APPENDIX F: ALTERNATIVE ANALYSES

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

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Abstract

The demersal fish community has been routinely sampled approximately every five years since 1994 during the Bight Regional Monitoring Program. Prior surveys reviewed data as catch per trawl during 10-min tows. This included doubling the abundance and biomass for catches taken during 5-min tows in bays and harbors to make data comparable to results from sampling on the open coast. Comparisons between the analytical methods previously used by the program and one standardized to the area swept by each trawl revealed a vessel-effect sampling bias. Standardization based on area swept derived from GPS coordinates of start and stop fishing times partially addressed this bias, although this assumed constant bottom contact which cannot be verified. Densities (count/1000 m^2) were less variable than was observed with raw abundances and more effectively handled the prescribed trawl time differences between bay/harbor sampling sites and open coast sampling sites. This density analytical technique holds the promise of greater utilization, such as in productivity estimates, standing stock estimates, or other analyses utilized to evaluate the efficacy of ecosystem based management.

Introduction

As a supplement to site-specific annual monitoring programs (Mearns 1979; Love et al. 1986; Stull and Tang 1996), a regional survey (Bight survey) was developed in 1994 to provide a broader overview of the demersal fish communities across the Southern California Bight (SCB) and have continued at nearly 5-year intervals (Allen et al. 1998[1]; Allen et al. 2002[2]; Allen et al. 2007[3]). These surveys have implemented a standardized sampling methodology used by all participating agencies, including the use of a standard sampling gear (7.6-m otter trawl net) and tow time. Reaffirmation of this net choice was made after extensive comparative analyses between a variety of commonly used nets in the 1970s (Mearns and Stubbs 1974[4]). Mearns (1974[5]) and Mearns and Stubbs (1974[4]) found that the 7.6-m Marinovich net, now standard equipment used in regulated discharge monitoring throughout the SCB, had a substantially wider mouth (4.9-m) when fishing than other commonly used 7.6-m trawl nets.

During the Bight programs, all open coast sampling utilized a 10-min tow, but the inclusion of bay/harbor stations required the use of a 5-min tow in these areas due to space limitations (Allen et al. 2007[3]). Integration of catches resulting from differing efforts, by design, posed a data analysis problem that was uniquely overcome by doubling the abundance and biomass taken during the 5-min tows to estimate the comparable 10-min tow catch. Prior and

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[1] Allen, M. J., S. L. Moore, K. C. Schiff, et al. 1998. Southern California Bight 1994 Pilot Project: V. Demersal fishes and megabenthic invertebrates. Southern California Coastal Water Research Project, Westminster, CA.

[2] Allen, M.J., A.K. Groce, D. Deiner, et. al. 2002. Southern California Bight 1998 Regional Monitoring Program: V. Demersal fishes and megabenthic invertebrates. Southern California Coastal Water Research Project. Westminster, California.

[3] Allen, M.J., T. Mikel, D. Cadien, et al. 2007. Southern California Bight 2003 Regional Monitoring Program: IV. Demersal fishes and megabenthic invertebrates. Southern California Coastal Water Research Project. Costa Mesa, California.

[4] Mearns, A.J. and H.H. Stubbs. 1974. Comparison of otter trawls used in southern California Coastal surveys. Southern California Coastal Water Research Project TM 213.

[5] Mearns, A.J. 1974. Standardizing sampling procedures. Southern California Coastal Water Research Project Annual Report.
ftp://ftp.sccwrp.org/pub/download/DOCUMENTS/AnnualReports/1974AnnualReport/ar-09.pdf

recent ecological sampling, however, has trended towards the standardization of abundance or biomass to effort, including trawl surveys. To this end, Hayes et al. (1996) described the major advantage of active sampling gears, such as otter trawls, as sweeping a relatively known space or area. This fact allows for a relatively accurate estimation of catch per unit effort (CPUE) or density (count/area swept) for calculated abundance indices (Hayes et al. 1996; Bertrand et al. 2002a). Using these metrics, intersurvey comparisons can be made, even across disparate sampling programs utilizing different otter trawl nets. Mearns and Word (1975[6]) used this concept (kg/ha) to compare the trawl catches from offshore of Laguna Beach and Dana Point, California to reported catches made at other sites ranging from Point Loma to Ventura, California. This technique is consistent with similar, recent multi-agency programs conducted outside of California (Biagi et al. 2002; Bertrand et al. 2002a,b). These studies utilized standardized demersal fish sampling gear, prescribed tow distances, and data processing, commonly standardizing data to area swept by the trawl net (Johnson et al. 1994; Adams et al. 1995; Bond et al. 1999; Bertrand et al. 2002a; Somerton et al. 2002; Field et al. 2006). Therefore, the current method of doubling trawl catches appears to be a more recent and novel development than the reliance on catch per area swept. In either case, intersurvey comparisons assume a 100% catch efficiency which is probably invalid (Mearns and Word 1975[6]).

Use of doubled catches, while informative, may not have fully accounted for the inherent variability in sampling efficiency between participating agencies, vessels, personnel, etc. despite the use of standardized sampling equipment and protocols (Wallace and West 2006). While some of these biases cannot be completely accounted for, the data can be standardized for the area swept with the trawl net. Differences in tow duration can measurably impact abundance indices

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[6] Mearns, A.J. and L.S. Word. 1975. A trawl survey off Laguna Beach and Dana Point. Southern California Water Research Project Annual Report.
ftp://ftp.sccwrp.org/pub/download/DOCUMENTS/AnnualReports/1975AnnualReport/17_.pdf

(Somerton et al. 2002), but without accurate bottom sensing equipment researchers are required to assume consistent bottom-time based on recorded trawl time. Tow distance can be estimated based on start- and stop-fishing GPS coordinates (Bond et al. 1999), although this also assumes the net remained in contact with the bottom during the estimated fishing time.

Sampling effort standardizations, such as a CPUE or area swept result in density estimates that can transcend sampling methodology and area (Johnson et al. 1994; Adams et al. 1995; Bond et al. 1999). These allow more direct comparisons between ecosystems, e.g. soft-bottom communities versus rocky reefs (Bond et al. 1999) as well as accounting for the general non-uniformity in species distributions (King 2007). As ecosystem-based management (EBM) efforts continue in the Southern California Bight (Stokstad 2010), such densities may become informative in evaluating the overall effectiveness of EBM policies. Prior EBM studies commonly utilized population densities to as a primary parameter (Abesamis and Russ 2005; Gaylord et al. 2005; Froeschke et al. 2006). While most of these prior works utilized diver transect data, it does not preclude the use of trawl sampling in the adjacent open areas to assess the overall ecological benefit of the hypothesized spillover of biological production out of the reserve (Paddack and Estes 2000; Abesamis and Russ 2005). As regulatory-required trawl sampling will likely continue into the foreseeable future, potential future inclusion of these data in a greater ecosystem analytical context suggests a reevaluation of current Bight analytical methods may be warranted.

How to most effectively analyze the data to maximize its utilization and efficacy is the pressing question. This study aims to compare the analytical methods used in the preceding Bight surveys (e.g. catch per 10-min tow including doubling 5-min tows) and a CPUE metric. Both techniques share similar assumptions, including assuming constant bottom contact while fishing, but they differ in how they account for sampling effort variability. Such standardizations have become vitally important in ecological research (Johnson et al. 1994; Bond et al. 1999; Field et al. 2006), and will likely continue to do so after EBM implementation. Furthermore, utilization of a density metric such as CPUE provides for the estimation of standing stock if additional parameters (area subsampled and net catch efficiency) are known in addition to the sampling being of sufficient spatial extent and random designation (Pauly 1983; King 2007). In this analysis, the Bight 2008 demersal catch data was examined to evaluate the effectiveness of the unique analytical technique of doubling 5-min trawls to equate to 10-min trawl. As an example of the utility of a density metric, attempts to derive a standing stock estimate for a candidate species were made.

Materials and Methods

Sampling Station Description – Demersal fish taken during otter trawl surveys completed across the SCB in the summer (July – September) 2008 were included. Sampling sites were selected *a priori* among soft-bottom areas based on reviews of bathymetric maps. Stations were aggregated into strata based on shelf zone. All open coast data, when possible, were reclassified into consistent shelf (depth) strata by actual sampling depth: 5-30 m = inner shelf (IS), 31-120 m = middle shelf (MS), 121-200 m = outer shelf (OS), and > 200 m = upper slope (US). Sampling results from bays and harbors were classified into the bay/harbor depth stratum. Latitudinal areas were defined as > 34°N = north, 33.5 – 34.0°N = central, and < 33.5°N = south.

Sampling Methods – All sampling was completed with 7.6-m head-rope semi-balloon otter trawl nets with a 1.25-cm cod-end mesh. Trawl nets were towed along open-coast isobaths for ~10 min (~5 min in bays and harbors) at 0.8-1.0 m/sec. These tows were to designed to sweep a targeted distance of 300 and 600 m for 5 and 10 min tows, respectively. The tow distance was calculated from the difference between the start- and stop-fishing GPS coordinates recorded on the deck of the towing vessel. These acted as a proxy for the net's relative position. For this study, only the total abundance of all fishes, combined, per tow were included in the analysis.

Data Analysis – Initial analyses utilized prior Bight monitoring techniques, e.g. raw abundance recorded during ~10-min tows and doubling the abundance recorded during ~5-min tow (Allen et al. 2002[2]). In the current study, data was also analyzed as a density or CPUE by standardizing all catch data to the area swept (count/1000 m^2) similar to that used by Biagi et al. (2002). Underwater measurements by EQA-MBC (1975[7]) determined the 7.6-m trawl net spread 4.9 m on average while under tow and fishing. The area sampled in this analysis represents the distance towed (m) x 4.9 m.

From these derived densities, the standing stock of Pacific sanddab (*Citharichthys sordidus*) was estimated using an equation modified from Allen et al. (2002): Stock = (Mean Density x Area)/(Net Catch Efficiency). Standing stock estimates were made utilizing data from the last three Bight surveys (1998, 2003, and 2008) and compared against each other to examine trends based on the estimated standing stock. The mean density was calculated by shelf stratum and latitudinal area (North, Central, and South) for each year and area estimates were gathered from prior Bight survey reports. Net catch efficiency has not been derived for the 7.6-m Marinovich-style net. Therefore, an estimate of 0.5 was used in all calculations as discussed by Pauly (1983) and King (2007). This estimate seems plausible, but perhaps slightly high, and within reason based on Stokesbury et al.'s (1999) reporting of up to 37.4% catch efficiency in a

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[7] Environmental Quality Analysts and Marine Biological Consultants (EQA-MBC). 1975. Southern California Edison Company Long Beach Generating Station marine monitoring studies: 1975 Annual Report Volume I.

similar 4.9-m net without a tickler chain. They estimated the use of a tickler chain would have likely increased the catch efficiency, especially benthic species such as flatfish.

Results

The distance towed in 2008 varied considerably among stations in each depth strata (Figure 1), suggesting variable effort. Both metrics (raw abundance and density [count/1000 m^2]) were generally similar for most stations across four of the five shelf strata (excluding the OS), although substantial site-specific differences were detected within each stratum (Figure 2). These differences were not significant among each of the strata. Often, the station-specific differences between sites within a stratum were more muted in the density analysis, although some density estimates increased the significance of a site-specific catch over that indicated by the raw abundance analysis, e.g. stations 6448 and 6404 in the BH stratum. Otherwise, the raw abundance estimates generally overestimated the relative abundance with greater differences between the stations. Excluding stations 7668, 7579, and 7030, the differences between station-specific densities were relatively muted in comparison to those represented by the raw abundances across all strata. Few deviations from the expected 1:1 ratio between the two metrics were detected among the shallowest three strata. In each, the distribution of the raw catch versus the density was best described by a linear relationship with an $R^2 > 0.93$ (Figure 3). At greater depths, however, this pattern decomposed. The relationship between the two metrics along the OS was $R^2 = 0.73$ while the US was slightly higher at $R^2 = 0.86$.

Using the derived densities in each year, the estimated Pacific sanddab standing stock along the Southern California Bight IS, MS, and OS ranged from 83 to 300 million individuals. The MS was consistently home to more individuals than either remaining shelf zone (Figure 4). Latitudinal ranges varied as well with the northern and central assemblages more abundant on all three shelf strata. The population was most abundant in 2003 with an estimated 300 million individuals within the Southern California Bight. Pacific sanddab abundances were at their lowest point, of the three survey years, in 1998 when an estimated 83 million individuals resided in the SCB, or 28% of the estimated population size in 2003.

Discussion

Comparison of raw totals and those standardized to sampling effort revealed different patterns. The raw totals did not account for the large variability in effort (Figure 1) which could dramatically affect the catch at each station, often over- or underestimating the true relative abundance at the sampling site (Figure 2; Hayes et al. 1996; Bertrand et al. 2002a). Fish populations, including demersal species, are often patchily distributed (King 2007); therefore the sampling effort variability must be accounted for to remove sampling bias to the extent possible (Wallace and West 2006). While considerable similarity existed between the two methods, as indicated by the high R^2 values, their deviation from 100% similarity or a 1:1 ratio suggests differing results will ultimately be encountered. Therefore the inclusion of effort in any population parameter estimate is of significant importance. Hence, the prevalence of standardizing to a density of CPUE based on area swept (Mearns and Word 1975[6]; Adams et al. 1995; Betrand et al. 2002a,b; Somerton et al. 2002; Field et al. 2006).

