Southern California Bight 2013
Regional Monitoring Program

# Demersal Fishes and Megabenthic Invertebrates

BIGHT '13




Southern California Bight
2013 Regional Monitoring
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Volume VII

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# Southern California Bight 2013 Regional Monitoring Program: Volume VII. Demersal Fishes and Megabenthic Invertebrates

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## FOREWORD

The Southern California Bight 2013 Regional Monitoring Program (Bight '13) is an integrated, collaborative effort to provide large-scale assessments of the Southern California Bight (SCB). The Bight '13 survey is an extension of previous regional assessments conducted every five years dating back to 1994. The collaboration represents the combined efforts of nearly 100 organizations. Bight '13 is organized into five elements: 1) Contaminant Impact Assessment (formerly Coastal Ecology), 2) Shoreline Microbiology, 3) Nutrients, 4) Marine Protected Areas, and 5) Trash and Debris. This assessment report presents the results of the Demersal Fishes and Megabenthic Invertebrates portion of the survey, which is one component of the Contaminant Impact Assessment element. Copies of this and other Bight '13 reports, as well as work plans, lists of participating agencies and quality assurance plans, are available for download at www.sccwrp.org.

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## ACKNOWLEDGEMENTS

This report is a result of the dedication and hard work of many individuals who share a common goal of improving our understanding of the environmental quality of the Southern California Bight. The authors wish to thank the members of the Bight '13 Trawl Committee for their assistance with study design, sample analysis, data analysis, and report planning and review.

We also thank the Bight '13 Executive Advisory Committee and Contaminant Impact Assessment Committee for their guidance and support of demersal fish and megabenthic invertebrate measurements in regional monitoring. This study would not have been possible without the remarkable expertise of the Bight '13 Field Sampling & Logistics Committee, as well as field sampling personnel from the following organizations: Sanitation Districts of Los Angeles County, City of San Diego, Orange County Sanitation District, City of Los Angeles, City of Oxnard, Southern California Coastal Water Research Project, Aquatic Bioassay and Consulting Laboratories, MBC Applied Environmental Sciences, and AMEC Foster Wheeler. The trawl committee would like to thank the Bight '13 field auditors (Dario Diehl, Bill Power, Don Cadien, Fred Stern, Cheryl Brantley, and Megan Lilly), as well as members of SCAMIT and SCAITE for their time and expertise. We also wish to express our gratitude to Scott Martindale at SCCWRP for report formatting, and the Natural History Museum of Los Angeles County for storage of field reference materials.

# EXECUTIVE SUMMARY

Regional monitoring has become an important component of assessing the status of our coastal resources in the Southern California Bight (SCB). The Southern California Bight 2013 Regional Monitoring Program (Bight '13) is the fifth in a series of regional marine monitoring efforts beginning with a pilot project in 1994 and repeated in 1998, 2003, and 2008. More than 90 different organizations encompassing regulatory, regulated, academic, and non-governmental agencies collaborated to create Bight '13. Collectively, these organizations asked three primary questions:

1. What is the extent and magnitude of impact in the SCB?
2. Does the extent and magnitude of impact vary among different habitats of interest?
3. What are the temporal trends in impacts?

Bight '13 had five components: Contaminant Impact Assessment, Water Column Nutrients, Shoreline Microbiology, Marine Protected Areas, and Trash and Debris. The Contaminant Impact Assessment component evaluated sediment chemistry and toxicity, benthic infauna, fish assemblages, and bioaccumulation. The focus of this report is on demersal fishes and megabenthic invertebrates.

A stratified random sampling design was selected to ensure an unbiased sampling approach to provide areal assessments of environmental condition. There were 6 strata selected for the trawl-based study including three continental shelf strata (5-30 m, 30-120 m, 120-200 m), upper slope (200-500 m), and an embayment stratum. One new stratum, marine protected areas, was introduced in Bight '13.

A total of 165 trawl stations were sampled, capturing over 75,000 fishes from 127 species, and over 165,000 invertebrates from 229 species. Overall, trawls in 2013 had greater average abundance, greater biomass, and reduced average species count compared to previous Bight trawl surveys.

Southern California Bight trawl caught fish were generally in good condition. Based on the Fish Response Index (FRI), a measure of fish community response to pollution, 93% of the Bight's soft bottom habitat was unimpacted by sediment contaminants. In addition, <0.1% of fish had tumors, lesions, or fin rot, all symptoms of potentially stressed individuals. Overall, fish communities have remained healthy since the Bight '98 survey 15 years prior.

Despite the overall good health of fish populations, not all habitats supported healthy fish communities equally. Healthy fish communities were found less frequently in embayments (bays and harbors) compared to the continental shelf (83 vs 96% of area, respectively). A similar disparity has been observed each survey where fish communities in bays and harbors were sampled.

Recommendations included the following actions:

- a critical review and update of the Fish Response Index to enhance assessments
- improved information management to increase accuracy and efficiency
- further investigation of linkages between biological and oceanographic condition

- continued support of regional taxonomic societies that improve the comparability and quality of the organisms species identifications amongst regional Bight survey participants
- evaluation of additional potential indicators of contaminant impacts

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# I. INTRODUCTION

## Overview

Geographically, the Southern California Bight (SCB) is an open embayment in the coast between Point Conception and Cabo Colnett (south of Ensenada, Mexico). According to the most recent census data, approximately 17.2 million people inhabit the five coastal counties that border the SCB in California, a number that is projected to increase to over 20 million by 2045 (State of California 2014). Population growth generally results in conversion of open land into non-permeable surfaces. This “hardening of the coast” through development has increased stress to the coastal ocean environment. Urban and storm related runoff adds sediment, toxic chemicals, pathogens, and nutrients to the ocean (Stull et al. 1987, Dojiri et al. 2003, Schiff 2003, Pondella 2009, Sikich and James 2010, Erisman et al. 2011). Infrastructure to support urbanization has yielded fifteen municipal wastewater treatment facilities, eight power generating stations, ten industrial treatment facilities, and 23 oil and gas platforms, all discharging to the ocean. To comply with water quality standards associated with the California Ocean Plan and federal Clean Water Act, local, state, and federal agencies spend in excess of $31 million a year (Schiff et al. 2002) to monitor potential impacts of their discharges to the coastal ocean. Historically, these point source monitoring agencies seldom ventured outside of their discharge area to evaluate their findings on a regional scale.

Marine community attributes such as species composition and abundance are often affected by a wide variety of natural and anthropogenic factors. Natural forces such as oceanographic variability, current patterns, and habitat availability have historically shaped these communities (Dayton et al. 1998; Miller and McGowan 2013). In some cases, anthropogenic factors such as fishing, pollution, habitat degradation, etc. have contributed to the community structure now observed in some areas of the region (Hidalgo et al. 2011; Mora et al. 2011). Disentangling these interacting forces is a daunting task that requires robust data on both large spatial and temporal scales (Scavia et al. 2002; Harley et al. 2006; Hsieh et al. 2008). While the core monitoring programs performed by the various dischargers in the SCB have been conducted for decades, they are often localized. Therefore, while capable of addressing temporal patterns, the regional spatial scale was left under-evaluated for many years. The Southern California Bight Regional Monitoring Program was begun about 23 years ago to address this issue, specifically to examine the effects of anthropogenic discharges on the SCB’s soft-bottom marine ecology at a greater-than-local scale.

Otter trawls are typically the preferred method for sampling soft-bottom demersal fish and megabenthic invertebrate communities. Trawlable soft-bottom (mud) substrates within the SCB are diverse, relating to a complex topography, with harbors, sandy nearshore areas, submarine canyons, offshore islands, ridges, and basins (Dailey et al. 1993). The SCB also represents a transitional area influenced by cold northern currents, temperate ocean waters, and warm tropical waters from the south punctuated by oceanographic perturbations such as low-frequency oceanographic regime shifts and higher-frequency events such as the El Niño Southern Oscillation (Hickey 1993; Bograd and Lynn 2003; McGowan et al. 2003; Horn et al. 2006), the Pacific Decadal Oscillation (PDO) (Mantua et al. 1997), and the North Pacific Gyre Oscillation (NPGO) (Di Lorenzo et al. 2008; Koslow et al. 2011, 2013). The mixing of currents, episodic oceanographic events, and the multiple habitats allow for the coexistence of a broad spectrum of species, including more than 500 species of fish (Cross and Allen 1993) and thousands of invertebrate species (Thompson et al. 1993). Many of these species separate themselves by depth, habitat, and feeding guilds to reduce food competition and allow multi-species coexistence (Allen 2006; Allen et al. 1998, 2002, 2007). All of these factors complicate data interpretation.

The Southern California Bight 2013 Regional Monitoring Program (Bight ’13) is a continuation of earlier cooperative regional-scale monitoring studies that were piloted in 1994 and continued in 1998, 2003, and 2008. Each of these surveys built upon previous experiences and incorporated a multiple participant coalition to standardize procedures and techniques across the SCB.

### Objectives of the 2013 Regional Monitoring Program

The continuing goal of the SCB Regional Monitoring Programs has been to provide a broad overview of the region's ecological communities to allow, among other things, the opportunity to place local monitoring results into a greater regional context. A greater-than-local perspective provides better opportunities to identify areas of potential environmental impact related to ocean discharges. This document focuses on the trawl-caught fishes and megabenthic invertebrates primarily living on or near soft (mud) bottoms.

The objectives of this report are:

1. To estimate the extent and magnitude of contaminant exposure among different habitats on a regional scale using biological responses as indicators, as measured by trawl sampling

2. To determine temporal trends of these biological responses on a regional scale

This report includes sections on Methods (Section II), Results (Section III), Discussion (Section IV), Conclusions (Section V), Recommendations (Section VI), and References (Section VII).

Appendices provide additional information and data related to specific program context, including quality assurance and control (Appendix A), supplemental analyses (Appendix B), local discharger comparisons (Appendix C), special studies including Marine Protected Area comparisons (Appendix D), and changes in Southern California Bight sea urchin populations (Appendix E).

## II. METHODS

### Study Design

The design of this study followed those of the previous Bight trawl surveys conducted in 1994, 1998, 2003 and 2008 (Allen et al. 1998, 2002, 2007, 2011). The survey area for Bight ’13 spanned from Point Conception, CA in the north to the US-Mexico border in the south, and from coastal embayments out to the upper slope (Figure II-1). The trawlable soft bottom portions of this region were divided into five strata based upon established biogeographic breaks in community composition (Table II-1). These strata include: Embayments (Bays & Harbors, 4-30 m); Inner Shelf (4-30 m); Middle Shelf (31-120 m); Outer Shelf (121-200 m); and Upper Slope (201-500 m). Marine Protected Areas (MPA; 5-500 m) were an additional offshore stratum sampled during

Bight ’13; this stratum overlapped with the Inner Shelf, Middle Shelf, Outer Shelf, and Upper Slope strata.

A stratified random sampling design was selected to ensure an unbiased sampling approach with which to provide areal assessments of environmental condition (Stevens 1997). Stratification ensured that an appropriate number of samples were allocated to each stratum to characterize the stratums with adequate precision. The goal was to allocate approximately 30 stations to each stratum, yielding a 90% confidence interval of about ± 10% around estimates of areal extent.

Area weights were used for calculating unbiased areal assessments of condition in the survey area (Bergen 1996; Stevens 1997). To assist in assessing temporal trends between surveys, 70 stations were revisit stations that had previously been sampled as part of the 1998, 2003, and 2008 SCB Regional Monitoring Programs (Table II-1).

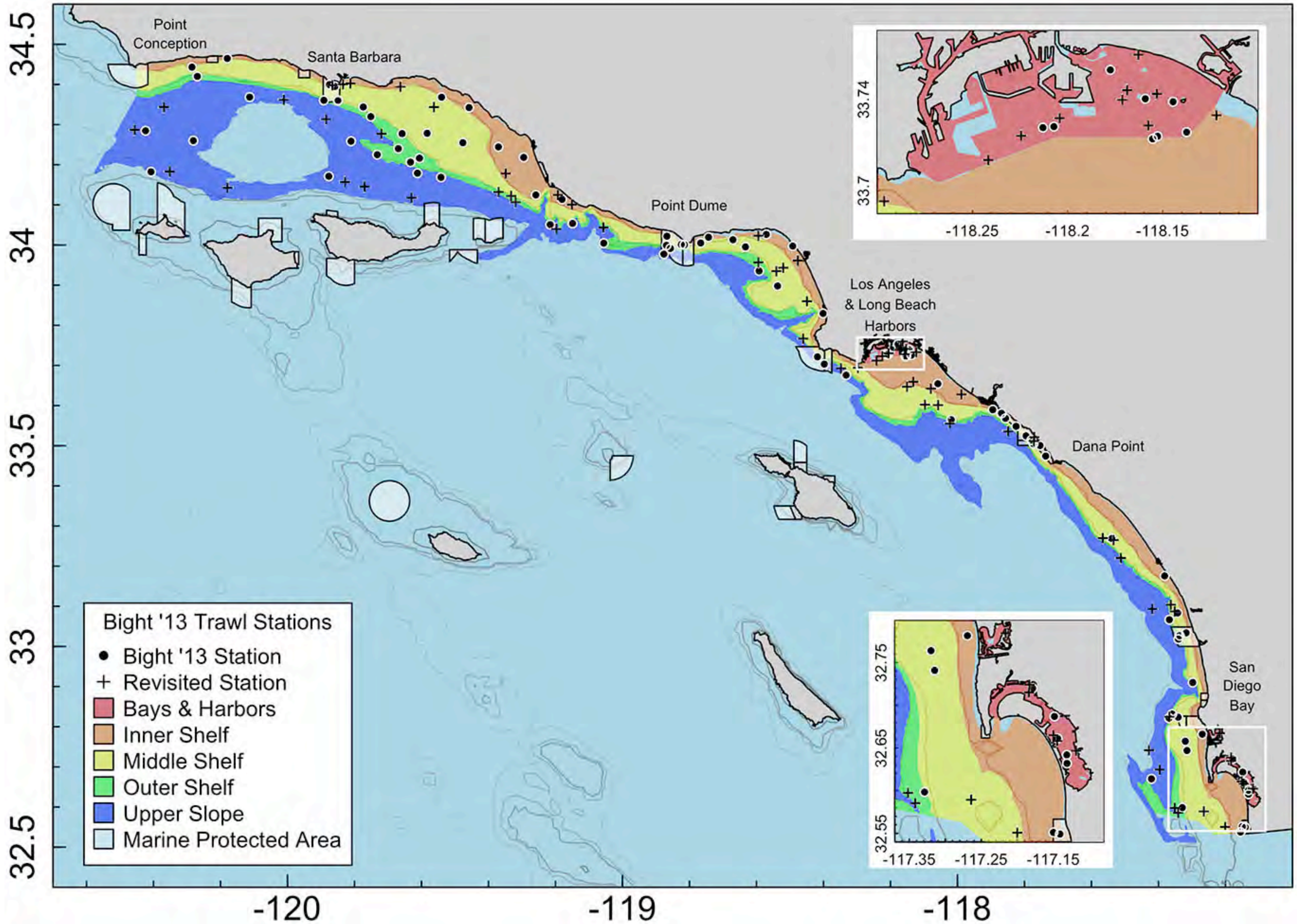



**Figure II-1. Distribution of trawl stations sampled in different strata during Bight '13.**

**Table II-1. Summary of habitats and strata sampled during the Bight '13 trawl survey. MPA stations were not included in the totals.**

| Habitat | Stratum | Depth Range (m) | Area ($km^2$) | Percent Area of Region | Samples | Sampling Success | Percent Revisit Sites |
|---|---|---|---|---|---|---|---|
| Bays | Bays & Harbors | 4-30 | 67.0 | 1% | 26 | | 54% |
| Continental Shelf | Inner Shelf | 4-30 | 1,002.1 | 17% | 35 | | 40% |
| | Middle Shelf | 31-120 | 1,665.1 | 27% | 43 | | 35% |
| | Outer Shelf | 121-200 | 446.7 | 7% | 29 | | 38% |
| Continental Slope | Upper Slope | 201-500 | 2,878.0 | 48% | 32 | | 50% |
| Multiple | MPA | 4-500 | 137.5 | 2% | 24 | | 0% |
| | **Total** | | **6,058.8** | **100%** | **165** | | **42%** |

## Field Methods: Sample Collection and Processing

### Trawling

Fish and invertebrate samples were collected from 165 trawl stations from Point Conception, California to the United States-Mexico international border between July 1 and September 30, 2013 (Table II-1, Figure II-1). Station coordinates, depths, and the stratum classification of each station are given in Appendix A.

Trawl samples were collected according to standard methods described in the Contaminant Impact Assessment Field Operations Manual (Bight '13 Contaminant Impact Assessment Committee 2013a). Stations were located by global positioning system (GPS) via Android tablet, or input via the research vessel's differential global positioning system (DGPS). If a station could not be trawled or was too deep, it was relocated up to 100 meters from the nominal location (not to exceed 10% of the nominal station depth).

Samples were collected with 7.6-m head-rope semi-balloon otter trawls with a 1.3 cm cod-end mesh. Trawls were towed along isobaths for 10 minutes (5-10 minutes in Bays & Harbors) at 0.8-1.0 m/sec (1.5-2 kts) as determined by GPS/DGPS. These tows covered an estimated distance of 300 and 600 m for 5- and 10-minute trawls, respectively (Bight '13 Contaminant Impact Assessment Committee 2013a). Agencies used a pressure-temperature (PT) sensor attached to one of the otter trawl boards throughout the survey to provide net on-bottom data. Stations were re-trawled if the on-bottom time, as measured by the PT sensor, was less than 8 minutes.

### Processing the Fish and Invertebrate Catch

Fish and megabenthic invertebrates from the trawls were identified and processed. Allowable invertebrates included megabenthic species with a minimum dimension of 1 cm; specimens less than 1 cm were excluded from the analysis. Other excluded species were pelagic, infaunal, and colonial, as well as unattached fish parasites (e.g., leeches, cymothoid isopods).

Fishes and invertebrates were identified, individuals were counted, and species were batch-weighed to the nearest 0.1 kg using spring scales. Species weighing less than 0.1 kg were recorded as "<0.1 kg". These <0.1 kg species were then weighed together with all other <0.1 kg specimens from the same sample to provide a composite weight for fishes and a separate composite weight for invertebrates. These weights were then used to calculate the total biomass of the fish and invertebrate catches.

Lengths of individual fish were measured to centimeter size class on measuring boards. Bony fish were measured for standard length (anterior tip of head to end of caudal peduncle at the posterior border of the hypural plate). Cartilaginous fish size measurements were total lengths, from the anterior end of the head to the posterior end of the tail. In addition, wingspan was measured for skates and stingrays.

Each organism was also examined for gross external anomalies. Targeted fish anomalies included fin erosion, tumors, external parasites, ambicoloration, albinism, diffuse pigmentation, skeletal deformities, and lesions. Targeted invertebrate anomalies included burnspot disease, echinoderm wasting disease, structural deformities, and external parasites.

It should be noted that over 3,300 individual fish were not measured for size class, nor examined for occurrence of health anomalies. These fish are not included in the results for either measurement. The abundance of these individuals was estimated using an aliquot method and did not have a size estimation, nor health assessment component. Two of the species not measured were in the top 10 for abundance. These included one sample each of California Lizardfish (over 1,700 in the Middle Shelf) and Halfbanded Rockfish (over 1,450 in the Middle Shelf). A third species so treated was the Slough Anchovy (155 individuals in the Bays & Harbors stratum).

Voucher specimens, fish, and invertebrate specimens of unknown identity, and those with anomalies that required further examination 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. At least one voucher specimen of each species captured by each agency was retained to confirm identifications.

## Laboratory Methods: Sample Preservation for Collections

Retained fish and invertebrate samples that were taken as voucher or FID specimens were preserved in the field with buffered formalin, transferred to water in the laboratory, then to 70% ethyl alcohol for final storage according to standard methods described in the Contaminant Impact Assessment Field Operations Manual (Bight '13 Contaminant Impact Assessment Committee, 2013a).

## Information Management

### Field Computer System

An Android tablet-based Field Data System application was developed for Bight'13. The system facilitated the collection of required station occupation and field sampling event information by providing data entry templates. The tablet application used internal GPS and produced files suitable for Bight '13 IM-compatible submission. For those who were not able to use an Android tablet, a Microsoft Access-based field computer system was redesigned for the Bight '13 regional survey based on the systems used during the Bight '03 and Bight '08 surveys. Similar in function to the Android-based application, it stored the data in a database application, received direct input from DGPS, and exported files suitable for electronic submission. Those agencies not opting to use either system or those that experienced computer problems used standard data forms found in the field operations manual and manually entered the data.

### Data Submittal

Sampling agencies submitted their data electronically to a centralized SCCWRP database. Submitted datasets were provided to the Bight '13 Trawl Report Committee for review, QC checks, and analysis.

## Data Analyses

Most data analysis methods are similar to those used in previous regional sampling reports (Allen et al. 1998, 2002, 2007, 2011). Unless otherwise noted, analyses were performed using R 3.3.2 (R Core Team 2015) using the following packages: reshape2 (Wickham 2007), ggplot2 (Wickham 2009), plyr (Wickham 2011), isotone (de Leeuw et al. 2009), vegan (Oksanen et al. 2017), grid (R Core Team 2015), quantreg (Koenker 2016), scales (Wickham 2016), MASS (Venables and Ripley 2002), geoR (Ribeiro and Diggle 2016), gridExtra (Auguie 2016), Plotrix (Lemon 2006), PBSmapping (Schnute et al. 2015), gpclib (Peng et al. 2013), rgdal (Bivand et al. 2016), maptools (Bivand and Lewin-Koh 2017), lubridate (Grolemund and Wickham 2011), and clustsig (Whitaker and Christman 2014).

The condition of SCB habitat in 2013 was assessed using demersal fish and megabenthic invertebrate community metrics including abundance, biomass, and Shannon diversity (H') (Shannon 1948), and with population measures including fish size class and signs of disease. Biointegrity on the shelf was assessed using the Fish Response Index (FRI) (Allen et al. 2001). The FRI, a biointegrity index, was created as a tool for gauging anthropogenic impacts on fish assemblages in the SCB inhabiting soft-bottom habitats on the continental shelf in depths ranging from 9 to 215 m depth (Allen et al. 2001a). The FRI was calibrated and validated using almost 30 years of data around wastewater outfalls in depths between 20 and 215 m (Allen et al. 2001). The FRI was applied to all assemblages of the survey area except for the Upper Slope (201-500 m) stratum. FRI values ≤ 45 are indicative of reference or unimpacted conditions on the shelf. Because the depth of the origination dataset was limited to 215 m, the index cannot be used at depths greater than the outer shelf which extends to 200 m. The FRI is representative of generalized disturbance gradients; however, the purpose of this index is not meant to be indicative of fluctuations in the total standing stock of the fish species. Total standing stock can be influenced by, among other things, fishing pressure, habitat degradation, oceanographic conditions, etc. in addition to pollution. Assemblage analysis was determined based on Bray-Curtis dissimilarity.

### Description of Populations: Data Adjustments

As in the 2003 and 2008 regional surveys (Allen et al. 2007, Allen et al. 2011), some stations in the Bight'13 survey were trawled for 5 min rather than 10 min due to inadequate space in some bays or harbors. The approach used in Allen et al. (2007) was also used in the present study. The following two points were considered: 1) the time that the net was on the bottom during a trawl is uncertain (Diener and Rimer 1993), and 2) the distribution of the fishes and invertebrates in the trawl path varies by species, ranging from random to clumped. Through this analysis, it became clear that a 10-minute trawl had a higher catch than a 5-minute trawl. To account for this, fish and invertebrate abundance and biomass values for 5-minute trawls were adjusted to 10-minute trawl values by doubling the 5-minute trawl values. Numbers of fish and invertebrate species between 5- and 10-minute trawls were adjusted by multiplying species values by 1.4. This latter adjustment was used for calculating mean values for each stratum as was used in previous Bight survey reports (Allen et al. 2007, Allen et al. 2011). However, to determine the total species in a stratum, unadjusted species (or taxa) counts were used. This approach was also used to perform the diversity index calculations.

#### Multivariate Analyses: Ordination and nMDS

Demersal fish and megabenthic invertebrate community composition among the different strata and changes over time were evaluated using non-metric Multi-Dimensional Scaling (nMDS) ordination of Bray-Curtis similarity values calculated using abundance data which were log(x+1) transformed in order to achieve a normal distribution. Multivariate analyses were conducted using the Vegan package in R (Oksanen et al. 2017).

### Quality Assurance/Quality Control Procedures

A Quality Assurance/Quality Control (QA/QC) plan was developed to ensure comparability among participating organizations within the survey. QA/QC activities included an intercalibration cruise for taxonomists, a taxonomy proficiency examination on common trawl fish and invertebrate species, an on-board field audit, on-board rechecks of species measurements, and a post-survey taxonomic review of voucher specimens. Other QA/QC checks involved checking actual station data relative to nominal survey design strata. Detailed standardized field protocols and QA/QC procedures are described in the Contaminant Impact Assessment QA Manual (Bight ’13Contaminant Impact Assessment Committee, 2013b) and Field Operations Manual (Bight ’13Contaminant Impact Assessment Committee, 2013a). QA/QC results are presented in Appendix A.

## III. Results

### SCB Soft-Bottom Habitat Condition in 2013

#### Community Attributes – Demersal Fishes

A total of 75,383 fishes was collected during Bight ’13 (Appendix B-1), with an overall median abundance of 278 individuals per trawl (Appendix B-2). The number of fishes collected per haul ranged from 1 to 3,088. Median abundance ranged from 201 individuals per haul (Upper Slope) to 604 individuals per haul (Outer Shelf) (Figure III-1, Table III-1, Appendix B-2). Fish biomass yielded 1,943 kg over the entire survey (Appendix B-3). Median biomass was highest in the Bays & Harbors (14.4 kg) and lowest on the Inner Shelf (4.6 kg) (Figure III-1, Table III-1, Appendix B-3). Median fish diversity was highest on the Middle Shelf (1.75 per haul) and ranged from 1.26 to 1.47 over the rest of the SCB (Figure III-1, Table III-1, Appendix B-4). There was no clear pattern in fish diversity (H’) along the north to south gradient of the coast (Figure III-2). A total of 127 demersal fish species were collected during the survey. Median fish species richness (measured as the number of species per haul) was highest on the Middle and Outer Shelf (16 and 15 species per haul, respectively) (Appendix B-5).

During Bight ’13, FRI scores ranged from -1.1 to 61, with an overall median of 26.6 across the SCB shelf (Figure III-1, Appendix B-6). The median FRI score was ≤ 45 (reference condition) throughout the SCB shelf, with 93% of the area measured in reference condition (Table III-1, Appendix B-6). The amount of area in reference condition increased with depth on the shelf, ranging from 83.2% in Bays & Harbors to 99% on the Outer Shelf. Non-reference fish communities were present, but rare in the SCB, comprising only 7% of the area measured (10 stations). The impacted stations were distributed throughout the SCB as follows: four stations located in the northern region between Point Dume and Point Conception, one station located northwest of Palos Verdes, two stations located within the Los Angeles and Long Beach harbors, one station located off Mission Bay, and two stations located within San Diego Bay (Figure III-3). Additionally, the proportion of impacted area differed by shelf stratum. Of the non-reference stations, most were in the Bays & Harbors stratum (17% of the stratum area) and Inner Shelf stratum (14% of the stratum area) (Figure III-3, Table III-1, Appendix B-6).

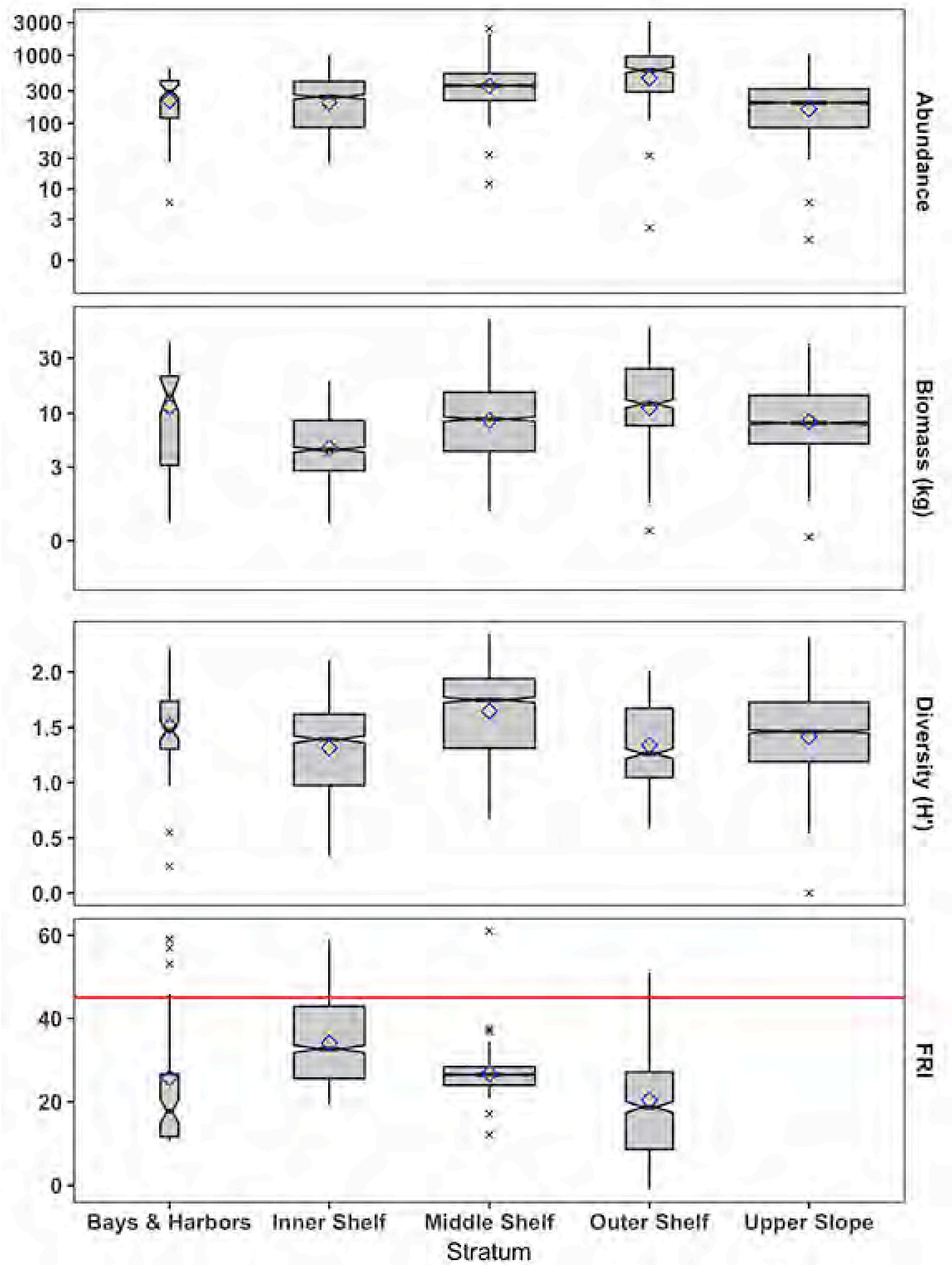



**Figure III-1. Area-Weighted Demersal Fish Community Metrics by Stratum: Abundance, Biomass, Diversity (H'), and Fish Response Index (FRI) during the Bight '13 trawl survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size (see Table II-1). For FRI, red line represents maximum FRI score (45) associated with a reference community; FRI not applicable at Upper Slope depths.**

**Table III-1. Area-Weighted Demersal Fish Community Metrics by Stratum: Abundance, Biomass, Diversity, Species Richness, and Fish Response Index (FRI) during the Bight '13 trawl survey. FRI score of 45 or less associated with a reference community; FRI not applicable at Upper Slope depths.**

| | | *Abundance* | | | | | *Biomass* | | | | | *Diversity* | | | | *Species Richness* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **N Trawls** | **Min** | **Median** | **Mean** | **Max** | **Total** | **Min** | **Median** | **Mean** | **Max** | **Total** | **Min** | **Median** | **Mean** | **Max** | **Min** | **Median** | **Mean** | **Max** | **Total** |
| All Strata | 165 | 1 | 278 | 389 | 3,088 | 75,383 | 0.1 | 8.1 | 11.0 | 64.2 | 1,943 | 0.00 | 1.49 | 1.44 | 2.35 | 1 | 12 | 12.1 | 25 | 127 |
| Bays & Harbors | 26 | 6 | 294 | 292 | 652 | 8,239 | 0.4 | 14.4 | 14.3 | 40.8 | 407 | 0.24 | 1.47 | 1.43 | 2.22 | 4 | 8 | 9.0 | 15 | 41 |
| Inner Shelf | 35 | 25 | 245 | 323 | 1,013 | 10,711 | 0.4 | 4.5 | 5.6 | 19.1 | 202 | 0.33 | 1.39 | 1.31 | 2.11 | 4 | 10 | 10.1 | 18 | 48 |
| Middle Shelf | 43 | 12 | 359 | 512 | 2,446 | 22,674 | 0.7 | 8.8 | 11.8 | 64.2 | 495 | 0.67 | 1.75 | 1.65 | 2.35 | 5 | 16 | 15.5 | 25 | 66 |
| Outer Shelf | 29 | 2 | 604 | 791 | 3,088 | 24,500 | 0.2 | 12.1 | 16.0 | 54.5 | 456 | 0.59 | 1.26 | 1.34 | 2.01 | 2 | 15 | 14.3 | 21 | 50 |
| Upper Slope | 32 | 1 | 201 | 280 | 1,071 | 9,259 | 0.1 | 8.2 | 11.5 | 40.1 | 382 | 0.00 | 1.46 | 1.39 | 2.32 | 1 | 10 | 10.5 | 24 | 54 |

| | | *FRI* | | | | | |
|---|---|---|---|---|---|---|---|
| | **N Trawls** | **Min** | **Median** | **Mean** | **Max** | **Percent Reference Sites** | **Percent Reference Area** |
| All Strata | 165 | -1.1 | 26.6 | 28.4 | 61.0 | 92.5 | 93.3 |
| Bays & Harbors | 26 | 10.6 | 17.7 | 24.6 | 59.0 | 84.6 | 83.2 |
| Inner Shelf | 35 | 19.2 | 32.7 | 34.2 | 58.8 | 88.6 | 85.8 |
| Middle Shelf | 43 | 12.1 | 26.5 | 27.5 | 61.0 | 97.7 | 96.6 |
| Outer Shelf | 29 | -1.1 | 18.7 | 19.6 | 50.9 | 96.6 | 99 |
| Upper Slope | 32 | | | | | | |

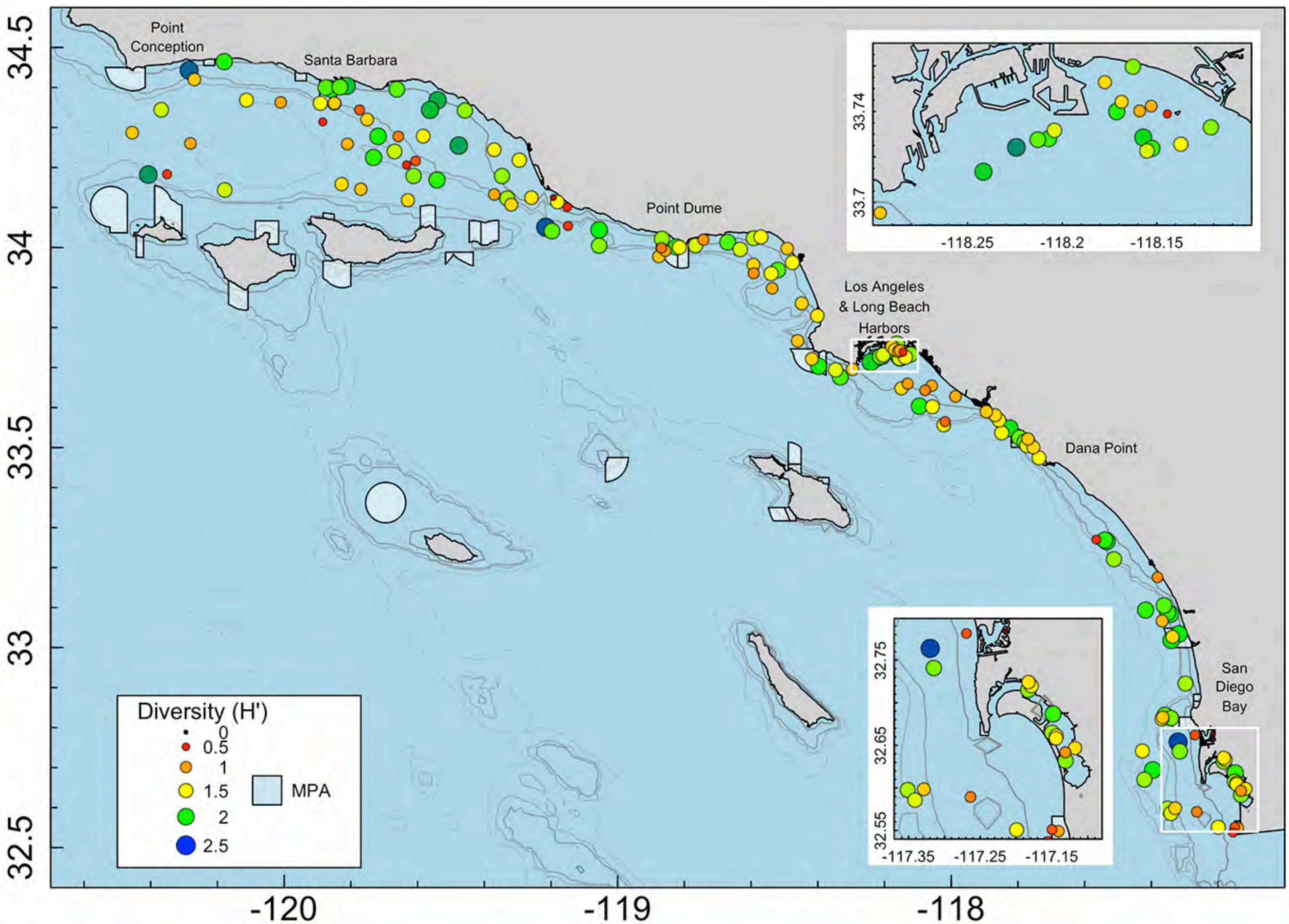



**Figure III-2. Demersal fish diversity (H') per haul during the Bight '13 trawl survey.**

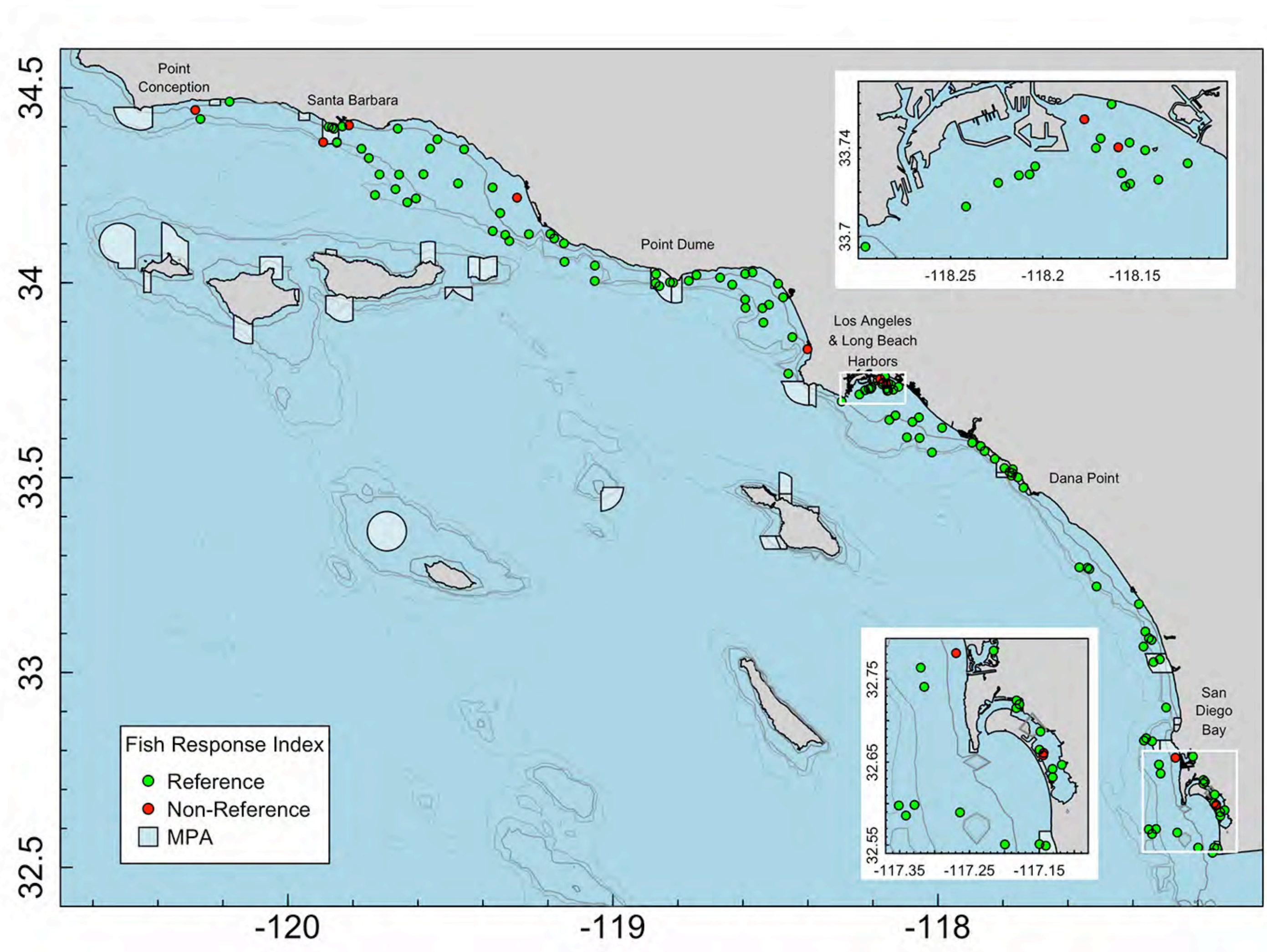



**Figure III-3. Reference and Non-Reference stations as measured by the Fish Response Index (FRI) during the Bight '13 trawl survey. An FRI score less than 45 is associated with a fish community in reference condition.**

### Community Attributes – Megabenthic Invertebrates

A total of 165,870 individuals were taken during the Bight ’13 survey (Appendix B-7). Overall, median invertebrate abundance was 855 individuals per haul (Figure III-4, Table III-2, Appendix B-8). Abundance increased with depth, ranging from a median value of 37 individuals per haul in Bays & Harbors to 2,240 individuals per haul on the Upper Slope (Figure III-4, Appendix B-8). Invertebrates yielded 2,765 kg of biomass, with an overall median of 10.3 kg per haul (Appendix B-9). As with abundance, the median yields were lowest in the Bays & Harbors (1.8 kg per haul) and Inner Shelf (1.1 kg per haul) strata, and then increased with depth to 41.5 kg per haul on the Upper Slope (Figure III-4). Compared to invertebrate abundance and biomass, median invertebrate diversity (H’) values were much less variable across the different strata, ranging from 0.82 per haul on the Upper Slope to 1.39 on the Inner Shelf (Appendix B-10). As with demersal fishes, there was no clear pattern in invertebrate diversity by depth or latitude along the SCB coast (Figure III-5). Species richness ranged from 2 to 29 invertebrate species per haul, with an overall median value of 10 species per haul across the SCB (Appendix B-11). Median species richness for each stratum ranged from a low of 5 species per haul in Bays & Harbors to a high of 16 species per haul on the Outer Shelf.

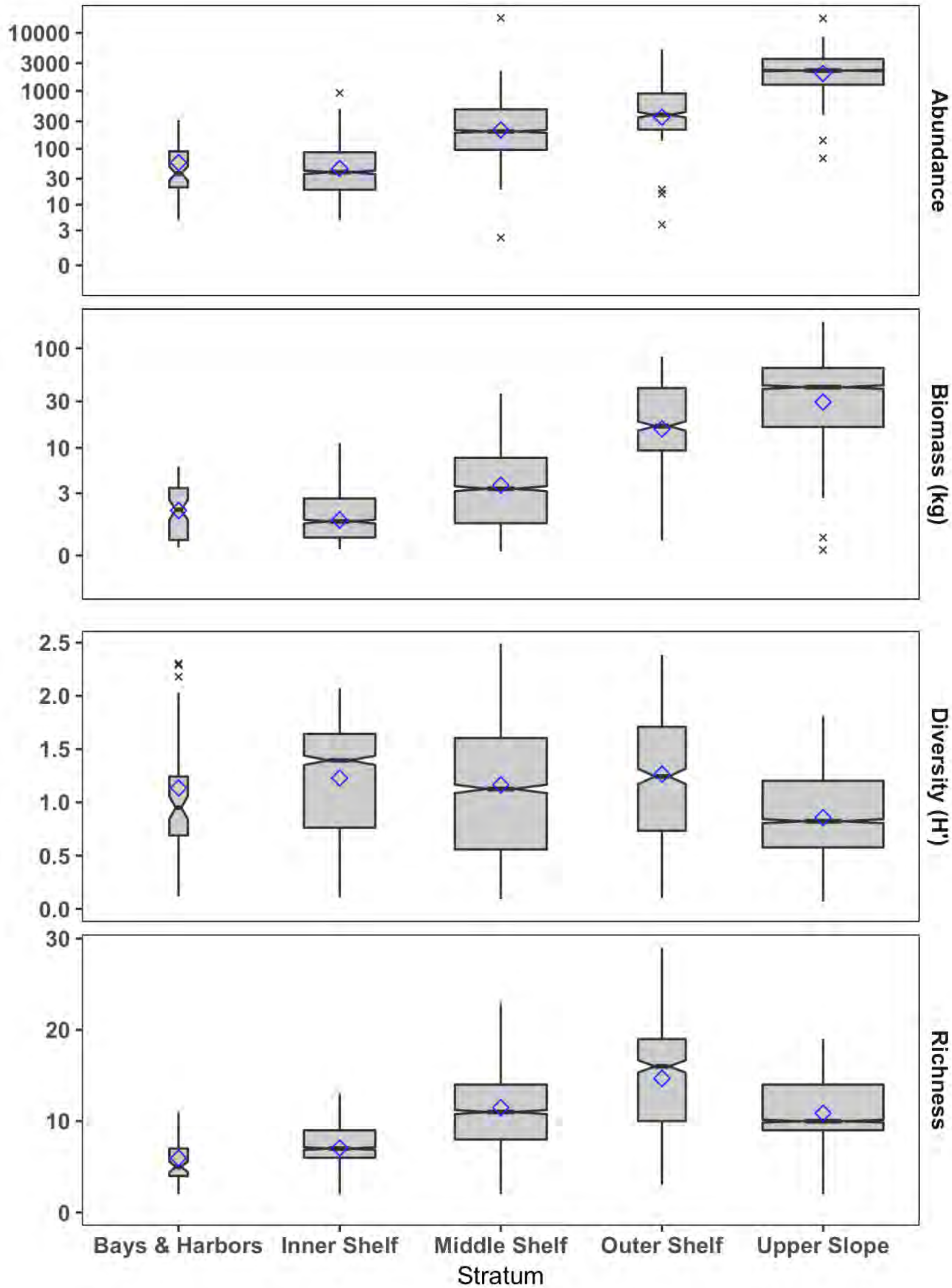



**Figure III-4. Area-Weighted Megabenthic Invertebrate Community Metrics by Stratum: Abundance, Biomass, Diversity (H'), and Species Richness during the Bight '13 trawl survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size (see Table II-1).**

**Table III-2. Area-Weighted Megabenthic Invertebrate Community Metrics by Stratum: Abundance, Biomass, Diversity (H'), and Species Richness during the Bight '13 trawl survey.**

| | | *Abundance* | | | | | *Biomass* | | | | | *Diversity* | | | | *Species Richness* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **N Trawls** | **Min** | **Median** | **Mean** | **Max** | **Total** | **Min** | **Median** | **Mean** | **Max** | **Total** | **Min** | **Median** | **Mean** | **Max** | **Min** | **Median** | **Mean** | **Max** | **Total** |
| All Strata | 165 | 2 | 855 | 1,929 | 17,973 | 165,870 | 0 | 10 | 28 | 182 | 2,765 | 0.07 | 1.02 | 1.04 | 2.49 | 2 | 10 | 10.7 | 29 | 229 |
| Bays/Harbors | 26 | 5 | 37 | 80 | 316 | 2,559 | 0 | 2 | 2 | 6 | 58 | 0.12 | 0.95 | 1.08 | 2.30 | 2 | 5 | 5.7 | 11 | 53 |
| Inner Shelf | 35 | 5 | 39 | 89 | 921 | 3,443 | 0 | 1 | 2 | 11 | 58 | 0.11 | 1.39 | 1.25 | 2.07 | 2 | 7 | 7.0 | 13 | 66 |
| Middle Shelf | 43 | 2 | 200 | 1,052 | 17,973 | 34,678 | 0 | 3 | 5 | 36 | 261 | 0.09 | 1.13 | 1.12 | 2.49 | 2 | 11 | 11.6 | 23 | 107 |
| Outer Shelf | 29 | 4 | 388 | 718 | 5,160 | 23,338 | 0 | 17 | 27 | 83 | 780 | 0.10 | 1.24 | 1.26 | 2.39 | 3 | 16 | 14.8 | 29 | 76 |
| Upper Slope | 32 | 68 | 2,240 | 3,307 | 17,600 | 101,852 | 0 | 42 | 51 | 182 | 1,608 | 0.07 | 0.82 | 0.89 | 1.81 | 2 | 10 | 11.0 | 19 | 83 |

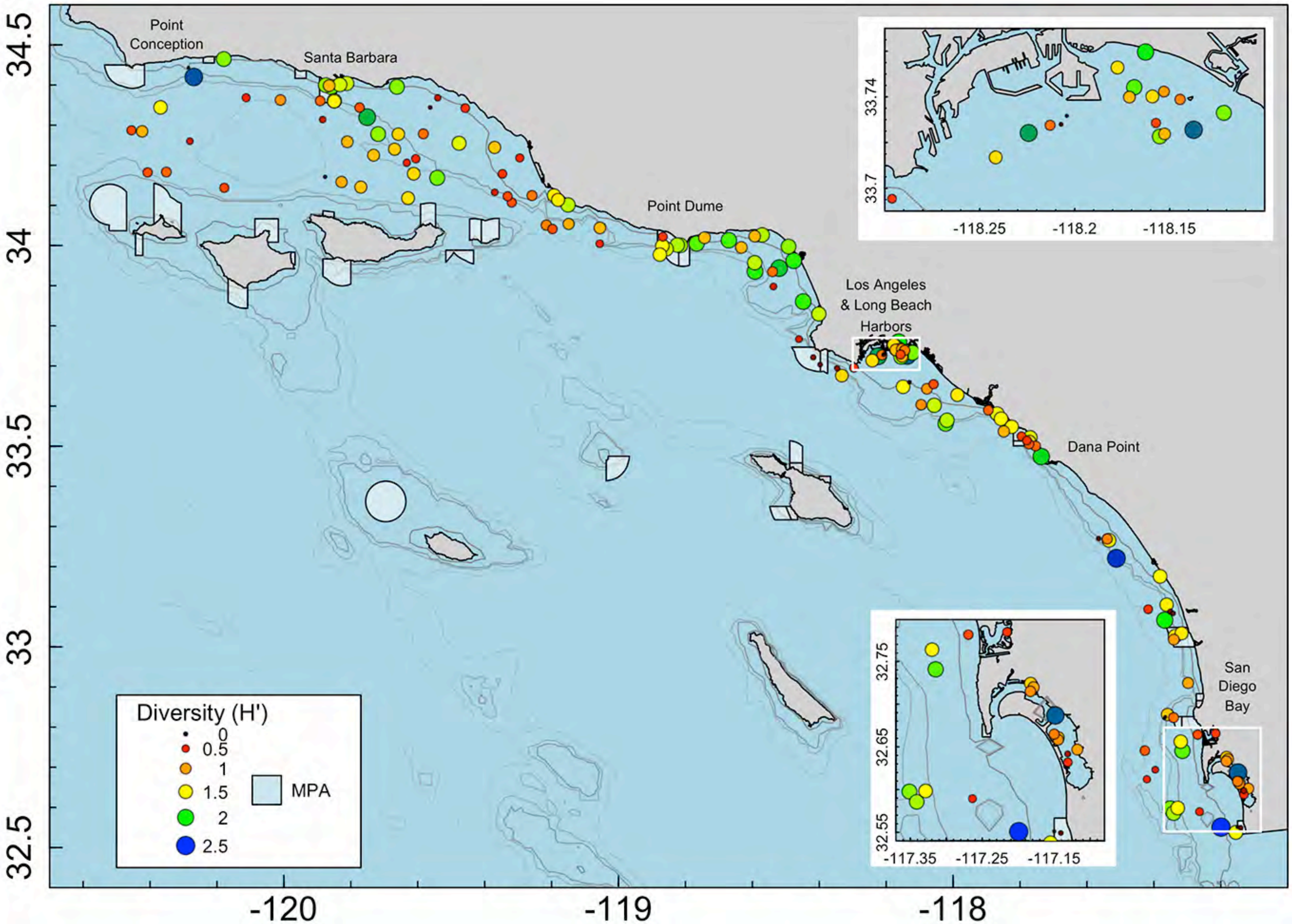



**Figure III-5. Megabenthic invertebrate diversity (H') per haul during Bight '13 trawl survey.**

## Population Attributes – Demersal Fishes

A total of 127 fish taxa, some of which were not identified to species level, were collected during Bight '13, representing 44 families (Appendix B-1 and B-12). Ten of these families accounted for 95% of the total abundance (Paralichthyidae, Synodontidae, Pleuronectidae, Scorpaenidae, Hexagrammidae, Sciaenidae, Cottidae, Zoarcidae, Engraulidae, Agonidae). Five species accounted for about 64% of the total fish abundance: Pacific Sanddab, California Lizardfish, Speckled Sanddab, Dover Sole, and Slender Sole (Table III-3). The highest number of Pacific Sanddab (12,511 individuals) was collected on the Outer Shelf, where it was the most abundant species (Appendix B-12). Pacific Sanddab also occurred in relatively high numbers on the Inner Shelf, Middle Shelf, and Upper Slope. In contrast, this species was absent from Bays & Harbors. The highest number of California Lizardfish was found on the Middle Shelf, followed by the Inner Shelf, and Bays & Harbors. Although California Lizardfish was the most abundant species collected from the Bays & Harbors and Middle Shelf strata, its abundances were comparatively low on the Outer Shelf and Upper Slope. The highest number of Speckled Sanddab was collected on the Inner Shelf where it was the most abundant species collected. Speckled Sanddabs were also collected from Bays & Harbors and Middle Shelf, while this species was absent from the Outer Shelf and Upper Slope. Dover Sole was the second most abundant species on the Outer Shelf and Upper Slope; this species also occurred on the Middle Shelf, but was absent from the Inner Shelf and Bays & Harbors. Slender Sole was the most abundant species captured on the Upper Slope and also occurred in high numbers on the Outer Shelf. However, this species was rare on the Middle Shelf and as with Dover Sole, Slender Sole was absent from the Inner Shelf and Bays & Harbors.

As with abundance, relatively few fish species dominated the overall biomass. The top five species ranked by biomass included Pacific Sanddab, California Lizardfish, White Croaker, Slender Sole, and Dover Sole (Table III-3). Together, these five species accounted for 54% of the total fish biomass (Appendix B-13). A total of 395 kg of Pacific Sanddab was collected during Bight '13, 53% of which was collected on the Outer Shelf and reflected the numerical dominance of this species at those stations. California Lizardfish biomass ranged from 0.1 kg on the Upper Slope to 86 kg in Bays & Harbors, and dominated fish biomass on the Inner Shelf. White Croaker, ranked eighth in total abundance, was ranked third in fish biomass, most of which was collected in Bays & Harbors (96%) where it had the highest biomass of all fishes.

Dover Sole, English Sole and Pacific Sanddab were the most frequently occurring species, each being present in over half of the trawl samples (Appendix B-14). In Bays & Harbors, California Halibut occurred in 73% of trawl samples, followed by California Tonguefish. On the Inner Shelf, Speckled Sanddab and California Lizardfish were most common, both occurring in 96% of trawls, followed by Hornyhead Turbot (77%), English Sole (62%), and Fantail Sole (62%). The most common species on the Middle Shelf was the Pacific Sanddab, occurring in 97% of trawls in that stratum, followed by English Sole (93%) and California Lizardfish (92%). Dover Sole, Pacific Sanddab, and Shortspine Combfish were the three most common species on the Outer Shelf, with each occurring in 96% of the trawls, followed by Slender Sole, occurring in 85% of the trawls in that stratum. On the Upper Slope, Dover Sole and Slender Sole occurred in 90% of the samples, followed by Pacific Hake, which occurred in 73% of the trawls in that stratum.

**Table III-3. Abundance of top 10 demersal fish species in each stratum collected during the Bight '13 trawl survey. Table sorted by abundance rank. Shaded areas indicate species was top ten most abundant in a given stratum.**

| | | | | | *Abundance* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Common Name** | **Family** | **Abundance Rank** | **Biomass Rank** | **Freq. of Occurrence Rank** | **Southern California Bight** | **Bays & Harbors** | **Inner Shelf** | **Middle Shelf** | **Outer Shelf** | **Upper Slope** |
| Pacific Sanddab | Paralichthyidae | 1 | 1 | 3 | 19,004 | – | 373 | 5,232 | 12,511 | 888 |
| California Lizardfish | Synodontidae | 2 | 2 | 5 | 13,434 | 3,290 | 3,758 | 6,280 | 103 | 3 |
| Speckled Sanddab | Paralichthyidae | 3 | 9 | 12 | 5,437 | 330 | 4,386 | 721 | – | – |
| Dover Sole | Pleuronectidae | 4 | 5 | 1 | 5,045 | – | – | 122 | 3,709 | 1,214 |
| Slender Sole | Pleuronectidae | 5 | 4 | 4 | 5,040 | – | – | 1 | 2,015 | 3,024 |
| Longspine Combfish | Hexagrammidae | 6 | 11 | 8 | 2,560 | 116 | 89 | 2,291 | 29 | 35 |
| Halfbanded Rockfish | Scorpaenidae | 7 | 8 | 31 | 2,440 | – | – | 1,925 | 240 | 275 |
| White Croaker | Sciaenidae | 8 | 3 | 75 | 2,324 | 2,048 | 273 | 3 | – | – |
| Splitnose Rockfish | Scorpaenidae | 9 | 12 | 19 | 2,206 | – | – | – | 1,638 | 568 |
| Yellowchin Sculpin | Cottidae | 10 | 29 | 13 | 2,070 | 16 | 306 | 1,748 | – | – |
| Stripetail Rockfish | Scorpaenidae | 11 | 13 | 10 | 1,916 | – | 5 | 1,035 | 678 | 198 |
| Blackbelly Eelpout | Zoarcidae | 12 | 15 | 29 | 1,314 | – | 2 | 19 | 1,134 | 159 |
| Shortspine Combfish | Hexagrammidae | 13 | 16 | 14 | 1,270 | – | – | 55 | 1,073 | 142 |
| English Sole | Pleuronectidae | 14 | 6 | 2 | 827 | – | 114 | 469 | 204 | 40 |
| Blacktip Poacher | Agonidae | 15 | 30 | 17 | 773 | – | – | 2 | 326 | 445 |
| California Tonguefish | Cynoglossidae | 16 | 23 | 9 | 703 | 271 | 107 | 325 | – | – |
| Slough Anchovy | Engraulidae | 17 | 89 | 108 | 697 | 697 | – | – | – | – |
| Pink Seaperch | Embiotocidae | 18 | 27 | 15 | 617 | – | 22 | 588 | 6 | 1 |
| Curlfin Sole | Pleuronectidae | 19 | 34 | 21 | 410 | 4 | 263 | 140 | 3 | – |
| Queenfish | Sciaenidae | 20 | 37 | 107 | 409 | 408 | 1 | – | – | – |
| Bearded Eelpout | Zoarcidae | 21 | 45 | 20 | 404 | – | – | 1 | 56 | 347 |
| Longfin Sanddab | Paralichthyidae | 22 | 17 | 25 | 394 | – | 52 | 342 | – | – |
| Vermilion Rockfish | Scorpaenidae | 23 | 28 | 32 | 389 | – | 174 | 215 | – | – |
| Hornyhead Turbot | Pleuronectidae | 24 | 14 | 7 | 350 | 30 | 178 | 131 | 11 | – |
| Rubynose Brotula | Bythitidae | 25 | 40 | 41 | 336 | – | – | – | – | 336 |
| Deepbody Anchovy | Engraulidae | 26 | 74 | 108 | 322 | 322 | – | – | – | – |
| unidentified pipefish | Syngnathidae | 28 | 53 | 37 | 280 | 10 | 264 | 4 | 1 | 1 |
| Black Eelpout | Zoarcidae | 30 | 36 | 49 | 244 | – | – | – | – | 244 |
| Round Stingray | Urotrygonidae | 35 | 7 | 99 | 176 | 176 | – | – | – | – |
| Specklefin Midshipman | Batrachoididae | 39 | 39 | 56 | 135 | 122 | 9 | 4 | – | – |

### Population Attributes – Megabenthic Invertebrates

A total of 229 megabenthic invertebrate taxa, some of which were not identified to species level, were encountered during Bight '13, representing 120 families (Appendix B-7, B-11). Invertebrates had a much more stratified depth distribution than fishes, and dominant taxa differed among depth strata. Nearly half of the total invertebrate catch of 165,870 individuals was contributed by the three most abundant taxa (Table III-4), all of which were echinoderms. In fact, the eight most abundant invertebrate species were all echinoderms, including the sea urchins *Brisaster townsendi*, *Strongylocentrotus fragilis* (known as *Allocentrotus fragilis* in historical data), *Brissopsis pacifica*, *Lytechinus pictus*, and *Brisaster* sp, the brittle stars *Ophiura luetkenii* and *Asteronyx longifissus*, and the sea star *Myxoderma platyacanthum* (Table III-4).

Seven of the top 10 invertebrate species were most abundant on the Upper Slope. Of those, only the sea star *Myxoderma platyacanthum*, brittle-star *Asteronyx longifissus*, and *Astyris permodesta*, a gastropod mollusk which was ninth most abundant, were restricted to the Upper Slope (Appendix B-7). A crustacean, the shrimp *Pandalus jordani*, was the tenth most abundant species (Table III-4).

The top taxa, measured as those with highest abundance, were diverse. Echinoderms figured prominently, with 16 of the 33 most abundant species in that phylum. The two most abundant species were both sea urchins; the irregular urchin *Brisaster townsendi* representing nearly 20% of the total catch for Bight'13, and the regular urchin *Strongylocentrotus fragilis* that comprised nearly 15% of the total invertebrate catch.

In the Bays & Harbors stratum, two shrimp were clear abundance dominants: *Sicyonia ingentis* and *S. penicillata*, the latter which is typically an El Niño visitor from the south and was the most abundant invertebrate species in these shallow trawls (i.e., nearly half the total catch abundance) (Appendix B-7). Other prominent crustaceans included the shrimp *Crangon nigromaculata*, and the crab *Pyromaia tuberculata*. Several other major phyla were also prominent, if less abundant, including the mollusks *Musculista senhousia*, *Philine auriformis* and *Octopus rubescens*, the cnidarian *Epiactis prolifera*, and the silicean sponge *Tetilla* sp (Appendix B-7). Some taxa which were among the most abundant in this stratum, including *Musculista senhousia, Epiactis prolifera*, *Tetilla* sp., were not collected in other strata.

On the Inner Shelf, nearly three-fourths of the total abundance was concentrated in two species: the sea star *Astropecten californicus* (*A. verrilli* in earlier reports) and the shrimp *Crangon nigromaculata* (Appendix B-7). The Middle Shelf depth zone was even more heavily dominated by just a few species, with the brittle-star *Ophiura luetkenii* alone being nearly 63% of the total catch. Adding the numbers of the sea urchin *Lytechinus pictus*, the second most abundant species in this stratum, the top two species comprised over 86 % of the catch at these depths. On the Outer Shelf, sea urchins again dominated, with three of the four most abundant species and nearly 54% of total catch. An anomalous large catch of 4,180 individuals of the pink shrimp *Pandalus jordani* at a single station in the northern Santa Barbara Channel ranked that species second in abundance for this stratum.

On all three shelf strata the most abundant species were evenly distributed among groups, although crustaceans and echinoderms shared numerical dominance in each shelf stratum. In contrast, echinoderms were the clear dominants on the Upper Slope, representing 6 of the 10 most abundant taxa. No one family dominated abundance across the different strata (Table III-4,

Appendix B-7), although sea urchins of several families came closest, particularly on the Upper Slope. Invertebrate abundance at these deeper depths was several times that of any of the other four strata, due nearly entirely to echinoderms. The most abundant species in Bight '13 trawls, the sea urchin *Brisaster townsendi*, had over 99% of its individuals on the Upper Slope (Table III-4, Appendix B-7). Second ranked *Strongylocentrotus fragilis* had 67% of its populations there, and fourth ranked sea urchin *Brissopsis pacifica,* 97%. Numerical dominance was less concentrated on the Upper Slope than on the shelf strata, with the top two species contributing just over 46% of the total catch.

The relative importance of abundance and biomass were rarely the same for a species, but most had similar patterns in the two parameters (Table III-4, Appendix B-7, Appendix B-15). Nearly 70% of total invertebrate biomass was contributed by five invertebrate species, which included *Strongylocentrotus fragilis*, *Brisaster townsendi*, and *Brissopsis pacifica,* previously noted for high abundance, plus the sea cucumber *Parastichopus californicus* and the shrimp *Pandalus platyceros*. Relative biomass importance tended to follow abundance, except for a couple of species such as the brittle-star *Ophiura luetkenii*, which ranked high in overall abundance, but was only moderately ranked in total biomass (Table III-4). The opposite relationship occurred with *Parastichopus californicus*, which was not remarkably abundant, but ranked among the top species in total biomass.

Those species most widely distributed in the Bight '13 catch were three predatory mollusks (*Pleurobranchaea californica*, *Octopus rubescens*, and *Octopus californicus*) and six echinoderms (*Luidia foliolata*, *Brissopsis pacifica*, *Astropecten californicus*, *Brisaster townsendi*, *Strongylocentrotus fragilis*, and *Ophiura luetkenii*), which occurred in 27% to 62% of samples (Appendix B-16). Crustaceans were also well represented on the list, but ranked lower in frequency of occurrence, with the shrimp *Sicyonia ingentis* ranking 10$^{th}$ and occurring in 25% of the trawl samples. Sponges and cnidarians rounded out the list of those taxa most broadly distributed. Many of these species were restricted to particular depth strata, with only the shrimp *Sicyonia ingentis*, the brittle star *Ophiothrix spiculata*, and the octopus *Octopus rubescens* occurring in all five strata (Appendix B-16).

**Table III-4. Abundance of top 10 megabenthic invertebrate species in each stratum collected during the Bight '13 trawl survey. Table sorted by abundance rank. Shaded areas indicate species was top ten most abundant in a given stratum.**

| | | | | | *Abundance* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Scientific Name** | **Phylum:Family** | **Abundance Rank** | **Biomass Rank** | **Freq. of Occurrence Rank** | **Southern California Bight** | **Bays & Harbors** | **Inner Shelf** | **Middle Shelf** | **Outer Shelf** | **Upper Slope** |
| *Brisaster townsendi* | Echinodermata:Schizasteridae | 1 | 2 | 7 | 31,319 | – | – | – | 250 | 31,069 |
| *Strongylocentrotus fragilis* | Echinodermata:Strongylocentrotidae | 2 | 1 | 8 | 24,252 | – | – | – | 8,087 | 16,165 |
| *Ophiura luetkenii* | Echinodermata:Ophiuridae | 3 | 16 | 9 | 21,904 | – | 3 | 21,697 | 202 | 2 |
| *Brissopsis pacifica* | Echinodermata:Brissidae | 4 | 3 | 5 | 16,869 | – | – | – | 478 | 16,391 |
| *Myxoderma platyacanthum* | Echinodermata:Zoroasteridae | 5 | 8 | 11 | 14,905 | – | – | – | – | 14,905 |
| *Lytechinus pictus* | Echinodermata:Toxopneustidae | 6 | 24 | 12 | 8,321 | – | 77 | 8,137 | 107 | – |
| *Asteronyx longifissus* | Echinodermata:Asteronychidae | 7 | 17 | 21 | 7,550 | – | – | – | – | 7,550 |
| *Brisaster* sp | Echinodermata:Schizasteridae | 8 | 9 | 23 | 6,201 | – | – | – | 3,075 | 3,126 |
| *Astyris permodesta* | Mollusca:Columbellidae | 9 | 52 | 71 | 4,935 | – | – | – | – | 4,935 |
| *Pandalus jordani* | Arthropoda:Pandalidae | 10 | 11 | 181 | 4,180 | – | – | – | 4,180 | – |
| *Sicyonia ingentis* | Arthropoda:Sicyoniidae | 11 | 14 | 10 | 3,071 | 472 | 3 | 1,661 | 901 | 34 |
| *Spirontocaris holmesi* | Arthropoda:Hippolytidae | 12 | 41 | 19 | 3,008 | – | – | – | 788 | 2,220 |
| *Astropecten californicus* | Echinodermata:Astropectinidae | 13 | 32 | 6 | 1,928 | – | 1,588 | 334 | 5 | 1 |
| *Brisaster latifrons* | Echinodermata:Schizasteridae | 14 | 19 | 28 | 1,850 | – | – | – | 1,355 | 495 |
| *Sicyonia penicillata* | Arthropoda:Sicyoniidae | 15 | 13 | 25 | 1,491 | 1,208 | 54 | 229 | – | – |
| *Pandalus platyceros* | Arthropoda:Pandalidae | 16 | 5 | 30 | 1,258 | – | 1 | 16 | 433 | 808 |
| *Crangon nigromaculata* | Arthropoda:Crangonidae | 17 | 36 | 35 | 1,098 | 160 | 935 | 3 | – | – |
| *Luidia foliolata* | Echinodermata:Luidiidae | 18 | 7 | 4 | 1,007 | – | 3 | 409 | 236 | 359 |
| *Spatangus californicus* | Echinodermata:Spatangidae | 19 | 6 | 16 | 823 | – | – | 1 | 528 | 294 |
| *Neocrangon zacae* | Arthropoda:Crangonidae | 20 | 48 | 20 | 798 | – | – | 3 | 747 | 48 |
| *Pannychia moseleyi* | Echinodermata:Laetmogonidae | 21 | 18 | 33 | 670 | – | – | – | – | 670 |
| *Pleurobranchaea californica* | Mollusca:Pleurobranchidae | 22 | 12 | 1 | 664 | – | 7 | 253 | 241 | 163 |
| *Ophiothrix spiculata* | Echinodermata:Ophiotricidae | 23 | 51 | 17 | 568 | 10 | 52 | 485 | 20 | 1 |

**Table III-4 (cont.)**

| Scientific Name | Phylum:Family | Abundance Rank | Biomass Rank | Freq. of Occurrence Rank | *Abundance* Southern California Bight | Bays & Harbors | Inner Shelf | Middle Shelf | Outer Shelf | Upper Slope |
|---|---|---|---|---|---|---|---|---|---|---|
| *Octopus rubescens* | Mollusca:Octopodidae | 24 | 28 | 2 | 552 | 22 | 178 | 183 | 153 | 16 |
| *Parastichopus californicus* | Echinodermata:Stichopodidae | 26 | 4 | 14 | 412 | – | 5 | 344 | 62 | 1 |
| *Metacarcinus gracilis* | Arthropoda:Cancridae | 34 | 22 | 26 | 254 | 13 | 223 | 18 | – | – |
| *Thesea* sp B | Cnidaria:Plexauridae | 35 | 64 | 24 | 212 | – | 1 | 205 | 6 | – |
| *Pyromaia tuberculata* | Arthropoda:Inachoididae | 36 | 58 | 34 | 207 | 155 | 42 | 10 | – | – |
| *Octopus californicus* | Mollusca:Octopodidae | 40 | 25 | 3 | 156 | – | – | 1 | 56 | 99 |
| *Musculista senhousia* | Mollusca:Mytilidae | 41 | 102 | 179 | 134 | 134 | – | – | – | – |
| *Lopholithodes foraminatus* | Arthropoda:Lithodidae | 47 | 10 | 86 | 72 | – | – | – | 71 | 1 |
| *Epiactis prolifera* | Cnidaria:Actiniidae | 48 | 161 | 205 | 70 | 70 | – | – | – | – |
| *Astropecten armatus* | Echinodermata:Astropectinidae | 49 | 57 | 51 | 68 | 32 | 36 | – | – | – |
| *Pisaster brevispinus* | Echinodermata:Asteriidae | 53 | 26 | 43 | 45 | – | 44 | 1 | – | – |
| *Philine auriformis* | Mollusca:Philinidae | 54 | 83 | 61 | 43 | 34 | 2 | 6 | – | 1 |
| *Tetilla* sp | Silicea:Tetillidae | 62 | 35 | 195 | 33 | 33 | – | – | – | – |
| *Heptacarpus stimpsoni* | Arthropoda:Hippolytidae | 70 | 88 | 199 | 23 | 22 | – | 1 | – | – |

## Fish Species Size (Length) Distribution

The length-frequency distributions for each of the top 10 most abundant species during Bight '13 are shown in Figure III-6, and distributions for the most pollution-tolerant fish caught Bight '13 (based on high p-code scores used for the FRI; Allen et al. 2001) are shown in Figure III-7. Overall, fish lengths ranged from 2 to 103 cm standard length (Appendix B-1). Among the major strata, the most abundant fish species and the most pollution-tolerant fish were most abundant in the smaller size classes (<20 cm) (Figure III-6 and Figure III-7). Across all species, there was no single stratum that contained the largest fish. In general, length-frequency distributions were skewed to the right in each stratum. Although their abundances differed amongst strata, the lengths of many fish species did not differ greatly by stratum. There were some exceptions such as Dover Sole and Splitnose Rockfish that were larger on the Upper Slope than the Outer Shelf, and Stripetail Rockfish which was increasingly larger from the Middle Shelf to Upper Slope.

The top 10 most abundant fish species ranged from 2 to 35 cm in length (Figure III-6, Appendix B-1). Recent recruitment of small juveniles (as indicated by fish lengths of 5 cm or less) was apparent in 9 of the top 10 species (Figure III-6). Only Longspine Combfish individuals were all above 5 cm in length. The pollution-tolerant fish species, which ranged in size from 3 to 31 cm in length and included Calico Rockfish, Curlfin Sole, Stripetail Rockfish, and Vermilion Rockfish, had more juvenile recruits than the top 10 most abundant fish species (Figure III-7, Appendix B-1).

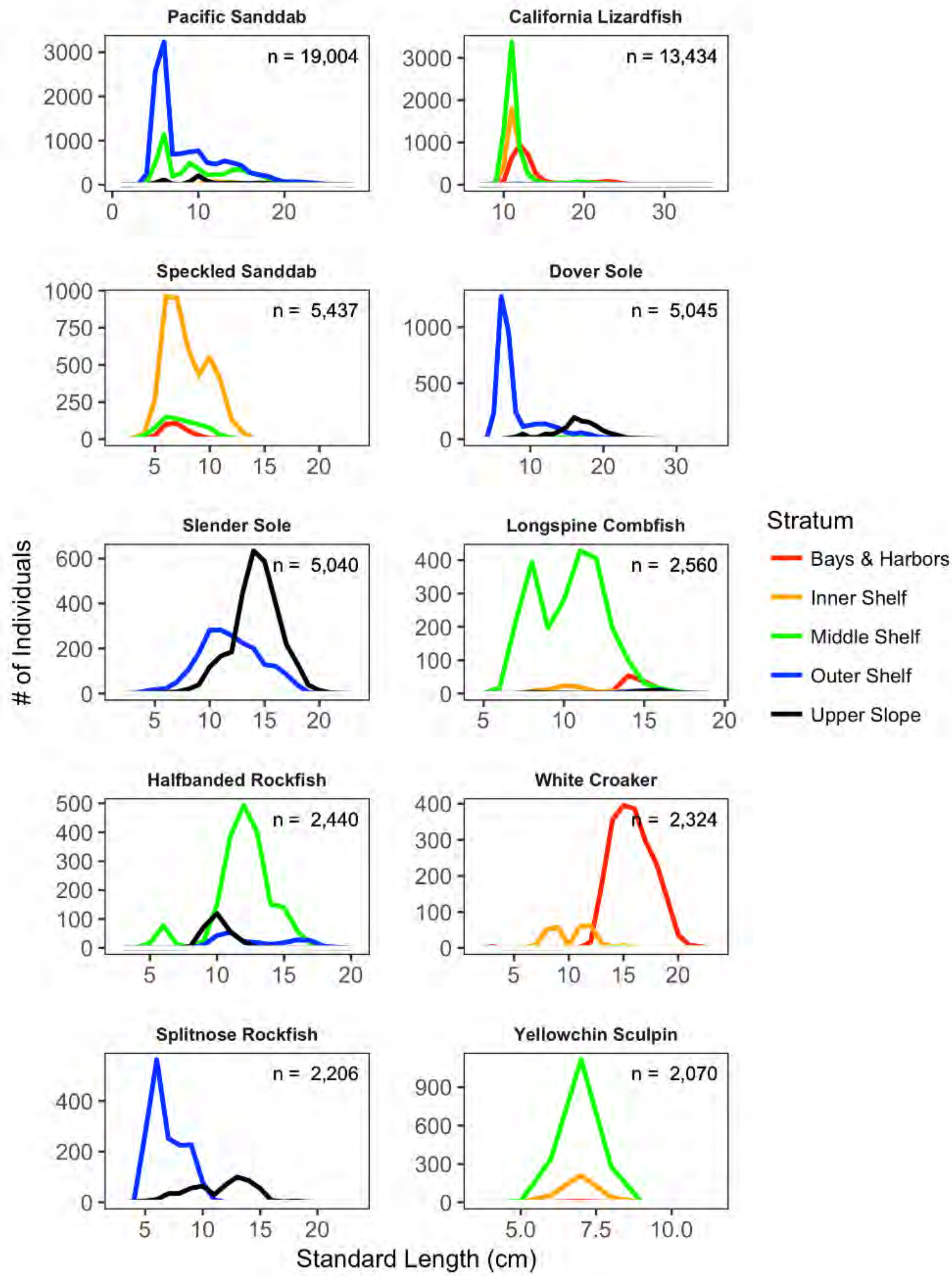



**Figure III-6. Length-frequency by stratum for the top ten most abundant demersal fishes collected during the Bight '13 trawl survey. Total number of individuals per species (n) is indicated.**

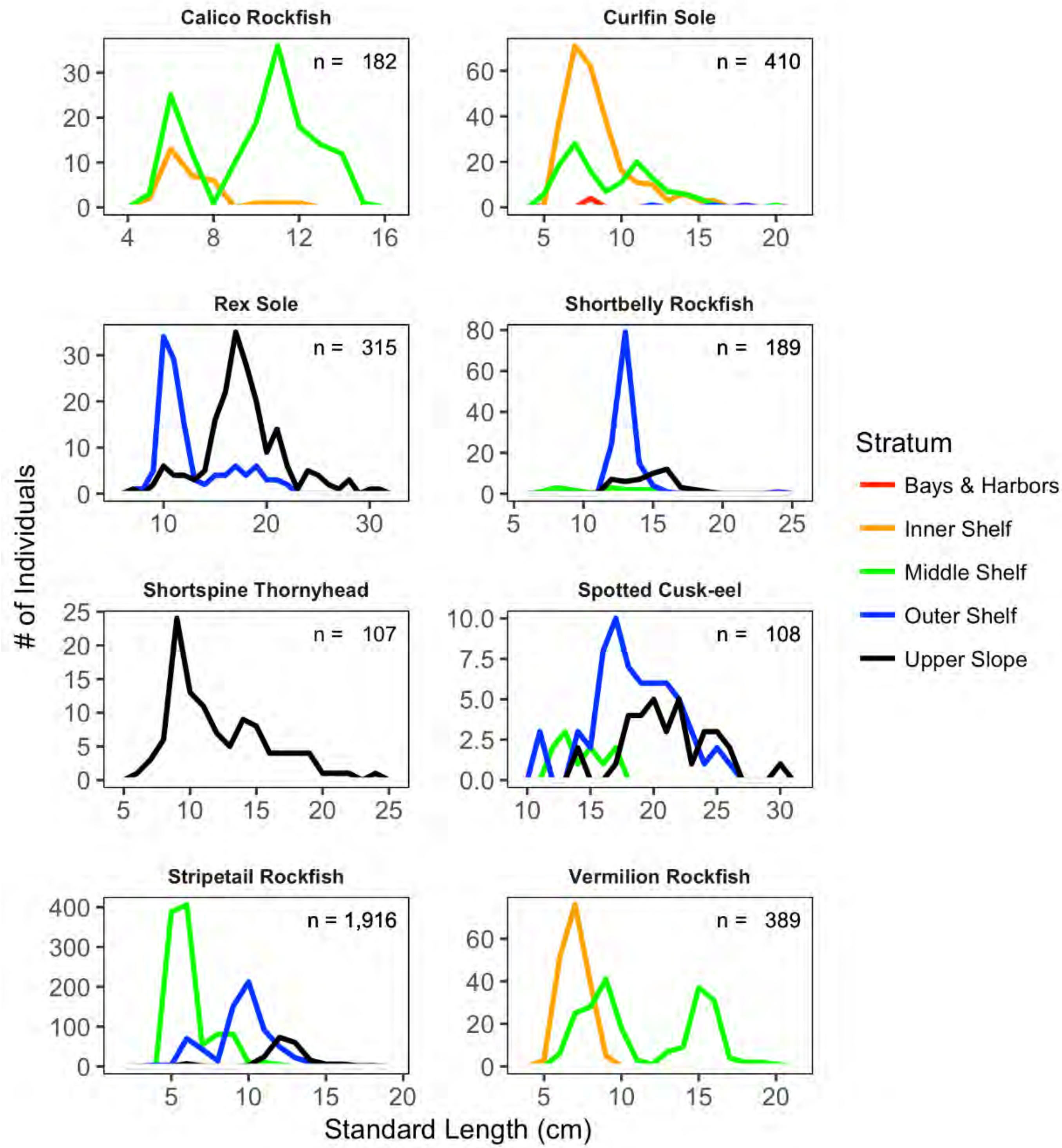


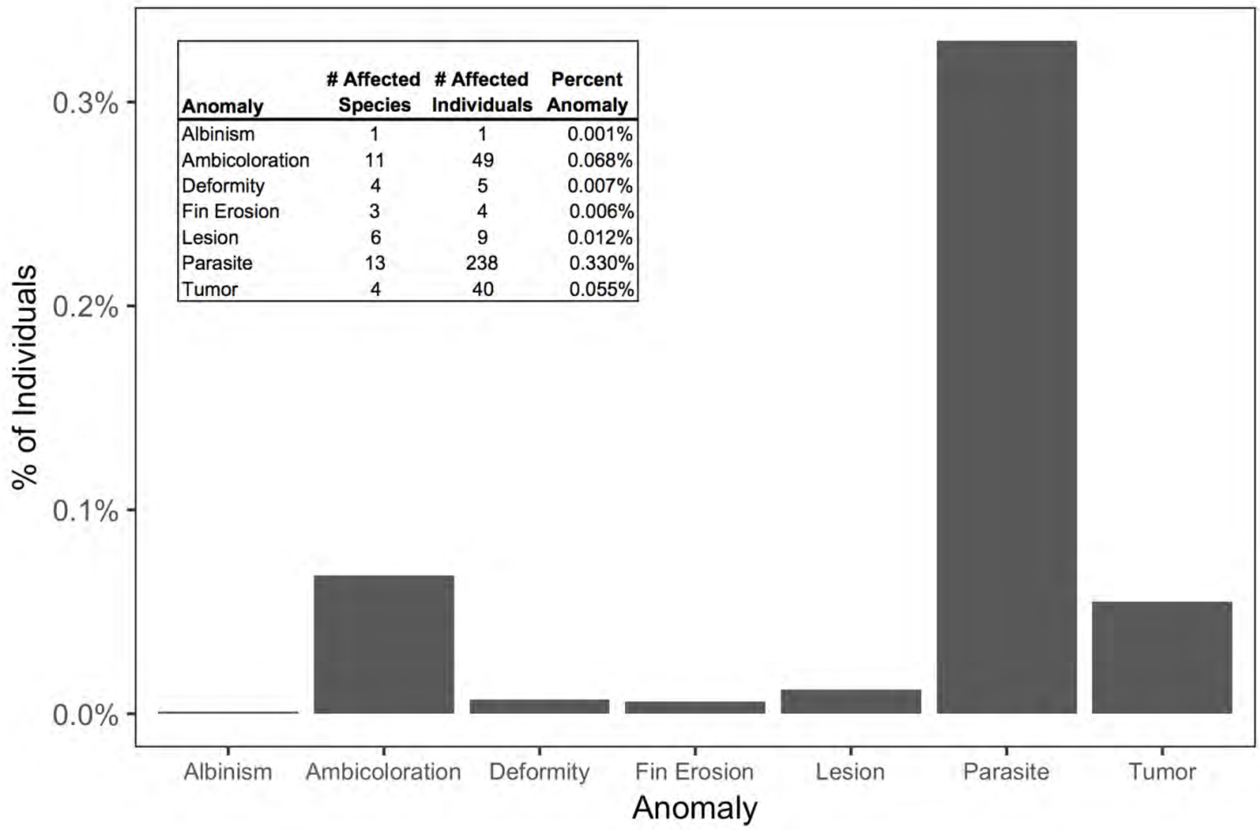

**Figure III-7. Length-frequency by stratum for demersal fish species with high pollution-tolerance (Allen et al. 2001) collected during the Bight ’13 trawl survey. Total number of individuals per species (n) is indicated.**

## Anomalies

The prevalence of fish anomalies was low and incidences were scattered throughout the SCB. Anomalies reported in the study included parasites, tumors, lesions, ambicoloration, skeletal deformities, and albinism (Figure III-8, Appendix B-17). A total of 0.46% (346 out of 75,383 individuals) of the fishes examined during the survey were anomalous. Only 0.07% of fishes examined had signs of disease (pathologies) including fin erosion, tumors, and lesions. Anomalies were found in 20 (16%) of the 128 fish species in the survey (Appendix B-17). Most anomalies (69%) were eye parasites (Figure III-8). Of the remaining anomalies, ambicoloration was most abundant, followed by tumors, lesions, skeletal deformities, fin erosion, and albinism. In this study, 238 individual fishes were parasitized (0.3%); 90% of these were Pacific Sanddab (Appendix B-17). Tumors were present in 40 individual fishes (0.1%). Dover Sole accounted for 75% of all fishes encountered with tumors. Forty-nine fishes (0.1%) had ambicoloration, 43% of which were Curlfin Sole. Four individual fishes (two Curlfin Sole, one Dover Sole, and one Spotted Sandbass) were found with fin erosion (0.005% of all examined, Figure III-8, Appendix B-17). Dover Sole was the only species collected with albinism (Appendix B-17).

Fishes that had pathologies including tumors, lesions, or fin erosion, all symptoms of potentially stressed individuals, constituted 0.07% of the total population of fish examined. Overall, fishes with anomalies indicative of disease or stress occurred in 12.7% of the area of the SCB (Figure III-9, Appendix B-18). Stations in which fishes with indicators of disease were detected were most prevalent on the Outer Shelf (27.6% of the area), followed by 11.6% of the area of the Middle Shelf, 9.4% of the Upper Slope area, 8.6% of the Inner Shelf area, and 7.7% of the area in Bays & Harbors.

External anomalies were rarely seen on invertebrates, with an overall incidence rate of <0.1% (Table III-5). Anomalies were almost exclusively limited to parasites, with the exception of one individual sea star that had an extra leg (Table III-5). Occurrence of invertebrate anomalies ranged from 0.1% to 21%, and increased as species abundance decreased.




| Anomaly | # Affected Species | # Affected Individuals | Percent Anomaly |
|---|---|---|---|
| Albinism | 1 | 1 | 0.001% |
| Ambicoloration | 11 | 49 | 0.068% |
| Deformity | 4 | 5 | 0.007% |
| Fin Erosion | 3 | 4 | 0.006% |
| Lesion | 6 | 9 | 0.012% |
| Parasite | 13 | 238 | 0.330% |
| Tumor | 4 | 40 | 0.055% |

**Figure III-8. Percent demersal fish anomalies by type during the Bight ’13 trawl survey. Number of affected species and number of individuals by anomaly shown in inset.**

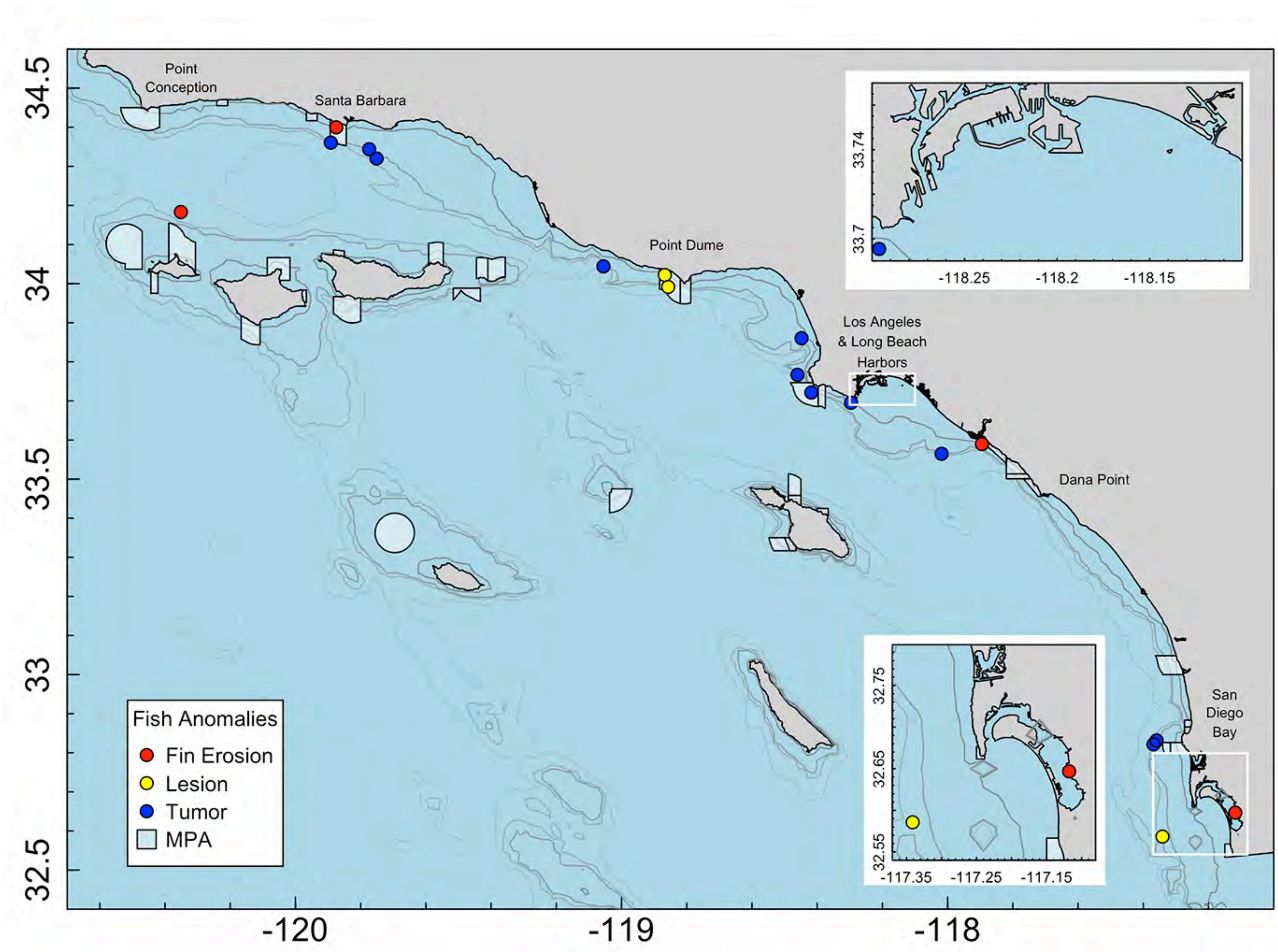



**Figure III-9. Distribution of demersal fishes collected during Bight '13 trawl survey with anomalies indicative of disease or stress.**

**Table III-5. Number of megabenthic invertebrate anomalies by type, species and stratum during the Bight '13 trawl survey.**

| | | ***Number of Anomalies*** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Anomaly** | **Species** | **Bays & Harbors** | **Inner Shelf** | **Middle Shelf** | **Outer Shelf** | **Upper Slope** | **All Shelf Zones** | **Total Observed Invertebrates** | **Percent Anomaly** |
| Parasite | | | | | | | | | |
| | *Crangon nigromaculata* | 2 | 4 | - | - | - | 6 | 1,098 | 0.5 |
| | *Paralithodes californiensis* | - | - | - | 1 | 2 | 3 | 14 | 21.4 |
| | *Pisaster brevispinus* | - | 1 | - | - | - | 1 | 45 | 2.2 |
| Other (extra arm) | | | | | | | | | |
| | *Pisaster brevispinus* | - | 1 | - | - | - | 1 | 45 | 2.2 |
| **All Anomalies** | **All Species** | **2** | **6** | **-** | **1** | **2** | **11** | **165,870** | **< 0.1** |

## Temporal Trends

### Community Attributes

Trends in the condition of SCB habitat from 1994 to 2013 were assessed using fish and invertebrate community metrics such as the Fish Response Index (FRI), an index of fish community response to environmental disturbance (Allen et al. 2001), and by examining patterns of community assemblages using multivariate statistics. For supporting descriptive analyses of catch abundance, biomass, and Shannon diversity, see Appendix B.

Across the SCB, most trawl-caught fish communities have been in reference condition since 1994 as indicated by median FRI scores that have remained under the reference threshold of 45 (Figure III-10). There have been no trends of impact over time or strata. The Inner Shelf and Bays & Harbors consistently had the highest FRI scores in each of the past Bight Regional surveys (Figure III-10), although scores in Bays & Harbors have generally decreased (a sign of recovery) since 1998. There was less variability in scores for Bays & Harbors than was observed along the Inner Shelf. Conditions on the Middle Shelf during Bight '13 were consistent with past surveys. Outer Shelf conditions in 2013 were consistent with those recorded during the 1998 survey and were improved (i.e. a greater area of the Bight was in reference condition) from what was observed during the 2003 survey, although some disturbed areas were identified in both 2003 and 2013. In general, in 2013 there were some differences from prior surveys, but no consistent upward or downward trend amongst any of the strata.

Most of the trawled area of the Bight shelf has remained in reference condition during all five regional monitoring surveys conducted since 1994, ranging from 93 – 99% of the SCB area (Table III-6). Although there was a decrease of 6% of reference area from 1994 to 2013, the area in reference condition during Bight '13 is consistent with past surveys, being within 2 standard deviations of the mean of the previous four surveys ($\bar{x} = 96.23$, $\sigma = 2.79$).

In the five regional monitoring surveys conducted between 1994 and 2013, no temporal trend existed in any stratum for fish abundance, invertebrate abundance, or diversity (Appendices B-19 through B-24). On the Upper Slope, invertebrate biomass was similar during the 1994 and 2003 surveys, and increased in each of the 2008 and 2013 surveys.

Multivariate analyses of fish and invertebrate assemblages distinguished a distinct separation of assemblages by strata (Figure III-11 and Figure III-12), but not by region or survey. This is expected, as depth is considered the primary environmental gradient in SCB waters. The distribution of fish and invertebrate assemblages in Bays & Harbors differed strongly from one another. In the invertebrate distribution, aside from the compact primary cluster there was a long tail containing Bays & Harbors stations, primarily from San Diego Bay (Figure III-12b) during the 1998 survey (Figure III-12c). Invertebrate community composition at these stations from the 1998 survey overlapped little with that at the other surveys (Figure III-12). This shallow warm habitat of the south bay is not well represented elsewhere in other embayments sampled in the program, where they are only present in very restricted and seldom sampled patches. Fish communities, being more mobile than those of invertebrates, had a greater spread in the multivariate space.

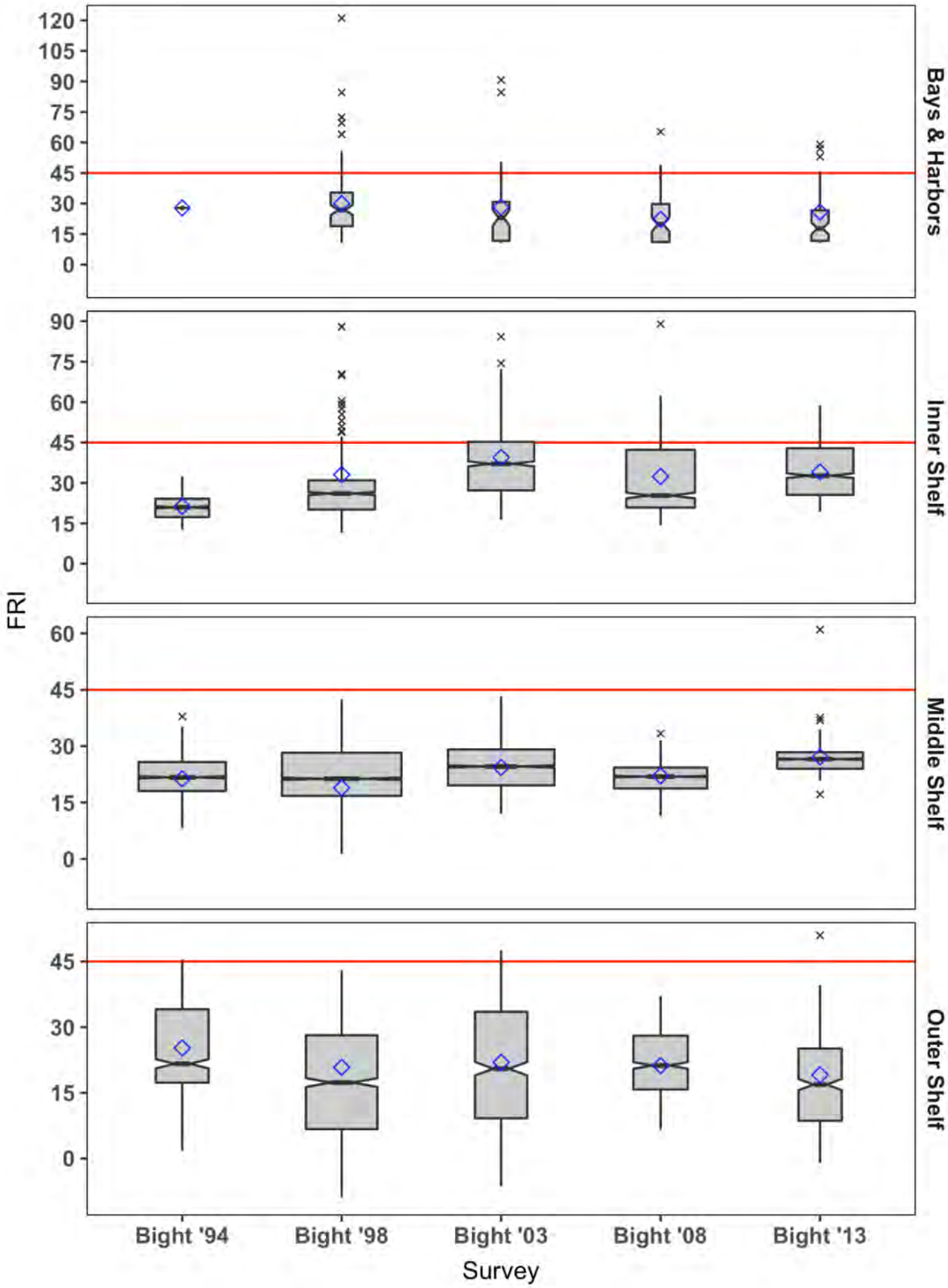



**Figure III-10. Fish Response Index (FRI) scores in the SCB by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers (“x”). Box width indicates relative sample size. Red line represents maximum FRI score (45) associated with a reference community.**

**Table III-6. Percent of stations in reference condition and percent area in reference condition as measured by Fish Response Index (FRI) scores in the SCB by survey.**

| | N Trawls | Percent Reference Sites | Percent Reference Area |
|---|---|---|---|
| Bight '94 | 111 | 99.1% | 99.2% |
| Bight '98 | 285 | 91.6% | 97.7% |
| Bight '03 | 161 | 89.4% | 92.9% |
| Bight '08 | 98 | 93.3% | 95.1% |
| Bight '13 | 121 | 92.4% | 93.2% |
| **All Surveys** | **776** | **92.5%** | **95.7%** |

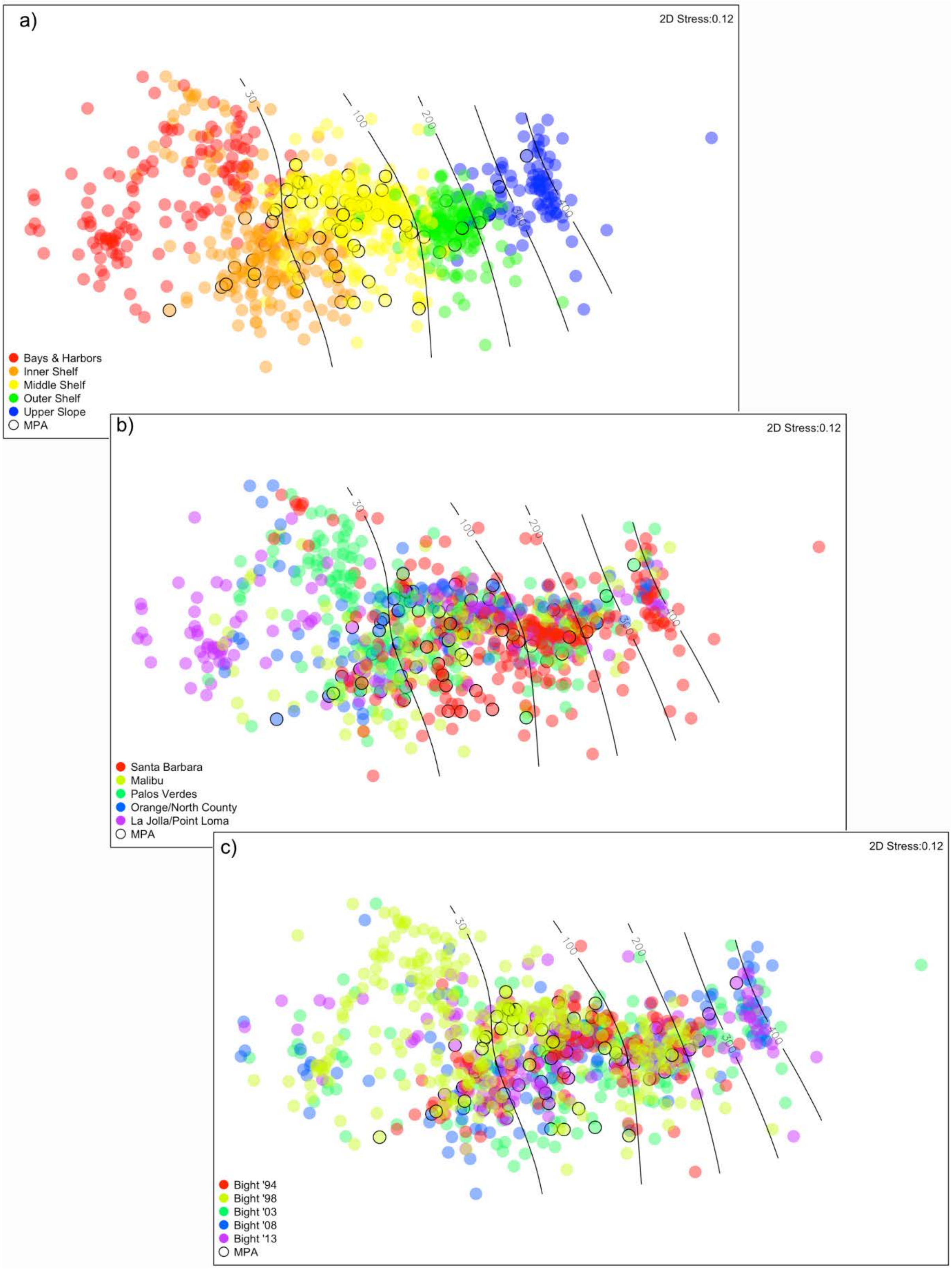



**Figure III-11. Ordination (nMDS) of demersal fish abundance per haul by Stratum (a), Region (b), and Survey (c), with a surface plot of trawl depth overlain (black lines). Stations that are located in current MPAs are outlined in black.**

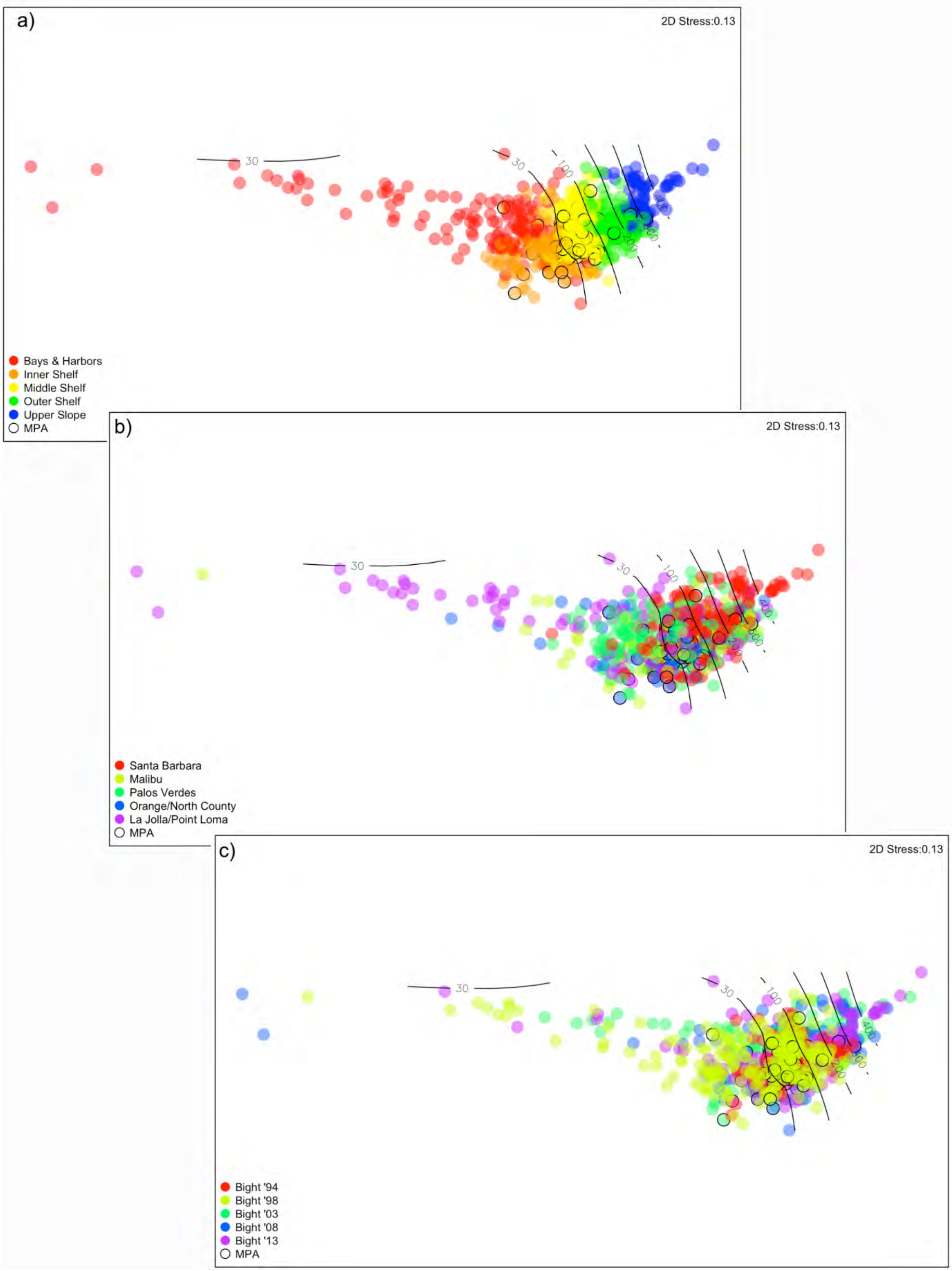



**Figure III-12. Ordination (nMDS) of megabenthic invertebrate abundance per haul by Stratum (a), Region (b), and Survey (c), with a surface plot of trawl depth overlain (black lines). Stations that are located in current MPAs are outlined in black.**

## Population Attributes

### Trends in Top Taxa

Plots of the top fish and invertebrate species abundances over time are shown in Appendix B25-B52. The largest numbers of Pacific Sanddab collected during Bight surveys were caught on the Outer Shelf in 2013 (Figure III-13). The median abundance of Pacific Sanddab in this depth zone was 275 individuals, compared to median abundances per haul of less than 100 individuals in the same stratum during each of the previous surveys.

California Lizardfish experienced a dramatic increase in abundance in 2013 compared to previous Bight surveys across all depth zones except for the Upper Slope where it is rarely found (Figure III-14). In 2013, this species was caught in 109 trawls with an average abundance of 110 individuals per trawl, outnumbering the historical average abundance of 1 to 13 California Lizardfish per trawl over the past several Bight surveys. In Bays & Harbors, the median California Lizardfish catch was 72 individuals per haul, a historic high for Bight surveys in this stratum. Like Bays & Harbors, there were record catches of California Lizardfish in the Inner Shelf during Bight '13 compared to previous Bight surveys with a median catch of 46 individuals and a maximum of 641 individuals caught in a single trawl sample.

Also of note were changes in California Tonguefish, Longspine Combfish, Dover Sole, and Splitnose Rockfish populations. California Tonguefish had a record high abundance in the Bays & Harbors and Inner Shelf strata in Bight '13 compared to any previous Bight survey (Appendix B-25). Longspine Combfish also had a record high abundance in Bight '13 compared to previous Bight surveys in the Bays & Harbors and Middle strata (Appendix B-34). Dover Sole also had a record abundance on the Outer Shelf in 2013 compared to past Bight surveys (Appendix B-32). Finally, Splitnose Rockfish had a couple of individual hauls on the Outer Shelf and Upper Slope with record abundances during the B'13 survey (Appendix B-37).

The sea urchin *Strongylocentrotus fragilis* has been one of the most numerous species in SCB trawls. Its abundance increased on the Outer Shelf and Upper Slope between 2008 and 2013 (Figure III-15). A similar pattern was seen in populations of the sea star *Luidia foliolata*, which ranked fourth in frequency of occurrence during Bight '13 (Figure III-16) and has shown an increase in population density on the Outer Shelf since 2003.

Seven other species of invertebrates showed population increases in 2013 compared to previous Bight surveys, including two species of mollusks (*Octopus rubescens* and *Pleurobranchaea californica*), 2 species of echinoderms (*Ophiura luetkenii* and *Astropecten californicus*), and three species of crustaceans (*Pandalus jordani*, *Pandalus platyceros*, and *Spirontocaris holmesi*). The octopus *Octopus rubescens* was found in record abundances on the Inner Shelf through Outer Shelf depth zones (Appendix B-44); the brittle-star *Ophiura luetkenii* saw a moderate increase in mean catch on the Middle- and Outer Shelf as well as an overall increase of about 350 to almost 22,000 individuals between the 1998 and 2013 surveys (Appendix B-45); the catch of the sea star *Astropecten californicus* more than doubled on the Inner Shelf from 2008 (841 individuals) to 2013 (1,928 individuals); the shrimp *Pandalus jordani*, a rarely seen species in the SCB surveys, had over 4,100 individuals caught in a single haul on the Outer Shelf in 2013 (Appendix B-46); the shrimp *Pandalus platyceros,* had some historic high abundances in individual hauls on the Outer Shelf (158 individuals) and Upper Slope (700 individuals) in 2013 (Appendix B-47); the opistobranch *Pleurobranchaea californica* had the highest historic catches on the Middle Shelf (Appendix B-49); and the shrimp *Spirontocaris holmesi*had record high abundances of more than 1,000 individuals in two different trawls in 2013 on the Upper Slope (Appendix B-52).

