Palos Verdes Shelf decreased with increasing distance from the outfall and also with time from 1971-1983 (Cross 1988). In 1998, epidermal tumors occurred sporadically in small Dover sole from San Diego to the northwest Channel Islands (Allen *et al.* 2002a). Epidermal tumors are x-cell lesions thought to be caused by an amoebic parasite (Dawe *et al.* 1979).

Ectoparasitism of Fishes

The prevalence of typically monitored parasites in fish in 2003 was 1%, increasing from 0.5% in 1998, and 0.4% in 1994 (Allen *et al.* 1998, 2002a). In all three surveys the Pacific sanddab was most parasitized, with a prevalence of 66%, 77%, and 93% in 1994, 1998, and 2003, respectively. The eye copepod (*Phrixocephalus cincinnatus*) was the primary parasite in this species.

A detailed study of fish ectoparasites relative to wastewater discharge was conducted for the first time during the 2003 survey (Kalman 2006). A detailed study of fish ectoparasites in 2003 revealed that flatworms, leeches, and crustaceans were found on demersal fishes, with copepods comprising 88% of the parasites. Parasite infestation varied by host (fish) species and prevalence by parasite species. Some parasite-host combinations appear to be good indicators of outfall conditions. Prevalence of ectoparasites on bigmouth sole were highest at large- and small-POTW areas and on hornyhead turbot at small-POTW areas. The total prevalence of ectoparasites on hornyhead turbot was significantly highest at small-POTW areas. Three new species of leeches and one new species of parasitic copepod were found in this study. The cause of increased parasitism of some fish species near the outfalls is not known and should be the focus of future studies to determine its significance.

Bioaccumulation

DDT was prevalent in pelagic forage fish tissue in the Southern California Bight. Contamination of wildlife-risk concern was restricted primarily to DDT. An estimated 99% of northern anchovy landings, 86% of Pacific sardine, 33% of Pacific chub mackerel, and 0% of California market squid composites exceeded wildlife (seabird and marine mammal) risk screening values for total DDT. Northern anchovy had the greatest biomass-weighted mean concentrations (60 ng/g ww), followed by Pacific chub mackerel (41 ng/g), Pacific sardine (34 ng/g), and California market squid (0.8 ng/g). Concentrations of DDT were generally highest in the central SCB, the location with the highest sediment concentrations. The pathway of DDT to these organisms is uncertain but is related to tissue lipid concentrations and perhaps to age. Virtually none of the landings exceeded wildlife risk screening values for PCBs.

In 1998, the mean DDT in sanddab-guild fishes was 97 ng/g, higher than the means of the pelagic forage fishes and squid examined here (Allen *et al.* 2002a, Allen *et al.* 2004b). These fishes are benthic rather than pelagic, and hence live on sediments and likely have contact with contaminated sediments. Whereas the extent of area of the shelf with fish above a wildlife-risk screening value was 70% for sanddab-guild fish, such an areal extent could not be estimated for the pelagic fish samples collected at landings docks. Nevertheless, the high contaminant levels in the pelagic fishes analyzed as well as their greater availability to seabird and marine mammal predators suggest that contaminated pelagic fishes pose a greater risk to more species of these predators than do benthic flatfishes.

The Canadian wildlife-risk screening values (Ridgway *et al.* 2000, Roe *et al.* 2000) used in this study identify tissue concentrations of DDT and PCB that may pose health-risk concerns to sensitive wildlife species. Because the screening values are based on responses of the most sensitive species studied, values below the screening value are not likely to be of risk to most bird and mammal species. Although these screening values identify levels of potential concern, they may or may not be pertinent to seabirds or marine mammals of concern in the SCB. Additional study is necessary to determine what tissue concentrations in pelagic forage fishes are critical to local bird and mammal species of concern.

Although DDT in fish samples was widespread in 1994, 1998, and 2003, concentrations were likely to be at least an order of magnitude lower than they might have been two decades earlier (Allen *et al.* 1998; Schiff and Allen 2000; Allen *et al.* 2002a, 2004b). The DDT in the Southern California Bight is a remnant of historical discharges and dumping. Although it has not been discharged to the SCB for 30 years (Mearns *et al.* 1991), DDT is still widespread in sediments throughout the SCB, with highest concentrations on the Palos Verdes Shelf and in Santa Monica Bay (Schiff and Gossett 1998, Noblet *et al.* 2002).

Debris

Anthropogenic debris (mostly plastic) was found in 25% of the southern California shelf, 23% in 1998, and 14% in 1994 (Allen *et al.* 1998, Moore and Allen 2000, Allen *et al.* 2002a). In

2003, debris was most common in the central region outer and middle shelf non-POTW areas. The percent area of plastic debris, metal cans, and glass bottles have decreased since the 1994 regional survey but fishing gear and other debris were highest in 2003. In 1998, anthropogenic debris was most common in areas frequented by boats such as ports, marinas, and Santa Catalina Island. Terrestrial debris was less common than in previous surveys, perhaps resulting from a lack of rain and runoff before the 2003 survey.

Assessment of Natural Effects

Depth Zonation of Assemblages

Assemblages were defined for fishes, invertebrates, and combined fish/invertebrates. Although a variety of methods were used, assemblages differed more by depth (or shelf zone) than by geographic region (as in Allen *et al.* 1998, 2002a; Allen 2006a). Fish and invertebrate assemblages were generally associated with major depth zones on the shelf and upper slope, with distinct assemblages also in bay and harbor areas. The upper slope depth zone (not sampled in previous regional surveys) had a distinct assemblage with some species restricted to this zone and others overlapping this and the outer shelf zone. Invertebrate and combined fish and invertebrate assemblages in the island region differed somewhat from those of the mainland region whereas island fish assemblages were not distinct. Assemblages in San Diego Bay (a natural embayment) differed from those in Los Angeles/Long Beach Harbor (an artificially enclosed area of the open coast) by having distinctive inner bay species. The association of assemblages with specific depth-related life zones is a reflection that these are adaptive zones, with a sharp decreasing physical gradient in temperature, ambient light, and oxygen, and an increasing gradient in pressure with depth (Allen 2006a).

Functional structure of fish communities for the shelf (based on distribution and composition of foraging guilds) was similar to that predicted for the SCB (Allen 1982), consisting of 94% of the expected guilds. The structure of fish communities on the upper slope was less diverse, consisting of 61% of the guilds found on the shelf.

The Upper Slope Stratum

The Bight '03 survey was the first of the regional surveys to venture off the continental shelf and onto the slope. Worldwide, the boundary dividing the shelf and slope is conventionally set at 200m, although the geological boundary between the flat shelf and the steeper slope lies shallower (80-130 m) in southern California (Emery 1960, Curray 1966, Allen 2006a). The upper slope region between 200-500m depths is a distinct life zone, the Mesobenthal Slope, which connects the shelf with the Bathybenthal Slope (500-1,000 m), which extend into the southern California basins (Hedgpeth 1957, Allen 2006a). The complex continental borderland is located between the shelf and the true continental slope seaward at the Patton Escarpment (Uchupi and Emery 1963). The geological demarcation between the shelf and this slope is subtle and variable in depth. It is usually marked by a relatively abrupt change in the angle of the sea floor relative to the sea surface. The shelf usually tends down only 1 to 2°, while the slope tends downward at 4° or greater. This change is often accompanied by changes in current velocity which tend to remove fine particulates from the edge of the shelf, exposing underlying bedrock. Fish communities occupying both shelf and slope bathymetric zones were treated by Allen (2006a).

Cyclic Oceanographic Phenomena and Temporal Change

Macroscalar patterns are visible in the comparison of 1993, 1998, and 2003 regional data. Comparisons are complicated by differing effort levels and stratum coverage over time. To examine the data for trends a comparison of invertebrate species "importance" was made (Table V-18). Each species was ranked by abundance, biomass, and % occurrence at sampled sites in each survey. Weighted ranks were generated for each survey and for the three survey set (abundance and occurrence were weighted twice as heavily as biomass). Data from Thompson *et al.* (1993a) was not included, as they were strongly associated with POTWs, and were not collected using the same area-weighted random allocation strategy. They remain useful as a benchmark of temporal changes in data predating the recent bight wide regional studies. Some of the data used by Thompson *et al.* (1993a) was also included in analyses summarized in Walther (2005), which extended the examination of invertebrate catch around the POTW discharge on Palos Verdes through 2004. While the data are influenced by POTW discharge (but with much lower particulate and toxicant loads than the data used by Thompson *et al.* (1993a), it provides both a long period of examination, and the ability to compare trends in a single area before and during the period covered by regional synoptic surveys.

The three regional surveys of the SCB cover a period of phase shift in oceanographic regime associated with the Pacific Decadal Oscillation (PDO; Francis *et al.* 1998). During the period covered by the three standardized regional surveys (1994, 1998, 2003) the SCB went from warm regime to El Niño to cold regime. The 1994 survey was performed in the middle of a prolonged warm regime; the 1998 survey during an intense El Niño event, and the 2003 survey in a cold regime in the California Current (Goericke *et al.* 2005). The regime shift occurring in 1999 resulted in a swing of 9ºC, from 6ºC above the seasonal mean sea-surface temperature to 3ºC below it (Schwing and Moore 2000). This decadal scale trend is independent of the shorter cycle El Niño Southern Oscillation (ENSO; Wolter 1987) which moves between warm (El Niño) and cool (La Niña) states every 1-2 years, although individual states may rarely persist for up to 7 years. In addition, El Niño periods identified at the equator do not always show major signs in the SCB. Such oceanographic changes are reflected in the composition of the demersal fish and megabenthic invertebrate fauna, although these animals often live for several years, and respond after a time-lag. Each species will have a somewhat different response lag.

Interactions of the PDO and ENSO cycles produce a complex temporal mosaic of oceanographic conditions, primarily associated with temperature, but also influenced by associated changes in current transport of larvae, and upwelling driven by both oceanic and atmospheric circulation states, which affect the availability of nutrients in waters over the continental margin. Examination for temporal changes in the SCB must be performed with the above complexity in mind. The correlations of these environmental variables with fishes within the SCB were evaluated by Allen *et al.* (2004c). They tested time-lags of 1, 2, and 3 years, finding different species exhibited different apparent lags. In this study 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 nearly half of the fish populations examined lacked strong correlations to the oceanographic variables examined. A similar analysis has not been performed for trawl megabenthic invertebrates, and the present database is not yet long enough to permit one.

However, it is expected that the patterns reported for fishes by Allen *et al.* (2004c) will be repeated in the invertebrates.

Responses of Assemblages to Changing Oceanic Regimes

Fish and invertebrate populations and assemblages have changed somewhat over time. in response to changing oceanic regimes (1994-warm regime; 1998-El Niño; and 2003-cold regime). Mean fish abundance and species richness per haul have increased with fish abundance in 2003 (cold regime) about two times greater than in any of the previous surveys. In contrast, mean invertebrate abundance was highest in 1994 (warm regime) but biomass was highest in 2003 (cold regime).