Standardized sampling methodologies (net size, tow time and speed, “fishing” definition, etc.) are perhaps the best tools to minimize vessel-effect in an otter trawl sampling program; they cannot, however, account for all variability. Absent post-sampling standardization, the vessel-effect can continue to artificially skew sampling results, thus rendering a less than accurate representation of the conditions sampled. Of course, Wallace and West (2006), among others, detailed the problems that may continue to arise even after such simplistic standardizations as catch per area swept, but without the investment in more refined bottom sensing equipment few options exist. This was exemplified by catches at those stations with well-above-average area sampled (Figure 1). Raw abundances from some of these stations (e.g. 7269, 7688, and 7714) were much higher than average, but after standardization their relative abundances were often consistent with the remaining stations in the stratum (Figure 2). Changes such as this highlight the need to remove sampling effects from the data analysis to arrive at more comparable values.

Calculations of abundance indices, such as density or CPUE, allow for greater use of the reported results. Within the SCB alone, numerous environmental monitoring programs utilize otter trawls as a core component, yet differences in sampling methodology can lead to sufficient incompatibilities between the series that any comparisons are limited to gross examinations of species abundance distributions or similar, e.g. comparing results of the 5-min tows used by Love et al. (1986) and the 10-min tows used by Stull and Tang (1996). Effort-standardized results, however, are more easily translated with some caveats, across sampling programs similar to that used by Mearns and Word (1975[6]). This technique, and the resulting density estimate, facilitates comparisons between marine subtidal habitats and sampling programs through habitat value calculations (Johnson et al. 1994; Bond et al. 1999) or the estimation of standing stock (Figure 4). Furthermore, with the pending implementation of EBM in southern California (Stokstad 2010), the subsequent evaluations of EBM effectiveness will benefit from easily translated data and incorporation into models such as the habitat value or standing stock estimates.

Acknowledgements – This report was prepared under the auspices of the Bight'08 Regional Monitoring Program. I would like to thank all the participating agencies' representatives for their sampling efforts, comments, and discussion. Comments by and discussions with D.S. Beck, D. Pondella, and S. Walther greatly improved this manuscript. This report was inspired by R.A. Miller.

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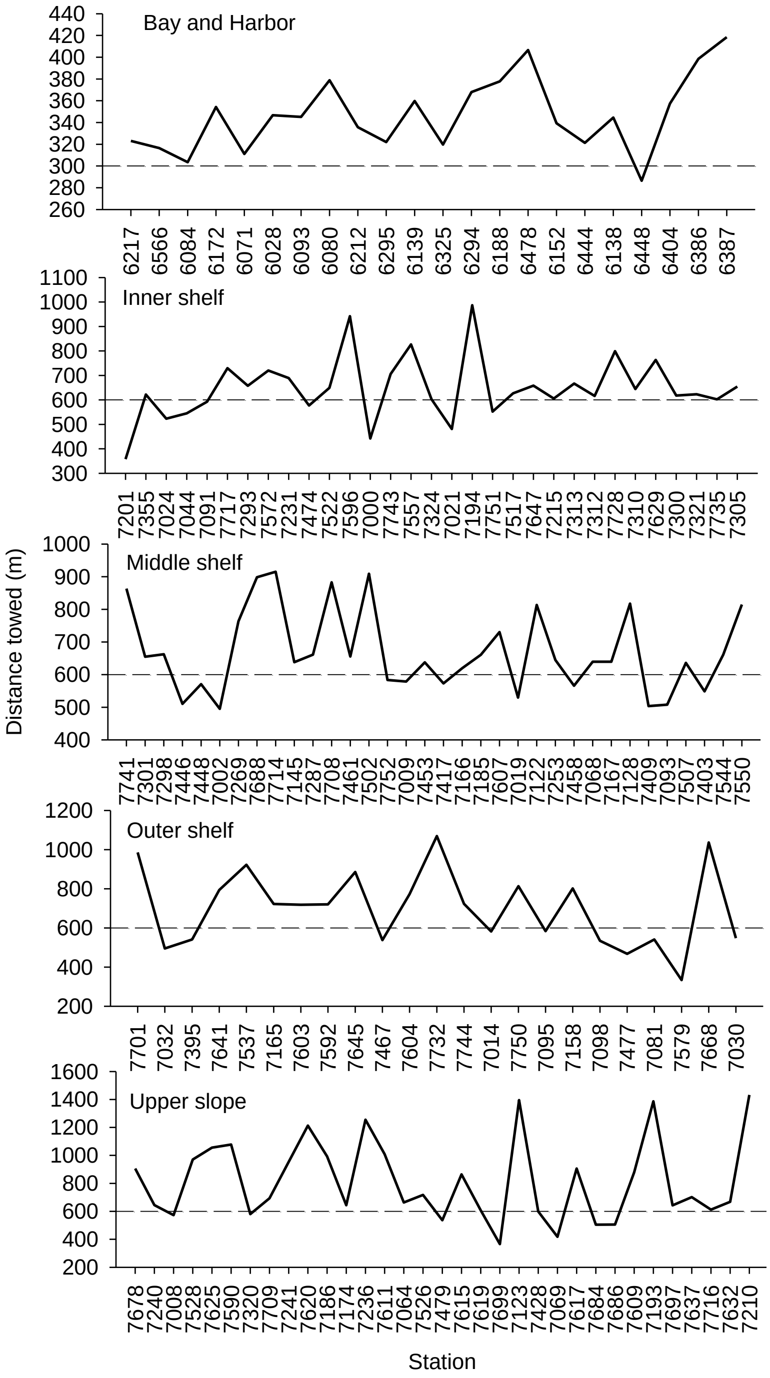

Figure 1. Station-specific trawl distance by shelf strata with station depths increasing from left to right along x-axis in each strata. Dashed lines represent the expected trawl distance by a 5-min tow (Bay and Harbor) or a 10-min tow at all open coast stations sampled in summer 2008.

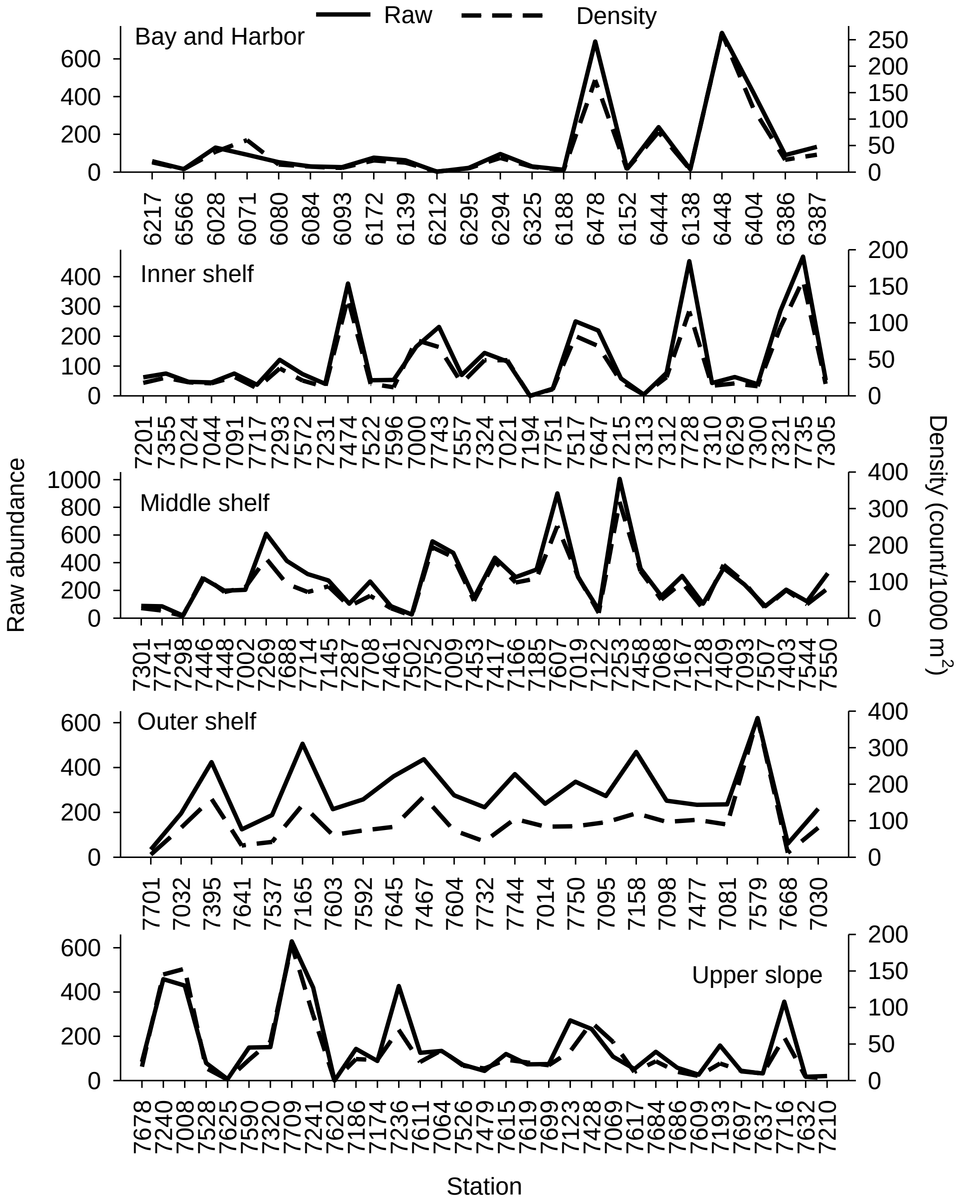

Figure 2. Raw catch and standardized density (count/1000 m^2) for each station in each depth strata recorded during the summer 2008 Southern California Bight demersal fish sampling program. Sampling station depth increases from left to right along the x-axis in each strata.

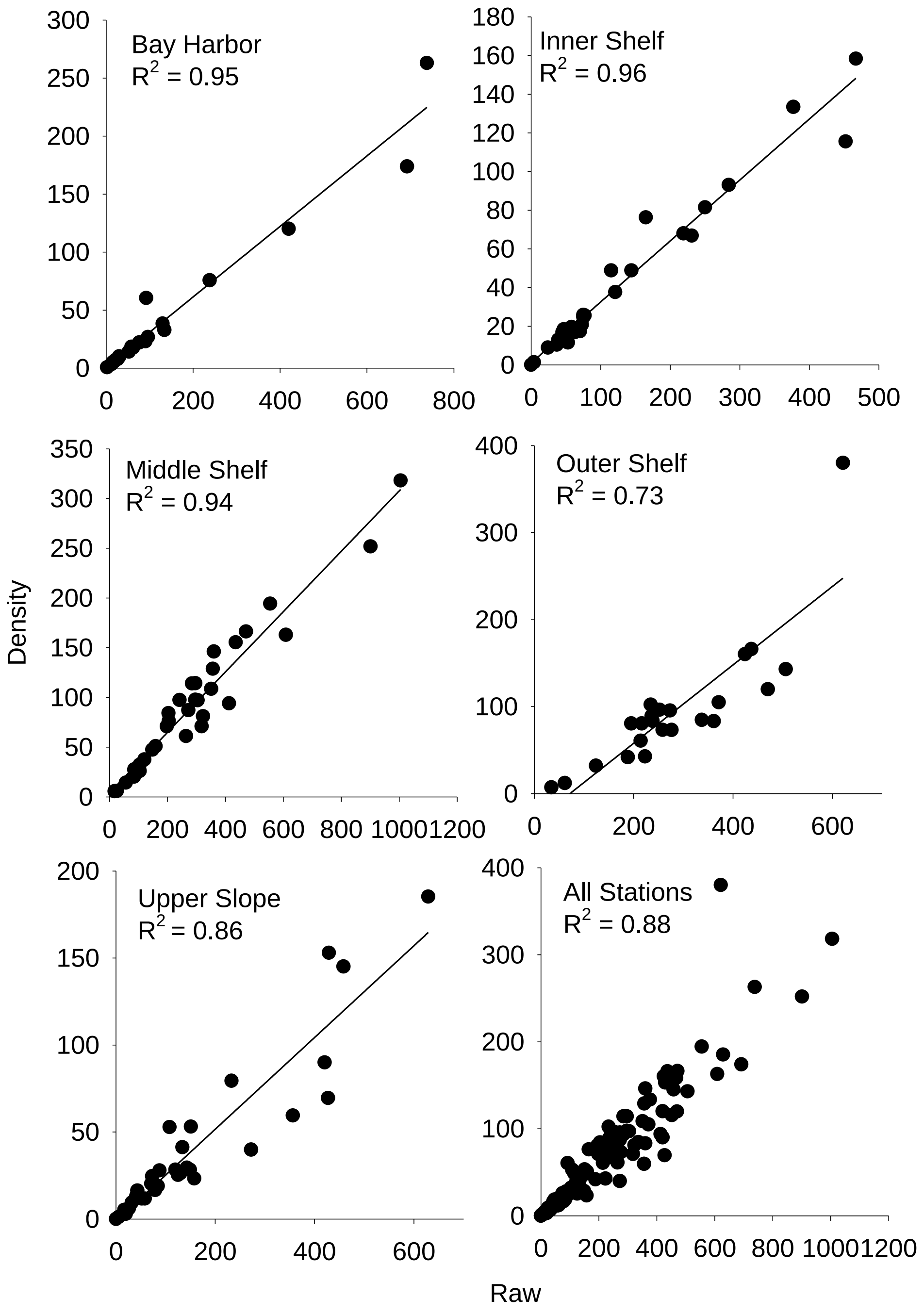

Figure 3. Scatterplot comparison of station-specific raw abundances (after doubling of all 5-min tow catches in bays/harbors) and densities (count/1000 m^2) recorded during the summer 2008 Bight demersal fish sampling.