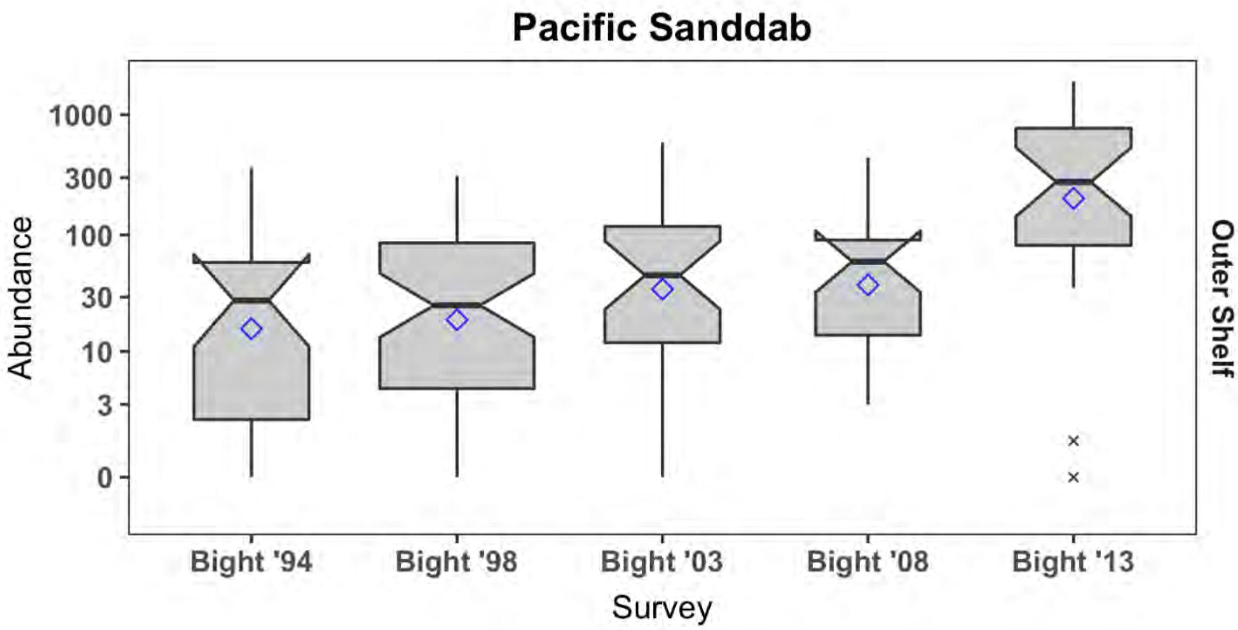



**Figure III-13. Abundance of Pacific Sanddab by survey in the SCB Outer Shelf stratum. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers (“x”). Box width indicates relative sample size.**

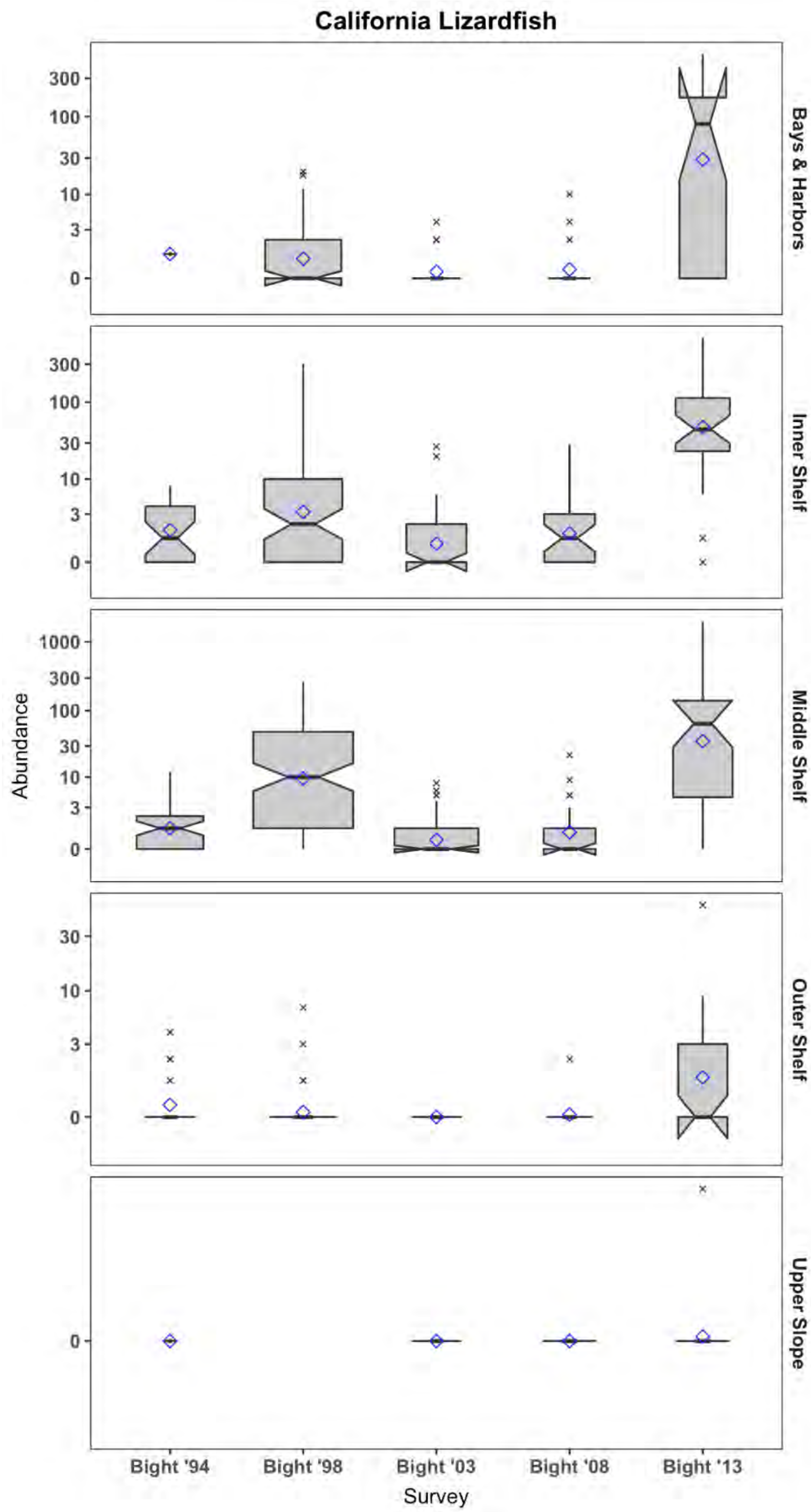



**Figure III-14. Abundance of California Lizardfish by survey and stratum in the SCB. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size.**

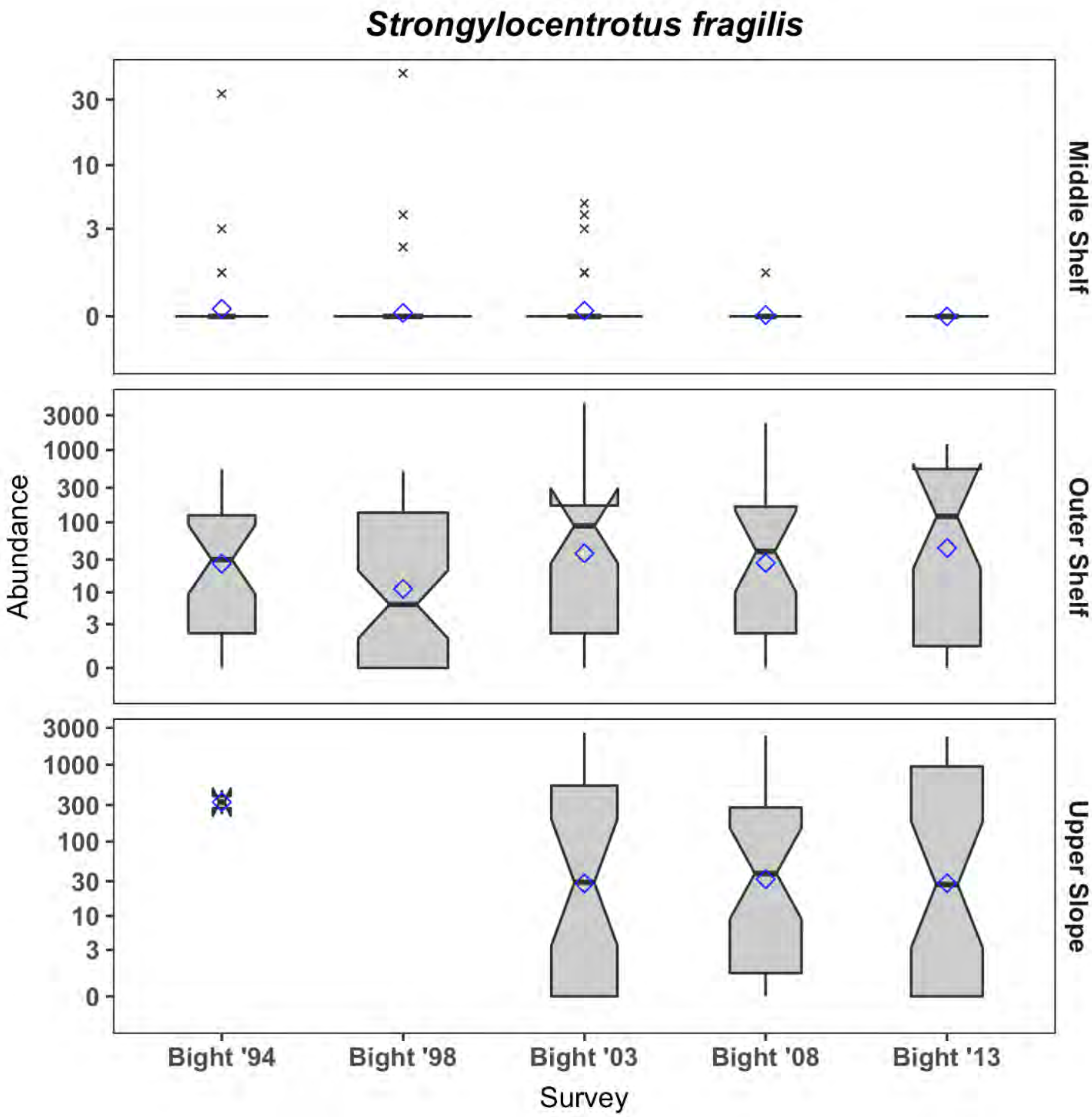



**Figure III-15. Abundance of *Strongylocentrotus fragilis* by survey and stratum. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers (“x”). Box width indicates relative sample size.**

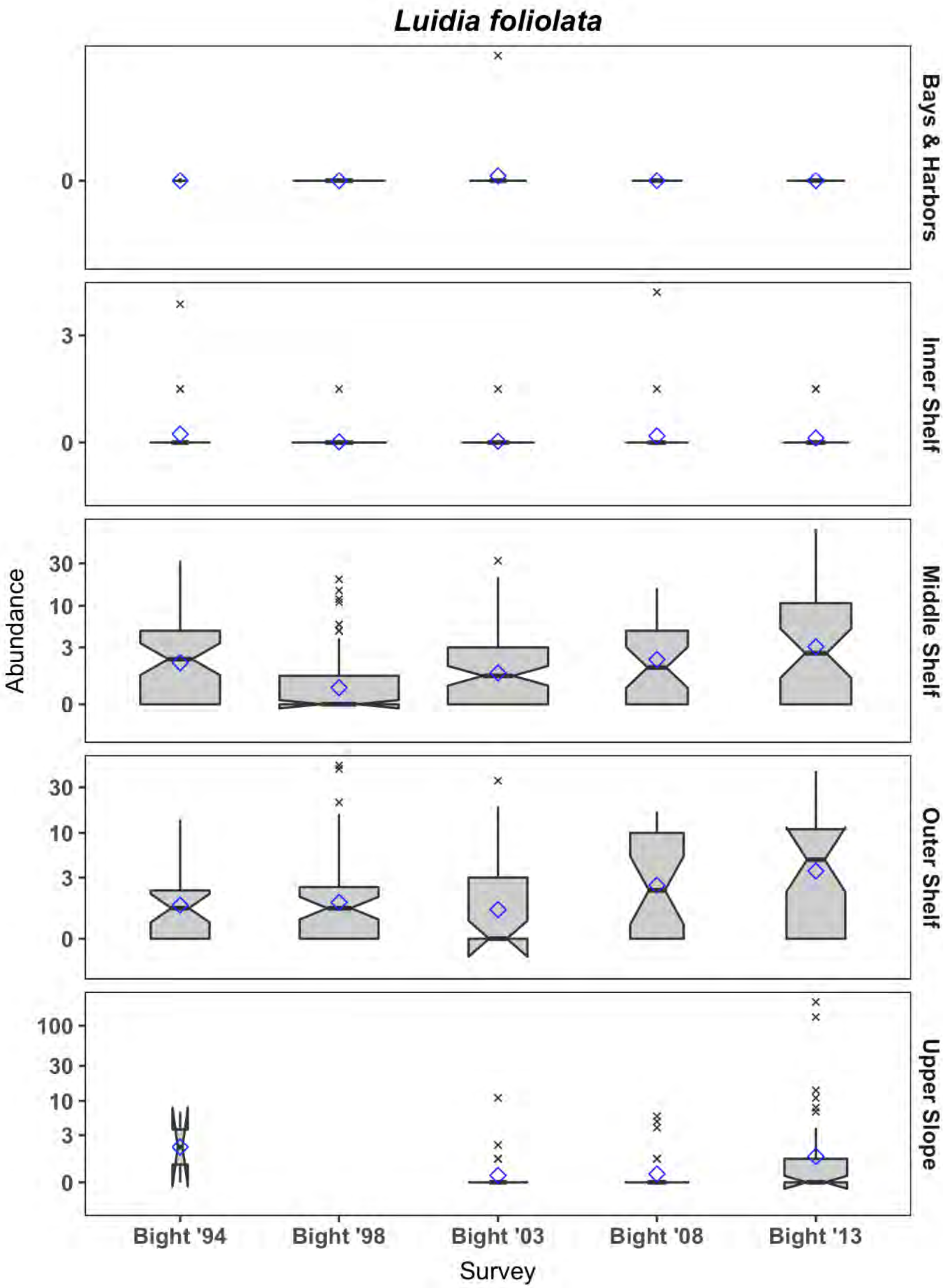



**Figure III-16. Abundance of *Luidia foliolata* by survey and stratum. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size.**

### Trends in Species Size (Length) Distribution

Length-frequency distributions were compared over time for each of the top 10 most abundant species during Bight '13 (Figure III-17) and the most pollution-tolerant fish species (based on high p-code scores used for the FRI; Allen et al. 2001) (Figure III-18). Length-frequency distributions of both groups of fish most frequently peaked in the smaller size classes (<20 cm) across all surveys. There were no trends of increasing or decreasing size classes over time.

Some notable species included White Croaker, which peaked at smaller size classes (<20 cm) in 1998 when it was most abundant relative to other surveys (Figure III-17), and Vermilion Rockfish which had peak abundance in 2013 with bi-modal size distribution (Figure III-18). Although there were also record high abundances in 2013 for Pacific Sanddab, California Lizardfish, Dover Sole, and Splitnose Rockfish, their length-frequencies remained similarly distributed between surveys regardless of the total size of the population (Figure III-17).

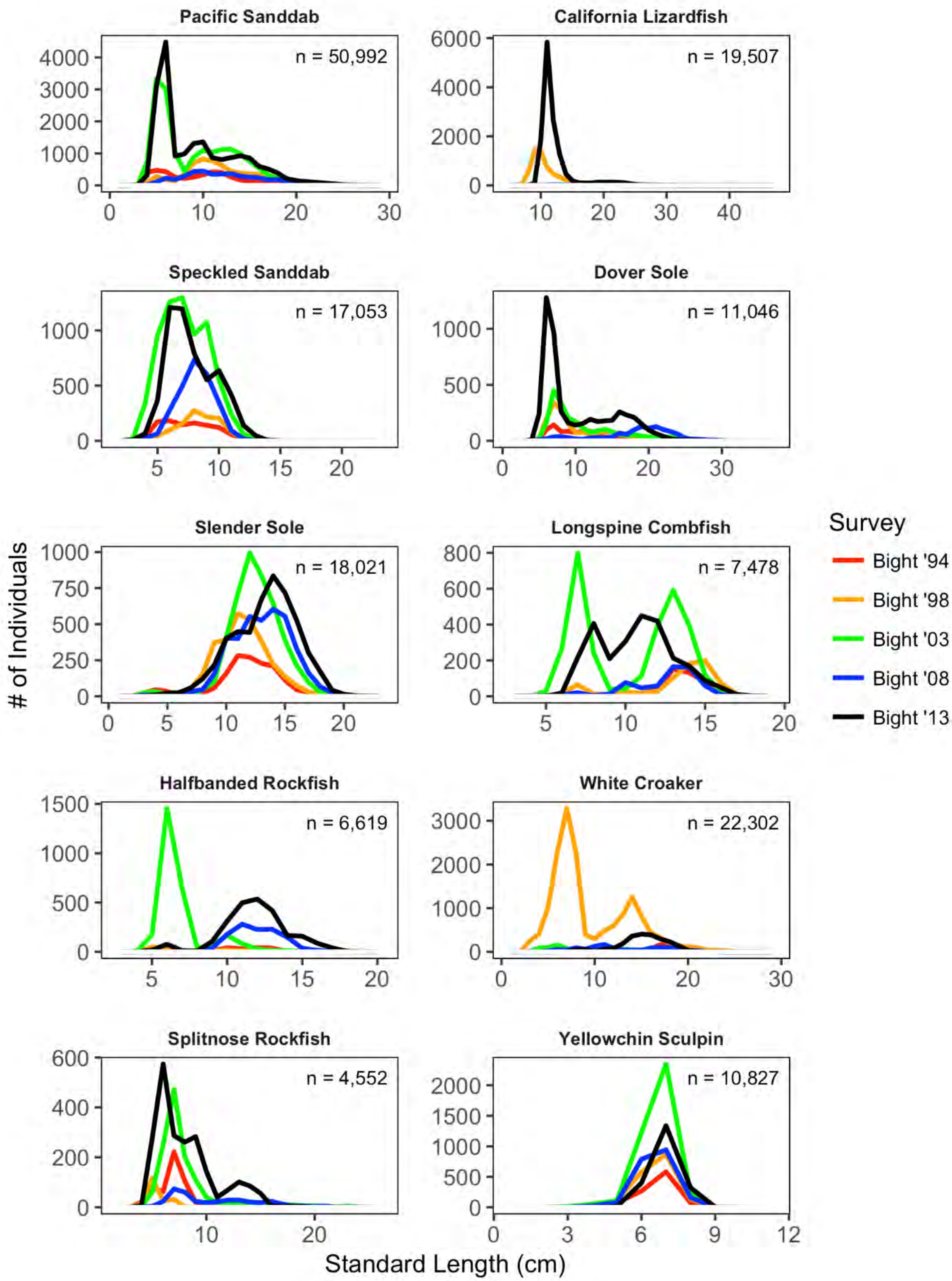



**Figure III-17. Length frequency by survey for the top 10 most abundant demersal fishes during the Bight ’13 trawl survey. Total number of individuals (n) is noted.**

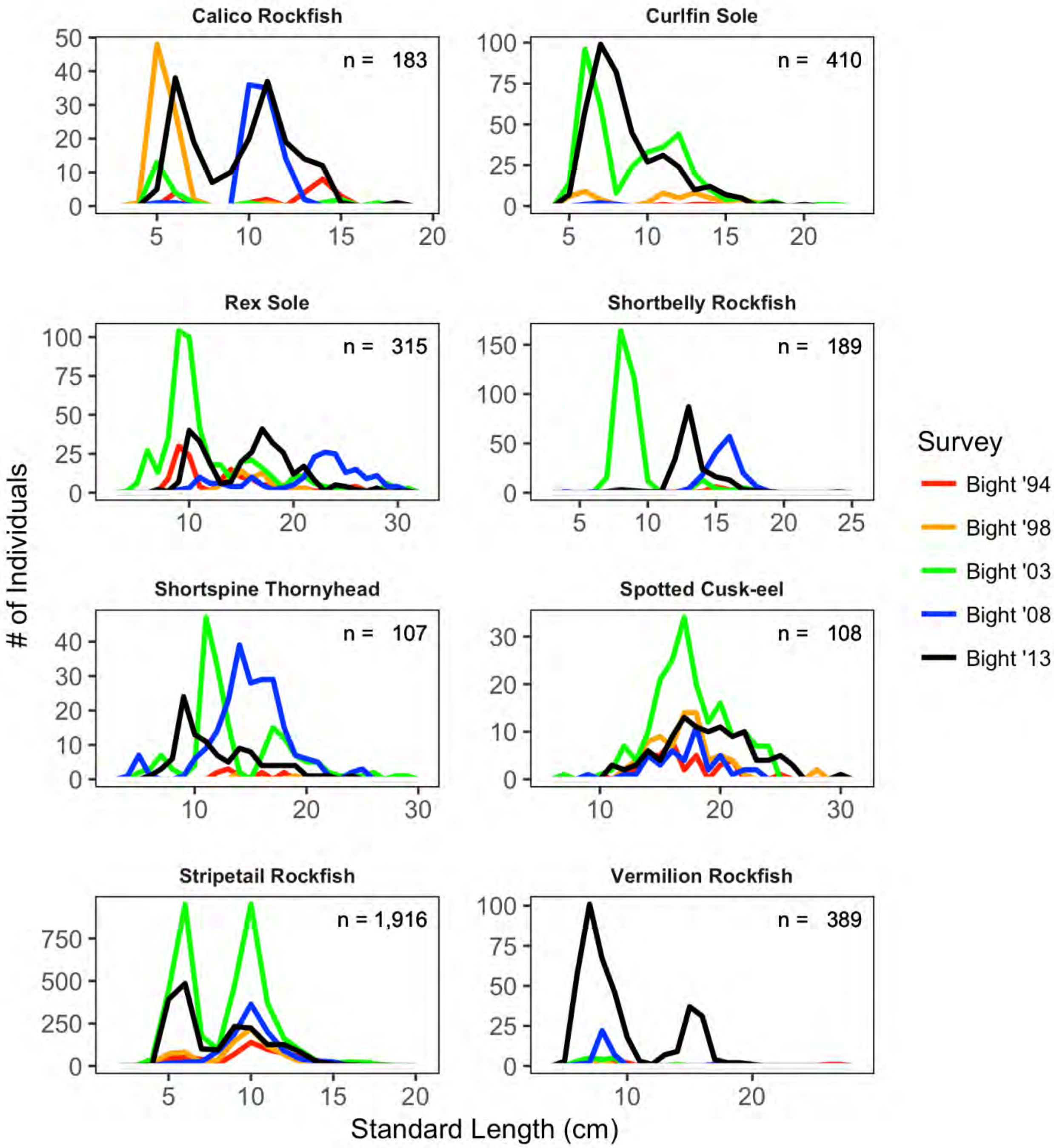



**Figure III-18. Length frequency for fish species with high pollution-tolerance (Allen et al. 2001) by survey. Total number of individuals (n) is noted.**

**Trends in Anomalies**
The total percentage of fish anomalies among the five regional monitoring surveys was lowest in 2013 and decreased in each survey since 1998 (Figure III-19). The amounts of anomalous fish have not varied by more than 1% among these surveys. Indicators of disease and stress such as fin erosion, tumors and lesions were present throughout the past five surveys. There was no trend of increase or decrease in these anomalies. Fin erosion was detected in four individuals in 2013 and occurred in 2.4% of the entire SCB (Appendix B-18). Fin erosion, which had been relatively rare in recent surveys, was also detected in 1994 in 3% of the SCB area, and 0.5% of the area in 2003 (Allen et al. 1998, Allen et al. 2007). Tumors, a more common anomaly, were present in 1994 (5% of the area), in 1998 (2% of the area); in 2003 (4% of the area); in 2008 (1% of the area) and was found in 6% of the area in 2013. Lesions were present in 1994 (4% of area), 1998 (1% of area), 2003 (2% of area) and 2013 (0.5% of area) (Allen et al. 1998, Allen et al. 2002, Allen et al. 2007, Allen et al. 2011). See also Appendix B-53.

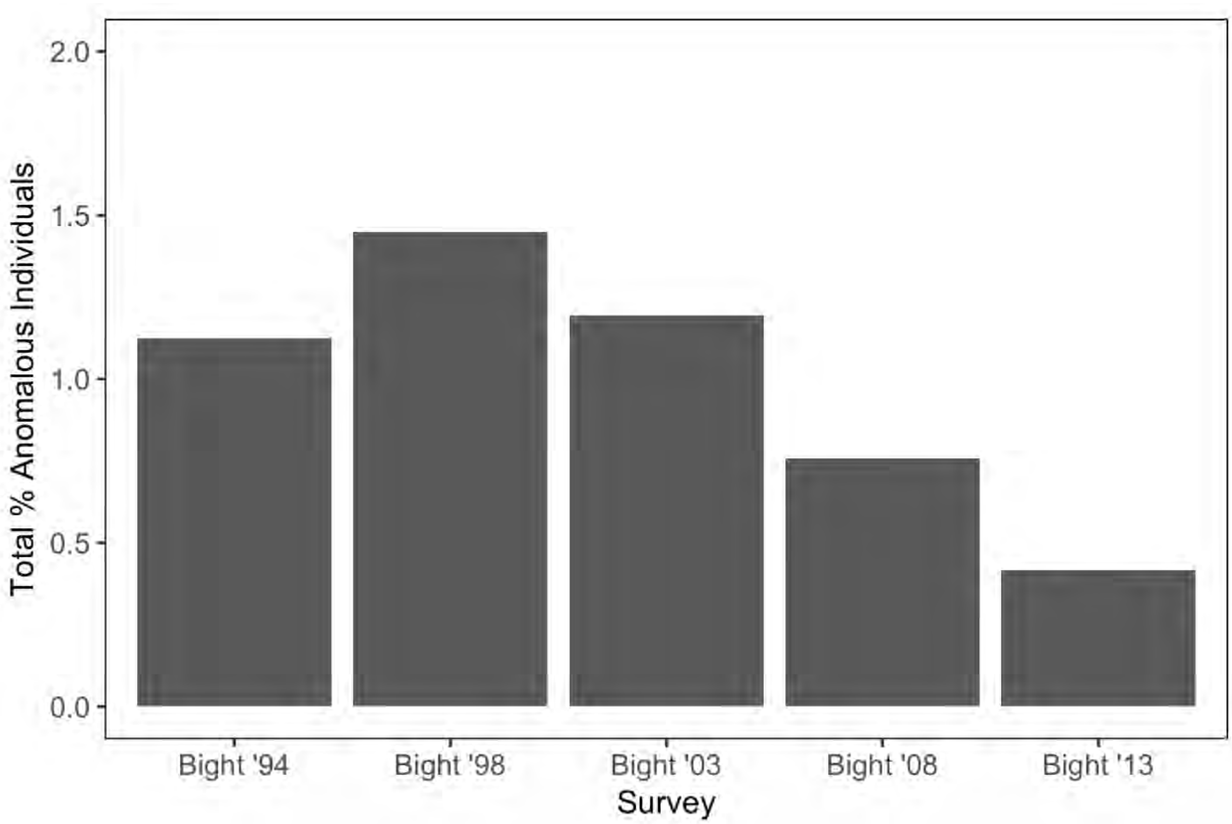



**Figure III-19. Percentages of fishes with anomalies by survey.**

## Special Studies

### MPAs

Marine Protected Areas (MPAs) were incorporated as an additional stratum during the Bight '13 regional trawl survey. There were strong spatial differences with respect to variation in soft-bottom fauna. The primary source of variation was the distinct gradient of both fish and invertebrate community structure with respect to depth. A separation of the *a priori* determined strata was found (Appendix D). MPAs in this region incorporated all four distinct soft-bottom strata and this ecosystem variability should be considered in future studies. A second source of variability was clear temporal differences in the soft-bottom fauna throughout the SCB, largely resulting from a significantly higher catch and lower diversity of fish and invertebrates in the Bight '13 survey. There were generally few differences between the newly established MPA areas and non-MPA areas, suggesting that the randomly selected areas of past Bight Program trawling efforts are satisfactory for use as a baseline for future MPA studies.

Using historical trawl data as the "before" part of a spatially integrated Before-After Control-Impact (BACI) experimental approach presents a challenge due to the highly variable nature of the region over time and space. However, by using a rigorous study design that has enough control and impacted replicates to properly account for that variability, the efficacy of MPAs on soft-bottom communities can be assessed.

### Changes in Sea Urchin Populations

Sea urchins along the continental shelf and slope of the eastern Pacific often dominate the megafaunal community. This occurs despite their exposure to naturally low dissolved oxygen (DO) waters (<60 µmol kg-1) associated with the Oxygen Limited Zone and low-pH waters undersaturated with respect to calcium carbonate ($\Omega CaCO3<1$). Sato et al. (2017) present vertical depth distribution and density analyses of historical trawl data collected in the Southern California Bight (SCB) from 1994 to 2013 to address the question: "Do changes in echinoid density and species' depth distributions along the continental margin in the SCB reflect observed secular or interannual changes in climate?" (Appendix E). Deep-dwelling burrowing urchins (*Brissopsis pacifica*, *Brisaster* spp. and *Spatangus californicus*), which are adapted to low-DO, low-pH conditions appeared to have expanded their vertical distributions and populations upslope over the past decade (2003–2013), and densities of the deep pink urchin, *Strongylocentrotus fragilis*, increased significantly in the upper 500 m of the SCB. Conversely, the shallower urchin, *Lytechinus pictus*, exhibited depth shoaling and density decreases within the upper 200 m of the SCB from 1994 to 2013. Oxygen and pH in the SCB also vary inter-annually due to varying strengths of the El Niño Southern Oscillation (ENSO). Changes in depth distributions and densities were correlated with bi-monthly ENSO climate indices in the region. Results suggest that both a secular trend in ocean deoxygenation and acidification and varying strength of ENSO may be linked to echinoid species distributions and densities, creating potential habitat compression in some and habitat expansion in others. Potential life-history mechanisms underlying depth and density changes observed over these time periods include migration, mortality, and recruitment. These types of analyses are needed for a broad suite of benthic species in order to identify and manage climate-sensitive species on the margin.

## QA/QC

Cumulatively, participating organizations met or exceeded the MQOs established for the Bight '13 regional survey (Table III-7, Appendix A). Trawl sampling was complete and representative. Taxonomic identifications were complete, accurate, and precise. Counting, measuring, and weighing were also complete, accurate, and precise. Ultimately, no deviations occurred that required exclusion of data.

**Table III-7. Summary of Method Quality Objectives (MQOs) and actual measurements during the Bight'13 regional monitoring trawl survey. Identification accuracy and precision are from fish and invertebrates combined.**

| | MQO | | | Actual | | |
|---|---|---|---|---|---|---|
| Indicators | Accuracy | Precision | Completeness | Accuracy | Precision | Completeness |
| Sample collection | NA | NA | 90% | NA | NA | 95% |
| Counting | 10% | NA | 90% | < 1% | < 1% | 99% |
| Identification | 10% | NA | 90% | 3% | 4% | 97% |
| Length | 10% | NA | 90% | 3% | 3% | 97% |
| Biomass | 10% | NA | 90% | 1% | 2% | 99% |
| External Anomalies | 10% | NA | 95% | 0% | 0% | 100% |

# IV. DISCUSSION

This report has provided a descriptive assessment of benthic fish and invertebrate populations captured during the Bight '13 trawling efforts. The goal from these measures is to evaluate the extent and magnitude of biointegrity, a measure of community health that assesses the degree to which the biological condition of a system has been modified relative to its natural state. Based on two primary lines of evidence, the biointegrity of SCB fish populations appeared healthy in 2013. First, the primary biointegrity assessment tool – the Fish Response Index (FRI), which was designed to measure fish community response to pollution gradients on the continental shelf (Allen et al. 2001), found that 93% of the SCB areas sampled had fish communities representative of a reference condition. Second, few external anomalies or parasites were observed among the individual fish examined during the 2013 survey. Tumors, lesions, and fin rot are all examples of external pathologies in stressed individuals. During Bight '13, only 53 of the roughly 75,000 fishes examined had these pathologies, an overall rate of 0.07%. Most of these were observed in the 5,045 Dover sole individuals captured during the survey, a rate of 1%. This rate of external pathologies is exceptionally low compared to their occurrence in the 1970's when fin rot was observed in 31%, and tumors were observed in 3.3%, of the Dover sole specimens collected between Pt Conception and San Diego (Word et al. 1977). Other community metric lines of evidence (e.g., diversity and dominance) supported the conclusions based on the FRI and anomalies that fish communities in the SCB appear to be in healthy condition.

Not only was the biointegrity of fish communities in the SCB considered to be healthy in 2013, but the area with healthy communities has remained large since the first Bight regional surveys in 1994. The extent of fish communities in reference condition has been consistently greater than 90% of the SCB for the last 20 years (Allen et al. 1998, 2002, 2007, 2011). Moreover, the rate of external pathologies in 2013 is the lowest observed in any Bight survey to date. For the first time during a Bight regional survey, fish length distributions for several prevalent non-commercial species were compared over time. In each species examined, there was no increasing or decreasing trend in size distribution over time indicating relatively stable populations.

There are a variety of challenges to assessing the biointegrity of fish communities, which modestly limits our assessment. First, fishing is inherently variable. Trawl-to-trawl catches are known to vary widely in terms of abundance and sometimes species assemblage (Stransky et al. 2016, Doubleday and Rivard, 1981). Second, the Bight survey is designed to be a snapshot in time, and there have been changes in community structure over short temporal scales such as populations of California Lizardfish found during the Bight '13 survey in quantities and areas not typically observed. Third, there is sampling variability associated with how well individual trawls are performed in terms of fishing efficiency. The Bight program attempts to overcome these three limitations by focusing on cumulative Bight-wide (or stratum-wide) results rather than individual sites, and an extensive QA/QC program to standardize maximum sampling efficiency (e.g., Appendix A).

Using demersal fishes and megabenthic invertebrates to assess biointegrity is not ideal, as they are less sensitive to sediment contamination than infauna, and respond only when conditions are very bad (Allen et al. 2001). While the FRI assessment tool estimates biointegrity on the continental shelf, it is not validated for assessment of some portions of the SCB. The FRI was calibrated and validated using data near wastewater outfalls in depths between 20 and 215 m (Allen et al. 2001). This inhibits the ability to use the FRI in the deepest stratum (>200 m). Moreover, during the FRI development there were no impacted sites on the inner shelf (<30 m) available for use in the calibration dataset, somewhat diminishing confidence in FRI-based assessment in these shallow waters. This challenge is noteworthy because non-reference FRI scores were most frequently observed on the Inner shelf and in Embayments, closest to land-based anthropogenic sources, almost exclusively <30 m depth. Still, it is the best available index for assessing the biointegrity of demersal fish communities within the Bight, and has accurately tracked ecological impairment and recovery in some of the historically most heavily impacted areas of the Bight with trends seen in the widely-accepted Benthic Response Index (Smith et al. 2001, LACSD 2016).

The Bight '13 survey provides a comprehensive regional characterization of the trawl-caught megabenthic invertebrate community, but it provides little in the way of biointegrity assessment for megabenthic invertebrates. This is largely because there is no reliable tool for invertebrates. In previous Bight surveys, the Megabenthic Invertebrate Response Index (MIRI) was utilized for biointegrity assessments (Allen et al. 2011). However, scientists have raised concerns about its use because MIRI responses are insensitive to sediment contamination (Allen et al. 2001). Because of the relative insensitivity of MIRI to pollution gradients, Bight scientists have opted to discontinue use of this potential assessment tool.

Despite the lack of reliable biointegrity tools for invertebrates, potential impacts to trawl invertebrates were identified during Bight '13 by examining biogeographic changes in populations of sensitive species. Specifically, sea urchin distributions were examined relative to depth and the encroachment of decreased pH/low dissolved oxygen bottom waters. Results compiled over the last four regional surveys spanning 20 years indicated potential habitat compression in sensitive urchin species, and the habitat expansion of less sensitive species (Sato et al. 2017). Species-specific population impacts like these may be a harbinger of future region-wide impacts due to ocean acidification.

Community metrics and assemblage characteristics of both fish and invertebrates follow spatial patterns observed in previous Bight surveys (Miller and Schiff 2012, Williams et al. 2015). Changes in biological assemblages are mostly driven by biogeographic differences in depth (water pressure) and, to a lesser extent, water temperature. Stratification of fish and invertebrate populations along depth gradients are well-known (Kaiser 2011, Smith and Lindholm 2016) and reflected in the stratum definitions used by Bight '13. The water temperature differences are reflected by increased abundance of warm water communities during El Niño and cold water communities in La Niña episodes. Like depth differences, the presence of warm- and cold-water species in relation to the El Niño Oscillation (ENSO) is well-characterized (Leising et al. 2014). Overall in the California Current, 2013 was a record-breaking year in terms of upwelling, which brought cooler than average waters to most of the region, increasing productivity in the nearshore waters of the SCB (Leising et al. 2014). This productivity was reflected in the largest average abundance and biomass per trawl during Bight '13 compared to previous Bight surveys. Notable increases in fish species such as California Lizardfish, White Croaker, and the invertebrate species *Ophiura luetkenii*, *Astropecten californicus*, *Octopus rubescens*, and *Pleurobranchaea californica* were observed during the 2013 regional survey. Notable decreases of *Sicyonia ingentis*, and of Dover Sole and Halfbanded Rockfish on the middle shelf, as well as decreases in invertebrate diversity in the Bays & Harbors stratum were also observed during the 2013 regional survey.

One value of Bight Regional Monitoring is the large-scale characterization of changes in biointegrity and species assemblage characteristics (Schiff et al. 2016). This allows local dischargers and other agencies to put their monitoring in context of regional-scale events (for example see Appendix C). Regional monitoring is key to understanding fundamental biogeographic changes that can influence local monitoring results such as naturally-occurring depth or water temperature related effects, or the regionwide anthropogenic effects of ocean acidification, all of which supersede any potential local impacts. The larger spatial-scale view of fish biointegrity should help convince environmental managers and the public that there were not wholesale perturbations in trawl-caught organisms during 2013 and, where non-reference fish communities do exist, they were not selectively grouped near a single hot spot that requires immediate attention. One caution to using large-scale data sets to make overarching conclusions about regional condition is Bight surveys have covered relatively "routine" El Niño and La Niña cycles. When extreme conditions occur, perhaps associated with climate change or other factors, the regional baseline expectations may also shift (i.e. during the 2015 El Niño [Leising et al. 2015]).

## V. CONCLUSIONS

- **Southern California Bight trawl-caught fish and invertebrate communities are generally in good condition**

  This assessment is based on the large extent of healthy fish and invertebrate assemblages; 93% of the Southern California Bight had Fish Response Index (FRI) values indicative of reference communities. Also, the prevalence of fish pathologies was low. Approximately 0.07% of fish had tumors, lesions, or fin rot, which are all symptoms of potentially stressed individuals.

- **The extent of healthy fish communities has remained similar over the last 15 years**

  The extent of reference-like fish communities based on the FRI has ranged from 93 to 97% of the area measured without any upward or downward trend since 1998. Also, the percentage of fish with visible anomalies has not varied by more than 1% among the five regional monitoring surveys. However, this does not mean the number of species or number of individuals per species has remained constant. Fish and invertebrate species will naturally vary over time with changes in oceanographic conditions.

- **Of all the habitats examined, Embayments had the greatest relative extent of unhealthy fish communities**

  Unlike the continental shelf where the extent of healthy fish communities exceeded 93%, the extent of healthy fish communities in embayments was 83% as measured by the FRI. This relatively lower extent of healthy fish communities in embayments has persisted across Southern California Bight regional surveys since this stratum was first sampled in 1998.

- **The diversity and abundance of fish and invertebrates in southern California Bight's Marine Protected Areas look comparable to areas outside of these newly promulgated fishing reserves**

  Marine Protected Areas (MPAs), promulgated in January 2012, were integrated into the Bight Regional Monitoring survey for 2013. No significant differences in the number of species, total abundance, or total biomass were detected between areas inside of MPAs and outside of MPAs at comparable depths. Therefore, the Bight Regional Monitoring Program can serve as a good baseline for assessing future changes in MPA species, abundance, or biomass.

- **The populations of several fish and invertebrate species in 2013 were the largest observed in any previous Bight regional monitoring survey**

  Population explosions are not uncommon in fish or invertebrate communities. In 2013, record high abundances of several fish species were observed, including Pacific Sanddab, California Lizardfish, Dover Sole, and Splitnose Rockfish. Of particular note was California Lizardfish, which was caught in 109 trawls with an average abundance of 110 individuals per trawl, exceeding this species' historical average abundance in the previosu regional surveys by an order of magnitude.

## VI. RECOMMENDATIONS

- **Critically review and update the Fish Response Index.**

  The Fish Response Index (FRI) is a critical tool used for assessing whether fish communities are healthy based on the pollution tolerance weighted abundance of all species found in a trawl. However, scientists suspect that the FRI has sensitivity to certain species, and the index cannot be applied beyond shelf depth. The construct of the FRI needs to be evaluated and either modified to overcome these limitations or a more robust approach for assessing the biointegrity of fish and invertebrate communities needs to be developed.

- **Improve Information Management.**

  Although Information Management methods of collecting field data were upgraded over previous Bight surveys through implementation of on-board field computing that automatically logged trawl times, distances, and location, other aspects of Bight '13 Information Management proved insufficient to rapidly support the data accuracy and assessments needed for trawl caught fishes and invertebrates. One challenge was associated with uploading and verifying the trawl data. Perhaps the greatest challenge, which required significant time and effort, was the process of receiving accurate updates to errors found in the trawl datasets after they'd been loaded into the Information Management database. If this process can be improved, with advanced quality control checks and automation, as well as a dramatically improved system to verify data updates, significant gains in accuracy and time savings may be realized.

- **Further investigate linkages between biological and oceanographic condition.**

  As Regional Monitoring data accumulate we are increasingly able to examine linkages between past and present biological conditions and the changing oceanographic environment. Regime level changes are difficult to connect with local trends, but our ability to do so grows with each additional survey. We should pursue additional analyses of such linkages in future regional efforts.

- **Continue to incorporate SCAITE and SCAMIT into pre-field surveys to further improve in-field identifications.**

  The quality assurance and quality control of trawl-caught fish and invertebrates during Bight 2013 was better than in any previous Bight Regional survey. This improvement was largely a function of increased emphasis of pre-field training activities on methods and species identifications. These activities should be continued in future Bight surveys utilizing local scientific societies with parallel missions: The Southern California Association of Ichthyological Taxonomists and Ecologists (www.SCAITE.org) and the Southern California Association of Marine Invertebrate Taxonomists (www.SCAMIT.org).

- **Evaluate additional indicators of contaminant impacts.**

The measurements of abundance, diversity, biomass, age structure and external health anomalies have traditionally been used to assess the condition of demersal fishes and megabenthic invertebrates, and whether there have been effects of contaminant exposure on a community level. Additional indicators of organism response that are linked to sublethal effects of contaminant exposure, such as changes in tissue pathology and molecular markers (e.g. genes, hormones), should be evaluated for inclusion in future trawl surveys to the extent feasible, focusing on embayment strata where healthy fish communities were found less frequently.

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# APPENDIX A:  QUALITY ASSURANCE AND QUALITY CONTROL

# APPENDIX A: QUALITY ASSURANCE AND QUALITY CONTROL

## Introduction

Quality assurance (QA) and quality control (QC) for the Bight ‘13 trawl program was designed to ensure data generated from the participating agencies are complete, representative, accurate, and unbiased. The QA elements are implemented during the design, planning, and management activities of Bight ’13. The QC elements are implemented during the data collection phase of Bight ’13 ensuring the QA processes are adhered to. Method quality objectives (MQOs) established during the QA process are the metrics by which the QC elements are evaluated. All of these QA/QC elements are designed to maintain comparability among the 13 participating organizations in the Bight ’13 trawl program. The QA activities during Bight ’13 included preparation of method manuals, planning of in-survey QC activities, plus pre-survey training and proficiency. The method manuals can be found in three planning documents: Contaminant Impact Assessment Workplan (Bight’13 2013a), Quality Assurance Manual (Bight’13 2013b), and Contaminant Impact Assessment Field Operations Manual (Bight’13 2013c). These manuals dictate the QC activities and the MQOs necessary to achieve QA goals.

## Quality Assurance

The Bight ’13 QA focused on both pre-survey and in-survey elements. Pre-survey activities included training and a taxonomy proficiency exam. Pre-survey training was comprised of an “intercalibration” cruise for lead taxonomists (fish and invertebrates). Twenty-three field taxonomists attended the cruise from 13 different organizations on March 28, 2013. The goal was to demonstrate trawling techniques, then observe a variety of animals from many depths and discuss key identification characteristics. Additional pre-survey training was a Captain/Chief Scientist briefing. Sixteen organizations attended the meeting prior to sampling. The goal of the briefing was to review QC protocols, ensure each boat crew understood what was expected during the survey, and to answer any remaining questions prior to field deployment.

The second pre-survey QA activity was a taxonomy proficiency examination of common trawl fishes and invertebrates prior to organizations commencing field deployments (Table A-1). All eight participating field organizations passed the proficiency examination. Correct identification exceeded the MQO of 90% accuracy both for fishes and invertebrates. A limited number of animals were categorized as needing further identification (FID) by experienced taxonomists. FIDs were not treated as a misidentification. As a result of the successful examination, no organization was excluded from the survey or required to carry qualified taxonomists (recognized by the trawl committee) onboard their boats.

**Table A-1. Results of the Bight '13 pre-survey taxonomic proficiency examination results for trawl fish and invertebrate identification.**

| Organization | Fish (N=30) | | | | Invertebrates (N=31) | | | |
|---|---|---|---|---|---|---|---|---|
| | No. FID | No. Wrong | % Accuracy | Accuracy MQO | No. FID | No. Wrong | % Accuracy | Accuracy MQO |
| 1 | 0 | 2 | 93 | ≥90% | 0 | 2 | 93 | ≥90% |
| 2 | 2 | 1 | 97 | ≥90% | 1 | 2 | 93 | ≥90% |
| 3 | 1 | 0 | 100 | ≥90% | 1 | 0 | 100 | ≥90% |
| 4 | 0 | 0 | 100 | ≥90% | 0 | 0 | 100 | ≥90% |
| 5 | 0 | 0 | 100 | ≥90% | 0 | 0 | 100 | ≥90% |
| 6 | 1 | 1 | 97 | ≥90% | 0 | 0 | 100 | ≥90% |
| 7 | 1 | 2 | 93 | ≥90% | 0 | 2 | 93 | ≥90% |
| 8 | 0 | 1 | 97 | ≥90% | 0 | 0 | 100 | ≥90% |

In-survey QA activities focused on field audits to ensure internal QC checks were being followed appropriately and comparably among field crews. As shown in audit results, field crews followed instructions, used similar equipment, and trawled following the methods prescribed in the field manual. Auditors also observed crews doing internal QC checks as specified in the field manual. As shown in random audits, correct counts and biomass measurements were made. Species were identified correctly during field audits, or appropriately returned for laboratory identification as FIDs. During every audit, organizations retained voucher specimens for post-survey species validation by independent taxonomists. All observed anomalies were noted correctly.

There was one organization that was not audited, which was due to a scheduling conflict with the auditor. The Trawl Committee accepted the agency's trawl data because the agency had participated in three previous Bight surveys, trained their staff to follow Bight protocols during their routine monitoring, and had been previously observed by auditors on numerous occasions.

## Quality Control

Quality control is broken into four elements: completeness; representativeness; accuracy of taxonomy; and accuracy and precision of counts, lengths and weights.

## Completeness

The Bight '13 survey met the overall MQO of 95% completeness (Table A-2). Each survey stratum had pre-defined sample sites inherent to the random design. If a site was not sampleable, agencies were allowed to sample a pre-defined alternate site in order to attain the completeness MQO. Ultimately, 165 sites were sampled from a planned 174 site total. This level of completeness required visiting 201 sites because 36 sites were abandoned (Table A-3). Most abandonments were due to a variety of obstructions (Table A-4) or known untrawlable conditions. Failures such as too deep or shallow relate to incorrect GIS depths used during station selection in the design phase of the survey.

**Table A-2. Station sampling success during the Bight'13 Regional Monitoring Survey. Associated depths for each stratum can be found in the methods section of this report.**

| Stratum | Planned | Attempted | Success | Design Success | MQO |
|---|---|---|---|---|---|
| Bays/Harbors | 26 | 28 | 26 | 100% | $\geq$95% |
| Inner Shelf | 30 | 31 | 27 | 90% | $\geq$95% |
| Mid Shelf | 30 | 34 | 28 | 93% | $\geq$95% |
| Outer Shelf | 30 | 33 | 26 | 87% | $\geq$95% |
| Upper Slope | 31 | 35 | 29 | 94% | $\geq$95% |
| MPAs | 27 | 40 | 29 | 107% | $\geq$95% |
| **Totals** | **174** | **201** | **165** | **95%** | **$\geq$95%** |

MPAs = marine protected areas. MQO=method quality objective

**Table A-3. Trawl station locations and characteristics for the Southern California Bight 2013 Regional Survey, July-September 2013.**

| Station ID | B13 Stratum Final | Target Latitude (dec deg) | Target Longitude (dec deg) | Samp Org | Trawl Num | Samp Date | Failure Codes | Expected Tow Time | Distance To Target (m) | Tow Time (min) | Avg Boat Depth (m) | Trawl Length (m) | PT Time (min) | PT Temp (°C) | PT Depth (m) | Trawl Area Weight |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B13-8017 | Bay | 32.631911 | -117.130957 | AM | 1 | 9/6/2013 | S1,T1 | 10 | 63.89 | 9.15 | 4.5 | 510.7 | 9.13 | 25.8 | 3.9 | 3.859723473 |
| B13-8020 | Bay | 32.641832 | -117.131229 | AM | 1 | 9/5/2013 | S1,T1 | 10 | 35.06 | 9.13 | 4 | 528.5 | 9.37 | 26.0 | 3.7 | 3.859723473 |
| B13-8029 | Bay | 32.6468 | -117.1178 | AM | 1 | 9/5/2013 | S1,T1 | 10 | 58.00 | 10.28 | 12 | 662.3 | 9.73 | 22.5 | 11.4 | 0.200865713 |
| B13-8052 | Bay | 32.65828 | -117.14434 | AM | 1 | 9/5/2013 | S1,T1 | 10 | 10.13 | 9.18 | 5 | 570.0 | 9.50 | 23.6 | 4.9 | 3.859723473 |
| B13-8058 | Bay | 32.661056 | -117.143999 | AM | 1 | 9/4/2013 | S1,T1 | 10 | 11.58 | 9.78 | 4 | 594.6 | 10.10 | 23.8 | 3.9 | 3.859723473 |
| B13-8060 | Bay | 32.66493 | -117.14993 | AM | 1 | 9/4/2013 | S1,T1 | 10 | 5.16 | 8.60 | 4.5 | 491.7 | 8.83 | 22.5 | 4.7 | 3.859723473 |
| B13-8078 | Bay | 32.686838 | -117.148392 | AM | 1 | 9/4/2013 | S1,T1 | 10 | 0.63 | 9.70 | 13 | 645.7 | 9.60 | 20.9 | 12.4 | 3.615303919 |
| B13-8109 | Bay | 32.71504 | -117.18308 | AM | 1 | 9/3/2013 | S1,T1 | 10 | 21.28 | 9.55 | 10.5 | 527.1 | 9.53 | 19.1 | 11.2 | 3.615303919 |
| B13-8118 | Bay | 32.719794 | -117.178628 | AM | 2 | 9/3/2013 | S1,T1 | 10 | 13.48 | 9.53 | 11.5 | 545.3 | 9.47 | 19.0 | 10.9 | 3.615303919 |
| B13-8122 | Bay | 32.72427 | -117.18276 | AM | 1 | 9/3/2013 | S1,T1 | 10 | 20.61 | 9.47 | 9.5 | 564.4 | 9.33 | 19.8 | 6.2 | 3.615303919 |
| B13-8159 | Bay | 32.78439 | -117.2155 | AM | 1 | 8/8/2013 | S1,T1 | 10 | 85.07 | 8.98 | 3.5 | 409.8 | 9.50 | 24.6 | 2.7 | 6.489375121 |
| B13-8302 | None | 33.71205 | -118.25789 | CLA | -99 | | S13,T13 | NA | -99.00 | -99.00 | -99 | -99.0 | | | | 0 |
| B13-8304 | Bay | 33.71351 | -118.24162 | CLA | 1 | 9/24/2013 | S1,T1 | 5 | 20.85 | 5.60 | 24 | 302.2 | 6.47 | 13.9 | 22.5 | 1.767462229 |
| B13-8306 | None | 33.714643 | -118.28328 | CLA | -99 | | S5,T13 | NA | -99.00 | -99.00 | -99 | -99.0 | | | | 0 |
| B13-8315 | Bay | 33.723776 | -118.152675 | LAC | 1 | 8/12/2013 | S1,T1 | 5 | 84.20 | 5.03 | 16 | 270.9 | 5.20 | 13.5 | 15.7 | 1.767462229 |
| B13-8318 | Bay | 33.72421 | -118.22423 | CLA | 2 | 9/24/2013 | S1,T1 | 5 | 11.62 | 5.18 | 15 | 238.1 | 4.53 | 14.0 | 16.0 | 1.767462229 |
| B13-8319 | Bay | 33.725599 | -118.137381 | LAC | 1 | 8/12/2013 | S1,T1 | 5 | 1.08 | 5.02 | 30.5 | 269.5 | 5.93 | 13.9 | 14.1 | 1.767462229 |
| B13-8322 | Bay | 33.727575 | -118.212945 | CLA | 1 | 9/19/2013 | S1,T1 | 5 | 29.14 | 5.07 | 20 | 341.7 | 5.17 | 14.8 | 19.8 | 1.767462229 |
| B13-8323 | Bay | 33.728014 | -118.207181 | CLA | 1 | 9/24/2013 | S1,T1 | 5 | 5.71 | 5.53 | 20 | 322.8 | 4.82 | 14.4 | 19.8 | 1.767462229 |
| B13-8325 | Bay | 33.72857 | -118.15722 | LAC | 1 | 8/12/2013 | S1,T1 | 5 | 0.92 | 5.02 | 15.5 | 269.9 | 5.60 | 13.5 | 15.4 | 1.767462229 |
| B13-8335 | Bay | 33.73168 | -118.20415 | CLA | 1 | 9/24/2013 | S1,T1 | 5 | 6.92 | 5.75 | 20.5 | 377.7 | 5.10 | 14.5 | 19.7 | 1.767462229 |
| B13-8346 | Bay | 33.738889 | -118.144527 | MBC | 1 | 9/11/2013 | S1,T1 | 5 | 25.30 | 5.05 | 11 | 299.6 | 7.83 | 14.4 | 8.8 | 1.767462229 |
| B13-8350 | Bay | 33.73992 | -118.17122 | LAC | 1 | 8/12/2013 | S1,T1 | 5 | 12.90 | 5.02 | 13 | 275.2 | 5.67 | 14.1 | 12.6 | 1.767462229 |
| B13-8351 | Bay | 33.740201 | -118.159117 | MBC | 1 | 9/11/2013 | S1,T1 | 5 | 80.39 | 5.02 | 13 | 284.2 | 7.50 | 14.1 | 10.1 | 1.767462229 |
| B13-8355 | Bay | 33.74233 | -118.15301 | MBC | 1 | 9/11/2013 | S1,T1 | 5 | 30.94 | 5.05 | 11 | 286.0 | 7.50 | 14.2 | 9.2 | 1.767462229 |
| B13-8358 | Bay | 33.7442 | -118.16867 | MBC | 1 | 9/11/2013 | S1,T1 | 5 | 81.55 | 5.02 | 12 | 289.9 | 7.50 | 14.4 | 9.5 | 1.767462229 |
| B13-8375 | Bay | 33.75284 | -118.177488 | MBC | 1 | 9/11/2013 | S1,T1 | 5 | 71.84 | 5.02 | 10 | 287.5 | 8.17 | 14.7 | 8.3 | 1.767462229 |
| B13-8388 | Bay | 33.75964 | -118.16271 | MBC | 1 | 9/11/2013 | S1,T1 | 5 | 33.33 | 5.03 | 6 | 284.6 | 6.00 | 15.6 | 5.7 | 1.767462229 |

| Station ID | B13 Stratum Final | Target Latitude (dec deg) | Target Longitude (dec deg) | Samp Org | Trawl Num | Samp Date | Failure Codes | Expected Tow Time | Distance To Target (m) | Tow Time (min) | Avg Boat Depth (m) | Trawl Length (m) | PT Time (min) | PT Temp (°C) | PT Depth (m) | Trawl Area Weight |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B13-9005 | Inner Shelf | 32.537609 | -117.155113 | CSD | 1 | 7/16/2013 | S1,T1 | 10 | 30.04 | 10.33 | 18 | 386.9 | 12.83 | 13.3 | 18.3 | 35.65453697 |
| B13-9006 | MPA | 32.549235 | -117.140774 | CSD | 1 | 7/16/2013 | S1,T1 | 10 | 39.90 | 9.18 | 12.5 | 396.9 | 11.33 | 14.1 | 13.7 | 4.074379947 |
| B13-9007 | Mid Shelf | 32.55081 | -117.19931 | CSD | 1 | 7/23/2013 | S1,T1 | 10 | 36.73 | 8.98 | 34.5 | 408.5 | 10.67 | 11.2 | 35.4 | 56.20926257 |
| B13-9008 | MPA | 32.5511 | -117.149856 | CSD | 1 | 7/23/2013 | S1,T1 | 10 | 3.88 | 9.77 | 16 | 467.0 | 13.17 | 12.2 | 16.9 | 4.074379947 |
| B13-9011 | Outer Shelf | 32.58567 | -117.3411 | CSD | 1 | 7/22/2013 | S1,T1 | 10 | 53.18 | 10.17 | 174.5 | 370.4 | 13.83 | 9.9 | 167.0 | 16.67756423 |
| B13-9012 | Mid Shelf | 32.58938 | -117.26361 | CSD | 1 | 7/24/2013 | S1,T1 | 10 | 33.72 | 10.02 | 56.5 | 656.0 | 20.00 | 10.6 | 56.0 | 56.20926257 |
| B13-9013 | Outer Shelf | 32.5977 | -117.35125 | CSD | 1 | 7/22/2013 | S1,T1 | 10 | 73.08 | 11.03 | 180.5 | 465.4 | 12.17 | 9.8 | 174.4 | 16.67756423 |
| B13-9014 | Outer Shelf | 32.598426 | -117.328759 | CSD | 1 | 8/6/2013 | S1,T1 | 10 | 15.69 | 10.28 | 135.5 | 531.0 | 9.50 | 10.0 | 138.6 | 16.67756423 |
| B13-9017 | None | 32.62985 | -117.249261 | CSD | -99 | | S14,T13 | NA | -99.00 | -99.00 | -99 | -99.0 | | | | 0 |
| B13-9019 | None | 32.643433 | -117.42767 | CSD | 1 | 8/1/2013 | S16,T8 | NA | -99.00 | 9.43 | 153.5 | -99.0 | 8.00 | 10.2 | 148.7 | 0 |
| B13-9023 | Upper Slope | 32.670064 | -117.420914 | CSD | 1 | 8/1/2013 | S1,T1 | 10 | 93.76 | 12.27 | 417.5 | 600.1 | 11.33 | 7.9 | 407.7 | 98.50645161 |
| B13-9025 | None | 32.672841 | -117.299201 | CSD | -99 | | S13,T13 | NA | -99.00 | -99.00 | -99 | -99.0 | | | | 0 |
| B13-9026 | Upper Slope | 32.69385 | -117.39582 | CSD | 1 | 8/1/2013 | S1,T1 | 10 | 9.98 | 10.42 | 376 | 543.2 | 6.33 | 7.7 | 371.6 | 98.50645161 |
| B13-9034 | Mid Shelf | 32.740758 | -117.314802 | CSD | 1 | 8/6/2013 | S1,T1 | 10 | 2.84 | 9.85 | 72.5 | 535.1 | 9.83 | 10.6 | 73.0 | 56.20926257 |
| B13-9035 | Upper Slope | 32.74149 | -117.42695 | CSD | 1 | 8/6/2013 | S1,T1 | 10 | 47.94 | 13.32 | 463.5 | 734.4 | 7.17 | 7.0 | 464.3 | 98.50645161 |
| B13-9037 | Mid Shelf | 32.76383 | -117.319844 | CSD | 1 | 8/2/2013 | S1,T1 | 10 | 28.17 | 10.62 | 68 | 635.9 | 9.50 | 10.6 | 68.2 | 56.20926257 |
| B13-9040 | Inner Shelf | 32.781347 | -117.2693 | CSD | 1 | 8/8/2013 | S1,T1 | 10 | 14.08 | 9.80 | 16.5 | 446.9 | 12.50 | 12.6 | 16.9 | 35.65453697 |
| B13-9045 | None | 32.80287 | -117.268062 | CSD | -99 | | S14,T13 | NA | -99.00 | -99.00 | -99 | -99.0 | | | | 0 |
| B13-9049 | None | 32.820018 | -117.339304 | CSD | 1 | 8/8/2013 | S16,T8 | NA | -99.00 | 2.15 | 80 | -99.0 | | | | 0 |
| B13-9051 | Upper Slope | 32.821595 | -117.368521 | CSD | 1 | 8/7/2013 | S1,T1 | 10 | 45.56 | 10.22 | 190.5 | 591.5 | 11.33 | 9.8 | 185.9 | 98.50645161 |
| B13-9052 | MPA | 32.823742 | -117.341211 | CSD | 1 | 8/8/2013 | S1,T1 | 10 | 28.81 | 9.17 | 86 | 410.6 | 9.33 | 10.2 | 84.8 | 2.794015503 |
| B13-9053 | Outer Shelf | 32.82544 | -117.36599 | CSD | 1 | 8/8/2013 | S1,T1 | 10 | 69.98 | 9.67 | 180.5 | 429.3 | 6.00 | 9.8 | 182.0 | 16.67756423 |
| B13-9056 | Outer Shelf | 32.831489 | -117.359136 | CSD | 1 | 8/8/2013 | S1,T1 | 10 | 9.14 | 9.42 | 140.5 | 383.9 | 8.50 | 10.0 | 141.1 | 16.67756423 |
| B13-9059 | None | 32.859233 | -117.266702 | CSD | -99 | | S14,T13 | NA | -99.00 | -99.00 | -99 | -99.0 | | | | 0 |
| B13-9068 | None | 32.883938 | -117.283192 | CSD | -99 | | S16,T13 | NA | -99.00 | -99.00 | -99 | -99.0 | | | | 0 |
| B13-9073 | Outer Shelf | 32.910149 | -117.297734 | CSD | 1 | 8/7/2013 | S1,T1 | 10 | 0.20 | 11.05 | 184 | 607.0 | 16.00 | 9.9 | 175.5 | 16.67756423 |
| B13-9087 | None | 33.002986 | -117.298133 | CSD | -99 | | S13,T13 | NA | -99.00 | -99.00 | -99 | -99.0 | | | | 0 |
| B13-9091 | MPA | 33.018232 | -117.340525 | CSD | 2 | 8/12/2013 | S1,T1 | 10 | 51.24 | 13.00 | 242 | 749.0 | 7.17 | 9.3 | 254.3 | 7.102222866 |

| Station ID | B13 Stratum Final | Target Latitude (dec deg) | Target Longitude (dec deg) | Samp Org | Trawl Num | Samp Date | Failure Codes | Expected Tow Time | Distance To Target (m) | Tow Time (min) | Avg Boat Depth (m) | Trawl Length (m) | PT Time (min) | PT Temp (°C) | PT Depth (m) | Trawl Area Weight |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B13-9092 | MPA | 33.026858 | -117.336662 | CSD | 1 | 8/12/2013 | S1,T1 | 10 | 47.90 | 13.37 | 169.5 | 671.5 | 11.17 | 9.4 | 173.3 | 4.35019692 |
| B13-9094 | MPA | 33.033836 | -117.317262 | CSD | 1 | 8/12/2013 | S1,T1 | 10 | 27.12 | 8.88 | 53 | 408.6 | 11.00 | 10.6 | 52.6 | 7.726445873 |
| B13-9100 | Outer Shelf | 33.066573 | -117.367481 | CSD | 1 | 8/13/2013 | S1,T1 | 10 | 48.69 | 10.57 | 191 | 415.4 | 12.17 | 9.5 | 191.5 | 16.67756423 |
| B13-9104 | Mid Shelf | 33.083433 | -117.342651 | CSD | 1 | 8/12/2013 | S1,T1 | 10 | 11.07 | 8.72 | 62 | 425.1 | 10.50 | 10.4 | 62.6 | 56.20926257 |
| B13-9105 | Mid Shelf | 33.08807 | -117.35098 | CSD | 1 | 8/13/2013 | S1,T1 | 10 | 90.10 | 11.37 | 73 | 549.2 | 11.50 | 10.2 | 73.2 | 56.20926257 |
| B13-9107 | Upper Slope | 33.09375 | -117.41715 | CSD | 1 | 8/13/2013 | S1,T1 | 10 | 34.84 | 16.20 | 403.5 | 769.5 | 14.17 | 7.7 | 409.8 | 98.50645161 |
| B13-9111 | Mid Shelf | 33.10513 | -117.36191 | CSD | 1 | 8/13/2013 | S1,T1 | 10 | 18.30 | 9.88 | 83.5 | 472.1 | 11.67 | 10.1 | 83.8 | 56.20926257 |
| B13-9121 | Inner Shelf | 33.175658 | -117.381491 | CSD | 1 | 8/13/2013 | S1,T1 | 10 | 11.43 | 9.27 | 13.5 | 447.5 | 10.50 | 15.0 | 13.8 | 35.65453697 |
| B13-9122 | None | 33.1878 | -117.495309 | OC | 1 | 9/4/2013 | S14,T6 | 10 | -99.00 | 6.50 | 258 | -99.0 | 6.30 | 9.1 | 260.2 | 0 |
| B13-9125 | Outer Shelf | 33.22069 | -117.51202 | OC | 1 | 8/29/2013 | S1,T1 | 10 | 1.17 | 10.10 | 188 | 506.2 | 14.97 | 9.8 | 196.4 | 16.67756423 |
| B13-9129 | Mid Shelf | 33.26553 | -117.53393 | OC | 1 | 8/27/2013 | S1,T1 | 10 | 5.81 | 10.03 | 62 | 567.3 | 11.48 | 10.6 | 62.7 | 56.20926257 |
| B13-9130 | Mid Shelf | 33.268822 | -117.539421 | OC | 1 | 8/22/2013 | S1,T1 | 10 | 17.04 | 10.02 | 63 | 522.9 | 11.73 | 10.6 | 64.8 | 56.20926257 |
| B13-9131 | Mid Shelf | 33.26991 | -117.56485 | OC | 1 | 8/22/2013 | S1,T1 | 10 | 33.74 | 10.03 | 78 | 512.1 | 9.83 | 10.3 | 80.7 | 56.20926257 |
| B13-9135 | None | 33.352721 | -117.563489 | OC | -99 | | S14,T13 | NA | -99.00 | -99.00 | -99 | -99.0 | | | | 0 |
| B13-9137 | None | 33.369648 | -117.689861 | OC | -99 | | S16,T13 | NA | -99.00 | -99.00 | -99 | -99.0 | | | | 0 |
| B13-9140 | None | 33.41845 | -118.02251 | OC | -99 | | S14,T13 | NA | -99.00 | -99.00 | -99 | -99.0 | | | | 0 |
| B13-9152 | MPA | 33.474269 | -117.736624 | OC | 1 | 8/27/2013 | S1,T1 | 10 | 6.71 | 10.03 | 27 | 573.5 | 10.20 | 12.7 | 28.6 | 4.074379947 |
| B13-9159 | MPA | 33.500564 | -117.753666 | OC | 1 | 8/27/2013 | S1,T1 | 10 | 17.55 | 10.02 | 24 | 566.6 | 9.13 | 13.4 | 25.2 | 4.074379947 |
| B13-9161 | MPA | 33.505059 | -117.773131 | OC | 1 | 9/4/2013 | S1,T1 | 10 | 11.85 | 10.03 | 50 | 521.3 | 10.20 | 11.7 | 51.4 | 2.794015503 |
| B13-9163 | None | 33.507918 | -117.814132 | OC | -99 | | S16,T13 | NA | -99.00 | -99.00 | -99 | -99.0 | | | | 0 |
| B13-9166 | MPA | 33.51182 | -117.77133 | OC | 1 | 8/20/2013 | S1,T1 | 10 | 43.64 | 10.02 | 41 | 526.6 | 10.05 | 11.4 | 42.7 | 2.794015503 |
| B13-9168 | MPA | 33.514143 | -117.779428 | OC | 1 | 8/20/2013 | S1,T1 | 10 | 17.69 | 10.02 | 51 | 565.4 | 10.47 | 11.0 | 52.4 | 7.726445873 |
| B13-9171 | MPA | 33.5214 | -117.7698 | OC | 1 | 8/27/2013 | S1,T1 | 10 | 39.46 | 10.03 | 15 | 562.4 | 10.25 | 13.4 | 16.1 | 6.359690968 |
| B13-9173 | MPA | 33.524555 | -117.795335 | OC | 1 | 9/5/2013 | S1,T1 | 10 | 22.95 | 10.03 | 61 | 574.2 | 10.15 | 11.1 | 62.2 | 7.726445873 |
| B13-9174 | Upper Slope | 33.53686 | -117.84848 | OC | 1 | 8/21/2013 | S1,T1 | 10 | 27.27 | 10.07 | 345.5 | 479.2 | 15.20 | 8.1 | 356.9 | 98.50645161 |
| B13-9176 | None | 33.547898 | -117.85292 | OC | 1 | 8/20/2013 | S1,T12 | NA | -99.00 | 10.02 | 212.5 | -99.0 | 7.92 | 9.4 | 233.4 | 0 |
| B13-9177 | MPA | 33.548311 | -117.82495 | OC | 1 | 8/20/2013 | S1,T1 | 10 | 2.52 | 10.00 | 54.5 | 562.4 | 12.93 | 11.0 | 55.7 | 2.794015503 |
| B13-9179 | Upper Slope | 33.55625 | -118.02254 | OC | 2 | 8/15/2013 | S1,T1 | 10 | 28.18 | 10.07 | 228.5 | 592.9 | 15.95 | 9.7 | 232.9 | 98.50645161 |
| B13-9185 | Outer Shelf | 33.564688 | -118.01844 | OC | 1 | 8/15/2013 | S1,T1 | 10 | 4.22 | 10.02 | 149 | 568.7 | 10.90 | 9.9 | 146.1 | 16.67756423 |

| Station ID | B13 Stratum Final | Target Latitude (dec deg) | Target Longitude (dec deg) | Samp Org | Trawl Num | Samp Date | Failure Codes | Expected Tow Time | Distance To Target (m) | Tow Time (min) | Avg Boat Depth (m) | Trawl Length (m) | PT Time (min) | PT Temp (°C) | PT Depth (m) | Trawl Area Weight |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B13-9186 | None | 33.565397 | -117.847047 | OC | -99 | | S14,T13 | NA | -99.00 | -99.00 | -99 | -99.0 | | | | 0 |
| B13-9187 | MPA | 33.568224 | -117.856585 | OC | 1 | 8/14/2013 | S1,T1 | 10 | 29.55 | 10.05 | 52.5 | 567.8 | 12.52 | 10.7 | 53.8 | 2.794015503 |
| B13-9192 | MPA | 33.580857 | -117.86846 | OC | 1 | 8/21/2013 | S1,T1 | 10 | 17.30 | 10.03 | 25 | 527.4 | 10.80 | 11.9 | 26.5 | 4.074379947 |
| B13-9194 | Mid Shelf | 33.589758 | -117.894685 | OC | 1 | 8/13/2013 | S1,T1 | 10 | 26.55 | 10.15 | 33.5 | 631.9 | 10.80 | 11.9 | 34.3 | 56.20926257 |
| B13-9199 | Mid Shelf | 33.60185 | -118.05647 | OC | 1 | 8/13/2013 | S1,T1 | 10 | 17.42 | 10.10 | 37.5 | 656.1 | 10.43 | 11.2 | 38.8 | 56.20926257 |
| B13-9200 | Mid Shelf | 33.60346 | -118.09545 | LAC | 1 | 8/13/2013 | S1,T1 | 10 | 18.20 | 10.03 | 54.5 | 521.7 | 10.07 | 10.3 | 53.4 | 56.20926257 |
| B13-9202 | None | 33.62105 | -118.19507 | LAC | 1 | 8/13/2013 | S16,T8 | NA | -99.00 | 10.03 | 43 | -99.0 | 9.33 | 11.6 | 42.8 | 0 |
| B13-9204 | Inner Shelf | 33.6278 | -117.9872 | OC | 1 | 8/13/2013 | S1,T1 | 10 | 30.53 | 10.12 | 14 | 594.9 | 10.10 | 14.4 | 15.1 | 35.65453697 |
| B13-9214 | Inner Shelf | 33.643 | -118.07835 | OC | 1 | 8/14/2013 | S1,T1 | 10 | 14.32 | 10.08 | 26 | 608.4 | 10.15 | 12.6 | 28.1 | 35.65453697 |
| B13-9217 | Mid Shelf | 33.648 | -118.1495 | LAC | 1 | 8/13/2013 | S1,T1 | 10 | 17.63 | 10.02 | 31 | 511.9 | 11.47 | 13.1 | 30.5 | 56.20926257 |
| B13-9219 | Inner Shelf | 33.654498 | -118.058379 | OC | 1 | 8/14/2013 | S1,T1 | 10 | 19.87 | 10.05 | 18 | 634.4 | 9.17 | 14.3 | 19.3 | 35.65453697 |
| B13-9221 | Inner Shelf | 33.65956 | -118.13065 | LAC | 1 | 8/13/2013 | S1,T1 | 10 | 7.57 | 10.03 | 28 | 521.0 | 10.33 | 13.3 | 27.7 | 35.65453697 |
| B13-9223 | Upper Slope | 33.675873 | -118.332471 | LAC | 2 | 8/16/2013 | S1,T1 | 10 | 48.90 | 13.03 | 458.5 | 522.8 | 13.80 | 6.9 | 451.8 | 98.50645161 |
| B13-9228 | Upper Slope | 33.69409 | -118.34651 | LAC | 1 | 8/14/2013 | S1,T1 | 10 | 7.02 | 10.00 | 262 | 534.4 | 11.67 | 8.7 | 280.8 | 98.50645161 |
| B13-9229 | Inner Shelf | 33.69541 | -118.29616 | LAC | 1 | 8/13/2013 | S1,T1 | 10 | 22.52 | 10.05 | 28 | 518.2 | 10.47 | 13.0 | 27.7 | 35.65453697 |
| B13-9235 | MPA | 33.703352 | -118.397495 | LAC | 1 | 8/14/2013 | S1,T1 | 10 | 40.22 | 10.02 | 483 | 481.4 | 8.47 | 7.0 | 459.1 | 7.102222866 |
| B13-9237 | MPA | 33.721411 | -118.417921 | LAC | 1 | 8/16/2013 | S1,T1 | 10 | 1.26 | 10.03 | 294.5 | 428.5 | 13.47 | 8.5 | 305.0 | 7.102222866 |
| B13-9239 | Inner Shelf | 33.722658 | -118.155259 | LAC | 1 | 8/12/2013 | S1,T1 | 10 | 106.95 | 10.03 | 18 | 536.0 | 10.93 | 13.4 | 17.9 | 35.65453697 |
| B13-9245 | Inner Shelf | 33.733 | -118.1215 | LAC | 1 | 8/12/2013 | S1,T1 | 10 | 4.28 | 10.02 | 8 | 545.5 | 11.00 | 16.3 | 7.4 | 35.65453697 |
| B13-9251 | Outer Shelf | 33.76682 | -118.46048 | LAC | 1 | 8/14/2013 | S1,T1 | 10 | 15.51 | 10.03 | 130.5 | 519.2 | 10.40 | 9.8 | 133.9 | 16.67756423 |
| B13-9257 | Inner Shelf | 33.829487 | -118.401262 | CLA | 1 | 9/17/2013 | S1,T1 | 10 | 31.01 | 10.10 | 18 | 567.6 | 11.05 | 13.6 | 16.6 | 35.65453697 |
| B13-9260 | None | 33.83546 | -118.46982 | CLA | -99 | | S5,T13 | NA | -99.00 | -99.00 | -99 | -99.0 | | | | 0 |
| B13-9261 | None | 33.835548 | -118.567524 | CLA | -99 | | S5,T13 | NA | -99.00 | -99.00 | -99 | -99.0 | | | | 0 |
| B13-9262 | None | 33.836758 | -118.509922 | CLA | -99 | | S13,T13 | NA | -99.00 | -99.00 | -99 | -99.0 | | | | 0 |
| B13-9264 | None | 33.851195 | -118.455724 | CLA | -99 | | S5,T13 | NA | -99.00 | -99.00 | -99 | -99.0 | | | | 0 |
| B13-9266 | Mid Shelf | 33.86038 | -118.44805 | CLA | 1 | 9/3/2013 | S1,T1 | 10 | 21.91 | 10.12 | 60 | 451.6 | 10.60 | 11.1 | 57.3 | 56.20926257 |
| B13-9267 | None | 33.860836 | -118.559169 | CLA | -99 | | S14,T13 | NA | -99.00 | -99.00 | -99 | -99.0 | | | | 0 |
| B13-9271 | Mid Shelf | 33.897933 | -118.536994 | CLA | 1 | 9/17/2013 | S1,T1 | 10 | 6.17 | 10.15 | 59.5 | 517.0 | 9.72 | 10.8 | 57.1 | 56.20926257 |

| Station ID | B13 Stratum Final | Target Latitude (dec deg) | Target Longitude (dec deg) | Samp Org | Trawl Num | Samp Date | Failure Codes | Expected Tow Time | Distance To Target (m) | Tow Time (min) | Avg Boat Depth (m) | Trawl Length (m) | PT Time (min) | PT Temp (°C) | PT Depth (m) | Trawl Area Weight |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B13-9283 | None | 33.92867 | -118.48282 | CLA | 1 | 9/17/2013 | S13,T8 | NA | -99.00 | 10.17 | 35.5 | -99.0 | | | | 0 |
| B13-9286 | Mid Shelf | 33.93486 | -118.53976 | CLA | 1 | 9/17/2013 | S1,T1 | 10 | 15.96 | 10.08 | 57 | 502.0 | 9.28 | 11.0 | 56.7 | 56.20926257 |
| B13-9287 | Outer Shelf | 33.935507 | -118.592121 | CLA | 1 | 9/4/2013 | S1,T1 | 10 | 18.37 | 10.08 | 201.5 | 484.6 | 11.53 | 9.8 | 199.5 | 16.67756423 |
| B13-9292 | Mid Shelf | 33.94372 | -118.51978 | CLA | 2 | 8/21/2013 | S1,T1 | 10 | 38.87 | 9.98 | 48 | 434.6 | 13.12 | 11.3 | 45.1 | 56.20926257 |
| B13-9300 | Outer Shelf | 33.95711 | -118.59303 | CLA | 1 | 9/4/2013 | S1,T1 | 10 | 34.47 | 10.08 | 155 | 485.6 | 13.28 | 10.0 | 97.0 | 16.67756423 |
| B13-9303 | Inner Shelf | 33.9625 | -118.4762 | CLA | 2 | 9/9/2013 | S1,T1 | 10 | 28.31 | 10.03 | 15 | 559.3 | 10.42 | 13.2 | 15.0 | 35.65453697 |
| B13-9309 | Upper Slope | 33.97742 | -118.876393 | VRG | 1 | 8/20/2013 | S1,T1 | 10 | 13.28 | 10.15 | 445.5 | 633.9 | 18.30 | 7.5 | 438.1 | 98.50645161 |
| B13-9310 | None | 33.982016 | -118.814626 | CLA | -99 | | S5,S14,T13 | NA | -99.00 | -99.00 | -99 | -99.0 | | | | 0 |
| B13-9311 | None | 33.982461 | -118.802405 | CLA | -99 | | S5,S14,T13 | NA | -99.00 | -99.00 | -99 | -99.0 | | | | 0 |
| B13-9312 | None | 33.983461 | -118.827219 | NA | -99 | | S5,S16,T13 | NA | -99.00 | -99.00 | -99 | -99.0 | | | | 0 |
| B13-9314 | MPA | 33.991549 | -118.857031 | ABC | 2 | 9/18/2013 | S1,T1 | 10 | 72.05 | 10.57 | 163 | 811.7 | 28.27 | 10.3 | 148.0 | 4.35019692 |
| B13-9316 | Mid Shelf | 33.995275 | -118.632803 | CLA | 1 | 9/4/2013 | S1,T1 | 10 | 30.81 | 10.02 | 62.5 | 574.5 | 13.67 | 11.4 | 3.1 | 56.20926257 |
| B13-9319 | Inner Shelf | 33.997437 | -118.491824 | CLA | 1 | 9/10/2013 | S1,T1 | 10 | 10.34 | 10.03 | 8 | 606.0 | 10.57 | 16.1 | 7.3 | 35.65453697 |
| B13-9320 | MPA | 33.999172 | -118.868867 | ABC | 1 | 9/18/2013 | S1,T1 | 10 | 20.11 | 10.03 | 96.5 | 713.4 | 22.40 | 10.7 | 89.8 | 7.726445873 |
| B13-9321 | MPA | 34.000422 | -118.815077 | VRG | 1 | 7/22/2013 | S1,T1 | 10 | 30.72 | 10.05 | 43.5 | 600.3 | 11.00 | 10.9 | 45.3 | 7.726445873 |
| B13-9323 | MPA | 34.001255 | -118.824445 | VRG | 1 | 7/22/2013 | S1,T1 | 10 | 1.74 | 10.22 | 40.5 | 698.0 | 11.50 | 0.0 | 40.4 | 7.726445873 |
| B13-9324 | None | 34.002434 | -118.917967 | ABC | 1 | 9/18/2013 | S1,T3 | NA | -99.00 | -99.00 | -99 | -99.0 | | | | 0 |
| B13-9325 | Outer Shelf | 34.004587 | -119.055957 | VRG | 1 | 8/20/2013 | S1,T1 | 10 | 8.74 | 5.43 | 188 | 290.8 | 16.45 | 9.8 | 205.7 | 16.67756423 |
| B13-9326 | Mid Shelf | 34.005089 | -118.766627 | CLA | 1 | 8/29/2013 | S1,T1 | 10 | 2.95 | 10.03 | 39 | 588.6 | 11.70 | 11.9 | 37.0 | 56.20926257 |
| B13-9331 | Mid Shelf | 34.013198 | -118.670188 | CLA | 1 | 8/30/2013 | S1,T1 | 10 | 36.66 | 10.05 | 41 | 650.5 | 11.63 | 11.7 | 39.1 | 56.20926257 |
| B13-9336 | Inner Shelf | 34.019478 | -118.743049 | CLA | 1 | 8/29/2013 | S1,T1 | 10 | 35.53 | 10.42 | 22 | 670.7 | 10.58 | 13.0 | 20.8 | 35.65453697 |
| B13-9339 | MPA | 34.022047 | -118.867355 | ABC | 1 | 9/18/2013 | S1,T1 | 10 | 89.97 | 11.77 | 43 | 725.0 | 13.33 | 12.6 | 38.3 | 7.726445873 |
| B13-9341 | Inner Shelf | 34.02321 | -118.59282 | CLA | 1 | 9/10/2013 | S1,T1 | 10 | 17.87 | 10.02 | 23 | 602.6 | 9.73 | 13.1 | 21.7 | 35.65453697 |
| B13-9342 | Inner Shelf | 34.026464 | -118.570654 | CLA | 1 | 9/10/2013 | S1,T1 | 10 | 22.25 | 10.10 | 14 | 582.3 | 10.27 | 13.8 | 13.4 | 35.65453697 |
| B13-9346 | None | 34.03663 | -118.91685 | ABC | -99 | | S15,T13 | NA | -99.00 | -99.00 | -99 | -99.0 | | | | 0 |
| B13-9348 | Upper Slope | 34.04114 | -119.19721 | LAC | 1 | 7/30/2013 | S1,T1 | 10 | 11.84 | 10.03 | 400.5 | 472.1 | 12.40 | 7.6 | 398.9 | 98.50645161 |
| B13-9350 | Outer Shelf | 34.04406 | -119.05558 | LAC | 1 | 7/30/2013 | S1,T1 | 10 | 2.33 | 10.03 | 206 | 511.4 | 16.27 | 9.1 | 207.7 | 16.67756423 |

| Station ID | B13 Stratum Final | Target Latitude (dec deg) | Target Longitude (dec deg) | Samp Org | Trawl Num | Samp Date | Failure Codes | Expected Tow Time | Distance To Target (m) | Tow Time (min) | Avg Boat Depth (m) | Trawl Length (m) | PT Time (min) | PT Temp (°C) | PT Depth (m) | Trawl Area Weight |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B13-9354 | Upper Slope | 34.050849 | -119.215754 | LAC | 1 | 7/30/2013 | S1,T1 | 10 | 49.34 | 10.02 | 238 | 512.3 | 15.80 | 8.7 | 234.6 | 98.50645161 |
| B13-9356 | Outer Shelf | 34.053794 | -119.148966 | ABC | 1 | 9/6/2013 | S1,T1 | 10 | 73.60 | 9.60 | 126 | 637.5 | 14.13 | 10.2 | 119.4 | 16.67756423 |
| B13-9372 | Inner Shelf | 34.10112 | -119.15082 | ABC | 1 | 8/21/2013 | S1,T1 | 10 | 25.89 | 9.85 | 15 | 557.9 | 12.67 | 12.3 | 13.5 | 35.65453697 |
| B13-9374 | Outer Shelf | 34.10717 | -119.31902 | VRG | 1 | 8/23/2013 | S1,T1 | 10 | 76.58 | 8.58 | 195 | 696.3 | 12.85 | 9.3 | 197.8 | 16.67756423 |
| B13-9377 | Inner Shelf | 34.113712 | -119.180458 | ABC | 1 | 8/21/2013 | S1,T1 | 10 | 34.94 | 9.57 | 17 | 699.1 | 12.13 | 12.2 | 15.0 | 35.65453697 |
| B13-9379 | Upper Slope | 34.11821 | -119.62891 | VRG | 1 | 8/21/2013 | S1,T1 | 10 | 5.87 | 9.62 | 257 | 679.5 | 14.05 | 8.5 | 263.8 | 98.50645161 |
| B13-9380 | Outer Shelf | 34.12281 | -119.33129 | ABC | 1 | 8/20/2013 | S1,T1 | 10 | 13.65 | 9.90 | 137.5 | 788.6 | 21.07 | 9.8 | 127.0 | 16.67756423 |
| B13-9382 | Inner Shelf | 34.124595 | -119.258562 | VRG | 1 | 8/23/2013 | S1,T1 | 10 | 35.44 | 10.15 | 24 | 749.4 | 13.45 | 12.1 | 23.8 | 35.65453697 |
| B13-9383 | Inner Shelf | 34.12507 | -119.19268 | ABC | 1 | 9/6/2013 | S1,T1 | 10 | 0.23 | 9.87 | 16 | 672.0 | 13.20 | 13.0 | 13.1 | 35.65453697 |
| B13-9385 | Outer Shelf | 34.132675 | -119.369899 | VRG | 1 | 8/23/2013 | S1,T1 | 10 | 58.61 | 9.38 | 165 | 609.5 | 15.40 | 9.6 | 170.9 | 16.67756423 |
| B13-9387 | Upper Slope | 34.14379 | -120.17822 | VRG | 1 | 7/23/2013 | S1,T1 | 10 | 15.76 | 10.95 | 430 | 655.2 | 10.80 | 7.4 | 443.7 | 98.50645161 |
| B13-9388 | Upper Slope | 34.14562 | -119.77009 | VRG | 1 | 7/26/2013 | S1,T1 | 10 | 17.28 | 10.50 | 362.5 | 757.8 | 10.40 | 7.7 | 366.3 | 98.50645161 |
| B13-9391 | Upper Slope | 34.15836 | -119.82763 | VRG | 1 | 7/26/2013 | S1,T1 | 10 | 39.98 | 7.72 | 405 | 583.2 | 8.05 | 7.1 | 415.2 | 98.50645161 |
| B13-9394 | Upper Slope | 34.168699 | -119.541697 | VRG | 1 | 8/22/2013 | S1,T1 | 10 | 34.47 | 10.30 | 237 | 739.0 | 15.65 | 8.5 | 242.1 | 98.50645161 |
| B13-9396 | Upper Slope | 34.171238 | -119.876761 | VRG | 3 | 7/26/2013 | S1,T1 | 10 | 46.79 | 8.60 | 460.5 | 440.8 | 8.75 | 6.6 | 468.6 | 98.50645161 |
| B13-9397 | Inner Shelf | 34.17867 | -119.34686 | ABC | 1 | 8/20/2013 | S1,T1 | 10 | 101.33 | 10.78 | 26 | 704.0 | 12.53 | 13.5 | 24.6 | 35.65453697 |
| B13-9398 | Upper Slope | 34.17889 | -119.612044 | VRG | 1 | 8/22/2013 | S1,T1 | 10 | 36.00 | 9.53 | 256.5 | 645.3 | 15.20 | 8.3 | 261.3 | 98.50645161 |
| B13-9399 | Upper Slope | 34.182353 | -120.407324 | VRG | 1 | 7/23/2013 | S1,T1 | 10 | 45.10 | 9.70 | 259 | 587.3 | 12.10 | 8.8 | 259.3 | 98.50645161 |
| B13-9400 | Upper Slope | 34.18317 | -120.35129 | VRG | 1 | 7/23/2013 | S1,T1 | 10 | 26.80 | 10.22 | 458.5 | 646.1 | 11.45 | 7.0 | 457.2 | 98.50645161 |
| B13-9403 | Outer Shelf | 34.20641 | -119.632707 | VRG | 1 | 8/22/2013 | S1,T1 | 10 | 13.65 | 9.62 | 160 | 700.1 | 15.50 | 9.3 | 153.0 | 16.67756423 |
| B13-9404 | None | 34.20677 | -119.56748 | ABC | -99 | | S15,T13 | NA | -99.00 | -99.00 | -99 | -99.0 | | | | 0 |
| B13-9407 | Outer Shelf | 34.216258 | -119.605949 | VRG | 1 | 8/22/2013 | S1,T1 | 10 | 79.53 | 9.68 | 160 | 778.3 | 9.00 | 9.6 | 162.4 | 16.67756423 |
| B13-9409 | Inner Shelf | 34.218317 | -119.295039 | ABC | 1 | 8/20/2013 | S1,T1 | 10 | 83.01 | 9.62 | 18 | 665.4 | 13.07 | 16.4 | 16.6 | 35.65453697 |
| B13-9414 | Outer Shelf | 34.225077 | -119.731981 | VRG | 1 | 8/21/2013 | S1,T1 | 10 | 22.13 | 9.40 | 196 | 539.6 | 23.95 | 9.0 | 200.2 | 16.67756423 |
| B13-9415 | None | 34.227484 | -119.697116 | ABC | 1 | 9/12/2013 | S1,T8 | NA | -99.00 | 10.02 | 135.5 | -99.0 | | | | 0 |

| Station ID | B13 Stratum Final | Target Latitude (dec deg) | Target Longitude (dec deg) | Samp Org | Trawl Num | Samp Date | Failure Codes | Expected Tow Time | Distance To Target (m) | Tow Time (min) | Avg Boat Depth (m) | Trawl Length (m) | PT Time (min) | PT Temp (°C) | PT Depth (m) | Trawl Area Weight |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B13-9419 | Outer Shelf | 34.240059 | -119.669104 | ABC | 2 | 9/13/2013 | S1,T1 | 10 | 57.56 | 10.47 | 190 | 1317.2 | 21.07 | 9.7 | 186.2 | 16.67756423 |
| B13-9420 | None | 34.243638 | -119.639441 | ABC | -99 | | S15,T13 | NA | -99.00 | -99.00 | -99 | -99.0 | | | | 0 |
| B13-9421 | Inner Shelf | 34.244405 | -119.37034 | ABC | 1 | 8/20/2013 | S1,T1 | 10 | 36.73 | 9.52 | 24.5 | 637.3 | 11.07 | 14.8 | 21.8 | 35.65453697 |
| B13-9424 | Mid Shelf | 34.254866 | -119.476489 | ABC | 1 | 9/12/2013 | S1,T1 | 10 | 129.34 | 17.20 | 63 | 985.6 | 19.60 | 11.3 | 56.3 | 56.20926257 |
| B13-9426 | Upper Slope | 34.258585 | -119.8104 | VRG | 1 | 7/26/2013 | S1,T1 | 10 | 60.80 | 8.12 | 289 | 542.0 | | | | 98.50645161 |
| B13-9427 | Upper Slope | 34.260016 | -120.281134 | VRG | 1 | 7/24/2013 | S1,T1 | 10 | 14.54 | 9.28 | 463.5 | 583.3 | 15.70 | 7.1 | 460.8 | 98.50645161 |
| B13-9431 | Outer Shelf | 34.27751 | -119.65789 | ABC | 1 | 9/13/2013 | S1,T1 | 10 | 43.18 | 9.43 | 12.5 | 1003.8 | 25.87 | 10.0 | 123.1 | 16.67756423 |
| B13-9432 | Outer Shelf | 34.27781 | -119.71827 | VRG | 1 | 8/21/2013 | S1,T1 | 10 | 67.05 | 9.18 | 200 | 658.5 | 13.00 | 9.1 | 202.6 | 16.67756423 |
| B13-9433 | Mid Shelf | 34.278317 | -119.583145 | ABC | 1 | 9/11/2013 | S1,T1 | 10 | 37.42 | 9.65 | 92 | 803.3 | 23.73 | 11.0 | 90.4 | 56.20926257 |
| B13-9435 | Upper Slope | 34.284559 | -120.423706 | VRG | 1 | 7/24/2013 | S1,T1 | 10 | 79.95 | 9.47 | 412.5 | 649.8 | 11.55 | 7.3 | 421.3 | 98.50645161 |
| B13-9436 | Upper Slope | 34.28711 | -120.45557 | VRG | 1 | 7/24/2013 | S1,T1 | 10 | 75.39 | 12.67 | 424.5 | 590.3 | 17.20 | 7.0 | 437.6 | 98.50645161 |
| B13-9441 | Upper Slope | 34.3138 | -119.88421 | VRG | 1 | 7/25/2013 | S1,T1 | 10 | 61.41 | 9.57 | 420.5 | 506.7 | 10.50 | 6.9 | 419.1 | 98.50645161 |
| B13-9444 | Outer Shelf | 34.319879 | -119.751125 | VRG | 1 | 8/21/2013 | S1,T1 | 10 | 34.02 | 9.47 | 160 | 752.6 | 12.35 | 9.6 | 159.7 | 16.67756423 |
| B13-9447 | Inner Shelf | 34.342466 | -119.457997 | ABC | 1 | 9/12/2013 | S1,T1 | 10 | 64.66 | 9.98 | 23.5 | 617.7 | 12.93 | 13.1 | 21.2 | 35.65453697 |
| B13-9448 | Mid Shelf | 34.343842 | -119.77376 | ABC | 2 | 8/6/2013 | S1,T1 | 10 | 111.75 | 10.18 | 85.5 | 1147.0 | | | | 56.20926257 |
| B13-9449 | Mid Shelf | 34.34408 | -119.56258 | VRG | 1 | 8/21/2013 | S1,T1 | 10 | 19.52 | 9.78 | 46 | 599.9 | 13.55 | 11.5 | 42.5 | 56.20926257 |
| B13-9450 | Upper Slope | 34.34424 | -120.36861 | VRG | 1 | 7/24/2013 | S1,T1 | 10 | 84.36 | 10.02 | 291 | 623.1 | 16.10 | 8.4 | 289.6 | 98.50645161 |
| B13-9454 | MPA | 34.359302 | -119.849501 | ABC | 1 | 8/7/2013 | S1,T1 | 10 | 100.00 | 10.02 | 100.5 | 1188.2 | 28.00 | 9.7 | 98.4 | 7.726445873 |
| B13-9455 | MPA | 34.360504 | -119.891456 | VRG | 1 | 7/23/2013 | S1,T1 | 10 | 13.35 | 11.13 | 177.5 | 759.3 | 10.50 | 9.4 | 180.7 | 4.35019692 |
| B13-9456 | MPA | 34.360839 | -119.849221 | ABC | 1 | 8/7/2013 | S1,T1 | 10 | 77.07 | 5.75 | 92.5 | 958.1 | 21.33 | 9.7 | 90.4 | 7.726445873 |
| B13-9457 | Upper Slope | 34.36268 | -120.01034 | VRG | 1 | 7/24/2013 | S1,T1 | 10 | 43.72 | 9.88 | 442 | 814.6 | 13.60 | 6.8 | 451.2 | 98.50645161 |
| B13-9458 | Mid Shelf | 34.36812 | -119.540117 | ABC | 1 | 9/11/2013 | S1,T1 | 10 | 27.19 | 9.82 | 34 | 559.8 | 12.20 | 12.3 | 31.0 | 56.20926257 |
| B13-9459 | Upper Slope | 34.368389 | -120.113018 | VRG | 1 | 7/25/2013 | S1,T1 | 10 | 84.02 | 7.72 | 429.5 | 371.3 | 13.35 | 6.9 | 433.3 | 98.50645161 |
| B13-9465 | MPA | 34.39505 | -119.858616 | VRG | 1 | 7/23/2013 | S1,T1 | 10 | 12.51 | 9.68 | 42 | 729.7 | 11.05 | 11.6 | 41.7 | 7.726445873 |
| B13-9466 | Inner Shelf | 34.39548 | -119.66218 | ABC | 1 | 8/6/2013 | S1,T1 | 10 | 36.13 | 10.02 | 24 | 787.6 | | | | 35.65453697 |
| B13-9467 | MPA | 34.39839 | -119.86476 | ABC | 1 | 9/11/2013 | S1,T1 | 10 | 45.49 | 9.83 | 29.5 | 596.5 | 13.27 | 25.5 | 25.3 | 6.359690968 |
| B13-9468 | MPA | 34.39975 | -119.874813 | ABC | 1 | 9/11/2013 | S1,T1 | 10 | 34.08 | 9.72 | 25 | 440.0 | 11.60 | 14.6 | 21.5 | 6.359690968 |

| Station ID | B13 Stratum Final | Target Latitude (dec deg) | Target Longitude (dec deg) | Samp Org | Trawl Num | Samp Date | Failure Codes | Expected Tow Time | Distance To Target (m) | Tow Time (min) | Avg Boat Depth (m) | Trawl Length (m) | PT Time (min) | PT Temp (°C) | PT Depth (m) | Trawl Area Weight |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B13-9470 | Mid Shelf | 34.401 | -119.8328 | ABC | 1 | 9/11/2013 | S1,T1 | 10 | 65.13 | 9.78 | 30.5 | 592.3 | 10.67 | 14.3 | 29.7 | 56.20926257 |
| B13-9471 | Inner Shelf | 34.40395 | -119.81211 | VRG | 2 | 7/25/2013 | S1,T1 | 10 | 26.76 | 10.22 | 16 | 849.7 | 11.10 | 14.2 | 15.1 | 35.65453697 |
| B13-9474 | None | 34.406366 | -120.417314 | NA | -99 | | S16,T13 | NA | -99.00 | -99.00 | -99 | -99.0 | | | | 0 |
| B13-9476 | Outer Shelf | 34.420032 | -120.269188 | VRG | 1 | 7/25/2013 | S1,T1 | 10 | 20.53 | 9.68 | 158 | 738.6 | 10.80 | 9.8 | 155.2 | 16.67756423 |
| B13-9481 | None | 34.44262 | -120.427592 | NA | -99 | | S16,T13 | NA | -99.00 | -99.00 | -99 | -99.0 | | | | 0 |
| B13-9482 | Mid Shelf | 34.443088 | -120.285164 | VRG | 1 | 7/25/2013 | S1,T1 | 10 | 37.55 | 10.45 | 28 | 842.3 | 10.85 | 11.6 | 23.2 | 56.20926257 |
| B13-9484 | None | 34.459108 | -120.31709 | VRG | 1 | 7/25/2013 | S14,T13 | NA | -99.00 | -99.00 | -99 | -99.0 | | | | 0 |
| B13-9487 | Inner Shelf | 34.464703 | -120.179707 | VRG | 1 | 7/25/2013 | S1,T1 | 10 | 23.68 | 10.12 | 17 | 817.2 | 12.20 | 12.5 | 13.9 | 35.65453697 |
| B13-9488 | None | 34.467422 | -120.216859 | NA | -99 | | S14,T13 | NA | -99.00 | -99.00 | -99 | -99.0 | | | | 0 |

* = extra trawl not part of survey; ABC = Aquatic Bioassay and Consulting Laboratories; AM = AMEC Environment & Infrastructure; CLA = City of Los Angeles, Environmental Monitoring Division; CSD = City of San Diego, Public Utilities Department; LAC = County Sanitation Districts of Los Angeles County; MBC = MBC Applied Environmental Sciences, Inc.; NA = Not Available; OC = Orange County Sanitation Districts; VRG = Vantuna Research Group - Occidental College; S1 = None; S5 = Pre-abandoned; S13 = Anthropogenic obstruction; S14 = Natural hard bottom obstructions; S15 = Not trawlable - smooth, undulating bottom; S16 = Not sampleable - other; T1 = None; T3 = Outside Target Depth; T6 = Trawl hit unknown obstruction; T8 = Torn Net; T12 = Inadequate trawl track; T13 = Other - Trawl Failure; PT = Pressure/Temperature sensor bottom values.

**Table A-4. Reasons for unsuccessful trawl stations during the Bight'13 Regional Trawl Survey. Failure codes, as reported by sampling organizations and listed in Table A-3, were recategorized.**

| Failure Reason | Number of Stations | Percent of stations |
|---|---|---|
| CDFW interagency cooperation | 9 | 4.5% |
| Man-made obstruction | 6 | 3.0% |
| Torn net | 5 | 2.5% |
| Natural obstruction-Rocks/Reef | 4 | 2.0% |
| Natural obstruction-Kelp | 3 | 1.5% |
| Natural obstruction-Unknown | 1 | 0.5% |
| Variable depth, > 10% | 3 | 1.5% |
| Other | 2 | 1.0% |
| Too deep to trawl | 2 | 1.0% |
| Too shallow | 1 | 0.5% |
| **Total** | **36** | **17.9%** |

CDFW: California Department of Fish and Wildlife; man-made obstructions include cable crossings, moored ships, pipes, etc.; Other: inadequate trawl track or never attempted; Too deep to trawl: vessel did not have enough wire to sample site

## Representativeness

**Distance to target criteria**. Ninety-eight percent of trawl paths came within 100 m of their designated sampling station coordinates. This passed the MQO of >95%. Only four of 165 sites were trawled at distances greater than 100 m. Two were on the Inner Shelf (5 - 30 m depth) and the other two were on the mid shelf (30 - 120 m depth). However, none of these trawls exceeded the criteria by more than 30 m. Therefore, these trawls are flagged in the database, but the trawl committee did not reject the data due to the catches being representative of others in the same stratum.

**Depth criteria**. The depth of the start and end of the trawl were within 10% of the station occupation depth for 96% of all trawls. This passed the MQO of ≥95%. If either the start or the end of the trawl was within 10% of the station occupation depth, then the trawl was thought to be representative of others in the same stratum Generally, sites missing the depth criteria range were in shallow water (≤ 20m), meaning small relative depth changes (depth deviations ranged from -4 to +6 m). Therefore, these trawls are flagged in the database, but the trawl committee did not reject the data due to representativeness. At one site, an end-of-trawl depth was not recorded, which resulted in a “-99” value for that data field.

## Accuracy and Precision

**Counts, Lengths, Weights**. Field crews met the 90% MQO for accuracy and precision of counts, lengths and biomass of both fishes and invertebrates (Table A-5). Counts tended to be the most accurate and precise measurement, with error rates ≤1%. Fish lengths were the most variable with error rates averaging 4% and reaching as high as 10%. The errors frequently differed by ±1 centimeter size class. Bight '13 was the first regional survey to collect "tweeners" information, or lengths very near the centimeter mark. The tweener information clearly illustrated that tweeners accounted for 17 to 55% of the count variability, explaining the majority of deviations encountered by field crews. Re-training did not improve length variability measurements and subsequent re-measures by different individuals still had slight differences.

**Table A-5. Summary of field organizations internal audits on fish and invertebrate groupings during the Bight'13 regional trawl survey. Measurement Quality Objectives (MQOs) were on species identification, counts, weights, fish lengths, and pathology identification. "Tweeners" are lengths that straddle a centimeter mark by ±2 mm. NA: information was not available.**

| | Participating Organization | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | MQO |
| **Fishes** | | | | | | | | | |
| Number of Species | 15 | 15 | 19 | 19 | 10 | NA | 20 | 11 | |
| Number of Individuals | 330 | 185 | 673 | 404 | NA | NA | 805 | NA | |
| Avg. Species ID % error | 0 | 0 | <1(1) | 0 | 0 | NA | 0 | <1 | ≤10% |
| Avg. Pathology ID % error | 0 | 0 | 0 | 0 | 0 | NA | 0 | 0 | ≤5% |
| Avg. Count % error (SD) | <1(1) | <1(1) | <1(1) | <1(1) | 0 | NA | 1(2) | 1(1) | ≤10% |
| Avg. Length % error (SD) | 1(1) | 3(6) | 2(3) | 2(2) | 2(2) | NA | 6(8) | 10(2) | ≤10% |
| Avg. Biomass % error (SD) | 4(4) | 1(1) | 1(2) | 0 | 0 | NA | 3(1) | 2(2) | ≤10% |
| Avg. % Tweeners (SD) | 17(11) | 55(7) | 36(12) | NA | NA | NA | 47(18) | NA | |
| Retraining occurred | N | Y | Y | Y | N | NA | Y | Y | |
| **Invertebrates** | | | | | | | | | |
| Number of Species | 14 | 10 | 16 | 18 | 10 | NA | 20 | NA | |
| Avg. Species ID % error | 1(2) | 0 | 0 | 0 | 0 | NA | 0 | NA | ≤10% |
| Avg. Pathology ID % error | 0 | 0 | 0 | 0 | 0 | NA | 0 | NA | ≤10% |
| Avg. Count % error (SD) | 0 | 0 | 0 | 2(2) | 0 | NA | 2(2) | NA | ≤10% |
| Avg. Biomass % error (SD) | 1(2) | 0 | 0 | 0 | 0 | NA | 5(10) | NA | ≤10% |

## Accuracy – Taxonomy

**Fishes.** All organizations met the Bight '13 MQO for taxonomic accuracy of fishes (Table A-6). Field crews submitted 440 taxonomic fish vouchers for data validation. Twenty species were identified from FID specimens. Eight species were corrected from misidentifications. Seventeen individuals were reclassified and lumped as a single species (*Syngnathus* sp); an anticipated scientific paper may synonymize many species within this genus for future surveys. Secondary voucher specimens, such as anomalies and DNA, represent a subset of the primary voucher species. The synoptic data review, conducted after all fish FID and voucher specimens were confirmed, identified odd occurrences of specimens that were sampled outside of historic depth ranges. Detailed review by the sampling organizations resulted in numerous corrections to the database. Ultimately, no specimens were removed or flagged in the trawl abundance database for fishes due to QA/QC deviations.

**Table A-6. Summary of fish voucher validation for the Bight'13 regional trawl survey. Measurement quality objective (MQO) was accuracy in species identification. Minor errors included old nomenclature, bad labeling, and extra species.**

| | Participating Organization | | | | | | | | All | MQO |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | | |
| **Primary Voucher Summary** | | | | | | | | | | |
| Total submitted for vouchers/FID (no. jars) | 56 | 27 | 55 | 69 | 70 | 16 | 65 | 82 | 440 | |
| Total valid species vouchers | 48 | 27 | 53 | 67 | 70 | 16 | 63 | 80 | 424 | |
| Photos as species vouchers | 0 | 6 | 6 | 11 | 2 | 1 | 4 | 4 | | |
| FIDs identified (no. species) | 3 | 1 | 5 | 3 | 1 | 1 | 3 | 3 | 20 | |
| FIDs unidentified (no. individuals) | 8* | 0 | 2* | 2* | 1* | 1* | 2* | 1* | | |
| Duplicates (no. species) | 1 | 0 | 2 | 1 | 0 | 0 | 1 | 2 | | |
| Identification Error (no. individuals) | 1 | 0 | 1 | 0 | 0 | 0 | 4 | 2 | 8 (2%) | ≤10% |
| Missing (no. individuals) | 1 | NA | 2 | 1*** | 1 | 0 | 0 | 0 | | |
| Minor Errors (no. individuals) | NA | NA | 0 | 1 | 1 | 0 | 1 | 3 | | |
| **Secondary Voucher Summary** | | | | | | | | | | |
| Anomaly submittals (no. individuals) | 1 | 1 | 1 | 6 | 7 | 1 | 3 | 6 | | |
| DNA submittals (no. individuals) | 25 | 26** | 38$^{3}$** | 64** | 50 | 13$^{1}$** | 45 | 69$^{2}$** | | |

MQO = 90% correct. FID = specimen need further expert identification. * = unidentified Pipefish lumped as *Syngnathus sp*. ** = only fin clips available or the subscript indicates the number. *** = Juvenile *Sebastes sp.* with 6 individuals missing. NA = information not unavailable.

**Invertebrates**. Cumulatively, all organizations met the Bight '13 MQO for taxonomic accuracy of invertebrates (Table A-7). Field crews submitted 588 taxonomic invertebrate vouchers for data validation. Twelve species were identified from FID specimens. Nineteen species were corrected from misidentifications. Eight individuals were reclassified to higher taxonomic groupings because the taxonomy was in flux or a consensus among taxonomists could not be made. The result from the voucher checks were 69 unqualified changes to the database. Secondary voucher specimens, such as anomalies and DNA, represent a subset of the primary voucher species. The synoptic data review, conducted after all invertebrate FID and voucher specimens were confirmed, identified odd occurrences of specimens that were sampled outside of historic depth ranges. Detailed review by the sampling organizations resulted in numerous corrections to the database. Ultimately, no specimens were removed or flagged in the trawl abundance database for invertebrates due to QA/QC deviation.

**Table A-7. Summary of invertebrate voucher validation for the Bight'13 regional trawl survey. Measurement quality objective (MQO) was accuracy in species identification. Inappropriate inclusion as vouchers included pelagic species, benthic species, damaged, or smaller than the net mesh. Minor errors included old nomenclature, correct but incomplete identifications, bad labeling, and extra species.**

| | Participating Organization | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | All | MQO |
| **Primary Voucher Summary** | | | | | | | | | | |
| Total submitted for vouchers/FID (no. lots) | 64 | 56 | 106 | 79 | 81 | 21 | 81 | 99 | 588 | |
| Total valid species vouchers | 64 | 51 | 106 | 76 | 81 | 18 | 79 | 88 | 563 | |
| Photos as species vouchers | NA | NA | NA | NA | NA | NA | NA | NA | | |
| FIDs identified (no. species) | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 10 | 12 | |
| FIDs unidentified (no. individuals) | 2 | 2 | 1 | 0 | 1 | 1 | 0 | 1 | | |
| Inappropriate Inclusion as voucher (no. individuals) | 0 | 5 | 0 | 3 | 0 | 2 | 0 | 0 | | |
| Identification Error (no. individuals) | 3 | 6* | 1 | 0 | 3 | 2 | 2 | 2 | 19 (3%) | $\leq$10% |
| Missing (no. individuals) | NA | NA | NA | NA | NA | NA | NA | NA | | |
| Minor Errors (no. individuals) | 0 | 8 | 2 | 1 | 1 | 3 | 1 | 0 | | |
| **Secondary Voucher Summary** | | | | | | | | | | |
| Anomaly submittals (no. individuals) | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | | |
| DNA submittals (no. individuals) | NA | NA | NA | NA | NA | NA | NA | NA | | |

MQO = 90% correct. FID = specimen need further expert identification. NA = information not unavailable. * this organization missed MQO by 1 specimen

## Bias

**Temperature/Pressure sensors.** Organizations submitted 98% of the trawl sensor data (Table A-3). In shallow bay/harbor areas, 5 minute boat tow averaged 6.2 minutes (±1.2 SD) of net bottom time (Figure A-1). Field organizations were asked to adjust their standard 10-minute boat trawls so net bottom times fall within an 8–15 minute window. Nineteen percent of trawls fell outside the window (4 sites were below the 8-minute minimum with the shortest trawl at 6 minutes; 25 sites were above the 15-minute maximum with the longest trawl at 28.27 minutes). The field manual instructed crews to re-trawl if sensor indicated less than 8-minute bottom time and depths were greater than 30 meters. For trawls greater than 15 minutes, crews were asked to adjust subsequent tows at that depth. Many of the organizations were unwilling to absorb the cost of re-trawling sites (D. Diehl, personal communication). One organization was using a vessel with a slow winch during the survey.

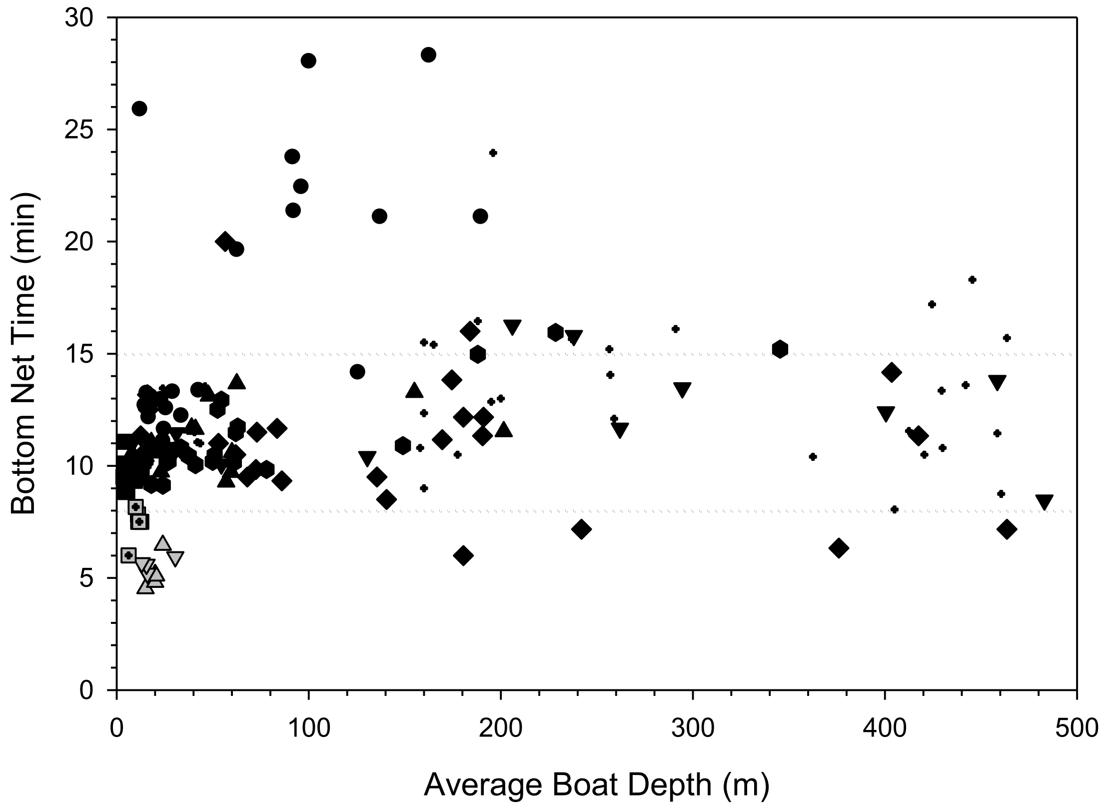



**Figure A-1. On bottom times recorded by pressure/temperature sensors mounted on trawl doors during the Bight'13 regional survey. Grey color represents five-minute bay and harbor tows. The eight symbols represent the field organizations participating in the survey.**

## Discussion

Cumulatively, participating organizations met or exceeded the MQOs established for the Bight '13 reginal survey (Table A-8). Trawl sampling was complete and representative. Taxonomic identifications were complete, accurate, and precise. Counting, measuring, and weighing were also complete, accurate, and precise. Ultimately, no deviations occurred that required exclusion of data.

**Table A-8. Summary of Method Quality Objectives (MQOs) versus actual measurements during the Bight'13 regional monitoring trawl survey. Identification accuracy and precision are from fish and invertebrates combined.**

| | MQO | | | Actual | | |
|---|---|---|---|---|---|---|
| Indicators | Accuracy | Precision | Completeness | Accuracy | Precision | Completeness |
| Sample collection | NA | NA | 90% | NA | NA | 95% |
| Counting | 10% | NA | 90% | < 1% | < 1% | 99% |
| Identification | 10% | NA | 90% | 3% | 4% | 97% |
| Length | 10% | NA | 90% | 3% | 3% | 97% |
| Biomass | 10% | NA | 90% | 1% | 2% | 99% |
| External Anomalies | 10% | NA | 95% | 0% | 0% | 100% |

The QA/QC system in place for Bight '13 trawl surveys is designed to be rigorous and robust. This is particularly important for taxonomic identification because specimens, other than vouchers, are not retained or archived. Thus, special emphasis is placed on these measurements. One reason the Bight '13 regional survey had such taxonomic success was due to the activities of regional scientific associations that focus on this challenge; the Southern California Association of Ichthyological Taxonomists and Ecologists (http://www.SCAITE.org) and the Southern California Association of Marine Invertebrate Taxonomists (http://www.SCAMIT.org). The ongoing commitment to research and training from these organizations is crucial for the continued taxonomic success of Bight trawl survey monitoring.

The trawl committee expected all previous Bight program participants to comply with the QA activities as designed. Unfortunately, one agency was unable to arrange their boat time to accommodate the field auditor's schedule. The Bight program relies heavily upon in-kind services to sample large areas of the Southern California Bight. The agency had sampled 17% of the successful stations. While the Bight'13 trawl committee was troubled that one agency had not been field audited, they recognized that the agency had participated in many previous surveys and was well-versed with Bight protocols. Field audits are implemented to ensure data consistency across all participants. The Bight'13 trawl committee does not encourage the use of "previous participation" as a reason for future organizations not to fully participate in field audits. The committee will revisit this issue in future surveys.

The continued use of P/T sensors during Bight surveys should increase accuracy in trawl time and distance covered. This is the general trend, however there are still numerous outliers. The distance cover by the net for a 10 minute trawl was expected to cover approximately 600 meters for a 10 minute trawl. During the Bight '13 trawl survey, the distance trawled ranged from 290.8 to 1,317.2 meters. Trawls times using the P/Ts ranged from 6.0-28.27 minutes while trawl times using the onboard start/stop trawl timing ranged from 5.43-17.2 minutes. While the scientific crew was allowed to alter the onboard trawl timing to better facilitate a ten minute bottom time it should be noted that both short and long trawl times (5 or 17 minutes) produced a trawl greater than 16 minutes.

The pressure/temperature (P/T) sensor data continues to show the need for improved field crew decision making. Although some procedural decisions may have been made at an organizational level regarding re-trawling and incurring additional costs, the goal of using the P/T sensor in the field was to standardize the time a net was dragging the bottom and reduce data variability. Field crews work on many different boats, with many different characteristics (e.g. slow or fast winch speeds, single hydrolic systems, minimum boat speeds greater than 1.5 to 2.0 kt). The pressure data provides a simple measure for adjusting surface times or trawl procedures on their particular boat to standardize bottom times. For example, a boat may need to reduce surface tows to 5 minutes because their slow winch allows the net to stay longer on the bottom. During retrieval, it may be helpful if boats with single hydrolic systems shift power back and forth between engines and winch so speed is maintained and the net comes off the bottom within the prescribed time limits. QA measures of start/end tow distances and bottom times are a reflection of the captain and field crew's abilities to adjust during a trawl at many different depths. The committee's desire was for field crews to self-regulate themselves and adjust. The variability in the distance trawled and the time on bottom between field crews and boats suggests that goal was not achieved. Continued effort to standardize trawl length and time should be a focus of future Bight surveys. Future discussions and training should focus on criteria for re-trawling sites.

Of the QC checks for counting, measuring, and weighing, the greatest error was detected in measuring. It becomes difficult to completely eliminate human error when field crews are processing hundreds of animals in a relatively short period. The “tweener” data sheets contained a high percentage of fish straddling a centimeter mark by a few millimeters. Scientific crews’ ability to rapidly and accurately call out and record data can vary. The re-training exercises seemingly did little to improve the differences in perception. The smallest unit of measurement error for the Bight survey was ±1 cm.

Additional counting errors that should be clarified in future surveys include: clearer definitions for countable animals including colonials (such as Ascidians and Anthozoans), parasites, anomalies, ambicoloration, premature juvenile dispersal, limits for aliquoting fish, and situations where dead organisms are mixed with live organisms (e.g., bivalve shells).

The IM system needs improvement to facilitate accurate and timely updates to data changes. The IM system for Bight ’13 was intended to provide value in two areas: uniform formatting for data submittal, and automated error checking. During Bight ’13, many data errors were later identified during the data analysis stage, which required re-submittal of entire data sets from most organizations. The automated error checking programs insufficiently evaluated the acceptability of the data. Requested corrections to the datasets by participating agencies often resulted in further errors generated due to faulty data queries and lack of confirmation during the attempt to correct the primary error. Data that were not part of the Bight survey resided in the same database, causing errors in generating analysis datasets. Finally, invalid trawl data that were either not part of the Bight ’13 survey, or were from invalid Bight ’13 trawls were included in data exports. Ultimately, this resulted in numerous labor hours and months of delay to achieve a final data set. Dramatic improvements to IM should be a top priority in the next regional Bight survey. These improvements include the following:

1. Bight database structure and automated error checkers should agree with a pre-approved IM plan.

2. Only valid Bight data used for reporting should be made available for data export. Exported data should include all fields needed for analysis including stratum, area weights and station information.

3. There should be an automated data submittal error checker which is accurate, comprehensive, beta-tested, and based on common errors encountered during previous surveys.

4. Details of all post-submission data changes should be confirmed and logged.

5. There should be database version control which allows a roll-back to a previous version for each change made in the database.

## Conclusions

- Sampling met the study design requirements
- QA/QC protocols were followed by participating field sampling organizations.

- MQOs were universally achieved
- The Trawl Committee deemed data comparable and acceptable; no data were excluded from Bight ’13 trawl data collection

### Improvements for future surveys

- Continue and enhance pre-survey training, perhaps the most effective QA system
- Better coordinate in-survey audits so that all organizations are audited.
- Ask survey crews to improve bottom times by following recommended criteria found in the field sampling manual.
- Keep the “tweener” QAQC processing, remove the re-training aspect, and accept the human perception error associated with length measurements.
- Refine and improve Information Management associated with error checking and data submission using the provided web-based data submission portal. Add a system for confirming data change requests. MQOs should be evaluated for IM.
- Develop curriculum and train participants to better identify parasite and anomaly features.

## References

Bight'13 Contaminant Impact Assessment Committee. 2013a. Southern California Bight 2013 Regional Marine Monitoring Survey (Bight'13) Contaminant Impact Assessment Workplan. Southern California Coastal Water Research Project. June 13, 2013. 80pp.

Bight'13 Contaminant Impact Assessment Committee. 2013b. Southern California Bight 2013 Regional Marine Monitoring Survey (Bight'13) Quality Assurance Manual. Southern California Coastal Water Research Project. June 13, 2013. 55pp.

Bight'13 Field Sampling & Logistics Committee. 2013c. Southern California Bight 2013 Regional Marine Monitoring Survey (Bight'13) Contaminant Impact Assessment Field Operations Manual Southern California Coastal Water Research Project. July 2013. 76pp.

