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ANALYZING AND MAPPING FISH ASSEMBLAGES OFF CENTRAL CALIFORNIA, USA

WENDY MORRISON
National Marine Fisheries Service
1315 East-West Highway
Silver Spring, MD 20910

LARRY CLAFLIN, MARK MONACO
Biogeography Branch
Center for Coastal Monitoring and Assessment
National Center for Coastal Ocean Science
National Ocean Service, NOAA
1305 East West Highway
Silver Spring, MD 20910
Larry.Claflin@noaa.gov

TERESA TURK
National Marine Fisheries Service
1315 East-West Highway
Silver Spring, MD 20910

DEB WILSON-VANDENBERG
California Department of Fish and Game
20 Lower Ragsdale Dr., Suite 100
Monterey, CA 93940

This study describes fish assemblages and their spatial patterns off the coast of California from Point Arena to Point Sal, by combining the results of the multivariate analyses of several fisheries datasets with a geographic information system. In order to provide comprehensive spatial coverage for the areas of inshore, continental shelf, and continental slope, three fisheries datasets were analyzed: 1) Inshore: the California Department of Fish and Game dataset of fishery-dependent commercial passenger fishing vessel trips that targeted rockfish; 2) Continental Shelf: the National Marine Fisheries Service (NMFS) fishery-independent bottom trawls; and 3) Continental Slope: the NMFS fishery-independent bottom trawls on the continental slope. One-hundred seven species were analyzed. These species represented those captured in at least 5% of the fishing trips or trawls in at least one of the three data sets. We analyzed each of the three datasets separately, and the three sets of results were combined to define 28 species assemblages and 23 site groups. A species assemblage consisted of species caught together, whereas a site group consisted of fishing trips or trawl locations that tended to have the same species assemblages. At the scale of these datasets, 97% of all site groups were significantly segregated by depth.

Key Words: benthic, fish assemblages, surveys, California

INTRODUCTION

Management of marine ecosystems can be a daunting task because diverse organisms with variable life history characteristics sometimes are captured together by fishing techniques of varying selectivity. Species co-exist and share their environments, and management rarely affects only one species. Analyzing each species individually is time-consuming, and it is difficult to determine how to organize the information for making important management decisions. Grouping species into assemblages and sampled locations within easily definable areas will reduce the number of parameters investigated and analyzed for management decisions.

Multivariate analytical methods provide a method for completing this task, and are gaining popularity in fisheries management as scientists discover their power and applicability of the techniques (Paukert and Wittig 2002). We used a hierarchical clustering technique to not only group the fish species into hierarchical assemblages, but also group the sampled stations into areas with similar catches. This analytical approach enabled us to define biogeographic spatial patterns of fishes off the central California coastline. The specific objectives of this study were to (1) identify assemblages of species that tend to co-occur; (2) identify coastal areas and depth ranges with similar species and utilize Geographical Information Systems (GIS) to display the spatial results; and, (3) identify locations of where species assemblages were being caught by studying the intersections of species assemblages and site groups.

Because of the economic importance of recreational and commercial fisheries in California, several studies have been completed that examined co-occurrences of species. NMFS publishes yearly reports on the status of demersal fish species by analyzing results from their shelf and slope trawls (Shaw et al. 2000, Lauth 2001, Turk et al. 2001, Weinberg et al. 2002). Williams and Ralston (2002) analyzed data from NMFS shelf trawls to determine rockfish species assemblages. The overall conclusion from Williams and Ralston (2002) was that depth and latitude were the main determinants of rockfish assemblages. Jay (1996) analyzed the 1977-1992 NMFS shelf trawls to determine site groups that contained similar catches. Using 33 species of fish, he identified 23 site groups, many of which contained the same species, but with different relative abundances. Even though depth and latitude showed some influence on site groups, overall he found few associations among the site groups and a suite of environmental parameters.

Tolimieri and Levin (2006) analyzed 26 fish species from the entire range of the NMFS slope data (southern California through Cape Flattery, Washington) to identify five species assemblages characterized by unique depth and latitude distributions. Gabriel and Tyler (1980) used data from the Oregon Department of Fish and Wildlife Trawl Survey and the West Coast Joint Agency Rockfish Survey to look for site groups from California to Alaska. They differentiated three large site groups: “intermediate” at less than 145 m, “deep” between 145 and 200 m, and “slope” greater than 200 m deep. They found that site groups were “strongly associated with depth contours.” Matthews and Richards (1991) compared gill net catches from trawlable and untrawlable areas to determine if untrawlable areas could be considered de-facto fish reserves. Even though some species overlapped, they concluded that the species assemblages were significantly different, suggesting that species assemblages determined from trawls cannot be extrapolated to non-trawlable habitats.