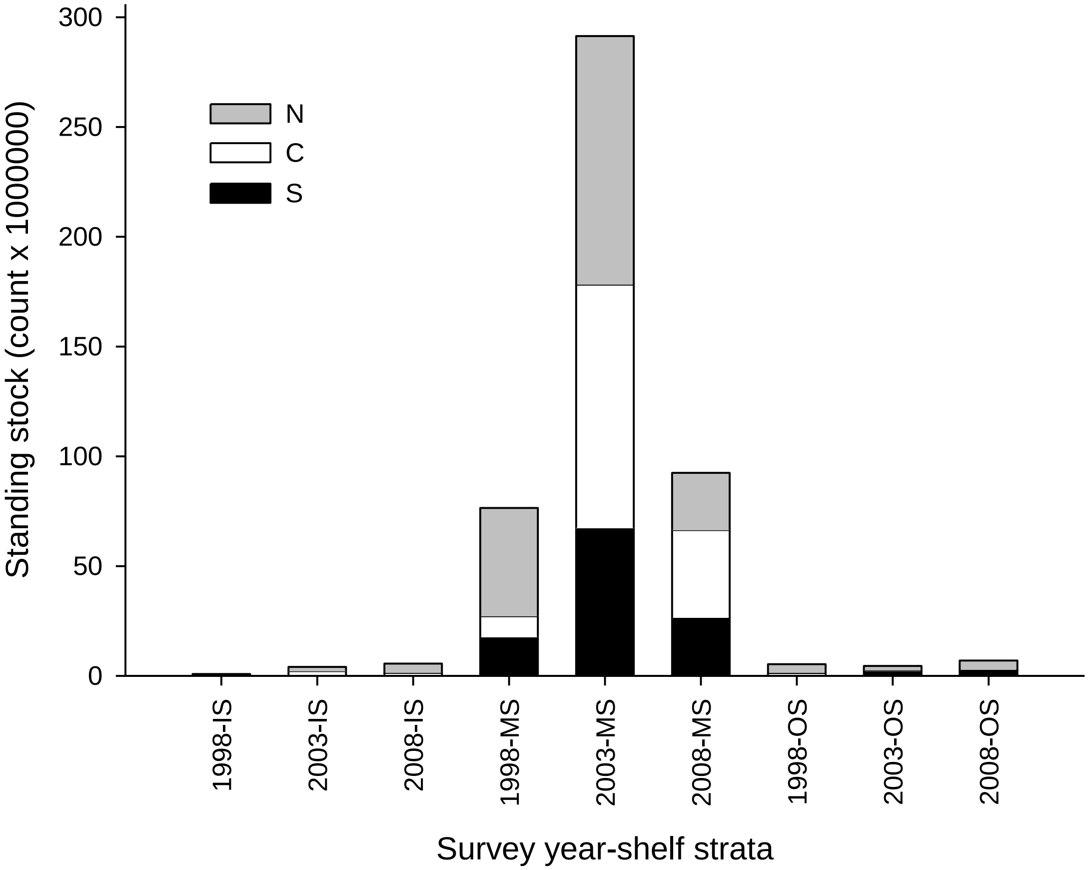

Figure 4. Estimated standing stock of Pacific sanddab by survey year, shelf strata, and latitudinal area along the Southern California Bight based on summer otter trawl sampling in 1998, 2003, and 2008. IS = inner shelf (5 - 30 m), MS = middle shelf (31 – 120 m), OS = outer shelf (121 – 200 m), S = South (< 33.5°N), C = Central (33.5 – 34.0), and N = North (> 34°N).

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

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Abstract

In an effort to better characterize the spatial dynamics of the assemblage the demersal fish communities throughout the Southern California Bight (Point Conception, California to the United States-Mexico border) were sampled in 2008 utilizing standardized methods under an inter-agency program. Otter trawl sampling was conducted in habitats ranging from select bays and harbors out to the upper continental slope. Pacific sanddab (*Citharichthys sordidus*) was the most commonly caught species and contributed the greatest biomass. The catch compositions at each site generally segregated along depth gradients, but not latitudinal gradients except for within the bay/harbor strata. The largest catches were recorded in the central area, which includes the Santa Monica Bay and the Los Angeles/Long Beach Harbor. Offshore densities peaked along the middle and outer shelf (30 – 200 m depth). Species diversity was comparatively stable and elevated along the deeper portions of the continental shelf relative to the inner shelf (< 31 m depth) with the minimum diversity recorded in the southern portion of the inner shelf.

Introduction

The Southern California Bight (SCB) is a diverse area characterized by heterogeneous habitats (Dailey et al. 1993), the convergence of the cold southward flowing California Current and the warm poleward flowing California Countercurrent (Hickey 1992), a variable width continental shelf, and multiple, densely populated, metropolitan areas (e.g. Los Angeles, San Diego, etc.). Fishes within the SCB represent a transitional fauna indicative of the dynamic environmental conditions present, with species representative of the Oregonian and San Diegan biogeographic provinces commonly occurring in the area (Horn et al. 2006).

Environmental conditions can fluctuate widely on annual to decadal scales, often related to larger scale oceanographic phenomena affecting the California Current such as El Niño Southern Oscillation (ENSO) events (1997-98 ENSO; McGowan et al. 2003) or variability in the strength and position of the Aleutian Low (Bograd and Lynn 2003). Both low- and high-frequency variability has been linked to marked changes in the abundance and distribution of fishes, including demersal species (Mearns 1979; Stull and Tang 1996; Perry et al. 2005; Hsieh et al. 2009). Recent identification of declining dissolved oxygen concentrations and an expanding oxygen minimum zone (OMZ) in the Eastern North Pacific basin, and its potential negative impact on demersal and benthic life raises additional concern (Levin 2003; Grantham et al. 2004; Powers et al. 2005; Bograd et al. 2008; Chan et al. 2008; Diaz and Rosenberg 2008; McClatchie et al. 2010). Within the SCB specifically, Bograd et al. (2008) identified areas with the highest rate of dissolved oxygen decline along the inner and middle shelves near the greater Los Angeles and Orange County, California coastlines.

While fishes typically exhibit population level responses to environmental variation (Juan-Jorda et al. 2009), these oscillations can be exaggerated or masked by anthropogenic impacts such as harvesting (Brander 2007; Perry et al. 2010; Hidalgo et al. 2011), habitat alteration (Dayton et al. 1995), and ocean discharge from both point (e.g. wastewater discharge) and non-point sources (e.g. storm drain; Allen 2006a). Historically, SCB demersal fish community changes were traced to effects of wastewater discharge through either altered community demographics (composition, abundance, species diversity, etc.) or prevalence of tumors and other physical abnormalities (Perkins 1995; Stull and Tang 1996; Allen 2006a). While most wastewater discharge effects on the demersal fish community have subsided (Stull and Tang 1996; Allen 2006a,b), impacts of fishing and other anthropogenic interactions with the coastal waters can still be detected (Schroeder and Love 2002). Concerns over large, point-source ocean discharges resulted in permit-required demersal fish monitoring (Mearns 1979; Love et al. 1986; Stull and Tang 1996). Demographic indices (abundance, biomass, composition, etc.) on the demersal fish stocks of the SCB shelf are routinely monitored through this permit-required monitoring.

Despite the level of effort devoted to monitoring, however, little primary research documenting the soft-bottom demersal fish communities of the SCB beyond site-specific programs (see Stull and Tang 1996) has been published in the primary literature (but see Allen et al. [2007[9]] for related regional monitoring reports) since Love et al. (1986), which was limited to communities inshore of the 20-m isobath. An integrated, area-wide sampling effort utilizing standardized methods can provide the necessary robust snapshot of baseline conditions to not only provide context for site-specific monitoring results but also, after repeated surveys, provide tractable evidence of community changes (Bertrand et al. 2002). The Southern California Bight 2008 Monitoring Program (Bight 2008) was conducted to provide this general overview of the

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[9] Allen, M.J., T. Mikel, D. Cadien, et al. 2007. Southern California Bight 2003 Regional Monitoring Program: IV. Demersal fishes and megabenthic invertebrates. Southern California Coastal Water Research Project. Costa Mesa, California.

SCB demersal fish community spatial dynamics. It was the fourth such survey conducted in the area since 1994, but only the results of the most recent survey were examined. Utilizing the Bight 2008 results, this study aims to describe the spatial pattern of the SCB soft-bottom demersal fish stocks with a specific goal of characterizing the assemblage variability between discrete depth strata and latitudinal regions, for both the community as a whole but also at species-specific levels. Such information is lacking in the recently published literature and will likely benefit future evaluations of the various anthropogenic and environmental factors previously mentioned, e.g. the expanding OMZ, for which insufficient paired data (e.g. fish abundance with concurrent oxygen measurement) currently exists at a spatial scale similar to that of the Bight surveys.

Materials and Methods

Sampling Station Description – Demersal fish on soft-bottom habitat were sampled at 143 stations by otter trawl across the SCB at stations using a probability based design (Stevens 1997) that selects sampling sites *a priori* among areas determined to be free of obstructions (able to be sampled with an otter trawl) based on reviews of bathymetric maps (fig. 1). During the Bight 2008 planning, stations were segregated into discrete shelf (depth) strata and latitudinal groups. To account for differences between expected and actual depths at each sampling site, all open coast data were reclassified after sampling into consistent shelf strata by actual sampling depth: 5-30 m = inner shelf (IS), 31-120 m = middle shelf (MS), 121-200 m = outer shelf (OS), and > 200 m = upper slope (US). Sampling results from bays and harbors remained classified into the bay/harbor (BH) shelf strata. Within each stratum, latitudinal distributions were designated as: > 34°N = north, 33.5 - 34°N = central, and < 33.5°N = south. Henceforward, shelf strata-region combinations (e.g. IS-S) are referred to as blocks (e.g. IS-S block) for simplicity.

Sampling Methods – Sampling was completed during the summer (July – September, 2008) with 7.6-m head-rope semi-balloon otter trawl nets fitted with 1.25-cm cod-end mesh during daylight hours. Trawls were towed along open-coast isobaths for ~10 min (~5 min in bays and harbors) at 0.8-1.0 m/sec. These tows were designed to cover an estimated distance of 300 and 600 m for 5 and 10 min trawls, respectively. The actual trawl distance was calculated from the difference between the start and stop fishing GPS coordinates recorded on the deck of the towing vessel. These acted as a proxy for the net's relative position. It was assumed the net remained on the bottom and fishing the entire time. Upon retrieval, catches were sorted, identified to species, enumerated, and batch weighed to the nearest gram (g). Each station was sampled once per survey. Catches from sampling events aborted due to equipment malfunction or protocol violations were discarded and the station was resampled, if possible.

Data Analysis – The analysis focused on the demersal communities; therefore pelagic, midwater fishes (Allen and Pondella 2006), e.g. northern anchovy (*Engraulis mordax*), were excluded as their catches likely include sampling during midwater deployment or retrieval (Biagi et al. 2002). Underwater measurements by Environmental Quality Analysts and Marine Biological Consultants (1975) determined the 7.6-m trawl net used in all four Bight surveys spread 4.9 m, on average, while under tow and fishing. The area swept in this analysis represents the distance trawled (m) x 4.9 m. Densities represent the abundance (biomass) per area swept (m^2).

Mean density (count/1000 m^2) for each species and its frequency of occurrence in individual trawl samples were derived by shelf strata. The mean density by block (e.g. inner shelf south) for the 21 most abundant species caught across the three open coast shelf strata (inner, middle, and outer shelf). Based on the probabilistic design, density by stratum was area-weighted using the ratio estimator approach following Thompson (1992):

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

Where:

m = Area-weighted mean density for stratum j.

p_i = Parameter value (e.g., density) at station i.

w_i = Area weight for station i.

n = Number of stations in population j.

The standard error of the mean was calculated using the following equation where the 95% confidence intervals about the mean were calculated as 1.96 times the standard error.

$$\text{Standard error (SE)} = \sqrt{\frac{\sum_{i=1}^{n}((p_i - m) * w_i)^2}{\left(\sum_{i=1}^{n} w_i\right)^2}} ,$$

where:

m = Area-weighted mean concentration for population j.

p_i = Parameter value (e.g., density) at station i.

w_i = Area weight for station i.

n = Number of stations in population j.