# APPENDIX B: SUPPLEMENTAL ANALYSES

## Bight ’13 Trawl Survey Results



## Temporal Trends

**Appendix B-1. Taxonomic listing of demersal fish species collected during the Bight '13 trawl survey. Data are fish abundance (n), mean, standard deviation (Std Dev), minimum (Min), and maximum (Max) length (standard length, cm). Taxonomic arrangement and scientific names are of Eschmeyer and Herold (1998) and Lawrence et al. (2013).**

| Class | Order | Family | Species | Common Name | n | Mean | Std Dev | Min | Max |
|---|---|---|---|---|---|---|---|---|---|
| **MYXINI** | | | | | | | | | |
| | **MYXINIFORMES** | | | | | | | | |
| | | Myxinidae | *Eptatretus stoutii* | Pacific Hagfish | 15 | 33 | 6 | 21 | 44 |
| **CHONDRICHTHYES** | | | | | | | | | |
| | **HETERODONTIFORMES** | | | | | | | | |
| | | Heterodontidae | *Heterodontus francisci* | Horn Shark | 1 | 23 | | 23 | 23 |
| | **CARCHARHINIFORMES** | | | | | | | | |
| | | Scyliorhinidae | *Parmaturus xaniurus* | Filetail Cat Shark | 192 | 19 | 4 | 11 | 28 |
| | | Triakidae | *Mustelus californicus* | Gray Smoothhound | 11 | 40 | 10 | 33 | 62 |
| | **TORPEDINIFORMES** | | | | | | | | |
| | | Torpedinidae | *Torpedo californica* | Pacific Electric Ray | 4 | 43 | 28 | 19 | 78 |
| | **RAJIFORMES** | | | | | | | | |
| | | Rhinobatidae | *Rhinobatos productus* | Shovelnose Guitarfish | 1 | 84 | | 84 | 84 |
| | | Rajidae | *Bathyraja interrupta* | Sandpaper Skate | 2 | 48 | 8 | 42 | 54 |
| | | | *Raja inornata* | California Skate | 56 | 28 | 12 | 9 | 55 |
| | | | *Raja rhina* | Longnose Skate | 20 | 34 | 19 | 16 | 70 |
| | **MYLIOBATIFORMES** | | | | | | | | |
| | | Urotrygonidae | *Urobatis halleri* | Round Stingray | 176 | 27 | 3 | 18 | 36 |
| | | Gymnuridae | *Gymnura marmorata* | California Butterfly Ray | 6 | 23 | 5 | 17 | 30 |
| | | Myliobatidae | *Myliobatis californica* | Bat Ray | 4 | 75 | 21 | 56 | 103 |
| **ACTINOPTERYGII** | | | | | | | | | |
| | **ANGUILLIFORMES** | | | | | | | | |
| | | Nettastomatidae | *Facciolella equatorialis* | Dogface Witch Eel | 152 | 34 | 4 | 21 | 49 |
| | **CLUPEIFORMES** | | | | | | | | |
| | | Engraulidae | *Anchoa compressa* | Deepbody Anchovy | 322 | 7 | 1 | 5 | 12 |
| | | | *Anchoa delicatissima* | Slough Anchovy | 697 | 3 | 1 | 2 | 7 |
| | | | *Engraulis mordax* | Northern Anchovy | 36 | 4 | 0 | 4 | 4 |
| | **ARGENTINIFORMES** | | | | | | | | |
| | | Argentinidae | *Argentina sialis* | Pacific Argentine | 18 | 8 | 2 | 7 | 14 |
| | **STOMIIFORMES** | | | | | | | | |
| | | Phosichthyidae | *Stomias atriventer* | Black-belly dragonfish | 1 | 10 | | 10 | 10 |
| | | | *Idiacanthus antrostomus* | Pacific Blackdragon | 1 | 38 | | 38 | 38 |

**Appendix B-1 (continued)**

| Class | Order | Family | Species | Common Name | n | Mean | Std Dev | Min | Max |
|---|---|---|---|---|---|---|---|---|---|
| | **AULOPIFORMES** | | | | | | | | |
| | | Synodontidae | *Synodus lucioceps* | California Lizardfish | 13,434 | 12 | 3 | 8 | 35 |
| | **MYCTOPHIFORMES** | | | | | | | | |
| | | Myctophidae | *Stenobrachius leucopsarus* | Northern Lampfish | 1 | 6 | | 6 | 6 |
| | **LAMPRIFORMES** | | | | | | | | |
| | | Trachipteridae | *Trachipterus altivelis* | King-of-the-salmon | 2 | 26 | 25 | 8 | 43 |
| | **GADIFORMES** | | | | | | | | |
| | | Macrouridae | *Nezumia stelgidolepis* | California Grenadier | 42 | 22 | 6 | 7 | 32 |
| | | Moridae | *Physiculus rastrelliger* | Hundred-fathom Codling | 74 | 12 | 3 | 6 | 20 |
| | | Merlucciidae | *Merluccius productus* | Pacific Hake | 181 | 23 | 6 | 12 | 41 |
| | **OPHIDIIFORMES** | | | | | | | | |
| | | Ophidiidae | *Chilara taylori* | Spotted Cusk-eel | 108 | 19 | 4 | 11 | 30 |
| | | | *Ophidion scrippsae* | Basketweave Cusk-eel | 1 | 14 | | 14 | 14 |
| | | Bythitidae | *Cataetyx rubrirostris* | Rubynose Brotula | 336 | 10 | 1 | 6 | 14 |
| | **BATRACHOIDIFORMES** | | | | | | | | |
| | | Batrachoididae | *Porichthys myriaster* | Specklefin Midshipman | 135 | 16 | 3 | 4 | 29 |
| | | | *Porichthys notatus* | Plainfin Midshipman | 267 | 13 | 3 | 3 | 22 |
| | **GASTEROSTEIFORMES** | | | | | | | | |
| | | Syngnathidae | *Syngnathus* sp | Unidentified Pipefish | 280 | 22 | 4 | 10 | 31 |
| | **SCORPAENIFORMES** | | | | | | | | |
| | | Scorpaenidae | *Scorpaena guttata* | California Scorpionfish | 55 | 19 | 4 | 5 | 32 |
| | | | *Sebastes* sp | Unidentified Rockfish | 13 | 4 | 1 | 3 | 7 |
| | | | *Sebastes auriculatus* | Brown Rockfish | 3 | 15 | 1 | 14 | 15 |
| | | | *Sebastes aurora* | Aurora Rockfish | 9 | 15 | 6 | 9 | 23 |
| | | | *Sebastes carnatus* | Gopher Rockfish | 5 | 6 | 1 | 5 | 7 |
| | | | *Sebastes caurinus* | Copper Rockfish | 72 | 7 | 3 | 4 | 24 |
| | | | *Sebastes chlorostictus* | Greenspotted Rockfish | 5 | 13 | 3 | 9 | 16 |
| | | | *Sebastes crameri* | Darkblotched Rockfish | 3 | 6 | 2 | 4 | 8 |
| | | | *Sebastes dallii* | Calico Rockfish | 182 | 10 | 3 | 5 | 15 |
| | | | *Sebastes diploproa* | Splitnose Rockfish | 2206 | 8 | 3 | 4 | 22 |
| | | | *Sebastes elongatus* | Greenstriped Rockfish | 98 | 14 | 4 | 4 | 30 |
| | | | *Sebastes eos* | Pink Rockfish | 40 | 9 | 5 | 4 | 23 |
| | | | *Sebastes goodei* | Chilipepper | 16 | 13 | 4 | 10 | 25 |
| | | | *Sebastes hopkinsi* | Squarespot Rockfish | 29 | 13 | 2 | 8 | 18 |

**Appendix B-1 (continued)**

| Class | Order | Family | Species | Common Name | n | Mean | Std Dev | Min | Max |
|---|---|---|---|---|---|---|---|---|---|
| | | | *Sebastes jordani* | Shortbelly Rockfish | 189 | 13 | 2 | 7 | 24 |
| | | | *Sebastes levis* | Cowcod | 10 | 12 | 8 | 7 | 32 |
| | | | *Sebastes macdonaldi* | Mexican Rockfish | 2 | 10 | 1 | 9 | 10 |
| | | | *Sebastes melanostomus* | Blackgill Rockfish | 17 | 13 | 7 | 10 | 39 |
| | | | *Sebastes miniatus* | Vermilion Rockfish | 389 | 9 | 4 | 5 | 20 |
| | | | *Sebastes mystinus* | Blue Rockfish | 28 | 7 | 1 | 6 | 8 |
| | | | *Sebastes paucispinis* | Bocaccio | 16 | 13 | 1 | 11 | 15 |
| | | | *Sebastes rastrelliger* | Grass Rockfish | 1 | 18 | | 18 | 18 |
| | | | *Sebastes rosenblatti* | Greenblotched Rockfish | 20 | 18 | 8 | 10 | 38 |
| | | | *Sebastes rubrivinctus* | Flag Rockfish | 5 | 13 | 4 | 7 | 18 |
| | | | *Sebastes saxicola* | Stripetail Rockfish | 1916 | 8 | 3 | 3 | 18 |
| | | | *Sebastes semicinctus* | Halfbanded Rockfish | 2440 | 12 | 2 | 4 | 19 |
| | | | *Sebastes simulator* | Pinkrose Rockfish | 1 | 12 | | 12 | 12 |
| | | | *Sebastolobus alascanus* | Shortspine Thornyhead | 107 | 12 | 4 | 6 | 24 |
| | | | *Sebastolobus altivelis* | Longspine Thornyhead | 31 | 12 | 3 | 7 | 17 |
| | | Anoplopomatidae | *Anoplopoma fimbria* | Sablefish | 36 | 33 | 8 | 19 | 45 |
| | | Hexagrammidae | *Hexagrammos decagrammus* | Kelp Greenling | 1 | 11 | | 11 | 11 |
| | | | *Ophiodon elongatus* | Lingcod | 53 | 20 | 6 | 11 | 36 |
| | | | *Oxylebius pictus* | Painted Greenling | 2 | 12 | 4 | 9 | 15 |
| | | | *Zaniolepis frenata* | Shortspine Combfish | 1270 | 12 | 3 | 6 | 24 |
| | | | *Zaniolepis latipinnis* | Longspine Combfish | 2560 | 11 | 2 | 6 | 18 |
| | | Cottidae | *Chitonotus pugetensis* | Roughback Sculpin | 94 | 10 | 2 | 5 | 14 |
| | | | *Enophrys taurina* | Bull Sculpin | 2 | 10 | 4 | 7 | 13 |
| | | | *Icelinus cavifrons* | Pit-head Sculpin | 1 | 7 | | 7 | 7 |
| | | | *Icelinus quadriseriatus* | Yellowchin Sculpin | 2070 | 7 | 1 | 5 | 10 |
| | | | *Icelinus tenuis* | Spotfin Sculpin | 4 | 10 | 1 | 10 | 11 |
| | | | *Leptocottus armatus* | Pacific Staghorn Sculpin | 12 | 14 | 2 | 10 | 17 |
| | | | *Scorpaenichthys marmoratus* | Cabezon | 10 | 9 | 2 | 5 | 12 |
| | | Agonidae | *Agonopsis sterletus* | Southern Spearnose Poacher | 8 | 11 | 2 | 7 | 13 |
| | | | *Bathyagonus pentacanthus* | Bigeye Poacher | 64 | 15 | 1 | 12 | 18 |
| | | | *Odontopyxis trispinosa* | Pygmy Poacher | 130 | 8 | 1 | 5 | 9 |
| | | | *Xeneretmus latifrons* | Blacktip Poacher | 773 | 14 | 2 | 5 | 17 |
| | | | *Xeneretmus triacanthus* | Bluespotted Poacher | 38 | 14 | 2 | 6 | 16 |
| | | Liparidae | *Careproctus melanurus* | Blacktail Snailfish | 43 | 14 | 4 | 5 | 22 |

**Appendix B-1 (continued)**

| Class | Order | Family | Species | Common Name | n | Mean | Std Dev | Min | Max |
|---|---|---|---|---|---|---|---|---|---|
| | **PERCIFORMES** | | | | | | | | |
| | | Serranidae | *Paralabrax clathratus* | Kelp Bass | 6 | 3 | 1 | 3 | 4 |
| | | | *Paralabrax maculatofasciatus* | Spotted Sand Bass | 57 | 20 | 3 | 16 | 29 |
| | | | *Paralabrax nebulifer* | Barred Sand Bass | 68 | 14 | 3 | 10 | 26 |
| | | Haemulidae | *Anisotremus davidsonii* | Sargo | 4 | 19 | 6 | 14 | 27 |
| | | Sciaenidae | *Atractoscion nobilis* | White Seabass | 2 | 23 | 2 | 21 | 24 |
| | | | *Cheilotrema saturnum* | Black Croaker | 6 | 19 | 2 | 16 | 22 |
| | | | *Genyonemus lineatus* | White Croaker | 2324 | 15 | 3 | 3 | 22 |
| | | | *Seriphus politus* | Queenfish | 409 | 9 | 4 | 4 | 19 |
| | | | *Umbrina roncador* | Yellowfin Croaker | 3 | 24 | 7 | 16 | 29 |
| | | Embiotocidae | *Brachyistius frenatus* | Kelp Perch | 5 | 8 | 2 | 7 | 10 |
| | | | *Cymatogaster aggregata* | Shiner Perch | 56 | 11 | 2 | 7 | 13 |
| | | | *Damalichthys vacca* | Pile Perch | 1 | 7 | | 7 | 7 |
| | | | *Hypsurus caryi* | Rainbow Seaperch | 7 | 8 | 2 | 6 | 13 |
| | | | *Phanerodon furcatus* | White Seaperch | 2 | 10 | 5 | 6 | 13 |
| | | | *Rhacochilus toxotes* | Rubberlip Seaperch | 1 | 9 | | 9 | 9 |
| | | | *Zalembius rosaceus* | Pink Seaperch | 617 | 9 | 2 | 2 | 15 |
| | | Bathymasteridae | *Rathbunella hypoplecta* | Bluebanded Ronquil | 2 | 12 | 3 | 10 | 14 |
| | | Zoarcidae | *Lycodapus mandibularis* | Pallid Eelpout | 17 | 14 | 2 | 11 | 18 |
| | | | *Lycodes cortezianus* | Bigfin Eelpout | 34 | 20 | 8 | 8 | 34 |
| | | | *Lycodes diapterus* | Black Eelpout | 244 | 21 | 5 | 7 | 30 |
| | | | *Lycodes pacificus* | Blackbelly Eelpout | 1314 | 15 | 6 | 5 | 29 |
| | | | *Lyconema barbatum* | Bearded Eelpout | 404 | 15 | 2 | 6 | 20 |
| | | | *Melanostigma pammelas* | Midwater Eelpout | 1 | 9 | | 9 | 9 |
| | | Stichaeidae | *Plectobranchus evides* | Bluebarred Prickleback | 73 | 9 | 3 | 4 | 13 |
| | | Clinidae | *Heterostichus rostratus* | Giant Kelpfish | 2 | 7 | 1 | 6 | 8 |
| | | Labrisomidae | *Neoclinus blanchardi* | Sarcastic Fringehead | 32 | 13 | 3 | 8 | 23 |
| | | | *Neoclinus uninotatus* | Onespot Fringehead | 2 | 12 | 0 | 12 | 12 |
| | | Gobiidae | *Lepidogobius lepidus* | Bay Goby | 10 | 5 | 2 | 3 | 10 |
| | | | *Quietula y-cauda* | Shadow Goby | 1 | 3 | | 3 | 3 |
| | | Stromateidae | *Peprilus simillimus* | Pacific Pompano | 29 | 12 | 3 | 2 | 15 |

**Appendix B-1 (continued)**

| Class | Order | Family | Species | Common Name | n | Mean | Std Dev | Min | Max |
|---|---|---|---|---|---|---|---|---|---|
| | **PLEURONECTIFORMES** | | | | | | | | |
| | | Paralichthyidae | *Pleuronectiformes* | Pleuronectiformes | 2 | 3 | 0 | 3 | 3 |
| | | | *Citharichthys fragilis* | Gulf Sanddab | 34 | 11 | 4 | 5 | 16 |
| | | | *Citharichthys sordidus* | Pacific Sanddab | 19,005 | 9 | 4 | 2 | 27 |
| | | | *Citharichthys stigmaeus* | Speckled Sanddab | 5437 | 8 | 2 | 3 | 22 |
| | | | *Citharichthys xanthostigma* | Longfin Sanddab | 394 | 14 | 3 | 6 | 22 |
| | | | *Hippoglossina stomata* | Bigmouth Sole | 138 | 16 | 5 | 6 | 28 |
| | | | *Paralichthys californicus* | California Halibut | 104 | 25 | 11 | 9 | 75 |
| | | | *Xystreurys liolepis* | Fantail Sole | 141 | 15 | 3 | 9 | 26 |
| | | Pleuronectidae | *Eopsetta jordani* | Petrale Sole | 12 | 30 | 3 | 24 | 34 |
| | | | *Glyptocephalus zachirus* | Rex Sole | 315 | 16 | 5 | 7 | 31 |
| | | | *Lyopsetta exilis* | Slender Sole | 5040 | 13 | 3 | 3 | 22 |
| | | | *Microstomus pacificus* | Dover Sole | 5045 | 10 | 5 | 4 | 34 |
| | | | *Parophrys vetulus* | English Sole | 827 | 17 | 4 | 6 | 31 |
| | | | *Pleuronichthys coenosus* | C-O Sole | 1 | 22 | | 22 | 22 |
| | | | *Pleuronichthys decurrens* | Curlfin Sole | 410 | 9 | 3 | 5 | 20 |
| | | | *Pleuronichthys guttulatus* | Diamond Turbot | 9 | 20 | 3 | 18 | 26 |
| | | | *Pleuronichthys ritteri* | Spotted Turbot | 29 | 15 | 3 | 10 | 22 |
| | | | *Pleuronichthys verticalis* | Hornyhead Turbot | 350 | 14 | 3 | 6 | 22 |
| | | Cynoglossidae | *Symphurus atricaudus* | California Tonguefish | 703 | 11 | 3 | 5 | 21 |

**Appendix B-2. Demersal fish abundance by MPA designation and stratum during the Bight '13 trawl survey.**

| | No. of Stations | Total | Range | | Area-Weighted Values | | | | Percent Above Bight Median |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Max | Median | Mean | SD | 95% CL | |
| *MPA/Non-MPA* | | | | | | | | | |
| MPA | 24 | 12,497 | 88 | 1,638 | 431 | 537 | 442 | 188 | 55.0 |
| Non-MPA | 141 | 62,886 | 1 | 3,088 | 278 | 385 | 444 | 81 | 0.0 |
| *Stratum* | | | | | | | | | |
| **Bays and Harbors (3-30 m)** | **26** | **8,239** | **6** | **652** | **294** | **292** | **191** | **80** | **5.8** |
| **Inner Shelf (8-30 m)** | **35** | **10,711** | **25** | **1,013** | **245** | **323** | **296** | **109** | **-11.9** |
| MPA | 6 | 1,696 | 117 | 413 | 317 | 286 | 108 | 83 | 14.0 |
| Non-MPA | 29 | 9,015 | 25 | 1,013 | 245 | 324 | 300 | 112 | -11.9 |
| **Middle Shelf (31-120 m)** | **43** | **22,674** | **12** | **2,446** | **359** | **512** | **538** | **191** | **29.1** |
| MPA | 13 | 7,912 | 88 | 1,638 | 512 | 624 | 459 | 271 | 84.2 |
| Non-MPA | 30 | 14,762 | 12 | 2,446 | 349 | 506 | 541 | 200 | 25.5 |
| **Outer Shelf (121-200 m)** | **29** | **24,500** | **2** | **3,088** | **604** | **791** | **778** | **286** | **117.3** |
| MPA | 2 | 1,729 | 108 | 1,621 | 865 | 865 | 757 | 1048 | 211.0 |
| Non-MPA | 27 | 22,771 | 2 | 3,088 | 604 | 790 | 778 | 291 | 117.3 |
| **Upper slope (201-500 m)** | **32** | **9,259** | **1** | **1,071** | **201** | **280** | **275** | **99** | **-27.7** |
| MPA | 3 | 1,160 | 111 | 578 | 471 | 387 | 200 | 226 | 69.4 |
| Non-MPA | 29 | 8,099 | 1 | 1,071 | 201 | 279 | 275 | 100 | -27.7 |
| **Total (all stations)** | **165** | **75,383** | **1** | **3,088** | **278** | **389** | **444** | **80** | |

**Appendix B-3. Demersal fish biomass by MPA designation and stratum during the Bight '13 trawl survey.**

| | No. of Stations | Total | Range Min | Range Max | Area-Weighted Values Median | Area-Weighted Values Mean | Area-Weighted Values SD | Area-Weighted Values 95% CL | Percent Above Bight Median |
|---|---|---|---|---|---|---|---|---|---|
| *MPA/Non-MPA* | | | | | | | | | |
| MPA | 24 | 254 | 1.7 | 24.3 | 11.0 | 11.0 | 7.0 | 3.0 | 35.0 |
| Non-MPA | 141 | 1,689 | 0.1 | 64.2 | 8.1 | 11.0 | 10.6 | 2.2 | 0.0 |
| *Stratum* | | | | | | | | | |
| **Bays and Harbors (3-30 m)** | **26** | **407** | **0.4** | **40.8** | **14.4** | **14.3** | **10.9** | **4.8** | **77.1** |
| **Inner Shelf (8-30 m)** | **35** | **202** | **0.4** | **19.1** | **4.6** | **5.6** | **4.1** | **1.5** | **-43.9** |
| MPA | 6 | 37 | 3.7 | 9.7 | 4.9 | 6.1 | 2.2 | 1.7 | -39.7 |
| Non-MPA | 29 | 165 | 0.4 | 19.1 | 4.6 | 5.6 | 4.2 | 1.6 | -43.9 |
| **Middle Shelf (31-120 m)** | **43** | **495** | **0.7** | **64.2** | **8.8** | **11.8** | **11.9** | **4.2** | **9.0** |
| MPA | 13 | 153 | 2.0 | 24.3 | 13.0 | 11.7 | 7.4 | 4.3 | 59.7 |
| Non-MPA | 30 | 342 | 0.7 | 64.2 | 8.8 | 11.9 | 12.0 | 4.4 | 8.0 |
| **Outer Shelf (121-200 m)** | **29** | **456** | **0.2** | **54.5** | **12.1** | **16.0** | **12.7** | **4.8** | **49.2** |
| MPA | 2 | 16 | 1.7 | 13.9 | 7.8 | 7.8 | 6.1 | 8.4 | -4.1 |
| Non-MPA | 27 | 440 | 0.2 | 54.5 | 12.1 | 16.2 | 12.8 | 4.9 | 49.2 |
| **Upper slope (201-500 m)** | **32** | **382** | **0.1** | **40.1** | **8.2** | **11.5** | **10.2** | **3.7** | **0.5** |
| MPA | 3 | 49 | 12.1 | 22.7 | 14.1 | 16.3 | 4.6 | 5.2 | 74.0 |
| Non-MPA | 29 | 333 | 0.1 | 40.1 | 8.2 | 11.5 | 10.2 | 3.7 | 0.5 |
| **Total (all stations)** | **165** | **1,943** | **0.1** | **64.2** | **8.1** | **11.0** | **10.5** | **2.2** | |

**Appendix B-4. Demersal fish diversity (Shannon, H') by MPA designation and stratum during the Bight '13 trawl survey.**

| | | Range | | Area-Weighted Values | | | | Percent Above Bight Median |
|---|---|---|---|---|---|---|---|---|
| | No. of Stations | Min | Max | Median | Mean | SD | 95% CL | |
| *MPA/Non-MPA* | | | | | | | | |
| MPA | 24 | 0.78 | 2.05 | 1.70 | 1.57 | 0.37 | 0.16 | 13.7 |
| Non-MPA | 141 | 0.00 | 2.35 | 1.49 | 1.44 | 0.51 | 0.11 | 0.0 |
| *Stratum* | | | | | | | | |
| **Bays and Harbors (3-30 m)** | **26** | **0.24** | **2.22** | **1.47** | **1.43** | **0.51** | **0.26** | **-1.3** |
| **Inner Shelf (8-30 m)** | **35** | **0.33** | **2.11** | **1.39** | **1.31** | **0.42** | **0.15** | **-6.8** |
| MPA | 6 | 0.78 | 1.84 | 1.30 | 1.34 | 0.36 | 0.31 | -13.0 |
| Non-MPA | 29 | 0.33 | 2.11 | 1.39 | 1.30 | 0.42 | 0.16 | -6.8 |
| **Middle Shelf (31-120 m)** | **43** | **0.67** | **2.35** | **1.75** | **1.65** | **0.43** | **0.15** | **17.1** |
| MPA | 13 | 0.87 | 2.05 | 1.76 | 1.65 | 0.34 | 0.20 | 17.8 |
| Non-MPA | 30 | 0.67 | 2.35 | 1.75 | 1.65 | 0.44 | 0.16 | 17.0 |
| **Outer Shelf (121-200 m)** | **29** | **0.59** | **2.01** | **1.26** | **1.34** | **0.40** | **0.15** | **-15.5** |
| MPA | 2 | 1.04 | 1.31 | 1.18 | 1.18 | 0.14 | 0.19 | -21.2 |
| Non-MPA | 27 | 0.59 | 2.01 | 1.26 | 1.35 | 0.40 | 0.15 | -15.5 |
| **Upper slope (201-500 m)** | **32** | **0.00** | **2.32** | **1.46** | **1.39** | **0.55** | **0.20** | **-2.1** |
| MPA | 3 | 1.28 | 1.98 | 1.94 | 1.73 | 0.32 | 0.37 | 30.2 |
| Non-MPA | 29 | 0.00 | 2.32 | 1.46 | 1.38 | 0.55 | 0.20 | -2.1 |
| **Total (all stations)** | **165** | **0.00** | **2.35** | **1.49** | **1.44** | **0.50** | **0.11** | |

**Appendix B-5. Demersal fish species richness by MPA designation and stratum during the Bight '13 trawl survey.**

| | No. of Stations | Total | Range | | Area-Weighted Values | | | | Percent Above Bight Median |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Max | Median | Mean | SD | 95% CL | |
| *MPA/Non-MPA* | | | | | | | | | |
| MPA | 24 | 72 | 6 | 25 | 14 | 15.1 | 4.8 | 2.0 | 16.7 |
| Non-MPA | 141 | 124 | 1 | 24 | 12 | 12.0 | 4.7 | 1.0 | 0.0 |
| *Stratum* | | | | | | | | | |
| **Bays and Harbors (3-30m)** | **26** | **41** | **4** | **15** | **8** | **9.0** | **2.6** | **1.1** | **-33.3** |
| **Inner Shelf (8-30m)** | **35** | **48** | **4** | **18** | **10** | **10.1** | **3.4** | **1.2** | **-16.7** |
| MPA | 6 | 31 | 7 | 16 | 12 | 12.2 | 3.2 | 2.7 | 0.0 |
| Non-MPA | 29 | 45 | 4 | 18 | 10 | 10.1 | 3.4 | 1.3 | -16.7 |
| **Middle Shelf (31-120 m)** | **43** | **66** | **5** | **25** | **16** | **15.5** | **3.6** | **1.2** | **33.3** |
| MPA | 13 | 41 | 9 | 25 | 19 | 17.0 | 5.0 | 2.9 | 58.3 |
| Non-MPA | 30 | 64 | 5 | 24 | 16 | 15.4 | 3.5 | 1.3 | 33.3 |
| **Outer Shelf (121-200 m)** | **29** | **50** | **2** | **21** | **15** | **14.3** | **3.9** | **1.5** | **25.0** |
| MPA | 2 | 14 | 6 | 13 | 10 | 9.5 | 3.5 | 4.9 | -20.8 |
| Non-MPA | 27 | 50 | 2 | 21 | 15 | 14.4 | 3.9 | 1.5 | 25.0 |
| **Upper slope (201-500 m)** | **32** | **54** | **1** | **24** | **10** | **10.5** | **4.7** | **1.7** | **-16.7** |
| MPA | 3 | 27 | 13 | 14 | 14 | 13.7 | 0.5 | 0.5 | 16.7 |
| Non-MPA | 29 | 51 | 1 | 24 | 10 | 10.5 | 4.7 | 1.7 | -16.7 |
| **Total (all stations)** | **165** | **127** | **1** | **25** | **12** | **12.1** | **4.8** | **1.0** | |

**Appendix B-6. Fish Response Index (FRI) by stratum and MPA designation during the Bight'13 trawl survey. FRI scores higher than 45 (in red) are associated with a non-reference fish community.**

| | No. of Stations | Range | | Area-Weighted Values | | | | Percent Above Bight Median | Percent Reference Sites | Percent Reference Area |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Min | Max | Median | Mean | SD | 95% CL | | | |
| *MPA/Non-MPA* | | | | | | | | | | |
| MPA | 21 | 12.1 | 42.9 | 26.9 | 26.9 | 6.6 | 3.0 | 1.0 | 100.0 | 100.0 |
| Non-MPA | 112 | -1.1 | 61.0 | 26.6 | 28.5 | 10.5 | 2.2 | 0.0 | 91.1 | 93.0 |
| *Stratum* | | | | | | | | | | |
| **Bays and Harbors (3-30 m)** | **26** | **10.6** | **59.0** | **17.7** | **24.6** | **14.7** | **6.7** | **-33.2** | **84.6** | **83.2** |
| **Inner Shelf (8-30 m)** | **35** | **19.2** | **58.8** | **32.7** | **34.2** | **10.4** | **3.8** | **22.9** | **88.6** | **85.8** |
| MPA | 6 | 26.9 | 42.9 | 31.5 | 32.9 | 5.1 | 4.0 | 18.5 | 100.0 | 100.0 |
| Non-MPA | 29 | 19.2 | 58.8 | 32.7 | 34.2 | 10.5 | 3.9 | 22.9 | 86.2 | 85.4 |
| **Middle Shelf (31-120 m)** | **43** | **12.1** | **61.0** | **26.5** | **27.5** | **7.4** | **2.6** | **-0.2** | **97.7** | **96.6** |
| MPA | 13 | 12.1 | 36.8 | 26.1 | 25.7 | 5.8 | 3.5 | -1.6 | 100.0 | 100.0 |
| Non-MPA | 30 | 17.1 | 61.0 | 26.5 | 27.6 | 7.5 | 2.8 | -0.2 | 96.7 | 96.5 |
| **Outer Shelf (121-200 m)** | **29** | **-1.1** | **50.9** | **18.7** | **19.6** | **11.5** | **4.2** | **-29.6** | **96.6** | **99.0** |
| MPA | 2 | 16.9 | 23.0 | 20.0 | 20.0 | 3.1 | 4.3 | -24.9 | 100.0 | 100.0 |
| Non-MPA | 27 | -1.1 | 50.9 | 18.7 | 19.6 | 11.6 | 4.3 | -29.6 | 96.3 | 99.0 |
| **Total (all stations)** | **133** | **-1.1** | **61.0** | **26.6** | **28.4** | **10.4** | **2.1** | | **92.5** | **93.3** |

**Appendix B-7. Taxonomic listing of all megabenthic invertebrate species collected during the Bight '13 trawl survey. Data are total abundance, taxonomic hierarchies from SCAMIT (2013). Shaded areas indicate species is one of the top ten most abundant in that stratum. SCB=Southern California Bight, B/H = Bays and Harbors, IS = Inner Shelf, MS = Middle Shelf, OS = Outer Shelf, US = Upper Slope.**

| | | | | | *Abundance* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Phylum** | **Class** | **Order** | **Family** | **Species** | **SCB** | **B/H** | **IS** | **MS** | **OS** | **US** |
| **SILICEA** | | | | | | | | | | |
| | Hexactinellida | | | | | | | | | |
| | | Lyssacinosa | | | | | | | | |
| | | | Rossellidae | *Staurocalyptus dowlingi* | 1 | – | – | – | – | 1 |
| | Demospongiae | | | | | | | | | |
| | | Spirophorida | | | | | | | | |
| | | | Tetillidae | *Tetilla sp* | 33 | 33 | – | – | – | – |
| | | Hadromerida | | | | | | | | |
| | | | Suberitidae | *Suberites latus* | 177 | 14 | – | – | 1 | 162 |
| | | Poecilosclerida | | | | | | | | |
| | | | Acarnidae | *Acarnidae sp SD 1* | 1 | – | – | 1 | – | – |
| | | | Microcionidae | *Microcionina sp SD 1* | 1 | – | – | 1 | – | – |
| | | | | *Microcionina sp SD 2* | 5 | – | – | 5 | – | – |
| | | Halichondrida | | | | | | | | |
| | | | Axinellidae | *Dragmacidon sp* | 1 | 1 | – | – | – | – |
| | | | Halichondriidae | *Halichondria bowerbanki* | 20 | 20 | – | – | – | – |
| | | | | *Halichondria panicea* | 1 | – | 1 | – | – | – |
| | | Haplosclerida | | | | | | | | |
| | | | Chalinidae | *Haliclona sp* | 1 | 1 | – | – | – | – |
| **CALCAREA** | | | | | | | | | | |
| | Calcerea | | | | | | | | | |
| | | Scycettida | | | | | | | | |
| | | | Amphoriscidae | *Leucilla nuttingi* | 3 | – | – | 3 | – | – |

**Appendix B-7 (continued)**

| Phylum | Class | Order | Family | Species | Abundance SCB | B/H | IS | MS | OS | US |
|---|---|---|---|---|---|---|---|---|---|---|
| **CNIDARIA** | | | | | | | | | | |
| | Hydrozoa | | | | | | | | | |
| | | Siphonophora | | | | | | | | |
| | | | Rhodaliidae | *Dromalia alexandri* | 460 | – | – | – | 22 | 438 |
| | Anthozoa | | | | | | | | | |
| | | Stolonifera | | | | | | | | |
| | | | Telestidae | *Telesto californica* | 103 | – | – | 103 | – | – |
| | | Alcyonacea | | | | | | | | |
| | | | Gorgoniidae | *Eugorgia rubens* | 22 | – | – | 22 | – | – |
| | | | | *Heterogorgia tortuosa* | 1 | – | 1 | – | – | – |
| | | | | *Leptogorgia chilensis* | 1 | – | 1 | – | – | – |
| | | | Plexauridae | *Muricea californica* | 4 | 2 | 2 | – | – | – |
| | | | | *Thesea sp B* | 212 | – | 1 | 205 | 6 | – |
| | | | | *Thesea sp SD 1* | 19 | – | – | 19 | – | – |
| | | Pennatulacea | | | | | | | | |
| | | | Renillidae | *Renilla koellikeri* | 8 | – | 7 | 1 | – | – |
| | | | Stachyptilidae | *Stachyptilum superbum* | 4 | – | – | – | – | 4 |
| | | | Halipteridae | *Halipteris californica* | 6 | – | – | – | – | 6 |
| | | | Virgulariidae | *Acanthoptilum sp* | 125 | 6 | 3 | 32 | 84 | – |
| | | | | *Stylatula elongata* | 43 | 4 | 3 | 35 | 1 | – |
| | | | | *Virgularia agassizii* | 2 | – | – | 2 | – | – |
| | | | | *Virgularia californica* | 4 | 2 | 1 | 1 | – | – |
| | | | Pennatulidae | *Pennatula californica* | 4 | – | – | – | – | 4 |
| | | | | *Ptilosarcus gurneyi* | 13 | – | – | – | 8 | 5 |
| | | Scleractinia | | | | | | | | |
| | | | Caryophylliidae | *Coenocyathus bowersi* | 1 | – | – | 1 | – | – |
| | | | | *Paracyathus stearnsii* | 4 | – | – | 4 | – | – |
| | | Actiniaria | | | | | | | | |
| | | | Actiniidae | *Epiactis prolifera* | 70 | 70 | – | – | – | – |
| | | | | *Urticina sp A* | 11 | – | 11 | – | – | – |
| | | | Liponematidae | *Liponema brevicorne* | 52 | – | – | – | – | 52 |
| | | | Actinostolidae | *Actinostola sp* | 12 | – | – | – | – | 12 |
| | | | Hormathiidae | *Hormathia digitata* | 3 | – | – | – | – | 3 |
| | | | | *Stephanauge sp* | 264 | – | – | – | – | 264 |
| | | | Metridiidae | *Metridium farcimen* | 28 | – | – | 5 | 21 | 2 |

**Appendix B-7 (continued)**

| Phylum | Class | Order | Family | Species | Abundance SCB | B/H | IS | MS | OS | US |
|---|---|---|---|---|---|---|---|---|---|---|
| **MOLLUSCA** | | | | | | | | | | |
| | Polyplacophora | | | | | | | | | |
| | | Chitonida | | | | | | | | |
| | | | Ischnochitonidae | *Lepidozona scrobiculata* | 1 | – | – | 1 | – | – |
| | Gastropoda | | | | | | | | | |
| | | Tryblidiida | | | | | | | | |
| | | | Calliostomatidae | *Calliostoma canaliculatum* | 1 | – | 1 | – | – | – |
| | | | | *Calliostoma keenae* | 1 | – | – | 1 | – | – |
| | | | | *Calliostoma platinum* | 2 | – | – | – | – | 2 |
| | | | | *Calliostoma tricolor* | 1 | – | 1 | – | – | – |
| | | | | *Calliostoma turbinum* | 3 | – | – | 3 | – | – |
| | | | Turbinidae | *Chlorostoma aureotincta* | 1 | – | – | 1 | – | – |
| | | | | *Norrisia norrisi* | 3 | – | – | 3 | – | – |
| | | Hypsogastropoda | | | | | | | | |
| | | | Ovulidae | *Simnia barbarensis* | 2 | – | – | – | 2 | – |
| | | | Naticidae | *Calinaticina oldroydii* | 8 | – | – | – | 4 | 4 |
| | | | | *Euspira draconis* | 1 | – | – | 1 | – | – |
| | | | | *Euspira lewisii* | 2 | – | 1 | – | 1 | – |
| | | | | *Glossaulax reclusianus* | 1 | – | 1 | – | – | – |
| | | | | *Sinum scopulosum* | 1 | – | – | – | 1 | – |
| | | | Bursidae | *Crossata ventricosa* | 3 | – | – | 1 | – | 2 |
| | | | Velutinidae | *Lamellaria diegoensis* | 4 | – | – | 4 | – | – |
| | | | Buccinidae | *Kelletia kelletii* | 8 | 2 | 4 | 2 | – | – |
| | | | | *Neptunea tabulata* | 3 | – | – | – | 2 | 1 |
| | | | Columbellidae | *Astyris permodesta* | 4,935 | – | – | – | – | 4,935 |
| | | | Fasciolariidae | *Barbarofusus barbarensis* | 4 | – | – | 4 | – | – |
| | | | Nassariidae | *Arcularia tiarula* | 4 | 4 | – | – | – | – |
| | | | | *Caesia perpinguis* | 5 | – | – | 5 | – | – |
| | | | | *Hinea insculpta* | 20 | – | – | 2 | 16 | 2 |
| | | | Muricidae | *Babelomurex oldroydi* | 1 | – | – | 1 | – | – |

**Appendix B-7 (continued)**

| Phylum | Class | Order | Family | Species | SCB | B/H | IS | MS | OS | US |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | ***Abundance*** | | | | | |
| **MOLLUSCA** | | | | | | | | | | |
| | | | | *Pteropurpura festiva* | 1 | – | 1 | – | – | – |
| | | | | *Boreotrophon bentleyi* | 3 | – | – | – | 2 | 1 |
| | | | Conidae | *Conus californicus* | 5 | 2 | 2 | 1 | – | – |
| | | | Borsoniidae | *Borsonella merriami* | 2 | – | – | – | – | 2 |
| | | | Pseudomelatomidae | *Antiplanes catalinae* | 12 | – | – | – | 12 | – |
| | | | | *Antiplanes thalea* | 26 | – | – | – | 6 | 20 |
| | | | | *Crassispira semiinflata* | 1 | – | 1 | – | – | – |
| | | | | *Megasurcula carpenteriana* | 12 | – | – | 8 | 3 | 1 |
| | | | Cancellariidae | *Cancellaria crawfordiana* | 6 | – | – | 2 | 3 | 1 |
| | | Opisthobranchia | | | | | | | | |
| | | | Bullidae | *Bulla gouldiana* | 3 | 3 | – | – | – | – |
| | | | Philinidae | *Philine alba* | 5 | – | – | – | 5 | – |
| | | | | *Philine auriformis* | 43 | 34 | 2 | 6 | – | 1 |
| | | | Aglajidae | *Aglaja ocelligera* | 1 | – | – | 1 | – | – |
| | | | | *Navanax inermis* | 8 | 8 | – | – | – | – |
| | | | Aplysiidae | *Aplysia californica* | 8 | – | 4 | 4 | – | – |
| | | | Pleurobranchidae | *Pleurobranchaea californica* | 664 | – | 7 | 253 | 241 | 163 |
| | | | Discodorididae | *Diaulula sandiegensis* | 2 | 1 | – | 1 | – | – |
| | | | | *Platydoris macfarlandi* | 1 | – | – | 1 | – | – |
| | | | Onchidorididae | *Acanthodoris brunnea* | 101 | 6 | 11 | 45 | 24 | 15 |
| | | | | *Acanthodoris rhodoceras* | 1 | – | – | 1 | – | – |
| | | | | *Corambe pacifica* | 2 | 2 | – | – | – | – |

**Appendix B-7 (continued)**

| Phylum | Class | Order | Family | Species | Abundance SCB | B/H | IS | MS | OS | US |
|---|---|---|---|---|---|---|---|---|---|---|
| **MOLLUSCA** | | | | | | | | | | |
| | | | Polyceridae | *Polycera hedgpethi* | 4 | 4 | – | – | – | – |
| | | | | *Triopha catalinae* | 1 | – | – | 1 | – | – |
| | | | | *Triopha maculata* | 4 | 2 | 1 | 1 | – | – |
| | | | Arminidae | *Armina californica* | 10 | 2 | 3 | 4 | 1 | – |
| | | | Tritoniidae | *Tritonia tetraquetra* | 8 | 4 | – | 4 | – | – |
| | | | Dendronotidae | *Dendronotus albus* | 1 | – | – | 1 | – | – |
| | | | | *Dendronotus iris* | 10 | 10 | – | – | – | – |
| | | | Flabellinidae | *Flabellina iodinea* | 5 | – | 2 | 3 | – | – |
| | | | Aeolidiidae | *Aeolidiella chromosoma* | 1 | – | 1 | – | – | – |
| | | | Facelinidae | *Hermissenda crassicornis* | 1 | – | 1 | – | – | – |
| | | | Zephyrinidae | *Janolus barbarensis* | 4 | 4 | – | – | – | – |
| | Bivalvia | | | | | | | | | |
| | | Mytilida | | | | | | | | |
| | | | Mytilidae | *Musculista senhousia* | 134 | 134 | – | – | – | – |
| | | Ostreida | | | | | | | | |
| | | | Ostreidae | *Ostrea lurida* | 6 | 6 | – | – | – | – |
| | Cephalopoda | | | | | | | | | |
| | | Sepioidea | | | | | | | | |
| | | | Sepiolidae | *Rossia pacifica* | 32 | – | – | – | 31 | 1 |
| | | Teuthida | | | | | | | | |
| | | | Loliginidae | *Doryteuthis opalescens* | 21 | – | – | – | 19 | 2 |
| | | Octopoda | | | | | | | | |
| | | | Opisthoteuthidae | *Opisthoteuthis sp A* | 5 | – | – | – | – | 5 |
| | | | Octopodidae | *Octopus californicus* | 156 | – | – | 1 | 56 | 99 |
| | | | | *Octopus rubescens* | 552 | 22 | 178 | 183 | 153 | 16 |
| | | | | *Octopus veligero* | 1 | – | – | 1 | – | – |

**Appendix B-7 (continued)**

| Phylum | Class | Order | Family | Species | *Abundance* SCB | B/H | IS | MS | OS | US |
|---|---|---|---|---|---|---|---|---|---|---|
| **ANNELIDA** | | | | | | | | | | |
| | Polychaeta | | | | | | | | | |
| | | Amphinomida | | | | | | | | |
| | | | Amphinomidae | *Chloeia pinnata* | 157 | – | – | – | – | 157 |
| | | Phyllodocida | | | | | | | | |
| | | | Aphroditidae | *Aphrodita sp* | 2 | – | – | 2 | – | – |
| | | | | *Aphrodita armifera* | 2 | – | – | – | 2 | – |
| | | | | *Aphrodita castanea* | 14 | – | – | 1 | 9 | 4 |
| | | | | *Aphrodita japonica* | 8 | – | – | 1 | 1 | 6 |
| | | | Polynoidae | *Harmothoe sp* | 1 | 1 | – | – | – | – |
| **ARTHROPODA** | | | | | | | | | | |
| | Pycnogonida | | | | | | | | | |
| | | Pegmata | | | | | | | | |
| | | | Nymphonidae | *Nymphon pixellae* | 38 | – | – | 33 | 4 | 1 |
| | | | Phoxichilidiidae | *Anoplodactylus erectus* | 1 | 1 | – | – | – | – |
| | Maxillopoda | | | | | | | | | |
| | | Pedunculata | | | | | | | | |
| | | | Scalpellidae | *Hamatoscalpellum californicum* | 112 | – | 18 | 93 | 1 | – |
| | Malacostraca | | | | | | | | | |
| | | Stomatopoda | | | | | | | | |
| | | | Hemisquillidae | *Hemisquilla californiensis* | 1 | – | – | 1 | – | – |
| | | Decapoda | | | | | | | | |
| | | | Aristeidae | *Bentheogennema burkenroadi* | 1 | – | – | – | – | 1 |
| | | | Penaeidae | *Farfantepenaeus californiensis* | 14 | 10 | 4 | – | – | – |
| | | | Sicyoniidae | *Sicyonia sp* | 2 | 2 | – | – | – | – |
| | | | | *Sicyonia ingentis* | 3,071 | 472 | 3 | 1,661 | 901 | 34 |
| | | | | *Sicyonia penicillata* | 1,491 | 1,208 | 54 | 229 | – | – |

**Appendix B-7 (continued)**

| Phylum | Class | Order | Family | Species | SCB | B/H | IS | MS | OS | US |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | ***Abundance*** | | | | | |
| **ARTHROPODA** | | | | | | | | | | |
| | | | Hippolytidae | *Heptacarpus brevirostris* | 3 | 2 | – | 1 | – | – |
| | | | | *Heptacarpus palpator* | 10 | 10 | – | – | – | – |
| | | | | *Heptacarpus stimpsoni* | 23 | 22 | – | 1 | – | – |
| | | | | *Heptacarpus tenuissimus* | 1 | – | – | – | 1 | – |
| | | | | *Hippolyte californiensis* | 1 | 1 | – | – | – | – |
| | | | | *Lysmata californica* | 1 | – | 1 | – | – | – |
| | | | | *Spirontocaris sp* | 268 | – | – | – | 202 | 66 |
| | | | | *Spirontocaris holmesi* | 3,008 | – | – | – | 788 | 2,220 |
| | | | | *Spirontocaris prionota* | 2 | 2 | – | – | – | – |
| | | | | *Spirontocaris sica* | 269 | – | – | – | 6 | 263 |
| | | | Pandalidae | *Pandalus jordani* | 4,180 | – | – | – | 4,180 | – |
| | | | | *Pandalus platyceros* | 1,258 | – | 1 | 16 | 433 | 808 |
| | | | Crangonidae | *Crangon alaskensis* | 3 | – | – | 3 | – | – |
| | | | | *Crangon nigricauda* | 2 | 2 | – | – | – | – |
| | | | | *Crangon nigromaculata* | 1,098 | 160 | 935 | 3 | – | – |
| | | | | *Metacrangon spinosissima* | 41 | – | – | 3 | 37 | 1 |
| | | | | *Neocrangon sp* | 14 | – | – | – | 12 | 2 |
| | | | | *Neocrangon resima* | 323 | – | – | 7 | 312 | 4 |
| | | | | *Neocrangon zacae* | 798 | – | – | 3 | 747 | 48 |
| | | | Palinuridae | *Panulirus interruptus* | 1 | 1 | – | – | – | – |
| | | | Diogenidae | *Paguristes bakeri* | 5 | – | 1 | 1 | 2 | 1 |
| | | | | *Paguristes turgidus* | 12 | – | – | – | – | 12 |
| | | | Paguridae | *Pagurus armatus* | 17 | – | – | 17 | – | – |

**Appendix B-7 (continued)**

| Phylum | Class | Order | Family | Species | Abundance | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | SCB | B/H | IS | MS | OS | US |
| **ARTHROPODA** | | | | | | | | | | |
| | | | | *Phimochirus californiensis* | 2 | – | 2 | – | – | – |
| | | | Munididae | *Munididae* | 5 | – | – | – | – | 5 |
| | | | | *Munida hispida* | 15 | – | – | – | – | 15 |
| | | | | *Munida quadrispina* | 265 | – | – | – | – | 265 |
| | | | | *Munida tenella* | 8 | – | – | – | 8 | – |
| | | | Munidopsidae | *Munidopsis aspera* | 1 | – | – | – | – | 1 |
| | | | Porcellanidae | *Pachycheles pubescens* | 4 | – | 4 | – | – | – |
| | | | | *Pachycheles rudis* | 1 | – | – | 1 | – | – |
| | | | Lithodidae | *Glyptolithodes cristatipes* | 29 | – | – | – | – | 29 |
| | | | | *Lopholithodes foraminatus* | 72 | – | – | – | 71 | 1 |
| | | | | *Paralithodes californiensis* | 14 | – | – | – | 8 | 6 |
| | | | | *Paralithodes rathbuni* | 3 | – | – | – | – | 3 |
| | | | Calappidae | *Platymera gaudichaudii* | 20 | – | – | 10 | 10 | – |
| | | | Leucosiidae | *Randallia ornata* | 4 | – | 4 | – | – | – |
| | | | Epialtidae | *Pisinae* | 1 | – | – | 1 | – | – |
| | | | | *Pugettia producta* | 1 | – | 1 | – | – | – |
| | | | | *Chorilia longipes* | 5 | – | – | – | – | 5 |
| | | | | *Loxorhynchus sp* | 3 | – | – | 3 | – | – |
| | | | | *Loxorhynchus crispatus* | 8 | – | 2 | 6 | – | – |
| | | | | *Loxorhynchus grandis* | 35 | 2 | 22 | 11 | – | – |
| | | | | *Scyra acutifrons* | 1 | – | 1 | – | – | – |

**Appendix B-7 (continued)**

| Phylum | Class | Order | Family | Species | Abundance SCB | B/H | IS | MS | OS | US |
|---|---|---|---|---|---|---|---|---|---|---|
| **ARTHROPODA** | | | | | | | | | | |
| | | | Inachidae | *Ericerodes hemphillii* | 5 | – | 3 | 2 | – | – |
| | | | | *Podochela lobifrons* | 9 | – | 4 | 5 | – | – |
| | | | Inachoididae | *Pyromaia tuberculata* | 207 | 155 | 42 | 10 | – | – |
| | | | Parthenopidae | *Latulambrus occidentalis* | 25 | – | 11 | 14 | – | – |
| | | | Cancridae | *Cancridae* | 5 | 2 | 2 | 1 | – | – |
| | | | | *Cancer productus* | 8 | – | 3 | 3 | 2 | – |
| | | | | *Metacarcinus anthonyi* | 5 | – | 1 | 1 | 3 | – |
| | | | | *Metacarcinus gracilis* | 254 | 13 | 223 | 18 | – | – |
| | | | | *Romaleon antennarium* | 1 | – | 1 | – | – | – |
| | | | | *Romaleon jordani* | 1 | – | 1 | – | – | – |
| | | | Portunidae | *Portunus xantusii* | 33 | 13 | 20 | – | – | – |
| | | | Panopeidae | *Lophopanopeus bellus* | 1 | – | – | 1 | – | – |
| | | | | *Lophopanopeus frontalis* | 6 | 6 | – | – | – | – |
| **ECHINODERMATA** | | | | | | | | | | |
| | Crinoidea | | | | | | | | | |
| | | Comatulida | | | | | | | | |
| | | | Antedonidae | *Florometra serratissima* | 65 | – | – | 4 | 56 | 5 |
| | Asteroidea | | | *Asteroidea* | 2 | – | – | 2 | – | – |
| | | Paxillosida | | | | | | | | |
| | | | Luidiidae | *Luidia sp* | 15 | – | 1 | 7 | 7 | – |
| | | | | *Luidia armata* | 42 | – | 4 | 38 | – | – |
| | | | | *Luidia asthenosoma* | 34 | – | – | 24 | 10 | – |
| | | | | *Luidia foliolata* | 1,007 | – | 3 | 409 | 236 | 359 |

**Appendix B-7 (continued)**

| Phylum | Class | Order | Family | Species | Abundance SCB | B/H | IS | MS | OS | US |
|---|---|---|---|---|---|---|---|---|---|---|
| **ECHINODERMATA** | | | | | | | | | | |
| | | | Astropectinidae | *Astropecten sp* | 10 | – | 9 | 1 | – | – |
| | | | | *Astropecten armatus* | 68 | 32 | 36 | – | – | – |
| | | | | *Astropecten californicus* | 1,29 | – | 1,588 | 334 | 5 | 1 |
| | | | | *Astropecten ornatissimus* | 282 | – | – | – | 282 | – |
| | | | | *Thrissacanthias penicillatus* | 7 | – | – | – | 1 | 6 |
| | | Valvatida | | | | | | | | |
| | | | Odontasteridae | *Odontaster crassus* | 3 | – | – | – | 1 | 2 |
| | | | Goniasteridae | *Ceramaster leptoceramus* | 101 | – | – | – | – | 101 |
| | | | | *Hippasteria spinosa* | 1 | – | – | – | – | 1 |
| | | | | *Mediaster aequalis* | 1 | – | – | – | 1 | – |
| | | | | *Pseudarchaster pusillus* | 286 | – | – | – | – | 286 |
| | | Spinulosida | | | | | | | | |
| | | | Poraniidae | *Poraniopsis inflata* | 2 | – | – | – | 2 | – |
| | | Forcipulatida | | | | | | | | |
| | | | Asteriidae | *Pisaster brevispinus* | 45 | – | 44 | 1 | – | – |
| | | | | *Pisaster ochraceus* | 2 | 2 | – | – | – | – |
| | | | | *Pycnopodia helianthoides* | 2 | 2 | – | – | – | – |
| | | | | *Rathbunaster californicus* | 160 | – | – | – | – | 160 |
| | | | | *Sclerasterias heteropaes* | 2 | – | 1 | 1 | – | – |
| | | | | *Stylasterias forreri* | 19 | – | – | 4 | 4 | 11 |
| | | Zorocallida | | | | | | | | |
| | | | Zoroasteridae | *Myxoderma platyacanthum* | 14,905 | – | – | – | – | 14,905 |

**Appendix B-7 (continued)**

| Phylum | Class | Order | Family | Species | Abundance SCB | B/H | IS | MS | OS | US |
|---|---|---|---|---|---|---|---|---|---|---|
| **ECHINODERMATA** | | | | | | | | | | |
| | Ophiuroidea | | | | | | | | | |
| | | Euryalida | | | | | | | | |
| | | | Asteronychidae | *Asteronyx longifissus* | 7,550 | – | – | – | – | 7,550 |
| | | | Gorgonocephalidae | *Gorgonocephalus eucnemis* | 47 | – | – | – | 46 | 1 |
| | | Ophiurida | | | | | | | | |
| | | | Ophiacanthidae | *Ophiacantha diplasia* | 2 | – | – | – | 2 | – |
| | | | | *Ophiacantha quadrispina* | 1 | – | – | – | 1 | – |
| | | | Ophiuridae | *Ophiosphalma jolliense* | 16 | – | – | – | – | 16 |
| | | | | *Ophiura luetkenii* | 21,904 | – | 3 | 21,697 | 202 | 2 |
| | | | Amphiuridae | *Amphiuridae* | 23 | – | – | – | 23 | – |
| | | | | *Amphichondrius granulatus* | 8 | – | – | 1 | 7 | – |
| | | | | *Amphiodia sp* | 1 | – | – | – | 1 | – |
| | | | | *Amphiodia digitata* | 1 | – | – | – | 1 | – |
| | | | | *Amphiodia psara* | 1 | – | – | 1 | – | – |
| | | | | *Amphiodia urtica* | 1 | – | – | – | 1 | – |
| | | | | *Amphiura arcystata* | 3 | – | 1 | 2 | – | – |
| | | | | *Amphiura diomedeae* | 1 | – | – | – | – | 1 |
| | | | | *Dougaloplus amphacanthus* | 2 | – | – | – | 2 | – |
| | | | | *Ophiocnida hispida* | 1 | 1 | – | – | – | – |
| | | | Ophiotricidae | *Ophiothrix spiculata* | 568 | 10 | 52 | 485 | 20 | 1 |
| | | | Ophiactidae | *Ophiopholis bakeri* | 40 | – | – | 11 | 10 | 19 |
| | | | | *Ophiopholis longispina* | 24 | – | – | – | – | 24 |
| | | | Ophiocomidae | *Ophiopteris papillosa* | 3 | – | – | 3 | – | – |

**Appendix B-7 (continued)**

| | | | | | *Abundance* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Phylum** | **Class** | **Order** | **Family** | **Species** | **SCB** | **B/H** | **IS** | **MS** | **OS** | **US** |
| **ECHINODERMATA** | | | | | | | | | | |
| | Echinoidea | | | | | | | | | |
| | | Camarodonta | | | | | | | | |
| | | | Toxopneustidae | *Lytechinus pictus* | 8,321 | – | 77 | 8,137 | 107 | – |
| | | | Strongylocentrotidae | *Strongylocentrotus sp* | 6 | 4 | – | 2 | – | – |
| | | | | *Strongylocentrotus fragilis* | 24,252 | – | – | – | 8,087 | 16,165 |
| | | | | *Strongylocentrotus franciscanus* | 18 | 16 | – | 2 | – | – |
| | | | | *Strongylocentrotus purpuratus* | 1 | – | – | 1 | – | – |
| | | Clypeasteroida | | | | | | | | |
| | | | Dendrasteridae | *Dendraster terminalis* | 1 | – | 1 | – | – | – |
| | | Spatangoida | | | | | | | | |
| | | | Schizasteridae | *Brisaster sp* | 6,201 | – | – | – | 3,075 | 3,126 |
| | | | | *Brisaster latifrons* | | – | – | – | | |
| | | | | *Brisaster townsendi* | | – | – | – | | |
| | | | Brissidae | *Brissopsis pacifica* | 16,869 | – | – | – | 478 | 16,391 |
| | | | Spatangidae | *Spatangus californicus* | 823 | – | – | 1 | 528 | 294 |
| | Holothuroidea | | | | | | | | | |
| | | Dendrochirotida | | | | | | | | |
| | | | Phyllophoridae | *Havelockia benti* | 1 | – | 1 | – | – | – |
| | | | | *Pentamera pseudocalcigera* | 6 | – | – | – | 4 | 2 |
| | | Aspidochirotida | | | | | | | | |
| | | | Stichopodidae | *Parastichopus californicus* | 412 | – | 5 | 344 | 62 | 1 |
| | | | | *Parastichopus parvimensis* | 5 | 4 | – | 1 | – | – |
| | | | | *Parastichopus sp A* | 9 | – | – | – | 6 | 3 |

**Appendix B-7 (continued)**

| Phylum | Class | Order | Family | Species | *Abundance* SCB | B/H | IS | MS | OS | US |
|---|---|---|---|---|---|---|---|---|---|---|
| **ECHINODERMATA** | | | | | | | | | | |
| | | | Synallactidae | *Synallactes virgulisolida* | 1 | – | – | – | – | 1 |
| | | Elasipodida | | | | | | | | |
| | | | Laetmogonidae | *Pannychia moseleyi* | 670 | – | – | – | – | 670 |
| | | Molpadida | | | | | | | | |
| | | | Molpadiidae | *Molpadia intermedia* | 1 | – | – | 1 | – | – |
| | | | Caudinidae | *Caudina arenicola* | 1 | – | – | 1 | – | – |
| **CHORDATA** | | | | | | | | | | |
| | Ascidiacea | | | | | | | | | |
| | | Stolidobranchiata | | | | | | | | |
| | | | Styelidae | *Styela gibbsii* | 3 | – | – | 3 | – | – |
| | | | | *Styela montereyensis* | 2 | – | – | 2 | – | – |
| | | | | *Styela plicata* | 3 | – | – | 3 | – | – |
| | | | Pyuridae | *Boltenia villosa* | 1 | – | – | 1 | – | – |

**Appendix B-8. Megabenthic invertebrate abundance by MPA designation and stratum during the Bight '13 trawl survey.**

| | No. of Stations | Total | Range Min | Range Max | Area-Weighted Values Median | Area-Weighted Values Mean | Area-Weighted Values SD | Area-Weighted Values 95% CL | Percent Above Bight Median |
|---|---|---|---|---|---|---|---|---|---|
| *MPA/Non-MPA* | | | | | | | | | |
| MPA | 24 | 10,541 | 2 | 2,471 | 200 | 477 | 649 | 285 | -76.6 |
| Non-MPA | 141 | 155,329 | 4 | 17,973 | 855 | 1,962 | 3,260 | 747 | 0.0 |
| *Stratum* | | | | | | | | | |
| **Bays and Harbors (3-30 m)** | **26** | **2,559** | **5** | **316** | **37** | **80** | **85** | **30** | **-95.7** |
| **Inner Shelf (8-30 m)** | **35** | **3,443** | **5** | **921** | **39** | **89** | **170** | **62** | **-95.4** |
| MPA | 6 | 1,023 | 22 | 490 | 46 | 160 | 181 | 142 | -94.6 |
| Non-MPA | 29 | 2,420 | 5 | 921 | 39 | 87 | 170 | 64 | -95.4 |
| **Middle Shelf (31-120 m)** | **43** | **34,678** | **2** | **17,973** | **200** | **1,052** | **3,220** | **1,158** | **-76.6** |
| MPA | 13 | 3,469 | 2 | 945 | 187 | 241 | 191 | 96 | -78.1 |
| Non-MPA | 30 | 31,209 | 19 | 17,973 | 205 | 1,093 | 3,295 | 1,216 | -76.0 |
| **Outer Shelf (121-200 m)** | **29** | **23,338** | **4** | **5,160** | **388** | **718** | **981** | **342** | **-54.6** |
| MPA | 2 | 404 | 16 | 388 | 202 | 202 | 186 | 258 | -76.4 |
| Non-MPA | 27 | 22,934 | 4 | 5,160 | 542 | 728 | 987 | 349 | -36.6 |
| **Upper slope (201-500 m)** | **32** | **101,852** | **68** | **17,600** | **2,240** | **3,307** | **3,464** | **1,255** | **162.0** |
| MPA | 3 | 5,645 | 1,459 | 2,471 | 1,715 | 1,882 | 430 | 486 | 100.6 |
| Non-MPA | 29 | 96,207 | 68 | 17,600 | 2,240 | 3,317 | 3,475 | 1,265 | 162.0 |
| **Total (all stations)** | **165** | **165,870** | **2** | **17,973** | **855** | **1,929** | **3,232** | **731** | |

**Appendix B-9. Megabenthic invertebrate biomass by MPA designation and stratum during the Bight '13 trawl survey.**

| | No. of Stations | Total | Range | | Area-Weighted Values | | | | Percent Above Bight Median |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Max | Median | Mean | SD | 95% CL | |
| *MPA/Non-MPA* | | | | | | | | | |
| MPA | 24 | 223 | 0.09 | 65 | 4.8 | 11.0 | 16.7 | 7.3 | -52.8 |
| Non-MPA | 141 | 2,542 | 0.13 | 182 | 10.3 | 28.4 | 40.1 | 9.5 | 0.0 |
| *Stratum* | | | | | | | | | |
| **Bays and Harbors (3-30m)** | **26** | **58** | **0.19** | **6** | **1.8** | **2.0** | **1.7** | **0.7** | **-82.9** |
| **Inner Shelf (8-30m)** | **35** | **58** | **0.15** | **11** | **1.1** | **1.8** | **2.3** | **0.8** | **-89.0** |
| MPA | 6 | 6 | 0.18 | 3 | 0.8 | 1.0 | 0.8 | 0.6 | -92.4 |
| Non-MPA | 29 | 52 | 0.15 | 11 | 1.1 | 1.9 | 2.3 | 0.9 | -89.0 |
| **Middle Shelf (31-120 m)** | **43** | **261** | **0.09** | **36** | **3.4** | **5.1** | **5.4** | **1.7** | **-66.7** |
| MPA | 13 | 90 | 0.09 | 21 | 8.3 | 7.6 | 6.3 | 3.7 | -19.2 |
| Non-MPA | 30 | 171 | 0.31 | 36 | 3.4 | 4.9 | 5.3 | 1.8 | -66.7 |
| **Outer Shelf (121-200 m)** | **29** | **780** | **0.39** | **83** | **16.9** | **26.6** | **22.7** | **8.4** | **64.0** |
| MPA | 2 | 10 | 0.92 | 9 | 4.9 | 4.9 | 4.0 | 5.5 | -52.3 |
| Non-MPA | 27 | 771 | 0.39 | 83 | 19.3 | 27.0 | 22.7 | 8.5 | 87.5 |
| **Upper slope (201-500 m)** | **32** | **1,608** | **0.13** | **182** | **41.5** | **51.3** | **46.2** | **16.7** | **304.2** |
| MPA | 3 | 117 | 3.25 | 65 | 48.8 | 38.9 | 26.0 | 29.4 | 374.9 |
| Non-MPA | 29 | 1,491 | 0.13 | 182 | 41.5 | 51.4 | 46.3 | 16.9 | 304.2 |
| **Total (all stations)** | **165** | **2,765** | **0.09** | **182** | **10.3** | **28.1** | **39.8** | **9.3** | |

**Appendix B-10. Megabenthic invertebrate diversity (Shannon, H') by MPA designation and stratum during the Bight '13 trawl survey.**

| | | Range | | Area-Weighted Values | | | | Percent Above Bight Median |
|---|---|---|---|---|---|---|---|---|
| | **No. of Stations** | **Min** | **Max** | **Median** | **Mean** | **SD** | **95% CL** | |
| *MPA/Non-MPA* | | | | | | | | |
| MPA | 24 | 0.11 | 2.07 | 1.39 | 1.13 | 0.55 | 0.23 | 35.8 |
| Non-MPA | 141 | 0.07 | 2.49 | 1.02 | 1.04 | 0.55 | 0.11 | 0.0 |
| *Stratum* | | | | | | | | |
| **Bays and Harbors (3-30 m)** | **26** | **0.12** | **2.30** | **0.95** | **1.08** | **0.56** | **0.22** | **-6.9** |
| **Inner Shelf (8-30 m)** | **35** | **0.11** | **2.07** | **1.39** | **1.25** | **0.47** | **0.17** | **36.7** |
| MPA | 6 | 0.11 | 2.07 | 1.54 | 1.13 | 0.73 | 0.58 | 50.9 |
| Non-MPA | 29 | 0.14 | 1.91 | 1.39 | 1.25 | 0.46 | 0.17 | 36.7 |
| **Middle Shelf (31-120 m)** | **43** | **0.09** | **2.49** | **1.13** | **1.12** | **0.65** | **0.23** | **10.4** |
| MPA | 13 | 0.67 | 1.77 | 1.43 | 1.26 | 0.42 | 0.25 | 40.6 |
| Non-MPA | 30 | 0.09 | 2.49 | 1.13 | 1.11 | 0.66 | 0.24 | 10.4 |
| **Outer Shelf (121-200 m)** | **29** | **0.10** | **2.39** | **1.24** | **1.26** | **0.61** | **0.23** | **21.8** |
| MPA | 2 | 1.45 | 1.58 | 1.51 | 1.51 | 0.07 | 0.09 | 48.1 |
| Non-MPA | 27 | 0.10 | 2.39 | 1.22 | 1.26 | 0.62 | 0.24 | 19.6 |
| **Upper slope (201-500 m)** | **32** | **0.07** | **1.81** | **0.82** | **0.89** | **0.45** | **0.16** | **-19.4** |
| MPA | 3 | 0.22 | 0.99 | 0.27 | 0.49 | 0.35 | 0.39 | -73.2 |
| Non-MPA | 29 | 0.07 | 1.81 | 0.82 | 0.89 | 0.45 | 0.16 | -19.4 |
| **Total (all stations)** | **165** | **0.07** | **2.49** | **1.02** | **1.04** | **0.55** | **0.11** | |

**Appendix B-11. Megabenthic invertebrate species richness by MPA designation and stratum during the Bight '13 trawl survey.**

| | No. of Stations | Total | Range Min | Range Max | Area-Weighted Values Median | Area-Weighted Values Mean | Area-Weighted Values SD | Area-Weighted Values 95% CL | Percent Above Bight Median |
|---|---|---|---|---|---|---|---|---|---|
| *MPA/Non-MPA* | | | | | | | | | |
| MPA | 24 | 40 | 2 | 22 | 10 | 10.0 | 4.2 | 1.6 | 0.0 |
| Non-MPA | 141 | 71 | 2 | 29 | 10 | 10.7 | 4.9 | 1.0 | 0.0 |
| *Stratum* | | | | | | | | | |
| **Bays and Harbors (3-30 m)** | **26** | **53** | **2** | **11** | **5** | **5.7** | **2.6** | **1.0** | **-50.0** |
| **Inner Shelf (8-30 m)** | **35** | **53** | **2** | **13** | **7** | **7.0** | **2.5** | **0.9** | **-30.0** |
| MPA | 6 | 29 | 5 | 13 | 8 | 8.0 | 2.5 | 1.9 | -20.0 |
| Non-MPA | 29 | 58 | 2 | 12 | 7 | 7.0 | 2.5 | 0.9 | -30.0 |
| **Middle Shelf (31-120 m)** | **43** | **75** | **2** | **23** | **11** | **11.6** | **4.5** | **1.6** | **10.0** |
| MPA | 13 | 53 | 2 | 22 | 11 | 10.4 | 4.3 | 2.3 | 10.0 |
| Non-MPA | 30 | 85 | 3 | 23 | 11 | 11.6 | 4.5 | 1.7 | 10.0 |
| **Outer Shelf (121-200 m)** | **29** | **70** | **3** | **29** | **16** | **14.8** | **6.1** | **2.3** | **60.0** |
| MPA | 2 | 21 | 6 | 21 | 14 | 13.5 | 7.5 | 10.4 | 35.0 |
| Non-MPA | 27 | 74 | 3 | 29 | 16 | 14.8 | 6.0 | 2.3 | 60.0 |
| **Upper slope (201-500 m)** | **32** | **76** | **2** | **19** | **10** | **11.0** | **4.7** | **1.7** | **0.0** |
| MPA | 3 | 19 | 7 | 12 | 10 | 9.7 | 2.1 | 2.3 | 0.0 |
| Non-MPA | 29 | 82 | 2 | 19 | 10 | 11.0 | 4.7 | 1.7 | 0.0 |
| **Total (all stations)** | **165** | **229** | **2** | **29** | **10** | **10.7** | **4.9** | **1.0** | |

**Appendix B-12. Total abundance for all demersal fish species collected during the Bight '13 trawl survey. Shaded areas indicate species is one of the top ten most abundant in that stratum. SCB=Southern California Bight, B/H = Bays and Harbors, IS = Inner Shelf, MS = Middle Shelf, OS = Outer Shelf, US = Upper Slope.**

| | | *Abundance* | | | | | |
|---|---|---|---|---|---|---|---|
| **Common Name** | **Family** | **SCB** | **B/H** | **IS** | **MS** | **OS** | **US** |
| Pacific Sanddab | Paralichthyidae | 19,004 | – | 373 | 5,232 | 12,511 | 888 |
| California Lizardfish | Synodontidae | 13,434 | 3,290 | 3,758 | 6,280 | 103 | 3 |
| Speckled Sanddab | Paralichthyidae | 5,437 | 330 | 4,386 | 721 | – | – |
| Dover Sole | Pleuronectidae | 5,045 | – | – | 122 | 3,709 | 1,214 |
| Slender Sole | Pleuronectidae | 5,040 | – | – | 1 | 2,015 | 3,024 |
| Longspine Combfish | Hexagrammidae | 2,560 | 116 | 89 | 2,291 | 29 | 35 |
| Halfbanded Rockfish | Scorpaenidae | 2,440 | – | – | 1,925 | 240 | 275 |
| White Croaker | Sciaenidae | 2,324 | 2,048 | 273 | 3 | – | – |
| Splitnose Rockfish | Scorpaenidae | 2,206 | – | – | – | 1,638 | 568 |
| Yellowchin Sculpin | Cottidae | 2,070 | 16 | 306 | 1,748 | – | – |
| Stripetail Rockfish | Scorpaenidae | 1,916 | – | 5 | 1,035 | 678 | 198 |
| Blackbelly Eelpout | Zoarcidae | 1,314 | – | 2 | 19 | 1,134 | 159 |
| Shortspine Combfish | Hexagrammidae | 1,270 | – | – | 55 | 1,073 | 142 |
| English Sole | Pleuronectidae | 827 | – | 114 | 469 | 204 | 40 |
| Blacktip Poacher | Agonidae | 773 | – | – | 2 | 326 | 445 |
| California Tonguefish | Cynoglossidae | 703 | 271 | 107 | 325 | – | – |
| Slough Anchovy | Engraulidae | 697 | 697 | – | – | – | – |
| Pink Seaperch | Embiotocidae | 617 | – | 22 | 588 | 6 | 1 |
| Curlfin Sole | Pleuronectidae | 410 | 4 | 263 | 140 | 3 | – |
| Queenfish | Sciaenidae | 409 | 408 | 1 | – | – | – |
| Bearded Eelpout | Zoarcidae | 404 | – | – | 1 | 56 | 347 |
| Longfin Sanddab | Paralichthyidae | 394 | – | 52 | 342 | – | – |
| Vermilion Rockfish | Scorpaenidae | 389 | – | 174 | 215 | – | – |
| Hornyhead Turbot | Pleuronectidae | 350 | 30 | 178 | 131 | 11 | – |
| Rubynose Brotula | Bythitidae | 336 | – | – | – | – | 336 |
| Deepbody Anchovy | Engraulidae | 322 | 322 | – | – | – | – |
| Rex Sole | Pleuronectidae | 315 | – | – | – | 122 | 193 |
| unidentified pipefish | Syngnathidae | 280 | 10 | 264 | 4 | 1 | 1 |
| Plainfin Midshipman | Batrachoididae | 267 | 10 | 6 | 156 | 95 | – |
| Black Eelpout | Zoarcidae | 244 | – | – | – | – | 244 |
| Filetail Cat Shark | Scyliorhinidae | 192 | – | – | – | – | 192 |
| Shortbelly Rockfish | Scorpaenidae | 189 | – | 1 | 16 | 124 | 48 |
| Calico Rockfish | Scorpaenidae | 182 | – | 31 | 151 | – | – |

## Appendix B-12 (continued)

| Common Name | Family | Abundance | | | | | |
|---|---|---|---|---|---|---|---|
| | | SCB | B/H | IS | MS | OS | US |
| Pacific Hake | Merlucciidae | 181 | – | – | – | 43 | 138 |
| Round Stingray | Urotrygonidae | 176 | 176 | – | – | – | – |
| Dogface Witch Eel | Nettastomatidae | 152 | – | – | – | – | 152 |
| Fantail Sole | Paralichthyidae | 141 | 51 | 75 | 15 | – | – |
| Bigmouth Sole | Paralichthyidae | 138 | – | 5 | 99 | 33 | 1 |
| Specklefin Midshipman | Batrachoididae | 135 | 122 | 9 | 4 | – | – |
| Pygmy Poacher | Agonidae | 130 | 4 | 13 | 113 | – | – |
| Spotted Cusk-eel | Ophidiidae | 108 | – | – | 11 | 63 | 34 |
| Shortspine Thornyhead | Scorpaenidae | 107 | – | – | – | – | 107 |
| California Halibut | Paralichthyidae | 104 | 74 | 29 | 1 | – | – |
| Greenstriped Rockfish | Scorpaenidae | 98 | – | – | 6 | 27 | 65 |
| Roughback Sculpin | Cottidae | 94 | – | 22 | 70 | 2 | – |
| Hundred-fathom Codling | Moridae | 74 | – | – | – | 33 | 41 |
| Bluebarred Prickleback | Stichaeidae | 73 | – | – | – | 48 | 25 |
| Copper Rockfish | Scorpaenidae | 72 | 2 | 58 | 12 | – | – |
| Barred Sand Bass | Serranidae | 68 | 65 | 3 | – | – | – |
| Bigeye Poacher | Agonidae | 64 | – | – | – | 1 | 63 |
| Spotted Sand Bass | Serranidae | 57 | 57 | – | – | – | – |
| Shiner Perch | Embiotocidae | 56 | 7 | 6 | 43 | – | – |
| California Skate | Rajidae | 56 | 10 | 6 | 35 | 5 | – |
| California Scorpionfish | Scorpaenidae | 55 | 2 | 9 | 44 | – | – |
| Lingcod | Hexagrammidae | 53 | – | 2 | 49 | 2 | – |
| Blacktail Snailfish | Liparidae | 43 | – | – | – | 1 | 42 |
| California Grenadier | Macrouridae | 42 | – | – | – | – | 42 |
| Pink Rockfish | Scorpaenidae | 40 | – | – | – | 11 | 29 |
| Bluespotted Poacher | Agonidae | 38 | – | – | 25 | 13 | – |
| Sablefish | Anoplopomatidae | 36 | – | – | – | 9 | 27 |
| Northern Anchovy | Engraulidae | 36 | 36 | – | – | – | – |
| Gulf Sanddab | Paralichthyidae | 34 | – | – | 2 | 28 | 4 |
| Bigfin Eelpout | Zoarcidae | 34 | – | – | – | 21 | 13 |
| Sarcastic Fringehead | Labrisomidae | 32 | 2 | 13 | 17 | – | – |
| Longspine Thornyhead | Scorpaenidae | 31 | – | – | – | – | 31 |
| Pacific Pompano | Stromateidae | 29 | 4 | – | 25 | – | – |
| Spotted Turbot | Pleuronectidae | 29 | 19 | 9 | 1 | – | – |
| Squarespot Rockfish | Scorpaenidae | 29 | – | – | 28 | 1 | – |

**Appendix B-12 (continued)**

| Common Name | Family | Abundance SCB | B/H | IS | MS | OS | US |
|---|---|---|---|---|---|---|---|
| Blue Rockfish | Scorpaenidae | 28 | – | – | 28 | – | – |
| Longnose Skate | Rajidae | 20 | – | 1 | – | 9 | 10 |
| Greenblotched Rockfish | Scorpaenidae | 20 | – | – | – | 15 | 5 |
| Pacific Argentine | Argentinidae | 18 | – | – | – | 17 | 1 |
| Pallid Eelpout | Zoarcidae | 17 | – | – | – | – | 17 |
| Blackgill Rockfish | Scorpaenidae | 17 | – | – | – | 1 | 16 |
| Chilipepper | Scorpaenidae | 16 | – | – | 10 | 5 | 1 |
| Bocaccio | Scorpaenidae | 16 | – | – | 16 | – | – |
| Pacific Hagfish | Myxinidae | 15 | – | – | – | – | 15 |
| unidentified rockfish | Scorpaenidae | 13 | – | – | 2 | 7 | 4 |
| Petrale Sole | Pleuronectidae | 12 | – | – | 1 | 7 | 4 |
| Pacific Staghorn Sculpin | Cottidae | 12 | – | 12 | – | – | – |
| Gray Smoothhound | Triakidae | 11 | 11 | – | – | – | – |
| Bay Goby | Gobiidae | 10 | – | 1 | 9 | – | – |
| Cabezon | Cottidae | 10 | – | 8 | 2 | – | – |
| Cowcod | Scorpaenidae | 10 | – | – | – | 9 | 1 |
| Diamond Turbot | Pleuronectidae | 9 | 9 | – | – | – | – |
| Aurora Rockfish | Scorpaenidae | 9 | – | – | – | – | 9 |
| Southern Spearnose Poacher | Agonidae | 8 | – | – | 8 | – | – |
| Rainbow Seaperch | Embiotocidae | 7 | – | 7 | – | – | – |
| Black Croaker | Sciaenidae | 6 | 6 | – | – | – | – |
| California Butterfly Ray | Gymnuridae | 6 | 6 | – | – | – | – |
| Kelp Bass | Serranidae | 6 | 6 | – | – | – | – |
| Kelp Perch | Embiotocidae | 5 | – | 5 | – | – | – |
| Gopher Rockfish | Scorpaenidae | 5 | – | 5 | – | – | – |
| Greenspotted Rockfish | Scorpaenidae | 5 | – | – | 4 | 1 | – |
| Flag Rockfish | Scorpaenidae | 5 | – | – | 1 | 4 | – |
| Sargo | Haemulidae | 4 | 4 | – | – | – | – |
| Spotfin Sculpin | Cottidae | 4 | – | – | 4 | – | – |
| Bat Ray | Myliobatidae | 4 | 3 | – | 1 | – | – |
| Pacific Electric Ray | Torpedinidae | 4 | – | – | 2 | 2 | – |
| Brown Rockfish | Scorpaenidae | 3 | 2 | – | 1 | – | – |
| Darkblotched Rockfish | Scorpaenidae | 3 | – | – | 1 | 1 | 1 |
| Yellowfin Croaker | Sciaenidae | 3 | 3 | – | – | – | – |
| White Seabass | Sciaenidae | 2 | 2 | – | – | – | – |

## Appendix B-12 (continued)

| Common Name | Family | Abundance SCB | B/H | IS | MS | OS | US |
|---|---|---|---|---|---|---|---|
| Sandpaper Skate | Rajidae | 2 | – | – | – | – | 2 |
| Bull Sculpin | Cottidae | 2 | – | – | 2 | – | – |
| Giant Kelpfish | Clinidae | 2 | – | 2 | – | – | – |
| Onespot Fringehead | Labrisomidae | 2 | 2 | – | – | – | – |
| Painted Greenling | Hexagrammidae | 2 | – | – | 2 | – | – |
| White Seaperch | Embiotocidae | 2 | – | 1 | 1 | – | – |
| unidentified flatfish | unidentified | 2 | – | – | 2 | – | – |
| Bluebanded Ronquil | Bathymasteridae | 2 | – | – | 2 | – | – |
| Mexican Rockfish | Scorpaenidae | 2 | – | – | – | 2 | – |
| King-of-the-salmon | Trachipteridae | 2 | – | – | 1 | – | 1 |
| Pile Perch | Embiotocidae | 1 | – | 1 | – | – | – |
| Horn Shark | Heterodontidae | 1 | – | 1 | – | – | – |
| Kelp Greenling | Hexagrammidae | 1 | – | 1 | – | – | – |
| Pit-head Sculpin | Cottidae | 1 | – | – | 1 | – | – |
| Pacific Blackdragon | Phosichthyidae | 1 | – | – | – | – | 1 |
| Midwater Eelpout | Zoarcidae | 1 | – | – | – | – | 1 |
| Basketweave Cusk-eel | Ophidiidae | 1 | – | – | – | 1 | – |
| C-O Sole | Pleuronectidae | 1 | – | 1 | – | – | – |
| Shadow Goby | Gobiidae | 1 | 1 | – | – | – | – |
| Rubberlip Seaperch | Embiotocidae | 1 | – | 1 | – | – | – |
| Shovelnose Guitarfish | Rhinobatidae | 1 | 1 | – | – | – | – |
| Grass Rockfish | Scorpaenidae | 1 | – | – | 1 | – | – |
| Pinkrose Rockfish | Scorpaenidae | 1 | – | – | – | – | 1 |
| Northern Lampfish | Myctophidae | 1 | – | – | – | – | 1 |
| Black-belly Dragonfish | Phosichthyidae | 1 | – | – | – | – | 1 |

**Appendix B-13. Total biomass (kg) for all demersal fish species collected during the Bight '13 trawl survey. Shaded areas indicate the species is ranked within the top ten species for biomass in that stratum. SCB=Southern California Bight, B/H = Bays and Harbors, IS = Inner Shelf, MS = Middle Shelf, OS = Outer Shelf, US = Upper Slope.**

| | | *Biomass (kg)* | | | | | |
|---|---|---|---|---|---|---|---|
| **Common Name** | **Family** | **SCB** | **B/H** | **IS** | **MS** | **OS** | **US** |
| Pacific Sanddab | Paralichthyidae | 395.4 | – | 12.8 | 137.4 | 210.7 | 34.4 |
| California Lizardfish | Synodontidae | 220.9 | 85.9 | 52.7 | 78.4 | 3.8 | 0.1 |
| White Croaker | Sciaenidae | 160.7 | 154.4 | 6.0 | 0.3 | – | – |
| Slender Sole | Pleuronectidae | 138.0 | – | – | 0.1 | 41.2 | 96.7 |
| Dover Sole | Pleuronectidae | 123.1 | – | – | 7.3 | 40.3 | 75.5 |
| English Sole | Pleuronectidae | 71.6 | – | 7.0 | 35.4 | 21.5 | 7.8 |
| Round Stingray | Urotrygonidae | 66.1 | 66.1 | – | – | – | – |
| Halfbanded Rockfish | Scorpaenidae | 61.8 | – | – | 44.1 | 10.9 | 6.8 |
| Speckled Sanddab | Paralichthyidae | 47.4 | 2.7 | 38.8 | 5.8 | – | – |
| California Halibut | Paralichthyidae | 47.0 | 15.6 | 28.4 | 3.0 | – | – |
| Longspine Combfish | Hexagrammidae | 33.8 | 4.0 | 1.6 | 25.9 | 1.1 | 1.2 |
| Splitnose Rockfish | Scorpaenidae | 33.4 | – | – | – | 11.8 | 21.6 |
| Stripetail Rockfish | Scorpaenidae | 29.5 | – | 0.1 | 7.1 | 14.0 | 8.4 |
| Hornyhead Turbot | Pleuronectidae | 29.3 | 2.8 | 14.2 | 10.9 | 1.4 | – |
| Blackbelly Eelpout | Zoarcidae | 26.1 | – | 0.1 | 0.8 | 19.9 | 5.3 |
| Shortspine Combfish | Hexagrammidae | 23.7 | – | – | 1.5 | 19.0 | 3.3 |
| Longfin Sanddab | Paralichthyidae | 23.4 | – | 3.3 | 20.0 | – | – |
| Pacific Hake | Merlucciidae | 22.3 | – | – | – | 2.7 | 19.6 |
| California Skate | Rajidae | 16.5 | 5.6 | 2.2 | 8.2 | 0.5 | – |
| Sablefish | Anoplopomatidae | 15.6 | – | – | – | 0.9 | 14.7 |
| Rex Sole | Pleuronectidae | 15.0 | – | – | – | 3.4 | 11.6 |
| California Scorpionfish | Scorpaenidae | 14.5 | 1.2 | 1.6 | 11.8 | – | – |
| California Tonguefish | Cynoglossidae | 14.2 | 3.8 | 2.3 | 8.1 | – | – |
| Fantail Sole | Paralichthyidae | 12.5 | 4.6 | 6.6 | 1.2 | – | – |
| Bat Ray | Myliobatidae | 12.0 | 11.4 | – | 0.6 | – | – |
| Pacific Electric Ray | Torpedinidae | 12.0 | – | – | 4.7 | 7.3 | – |
| Pink Seaperch | Embiotocidae | 11.9 | – | 0.4 | 11.2 | 0.2 | 0.1 |
| Vermilion Rockfish | Scorpaenidae | 11.6 | – | 1.8 | 9.8 | – | – |
| Yellowchin Sculpin | Cottidae | 11.4 | 0.6 | 1.9 | 8.9 | – | – |
| Blacktip Poacher | Agonidae | 11.2 | – | – | 0.1 | 5.6 | 5.6 |
| Longnose Skate | Rajidae | 11.0 | – | 0.1 | – | 3.6 | 7.3 |
| Spotted Sand Bass | Serranidae | 10.8 | 10.8 | – | – | – | – |
| Bigmouth Sole | Paralichthyidae | 10.8 | – | 0.3 | 5.6 | 4.8 | 0.1 |

**Appendix B-13 (continued)**

| Common Name | Family | Biomass (kg) SCB | B/H | IS | MS | OS | US |
|---|---|---|---|---|---|---|---|
| Curlfin Sole | Pleuronectidae | 10.0 | 0.1 | 5.2 | 4.4 | 0.3 | – |
| Plainfin Midshipman | Batrachoididae | 8.5 | 0.5 | 0.2 | 5.4 | 2.5 | – |
| Black Eelpout | Zoarcidae | 7.9 | – | – | – | – | 7.9 |
| Queenfish | Sciaenidae | 7.3 | 7.2 | 0.1 | – | – | – |
| Shortbelly Rockfish | Scorpaenidae | 7.1 | – | 0.1 | 1.0 | 3.8 | 2.2 |
| Specklefin Midshipman | Batrachoididae | 7.1 | 5.8 | 0.3 | 1.0 | – | – |
| Rubynose Brotula | Bythitidae | 6.7 | – | – | – | – | 6.7 |
| Greenstriped Rockfish | Scorpaenidae | 6.6 | – | – | 0.9 | 1.6 | 4.2 |
| Filetail Cat Shark | Scyliorhinidae | 6.0 | – | – | – | – | 6.0 |
| Petrale Sole | Pleuronectidae | 6.0 | – | – | 0.7 | 3.4 | 1.9 |
| Lingcod | Hexagrammidae | 5.6 | – | 0.1 | 5.4 | 0.1 | – |
| Bearded Eelpout | Zoarcidae | 5.3 | – | – | 0.1 | 0.7 | 4.5 |
| Calico Rockfish | Scorpaenidae | 5.0 | – | 0.4 | 4.6 | – | – |
| Greenblotched Rockfish | Scorpaenidae | 4.9 | – | – | – | 4.7 | 0.3 |
| Spotted Cusk-eel | Ophidiidae | 4.9 | – | – | 0.6 | 2.7 | 1.6 |
| Barred Sand Bass | Serranidae | 4.9 | 3.9 | 1.0 | – | – | – |
| Shortspine Thornyhead | Scorpaenidae | 4.5 | – | – | – | – | 4.5 |
| Spotted Turbot | Pleuronectidae | 2.7 | 1.4 | 1.0 | 0.3 | – | – |
| Dogface Witch Eel | Nettastomatidae | 2.6 | – | – | – | – | 2.6 |
| unidentified pipefish | Syngnathidae | 2.6 | 0.4 | 1.8 | 0.2 | 0.1 | 0.1 |
| Pygmy Poacher | Agonidae | 2.5 | 0.1 | 0.4 | 2.0 | – | – |
| Gray Smoothhound | Triakidae | 2.5 | 2.5 | – | – | – | – |
| Shiner Perch | Embiotocidae | 2.4 | 0.4 | 0.2 | 1.7 | – | – |
| Diamond Turbot | Pleuronectidae | 2.2 | 2.2 | – | – | – | – |
| Blacktail Snailfish | Liparidae | 2.2 | – | – | – | 0.1 | 2.1 |
| Blackgill Rockfish | Scorpaenidae | 2.2 | – | – | – | 0.1 | 2.1 |
| California Butterfly Ray | Gymnuridae | 2.2 | 2.2 | – | – | – | – |
| Sarcastic Fringehead | Labrisomidae | 2.0 | 0.1 | 0.6 | 1.2 | – | – |
| Shovelnose Guitarfish | Rhinobatidae | 2.0 | 2.0 | – | – | – | – |
| Roughback Sculpin | Cottidae | 1.9 | – | 0.6 | 1.2 | 0.1 | – |
| California Grenadier | Macrouridae | 1.9 | – | – | – | – | 1.9 |
| Bigfin Eelpout | Zoarcidae | 1.7 | – | – | – | 0.5 | 1.2 |
| Pacific Pompano | Stromateidae | 1.7 | 0.3 | – | 1.4 | – | – |
| Hundred-fathom Codling | Moridae | 1.6 | – | – | – | 0.6 | 1.1 |
| Copper Rockfish | Scorpaenidae | 1.4 | 0.1 | 0.3 | 0.9 | – | – |

**Appendix B-13 (continued)**

| | | Biomass (kg) | | | | | |
|---|---|---|---|---|---|---|---|
| **Common Name** | **Family** | **SCB** | **B/H** | **IS** | **MS** | **OS** | **US** |
| Squarespot Rockfish | Scorpaenidae | 1.4 | – | – | 1.3 | 0.1 | – |
| Longspine Thornyhead | Scorpaenidae | 1.3 | – | – | – | – | 1.3 |
| Pacific Hagfish | Myxinidae | 1.3 | – | – | – | – | 1.3 |
| Pink Rockfish | Scorpaenidae | 1.3 | – | – | – | 1.1 | 0.2 |
| Cowcod | Scorpaenidae | 1.2 | – | – | – | 0.5 | 0.7 |
| Deepbody Anchovy | Engraulidae | 1.2 | 1.2 | – | – | – | – |
| Sandpaper Skate | Rajidae | 1.1 | – | – | – | – | 1.1 |
| Sargo | Haemulidae | 1.1 | 1.1 | – | – | – | – |
| Bigeye Poacher | Agonidae | 1.1 | – | – | – | 0.1 | 1.0 |
| Black Croaker | Sciaenidae | 1.0 | 1.0 | – | – | – | – |
| Yellowfin Croaker | Sciaenidae | 0.9 | 0.9 | – | – | – | – |
| Aurora Rockfish | Scorpaenidae | 0.9 | – | – | – | – | 0.9 |
| Gulf Sanddab | Paralichthyidae | 0.8 | – | – | 0.1 | 0.7 | 0.1 |
| Chilipepper | Scorpaenidae | 0.8 | – | – | 0.2 | 0.3 | 0.3 |
| Bluebarred Prickleback | Stichaeidae | 0.7 | – | – | – | 0.5 | 0.1 |
| Bluespotted Poacher | Agonidae | 0.6 | – | – | 0.5 | 0.2 | – |
| unidentified rockfish | Scorpaenidae | 0.6 | – | – | 0.1 | 0.2 | 0.3 |
| Cabezon | Cottidae | 0.6 | – | 0.5 | 0.1 | – | – |
| Pacific Staghorn Sculpin | Cottidae | 0.6 | – | 0.6 | – | – | – |
| Bocaccio | Scorpaenidae | 0.5 | – | – | 0.5 | – | – |
| Slough Anchovy | Engraulidae | 0.5 | 0.5 | – | – | – | – |
| Pacific Argentine | Argentinidae | 0.5 | – | – | – | 0.5 | 0.1 |
| C-O Sole | Pleuronectidae | 0.4 | – | 0.4 | – | – | – |
| Flag Rockfish | Scorpaenidae | 0.4 | – | – | 0.1 | 0.3 | – |
| Bay Goby | Gobiidae | 0.3 | – | 0.1 | 0.2 | – | – |
| Greenspotted Rockfish | Scorpaenidae | 0.3 | – | – | 0.2 | 0.1 | – |
| Brown Rockfish | Scorpaenidae | 0.3 | 0.2 | – | 0.1 | – | – |
| White Seabass | Sciaenidae | 0.3 | 0.3 | – | – | – | – |
| Rainbow Seaperch | Embiotocidae | 0.2 | – | 0.2 | – | – | – |
| Southern Spearnose Poacher | Agonidae | 0.2 | – | – | 0.2 | – | – |
| Darkblotched Rockfish | Scorpaenidae | 0.2 | – | – | 0.1 | 0.1 | 0.1 |
| Horn Shark | Heterodontidae | 0.2 | – | 0.2 | – | – | – |
| Blue Rockfish | Scorpaenidae | 0.2 | – | – | 0.2 | – | – |
| Pallid Eelpout | Zoarcidae | 0.2 | – | – | – | – | 0.2 |
| King-of-the-salmon | Trachipteridae | 0.2 | – | – | 0.1 | – | 0.1 |

**Appendix B-13 (continued)**

| Common Name | Family | Biomass (kg) | | | | | |
|---|---|---|---|---|---|---|---|
| | | SCB | B/H | IS | MS | OS | US |
| Northern Anchovy | Engraulidae | 0.1 | 0.1 | – | – | – | – |
| Onespot Fringehead | Labrisomidae | 0.1 | 0.1 | – | – | – | – |
| Kelp Bass | Serranidae | 0.1 | 0.1 | – | – | – | – |
| Giant Kelpfish | Clinidae | 0.1 | – | 0.1 | – | – | – |
| Bull Sculpin | Cottidae | 0.1 | – | – | 0.1 | – | – |
| Painted Greenling | Hexagrammidae | 0.1 | – | – | 0.1 | – | – |
| Bluebanded Ronquil | Bathymasteridae | 0.1 | – | – | 0.1 | – | – |
| White Seaperch | Embiotocidae | 0.1 | – | 0.1 | 0.1 | – | – |
| Mexican Rockfish | Scorpaenidae | 0.1 | – | – | – | 0.1 | – |
| Grass Rockfish | Scorpaenidae | 0.1 | – | – | 0.1 | – | – |
| Shadow Goby | Gobiidae | 0.1 | 0.1 | – | – | – | – |
| Kelp Perch | Embiotocidae | 0.1 | – | 0.1 | – | – | – |
| Pile Perch | Embiotocidae | 0.1 | – | 0.1 | – | – | – |
| Kelp Greenling | Hexagrammidae | 0.1 | – | 0.1 | – | – | – |
| Rubberlip Seaperch | Embiotocidae | 0.1 | – | 0.1 | – | – | – |
| Gopher Rockfish | Scorpaenidae | 0.1 | – | 0.1 | – | – | – |
| Pit-head Sculpin | Cottidae | 0.1 | – | – | 0.1 | – | – |
| Spotfin Sculpin | Cottidae | 0.1 | – | – | 0.1 | – | – |
| unidentified flatfish | unidentified | 0.1 | – | – | 0.1 | – | – |
| Basketweave Cusk-eel | Ophidiidae | 0.1 | – | – | – | 0.1 | – |
| Pacific Blackdragon | Phosichthyidae | 0.1 | – | – | – | – | 0.1 |
| Midwater Eelpout | Zoarcidae | 0.1 | – | – | – | – | 0.1 |
| Pinkrose Rockfish | Scorpaenidae | 0.1 | – | – | – | – | 0.1 |
| Northern Lampfish | Myctophidae | 0.1 | – | – | – | – | 0.1 |
| Black-belly Dragonfish | Phosichthyidae | 0.1 | – | – | – | – | 0.1 |

**Appendix B-14. Percent frequency of occurrence for all demersal fish species collected during the Bight '13 trawl survey. Shaded areas indicate species is one of the top ten most frequently occurring in that stratum. SCB=Southern California Bight, B/H = Bays and Harbors, IS = Inner Shelf, MS = Middle Shelf, OS = Outer Shelf, US = Upper Slope.**

| | | *Frequency of Occurence* | | | | | |
|---|---|---|---|---|---|---|---|
| **Common Name** | **Family** | **SCB** | **B/H** | **IS** | **MS** | **OS** | **US** |
| Dover Sole | Pleuronectidae | 60.7 | – | – | 40.1 | 96.3 | 89.7 |
| English Sole | Pleuronectidae | 52.5 | – | 61.9 | 92.6 | 71.9 | 24.2 |
| Pacific Sanddab | Paralichthyidae | 52.5 | – | 44.4 | 96.6 | 96.3 | 24.2 |
| Slender Sole | Pleuronectidae | 49.8 | – | – | 3.4 | 85.1 | 89.7 |
| California Lizardfish | Synodontidae | 47.2 | 55.8 | 96.4 | 92.3 | 49.5 | 3.4 |
| Pacific Hake | Merlucciidae | 37.3 | – | – | – | 38.3 | 72.6 |
| Hornyhead Turbot | Pleuronectidae | 37.3 | 10.6 | 77.4 | 81.7 | 26.1 | – |
| Longspine Combfish | Hexagrammidae | 32.1 | 13.2 | 30.5 | 86.0 | 22.4 | 3.4 |
| California Tonguefish | Cynoglossidae | 30.7 | 61.6 | 57.7 | 74.5 | – | – |
| Stripetail Rockfish | Scorpaenidae | 28.9 | – | 3.6 | 44.9 | 81.3 | 21.0 |
| Rex Sole | Pleuronectidae | 27.8 | – | – | – | 42.0 | 52.1 |
| Speckled Sanddab | Paralichthyidae | 26.2 | 34.3 | 96.4 | 35.8 | – | – |
| Yellowchin Sculpin | Cottidae | 25.9 | 10.6 | 30.5 | 75.3 | – | – |
| Shortspine Combfish | Hexagrammidae | 24.9 | – | – | 28.9 | 96.3 | 20.8 |
| Pink Seaperch | Embiotocidae | 24.2 | – | 14.6 | 70.5 | 11.2 | 3.4 |
| Dogface Witch Eel | Nettastomatidae | 22.9 | – | – | – | – | 48.2 |
| Blacktip Poacher | Agonidae | 22.8 | – | – | 0.5 | 61.7 | 38.1 |
| Bigmouth Sole | Paralichthyidae | 22.7 | – | 7.9 | 60.5 | 42.0 | 3.4 |
| Splitnose Rockfish | Scorpaenidae | 22.6 | – | – | – | 39.3 | 41.6 |
| Bearded Eelpout | Zoarcidae | 20.5 | – | – | 0.5 | 30.8 | 38.1 |
| Curlfin Sole | Pleuronectidae | 20.3 | 2.6 | 52.9 | 39.0 | 11.2 | – |
| Blacktail Snailfish | Liparidae | 19.8 | – | – | – | 3.7 | 41.1 |
| Pygmy Poacher | Agonidae | 18.8 | 2.6 | 11.7 | 61.3 | – | – |
| Spotted Cusk-eel | Ophidiidae | 18.6 | – | – | 24.3 | 49.5 | 17.4 |
| Longfin Sanddab | Paralichthyidae | 18.2 | – | 25.7 | 50.9 | – | – |
| Plainfin Midshipman | Batrachoididae | 17.9 | 7.9 | 7.5 | 55.3 | 18.7 | – |
| Shortspine Thornyhead | Scorpaenidae | 16.5 | – | – | – | – | 34.7 |
| Filetail Cat Shark | Scyliorhinidae | 16.3 | – | – | – | – | 34.2 |

**Appendix B-14 (continued)**

| Common Name | Family | *Frequency of Occurence* | | | | | |
|---|---|---|---|---|---|---|---|
| | | **SCB** | **B/H** | **IS** | **MS** | **OS** | **US** |
| Blackbelly Eelpout | Zoarcidae | 16.0 | – | 3.6 | 12.6 | 72.9 | 13.9 |
| California Skate | Rajidae | 14.9 | 13.2 | 21.3 | 36.9 | 14.9 | – |
| Halfbanded Rockfish | Scorpaenidae | 14.0 | – | – | 27.6 | 43.0 | 6.8 |
| Vermilion Rockfish | Scorpaenidae | 13.8 | – | 40.4 | 26.0 | – | – |
| Longnose Skate | Rajidae | 13.8 | – | 3.6 | – | 23.4 | 24.2 |
| Calico Rockfish | Scorpaenidae | 12.8 | – | 4.8 | 43.5 | – | – |
| Roughback Sculpin | Cottidae | 12.7 | – | 22.4 | 31.6 | 3.7 | – |
| Sablefish | Anoplopomatidae | 12.4 | – | – | – | 12.2 | 24.2 |
| unidentified pipefish | Syngnathidae | 12.0 | 7.9 | 52.9 | 10.1 | 3.7 | 0.2 |
| Fantail Sole | Paralichthyidae | 11.8 | 26.5 | 61.7 | 4.6 | – | – |
| Bigeye Poacher | Agonidae | 11.8 | – | – | – | 3.7 | 24.2 |
| Lingcod | Hexagrammidae | 11.8 | – | 0.6 | 40.4 | 7.5 | – |
| Rubynose Brotula | Bythitidae | 11.4 | – | – | – | – | 24.0 |
| Aurora Rockfish | Scorpaenidae | 11.4 | – | – | – | – | 24.0 |
| Greenstriped Rockfish | Scorpaenidae | 11.0 | – | – | 7.2 | 33.6 | 13.7 |
| California Scorpionfish | Scorpaenidae | 10.9 | 2.6 | 7.9 | 34.7 | – | – |
| Bigfin Eelpout | Zoarcidae | 10.7 | – | – | – | 11.2 | 20.8 |
| Hundred-fathom Codling | Moridae | 9.8 | – | – | – | 19.6 | 17.6 |
| Sarcastic Fringehead | Labrisomidae | 9.6 | 2.6 | 25.9 | 19.2 | – | – |
| Shortbelly Rockfish | Scorpaenidae | 8.8 | – | 3.6 | 3.8 | 8.4 | 13.7 |
| Black Eelpout | Zoarcidae | 8.2 | – | – | – | – | 17.4 |
| California Grenadier | Macrouridae | 8.2 | – | – | – | – | 17.4 |
| Pacific Hagfish | Myxinidae | 8.1 | – | – | – | – | 17.1 |
| Petrale Sole | Pleuronectidae | 7.2 | – | – | 3.4 | 18.7 | 10.3 |
| California Halibut | Paralichthyidae | 6.8 | 73.1 | 30.7 | 3.4 | – | – |
| unidentified rockfish | Scorpaenidae | 6.8 | – | – | 3.5 | 11.2 | 10.5 |
| Blackgill Rockfish | Scorpaenidae | 5.2 | – | – | – | 3.7 | 10.3 |
| Specklefin Midshipman | Batrachoididae | 5.1 | 43.0 | 11.3 | 10.1 | – | – |
| Bluebarred Prickleback | Stichaeidae | 5.0 | – | – | – | 23.4 | 6.8 |
| Greenblotched Rockfish | Scorpaenidae | 4.4 | – | – | – | 15.9 | 6.8 |
| Cabezon | Cottidae | 4.4 | – | 15.3 | 6.8 | – | – |
| Pink Rockfish | Scorpaenidae | 3.9 | – | – | – | 29.9 | 3.7 |
| Copper Rockfish | Scorpaenidae | 3.8 | 2.6 | 10.7 | 7.4 | – | – |
| Chilipepper | Scorpaenidae | 3.7 | – | – | 3.4 | 14.9 | 3.4 |
| Longspine Thornyhead | Scorpaenidae | 3.4 | – | – | – | – | 7.1 |
| Shiner Perch | Embiotocidae | 3.3 | 16.8 | 7.5 | 6.9 | – | – |
| Sandpaper Skate | Rajidae | 3.3 | – | – | – | – | 6.8 |
| Pallid Eelpout | Zoarcidae | 3.3 | – | – | – | – | 6.8 |
| Gulf Sanddab | Paralichthyidae | 3.1 | – | – | 3.4 | 7.5 | 3.4 |
| Pacific Argentine | Argentinidae | 3.1 | – | – | – | 19.6 | 3.4 |

**Appendix B-14 (continued)**

| Common Name | Family | Frequency of Occurence SCB | B/H | IS | MS | OS | US |
|---|---|---|---|---|---|---|---|
| Spotted Turbot | Pleuronectidae | 2.9 | 21.5 | 10.7 | 3.4 | – | – |
| Cowcod | Scorpaenidae | 2.8 | – | – | – | 15.9 | 3.4 |
| Darkblotched Rockfish | Scorpaenidae | 2.6 | – | – | 3.4 | 1.0 | 3.4 |
| Bay Goby | Gobiidae | 2.6 | – | 3.6 | 7.2 | – | – |
| King-of-the-salmon | Trachipteridae | 2.6 | – | – | 3.4 | – | 3.4 |
| Pacific Staghorn Sculpin | Cottidae | 2.4 | – | 14.6 | – | – | – |
| White Croaker | Sciaenidae | 2.3 | 34.3 | 0.4 | 6.8 | – | – |
| Flag Rockfish | Scorpaenidae | 2.0 | – | – | 3.4 | 14.9 | – |
| Southern Spearnose Poacher | Agonidae | 2.0 | – | – | 7.2 | – | – |
| Pacific Pompano | Stromateidae | 1.9 | 5.3 | – | 6.8 | – | – |
| Bluebanded Ronquil | Bathymasteridae | 1.9 | – | – | 6.8 | – | – |
| Bluespotted Poacher | Agonidae | 1.7 | – | – | 4.3 | 7.5 | – |
| Pacific Blackdragon | Phosichthyidae | 1.6 | – | – | – | – | 3.4 |
| Midwater Eelpout | Zoarcidae | 1.6 | – | – | – | – | 3.4 |
| Pinkrose Rockfish | Scorpaenidae | 1.6 | – | – | – | – | 3.4 |
| White Seaperch | Embiotocidae | 1.5 | – | 3.6 | 3.4 | – | – |
| Greenspotted Rockfish | Scorpaenidae | 1.3 | – | – | 3.8 | 3.7 | – |
| Rainbow Seaperch | Embiotocidae | 1.3 | – | 7.8 | – | – | – |
| Squarespot Rockfish | Scorpaenidae | 1.2 | – | – | 3.4 | 3.7 | – |
| Bat Ray | Myliobatidae | 1.1 | 16.6 | – | 3.4 | – | – |
| Bull Sculpin | Cottidae | 1.1 | – | – | 3.8 | – | – |
| Painted Greenling | Hexagrammidae | 1.1 | – | – | 3.8 | – | – |
| Bocaccio | Scorpaenidae | 1.0 | – | – | 3.5 | – | – |
| Brown Rockfish | Scorpaenidae | 1.0 | 2.6 | – | 3.4 | – | – |
| Pit-head Sculpin | Cottidae | 0.9 | – | – | 3.4 | – | – |
| Blue Rockfish | Scorpaenidae | 0.9 | – | – | 3.4 | – | – |
| Grass Rockfish | Scorpaenidae | 0.9 | – | – | 3.4 | – | – |
| Barred Sand Bass | Serranidae | 0.9 | 58.6 | 1.4 | – | – | – |
| Pacific Electric Ray | Torpedinidae | 0.8 | – | – | 0.9 | 7.5 | – |
| Giant Kelpfish | Clinidae | 0.7 | – | 4.2 | – | – | – |
| Round Stingray | Urotrygonidae | 0.6 | 54.6 | – | – | – | – |
| Kelp Perch | Embiotocidae | 0.6 | – | 3.6 | – | – | – |
| Pile Perch | Embiotocidae | 0.6 | – | 3.6 | – | – | – |
| Horn Shark | Heterodontidae | 0.6 | – | 3.6 | – | – | – |
| Kelp Greenling | Hexagrammidae | 0.6 | – | 3.6 | – | – | – |

**Appendix B-14 (continued)**

| Common Name | Family | *Frequency of Occurence* SCB | B/H | IS | MS | OS | US |
|---|---|---|---|---|---|---|---|
| C-O Sole | Pleuronectidae | 0.6 | – | 3.6 | – | – | – |
| Gopher Rockfish | Scorpaenidae | 0.6 | – | 3.6 | – | – | – |
| Spotted Sand Bass | Serranidae | 0.5 | 45.0 | – | – | – | – |
| Queenfish | Sciaenidae | 0.4 | 33.1 | 0.4 | – | – | – |
| Deepbody Anchovy | Engraulidae | 0.4 | 38.5 | – | – | – | – |
| Slough Anchovy | Engraulidae | 0.4 | 38.5 | – | – | – | – |
| Gray Smoothhound | Triakidae | 0.4 | 37.8 | – | – | – | – |
| Mexican Rockfish | Scorpaenidae | 0.3 | – | – | – | 4.7 | – |
| Basketweave Cusk-eel | Ophidiidae | 0.3 | – | – | – | 3.7 | – |
| Diamond Turbot | Pleuronectidae | 0.3 | 24.6 | – | – | – | – |
| Black Croaker | Sciaenidae | 0.2 | 22.3 | – | – | – | – |
| Yellowfin Croaker | Sciaenidae | 0.2 | 20.9 | – | – | – | – |
| California Butterfly Ray | Gymnuridae | 0.2 | 20.5 | – | – | – | – |
| Spotfin Sculpin | Cottidae | 0.1 | – | – | 0.5 | – | – |
| White Seabass | Sciaenidae | 0.1 | 10.8 | – | – | – | – |
| Northern Lampfish | Myctophidae | 0.1 | – | – | – | – | 0.2 |
| Black-belly Dragonfish | Phosichthyidae | 0.1 | – | – | – | – | 0.2 |
| Shadow Goby | Gobiidae | 0.1 | 9.7 | – | – | – | – |
| Rubberlip Seaperch | Embiotocidae | 0.1 | – | 0.6 | – | – | – |
| Sargo | Haemulidae | 0.1 | 5.8 | – | – | – | – |
| Shovelnose Guitarfish | Rhinobatidae | 0.1 | 5.4 | – | – | – | – |
| unidentified flatfish | unidentified | < 0.1 | – | – | 0.2 | – | – |
| Northern Anchovy | Engraulidae | < 0.1 | 2.6 | – | – | – | – |
| Onespot Fringehead | Labrisomidae | < 0.1 | 2.6 | – | – | – | – |
| Kelp Bass | Serranidae | < 0.1 | 2.6 | – | – | – | – |

**Appendix B-15. Total biomass (kg) for all megabenthic invertebrate species collected during the Bight '13 trawl survey. Shaded areas indicate species ranked within the top ten species for biomass in that stratum. SCB=Southern California Bight, B/H = Bays and Harbors, IS = Inner Shelf, MS = Middle Shelf, OS = Outer Shelf, US = Upper Slope.**

| | | *Biomass (kg)* | | | | | |
|---|---|---|---|---|---|---|---|
| **Scientific Name** | **Phylum:Family** | **SCB** | **B/H** | **IS** | **MS** | **OS** | **US** |
| *Strongylocentrotus fragilis* | Echinodermata:Strongylocentrotidae | 916.0 | – | – | – | 419.8 | 496.1 |
| *Brisaster townsendi* | Echinodermata:Schizasteridae | 507.9 | – | – | – | 4.3 | 503.6 |
| *Brissopsis pacifica* | Echinodermata:Brissidae | 206.9 | – | – | – | 12.3 | 194.6 |
| *Parastichopus californicus* | Echinodermata:Stichopodidae | 158.3 | – | 1.4 | 127.2 | 29.4 | 0.3 |
| *Pandalus platyceros* | Arthropoda:Pandalidae | 83.7 | – | < 0.1 | 0.1 | 22.3 | 61.3 |
| *Spatangus californicus* | Echinodermata:Spatangidae | 71.5 | – | – | < 0.1 | 36.4 | 35.1 |
| *Luidia foliolata* | Echinodermata:Luidiidae | 62.7 | – | 0.1 | 12.1 | 18.6 | 31.9 |
| *Myxoderma platyacanthum* | Echinodermata:Zoroasteridae | 62.6 | – | – | – | – | 62.6 |
| *Brisaster sp* | Echinodermata:Schizasteridae | 51.6 | – | – | – | 17.0 | 34.7 |
| *Lopholithodes foraminatus* | Arthropoda:Lithodidae | 50.1 | – | – | – | 49.8 | 0.3 |
| *Pandalus jordani* | Arthropoda:Pandalidae | 41.7 | – | – | – | 41.7 | – |
| *Pleurobranchaea californica* | Mollusca:Pleurobranchidae | 38.2 | – | 0.2 | 10.5 | 21.4 | 6.1 |
| *Sicyonia penicillata* | Arthropoda:Sicyoniidae | 38.1 | 25.8 | 1.2 | 11.2 | – | – |
| *Sicyonia ingentis* | Arthropoda:Sicyoniidae | 36.2 | 4.7 | 0.1 | 14.1 | 16.4 | 1.0 |
| *Suberites latus* | Silicea:Suberitidae | 34.1 | 9.2 | – | – | 0.2 | 24.7 |
| *Ophiura luetkenii* | Echinodermata:Ophiuridae | 31.9 | – | < 0.1 | 31.5 | 0.3 | < 0.1 |
| *Asteronyx longifissus* | Echinodermata:Asteronychidae | 28.9 | – | – | – | – | 28.9 |
| *Pannychia moseleyi* | Echinodermata:Laetmogonidae | 28.5 | – | – | – | – | 28.5 |
| *Brisaster latifrons* | Echinodermata:Schizasteridae | 28.2 | – | – | – | 21.2 | 7.0 |
| *Dromalia alexandri* | Cnidaria:Rhodaliidae | 20.9 | – | – | – | 0.9 | 20.0 |
| *Rathbunaster californicus* | Echinodermata:Asteriidae | 20.2 | – | – | – | – | 20.2 |
| *Metacarcinus gracilis* | Arthropoda:Cancridae | 19.7 | 1.7 | 15.5 | 2.6 | – | – |
| *Metridium farcimen* | Cnidaria:Metridiidae | 18.5 | – | – | 0.3 | 17.6 | 0.6 |
| *Lytechinus pictus* | Echinodermata:Toxopneustidae | 18.3 | – | 0.4 | 17.4 | 0.4 | – |
| *Octopus californicus* | Mollusca:Octopodidae | 16.9 | – | – | 0.1 | 7.0 | 9.8 |

**Appendix B-15 (continued)**

| Scientific Name | Phylum:Family | *Biomass (kg)* | | | | | |
|---|---|---|---|---|---|---|---|
| | | SCB | B/H | IS | MS | OS | US |
| *Pisaster brevispinus* | Echinodermata:Asteriidae | 15.4 | – | 15.4 | < 0.1 | – | – |
| *Loxorhynchus grandis* | Arthropoda:Epialtidae | 12.7 | 0.4 | 2.3 | 10.0 | – | – |
| *Octopus rubescens* | Mollusca:Octopodidae | 11.9 | 0.4 | 3.6 | 4.1 | 3.3 | 0.5 |
| *Paralithodes californiensis* | Arthropoda:Lithodidae | 9.2 | – | – | – | 5.5 | 3.6 |
| *Gorgonocephalus eucnemis* | Echinodermata:Gorgonocephalidae | 8.8 | – | – | – | 8.8 | < 0.1 |
| *Ceramaster leptoceramus* | Echinodermata:Goniasteridae | 6.9 | – | – | – | – | 6.9 |
| *Astropecten californicus* | Echinodermata:Astropectinidae | 6.0 | – | 4.2 | 1.6 | 0.1 | < 0.1 |
| *Actinostola sp* | Cnidaria:Actinostolidae | 4.9 | – | – | – | – | 4.9 |
| *Platymera gaudichaudii* | Arthropoda:Calappidae | 4.7 | – | – | 1.8 | 2.9 | – |
| *Tetilla sp* | Silicea:Tetillidae | 3.9 | 3.9 | – | – | – | – |
| *Crangon nigromaculata* | Arthropoda:Crangonidae | 3.8 | 0.7 | 3.0 | 0.1 | – | – |
| *Astropecten ornatissimus* | Echinodermata:Astropectinidae | 3.7 | – | – | – | 3.7 | – |
| *Glyptolithodes cristatipes* | Arthropoda:Lithodidae | 3.6 | – | – | – | – | 3.6 |
| *Parastichopus sp A* | Echinodermata:Stichopodidae | 3.5 | – | – | – | 2.6 | 0.9 |
| *Cancer productus* | Arthropoda:Cancridae | 3.2 | – | 0.5 | 1.7 | 1.0 | – |
| *Spirontocaris holmesi* | Arthropoda:Hippolytidae | 2.8 | – | – | – | 0.8 | 2.1 |
| *Stylasterias forreri* | Echinodermata:Asteriidae | 2.5 | – | – | < 0.1 | 1.2 | 1.3 |
| *Metacarcinus anthonyi* | Arthropoda:Cancridae | 2.5 | – | < 0.1 | 0.3 | 2.2 | – |
| *Muricea californica* | Cnidaria:Plexauridae | 2.1 | 1.0 | 1.1 | – | – | – |
| *Luidia armata* | Echinodermata:Luidiidae | 1.8 | – | 0.1 | 1.7 | – | – |
| *Ptilosarcus gurneyi* | Cnidaria:Pennatulidae | 1.6 | – | – | – | 0.5 | 1.1 |
| *Neocrangon zacae* | Arthropoda:Crangonidae | 1.5 | – | – | 0.1 | 1.2 | 0.2 |
| *Pseudarchaster pusillus* | Echinodermata:Goniasteridae | 1.5 | – | – | – | – | 1.5 |

**Appendix B-15 (continued)**

| Scientific Name | Phylum:Family | Biomass (kg) | | | | | |
|---|---|---|---|---|---|---|---|
| | | SCB | B/H | IS | MS | OS | US |
| *Calinaticina oldroydii* | Mollusca:Naticidae | 1.4 | – | – | – | 0.4 | 1.0 |
| *Euspira lewisii* | Mollusca:Naticidae | 1.4 | – | 1.2 | – | 0.2 | – |
| *Astyris permodesta* | Mollusca:Columbellidae | 1.3 | – | – | – | – | 1.3 |
| *Ophiothrix spiculata* | Echinodermata:Ophiotricidae | 1.3 | 0.2 | 0.3 | 0.8 | 0.1 | < 0.1 |
| *Acanthoptilum sp* | Cnidaria:Virgulariidae | 1.2 | 0.1 | 0.1 | 0.3 | 0.8 | – |
| *Kelletia kelletii* | Mollusca:Buccinidae | 1.2 | 0.8 | 0.3 | 0.2 | – | – |
| *Spirontocaris sica* | Arthropoda:Hippolytidae | 1.1 | – | – | – | < 0.1 | 1.1 |
| *Pyromaia tuberculata* | Arthropoda:Inachoididae | 1.1 | 0.7 | 0.3 | 0.1 | – | – |
| *Eugorgia rubens* | Cnidaria:Gorgoniidae | 1.1 | – | – | 1.1 | – | – |
| *Astropecten armatus* | Echinodermata:Astropectinidae | 1.1 | 0.6 | 0.4 | – | – | – |
| *Paralithodes rathbuni* | Arthropoda:Lithodidae | 1.0 | – | – | – | – | 1.0 |
| *Aplysia californica* | Mollusca:Aplysiidae | 0.9 | – | 0.6 | 0.2 | – | – |
| *Rossia pacifica* | Mollusca:Sepiolidae | 0.9 | – | – | – | 0.9 | < 0.1 |
| *Staurocalyptus dowlingi* | Silicea:Rossellidae | 0.8 | – | – | – | – | 0.8 |
| *Thesea sp B* | Cnidaria:Plexauridae | 0.8 | – | < 0.1 | 0.6 | 0.2 | – |
| *Acanthodoris brunnea* | Mollusca:Onchidorididae | 0.8 | 0.1 | 0.1 | 0.4 | 0.2 | < 0.1 |
| *Liponema brevicorne* | Cnidaria:Liponematidae | 0.7 | – | – | – | – | 0.7 |
| *Hormathia digitata* | Cnidaria:Hormathiidae | 0.6 | – | – | – | – | 0.6 |
| *Tritonia tetraquetra* | Mollusca:Tritoniidae | 0.6 | 0.1 | – | 0.4 | – | – |
| *Portunus xantusii* | Arthropoda:Portunidae | 0.6 | 0.4 | 0.3 | – | – | – |
| *Hamatoscalpellum californicum* | Arthropoda:Scalpellidae | 0.6 | – | 0.2 | 0.4 | < 0.1 | – |
| *Neocrangon resima* | Arthropoda:Crangonidae | 0.6 | – | – | 0.1 | 0.5 | < 0.1 |
| *Chloeia pinnata* | Annelida:Amphinomidae | 0.5 | – | – | – | – | 0.5 |
| *Munida quadrispina* | Arthropoda:Munididae | 0.5 | – | – | – | – | 0.5 |
| *Stephanauge sp* | Cnidaria:Hormathiidae | 0.5 | – | – | – | – | 0.5 |