Assemblages showed minor changes between the three sampling periods (1994 , 1998, and 2003), with changes most pronounced in 1998. Among fish foraging guilds, the sanddab guild was most widespread, comprising 93-99% of the shelf area in 1994, 1998, and 2003. The turbot guild was the second most prevalent guild in 1994 and 2003, with the lizardfish/halibut guild second in 1998 (Allen *et al.* 1998, 2002a).

Depth displacement patterns among dominant fish species in foraging guilds were most similar in cold regimes (1972, 2003), less in 1994 (warm), and least in the 1998 El Niño period (Figures VI-28a through VI-28d; Allen 1982; Allen *et al.* 1998, 2002a). During the 1998 El Niño period, many important community members expanded or shifted their distributions to deeper parts of the shelf. The areal occurrence of many fish foraging guilds decreased between 1994 and 1998. The benthic pelagobenthivore (sanddab) guild was the most widespread guild on the shelf in 1994, 1998, and 2003, occurring in 93-99% of the area; the benthic extracting benthivore (turbot) guild was second most widespread in 1994 and 2003, with benthic pelagivore (lizardfish) guild second in 1998. Comparing depth displacement patterns among dominant guild species between the time periods (two cold regime periods, 1972 and 2003; a warm regime period 1994; and an El Niño period, 1998) showed that the structure of fish communities was most similar in the two cold regime periods, and least during the 1998 El Niño period.

The Broader Context of Regional Survey Observations

We should not infer from this that the SCB is in a pristine state. Recent examinations of historical and paleontological data from coastal oceans (e. g. Jackson 2001) have shown that coastal ecosystems have been so modified by human influence that fisheries and ecological monitoring data can only reflect the modified state. This has also been noticed in local waters (MBC 1988) where extirpation of large keystone predators and grazers by aboriginal inhabitants modified the coastal ecosystem prior to European settlement. The consequences of such events, which predate record-keeping, can be severe and underappreciated (Jackson *et al.* 2001). Current appraisal, based on data extending back no more than 35 years, suggests that biological conditions in the SCB are not noticeably worsening from earliest recorded observations. Within this context the data provided by the three regional monitoring efforts (Allen *et al.* 1998, 2002a; the present study) are hopeful, and demonstrate that while concern for the SCB marine environment is appropriate, dispair over its state is not.

XI. CONCLUSIONS

1. Demersal fish and invertebrate populations and assemblages on the southern California shelf were healthy in 2003.

   - Biointegrity indices identified 96% of the southern California shelf as reference (normal) for fish, 84% for invertebrates, and 92% for fish and invertebrates combined. Nonreference (disrupted) assemblages occurred primarily on the inner shelf or bay/harbor areas, suggesting nearshore influences.

   - Fish populations had background levels of anomalies and parasites. The prevalence of diseases and anomalies had decreased significantly from 5.0 to 0.9% from the 1970s to 2003, but increased slightly from 0.5 to 0.9% since 1998. There was no incidence of fin erosion, an important fish response to contaminated sediments in the past.

   - A detailed baseline study of fish ectoparasites conducted regionally for the first time in 2003 revealed many fish ectoparasites included flatworms, leeches, and crustaceans, with copepods comprising 88% of the parasites. California scorpionfish had by far the highest intensity of parasitism of any fish species examined. Prevalence of ectoparasites on bigmouth sole were highest at large- and small POTW areas and on hornyhead turbot at small POTW areas. The increase in prevalence of ectoparasites at small POTW areas may be due to the shallow depth and higher water temperature of these sites.

2. DDT was prevalent in pelagic forage fish tissue in the Southern California Bight

   - Contamination above Canadian screening values protective of wildlife (seabirds and marine mammals) consumers of fish was restricted primarily to DDT. Virtually none of the landings exceeded screening values for PCBs.

   - An estimated 99% of northern anchovy landings, 86% of Pacific sardine, 33% of Pacific chub mackerel, and 0% of California market squid composites exceeded Canadian wildlife screening values for total DDT.

   - Northern anchovy had the greatest biomass-weighted mean concentrations (60 ng/g ww), followed by Pacific chub mackerel (41 ng/g), Pacific sardine (34 ng/g), and California market squid (0.8 ng/g). Tissue concentrations of DDT were generally highest in the central SCB, the location with the highest sediment concentrations.

   - The Canadian wildlife-risk screening values used in this study identify tissue concentrations of DDT and PCB that may pose health-risk concerns to sensitive wildlife species. Although these screening values (based on responses of sensitive species) identify levels of potential concern, they may or may not be pertinent to seabirds or marine mammals of concern in the SCB. Additional study is necessary to determine what tissue concentrations in pelagic forage fishes are critical to local bird and mammal species of concern.

3. Anthropogenic debris (mostly plastic) was found in 25% of the southern California shelf.

    - Debris was most common in the central region, particularly in the outer and middle shelf non-POTW areas.

    - The percent area of plastic debris, metal cans, and glass bottles have decreased since the 1994 regional survey but fishing gear and other debris were highest in 2003.

4. Fish and invertebrate assemblages were generally associated with major depth zones on the shelf and upper slope, with distinct assemblages also in bay and harbor areas. Assemblages in the island region differed only slightly from those of the mainland region.

    - Assemblages in San Diego Bay (a natural embayment) differed from those in Los Angeles/Long Beach Harbor (an artificially enclosed area of the open coast) by having distinctive inner bay species.

    - The fish and invertebrate assemblages of the upper slope (depth 200-500 m; a new stratum for the survey in 2003) have distinctive deepwater species seldom found on the shelf. These assemblages had lower species richness and abundance than the outer and middle shelf but similar to that of the inner shelf and bays.

5. Fish and invertebrate populations and assemblages have changed over time in response to the prevailing ocean climate during the survey (1994-warm regime; 1998-El Niño; and 2003-cold regime) and in an earlier (1972) cold-regime survey.

    - Depth displacement patterns among dominant fish foraging guild species were most similar in cold regimes (1972, 2003), less in 1994 (warm), and least in the 1998 El Niño period. Displacement patterns were identical in both cold regime periods for the midshipman, sanddab, and combfish guilds, suggesting a characteristic cold regime pattern for these guilds. During the 1998 El Niño period, important community members in 13 guilds expanded or shifted their distributions to deeper parts of the shelf. For example, in the most widespread guilds, Pacific sanddab shifted its range deeper in the sanddab guild and Dover sole and hornyhead turbot shifted deeper in the turbot guild. Both were replaced in shallow water by more southerly species (longfin sanddab and spotted turbot, respectively) during the 1998 El Niño.

    - Mean fish abundance and species richness per haul have increased with fish abundance in 2003 (cold regime) about two times greater than in any of the previous surveys.

    - In contrast, mean invertebrate abundance was highest in 1994 (warm regime) but biomass was highest in 2003 (cold regime)

    - These surveys have demonstrated that characteristics of the fish communities (abundance, biomass, and depth distribution of component species) vary by oceanic regime, with evidence that some fish foraging guilds return to similar patterns in at least one of these regimes (cold). The results demonstrate that assessments of anthropogenic effects on demersal fish communities must consider the oceanic regime of the assessment period to avoid confusing natural changes with anthropogenic effects.

XII. RECOMMENDATIONS

I. Conduct regional trawl surveys to assess temporal trends of areas previously surveyed and expand into areas not previously surveyed

Trawl surveys have been an important part of the past three regional surveys because they provide much useful information on the fauna that has historically been most effected by wastewater discharge on the southern California shelf. In the past three surveys, the first synoptic survey of the mainland shelf was conducted and continued, with additions of survey of the fauna at nearshore islands, bays and harbors, and most recently the upper slope. Nevertheless, gaps in our knowledge still exist and the regional surveys provide an opportunity to fill in these gaps by extending the survey into new areas, as discussed below.

A. Extend trawl survey south to Cabo Colnett, Baja California.

The past three regional surveys of the SCB have focused on that part of the SCB that lies north of the US-Mexico International Border. However, the SCB is defined as extending to Cabo Colnett in northern Baja California. The 1998 regional survey extended the benthic survey as far south as Ensenada but the trawl survey has not been extended into Baja California. There are interested persons at CICESE in Ensenada that have professed an interest in helping to extend the survey into northern Baja California. A trawl survey of the type used in the SCB regional surveys has never been conducted off the coast of northern Baja California. Extending the survey to Cabo Colnett would complete our assessment of the SCB.

B. Conduct trawl surveys at all islands in the Southern California Bight

Among SCB islands, an assessment of the demersal fish and invertebrate fauna on the shelf and upper slope has only been conducted at the Channel Islands (1998, 2003) and Santa Catalina Island (shelf only, 1998). If possible, this assessment should be made on all islands off southern California (San Nicolas and San Clemente Islands have not been surveyed) at the same time for comparison and repeated in future surveys to assess temporal changes. Information from surveys of the demersal fish and invertebrate fauna of these islands during the regional surveys may provide a basis for assessing areas suitable for Marine Protected Areas.

II. Improve training of field personnel

The quality of much of the data used in assessment of demersal fishes and megabenthic invertebrates is dependent on the quality of the fish and invertebrate identification and the consistency by which the field protocol is carried out. Early establishment of presurvey (one to two years before the next regional survey) training of field personnel would ensure that field data are accurate and meaningful.

A. Implement SCAMIT-like Fish Group to train people to identify demersal fishes prior to next regional survey

Marine invertebrate taxonomists in southern California have established the Southern California Association of Marine Invertebrate Taxonomists (SCAMIT). This organization provides a forum and community of expert knowledge of the taxonomy of local marine invertebrates. Hence it provides training of local marine invertebrate taxonomists on the nomenclature and characteristics for identifying marine invertebrates found in southern California benthic infauna and trawl monitoring programs. Such a program does not exist for local fish taxonomists and most ichthyologists learn fish identification on the job, rather in a formal educational environment. As a result, there is some variability in fish identification skills among the organizations participating in the regional survey program. There is a need for such an organization as persons that have accumulated this knowledge over decades are reaching retirement age and are leaving the field. Implementing a SCAMIT-like fish group would provide a forum for teaching identification of fishes likely caught in the regional surveys, including the recommendation of pertinent books, guides, and keys. We recommend that such an organization be implemented as soon as possible to provide training for persons doing fish identification in the next regional survey.

B. Train people to conduct pressure-temperature sensor measurements of trawl surveys prior to next regional survey.

In the 2003 regional survey, the trawl survey experimented with the use of pressure-temperature sensors mounted on the doors of the trawl net to assess when the trawl was on the bottom. These devices worked erratically in the survey, but showed possible value at assessing on-bottom time during a trawl, as well as providing other physical information. However, the success rate was low, in part due to the need for field personnel that are better trained in the use of the device. We recommend finding an acceptable device, evaluate the performance of the device, and train people to use it prior to the next regional trawl survey so that these devices can be incorporated into the trawl survey.

III. Continue development of bioassessment tools

Bioassessment tools are used to assess the status and health of fish and invertebrate populations and assemblages collected in the regional surveys. These tools include indices such as biointegrity indices and functional organization models to identify altered, disrupted, or nonreference conditions. They also include bioindicators such as prevalence of disease and parasitism, bioaccumulation, endocrine disruption, and biomarkers. As natural and anthropogenic conditions change in the SCB, bioassessment tools may need to be periodically or continually developed to provide better assessments of human impact on demersal fish assemblages.