Differences in the species-specific densities between blocks were compared using a one-way ANOVA with a Bonferroni multiple comparison test after Ln (x+1) transforming the data (Sokal and Rohlf 1995). The Pacific sanddab (*Citharichthys sordidus*) and hornyhead turbot (*Pleuronichthys verticalis*) distributions were the only ones to meet the parametric assumptions after transformation. A Kruskall-Wallis ANOVA, correcting for ties, (Sokal and Rohlf 1995) was used to compare block-specific patterns in the remaining 19 species. The Shannon-Wiener species diversity index (Shannon and Weaver 1962) was derived based on the raw counts by block. Species diversity by block was compared using a Kruskall-Wallis ANOVA, correcting for ties, using station-specific values. All comparisons were executed using Number Cruncher Statistical Software (Hintze 1998). Each species' significance to the shelf stratum community was described using the rank of the index of community importance (ICI; Stephens and Zerba 1981; Love et al. 1986). Differences in assemblages between regions within each shelf stratum were subjectively examined using the species abundance distributions (SAD; McGill et al. 2007) among the ten most abundant species in each shelf stratum. The station-specific proportion of the total catch in each block and the mean across all stations in each block were derived to illustrate comparative changes in the species rank abundance with latitude. Spearman rank correlation was used to compare the means among the regions within each shelf stratum with n = 10 (species included) in all comparisons.

Similarities along the full latitudinal and depth gradients sampled were characterized using percent similarity index (PSI, Whittaker 1952; Whittaker and Fairbanks 1958) using the equation: $\text{PSI} = 100 - 0.5 * \sum \left| A_i - B_i \right|$ where A_i and B_i are the percentages of species i in samples *A* and *B*, respectively. Stations were segregated into 0.2° latitude bins for spatial analysis and 20-m bins for depth analysis. Each PSI distribution was evaluated to determine if the pattern fit either a linear or non-linear regression model. Non-metric multidimensional scaling (nMDS) was used to illustrate the station groupings within each shelf strata based on the observed assemblage after the calculation of Bray-Curtis dissimilarities of fourth-root transformed species-specific densities (Clarke and Ainsworth 1993). The bay-harbor strata was excluded from the nMDS analysis due to the lack of a northern region sampling area and the general concentration of sampling in Los Angeles and Long Beach harbors within the central region (fig. 1). A similar nMDS analysis was done to visualize the relationships between the block species diversities after calculation of the Bray-Curtis dissimilarities. These data were not transformed prior to calculation of the dissimilarities. Station-specific diversities were included in the analysis, similar to the execution of the Kruskall-Wallis ANOVA, correcting for ties. All nMDS analyses were completed using SYSTAT v. 9.0 (SYSTAT 1998).

Results

Appendix A includes a master species list of all fishes caught during the 2008 sampling while appendices B1-B5 list the mean density (± standard error), frequency of occurrence, and ICI rank by shelf stratum for all fishes caught. A total of 26,546 fish weighing 932.215 kg representing 133 demersal species were caught amongst 143 stations dispersed across five shelf strata spanning three designated latitudinal regions of the SCB (tab. 1 and fig. 1). Fish were caught at all but three stations, one each in the BH-S, IS-S, and US-N blocks. Sampling stations were randomly distributed over the soft-bottom habitat although some blocks were more intensively sampled (e.g. US-N) than others (e.g. OS-C; tab. 1). Pockets of elevated densities (count/1000 m^2) were observed in the Santa Monica Bay, Los Angeles and Long Beach harbors, and offshore of San Diego. Additional individual sampling sites outside these areas registered elevated densities, but their occurrence was not as clustered. The Santa Monica Bay and offshore San Diego abundance hot spots were primarily from the MS and OS strata. Relatively high density catches (> 101 fish/1000 m^2) were recorded at three IS stations, with two out of the three in the northern region. Similarly high density catches were also comparatively rare in the US with sampling at two stations recording densities greater than 101 fish/1000 m^2. Biomass records (kg/1000 m^2) suggested a more dispersed pattern for the above average catch weights, although stations in the Los Angeles and Long Beach harbor area and offshore of San Diego continued to record above average values. Species diversity ranged wildly among blocks, but was lower along the IS and BH shelf strata while relatively stable throughout the deeper sampling areas (fig. 2a). Peak diversity occurred along the MS-S with diversity at all but one station greater than 1.50 while the IS-S recorded the lowest diversity with all station-specific H´ < 1.40. Blocks with predominately H´ < 1.50 were segregated from the main grouping in the nMDS (fig. 2b), resulting in a significant difference between station-specific diversity (KW, H = 37.25, df = 13, $p < 0.001$).

The SADs by block revealed community variation along a latitudinal gradient within each shelf stratum (fig. 3). Differences between the two BH regions were the most pronounced; white croaker (*Genyonemus lineatus*) dominated the BH-C but was minimally abundant in the BH-S. This was the only shelf stratum where a negative correlation was detected between latitudinal regions ($r = -0.69$, $p < 0.02$). No significant correlations were detected for the IS between regions. This was consistent with the steady dominance of speckled sanddab (*Citharichthys stigmaeus*) throughout the stratum but variability among the lesser abundant species differentiated the regions. The same was true along the MS, except that Pacific sanddab replaced speckled sanddab as the dominant form. Along the OS and US, each region significantly correlated with the next most southerly region (OS-N:OS-C, r = 0.89, p<0.01; OS-C:OS-S, r = 0.62, p = 0.05; US-N:US-C, r = 0.71, p = 0.02; US-C:US-S, r = 0.76, p < 0.001). No correlations, positive or negative, were detected between the northernmost and southernmost regions in any shelf stratum. Other than in the BH stratum, only the OS-C block community exhibited a substantial decline in the proportional contribution of the most abundant species across the stratum, Pacific sanddab.

Distribution of the 21 most abundant species, overall, revealed significant differences in their occurrence among the three shallowest offshore blocks (fig. 4, tab. 2). These differences were often predicated on a species complete or near-complete absence at select blocks. Four species were either entirely or largely absent outside of one stratum. Of these, splitnose rockfish (*Sebastes diploproa*) was uniquely caught in one stratum (OS), the remaining three species were represented by densities < 2% of their peak block outside of their principle stratum. Only English sole (*Parophrys vetulus*) was caught in all blocks, although their peak densities were recorded in the MS-N. Pacific sanddab was the most common species (fig. 4), ranking first in abundance and the MS and OS ICI (Appendices B-3 and B-4). Speckled sanddab occupied the top rank in both categories along the IS, while slender sole (*Lyopsetta exilis*) ranked first along the US in both metrics (Appendix B-5). Speckled sanddab dominated the shallower IS sampling before its abundance diminished with depth where it was replaced by Pacific sanddab in the MS and OS sampling which ultimately gave way to slender sole at the greatest depths sampled.

The PSI calculated across the shelf stations (IS, MS, OS) indicated limited differences along the latitudinal gradient, although a depression was observed at ~ 33ºN, or offshore of northern San Diego County (fig. 5a). Distance between stations did not result in a predictable pattern (fig. 5b). Stations along the north – south latitudinal gradient by shelf strata were generally overlapping in the nMDS analysis (fig. 6). Subtle gradients were observed in the IS and US, but stations from other regions were interspersed throughout the 2D space. Catches between ~ 160 and 420 m had the highest mean PSI scores (30-40%), but little similarity overall was detected with depth outside the immediately proximate depth bins (fig. 5c). Few comparisons exceeded 60% similarity, with a large proportion at < 10% similarity. Similarity between depth-stratified catches declined in a linear pattern ($R^2 = 0.58$) with a negative slope ($m = -0.16$) as increasing differences in depth reduced the similarity between two catches (fig. 5d).

Discussion

Demersal fish sampling in 2008 recorded a diverse and spatially distinct soft-bottom demersal community across the SCB. As expected, there was a clear difference in the species composition between the BH and offshore strata. Most species taken in BH sampling were absent or minimally present at sampling sites from the continental shelf or upper slope. Of the shelf sites, differences in species composition occurred with increasing depth. Abundance and diversity was much greater at MS and OS depths in comparison to the IS. The greatest abundance in trawl catch was observed in MS and OS depths offshore Santa Monica Bay and San Diego. In the BH straum, substantially elevated abundance was observed in the Los Angeles and Long Beach Harbor. Finally, there was little difference in species composition across latitudinal gradients on the continental shelf, although shifts in species composition were observed in the BH stratum moving north to south.

The results observed during this survey were indicative of results from previous studies, such as depth stratification of the dominant flatfishes (Fager and Longhurst 1968; Biagi et al. 2002; Allen 2006b; Allen and Pondella 2006). For example, the prevalence of sanddab species, especially speckled sanddab and Pacific sanddab, has been a consistent biological feature in the SCB for over 30 years (Love et al. 1986; Stull and Tang 1996; Mearns 1979). These dominant flatfishes stratified by depth along the continental shelf in 2008; speckled sanddabs occurred shallow (<30m), before transitioning to Pacific sanddab, and then slender sole in the deepest reaches (>200m). This is also consistent with past survey results (Stull and Tang 1997) and Allen's (2006b) soft-bottom fish community functional structure.

Results observed during this survey were also not indicative of studies previously published in the peer-reviewed literature. For example, the Los Angeles and Long Beach harbors area was numerically dominated by white croaker and queenfish (*Seriphus politus*), whereas these species were caught in only 4% of the remaining SCB. The comparatively low abundances of white croaker along the open coast and in the southern BH varies dramatically from Allen (2006b) who indicated that the white croaker foraging guild occurred in >20% of all samples he examined from the IS and MS. Previously, demersal fish sampling inside of the 20-m isobaths along the SCB open coast consistently recorded both queenfish and white croaker among the most abundant species, with either one often ranking first in abundance (DeMartini and Allen 1984; Love et al. 1986). Stull and Tang (1996) first reported on the area's white croaker decline using identical techniques as the current investigation. The demise of white croaker and queenfish, especially within the central region, is consistent with the reported correlations between the planktivorous queenfish and declining nearshore zooplankton volumetric biomass beginning circa 1980 (Miller et al. 2009). Unfortunately, no studies have examined the feeding preferences of these species over time to determine if there has been an transition in prey selection commensurate with any detectable changes in the available prey items.

The presence of latitutinal gradients in demersal fishes has been more equivocal. For example, variations in the SADs between regional areas for each open coast shelf stratum were muted in 2008. While some community variability was detected, which may indicate some latitudinal differences within shelf stratum, it was not at a statistically significant level. However, Love et al. (1986) found significant differences with latitude, but their sampling was more intensive and focused on a limited depth range. Hence, the relatively small sample size and large spatial scale may play a role in our study, with the interaction of the two masking potential latitudinal differences.

Demonstrative conclusions regarding factors (outside of depth influences) stimulating the dispersion of soft-bottom demersal fishes in the SCB is outside the scope of one set of summer samples. These patterns, however, do provide baseline information for future comparisons. As such, these data begin to address a critical void in our ability to evaluate impacts from growing concerns, particularly at large spatial scales, such as the expanding OMZ. Given the previously documented devastating effects of nearshore hypoxia (Grantham et al. 2004), the need for baseline ecological information is becoming increasingly apparent. Programs such as the Bight 2008 demersal fish study may begin to fill this void, especially if future renditions were able to pair fish sampling with concurrent dissolved oxygen concentration measurements.

Conclusions – The SCB demersal fish community was diverse and largely depth-stratified in 2008. Comparisons with previous reports indicated changes in the faunal composition have occurred, specifically the decline of the once abundant sciaenids white croaker and queenfish while various flatfish, especially sanddabs, continue to dominate the system. Bays and harbors remain unique along the SCB with several species largely limited to these areas.

Likewise, the most abundant species on the upper slope were relatively uncommon along the other strata. The remaining shelf strata had a high degree of overlap amongst the species.

Acknowledgements – This report was prepared under the auspices of the Bight'08 Regional Monitoring Program and benefitted from comments and discussions with the Bight '08 Trawl Report Group. We would like to thank all the agencies participating in the regional survey. Kerry Ritter provided pivotal help in survey design. Comments by D.S. Beck and two anonymous reviewers greatly improved this manuscript. J. Rankin provided significant assistance with the preparation of the maps used. Discussions with C. Thomas significantly contributed impetus to undertake this analysis. This work was inspired by R.A. Miller.

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Table 1. Number of stations by shelf strata and latitudinal region sampled during the 2008 Southern California Bight monitoring survey.

Shelf Strata	Latitudinal Region	Number of Stations
Bays and Harbors	Central	6
	Southern	16
Strata Total		22
Inner Shelf (5-30 m)	Northern	12
	Central	13
	Southern	7
Strata Total		32
Middle Shelf (31-120 m)	Northern	9
	Central	13
	Southern	11
Strata Total		33
Outer Shelf (121-200 m)	Northern	11
	Central	3
	Southern	9
Strata Total		23
Upper slope (200-500 m)	Northern	20
	Central	9
	Southern	4
Strata Total		33
Total Number of Stations		143

Table 2. Results of one-way ANOVA (ANOVA) or Kruskall-Wallis (KW) test comparing the shelf strata-region trawl caught densities (count/1000 m^2) for the 21 species most commoly captured during the 2008 Southern California Bight monitoring survey. Inner shelf (IS), Middle shelf (MS), Outer shelf (OS), North (N), Central (C), and South (S). See text for depth ranges and latitudinal ranges for each shelf stratum and latitudinal region.