**Appendix B-15 (continued)**

| Scientific Name | Phylum:Family | Biomass (kg) | | | | | |
|---|---|---|---|---|---|---|---|
| | | SCB | B/H | IS | MS | OS | US |
| *Luidia asthenosoma* | Echinodermata:Luidiidae | 0.5 | – | – | 0.4 | 0.2 | – |
| *Farfantepenaeus californiensis* | Arthropoda:Penaeidae | 0.5 | 0.3 | 0.2 | – | – | – |
| *Parastichopus parvimensis* | Echinodermata:Stichopodidae | 0.5 | 0.5 | – | < 0.1 | – | – |
| *Stylatula elongata* | Cnidaria:Virgulariidae | 0.5 | 0.1 | 0.1 | 0.3 | < 0.1 | – |
| *Munida hispida* | Arthropoda:Munididae | 0.4 | – | – | – | – | 0.4 |
| *Thrissacanthias penicillatus* | Echinodermata:Astropectinidae | 0.4 | – | – | – | < 0.1 | 0.4 |
| *Randallia ornata* | Arthropoda:Leucosiidae | 0.4 | – | 0.4 | – | – | – |
| *Pisaster ochraceus* | Echinodermata:Asteriidae | 0.4 | 0.4 | – | – | – | – |
| *Florometra serratissima* | Echinodermata:Antedonidae | 0.4 | – | – | < 0.1 | 0.3 | < 0.1 |
| *Metacrangon spinosissima* | Arthropoda:Crangonidae | 0.4 | – | – | 0.1 | 0.4 | < 0.1 |
| *Doryteuthis opalescens* | Mollusca:Loliginidae | 0.4 | – | – | – | 0.4 | < 0.1 |
| *Philine auriformis* | Mollusca:Philinidae | 0.4 | 0.2 | 0.1 | 0.1 | – | < 0.1 |
| *Aphrodita castanea* | Annelida:Aphroditidae | 0.3 | – | – | < 0.1 | 0.2 | 0.1 |
| *Paguristes turgidus* | Arthropoda:Diogenidae | 0.3 | – | – | – | – | 0.3 |
| *Munida tenella* | Arthropoda:Munididae | 0.3 | – | – | – | 0.3 | – |
| *Dendronotus iris* | Mollusca:Dendronotidae | 0.3 | 0.3 | – | – | – | – |
| *Dragmacidon sp* | Silicea:Axinellidae | 0.3 | 0.3 | – | – | – | – |
| *Heptacarpus stimpsoni* | Arthropoda:Hippolytidae | 0.3 | 0.2 | – | < 0.1 | – | – |
| *Antiplanes thalea* | Mollusca:Pseudomelatomidae | 0.2 | – | – | – | 0.1 | 0.1 |
| *Spirontocaris sp* | Arthropoda:Hippolytidae | 0.2 | – | – | – | 0.1 | 0.1 |
| *Hinea insculpta* | Mollusca:Nassariidae | 0.2 | – | – | < 0.1 | 0.1 | 0.1 |
| *Aphrodita japonica* | Annelida:Aphroditidae | 0.2 | – | – | < 0.1 | < 0.1 | 0.1 |
| *Luidia sp* | Echinodermata:Luidiidae | 0.2 | – | < 0.1 | 0.1 | 0.1 | – |
| *Antiplanes catalinae* | Mollusca:Pseudomelatomidae | 0.2 | – | – | – | 0.2 | – |
| *Latulambrus occidentalis* | Arthropoda:Parthenopidae | 0.2 | – | 0.1 | 0.1 | – | – |

**Appendix B-15 (continued)**

| Scientific Name | Phylum:Family | Biomass (kg) | | | | | |
|---|---|---|---|---|---|---|---|
| | | SCB | B/H | IS | MS | OS | US |
| *Podochela lobifrons* | Arthropoda:Inachidae | 0.2 | – | 0.1 | 0.1 | – | – |
| *Strongylocentrotus franciscanus* | Echinodermata:Strongylocentrotidae | 0.2 | 0.1 | – | 0.1 | – | – |
| *Halichondria bowerbanki* | Silicea:Halichondriidae | 0.2 | 0.2 | – | – | – | – |
| *Heptacarpus palpator* | Arthropoda:Hippolytidae | 0.2 | 0.2 | – | – | – | – |
| *Panulirus interruptus* | Arthropoda:Palinuridae | 0.2 | 0.2 | – | – | – | – |
| *Musculista senhousia* | Mollusca:Mytilidae | 0.2 | 0.2 | – | – | – | – |
| *Renilla koellikeri* | Cnidaria:Renillidae | 0.2 | – | 0.1 | < 0.1 | – | – |
| *Armina californica* | Mollusca:Arminidae | 0.2 | 0.1 | < 0.1 | 0.1 | < 0.1 | – |
| *Megasurcula carpenteriana* | Mollusca:Pseudomelatomidae | 0.2 | – | – | 0.1 | 0.1 | < 0.1 |
| *Cancellaria crawfordiana* | Mollusca:Cancellariidae | 0.2 | – | – | 0.1 | 0.1 | < 0.1 |
| *Neocrangon sp* | Arthropoda:Crangonidae | 0.2 | – | – | – | 0.1 | < 0.1 |
| *Paguristes bakeri* | Arthropoda:Diogenidae | 0.2 | – | < 0.1 | < 0.1 | 0.1 | < 0.1 |
| *Ophiopholis bakeri* | Echinodermata:Ophiactidae | 0.2 | – | – | < 0.1 | 0.2 | < 0.1 |
| *Nymphon pixellae* | Arthropoda:Nymphonidae | 0.2 | – | – | 0.1 | < 0.1 | < 0.1 |
| *Opisthoteuthis sp A* | Mollusca:Opisthoteuthidae | 0.1 | – | – | – | – | 0.1 |
| *Pennatula californica* | Cnidaria:Pennatulidae | 0.1 | – | – | – | – | 0.1 |
| *Hippasteria spinosa* | Echinodermata:Goniasteridae | 0.1 | – | – | – | – | 0.1 |
| *Synallactes virgulisolida* | Echinodermata:Synallactidae | 0.1 | – | – | – | – | 0.1 |
| *Chorilia longipes* | Arthropoda:Epialtidae | 0.1 | – | – | – | – | 0.1 |
| *Halipteris californica* | Cnidaria:Halipteridae | 0.1 | – | – | – | – | 0.1 |
| *Munididae* | Arthropoda:Munididae | 0.1 | – | – | – | – | 0.1 |
| *Ophiosphalma jolliense* | Echinodermata:Ophiuridae | 0.1 | – | – | – | – | 0.1 |
| *Poraniopsis inflata* | Echinodermata:Poraniidae | 0.1 | – | – | – | 0.1 | – |
| *Amphiuridae* | Echinodermata:Amphiuridae | 0.1 | – | – | – | 0.1 | – |
| *Simnia barbarensis* | Mollusca:Ovulidae | 0.1 | – | – | – | 0.1 | – |
| *Amphichondrius granulatus* | Echinodermata:Amphiuridae | 0.1 | – | – | < 0.1 | 0.1 | – |
| *Ericerodes hemphillii* | Arthropoda:Inachidae | 0.1 | – | 0.1 | 0.1 | – | – |
| *Hemisquilla californiensis* | Arthropoda:Hemisquillidae | 0.1 | – | – | 0.1 | – | – |

**Appendix B-15 (continued)**

| Scientific Name | Phylum:Family | Biomass (kg) | | | | | |
|---|---|---|---|---|---|---|---|
| | | SCB | B/H | IS | MS | OS | US |
| Asteroidea | Echinodermata:Class Asteroidea | 0.1 | – | – | 0.1 | – | – |
| *Calliostoma turbinum* | Mollusca:Calliostomatidae | 0.1 | – | – | 0.1 | – | – |
| *Pagurus armatus* | Arthropoda:Paguridae | 0.1 | – | – | 0.1 | – | – |
| *Styela gibbsii* | Chordata:Styelidae | 0.1 | – | – | 0.1 | – | – |
| *Virgularia agassizii* | Cnidaria:Virgulariidae | 0.1 | – | – | 0.1 | – | – |
| *Flabellina iodinea* | Mollusca:Flabellinidae | 0.1 | – | < 0.1 | 0.1 | – | – |
| *Phimochirus californiensis* | Arthropoda:Paguridae | 0.1 | – | 0.1 | – | – | – |
| *Lophopanopeus frontalis* | Arthropoda:Panopeidae | 0.1 | 0.1 | – | – | – | – |
| *Navanax inermis* | Mollusca:Aglajidae | 0.1 | 0.1 | – | – | – | – |
| *Janolus barbarensis* | Mollusca:Zephyrinidae | 0.1 | 0.1 | – | – | – | – |
| *Ostrea lurida* | Mollusca:Ostreidae | 0.1 | 0.1 | – | – | – | – |
| *Arcularia tiarula* | Mollusca:Nassariidae | 0.1 | 0.1 | – | – | – | – |
| *Corambe pacifica* | Mollusca:Onchidorididae | 0.1 | 0.1 | – | – | – | – |
| *Crangon nigricauda* | Arthropoda:Crangonidae | 0.1 | 0.1 | – | – | – | – |
| *Polycera hedgpethi* | Mollusca:Polyceridae | 0.1 | 0.1 | – | – | – | – |
| *Pycnopodia helianthoides* | Echinodermata:Asteriidae | 0.1 | 0.1 | – | – | – | – |
| *Sicyonia sp* | Arthropoda:Sicyoniidae | 0.1 | 0.1 | – | – | – | – |
| *Spirontocaris prionota* | Arthropoda:Hippolytidae | 0.1 | 0.1 | – | – | – | – |
| *Astropecten sp* | Echinodermata:Astropectinidae | 0.1 | – | 0.1 | < 0.1 | – | – |
| *Loxorhynchus crispatus* | Arthropoda:Epialtidae | 0.1 | – | 0.1 | < 0.1 | – | – |
| *Heptacarpus brevirostris* | Arthropoda:Hippolytidae | 0.1 | 0.1 | – | < 0.1 | – | – |
| *Strongylocentrotus sp* | Echinodermata:Strongylocentrotidae | 0.1 | 0.1 | – | < 0.1 | – | – |
| *Diaulula sandiegensis* | Mollusca:Discodorididae | 0.1 | < 0.1 | – | < 0.1 | – | – |
| *Cancridae* | Arthropoda:Cancridae | 0.1 | 0.1 | < 0.1 | < 0.1 | – | – |
| *Conus californicus* | Mollusca:Conidae | 0.1 | 0.1 | < 0.1 | < 0.1 | – | – |
| *Triopha maculata* | Mollusca:Polyceridae | 0.1 | 0.1 | < 0.1 | < 0.1 | – | – |
| *Virgularia californica* | Cnidaria:Virgulariidae | 0.1 | 0.1 | < 0.1 | < 0.1 | – | – |

**Appendix B-15 (continued)**

| Scientific Name | Phylum:Family | Biomass (kg) | | | | | |
|---|---|---|---|---|---|---|---|
| | | SCB | B/H | IS | MS | OS | US |
| *Amphiura arcystata* | Echinodermata:Amphiuridae | 0.1 | – | < 0.1 | < 0.1 | – | – |
| *Sclerasterias heteropaes* | Echinodermata:Asteriidae | 0.1 | – | < 0.1 | < 0.1 | – | – |
| *Boreotrophon bentleyi* | Mollusca:Muricidae | 0.1 | – | – | – | 0.1 | < 0.1 |
| *Pentamera pseudocalcigera* | Echinodermata:Phyllophoridae | 0.1 | – | – | – | 0.1 | < 0.1 |
| *Crossata ventricosa* | Mollusca:Bursidae | 0.1 | – | – | 0.1 | – | < 0.1 |
| *Neptunea tabulata* | Mollusca:Buccinidae | 0.1 | – | – | – | < 0.1 | < 0.1 |
| *Odontaster crassus* | Echinodermata:Odontasteridae | 0.1 | – | – | – | < 0.1 | < 0.1 |
| *Anoplodactylus erectus* | Arthropoda:Phoxichilidiidae | < 0.1 | < 0.1 | – | – | – | – |
| *Bulla gouldiana* | Mollusca:Bullidae | < 0.1 | < 0.1 | – | – | – | – |
| *Epiactis prolifera* | Cnidaria:Actiniidae | < 0.1 | < 0.1 | – | – | – | – |
| *Haliclona sp* | Silicea:Chalinidae | < 0.1 | < 0.1 | – | – | – | – |
| *Harmothoe sp* | Annelida:Polynoidae | < 0.1 | < 0.1 | – | – | – | – |
| *Hippolyte californiensis* | Arthropoda:Hippolytidae | < 0.1 | < 0.1 | – | – | – | – |
| *Ophiocnida hispida* | Echinodermata:Amphiuridae | < 0.1 | < 0.1 | – | – | – | – |
| *Aeolidiella chromosoma* | Mollusca:Aeolidiidae | < 0.1 | – | < 0.1 | – | – | – |
| *Calliostoma canaliculatum* | Mollusca:Calliostomatidae | < 0.1 | – | < 0.1 | – | – | – |
| *Calliostoma tricolor* | Mollusca:Calliostomatidae | < 0.1 | – | < 0.1 | – | – | – |
| *Crassispira semiinflata* | Mollusca:Pseudomelatomidae | < 0.1 | – | < 0.1 | – | – | – |
| *Dendraster terminalis* | Echinodermata:Dendrasteridae | < 0.1 | – | < 0.1 | – | – | – |
| *Glossaulax reclusianus* | Mollusca:Naticidae | < 0.1 | – | < 0.1 | – | – | – |
| *Halichondria panicea* | Silicea:Halichondriidae | < 0.1 | – | < 0.1 | – | – | – |

**Appendix B-15 (continued)**

| Scientific Name | Phylum:Family | Biomass (kg) | | | | | |
|---|---|---|---|---|---|---|---|
| | | SCB | B/H | IS | MS | OS | US |
| *Havelockia benti* | Echinodermata:Phyllophoridae | < 0.1 | – | < 0.1 | – | – | – |
| *Hermissenda crassicornis* | Mollusca:Facelinidae | < 0.1 | – | < 0.1 | – | – | – |
| *Heterogorgia tortuosa* | Cnidaria:Gorgoniidae | < 0.1 | – | < 0.1 | – | – | – |
| *Leptogorgia chilensis* | Cnidaria:Gorgoniidae | < 0.1 | – | < 0.1 | – | – | – |
| *Lysmata californica* | Arthropoda:Hippolytidae | < 0.1 | – | < 0.1 | – | – | – |
| *Pachycheles pubescens* | Arthropoda:Porcellanidae | < 0.1 | – | < 0.1 | – | – | – |
| *Pteropurpura festiva* | Mollusca:Muricidae | < 0.1 | – | < 0.1 | – | – | – |
| *Pugettia producta* | Arthropoda:Epialtidae | < 0.1 | – | < 0.1 | – | – | – |
| *Romaleon antennarium* | Arthropoda:Cancridae | < 0.1 | – | < 0.1 | – | – | – |
| *Romaleon jordani* | Arthropoda:Cancridae | < 0.1 | – | < 0.1 | – | – | – |
| *Scyra acutifrons* | Arthropoda:Epialtidae | < 0.1 | – | < 0.1 | – | – | – |
| *Urticina sp A* | Cnidaria:Actiniidae | < 0.1 | – | < 0.1 | – | – | – |
| *Acanthodoris rhodoceras* | Mollusca:Onchidorididae | < 0.1 | – | – | < 0.1 | – | – |
| *Acarnidae sp SD 1* | Silicea:Acarnidae | < 0.1 | – | – | < 0.1 | – | – |
| *Aglaja ocelligera* | Mollusca:Aglajidae | < 0.1 | – | – | < 0.1 | – | – |
| *Amphiodia psara* | Echinodermata:Amphiuridae | < 0.1 | – | – | < 0.1 | – | – |
| *Aphrodita sp* | Annelida:Aphroditidae | < 0.1 | – | – | < 0.1 | – | – |
| *Babelomurex oldroydi* | Mollusca:Muricidae | < 0.1 | – | – | < 0.1 | – | – |
| *Barbarofusus barbarensis* | Mollusca:Fasciolariidae | < 0.1 | – | – | < 0.1 | – | – |
| *Boltenia villosa* | Chordata:Pyuridae | < 0.1 | – | – | < 0.1 | – | – |
| *Caesia perpinguis* | Mollusca:Nassariidae | < 0.1 | – | – | < 0.1 | – | – |
| *Calliostoma keenae* | Mollusca:Calliostomatidae | < 0.1 | – | – | < 0.1 | – | – |
| *Caudina arenicola* | Echinodermata:Caudinidae | < 0.1 | – | – | < 0.1 | – | – |
| *Chlorostoma aureotincta* | Mollusca:Turbinidae | < 0.1 | – | – | < 0.1 | – | – |
| *Coenocyathus bowersi* | Cnidaria:Caryophylliidae | < 0.1 | – | – | < 0.1 | – | – |

**Appendix B-15 (continued)**

| Scientific Name | Phylum:Family | Biomass (kg) | | | | | |
|---|---|---|---|---|---|---|---|
| | | SCB | B/H | IS | MS | OS | US |
| *Aphrodita armifera* | Annelida:Aphroditidae | < 0.1 | – | – | – | < 0.1 | – |
| *Dougaloplus amphacanthus* | Echinodermata:Amphiuridae | < 0.1 | – | – | – | < 0.1 | – |
| *Heptacarpus tenuissimus* | Arthropoda:Hippolytidae | < 0.1 | – | – | – | < 0.1 | – |
| *Mediaster aequalis* | Echinodermata:Goniasteridae | < 0.1 | – | – | – | < 0.1 | – |
| *Ophiacantha diplasia* | Echinodermata:Ophiacanthidae | < 0.1 | – | – | – | < 0.1 | – |
| *Ophiacantha quadrispina* | Echinodermata:Ophiacanthidae | < 0.1 | – | – | – | < 0.1 | – |
| *Philine alba* | Mollusca:Philinidae | < 0.1 | – | – | – | < 0.1 | – |
| *Sinum scopulosum* | Mollusca:Naticidae | < 0.1 | – | – | – | < 0.1 | – |
| *Amphiura diomedeae* | Echinodermata:Amphiuridae | < 0.1 | – | – | – | – | < 0.1 |
| *Bentheogennema burkenroadi* | Arthropoda:Aristeidae | < 0.1 | – | – | – | – | < 0.1 |
| *Borsonella merriami* | Mollusca:Borsoniidae | < 0.1 | – | – | – | – | < 0.1 |
| *Calliostoma platinum* | Mollusca:Calliostomatidae | < 0.1 | – | – | – | – | < 0.1 |
| *Munidopsis aspera* | Arthropoda:Munidopsidae | < 0.1 | – | – | – | – | < 0.1 |
| *Ophiopholis longispina* | Echinodermata:Ophiactidae | < 0.1 | – | – | – | – | < 0.1 |
| *Stachyptilum superbum* | Cnidaria:Stachyptilidae | < 0.1 | – | – | – | – | < 0.1 |

**Appendix B-16. Percent frequency of occurrence for all megabenthic invertebrate species collected during the Bight '13 trawl survey. Shaded areas indicate species is one of the top ten most frequently occurring species in that stratum. SCB=Southern California Bight, B/H = Bays and Harbors, IS = Inner Shelf, MS = Middle Shelf, OS = Outer Shelf, US = Upper Slope.**

| | | *Frequency of Occurrence* | | | | | |
|---|---|---|---|---|---|---|---|
| **Scientific Name** | **Phylum:Family** | **SCB** | **B/H** | **IS** | **MS** | **OS** | **US** |
| *Pleurobranchaea californica* | Mollusca:Pleurobranchidae | 61.8 | – | 7.5 | 78.0 | 84.1 | 69.2 |
| *Octopus rubescens* | Mollusca:Octopodidae | 42.6 | 13.2 | 60.0 | 72.2 | 84.1 | 13.7 |
| *Octopus californicus* | Mollusca:Octopodidae | 38.8 | – | – | 0.5 | 35.6 | 75.8 |
| *Luidia foliolata* | Echinodermata:Luidiidae | 38.3 | – | 7.5 | 68.0 | 70.1 | 27.9 |
| *Brissopsis pacifica* | Echinodermata:Brissidae | 35.0 | – | – | – | 54.2 | 65.3 |
| *Astropecten californicus* | Echinodermata:Astropectinidae | 34.2 | – | 80.8 | 66.8 | 11.2 | 3.4 |
| *Brisaster townsendi* | Echinodermata:Schizasteridae | 33.4 | – | – | – | 8.4 | 68.9 |
| *Strongylocentrotus fragilis* | Echinodermata:Strongylocentrotidae | 32.4 | – | – | – | 81.3 | 55.5 |
| *Ophiura luetkenii* | Echinodermata:Ophiuridae | 26.9 | – | 3.6 | 78.8 | 41.1 | 3.4 |
| *Sicyonia ingentis* | Arthropoda:Sicyoniidae | 25.4 | 10.6 | 7.1 | 65.8 | 58.0 | 3.7 |
| *Myxoderma platyacanthum* | Echinodermata:Zoroasteridae | 24.4 | – | – | – | – | 51.3 |
| *Lytechinus pictus* | Echinodermata:Toxopneustidae | 23.5 | – | 22.4 | 63.6 | 31.8 | – |
| *Pseudarchaster pusillus* | Echinodermata:Goniasteridae | 22.8 | – | – | – | – | 47.9 |
| *Parastichopus californicus* | Echinodermata:Stichopodidae | 22.4 | – | 3.6 | 63.3 | 38.3 | 3.4 |
| *Spirontocaris sica* | Arthropoda:Hippolytidae | 21.6 | – | – | – | 3.7 | 45.0 |
| *Ophiothrix spiculata* | Echinodermata:Ophiotricidae | 21.1 | 7.9 | 19.9 | 55.6 | 11.2 | 3.4 |
| *Spatangus californicus* | Echinodermata:Spatangidae | 21.1 | – | – | 0.2 | 42.0 | 37.9 |
| *Dromalia alexandri* | Cnidaria:Rhodaliidae | 19.1 | – | – | – | 12.2 | 38.4 |
| *Spirontocaris holmesi* | Arthropoda:Hippolytidae | 18.1 | – | – | – | 23.4 | 34.5 |
| *Neocrangon zacae* | Arthropoda:Crangonidae | 16.6 | – | – | 0.9 | 66.4 | 24.2 |
| *Asteronyx longifissus* | Echinodermata:Asteronychidae | 16.3 | – | – | – | – | 34.2 |
| *Acanthodoris brunnea* | Mollusca:Onchidorididae | 16.2 | 2.6 | 4.0 | 44.5 | 22.4 | 3.4 |
| *Brisaster sp* | Echinodermata:Schizasteridae | 16.1 | – | – | – | 19.6 | 30.8 |
| *Thesea sp B* | Cnidaria:Plexauridae | 15.3 | – | 3.6 | 48.7 | 18.7 | – |

**Appendix B-16 (continued)**

| Scientific Name | Phylum:Family | Frequency of Occurrence | | | | | |
|---|---|---|---|---|---|---|---|
| | | SCB | B/H | IS | MS | OS | US |
| *Sicyonia penicillata* | Arthropoda:Sicyoniidae | 15.1 | 31.7 | 55.6 | 20.2 | – | – |
| *Metacarcinus gracilis* | Arthropoda:Cancridae | 14.2 | 10.7 | 61.3 | 14.4 | – | – |
| *Hamatoscalpellum californicum* | Arthropoda:Scalpellidae | 11.6 | – | 11.9 | 34.1 | 3.7 | – |
| *Brisaster latifrons* | Echinodermata:Schizasteridae | 11.4 | – | – | – | 43.0 | 17.4 |
| *Luidia asthenosoma* | Echinodermata:Luidiidae | 10.5 | – | – | 34.1 | 15.9 | – |
| *Pandalus platyceros* | Arthropoda:Pandalidae | 10.4 | – | 3.6 | 0.5 | 42.0 | 13.9 |
| *Suberites latus* | Silicea:Suberitidae | 10.3 | 21.6 | – | – | 3.7 | 20.5 |
| *Pannychia moseleyi* | Echinodermata:Laetmogonidae | 9.8 | – | – | – | – | 20.5 |
| *Acanthoptilum sp* | Cnidaria:Virgulariidae | 9.8 | 10.8 | 7.5 | 24.7 | 22.4 | – |
| *Crangon nigromaculata* | Arthropoda:Crangonidae | 9.5 | 31.7 | 44.1 | 6.8 | – | – |
| *Pyromaia tuberculata* | Arthropoda:Inachoididae | 9.5 | 46.4 | 32.0 | 13.5 | – | – |
| *Aphrodita japonica* | Annelida:Aphroditidae | 7.7 | – | – | 3.4 | 3.7 | 13.7 |
| *Antiplanes thalea* | Mollusca:Pseudomelatomidae | 7.6 | – | – | – | 14.9 | 13.7 |
| *Stylatula elongata* | Cnidaria:Virgulariidae | 7.5 | 5.3 | 7.5 | 21.5 | 3.7 | – |
| *Pennatula californica* | Cnidaria:Pennatulidae | 6.5 | – | – | – | – | 13.7 |
| *Paralithodes californiensis* | Arthropoda:Lithodidae | 6.3 | – | – | – | 18.7 | 10.3 |
| *Luidia armata* | Echinodermata:Luidiidae | 6.2 | – | 4.0 | 20.3 | – | – |
| *Neocrangon resima* | Arthropoda:Crangonidae | 6.1 | – | – | 0.9 | 57.0 | 3.4 |
| *Pisaster brevispinus* | Echinodermata:Asteriidae | 6.1 | – | 36.0 | 0.5 | – | – |
| *Loxorhynchus grandis* | Arthropoda:Epialtidae | 6.0 | 2.6 | 17.8 | 10.9 | – | – |
| *Metridium farcimen* | Cnidaria:Metridiidae | 5.9 | – | – | 0.5 | 33.6 | 6.8 |
| *Spirontocaris sp* | Arthropoda:Hippolytidae | 5.8 | – | – | – | 11.2 | 10.5 |
| *Latulambrus occidentalis* | Arthropoda:Parthenopidae | 5.3 | – | 14.2 | 10.6 | – | – |
| *Thrissacanthias penicillatus* | Echinodermata:Astropectinidae | 5.2 | – | – | – | 3.7 | 10.3 |
| *Rossia pacifica* | Mollusca:Sepiolidae | 5.1 | – | – | – | 46.8 | 3.4 |
| *Glyptolithodes cristatipes* | Arthropoda:Lithodidae | 5.0 | – | – | – | – | 10.5 |

**Appendix B-16 (continued)**

| Scientific Name | Phylum:Family | *Frequency of Occurrence* | | | | | |
|---|---|---|---|---|---|---|---|
| | | **SCB** | **B/H** | **IS** | **MS** | **OS** | **US** |
| *Actinostola sp* | Cnidaria:Actinostolidae | 4.9 | – | – | – | – | 10.3 |
| *Chorilia longipes* | Arthropoda:Epialtidae | 4.9 | – | – | – | – | 10.3 |
| *Halipteris californica* | Cnidaria:Halipteridae | 4.9 | – | – | – | – | 10.3 |
| *Paguristes turgidus* | Arthropoda:Diogenidae | 4.9 | – | – | – | – | 10.3 |
| *Astropecten armatus* | Echinodermata:Astropectinidae | 4.9 | 15.8 | 28.5 | – | – | – |
| *Metacrangon spinosissima* | Arthropoda:Crangonidae | 4.8 | – | – | 0.9 | 39.3 | 3.4 |
| *Stylasterias forreri* | Echinodermata:Asteriidae | 4.5 | – | – | 3.4 | 3.7 | 6.8 |
| *Ptilosarcus gurneyi* | Cnidaria:Pennatulidae | 4.4 | – | – | – | 14.9 | 6.8 |
| *Armina californica* | Mollusca:Arminidae | 4.4 | 2.6 | 3.6 | 13.5 | 1.0 | – |
| *Podochela lobifrons* | Arthropoda:Inachidae | 4.4 | – | 14.2 | 7.4 | – | – |
| *Philine auriformis* | Mollusca:Philinidae | 4.3 | 10.6 | 4.0 | 6.8 | – | 3.4 |
| *Ophiopholis bakeri* | Echinodermata:Ophiactidae | 4.2 | – | – | 3.4 | 22.4 | 3.4 |
| *Nymphon pixellae* | Arthropoda:Nymphonidae | 3.9 | – | – | 7.2 | 3.7 | 3.4 |
| *Calinaticina oldroydii* | Mollusca:Naticidae | 3.8 | – | – | – | 7.5 | 6.8 |
| *Paguristes bakeri* | Arthropoda:Diogenidae | 3.7 | – | 3.6 | 3.4 | 7.5 | 3.4 |
| *Florometra serratissima* | Echinodermata:Antedonidae | 3.7 | – | – | 3.4 | 14.9 | 3.4 |
| *Hinea insculpta* | Mollusca:Nassariidae | 3.6 | – | – | 3.4 | 12.2 | 3.7 |
| *Munida hispida* | Arthropoda:Munididae | 3.4 | – | – | – | – | 7.1 |
| *Gorgonocephalus eucnemis* | Echinodermata:Gorgonocephalidae | 3.3 | – | – | – | 22.4 | 3.4 |
| *Aphrodita castanea* | Annelida:Aphroditidae | 3.3 | – | – | 0.5 | 19.6 | 3.7 |
| *Astyris permodesta* | Mollusca:Columbellidae | 3.3 | – | – | – | – | 6.8 |
| *Chloeia pinnata* | Annelida:Amphinomidae | 3.3 | – | – | – | – | 6.8 |
| *Munida quadrispina* | Arthropoda:Munididae | 3.3 | – | – | – | – | 6.8 |

**Appendix B-16 (continued)**

| Scientific Name | Phylum:Family | *Frequency of Occurrence* | | | | | |
|---|---|---|---|---|---|---|---|
| | | SCB | B/H | IS | MS | OS | US |
| *Munididae* | Arthropoda:Munididae | 3.3 | – | – | – | – | 6.8 |
| *Ophiosphalma jolliense* | Echinodermata:Ophiuridae | 3.3 | – | – | – | – | 6.8 |
| *Opisthoteuthis sp A* | Mollusca:Opisthoteuthidae | 3.3 | – | – | – | – | 6.8 |
| *Stephanauge sp* | Cnidaria:Hormathiidae | 3.3 | – | – | – | – | 6.8 |
| *Cancellaria crawfordiana* | Mollusca:Cancellariidae | 3.2 | – | – | 3.8 | 7.5 | 3.4 |
| *Luidia sp* | Echinodermata:Luidiidae | 3.0 | – | 3.6 | 6.8 | 7.5 | – |
| *Platymera gaudichaudii* | Arthropoda:Calappidae | 3.0 | – | – | 7.8 | 11.2 | – |
| *Cancer productus* | Arthropoda:Cancridae | 2.7 | – | 7.8 | 4.3 | 3.7 | – |
| *Astropecten sp* | Echinodermata:Astropectinidae | 2.7 | – | 10.7 | 3.4 | – | – |
| *Megasurcula carpenteriana* | Mollusca:Pseudomelatomidae | 2.5 | – | – | 0.9 | 8.4 | 3.4 |
| *Doryteuthis opalescens* | Mollusca:Loliginidae | 2.5 | – | – | – | 11.2 | 3.4 |
| *Lopholithodes foraminatus* | Arthropoda:Lithodidae | 2.5 | – | – | – | 11.2 | 3.4 |
| *Parastichopus sp A* | Echinodermata:Stichopodidae | 2.5 | – | – | – | 11.2 | 3.4 |
| *Neocrangon sp* | Arthropoda:Crangonidae | 2.5 | – | – | – | 12.2 | 3.4 |
| *Renilla koellikeri* | Cnidaria:Renillidae | 2.5 | – | 14.2 | 0.5 | – | – |
| *Flabellina iodinea* | Mollusca:Flabellinidae | 2.4 | – | 3.6 | 6.8 | – | – |
| *Boreotrophon bentleyi* | Mollusca:Muricidae | 2.2 | – | – | – | 7.5 | 3.4 |
| *Pentamera pseudocalcigera* | Echinodermata:Phyllophoridae | 2.2 | – | – | – | 7.5 | 3.4 |
| *Neptunea tabulata* | Mollusca:Buccinidae | 1.9 | – | – | – | 3.7 | 3.4 |
| *Odontaster crassus* | Echinodermata:Odontasteridae | 1.9 | – | – | – | 3.7 | 3.4 |
| *Calliostoma turbinum* | Mollusca:Calliostomatidae | 1.9 | – | – | 6.8 | – | – |
| *Pagurus armatus* | Arthropoda:Paguridae | 1.9 | – | – | 6.8 | – | – |
| *Styela gibbsii* | Chordata:Styelidae | 1.9 | – | – | 6.8 | – | – |
| *Virgularia agassizii* | Cnidaria:Virgulariidae | 1.9 | – | – | 6.8 | – | – |
| *Crossata ventricosa* | Mollusca:Bursidae | 1.8 | – | – | 0.5 | – | 3.4 |
| *Metacarcinus anthonyi* | Arthropoda:Cancridae | 1.8 | – | 3.6 | 3.4 | 3.7 | – |
| *Antiplanes catalinae* | Mollusca:Pseudomelatomidae | 1.7 | – | – | – | 22.4 | – |

**Appendix B-16 (continued)**

| Scientific Name | Phylum:Family | *Frequency of Occurrence* | | | | | |
|---|---|---|---|---|---|---|---|
| | | SCB | B/H | IS | MS | OS | US |
| *Amphiura diomedeae* | Echinodermata:Amphiuridae | 1.6 | – | – | – | – | 3.4 |
| *Borsonella merriami* | Mollusca:Borsoniidae | 1.6 | – | – | – | – | 3.4 |
| *Calliostoma platinum* | Mollusca:Calliostomatidae | 1.6 | – | – | – | – | 3.4 |
| *Ceramaster leptoceramus* | Echinodermata:Goniasteridae | 1.6 | – | – | – | – | 3.4 |
| *Hippasteria spinosa* | Echinodermata:Goniasteridae | 1.6 | – | – | – | – | 3.4 |
| *Hormathia digitata* | Cnidaria:Hormathiidae | 1.6 | – | – | – | – | 3.4 |
| *Liponema brevicorne* | Cnidaria:Liponematidae | 1.6 | – | – | – | – | 3.4 |
| *Munidopsis aspera* | Arthropoda:Munidopsidae | 1.6 | – | – | – | – | 3.4 |
| *Ophiopholis longispina* | Echinodermata:Ophiactidae | 1.6 | – | – | – | – | 3.4 |
| *Paralithodes rathbuni* | Arthropoda:Lithodidae | 1.6 | – | – | – | – | 3.4 |
| *Rathbunaster californicus* | Echinodermata:Asteriidae | 1.6 | – | – | – | – | 3.4 |
| *Stachyptilum superbum* | Cnidaria:Stachyptilidae | 1.6 | – | – | – | – | 3.4 |
| *Staurocalyptus dowlingi* | Silicea:Rossellidae | 1.6 | – | – | – | – | 3.4 |
| *Synallactes virgulisolida* | Echinodermata:Synallactidae | 1.6 | – | – | – | – | 3.4 |
| *Loxorhynchus crispatus* | Arthropoda:Epialtidae | 1.6 | – | 4.2 | 3.4 | – | – |
| Cancridae | Arthropoda:Cancridae | 1.5 | 2.6 | 3.6 | 3.4 | – | – |
| *Virgularia californica* | Cnidaria:Virgulariidae | 1.5 | 2.6 | 3.6 | 3.4 | – | – |
| *Amphiura arcystata* | Echinodermata:Amphiuridae | 1.5 | – | 3.6 | 3.4 | – | – |
| *Sclerasterias heteropaes* | Echinodermata:Asteriidae | 1.5 | – | 3.6 | 3.4 | – | – |
| *Portunus xantusii* | Arthropoda:Portunidae | 1.5 | 21.6 | 7.5 | – | – | – |
| *Astropecten ornatissimus* | Echinodermata:Astropectinidae | 1.4 | – | – | – | 18.7 | – |
| *Aplysia californica* | Mollusca:Aplysiidae | 1.3 | – | 7.5 | 0.2 | – | – |
| *Kelletia kelletii* | Mollusca:Buccinidae | 1.2 | 2.6 | 1.4 | 3.5 | – | – |
| *Ericerodes hemphillii* | Arthropoda:Inachidae | 1.2 | – | 1.0 | 3.8 | – | – |
| *Tritonia tetraquetra* | Mollusca:Tritoniidae | 1.2 | 5.3 | – | 4.0 | – | – |
| *Randallia ornata* | Arthropoda:Leucosiidae | 1.2 | – | 7.1 | – | – | – |
| *Strongylocentrotus franciscanus* | Echinodermata:Strongylocentrotidae | 1.1 | 5.3 | – | 3.8 | – | – |
| *Strongylocentrotus sp* | Echinodermata:Strongylocentrotidae | 1 | 2.6 | – | 3.4 | – | – |

**Appendix B-16 (continued)**

| Scientific Name | Phylum:Family | Frequency of Occurrence SCB | B/H | IS | MS | OS | US |
|---|---|---|---|---|---|---|---|
| *Diaulula sandiegensis* | Mollusca:Discodorididae | 1 | 5.4 | – | 3.4 | – | – |
| Asteroidea | Echinodermata:Class Asteroidea | 1 | – | – | 3.5 | – | – |
| *Euspira lewisii* | Mollusca:Naticidae | 0.9 | – | 3.6 | – | 3.7 | – |
| *Acarnidae sp SD 1* | Silicea:Acarnidae | 0.9 | – | – | 3.4 | – | – |
| *Aglaja ocelligera* | Mollusca:Aglajidae | 0.9 | – | – | 3.4 | – | – |
| *Amphiodia psara* | Echinodermata:Amphiuridae | 0.9 | – | – | 3.4 | – | – |
| *Aphrodita sp* | Annelida:Aphroditidae | 0.9 | – | – | 3.4 | – | – |
| *Babelomurex oldroydi* | Mollusca:Muricidae | 0.9 | – | – | 3.4 | – | – |
| *Boltenia villosa* | Chordata:Pyuridae | 0.9 | – | – | 3.4 | – | – |
| *Caesia perpinguis* | Mollusca:Nassariidae | 0.9 | – | – | 3.4 | – | – |
| *Calliostoma keenae* | Mollusca:Calliostomatidae | 0.9 | – | – | 3.4 | – | – |
| *Caudina arenicola* | Echinodermata:Caudinidae | 0.9 | – | – | 3.4 | – | – |
| *Coenocyathus bowersi* | Cnidaria:Caryophylliidae | 0.9 | – | – | 3.4 | – | – |
| *Crangon alaskensis* | Arthropoda:Crangonidae | 0.9 | – | – | 3.4 | – | – |
| *Dendronotus albus* | Mollusca:Dendronotidae | 0.9 | – | – | 3.4 | – | – |
| *Eugorgia rubens* | Cnidaria:Gorgoniidae | 0.9 | – | – | 3.4 | – | – |
| *Euspira draconis* | Mollusca:Naticidae | 0.9 | – | – | 3.4 | – | – |
| *Leucilla nuttingi* | Calcarea:Amphoriscidae | 0.9 | – | – | 3.4 | – | – |
| *Loxorhynchus sp* | Arthropoda:Epialtidae | 0.9 | – | – | 3.4 | – | – |
| *Microcionina sp SD 1* | Silicea:Microcionidae | 0.9 | – | – | 3.4 | – | – |
| *Microcionina sp SD 2* | Silicea:Microcionidae | 0.9 | – | – | 3.4 | – | – |
| *Molpadia intermedia* | Echinodermata:Molpadiidae | 0.9 | – | – | 3.4 | – | – |
| *Octopus veligero* | Mollusca:Octopodidae | 0.9 | – | – | 3.4 | – | – |

**Appendix B-16 (continued)**

| Scientific Name | Phylum:Family | *Frequency of Occurrence* | | | | | |
|---|---|---|---|---|---|---|---|
| | | SCB | B/H | IS | MS | OS | US |
| *Paracyathus stearnsii* | Cnidaria:Caryophylliidae | 0.9 | – | – | 3.4 | – | – |
| Pisinae | Arthropoda:Epialtidae | 0.9 | – | – | 3.4 | – | – |
| *Platydoris macfarlandi* | Mollusca:Discodorididae | 0.9 | – | – | 3.4 | – | – |
| *Styela montereyensis* | Chordata:Styelidae | 0.9 | – | – | 3.4 | – | – |
| *Styela plicata* | Chordata:Styelidae | 0.9 | – | – | 3.4 | – | – |
| *Telesto californica* | Cnidaria:Telestidae | 0.9 | – | – | 3.4 | – | – |
| *Thesea sp SD 1* | Cnidaria:Plexauridae | 0.9 | – | – | 3.4 | – | – |
| *Triopha catalinae* | Mollusca:Polyceridae | 0.9 | – | – | 3.4 | – | – |
| *Farfantepenaeus californiensis* | Arthropoda:Penaeidae | 0.9 | 23.5 | 4 | – | – | – |
| *Triopha maculata* | Mollusca:Polyceridae | 0.7 | 2.6 | 3.6 | 0.2 | – | – |
| *Phimochirus californiensis* | Arthropoda:Paguridae | 0.7 | – | 4 | – | – | – |
| *Amphichondrius granulatus* | Echinodermata:Amphiuridae | 0.6 | – | – | 0.2 | 7.5 | – |
| *Amphiuridae* | Echinodermata:Amphiuridae | 0.6 | – | – | – | 7.5 | – |
| *Simnia barbarensis* | Mollusca:Ovulidae | 0.6 | – | – | – | 7.5 | – |
| *Muricea californica* | Cnidaria:Plexauridae | 0.6 | 2.6 | 3.6 | – | – | – |
| *Aeolidiella chromosoma* | Mollusca:Aeolidiidae | 0.6 | – | 3.6 | – | – | – |
| *Dendraster terminalis* | Echinodermata:Dendrasteridae | 0.6 | – | 3.6 | – | – | – |
| *Halichondria panicea* | Silicea:Halichondriidae | 0.6 | – | 3.6 | – | – | – |
| *Hermissenda crassicornis* | Mollusca:Facelinidae | 0.6 | – | 3.6 | – | – | – |

**Appendix B-16 (continued)**

| Scientific Name | Phylum:Family | SCB | B/H | IS | MS | OS | US |
|---|---|---|---|---|---|---|---|
| | | *Frequency of Occurrence* | | | | | |
| *Leptogorgia chilensis* | Cnidaria:Gorgoniidae | 0.6 | – | 3.6 | – | – | – |
| *Lysmata californica* | Arthropoda:Hippolytidae | 0.6 | – | 3.6 | – | – | – |
| *Pachycheles pubescens* | Arthropoda:Porcellanidae | 0.6 | – | 3.6 | – | – | – |
| *Pteropurpura festiva* | Mollusca:Muricidae | 0.6 | – | 3.6 | – | – | – |
| *Pugettia producta* | Arthropoda:Epialtidae | 0.6 | – | 3.6 | – | – | – |
| *Romaleon jordani* | Arthropoda:Cancridae | 0.6 | – | 3.6 | – | – | – |
| *Scyra acutifrons* | Arthropoda:Epialtidae | 0.6 | – | 3.6 | – | – | – |
| *Urticina sp A* | Cnidaria:Actiniidae | 0.6 | – | 3.6 | – | – | – |
| *Halichondria bowerbanki* | Silicea:Halichondriidae | 0.4 | 32.7 | – | – | – | – |
| *Musculista senhousia* | Mollusca:Mytilidae | 0.4 | 38.8 | – | – | – | – |
| *Amphiodia digitata* | Echinodermata:Amphiuridae | 0.3 | – | – | – | 3.7 | – |
| *Amphiodia sp* | Echinodermata:Amphiuridae | 0.3 | – | – | – | 3.7 | – |
| *Amphiodia urtica* | Echinodermata:Amphiuridae | 0.3 | – | – | – | 3.7 | – |
| *Aphrodita armifera* | Annelida:Aphroditidae | 0.3 | – | – | – | 3.7 | – |
| *Dougaloplus amphacanthus* | Echinodermata:Amphiuridae | 0.3 | – | – | – | 3.7 | – |
| *Heptacarpus tenuissimus* | Arthropoda:Hippolytidae | 0.3 | – | – | – | 3.7 | – |
| *Mediaster aequalis* | Echinodermata:Goniasteridae | 0.3 | – | – | – | 3.7 | – |
| *Munida tenella* | Arthropoda:Munididae | 0.3 | – | – | – | 3.7 | – |
| *Ophiacantha diplasia* | Echinodermata:Ophiacanthidae | 0.3 | – | – | – | 3.7 | – |
| *Ophiacantha quadrispina* | Echinodermata:Ophiacanthidae | 0.3 | – | – | – | 3.7 | – |
| *Philine alba* | Mollusca:Philinidae | 0.3 | – | – | – | 3.7 | – |

**Appendix B-16 (continued)**

| Scientific Name | Phylum:Family | *Frequency of Occurrence* | | | | | |
|---|---|---|---|---|---|---|---|
| | | SCB | B/H | IS | MS | OS | US |
| *Poraniopsis inflata* | Echinodermata:Poraniidae | 0.3 | – | – | – | 3.7 | – |
| *Pandalus jordani* | Arthropoda:Pandalidae | 0.3 | – | – | – | 4.7 | – |
| *Lophopanopeus frontalis* | Arthropoda:Panopeidae | 0.3 | 22.7 | – | – | – | – |
| *Conus californicus* | Mollusca:Conidae | 0.2 | 2.6 | 0.6 | 0.2 | – | – |
| *Heptacarpus stimpsoni* | Arthropoda:Hippolytidae | 0.2 | 10.6 | – | 0.2 | – | – |
| *Arcularia tiarula* | Mollusca:Nassariidae | 0.2 | 15.5 | – | – | – | – |
| *Ostrea lurida* | Mollusca:Ostreidae | 0.2 | 16.2 | – | – | – | – |
| *Tetilla sp* | Silicea:Tetillidae | 0.2 | 17.3 | – | – | – | – |
| *Bentheogennema burkenroadi* | Arthropoda:Aristeidae | 0.1 | – | – | – | – | 0.2 |
| *Sinum scopulosum* | Mollusca:Naticidae | 0.1 | – | – | – | 1 | – |
| *Heptacarpus brevirostris* | Arthropoda:Hippolytidae | 0.1 | 2.6 | – | 0.2 | – | – |
| *Parastichopus parvimensis* | Echinodermata:Stichopodidae | 0.1 | 5.3 | – | 0.2 | – | – |
| *Barbarofusus barbarensis* | Mollusca:Fasciolariidae | 0.1 | – | – | 0.5 | – | – |
| *Lepidozona scrobiculata* | Mollusca:Ischnochitonidae | 0.1 | – | – | 0.5 | – | – |
| *Calliostoma canaliculatum* | Mollusca:Calliostomatidae | 0.1 | – | 0.4 | – | – | – |
| *Crassispira semiinflata* | Mollusca:Pseudomelatomidae | 0.1 | – | 0.4 | – | – | – |
| *Glossaulax reclusianus* | Mollusca:Naticidae | 0.1 | – | 0.4 | – | – | – |
| *Havelockia benti* | Echinodermata:Phyllophoridae | 0.1 | – | 0.4 | – | – | – |
| *Heterogorgia tortuosa* | Cnidaria:Gorgoniidae | 0.1 | – | 0.4 | – | – | – |
| *Calliostoma tricolor* | Mollusca:Calliostomatidae | 0.1 | – | 0.6 | – | – | – |
| *Romaleon antennarium* | Arthropoda:Cancridae | 0.1 | – | 0.6 | – | – | – |
| *Anoplodactylus erectus* | Arthropoda:Phoxichilidiidae | 0.1 | 5.4 | – | – | – | – |
| *Dragmacidon sp* | Silicea:Axinellidae | 0.1 | 5.4 | – | – | – | – |
| *Haliclona sp* | Silicea:Chalinidae | 0.1 | 5.4 | – | – | – | – |
| *Harmothoe sp* | Annelida:Polynoidae | 0.1 | 5.4 | – | – | – | – |

**Appendix B-16 (continued)**

| Scientific Name | Phylum:Family | Frequency of Occurrence | | | | | |
|---|---|---|---|---|---|---|---|
| | | SCB | B/H | IS | MS | OS | US |
| *Ophiocnida hispida* | Echinodermata:Amphiuridae | 0.1 | 5.4 | – | – | – | – |
| *Panulirus interruptus* | Arthropoda:Palinuridae | 0.1 | 5.4 | – | – | – | – |
| *Bulla gouldiana* | Mollusca:Bullidae | 0.1 | 5.8 | – | – | – | – |
| *Hippolyte californiensis* | Arthropoda:Hippolytidae | 0.1 | 5.8 | – | – | – | – |
| *Janolus barbarensis* | Mollusca:Zephyrinidae | 0.1 | 8 | – | – | – | – |
| *Navanax inermis* | Mollusca:Aglajidae | 0.1 | 8.7 | – | – | – | – |
| *Epiactis prolifera* | Cnidaria:Actiniidae | 0.1 | 9.7 | – | – | – | – |
| *Heptacarpus palpator* | Arthropoda:Hippolytidae | 0.1 | 10.6 | – | – | – | – |
| *Dendronotus iris* | Mollusca:Dendronotidae | 0.1 | 13.2 | – | – | – | – |
| *Acanthodoris rhodoceras* | Mollusca:Onchidorididae | < 0.1 | – | – | 0.2 | – | – |
| *Chlorostoma aureotincta* | Mollusca:Turbinidae | < 0.1 | – | – | 0.2 | – | – |
| *Hemisquilla californiensis* | Arthropoda:Hemisquillidae | < 0.1 | – | – | 0.2 | – | – |
| *Lamellaria diegoensis* | Mollusca:Velutinidae | < 0.1 | – | – | 0.2 | – | – |
| *Lophopanopeus bellus* | Arthropoda:Panopeidae | < 0.1 | – | – | 0.2 | – | – |
| *Norrisia norrisi* | Mollusca:Turbinidae | < 0.1 | – | – | 0.2 | – | – |
| *Ophiopteris papillosa* | Echinodermata:Ophiocomidae | < 0.1 | – | – | 0.2 | – | – |
| *Pachycheles rudis* | Arthropoda:Porcellanidae | < 0.1 | – | – | 0.2 | – | – |
| *Strongylocentrotus purpuratus* | Echinodermata:Strongylocentrotidae | < 0.1 | – | – | 0.2 | – | – |
| *Corambe pacifica* | Mollusca:Onchidorididae | < 0.1 | 2.6 | – | – | – | – |
| *Crangon nigricauda* | Arthropoda:Crangonidae | < 0.1 | 2.6 | – | – | – | – |
| *Pisaster ochraceus* | Echinodermata:Asteriidae | < 0.1 | 2.6 | – | – | – | – |
| *Polycera hedgpethi* | Mollusca:Polyceridae | < 0.1 | 2.6 | – | – | – | – |
| *Pycnopodia helianthoides* | Echinodermata:Asteriidae | < 0.1 | 2.6 | – | – | – | – |
| *Sicyonia sp* | Arthropoda:Sicyoniidae | < 0.1 | 2.6 | – | – | – | – |
| *Spirontocaris prionota* | Arthropoda:Hippolytidae | < 0.1 | 2.6 | – | – | – | – |

**Appendix B-17. Demersal fish anomalies by type, species and stratum during the Bight '13 trawl survey. SCB = Southern California Bight**

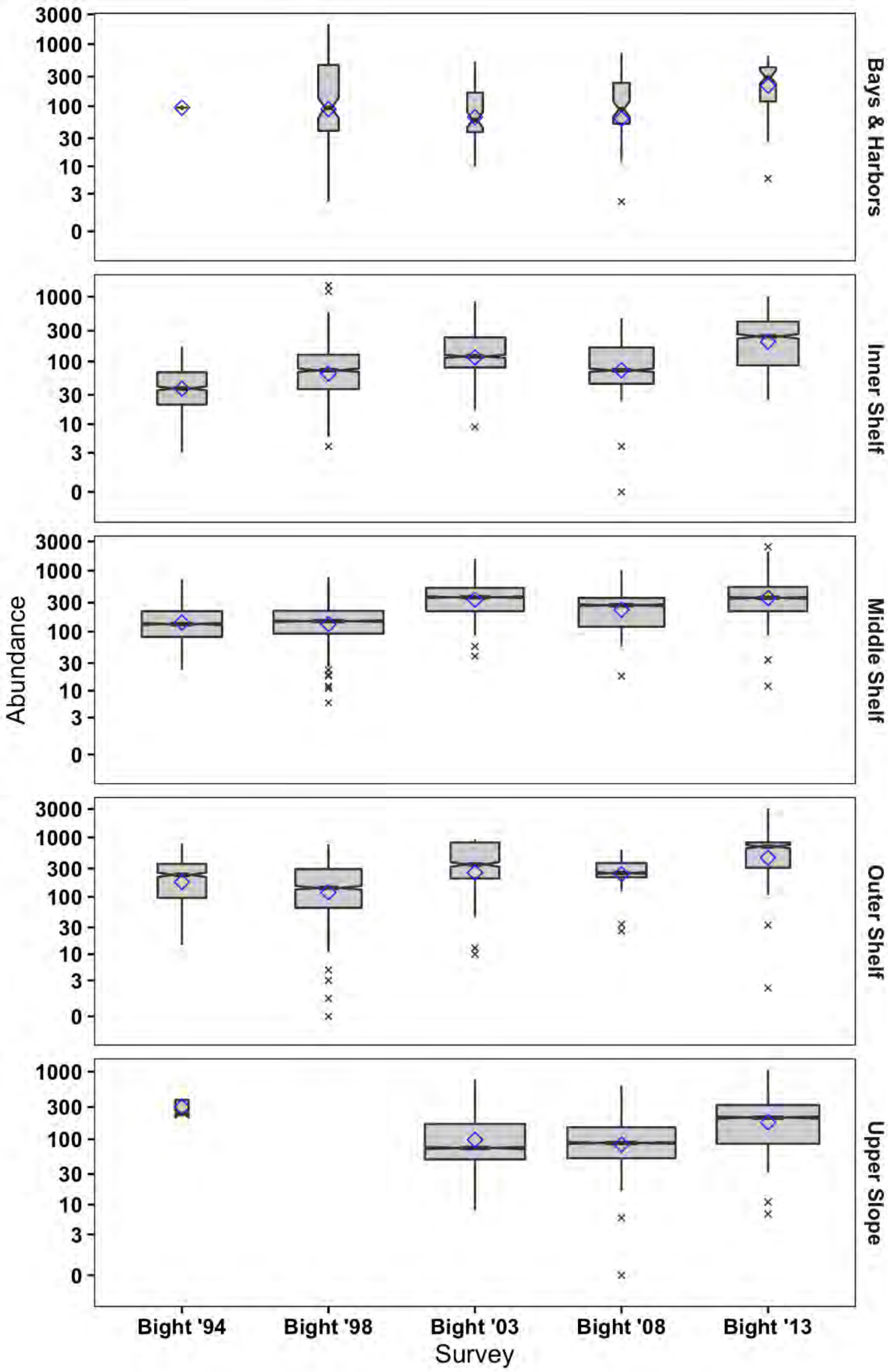
| Anomaly | Common Name | Bays & Harbors | Inner Shelf | Mid Shelf | Outer Shelf | Upper Slope | Entire SCB | Total Examined Fish | Percent Anomaly |
|---|---|---|---|---|---|---|---|---|---|
| Albinism | Dover Sole | – | – | – | 1 | – | 1 | 5,045 | < 0.1 |
| | **All Species** | **–** | **–** | **–** | **1** | **–** | **1** | **72,221** | **< 0.1** |
| Ambicoloration | Bigmouth Sole | – | – | 1 | – | – | 1 | 138 | 0.7 |
| | California Halibut | 3 | – | – | – | – | 3 | 88 | 3.4 |
| | California Tonguefish | 3 | – | 5 | – | – | 8 | 581 | 1.4 |
| | Curlfin Sole | – | 15 | 6 | – | – | 21 | 408 | 5.1 |
| | English Sole | – | 1 | – | – | – | 1 | 827 | 0.1 |
| | Hornyhead Turbot | – | 4 | – | – | – | 4 | 335 | 1.2 |
| | Pacific Sanddab | – | – | 2 | 1 | – | 3 | 19,004 | < 0.1 |
| | Roughback Sculpin | – | – | 1 | – | – | 1 | 94 | 1.1 |
| | Slender Sole | – | – | – | 1 | 2 | 3 | 5,040 | 0.1 |
| | Speckled Sanddab | – | 1 | – | – | – | 1 | 5,272 | < 0.1 |
| | Spotted Turbot | 2 | 1 | – | – | – | 3 | 25 | 12.0 |
| | **All Species** | **8** | **22** | **15** | **2** | **2** | **49** | **72,221** | **0.1** |
| Deformity | English Sole | – | – | 1 | – | – | 1 | 827 | 0.1 |
| | Pacific Sanddab | – | – | – | 1 | – | 1 | 19,004 | < 0.1 |
| | Speckled Sanddab | – | 2 | – | – | – | 2 | 5,272 | < 0.1 |
| | Spotted Sand Bass | 1 | – | – | – | – | 1 | 57 | 1.8 |
| | **All Species** | **1** | **2** | **1** | **1** | **–** | **5** | **72,221** | **< 0.1** |
| Fin Erosion | Curlfin Sole | – | 1 | 1 | – | – | 2 | 408 | 0.5 |
| | Dover Sole | – | – | – | – | 1 | 1 | 5,045 | < 0.1 |
| | Spotted Sand Bass | 1 | – | – | – | – | 1 | 57 | 1.8 |
| | **All Species** | **1** | **1** | **1** | **–** | **1** | **4** | **72,221** | **< 0.1** |

**Appendix B-17 (continued)**

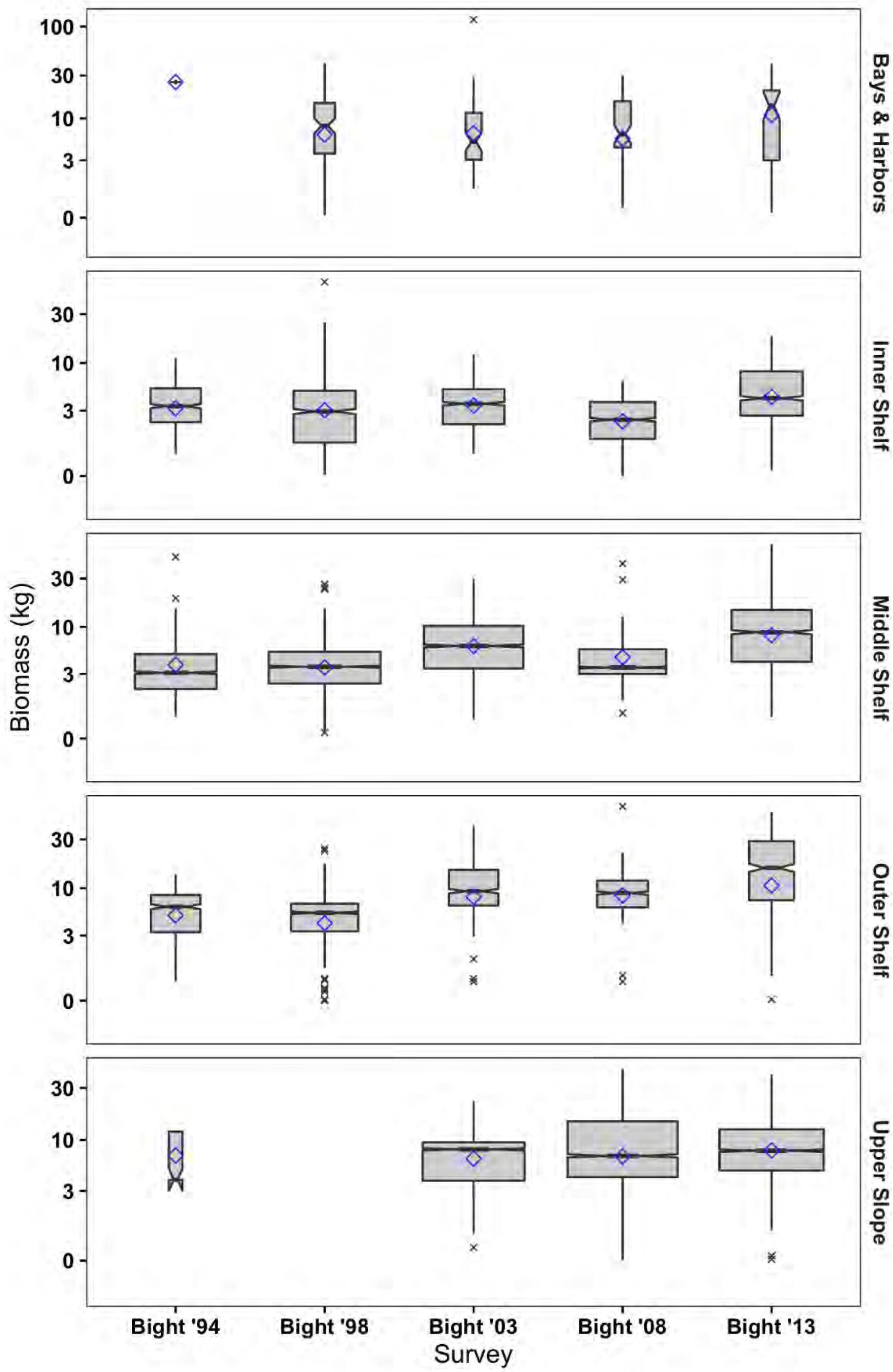
| Anomaly | Common Name | Bays & Harbors | Inner Shelf | Mid Shelf | Outer Shelf | Upper Slope | Entire SCB | Total Examined Fish | Percent Anomaly |
|---|---|---|---|---|---|---|---|---|---|
| Lesion | Dover Sole | – | – | – | 1 | – | 1 | 5,045 | < 0.1 |
| | English Sole | – | – | 2 | – | – | 2 | 827 | 0.2 |
| | Gulf Sanddab | – | – | – | 1 | – | 1 | 34 | 2.9 |
| | Pacific Sanddab | – | – | 1 | 1 | – | 2 | 19,004 | < 0.1 |
| | Speckled Sanddab | – | 1 | – | – | – | 1 | 5,272 | < 0.1 |
| | Spotted Turbot | 2 | – | – | – | – | 2 | 25 | 8.0 |
| | **All Species** | **2** | **1** | **3** | **3** | **–** | **9** | **72,221** | **< 0.1** |
| Parasite | California Halibut | 1 | 1 | – | – | – | 2 | 88 | 2.3 |
| | Curlfin Sole | – | 1 | – | – | – | 1 | 408 | 0.2 |
| | Dover Sole | – | – | – | 3 | 1 | 4 | 5,045 | 0.1 |
| | English Sole | – | – | – | 1 | – | 1 | 827 | 0.1 |
| | Fantail Sole | – | 1 | – | – | – | 1 | 116 | 0.9 |
| | Gulf Sanddab | – | – | – | 1 | – | 1 | 34 | 2.9 |
| | Hornyhead Turbot | – | 2 | 2 | – | – | 4 | 335 | 1.2 |
| | Pacific Hake | – | – | – | 2 | – | 2 | 181 | 1.1 |
| | Pacific Sanddab | – | 9 | 140 | 63 | 3 | 215 | 19,004 | 1.1 |
| | Pink Rockfish | – | – | – | 1 | – | 1 | 40 | 2.5 |
| | Rubynose Brotula | – | – | – | – | 1 | 1 | 336 | 0.3 |
| | Speckled Sanddab | – | 4 | – | – | – | 4 | 5,272 | 0.1 |
| | White Croaker | 1 | – | – | – | – | 1 | 1,300 | 0.1 |
| | **All Species** | **2** | **18** | **142** | **71** | **5** | **238** | **72,221** | **0.3** |
| Tumor | Dover Sole | – | – | 2 | 26 | 2 | 30 | 5,045 | 0.6 |
| | Pacific Sanddab | – | – | – | 7 | – | 7 | 19,004 | < 0.1 |
| | Pink Rockfish | – | – | – | 2 | – | 2 | 40 | 5.0 |
| | Yellowchin Sculpin | – | 1 | – | – | – | 1 | 2,062 | < 0.1 |
| | **All Species** | **–** | **1** | **2** | **35** | **2** | **40** | **72,221** | **0.1** |

**Appendix B-18. Total area of Southern California Bight (SCB) with demersal fish anomalies indicative of stress or disease, including fin erosion, tumors or lesions by stratum during the Bight '13 trawl survey.**

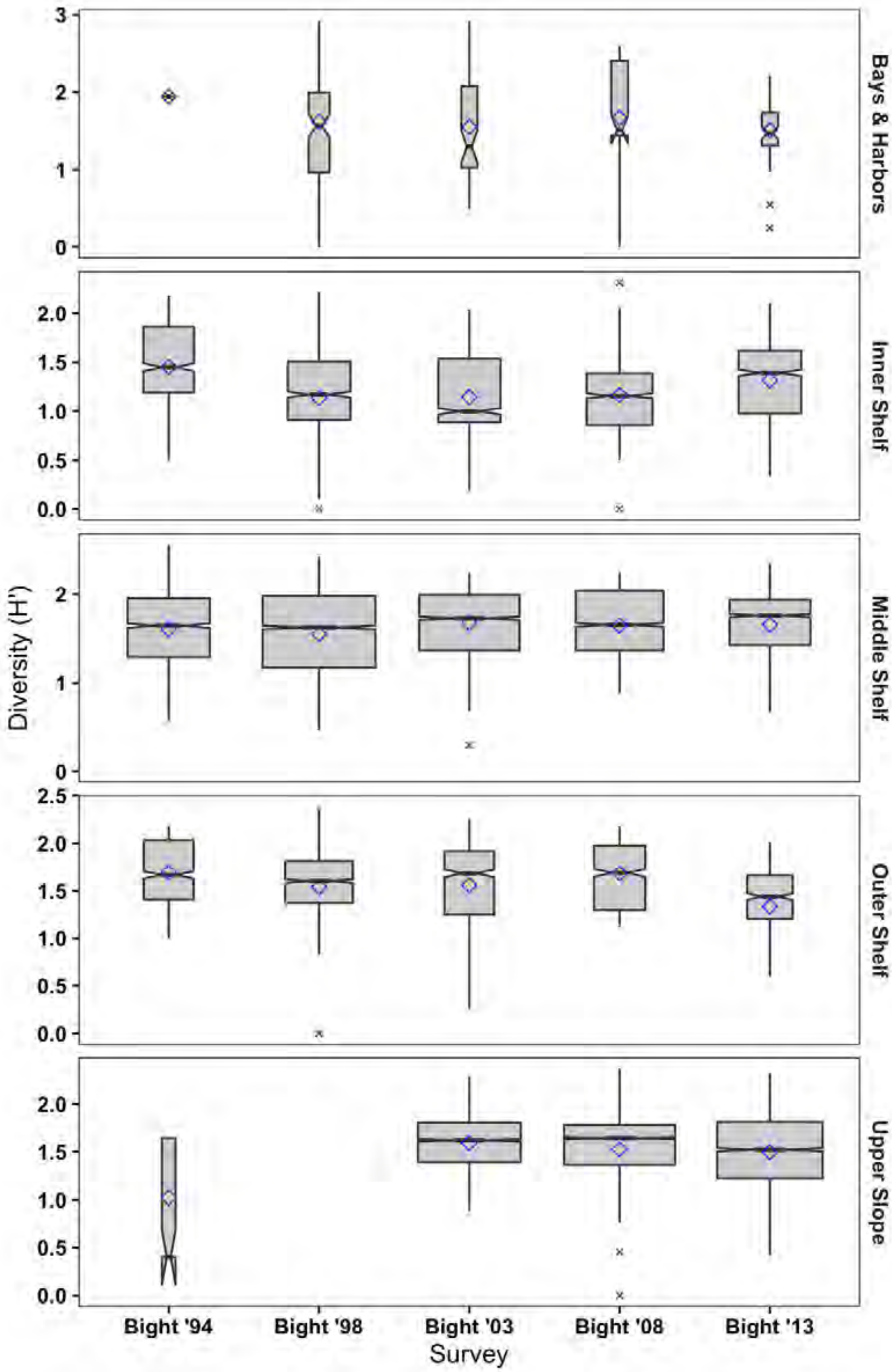
| Stratum | *Percent of Area with Disease* Fin Erosion | Lesions | Tumors | Total | Total Area with Disease ($km^2$) |
|---|---|---|---|---|---|
| Bays & Harbors | 3.8 | 3.8 | - | 7.7 | 5.2 |
| Inner Shelf | 2.9 | 2.9 | 2.9 | 8.6 | 86.2 |
| Middle Shelf | 2.3 | 7 | 4.7 | 11.6 | 193.2 |
| Outer Shelf | - | 6.9 | 20.7 | 27.6 | 123.3 |
| Upper Slope | 3.1 | - | 6.2 | 9.4 | 270.5 |
| **All Strata** | **2.4** | **4.2** | **6.7** | **12.7** | **769.5** |



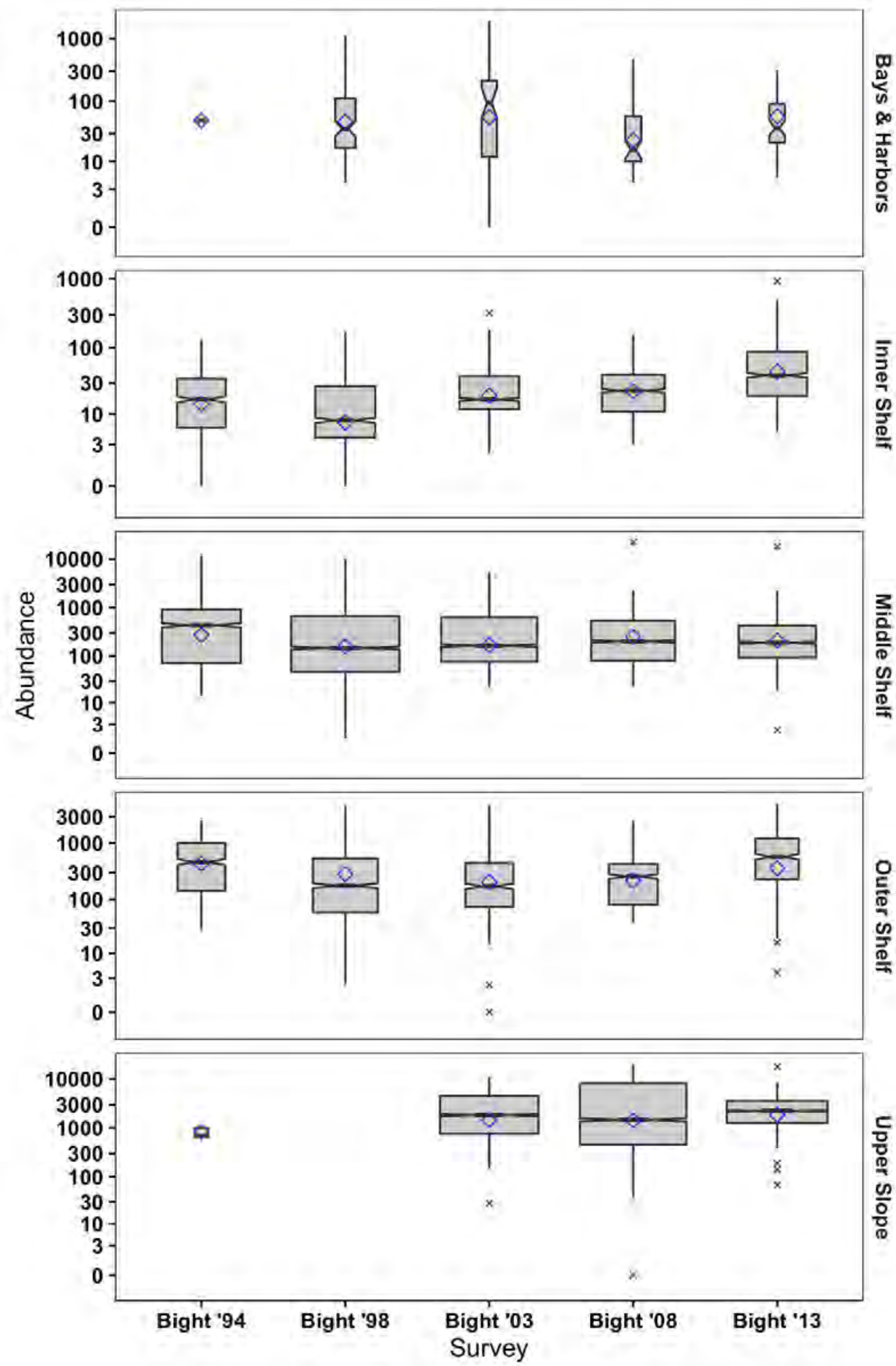

**Appendix B-19. Demersal fish abundance by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates width indicates relative sample size.**



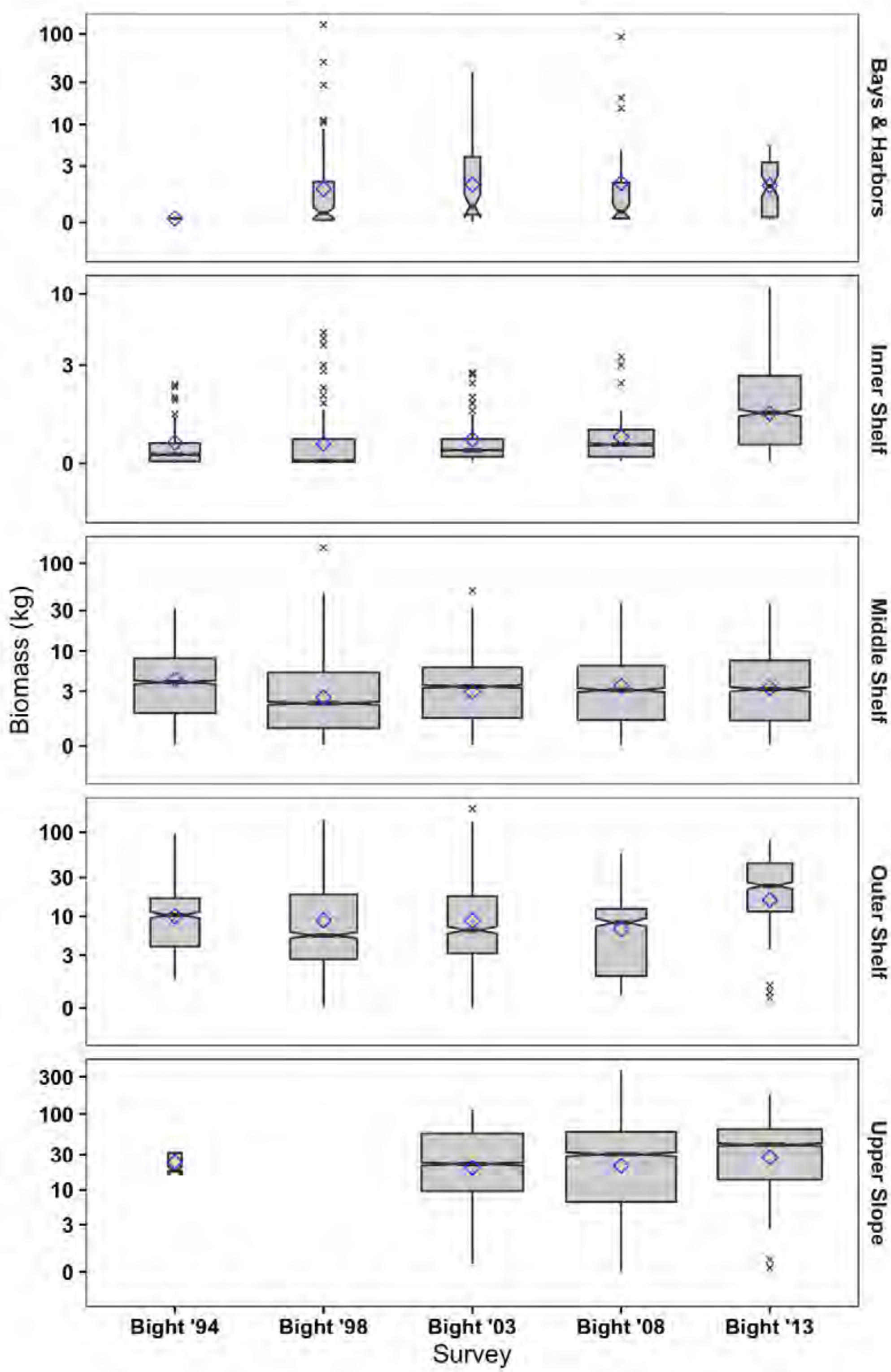

**Appendix B-20. Demersal fish biomass by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size.**



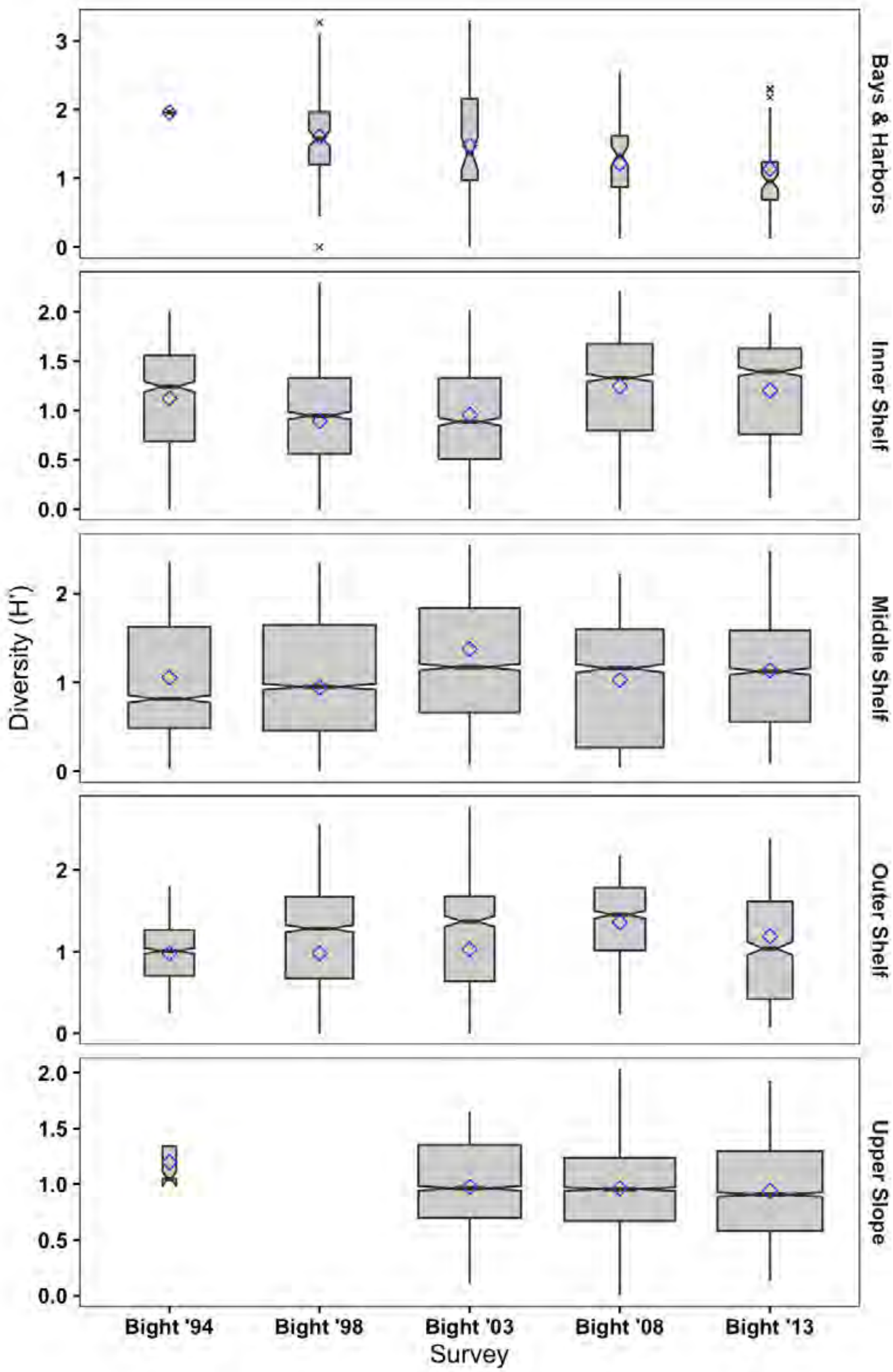

**Appendix B-21. Demersal fish diversity (Shannon, H') by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size.**



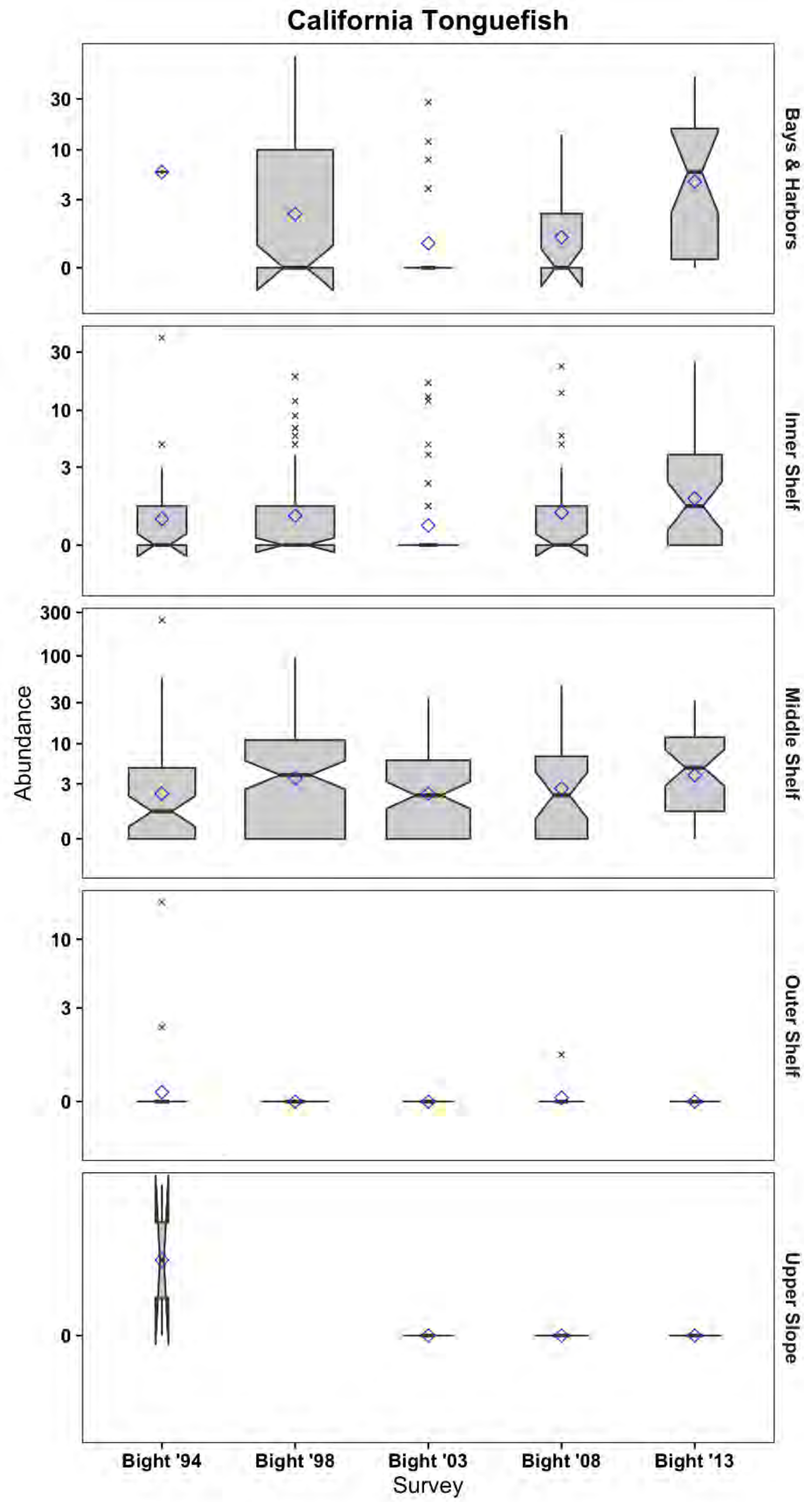

**Appendix B-22. Megabenthic invertebrate abundance by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size.**



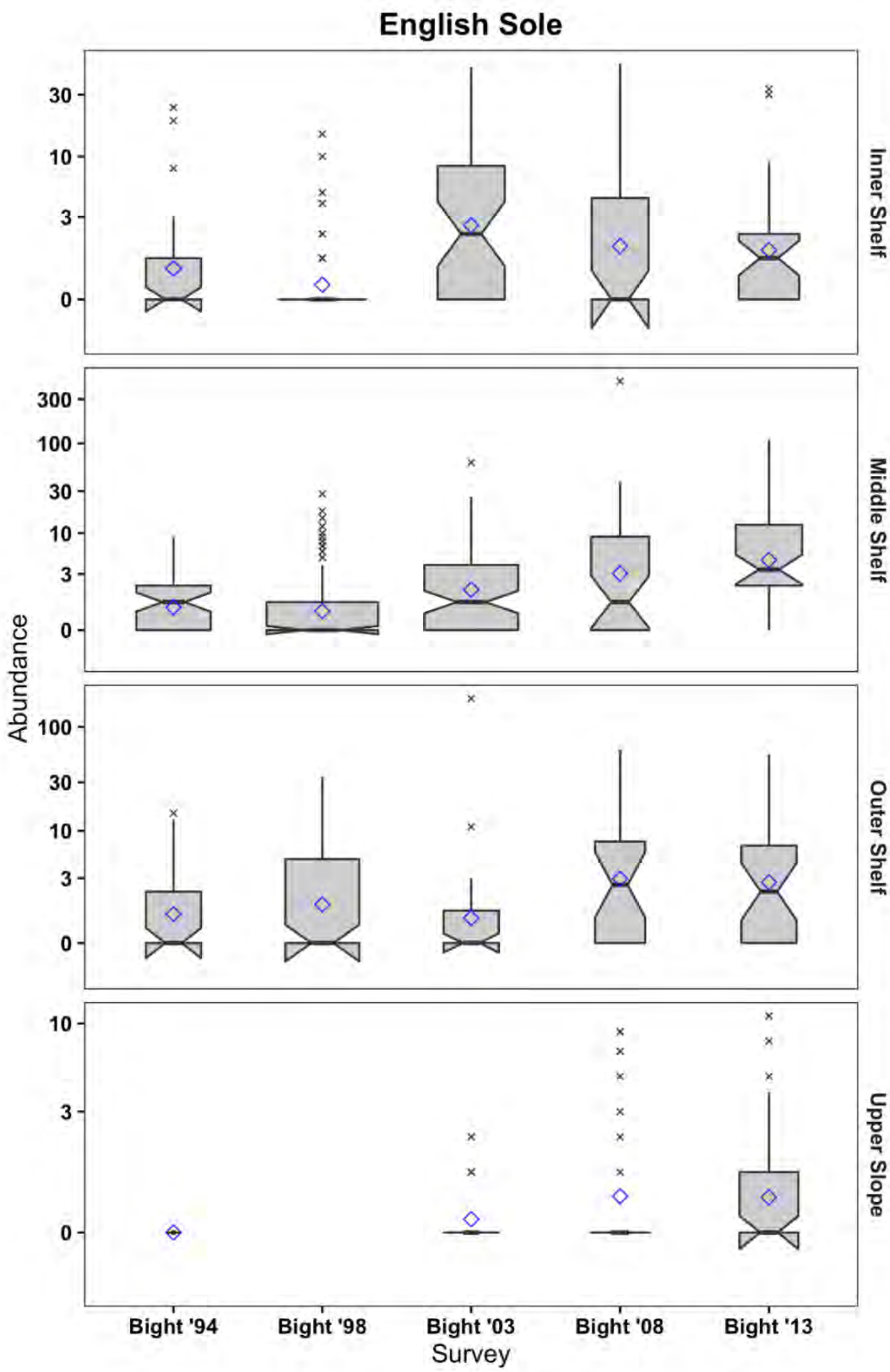

**Appendix B-23. Megabenthic invertebrate biomass by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size.**



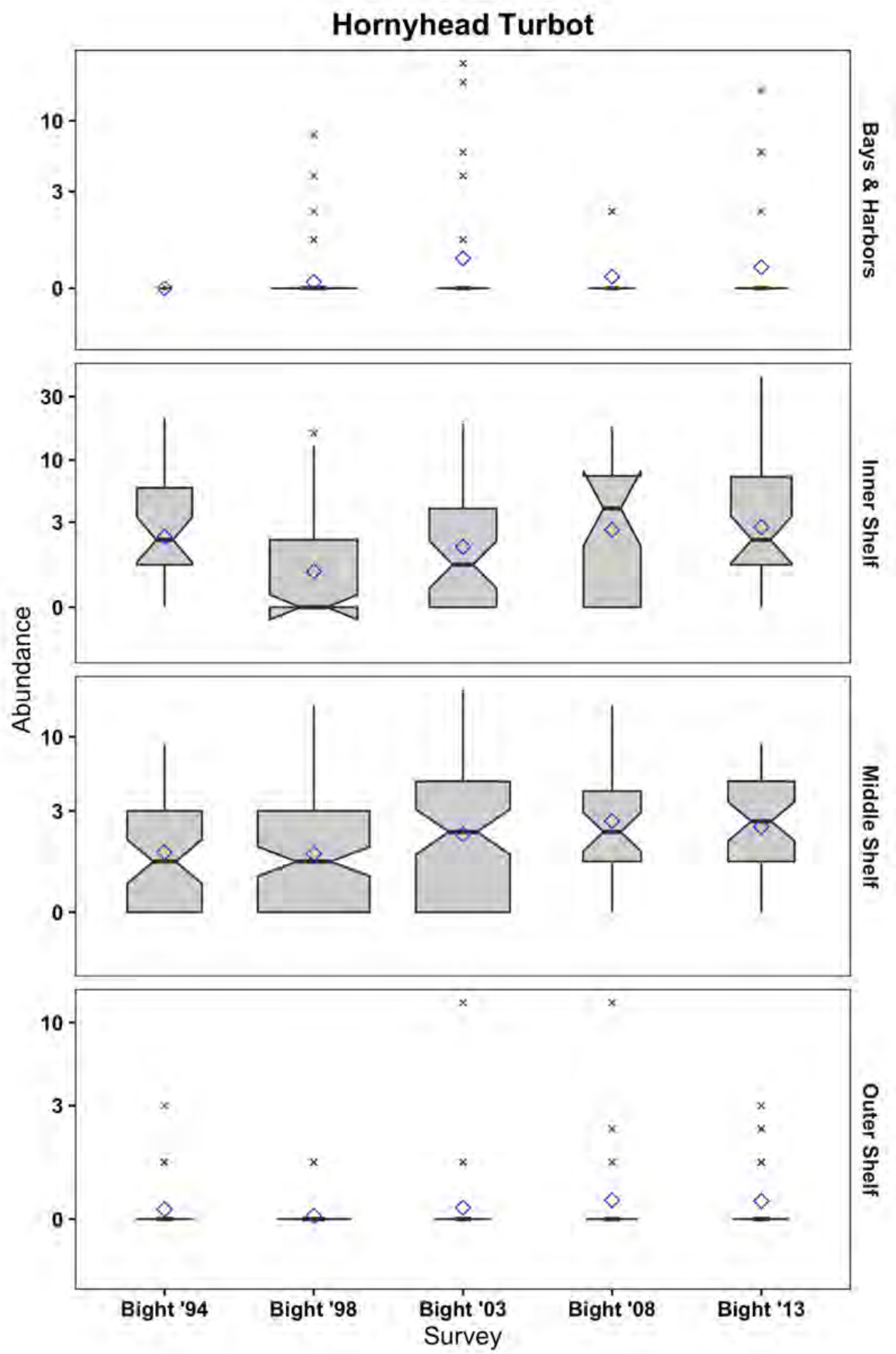

**Appendix B-24. Megabenthic invertebrate diversity (Shannon, H') by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size.**



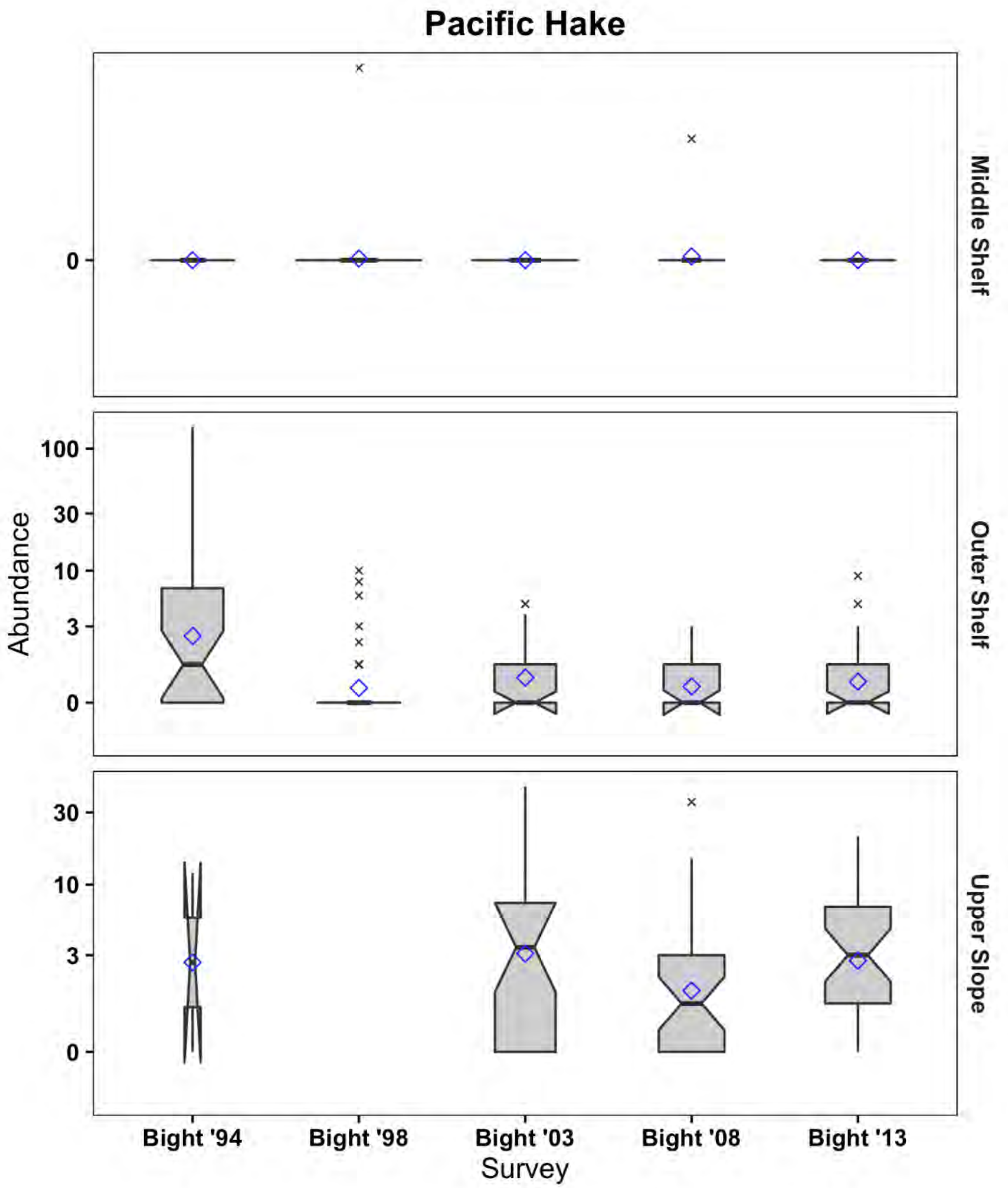

**Appendix B-25. Abundance of California Tonguefish by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size.**



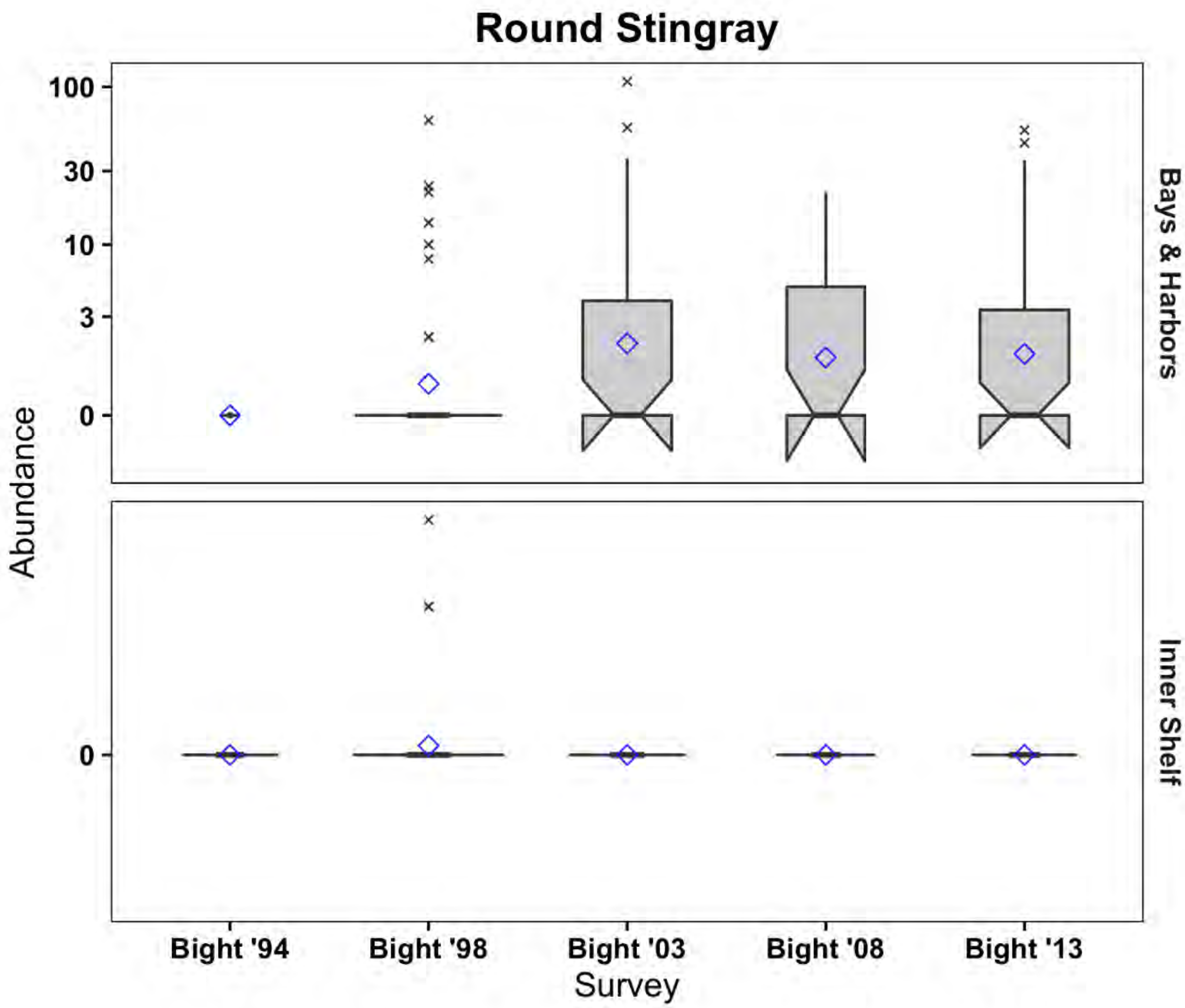

**Appendix B-26. Abundance of English Sole by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size.**



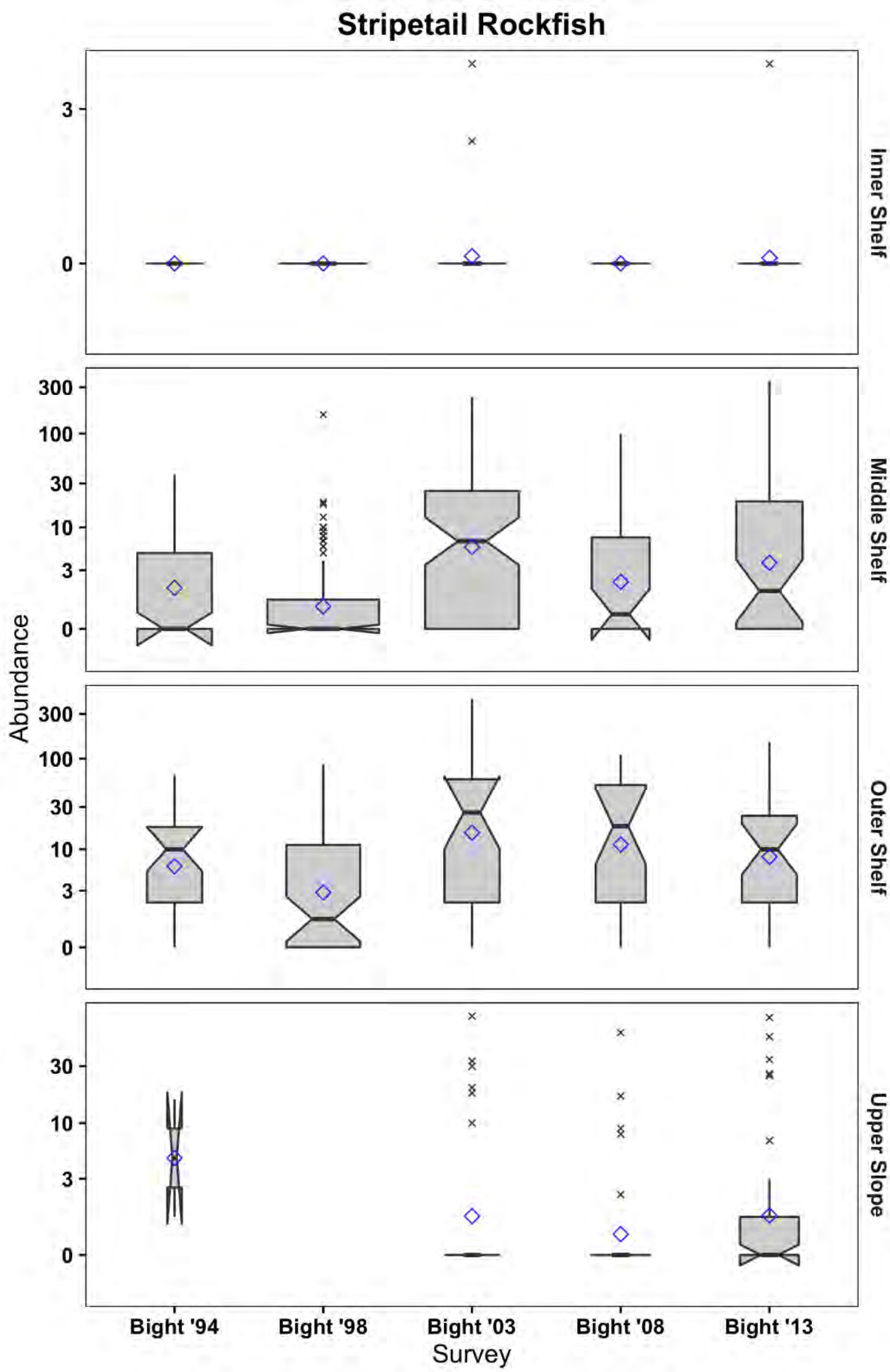

**Appendix B-27. Abundance of Hornyhead Turbot by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers (“x”). Box width indicates relative sample size.**



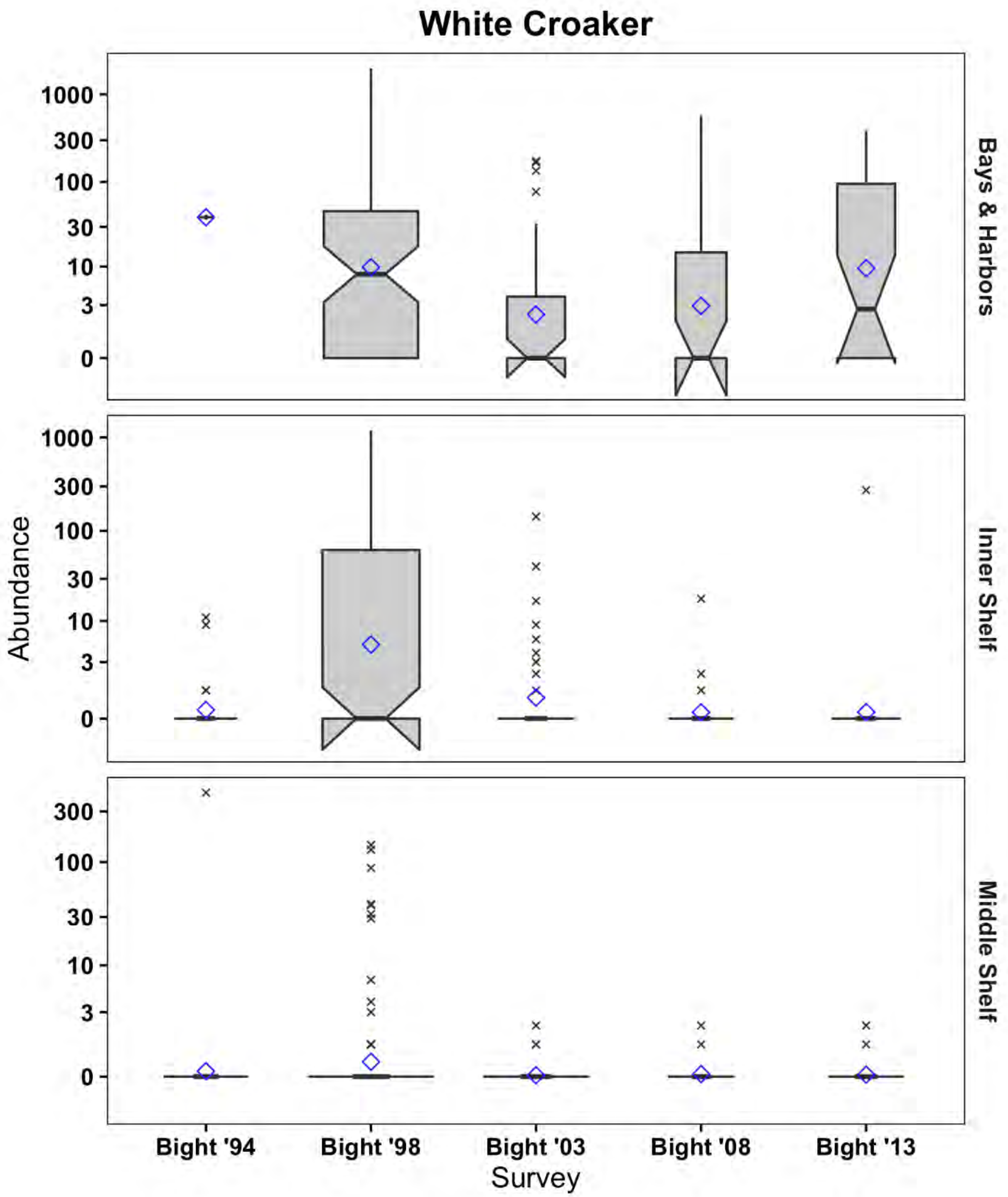

**Appendix B-28. Abundance of Pacific Hake by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers (“x”). Box width indicates relative sample size.**



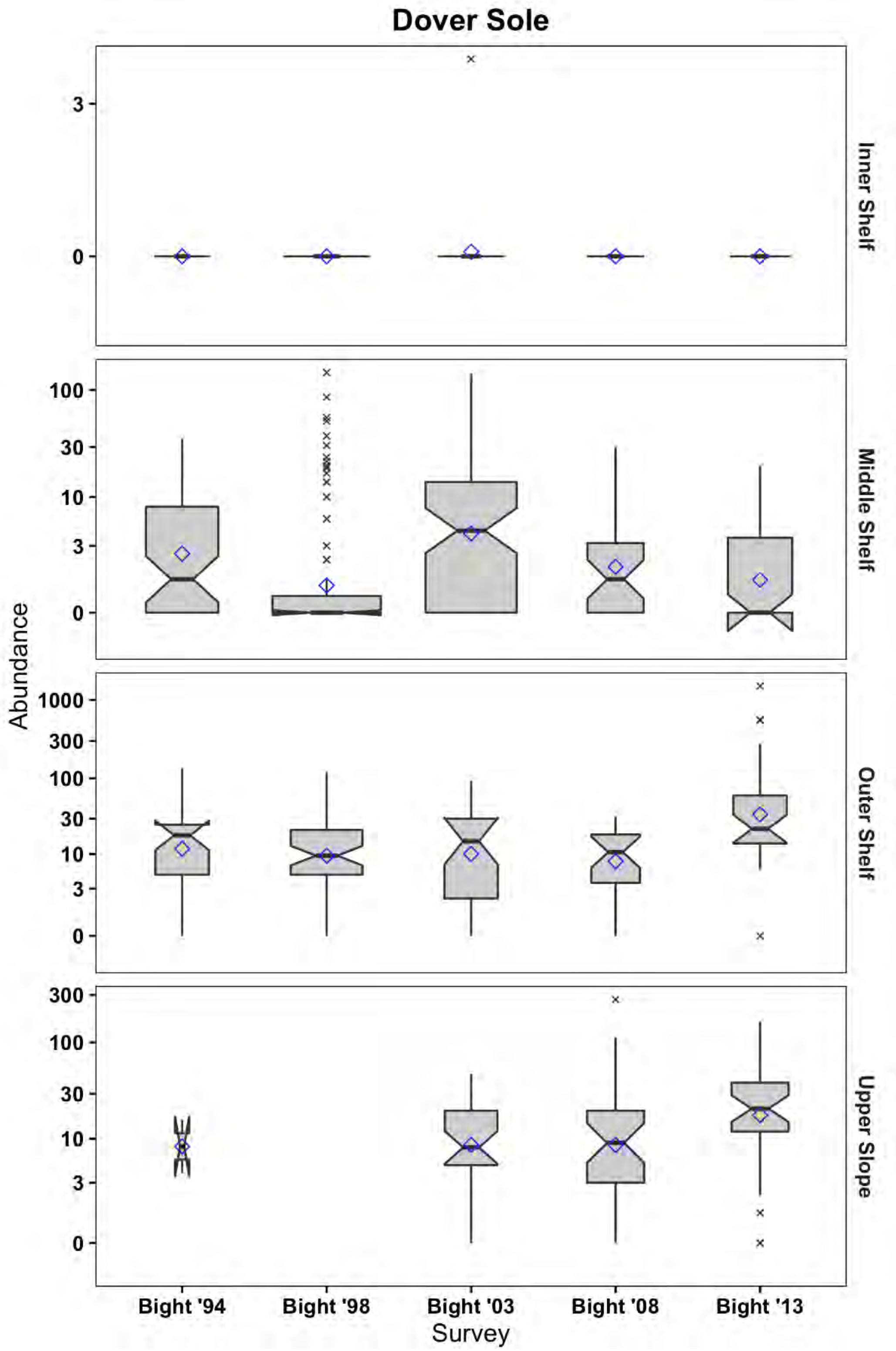

**Appendix B-29. Abundance of Round Stingray by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size.**



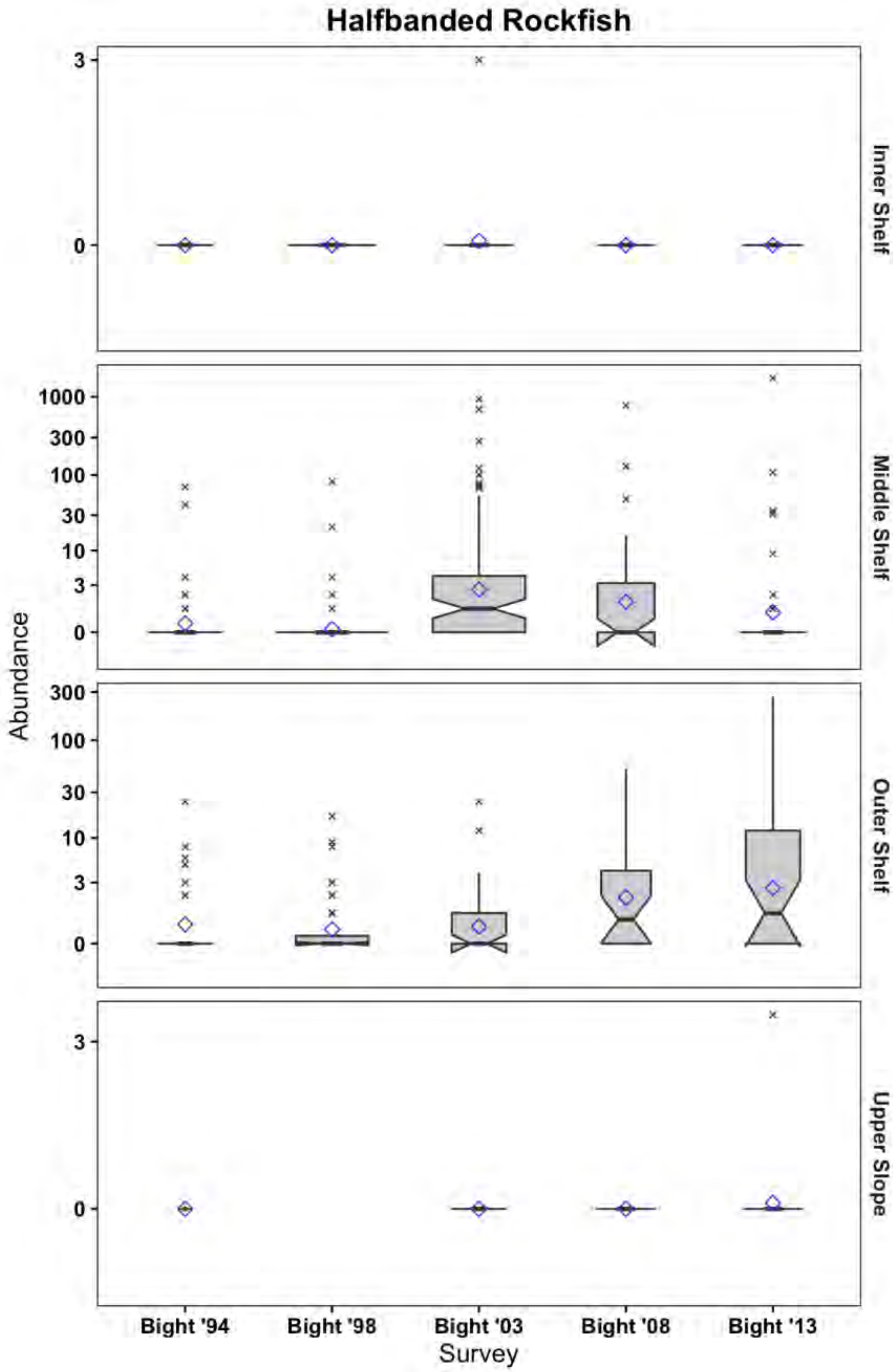

**Appendix B-30. Abundance of Stripetail Rockfish by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size.**



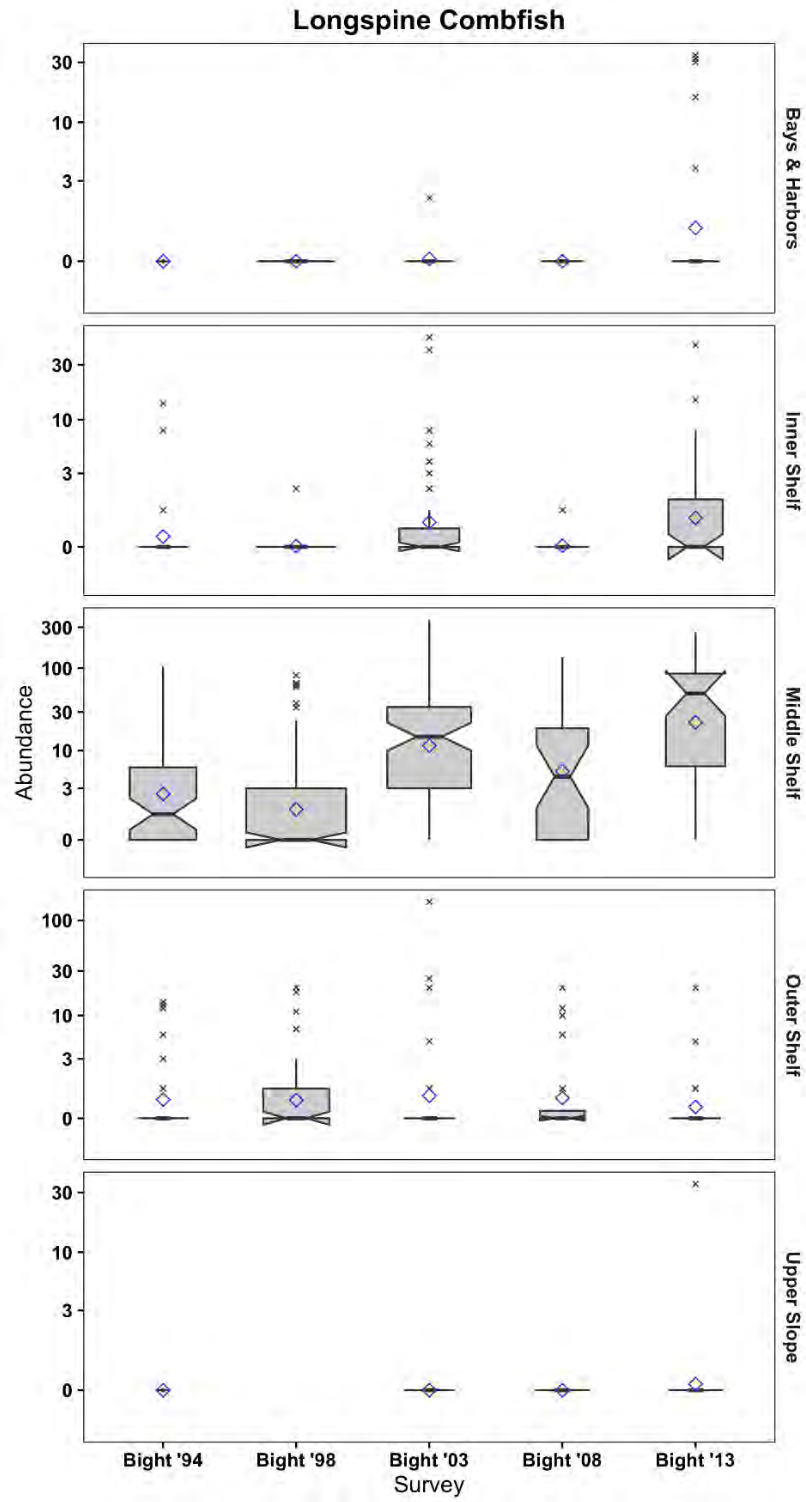

**Appendix B-31. Abundance of White Croaker by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers (“x”). Box width indicates relative sample size.**