Only a few studies have analyzed recreational hook-and-line data. Mason (1995) analyzed various California Department of Fish and Game (CDFG) recreational fishing surveys and documented trends in effort, fishing location, and species catch. She documented two principal rockfish species assemblages and distinguished them by depth (less than 70 m and greater than 70 m). Sullivan (1995) examined CDFG Commercial Passenger Fishing Vessel (CPFV) recreational fishing data (1987-1992) to determine site groups using cluster analysis. He did separate analyses for benthic and midwater schooling species. His overall conclusion was that the rockfish management groups could be defined, and that both depth and latitude were important.

Underwater submersibles have been used to describe fish assemblages and their interaction with habitat at spatial scales relevant to the fish themselves (Yoklavich et al. 2000, Tissot et al. 2007). Hixon et al. (1991) documented that the species composition observed from submersibles was different than that seen in trawls. The results from these studies reveal the importance of habitat, especially rugosity, to fish species composition.

Our study is different from previous investigations because it was based on a synthesis of three large-scale databases collected by two different government agencies that were spatially comprehensive throughout the study areas. The study makes maximum use of fishery-dependent and fishery-independent surveys to define biologically relevant species assemblages. Although each data set did not provide information for all habitats, combining results from all three data sets provided a more robust analysis of the central California marine ecosystem.

CDFG recreational hook-and-line data complement the National Marine Fisheries Service (NMFS) data sets by providing information on midwater as well as demersal species collected over soft bottom and hard bottom habitats between 2 and 360 m depth. NMFS surveys on the continental shelf and slope provided information on the diverse demersal fish assemblages found on trawlable habitats between 55 and 1280 m depth throughout the study area. Pelagic fish encountered either as the trawl descended or ascended were also included in these analyses.

The results of this research support three National Marine Sanctuaries: 1) Cordell Bank, 2) Gulf of the Farallones, and 3) Monterey Bay in their joint management plan review process. The results of this investigation were a component of an assessment to aid the sanctuaries in defining and understanding the distribution of species and their associated habitats within and outside sanctuary boundaries (Starr 1998, National Centers for Coastal Ocean Science 2007). For example, some economically important rockfish species have been formally "overfished" and are now recovering (National Centers for Coastal Ocean Science 2003), and information on West Coast species' assemblages is needed for making informed management decisions (Wilson-Vandenberg et al. 1996).

METHODS

Study Area

The study area boundaries were designated north and south of the boundaries of the three aforementioned sanctuaries and covered the area from Point Arena (lat 39.0° N) to Point Sal (lat 34.9° N). The inshore/offshore boundary boundaries were dependent on the data sources (see below), but in general covered an area from the coastline west to a depth of 1200 m.

The waters and seafloor off northern and central California are a temperate region that includes areas of high relief (banks, seamounts, and canyons) to extremely low relief (shelf). Key features with high relief include the Farallon Islands, Monterey Canyon, Cordell Bank, Pioneer Canyon, and Ascencion Canyon. The continental shelf is characterized by low relief and predominately soft sediment that changes from a relatively wide shelf (greater than 30 km offshore) to a relatively narrow shelf at approximately 37° N latitude. By definition, the shelf break occurs between 200-300 m depth throughout the study area.

Data Sets

Inshore: CDFG Recreational Hook-and-Line Trips

Data from 2,167 commercial passenger fishing vessel trips targeting rockfish (*Sebastes* spp.) or lingcod (*Ophiodon elongates*) using hook-and-line were collected by on-board observers from 1987 to 1998 at depths between 2-360 m along the central and northern coasts of California from Point Arena to Point Sal. Each trip visited between one and eight locations, with each trip/location combination considered a “site.” For our analyses we used only presence/absence of each species at each trip/location combination. The data set contained information on 103 fish species, but after removal of species caught in less than 5% of the sites, the data matrix used for classification contained information on 27 fish species at 4,357 trip/location combinations. To protect individual fishing locations as requested by CDFG, we did not map independent fishing sites, but instead, presented the results in 2.5 minute grid cells. For more information on the data collection process see Wilson-Vandenberg (1996).