Species	Test	Statistic	DF	p	Significantly Differing Strata
Pacific sanddab	ANOVA	8.20	8,79	<0.001	IS:MS, OS
slender sole	KW	76.34	8	<0.001	OS: IS, MS
hornyhead turbot	ANOVA	5.71	8,79	<0.001	IS-C:MS, OS, IS-N; MS-C:OS
plainfin midshipman	KW	34.40	8	<0.001	IS-N & IS-S:MS-N, MS-S, OS-N; IS-C:MS, OS-C, OS-N
English sole	KW	8.49	8	0.39	NS
speckled sanddab	KW	54.54	8	<0.001	IS:MS, OS; MS-C:OS-N
roughback sculpin	KW	40.42	8	<0.001	MS-C: IS, OS, MS-S; MS-N:MS-C, MS-S; IS-C & IS-S:MS-S;
California lizardfish	KW	19.95	8	0.01	IS-N, IS-S, MS-C, MS-S: OS-N, OS-S
California tonguefish	KW	27.29	8	<0.001	MS-C: IS-C, IS-S, OS; MS-S:IS-S, OS-N, OS-S; OS-C & OS-N:MS
longfin sanddab	KW	46.88	8		MS-S:IS, OS, MS-N, MS-C; MS-C:IS-S, IS-N
calico rockfish	KW	19.38	8	0.01	MS-S:IS, MS-C, OS
yellowchin sculpin	KW	52.15	8	<0.001	MS:IS, OS
halfbanded rockfish	KW	21.29	8	<0.01	OS-S:IS, MS-C, MS-S
longspine combfish	KW	39.93	8	<0.01	MS:IS, MS; MS-C:OS-S; MS-N:OS-N, OS-S; MS-S:OS-N, OS-S
pink seaperch	KW	32.70	8	<0.001	IS-C:MS, IS-N, OS-N;IS-N: MS-S; IS-N:MS-C, MS-N, OS-N; MS-C:OS-S, MS-S; MS-S:OS-S
Dover sole	KW	65.58	8	<0.001	IS:OS, MS-N, MS-S; MS-C:MS-N, MS-S, OS
blackbelly eelpout	KW	47.32	8	<0.001	OS-C:IS, MS, OS-S; OS-N:IS, MS, OS-S
stripetail rockfish	KW	48.62	8	<0.001	IS:MS-N, MS-S, OS; OS-S:MS; OS-N:MS-C
blacktip poacher	KW	61.85	8	<0.001	OS: IS, MS

shortspine combfish	KW	61.81	8	<0.001	IS:OS, MS-N; MS-C:OS; MS-N:OS-S
splitnose rockfish	KW	17.92	8	<0.001	OS-N & OS-S:IS, MS

List of Figures

Fig. 1. Demersal fish sampling stations occupied in summer 2008 distributed among the sampled shelf strata. Total sampling sites = 143. Upper panel depicts the total demersal fish abundance density (count/1000 m^2) recorded at each station per shelf strata. Lower panel depicts the total demersal fish biomass density (kg/1000 m^2) recorded at each station per shelf strata. Isobaths are depicted at 50-m intervals between the 50- and 500-m contour.

Fig. 2. a) Shannon-Wiener species diversity index values for each station (dots) within each shelf strata-region block and the mean diversity for each shelf strata-region block (line). b) Non-metric multidimensional scaling 2D distribution of the shelf strata-region blocks based on station-specific Shannon-Wiener diversity index values. Strata include: bays and harbors (BH), inner shelf (IS), middle shelf (MS), outer shelf (OS), and upper slope (US). Regions include north (N), central (C), and south (S).

Fig. 3. Demersal fish species abundance distribution as the percent of the total catch by shelf strata-region block for the ten most commonly taken species along each shelf stratum. a) Central bay & harbor, b) southern bay and harbor, c) northern inner shelf, d) central inner shelf, e) southern inner shelf, f) northern middle shelf, g) central middle shelf, h) southern middle shelf, i) northern outer shelf, j) central outer shelf, k) southern outer shelf, l) northern upper slope, m) central upper slope, n) southern upper slope. See text for bounds of strata and latitudinal ranges.

Fig. 4. Area-weight adjusted mean density (fish/1000 m^2) per shelf strata-region block for the 21 most commonly occurring species in summer 2008 Southern California Bight demersal fish sampling along the inner shelf (IS), middle shelf (MS), and outer shelf (OS). Latitudinal regions are north (N), central (C), and south (S) as described in materials and methods.

Fig. 5. Percent similarity index (PSI) for the 2008 summer Southern California Bight demersal fish sampling depicting the similarity in catch composition between stations separated by a) 0.2°

latitude bin, b) distance (degree latitude), c) 20-m depth bin, d) difference in depth (m). Solid lines in a and b represent the mean PSI at each x-axis value. Dashed line in d represents the best fit linear regression model ($R^2 = 0.58$) describing the observed pattern.

Fig. 6. Non-metric multidimensional scaling 2D distribution of stations based on sampled community density at each station segregated into latitudinal group (north = N, central = C, south = S) for the inner shelf (IS), middle shelf (MS), outer shelf (OS), and upper slope (US). Letters in each plot represent an individual station within the shelf stratum.

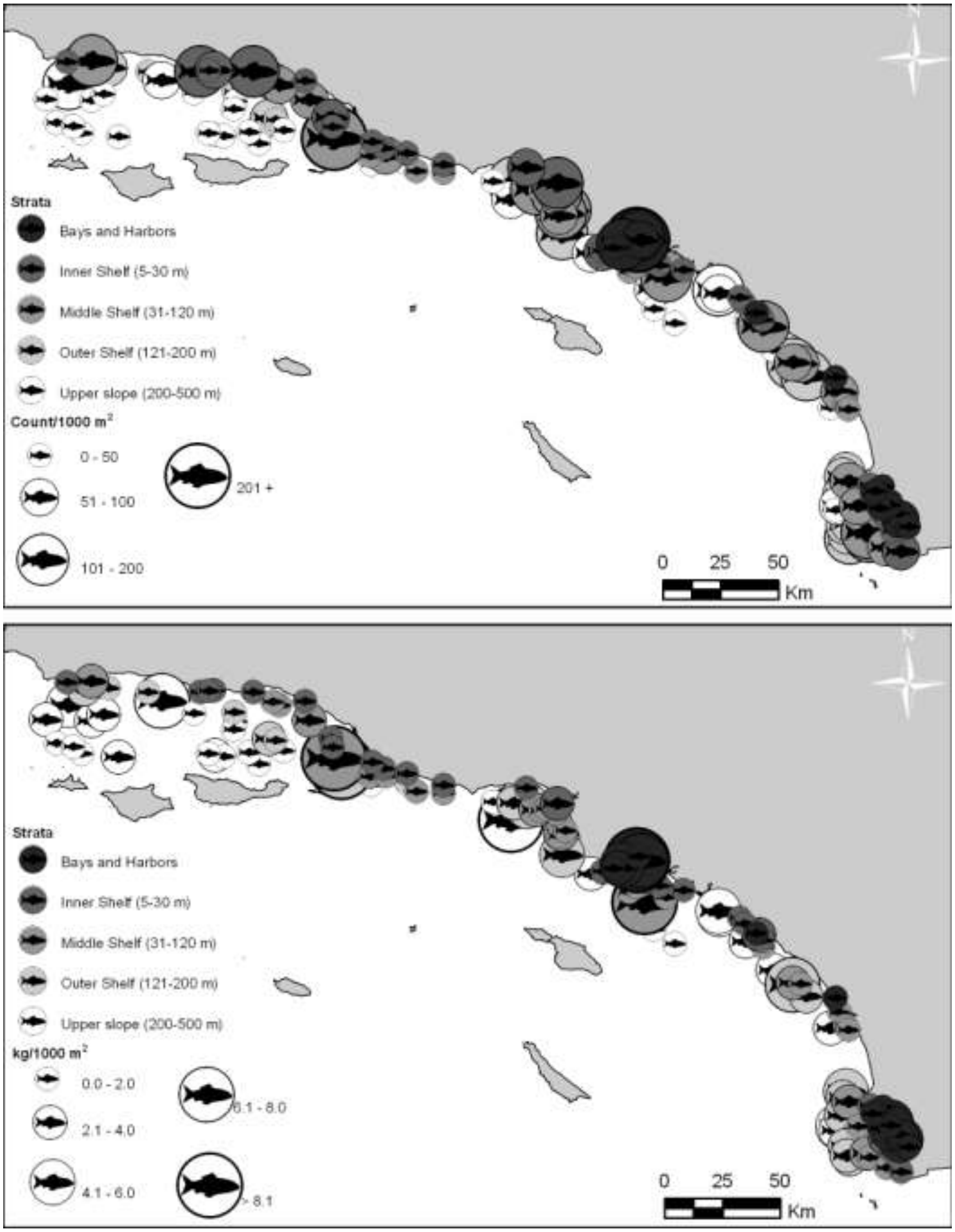

N
Strata
Bays and Harbors
Inner Shelf (5-30 m)
Middle Shelf (31-120 m)
Outer Shelf (121-200 m)
Upper slope (200-500 m)
Count/1000 m²
0 - 50
51 - 100
101 - 200
201 +
0 25 50
Km
N
Strata
Bays and Harbors
Inner Shelf (5-30 m)
Middle Shelf (31-120 m)
Outer Shelf (121-200 m)
Upper slope (200-500 m)
kg/1000 m²
0.0 - 2.0
2.1 - 4.0
4.1 - 6.0
6.1 - 8.0
> 8.1
0 25 50
Km

Fig. 1.

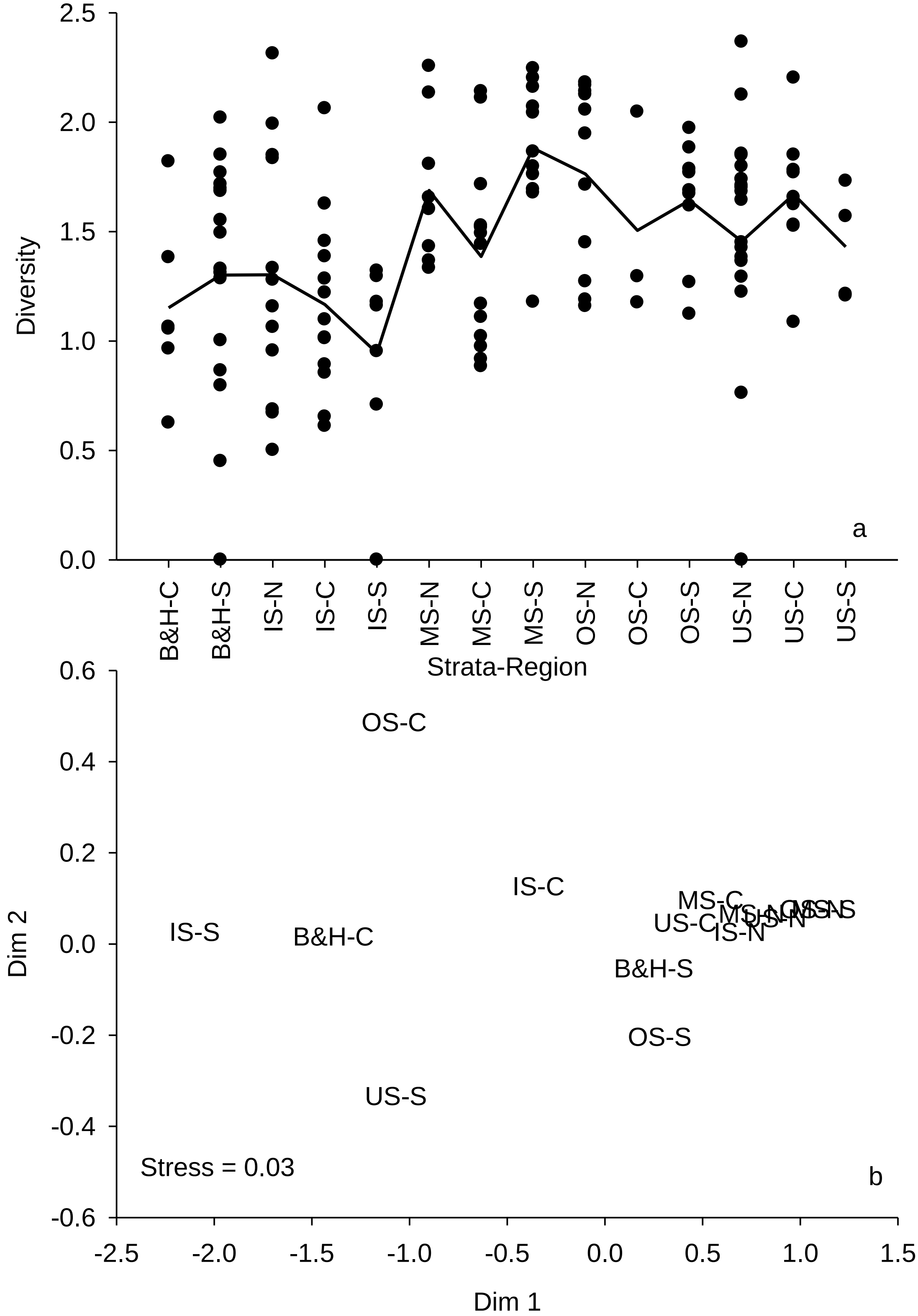

2.5
2.0
1.5
1.0
0.5
0.0
Diversity
a
B&H-C
B&H-S
IS-N
IS-C
IS-S
MS-N
MS-C
MS-S
OS-N
OS-C
OS-S
US-N
US-C
US-S
Strata-Region
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
Dim 2
OS-C
IS-C
MS-C
US-C
IS-N
IS-S
B&H-C
B&H-S
OS-S
US-S
Stress = 0.03
b
-2.5
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
Dim 1

Fig. 2.