A. Enhance and refine biointegrity indices

Currently four biointegrity indices (FRI, FFG, MIRI, TRI) have been developed for assessing fish and invertebrate assemblages in the SCB relative to those found in a severely disturbed area on the Palos Verdes Shelf in the early 1970s (Allen *et al.* 2001a). Application of these indices to fish and invertebrate assemblages in the SCB in the past two regional surveys have given conflicting results. This is in part due to each measuring a different component of the demersal community (fish, dominant fish foraging guilds, invertebrates, and combined fish and invertebrates). We recommend evaluating the performance of existing biointegrity indices and improve these by removing some species (in particular pelagic red crab, which can have anomalously high abundances during El Niño periods, in the MIRI and TRI) from the evaluation database and perhaps modifying indices to include fin erosion, parasites, and other bioindicators. From this evaluation, we recommend determining the most meaningful biointegrity index for use in assessing fish and/or invertebrate assemblages. Currently the FRI index appears to show the most meaningful results (i.e., interpretation of results relative to the assemblage at Palos Verdes in the 1970s). We recommend use of the FRI for assessing anthropogenic impact on fish assemblages in the SCB. The others look at different aspects of the assemblages and hence their results may differ from those of the FRI. Although there may not be coherence among these indices, the information they provide may prove valuable with more extensive evaluation.

B. Assess parasite load in fishes in other life zones in the SCB.

Although the ectoparasite load of demersal fishes was assessed by Dr. Kalman during the 2003 regional survey, this study assessed the prevalence of ectoparasites only on fishes of the middle shelf. This assessment should be extended in future studies to other life zones, such as bays and harbors, inner shelf, outer shelf, and upper slope. Given the amount of work involved, expanding to one or two new life zone would be most practical. We recommend extending the assessment of parasite load of fishes to bays and harbors and the inner shelf in the next regional survey as these strata are influenced by stormwater runoff, marine vessel activity, and wastewater discharge from small POTW outfalls and to some extent large POTWs. We also recommend examination of ectoparasites in a few individuals of bigmouth sole, hornyhead turbot, speckled sanddab, and California tonguefish as a special study in POTW monitoring programs to determine if this is something of concern.

IV. Continue bioaccumulation studies to assess contaminant trends, foodweb transfer, and risk to consumers.

Bioaccumulation studies have been an important part of the past three regional surveys because they provide much useful information about the exposure and effects of anthropogenic contamination on fish and invertebrate populations. These studies have assessed how liver contaminant levels have decreased over time (1994), and the extent of demersal fish (1998) and pelagic fish (2003) with contaminant levels of concern to wildlife consumers. Continued assessments of bioaccumulation in fish is important for assessing temporal changes in contamination, levels of contamination in the foodweb, and risks to human and wildlife consumers.

A. Assess bioaccumulation in mid-level predators relative to human health concerns.

In previous assessments of fish bioaccumulation in SCB regional surveys have not assessed the extent of contaminant levels above screening values for human consumers of mid-level fishes. Although agencies such as CDFG, OEHHA, and others have examined contaminant levels in local areas, it has not been done for the SCB as a whole. As recreational fishing is an important activity in the SCB with most of the catch being consumed, a Bight-wide assessment of the extent of contamination in recreational fish species would provide valuable information on the extent of fish with contamination levels posing potential health risks to human consumers. Unlike the previous SCB studies which have focused on liver or whole body contamination in fishes, this study would focus on contaminant levels in muscle tissue eaten by human consumers of fish. It would also focus on one or more widespread species of fish (e.g., California scorpionfish, California halibut, kelp bass, etc.) yet to be determined.

B. Conduct extent of contamination of concern in sanddab-guild species to provide recent regional context for local monitoring assessments

In 1998, the extent of fish with contaminant levels of concern was determined using sanddab-guild flatfishes, of which different species were earlier shown to have virtually the same uptake of DDT when collected from the same contaminated sediments (Allen *et al.* 2002b). This guild could hence be treated as a superspecies, with the combined depth range of the component species covering the entire depth range of the survey. Further, the species occupied different depth zones and the guild occurred in about 95% of the area of the SCB shelf. Being small and abundant, they are consumed by wildlife feeding on demersal fishes and hence their tissue contaminant levels could be compared to a level of concern (i.e., screening values for wildlife consumers of fish). In 1998 it was found that sanddab-guild species with DDT levels of concern to wildlife consumers of fish occurred in 70% of the area of the southern California shelf. Following the 1998 regional survey, assessment of bioaccumulation in sanddab guild species was incorporated into some local outfall monitoring programs. The extent of contamination levels of concern in this guild in the SCB provides context for assessing contamination of concern in this guild near specific outfalls. As the 2008 survey will have been conducted 10 years after the 1998 survey, we recommend that the extent of bioaccumulation of concern in the SCB be assessed again to provide recent context for on-going monitoring program assessments.

C. Develop SCB-specific contaminant levels of concern for species that are wildlife consumers of fish.

Wildlife-health risk (as well as those for human health) screening values are used to identify tissue contaminant levels of concern in food organisms in an area. For human health, these may be based on the lowest levels that may affect humans so as to be most protective of human health. Depending on their sensitivity to specific contaminants, individual humans may or may not be affected by consumption of fish with these low levels of a contaminant. For wildlife health, these are developed to be applied to a large area with many different species and may be based on contaminant concentrations that affect the health of the most sensitive species. Screening values for wildlife consumers of fish were used in this study to identify tissue contaminant levels that are not likely to pose a health risks (i.e., concentrations below the screening value). However, concentrations above the screening value may or may not pose a health risk to specific species in the SCB. These species may or may not be as sensitive as the species on which the screening value was based. Hence, levels of concern should be developed for species of concern in the SCB. Species of concern need to be identified and information on the effects of contaminants on these species need to be compiled. A review of existing information may identify data gaps that may suggest studies to identify levels that affect the species. These may or may not be able to be done in a regional survey context. Nevertheless, compilation of pertinent information would provide better understanding of what contaminant levels may pose a health risk to species of concern in the SCB. We recommend that wildlife or other species of concern in the SCB be identified and information on what levels of contaminants may pose health risks to them be compiled and evaluated for development of contaminant levels of concern for species of concern in the SCB.

XIII. LITERATURE CITED

Adams, S.M. 1990. Status and use of biological indicators for evaluating the effects of stress on fish. In: *Biological indicators of stress in fish*. (S. M. Adams, ed.). American Fisheries Society Symposium. 8:1-8.

Allen, G.R. and D.R. Robertson. 1994. Fishes of the tropical eastern Pacific. University of Hawaii Press. Honolulu, HI.

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, L.G., M.H. Horn, F.A. Edmands II and C.A. Usui. 1983. Structure and seasonal dynamics of the fish assemblage in the Cabrillo Beach area of Los Angeles Harbor, California. *Bulletin of the Southern California Academy of Sciences* 82:47-70.

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. 1990. The biological environment of the California halibut, *Paralichthys californicus.* pp. 7-29 *in*: C.W. Haugen (ed.), The California halibut, *Paralichthys californicus*, resource and fisheries. *California Department of Fish Game, Fish Bulletin* 174.

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, M.J., D.W. Diehl and E. Y. Zeng. 2004a. Bioaccumulation of contaminants in recreational and forage fishes in Newport Bay, California in 2000-2002. Technical Report 436.Southern California Coastal Water Research Project. Westminster, CA.

Allen, M.J., D. Diener, J. Mubarak, S.B. Weisberg and S.L. Moore. 1999a. Demersal fish assemblages of the mainland shelf of southern California in 1994. pp. 101-112 *in:* S.B. Weisberg and D. Hallock (eds.), Southern California Coastal Water Research Annual Report 1997-1998. Southern California Coastal Water Research Project. Westminster, CA.

Allen, M.J., D. Diener, J. Mubarak, S.B. Weisberg and S.L. Moore. 1999b. Megabenthic invertebrate assemblages of the mainland shelf of southern California in 1994. pp. 113-124 *in*:

S.B. Weisberg and D. Hallock (eds.), Southern California Coastal Water Research Annual Report 1997-1998. Southern California Coastal Water Research Project. Westminster, CA.

Allen, M.J. and A.K. Groce. 2001b. First occurrence of speckletail flounder, *Engyophrys sanctilaurentii* Jordan & Bollman (Pisces: Bothidae), in California. *Bulletin of the Southern California Academy of Sciences* 100:137-143

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

Allen, M.J., A.K. Groce and J.A. Noblet. 2004b. Distribution of contaminants above predator-risk guidelines in flatfishes on the southern California shelf in 1998. pp. 149-171 *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. 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. and S.L. Moore. 1996. Spatial variability in southern California demersal fish and invertebrate catch parameters in 1994. pp. 114-127 *in*: M.J. Allen, C. Francisco and D. Hallock (eds.), Southern California Coastal Water Research ProjectAnnual Report 1994-1995. Southern California Coastal Water Research Project. Westminster, CA.

Allen, M.J. and S.L. Moore. 1997a. Recurrent groups of demersal fishes on the mainland shelf of Southern California in 1994. pp. 121-128 *in*: S.B. Weisberg, C. Francisco, and D. Hallock (eds.), Southern California Coastal Water Research Project Annual Report 1995-1996. Southern California Coastal Water Research Project. Westminster, CA.

Allen, M.J. and S.L. Moore. 1997b. Recurrent groups of megabenthic invertebrates on the mainland shelf of Southern California in 1994. pp. 129-135 *in*: S.B. Weisberg, C. Francisco, and D. Hallock (eds.), Southern California Coastal Water Research Project Annual Report 1995-1996. Southern California Coastal Water Research Project. Westminster, 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. Southern California Coastal Water Research Project. Westminster, CA.

Allen, M.J., S.L. Moore, S.B. Weisberg, A.K. Groce and M. Leecaster. 2002b. Comparability of bioaccumulation within the sanddab feeding guild in coastal southern California. *Marine Pollution Bulletin* 44:452-458.

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.

Allen, M.J., R.W. Smith, E.T. Jarvis, V. Raco-Rands, B. Bernstein and K. Herbinson. 2004c. 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. 2001a. 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., J.K. Stull, S.L. Moore and C.L. Tang. 2001b. Relative abundance and health of demersal fish species on the southern California shelf in 1994. pp. 170-188 *in:* S.B. Weisberg and D. Hallock (eds.), Southern California Coastal Water Research Project Annual Report 1999-2000. 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.

Alton, Miles S. 1972. Bathymetric distribution of the echinoderms off the northern Oregon coast. pp. 475-537 *in*: A.T. Pruter and D.L. Alverson (eds.), The Columbia River Estuary and Adjacent Ocean Waters - Bioenvironmental Studies. University of Washington Press. Seattle, WA.

Anderson, J.W., D.J. Reish, R.B. Spies, M.E. Brady and E.W. Segelhorst. 1993. Human Impacts. pp. 682-766 *in*: M.D. Dailey, D.J. Reish and J.W. Anderson (eds.), Ecology of the Southern California Bight, A synthesis and interpretation. University of California Press. Berkeley, CA.