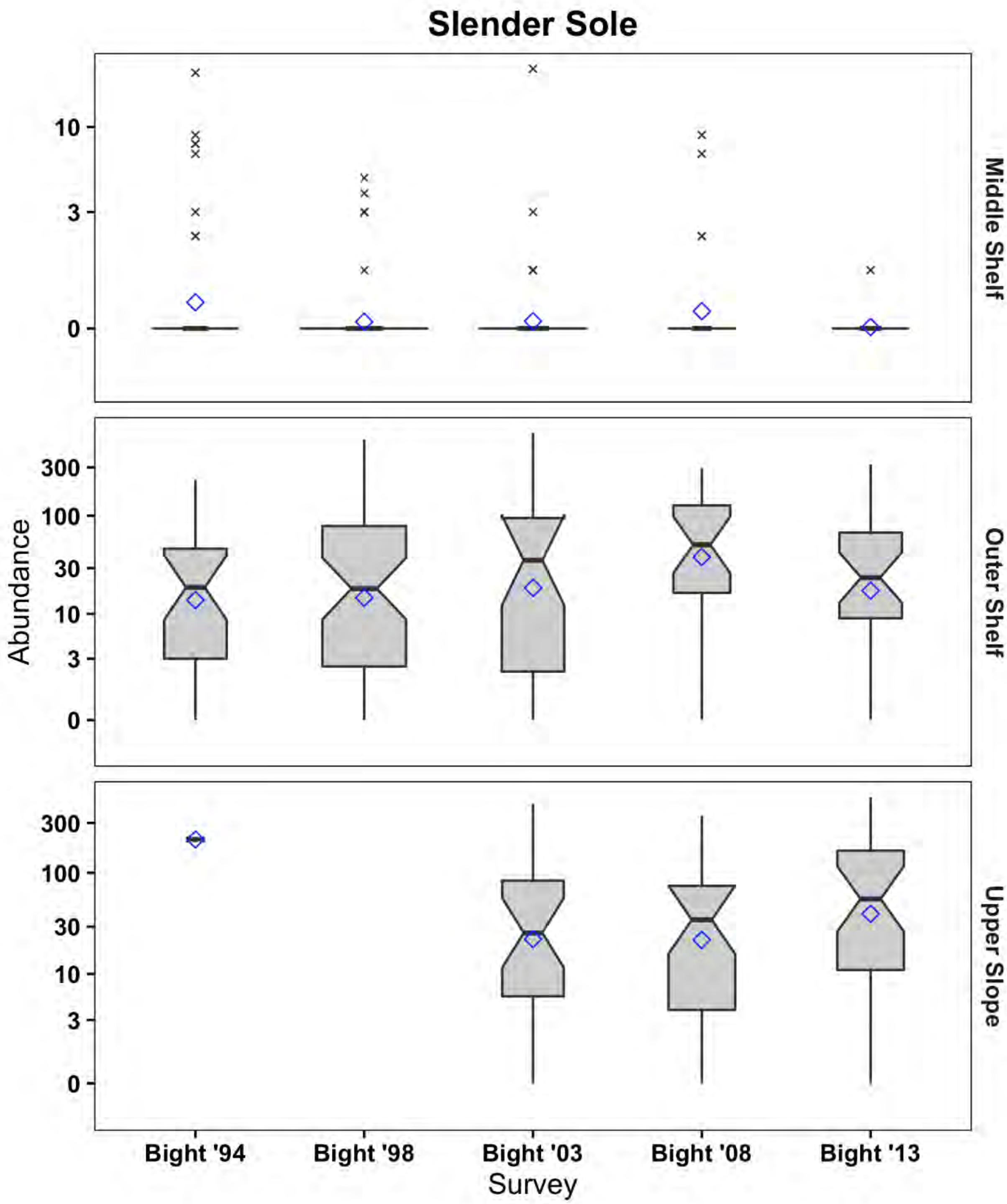

**Appendix B-32. Abundance of Dover Sole by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers (“x”). Box width indicates relative sample size.**



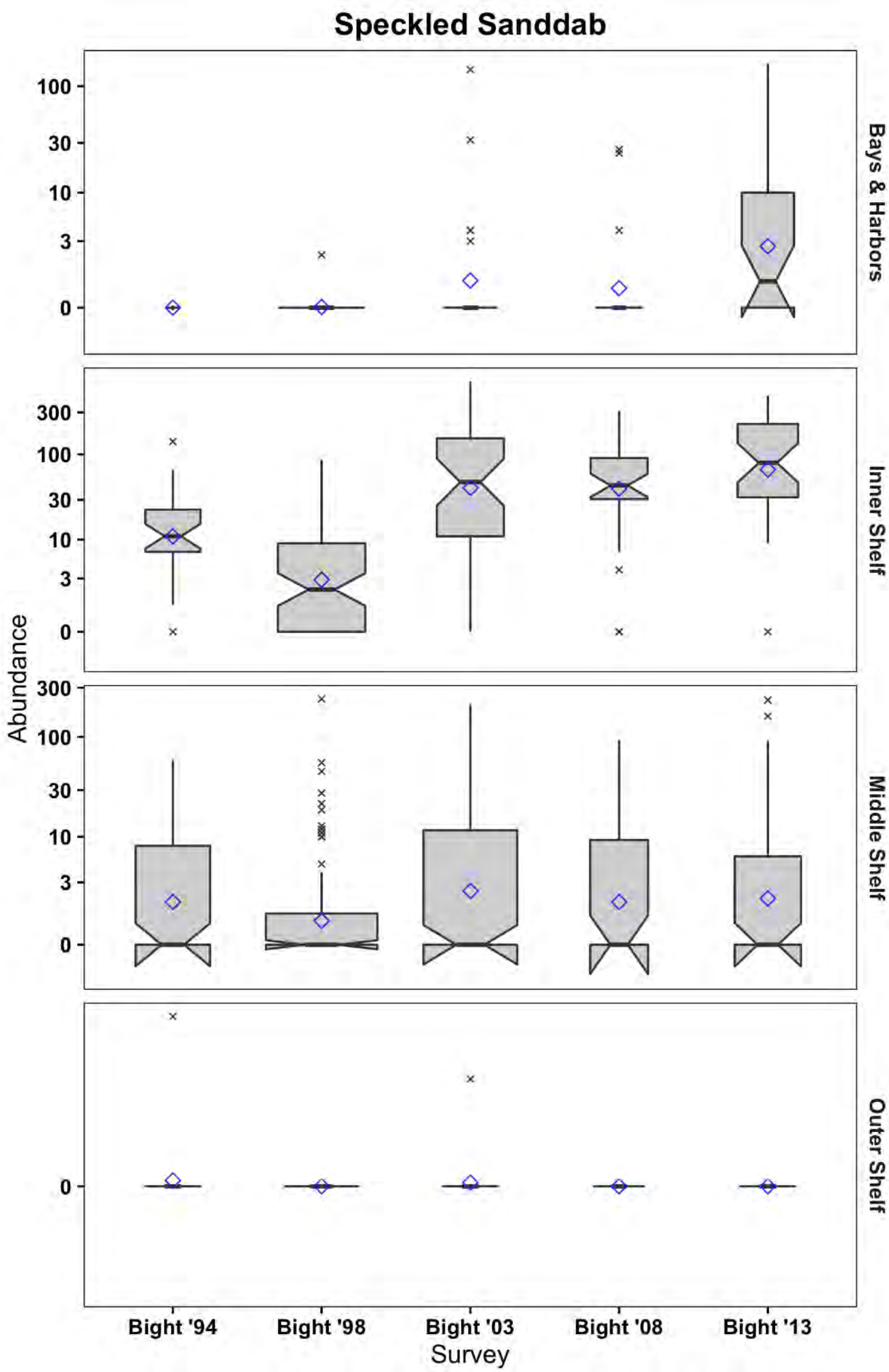

**Appendix B-33. Abundance of Halfbanded Rockfish by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers (“x”). Box width indicates relative sample size.**



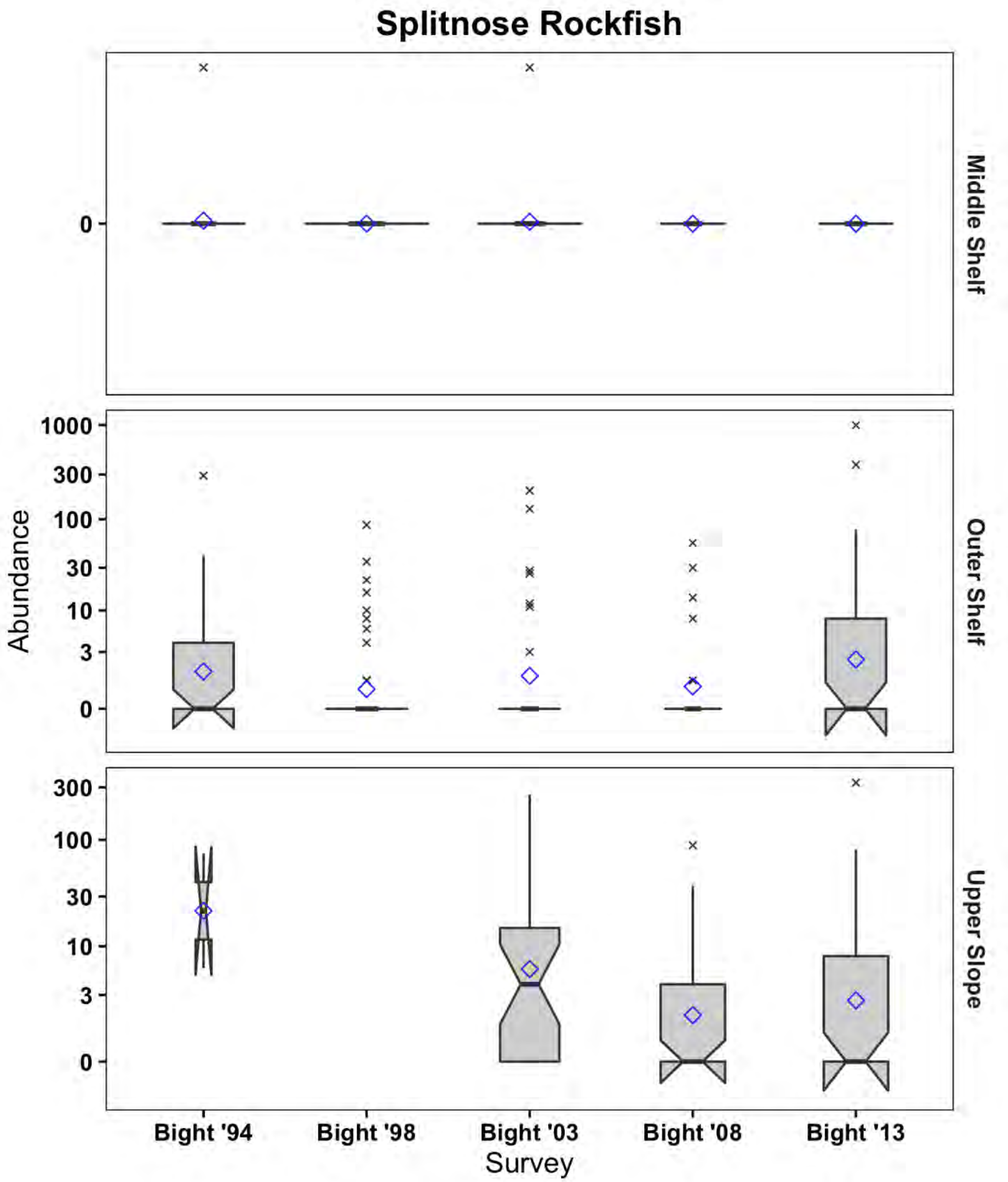

**Appendix B-34. Abundance of Longspine Combfish by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size.**



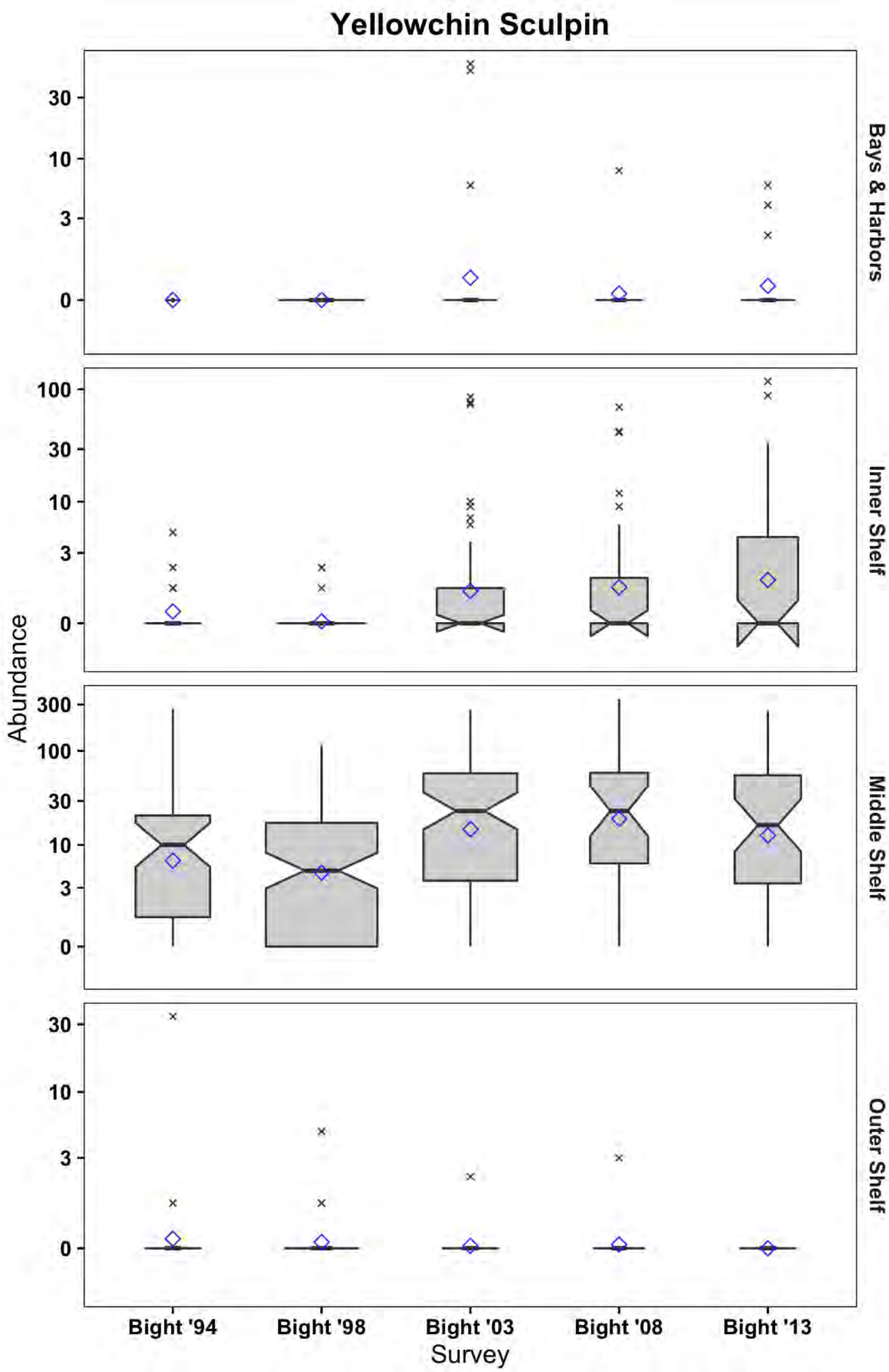

**Appendix B-35. Abundance of Slender Sole by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size.**



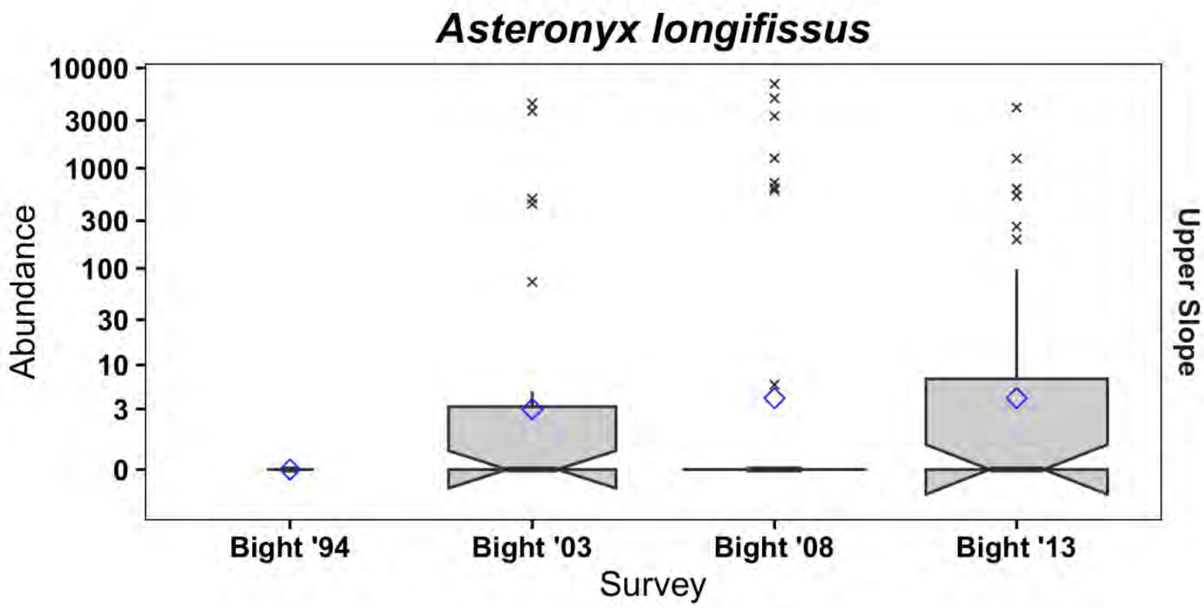

**Appendix B-36. Abundance of Speckled Sanddab by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size.**



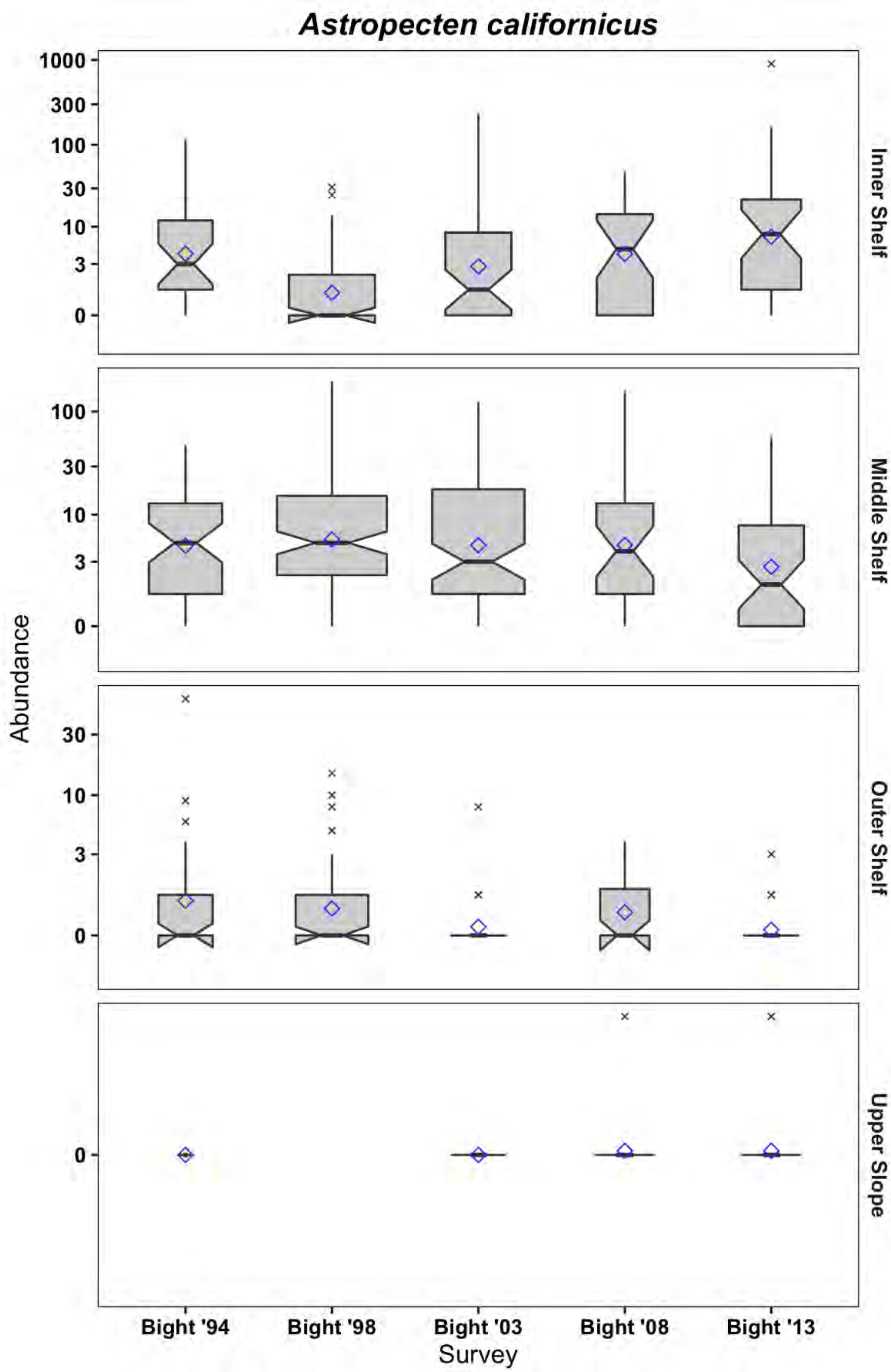

**Appendix B-37. Abundance of Splitnose Rockfish by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers (“x”). Box width indicates relative sample size.**



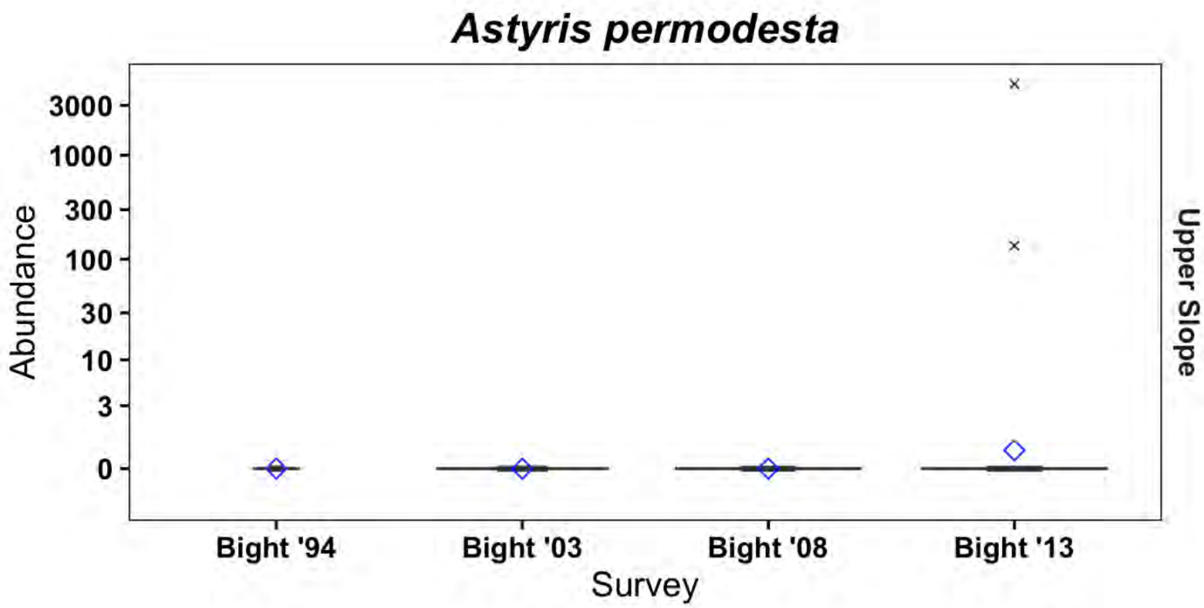

**Appendix B-38. Abundance of Yellowchin Sculpin by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size.**



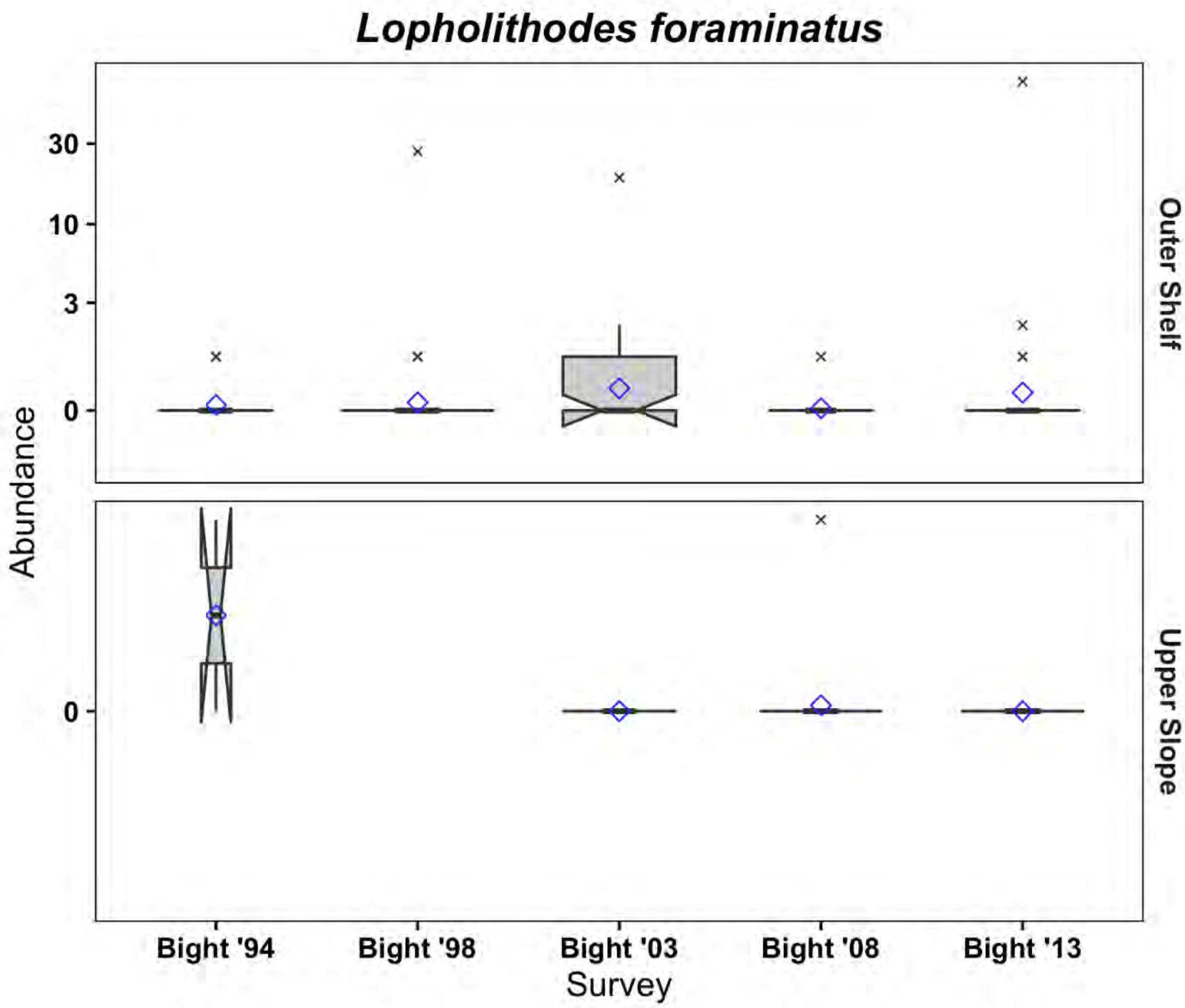

**Appendix B-39. Abundance of *Asteronyx longifissus* by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers (“x”). Box width indicates relative sample size.**



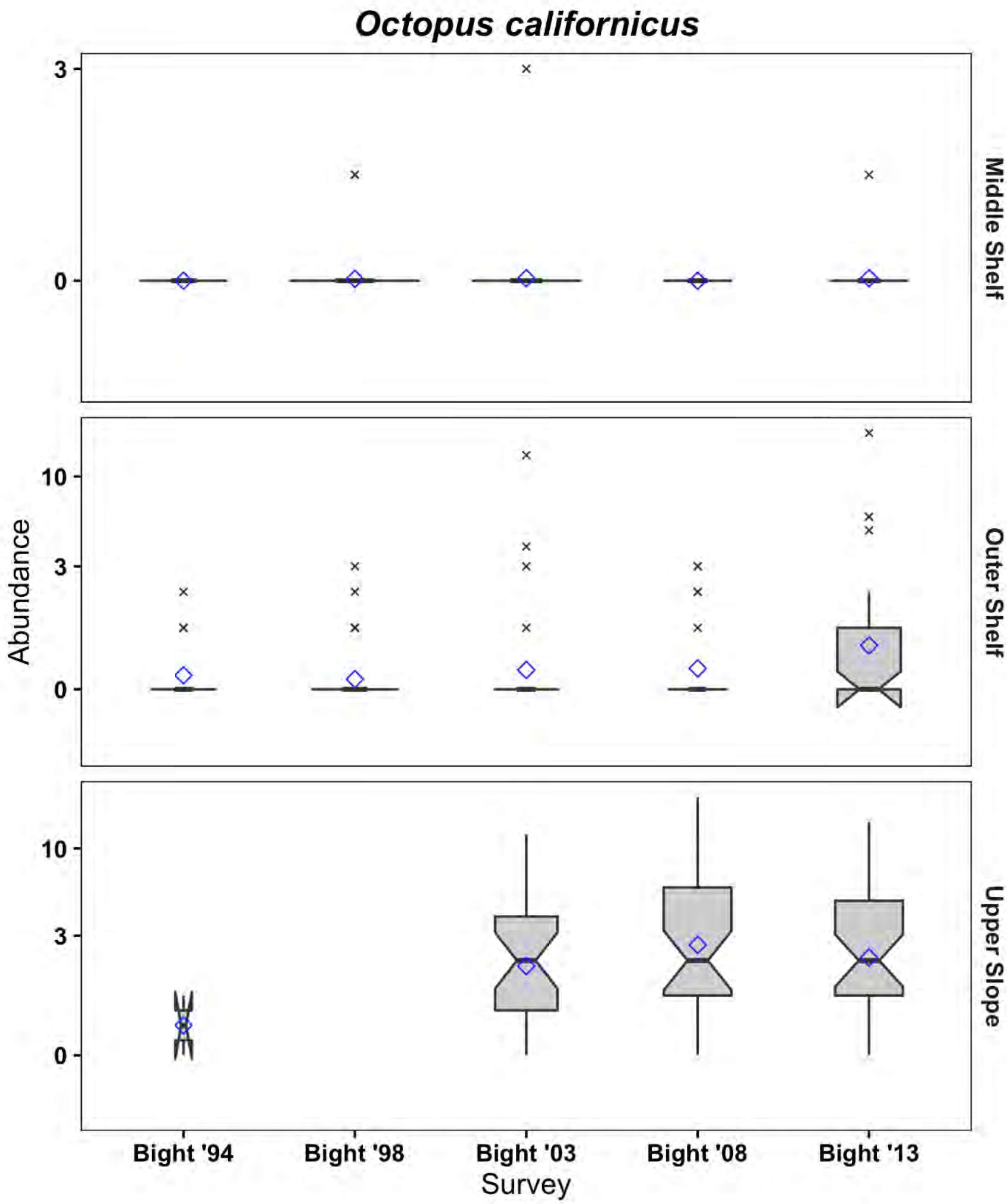

**Appendix B-40. Abundance of *Astropecten californicus* by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers (“x”). Box width indicates relative sample size.**



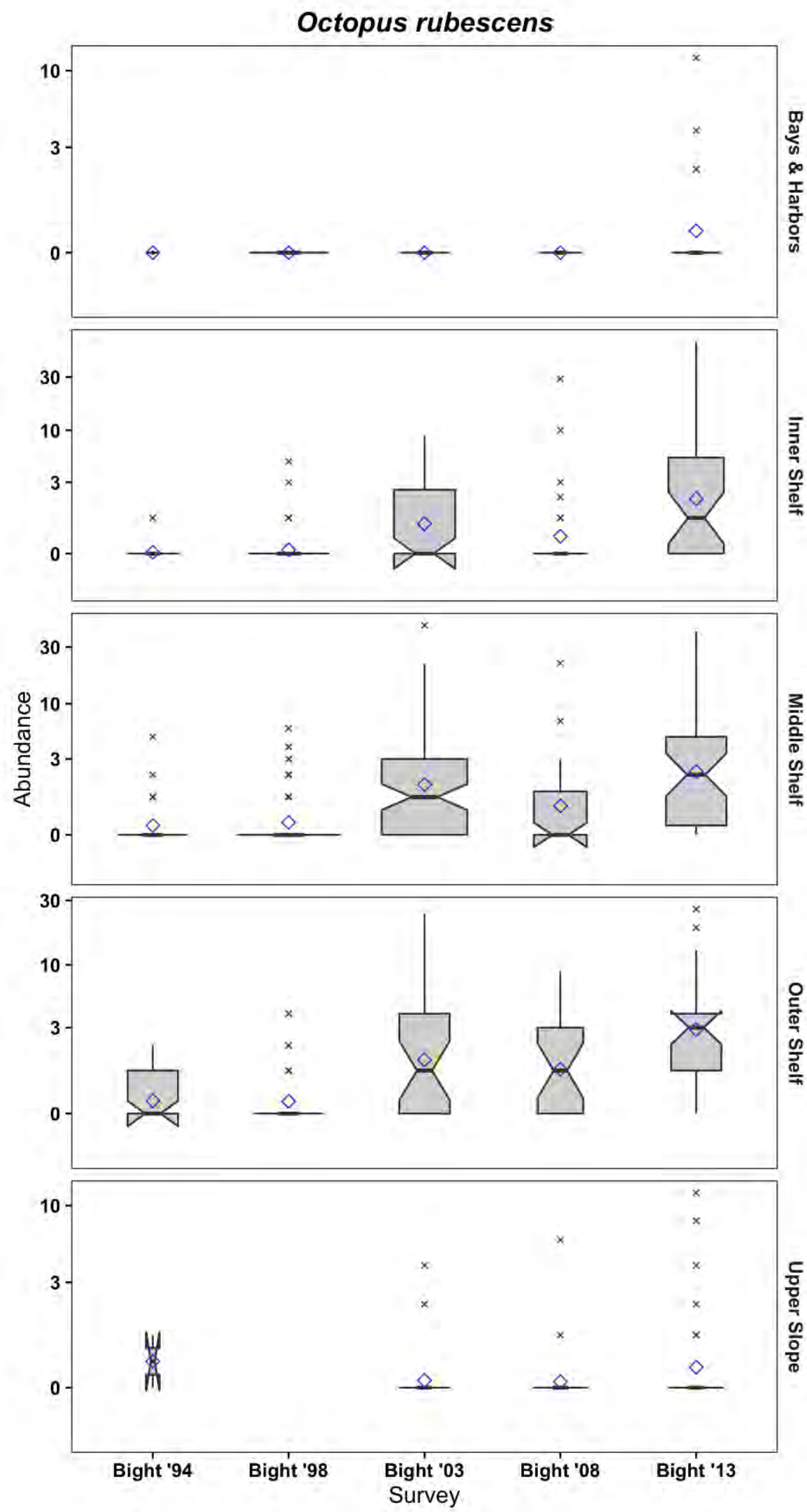

**Appendix B-41. Abundance of *Astyris permodesta* by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size.**



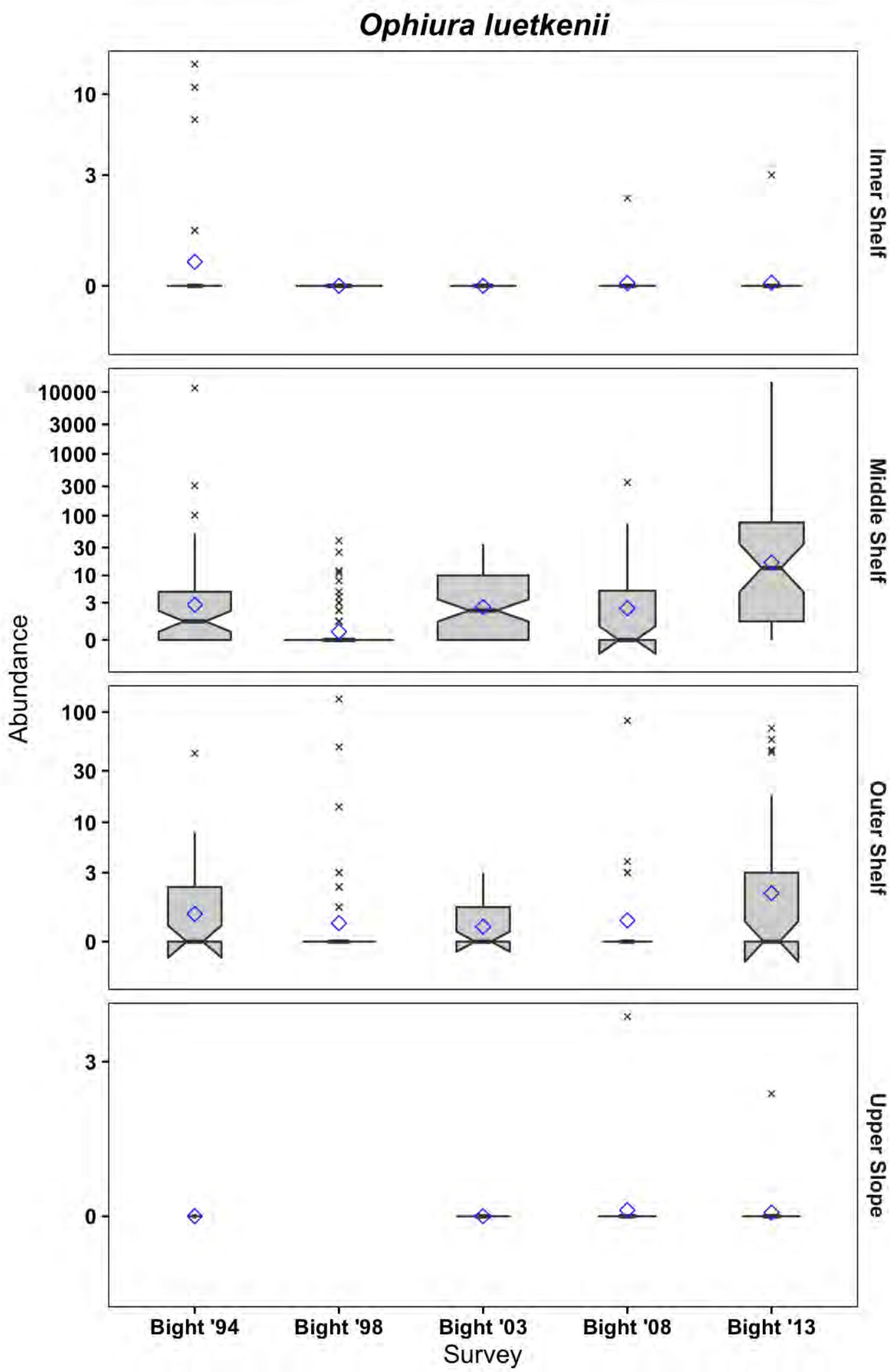

**Appendix B-42. Abundance of *Lopholitodes foraminatus* by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers (“x”). Box width indicates relative sample size.**



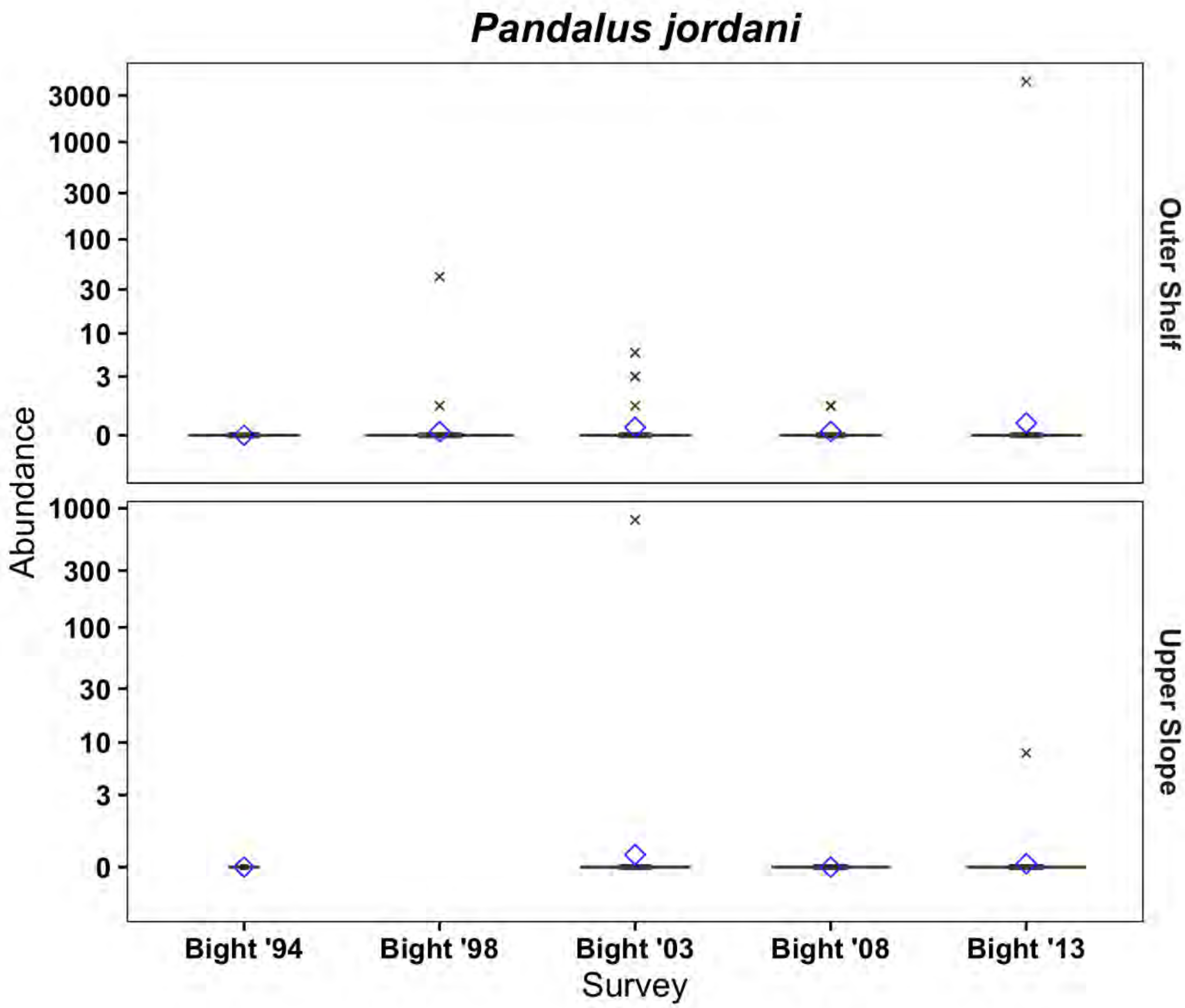

**Appendix B-43. Abundance of *Octopus californicus* by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers (“x”). Box width indicates relative sample size.**



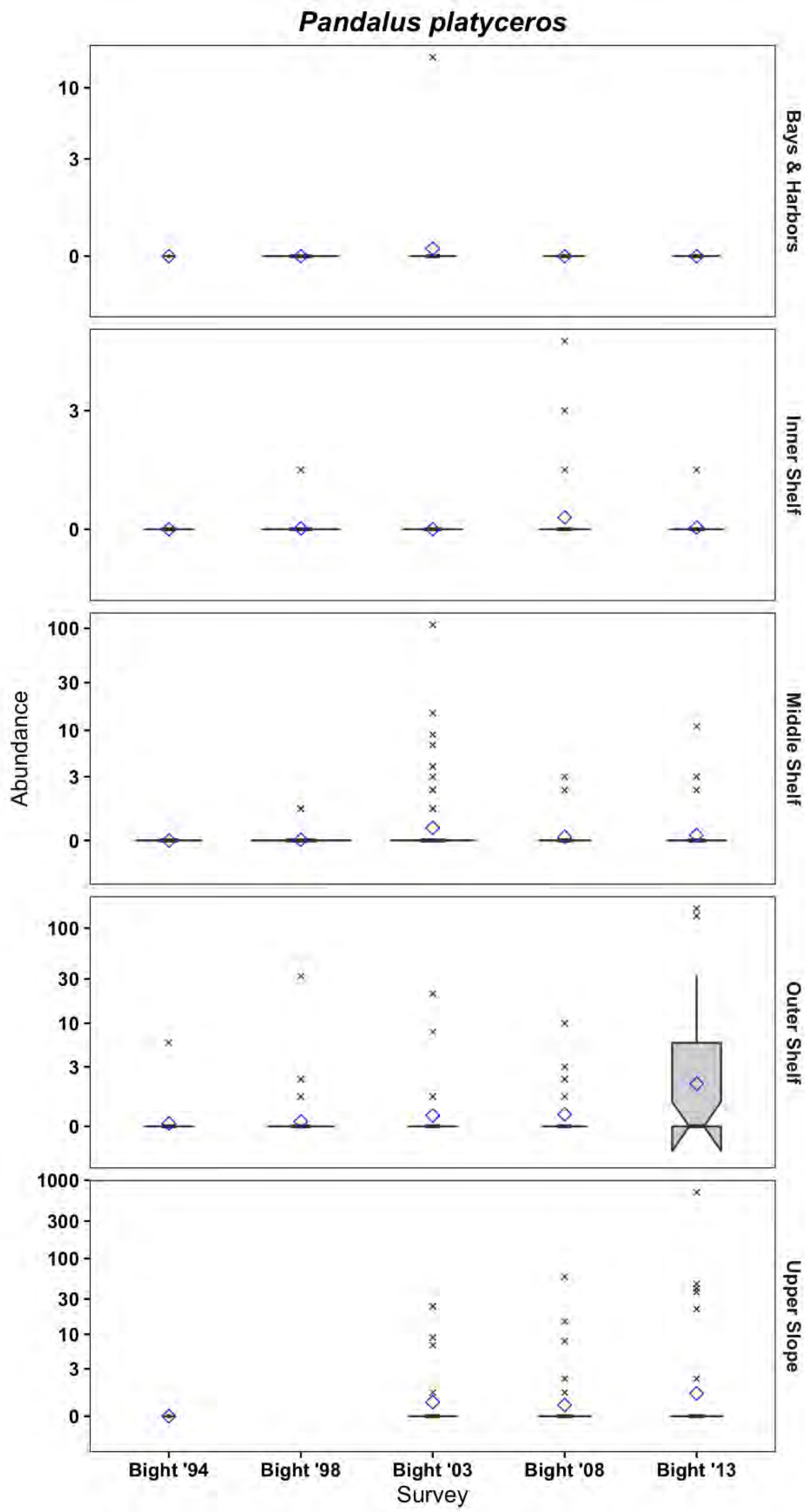

**Appendix B-44. Abundance of *Octopus rubescens* by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size.**



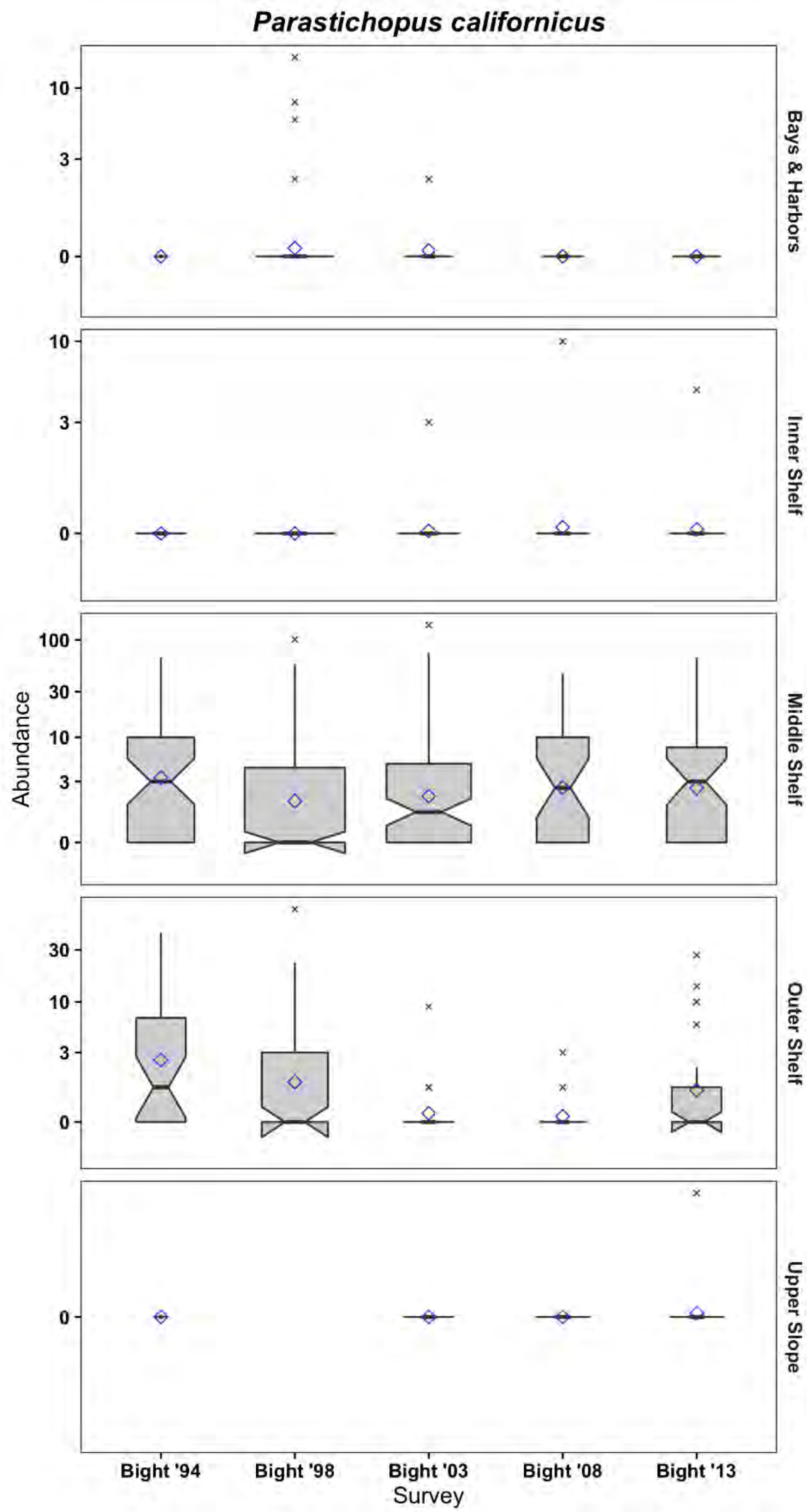

**Appendix B-45. Abundance of *Ophiura luetkenii* by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers (“x”). Box width indicates relative sample size.**



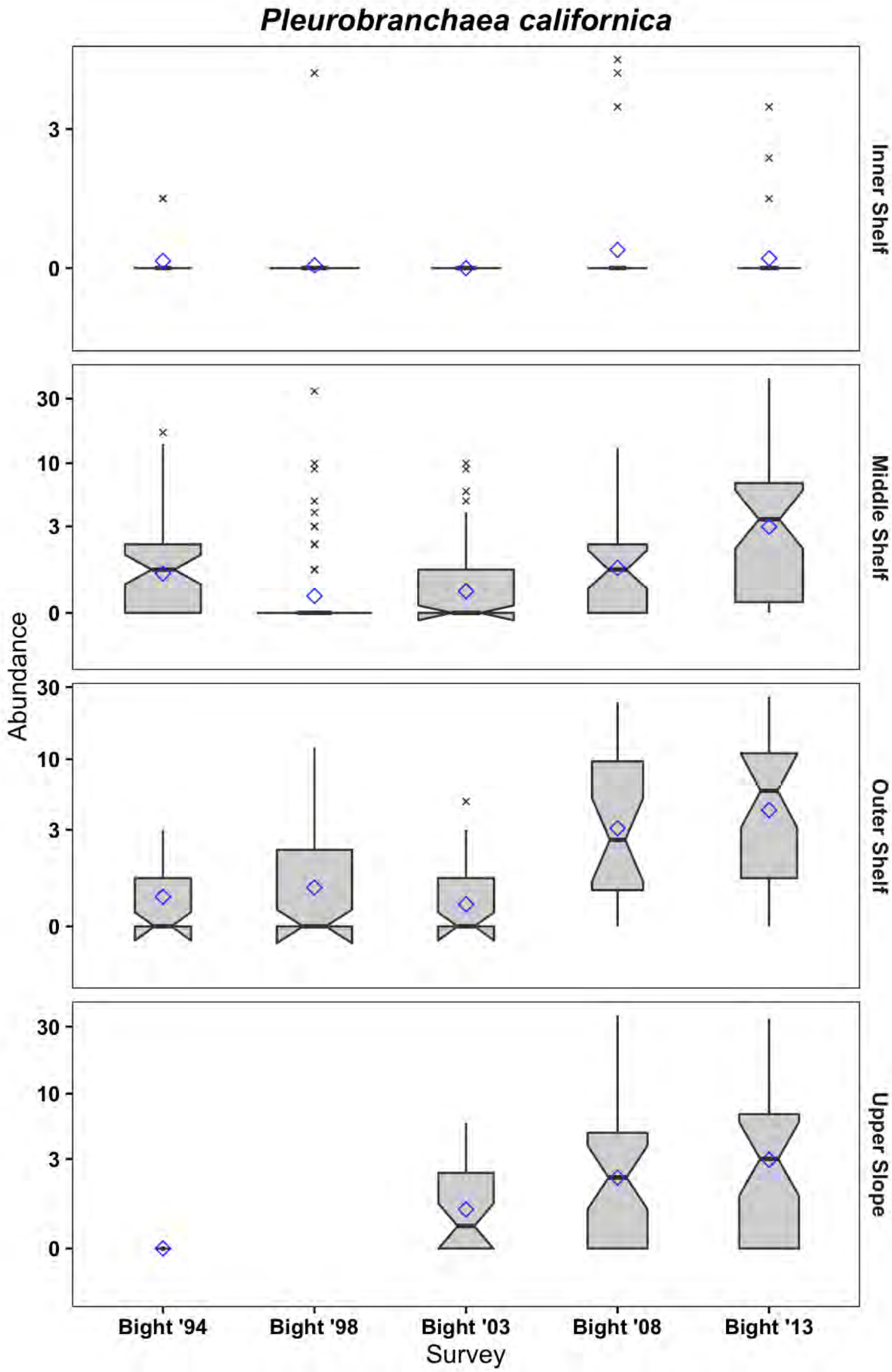

**Appendix B-46. Abundance of *Pandalus jordan*i by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size.**



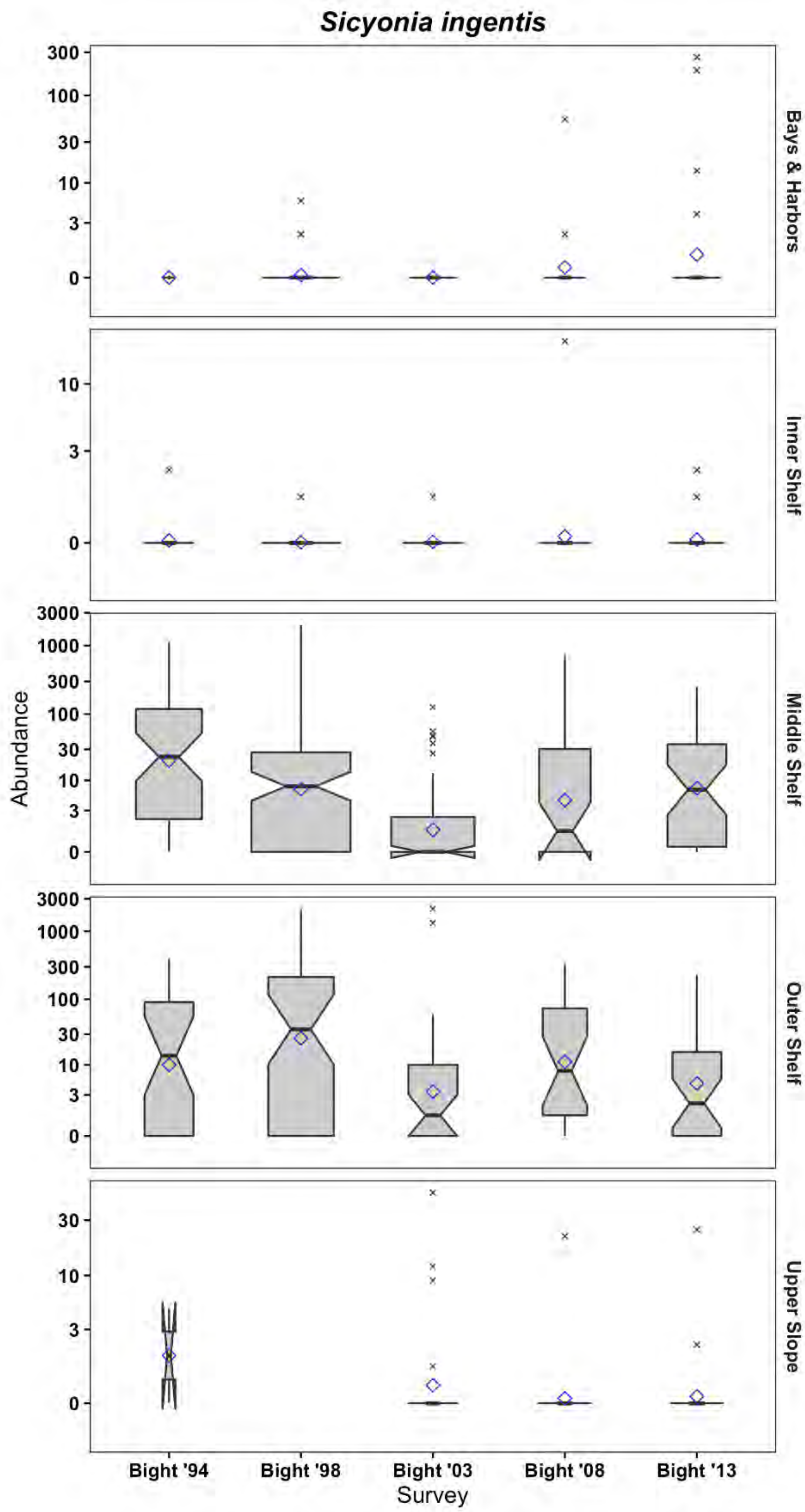

**Appendix B-47. Abundance of *Pandalus platyceros* by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size.**



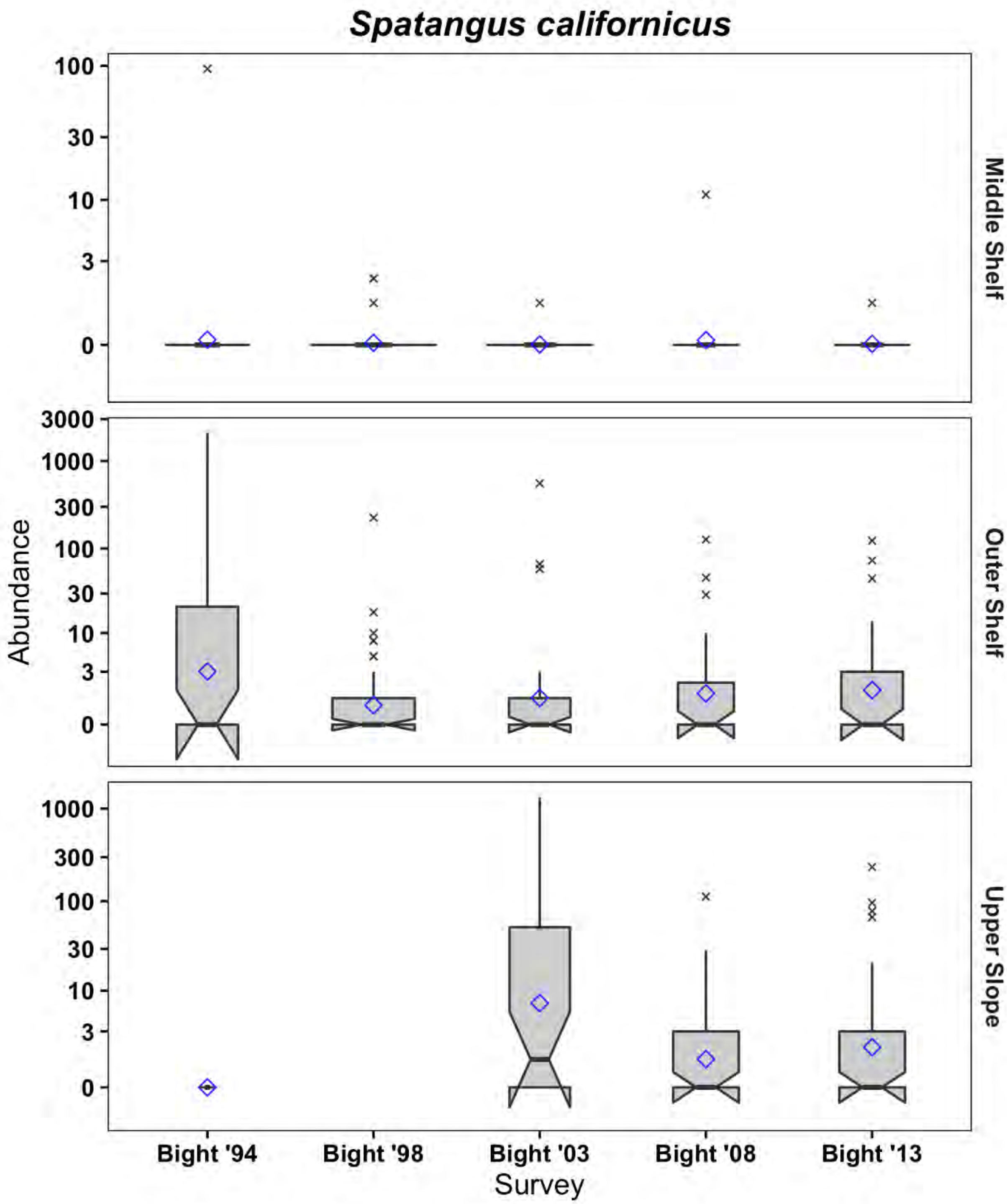

**Appendix B-48. Abundance of *Parastichopus californicus* by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size.**



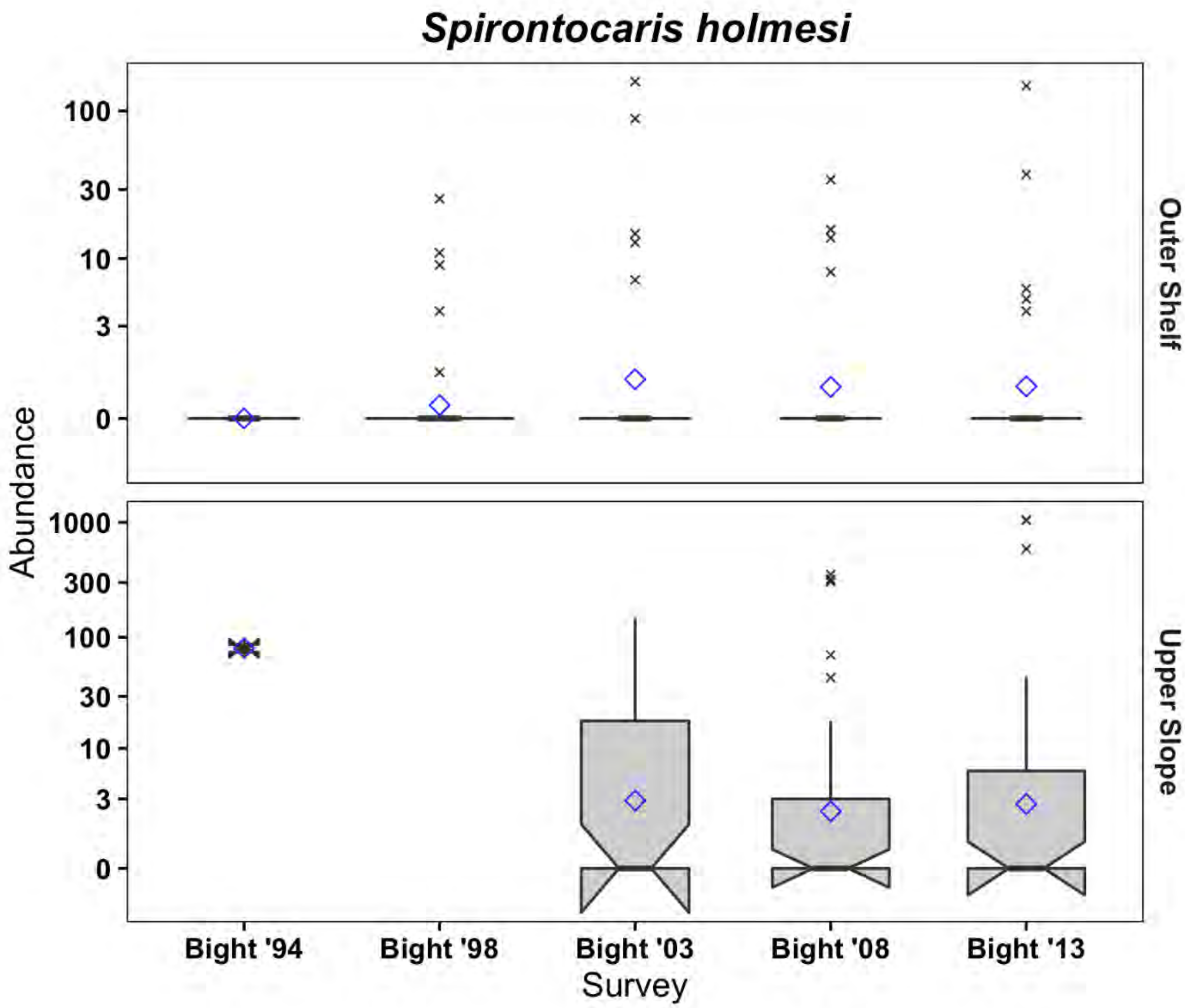

**Appendix B-49. Abundance of *Pleurobranchaea californica* by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size.**



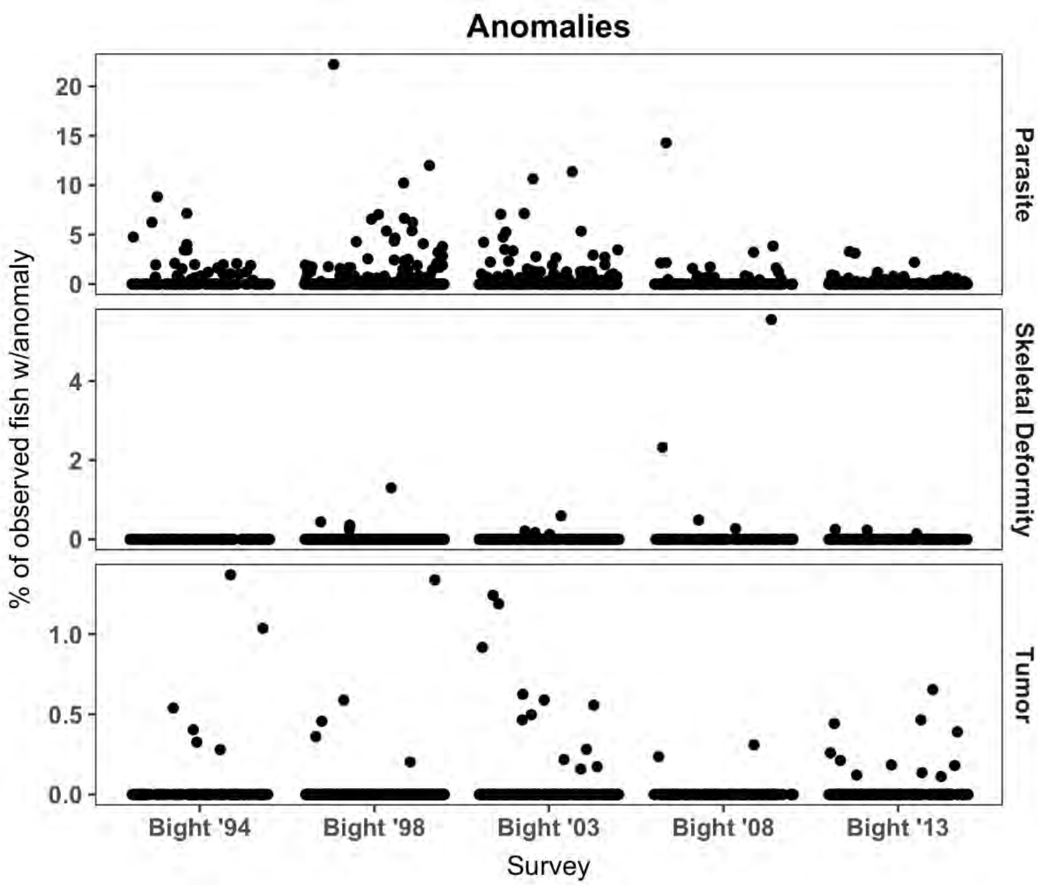

**Appendix B-50. Abundance of *Sicyonia ingentis* by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size.**




**Appendix B-51. Abundance of *Spatangus californicus* by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size.**




**Appendix B-52. Abundance of *Spirontocaris holmesi* by stratum and survey. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size.**




**Appendix B-53. Percent observed fish with parasite, skeletal deformity, and tumor anomalies by survey and anomaly type.**

**Literature Cited**

Eschmeyer, W.N. and E.S. Herald. 1983. A field guide to Pacific Coast fishes of North America from the Gulf of Alaska to Baja California. Houghton Mifflin, Boston.

Page, L.M., H. Espinosa-Pérez, L.T. Findley, C.R. Gilbert, R.N. Lea, N.E. Mandrak, R.L. Mayden and J.S. Nelson 2013. Common and scientific names of fishes from the United States, Canada, and Mexico p. 243. Bethesda, Maryland: American Fisheries Society.

# APPENDIX C:  POTW OUTFALL COMPARISON

## Station Information



## Demersal Fishes



## Megabenthic Invertebrates

## APPENDIX C: POTW OUTFALL COMPARISON

Demersal fish and megabenthic invertebrate data collected from the Southern California Bight 2013 Regional Monitoring Program (Bight ‘13) stations were compared to those collected from Publicly Owned Treatment Works (POTWs) monitoring stations located within the Southern California Bight (SCB) to evaluate habitat conditions within the monitoring regions against conditions present throughout the SCB. POTW data used for this comparison were provided by Aquatic Bioassay Consulting Laboratories Inc., on behalf of the City of Oxnard (Oxnard), the City of Los Angeles (CLAEMD), the Sanitation Districts of Los Angeles County (LACSD), the Orange County Sanitation District (OCSD), and the City of San Diego for the Point Loma Ocean Outfall (CSD-PLOO) and the South Bay Ocean Outfall (CSD-SBOO). Each agency submitted data for all stations within their monitoring area. POTW trawl surveys were conducted during the same time period as the Bight ’13 survey (July-September 2013), as well as during the same months in 2012 for CLAEMD, OCSD and Oxnard.

### Data Analysis

Comparisons between Bight ’13 and POTW demersal fish and megabenthic invertebrate data included the following community parameters:

**Abundance**, computed as the total number of individuals in a sample.

**Shannon diversity** (Shannon 1948) was used to compare species diversity (Hill 1973). It accounts for both richness (number of species per unit area) and evenness (their relative abundance). It was computed as:

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

where $n_j$ is number of individuals in the $j^{th}$ species in the sample, $S$ is the total number of species in the sample, and $N$ is the number of individuals in the sample.

The Number of species, calculated as the total number of taxa in a sample, and the **Margalef index** (Margalef 1958) was used to compare species richness. Margalef is a measure of the number of species present ($S$) for a given number of individuals ($N$):

$$d = (S-1) / \log N$$

The **Pielou index** (Pielou 1969) was used to compare equitability or evenness between samples. It was computed as:

$$J' = H' / \ln(S)$$

where $H'$ is Shannon diversity and $S$ is the total number of species in a sample, across all samples in dataset.

$J'$ is constrained between 0 and 1. The less variation in communities between the species, the higher the evenness ($J'$).

**Simpson's index** (Simpson 1949) was used to compare dominance. It measures the probability that any two individuals from the same sample, chosen at random, are from the same species. It was computed as:

$$\lambda = \sum_{i=1}^{R} p_i^2$$

where $p_i$ is the proportion of individuals in the total (i.e., it is the number of individuals of one species divided by the total number of individuals).

Additional analyses for demersal fish included the Fish Response Index (FRI), length frequencies for the top 10 most abundant fish species and for the fish species with high P-code values, and fish anomalies.

## Graphical Analyses

Box plots using POTW data are compared to tolerance intervals computed for the 10th and 90th percentiles of the Bight '13 data with confidence intervals of 95% ($\alpha = 0.05$). These tolerance intervals portray the SCB region covering 90% of the population distribution with 95% confidence.

Demersal fish and megabenthic invertebrate community composition among the different stratums was evaluated using non-metric Multi-Dimensional Scaling (nMDS) ordination of Bray-Curtis similarity values calculated using log(x+1) transformed data from all Bight '13 and POTW stations. The following species were excluded from the dataset for comparability within the POTW agencies as well as to the Bight '13 trawl invertebrate data: *Aglaophenia* sp, *Plumularia* sp, and *Thalamoporella californica*.

### Multivariate Analyses: Ordination and Clustering

Multivariate analyses were conducted using vegan (Oksanen et al. 2017). A log(x+1) transformation was performed on the invertebrate and fish abundance datasets, resulting in a data matrix for each dataset which decreased the influence of prevalent species and increased the weight of rare species. A Bray-Curtis similarity matrix was created from transformed data. Input data were the abundances of taxa occurring in the trawl surveys.

**Table C-1. List of POTW monitoring stations by stratum, for which data were provided for POTW/Bight '13 comparison. Oxnard= City of Oxnard, CLAEMD = City of Los Angeles Environmental Monitoring Division, LACSD = Sanitation Districts of Los Angeles County, OCSD = Orange County Sanitation District, CSD-PLOO = City of San Diego-Point Loma Ocean Outfall, and CSD-SBOO = City of San Diego-South Bay Ocean Outfall.**

| Stratum | Agency | Station | Latitude | Longitude | Depth (m) | Survey Year |
|---|---|---|---|---|---|---|
| Bay | CLAEMD | HT10 | 33.7143 | -118.2458 | 22 | 2012 |
| | | HT12 | 33.7242 | -118.2426 | 20 | 2012, 2013 |
| | | HT13 | 33.7227 | -118.2426 | 14 | 2012 |
| | | HT7 | 33.7239 | -118.2448 | 10 | 2012, 2013 |
| | | HT9 | 33.7260 | -118.2350 | 10 | 2012 |
| Inner Shelf | Oxnard | RWT-001 | 34.1318 | -119.2063 | 20 | 2012 |
| | | RWT-002 | 34.1231 | -119.1906 | 20 | 2012 |
| | | RWT-003 | 34.1177 | -119.1833 | 20 | 2012 |
| | CLAEMD | A1 | 33.9864 | -118.5020 | 17 | 2012 |
| | | A3 | 33.8675 | -118.4167 | 14 | 2012 |
| | | HT5 | 33.7108 | -118.2347 | 17 | 2012, 2013 |
| | LACSD | T0-23 | 33.8032 | -118.4173 | 23 | 2013 |
| | | T1-23 | 33.7442 | -118.4182 | 23 | 2013 |
| | | T4-23 | 33.7132 | -118.3413 | 27 | 2013 |
| | | T5-23 | 33.7048 | -118.3163 | 23 | 2013 |
| | OCSD | T0 | 33.6186 | -117.9881 | 18 | 2012, 2013 |
| | CSD-SBOO | SD15 | 32.4725 | -117.1750 | 27 | 2013 |
| | | SD16 | 32.5167 | -117.1787 | 27 | 2013 |
| | | SD17 | 32.5320 | -117.1880 | 30 | 2013 |
| | | SD18 | 32.5430 | -117.1892 | 30 | 2013 |
| | | SD19 | 32.5583 | -117.1847 | 28 | 2013 |
| | | SD20 | 32.5780 | -117.1908 | 29 | 2013 |
| | | SD21 | 32.6165 | -117.2115 | 29 | 2013 |
| Mid Shelf | CLAEMD | 1B | 33.9370 | -118.5638 | 120 | 2012 |
| | | 2B | 33.9401 | -118.4872 | 32 | 2012 |
| | | 3B | 33.8836 | -118.4976 | 58 | 2012 |
| | | C1 | 33.9972 | -118.7175 | 61 | 2012, 2013 |
| | | C3 | 33.9897 | -118.6006 | 64 | 2012 |
| | | C6 | 33.9281 | -118.5347 | 58 | 2012 |
| | | D1T | 33.9134 | -118.5369 | 63 | 2012 |
| | | Z2 | 33.9075 | -118.5245 | 60 | 2012, 2013 |
| | | Z3 | 33.9001 | -118.5066 | 57 | 2012 |
| | | Z4 | 33.9214 | -118.5097 | 53 | 2012 |

**Table C-1 (cont.)**

| Stratum | Agency | Station | Latitude | Longitude | Depth (m) | Survey Year |
|---|---|---|---|---|---|---|
| | CSD-PLOO | SD7 | 32.5843 | -117.3065 | 100 | 2013 |
| | | SD8 | 32.6257 | -117.3228 | 100 | 2013 |
| | | SD10 | 32.6527 | -117.3250 | 100 | 2013 |
| | | SD12 | 32.6775 | -117.3302 | 100 | 2013 |
| | | SD13 | 32.7138 | -117.3375 | 100 | 2013 |
| | | SD14 | 32.7383 | -117.3493 | 100 | 2013 |
| | LACSD | T0-61 | 33.8095 | -118.4307 | 68 | 2013 |
| | | T1-61 | 33.7360 | -118.4205 | 64 | 2013 |
| | | T4-61 | 33.7055 | -118.3487 | 58 | 2013 |
| | | T5-61 | 33.6908 | -118.3218 | 62 | 2013 |
| | OCSD | T1 | 33.5774 | -118.0095 | 55 | 2012, 2013 |
| | | T11 | 33.6009 | -118.0867 | 60 | 2012, 2013 |
| | | T12 | 33.5811 | -118.0278 | 57 | 2012, 2013 |
| | | T17 | 33.5860 | -118.0443 | 60 | 2012, 2013 |
| | | T18 | 33.6160 | -118.0878 | 36 | 2012 |
| | | T2 | 33.5948 | -117.9927 | 35 | 2012 |
| | | T22 | 33.5721 | -117.9976 | 60 | 2012, 2013 |
| | | T23 | 33.5723 | -117.9842 | 58 | 2012, 2013 |
| | | T24 | 33.5941 | -118.0212 | 36 | 2012 |
| | | T6 | 33.5991 | -118.0464 | 36 | 2012 |
| Outer Shelf | LACSD | T0-137 | 33.8138 | -118.4393 | 134 | 2013 |
| | | T1-137 | 33.7307 | -118.4223 | 149 | 2013 |
| | | T4-137 | 33.7010 | -118.3508 | 140 | 2013 |
| | | T5-137 | 33.6852 | -118.3268 | 136 | 2013 |
| | OCSD | T10 | 33.5629 | -118.0042 | 137 | 2012 |
| | | T14 | 33.5779 | -118.0533 | 137 | 2012 |
| | | T19 | 33.5899 | -118.0904 | 137 | 2012 |
| | | T25 | 33.5708 | -118.0328 | 137 | 2012 |
| Upper Slope | LACSD | T0-305 | 33.8205 | -118.4515 | 305 | 2013 |
| | | T1-305 | 33.7258 | -118.4273 | 309 | 2013 |
| | | T4-305 | 33.7000 | -118.3582 | 292 | 2013 |
| | | T5-305 | 33.6808 | -118.3308 | 311 | 2013 |

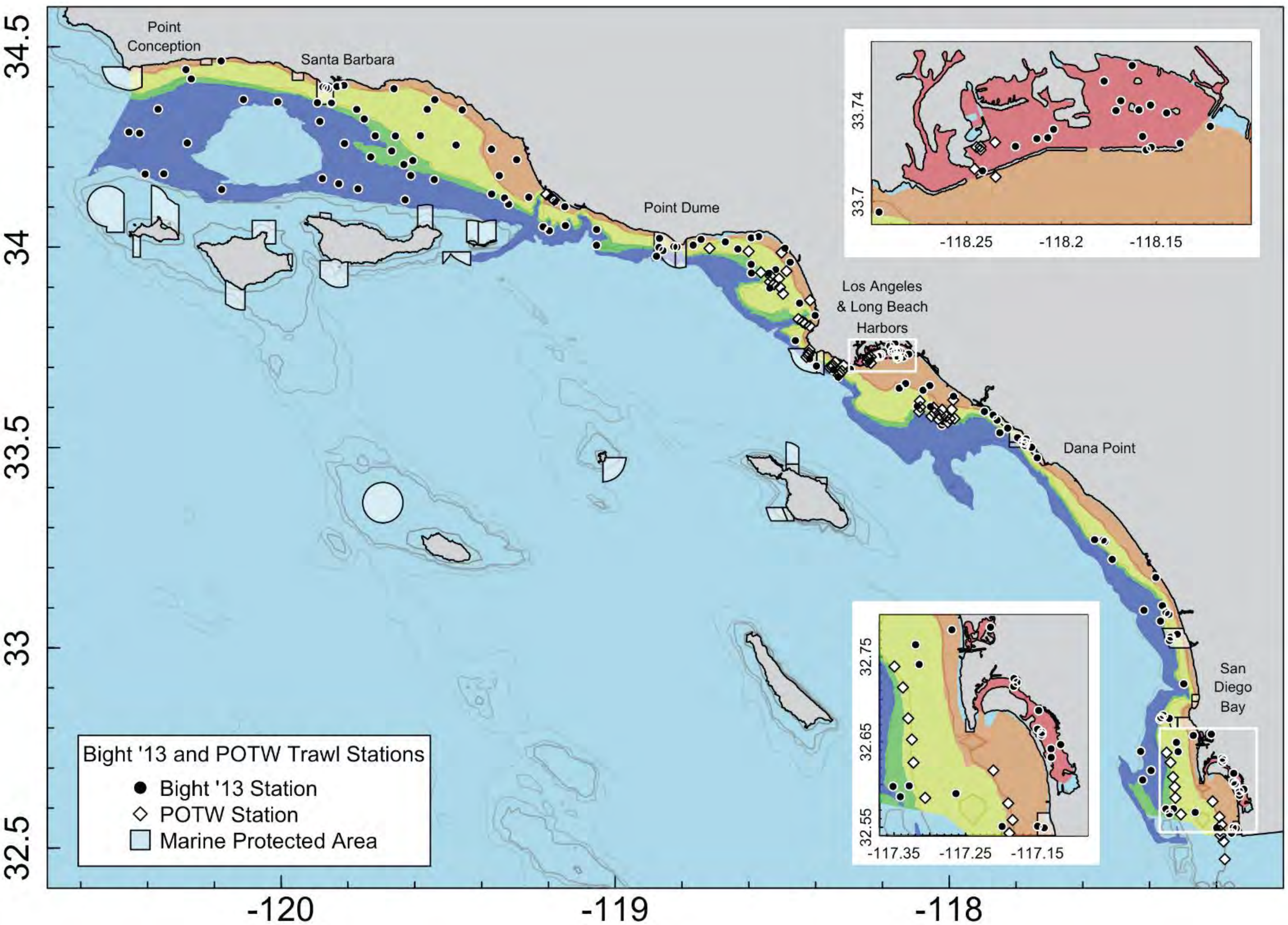



**Figure C-1. Distribution of Bight '13 stations sampled during 2013 and POTW monitoring stations sampled in 2012 and/or 2013.**

**Table C-2. Demersal fish abundance for Bight '13 and POTW stations by stratum and agency. Bight '13 data were collected July - September 2013, while data from the various POTWs were collected during the same months in 2012 and/or 2013 (see Table C-1). Oxnard = City of Oxnard, CLAEMD = City of Los Angeles Environmental Monitoring Division, LACSD = Sanitation Districts of Los Angeles County, OCSD = Orange County Sanitation District, CSD-PLOO = City of San Diego-Point Loma Ocean Outfall, and CSD-SBOO = City of San Diego-South Bay Ocean Outfall.**

| | No. of Stations | Total | Range | | Median | Mean | SD | 95% CL | Percent Above Bight Median |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Max | | | | | |
| *Overall* | | | | | | | | | |
| ***POTW*** | **76** | **49,248** | **16** | **10,632** | **348** | **648** | **1,295** | **291** | **8.8** |
| **Bight '13** | **165** | **75,383** | **1** | **3,088** | **316** | **457** | **515** | **79** | **-1.3** |
| *Stratum* | | | | | | | | | |
| **Bays and Harbors (3-30 m)** | **32** | **24,939** | **6** | **10,632** | **350** | **779** | **1,958** | **678** | **9.4** |
| *CLAEMD* | 6 | 16,700 | 210 | 10,632 | 499 | 2,783 | 4,200 | 3,361 | 55.9 |
| ***POTW*** | **6** | **16,700** | **210** | **10,632** | **499** | **2783** | **4,200** | **3,361** | **55.9** |
| **Bight '13** | **26** | **8,239** | **6** | **652** | **326** | **317** | **201** | **77** | **1.9** |
| **Inner Shelf (8-30 m)** | **55** | **18,877** | **16** | **1,229** | **279** | **343** | **309** | **82** | **-12.8** |
| *Oxnard* | 3 | 481 | 52 | 340 | 89 | 160 | 157 | 177 | -72.2 |
| *CLAEMD* | 4 | 562 | 16 | 302 | 122 | 141 | 121 | 119 | -61.9 |
| *LACSD* | 4 | 1,291 | 240 | 450 | 300.5 | 323 | 91 | 89 | -6.1 |
| *OCSD* | 2 | 335 | 109 | 226 | 167.5 | 168 | 83 | 115 | -47.7 |
| *CSD-SBOO* | 7 | 5,497 | 442 | 1,229 | 767 | 785 | 333 | 247 | 139.7 |
| ***POTW*** | **20** | **8,166** | **16** | **1,229** | **310** | **408** | **356** | **156** | **-3.1** |
| **Bight'13** | **35** | **10,711** | **25** | **1,013** | **245** | **306** | **277** | **92** | **-23.4** |
| **Middle Shelf (31-120 m)** | **81** | **39,855** | **12** | **2,446** | **349** | **492** | **429** | **93** | **9.1** |
| *CLAEMD* | 12 | 2,604 | 79 | 463 | 162 | 217 | 112 | 63 | -49.4 |
| *LACSD* | 4 | 3,988 | 316 | 1,399 | 1,136.5 | 997 | 495 | 485 | 255.2 |
| *OCSD* | 16 | 7,283 | 183 | 842 | 422 | 455 | 214 | 105 | 31.9 |
| *CSD-PLOO* | 6 | 3,306 | 319 | 810 | 525 | 551 | 173 | 138 | 64.1 |
| ***POTW*** | **38** | **17,181** | **79** | **1,399** | **344** | **452** | **313** | **99** | **7.5** |
| **Bight'13** | **43** | **22,674** | **12** | **2,446** | **359** | **527** | **511** | **153** | **12.2** |
| **Outer Shelf (121-200 m)** | **37** | **31,058** | **2** | **3,088** | **679** | **839** | **750** | **242** | **112.2** |
| *LACSD* | 4 | 3,113 | 641 | 902 | 785 | 778 | 142 | 139 | 145.3 |
| *OCSD* | 4 | 3,445 | 367 | 1,056 | 1,011 | 861 | 332 | 325 | 215.9 |
| ***POTW*** | **8** | **6,558** | **367** | **1,056** | **900.5** | **820** | **240** | **167** | **181.4** |
| **Bight '13** | **29** | **24,500** | **2** | **3,088** | **604** | **845** | **842** | **306** | **88.8** |
| **Upper slope (201-500 m)** | **36** | **9,902** | **1** | **1,071** | **198** | **275** | **263** | **86** | **-38.1** |
| *LACSD* | 4 | 643 | 95 | 258 | 145 | 161 | 70 | 69 | -54.7 |
| ***POTW*** | **4** | **643** | **95** | **258** | **145** | **161** | **70** | **69** | **-54.7** |
| **Bight '13** | **32** | **9,259** | **1** | **1,071** | **208.5** | **289** | **275** | **95** | **-34.8** |
| **Total (all stations)** | **241** | **124,631** | **1** | **10,632** | **320** | **517** | **845** | **107** | |

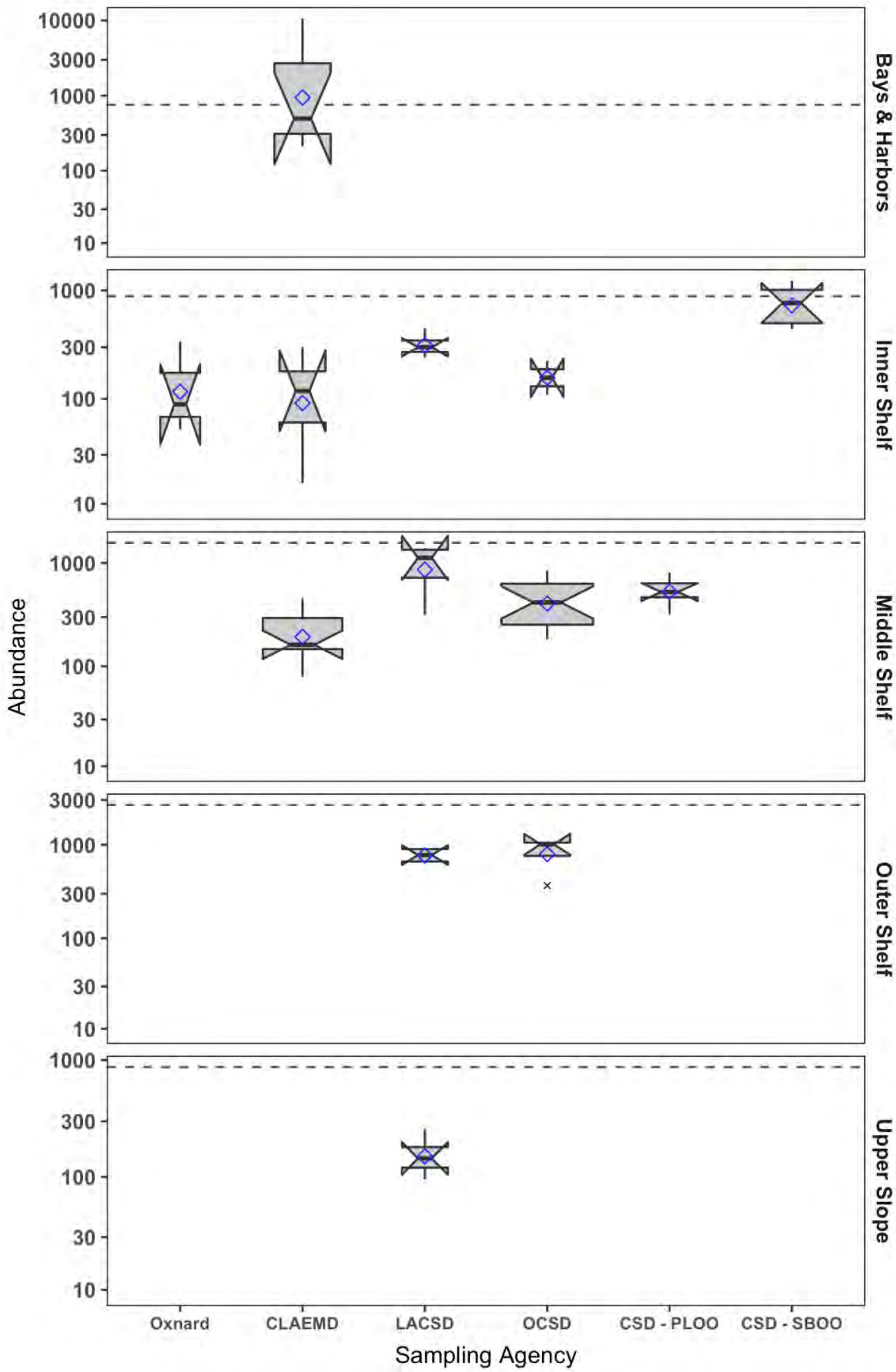



**Figure C-2. Demersal fish abundance by stratum for POTW monitoring stations sampled in 2012 and/or 2013. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size (see Table C-2). Dashed lines are tolerance intervals covering 90% of the Bight '13 population of the same stratum, with 95% confidence.**

**Table C-3. Demersal fish diversity (Shannon, H') for Bight '13 and POTW stations by stratum and agency. Bight '13 data were collected July - September 2013, while data from the various POTWs were collected during the same months in 2012 and/or 2013 (see Table C-1). Oxnard = City of Oxnard, CLAEMD = City of Los Angeles Environmental Monitoring Division, LACSD = Sanitation Districts of Los Angeles County, OCSD = Orange County Sanitation District, CSD-PLOO = City of San Diego-Point Loma Ocean Outfall, and CSD-SBOO = City of San Diego-South Bay Ocean Outfall.**

| Stratum/Agency | No. of Stations | Range Min | Range Max | Median | Mean | SD | 95% CL | Percent Above Bight Median |
|---|---|---|---|---|---|---|---|---|
| *Overall* | | | | | | | | |
| ***POTW*** | **76** | **0.10** | **2.12** | **1.35** | **1.33** | **0.42** | **0.09** | **-7.7** |
| **Bight '13** | **165** | **0.00** | **2.35** | **1.50** | **1.46** | **0.46** | **0.07** | **2.4** |
| *Stratum* | | | | | | | | |
| **Bays and Harbors (3-30 m)** | **32** | **0.10** | **2.22** | **1.43** | **1.38** | **0.54** | **0.19** | **-2.3** |
| *CLAEMD* | 6 | 0.10 | 1.37 | 0.94 | 0.82 | 0.51 | 0.41 | -35.7 |
| ***POTW*** | **6** | **0.10** | **1.37** | **0.94** | **0.82** | **0.51** | **0.41** | **-35.7** |
| **Bight '13** | **26** | **0.24** | **2.22** | **1.54** | **1.51** | **0.46** | **0.18** | **4.9** |
| **Inner Shelf (8-30 m)** | **55** | **0.33** | **2.11** | **1.22** | **1.23** | **0.42** | **0.11** | **-16.9** |
| *Oxnard* | 3 | 0.33 | 1.32 | 0.47 | 0.71 | 0.54 | 0.61 | -67.8 |
| *CLAEMD* | 4 | 0.78 | 1.69 | 1.01 | 1.13 | 0.39 | 0.39 | -30.7 |
| *LACSD* | 4 | 1.23 | 1.72 | 1.44 | 1.46 | 0.24 | 0.24 | -1.9 |
| *OCSD* | 2 | 0.75 | 1.08 | 0.91 | 0.91 | 0.23 | 0.32 | -37.7 |
| *CSD-SBOO* | 7 | 0.71 | 1.33 | 1.03 | 1.03 | 0.22 | 0.16 | -29.9 |
| ***POTW*** | **20** | **0.33** | **1.72** | **1.07** | **1.07** | **0.37** | **0.16** | **-27.0** |
| **Bight'13** | **35** | **0.33** | **2.11** | **1.38** | **1.31** | **0.42** | **0.14** | **-5.5** |
| **Middle Shelf (31-120 m)** | **81** | **0.67** | **2.35** | **1.61** | **1.60** | **0.36** | **0.08** | **10.2** |
| *CLAEMD* | 12 | 1.13 | 2.10 | 1.56 | 1.60 | 0.32 | 0.18 | 6.8 |
| *LACSD* | 4 | 1.20 | 1.86 | 1.73 | 1.63 | 0.30 | 0.29 | 18.2 |
| *OCSD* | 16 | 0.93 | 2.12 | 1.52 | 1.59 | 0.28 | 0.14 | 4.0 |
| *CSD-PLOO* | 6 | 0.99 | 1.62 | 1.33 | 1.34 | 0.27 | 0.21 | -9.2 |
| ***POTW*** | **38** | **0.93** | **2.12** | **1.54** | **1.56** | **0.30** | **0.09** | **5.0** |
| **Bight'13** | **43** | **0.67** | **2.35** | **1.75** | **1.65** | **0.41** | **0.12** | **19.4** |
| **Outer Shelf (121-200 m)** | **37** | **0.59** | **2.01** | **1.26** | **1.31** | **0.38** | **0.12** | **-13.9** |
| *LACSD* | 4 | 0.96 | 1.81 | 1.37 | 1.38 | 0.35 | 0.35 | -6.4 |
| *OCSD* | 4 | 0.77 | 1.33 | 1.03 | 1.04 | 0.24 | 0.24 | -29.6 |
| ***POTW*** | **8** | **0.77** | **1.81** | **1.22** | **1.21** | **0.33** | **0.23** | **-17.0** |
| **Bight '13** | **29** | **0.59** | **2.01** | **1.26** | **1.34** | **0.39** | **0.14** | **-13.9** |
| **Upper slope (201-500 m)** | **36** | **0.00** | **2.32** | **1.46** | **1.42** | **0.52** | **0.17** | **0.0** |
| *LACSD* | 4 | 1.08 | 1.77 | 1.46 | 1.44 | 0.29 | 0.28 | -0.4 |
| ***POTW*** | **4** | **1.08** | **1.77** | **1.46** | **1.44** | **0.29** | **0.28** | **-0.4** |
| **Bight '13** | **32** | **0.00** | **2.32** | **1.46** | **1.42** | **0.55** | **0.19** | **0.0** |
| **Total (all stations)** | **241** | **0.00** | **2.35** | **1.46** | **1.42** | **0.45** | **0.06** | |

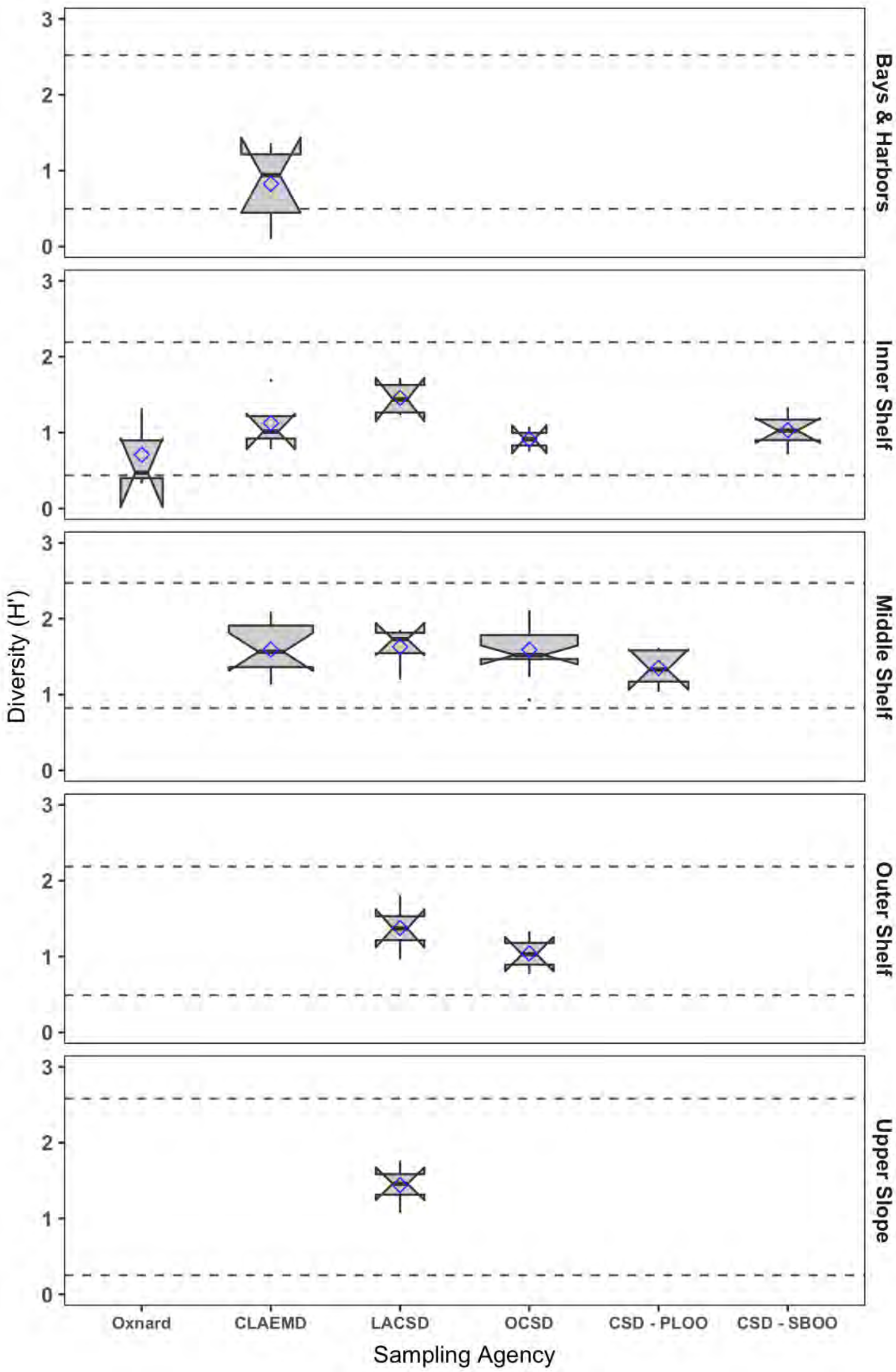



**Figure C-3. Demersal fish diversity (Shannon, H') by stratum for POTW monitoring stations sampled in 2012 and/or 2013. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size (see Table C-2). Dashed lines are tolerance intervals covering 90% of the Bight '13 population of the same stratum, with 95% confidence.**

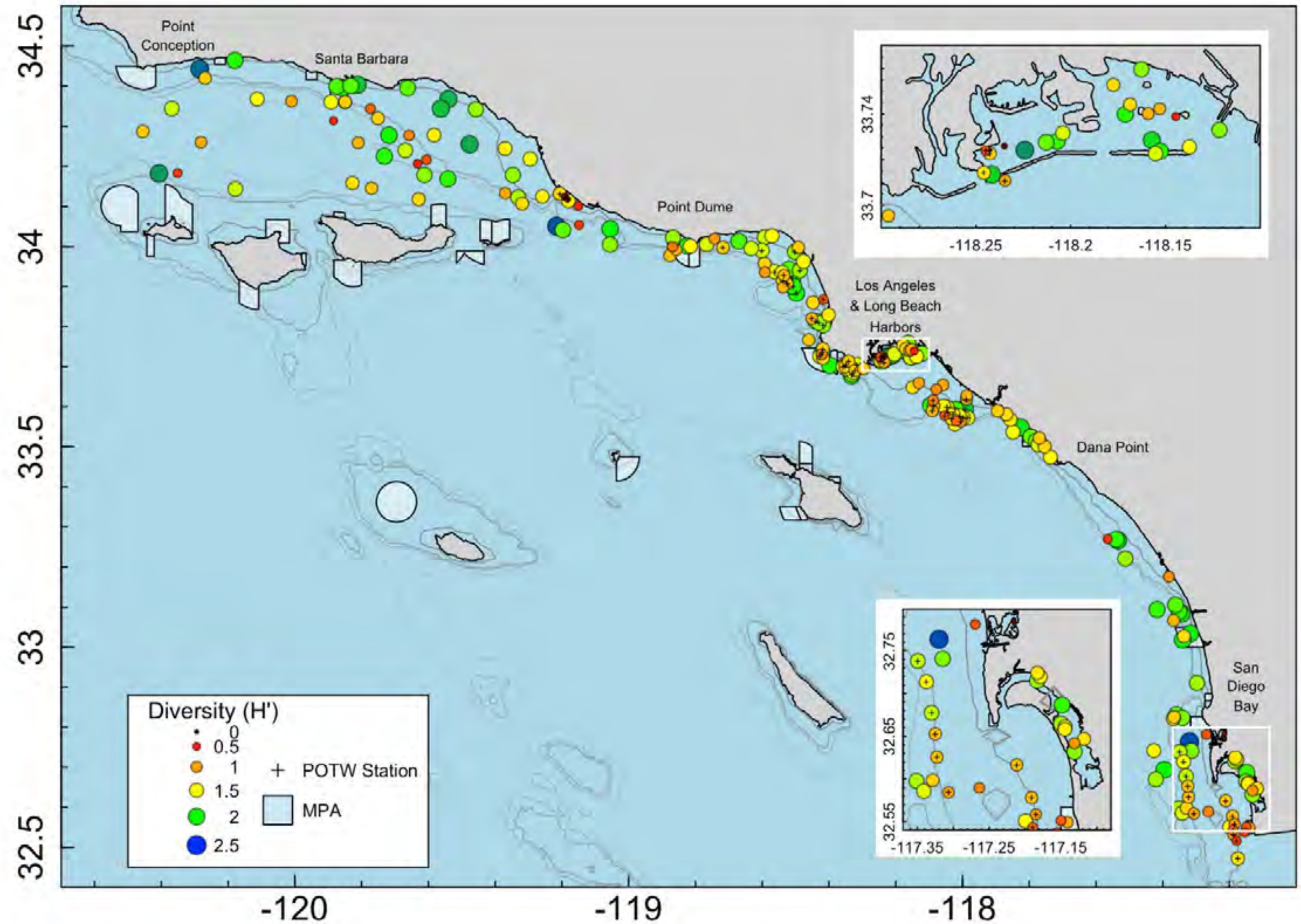



**Figure C-4. Distribution of fish diversity (Shannon, H') at Bight '13 stations sampled during 2013 and POTW monitoring stations sampled in 2012 and/or 2013.**

**Table C-4. Demersal fish species richness (number of species) for Bight '13 and POTW stations by stratum and agency. Bight '13 data were collected July - September 2013, while data from the various POTWs were collected during the same months in 2012 and/or 2013 (see Table C-1). Oxnard = City of Oxnard, CLAEMD = City of Los Angeles Environmental Monitoring Division, LACSD = Sanitation Districts of Los Angeles County, OCSD = Orange County Sanitation District, CSD-PLOO = City of San Diego-Point Loma Ocean Outfall, and CSD-SBOO = City of San Diego-South Bay Ocean Outfall.**

| Stratum/Agency | No. of Stations | Total | Range Min | Range Max | Median | Mean | SD | 95% CL | Percent Above Bight Median |
|---|---|---|---|---|---|---|---|---|---|
| *Overall* | | | | | | | | | |
| ***POTW*** | **76** | **88** | **3** | **23** | **13** | **13** | **4** | **1** | **0.0** |
| **Bight '13** | **165** | **127** | **1** | **25** | **12** | **12** | **5** | **1** | **-7.7** |
| | | | | | | | | | |
| *Stratum* | | | | | | | | | |
| **Bays and Harbors (3-30 m)** | **32** | **43** | **4** | **15** | **9** | **9** | **3** | **1** | **-30.8** |
| *CLAEMD* | 6 | 19 | 6 | 13 | 10 | 10 | 2 | 2 | -23.1 |
| ***POTW*** | **6** | **19** | **6** | **13** | **10** | **10** | **2** | **2** | **-23.1** |
| **Bight '13** | **26** | **41** | **4** | **15** | **8** | **9** | **3** | **1** | **-38.5** |
| **Inner Shelf (8-30 m)** | **55** | **55** | **3** | **18** | **10** | **10** | **3** | **1** | **-23.1** |
| *ABC* | 3 | 15 | 3 | 9 | 9 | 7 | 3 | 4 | -30.8 |
| *CLAEMD* | 4 | 20 | 7 | 8 | 7.5 | 8 | 1 | 1 | -42.3 |
| *CSD-SBOO* | 7 | 26 | 9 | 18 | 13 | 13 | 3 | 2 | 0.0 |
| *LACSD* | 4 | 21 | 10 | 15 | 10.5 | 12 | 2 | 2 | -19.2 |
| *OCSD* | 2 | 12 | 6 | 11 | 8.5 | 9 | 4 | 5 | -34.6 |
| ***POTW*** | **20** | **41** | **3** | **18** | **10** | **10** | **3** | **2** | **-23.1** |
| **Bight '13** | **35** | **48** | **4** | **18** | **10** | **10** | **3** | **1** | **-23.1** |
| **Middle Shelf (31-120 m)** | **81** | **72** | **5** | **25** | **16** | **15** | **4** | **1** | **23.1** |
| *CLAEMD* | 12 | 39 | 9 | 19 | 14 | 15 | 3 | 2 | 7.7 |
| *CSD-PLOO* | 6 | 32 | 14 | 18 | 16 | 16 | 2 | 1 | 23.1 |
| *LACSD* | 4 | 24 | 12 | 20 | 17.5 | 17 | 3 | 3 | 34.6 |
| *OCSD* | 16 | 28 | 8 | 18 | 13 | 14 | 3 | 1 | 0.0 |
| ***POTW*** | **38** | **50** | **8** | **20** | **14.5** | **15** | **3** | **1** | **11.5** |
| **Bight '13** | **43** | **66** | **5** | **25** | **16** | **16** | **4** | **1** | **23.1** |
| **Outer Shelf (121-200 m)** | **37** | **53** | **2** | **23** | **15** | **15** | **4** | **1** | **15.4** |
| *LACSD* | 4 | 29 | 15 | 23 | 18.5 | 19 | 4 | 4 | 42.3 |
| *OCSD* | 4 | 25 | 13 | 18 | 16.5 | 16 | 2 | 2 | 26.9 |
| ***POTW*** | **8** | **35** | **13** | **23** | **16.5** | **17** | **3** | **2** | **26.9** |
| **Bight '13** | **29** | **50** | **2** | **21** | **15** | **14** | **4** | **2** | **15.4** |
| **Upper slope (201-500 m)** | **36** | **55** | **1** | **24** | **11** | **11** | **4** | **1** | **-15.4** |
| *LACSD* | 4 | 23 | 9 | 16 | 12 | 12 | 3 | 3 | -7.7 |
| ***POTW*** | **4** | **23** | **9** | **16** | **12** | **12** | **3** | **3** | **-7.7** |
| **Bight '13** | **32** | **54** | **1** | **24** | **11** | **11** | **5** | **2** | **-15.4** |
| **Total (all stations)** | **241** | **133** | **1** | **25** | **13.0** | **12.6** | **4.5** | **0.6** | |

**Table C-5. Demersal fish species richness (Margalef index) for Bight '13 and POTW stations by stratum and agency. Bight '13 data were collected July - September 2013, while data from the various POTWs were collected during the same months in 2012 and/or 2013 (see Table C-1). Oxnard = City of Oxnard, CLAEMD = City of Los Angeles Environmental Monitoring Division, LACSD = Sanitation Districts of Los Angeles County, OCSD = Orange County Sanitation District, CSD-PLOO = City of San Diego-Point Loma Ocean Outfall, and CSD-SBOO = City of San Diego-South Bay Ocean Outfall.**

| | | Range | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Stratum/Agency** | **No. of Stations** | **Min** | **Max** | **Median** | **Mean** | **SD** | **95% CL** | **Percent Above Bight Median** |
| *Overall* | | | | | | | | |
| ***POTW*** | **76** | **0.45** | **3.65** | **2.17** | **2.08** | **0.60** | **0.13** | **4.6** |
| **Bight '13** | **164** | **0.00** | **3.57** | **2.01** | **2.01** | **0.65** | **0.10** | **-2.8** |
| *Stratum* | | | | | | | | |
| **Bays and Harbors (3-30 m)** | **32** | **0.77** | **2.68** | **1.46** | **1.45** | **0.48** | **0.17** | **-29.6** |
| *CLAEMD* | 6 | 0.89 | 1.90 | 1.27 | 1.30 | 0.39 | 0.31 | -38.6 |
| ***POTW*** | **6** | **0.89** | **1.90** | **1.27** | **1.30** | **0.39** | **0.31** | **-38.6** |
| **Bight '13** | **26** | **0.77** | **2.68** | **1.49** | **1.48** | **0.50** | **0.19** | **-28.1** |
| **Inner Shelf (8-30 m)** | **55** | **0.44** | **3.18** | **1.68** | **1.73** | **0.53** | **0.14** | **-18.9** |
| *ABC* | 3 | 0.45 | 2.02 | 1.37 | 1.28 | 0.79 | 0.90 | -33.7 |
| *CLAEMD* | 4 | 1.05 | 2.16 | 1.47 | 1.54 | 0.47 | 0.46 | -29.0 |
| *CSD-SBOO* | 7 | 1.31 | 2.56 | 1.83 | 1.82 | 0.42 | 0.31 | -11.7 |
| *LACSD* | 4 | 1.56 | 2.29 | 1.71 | 1.82 | 0.33 | 0.32 | -17.6 |
| *OCSD* | 2 | 1.07 | 1.84 | 1.46 | 1.46 | 0.55 | 0.76 | -29.7 |
| ***POTW*** | **20** | **0.45** | **2.56** | **1.60** | **1.65** | **0.48** | **0.21** | **-22.6** |
| **Bight '13** | **35** | **0.44** | **3.18** | **1.68** | **1.77** | **0.56** | **0.19** | **-18.7** |
| **Middle Shelf (31-120 m)** | **81** | **1.34** | **3.65** | **2.42** | **2.44** | **0.50** | **0.11** | **17.0** |
| *CLAEMD* | 12 | 1.76 | 3.65 | 2.59 | 2.57 | 0.54 | 0.31 | 25.3 |
| *CSD-PLOO* | 6 | 2.24 | 2.78 | 2.35 | 2.45 | 0.24 | 0.19 | 13.4 |
| *LACSD* | 4 | 1.91 | 2.62 | 2.35 | 2.31 | 0.31 | 0.31 | 13.6 |
| *OCSD* | 16 | 1.34 | 3.09 | 2.14 | 2.10 | 0.42 | 0.20 | 3.3 |
| ***POTW*** | **38** | **1.34** | **3.65** | **2.28** | **2.33** | **0.47** | **0.15** | **10.0** |
| **Bight '13** | **43** | **1.56** | **3.57** | **2.52** | **2.55** | **0.51** | **0.15** | **21.7** |
| **Outer Shelf (121-200 m)** | **37** | **1.07** | **3.38** | **2.21** | **2.20** | **0.45** | **0.14** | **6.5** |
| *LACSD* | 4 | 2.17 | 3.38 | 2.57 | 2.67 | 0.59 | 0.58 | 24.3 |
| *OCSD* | 4 | 1.72 | 2.54 | 2.39 | 2.26 | 0.37 | 0.36 | 15.2 |
| ***POTW*** | **8** | **1.72** | **3.38** | **2.39** | **2.47** | **0.51** | **0.35** | **15.2** |
| **Bight '13** | **29** | **1.07** | **2.90** | **2.19** | **2.12** | **0.41** | **0.15** | **5.6** |
| **Upper slope (201-500 m)** | **35** | **0.00** | **3.30** | **1.94** | **1.91** | **0.64** | **0.21** | **-6.4** |
| *LACSD* | 4 | 1.64 | 2.70 | 2.28 | 2.23 | 0.44 | 0.43 | 10.1 |
| ***POTW*** | **4** | **1.64** | **2.70** | **2.28** | **2.23** | **0.44** | **0.43** | **10.1** |
| **Bight '13** | **31** | **0.00** | **3.30** | **1.94** | **1.87** | **0.65** | **0.23** | **-6.4** |
| **Total (all stations)** | **240** | **0.00** | **3.65** | **2.07** | **2.03** | **0.63** | **0.08** | |

**Table C-6. Fish Response Index (FRI) for Bight '13 and POTW stations by stratum and agency. Bight '13 data were collected July - September 2013, while data from the various POTWs were collected during the same months in 2012 and/or 2013 (see Table C-1). Oxnard = City of Oxnard, CLAEMD = City of Los Angeles Environmental Monitoring Division, LACSD = Sanitation Districts of Los Angeles County, OCSD = Orange County Sanitation District, CSD-PLOO = City of San Diego-Point Loma Ocean Outfall, and CSD-SBOO = City of San Diego-South Bay Ocean Outfall. FRI scores higher than 45 (in red) are associated with a non-reference fish community.**

| Stratum/Agency | No. of Stations | Range | | Median | Mean | SD | 95% CL | Percent Above Bight Median | Percent Reference Sites |
|---|---|---|---|---|---|---|---|---|---|
| | | Min | Max | | | | | | |
| *Overall* | | | | | | | | | |
| ***POTW*** | **72** | **4.1** | **61.0** | **25.5** | **25.8** | **8.3** | **1.9** | **-2.4** | **98.6** |
| **Bight '13** | **133** | **-1.1** | **61.0** | **26.2** | **27.1** | **11.5** | **2.0** | **0.3** | **92.5** |
| *Stratum* | | | | | | | | | |
| **Bays and Harbors (3-30 m)** | **32** | **10.6** | **59.0** | **25.2** | **26.2** | **12.6** | **4.4** | **-3.7** | **87.5** |
| *CLAEMD* | 6 | 19.7 | 32.7 | 29.6 | 28.0 | 4.8 | 3.9 | 13.4 | 100 |
| ***POTW*** | **6** | **19.7** | **32.7** | **29.6** | **28.0** | **4.8** | **3.9** | **13.4** | **100** |
| **Bight '13** | **26** | **10.6** | **59.0** | **24.6** | **25.8** | **13.9** | **5.3** | **-6.0** | **84.6** |
| **Inner Shelf (8-30 m)** | **55** | **18.7** | **61.0** | **31.5** | **33.4** | **9.6** | **2.5** | **20.5** | **90.9** |
| *ABC* | 3 | 20.5 | 42.2 | 29.1 | 30.6 | 10.9 | 12.4 | 11.4 | 100 |
| *CLAEMD* | 4 | 18.7 | 33.4 | 28.3 | 27.2 | 6.2 | 6.1 | 8.3 | 100 |
| *CSD-SBOO* | 7 | 22.0 | 38.0 | 29.5 | 30.7 | 5.3 | 3.9 | 12.7 | 100 |
| *LACSD* | 4 | 33.8 | 61.0 | 39.1 | 43.3 | 12.5 | 12.2 | 49.5 | 75.0 |
| *OCSD* | 2 | 23.4 | 32.1 | 27.8 | 27.8 | 6.2 | 8.6 | 6.2 | 100 |
| ***POTW*** | **20** | **18.7** | **61.0** | **30.6** | **32.2** | **9.4** | **4.1** | **17.1** | **95.0** |
| **Bight '13** | **35** | **19.2** | **58.8** | **31.5** | **34.1** | **9.8** | **3.2** | **20.5** | **88.6** |
| **Middle Shelf (31-120 m)** | **81** | **12.1** | **61.0** | **25.4** | **25.9** | **5.8** | **1.3** | **-2.8** | **98.8** |
| *CLAEMD* | 12 | 15.7 | 32.2 | 28.1 | 27.0 | 4.7 | 2.7 | 7.5 | 100 |
| *CSD-PLOO* | 6 | 19.2 | 28.8 | 24.7 | 24.1 | 3.5 | 2.8 | -5.4 | 100 |
| *LACSD* | 4 | 24.7 | 30.1 | 27.4 | 27.4 | 2.2 | 2.2 | 4.9 | 100 |
| *OCSD* | 16 | 18.3 | 26.8 | 22.4 | 23.1 | 2.6 | 1.3 | -14.3 | 100 |
| ***POTW*** | **38** | **15.7** | **32.2** | **25.2** | **24.9** | **3.9** | **1.2** | **-3.5** | **100** |
| **Bight '13** | **43** | **12.1** | **61.0** | **26.1** | **26.8** | **7.0** | **2.1** | **0.0** | **97.7** |
| **Outer Shelf (121-200 m)** | **37** | **-1.1** | **50.9** | **16.9** | **18.7** | **11.7** | **3.8** | **-35.4** | **97.3** |
| *LACSD* | 4 | 11.4 | 23.0 | 15.4 | 16.3 | 5.2 | 5.1 | -41.2 | 100 |
| *OCSD* | 4 | 4.1 | 9.7 | 9.5 | 8.2 | 2.8 | 2.7 | -63.5 | 100 |
| ***POTW*** | **8** | **4.1** | **23.0** | **10.6** | **12.3** | **5.8** | **4.0** | **-59.6** | **100** |
| **Bight '13** | **29** | **-1.1** | **50.9** | **18.7** | **20.4** | **12.3** | **4.5** | **-28.4** | **96.6** |
| **Total (all stations)** | **205** | **-1.1** | **61.0** | **26.1** | **26.7** | **10.5** | **1.4** | | **94.6** |