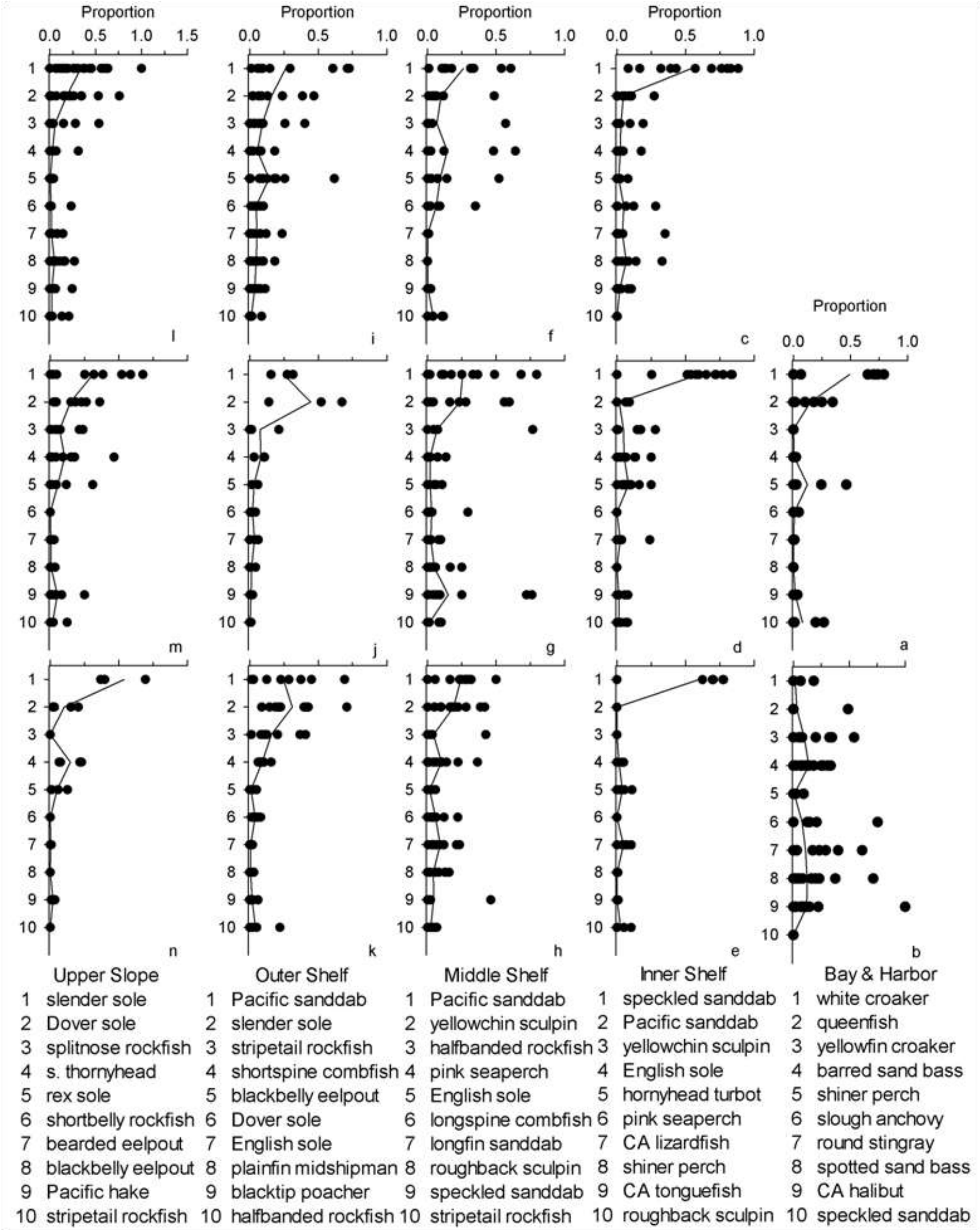
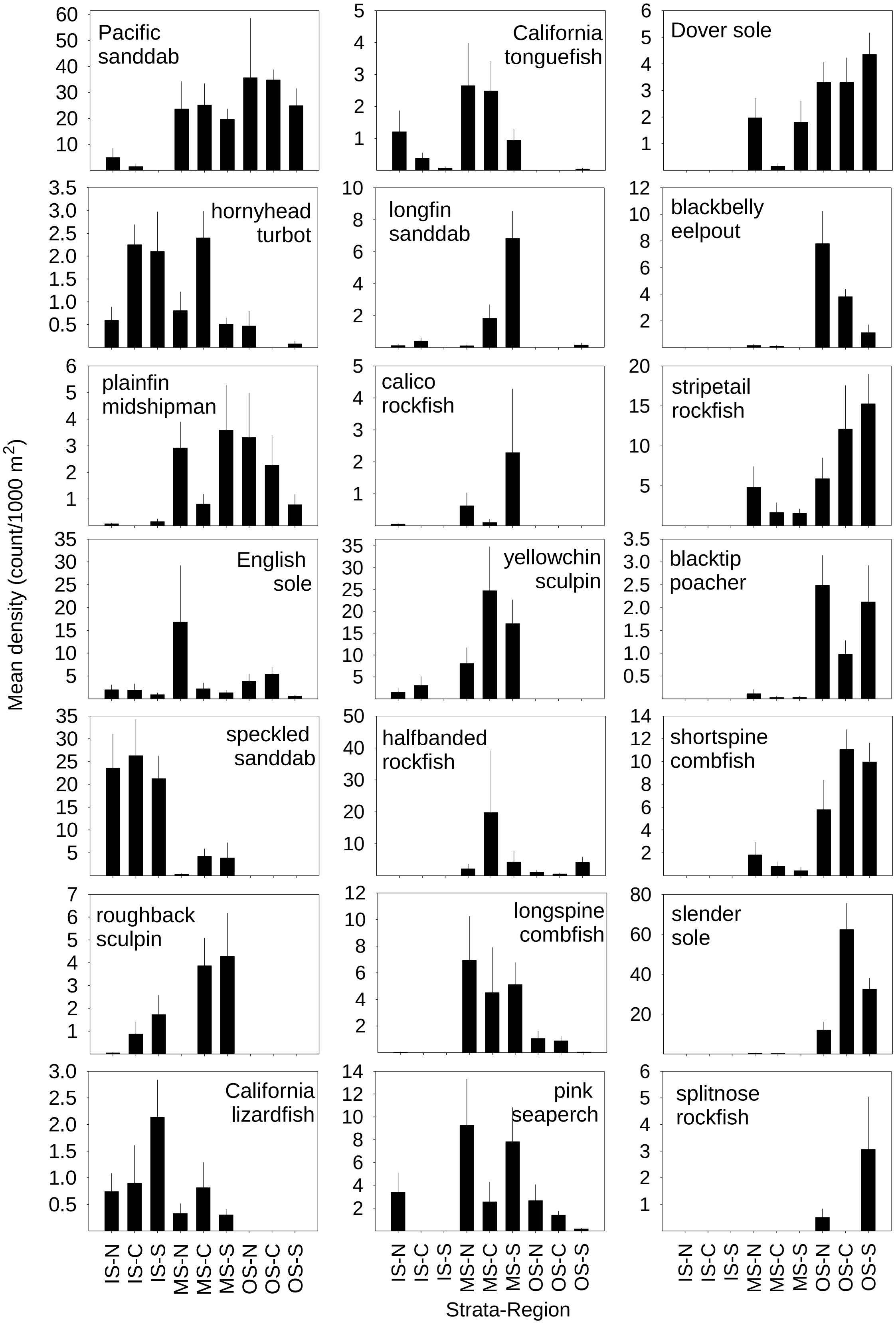
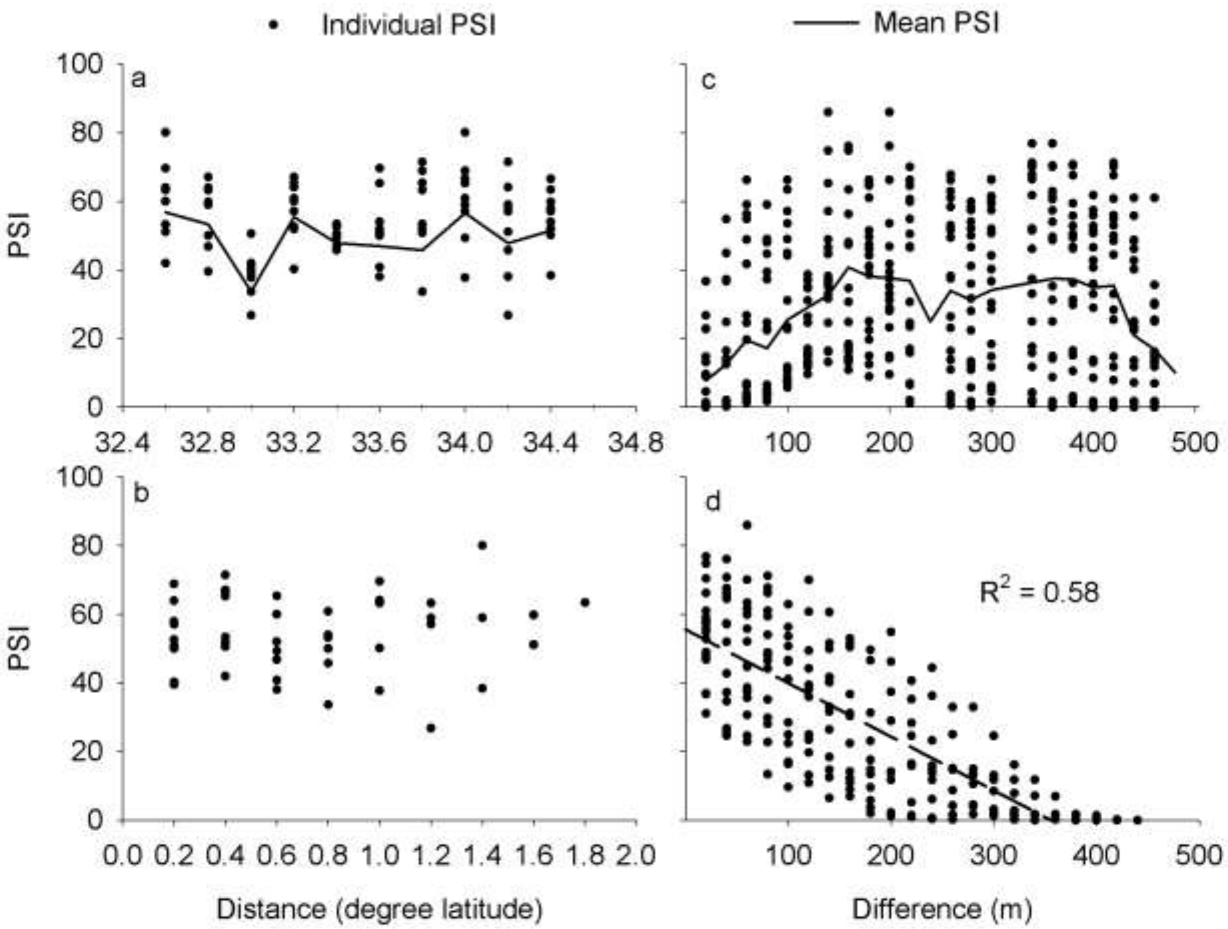
Proportion
0.0
0.5
1.0
1.5
1
2
3
4
5
6
7
8
9
10
l
i
f
c
m
j
g
d
a
n
k
h
e
b
Upper Slope
1 slender sole
2 Dover sole
3 splitnose rockfish
4 s. thornyhead
5 rex sole
6 shortbelly rockfish
7 bearded eelpout
8 blackbelly eelpout
9 Pacific hake
10 stripetail rockfish
Outer Shelf
1 Pacific sanddab
2 slender sole
3 stripetail rockfish
4 shortspine combfish
5 blackbelly eelpout
6 Dover sole
7 English sole
8 plainfin midshipman
9 blacktip poacher
10 halfbanded rockfish
Middle Shelf
1 Pacific sanddab
2 yellowchin sculpin
3 halfbanded rockfish
4 pink seaperch
5 English sole
6 longspine combfish
7 longfin sanddab
8 roughback sculpin
9 speckled sanddab
10 stripetail rockfish
Inner Shelf
1 speckled sanddab
2 Pacific sanddab
3 yellowchin sculpin
4 English sole
5 hornyhead turbot
6 pink seaperch
7 CA lizardfish
8 shiner perch
9 CA tonguefish
10 roughback sculpin
Bay & Harbor
1 white croaker
2 queenfish
3 yellowfin croaker
4 barred sand bass
5 shiner perch
6 slough anchovy
7 round stingray
8 spotted sand bass
9 CA halibut
10 speckled sanddab