Antonelis, G.A. Jr. and C.H. Fiscus. 1980. The pinnipeds of the California Current. *California Cooperative Oceanic Fisheries Investigations Reports* 21:68-78.

Barker, D.E., R.A. Khan and R. Hooper. 1994. Bioindicators of stress in winter flounder, *Pleuronectes americanus*, captured adjacent to a pulp and paper mill in St. George's Bay, Newfoundland. *Canadian Journal of Fisheries and Aquatic Sciences*. 51:2203-2209.

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.

Baxter, J.L. 1967. Summary of biological information on the northern anchovy, *Engraulis mordax* Girard. *California Cooperative Oceanic Fisheries Investigations Reports* 11:110-116.

Bergen, D.R. and L.D. Jacobson. 2001. Northern anchovy. pp. 303-305 *in*: W.S. Leet, C.M. Dewees, R. Klingbeil and E.J. Larson (eds.), California's living marine resources: a status report. California Department of Fish and Game. Sacramento, CA.

Berlocher, S.H. and D. Swofford. 1997. Searching for phylogenetic trees under the frequency parsimony criterion: An approximation using generalized parsimony. *Systematic Biology* 46: 211-215.

Bight'03 Coastal Ecology Committee. 2003a. Southern California Bight 2003 Regional Monitoring Survey (Bight'03): Coastal ecology workplan. Southern California Coastal Water Research Project. Westminster, CA.

Bight'03 Coastal Ecology Committee. 2003b. Southern California Bight 2003 Regional Monitoring Survey (Bight'03): Quality Assurance Plan. Southern California Coastal Water Research Project. Westminster, CA.

Bight'03 Field Sampling & Logistics Committee. 2003. Southern California Bight 2003 Regional Monitoring Survey (Bight'03): Field Operations Manual. Southern California Coastal Water Research Project. Westminster, CA.

Bight '98 Steering Committee. 2003. Southern California Bight 1998 Regional Monitoring Program: Executive Summary. Southern California Coastal Water Research Project. Westminster, CA.

Bijukumar, A. 1996. Studies on the host specificity of metazoan parasites associated with the flatfishes (Order Pleuronectiformes) of the Kerala coast. *Rivista Di Parassitologia*. 14:131-141.

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.

Bond, C.E. 1996. *Biology of fishes*, 2nd ed. Saunders College Publishing. Philadelphia, PA.

Boxshall, G. A. 1974. Infections with parasitic copepods in North Sea marine fishes. *Journal of Marine Biological Association of the United Kingdom* 54:355-372.

Bray, J.R. and J.T. Curtis. 1957. An ordination of the upland forest communities of southern Wisconsin. *Ecological Monographs* 27:325-349.

Brusca, R.C. 1981. A monograph on the Isopoda Cymothoidae (Crustacea) of the eastern Pacific. *Zoological Journal of the Linnean Society* 73:117-199.

Bush, A.O., K.D. Lafferty, J.M. Lotz and A.W. Shostak. 1997. Parasitology meets ecology on its own terms: Margolis *et al*. revisited. *Journal of Parasitology* 83:575-583.

Butler, J., D. Fuller, and M. Yaremko. 1999. Age and growth of California market squid (*Loligo opalescens*) off California during 1998. *California Cooperative Oceanic Fisheries Investigations Reports* 40:191-195.

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.

Cadien, D.B. and J.A. Ranasinghe. 2003. Invaders in the open sea: establishment of the New Zealand snail *Philine auriformis* in southern California coastal waters. pp. 253-265 *in*: S.B. Weisberg (ed.), Southern California Coastal Water Research Project Annual Report 2001-2002. Southern California Coastal Water Research Project. Westminster, CA.

California Department of Fish and Game. 2004. Review of some California fisheries for 2003: market squid, coastal pelagic finfish, Dungeness crab, sea urchin, groundfish, ocean salmon, tuna, nearshore live-fish, Pacific herring, and rock crab. *California Cooperative Oceanic Fisheries Investigations Reports* 45:9-26.

Cao, Y., D.D. Williams and N.E. Williams. 1998. How important are rare species in aquatic community ecology and bioassessment? *American Society of Limnology and Oceanography* 43 (7):1403-1409.

Cao, Y., D.P. Larsen and R.St-J. Thorne. 2001. Rare species in multivariate analysis for bioassessment: some considerations. *Journal of the North American Benthological Society* 20:144-153.

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.

Castro, R. and H. Baeza. 1986. Some species of *Neobrachiella* Kabata, 1979 (Copepod, Lernaeopodidae), parasitic on Chilean fishes, with description of *Neobrachiella paralichthyos* sp. nov. from *Paralichthys adspersus* (Steindachner). *Crustaceana* 51:245-253.

Causey, D. 1960. Parasitic Copepoda from Mexican coastal fishes. *Bulletin of Marine Science of the Gulf and Caribbean* 10:323-337.

Caux, P.-Y. and S. Roe (eds.). 2000. Environmental quality assessments for PCBs, DDT and Toxaphene. Environment Canada. Canadian Association on Water Quality. Ottawa, CN.

Chamberlain, D.W. 1979. Histology of the reproductive systems and comparison of selected morphological characters in four Eastern Pacific species *Citharichthys* (Pisces: Bothidae). Ph.D. dissertation, Univesity of Southern California. Los Angeles, CA.

Chavez, F.P., J. Ryan, S.E. Lluch-Cota and M.C. Niquen. 2003. From anchovies to sardines and back: Multidecadal change in the Pacific Ocean. *Science* 299:217-221.

Christensen, A.M. 1970. Feeding biology of the sea-star *Astropecten irregularis* Pennant. *Ophelia* 8:1-134.

Cimberg, R.L., R.W. Smith and D.B. Cadien. 1993. Distribution of benthic infaunal communities in the vicinity of Point Conception, California. pp. 221-232. *in*: F.G. Hochberg (ed.), Third California Islands Symposium - Recent Advances in Research on the California Islands. Santa Barbara Museum of Natural History. Santa Barbara, CA.

City of Los Angeles, Environmental Monitoring Division. 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. 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 Los Angeles, Environmental Monitoring Division. 2003a. 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 Divsion, Los Angeles, CA.

City of Los Angeles, Environmental Monitoring Division. 2003b. 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.

City of Los Angeles, Environmental Monitoring Division. 2005. *Marine Monitoring in Santa Monica Bay: Biennial Assessment Report for the Period January, 2003 through December 2004*. Report submitted to EPA and RWQCB (Los Angeles). Department of Public Works, Bureau of Sanitation, Hyperion Treatment Plant. Playa del Rey, CA.

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

City of San Diego, Metropolitan Wastewter Department. 2004. *Annual Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 2004*. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

Clark, Hubert L. 1948. A report on the Echini of the warmer Eastern Pacific, based on the collections of the *Velero III*. *Allan Hancock Pacific Expeditions* 8:225-352.

Clark, R., W. Morrison, M.J. Allen and L. Claflin. 2005. Biogeography of macroinvertebrates. pp. 57-88 *in*: R. Clark, J. Christensen, C. Caldow, M.[J.] Allen, M. Murray and S. MacWilliams (eds.), A Biogeographic Assessment of the Channel Islands National Marine Sanctuary. NOAA Technical Memorandum NOS NCCOS 21. Center for Coastal Monitoring and Assessment. Silver Springs, MD.

Clarke, K.R. 1993. Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology* 18:117-143.

Clarke, K.R. and R.N. Gorley. 2006. Primer v6: Plymouth Routines in Multivariate Ecological Research. Primer-E Ltd. Plymouth, UK.

Clarke, K.R. and R.H. Green. 1988. Statistical design and analysis for a 'biological effects' study. *Marine Ecological Progress Series* 46:213-226.

Clarke, K.R. and R.M. Warwick. 1998. A taxonomic distinctness index and its statistical properties. *Journal of Applied Ecology* 35:523-31.

Clarke, K.R. and R.M. Warwick. 1999. The taxonomic distinctness measure of biodiversity: weighting of step lengths between hierarchical levels. *Marine Ecological Progress Series* 184:21-29.

Clarke, K.R. and R.M. Warwick. 2001. A further biodiversity index applicable to species lists: variation in taxonomic distinctness. *Marine Ecology Progress Series* 216:265-78.

Clifford, H.T. and W. Stephenson. 1975. An introduction to numerical classification. Academic Press, Inc. San Francisco, CA.

Conser, R.J., K.T. Hill, P.R. Crone, N.C.H. Lo and D. Bergen. 2003. Stock assessment of Pacific sardine with management recommentions for 2004: Executive summary. Submitted to Pacific Fishery Management Council, Portland OR. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. La Jolla, CA.

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

County Sanitation Districts of Los Angeles County. 2000. Invertebrate and Fish Trawls in Palos

Verdes Ocean Monitoring Annual Report, 2000, County Sanitation Districts of Los Angeles County. Whittier, CA.

County Sanitation Districts of Los Angeles County. 2002. Palos Verdes Ocean Monitoring Annual Report, 2002, Chapter 4: Invertebrate and Fish Trawls. County Sanitation Districts of Los Angeles County. Whittier, CA.

County Sanitation Districts of Los Angeles County. 2005. Palos Verdes Ocean Monitoring Annual Report 2004. Submitted to the Los Angeles Regional Water Quality Control Board. Whittier, CA.

County Sanitation Districts of Los Angeles County. 2006. Palos Verdes Ocean Monitoring Annual Report, 2005, Chapter 4: Trawls. Submitted to Los Angeles Regional Water Quality Control Board. Whittier, CA.

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

Cressey, R.F. 1969. Five new parasitic copepods from California inshore fish. *Proceedings of the Biological Society of Washington* 82:409-428.

Cross, J.N. 1988. Fin erosion and epidermal tumors in demersal fish from southern California. pp. 57-64 *in*: D. A. Wolfe and T. P. O'Connor (eds.), Ocean Processes in Marine Pollution, Vol. 5, Urban Wastes in Coastal Marine Environments. Krieger Publishing Company. Malabar, FL.

Cross, J.N. and J.E. Hose. 1988. Evidence for impaired reproduction in white croaker (*Genyonemus lineatus*) from contaminated areas off southern California. *Marine Environmental Research* 24:185-188.

Cross, J.N. J. Roney and G.S. Kleppel. 1985. Fish food habits along a pollution gradient. *California Fish and Game* 71:28-39.

Cross, M.A., S.W.B. Irwin and S.M. Fitzpatrick. 2001. Effects of heavy metal pollution on swimming and longevity in cercariae of *Cryptocotyle lingua* (Digenea: Heterophyidae). *Parasitology*. 123:499-507.

Curray, J.R. 1966. The continental terrace. pp. 207-214 *in*: R.W. Fairbridge (ed.), The Encyclopedia of Oceanography. Reinhold Publishing. New York, NY.

Dailey, M.D. 1996. Meyer, Olsen & Schmidt's Essentials of Parasitology, 6th ed. W.C. Brown. Dubuque, IA.

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. Dailey, D.J. Reis, and J.W. Anderson (eds.), Ecology of the Southern California Bight: a synthesis and interpretation. University of California Press. Berkeley, CA.