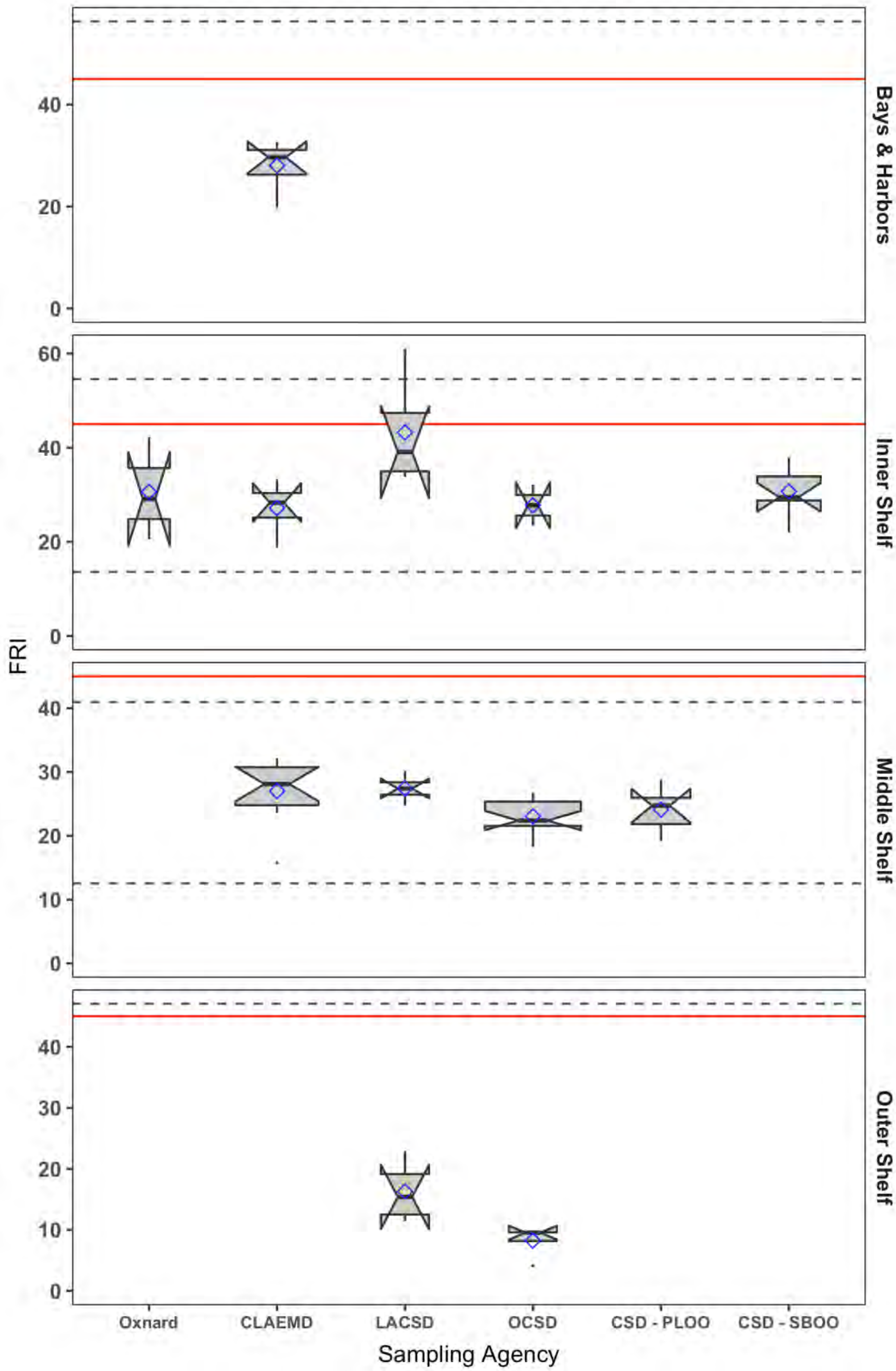



**Figure C-5. Fish Response Index (FRI) by stratum for POTW monitoring stations sampled in 2012 and/or 2013. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size (see Table C-2). Dashed lines are tolerance intervals covering 90% of the Bight '13 population of the same stratum, with 95% confidence. Red lines represent maximum FRI score (45) associated with a reference community.**

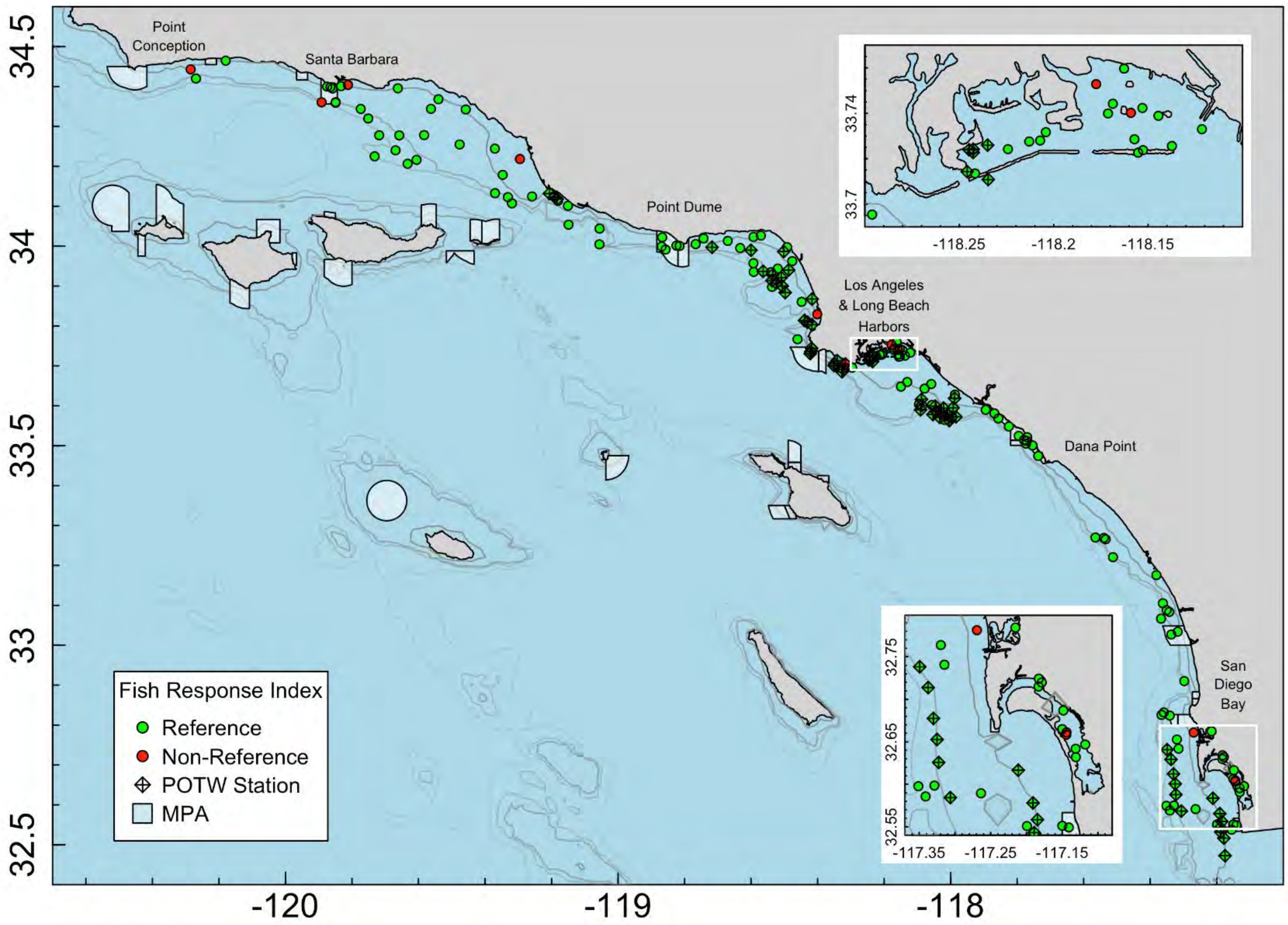



**Figure C-6. Distribution of Fish Response Index (FRI) values at Bight ’13 stations sampled during 2013 and POTW monitoring stations sampled in 2012 and/or 2013.**

**Table C-7. Demersal fish species evenness (Pielou's evenness) for Bight '13 and POTW stations by stratum and agency. Bight '13 data were collected July - September 2013, while data from the various POTWs were collected during the same months in 2012 and/or 2013 (see Table C-1). Oxnard = City of Oxnard, CLAEMD = City of Los Angeles Environmental Monitoring Division, LACSD = Sanitation Districts of Los Angeles County, OCSD = Orange County Sanitation District, CSD-PLOO = City of San Diego-Point Loma Ocean Outfall, and CSD-SBOO = City of San Diego-South Bay Ocean Outfall.**

| Stratum/Agency | No. of Stations | Range Min | Range Max | Median | Mean | SD | 95% CL | Percent Above Bight Median |
|---|---|---|---|---|---|---|---|---|
| *Overall* | | | | | | | | |
| ***POTW*** | **76** | **0.04** | **0.87** | **0.54** | **0.52** | **0.15** | **0.03** | **-8.7** |
| **Bight '13** | **163** | **0.12** | **1.00** | **0.63** | **0.61** | **0.17** | **0.03** | **6.8** |
| | | | | | | | | |
| *Stratum* | | | | | | | | |
| **Bays and Harbors (3-30 m)** | **32** | **0.04** | **0.99** | **0.67** | **0.65** | **0.25** | **0.09** | **13.9** |
| *CLAEMD* | 6 | 0.04 | 0.57 | 0.46 | 0.37 | 0.22 | 0.17 | -22.6 |
| ***POTW*** | **6** | **0.04** | **0.57** | **0.46** | **0.37** | **0.22** | **0.17** | **-22.6** |
| **Bight '13** | **26** | **0.12** | **0.99** | **0.71** | **0.71** | **0.20** | **0.08** | **20.1** |
| **Inner Shelf (8-30 m)** | **55** | **0.21** | **0.87** | **0.53** | **0.54** | **0.16** | **0.04** | **-9.4** |
| *ABC* | 3 | 0.21 | 0.60 | 0.30 | 0.37 | 0.20 | 0.23 | -49.2 |
| *CLAEMD* | 4 | 0.40 | 0.87 | 0.49 | 0.56 | 0.21 | 0.20 | -17.2 |
| *CSD-SBOO* | 7 | 0.28 | 0.61 | 0.39 | 0.41 | 0.10 | 0.08 | -33.1 |
| *LACSD* | 4 | 0.53 | 0.67 | 0.60 | 0.60 | 0.06 | 0.06 | 1.1 |
| *OCSD* | 2 | 0.42 | 0.45 | 0.43 | 0.43 | 0.02 | 0.03 | -26.5 |
| ***POTW*** | **20** | **0.21** | **0.87** | **0.45** | **0.47** | **0.15** | **0.07** | **-24.1** |
| **Bight '13** | **35** | **0.24** | **0.85** | **0.58** | **0.57** | **0.15** | **0.05** | **-2.1** |
| **Middle Shelf (31-120 m)** | **81** | **0.23** | **0.90** | **0.60** | **0.60** | **0.14** | **0.03** | **1.5** |
| *CLAEMD* | 12 | 0.44 | 0.74 | 0.58 | 0.60 | 0.10 | 0.06 | -1.4 |
| *CSD-PLOO* | 6 | 0.36 | 0.58 | 0.49 | 0.48 | 0.10 | 0.08 | -16.7 |
| *LACSD* | 4 | 0.40 | 0.75 | 0.60 | 0.59 | 0.14 | 0.14 | 2.6 |
| *OCSD* | 16 | 0.45 | 0.85 | 0.60 | 0.61 | 0.10 | 0.05 | 1.2 |
| ***POTW*** | **38** | **0.36** | **0.85** | **0.58** | **0.59** | **0.11** | **0.04** | **-1.1** |
| **Bight '13** | **43** | **0.23** | **0.90** | **0.65** | **0.61** | **0.15** | **0.05** | **9.5** |
| **Outer Shelf (121-200 m)** | **37** | **0.24** | **1.00** | **0.48** | **0.51** | **0.17** | **0.05** | **-18.4** |
| *LACSD* | 4 | 0.31 | 0.65 | 0.47 | 0.48 | 0.14 | 0.14 | -20.3 |
| *OCSD* | 4 | 0.27 | 0.48 | 0.38 | 0.38 | 0.10 | 0.10 | -35.3 |
| ***POTW*** | **8** | **0.27** | **0.65** | **0.45** | **0.43** | **0.12** | **0.09** | **-23.7** |
| **Bight '13** | **29** | **0.24** | **1.00** | **0.50** | **0.53** | **0.17** | **0.06** | **-15.4** |
| **Upper slope (201-500 m)** | **34** | **0.30** | **0.81** | **0.64** | **0.63** | **0.13** | **0.04** | **8.3** |
| *LACSD* | 4 | 0.49 | 0.74 | 0.55 | 0.58 | 0.11 | 0.11 | -7.3 |
| ***POTW*** | **4** | **0.49** | **0.74** | **0.55** | **0.58** | **0.11** | **0.11** | **-7.3** |
| **Bight '13** | **30** | **0.30** | **0.81** | **0.66** | **0.63** | **0.13** | **0.05** | **11.7** |
| **Total (all stations)** | **239** | **0.04** | **1.00** | **0.59** | **0.58** | **0.17** | **0.02** | |

**Table C-8. Demersal fish Dominance (Simpson's index) for Bight '13 and POTW stations by stratum and agency. Bight '13 data were collected July - September 2013, while data from the various POTWs were collected during the same months in 2012 and/or 2013 (see Table C-1). Oxnard = City of Oxnard, CLAEMD = City of Los Angeles Environmental Monitoring Division, LACSD = Sanitation Districts of Los Angeles County, OCSD = Orange County Sanitation District, CSD-PLOO = City of San Diego-Point Loma Ocean Outfall, and CSD-SBOO = City of San Diego-South Bay Ocean Outfall.**

| Stratum/Agency | No. of Stations | Range Min | Range Max | Median | Mean | SD | 95% CL | Percent Above Bight Median |
|---|---|---|---|---|---|---|---|---|
| *Overall* | | | | | | | | |
| ***POTW*** | **76** | **0.03** | **0.86** | **0.60** | **0.59** | **0.17** | **0.04** | **-9.9** |
| **Bight '13** | **165** | **0.00** | **0.99** | **0.69** | **0.65** | **0.19** | **0.03** | **4.2** |
| | | | | | | | | |
| *Stratum* | | | | | | | | |
| **Bays and Harbors (3-30 m)** | **32** | **0.03** | **0.99** | **0.72** | **0.66** | **0.25** | **0.09** | **8.4** |
| *CLAEMD* | 6 | 0.03 | 0.63 | 0.49 | 0.40 | 0.26 | 0.21 | -26.0 |
| ***POTW*** | **6** | **0.03** | **0.63** | **0.49** | **0.40** | **0.26** | **0.21** | **-26.0** |
| **Bight '13** | **26** | **0.08** | **0.99** | **0.75** | **0.73** | **0.21** | **0.08** | **13.1** |
| **Inner Shelf (8-30 m)** | **55** | **0.13** | **0.83** | **0.59** | **0.58** | **0.17** | **0.04** | **-10.8** |
| *ABC* | 3 | 0.15 | 0.55 | 0.18 | 0.29 | 0.23 | 0.25 | -72.7 |
| *CLAEMD* | 4 | 0.47 | 0.77 | 0.53 | 0.57 | 0.14 | 0.13 | -20.5 |
| *CSD-SBOO* | 7 | 0.33 | 0.70 | 0.53 | 0.52 | 0.12 | 0.09 | -20.5 |
| *LACSD* | 4 | 0.60 | 0.74 | 0.67 | 0.67 | 0.07 | 0.07 | 0.3 |
| *OCSD* | 2 | 0.42 | 0.55 | 0.48 | 0.48 | 0.09 | 0.13 | -27.4 |
| ***POTW*** | **20** | **0.15** | **0.77** | **0.55** | **0.52** | **0.17** | **0.07** | **-17.6** |
| **Bight '13** | **35** | **0.13** | **0.83** | **0.65** | **0.61** | **0.16** | **0.05** | **-2.9** |
| **Middle Shelf (31-120 m)** | **81** | **0.28** | **0.88** | **0.72** | **0.68** | **0.14** | **0.03** | **7.8** |
| *CLAEMD* | 12 | 0.46 | 0.79 | 0.67 | 0.66 | 0.11 | 0.06 | 0.0 |
| *CSD-PLOO* | 6 | 0.39 | 0.68 | 0.58 | 0.56 | 0.11 | 0.09 | -12.9 |
| *LACSD* | 4 | 0.49 | 0.81 | 0.76 | 0.70 | 0.15 | 0.14 | 13.7 |
| *OCSD* | 16 | 0.46 | 0.86 | 0.70 | 0.70 | 0.09 | 0.05 | 5.7 |
| ***POTW*** | **38** | **0.39** | **0.86** | **0.68** | **0.67** | **0.12** | **0.04** | **1.7** |
| **Bight '13** | **43** | **0.28** | **0.88** | **0.75** | **0.69** | **0.16** | **0.05** | **12.9** |
| **Outer Shelf (121-200 m)** | **37** | **0.24** | **0.81** | **0.53** | **0.56** | **0.17** | **0.05** | **-19.9** |
| *LACSD* | 4 | 0.37 | 0.75 | 0.58 | 0.57 | 0.16 | 0.16 | -12.4 |
| *OCSD* | 4 | 0.29 | 0.53 | 0.43 | 0.42 | 0.12 | 0.11 | -34.8 |
| ***POTW*** | **8** | **0.29** | **0.75** | **0.52** | **0.50** | **0.15** | **0.10** | **-22.1** |
| **Bight '13** | **29** | **0.24** | **0.81** | **0.59** | **0.58** | **0.17** | **0.06** | **-11.9** |
| **Upper slope (201-500 m)** | **36** | **0.00** | **0.87** | **0.66** | **0.63** | **0.20** | **0.07** | **-0.6** |
| *LACSD* | 4 | 0.51 | 0.78 | 0.62 | 0.63 | 0.12 | 0.11 | -6.6 |
| ***POTW*** | **4** | **0.51** | **0.78** | **0.62** | **0.63** | **0.12** | **0.11** | **-6.6** |
| **Bight '13** | **32** | **0.00** | **0.87** | **0.67** | **0.63** | **0.21** | **0.07** | **0.8** |
| **Total (all stations)** | **241** | **0.00** | **0.99** | **0.67** | **0.63** | **0.18** | **0.02** | |

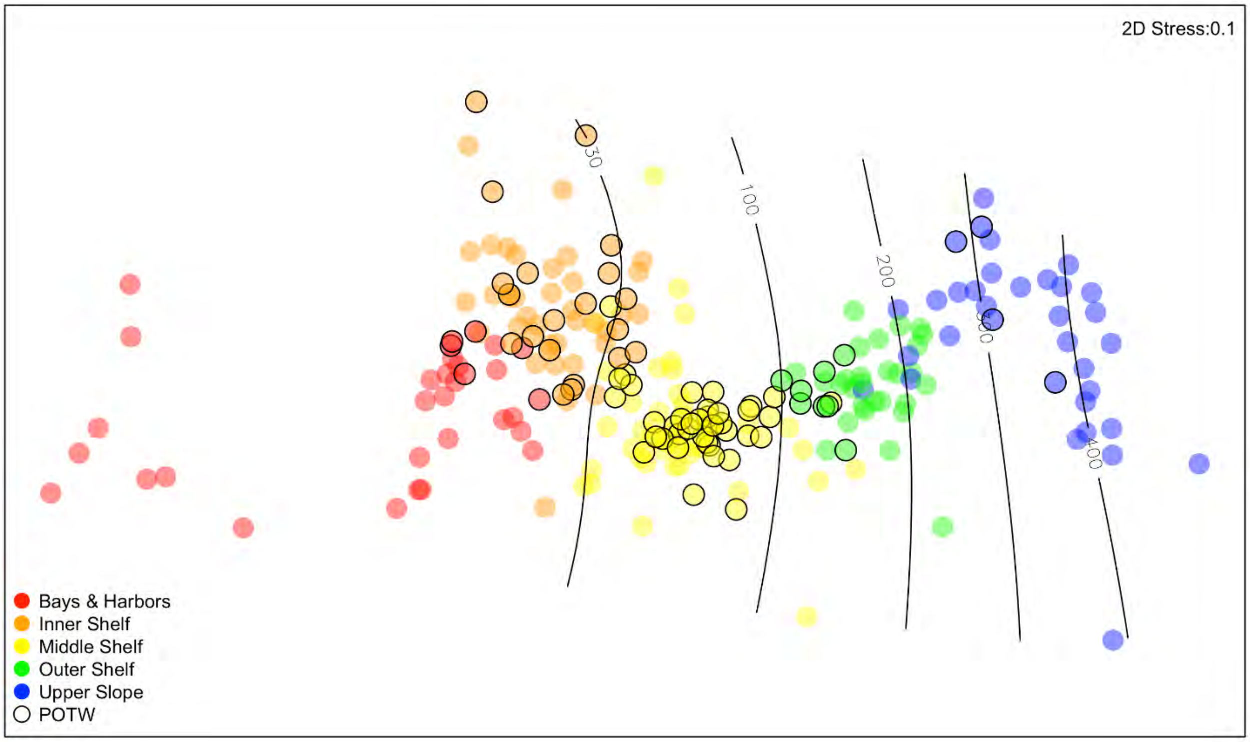



**Figure C-7. Ordination (nMDS) of demersal fish abundance per haul from Bight '13 and POTW stations by stratum with a surface plot of trawl depth overlain (black lines). POTW stations are outlined in black.**

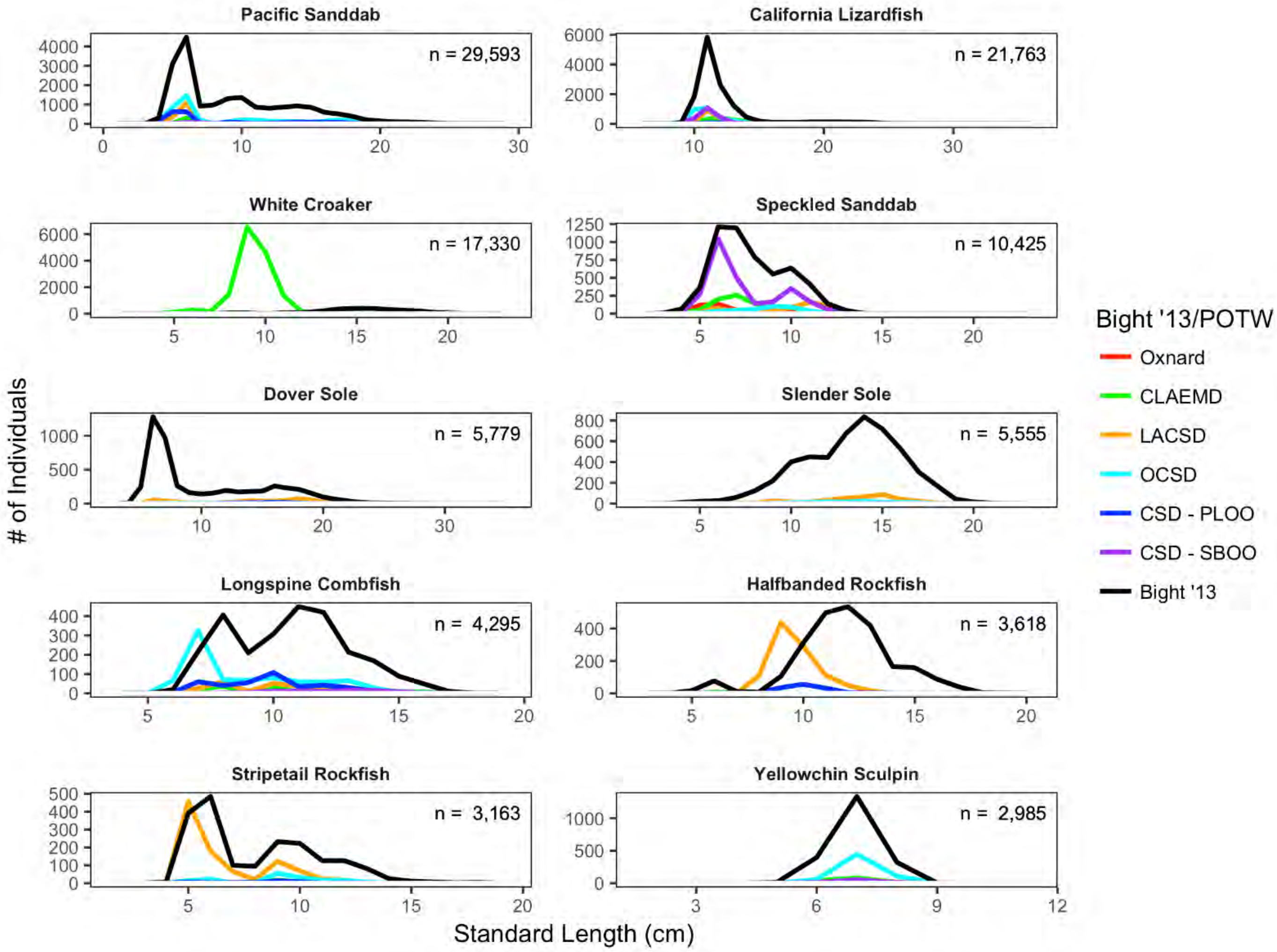



**Figure C-8. Length frequency for the top ten most abundant demersal fish species from Bight '13 and POTW stations. Bight '13 data were collected during the summer of 2013, while data from the various POTWs were collected during 2012 and/or 2013 (see Table C-1). Total number of individuals (n) are noted.**

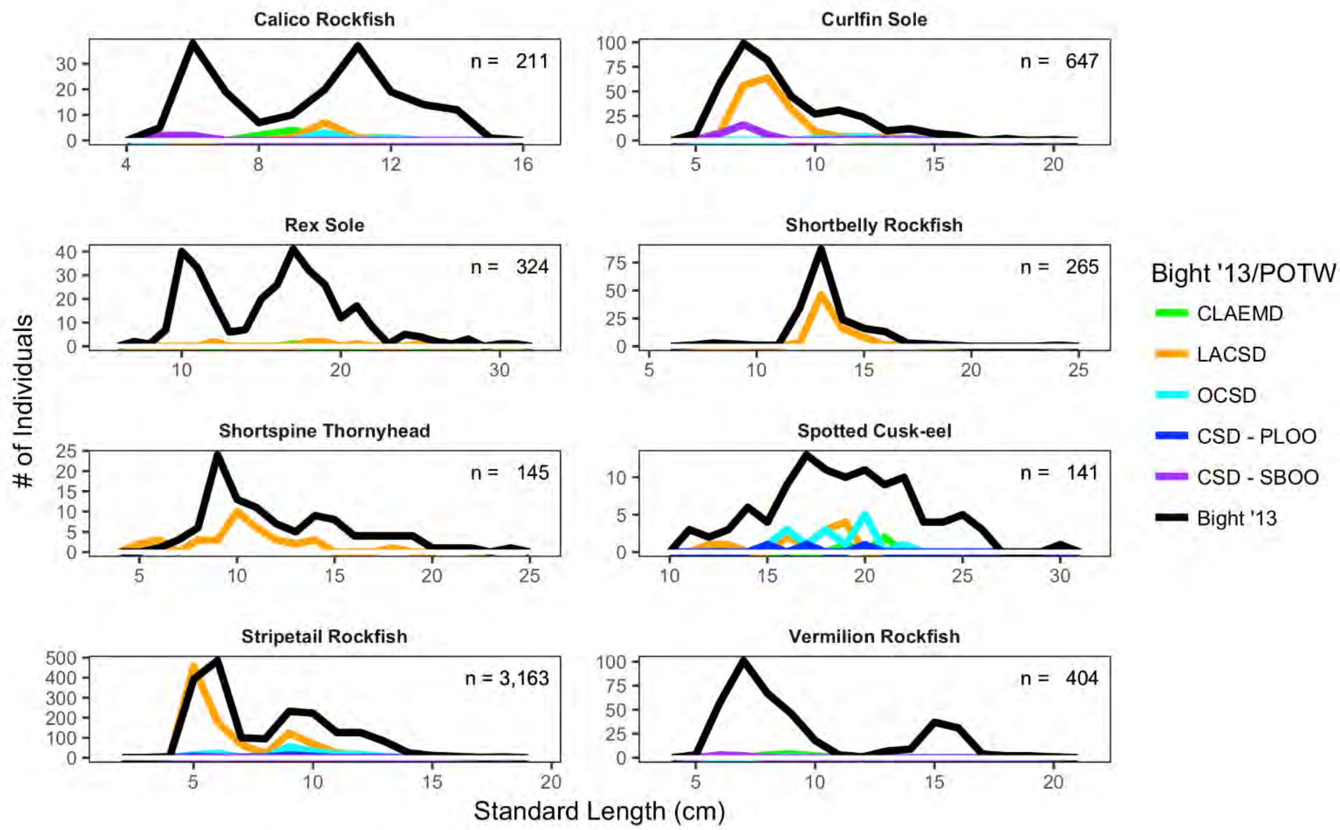



**Figure C-9. Length frequency for the demersal fish species with high pollution-tolerance (Allen et al. 2001) from Bight ’13 and POTW stations. Bight '13 data were collected during the summer of 2013, while data from the various POTWs were collected during 2012 and/or 2013 (see Table C-1). Total number of individuals (n) are noted.**

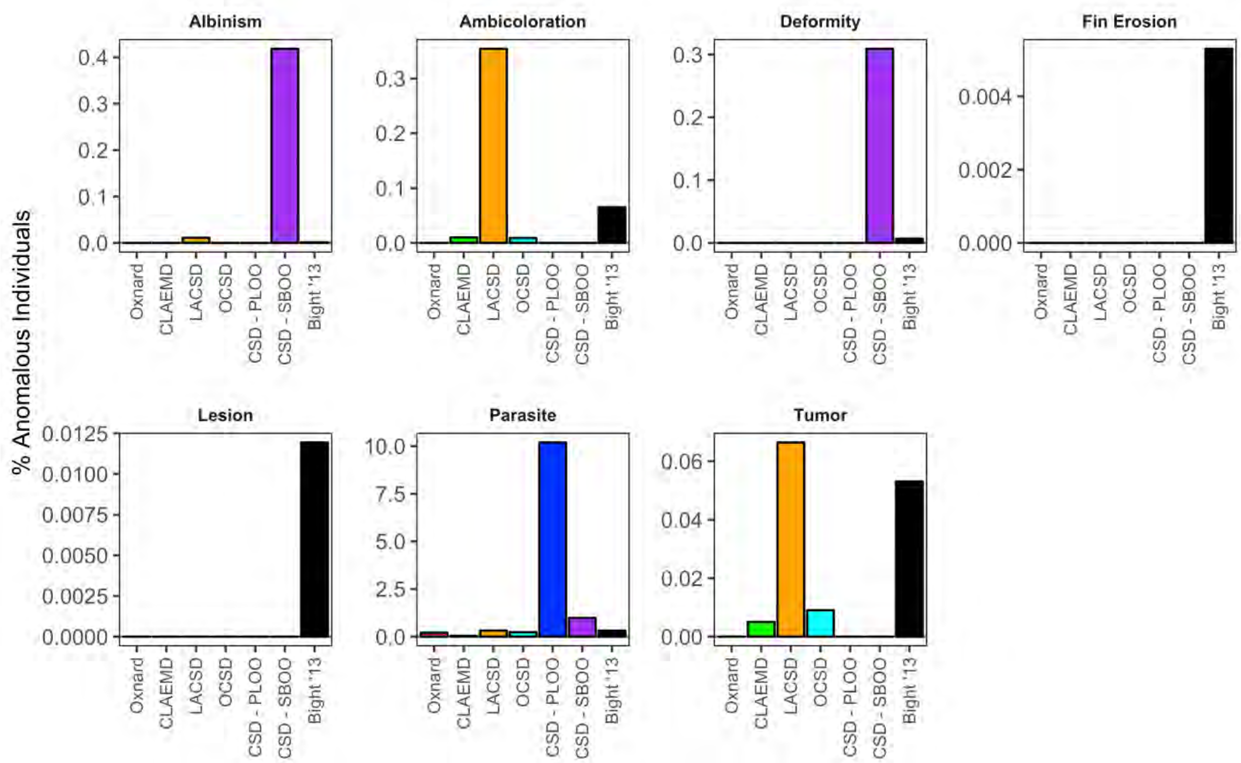



**Figure C-10. Percent anomalous fish from Bight '13 and POTW stations. Bight '13 data were collected during the summer of 2013, while data from the various POTWs were collected during 2012 and/or 2013 (see Table C-1).**

**Table C-9. Numbers of anomalous fish from Bight '13 and POTW stations. Bight '13 data were collected during the summer of 2013, while data from the various POTWs were collected during 2012 and/or 2013 (see Table C-1). Oxnard = City of Oxnard, CLAEMD = City of Los Angeles Environmental Monitoring Division, LACSD = Sanitation Districts of Los Angeles County, OCSD = Orange County Sanitation District, CSD-PLOO = City of San Diego-Point Loma Ocean Outfall, and CSD-SBOO = City of San Diego-South Bay Ocean Outfall.**

| Agency | Albinism | Ambicoloration | Deformity | Fin Erosion | Lesion | Parasite | Tumor | Total | Total Examined Fish |
|---|---|---|---|---|---|---|---|---|---|
| Oxnard | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 481 |
| CLAEMD | 0 | 2 | 0 | 0 | 0 | 8 | 1 | 11 | 19,866 |
| LACSD | 1 | 32 | 0 | 0 | 0 | 29 | 6 | 68 | 9,035 |
| OCSD | 0 | 1 | 0 | 0 | 0 | 26 | 1 | 28 | 11,063 |
| CSD - PLOO | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 10 | 3,307 |
| CSD - SBOO | 0 | 10 | 1 | 0 | 0 | 3 | 0 | 14 | 5,497 |
| *Bight '13* | 1 | 49 | 5 | 4 | 9 | 238 | 40 | 346 | 75,383 |

**Table C-10. Megabenthic invertebrate abundance for Bight '13 and POTW stations by stratum and agency. Bight '13 data were collected July - September 2013, while data from the various POTWs were collected during the same months in 2012 and/or 2013 (see Table C-1). Oxnard = City of Oxnard, CLAEMD = City of Los Angeles Environmental Monitoring Division, LACSD = Sanitation Districts of Los Angeles County, OCSD = Orange County Sanitation District, CSD-PLOO = City of San Diego-Point Loma Ocean Outfall, and CSD-SBOO = City of San Diego-South Bay Ocean Outfall.**

| Stratum/Agency | No. of Stations | Total | Range | | Median | Mean | SD | 95% CL | Percent Above Bight Median |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Max | | | | | |
| *Overall* | | | | | | | | | |
| ***POTW*** | **76** | **66,834** | **18** | **9,447** | **224** | **879** | **1,693** | **381** | **9.6** |
| **Bight '13** | **165** | **165,870** | **2** | **17,973** | **188** | **1,005** | **2,364** | **361** | **-7.8** |
| *Stratum* | | | | | | | | | |
| **Bays and Harbors (3-30 m)** | **32** | **3,069** | **5** | **316** | **65** | **96** | **94** | **33** | **-68.4** |
| *CLAEMD* | 6 | 510 | 28 | 246 | 53 | 85 | 83 | 66 | -74.0 |
| ***POTW*** | **6** | **510** | **28** | **246** | **53** | **85** | **83** | **66** | **-74.0** |
| **Bight '13** | **26** | **2,559** | **5** | **316** | **75** | **98** | **98** | **38** | **-63.5** |
| **Inner Shelf (8-30 m)** | **55** | **9,109** | **5** | **2,876** | **46** | **166** | **417** | **110** | **-77.5** |
| *ABC* | 3 | 116 | 20 | 69 | 27 | 39 | 27 | 30 | -86.8 |
| *CLAEMD* | 4 | 135 | 18 | 74 | 22 | 34 | 27 | 26 | -89.5 |
| *CSD-SBOO* | 7 | 997 | 38 | 489 | 95 | 142 | 157 | 116 | -53.4 |
| *LACSD* | 4 | 4,353 | 119 | 2,876 | 679 | 1,088 | 1,2 | 1,199 | 232.8 |
| *OCSD* | 2 | 65 | 31 | 34 | 33 | 33 | 2 | 3 | -84.1 |
| ***POTW*** | **20** | **5,666** | **18** | **2,876** | **72** | **283** | **646** | **283** | **-65.0** |
| **Bight '13** | **35** | **3,443** | **5** | **921** | **43** | **98** | **175** | **58** | **-78.9** |
| **Middle Shelf (31-120 m)** | **81** | **68,376** | **2** | **17,973** | **238** | **844** | **2,2** | **493** | **16.7** |
| *CLAEMD* | 12 | 10,147 | 38 | 8,432 | 138 | 846 | 2,3 | 1,353 | -32.4 |
| *CSD-PLOO* | 6 | 10,754 | 368 | 3,810 | 1,330 | 1,792 | 1,4 | 1,174 | 552.0 |
| *LACSD* | 4 | 4,797 | 154 | 3,822 | 411 | 1,199 | 1,7 | 1,725 | 101.2 |
| *OCSD* | 16 | 8,000 | 48 | 2,592 | 248 | 500 | 616 | 302 | 21.6 |
| ***POTW*** | **38** | **33,698** | **38** | **8,432** | **245** | **887** | **1,6** | **513** | **20.1** |
| **Bight '13** | **43** | **34,678** | **2** | **17,973** | **200** | **806** | **2,7** | **817** | **-2.0** |
| **Outer Shelf (121-200 m)** | **37** | **38,219** | **4** | **9,447** | **443** | **1,033** | **1,8** | **583** | **117.2** |
| *LACSD* | 4 | 13,910 | 443 | 9,447 | 2,010 | 3,478 | 4,0 | 3,977 | 885.3 |
| *OCSD* | 4 | 971 | 51 | 508 | 206 | 243 | 192 | 188 | 1.0 |
| ***POTW*** | **8** | **14,881** | **51** | **9,447** | **476** | **1,860** | **3,1** | **2,198** | **133.1** |
| **Bight '13** | **29** | **23,338** | **4** | **5,160** | **388** | **805** | **1,2** | **438** | **90.2** |
| **Upper slope (201-500 m)** | **36** | **113,931** | **68** | **17,600** | **2,286** | **3,165** | **3,2** | **1,047** | **1,020.6** |
| *LACSD* | 4 | 12,079 | 1,955 | 4,283 | 2,921 | 3,020 | 1,0 | 1,018 | 1,331.6 |
| ***POTW*** | **4** | **12,079** | **1,955** | **4,283** | **2,921** | **3,020** | **1,0** | **1,018** | **1,331.6** |
| **Bight '13** | **32** | **101,852** | **68** | **17,600** | **2,116** | **3,183** | **3,3** | **1,175** | **937.3** |
| **Total (all stations)** | **241** | **232,704** | **2** | **17,973** | **204** | **966** | **2,1** | **274** | |

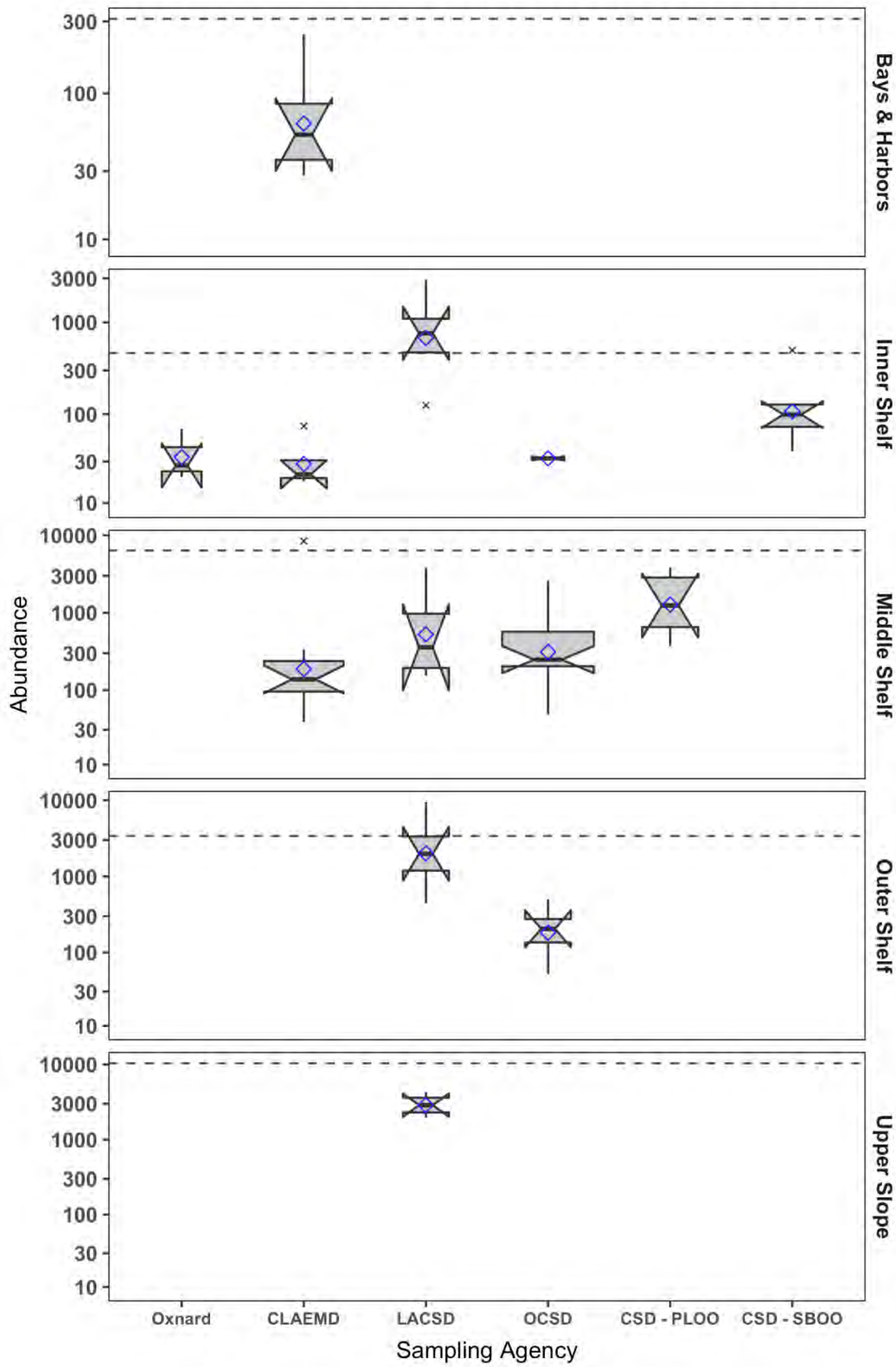



**Figure C-11. Megabenthic invertebrate abundance by stratum for POTW monitoring stations sampled in 2012/2013. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size (see Table C-9). Dashed lines are tolerance intervals covering 90% of the Bight '13 population of the same stratum, with 95% confidence.**

**Table C-11. Megabenthic invertebrate diversity (Shannon, H') for Bight '13 and POTW stations by stratum and agency. Bight '13 data were collected July - September 2013, while data from the various POTWs were collected during the same months in 2012 and/or 2013 (see Table C-1). Oxnard = City of Oxnard, CLAEMD = City of Los Angeles Environmental Monitoring Division, LACSD = Sanitation Districts of Los Angeles County, OCSD = Orange County Sanitation District, CSD-PLOO = City of San Diego-Point Loma Ocean Outfall, and CSD-SBOO = City of San Diego-South Bay Ocean Outfall.**

| Stratum/Agency | No. of Stations | Range Min | Range Max | Median | Mean | SD | 95% CL | Percent Above Bight Median |
|---|---|---|---|---|---|---|---|---|
| *Overall* | | | | | | | | |
| ***POTW*** | **76** | **0.05** | **2.48** | **1.14** | **1.18** | **0.56** | **0.13** | **0.9** |
| **Bight '13** | **165** | **0.07** | **2.49** | **1.13** | **1.13** | **0.57** | **0.09** | **-0.1** |
| *Stratum* | | | | | | | | |
| **Bays and Harbors (3-30 m)** | **32** | **0.12** | **2.30** | **1.11** | **1.18** | **0.55** | **0.19** | **-1.7** |
| *CLAEMD* | 6 | 0.80 | 1.68 | 1.50 | 1.35 | 0.33 | 0.26 | 32.7 |
| ***POTW*** | **6** | **0.80** | **1.68** | **1.50** | **1.35** | **0.33** | **0.26** | **32.7** |
| **Bight '13** | **26** | **0.12** | **2.30** | **1.02** | **1.14** | **0.59** | **0.23** | **-9.4** |
| **Inner Shelf (8-30 m)** | **55** | **0.11** | **2.48** | **1.52** | **1.32** | **0.57** | **0.15** | **35.0** |
| *ABC* | 3 | 0.76 | 1.64 | 1.14 | 1.18 | 0.44 | 0.50 | 1.0 |
| *CLAEMD* | 4 | 1.52 | 1.71 | 1.58 | 1.60 | 0.08 | 0.08 | 40.2 |
| *CSD-SBOO* | 7 | 0.44 | 2.48 | 1.89 | 1.63 | 0.76 | 0.56 | 67.5 |
| *LACSD* | 4 | 0.45 | 1.85 | 0.89 | 1.02 | 0.59 | 0.58 | -20.7 |
| *OCSD* | 2 | 2.11 | 2.18 | 2.14 | 2.14 | 0.05 | 0.07 | 90.2 |
| ***POTW*** | **20** | **0.44** | **2.48** | **1.61** | **1.49** | **0.61** | **0.27** | **43.2** |
| **Bight '13** | **35** | **0.11** | **2.07** | **1.39** | **1.23** | **0.52** | **0.17** | **23.7** |
| **Middle Shelf (31-120 m)** | **81** | **0.05** | **2.49** | **1.14** | **1.14** | **0.54** | **0.12** | **0.9** |
| *CLAEMD* | 12 | 0.05 | 1.82 | 1.24 | 1.22 | 0.50 | 0.28 | 10.4 |
| *CSD-PLOO* | 6 | 0.23 | 1.10 | 0.81 | 0.73 | 0.36 | 0.29 | -27.9 |
| *LACSD* | 4 | 0.33 | 1.83 | 0.93 | 1.01 | 0.68 | 0.67 | -17.2 |
| *OCSD* | 16 | 0.54 | 1.98 | 1.11 | 1.19 | 0.44 | 0.22 | -1.6 |
| ***POTW*** | **38** | **0.05** | **1.98** | **1.12** | **1.11** | **0.49** | **0.16** | **-0.9** |
| **Bight '13** | **43** | **0.09** | **2.49** | **1.39** | **1.16** | **0.59** | **0.18** | **22.9** |
| **Outer Shelf (121-200 m)** | **37** | **0.10** | **2.39** | **1.18** | **1.20** | **0.59** | **0.19** | **4.4** |
| *LACSD* | 4 | 0.44 | 0.94 | 0.63 | 0.66 | 0.22 | 0.21 | -44.5 |
| *OCSD* | 4 | 0.70 | 1.97 | 1.26 | 1.29 | 0.53 | 0.52 | 11.5 |
| ***POTW*** | **8** | **0.44** | **1.97** | **0.82** | **0.98** | **0.50** | **0.35** | **-27.3** |
| **Bight '13** | **29** | **0.10** | **2.39** | **1.24** | **1.26** | **0.61** | **0.22** | **10.3** |
| **Upper slope (201-500 m)** | **36** | **0.07** | **1.81** | **0.76** | **0.81** | **0.46** | **0.15** | **-32.5** |
| *LACSD* | 4 | 0.10 | 0.70 | 0.52 | 0.46 | 0.29 | 0.29 | -53.9 |
| ***POTW*** | **4** | **0.10** | **0.70** | **0.52** | **0.46** | **0.29** | **0.29** | **-53.9** |
| **Bight '13** | **32** | **0.07** | **1.81** | **0.81** | **0.86** | **0.46** | **0.16** | **-28.5** |
| **Total (all stations)** | **241** | **0.05** | **2.49** | **1.13** | **1.15** | **0.56** | **0.07** | |

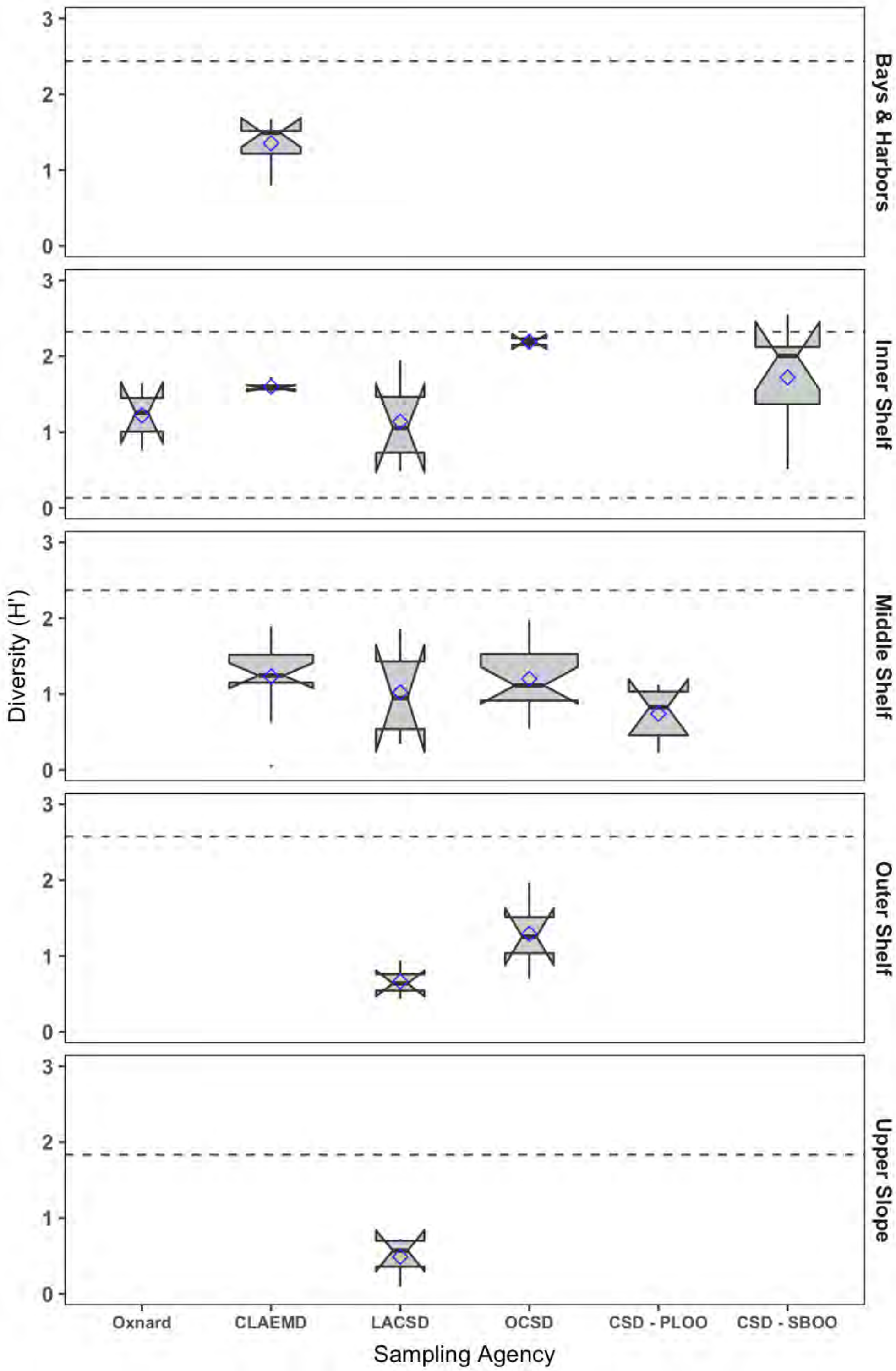



**Figure C-12. Megabenthic invertebrate diversity (Shannon, H') by stratum for POTW monitoring stations sampled in 2012/2013. Data are median, upper and lower quartiles, means (blue diamonds), 95% confidence intervals of the median (notches), 1.5 times the interquartile range (whiskers), and outliers ("x"). Box width indicates relative sample size (see Table C-9). Dashed lines are tolerance intervals covering 90% of the Bight '13 population of the same stratum, with 95% confidence.**

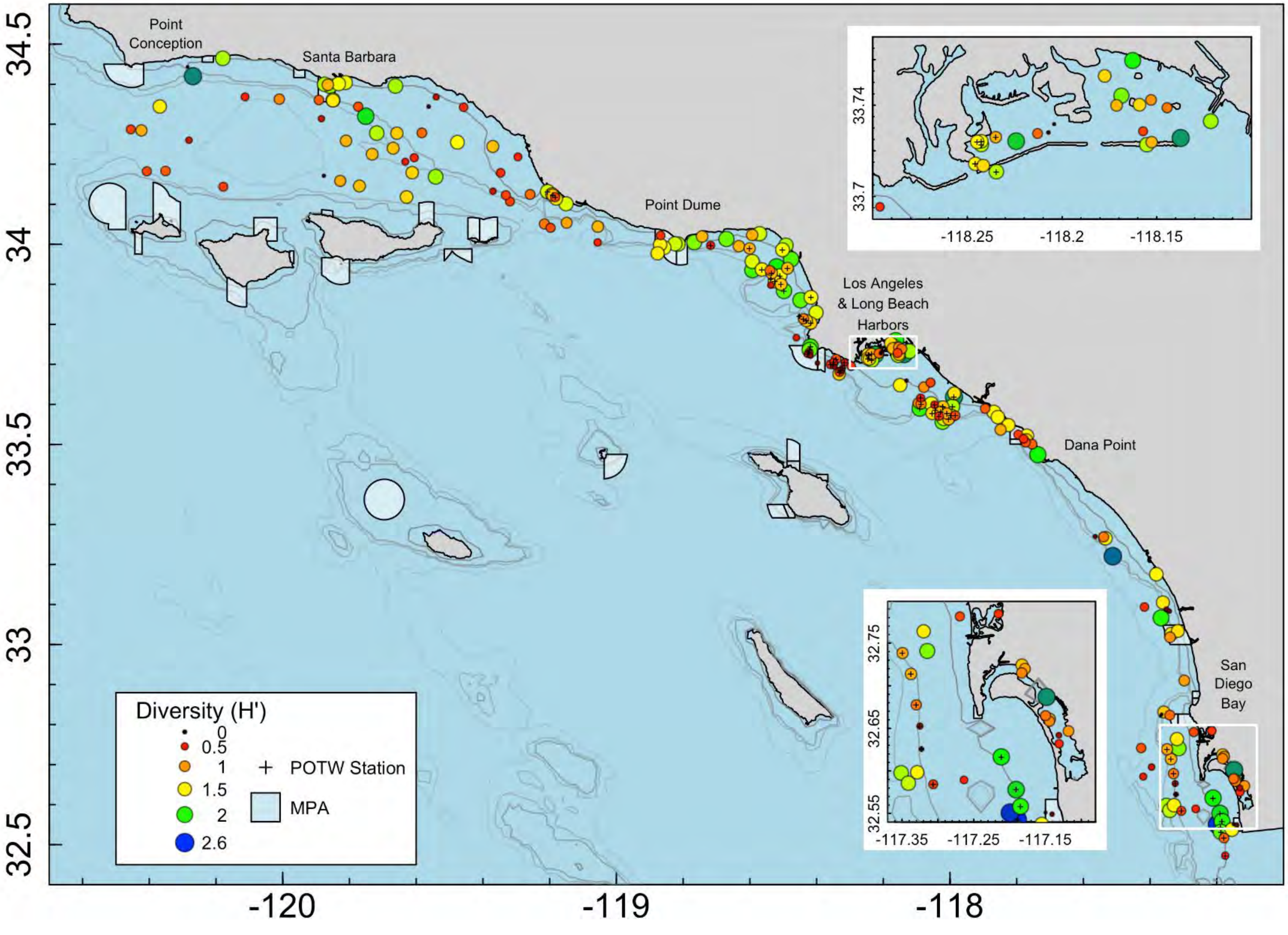



**Figure C-13. Distribution of megabenthic invertebrate diversity (Shannon, H') at Bight '13 stations sampled during 2013 and POTW monitoring stations sampled in 2012 and/or 2013.**

**Table C-12. Megabenthic invertebrate species richness (number of species) for Bight '13 and POTW stations by stratum and agency. Bight '13 data were collected July - September 2013, while data from the various POTWs were collected during the same months in 2012 and/or 2013 (see Table C-1). Oxnard = City of Oxnard, CLAEMD = City of Los Angeles Environmental Monitoring Division, LACSD = Sanitation Districts of Los Angeles County, OCSD = Orange County Sanitation District, CSD-PLOO = City of San Diego-Point Loma Ocean Outfall, and CSD-SBOO = City of San Diego-South Bay Ocean Outfall.**

| Stratum/Agency | No. of Stations | Total | Range | | Median | Mean | SD | 95% CL | Percent Above Bight Median |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Max | | | | | |
| *Overall* | | | | | | | | | |
| ***POTW*** | **76** | **133** | **3** | **25** | **11** | **11** | **4** | **1** | **10.0** |
| **Bight '13** | **165** | **229** | **2** | **29** | **10** | **10** | **5** | **1** | **0.0** |
| *Stratum* | | | | | | | | | |
| **Bays and Harbors (3-30 m)** | **32** | **60** | **2** | **11** | **5.5** | **6** | **3** | **1** | **-45.0** |
| *CLAEMD* | 6 | 22 | 3 | 8 | 7 | 6 | 2 | 1 | -30.0 |
| ***POTW*** | **6** | **22** | **3** | **8** | **7** | **6** | **2** | **1** | **-30.0** |
| **Bight '13** | **26** | **53** | **2** | **11** | **5** | **6** | **3** | **1** | **-50.0** |
| **Inner Shelf (8-30 m)** | **55** | **99** | **2** | **25** | **7** | **9** | **4** | **1** | **-30.0** |
| *ABC* | 3 | 9 | 5 | 7 | 6 | 6 | 1 | 1 | -40.0 |
| *CLAEMD* | 4 | 22 | 6 | 10 | 7.5 | 8 | 2 | 2 | -25.0 |
| *CSD-SBOO* | 7 | 46 | 10 | 25 | 13 | 15 | 5 | 4 | 30.0 |
| *LACSD* | 4 | 23 | 10 | 14 | 11 | 12 | 2 | 2 | 10.0 |
| *OCSD* | 2 | 22 | 12 | 13 | 12.5 | 13 | 1 | 1 | 25.0 |
| ***POTW*** | **20** | **73** | **5** | **25** | **11** | **11** | **5** | **2** | **10.0** |
| **Bight '13** | **35** | **66** | **2** | **13** | **7** | **7** | **3** | **1** | **-30.0** |
| **Middle Shelf (31-120 m)** | **81** | **125** | **2** | **23** | **11** | **11** | **4** | **1** | **10.0** |
| *CLAEMD* | 12 | 28 | 8 | 14 | 9.5 | 10 | 2 | 1 | -5.0 |
| *CSD-PLOO* | 6 | 30 | 7 | 18 | 15 | 14 | 5 | 4 | 50.0 |
| *LACSD* | 4 | 15 | 7 | 11 | 10 | 10 | 2 | 2 | 0.0 |
| *OCSD* | 16 | 34 | 7 | 17 | 12 | 12 | 3 | 2 | 20.0 |
| ***POTW*** | **38** | **55** | **7** | **18** | **12** | **12** | **3** | **1** | **20.0** |
| **Bight '13** | **43** | **107** | **2** | **23** | **11** | **11** | **5** | **1** | **10.0** |
| **Outer Shelf (121-200 m)** | **37** | **80** | **3** | **29** | **14** | **14** | **6** | **2** | **40.0** |
| *LACSD* | 4 | 27 | 9 | 23 | 12.5 | 14 | 6 | 6 | 25.0 |
| *OCSD* | 4 | 19 | 9 | 12 | 10.5 | 11 | 1 | 1 | 5.0 |
| ***POTW*** | **8** | **31** | **9** | **23** | **11** | **12** | **5** | **3** | **10.0** |
| **Bight '13** | **29** | **76** | **3** | **29** | **16** | **15** | **6** | **2** | **60.0** |
| **Upper slope (201-500 m)** | **36** | **87** | **2** | **19** | **10.5** | **11** | **4** | **1** | **5.0** |
| *LACSD* | 4 | 24 | 9 | 15 | 11.5 | 12 | 3 | 2 | 15.0 |
| ***POTW*** | **4** | **24** | **9** | **15** | **11.5** | **12** | **3** | **2** | **15.0** |
| **Bight '13** | **32** | **83** | **2** | **19** | **10** | **11** | **5** | **2** | **0.0** |
| **Total (all stations)** | **241** | **257** | **2** | **29** | **10.0** | **10.4** | **4.9** | **0.6** | |

**Table C-13. Megabenthic invertebrate species richness (Margalef index) for Bight '13 and POTW stations by stratum and agency. Bight '13 data were collected July - September 2013, while data from the various POTWs were collected during the same months in 2012 and/or 2013 (see Table C-1). Oxnard = City of Oxnard, CLAEMD = City of Los Angeles Environmental Monitoring Division, LACSD = Sanitation Districts of Los Angeles County, OCSD = Orange County Sanitation District, CSD-PLOO = City of San Diego-Point Loma Ocean Outfall, and CSD-SBOO = City of San Diego-South Bay Ocean Outfall.**

| | No. of Stations | Range Min | Range Max | Median | Mean | SD | 95% CL | Percent Above Bight Median |
|---|---|---|---|---|---|---|---|---|
| *Overall* | | | | | | | | |
| ***POTW*** | **76** | **0.60** | **5.27** | **1.79** | **1.91** | **0.78** | **0.18** | **5.7** |
| **Bight '13** | **165** | **0.19** | **4.60** | **1.64** | **1.72** | **0.82** | **0.13** | **-3.5** |
| *Stratum* | | | | | | | | |
| **Bays and Harbors (3-30 m)** | **32** | **0.19** | **3.79** | **1.18** | **1.26** | **0.64** | **0.22** | **-30.4** |
| *CLAEMD* | 6 | 0.60 | 1.73 | 1.29 | 1.24 | 0.40 | 0.32 | -24.0 |
| ***POTW*** | **6** | **0.60** | **1.73** | **1.29** | **1.24** | **0.40** | **0.32** | **-24.0** |
| **Bight '13** | **26** | **0.19** | **3.79** | **1.13** | **1.26** | **0.69** | **0.27** | **-33.7** |
| **Inner Shelf (8-30 m)** | **55** | **0.62** | **5.27** | **1.70** | **1.91** | **0.89** | **0.23** | **0.2** |
| *ABC* | 3 | 0.94 | 2.00 | 1.52 | 1.49 | 0.53 | 0.60 | -10.6 |
| *CLAEMD* | 4 | 1.67 | 2.42 | 2.00 | 2.02 | 0.32 | 0.31 | 18.0 |
| *CSD-SBOO* | 7 | 1.45 | 5.27 | 3.02 | 3.16 | 1.25 | 0.93 | 78.1 |
| *LACSD* | 4 | 1.26 | 1.95 | 1.73 | 1.67 | 0.32 | 0.31 | 1.9 |
| *OCSD* | 2 | 3.12 | 3.49 | 3.31 | 3.31 | 0.27 | 0.37 | 94.8 |
| ***POTW*** | **20** | **0.94** | **5.27** | **2.05** | **2.40** | **1.06** | **0.47** | **20.6** |
| **Bight '13** | **35** | **0.62** | **3.02** | **1.64** | **1.63** | **0.63** | **0.21** | **-3.5** |
| **Middle Shelf (31-120 m)** | **81** | **0.34** | **4.60** | **1.85** | **1.91** | **0.68** | **0.15** | **9.0** |
| *CLAEMD* | 12 | 1.22 | 2.60 | 1.86 | 1.82 | 0.41 | 0.23 | 9.3 |
| *CSD-PLOO* | 6 | 0.94 | 2.20 | 1.96 | 1.73 | 0.53 | 0.43 | 15.2 |
| *LACSD* | 4 | 0.93 | 1.99 | 1.39 | 1.42 | 0.49 | 0.48 | -18.2 |
| *OCSD* | 16 | 0.87 | 2.96 | 1.82 | 1.96 | 0.53 | 0.26 | 6.9 |
| ***POTW*** | **38** | **0.87** | **2.96** | **1.84** | **1.82** | **0.50** | **0.16** | **8.2** |
| **Bight '13** | **43** | **0.34** | **4.60** | **1.88** | **1.99** | **0.80** | **0.24** | **10.7** |
| **Outer Shelf (121-200 m)** | **37** | **0.78** | **4.02** | **2.06** | **2.21** | **0.87** | **0.28** | **21.2** |
| *LACSD* | 4 | 1.03 | 3.61 | 1.42 | 1.87 | 1.20 | 1.18 | -16.2 |
| *OCSD* | 4 | 1.28 | 2.54 | 1.88 | 1.90 | 0.55 | 0.53 | 10.9 |
| ***POTW*** | **8** | **1.03** | **3.61** | **1.71** | **1.88** | **0.87** | **0.60** | **0.6** |
| **Bight '13** | **29** | **0.78** | **4.02** | **2.19** | **2.30** | **0.87** | **0.32** | **29.1** |
| **Upper slope (201-500 m)** | **36** | **0.20** | **3.02** | **1.23** | **1.32** | **0.63** | **0.21** | **-27.6** |
| *LACSD* | 4 | 1.03 | 1.72 | 1.32 | 1.35 | 0.30 | 0.30 | -22.0 |
| ***POTW*** | **4** | **1.03** | **1.72** | **1.32** | **1.35** | **0.30** | **0.30** | **-22.0** |
| **Bight '13** | **32** | **0.20** | **3.02** | **1.23** | **1.32** | **0.67** | **0.23** | **-27.6** |
| **Total (all stations)** | **241** | **0.19** | **5.27** | **1.70** | **1.78** | **0.81** | **0.10** | |

**Table C-14. Megabenthic invertebrate species evenness (Pielou's evenness) for Bight '13 and POTW stations by stratum and agency. Bight '13 data were collected July - September 2013, while data from the various POTWs were collected during the same months in 2012 and/or 2013 (see Table C-1). Oxnard = City of Oxnard, CLAEMD = City of Los Angeles Environmental Monitoring Division, LACSD = Sanitation Districts of Los Angeles County, OCSD = Orange County Sanitation District, CSD-PLOO = City of San Diego-Point Loma Ocean Outfall, and CSD-SBOO = City of San Diego-South Bay Ocean Outfall.**

| Stratum/Agency | No. of Stations | Range Min | Range Max | Median | Mean | SD | 95% CL | Percent Above Bight Median |
|---|---|---|---|---|---|---|---|---|
| *Overall* | | | | | | | | |
| ***POTW*** | **76** | **0.02** | **0.89** | **0.50** | **0.51** | **0.24** | **0.05** | **-5.2** |
| **Bight '13** | **165** | **0.05** | **1.13** | **0.53** | **0.53** | **0.26** | **0.04** | **0.2** |
| | | | | | | | | |
| *Stratum* | | | | | | | | |
| **Bays and Harbors (3-30 m)** | **32** | **0.17** | **1.13** | **0.71** | **0.68** | **0.25** | **0.09** | **34.1** |
| *CLAEMD* | 6 | 0.70 | 0.86 | 0.75 | 0.76 | 0.06 | 0.05 | 41.6 |
| ***POTW*** | **6** | **0.70** | **0.86** | **0.75** | **0.76** | **0.06** | **0.05** | **41.6** |
| **Bight '13** | **26** | **0.17** | **1.13** | **0.66** | **0.66** | **0.28** | **0.11** | **25.6** |
| **Inner Shelf (8-30 m)** | **55** | **0.06** | **0.97** | **0.75** | **0.65** | **0.25** | **0.06** | **41.7** |
| *ABC* | 3 | 0.47 | 0.84 | 0.64 | 0.65 | 0.19 | 0.21 | 20.3 |
| *CLAEMD* | 4 | 0.66 | 0.88 | 0.82 | 0.79 | 0.09 | 0.09 | 54.3 |
| *CSD-SBOO* | 7 | 0.19 | 0.84 | 0.70 | 0.60 | 0.26 | 0.19 | 31.9 |
| *LACSD* | 4 | 0.17 | 0.80 | 0.37 | 0.43 | 0.27 | 0.26 | -29.5 |
| *OCSD* | 2 | 0.85 | 0.85 | 0.85 | 0.85 | 0.00 | 0.00 | 60.7 |
| ***POTW*** | **20** | **0.17** | **0.88** | **0.73** | **0.64** | **0.24** | **0.10** | **38.8** |
| **Bight '13** | **35** | **0.06** | **0.97** | **0.75** | **0.66** | **0.25** | **0.08** | **41.7** |
| **Middle Shelf (31-120 m)** | **81** | **0.02** | **1.00** | **0.48** | **0.48** | **0.23** | **0.05** | **-8.6** |
| *CLAEMD* | 12 | 0.02 | 0.75 | 0.57 | 0.53 | 0.22 | 0.12 | 7.7 |
| *CSD-PLOO* | 6 | 0.08 | 0.57 | 0.30 | 0.31 | 0.19 | 0.15 | -44.0 |
| *LACSD* | 4 | 0.14 | 0.76 | 0.43 | 0.44 | 0.28 | 0.27 | -19.0 |
| *OCSD* | 16 | 0.20 | 0.89 | 0.45 | 0.49 | 0.19 | 0.09 | -15.6 |
| ***POTW*** | **38** | **0.02** | **0.89** | **0.46** | **0.47** | **0.22** | **0.07** | **-12.3** |
| **Bight '13** | **43** | **0.06** | **1.00** | **0.53** | **0.50** | **0.24** | **0.07** | **-0.2** |
| **Outer Shelf (121-200 m)** | **37** | **0.05** | **0.95** | **0.50** | **0.48** | **0.23** | **0.07** | **-5.9** |
| *LACSD* | 4 | 0.18 | 0.31 | 0.26 | 0.25 | 0.06 | 0.06 | -51.3 |
| *OCSD* | 4 | 0.32 | 0.82 | 0.52 | 0.55 | 0.21 | 0.20 | -0.8 |
| ***POTW*** | **8** | **0.18** | **0.82** | **0.31** | **0.40** | **0.21** | **0.15** | **-40.4** |
| **Bight '13** | **29** | **0.05** | **0.95** | **0.51** | **0.50** | **0.23** | **0.09** | **-2.6** |
| **Upper slope (201-500 m)** | **36** | **0.04** | **0.69** | **0.32** | **0.35** | **0.18** | **0.06** | **-38.6** |
| *LACSD* | 4 | 0.04 | 0.31 | 0.21 | 0.19 | 0.13 | 0.13 | -60.2 |
| ***POTW*** | **4** | **0.04** | **0.31** | **0.21** | **0.19** | **0.13** | **0.13** | **-60.2** |
| **Bight '13** | **32** | **0.05** | **0.69** | **0.35** | **0.37** | **0.17** | **0.06** | **-32.9** |
| **Total (all stations)** | **241** | **0.02** | **1.13** | **0.53** | **0.53** | **0.25** | **0.03** | |

**Table C-15. Megabenthic invertebrate Dominance (Simpson's index) for Bight '13 and POTW stations by stratum and agency. Bight '13 data were collected July - September 2013, while data from the various POTWs were collected during the same months in 2012 and/or 2013 (see Table C-1). Oxnard = City of Oxnard, CLAEMD = City of Los Angeles Environmental Monitoring Division, LACSD = Sanitation Districts of Los Angeles County, OCSD = Orange County Sanitation District, CSD-PLOO = City of San Diego-Point Loma Ocean Outfall, and CSD-SBOO = City of San Diego-South Bay Ocean Outfall.**

| Stratum/Agency | No. of Stations | Range | | Median | Mean | SD | 95% CL | Percent Above Bight Median |
|---|---|---|---|---|---|---|---|---|
| | | Min | Max | | | | | |
| *Overall* | | | | | | | | |
| ***POTW*** | **76** | **0.01** | **0.86** | **0.54** | **0.53** | **0.23** | **0.05** | **-2.2** |
| **Bight '13** | **165** | **0.02** | **1.01** | **0.56** | **0.51** | **0.24** | **0.04** | **0.7** |
| *Stratum* | | | | | | | | |
| **Bays and Harbors (3-30 m)** | **32** | **0.04** | **1.01** | **0.57** | **0.56** | **0.25** | **0.09** | **2.3** |
| *CLAEMD* | 6 | 0.45 | 0.77 | 0.72 | 0.66 | 0.12 | 0.10 | 30.1 |
| ***POTW*** | **6** | **0.45** | **0.77** | **0.72** | **0.66** | **0.12** | **0.10** | **30.1** |
| **Bight '13** | **26** | **0.04** | **1.01** | **0.55** | **0.53** | **0.27** | **0.10** | **-1.6** |
| **Inner Shelf (8-30 m)** | **55** | **0.03** | **0.86** | **0.69** | **0.59** | **0.23** | **0.06** | **23.9** |
| *ABC* | 3 | 0.37 | 0.77 | 0.56 | 0.57 | 0.20 | 0.23 | 1.4 |
| *CLAEMD* | 4 | 0.67 | 0.77 | 0.75 | 0.73 | 0.04 | 0.04 | 34.6 |
| *CSD-SBOO* | 7 | 0.18 | 0.86 | 0.71 | 0.62 | 0.28 | 0.21 | 28.5 |
| *LACSD* | 4 | 0.16 | 0.82 | 0.48 | 0.48 | 0.27 | 0.26 | -13.8 |
| *OCSD* | 2 | 0.83 | 0.84 | 0.84 | 0.84 | 0.01 | 0.01 | 51.2 |
| ***POTW*** | **20** | **0.16** | **0.86** | **0.73** | **0.63** | **0.23** | **0.10** | **31.5** |
| **Bight '13** | **35** | **0.03** | **0.84** | **0.66** | **0.57** | **0.23** | **0.08** | **19.2** |
| **Middle Shelf (31-120 m)** | **81** | **0.01** | **0.88** | **0.53** | **0.50** | **0.23** | **0.05** | **-4.8** |
| *CLAEMD* | 12 | 0.01 | 0.80 | 0.54 | 0.54 | 0.23 | 0.13 | -3.1 |
| *CSD-PLOO* | 6 | 0.07 | 0.61 | 0.39 | 0.37 | 0.22 | 0.18 | -28.9 |
| *LACSD* | 4 | 0.12 | 0.81 | 0.44 | 0.46 | 0.30 | 0.29 | -19.8 |
| *OCSD* | 16 | 0.25 | 0.82 | 0.53 | 0.52 | 0.18 | 0.09 | -4.8 |
| ***POTW*** | **38** | **0.01** | **0.82** | **0.52** | **0.50** | **0.22** | **0.07** | **-5.5** |
| **Bight '13** | **43** | **0.03** | **0.88** | **0.56** | **0.50** | **0.24** | **0.07** | **0.7** |
| **Outer Shelf (121-200 m)** | **37** | **0.03** | **0.88** | **0.56** | **0.51** | **0.24** | **0.08** | **1.9** |
| *LACSD* | 4 | 0.21 | 0.47 | 0.27 | 0.30 | 0.12 | 0.12 | -52.0 |
| *OCSD* | 4 | 0.32 | 0.81 | 0.62 | 0.59 | 0.20 | 0.20 | 11.9 |
| ***POTW*** | **8** | **0.21** | **0.81** | **0.39** | **0.45** | **0.22** | **0.15** | **-29.1** |
| **Bight '13** | **29** | **0.03** | **0.88** | **0.60** | **0.53** | **0.24** | **0.09** | **8.6** |
| **Upper slope (201-500 m)** | **36** | **0.02** | **0.75** | **0.42** | **0.40** | **0.22** | **0.07** | **-23.4** |
| *LACSD* | 4 | 0.03 | 0.46 | 0.28 | 0.26 | 0.22 | 0.21 | -49.7 |
| ***POTW*** | **4** | **0.03** | **0.46** | **0.28** | **0.26** | **0.22** | **0.21** | **-49.7** |
| **Bight '13** | **32** | **0.02** | **0.75** | **0.42** | **0.41** | **0.21** | **0.07** | **-23.4** |
| **Total (all stations)** | **241** | **0.01** | **1.01** | **0.55** | **0.51** | **0.24** | **0.03** | |

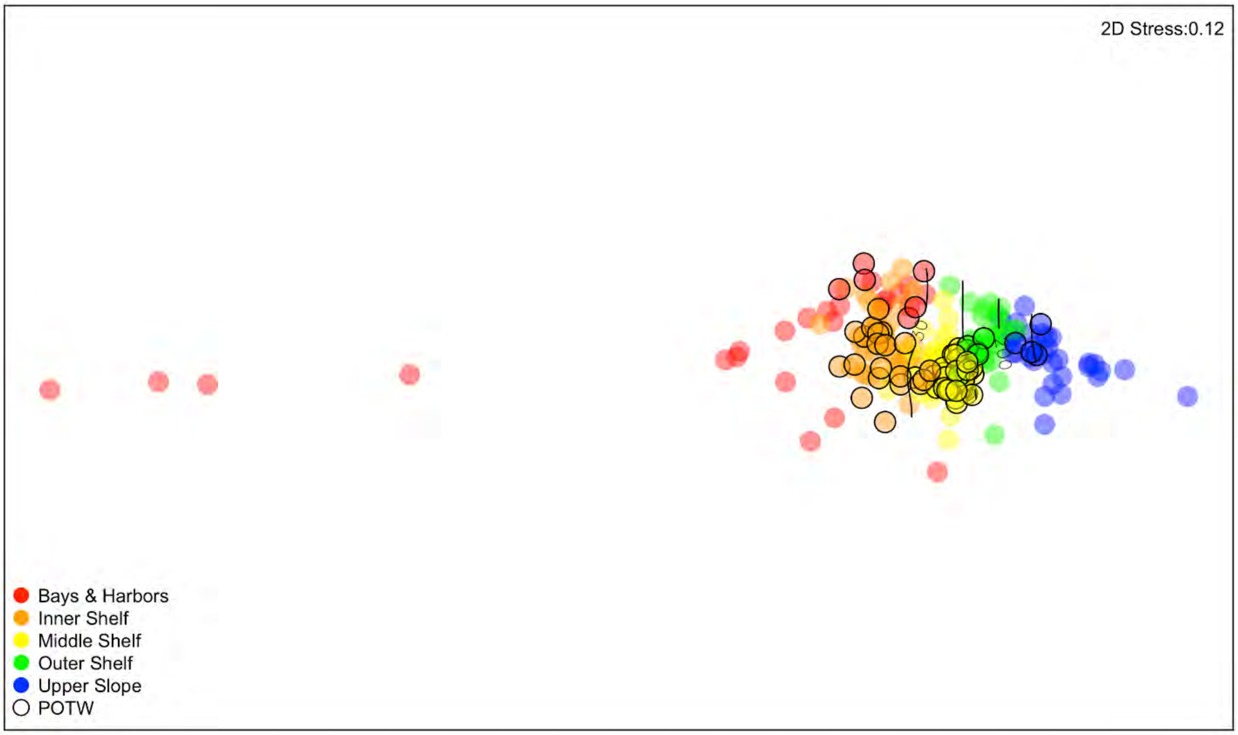



**Figure C-14. Ordination (nMDS) of megabenthic invertebrate abundance per haul from Bight '13 and POTW stations by stratum with a surface plot of trawl depth overlain (black lines). POTW stations are outlined in black.**

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# APPENDIX D: MARINE PROTECTED AREAS SPECIAL STUDY

# Analysis of Soft-Bottom Fish and Invertebrate Communities from the Southern California Bight, 1994-2013

## Including information regarding requirements for future assessment of Marine Protected Area effects

A report to:

<u>The California Ocean Science Trust</u>

*August 2015*

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# INTRODUCTION

The Southern California Bight (SCB) is an open embayment adjacent to the largest urban area on the west coast of the United States, extending from Point Conception, California to the United States-Mexico border. The most recent census data show that approximately 17.2 million people inhabit the five coastal counties that border the SCB (Santa Barbara, Ventura, Los Angeles, Orange, San Diego), a number that is projected to increase to over 20 million by 2040 (State of California 2014). The SCB is directly affected by anthropogenic impacts associated with urban development and human population increase, including an extensive and diverse set of stressors. In addition to consumptive use (including recreational and commercial fishing), conversion of open land into non-permeable surfaces provides pathways for increased urban and storm related runoff, which adds sediment, toxic chemicals, pathogens and nutrients to the ocean (Stull et al. 1987, Dojiri et al. 2003, Schiff 2003, Pondella 2009, Sikich and James 2010, Allen et al. 2011, Erisman et al. 2011). Infrastructure to support this large and expanding urbanization includes 15 municipal wastewater treatment facilities, 10 power generating stations, 10 industrial treatment facilities, and 27 oil platforms, all of which discharge effluent into the ocean. To comply with water quality standards associated with the California Ocean Plan and federal Clean Water Act, local, state and federal agencies spend in excess of $31 million a year to monitor potential impacts of their discharges to the coastal ocean (Schiff et al. 2002, Allen et al. 2011).

Marine community dynamics, including structure, abundance, biomass, and size distribution are often affected by a wide array of natural and anthropogenic influences. Soft-bottom substrates within the SCB are diverse, relating to a complex topography, with harbors, sandy nearshore areas, submarine canyons, offshore islands, ridges and basins (Dailey et al. 1993). The SCB as a whole is characterized by strong environmental gradients. It represents a transitional area influenced by the cold California Current from the north and the warmer Davidson Countercurrent from the south, punctuated by low-frequency oceanographic regime shifts and higher-frequency El Niño Southern Oscillation (ENSO) events (Hickey 1993; Bograd and Lynn 2003; McGowan et al. 2003; Horn et al. 2006). This natural, highly dynamic oceanographic variability has historically shaped these communities (Dayton et al. 1998), and multiple habitat types allow for the coexistence of a broad spectrum of species, including more than 500 species of fish (Cross and Allen 1993) and thousands of invertebrate species (Thompson et al. 1993). Many of these species separate themselves by depth, habitat, and feeding guilds to reduce food competition and allow multi-species coexistence (Allen 2006; Allen et al. 1998, 2002, 2007). However, consumptive use and anthropogenic influences including pollution and habitat degradation have significantly altered the historical marine community structure (Hidalgo et al. 2011; Mora et al. 2011). Additionally, 50 marine protected areas (MPAs) with widely varying restrictions were developed or redesigned throughout the SCB in 2012 in fulfillment of the Marine Life Protection Act of 1999 (Pondella et al. 2015).

Disentangling the interacting natural and anthropogenic forces affecting the past, present, and future status of the SCB's marine communities requires robust data on both large spatial and temporal scales (Scavia et al. 2002; Harley et al. 2006; Hsieh et al. 2008). Core monitoring programs have been conducted by various dischargers in the SCB for decades, but they are most often localized. While these programs are capable of addressing the temporal patterns, the regional spatial scale is left unevaluated. In order to determine relative health and temporal trends in abundance, biomass, community structure, and size distribution of soft-bottom fishes and invertebrates over the entire SCB, the SCB Regional Marine Monitoring Program (‘Bight’) has been facilitating regional-scale monitoring surveys every four to five years since 1994. Each of these surveys employed otter trawls to sample the soft-bottom demersal community and built upon previous experiences and incorporated a multiple participant coalition to standardize procedures and techniques across the SCB (Allen et al 2011).

While the goal of the Bight Program has been to provide a broad overview of the region’s soft-bottom ecological communities, the long-term and bight-wide nature of the program allows for an unprecedented assessment of the impact of the newly implemented MPAs on the soft-bottom community throughout the entire SCB. The large spatial scale of this program is especially important to the assessment as the MPAs were designed to function throughout the SCB as a network rather than as individual units. The goal of this study is to assist in the design of a spatially integrated Before-After Control-Impact (BACI) experiment that can be used to assess the impact of MPA implementation on soft-bottom fauna in the SCB. By analyzing the long-term and bight-wide ecological properties of the soft-bottom fish and invertebrates we are able to determine how and if spatial and temporal variation can be accounted for in the experimental design.

# METHODS

## Site Selection and Area Weighting

The Bight Program's regional trawl surveys began with a pilot project in 1994 (Bight '94) and was repeated four times since then (Bight '98, Bight '03, Bight '08, Bight '13) for a total of five complete surveys over a 20-year span. Site selection for each of the regional trawl surveys was based on a stratified random sampling design detailed in Stevens (1997). In summary, stratification consisted of identification of strata of interest and area-weighting factors were associated with the size of each stratum. Strata were defined by MPA status (MPA or non-MPA) and shelf zones, generalized as: Inner Shelf (3-30 m); Middle Shelf (31-120 m); Outer Shelf (121-200 m); and Upper Slope (201-500 m). These 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 2006). For the purpose of this determining area-weights for this study, all stations were treated independent of the survey in which they were sampled and reassigned an area-weight based upon the number of stations in each stratum. Fish and invertebrate samples for population and assemblage analysis were successfully collected from 799 trawl stations throughout the SCB, 72 of which were sampled within 21 of the newly implemented MPAs. Despite substantial variety in restrictions among the MPAs in the SCB, each of the sampled MPAs have the same general consumptive use restrictions that would prevent take of most (if not all) harvested soft-bottom fauna, and were therefore treated equally.

In order to determine appropriate area-weights, shelf zones represented by these five combined surveys were mapped out using a combination of NOAA Raster Navigational Charts (http://www.nauticalcharts.noaa.gov), seafloor topography data obtained from the Satellite Geodesy Research Group at the Scripps Institution of Oceanography, University of California San Diego (http://topex.ucsd.edu), and high resolution multi-beam bathymetry data collected and processed by the Seafloor Mapping Lab, California State University Monterey Bay (http://seafloor.otterlabs.org) where available **(Figure 1)**. The western edge of the represented area was delimited by the furthest reach of Point Conception SMR down to the northern edge of the Upper Slope shelf zone off of San Miguel Island. The Upper Slope shelf zone for areas around Santa Barbara Island, Santa Catalina Island, and the southern side of the northern Channel Islands were not included as represented areas as no sampling was performed in these areas. Additionally, areas around San Nicolas and San Clemente Islands were not considered to be properly represented and were therefore excluded. The United States-Mexico border delimited the southern edge of the represented area. Seafloor areas of each shelf zone/MPA status combination were calculated and divided by the number of trawl stations in each stratum to determine the area weight for each station within those strata **(Table 1)**. As calculated, the 799 trawls from 1994 to 2013 represent the seafloor communities covering 9,901.6 $km^2$ of the Southern California Bight.

**Table 1.** Seafloor area, number of trawl events (stations), and calculated area weight per trawl by shelf zone/MPA strata combination.

| Strata | Stratum Area (km$^2$) | # of Stations | Area Weight |
|---|---|---|---|
| *Non-MPA Inner Shelf* | 1,512.6 | 187 | 8.09 |
| *Non-MPA Middle Shelf* | 2,972.6 | 290 | 10.25 |
| *Non-MPA Outer Shelf* | 1,777.8 | 158 | 11.25 |
| *Non-MPA Upper Slope* | 2,944.7 | 92 | 32.01 |
| *MPA Inner Shelf* | 153.0 | 24 | 6.37 |
| *MPA Middle Shelf* | 394.0 | 40 | 9.85 |
| *MPA Outer Shelf* | 105.0 | 5 | 20.99 |
| *MPA Upper Slope* | 41.9 | 3 | 13.98 |
| **Total Area** | 9,901.6 | 799 | |

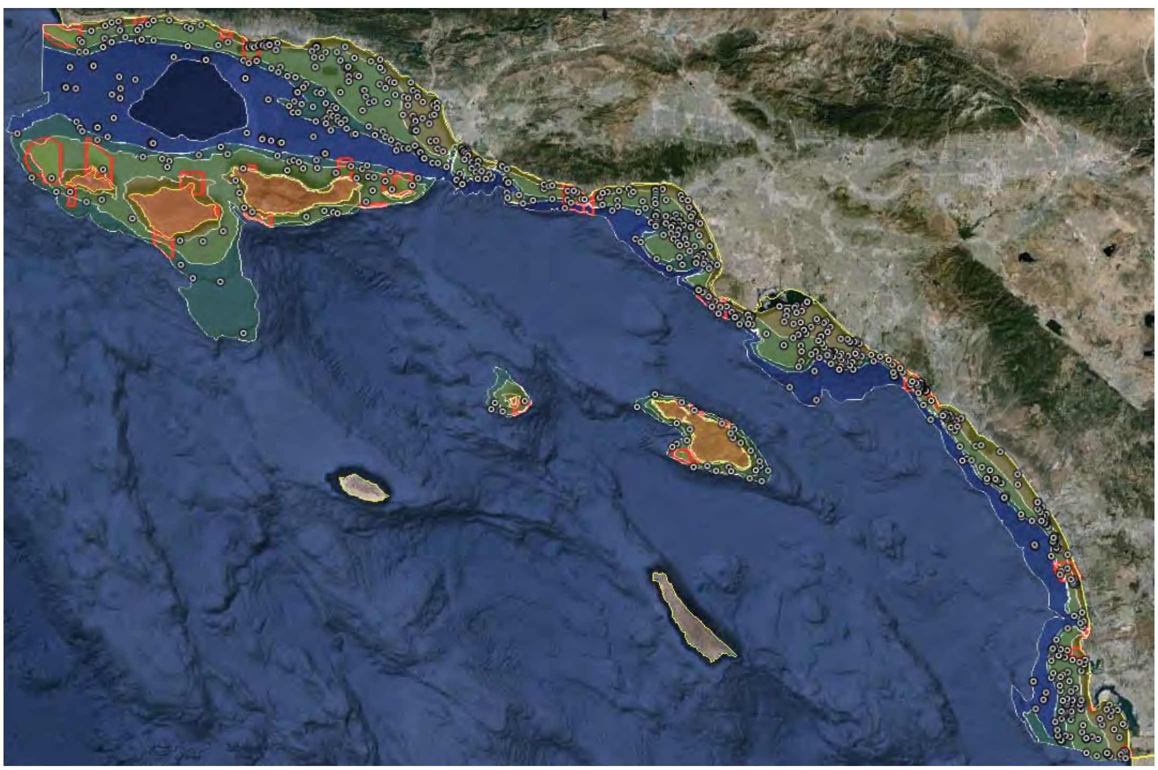


**Figure 1.** Mapped shelf zones and all 799 analyzed trawl stations within the Southern California Bight. MPAs are outlined in red.

## Sampling

Samples were collected during each of the surveys with 7.6-m head-rope semi-balloon otter trawls with 1.25-cm cod-end mesh. Trawls were towed along isobaths for 10 minutes at 0.8-1.0 m/sec (1.5-2 kts) covering an estimated distance of 600 m. In more recent surveys (Bight ’03 and later) pressure-temperature (PT) sensors were attached to one of the trawl doors to measure water temperature, depth, and time of the individual trawls to ensure proper contact with the ocean floor. All fish and megabenthic invertebrates from each trawl were identified and processed. Megabenthic invertebrates were defined as epibenthic species with a minimum dimension of 1 cm; specimens less than 1 cm were excluded from the analysis. Pelagic, infaunal, colonial species, and unattached fish parasites (e.g., leeches, cymothoid isopods) were also excluded. Fish and invertebrates were identified to species, individuals were counted, and species were batch-weighed to the nearest 0.1 kg. Fish and invertebrates batch-weighs less than 0.1 kg were given a weight of 0.0 kg. Lengths of individual fish were measured to centimeter size class on measuring boards; total length (TL) was measured for cartilaginous fishes and standard length (SL) was measured for bony fishes. In addition, wingspan was measured for Round Stingrays (*Urobatis halleri*). Voucher specimens and incompletely identified fish and invertebrate specimens 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. At least one voucher specimen of each species processed was retained to confirm identifications.

## Data Analysis

Spatial and temporal variability of soft-bottom fauna ecological properties throughout the SCB was assessed using an array of metrics, including abundance, biomass, diversity, and community structure of both fish and invertebrates, as well as length frequency and a biointegrity index for fish only. This fish response index (FRI) was produced from an analysis of calibrated species abundance data along a pollution gradient from which species-tolerance scores were determined (Allen et al. 2001). This index was designed to assess anthropogenic impacts to fish assemblages and provide a description of them as either describe reference (normal) or non-reference conditions.

Spatial variability was tested for with respect to depth using the *a priori* determined shelf zones, as well as geographic location. In previous Bight Program surveys, three geographic regions (North: Point Conception to Point Dume; Central: Point Dume to Dana Point; South: Dana Point to U.S./Mexico border) had also been included as a strata of interest in the site selection process. To assess spatial variability in this study, the SCB was divided into five regions that are delineated by large seafloor features (e.g. submarine canyons): Santa Barbara (including the northern Channel Islands), Malibu, Palos Verdes (including Santa Catalina and

Santa Barbara Islands), Orange and North San Diego County, and La Jolla and Point Loma. Temporal variability was tested for among the five surveys.

Abundance and biomass values were $\log_{10}(x+1)$ transformed to meet assumptions of normality. Differences between the transformed means of total abundance and total biomass, as well as the means of diversity and FRI for each factor were tested for using Type III analysis of variance (ANOVA using Holm-Bonferroni sequential corrections; Holm 1979) with post-hoc Tukey HSD tests (which correct for Type I error across multiple comparisons) when appropriate. Differences is those metrics between MPA status were tested using two-group t-tests. Community structure was assessed using the transformed species abundance values through non-metric multidimensional scaling (nMDS), and pairwise comparisons of community structure within each factor were assessed through tests of analysis of similarity (ANOSIM). Size frequency histograms were produced for four of the most commonly caught recreational and commercial fish species (Pacific Sanddab, *Citharichthys sordidus*; White Croaker, *Genyonemus lineatus*; Pacific Hake, *Merluccius productus*; and California Scorpionfish, *Scorpaena guttata*), and the mean of $\log_{10}(x)$ transformed sizes at each station were compared by ANOVA. Lastly, using mean values and standard deviations for each metric, power analyses were performed and power curves were created as a guide to determine appropriate sample sizes for future sampling using one-tailed paired t-tests that can account for variation in those metrics. Power curves were not provided for FRI; while the metric is calculated and reported as a number, the FRI value is not considered to be a gradient. That is to say, there is no functional difference between a FRI value of 2 and 44, each is simply considered to be “reference”.

# RESULTS

## Fish

Significant differences ($p$ < Holm-Bonferroni ranked corrected α) in fish abundance (**Figure 2**), biomass (**Figure 3**), diversity (**Figure 4**), FRI (**Figure 5**) and community structure were found among both surveys and shelf zones, and significant differences in all factors except diversity were found among regions (**Table 2**). Analysis of fish assemblages via nMDS using species abundance showed a distinct separation of assemblages by shelf zone rather than either region, survey, or MPA Status (**Figure 6**) and SIMPROF identified 44 unique fish communities throughout the bight ($\alpha$ = 0.001). Significant differences were not detected among MPA statuses for any of the metrics. Comparisons among factors and significant differences as determined by Tukey HSD post-hoc tests are illustrated in **Appendix A**, and maps of the SCB illustrating values of these factors at each station are located in **Appendix B**.

**Table 2.** Summary of ANOVA, t-test, and ANOSIM results for fish and invertebrate metrics. * and yellow highlighting indicate significance at $p$ < Holm-Bonferroni sequential corrected α.

| | Fish | | | | | Fish Size Class | | | | Invertebrates | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Abundance | Biomass | Diversity (H') | FRI | Community Structure | *Citharichthys sordidus* | *Genyonemus lineatus* | *Merluccius productus* | *Scorpaena guttata* | Abundance | Biomass | Diversity (H') | Community Structure |
| **Survey** | < 0.001* | < 0.001* | 0.045 | < 0.001* | < 0.001* | < 0.001* | 0.201 | 0.001* | 0.002* | < 0.001* | < 0.001* | 0.001* | < 0.001* |
| **Region** | 0.003* | 0.001* | 0.055 | < 0.001* | < 0.001* | < 0.001* | 0.704 | 0.416 | < 0.001* | < 0.001* | < 0.001* | 0.330 | < 0.001* |
| **Shelf Zone** | < 0.001* | < 0.001* | < 0.001* | < 0.001* | < 0.001* | < 0.001* | < 0.001 | < 0.001* | 0.174 | < 0.001* | < 0.001* | 0.288 | < 0.001* |
| **MPA Status** | 0.195 | 0.492 | 0.233 | 0.313 | 0.964 | 0.022* | 0.488 | 0.838 | 0.021* | 0.145 | 0.020* | 0.943 | 0.896 |

There were significant differences in mean transformed size among surveys for three of the four selected fish species of commercial and/or recreational importance (*Genyonemus lineatus* was not significant), among regions for *Citharichthys sordidus* and *Scorpaena guttata*, among shelf zones for all species but *Scorpaena guttata*, and among MPA Status for *Citharichthys sordidus* and *Scorpaena guttata* (**Table 2**). Length frequency histograms and boxplot comparisons of mean log transformed size class by survey, shelf zone, and MPA status for the four selected fish species can be found in **Appendix C**.

**Figure 2.** Fish abundance [$\log_{10}(x+1)$ transformed] by Shelf Zone, Survey, and Region. Outliers are indicated by "x"; blue diamonds indicate mean values; notches indicate 95% confidence intervals; box width indicates relative sample size.

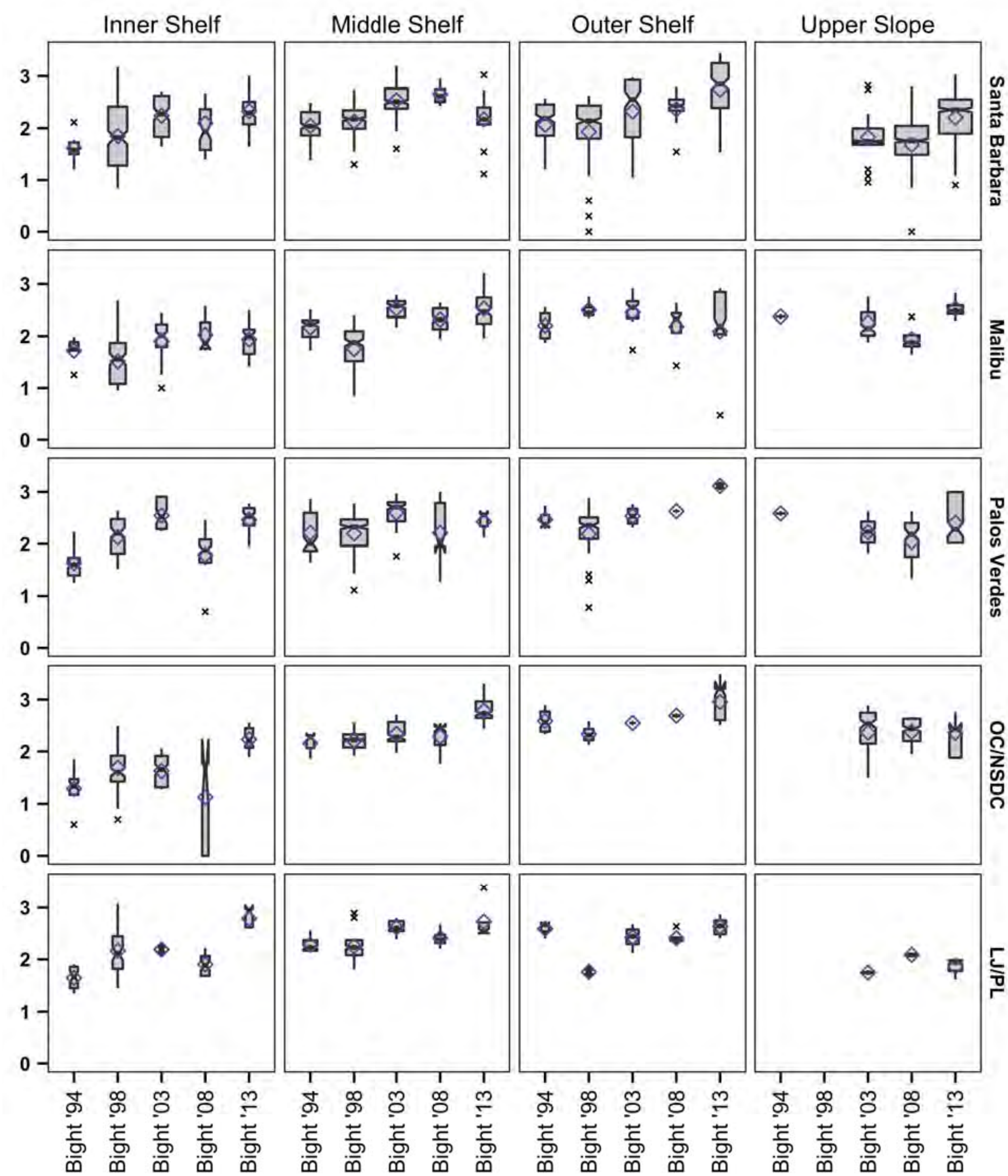


**Figure 3.** Fish biomass [$\log_{10}(x+1)$ transformed] by Shelf Zone, Survey, and Region. Outliers are indicated by "x"; blue diamonds indicate mean values; notches indicate 95% confidence intervals; box width indicates relative sample size.

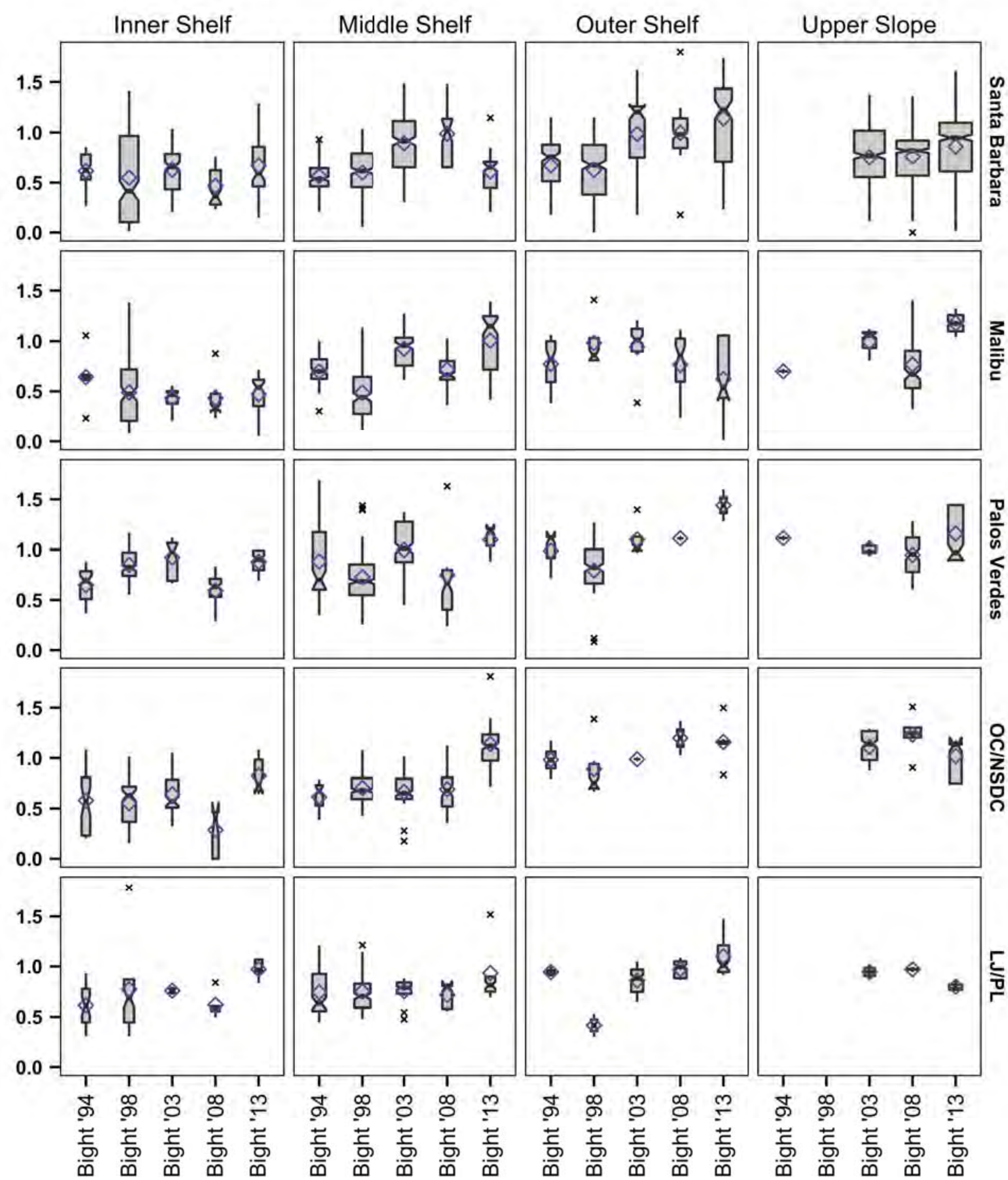


**Figure 4.** Fish diversity (H') by Shelf Zone, Survey, and Region. Outliers are indicated by "x"; blue diamonds indicate mean values; notches indicate 95% confidence intervals; box width indicates relative sample size.

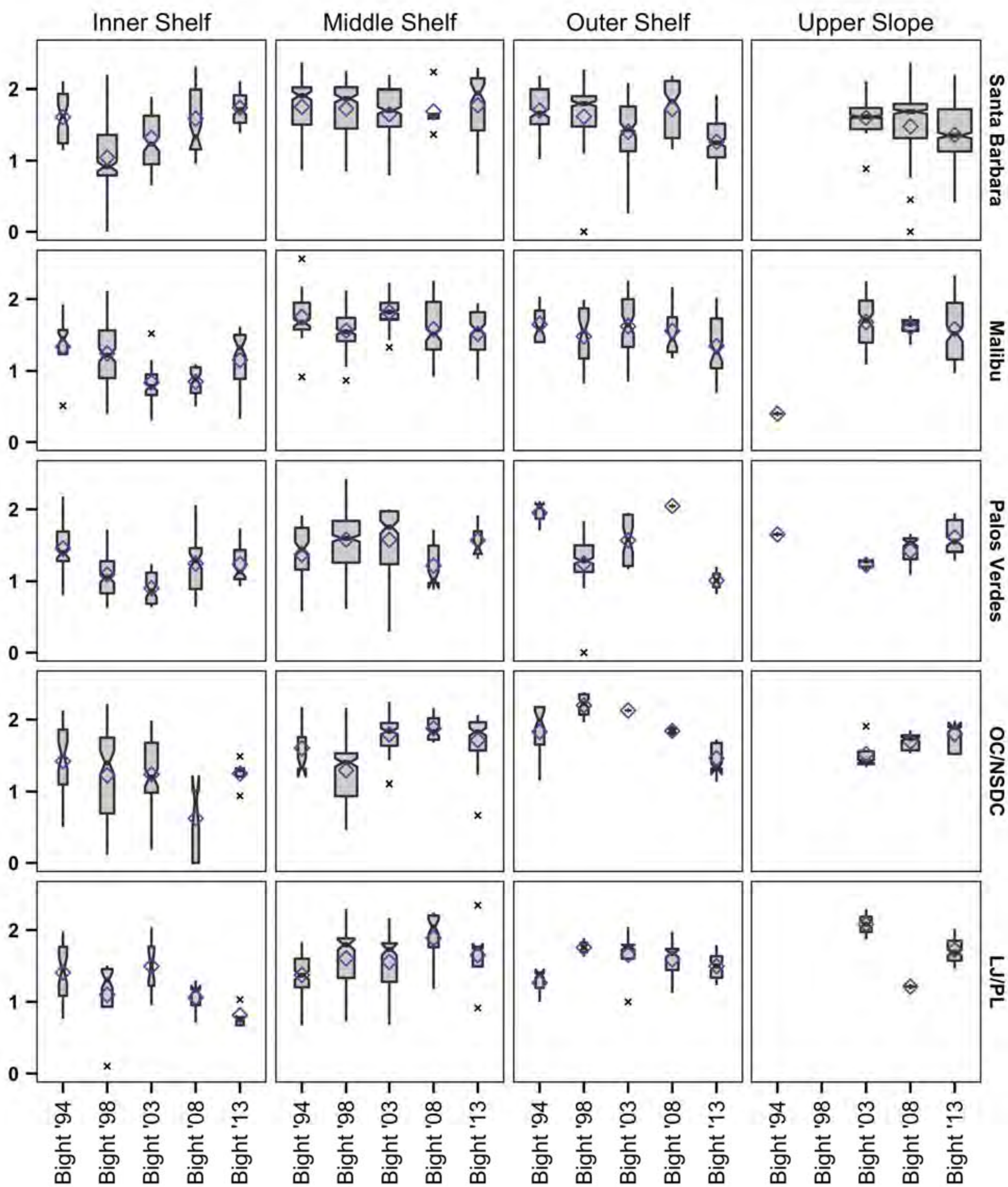


**Figure 5.** Fish Response Index (FRI) by Shelf Zone, Survey, and Region. Outliers are indicated by "x"; blue diamonds indicate mean values; notches indicate 95% confidence intervals; box width indicates relative sample size; red line indicates threshold for reference (< 45) vs non-reference (≥ 45) condition.

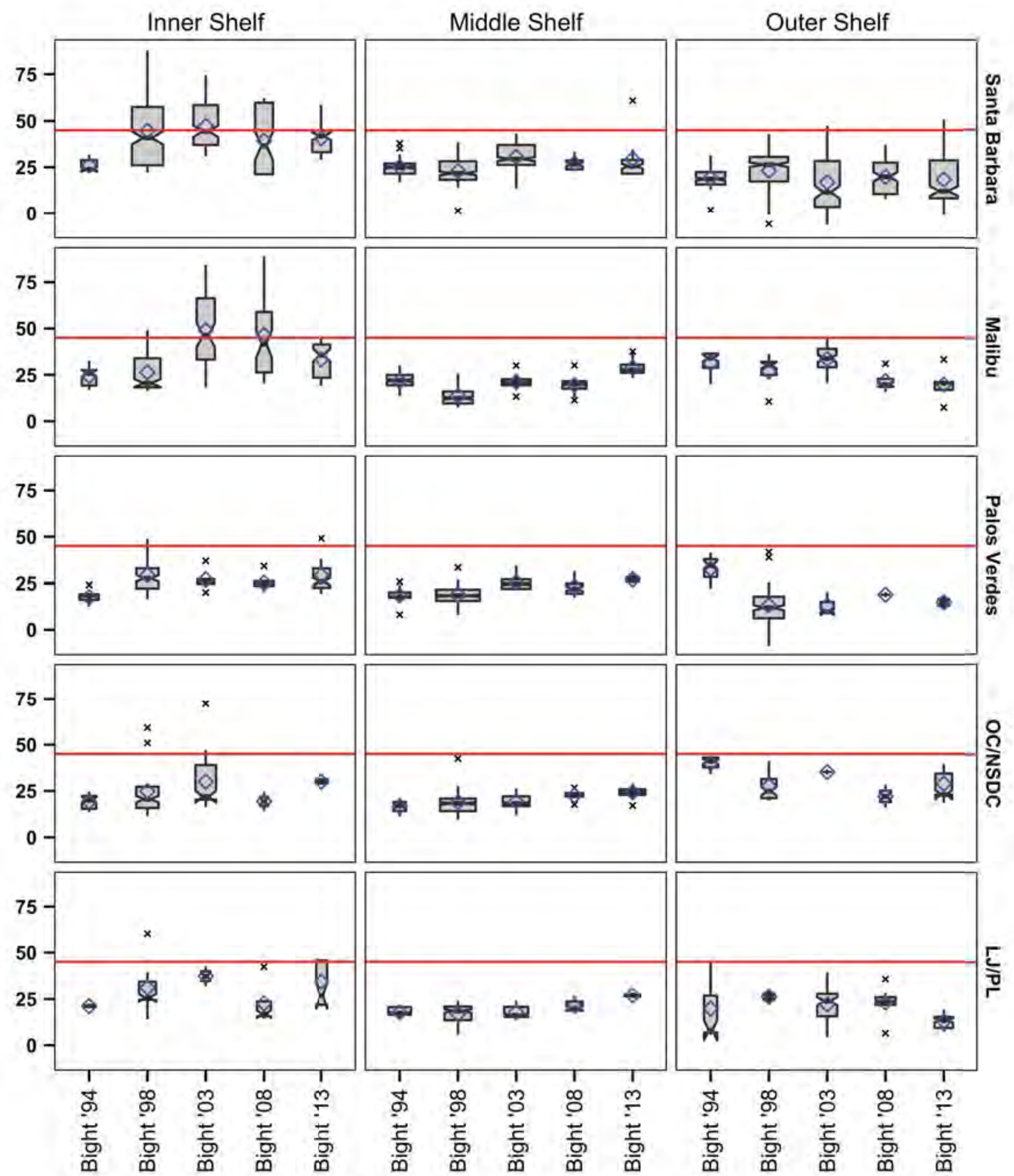
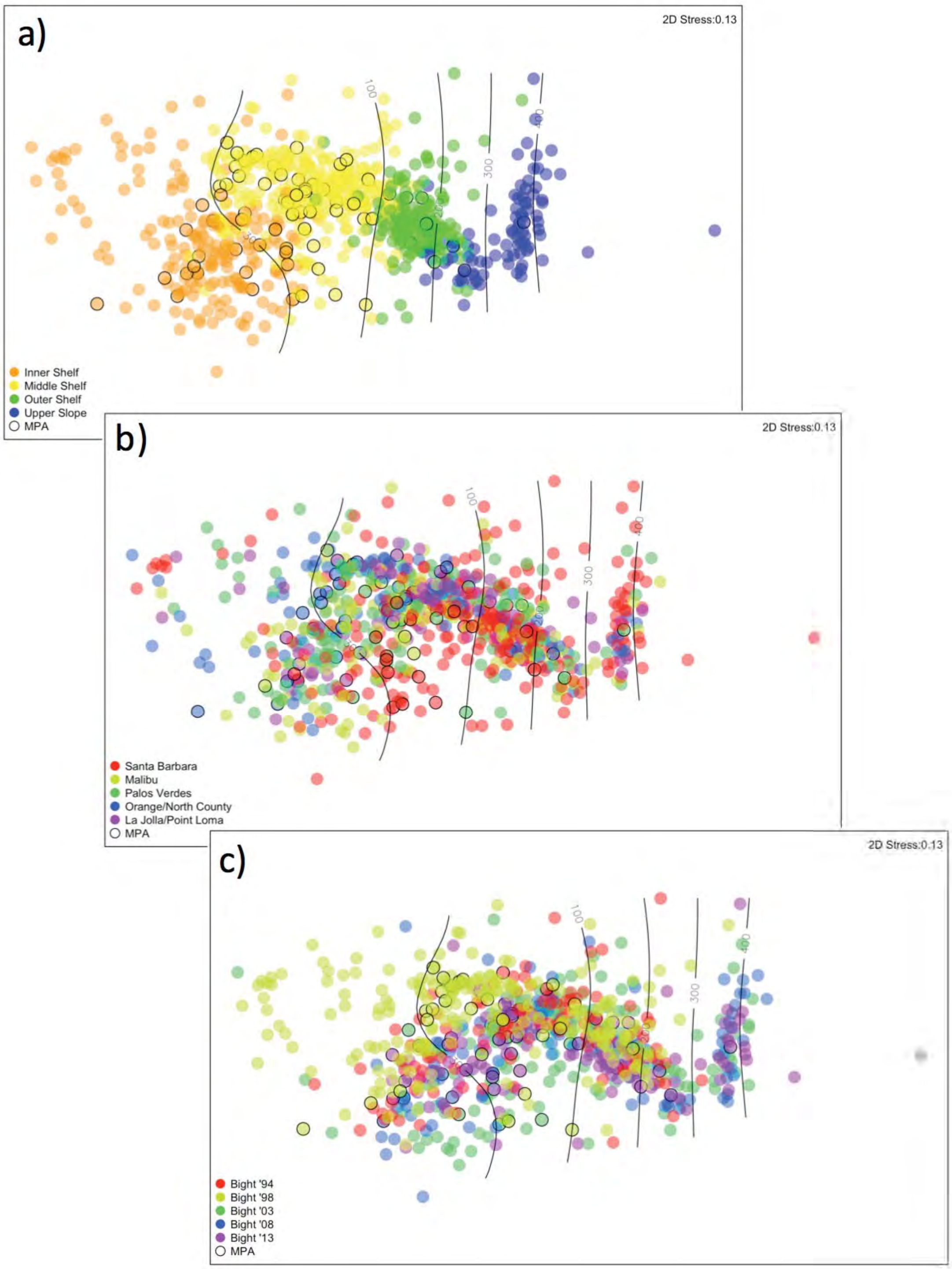


**Figure 6.** nMDS plot using trawl fish abundance at each station separated by Shelf Zone (a), Region (b), and Survey (c), with a surface plot of trawl depth overlain (black lines). Stations that are located in current MPAs are outlined in black.



## Invertebrates

Significant differences ($p$ < Holm-Bonferroni ranked corrected α) in invertebrate abundance (**Figure 7**), biomass (**Figure 8**), diversity (**Figure 9**) and community structure were found among surveys (**Table 2**). Significant differences in all factors except diversity were found among regions and shelf zones. Similar to fish assemblages, analysis of invertebrate assemblages via nMDS using species abundance showed a distinct separation of assemblages by shelf zone rather than either region, survey, or MPA Status (**Figure 10**) and SIMPROF identified 160 unique fish communities throughout the bight ($\alpha$ = 0.001). A significant difference was only detected among MPA statuses for invertebrate biomass. Comparisons among factors and significant differences as determined by Tukey HSD post-hoc tests are illustrated in **Appendix A**, and maps of the SCB illustrating values of these factors at each station are located in **Appendix B**.

**Figure 7.** Invertebrate abundance [$log_{10}(x+1)$ transformed] by Shelf Zone, Survey, and Region. Outliers are indicated by "x"; blue diamonds indicate mean values; notches indicate 95% confidence intervals; box width indicates relative sample size.