Fig. 3



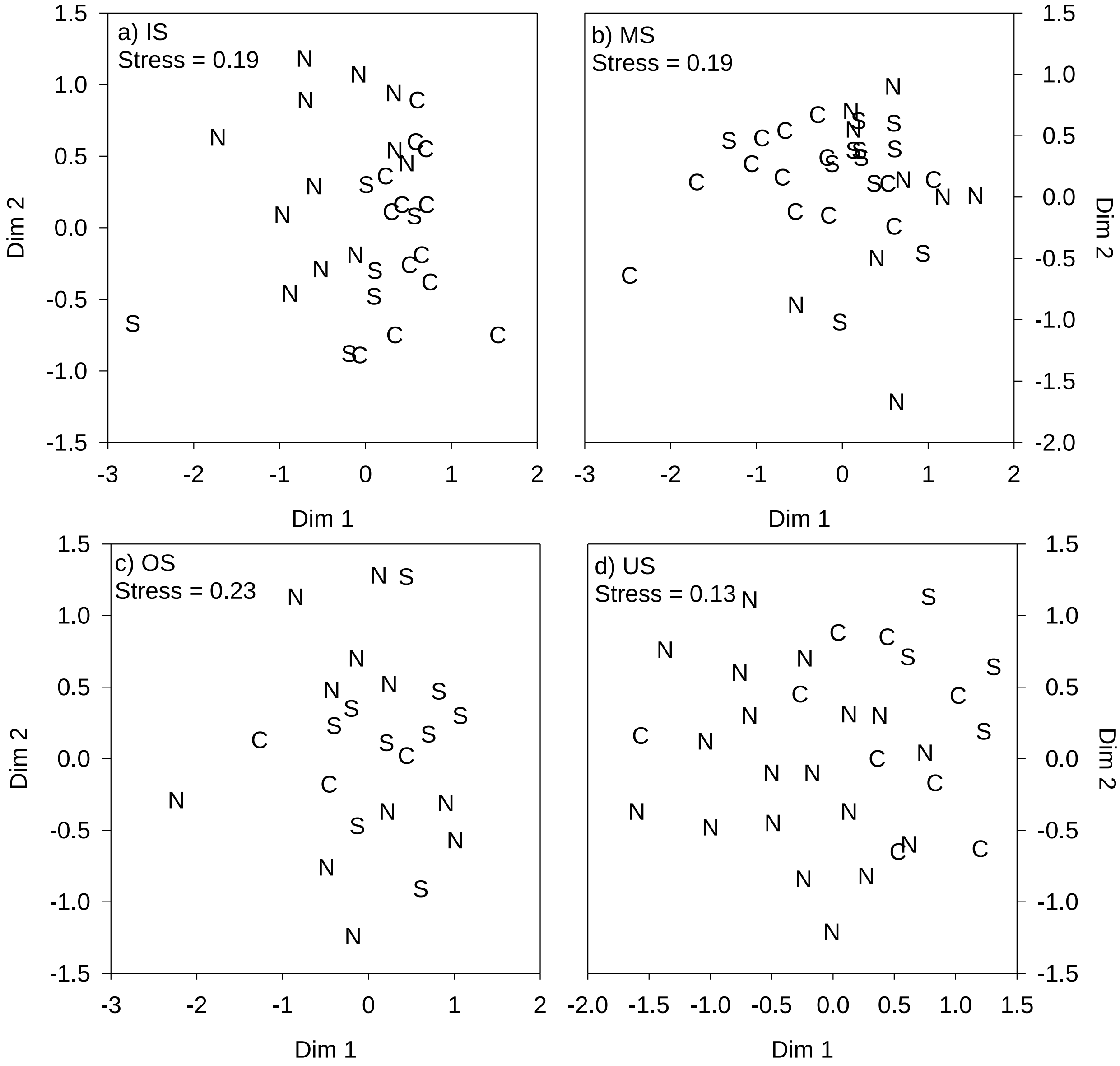
Mean density (count/1000 m²)
Strata-Region
IS-N
IS-C
IS-S
MS-N
MS-C
MS-S
OS-N
OS-C
OS-S
Pacific sanddab
California tonguefish
Dover sole
hornyhead turbot
longfin sanddab
blackbelly eelpout
plainfin midshipman
calico rockfish
stripetail rockfish
English sole
yellowchin sculpin
blacktip poacher
speckled sanddab
halfbanded rockfish
shortspine combfish
roughback sculpin
longspine combfish
slender sole
California lizardfish
pink seaperch
splitnose rockfish

Fig. 4.



● Individual PSI
— Mean PSI
a
b
c
d
PSI
PSI
100
80
60
40
20
0
32.4
32.8
33.2
33.6
34.0
34.4
34.8
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
100
200
300
400
500
$R^2 = 0.58$
Distance (degree latitude)
Difference (m)

Fig. 5



a) IS
Stress = 0.19
b) MS
Stress = 0.19
c) OS
Stress = 0.23
d) US
Stress = 0.13
Dim 1
Dim 2
-3
-2
-1
0
1
2
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
N
S
C

Fig. 6

Appendix A. Master species list of demersal fishes caught during 2008 Southern California Bight regional monitoring program.

Species	Common Name
Agonopsis sterletus	southern spearnose poacher
Anchoa compressa	deepbody anchovy
Anchoa delicatissima	slough anchovy
Anoplopoma fimbria	sablefish
Argyropelecus affinis	slender hatchetfish
Argyropelecus lychnus	silver hachetfish
Argyropelecus sladeni	lowcrest hatchetfish
Artedius notospilotus	bonyhead sculpin
Bathyagonus pentacanthus	bigeye poacher
Bathyraja interrupta	sandpaper skate
Careproctus melanurus	blacktail snailfish
Ceratoscopelus townsendi	dogtooth lampfish
Cheilotrema saturnum	black croaker
Chilara taylori	spotted cusk-eel
Chitonotus pugetensis	roughback sculpin
Citharichthys fragilis	Gulf sanddab
Citharichthys sordidus	Pacific sanddab
Citharichthys stigmaeus	speckled sanddab
Citharichthys xanthostigma	longfin sanddab
Cymatogaster aggregata	shiner perch
Embiotoca jacksoni	black perch
Enophrys taurina	bull sculpin
Eopsetta jordani	petrale sole
Eptatretus deani	black hagfish
Eptatretus stoutii	Pacific hagfish
Facciolella equatorialis	dogface witch eel
Genyonemus lineatus	white croaker
Gibbonsia elegans	spotted kelpfish
Gibbonsia metzi	striped kelpfish
Glyptocephalus zachirus	rex sole
Gymnura marmorata	California butterfly ray
Heterostichus rostratus	giant kelpfish
Hexagrammos decagrammus	kelp greenling
Hippocampus ingens	Pacific seahorse
Hippoglossina stomata	bigmouth sole
Hydrolagus colliei	spotted ratfish
Hypsurus caryi	rainbow seaperch
Icelinus burchami	dusky sculpin
Icelinus cavifrons	pit-head sculpin
Icelinus oculatus	frogmouth sculpin
Icelinus quadriseriatus	yellowchin sculpin
Icelinus tenuis	spotfin sculpin
Ilypnus gilberti	cheekspot goby

Species	Common Name
Lepidogobius lepidus	bay goby
Leptocottus armatus	Pacific staghorn sculpin
Lestidiops ringens	slender barracudina
Leuroglossus stilbius	California smoothtongue
Lycodapus fierasfer	blackmouth eelpout
Lycodapus mandibularis	pallid eelpout
Lycodes cortezianus	bigfin eelpout
Lycodes diapterus	black eelpout
Lycodes pacificus	blackbelly eelpout
Lyconema barbatum	bearded eelpout
Lyopsetta exilis	slender sole
Merluccius productus	Pacific hake
Microstomus pacificus	Dover sole
Mustelus henlei	brown smoothhound
Myliobatis californica	bat ray
Nezumia stelgidolepis	California grenadier
Odontopyxis trispinosa	pygmy poacher
Ophiodon elongatus	lingcod
Oxylebius pictus	painted greenling
Paralabrax clathratus	kelp bass
Paralabrax maculatofasciatus	spotted sand bass
Paralabrax nebulifer	barred sand bass
Paralichthys californicus	California halibut
Parmaturus xaniurus	filetail cat shark
Parophrys vetulus	English sole
Peprilus simillimus	Pacific pompano
Phanerodon furcatus	white seaperch
Physiculus rastrelliger	hundred-fathom codling
Platyrhinoidis triseriata	thornback
Plectobranchus evides	bluebarred prickleback
Pleuronichthys decurrens	curlfin sole
Pleuronichthys guttulatus	diamond turbot
Pleuronichthys ritteri	spotted turbot
Pleuronichthys verticalis	hornyhead turbot
Porichthys myriaster	specklefin midshipman
Porichthys notatus	plainfin midshipman
Raja inornata	California skate
Raja rhina	longnose skate
Rathbunella hypoplecta	bluebanded ronquil
Rhacochilus toxotes	rubberlip seaperch
Rhacochilus vacca	pile perch
Rhinobatos productus	shovelnose guitarfish
Rhinogobiops nicholsii	blackeye goby
Rimicola muscarum	kelp clingfish
Roncador stearnsii	spotfin croaker

Species	Common Name
Scorpaena guttata	California scorpionfish
Scorpaenichthys marmoratus	cabezon
Sebastes atrovirens	kelp rockfish
Sebastes aurora	aurora rockfish
Sebastes caurinus	copper rockfish
Sebastes chlorostictus	greenspotted rockfish
Sebastes crameri	darkblotched rockfish
Sebastes dallii	calico rockfish
Sebastes diploproa	splitnose rockfish
Sebastes elongatus	greenstriped rockfish
Sebastes eos	pink rockfish
Sebastes goodei	chilipepper
Sebastes hopkinsi	squarespot rockfish
Sebastes jordani	shortbelly rockfish
Sebastes levis	cowcod
Sebastes melanostomus	blackgill rockfish
Sebastes miniatus	vermilion rockfish
Sebastes rosaceus	rosy rockfish
Sebastes rosenblatti	greenblotched rockfish
Sebastes rubrivinctus	flag rockfish
Sebastes rufus	bank rockfish
Sebastes saxicola	stripetail rockfish
Sebastes semicinctus	halfbanded rockfish
Sebastes simulator	pinkrose rockfish
Sebastes umbrosus	honeycomb rockfish
Sebastolobus alascanus	shortspine thornyhead
Sebastolobus altivelis	longspine thornyhead
Seriphus politus	queenfish
Squalus acanthias	spiny dogfish
Stenobrachius leucopsarus	northern lampfish
Symphurus atricaudus	California tonguefish
Syngnathus exilis	barcheek pipefish
Syngnathus leptorhynchus	bay pipefish
Synodus lucioceps	California lizardfish
Torpedo californica	Pacific electric ray
Umbrina roncador	yellowfin croaker
Urobatis halleri	round stingray
Xeneretmus latifrons	blacktip poacher
Xeneretmus leiops	smootheye poacher
Xeneretmus triacanthus	bluespotted poacher
Xenistius californiensis	salema
Xystreurys liolepis	fantail sole
Zalembius rosaceus	pink seaperch
Zaniolepis frenata	shortspine combfish
Zaniolepis latipinnis	longspine combfish

Appendix B-1. Area-weight adjusted mean density (count/1000 m^2), standard error, frequency of occurrence (FO) and Index of Community Importance (ICI) rank for the demersal fishes caught during trawl surveys in the bay & harbor areas (n = 22) during the 2008 Southern California Bight regional monitoring survey.

Species	Mean Density (count/1000 m^2)	Density Std. Err.	FO	ICI Rank
Genyonemus lineatus	22.67	9.94	7	1
Paralabrax nebulifer	1.85	0.75	15	2
Seriphus politus	7.22	2.54	6	3
Paralichthys californicus	0.79	0.16	15	4
Umbrina roncador	2.16	1.50	6	4
Paralabrax maculatofasciatus	0.75	0.26	10	6
Urobatis halleri	0.86	0.40	7	6
Cymatogaster aggregata	2.09	1.15	5	8
Anchoa delicatissima	1.65	1.31	5	9
Symphurus atricaudus	0.77	0.26	7	9
Porichthys myriaster	0.54	0.18	6	11
Cheilotrema saturnum	0.49	0.30	5	12
Citharichthys stigmaeus	0.84	0.39	3	13
Phanerodon furcatus	0.45	0.18	4	14
Heterostichus rostratus	0.08	0.13	4	15
Roncador stearnsii	0.34	0.12	3	16
Synodus lucioceps	0.30	0.15	3	16
Myliobatis californica	0.15	0.07	4	18
Embiotoca jacksoni	0.40	0.23	2	19
Hippocampus ingens	0.07	0.05	3	20
Pleuronichthys verticalis	0.11	0.05	3	20
Pleuronichthys ritteri	0.16	0.11	2	22
Pleuronichthys guttulatus	0.07	0.07	2	23
Raja inornata	0.11	0.06	2	23
Rhinobatos productus	0.09	0.06	2	23
Anchoa compressa	0.08	0.04	2	26
Icelinus quadriseriatus	0.13	-	1	26
Paralabrax clathratus	0.03	0.04	2	26
Rhinogobiops nicholsii	0.09	-	1	29
Ilypnus gilberti	0.09	-	1	30
Lepidogobius lepidus	0.07	-	1	30
Rhacochilus vacca	0.08	-	1	30
Gymnura marmorata	0.02	-	1	33
Xystreurys liolepis	0.04	-	1	33
Syngnathus leptorhynchus	0.04	-	1	33

Gibbonsia elegans	<0.01	-	1	33

Appendix B-2. Area-weight adjusted mean density (count/1000 m^2), standard error, frequency of occurrence (FO) and Index of Community Importance (ICI) rank for the demersal fishes caught during trawl surveys in along the inner shelf (n = 32) during the 2008 Southern California Bight regional monitoring survey.