Dark, T.A. and M.E. Wilkins. 1994. Distribution, abundance, and biological characteristics of groundfish off the coast of Washington, Oregon, and California, 1977-1986. *NOAA Technical Report* NMFS 117.

Dawe, C.J., J. Bagshaw and C.M. Poore. 1979. Amebic pseudotumors in pseudobranch of Pacific cod, *Gadus macrocephalus*. *Proceedings of American Cancer Research* 20:245.

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.

Delong, R.L., W.G. Gilmartin and J.G. Simson. 1973. Premature births in California sea lions: association with high organochlorine pollutant residue levels. *Science* 18:1168-1170.

Department of Fisheries and Oceans. 2004. Pacific Sardine Stock Status Report. Department of Fisheries and Oceans Canadian Science Advisory Secretariat 2004/037.

Dickinson, John J. and Andrew G. Carey, Jr. 1978. Distribution of gammarid Amphipoda (Crustacea) on Cascadia Abyssal Plain (Oregon). *Deep-Sea Research* 25:97-106.

Diehl, D.W. 1992. Long term trends in trawl caught fishes off Point Loma, San Diego. pp. 88-97 *in*: J.N. Cross (ed.), Southern California Coastal Water Research Project Annual Report 1990-1991 and 1991-1992. Southern California Coastal Water Research Project. Long Beach, CA.

Diener, D.R. and J.P. Rimer. 1993. New way benthic sampling. Marine Technology Society Conference 1993.

Doherty, F.G., D.W. Evans and E.F. Neuhauser. 1993. An assessment of total and leachable contaminants in zebra mussels *(Dreissena polymorpha)* from Lake Erie. *Ecotoxicolgy Environmental Series* 25:328.340.

Dojiri, M. 1977. *Copepod parasites of Orange County sewer outfall*. M.A. Thesis, California State University. Long Beach. Long Beach, CA.

Dojiri, M. 1979. Two new species of *Lepeophtheirus* (Copepoda: Caligidae) parasitic on fishes from southern California waters. *Parasitology* 78:251-262.

Dojiri, M. 1981. Copepods of the families Lernaeopodidae and Naobranchiidae parasitic on fishes from southern California inshore waters. *Journal of Crustacean Biology* 1:251-264.

Dojiri, M. and R.A. Brantley. 1991. *Lepeophtheirus spatha*, a new species of copepod (Siphonostomatoida: Caligidae) parasitic on the California halibut from Santa Monica Bay, California. *Proceedings of the Biological Society of Washington* 104:727-735.

Dojiri, M. and P.S. Perkins. 1979. A new genus of Cyclopoid copepod (Chondracanthidae) parasitic on halibut from California inshore waters. *Journal of Parasitology* 65:794-803.

Dorsey, J.H., C.A. Phillips, A. Dalkey, J.D. Roney and G.B. Deets. 1995. Changes in assemblages of infaunal organisms around wastewater outfalls in Santa Monica Bay, California. *Bulletin of the Southern California Academy of Science* 94:46-64.

Durham, J.W., C.D. Wagner and D.P. Abbott. 1980. Echinoidea: The Sea Urchins. Chapter 11. pp.160-176 *in*: R.H. Morris, D.P. Abbott and E. C. Haderlie (eds.). Intertidal Invertebrates of California. Stanford University Press. Palo Alto, CA.

Ellis, A.E. 1981. Stress and the modulation of defense mechanisms in fish. pp. 147-169 *in*: A.D. Pickering (ed.), Stress and Fish. Academic Press. London, UK.

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

Environment Canada. 1997. Canadian tissue residue guidelines for DDT for the protection of wildlife consumers of aquatic biota. Final unpublished draft. Environment Canada, Science Policy and Environmental Quality Branch, Guidelines and Standards Division. Hull, CN.

Environment Canada. 1998. Canadian tissue residue guidelines for polychlorinated biphenyls for the protection of wildlife consumers of aquatic biota. Environment Canada, Environmental Quality Branch, Guidelines and Standards Division. Hull, CN.

Eschmeyer, W.N. (ed.). 1998. Catalog of Fishes. California Academy of Sciences. San Francisco, CA.

Fager, E.W. 1957. Determination and analysis of recurrent groups. *Ecology* 38:586-595.

Fager, E.W. 1963. Communities of organisms, Vol. 2. pp. 415-432 *in:* M.N. Hill (ed.), The Sea. John Wiley & Sons. New York, NY.

Fager, E.W. and J.A. McGowan. 1963. Zooplankton species groups in the North Pacific. *Science* 140:453-460.

Fitch, J.E. and R.J. Lavenberg. 1971. Marine food and game fishes of California. University of California Press. Berkeley, CA.

Ford, R.F. 1965. Distribution, population dynamics and behavior of a bothid flatfish, *Citharichthys stigmaeus*. Ph.D. dissertation. University of California, San Diego. La Jolla, CA.

Fournie, J.W., J.K. Summers and S.B. Weisberg. 1996. Prevalence of gross pathological abnormalities in estuarine fishes. *Transactions of the American Fisheries Society* 125:581-590.

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.

George-Nascimento, M., R.A. Khan, F. Garcias, V. Lobos, G. Muñoz and V. Valdebenito. 2000. Impaired health in flounder, *Paralichthys* spp. Inhabiting coastal Chile. *Bulletin of Environmental Contamination and Toxicology* 64:184-190.

Gibson, G.R., M.L. Bowman, J. Gerritsen and B.D. Snyder. 2000. Estuarine and coastal marine waters: Bioassessment and biocriteria technical guidance. EPA 822-B-00-024. U.S. Environmental Protection Agency, Office of Water. Washington, DC.

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.

Goldberg, S.R. 1980. Seasonal spawning cycle of the longspine combfish, *Zaniolepis latipinnis*, with notes on spawning of the shortspine combfish, *Zaniolepis frenata* (Zaniolepididae). *Copeia* 1980:882-884.

Gossett, R.W., D.A. Brown and D.R. Young. 1982. Predicting the bioaccumulation and toxicity of organic compounds. pp. 149-156 *in*: W. Bascom (ed.), Southern California Coastal Water Research Project Biennial Report 1981-1982. Southern California Coastal Water Research Project. Long Beach, CA.

Gress, F. 1994. Reproductive performance, eggshell thinning, and organochlorines in brown pelicans and double-crested cormorants breeding in the Southern California Bight. Report 18 of Southern California Bight natural resource damage assessment expert reports. United States Department of Justice, Environment and Natural Resources Division. Washington, DC.

Groce, A.K., R.H. Rosenblatt and M.J. Allen. 2001b. Addition of the blacklip dragonet, *Synchiropus atrilabiatus* (Garman 1899) (Pisces: Callionymidae) to the California ichthyofauna. *Bulletin of the Southern California Academy of Sciences*. 100:149-152.

Grutter, A.S., R.J.G. Lester and J. Greenwood. 2000. Emergence rates from the benthos of the parasitic juveniles of gnathiid isopods. *Marine Ecology Progress Series* 207:123-127.

Haaker, P. and E. Lane. 1973. Frequencies of anomalies in a bothid, *Paralichthys californicus*, and a pleuronectid, *Hypsopsetta guttulata*, flatfish. *Copeia* 1973:22-25

Hart, J.L. 1973. Pacific fishes of Canada. Fisheries Research Board of Canada, Bulletin 180.

Hayward, T.L. 2000. El Niño 1997-98 in the coastal waters of southern California: a timeline of events. *California Cooperative Oceanic Fisheries Investigations Reports* 41:98-116.

Hedgpeth, J.W. 1957. Classification of marine environments. pp. 17-27 *in*: J. W. Hedgpeth (ed.), Treatise on Marine Ecology and Paleoecology. *Memoirs of the Geological Society of America* 67.

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

Hillis, D.M. 1998. Phylogenetic analysis of frequency data in molecular ecological studies. pp. 25-38 *in*: G.R. Carvalho (ed.), Advances in Molecular Ecology. Proceedings of the NATO Advanced Study Institute on Molecular Ecology. IOS Press. Amsterdam, ND.

Ho, J.S. 1970. Revision of the genera of the Chondracanthidae, a copepod family parasitic on marine fishes. *Beaufortia* 17:105-218.

Ho, J. S. 1971. Parasitic copepods of the Family Chondracanthidae from fishes of Eastern North America. *Smithsonian Contributions to Zoology* 87:1-39.

Ho, J.S. 1972a. Four new parasitic copepods of the Family Chondracanthidae from California inshore fishes. *Proceedings of the Biological Society of Washington* 85:523-540.

Ho, J.S. 1972b. Copepod parasites of the California halibut, *Paralichthys californicus* (Ayres), in Anaheim Bay, California. *Journal of Parasitology* 58:993-998.

Ho, J.S. and I.H. Kim. 1995. *Acanthochondria* (Copepoda: Chondracanthidae) parasitic on fishes of Sado Island in the Sea of Japan, with a preliminary review of the genus. *Report of the Sado Marine Biological Station, Niigata University* 25:45-67.

Ho, J.S. and I.H. Kim. 1996. Copepods parasitic on fishes of Western North Pacific. *Publications of the Seto Marine Biological Laboratory* 37:275-303.

Hochberg, F. G. 1998. Class Cephalopoda. pp. 175-236 *in*: Scott, P. V., and J. A. Blake (eds.). *Taxonomic Atlas of the Benthic Fauna of the Santa Maria Basin and the Western Santa Barbara Channel - Volume 8.The Mollusca Part 1.* 175-236. Santa Barbara Museum of Natural History. Santa Barbara, CA.

Hochberg, F.G. and W.G. Fields. 1980. Cephalopoda: The squids and octopuses. pp. 429-444 *in*: R.H. Morris, D.P. Abbott and E.C. Haderlie (eds.), Intertidal Invertebrates of California. Stanford University Press. Palo Alto, CA.

Hogue, C.C. and J.M. Paris. 2002. Macroparasites of Pacific sanddab *Citharichthys sordidus* (Bothidae) from polluted waters of the Palos Verdes Shelf, southern California. *Bulletin of the Southern California Academy of Science* 101:36-41.

Hogue, C.C. and J.S. Peng. 2003. Relationships between fish parasitism and pollution exposure in the white croaker, *Genyonemus lineatus* (Sciaenidae), from Los Angeles Harbor, southern California, U.S.A. *Comparative Parasitology* 70:84-87.

Hood, S. and R. Mooi. 1996. Taxonomy and phylogenetics of extant *Brisaster* (Echinoidea, Spatangoida). pp. 681-686 *in*: *Proceedings of the 4th International Echinoderm Conference* A. A. Balkema. Rotterdam, ND.

Hose, J., J. Cross, S. Smith and D. Diehl. 1989. Reproductive impairment in a fish inhabiting a contaminated coastal environment off southern California. *Environmental Pollution* 57:139-148.

Hubbs, C.O., W.I. Follett and L.J. Dempster. 1979. List of fishes of California. *Occasional Papers of the California Academy of Sciences* 133.

Humes, A.G. and R.U. Gooding. 1963. A method for studying the external anatomy of copepods. *Crustaceana* 6:238-240.