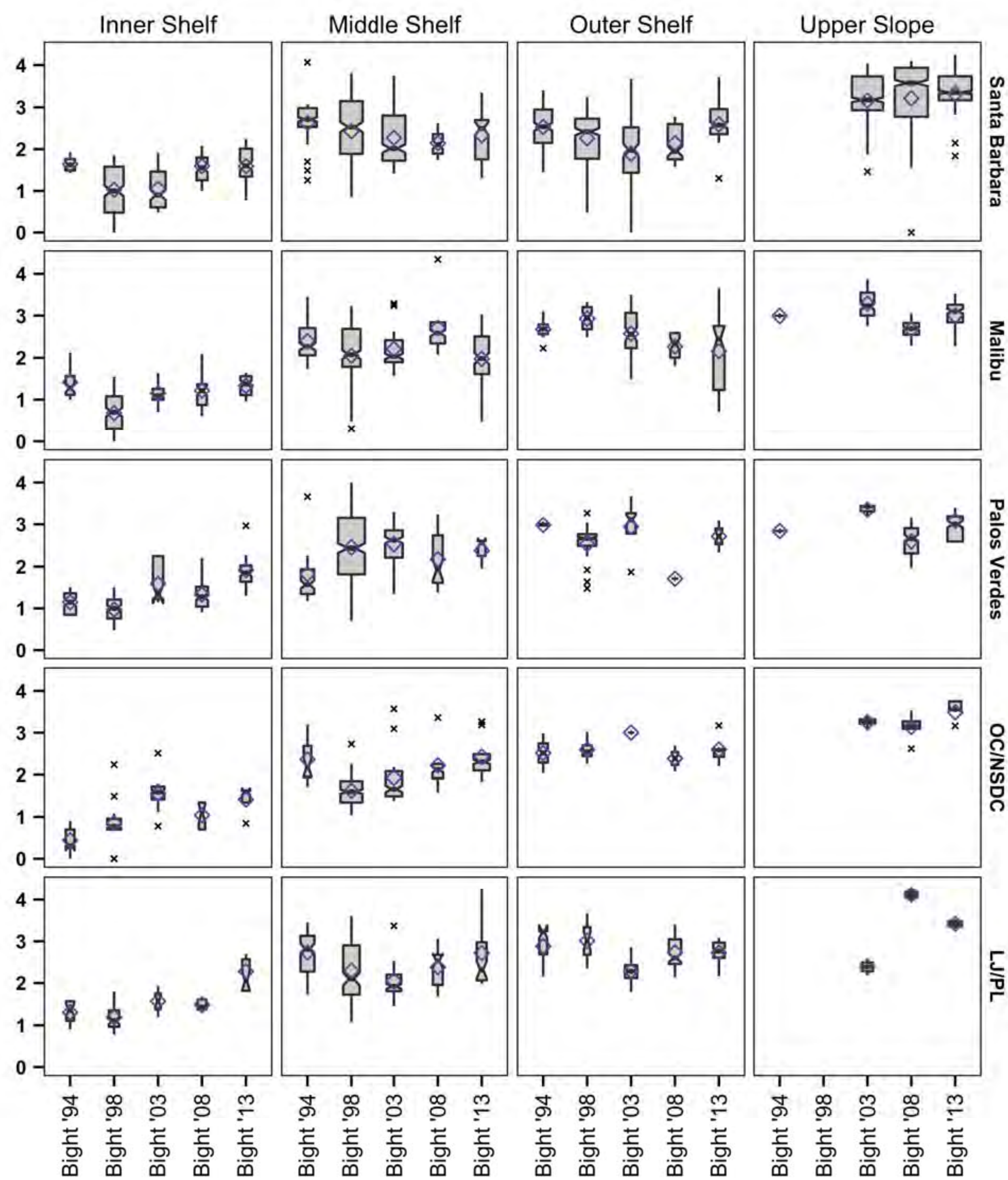


**Figure 8.** Invertebrate biomass [$\log_{10}(x+1)$ transformed] by Shelf Zone, Survey, and Region. Outliers are indicated by "x"; blue diamonds indicate mean values; notches indicate 95% confidence intervals; box width indicates relative sample size.

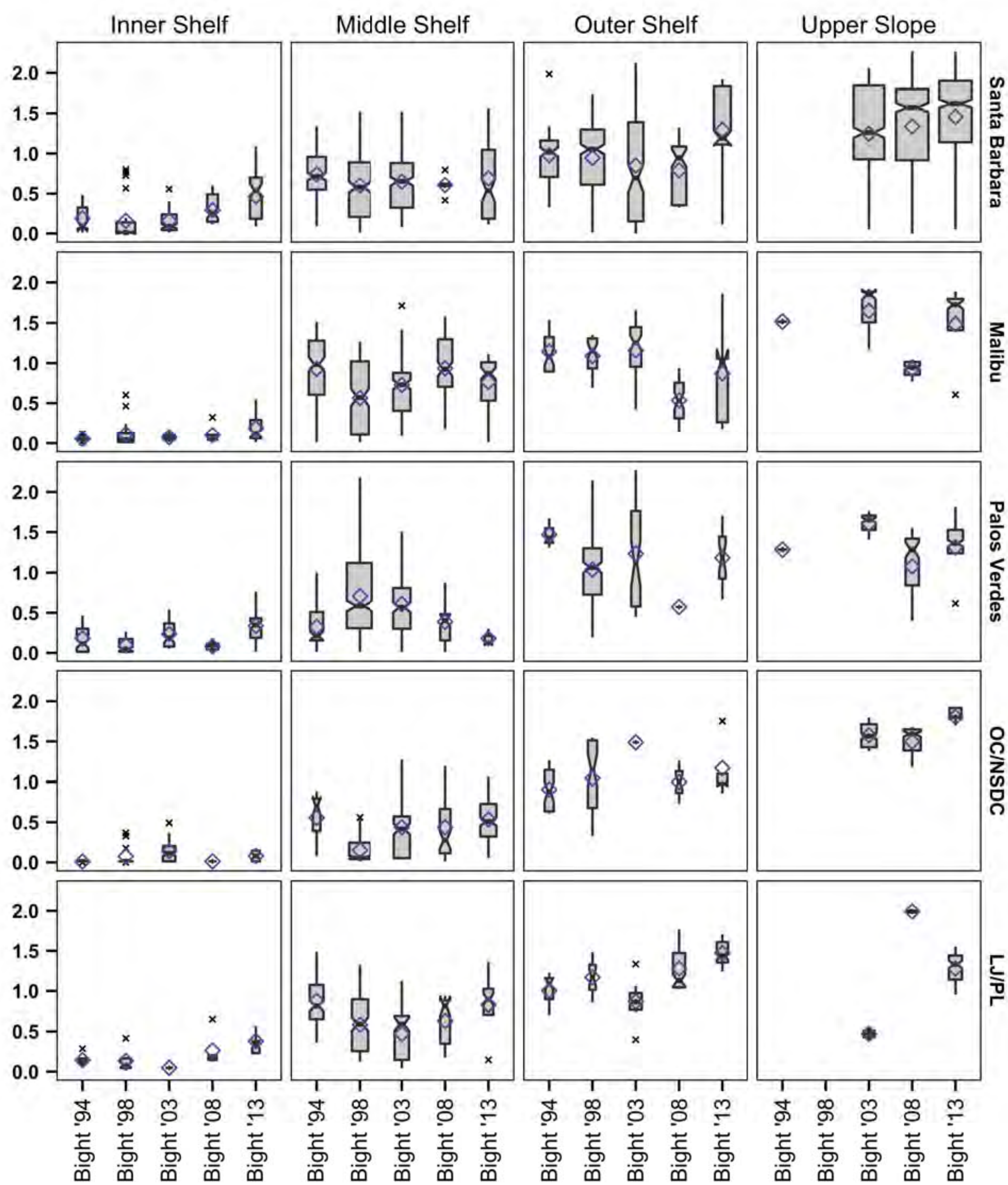


**Figure 9.** Invertebrate diversity (H') by Shelf Zone, Survey, and Region. Outliers are indicated by "x"; blue diamonds indicate mean values; notches indicate 95% confidence intervals; box width indicates relative sample size.

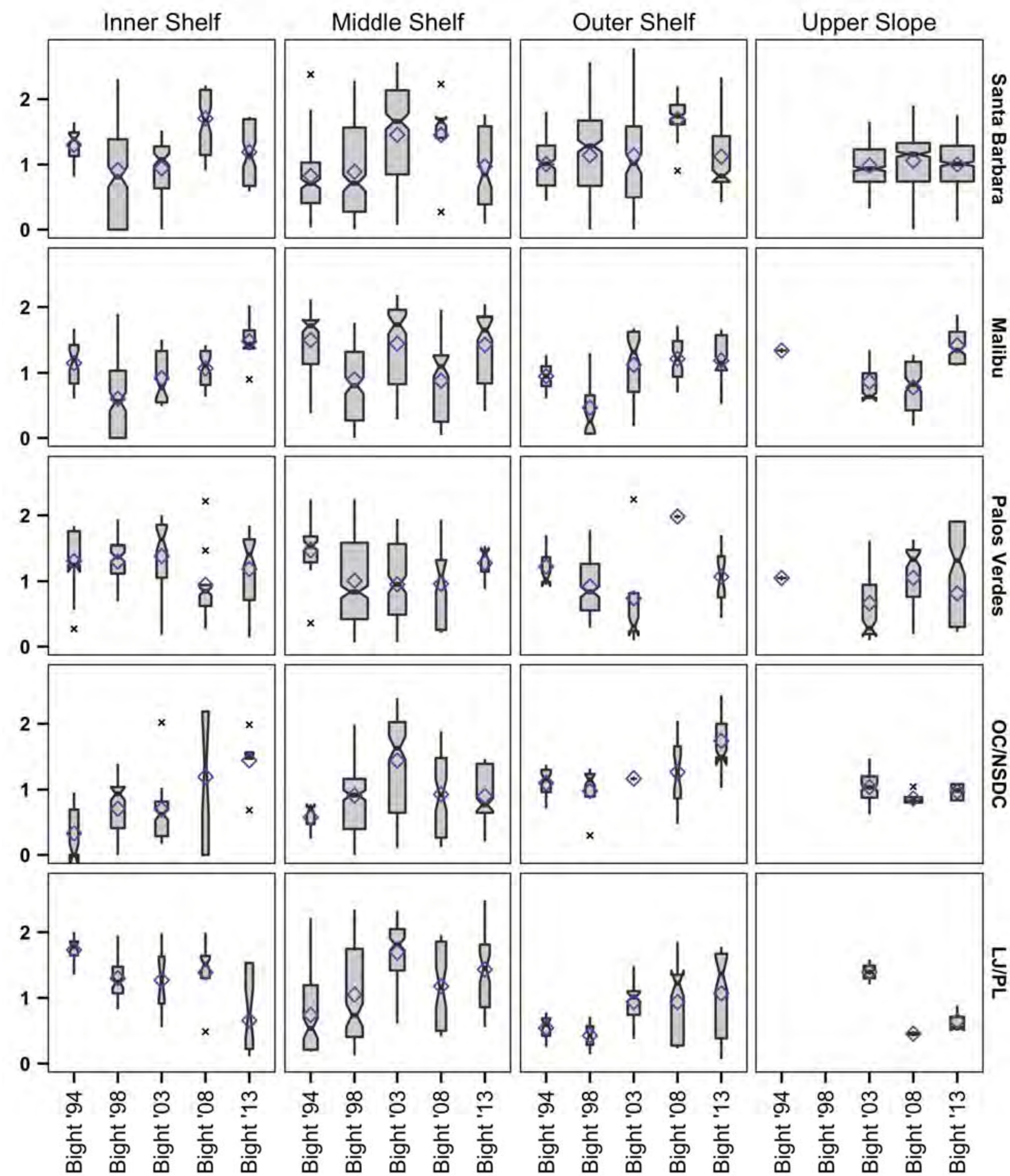
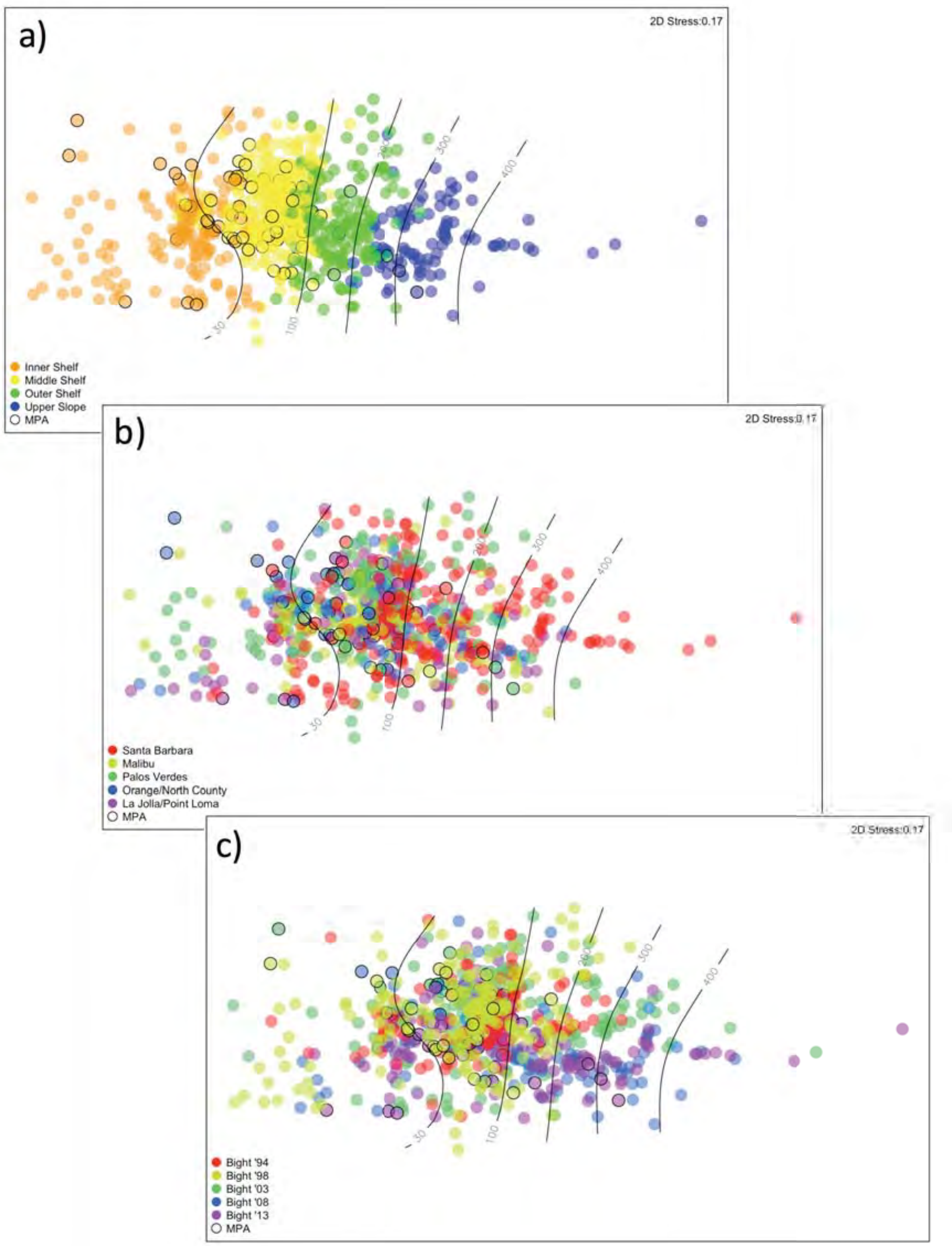


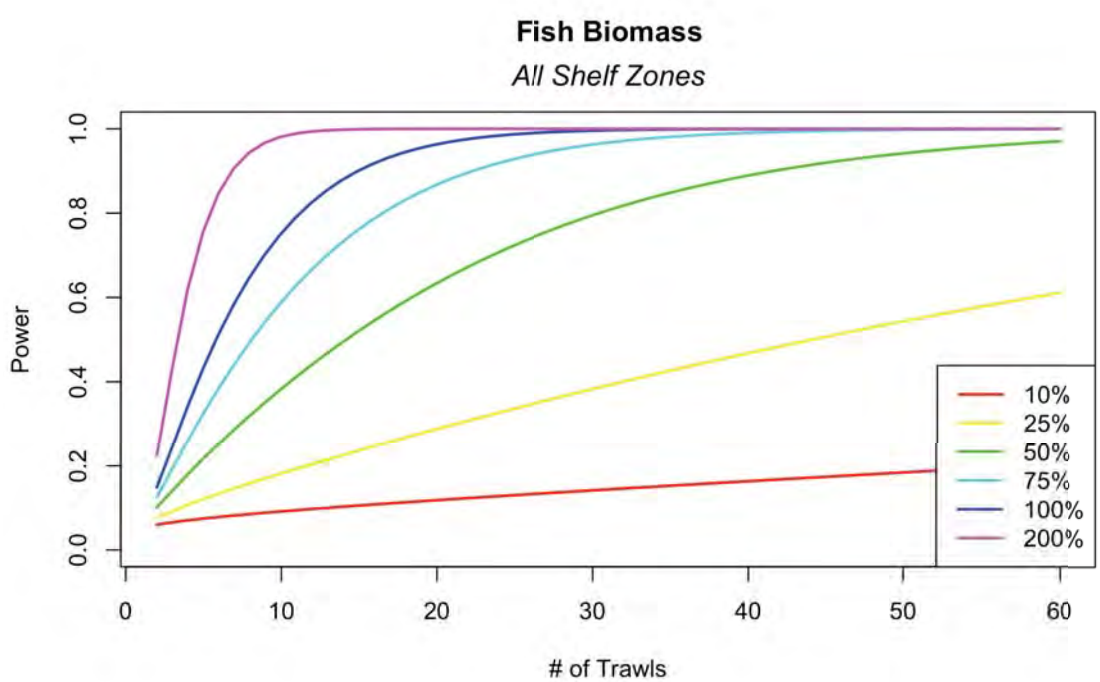
**Figure 10.** nMDS plot using trawl invertebrate abundance at each station separated by Shelf Zone (a), Region (b), and Survey (c), with a surface plot of trawl depth overlain (black lines). Stations that are located in current MPAs are outlined in black.



## Power Curves

Numerous power curves were developed for fish and invertebrate abundance, biomass, and diversity, as well as size structure of the four selected fish of commercial and/or recreational importance (**Appendix D**). Up to five figures were created for each metric, including one figure the utilizes data from all surveys and all shelf zones, and four figures that utilize data from all surveys for each of the shelf zones. Each figure contains several curves that represent the relationship between power (y-axis) and the number of paired trawls (both inside and outside of MPAs; x-axis) required to detect a certain percentage (the six colored lines) of absolute (non-transformed) detectable change in that metric. For example, **Figure 11** demonstrates power curves for detecting changes in fish biomass by performing a paired one-tailed t-test between MPA and non-MPA samples, calculated using data from all shelf zones and all previous surveys: To detect a 50% increase in fish biomass inside of MPAs versus outside of MPAs, with a significance level of 0.05 and an 80% probability (power = 0.8) of finding that 50% increase (assuming one exists), at least 30 trawl stations should be sampled both inside and outside of MPAs.

**Figure 11.** Power curves demonstrating the number of paired trawls (inside and outside of MPAs) necessary to detect minimum percentages of change in fish biomass using a one-tailed paired t-test, and the associated power of that test. Figures utilize data from all shelf zones and all surveys combined.



# DISCUSSION

The intent of this study was to provide guidance for a BACI-type experimental design for future studies to determine the effect of MPA establishment on soft-bottom fauna. In order to do this, we assessed the long-term and bight-wide ecological variance and properties of the soft-bottom fish and invertebrate. A few things are abundantly clear with this data set and will have a strong impact on the design and effort required in future sampling. First, there are strong spatial differences in soft-bottom fishes and invertebrates in the SCB, especially with respect to depth. Nearly every tested numerical metric had significantly different means among shelf zones, the exceptions being invertebrate diversity and mean size class of California Scorpionfish (*Scorpaena guttata*). Most salient with respect to variation in soft-bottom fauna throughout time and space is the distinct gradient of both fish and invertebrate community structure with respect to depth. A remarkable separation of the *a priori* determined shelf zones was found in the nMDS analysis, clearly outweighing the influence of survey year or region. Fish community clusters were also largely separated by shelf zone rather than any other spatial or temporal variable. Invertebrate community clusters showed less distinct separation based on shelf zone, though any other factors that caused separation into over 160 clusters were not evident and alludes to strong patchiness among species throughout the SCB.

Second, there are clear temporal differences in the soft-bottom fauna throughout the SCB. Every single metric was significantly different among surveys with the lone exception of mean size class of White Croaker (*Genyonemus lineatus*). Much of the temporal variability was a product of significantly higher catch (abundance and biomass) and lower diversity of fish and invertebrates in the Bight ’13 survey. While tempting to attribute higher bight-wide abundance and biomass to the implementation of MPAs in 2012, there were no significant differences in those metrics between MPA and non-MPA sites in 2013. Third, as should be the case with a 20-year long, region-wide data set, the sheer number of data are overwhelming – not just to the naked eye, but also statistically. Having too many data points is typically not considered to be a hindrance to statistical analysis, but at exceptionally large sample sizes the sample mean approaches the true mean, and the standard error and confidence intervals become so small that comparison of means among factors becomes irrelevant as even nearly identical means and distributions become significantly different at even the smallest critical values. Conversely, with a substantial number of data available over a wide area (in this case nearly 10,000 $km^2$) and long period of time (20 years), metrics begin to have a large amount of error associated with them when these measurements are all pooled.

Lastly, while there is significant variability among surveys, shelf zones, and regions, there are generally few differences between areas that are currently inside the newly established MPAs and areas that are not, suggesting that the randomly selected areas of past Bight Program trawling efforts are satisfactory for use as a baseline for most future studies without fear of confounding data due to inappropriate site selection. Using historical trawl data as the “before” part of a spatially integrated Before-After Control-Impact (BACI) experimental approach presents a challenge due to the highly variable nature of the region over time and space. However, by designing a rigorous experiment that has enough control and impacted replicates (e.g. trawl stations inside and outside of MPAs) to properly account for that variability in conjunction with the historical data, impacts of MPAs on soft-bottom fish and invertebrates (including abundance, biomass, length frequency, etc.) can be assessed. **Appendix D** provides a multitude of power curves that were developed to help guide the design process for a future experiment. The power curves can be used to determine the required number of trawl stations that should be sampled both inside and outside of MPAs in order to detect a certain minimum percentage of increase in a particular metric (if that increase exists) inside of MPAs versus outside of MPAs at a given power. Intuitively, a large change in any metric will be easier to detect than a small change, though the degree to which that change can be detected is partially dependent on the natural variability of the system. In the case of the soft-bottom fauna of the SCB, most variation is among shelf zones, which makes separating natural variation from management-related variation difficult to isolate. Therefore, power analyses were provided to guide future studies based upon either random sampling among all shelf zones, or by random sampling stratified within a single shelf zone. However, as the power curves demonstrate, there is little benefit to examining the shelf zones individually. In fact, to sample sufficiently in each area would require approximately three times the amount of trawls both inside and outside to detect any specified value of change than if the shelf zones were treated equally (or ignored).

Determining which metric to assess and the expected percentage of change is complicated, and partially driven by what is important to fisheries managers, but can be guided by past studies. Typically, changes in the ecology of an area as a result of management actions has been assessed using biomass, density, organism size, species diversity, or species richness. On average, the most noticeable increases are in biomass (median: 166%) and density (median: 61%), while increases in organism size and species richness are more moderate (medians: 17% and 15%, respectively; Lester et al. 2009). The larger change in biomass compared to size is logical, since increases in biomass are proportionally exponential to increases in length. Growth rates of organisms tend to slow at lower temperatures (Schmidt-Nielsen 1984; Gillooly et al. 2002; Brown et al. 2004), even within species (Brander 1995; Lehodey and Grandperrin 1996; Anderson and Dalley 2000; Môllmann et al. 2005, Williams et al. 2007). It would therefore be expected that changes in mean fish size would be slow to manifest in the SCB's cold-temperate waters, particularly at depths sampled as a part of the Bight Program (Mauchline 1972; Grassle and Sanders 1973; Turekian et al. 1975), but likely more noticeable in biomass values. Additionally, changes in size and abundance are often confounded as a product of habitat monopolization by larger, territorial individuals (Larson 1980; Paddack and Estes 2000). There have been reports of decreases in abundance and increases in size resulting in net overall increases in biomass (Garcia-Rubies and Zavala 1990; Paddack and Estes 2000). Richness and diversity are considered to have a lower scope for potential change in all systems, but the particularly non-diverse, patchy nature of soft-bottom fauna (**Figures 4 & 9**) and the small sampling area of 10-minute trawls also introduces a large amount of error into the values.

Of relevance to the SCB, median increases in biomass and abundance inside temperate MPAs are higher than the pooled median (which includes tropical MPAs), but median increases in organism size and richness are lower (Lester et al. 2009). Increases in biomass as a product of MPA establishment on the west coast of North America has been reported as high as 463% for rocky reef fish in Baja California (Aburto-Oropeza et al. 2011), though this MPA is located in highly productive, formerly-heavily fished area, unlike the soft-bottom areas of the SCB that only have a few highly utilized areas (PacFIN 2015). Within the SCB, fisheries-targeted rocky reef fish biomass increased by 52% in the ten years since implementation of the northern Channel Islands MPA network, though non-targeted rocky reef fish biomass only increased by 28% (Pondella et al. 2015). With previous efforts to determine the effect of MPAs in mind, as well as the location of the current study and physiological demands of species at depths sampled in the SCB, a 50% change in mean biomass per trawl would not be unreasonable if we assume that the soft-bottom fauna inside the newly established MPAs were previously impacted by fishing efforts.

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# **Appendix A** – Trawl Metrics by Factor

**Appendix A-1.** Fish abundance, biomass, diversity, and FRI by Survey.

**Appendix A-2.** Fish abundance, biomass, diversity, and FRI by Region.

**Appendix A-3.** Fish abundance, biomass, diversity, and FRI by Shelf Zone.

**Appendix A-4.** Fish abundance, biomass, diversity, and FRI by MPA Status.

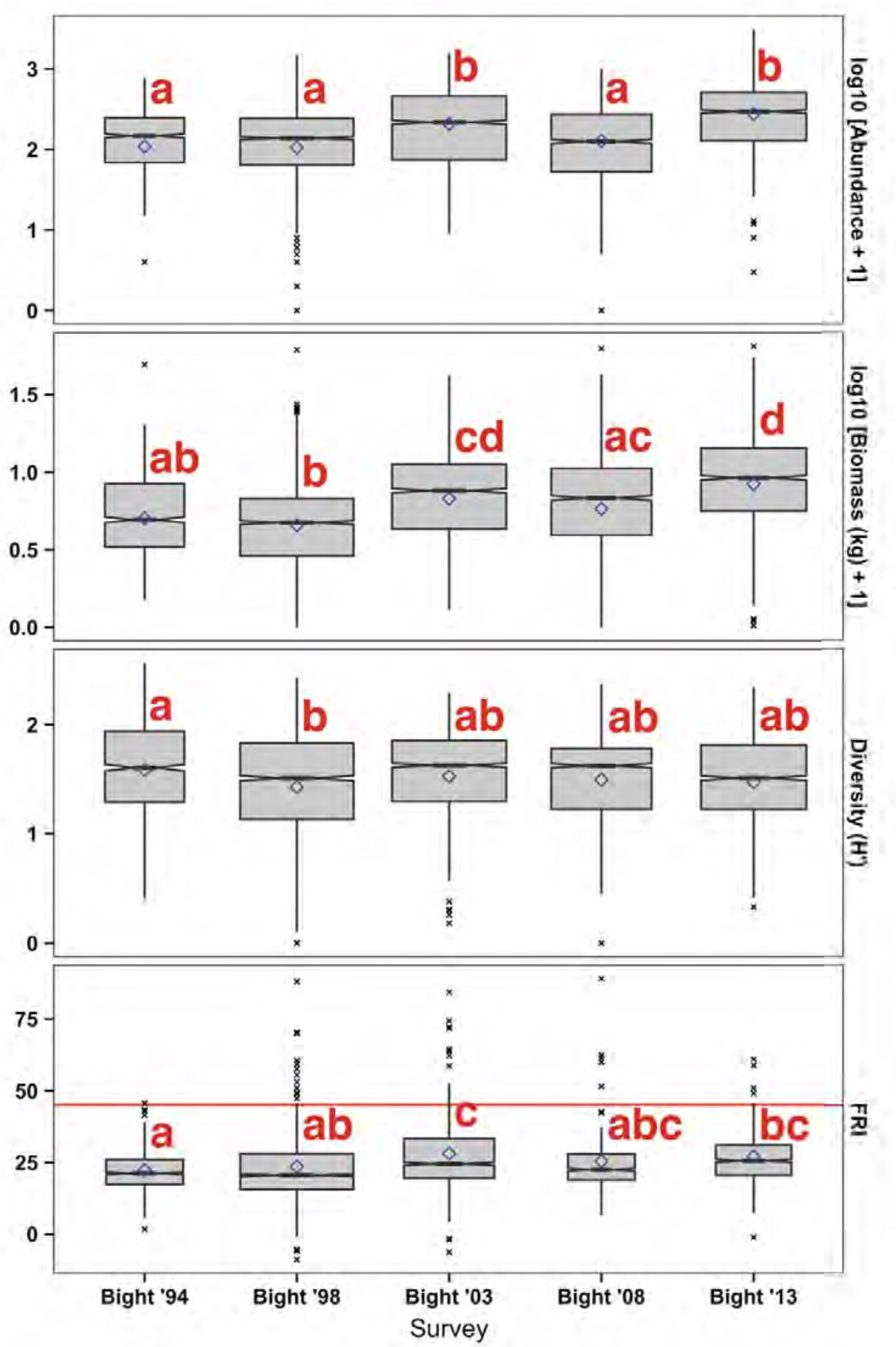
**Appendix A-5.** Invertebrate abundance, biomass, and diversity by Survey.

**Appendix A-6.** Invertebrate abundance, biomass, and diversity by Region.

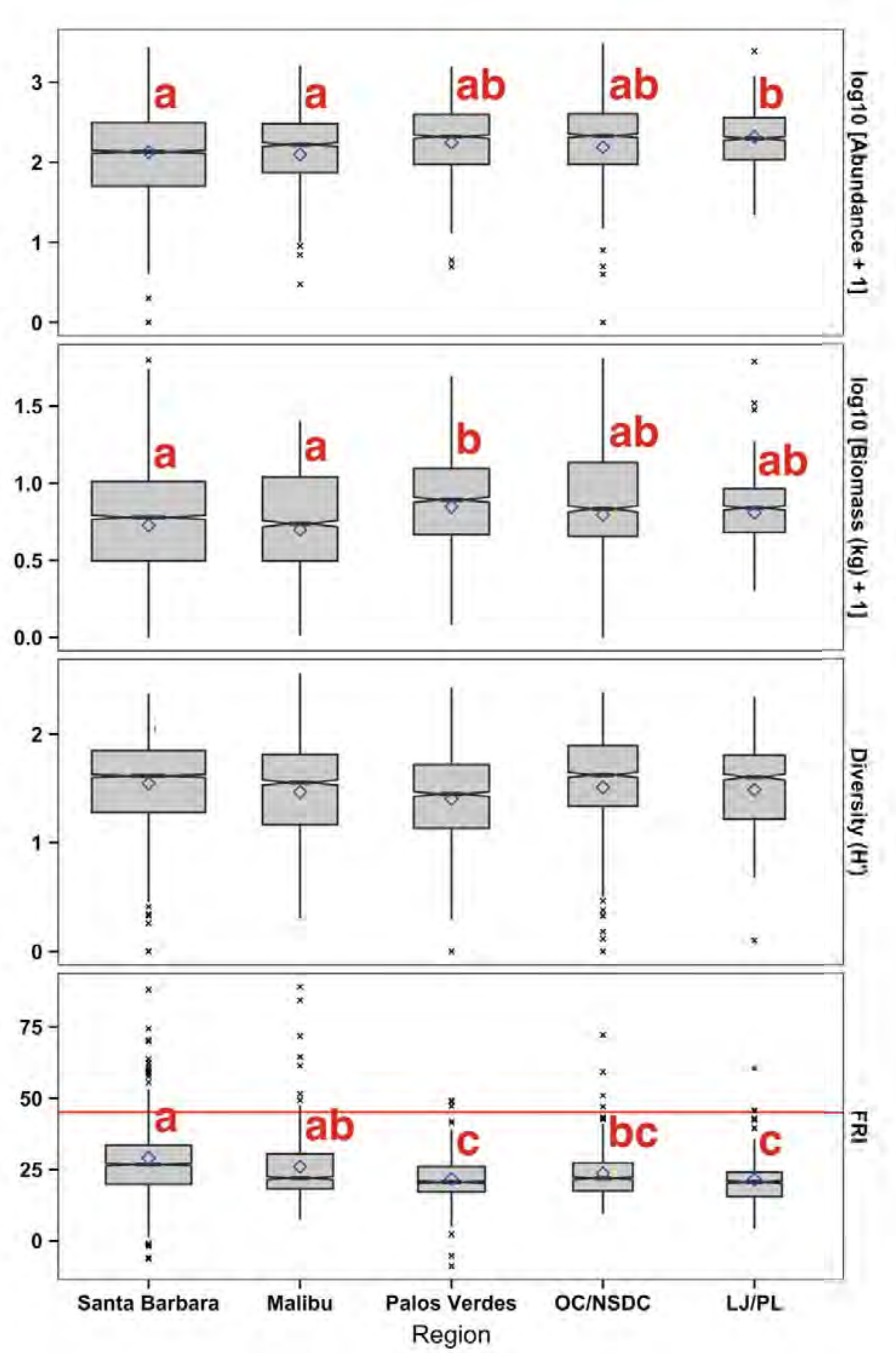
**Appendix A-7.** Invertebrate abundance, biomass, and diversity by Shelf Zone.

**Appendix A-8.** Invertebrate abundance, biomass, and diversity by MPA Status.

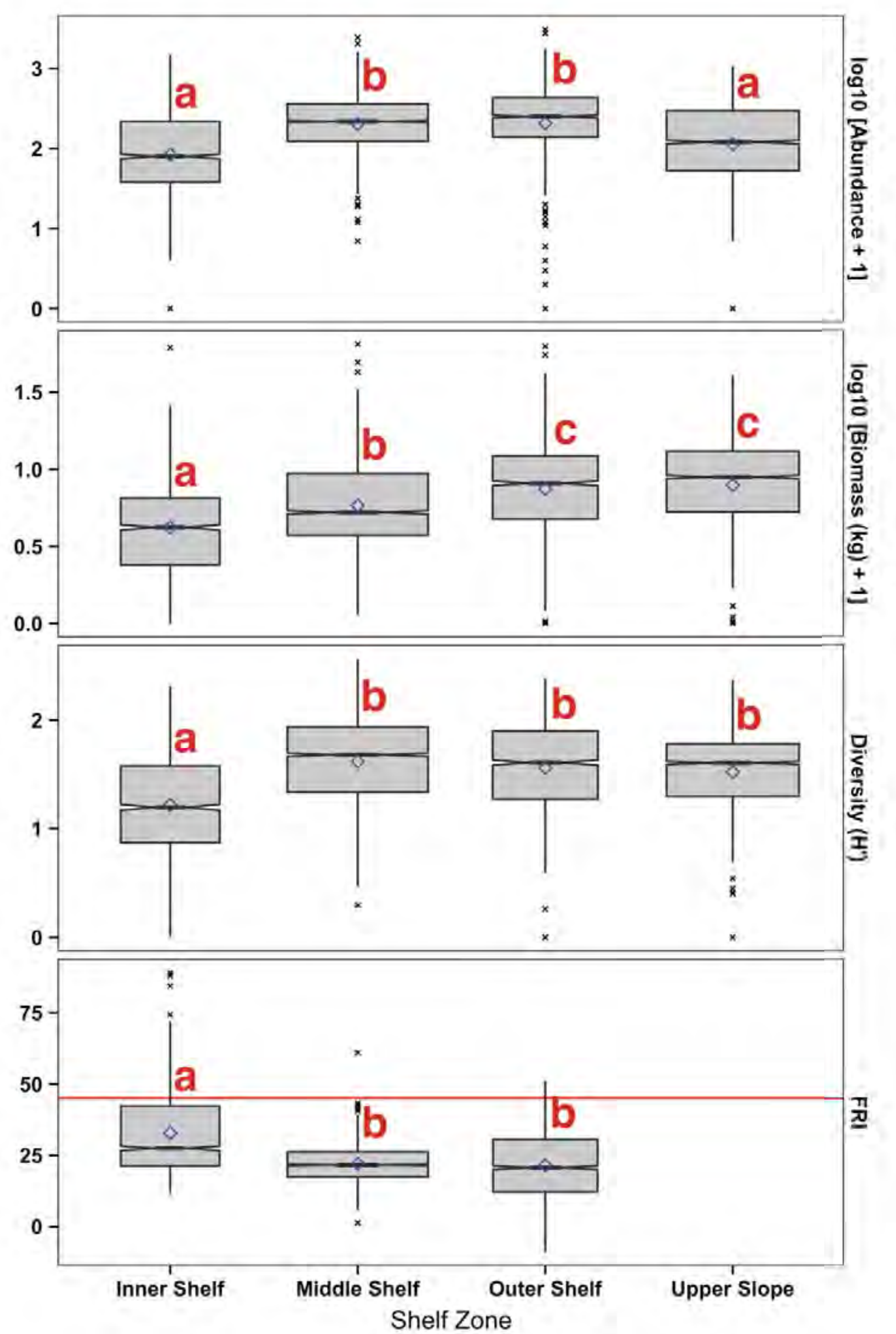
**Appendix A-1.** Fish abundance, biomass, diversity, and FRI by Survey. Outliers are indicated by "x"; blue diamonds indicate mean values; notches indicate 95% confidence intervals; box width indicates relative sample size; red letters indicate groups with non-significantly different means among Surveys by metric; metrics without lettering have non-significant differences among Surveys for that metric.



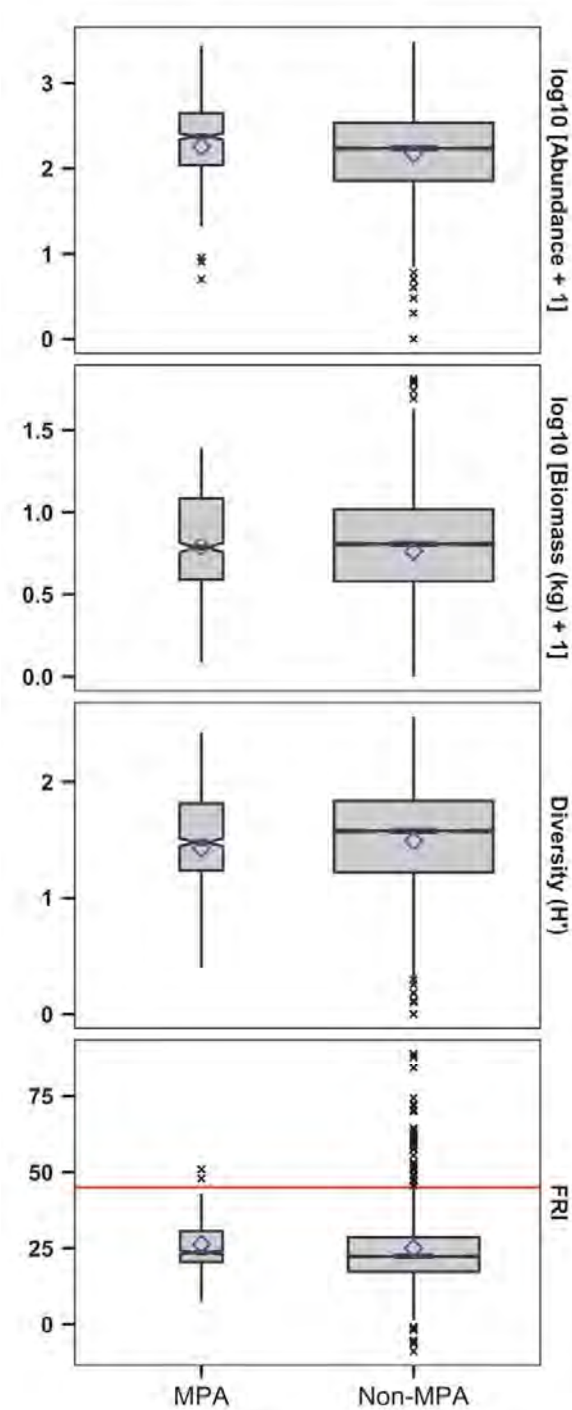
**Appendix A-2.** Fish abundance, biomass, diversity, and FRI by Region. Outliers are indicated by "x"; blue diamonds indicate mean values; notches indicate 95% confidence intervals; box width indicates relative sample size; red letters indicate groups with non-significantly different means among Regions by metric; metrics without lettering have non-significant differences among Regions for that metric.



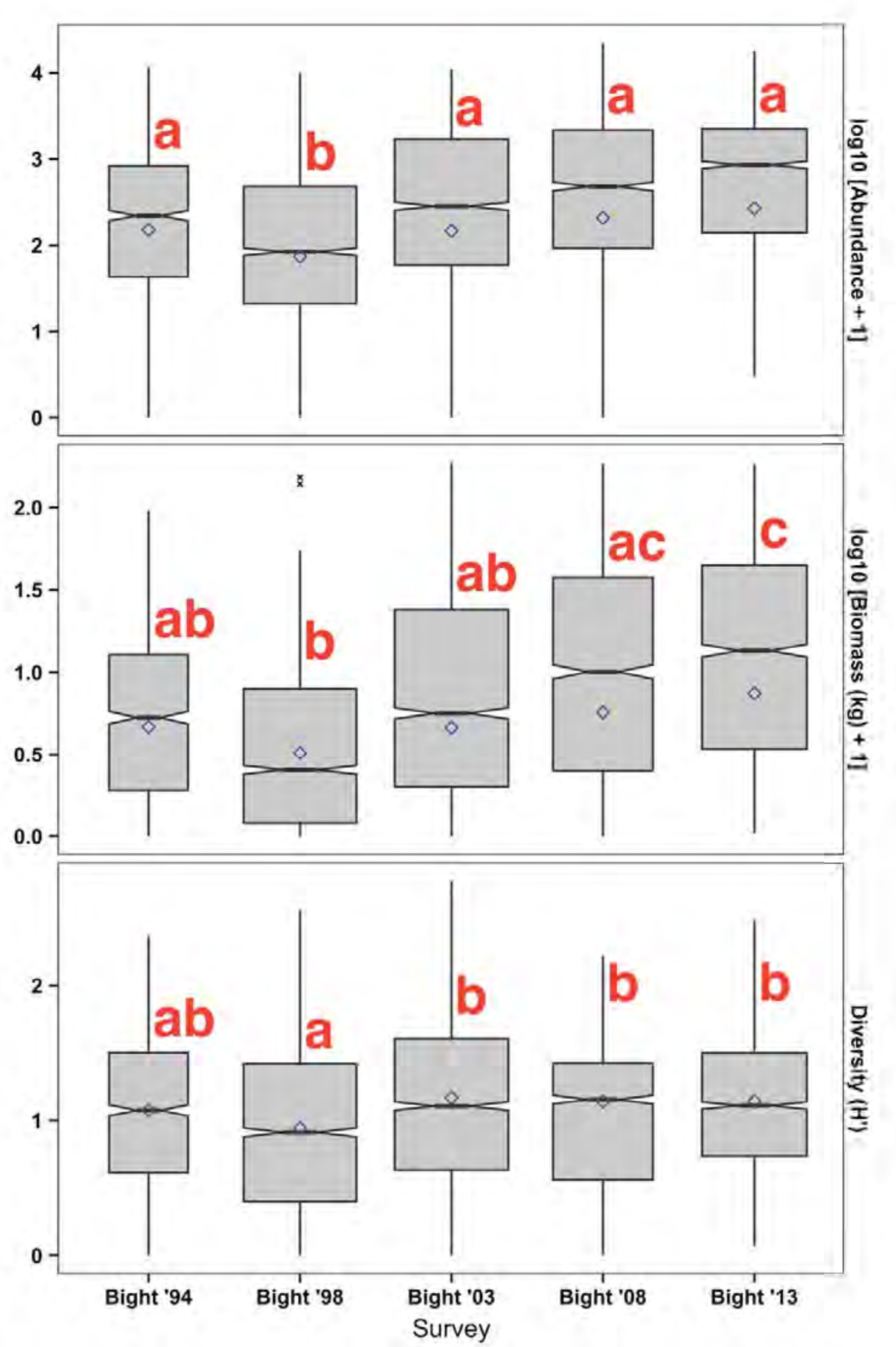
**Appendix A-3.** Fish abundance, biomass, diversity, and FRI by Shelf Zone. Outliers are indicated by "x"; blue diamonds indicate mean values; notches indicate 95% confidence intervals; box width indicates relative sample size; red letters indicate groups with non-significantly different means among Shelf Zones by metric; metrics without lettering have non-significant differences among Shelf Zone for that metric.



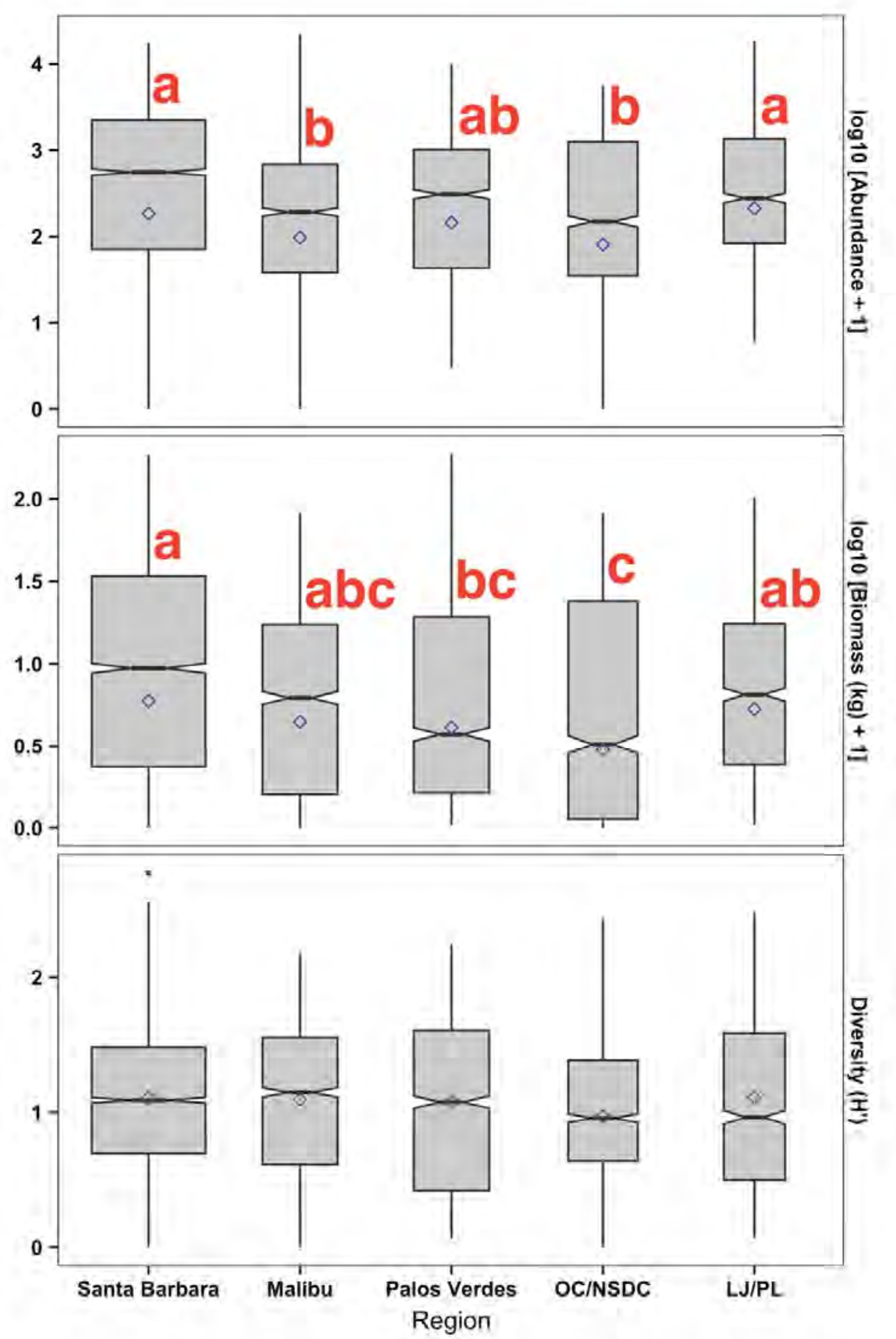
**Appendix A-4.** Fish abundance, biomass, diversity, and FRI by MPA Status. Outliers are indicated by "x"; blue diamonds indicate mean values; notches indicate 95% confidence intervals; box width indicates relative sample size.



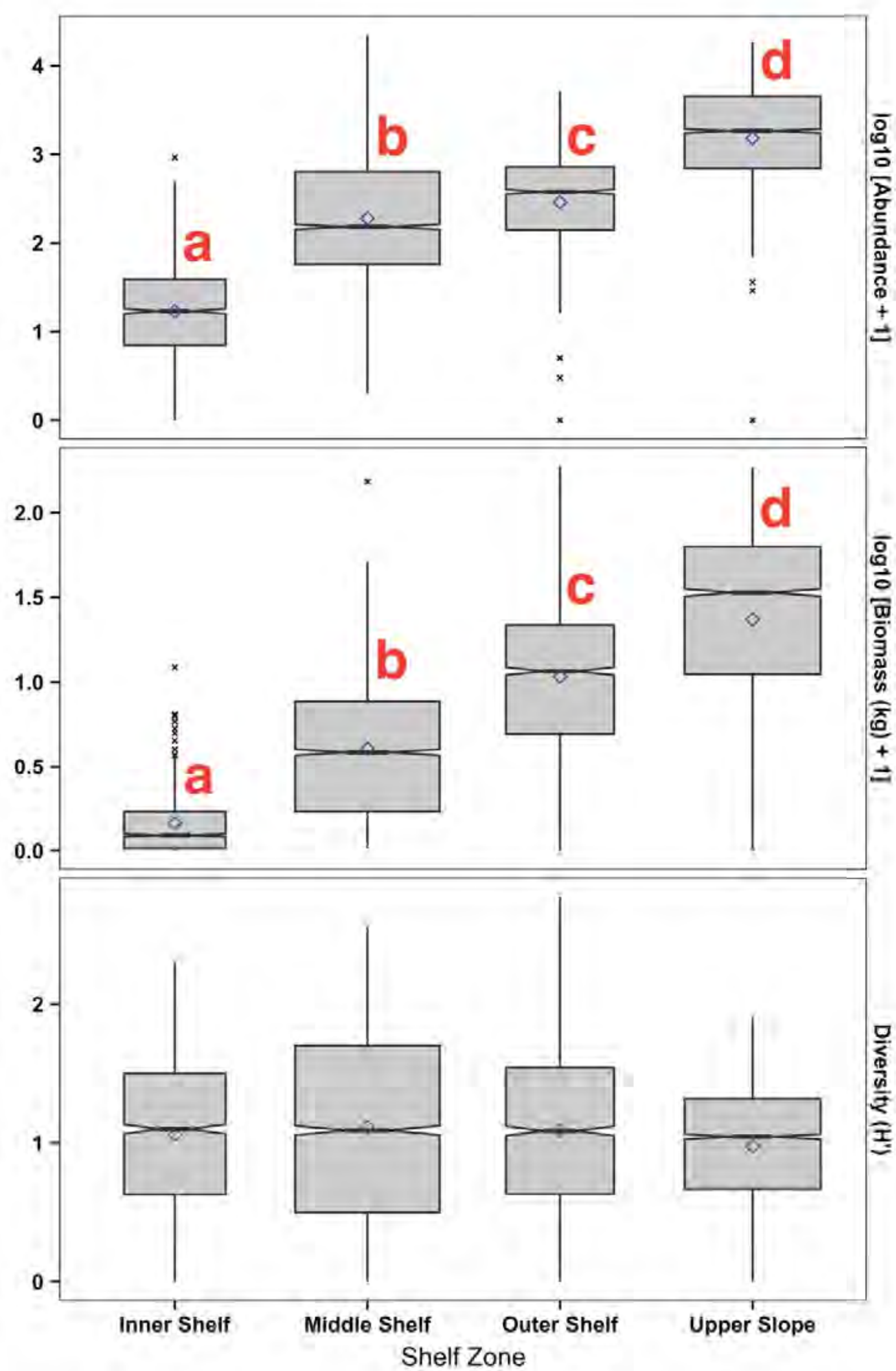
**Appendix A-5.** Invertebrate abundance, biomass, and diversity by Survey. Outliers are indicated by "x"; blue diamonds indicate mean values; notches indicate 95% confidence intervals; box width indicates relative sample size; red letters indicate groups with non-significantly different means among Surveys by metric; metrics without lettering have non-significant differences among Surveys for that metric.



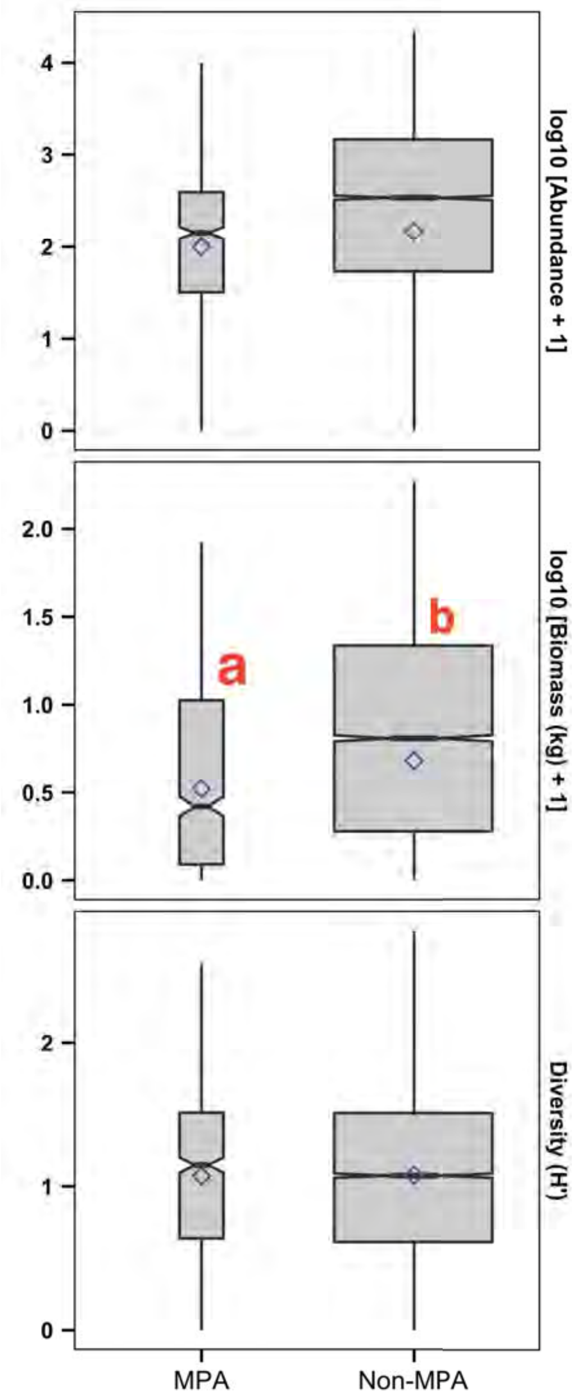
**Appendix A-6.** Invertebrate abundance, biomass, and diversity by Region. Outliers are indicated by "x"; blue diamonds indicate mean values; notches indicate 95% confidence intervals; box width indicates relative sample size; red letters indicate groups with non-significantly different means among Regions by metric; metrics without lettering have non-significant differences among Regions for that metric.



**Appendix A-7.** Invertebrate abundance, biomass, and diversity by Shelf Zone. Outliers are indicated by "x"; blue diamonds indicate mean values; notches indicate 95% confidence intervals; box width indicates relative sample size; red letters indicate groups with non-significantly different means among Shelf Zones by metric; metrics without lettering have non-significant differences among Shelf Zone for that metric.



**Appendix A-8.** Invertebrate abundance, biomass, and diversity by MPA Status. Outliers are indicated by "x"; blue diamonds indicate mean values; notches indicate 95% confidence intervals; box width indicates relative sample size; red letters indicate groups with non-significantly different means among MPA and non-MPA stations by metric; metrics without lettering have a non-significant difference among MPA Status for that metric.



# **Appendix B –** Maps of Metric by Trawl Station

**Appendix B-1.** Map of fish abundance at the 799 trawl survey stations throughout the SCB from 1994-2013.

**Appendix B-2.** Map of fish biomass at the 799 trawl survey stations throughout the SCB from 1994-2013.

**Appendix B-3.** Map of fish diversity at the 799 trawl survey stations throughout the SCB from 1994-2013.

**Appendix B-4.** Map of FRI at the 701 trawl survey stations throughout the SCB from 1994-2013.

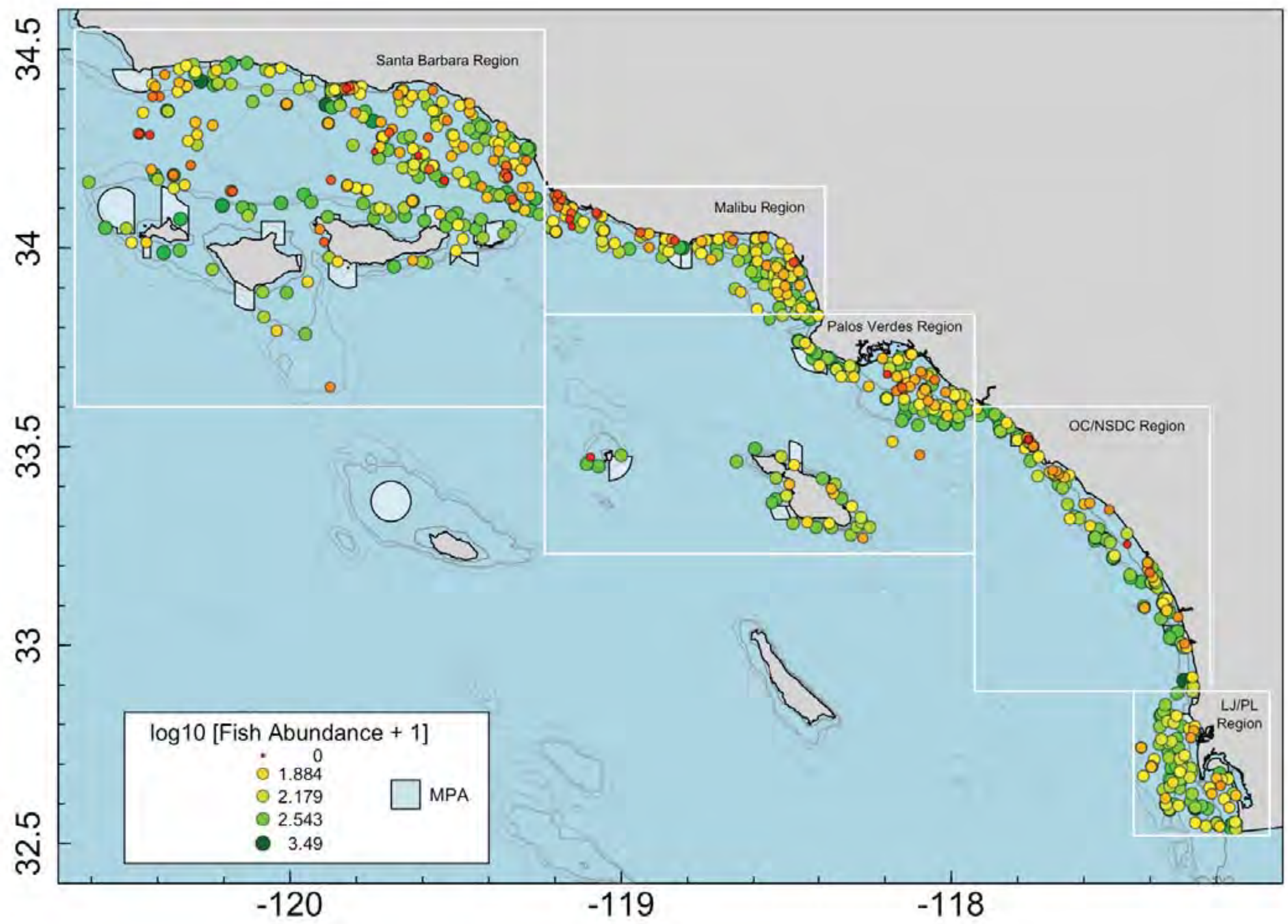
**Appendix B-5.** Map of fish community structure at the 799 trawl survey stations throughout the SCB from 1994-2013.

**Appendix B-6.** Map of invertebrate abundance at the 799 trawl survey stations throughout the SCB from 1994-2013.

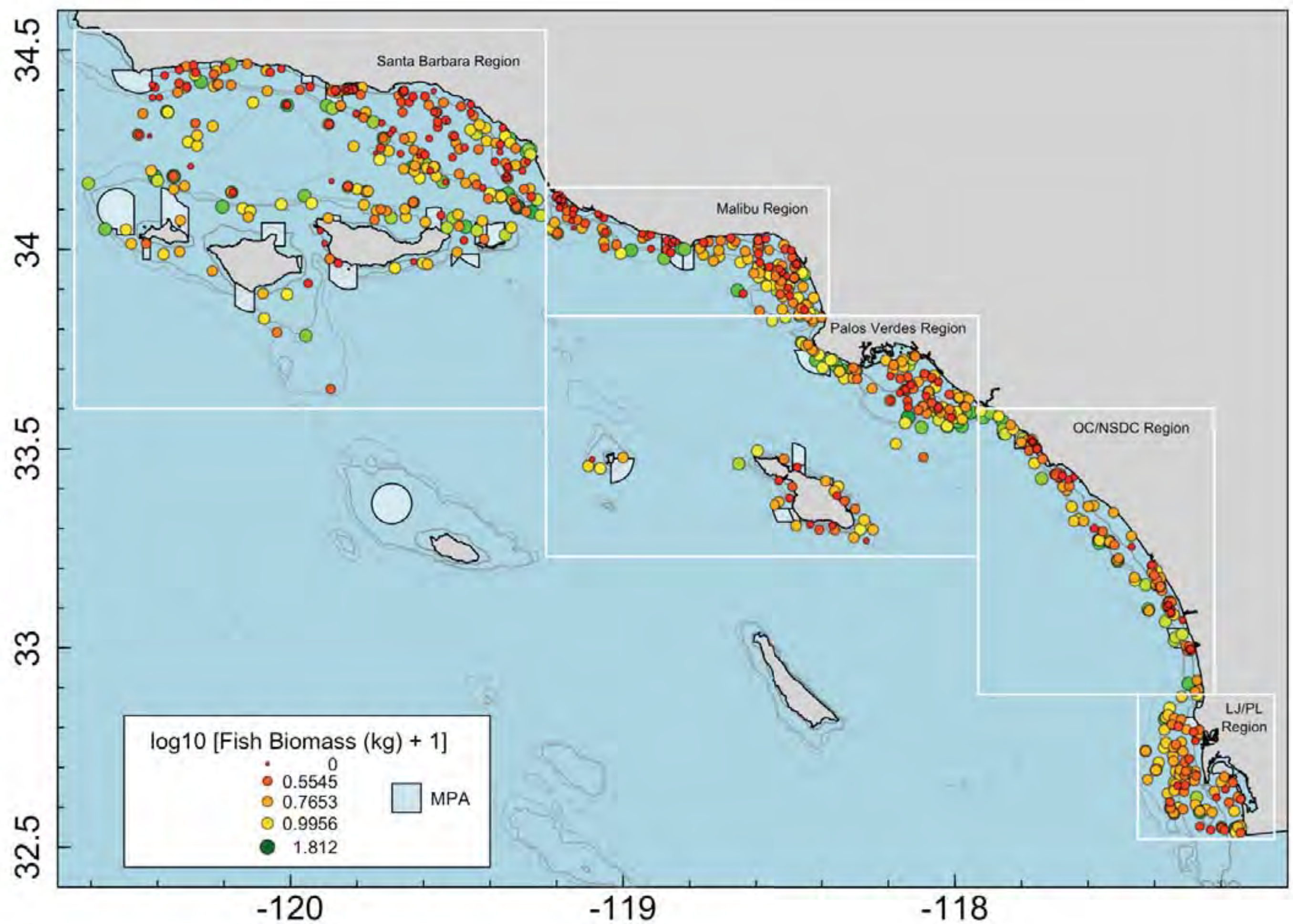
**Appendix B-7.** Map of invertebrate biomass at the 799 trawl survey stations throughout the SCB from 1994-2013.

**Appendix B-8.** Map of invertebrate diversity at the 799 trawl survey stations throughout the SCB from 1994-2013.

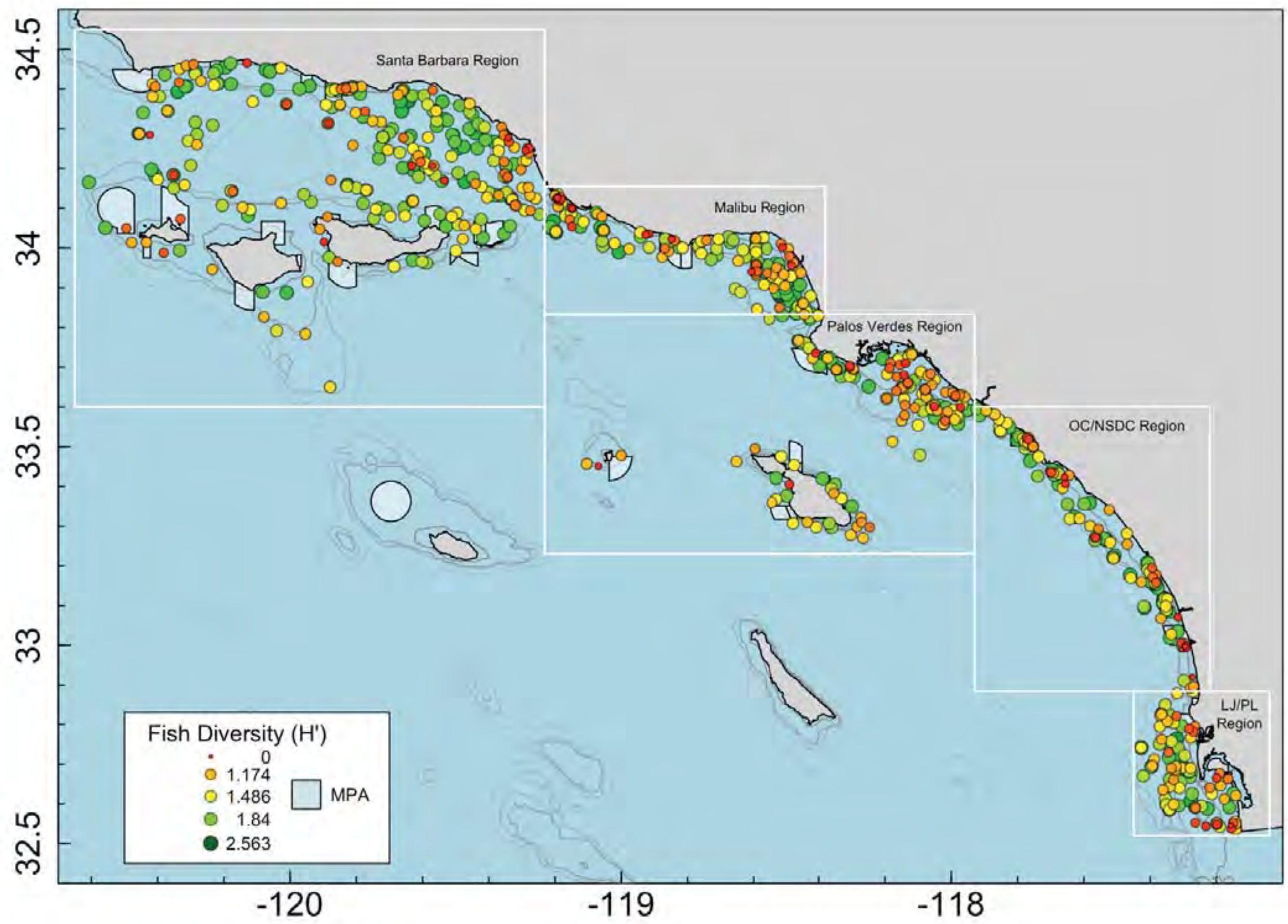
**Appendix B-1.** Map of fish abundance at the 799 trawl survey stations throughout the SCB from 1994-2013.



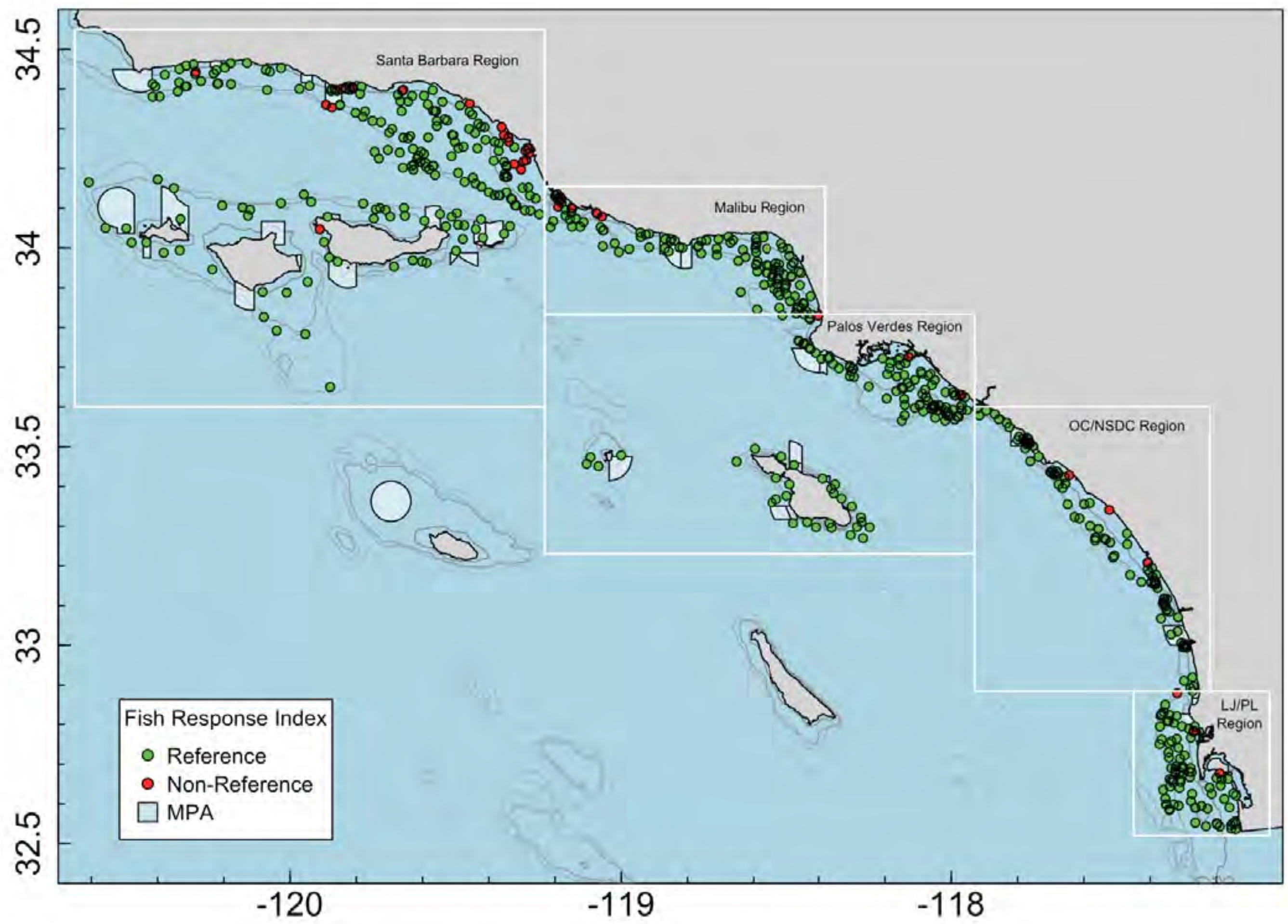
**Appendix B-2.** Map of fish biomass at the 799 trawl survey stations throughout the SCB from 1994-2013.



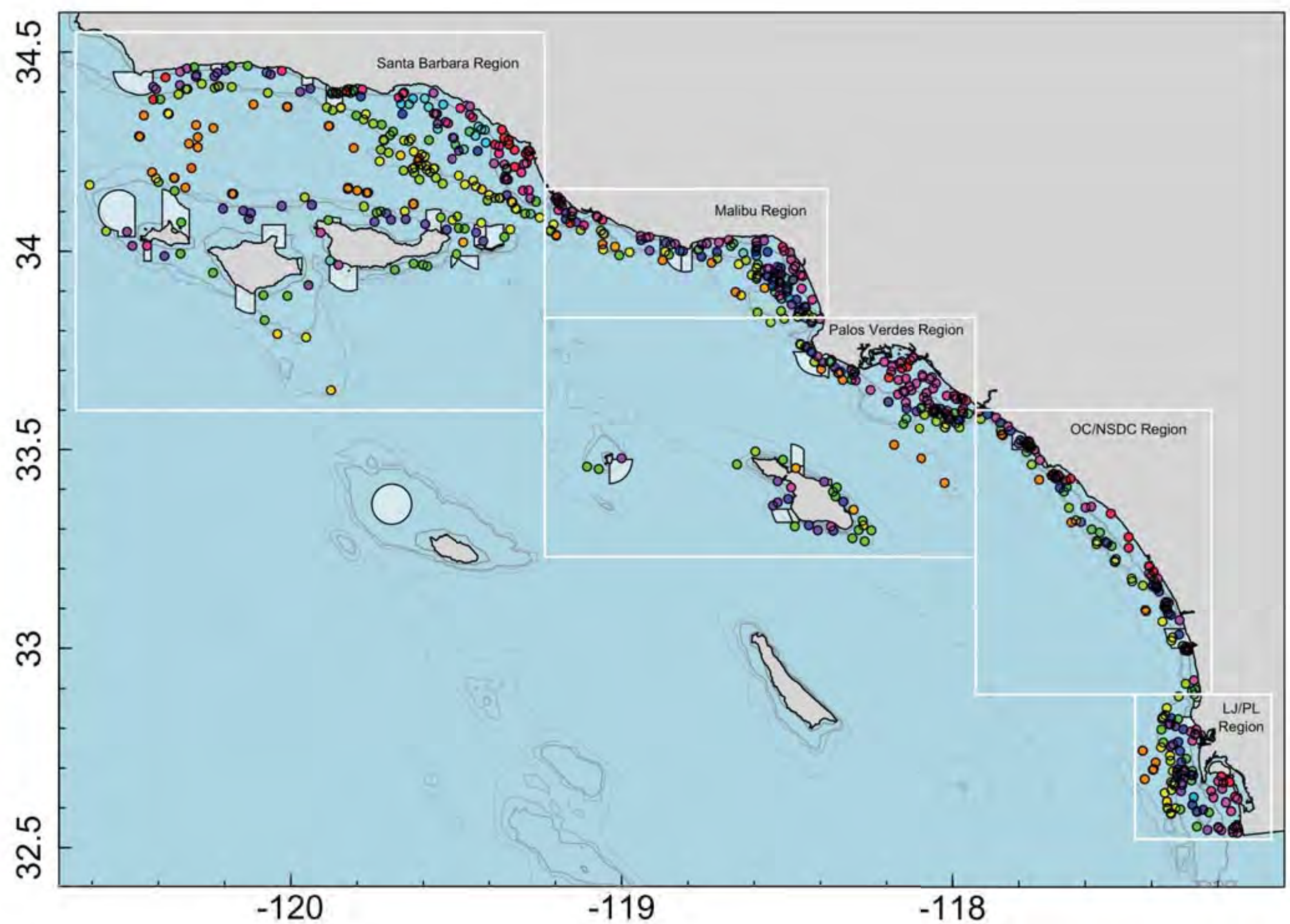
**Appendix B-3.** Map of fish diversity at the 799 trawl survey stations throughout the SCB from 1994-2013.



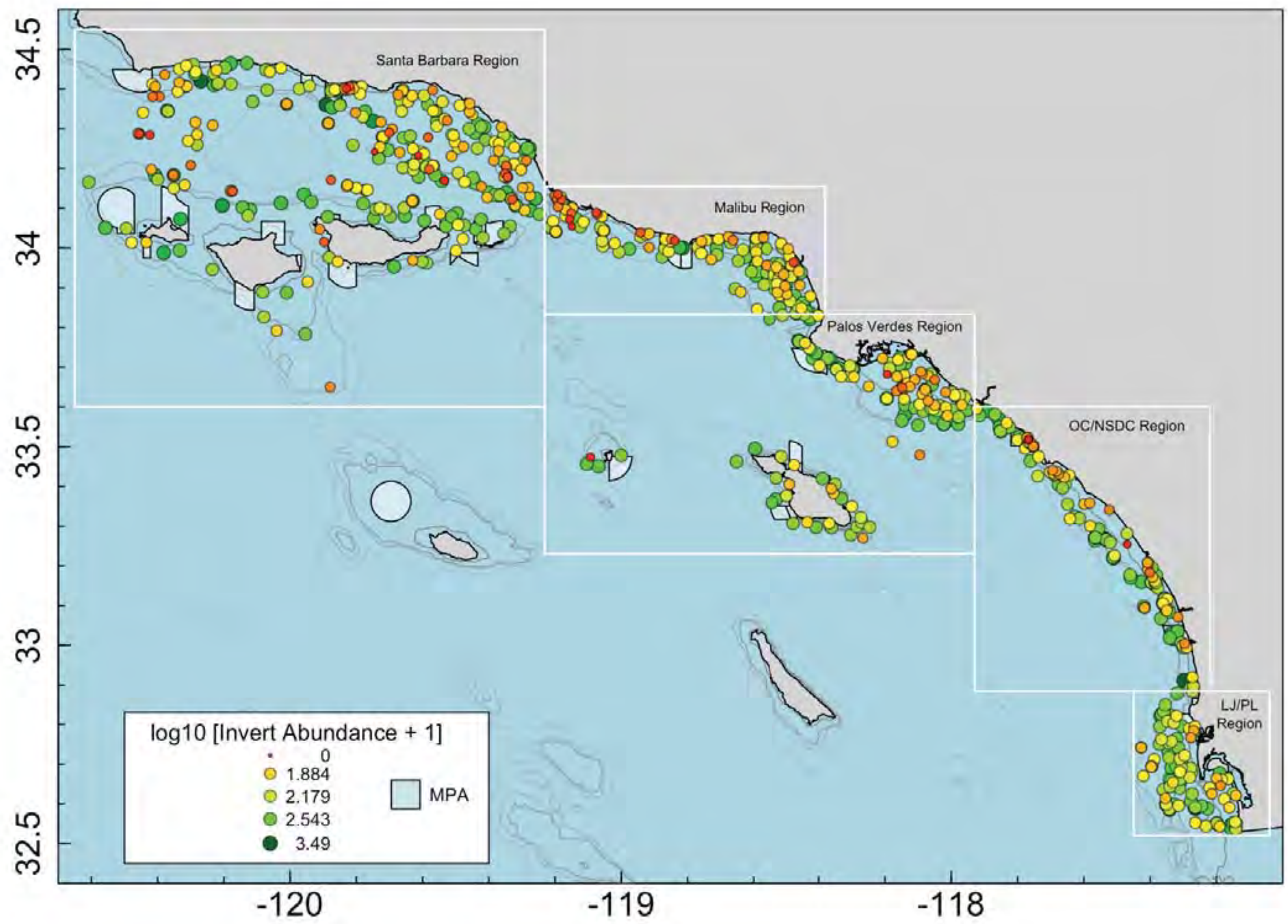
**Appendix B-4.** Map of FRI at the 701 trawl survey stations throughout the SCB from 1994-2013.



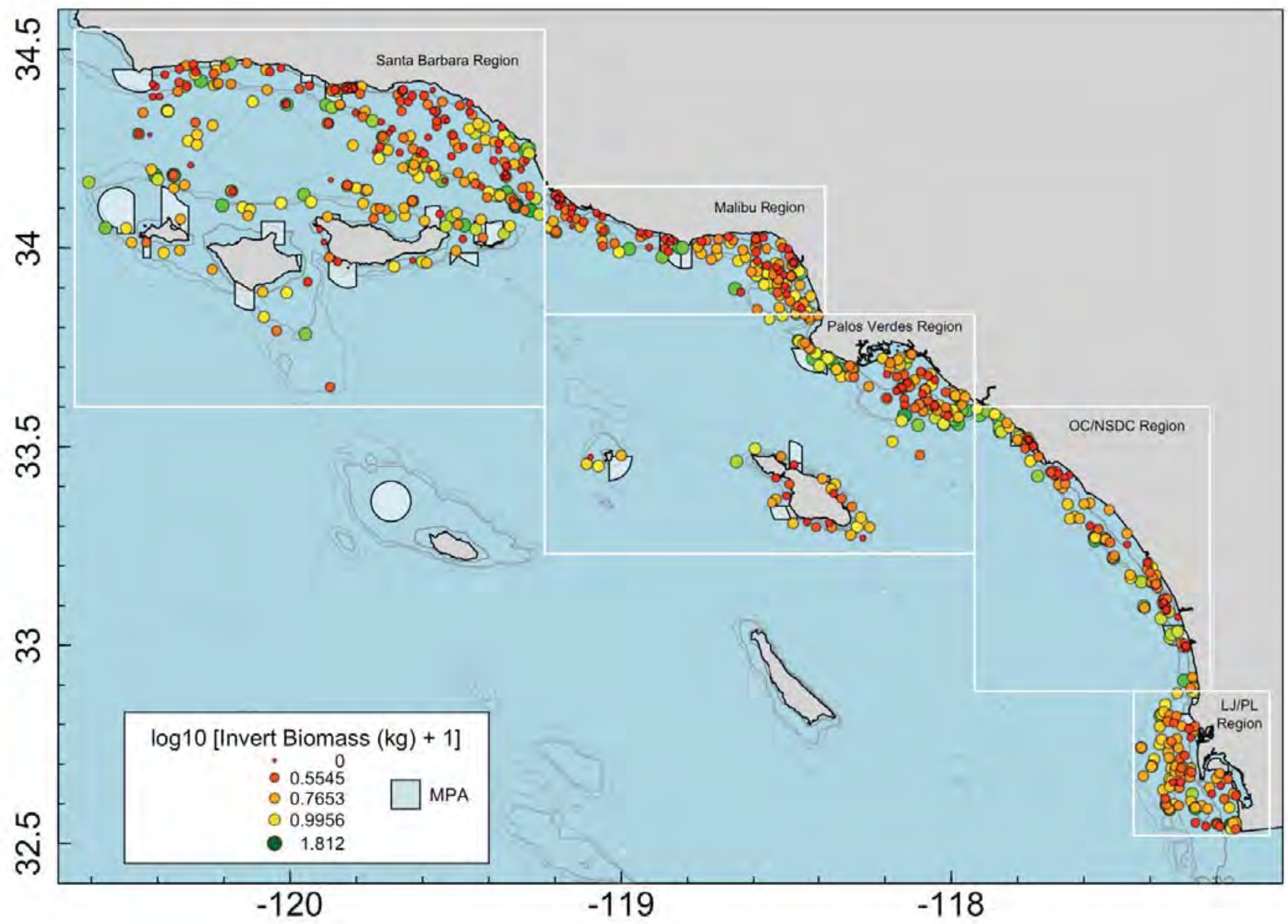
**Appendix B-5.** Map of fish community structure at the 799 trawl survey stations throughout the SCB from 1994-2013. Stations labeled with the same color have non-significantly different fish communities.



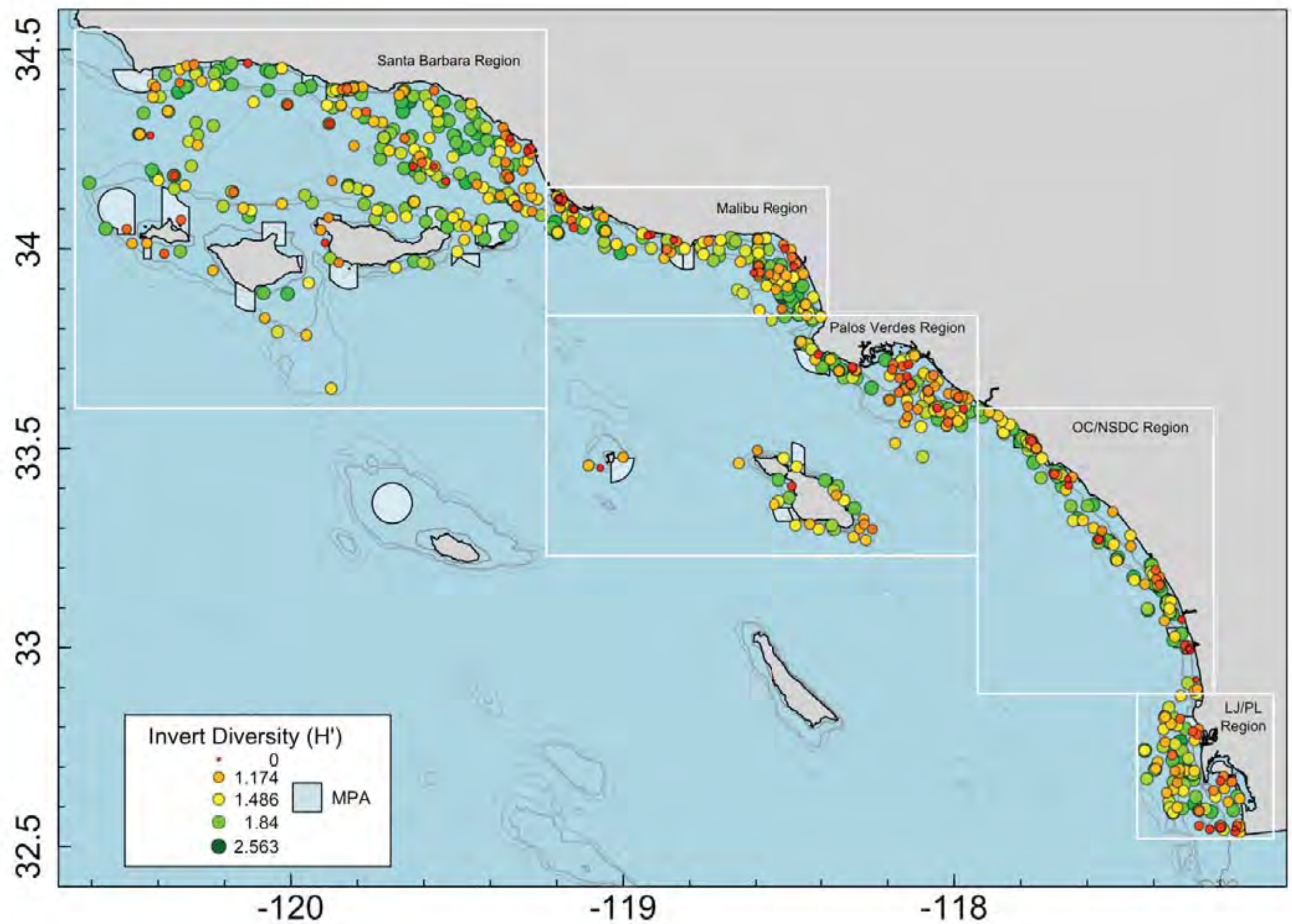
**Appendix B-6.** Map of invertebrate abundance at the 799 trawl survey stations throughout the SCB from 1994-2013.



**Appendix B-7.** Map of invertebrate biomass at the 799 trawl survey stations throughout the SCB from 1994-2013.



**Appendix B-8.** Map of invertebrate diversity at the 799 trawl survey stations throughout the SCB from 1994-2013.



# **Appendix C –** Size Classes of Pacific Sanddab, White Croaker, Pacific Hake, and California Scorpionfish

**Appendix C-1.** Length frequency of Pacific Sanddab (*Citharichthys sordidus*) by Survey, Shelf Zone, and MPA Status.

**Appendix C-2.** Length frequency of White Croaker (*Genyonemus lineatus*) by Survey, Shelf Zone, and MPA Status

**Appendix C-3.** Length frequency of Pacific Hake (*Merluccius productus*) by Survey, Shelf Zone, and MPA Status

**Appendix C-4.** Length frequency of California Scorpionfish (*Scorpaena guttata*) by Survey, Shelf Zone, and MPA Status.

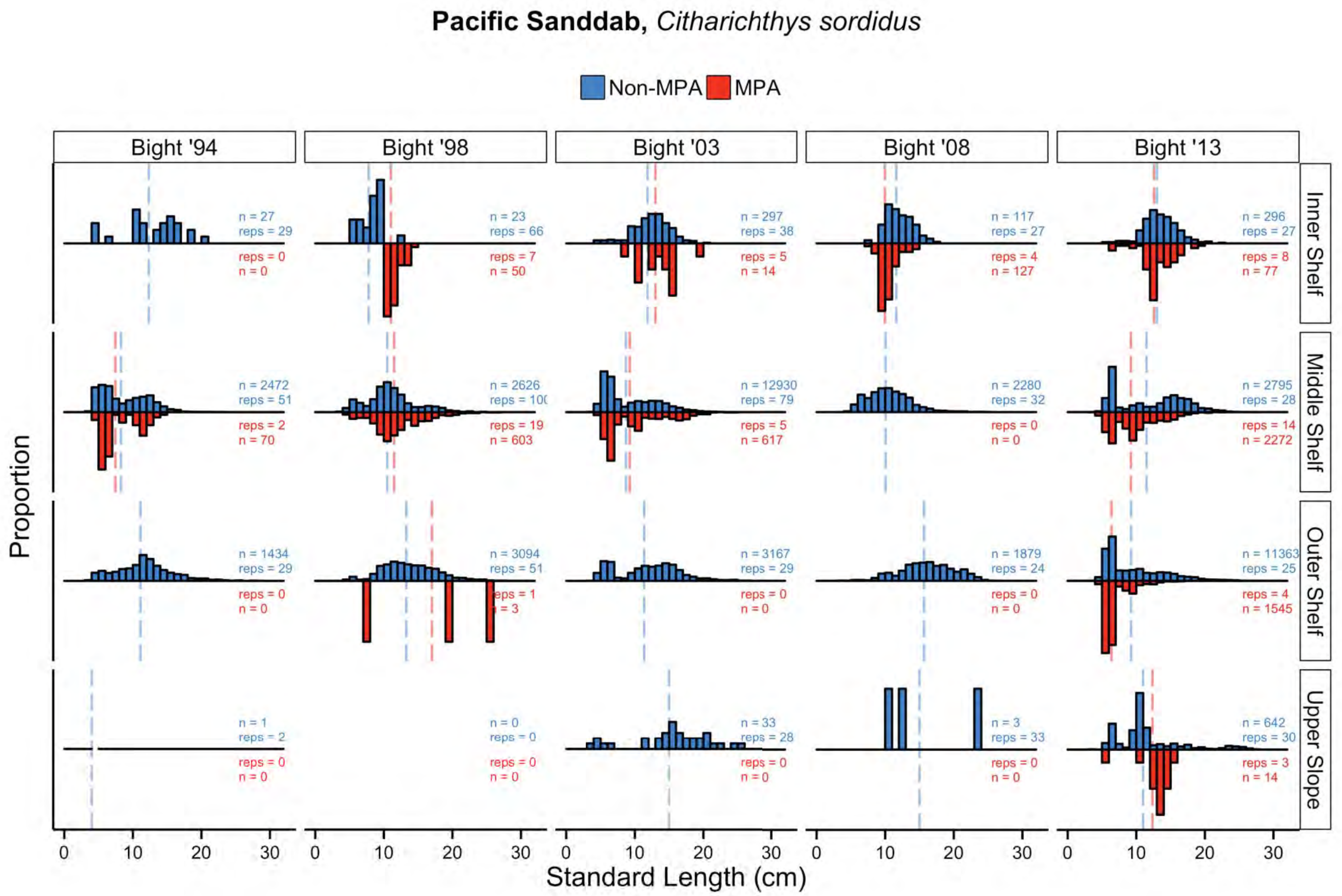
**Appendix C-5.** Mean size class by station of Pacific Sanddab, White Croaker, Pacific Hake, and California Scorpionfish by Survey.

**Appendix C-6.** Mean size class by station of Pacific Sanddab, White Croaker, Pacific Hake, and California Scorpionfish by Region.

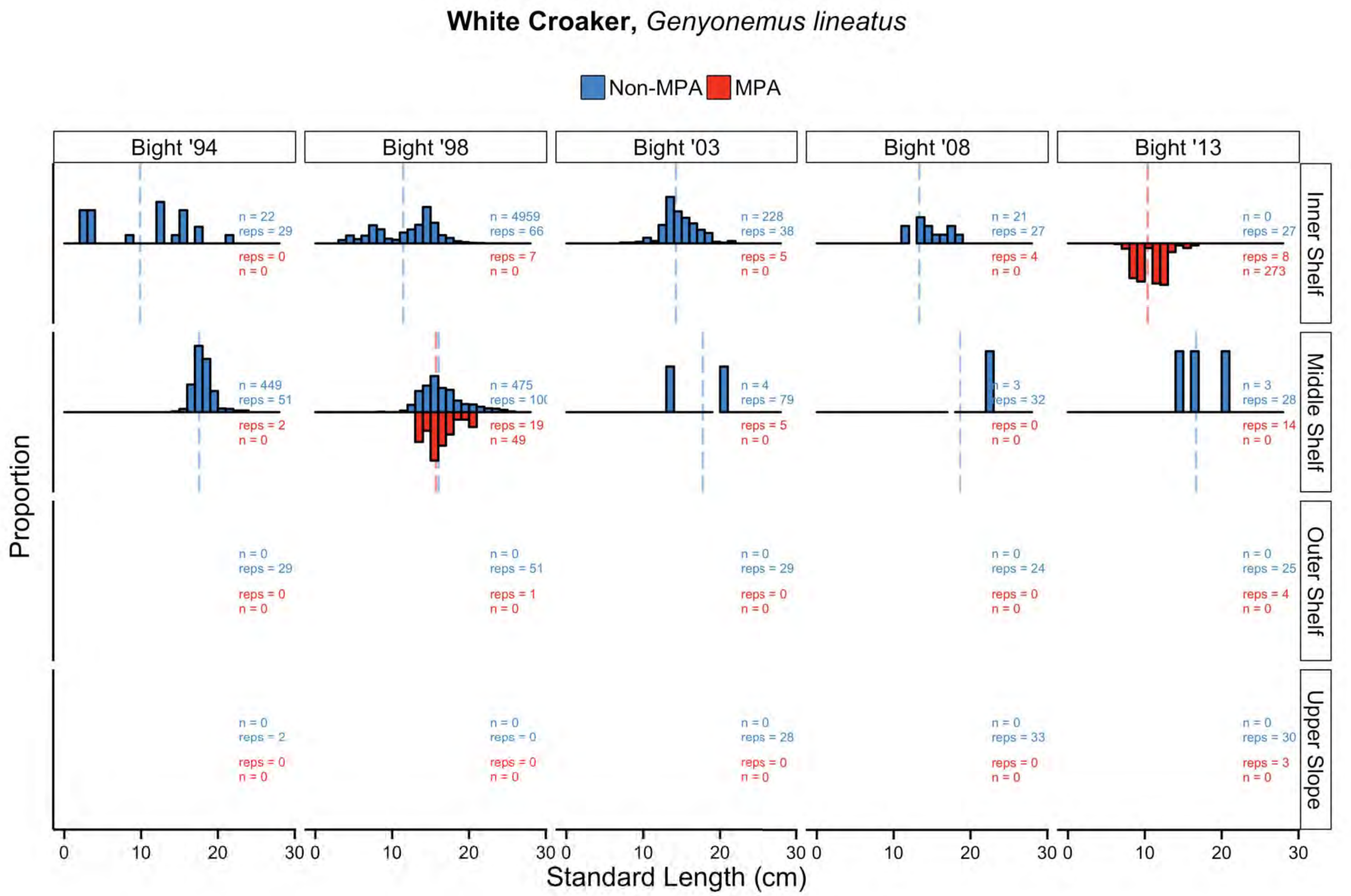
**Appendix C-7.** Mean size class by station of Pacific Sanddab, White Croaker, Pacific Hake, and California Scorpionfish by Shelf Zone.

**Appendix C-8.** Mean size class by station of Pacific Sanddab, White Croaker, Pacific Hake, and California Scorpionfish by MPA Status.

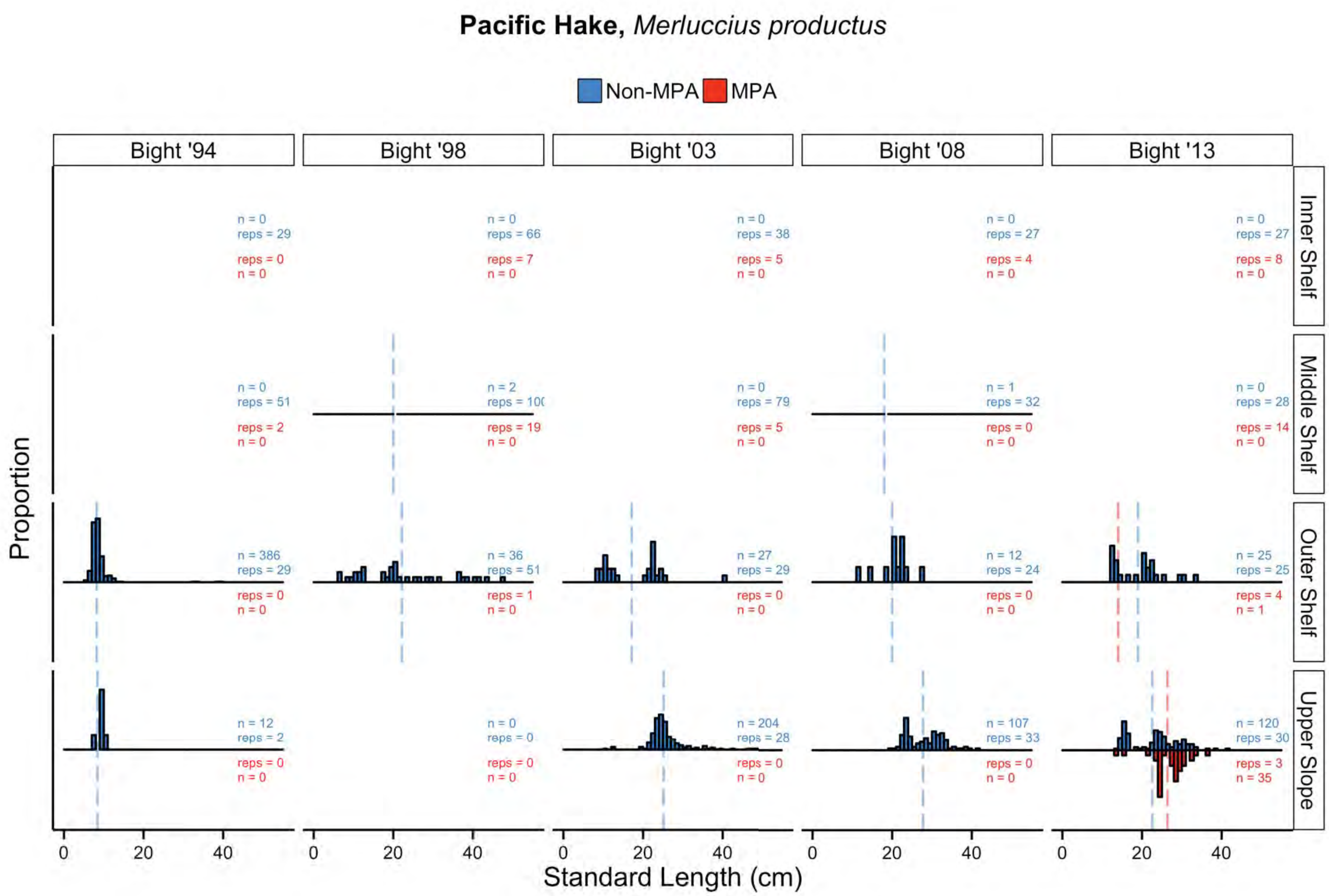
**Appendix C-1.** Length frequency of Pacific Sanddab (*Citharichthys sordidus*) by Survey, Shelf Zone, and MPA Status. Mean lengths for each combination are shown as dashed lines; number of individuals (n) and trawls (reps) are noted.



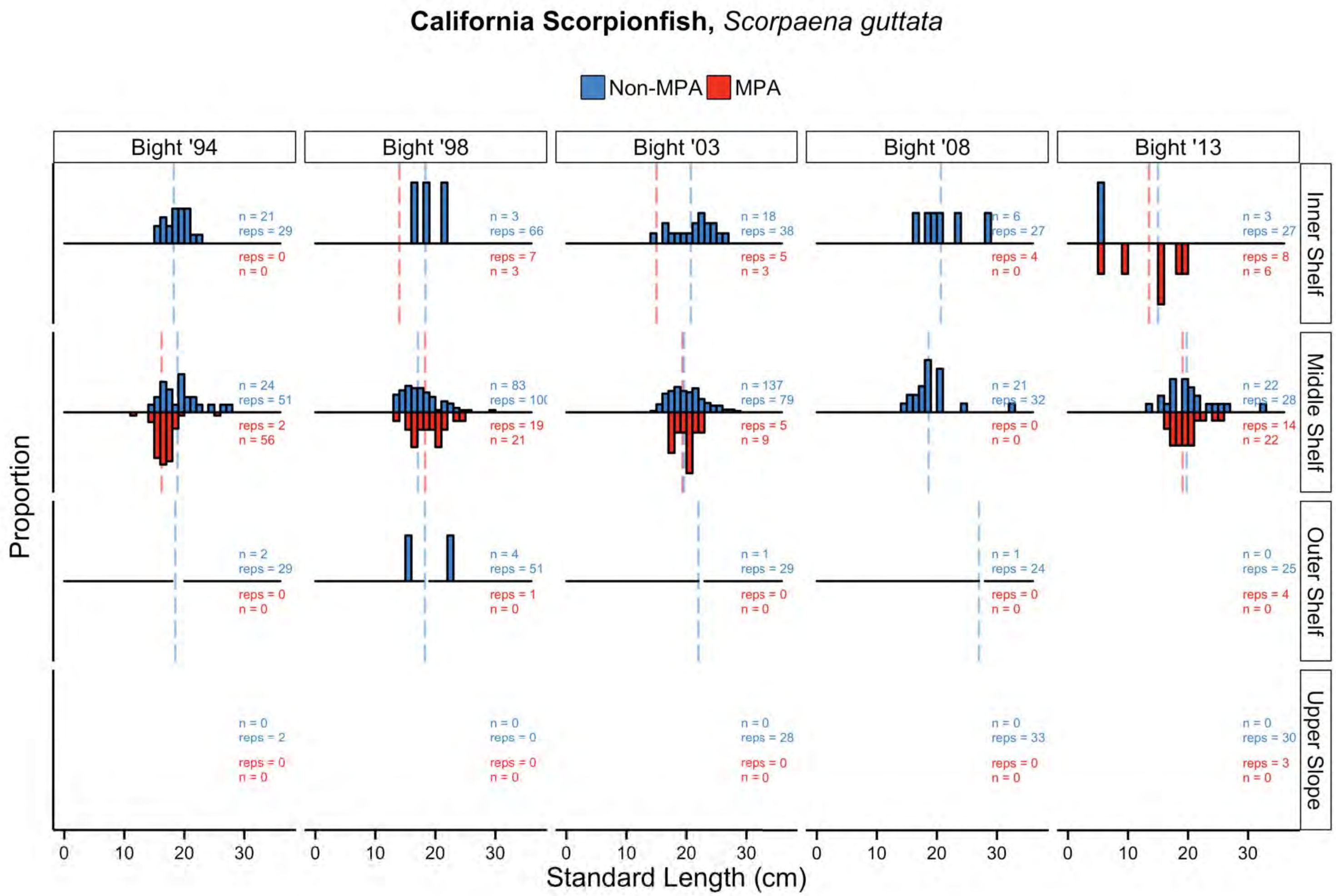
**Appendix C-2.** Length frequency of White Croaker (*Genyonemus lineatus*) by Survey, Shelf Zone, and MPA Status. Mean lengths for each combination are shown as dashed lines; number of individuals (n) and trawls (reps) are noted.



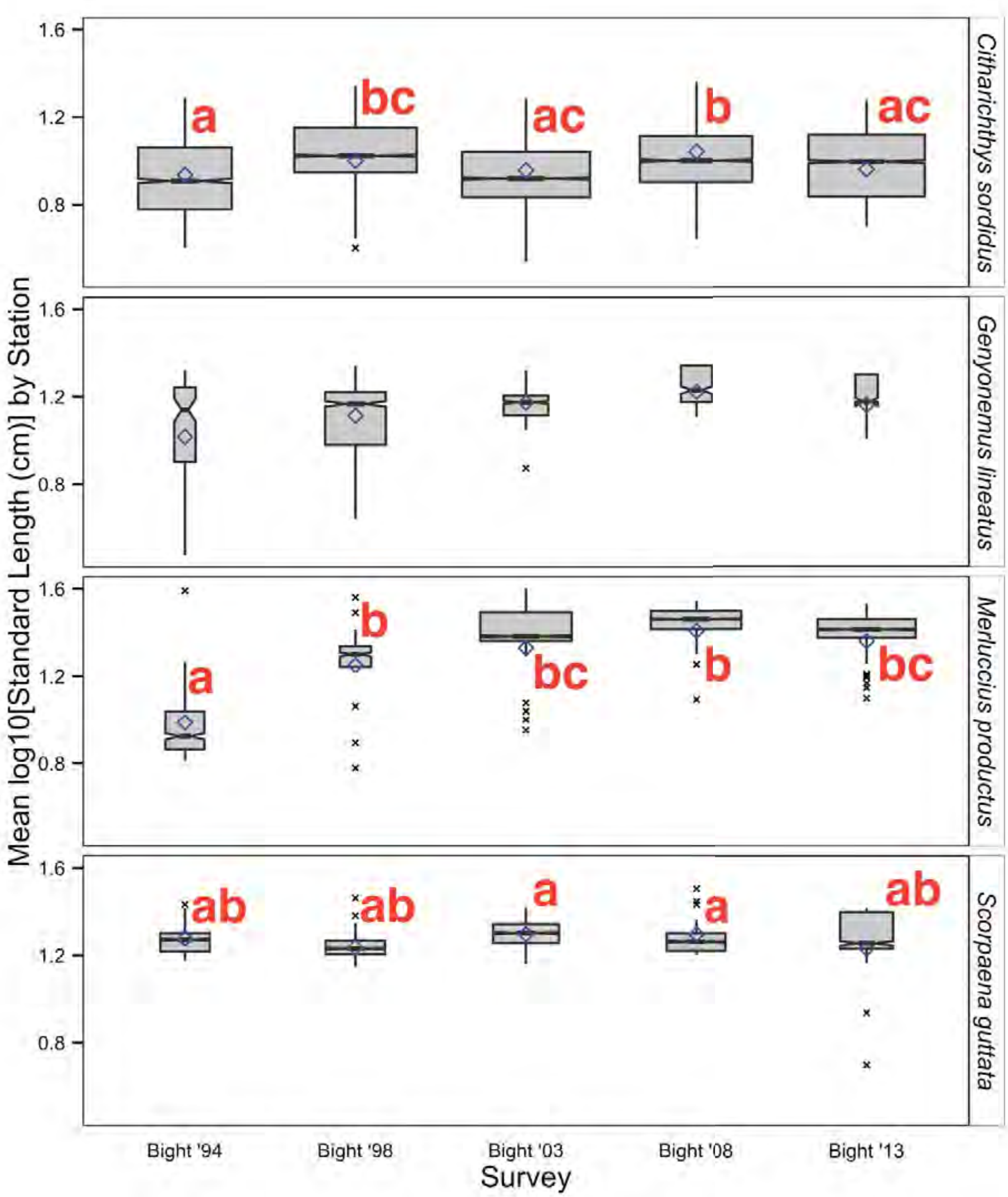
**Appendix C-3.** Length frequency of Pacific Hake (*Merluccius productus*) by Survey, Shelf Zone, and MPA Status. Mean lengths for each combination are shown as dashed lines; number of individuals (n) and trawls (reps) are noted.



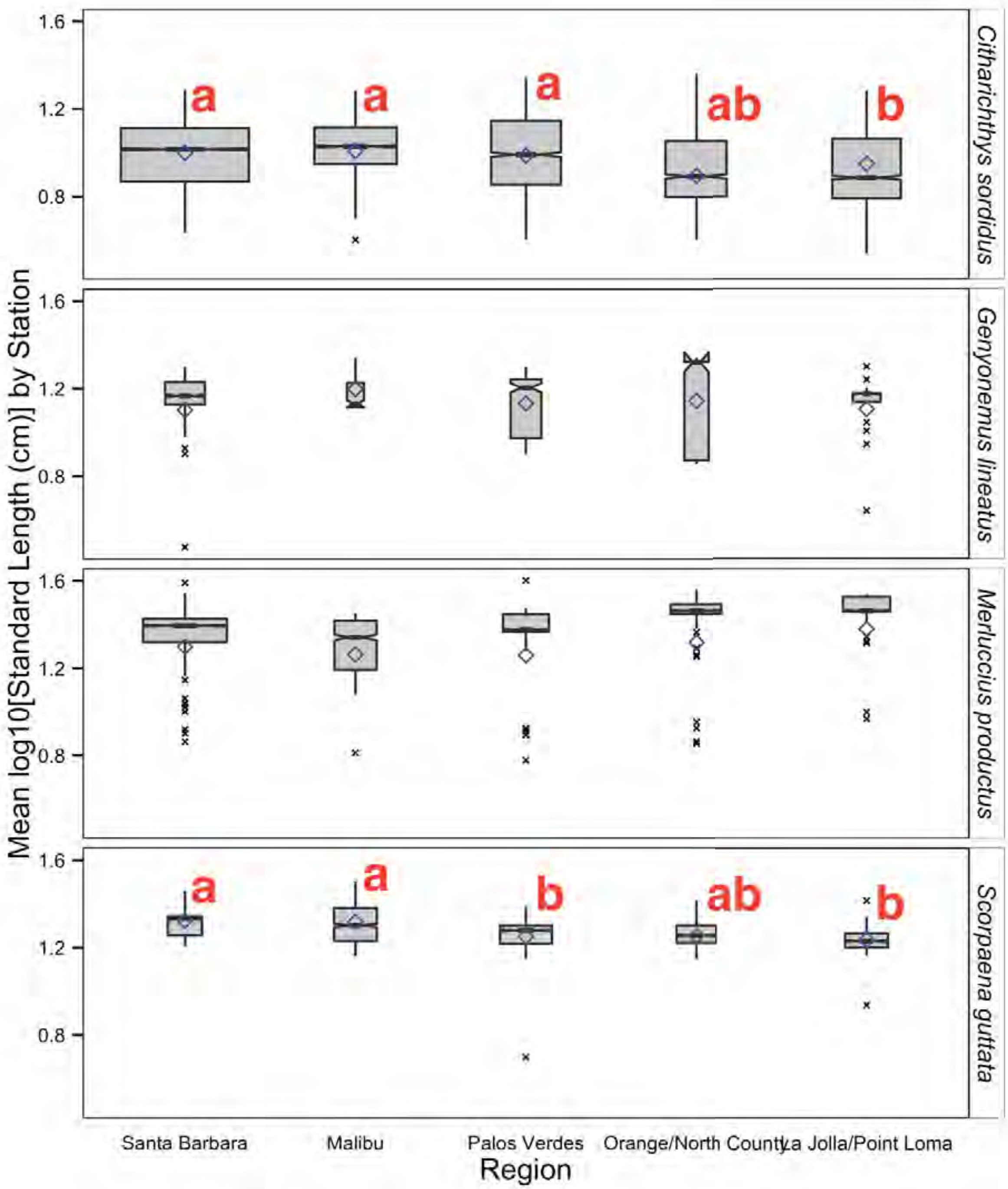
**Appendix C-4.** Length frequency of California Scorpionfish (*Scorpaena guttata*) by Survey, Shelf Zone, and MPA Status. Mean lengths for each combination are shown as dashed lines; number of individuals (n) and trawls (reps) are noted.



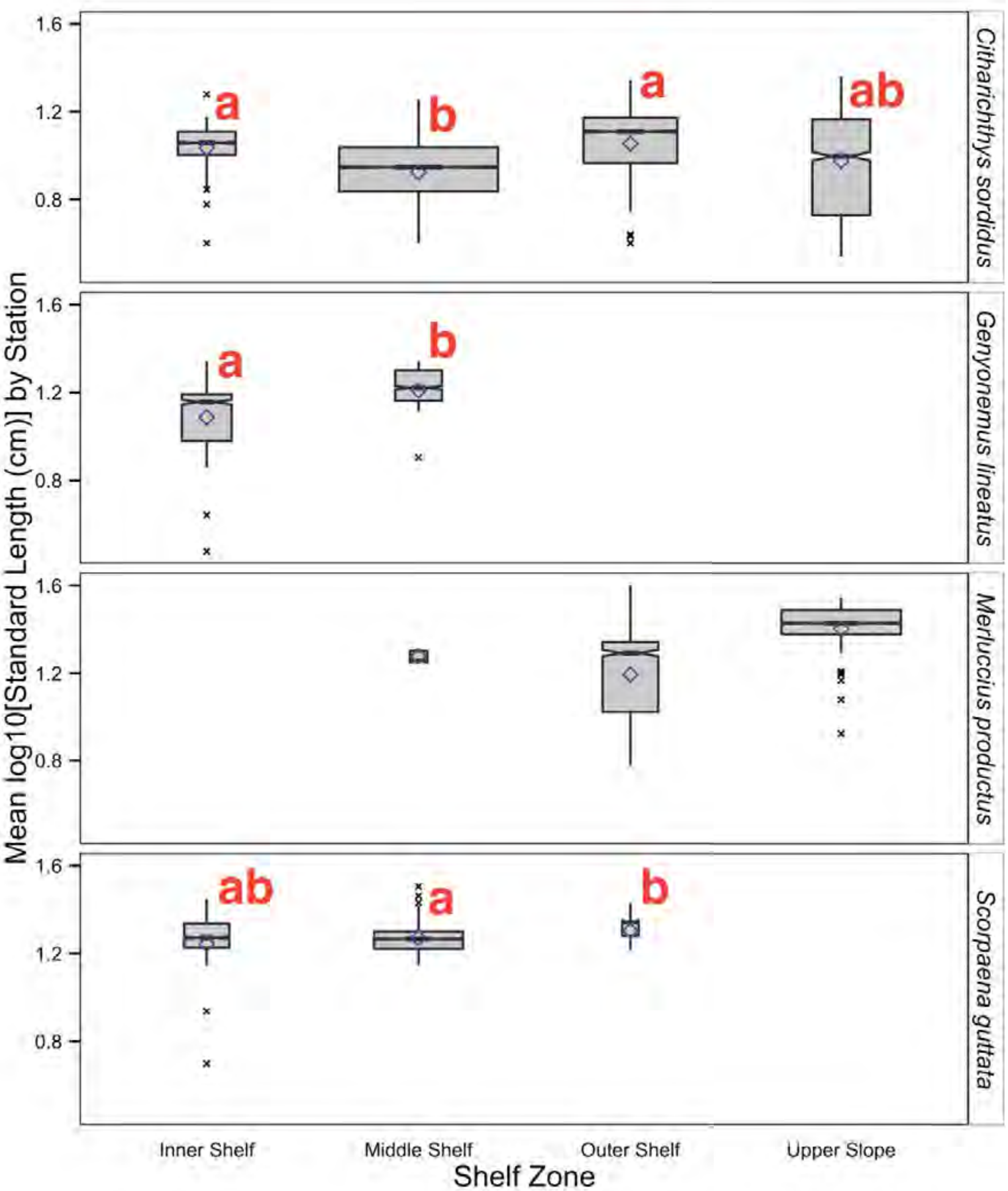
**Appendix C-5.** Mean size class by station of Pacific Sanddab (*Citharichthys sordidus*), White Croaker (*Genyonemus lineatus*), Pacific Hake (*Merluccius productus*), and California Scorpionfish (*Scorpaena guttata*) by Survey. Outliers are indicated by "x"; blue diamonds indicate grand mean values; notches indicate 95% confidence intervals; box width indicates relative sample size; red letters indicate groups with non-significantly different means among Surveys by metric; metrics without lettering have non-significant differences among Surveys for that metric.



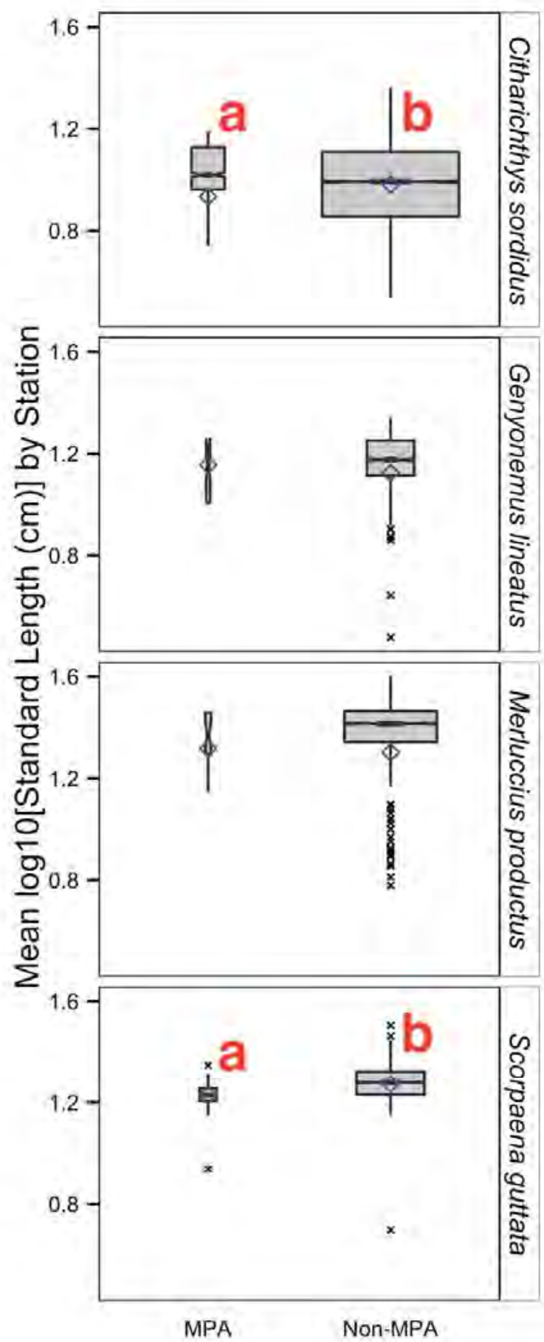
**Appendix C-6.** Mean size class by station of Pacific Sanddab (*Citharichthys sordidus*), White Croaker (*Genyonemus lineatus*), Pacific Hake (*Merluccius productus*), and California Scorpionfish (*Scorpaena guttata*) by Region. Outliers are indicated by "x"; blue diamonds indicate grand mean values; notches indicate 95% confidence intervals; box width indicates relative sample size; red letters indicate groups with non-significantly different means among Regions by metric; metrics without lettering have non-significant differences among Regions for that metric.



**Appendix C-7.** Mean size class by station of Pacific Sanddab (*Citharichthys sordidus*), White Croaker (*Genyonemus lineatus*), Pacific Hake (*Merluccius productus*), and California Scorpionfish (*Scorpaena guttata*) by Shelf Zone. Outliers are indicated by “x”; blue diamonds indicate grand mean values; notches indicate 95% confidence intervals; box width indicates relative sample size; red letters indicate groups with non-significantly different means among Shelf Zones by metric; metrics without lettering have non-significant differences among Shelf Zones for that metric.



**Appendix C-8.** Mean size class by station of Pacific Sanddab (*Citharichthys sordidus*), White Croaker (*Genyonemus lineatus*), Pacific Hake (*Merluccius productus*), and California Scorpionfish (*Scorpaena guttata*) by MPA Status. Outliers are indicated by "x"; blue diamonds indicate grand mean values; notches indicate 95% confidence intervals; box width indicates relative sample size; red letters indicate groups with non-significantly different means among MPA and non-MPA stations by species; species without lettering have a non-significant difference among MPA Status for that species.