Species	Mean Density (count/1000 m^2)	Density Std. Err.	FO	ICI Rank
Citharichthys stigmaeus	24.24	4.35	29	1
Pleuronichthys verticalis	1.58	0.34	21	2
Parophrys vetulus	1.74	0.67	14	3
Synodus lucioceps	1.08	0.36	17	4
Citharichthys sordidus	2.52	1.37	9	5
Icelinus quadriseriatus	1.86	0.86	9	6
Symphurus atricaudus	0.64	0.26	13	7
Cymatogaster aggregata	0.70	0.34	8	8
Paralichthys californicus	0.32	0.11	11	8
Chitonotus pugetensis	0.72	0.32	8	10
Pleuronichthys ritteri	0.28	0.10	10	11
Zalembius rosaceus	1.32	0.68	5	12
Xystreurys liolepis	0.22	0.07	11	13
Phanerodon furcatus	0.29	0.32	6	14
Citharichthys xanthostigma	0.21	0.09	7	15
Genyonemus lineatus	0.22	0.24	4	16
Leptocottus armatus	0.16	0.06	7	17
Odontopyxis trispinosa	0.23	0.15	5	17
Syngnathus exilis	0.12	0.06	6	19
Sebastes miniatus	0.23	0.13	3	20
Scorpaena guttata	0.06	0.02	6	21
Sebastes caurinus	0.23	0.13	3	21
Hypsurus caryi	0.17	0.09	4	23
Porichthys myriaster	0.09	0.04	5	23
Heterostichus rostratus	0.05	0.04	3	25
Hippoglossina stomata	0.06	0.04	3	25
Porichthys notatus	0.06	0.03	4	25
Pleuronichthys guttulatus	0.04	0.02	3	28
Rhacochilus toxotes	0.07	0.06	2	28
Platyrhinoidis triseriata	0.03	0.02	3	30
Sebastes atrovirens	0.04	0.03	2	31
Icelinus cavifrons	0.03	0.02	2	32
Paralabrax nebulifer	0.02	0.01	2	33
Raja inornata	0.02	0.01	2	33
Scorpaenichthys marmoratus	0.02	0.02	2	33

Sebastes dallii	0.02	0.01	2	33
Rhinobatos productus	0.05	-	1	37
Pleuronichthys decurrens	0.03	-	1	38
Artedius notospilotus	0.01	-	1	40
Zaniolepis latipinnis	0.01	-	1	40
Seriphus politus	0.01	-	1	40
Agonopsis sterletus	0.01	-	1	40
Rhinogobiops nicholsii	0.01	-	1	40
Gibbonsia metzi	0.01	-	1	40
Hexagrammos decagrammus	0.01	-	1	40
Oxylebius pictus	0.01	-	1	40
Embiotoca jacksoni	<0.01	-	1	40
Rimicola muscarum	<0.01	-	1	40
Roncador stearnsii	<0.01	-	1	40
Xenistius californiensis	<0.01	-	1	40

Appendix B-3. Area-weight adjusted mean density (count/1000 m^2), standard error, frequency of occurrence (FO) and Index of Community Importance (ICI) rank for the demersal fishes caught during trawl surveys along the middle shelf (n = 33) during the 2008 Southern California Bight regional monitoring survey.

Species	Mean Density (count/1000 m^2)	Density Std. Err.	FO	ICI Rank
Citharichthys sordidus	22.89	4.67	30	1
Icelinus quadriseriatus	17.68	4.45	30	2
Zalembius rosaceus	6.14	1.79	22	3
Zaniolepis latipinnis	5.37	1.70	23	3
Parophrys vetulus	5.90	3.95	21	5
Porichthys notatus	2.31	0.70	23	6
Pleuronichthys verticalis	1.34	0.30	27	7
Citharichthys xanthostigma	3.02	0.82	20	8
Symphurus atricaudus	2.02	0.56	22	9
Chitonotus pugetensis	2.96	0.84	18	10
Sebastes saxicola	2.48	0.96	16	11
Sebastes semicinctus	9.74	7.33	9	11
Microstomus pacificus	1.20	0.38	18	13
Citharichthys stigmaeus	3.00	1.34	11	14
Hippoglossina stomata	0.53	0.11	21	15
Zaniolepis frenata	0.97	0.39	12	16
Synodus lucioceps	0.51	0.19	16	17
Odontopyxis trispinosa	0.52	0.27	16	18
Sebastes dallii	0.97	0.71	8	19
Lepidogobius lepidus	0.56	0.28	7	20
Scorpaena guttata	0.21	0.07	10	21
Ophiodon elongatus	0.30	0.16	6	22
Raja inornata	0.11	0.03	11	22
Sebastes hopkinsi	0.23	0.17	4	24
Chilara taylori	0.11	0.05	7	25
Lyopsetta exilis	0.21	0.12	4	26
Xystreurys liolepis	0.12	0.06	5	26
Sebastes chlorostictus	0.18	0.14	4	28
Sebastes elongatus	0.10	0.05	5	28
Sebastes eos	0.08	0.05	4	30
Porichthys myriaster	0.06	0.03	4	31
Sebastes rosenblatti	0.06	0.03	4	31
Lycodes pacificus	0.07	0.04	3	33
Enophrys taurina	0.22	-	1	34
Sebastes miniatus	0.09	0.07	2	34

Xeneretmus latifrons	0.05	0.03	3	36
Sebastes rubrivinctus	0.06	0.05	2	37
Rathbunella hypoplecta	0.04	0.03	2	38
Genyonemus lineatus	0.03	0.02	2	39
Icelinus tenuis	0.02	0.01	2	40
Rhinogobiops nicholsii	0.02	0.01	2	40
Xeneretmus triacanthus	0.02	0.01	2	40
Cymatogaster aggregata	0.04	-	1	43
Sebastes umbrosus	0.04	-	1	44
Merluccius productus	0.01	-	1	45
Peprilus simillimus	0.01	-	1	45
Phanerodon furcatus	0.01	-	1	45
Plectobranchus evides	0.01	-	1	45
Pleuronichthys decurrens	0.01	-	1	45
Pleuronichthys ritteri	0.01	-	1	45
Sebastes jordani	0.01	-	1	45
Sebastes levis	0.01	-	1	45
Sebastes rosaceus	0.01	-	1	45
Sebastes rufus	0.01	-	1	45
Squalus acanthias	0.01	-	1	45
Torpedo californica	0.01	-	1	45

Appendix B-4. Area-weight adjusted mean density (count/1000 m^2), standard error, frequency of occurrence (FO) and Index of Community Importance (ICI) rank for the demersal fishes caught during trawl surveys along the outer shelf (n = 23) during the 2008 Southern California Bight regional monitoring survey.

Species	Mean Density (count/1000 m^2)	Density Std. Err.	FO	ICI Rank
Citharichthys sordidus	31.30	11.60	23	1
Lyopsetta exilis	26.54	5.60	23	2
Microstomus pacificus	3.71	0.57	23	3
Sebastes saxicola	10.36	2.56	20	4
Zaniolepis frenata	8.11	1.58	22	4
Lycodes pacificus	4.66	1.39	14	6
Parophrys vetulus	2.79	0.91	16	6
Xeneretmus latifrons	2.15	0.49	20	6
Porichthys notatus	2.19	0.90	14	9
Sebastes elongatus	1.00	0.30	15	10
Zalembius rosaceus	1.52	0.73	14	10
Sebastes semicinctus	2.16	0.93	12	12
Chilara taylori	0.48	0.15	12	13
Sebastes eos	0.33	0.10	12	14
Glyptocephalus zachirus	0.54	0.20	10	15
Sebastes diploproa	1.44	0.92	5	16
Zaniolepis latipinnis	0.64	0.30	6	16
Hippoglossina stomata	0.21	0.12	6	18
Sebastes rosenblatti	0.22	0.12	6	19
Merluccius productus	0.17	0.05	8	20
Sebastes chlorostictus	0.15	0.07	5	21
Pleuronichthys verticalis	0.25	0.17	4	22
Xeneretmus triacanthus	0.13	0.07	5	23
Eopsetta jordani	0.10	0.06	5	24
Hydrolagus colliei	0.09	0.04	5	24
Lycodes cortezianus	0.15	0.12	3	26
Sebastes melanostomus	0.28	-	1	27
Plectobranchus evides	0.09	0.07	3	28
Lyconema barbatum	0.04	0.03	3	29
Sebastes rubrivinctus	0.05	0.04	2	30
Citharichthys xanthostigma	0.06	-	1	31
Raja inornata	0.04	0.02	2	31
Raja rhina	0.03	0.02	2	31
Sebastes jordani	0.04	0.03	2	31
Citharichthys fragilis	0.04	-	1	36

Argyropelecus sladeni	0.01	-	1	37
Bathyraja interrupta	0.02	-	1	37
Icelinus tenuis	0.01	-	1	37
Mustelus henlei	0.02	-	1	37
Ophiodon elongatus	0.01	-	1	37
Scorpaena guttata	0.01	-	1	37
Sebastes goodei	0.01	-	1	37
Sebastes levis	0.02	-	1	37
Symphurus atricaudus	0.02	-	1	37

Appendix B-5. Area-weight adjusted mean density (count/1000 m^2), standard error, frequency of occurrence (FO) and Index of Community Importance (ICI) rank for the demersal fishes caught during trawl surveys along the upper slope (n = 33) during the 2008 Southern California Bight regional monitoring survey.

Species	Mean Density (count/1000 m^2)	Density Std. Err.	FO	ICI Rank
Lyopsetta exilis	16.18	4.12	30	1
Microstomus pacificus	5.01	1.48	30	2
Glyptocephalus zachirus	1.29	0.75	16	3
Sebastolobus alascanus	1.49	0.44	15	3
Sebastes diploproa	1.93	0.73	13	5
Merluccius productus	0.75	0.25	18	6
Lycodes pacificus	0.78	0.24	11	7
Xeneretmus latifrons	0.71	0.25	11	8
Lycodes cortezianus	0.50	0.13	14	9
Lyconema barbatum	1.02	0.80	8	9
Sebastes aurora	0.31	0.10	11	11
Facciolella equatorialis	0.42	0.17	9	12
Parophrys vetulus	0.34	0.13	8	13
Physiculus rastrelliger	0.61	0.35	6	14
Sebastes saxicola	0.77	0.55	5	15
Parmaturus xaniurus	0.19	0.07	8	16
Sebastes jordani	1.32	1.30	3	17
Nezumia stelgidolepis	0.21	0.10	7	18
Lycodes diapterus	0.28	0.12	7	19
Careproctus melanurus	0.12	0.04	10	20
Zaniolepis frenata	0.23	0.12	5	21
Sebastolobus altivelis	0.19	0.11	5	22
Stenobrachius leucopsarus	0.17	0.07	7	22
Lycodapus mandibularis	0.30	0.21	4	24
Bathyagonus pentacanthus	0.17	0.09	5	25
Raja rhina	0.08	0.03	6	26
Eptatretus stoutii	0.05	0.02	6	27
Sebastes melanostomus	0.12	0.09	3	28
Sebastes eos	0.06	0.03	4	29
Plectobranchus evides	0.03	0.01	4	30
Leuroglossus stilbius	0.07	0.05	2	31
Xeneretmus leiops	0.10	-	1	31
Icelinus burchami	0.06	-	1	33
Citharichthys sordidus	0.02	0.01	3	34
Porichthys notatus	0.02	0.02	2	34

Sebastes rosenblatti	0.04	0.03	2	34
Argyropelecus lychnus	0.07	-	1	37
Anoplopoma fimbria	0.02	0.01	2	38
Sebastes elongatus	0.02	-	1	39
Argyropelecus affinis	0.01	-	1	40
Chilara taylori	0.01	-	1	40
Argyropelecus sladeni	0.01	-	1	42
Ceratoscopelus townsendi	0.01	-	1	42
Eptatretus deani	0.01	-	1	42
Hydrolagus colliei	0.01	-	1	42
Icelinus oculatus	0.01	-	1	42
Lestidiops ringens	0.01	-	1	42
Lycodapus fierasfer	0.01	-	1	42
Sebastes crameri	0.01	-	1	42
Sebastes simulator	0.01	-	1	42