Jackson, Jeremy B.C. 2001. What was natural in the coastal oceans? *Proceedings of the National Academy of Sciences* 10:5411-18.

Jackson, Jeremy B.C., Michael X. Kirby, Wolfgang H. Berger, Karen A. Bjorndal, Louis W. Botsford, Bruce J. Bourque, Roger H. Bradbury, Richard Cooke, Jon Erlandson, James A. Estes, Terence P. Hughes, Susan Kidwell, Carina B. Lange, Hunter S. Lenihan, John M. Pandolfi, Charles H. Peterson, Robert S. Steneck, Mia J. Tegner and Robert R. Warner. 2001. Historical overfishing and the recent collapse of coastal ecosystems. *Science* 5530:629-38.

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.

Johnson, C.R. and J.P. Adams. 1970. Biology of *Zaniolepis latipinnis* (Zaniolepididae) in relation to vertical distribution. *Copeia* 1970:769-771.

Kabata, Z. 1963. Parasites as biological tags. *International Commission on Northwest Atlantic Fisheries, Special Publication* 4:31-37.

Kabata, Z. 1967. Morphology of *Phrixocephalus cincinnatus* Wilson, 1908 (Copepoda: Lernaeoceridae). *Journal of the Fisheries Research Board of Canada*. 24:515-526.

Kabata, Z. 1970a. Some Lernaeopodidae (Copepoda) from fishes of British Columbia. *Journal of the Fisheries Research Board of Canada* 27:865-885.

Kabata, Z. 1970b. Book 1: Crustacea as enemies of fishes. pp. 1-171 *in*: S.F. Snieszko and H.R. Axelrod (eds.), Diseases of Fishes. TFH Publishers. Jersey City, NJ.

Kabata, Z. 1972. Developmental stages of *Caligus clemensi* (Copepoda: Caligidae). *Journal of the Fisheries Research Board of Canada* 29:1571-1593.

Kabata, Z. 1973. The species of *Lepeophtheirus* (Copepoda: Caligidae) from fishes of British Columbia. *Journal of the Fisheries Research Board of Canada* 30:729-759.

Kabata, Z. 1979. Parasitic Copepoda of British Fishes. Ray Society. London, UK.

Kabata, Z. 1984. A contribution to the knowledge of Chondracanthidae (Copepoda: Poecilostomatoida) parasitic on fishes of British Columbia. *Canadian Journal of Zoology* 62:1703-1713.

Kabata, Z. 1988. Copepoda and Branchiura. pp. 3-127 *in*: L. Margolis and Z. Kabata, (eds.), Guide to the parasites of fishes of Canada Part II – Crustacea. Canadian Special Publication of Fisheries and Aquatic Sciences. Hull, CN.

Kalman, J.E. 2001. *Parasites of demersal fishes as potential indicators of wastewater discharge in Santa Monica Bay*. M. S. Thesis. California State University, Long Beach. Long Beach, CA.

Kalman, J.E. 2003. *Acanthochondria hoi*, a new species of parasitic copepod (Poecilostomatoida: Chondracanthidae) on the California halibut, *Paralichthys californicus*, from Santa Monica Bay, California, with an amended key to the genus *Acanthochondria*. *Proceedings of the Biological Society of Washington* 116:811-819.

Kalman, J.E. 2006a. Ectoparasites of demersal marine fishes in Santa Monica Bay, California, U.S.A., with 31 new host records and three range extensions. *Comparative Parasitology* 73:201-213.

Kalman, J.E. 2006b. Parasites of marine fishes associated with wastewater discharge in the Southern California Bight. Ph.D. Dissertation. University of California, Los Angeles. Los Angeles, CA.

Khan, R.A. and J. Thulin. 1991. Influence of pollution on parasites of aquatic animals. *Advanced Parasitology* 30:201-238.

Kikkawa, J. 1968. Ecological association of bird species and habitats in eastern Australia; similarity analysis. *Journal of Animal Ecology* 37:143-165.

Kitching, I.J. 1998. Cladogram construction, character polarity and rooting. pp. 38-69 *in*: Cladistics: the Theory and Practice of Parsimony Analysis, Second ed. Oxford University Press. New York, NY.

Konno, E.S. and P. Wolf. 2001. Pacific mackerel. pp. 306-308 *in*: W.S. Leet, C.M. Dewees, R. Klingbeil and E.J. Larson (eds.), California's living marine resources: a status report. California Department of Fish and Game. Sacramento, CA.

Kramer, D.E., W.H. Barss, B.C. Paust and B.E. Bracken. 1995. *Guide to the northeast Pacific Flatfishes: families Bothidae, Cynoglossidae, and Pleuronectidae. Marine advisory bulletin* 47.

Lambert, Philip. 1997. Sea cucumbers of British Columbia, Southeast Alaska and Puget Sound. UBC Press. Vancouver, CN.

Landsberg, J.H., B.A. Blakesley, R.O. Reese, G. McRae and P.R. Forstchen. 1998. Parasites of fish as indicators of environmental stress. *Environmental Monitoring and Assessment* 51:211-232.

Lawrence, John. 1987. A Functional Biology of Echinoderms. Johns Hopkins University Press. Baltimore, MD.

Leaman, B.M. and Z. Kabata. 1987. *Neobrachiella robusta* (Wilson, 1912) (Copepoda: Lernaeopodidae) as a tag for identification of stocks of its host, *Sebastes alutus* (Gilbert, 1890) (Pisces: Teleostei). *Canadian Journal of Zoology* 65:2579-2582.

Le Boeuf, B., J. Giesy, K. Kannan, N. Kajiwara, S. Tanabe and C. Debier. 2002. Organochloride pesticides in California sea lions revisited. BMC Ecol. 2002; 2: 11. Published online 2002 December 12. doi: 10.1186/1472-6785-2-11.
http://www.pubmedcentral.gov/articlerender.fcgi?tool=pmcentrez&artid=139123

Lee, H. and P. Wiborg. 2002. Character, fate, and biological effects of contaminated, effluent-affected sediment on the Palos Verdes margin, southern California: An overview. *Continental Shelf Research* 22:835-840.

Leet, W.S., C.M. Dewees, R. Klingbeil and E.J. Larson. 2001. California's living marine resources: a status report. California Department of Fish and Game. Sacramento, CA.

Legendre P. and L. Legendre. 1998. *Numerical ecology.* Second English edition. Elselvier. Amsterdam, ND.

Lissner, Andrew L. and Debra Hart. 1996. Class Echinoidea. pp. 181-194 *in*: J.A. Blake, P.H. Scott and A.L. Lissner (eds.), Taxonomic Atlas of the Benthic Fauna of the Santa Maria Basin and Western Santa Barbara Channel. Santa Barbara Museum of Natural History. Santa Barbara, CA.

Loukashkin, A.S. 1976. On biology of the market squid, *Loligo opalescens*, a contribution toward the knowledge of its food habits and feeding behavior. *California Cooperative Oceanic Fisheries Investigations Reports* 18:109-111.

Love, M. 1996. Probably More Than You Want to Know About Fishes of the Pacific Coast. Really Big Press. Santa Barbara, CA.

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.

Love, M.S., M. Yoklavich and L. Thorsteinson. 2002. The Rockfishes of the Northeast Pacific. University of California Press. Berkeley, CA.

Lowe, C.G. and R.N. Bray. 2006. Movement and activity patterns. pp. 524-553 *in:* L.G. Allen, D.J. Pondella II and M.H. Horn (eds.), *The Ecology of Marine Fish*: *California and Adjacent Waters*. University of California Press. Berkeley, CA.

MacKenzie, K. 1999. Parasites as pollution indicators in marine ecosystems: a proposed early warning system. *Marine Pollution Bulletin* 38:955-959.

Maddison, W.P. and D.R. Maddison. 2004. Mesquite: A modular system for evolutionary analysis. Version 1.05. http://mesquiteproject.org.

Magurran, A.E. 1988. Ecological Diversity and Its Measurement. Princeton University Press. Princeton, NJ.

Mais, K.F. 1974. Pelagic fish surveys in the California Current. *California Department of Fish and Game Fish Bulletin* 162.

Maluf, L.Y. 1988. Composition and distribution of the central eastern Pacific Echinoderms. Natural History Museum of Los Angeles, County, Technical Report Number 2. Allen Press. Lawrence, KS.

Markle, D.F., P.M. Harris and C.L. Toole. 1992. Metamorphosis and an overview of early-life-history stages in Dover sole *Microstomus pacificus. U.S. Fishery Bulletin* 90:285-301.

Martin, J.W. and G.E. Davis. 2001. An Updated Classification of the Recent Crustacea. Natural History Museum of Los Angeles County Science. Los Angeles, CA.

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.

McFarland, V.A. and J.U. Clarke. 1989. Environmental occurrence, abundance, and potential toxicity of polychlorinated biphenyl congeners: considerations for a congener-specific analysis. *Environmental Health Perspectives* 81:225-239.

McLean, J.H. 1996. The Prosobranchia. pp. 1-160 *in*: P.H. Scott, J.A. Blake and A.L. Lissner (eds.), Taxonomic Atlas of the Benthic Fauna of the Santa Maria Basin and Western Santa Barbara Channel. The Mollusca Part 2 - The Gastropoda. Santa Barbara Museum of Natural History. Santa Barbara, CA.

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. 1993. Contaminant trends in the Southern California Bight: the coast is cleaner. pp. 1002-1016 *in*: Coastal Zone '93: Proceedings, 8th Symposium on Coastal Management. American Shore and Beach Preservation/American Society of Civil Engineers. New Orleans, LA.

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., M. Matta, G. Shigenaka, D. MacDonald, M. Buchman, H. Harris, J. Golas, and G. Lauenstein. 1991. Contaminant trends in the Southern California Bight. NOAA Technical Memorandum NOS ORCA 62. United States Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service. Seattle, WA.

Mearns, A.J. and M.J. Sherwood. 1976. Fin erosion prevalence and environmental changes. pp. 139-141 *in*: Southern California Coastal Water Research Project Annual Report for the Year Ended 30 June 1977. Southern California Coastal Research Project. El Segundo, CA.

Mearns, A.J. and M.J. Sherwood. 1977. Distribution of neoplasms and other diseases in marine fishes relative to the discharge of waste water. pp. 210-224 *in*: H.F. Kraybill, C.J. Dawe, J.C.

Harshbarger and R.G. Tardiff (eds.), Aquatic pollutants and biological effects with emphasis on neoplasia. *Annals of New York Academy of Sciences* 298.

Mearns, A.J. and D.R. Young. 1980. Trophic structure and pollutant flow in a harbor ecosystem. pp. 287-308 in: Bascom, W. (ed.), Southern California Coastal Water Research Project. Biennial report 1979-1980. Southern California Coastal Water Research Project. Long Beach, CA.

Menzies, R.J., R.Y. George and G.T. Rowe. 1973. Abyssal Environment and Ecology of the World Oceans. Wiley-Interscience, John Wiley & Sons. New York, NY.

Miller, D.J. 1955. Age determination of the northern anchovy, *Engraulis mordax*. *California Department of Fish and Game Fish Bulletin* 101.