# **Appendix D –** Power Curves

**Appendix D-1.** Power curves demonstrating the number of paired trawls necessary to detect changes in fish abundance.

**Appendix D-2.** Power curves demonstrating the number of paired trawls necessary to detect changes in fish biomass.

**Appendix D-3.** Power curves demonstrating the number of paired trawls necessary to detect changes in fish diversity.

**Appendix D-4.** Power curves demonstrating the number of paired trawls necessary to detect changes in size class of Pacific Sanddab.

**Appendix D-5.** Power curves demonstrating the number of paired trawls necessary to detect changes size class of White Croaker.

**Appendix D-6.** Power curves demonstrating the number of paired trawls necessary to detect changes in size class of Pacific Hake.

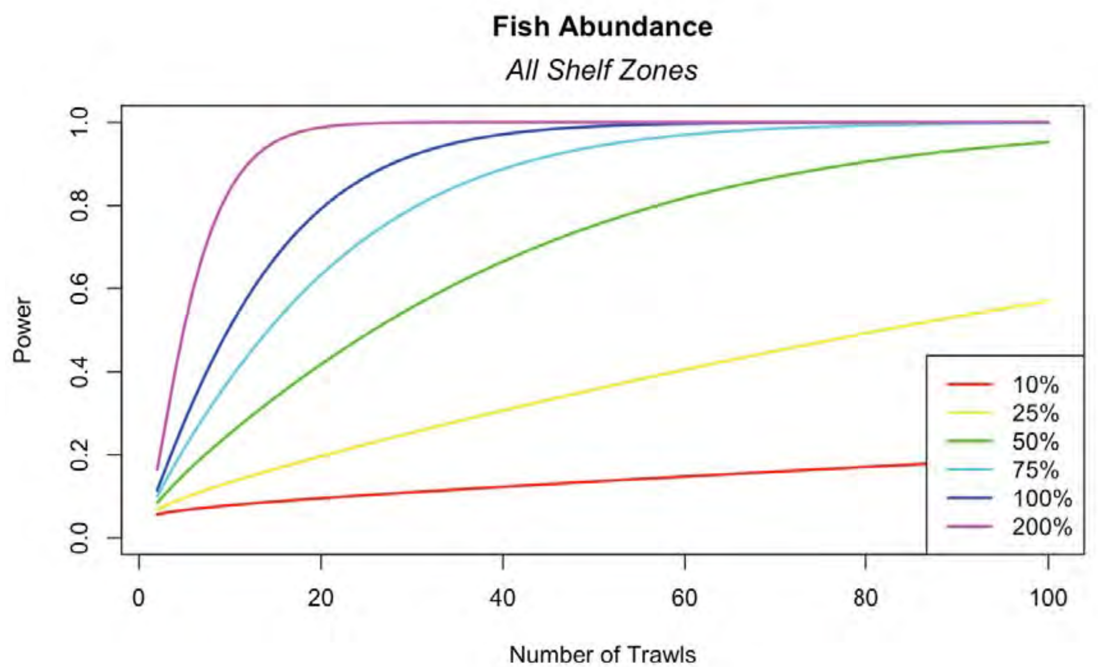
**Appendix D-7.** Power curves demonstrating the number of paired trawls necessary to detect changes in size class of California Scorpionfish.

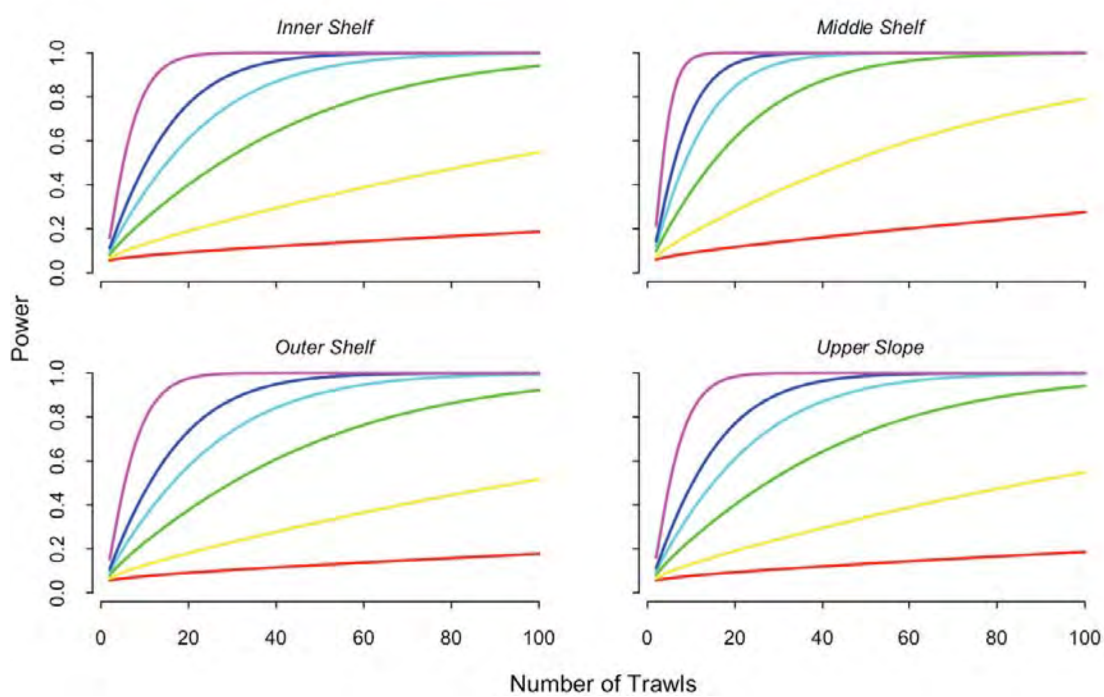
**Appendix D-8.** Power curves demonstrating the number of paired trawls necessary to detect changes in invertebrate abundance.

**Appendix D-9.** Power curves demonstrating the number of paired trawls necessary to detect changes in invertebrate biomass.

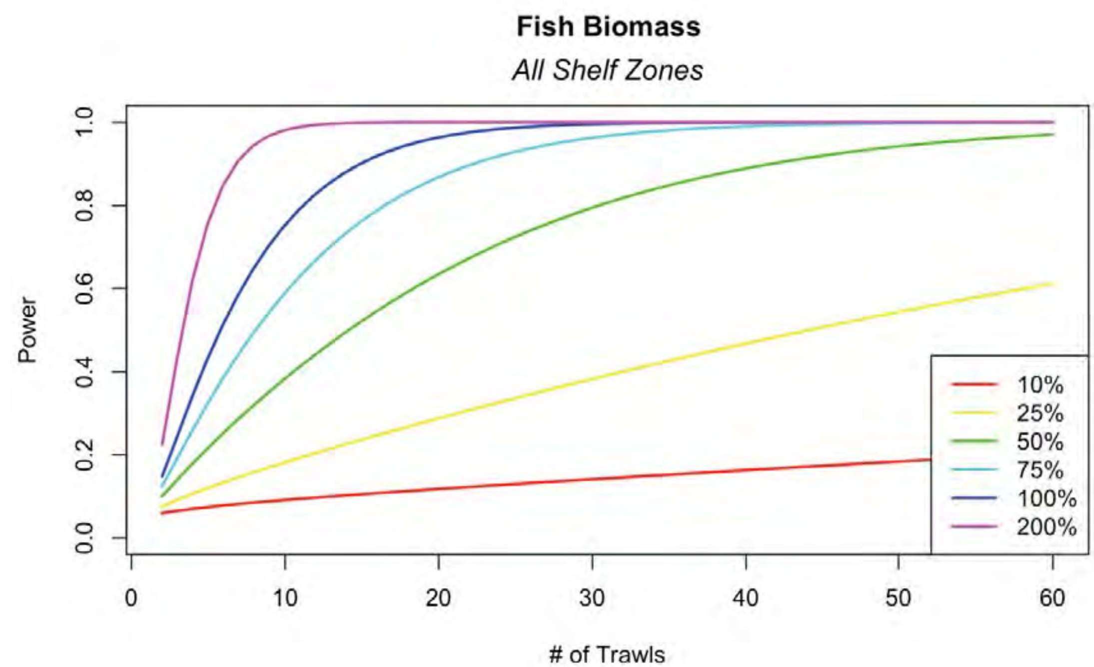
**Appendix D-10.** Power curves demonstrating the number of paired trawls necessary to detect changes in invertebrate diversity.

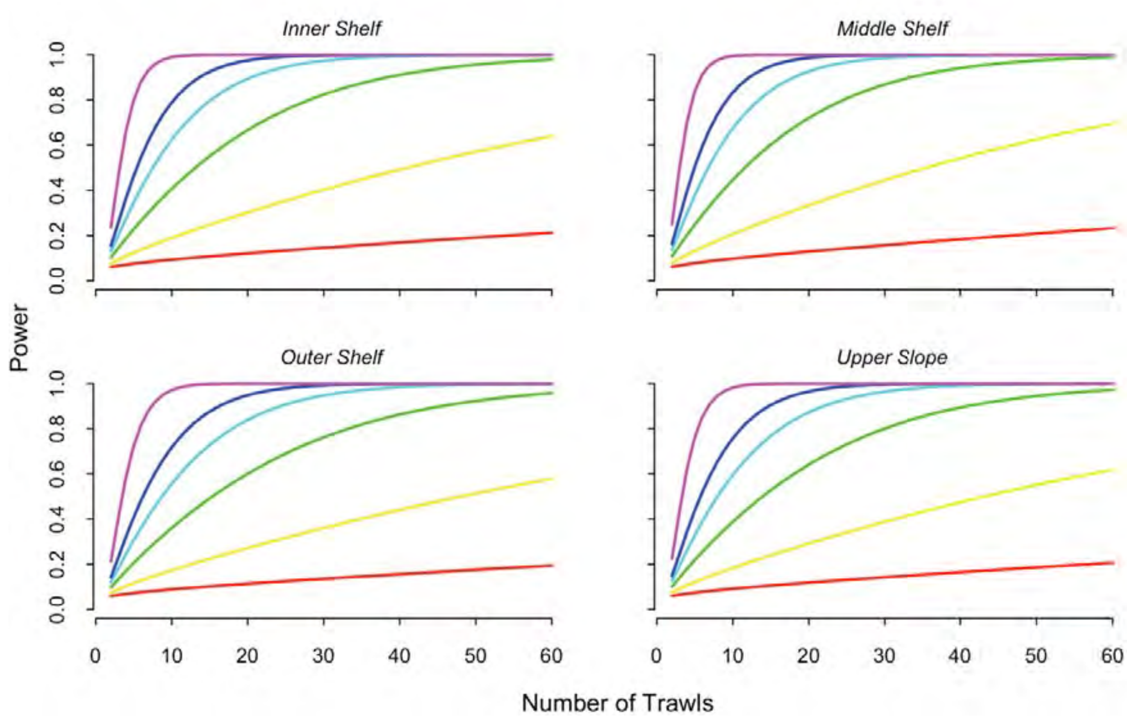
**Appendix D-1.** Power curves demonstrating the number of paired trawls (inside and outside of MPAs) necessary to detect minimum percentages of change in fish abundance using a one-tailed paired t-test and the associated power of that test. Figures utilize data from all shelf zones combined (top), as well as utilizing data from each of the shelf zones individually (bottom).



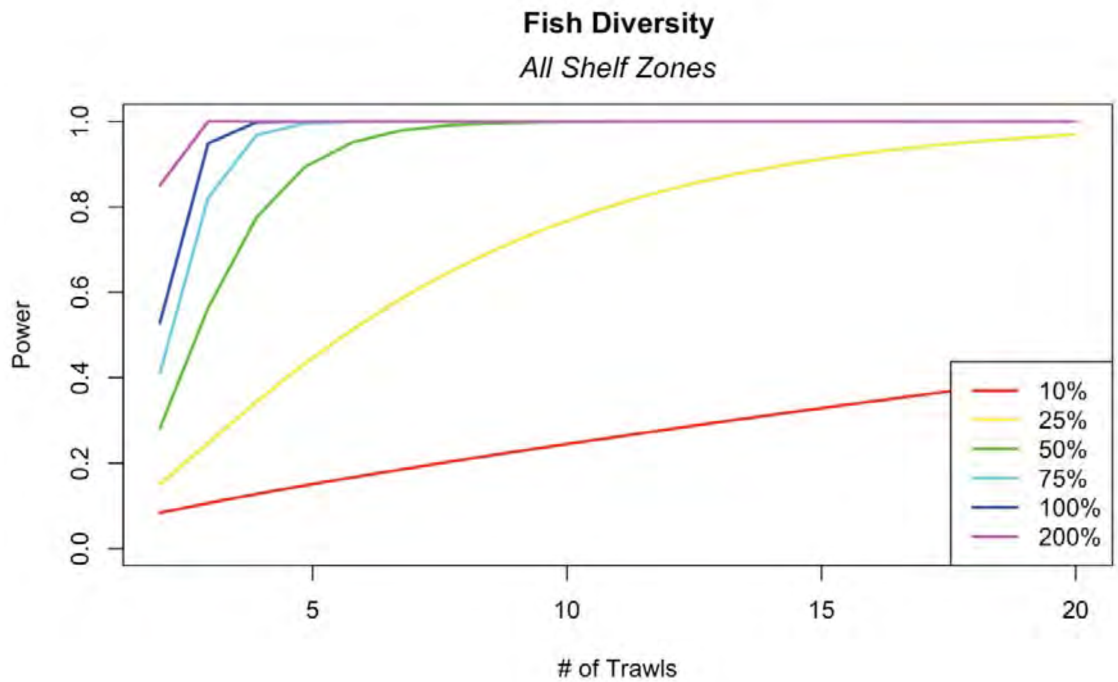



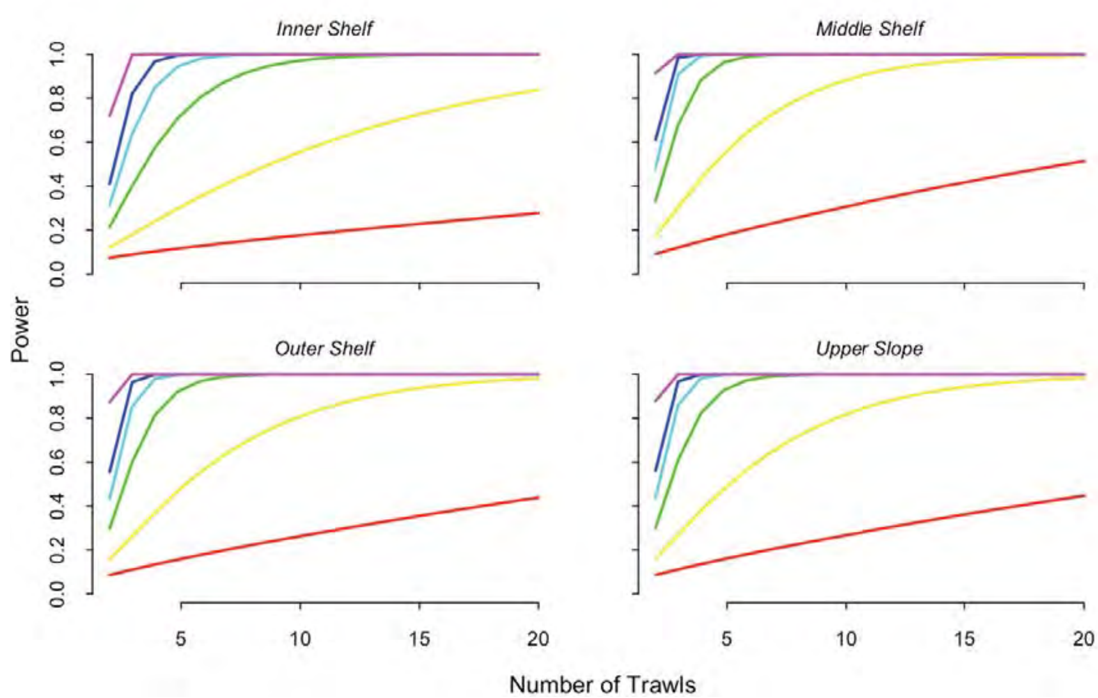
**Appendix D-2.** Power curves demonstrating the number of paired trawls (inside and outside of MPAs) necessary to detect minimum percentages of change in fish biomass using a one-tailed paired t-test and the associated power of that test. Figures utilize data from all shelf zones combined (top), as well as utilizing data from each of the shelf zones individually (bottom).



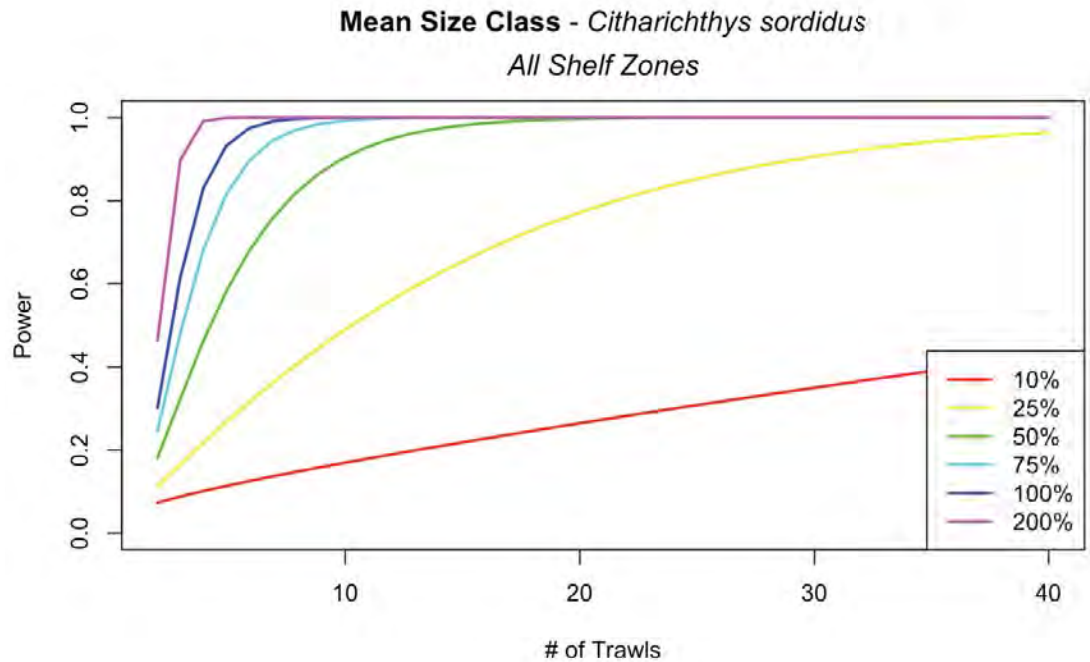



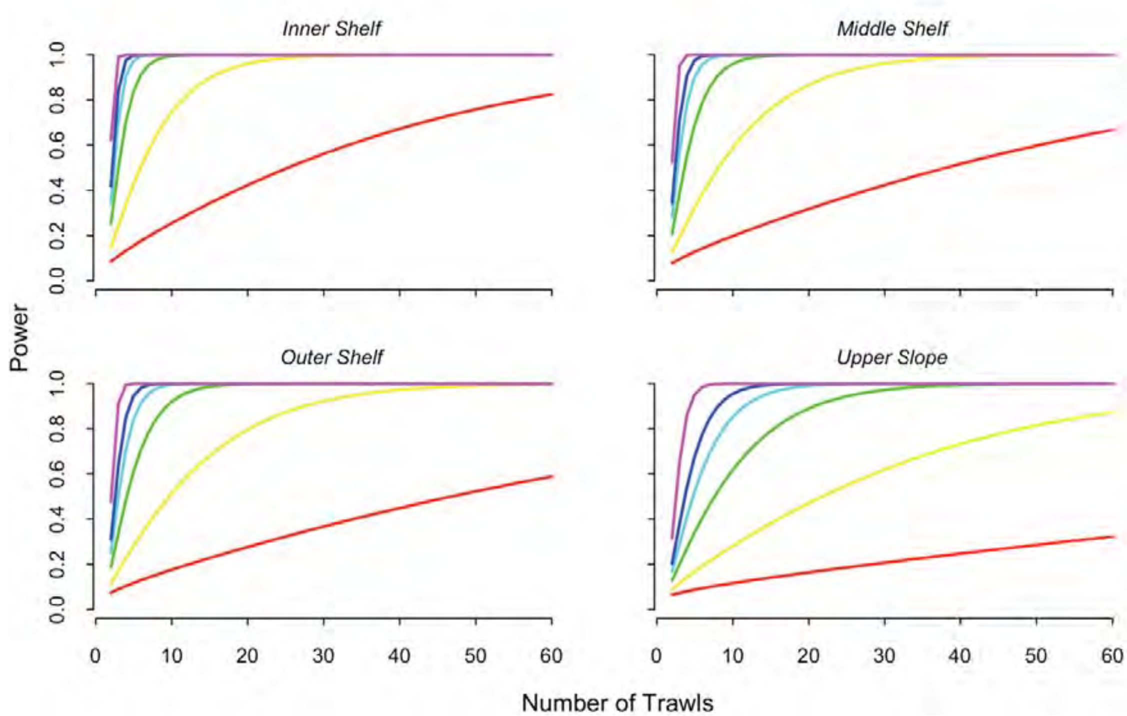
**Appendix D-3.** Power curves demonstrating the number of paired trawls (inside and outside of MPAs) necessary to detect minimum percentages of change in fish diversity using a one-tailed paired t-test and the associated power of that test. Figures utilize data from all shelf zones combined (top), as well as utilizing data from each of the shelf zones individually (bottom).



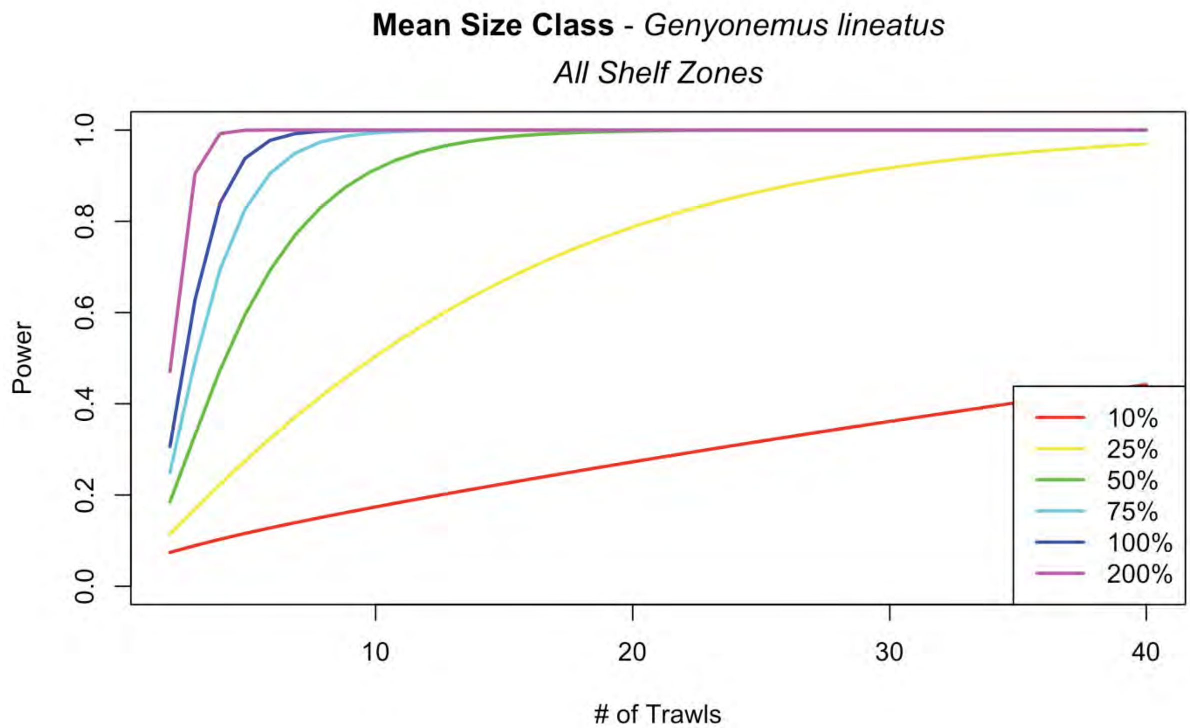



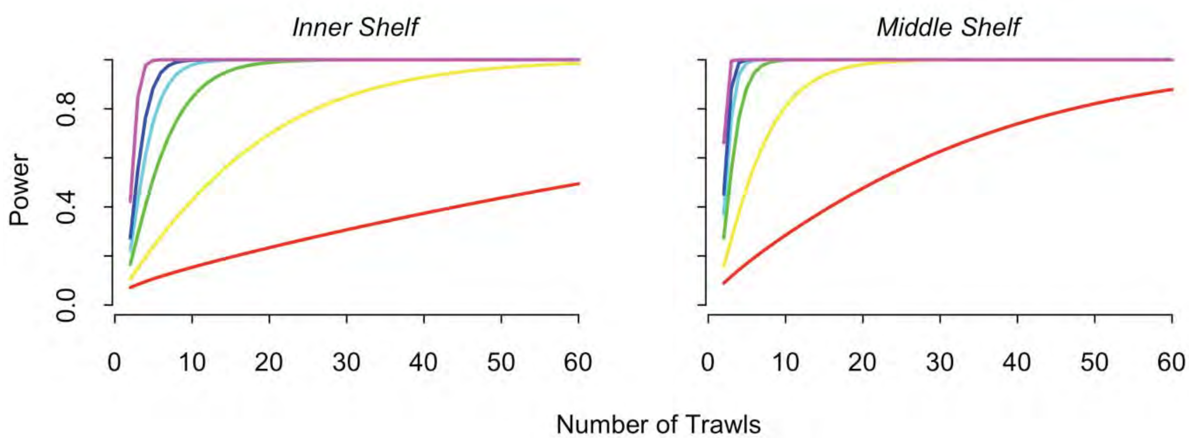
**Appendix D-4.** Power curves demonstrating the number of paired trawls (inside and outside of MPAs) necessary to detect minimum percentages of change in mean size class of Pacific Sanddab (*Citharichthys sordidus*) using a one-tailed paired t-test and the associated power of that test. Figures utilize data from all shelf zones combined (top), as well as utilizing data from each of the shelf zones individually (bottom).



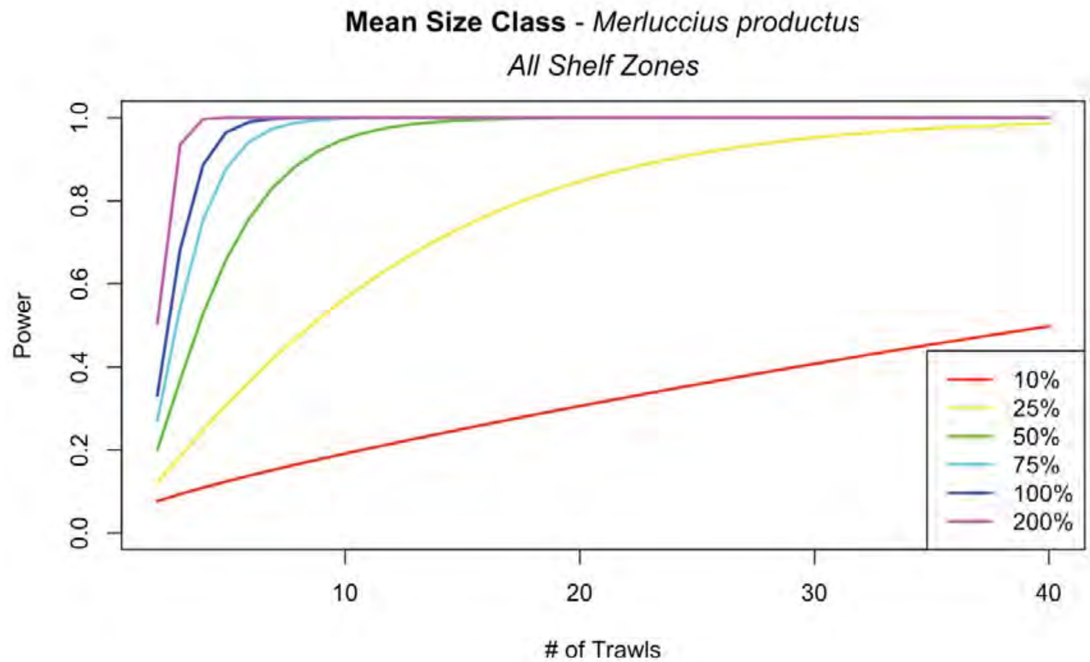



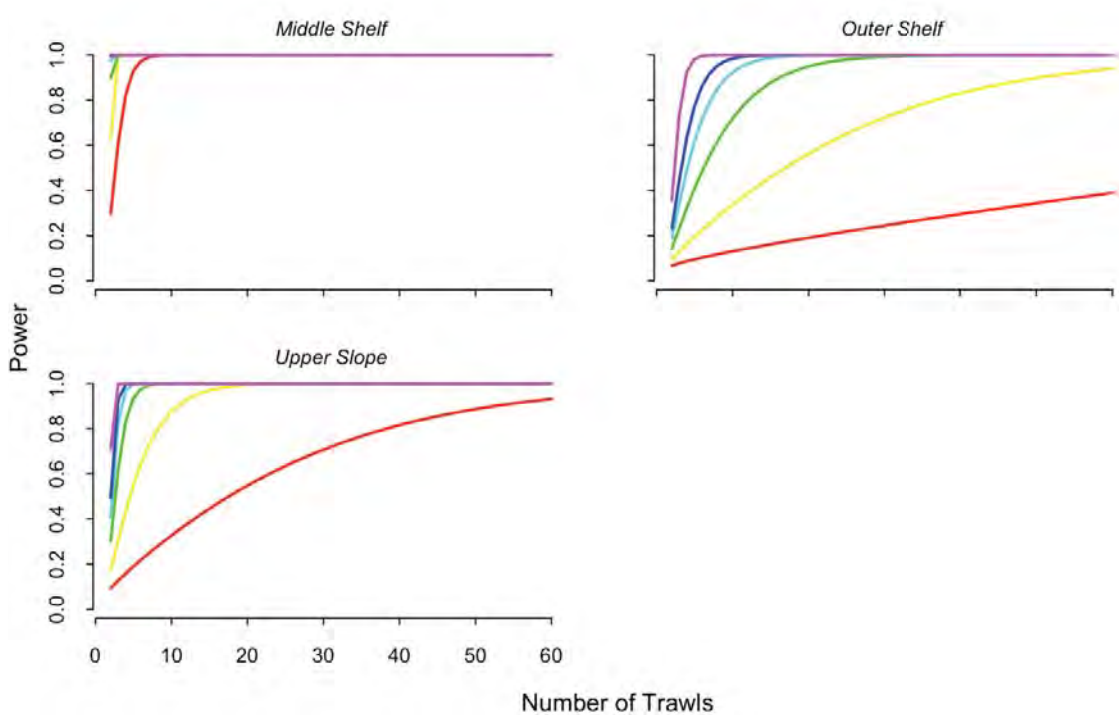
**Appendix D-5.** Power curves demonstrating the number of paired trawls (inside and outside of MPAs) necessary to detect minimum percentages of change in mean size class of White Croaker (*Genyonemus lineatus*) using a one-tailed paired t-test and the associated power of that test. Figures utilize data from all shelf zones combined (top), as well as utilizing data from each of the shelf zones individually (bottom).



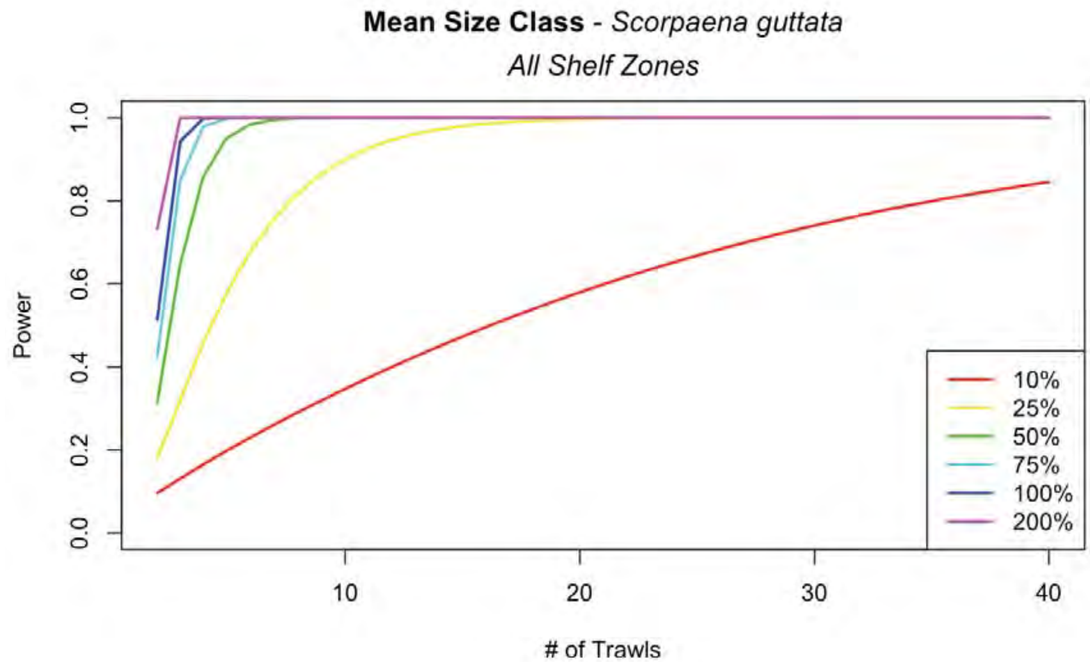



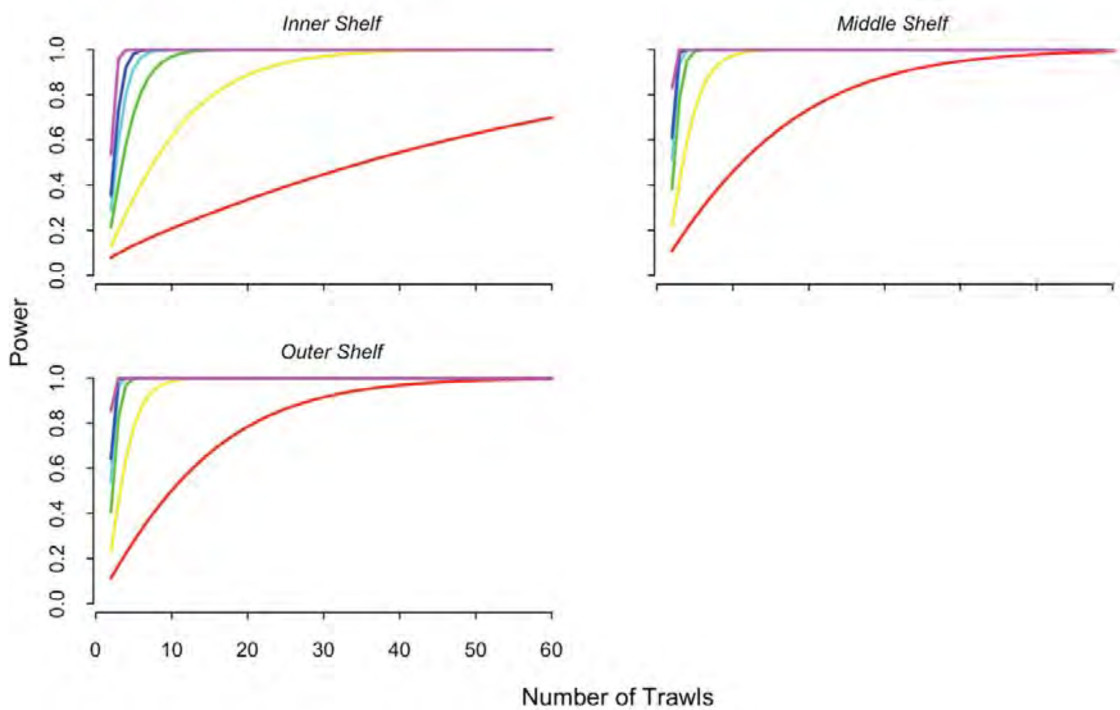
**Appendix D-6.** Power curves demonstrating the number of paired trawls (inside and outside of MPAs) necessary to detect minimum percentages of change in mean size class of Pacific Hake (*Merluccius productus*) using a one-tailed paired t-test and the associated power of that test. Figures utilize data from all shelf zones combined (top), as well as utilizing data from each of the shelf zones individually (bottom).



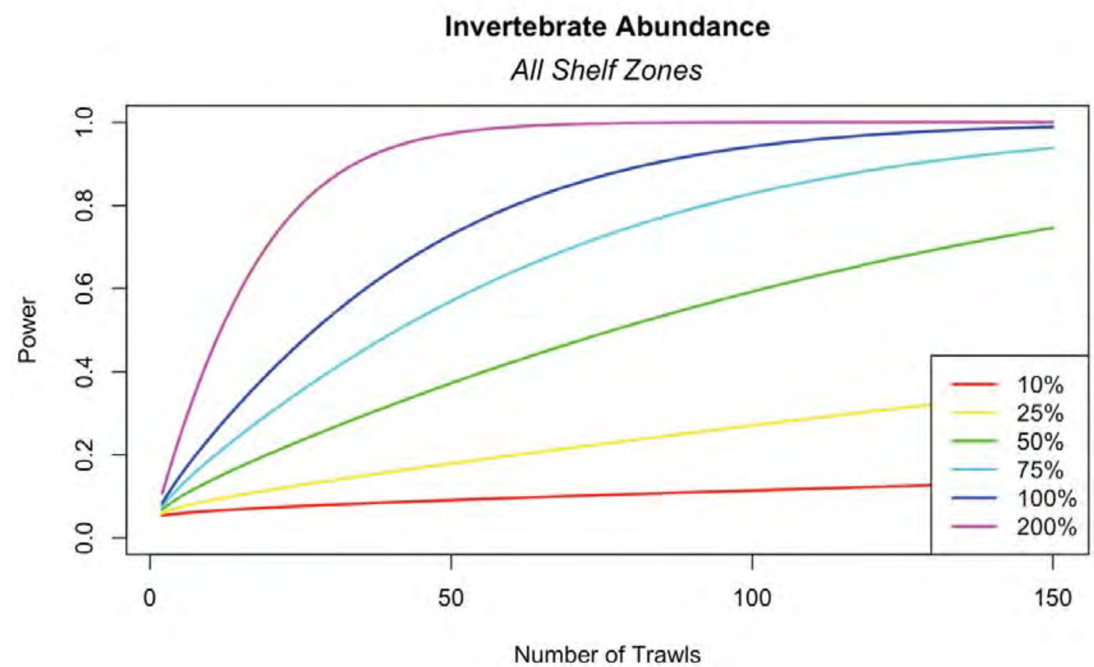



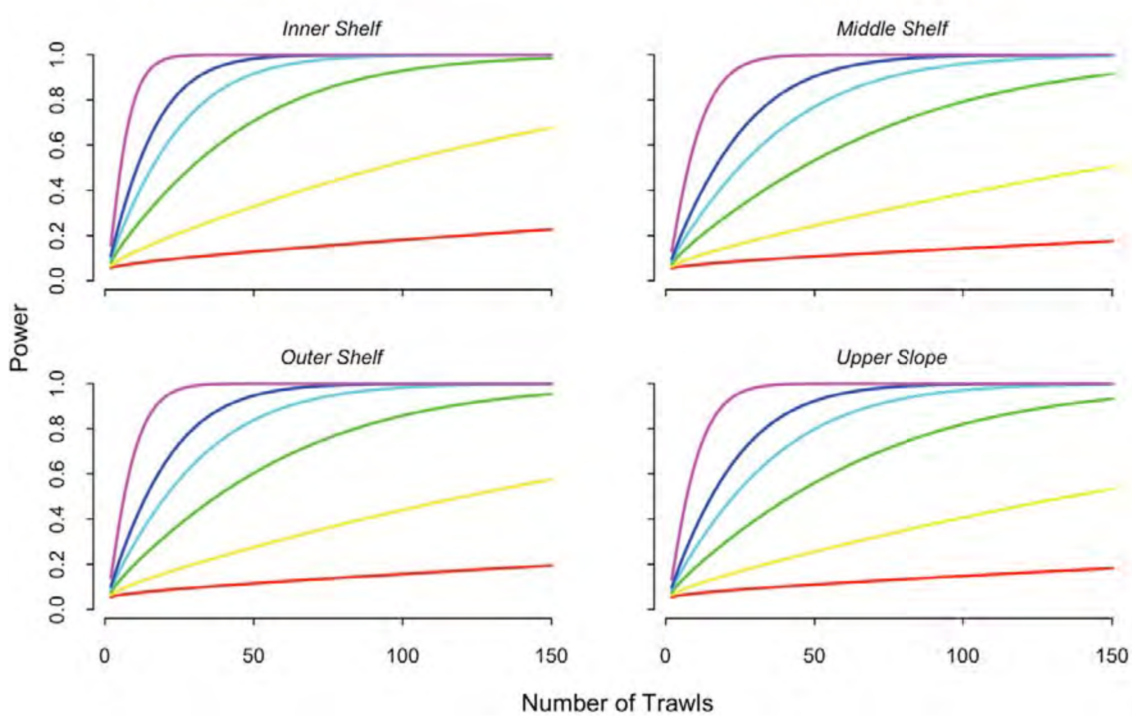
**Appendix D-7.** Power curves demonstrating the number of paired trawls (inside and outside of MPAs) necessary to detect minimum percentages of change in mean size class of California Scorpionfish (*Scorpaena guttata*) using a one-tailed paired t-test and the associated power of that test. Figures utilize data from all shelf zones combined (top), as well as utilizing data from each of the shelf zones individually (bottom).



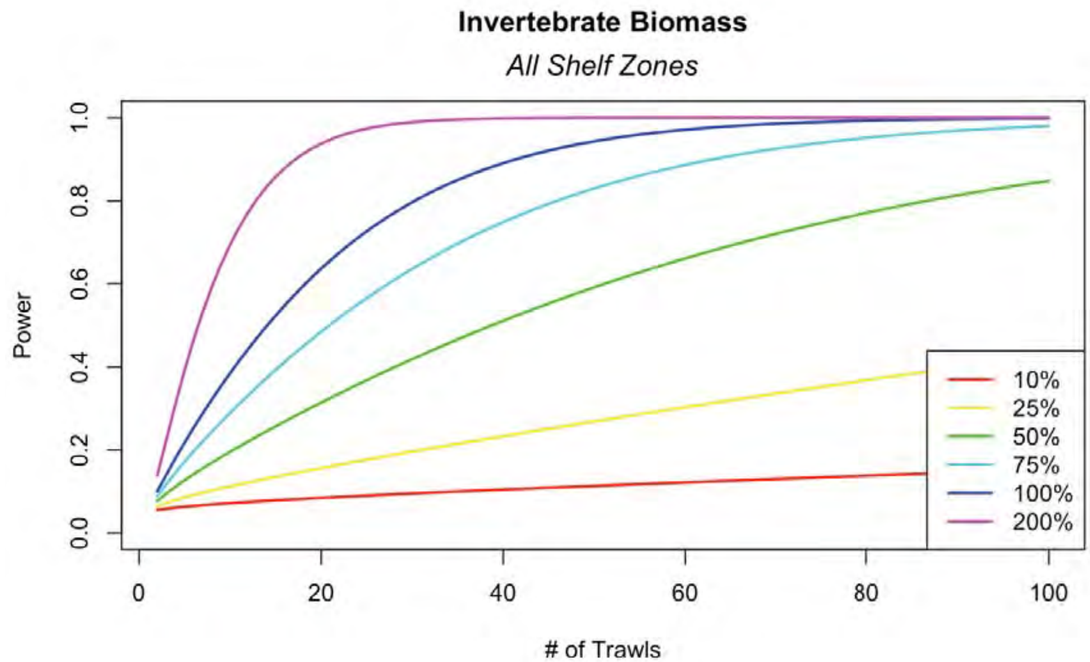



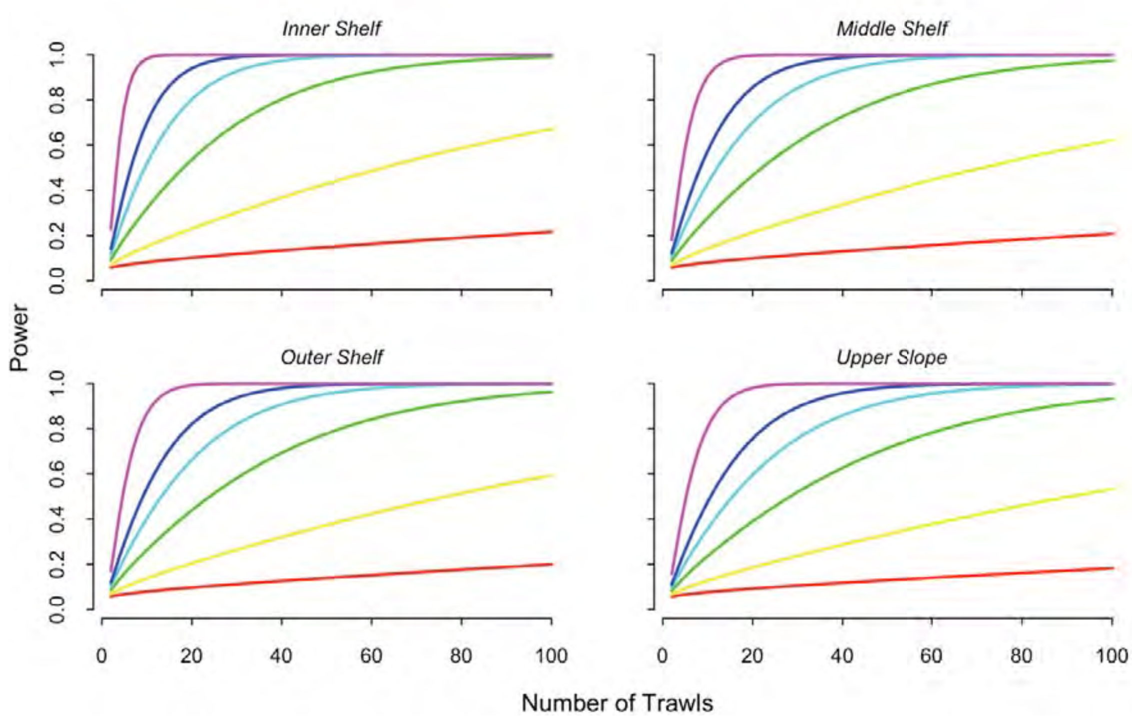
**Appendix D-8.** Power curves demonstrating the number of paired trawls (inside and outside of MPAs) necessary to detect minimum percentages of change in invertebrate abundance using a one-tailed paired t-test and the associated power of that test. Figures utilize data from all shelf zones combined (top), as well as utilizing data from each of the shelf zones individually (bottom).



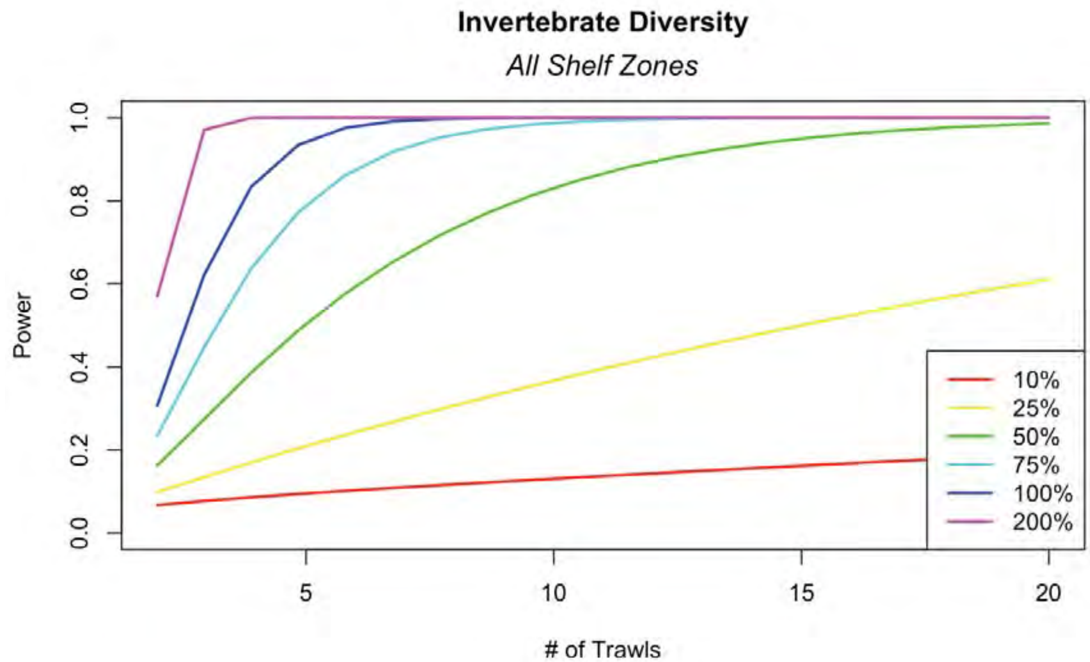



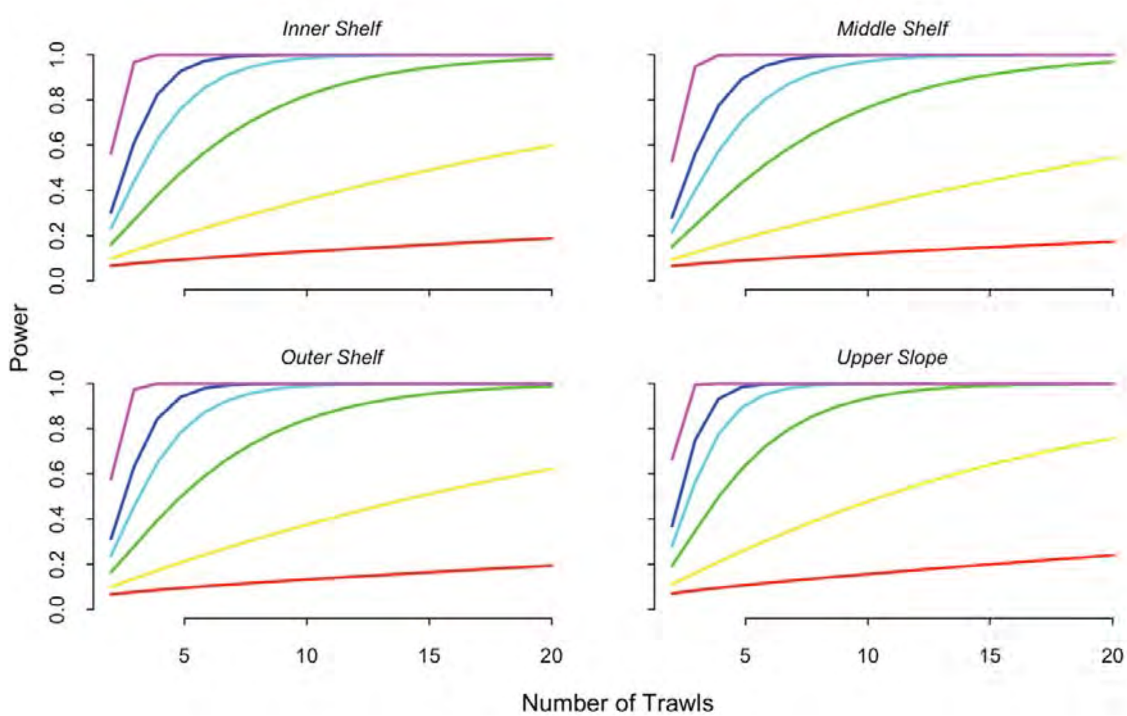
**Appendix D-9.** Power curves demonstrating the number of paired trawls (inside and outside of MPAs) necessary to detect minimum percentages of change in invertebrate biomass using a one-tailed paired t-test and the associated power of that test. Figures utilize data from all shelf zones combined (top), as well as utilizing data from each of the shelf zones individually (bottom)..



**Appendix D-10.** Power curves demonstrating the number of paired trawls (inside and outside of MPAs) necessary to detect minimum percentages of change in invertebrate diversity using a one-tailed paired t-test and the associated power of that test. Figures utilize data from all shelf zones combined (top), as well as utilizing data from each of the shelf zones individually (bottom).



# APPENDIX E: CHANGES IN SEA URCHIN POPULATIONS

Deep-Sea Research II 137 (2017) 377–389

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# Habitat compression and expansion of sea urchins in response to changing climate conditions on the California continental shelf and slope (1994–2013)

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ABSTRACT

Echinoid sea urchins with distributions along the continental shelf and slope of the eastern Pacific often dominate the megafauna community. This occurs despite their exposure to naturally low dissolved oxygen (DO) waters ($<60$ μmol kg$^{-1}$) associated with the Oxygen Limited Zone and low-pH waters undersaturated with respect to calcium carbonate ($\Omega_{CaCO3}<1$). Here we present vertical depth distribution and density analyses of historical otter trawl data collected in the Southern California Bight (SCB) from 1994 to 2013 to address the question: Do changes in echinoid density and species' depth distributions along the continental margin in the SCB reflect observed secular or interannual changes in climate? Deep-dwelling burrowing urchins (*Brissopsis pacifica*, *Brisaster* spp. and *Spatangus californicus*), which are adapted to low-DO, low-pH conditions appeared to have expanded their vertical distributions and populations upslope over the past decade (2003–2013), and densities of the deep pink urchin, *Strongylocentrotus fragilis*, increased significantly in the upper 500 m of the SCB. Conversely, the shallower urchin, *Lytechinus pictus*, exhibited depth shoaling and density decreases within the upper 200 m of the SCB from 1994 to 2013. Oxygen and pH in the SCB also vary inter-annually due to varying strengths of the El Niño Southern Oscillation (ENSO). Changes in depth distributions and densities were correlated with bi-monthly ENSO climate indices in the region. Our results suggest that both a secular trend in ocean deoxygenation and acidification and varying strength of ENSO may be linked to echinoid species distributions and densities, creating habitat compression in some and habitat expansion in others. Potential life-history mechanisms underlying depth and density changes observed over these time periods include migration, mortality, and recruitment. These types of analyses are needed for a broad suite of benthic species in order to identify and manage climate-sensitive species on the margin.



## 1. Introduction

Continental margin ecosystems in eastern boundary upwelling regions such as the west coast of North America experience dynamic natural variations in biogeochemical cycles on various spatiotemporal scales. Oscillations in ocean-atmosphere coupled processes occur naturally on millennial (Moffitt et al., 2015), decadal (Mantua et al., 1997), and interannual (Bjerknes, 1966) timescales; these can have basin-wide effects on population dynamics and global climate change variables such as seawater pH, dissolved oxygen (DO), and temperature (reviewed in Levin et al., 2015). The Southern California Bight (SCB) is a 700-km long region influenced by the upwelling of cold, nutrient-rich, deep water characterized by relatively low DO, low pH, and high carbon dioxide ($CO_2$). Benthic and epibenthic organisms may already be functioning at their physiological limits at the seawater-seafloor interface where the continental slope intersects with a permanent dissolved Oxygen Minimum Zone (OMZ) and Carbon Maximum Zone (Paulmier et al., 2011), therefore making these regions particular 'hotspots' of future climate change (Gruber, 2011).

Oxygen Limited Zones (OLZs) are the regions above and beneath the OMZ where DO concentrations of $<60$ μmol kg$^{-1}$ are often considered hypoxic habitat for marine organisms (Gilly et al., 2013), although this threshold may not be relevant for organisms with very low metabolic oxygen demands (Seibel, 2011; Somero et al., 2016). Time-series analysis from 1984 to 2006 of quarterly cruise data in the SCB collected by the

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0967-0645/

California Cooperative Ocean Fisheries Investigations (CalCOFI) reveal oxygen declines, with an average decrease in DO of $\sim 1\ \mu mol\ kg^{-1}\ yr^{-1}$ at 200-m stations and a shoaling of the OLZ boundary of $>80$ m at some inshore stations (Bograd et al., 2008). An updated analysis of these data (1984–2010) showed a decrease of $0.76\ \mu mol\ kg^{-1}\ yr^{-1}$ at the $25.8\ kg\ m^{-3}$ isopycnal (Bograd et al., 2015). Due to microbially-mediated remineralization processes, similar reductions in pH and increases in $pCO_2$ are expected to have accompanied the expansion of low oxygen zones in the SCB (Gilly et al., 2013; Gruber, 2011; Paulmier et al., 2011; Reum et al., 2016). Seawater pH and DO are strongly correlated in nearshore kelp forests (Frieder et al., 2012) and in the deep sea (Alin et al., 2012; Nam et al., 2015). In addition, secular increases in nutrient concentrations and chlorophyll *a* have been observed from the same CalCOFI dataset (Bograd et al., 2015). One potential mechanism for shoaling hypoxia and changes in nutrients in the SCB include a strengthening of the CA Undercurrent, which originates from subtropical equatorial water from the south and is characterized by relatively warm, high saline, low DO, and low pH water (Bograd et al., 2015).

Koslow et al. (2011) reported striking shifts in mesopelagic and demersal larval fish community structure accompanying these decadal changes in midwater DO. Twenty four of 27 larval fish taxa collected by seasonal CalCOFI cruises demonstrated a strong relationship with midwater DO and multiple climate indices such as the Pacific Decadal Oscillation (PDO), El Niño Southern Oscillation (ENSO), and the North Pacific Gyre Oscillation (NPGO) (Koslow et al., 2011, 2015). Although the CalCOFI biological time-series provides extensive spatial and temporal coverage of pelagic species, the interactions of benthic faunal populations with climate variability along the SCB continental margin have been understudied. The phenomenon of vertical habitat compression in the ocean due to shoaling hypoxia was hypothesized to negatively affect aerobic groundfish (McClatchie et al., 2010) and mesopelagic fish (Netburn and Koslow, 2015) in southern CA and billfish in the Eastern Tropical Pacific (Prince and Goodyear, 2006; Stramma et al., 2012). However, few datasets exist to assess trends in megafauna species populations that dominant the benthos such as echinoids in the SCB (Keller et al., 2012).

Beyond the longer-term changes in oxygenation and likely pH and $pCO_2$, the SCB is highly dynamic on interannual, seasonal, and even diurnal and semidiurnal time scales (Nam et al., 2015; Booth et al., 2012; Send and Nam, 2012). For example, during El Niño events, elevated temperatures and reduced upwelling lead to low productivity, less respiration and biogeochemical drawdown, thus higher oxygen levels (Ito and Deutsch, 2013), while the opposite occurs during La Niña events (Nam et al., 2011). Over the last 25 years, the Multivariate ENSO Index (MEI), a composite of six key ocean-atmospheric variables: sea-level pressure, zonal and meridional components of the surface wind, sea surface temperature, surface air temperature, and total cloudiness (Wolter and Timlin, 2011), indicates a range of El Niño and La Niña strengths occurring in the Pacific Ocean, including one exceedingly strong El Niño in 1997–1998 (Fig. 1). Nam et al. (2011) advise caution when extrapolating their correlation results from a single El Niño-La Niña cycle to other ENSO indices, and few studies examined the direct relationship between ENSO and dissolved oxygen (see Arntz et al., 2006) despite the abundance of historical cruise data and the potentially important ecological implications (McClatchie, 2014).

Echinoderms are important benthic fauna ecologically; they are often identified as ecosystem engineers and in some cases, keystone predators or grazers (Paine, 1966). Biocalcification by echinoderms (*e.g.* sea urchins, sea stars, cucumbers, brittle stars, crinoids) contributes to globally significant carbon production rates that may rival production rates of coral reefs (Lebrato et al., 2010), and are surprisingly tolerant to low carbonate saturation states (Lebrato et al., 2016).

In the SCB, multiple deep-dwelling sea urchin species are abundant over broad depth ranges (Thompson et al., 1993) characterized by sharp gradients in oxygen, pH, and $\Omega$ (saturation state) levels that are comparable to or much lower than future ocean acidification and deoxygenation scenarios predicted for the surface ocean (Alin et al., 2012; Levin and Dayton, 2009; Nam et al., 2015). Experiments suggest that multiple life-history stages of calcifying benthic organisms, including echinoid urchins, will respond negatively to ocean acidification and hypoxia conditions (Dupont et al., 2010; Frieder, 2014; Kroeker et al., 2013). The vast majority of these studies have been conducted on shallow-water species however, and the response of deep-margin species to deoxygenation, ocean acidification, and calcium carbonate saturation ($\Omega_{CaCO_3}=1$) reduction is poorly understood (Barry et al., 2014; Hofmann et al., 2010; Taylor et al., 2014).

Detecting faunal response to long-term environmental change requires time-series sampling (Glover et al., 2010). The Southern California Coastal Water Research Project (SCCWRP) is a collaborative inter-agency environmental monitoring program that makes publicly available a time-series dataset of georeferenced benthic and epibenthic megafauna community data in southern California along the continental shelf and slope. The SCCWRP otter trawl surveys of the SCB shelf and slope benthos have occurred every 4–5 years since 1994 to water depths of 200 m, providing 5 time points in order to assess population trends in benthic fauna. In 2003 the SCCWRP *Bight* program extended their sampling depths down to 500 m, providing only 3 survey time points to the present, but extending spatial coverage into deep waters. These fishery-independent data provide a unique suite of multi-decadal samples that can be used to address questions about benthic community changes over time in the SCB.

The objective of this study was to investigate temporal changes in (1) depth distributions and (2) density estimates of five continental margin sea urchin species throughout the SCB from 1994 to 2013 to better understand echinoid response to environmental change. We hypothesized that various depth distribution parameters of deeper-occurring urchin species, which are tolerant to low oxygen, high $CO_2$ conditions in the upper OMZ (Helly and Levin, 2004) and OLZ (Gilly et al., 2013) would exhibit evidence of habitat expansion consistent with observed shoaling oxyclines in the region (Bograd et al., 2015; Bograd et al., 2008). This secular trend would suggest that these species have expanded their distribution into shallower waters enabled by a combination of environmental adaptation and ecological interactions. Urchin species with shallower distributions were hypothesized to be more vulnerable to expanding OMZ conditions and to have experienced habitat compression over this time period. In addition, we hypothesized that the density of shallower-occurring urchins would decrease in the upper 200 m from 1994 to 2013 due to the shoaling and intensification of hypoxic waters, and the density of deeper-occurring urchins in the upper 500 m would increase from 2003 to 2013 due to migration from deeper depths as habitat compression excludes shallower competitors. Alternatively, these trends could also be driven by environmental factors other than oxygen that may co-vary with time, such as changes in dissolved $CO_2$, food, temperature, and ecological interactions. Chlorophyll *a* concentration in the SCB has increased over recent decades (Bograd et al., 2015) and could lead to more food and higher densities in all species over time. In contrast, El Niño conditions, which occurred in 1997–1998 and 2002–2003 are associated with higher oxygenation and lower phytoplankton and kelp production (Ito and Deutsch, 2013), and should produce an opposite response to that expected from expanding OMZs. We

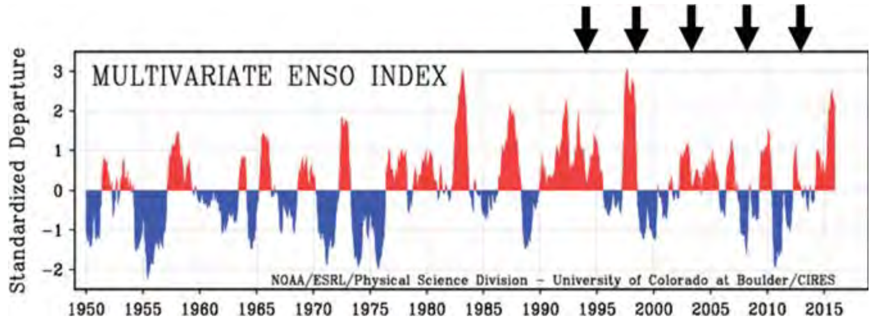


**Fig. 1.** Figure modified from http://www.esrl.noaa.gov/psd/enso/mei/. Time-series of MEI with black arrows indicating years when trawl surveys occurred throughout the Southern California Bight. Negative values of the MEI (blue) represent the cold ENSO phase (La Niña). Positive MEI values (red) represent the warm ENSO phase (El Niño). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

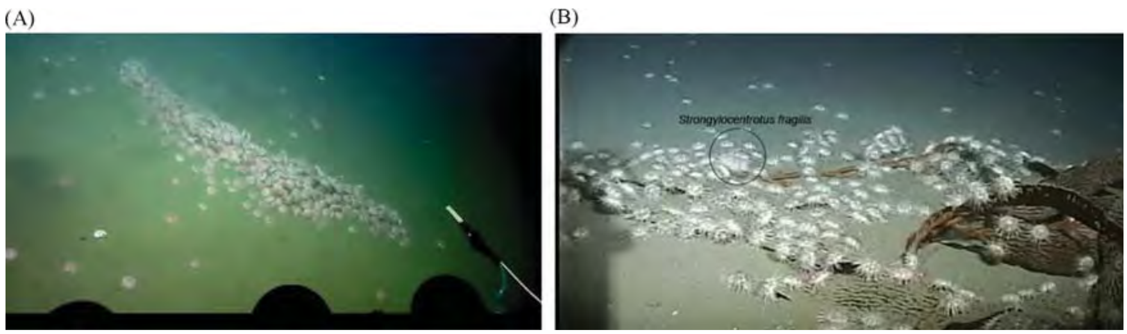


**Fig. 2.** A. Aggregation of pink urchins (*Strongylocentrotus fragilis*) in the OLZ ($\sim$400 m) off of San Diego, CA. Remotely operated vehicle (ROV) footage courtesy: R/V *Nautilus*, NOAA, cruise ID NA066. B. Feeding aggregation of white urchins (*Lytechinus pictus*) on giant kelp (*Macrocystis pyrifera*) at $\sim$100 m depth off the coast of La Jolla, CA. Presence of individual *S. fragilis* (circled) suggests these species compete for kelp resources at this depth. ROV footage courtesy: Scripps Institution of Oceanography, cruise ID MV1217.

hypothesized a deepening of hypoxia-intolerant species and possibly lower densities of all species in response to El Niño.

## 2. Materials and methods

We analyzed biological benthic survey data collected along the continental shelf and slope in the SCB. Depth distributions of shelf and slope sea urchins in the upper 200 and upper 500 m were determined for each survey year for five species of echinoderm echinoids: the white urchin (*Lytechinus pictus*), the pink urchin (*Strongylocentrotus fragilis*), and three burrowing urchins (*Brissopsis pacifica*, *Brisaster* spp. and *Spatangus californicus*). *Brisaster townsendi* and *B. latifrons* were grouped together as their ranges overlap in the SCB (Hood and Mooi, 1998) and they were often reported as *Brisaster* spp. in the field. Site-specific counts were standardized to obtain population density (count $m^{-2}$) for each sea urchin species and were compared among survey years and depth bins.

### 2.1. Data collection: trawl program and counts

The megafauna community was sampled at randomized stations by otter trawl across the SCB by trained taxonomists during the summer months (July–September) of years in which the Bight program was conducted (1994, 1998, 2003, 2008 and 2013) with 7.6 m head-rope semiballoon otter trawl nets fitted with 1.25-cm cod-end mesh. Trawls were towed along open-coast isobaths for $\sim$10 min at 1.5–2.0 nautical miles per hour during daylight hours. Trawl distance was calculated from the start and stop fishing GPS coordinates, which acted as a proxy for the net's relative position. It was assumed the net remained on the bottom and was fishing the entire time. *S. fragilis* and *L. pictus* often form feeding aggregations on kelp falls (Sato and Levin, *personal observation*; Fig. 2A, B), which may bias density estimates, but the high number of trawls conducted each survey year is likely to capture this variability. One exception where kelp falls have been found to be more abundant is in submarine canyons (Harrold et al., 1998), but sites were surveyed for flat, trawlable ground prior to net deployment and sites in canyons were avoided. Upon retrieval, catches were sorted, identified to species, and enumerated. Each station was sampled once per survey (Fig. 3). Bay sites and sites at water depths $<10$ m were removed from this analysis in order to minimize zero inflated data (Thompson et al., 1993). Only echinoid data representing 5 species are reported here.

### 2.2. Evaluation of area sampled and density estimates

The area swept by each trawl was calculated as the distance trawled (m) x 4.9 m (the width of the trawl) (*sensu* Miller and Schiff, 2012). Densities obtained per trawl were determined for each of the 5 urchin species for each survey year by dividing the species count by the area swept. Density means were also calculated for 50-m and 100-m depth bins in addition to 10–200 m (1994–2013 survey time period) and 10–500 m (2003–2013 surveys) depth bins.

### 2.3. Species distribution in the SCB

The start depths of each trawl station were recorded to the nearest meter on board survey vessels; trawls were made along depth contours so the start depth reflected the actual depth of the trawl. All individuals of each species were assigned the start depth of the trawl from which they were collected. Depth distributions of trawls containing one or more individuals were determined for each species for each survey year. For each species, trawls that contained one or more individuals were separated, and the upper and lower depth limits, the mean depth, and the first and third

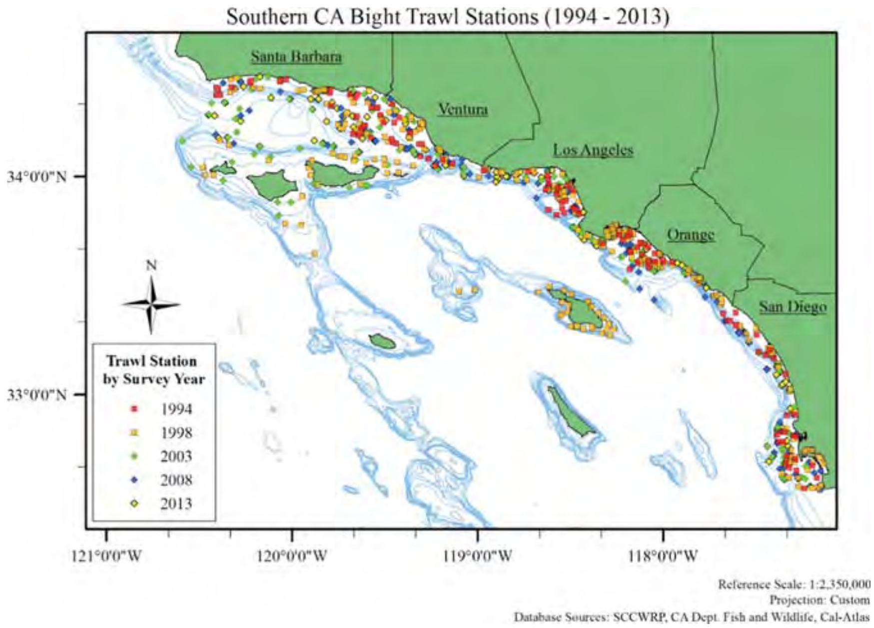


**Fig. 3.** Map of otter trawl survey stations from 1994 to 2013 in the Southern California Bight (SCCWRP). Black lines indicate boundaries between California counties (green) (Cal-Atlas, http://atlas.ca.gov/download.html#/). Ocean depth contours (light blue lines) are marked every 50-m starting at 50 m and extending to 500 m (CA Department of Fish and Wildlife, ftp://ftp.dfg.ca.gov/R7_MR/BATHYMETRY/). Diamond symbols indicate stations between 10 m and 500 m used for every urchin species during 2003 (light green), 2008 (blue), and 2013 (yellow) surveys. Square symbols indicate stations between 10 m and 200 m used in *L. pictus* analyses for 1994 (red) and 1998 (orange) surveys. Map created using ArcMap™ v.10.1. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

quartile depths were determined using R. In addition, for each species in each sampling year, the median urchin depth was identified (with 50% of urchins shallower and 50% deeper).

### 2.4. Temporal changes in depth

The assumptions of normality and homogeneous variances were tested using the Shapiro–Wilk normality test and the studentized Breusch–Pagan test in R. If the data met these assumptions, parametric analyses were used to determine temporal changes in depth. When the data violated these assumptions, we used the Box–Cox power transformation to transform the data. If the transformation did not improve normality or homoscedasticity of the data then non-parametric tests were used. Two-way Komolgorov–Smirnov tests were carried out for each species to compare depth distributions of trawl depths containing one or more individual among paired survey years. Linear regressions between various depth distribution parameters and survey years indicated how closely the changes in depth characteristics matched the secular changes in oceanographic variables observed over recent decades in this region (Bograd et al., 2015). The depth parameters analyzed were upper and lower limits, first and third quartiles, and mean and median depths of inhabited trawls, as well as the median depth of urchins for each species.

### 2.5. Temporal changes in density

Mean density for each species was calculated for each sampling date from all trawls including those where zero individuals were present. Due to the zero-inflated dataset, the implementation of data transformation had no effect on the normality nor the homogeneity of variance for any species. Thus, a Kruskal–Wallis test was used for each species to compare species density across years for the entire survey area and for each depth bin. If a significant difference was detected, a *post hoc* Dunn's test treated with a Bonferroni correction was conducted using the Pairwise Multiple Comparison of Mean Ranks Package in R.

### 2.6. Multivariate El Niño Southern Oscillation (ENSO) Index (MEI) relationships with depth distributions and density

Depth distribution and density data from trawl samples that contained urchins were examined for a relationship to the MEI obtained from the following NOAA website: http://www.esrl.noaa.gov/psd/enso/mei. Linear regressions for each depth parameter (see Section 2.4) and mean density (see Section 2.5) were conducted for each species' dataset with bi-monthly MEI values taken between Dec–Jan of the year before the trawl survey and Sept-Oct of the year that the SCCWRP trawl survey occurred. If the data were found to be normally distributed and have homogenous variances, then linear regression was carried out between the following metrics with bi-monthly MEI indices: various depth parameters, mean density, and depth-binned densities. Regression $R^2$ values indicated how closely the changes in depth characteristics and densities matched the strength of the El Niño conditions. If the t-statistic was negative, the distribution parameter was determined to shoal or density was determined to decrease during stronger El Niño conditions. In contrast, if the *t*-statistic was positive, the distribution parameter was determined to deepen or density was determined to increase during stronger El Niño conditions. If a significant regression was found with one or more bi-monthly MEI, relationships were reported with seasons rather than monthly pairs.

### 2.7. Dissolved oxygen and pH relationships with MEI in the SCB

To examine the relationship between ENSO cycles and DO and pH, seasonal DO data collected at 100 m, 200 m, and 300 m depth between 1994 and 2013 from 4 nearshore CalCOFI stations (line 81.8, station 46.9; line 86.7, station 35.0; line 90.0, station 30.0; line 93.3, station 30.0) were obtained from the CalCOFI website (http://calcofi.org/data.html). These stations provide a spatial overlap with the 1994–2013 trawl surveys used in this study. Estimates of pH (seawater scale) were calculated using empirical relationships with temperature and DO (Alin et al., 2012). Regression analysis of DO and pH were carried out to determine their respective relationships with respect to time and MEI. Bi-monthly MEI indices were assigned to DO and pH values based on the date of sample collection according to the CalCOFI database. To determine the magnitudes of DO and pH changes between strong El Niño years where MEI was greater than 1 and strong La Niña years where MEI was less than 1, DO and pH in those years were compared using a *t*-test.

### *2.8. DO and pH relationships with species depth distributions and densities*

Mean DO and mean pH were calculated among 4 CalCOFI stations for each survey year (4 cruises per year) and were matched with species distributions and densities depending on the approximate depth of peak density for that species (e.g., mean DO and pH at 100 m during 1994, 1998, 2003, 2008, and 2013 were matched with *L. pictus*). Collinearity between DO and pH in the study region prevented the use of multiple regression, and therefore, linear regressions of depth distributions and densities were carried out with DO and pH independently.

## 3. Results

### *3.1. Lytechinus pictus*

#### *3.1.1. Temporal changes in depth*

*L. pictus* was found deeper in 1998 than in 2003 and 2008 (KS test: $D > 0.25$, $p < 0.05$) (Fig. 4A) (Table 1). The upper part of its range (first quartile) appeared to shoal by 1.34 m yr$^{-1}$ from 54 m in 1994 to 34 m in 2013 ($t_3 = -3.931$, $p = 0.03$, $R^2 = 0.78$), as did the median depth of trawls with *L. pictus* by 0.94 m yr$^{-1}$ ($t_3 = -2.515$, $R^2 = 0.57$) from 74.5 m in 1994 to 59.5 m in 2013, but this latter relationship was not significant ($p = 0.09$). The median urchin depth shoaled by 1.44 m yr$^{-1}$ from 86 m in 1994 and 1998 to 58 m in 2013 ($t_3 = -5.143$, $p = 0.01$, $R^2 = 0.86$). The lower depth limit appeared to shoal from 191 m in 1993 to 137 m in 2003, but was found deeper in 2013 at 189 m (Table 1).

#### *3.1.2. Temporal changes in density*

The mean density of *L. pictus* throughout the upper 200 m varied significantly among survey years (Kruskal–Wallis Test: $\chi^2 = 11.98$, $p = 0.02$) (Fig. 5A) (Table 1). *L. pictus* mean density in 2008 (0.028 indiv. m$^{-2}$) and 2013 (0.023 indiv. m$^{-2}$) was 76% and 80% lower than in 1994 (0.117 indiv. m$^{-2}$), respectively (post hoc Dunn's test: $p < 0.05$), while densities in 1998 (0.087 indiv. m$^{-2}$) and 2003 (0.038 indiv. m$^{-2}$) were not significantly different from any other year. When evaluated by finer 50-m depth bins, *L. pictus* density varied significantly among survey years within 51–100 m (Kruskal–Wallis Test: $\chi^2 = 12.68$, $p = 0.01$) and 101–150 m depth bins ($\chi^2 = 14.15$, $p < 0.01$) (Fig. 6A). Density within the 51–100 m depth bin declined by 74% from 0.252 indiv. m$^{-2}$ in 1998 to 0.065 indiv. m$^{-2}$ in 2003 (post hoc Dunn's test: $p = 0.02$). During the 2003 survey, *L. pictus* density was reduced to zero in the 151–200 m depth bin and increased in 2008, but this increase is indistinguishable from the sampling error (Fig. 6A). Survey year significantly predicted density within the 101–150 m depth bin from 1994 to 2013, with density decreasing by 0.02 indiv. m$^{-2}$ yr$^{-1}$ ($t_{56} = -2.956$, $p = 0.02$, $R^2 = 0.12$).

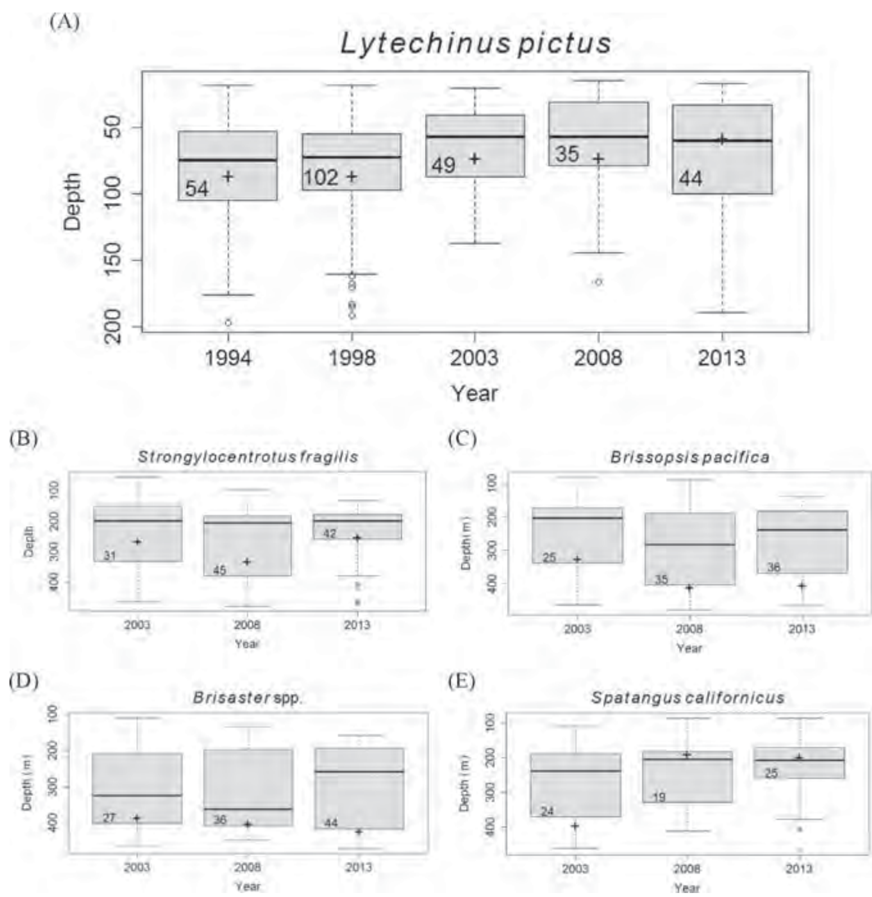


**Fig. 4.** Sea urchin depth distribution boxplots for the Southern California Bight based on trawls with one or more individual of each species. Box plots represent upper and lower depth limits, first and third quartile depths, and median depth. Plus signs indicate the median depth of urchins. Numbers within each boxplot indicate number of independent trawls used for the calculation. (A) *Lytechinus pictus*. (B) *Strongylocentrotus fragilis*. (C) *Brissopsis pacifica*. (D) *Brisaster* spp. (E) *Spatangus californicus*.

**Table 1**
Sea urchin depth distribution metrics and density changes over time in the Southern California Bight. No Change represents a non-significant change in depth distribution metrics or density over time. Negative results indicate a consistent shallowing of depth distribution metrics or a decrease in mean density over time ($p$-values $< 0.05$ indicate a significant relationship between depth distribution metric and time or a significant difference in density among years). Positive results indicate a consistent deepening of depth distribution metrics or an increase in density over time.

| Species | Time period | Depth range | Two-way K–S test | Linear regression | | | | | | | Kruskal–Wallis |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Depth distribution | Upper depth limit | Median trawl depth | Mean trawl depth | First quartile trawl depth | Third quartile trawl depth | Lower depth limit | Median urchin depth | Mean urchin density |
| *L. pictus* | 1994–2013 | 10–200 m | Significant | Negative $p=0.03$ | Negative $p=0.09$ | No Change | Negative $p=0.03$ | No Change | No Change | Negative $p=0.01$ | Negative $p=0.02$ |
| *S. fragilis* | 1994–2013 | 10–200 m | NA | | | | | | | | No Change |
| *S. fragilis* | 2003–2013 | 10–500 m | Not Significant | Positive $p=0.01$ | No Change | No Change | No Change | No Change | No Change | No Change | Positive $p=0.02$ |
| *B. pacifica* | 2003–2013 | 10–500 m | Not Significant | No Change | No Change | No Change | No Change | No Change | No Change | No Change | No Change |
| *Brisaster* spp. | 2003–2013 | 10–500 m | Not Significant | Positive $p=0.07$ | No Change | No Change | No Change | No Change | No Change | Positive $p=0.04$ | Positive $p=0.02$ |
| *S. californicus* | 2003–2013 | 10–500 m | Not Significant | No Change | No Change | No Change | Negative $p=0.06$ | Negative $p=0.10$ | No Change | No Change | No Change |

*3.1.3. Urchin relationship with MEI*

*L. pictus* median and first and third quartile depths were positively related to summer MEI ($F_{1,3} > 3.32$, $p < 0.05$, $R^2 > 0.70$) (Table 2), suggesting that the species occupied deeper depths during stronger El Niño conditions. In addition, the strength of El Niño conditions in the summer months significantly predicted *L. pictus* density ($t_3 = 3.978$, $p = 0.03$, $R^2 = 0.78$).

*3.1.4. Depth distribution and density relationship with DO and pH*

Between 1994 and 2013, *L. pictus* density in the upper 200 m was positively related to both mean DO ($t_3 = 6.121$, $p < 0.01$, $R^2 = 0.90$) and mean pH at 100 m ($t_3 = 4.535$, $p = 0.02$, $R^2 = 0.83$) (Table 3). pH significantly predicted the depths of the first quartile ($t_3 = 5.432$, $p = 0.01$, $R^2 = 0.88$), the median depth of trawls with *L. pictus* ($t_3 = 3.432$, $p = 0.04$, $R^2 = 0.73$), and the median urchin depth ($t_3 = 6.280$, $p < 0.01$, $R^2 = 0.91$) (Table 3).

*3.2. Strongylocentrotus fragilis*

*3.2.1. Temporal changes in depth*

The depth distribution of *S. fragilis* did not change in the upper 500 m from 2003 to 2013 (KS tests: $p > 0.05$) (Fig. 4B) (Table 1). The upper depth limit of *S. fragilis* was found to deepen by 7.7 m yr$^{-1}$ on average from 53.1 m in 2003 to 130.1 m in 2013 ($t_1 = 44.46$, $p = 0.01$, $R^2 = 0.99$), but no trend was found for any other depth metric over this time period (Fig. 4B) (Table 1).

*3.2.2. Temporal changes in density*

The mean density of *S. fragilis* throughout the upper 200 m varied significantly among survey years from 1994–2013 (Kruskal–Wallis Test: $\chi^2 = 11.84$, $p = 0.02$) (Fig. 5B) (Table 1). There was a significant positive relationship between density in the upper 200 m and year (1994–2013), with density increasing at 0.001 indiv. m$^{-2}$ yr$^{-1}$ ($t_3 = 14.61$, $p = 0.03$, $R^2 = 0.77$). Post hoc Dunn's test revealed significant differences in *S. fragilis* density among years, but when treated with a Bonferroni correction, these differences became insignificant (Fig. 5B). Compared to the 2003 mean density within the upper 500 m (0.028 indiv. m$^{-2}$), *S. fragilis* density was 35% higher in 2008 (0.039 indiv. m$^{-2}$) and 133% higher in 2013 (0.067 indiv. m$^{-2}$) (Kruskal–Wallis Test: $\chi^2 = 7.40$, $p = 0.02$) (Fig. 5C). This resulted in an annual density increase from 2003 to 2013 by 0.003 indiv. m$^{-2}$ yr$^{-1}$ ($t_{440} = 1.99$, $p < 0.05$, $R^2 < 0.01$) (Table 1). At finer depth bins, *S. fragilis* density varied significantly among survey years; between 101 and 200 m, density increased from 0.038 indiv. m$^{-2}$ in 2003 to 0.090 indiv. m$^{-2}$ in 2008 (138% increase) and from 2008 to 0.105 indiv. m$^{-2}$ in 2013 (17% increase) (Kruskal–Wallis Test: $\chi^2 = 6.62$, $p = 0.04$) (Fig. 5C). Although *S. fragilis* density appears to decrease in the upper 100 m between 2003 and 2013, these values correspond to very small densities ($\sim 10^{-5}$ indiv. m$^{-2}$), thus they are indistinguishable from sampling error.

*3.2.3. Urchin relationship with MEI*

*S. fragilis* median depths were negatively correlated with spring MEI ($t_1 = -134.5$, $p < 0.05$, $R^2 = 0.99$), and mean depths were negatively correlated with summer MEI ($t_1 = -43.2$, $p < 0.05$, $R^2 = 0.99$) (Table 2), suggesting that the species occupied shallower depths during stronger El Niño conditions. In addition, the strength of El Niño conditions in the summer months was negatively related to *S. fragilis* density ($R^2 = 0.98$), but this relationship was not significant ($p = 0.06$).

*3.2.4. Depth distribution and density relationship with DO and pH*

Between 2003 and 2013, *S. fragilis* density in the upper 500 m was significantly predicted by mean DO at 200 m ($t_1 = -13.9$, $p < 0.05$, $R^2 = 0.99$), but not pH at 200 m. However, *S. fragilis* density in the upper 200 m between 1994 and 2013 was

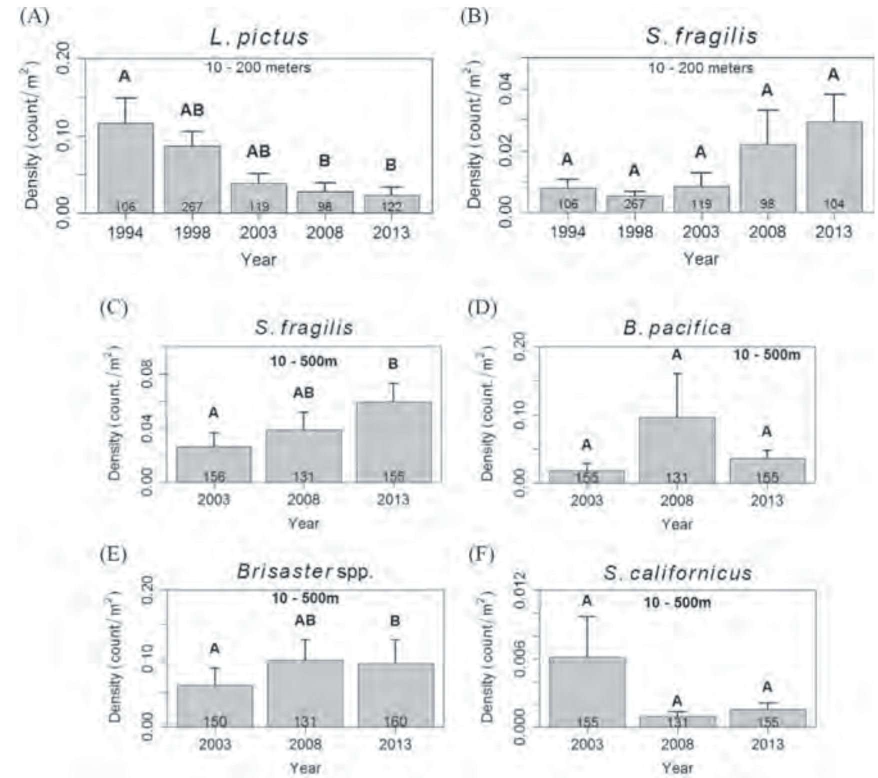


**Fig. 5.** Mean density (+1 SE) of sea urchins throughout the entire Southern California Bight survey region. For *Lytechinus pictus*, surveys dating back to 1994 covered depths from 10 to 200 m. For deeper species, surveys were extended to 500 m in 2003. Letter indicates significant difference resulting from a Kruskal–Wallis and *post hoc* Dunn's tests. Numbers within each barplot indicate the number of independent trawls used for the calculation. (A) *Lytechinus pictus*. (B) *Strongylocentrotus fragilis* (upper 200 m from 1994 to 2013). (C) *Strongylocentrotus fragilis* (upper 500 m from 2003 to 2013). (D) *Brissopsis pacifica*. (E) *Brisaster* spp. (F) *Spatangus californicus*.

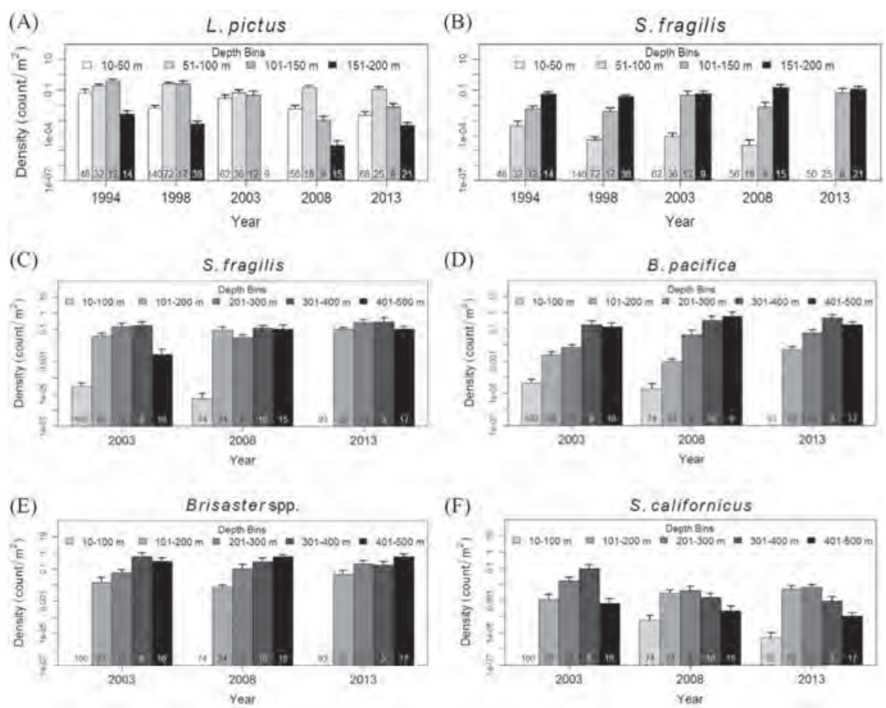


**Fig. 6.** Mean log-scale density (+1 SE) of (A) *Lytechinus pictus.* (B) and (C) *Strongylocentrotus fragilis*. (D) *Brissopsis pacifica*. (E) *Brisaster* spp. (F) *Spatangus californicus* in the Southern California Bight from 1994 to 2013. Urchins were separated into 50-m depth bins (*L. pictus and S. fragilis*) and 100-m depth bins (other species). Numbers within each barplot indicate number of independent trawls used for calculation.

**Table 2**
Linear regression results showing relationships of sea urchin depth distribution metrics to ENSO conditions based on bi-monthly MEI values. Negative relationships indicate shoaling of depth distribution metrics and decreasing density in response to stronger El Niño-like conditions (e.g., higher oxygen, higher pH). Positive relationships indicate deepening of depth distribution metrics and increasing density in response to stronger El Nino-like conditions (e.g., higher oxygen, higher pH). $p$-Values $<0.05$ indicate a significant relationship between depth distribution metrics and density with MEI values. NS indicates a non-significant relationship, and NA results indicate Not Available because these analyses were not ecologically relevant.

| Response to increasing strength of El Niño conditions | Upper depth limit | First quantile depth | Median trawl depth | Third quantile depth | Mean trawl depth | Lower limit depth | Mean urchin density | Median urchin depth |
|---|---|---|---|---|---|---|---|---|
| *L. pictus* | NS | Positive $p<0.05$ | Positive $p<0.05$ | Positive $p<0.05$ | NS | NS | Positive $p<0.05$ | Positive $p=0.07$ |
| *S. fragilis* 10–200 m | NA | | | | | | NS | NA |
| *S. fragilis* 10–500 m | Negative $p=0.09$ | Negative $p=0.06$ | Negative $p<0.05$ | NS | Negative $p<0.05$ | Negative $p<0.05$ | Negative $p=0.06$ | Negative $p=0.07$ |
| *B. pacifica* | Negative $p<0.05$ | Negative $p=0.07$ | Negative $p<0.05$ | Negative $p<0.01$ | Negative $p<0.01$ | Negative $p<0.05$ | Negative $p<0.05$ | Negative $p=0.12$ |
| *Brisaster* spp. | Positive $p<0.05$ | NS | Positive $p=0.06$ | Positive $p<0.01$ | NS | Positive $p<0.01$ | Negative $p=0.10$ | Negative $p=0.07$ |
| *S. californicus* | NS | NS | NS | NS | NS | Positive $p<0.05$ | NS | NS |

**Table 3**
Linear regression results of sea urchin depth distribution metrics and density with mean dissolved oxygen (DO) and pH in the Southern California Bight. Significant relationships with DO or pH at 100 m, 200 m, or 300 m are listed as response variable (+ or − sign of relationships). Negative relationships (−) indicate deepening of depth distribution metrics and increasing density in response to decreasing DO or decreasing pH ($p<0.05$). Positive relationships (+) indicate shallowing of depth distribution metrics and decreasing density in response to decreasing DO or decreasing pH ($p<0.05$). NS indicates a non-significant relationship, and NA results indicate Not Available because these analyses were not ecologically relevant.

| | | 100 m | | 200 m | | 300 m | |
|---|---|---|---|---|---|---|---|
| Species | Years analyzed | DO | pH | DO | pH | DO | pH |
| *L. pictus* 10–200 m | 1994–2013 | Density (+) | Density; 1st Quartile Depth; Median Trawl Depth; Median Urchin Depth (+) | Density; 1st Quartile Depth; Median Trawl Depth; Median Urchin Depth (+) | | NA | NA |
| *S. fragilis* 10–200 m | 1994–2013 | NS | Density (−) | NS | NS | NA | NA |
| *S. fragilis* 10–500 m | 2003–2013 | NS | NS | Density (−) | NS | NS | NS |
| *B. pacifica* 10–500 m | 2003–2013 | NS | NS | NS | NS | NS | NS |
| *Brisaster* spp. 10–500 m | 2003–2013 | Upper Depth Limit (−) | Upper Depth Limit; Median Urchin Depth (-) | NS | Upper Depth Limit; Median Urchin Depth (−) | NS | NS |
| *S. californicus* 10–500 m | 2003–2013 | 1st Quartile Depth (+) | 1st Quartile Depth; 3rd Quartile Depth (+) | 3rd Quartile Depth (+) | 1st Quartile Depth; 3rd Quartile Depth (+) | NS | NS |

significantly predicted by pH at 100 m ($t_3=-3.24$ $p<0.05$, $R^2=0.99$) (Table 3).

### 3.3. Burrowing urchins

#### 3.3.1. Temporal changes in depth

The depth distributions of each burrowing urchin species (*Brissopsis pacifica*, *Brisaster* spp. and *Spatangus californicus*) did not vary significantly in the upper 500 m from 2003 to 2013 (KS tests: $p>0.05$) (Fig. 4C–E) (Table 1). The first and third quartile depths of *B. pacifica* appeared to shoal, but these relationships were not significant (Fig. 4C). The median depth of *Brisaster* spp. deepened by 3.85 m yr$^{-1}$ ($t_1=14.82$, $p=0.04$, $R^2=0.99$) (Fig. 4D). From 2003 to 2013, the upper limit, first and third quartiles, mean and median depths of *S. californicus* appeared to shoal by 2–11 m yr$^{-1}$ (Fig. 4E) but again, these relationships were not significant.

#### 3.3.2. Temporal changes in density

Neither *B. pacifica* nor *S. californicus* density within the upper 500 m significantly varied across years (Kruskal–Wallis Test: *B. pacifica*: $\chi^2=4.85$, $p=0.08$; *S. californicus*: $\chi^2=0.13$, $p=0.94$) (Fig. 5D, F). *Brisaster* spp. density did vary significantly within the upper 500 m from 2003 to 2013 (Kruskal–Wallis Test: $\chi^2=7.66$, $p=0.02$), but density did not show a consistent change with time ($p=0.24$) (Fig. 5E) (Table 1). Compared to 2003 mean *Brisaster* spp. density (0.06 indiv. m$^{-2}$), density was 61% higher in 2008 and 54% higher in 2013 (post hoc Dunn's test: $p<0.05$).

*B. pacifica* and *S. californicus* density within each 100-m depth bin did not significantly vary among survey years (Fig. 6D, F). The mean *B. pacifica* density increased at a rate of 0.03 indiv. m$^{-2}$ yr$^{-1}$ within the 301–400 m depth bin from 2003 to 2013 ($t_1=166.6$, $p<0.01$, $R^2>0.99$) and at a rate of 0.005 indiv. m$^{-2}$ yr$^{-1}$ within the 201–300 m depth bin from 2003 to 2013, although this latter relationship was not significant ($p=0.13$) (Fig. 6D). From 2003 to 2013, the mean density of *S. californicus* increased within the 101–200 m depth bin and decreased within the 201–300 m, 301–400 m, and 401–500 m depth bins, but these relationships were not significant ($p>0.05$) (Fig. 6F). *Brisaster* spp. density varied significantly among survey years within the 101–200 m depth bin (Kruskal–Wallis Test: $\chi^2=8.14$, $p=0.02$), but mean density did not change consistently with time ($p=0.36$) (Fig. 6E).

#### 3.3.3. Depth and density relationship with MEI

*B. pacifica* mean, median, third quartile, and lower limit depths were negatively related to fall and winter MEI ($t_1<-10$, $p<0.05$, $R^2=0.99$), and upper limit depth was negatively related to summer MEI ($t_1<-14$, $p<0.05$, $R^2=0.99$) (Table 2), suggesting that the species occupied shallower depths during stronger El Niño conditions. In addition, the strength of El Niño conditions in the spring and summer months predicted *B. pacifica* density ($F_{1,1} < -16$, $p < 0.05$, $R^2 = 0.99$). *Brisaster* spp. upper and lower limit depths were positively related to summer MEI ($F_{1,1} > 23$, $p < 0.05$, $R^2 = 0.99$) (Table 2), suggesting that this species occupied deeper depths (or was more likely to be on the surface in deeper waters) during stronger El Niño conditions. *Brisaster* spp. third quartile depth was positively related to spring MEI ($t_1 = 10.4$, $p < 0.05$, $R^2 = 0.99$), and while spring MEI was also positively related to *Brisaster* spp. density, this latter relationship was not significant ($p = 0.10$) (Table 2). *S. californicus* lower depth limit was positively related to spring MEI ($t_1 = 13.4$, $p < 0.05$, $R^2 = 0.99$), but no other depth distribution metric or density were related to any bi-monthly MEI (Table 2).

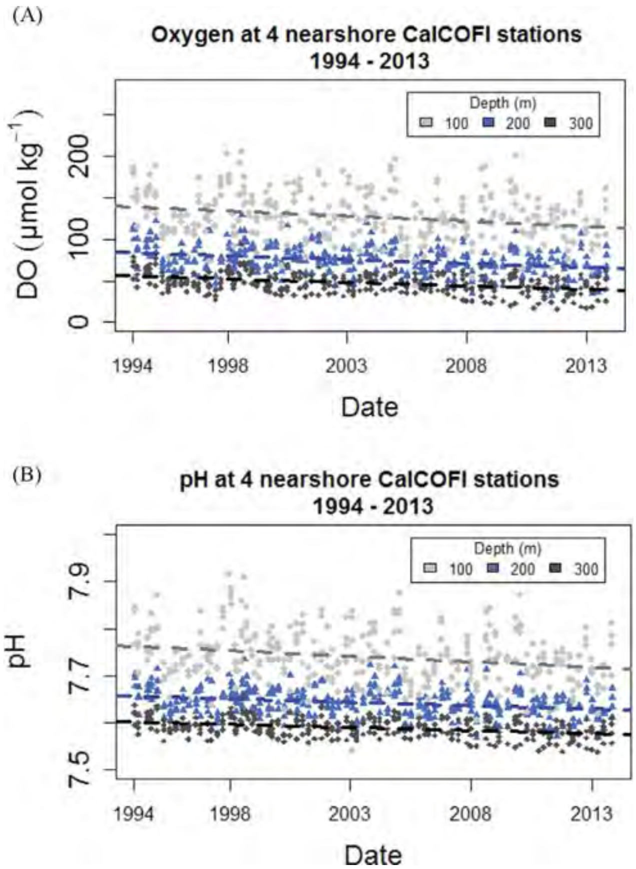


**Fig. 7.** Changes in (A) dissolved oxygen (DO) concentration and (B) pH for CalCOFI stations (line 81.8, station 46.9; line 86.7, station 35.0; line 90.0, station 30.0; line 93.3, station 30.0) at 100 m (gray), 200 m (blue), and 300 m (black) between 1994 and 2013 in the Southern California Bight. Depth-specific regression lines for DO and pH were all significantly related to time. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

### 3.3.4. Depth distribution and density relationship with DO and pH

The upper depth limit of *Brisaster* spp. was negatively related to mean DO at 100 m ($t_1 = -15.35$, $p = 0.04$, $R^2 = 0.99$), pH at 100 m ($t_1 = -32.56$, $p = 0.02$, $R^2 = 0.99$), and pH at 200 m ($t_1 = -54.13$, $p = 0.01$, $R^2 = 0.99$). The median depth of *Brisaster* spp. was also negatively related to pH at 100 m ($t_1 = -34.34$, $p = 0.02$, $R^2 = 0.99$), and pH at 200 m ($t_1 = -12.75$, $p < 0.05$, $R^2 = 0.99$). The 75% quartile of *S. californicus* was positively related to both DO and pH at 100 m and 200 m, while the 25% quartile was only positively related to pH (Table 3). No significant relationships between *B. pacifica* depth metrics or density and mean DO or pH were found (Table 3).

## 3.4. Dissolved oxygen and pH relationships with time and MEI in the SCB

Between 1994 and 2013, DO was negatively related to survey year at 100 m ($t_{329} = -4.551$, $p < 0.001$, $R^2 = 0.06$), 200 m ($t_{329} = -5.551$, $p < 0.001$, $R^2 = 0.08$), and 300 m ($t_{328} = -7.982$, $p < 0.001$, $R^2 = 0.16$) (Fig. 7A), as was pH at 100 m ($t_{329} = -4.6$, $p < 0.001$, $R^2 = 0.05$), 200 m ($t_{329} = -5.434$, $p < 0.001$, $R^2 = 0.08$), and 300 m ($t_{328} = -7.347$, $p < 0.001$, $R^2 = 0.14$) (Fig. 7B). DO and pH values at 100 m were positively related to MEI values from 1994 to 2013 (DO: $t_{336} = 4.306$, $p < 0.001$, $R^2 = 0.05$; pH: $t_{336} = 5.26$, $p < 0.001$, $R^2 = 0.07$), with DO increasing at a rate of 3.166 μmol DO kg$^{-1}$ MEI unit$^{-1}$ (Fig. 8A), and pH increasing at a rate of 0.015 pH units MEI unit$^{-1}$ (Fig. 8C). At 100 m in the SCB, mean DO during strong El Niño years (MEI > 1) between 1994 and 2013 ($145.5 \pm 29.8$ μmol kg$^{-1}$ [mean ± 1 SD]) was found to be 25%

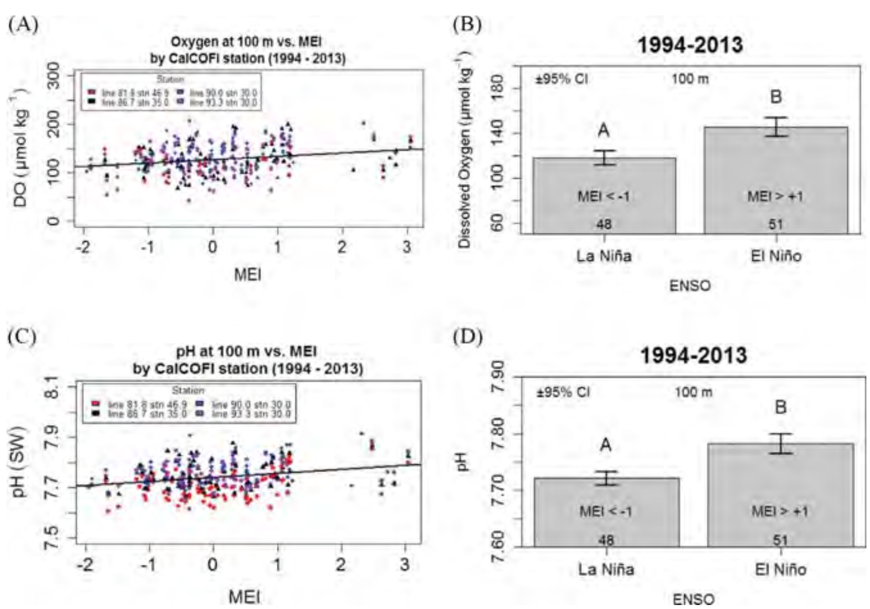


**Fig. 8.** (A) Dissolved oxygen (DO) concentration and (C) pH as a function of MEI (1994–2013) for CalCOFI stations (line 81.8, station 46.9; line 86.7, station 35.0; line 90.0, station 30.0; line 93.3, station 30.0) at 100 m in the Southern California Bight. (B) Mean DO concentration and (D) mean pH ± 95% confidence intervals for MEI < −1.0 (La Niña conditions) and MEI > 1.0 (El Niño conditions).

higher than during strong La Niña years ($118.0 \pm 22.3$ μmol kg$^{-1}$; *t*-Test: $t_{94} = -5.19$, $p < 0.001$) (Fig. 8B), while mean pH during strong El Niño years ($7.78 \pm 0.06$) was a significant 0.06 pH units higher than during strong La Niña years ($7.72 \pm 0.04$; *t*-Test: $t_{87} = -5.78$, $p < 0.001$; Fig. 8D).

## 4. Discussion

Observed temporal trends in echinoid species depth distributions and densities (Table 1, Figs. 4–6) suggest that deep-dwelling urchin species may have experienced habitat expansion upslope in the upper 500 m and shallower-dwelling urchin species may have experienced habitat compression in the upper 200 m over the past 21 years due to multiple climate stressors in the SCB such as DO, temperature, pH, Ω, and $pCO_2$ (Alin et al. 2012; Frieder et al., 2012; Nam et al. 2015). Trawl survey data reflect (1) shoaling of depth distributions and possible habitat compression in *L. pictus*, and (2) habitat expansion or upslope shifts in *Brisaster* spp. and *S. californicus* (Table 1). Examination of DO and pH data in the upper 200 m at single nearshore CalCOFI stations within the study region between 1994 and 2013 indicates that a change in habitation depth of 20–30 m can yield a 15–63 μmol kg$^{-1}$ change in DO exposure and a 0.03–0.15 unit change in pH exposure (Appendix 1). Although our data did not allow us to assess the potential intensification of the OMZ at depths greater than 500 m, these deep species may have responded to secular deoxygenation and acidification in the SCB, but may have also been influenced by variability in environmental conditions such as oxygen and pH associated with ENSO (Fig. 8). ENSO-related variations in the system can affect major population drivers such as food availability, food quality, and competition. However, other secular changes in the SCB over this time period such as increasing primary productivity and frontal frequency (Bograd et al., 2015; Kahru et al., 2012), intensifying upwelling winds (Sydeman et al., 2014), and warming in the upper 200 m (Di Lorenzo et al., 2005) are potential covariates that could contribute to interannual variability in suitability of urchin habitat. In addition, the positive and negative relationships of population size and distributions with MEI (Table 2), indicate that other factors may have driven temporal change in population densities and distributions in this system.

While changes in benthic fish and invertebrate populations in response to climate events are expected, our results indicate that these effects are species-specific (Arntz et al., 2006). A significant positive relationship between MEI and *L. pictus* density suggest stronger El Niño conditions favor this species, while negative relationships of *S. fragilis* and *B. pacifica* density with MEI suggest they are negatively affected by El Niño conditions. Significant relationships of *L. pictus* and *S. fragilis* density with annual means of DO and pH suggest that these species are affected by these environmental factors (Table 3), and opposite density trends suggest competition in the upper 200 m may also limit *L. pictus* and favor *S. fragilis* (Fig. 5A, B). Interpreting these differences requires a deeper understanding of life history, food sources, and spatio-temporal dynamics.

The urchin species discussed are grossly understudied despite the potentially high impact they may have on the deep-sea community, and specific mechanisms of population structure change cannot be revealed with the current sampling design. Possible lags in species response (i.e. changes in depth distribution or density) to environmental variables likely exist depending on the species' life history (Glover et al., 2010). For example, although the lifespan of *L. pictus* is unknown, the estimated lifespan of the congener, *L. variegatus*, is $< 5$ yr (Watts et al., 2007; Bodnar and Coffman, 2016). Five years after the strong El Niño of 1998, the mean density of *L. pictus* declined by 56%; this decline persisted until 2013 (Fig. 5A). Thus, it is possible that *L. pictus* populations responded to kelp food availability at shorter time scales than the longer-lived *S. fragilis* (Taylor et al., 2014), and trawl surveys at 5-yr intervals could not reveal the influence of ENSO events on *L. pictus* populations.

To determine the feasibility of urchin migration as a possible mechanism for the observed depth changes, we estimated the average slope of the continental shelf and slope in the SCB using Google Earth. We found that a 10 m reduction in depth for the shallower, *L. pictus* on the shelf might occur over a 1 km horizontal distance. Although the average travel speed of adult *L. pictus* is unknown, Pisut (2004) found the average speed of *L. variegatus* to be ~0.7 m h$^{-1}$, and Barry et al. (2014) found the average speed of *S. fragilis* to be ~0.25 m h$^{-1}$. Therefore, it is feasible for individuals to migrate 1 km in 5 years, so depth changes may reflect migration rather than mortality and recruitment. The significant decrease in density of *L. pictus* in the SCB over the time period of this study however, would suggest that mortality and lowered recruitment did occur. Potential mechanisms for increased mortality and lower recruitment for *L. pictus* over time include physiological intolerance to low pH or low DO, increased predation, increased competition and/or reduced larval supply.

*L. pictus* and *S. fragilis* are epibenthic omnivores that primarily feed on allochthonous kelp detritus (Barry et al., 2014; Thompson et al., 1983; Fig. 2A, B) that originates from the inshore zone of the coastal SCB (Dayton, 1985; Krumhansl and Scheibling, 2012; Parnell et al., 2010). During and following El Niño years, anomalously higher nearshore sea surface temperatures off the southern California coast can persist for at least 2 years (McGowan et al., 1998). Results of warmer surface waters include intensified stratification, reduced upwelling, and reduced primary production by phytoplankton (Barber and Chavez, 1983; Contreras et al., 2007) and kelp (Tegner and Dayton, 1987). This could negatively affect the availability of autochthonous food in the form of sinking organic matter (phytodetritus) for deep-sea benthic communities including epibenthic and burrowing urchins (Lange et al., 2000Gutierrez et al., 2000; Levin et al., 2002; Sellanes and Neira, 2006), and may also explain the negative relationships between MEI and *S. fragilis* and *B. pacifica* densities (Table 2). Alternatively, burrowing spatangoid urchins may benefit from increased input of terrestrial organic matter during stronger El Niño years as a result of increased runoff from winter storms (Lange et al., 2000, and others). However, sinking organic matter of terrestrial origin has been found to have lower protein content, higher C: N ratios and lower nutritional quality than marine sources (Cowie et al., 2009). Stable isotope analysis of deposit-feeding urchins combined with gonad analyses may help to better understand the differential effects of food source quality and origin on reproduction and fitness during El Niño and non-El Niño years.

Winter storms during El Niño years can also dislodge and export significant kelp forest biomass (Dayton and Tegner, 1984; Parnell et al., 2010), which may temporarily increase supply of allochthonous food to deep-sea habitats in the form of kelp detritus (Harrold et al., 1998; Vetter and Dayton, 1998). However, low overall production of *Macrocystis pyrifera* kelp canopy during summer El Niño years should limit food and reduce urchin populations (Edwards 2004 and references therein). While this understanding could explain the negative relationship between MEI and *S. fragilis*, it cannot explain the opposite response of *L. pictus* at depths less than 200 m. Instead the higher DO and pH associated with El Niño conditions may favor *L. pictus* (Fig. 8). However, the lower depth bins of *L. pictus* (101–200 m) overlap with *S. fragilis*, so it is possible that during strong El Niño years when there is limited food, a competitive interaction between the two urchins occurs. Density data support the hypothesis that these two species interact in the upper 200 m (Fig. 5A, B), and possibly within smaller depth bins where they coexist (Fig. 6A, B), but further analysis is required to test this. It is also possible that decadal oscillations in climate may affect trends in density. For example, changes in the NPGO and PDO in the last decade can affect bottom-up processes that likely influence entire marine communities (Bell et al., 2015; Di Lorenzo et al., 2008; Miller et al., 2015). A better understanding of how food source dynamics interact with stressors to influence margin urchin populations is required, particularly regarding the origin and fate of autochthonous and allochthonous food sources in response to physical oceanographic processes affected by ENSO cycles.

In addition to food availability, climate-related perturbations in the physical, chemical and biological structure of the environment can result in shifts in the vertical zonation of entire land- and seascapes (Cheung et al., 2011; Parmesan, 2006; Wishner et al., 2013). For example, La Niña years often follow El Niño years (Table 1) and are characterized by enhanced upwelling and prolonged exposure to hypoxic and acidic conditions (Booth et al., 2014; Nam et al., 2011). This pattern of low food years (El Niño), followed by low-oxygen, low-pH periods (La Niña) can represent a one-two punch and be detrimental to population growth (Ramajo et al., 2016). As OMZs expand and OLZs shoal, waters low in pH and high in $CO_2$ are also expected to creep upslope (Gruber et al., 2012) and onto the shelf (Feely et al., 2008). This may exacerbate negative consequences for vulnerable larval stages of calcifying urchin species adapted to shallower conditions by increasing metabolic energy demand (Pan et al., 2015), but it is unclear if larvae of deep-sea species have greater tolerance to future climate change than those of shallower species (Jager et al., 2016; Stumpp et al., 2012). These secular trends of deoxygenation and ocean acidification may induce a competitive advantage for deeper urchins (e.g. *S. fragilis*, *B. pacifica* and *Brisaster* spp.) equipped with the adaptive machinery to persist in hypoxic and hypercapnic environments over those restricted by such conditions (Byrne and Przeslawski, 2013; Portner et al., 2005; Taylor et al., 2014). Deep-sea, *in situ* manipulation experiments simulated future deep-ocean acidification and revealed longer foraging time and no difference in speed of adult *S. fragilis* under acidic conditions, which implied tolerance to acidification (Barry et al., 2014). Behavioral responses coupled with adaptive capacities for *S. fragilis* to regulate acid-base balance under acidic conditions (Taylor et al., 2014) and low oxygen-consumption rates under hypoxic conditions (Thompson et al., 1983) may induce a competitive advantage over *L. pictus*, which could explain the increase in *S. fragilis* density by 174% in the 101–200 m depth bin zone from 2003 to 2013 (Fig. 6A, B). Higher oxygen or pH limits in *L. pictus* may also explain the 56% decrease from 10 to 200 m from 2003 to 2013 given the positive relationship with oxygen and pH (Fig. 7A, B; Table 3).

Despite statistically insignificant density differences among years, *B. pacifica* and *Brisaster* spp. may be better competitors than *S. californicus* echinoids in a deoxygenated, acidic future. A shoaling of median depth of 50% and a density decrease of 75% from 2003 to 2013 suggests habitat compression in *S. californicus* (Figs. 4F, 5F). As infaunal burrowers, heart urchins are exposed to even more reduced conditions than that of overlying OMZ and OLZ waters (Reimers et al., 1990). Despite the function of fascioles, which direct currents over respiratory tube feet, burrowing urchins are still exposed to surrounding pore water that is reduced in pH and oxygen relative to near-bottom waters; this has been found in both *in situ* observations of sediment pore-water chemistry (Reimers et al., 1990) and laboratory experiments focused on burrowing urchins (Vopel et al., 2007). Accordingly, their distributions and peak densities indicate that they are tolerant of extremely low-oxygen, high-$CO_2$ environments (Moffitt et al., 2015).

Burrowing urchins in the eastern Pacific OMZ occur in dense patches (Thompson et al., 1993; Thompson and Jones, 1987) and contribute to significant nutrient recycling processes through bioturbation of sediments (Lohrer et al., 2004; Lohrer et al., 2005). Our density estimates likely underestimated the subsurface density of spatangoid heart urchins in the SCB since otter trawls cannot accurately sample all the urchins, which may dwell as deep as 20 cm and are best sampled by boxcorers (Kanazawa, 1992; Thompson and Jones, 1987). As such, trends of shoaling depth distributions and increasing density of *Brisaster* spp. associated with deoxygenation could simply reflect movement of heart urchins to the surface to access more oxygenated waters (i.e. higher catchability). It is interesting to note the varying responses to El Niño among the three burrowing spatangoid urchin species in the upper 500 m (Table 2). Further evidence for oxygen limitation in *Brisaster* spp. and *S. californicus* may be inferred from their deepening distributions during stronger El Niño years (Table 2). While density decreases during stronger El Niño years may be explained by the overall decrease in food availability in the SCB (Nichols et al., 1989), it is likely that competitive interactions occur among *B. pacifica, Brisaster* spp. and *S. californicus* during years when food is limited (Dayton and Hessler, 1972).

Future studies focusing on adaptations to combined hypoxia, hypercapnia, and food limitation in different deep-sea urchin species are needed. Phenomena such as the presence and activity of sulfide-oxidizing gut microbes (Thorsen, 1998) and resource partitioning (Thompson et al., 1983) among competitors could provide further insight into how deep-margin echinoids respond to future climate change.

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## Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.dsr2.2016.08.012.

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