Montagne, D. 2002a. Palos Verdes Ocean Monitoring Annual Report, 2002, Chapter 3: Sediments and infauna. County Sanitation Districts of Los Angeles County. Whittier, CA.

Montagne, D. 2002b. Palos Verdes Ocean Monitoring Annual Report, 2002, Chapter 4: Invertebrate and fish trawls. County Sanitation Districts of Los Angeles County. Whittier, CA.

Moore, M. and A.J. Mearns. 1978. Coastal fish data base of the Southern California Coastal Water Research Project. Southern California Coastal Water Research Project. El Segundo, CA.

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 Project Biennial Report 2001-2002. Southern California Coastal Water Research Project. Westminster, CA.

Moser, H.G. and B.Y. Sumida. 1996. Paralichthyidae. pp. 1325-1355 *in*: H.G. Moser (ed.), The Early Stages of Fishes in the California Current Region. California Cooperative Oceanic Fisheries Investigations Atlas No. 33. Allen Press. Lawrence, KS.

Nagasawa, K., Y. Ishida, M. Ogura, K. Tadokoro and K. Hiramatsu. 1993. The abundance and distribution of *Lepeophtheirus salmonis* (Copepoda: Caligidae) on six species of Pacific salmon in offshore waters of the North Pacific Ocean and Bering Sea. pp. 166-178 *in*: Pathogens of Wild and Farmed Fish: Sea Lice. Ellis. Horwood, UK.

National Academy of Sciences. 1974. Water Quality Criteria, 1972. National Academy of Sciences/National Academy of Engineering. United States Environmental Protection Agency, Ecological Research Service. Washington, DC.

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.

NIWQP (National Irrigation Water Quality Program). 1998. Guidelines for Interpretation of the Biological Effects of Selected Constituents in Biota, Water, and Sediment. United States Department of the Interior, National Irrigation Water Quality Program. Denver, CO.

NOAA National Centers for Coastal Ocean Science. 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.

Noblet, J.A., E.Y. Zeng, R. Baird, R.W. Gossett, R.J. Ozretich, and C.R. Phillips. 2002. Southern California Bight 1998 Regional Monitoring Programs: VI. Sediment Chemistry. Southern California Coastal Water Research Project. Westminster, CA.

Oliva, M.E., M.T. González and E. Acuña. 2004. Metazoan parasite fauna as a biological tag for the habitat of the flounder *Hippoglossina macrops* from northern Chile, in a depth gradient. *Journal of Parasitology* 90:1374-1377.

Orange County Sanitation District. 2006. *Annual Report 2005 (July 2004-June 2005)*. Orange County Sanitation District Marine Monitoring. Fountain Valley, CA.

OEHHA (Office of Environmental Health Hazard Assessment). 2001. California sport fisheries advisories. California Environmental Protection Agency, Office of Environmental Health Hazard Assessment. Sacramento, CA.

Office of Environmental Health Hazard Assessment. 2006. Site specific fish advisory information. Office of Environmental Health Hazard Assessment. Sacramento, CA http://www.oehha.org/fish/so_cal/index.html

Overton, W., D. White and D. Steven. 1990. Design report for EMAP. Environmental Monitoring and Assessment Program, U.S. Environmental Protection Agency, Report No. EPA/600/3-91/053. Silver Springs, MD.

Pauly, D., A.W. Trites, E. Capuli and V. Christensen. 1998. Diet composition and trophic levels of marine mammals. *ICES Journal of Marine Science* 55:467-481.

Perkins, E.M. 1995. An overview of hepatic neoplasms, putatively preneoplastic lesions, and associated conditions in fish sampled during the County Sanitation Districts of Orange County’s 1986-1992 Ocean Monitoring Program. *Bulletin of the Southern California Academy of Science* 94:75-91.

Perkins, P.S. and R. Gartman. 1997. Host-parasite relationship of the copepod eye parasite, *Phrixocephalus cincinnatus*, and Pacific sanddab (*Citharichthys sordidus*) collected from sewage outfall areas. *Bulletin of the Southern California Academy of Sciences* 96:87-104.

Perochon, E., G. Masselot and A. Nel. 2001. Freshwater macroinvertebrates sampling problems in synecological analyses and biomonitoring: A concrete example. *Annales Societie de Entomologie Francais* (N.S.). 37:341-346.

Phillips, C.R., D.J. Heilprin and M.A. Hart. 1997. Mercury accumulation in barred sand sass (*Paralabrax nebulifer*) near a large wastewater outfall in the Southern California Bight. *Marine Pollution Bulletin*. 34:96-102.

Piasecki W., J. Wierzbicka and J. Kempter. 2000. A new monogenean species parasitic on gills of bigmouth sole, *Hippoglossina stomata* Steindachner, 1876 from Southern California. *Acta Ichthyologica Et Piscatoria* 30:127–134.

Quicke, D.L.J. 1993. Principles and Techniques of Contemporary Taxonomy. Blackie Academic and Professional. New York, NY.

Quicke, D.L.J., J. Taylor and A. Purvis. 2001. Changing the landscape: A new strategy for estimating large phylogenies. *Systematic Biology* 50:60-66.

Raco-Rands, V. E., and A. Steinberger. 2001. Characteristics of effluents from large municipal wastewater treatment facilities in 1997. pp. 28-44 *in*: S.B. Weisberg and D. Hallock (eds.), Southern California Coastal Water Research Project Annual Report 1999-2000. Southern California Coastal Water Research Project. Westminster, CA.

Rempel, M.A., J. Reyes, S. Steinert, W. Hwang, J. Armstrong, K. Sakamoto, K. Kelley and D. Schlenk. 2006. Evaluation of relationships between reproductive metrics, gender and vitellogenin expression in demersal flatfish collected near the municipal wastewater outfall of Orange County, California, USA. *Aquatic Toxicology* 77:241-249.

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.

Ridgway, L., L. Juergensen, D. MacDonald, R. A. Kent, P.-Y. Caux and M. Palmer. 2000. Toxicity, fate and behaviour of DDT in Canadian Environment: risks to wildlife consumers of aquatic biota. pp. 1-178 *in*: P.-Y. Caux and S. Roe (eds.), Environmental Quality Assessments for PCBs, DDT and Toxaphene. Environment Canada, Canadian Association on Water Quality. Ottawa, CN.

Robins, C.R., R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea and W.B. Scott. 1991. Common and scientific names of fishes from the United States and Canada. 5th edition. *American Fisheries Society Special Publications* 20.

Robinson, G.R. 1982. Otter trawl sampling bias of the gill parasite, *Lironeca vulgaris* (Isopoda, Cymothoidae), from sanddab hosts. *Citharichthys* spp. *Fishery Bulletin* 80:907-909.

Roe, S., D.D. MacDonald, L. Ridgeway, D. Schudoma and P.-Y. Caux. 2000. Toxicity, fate and behaviour of PCBs in Canadian Environment: risks to wildlife consumers of aquatic biota. pp. 309-431 *in*: P.-Y. Caux and S. Roe (eds.), Environmental quality assessments for PCBs, DDT and Toxaphene. Environment Canada, Canadian Association on Water Quality. Ottawa, CN.

Roemmich, D. and J. McGowan. 1995. Climatic warming and the decline of zooplankton in the California Current. *Science* 267:1324-1326.

Rogers-Bennett, L. and D. S. Ono. 2001. Sea cucumbers. pp. 131-134 *in*: Leet, W.S., C.M. Dewees, R. Klingbeil and E.J. Larson (eds.), California's Living Marine Resources: A Status Report. California Department of Fish and Game. Sacramento, CA.

Roy, L. A., J.L. Armstrong, K. Sakamoto, S. Steinert, E. Perkins, D.P. Lomax, L.L. Johnson and D. Schlenk. 2003. the relationships of biochemical endpoints to histopathology and population metrics in feral flatfish species collected near the municipal wastewater outfall of Orange County, California, USA. *Environmental Toxicology and Chemistry* 22:1309-1317.

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

Salas, F., J. Patricio, C. Marcos, M.A. Pardal, A. Pérez-Rizafa and J.C. Marques. 2006. Are taxonomic distinctness measures compliant to other ecological indicators in assessing ecological status? *Marine Pollution Bulletin* 52:162-74.

Salazar, M.H. 1970. Phototaxis in the deep-sea urchin *Allocentrotus fragilis* (Jackson). *Journal of Experimental Marine Biology and Ecology* 5:254-64.

Sankoff, D. and R. J. Cedergren. 1983 Simultaneous comparison of three or more sequences related by a tree, Pp. 253-263, *in* D. Sankoff and J.B. Kruskal (eds.), *Time warps, string edits, and macromolecules: The theory and practice of sequence comparison*. Addison-Wesley, Reading, Massachusetts, 408 p.

Sankoff, D. and P. Rousseau. 1975. Locating the vertices of a Steiner tree in arbitrary space. *Mathematics Progress* 9:240-246.

SAS Institute. 1989. SAS/STAT User's Guide. SAS Institute Inc. Cary, NC. 1686 p.

Schafer, H.A., G.P. Hershelman, D.R. Young and A.J. Mearns. 1982. Contaminants in ocean food webs. pp. 17-28 *in*: Bascom, W. (ed.), Southern California Coastal Water Research Project Biennial Report 1981-1982. Southern California Coastal Water Research Project. Long Beach, CA.

Schell, S.C. 1985. *Handbook of trematodes of North America north of Mexico*. University Press of Idaho. Caldwell, ID.

Schiff, K. 2000. Sediment chemistry on the mainland shelf of the Southern California Bight. *Marine Pollution Bulletin* 40:267-276.

Schiff, K.C. and M.J. Allen. 1996. Bioaccumulation of chlorinated hydrocarbons in livers of flatfishes from the Southern California Bight. pp. 57-67 *in*: S.B. Weisberg (ed.), Southern California Coastal Water Research Project Annual Report 1996. Southern California Coastal Water Research Project. Westminster, CA.

Schiff, K. and M.J. Allen. 2000. Chlorinated hydrocarbons in flatfishes from the Southern California Bight. *Environmental Toxicology and Chemistry* 19:1559-1565.

Schiff, K.C., M.J. Allen, E.Y. Zeng and S.M. Bay. 2000. Southern California. *Marine Pollution Bulletin* 41:76-93.

Schiff, K. and R. Gossett. 1998. Southern California Bight 1994 Pilot Project: III Sediment Chemistry. Southern California Coastal Water Research Project. Westminster, CA.

Schiff, K., K. Maruya and K. Christensen. 2006. Southern California Bight 2003 Regional Monitoring Program: II. Sediment Chemistry. Southern California Coastal Water Research Project. Westminster, CA.

Schultz, G.A. 1969. How to Know the Marine Isopod Crustaceans. Wm. C. Brown Company. Dubuque, IA.

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.

Shannon, C.E. and W. Weaver. 1949. *The Mathematical Theory of communication*. University of Illinois Press. Urbana, IL.

Sherwood, M.J. and A.J. Mearns. 1976. Occurrence of tumor-bearing Dover sole (*Microstomus pacificus* Lockington) off Point Arguello, California and off Baja California, Mexico. *Transactions of the American Fisheries Society* 105:561-563.

Shields, J.R. and R.P. Goode. 1978. Host rejection of *Lernaea cyprinacea* L. (Copepoda). *Crustaceana* 35:301-307.

Shiino, S.M. 1965. Parasitic copepods of the Eastern Pacific fishes. *Report of Faculty of Fisheries, Prefectural University of Mie* 5:391-420.

Siddall, R., A.W. Pike and A.H. McVicar. 1994. Parasites of flatfish in relation to sewage sludge dumping. *Journal of Fish Biology* 45:193-209.

Sindermann, C.J. 1979. Pollution-associated diseases and abnormalities of fish and shellfish: a review. U.S. Fishery Bulletin 76:717-749.

Skinner, R.H. 1982. The interrelation of water quality, gill parasites and gill pathology of some fishes from south Biscayne Bay, Florida. *Fishery Bulletin* 80:269-280.

Smit, N.J. and A.J. Davies. 2004. The curious life-style of the parasitic stages of gnathiid isopods. *Advances in Parasitology* 58:289-403.

Smith, A.B. 1994. *Systematics and the Fossil Record: Documenting Evolutionary Patterns*. Blackwell Scientific. Oxford, U.K.

Smith, P.E. 1995. A warm decade in the Southern California Bight. *California Cooperative Oceanic Fisheries Investigations Reports* 36:120-126.

Smith, R.W., B.B. Bernstein and R.L. Cimberg. 1988a. Community-environmental relationships in the benthos: applications of multivariate analytical techniques. pp. 247-326 *in*: D. F. Soule and G. S. Kleppel (eds.), Marine Organisms as Indicators. Springer-Verlag. New York, NY.

Smith, R.W., M. Bergen, S.B. Weisberg, D. Cadien, A. Dalkey, D. Montagne, J.K. Stull and R.G. Velarde. 1998. Benthic response index for assessing infaunal communities on the mainland shelf of Southern California. *Ecological Applications* 11:1073-1087.

Sokal, R.R. and F.J. Rohlf. 1981. Biometry, 2nd Edition. W. H. Freeman and Company. San Francisco, CA.

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

Southern California Bight Pilot Project Steering Committee. 1998. Southern California Bight 1994 Pilot Project: I. Executive summary. Southern California Coastal Water Research Project. Westminster, CA.

Southern California Coastal Water Research Project. 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.

Stanley, R.D., D.L. Lee and D.J. Whitaker. 1992. Parasites of yellowtail rockfish, *Sebastes flavidus* (Ayres, 1862) (Pisces: Teleostei), from the Pacific coast of North America as potential biological tags for stock identification. *Canadian Journal of Zoology* 70:1086-1096.

StatSoft, Inc. 1984-2003. Electronic Textbook. www.statsoft.com/textbook/stmulsca.html.

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

Stevens, D.L., Jr. and T.M. Kincaid. 1997. Variance estimation for subpopulation parameters from samples of spatial environmental populations. Proceedings of the American Statistical Association Section on Statistics and the Environment, American Statistical Association. Alexandria, VA.

Stevens, D.L., Jr. and A.R. Olsen. 1991. Statistical issues in environmental monitoring and assessment. Proceedings of the American Statistical Association Section on Statistics and the Environment, American Statistical Association. Alexandria, VA.

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., 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. Southern California Coastal Water Research Project. Westminster, CA.

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.

Sunada, J. S. 1984. Spot prawn (*Pandalus platyceros*) and ridgeback prawn (*Sicyonia ingentis*) fisheries in the Santa Barbara Channel. *California Cooperative Oceanic Fisheries Investigations Reports* 25: 100-104.

Sunada, J. S., J. B. Richards and L. M. Laughlin. 2001. Ridgeback Prawn. pp. 124-126 *in*: Leet, W. S., C. M. Dewees, R. Klingbeil, and E. J. Larson (eds.) *California's Living Marine Resources: A Status Report*. California Department of Fish and Game. Sacramento, CA.

Sures, B., H. Taraschewski and M. Rydlo. 1997. Intestinal fish parasites as heavy metal bioindicators: a comparison between *Acanthocephalus lucii* (Palaeacanthocephala) and the zebra mussel, *Dreissena polymorpha*. *Bulletin of Environmental Contamination and Toxicology* 59:14-21.

Swofford, D. 2000. PAUP*: Phylogenetic analysis using parsimony (*and other methods), version 4.0b6. Sinauer. Sunderland, MA.

Swofford, D.L., G.L. Olsen, P.J. Waddel and D.M. Hillis. 1996. Phylogeny reconstruction. pp. 407-514 *in*: D.M. Hillis, C. Moritz and B.K. Mable (eds.), Molecular Systematics, Second edition. Sinauer Sunserland, MA.

Tetra Tech. 1985. Recommended Biological Indices for 301(h) Monitoring Programs. EPA Technical Report TC-3953-03. Prepared for United States Environmental Protection Agency, Washington, DC. Tetra Tech. San Diego, 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.

Thompson, B.E., G.F. Jones, J.D. Laughlin and D.T. Tsukada. 1987a. Distribution, abundance, and size compostion of echinoids from basin slopes off southern California. *Bulletin of the Southern California Academy of Sciences* 86:113-25.

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

Thompson, S.K. 1992. Sampling. John Wiley & Sons. New York, NY.

Toole, C.L., D.F. Markle and P.M. Harris. 1993. Relationships between otolith microstructure, microchemistry, and early life history events in Dover sole, *Microstomus pacificus. U.S. Fishery Bulletin* 91:732-753.

Tsai, C.F. 1973. Water quality and fish life below sewage outfalls. *Transactions of the American Fisheries Society* 102:281-292.

Uchupi, Elazar and K.O. Emery. 1963. The Continental slope between San Francisco, California and Cedros Island, Mexico. *Deep-Sea Research* 10:397-447.

United States Environmental Protection Agency. 2000. Guidance for assessing chemical contaminant data for use in fish consumption advisories, Vol. 1. Fish sampling and analysis. 3rd edition. EPA-823-B-00-007. United States Environmental Protection Agency, Office of Water. Washington, DC.

Van den Berg, M., L. Birnbaum, A. Bosveld, B. Brunstrom, P. Cook, M. Feeley, J.P. Giesy, A. Hanberg, R. Hasegawa, S.W. Kennedy, T. Kubiak, J.C. Larsen, R. Van Leeuwen, D. Liem, C. Nolt, R.E. Peterson, L. Poellinger, S. Safe, D. Schrenk, D. Tillitt, M. Tysklind, M. Younes, F. Waern and T. Zacharewski. 1998. Toxic equivalency factors (TEFs) for PCBs, PCDDs, PCDFs for humans and wildlife. *Environmental Health Perspective* 106:775-792.

Vervoort, W. 1969. Caribbean Bomolochidae (Copepoda: Cyclopoida). Studies on the Fauna of Curacao and other Caribbean Islands 105:1-125.

Walther, S. 2005. Invertebrate and fish trawls, *in*: Los Angeles County Sanitation Districts Palos Verdes Ocean Monitoring, 2004 Annual Report. County Sanitation Districts. Whittier, CA.

Warwick, R.M. and K.R. Clarke. 1995. Multivariate measures of community stress and their application to marine pollution studies in the east Asian region. *Phuket Marine Biological Center Research Bulletin*. 60:99-113.

Warwick, R.M. and K.R. Clarke. 1998. Taxonomic distinctness and environmental assessment. *Journal of Applied Ecology* 35:532-43.

Weisberg, S.B., J.A. Ranasinghe, D.M. Dauer, L.C. Schaffner, R.J. Diaz and J.B. Frithsen. 1997. An estuarine benthic index of biotic integrity (B-IBI) for Chesapeake Bay. *Estuaries* 20:149-158

Wetzer, R. and R.C. Brusca. 1996. Descriptions of the species of the suborders Anthuridea, Epicaridae, Flabellifera, Gnathiidea, and Valvifera *in*: J.A. Blake and P.H. Scott (eds.), Taxonomic Atlas of the Benthic Fauna of the Santa Maria Basin and Western Santa Barbara Channel Volume 11. The Crustacea Part 2: The Isopoda, Cumacea, and Tanaidacea. Santa Barbara Museum of Natural History. Santa Barbara, CA.

Williams, H.H. and K. MacKenzie. 2003. Marine parasites as pollution indicators: an update. *Parasitology* 126:S27-S41.

Wilson, C.B. 1905. North American parasitic copepods belonging to the family Caligidae. Part 1-The Caliginae. *Proceedings of the United States Nation Museum* 28:479-672.

Wilson, C.B. 1912. Parasitic copepods from Nanaimo, British Columbia, including eight species new to science. *Contributions to Canadian Biology* 1906-1910:85-101.

Wilson, J.G. 1994. The role of bioindicators in estuarine management. *Estuaries* 17:94-101.

Wolfe, D.A. 1992. Selection of bioindicators of pollution for marine monitoring programmes. *Chemistry and Ecology* 6:149-167.

Wolf, P., P.E. Smith and D.R. Bergin. 2001. Pacific sardine. pp. 299-302 *in*: W.S. Leet, C.M. Dewees, R. Klingbeil and E.J. Larson (eds.), California's living marine resources: a status report. California Department of Fish and Game. Sacramento, CA.

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. Southern California Coastal Water Research Project. El Segundo, CA.

Wurzian, Rolf Stephan. 1984. The role of higher trophic levels in a sublittoral benthic community I. Estimates of ingestion in *Astropecten aranciacus* (Linné). *Marine Ecology* 5:1-8.

Yamaguti, S. 1963. Systema Helminthum. Volume IV. Monogenea and Aspidocotylea. InterScience. New York, NY.

Yaremko, M. 2001. California market squid. pp. 295-298 *in*: W.S. Leet, C.M. Dewees, R. Klingbeil and E.J. Larson (eds.), California's living marine resources: a status report. California Department of Fish and Game. Sacramento, CA.

Zeidberg, L.D., W.M. Hamner, N.P. Nezlin and A. Henry. 2006. The fishery for California market squid (*Loligo opalescens*) (Cephalopoda: Myopsida), from 1981 through 2003. *Fishery Bulletin* 104:46-59.

Zeng, E., D. Tsukada and D.W. Diehl. 2004. Development of a solid-phase microextraction-based method for sampling of persistent chlorinated hydrocarbons in an urbanized coastal environment. *Environmental Science and Technology* 38:5737-5743

Zeng, E., D. Tsukada, D.W. Diehl, J. Peng, K. Schiff, J. Noblet and K. Maruya. 2005. Distribution and mass inventory of total dichlorodiphenyldichloroethylene in the water column of the Southern California Bight. *Environmental Science and Technology* 39:8170-8176.

APPENDIX A

ftp://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/505_Appendix_A.pdf

APPENDIX B

ftp://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/505_Appendix_B.pdf

APPENDIX C

ftp://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/505_Appendix_C.pdf

APPENDIX D

ftp://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/505_Appendix_D.pdf

APPENDIX E

ftp://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/505_Appendix_E.pdf

APPENDIX F

ftp://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/505_Appendix_F.pdf