Continental Shelf: NMFS Benthic Trawls (NMFS Shelf Trawls)

Data from 883 fishery-independent research trawls (55-500 m depth) were collected every 3rd year between 1977 and 2001 during the months of June-August from along the central and northern coasts of California from Point Arena to Point Sal. Gear included a Nor’eastern trawl (127-mm stretched- mesh body; 89-mm stretched -mesh cod-end; and 32-mm stretched- mesh cod-end liner) with a rubber bobbin roller which was trawled for 15- 30 min on the bottom. Zimmermann et al.’s (2003) analysis of benthic species biomass was used to remove trawls from the data set that appeared to have poor fishing performance. We adjusted for effort by dividing number of fish caught by the area swept for each trawl tow. The data set contained information on 167 fish species, but after we removed species caught in less than 5% of the trawls, the data matrix utilized for clustering contained 58 fish species. For more information on how the data were collected, including the site selection process and how it changed through time, see Shaw (2000), Weinberg et al. (2002), and Zimmermann et al. (2003).

Continental Slope: NMFS Benthic Trawls (NMFS Slope Trawls)

Data from 454 fishery-independent research trawls between depths of 190-1280 m were collected in 1991, 1997, 1999, 2000, and 2001 during the months of July-November from along the central and northern coasts of California from Point Arena to Point Sal. Two separate surveys from two different NMFS offices were combined for this data set. Data for 1999, 2000, and 2001 were collected by the Northwest Fisheries Science Center (NWFSC), and the gear included an Aberdeen net with a small mesh liner (5-cm stretched) at the cod-end which was trawled along east-west transects for 15 min on the bottom. Data for 1991, 1997, 1999, and 2000 were collected by the Alaskan Fisheries Science Center (AKFSC), and the gear included a Nor'eastern (127-mm stretched-mesh body; 89-mm stretched-mesh cod-end; and 32-mm stretched-mesh cod-end liner) with a rubber bobbin roller which was trawled for 15-30 min on the bottom.

Although different gears were utilized by the separate surveys, preliminary analyses found no significant difference between gears, allowing us to combine the data (Helser et al. 2004, T. Builder, NMFS, personal communication). For this publication, the combined dataset will be referred to as the "NMFS slope trawls." We adjusted for effort in the same manner as in the NMFS shelf trawls. The data set contained information on 161 fish species, but after removal of species caught in less than 5% of the trawls, we utilized a classification matrix containing 52 fish species. For more information on how the data were collected, including site selection procedures for each data set, see Turk et al. (2001) for the NWFSC trawls, and Lauth (2001) for the AKFSC trawls.

Analyses

In order to investigate which species commonly co-occur, we generated cluster analyses using SAS/STAT software. The analytical process began with either a site-by-species or species-by-site matrix, which at the end of the analytical process resulted in species assemblages or site groups, respectively. We initially filtered data sets to remove incomplete or incorrect data (i.e., sites with coordinates that place them on land, CPFV fishing trips that move greater than 0.01° latitude or longitude, etc.). In addition, we removed fish that were not identified to species, or were not present in at least 5% of the CPFV trip/location combinations or trawls. The 5% cutoff was implemented because it reduced the number of zeros present in the starting matrices, while keeping an adequate number of species for analysis. In addition, rare species can negatively impact results because their occurrences are often due to chance (Gauch 1982). Because the raw abundance data did not conform to assumptions of a normal distribution and homogeneity of variances, we implemented either natural log (when effort was available) or presence/absence (when no effort was provided) transformations. After the natural log transformation, we standardized the transformed data of each species by subtracting its mean from each data value and dividing the result by its standard deviation. This standardization resulted in all the species data having a mean of zero and a standard deviation of one and ensured that abundant species did not overly influence the results.

We utilized Pearson correlation coefficients to create a correlation matrix among species. This proximity matrix summarized the associations among species based on their absence at the sites. We utilized the Pearson correlation coefficient because it is a common proximity measure discussed by Romesburg (1990), it has been successfully used by us previously on a variety of data sets (Sullivan 1995), and it was easier to explain to non-statistical managers. Because the cluster procedure within the SAS/STAT software required input proximity matrices that are measures of distance or dissimilarity, we converted each Pearson coefficient into a measure of dissimilarity by subtracting the coefficient from one. We utilized the average linkage clustering on this matrix of dissimilarity to create a hierarchical clustering of species groups. We followed the same procedures to create a dissimilarity matrix among all the sites and calculate a hierarchical clustering of site groups.

In order to decide how many groups to keep, we analyzed scree plots to determine where breaks in the similarity level occurred (McGarigal et al. 2000). Subsequently, group composition was scrutinized to determine the best ecological groupings (i.e., if smaller or larger groups would provide a better ecological explanation). To determine the persistence of species assemblages within a dataset, we implemented a modified bootstrapping procedure. Bootstrapping techniques have been used to determine the statistical significance of cluster groups (Nemec and Brinkhurst 1988, Pillar 1999). However, for this study, we utilized a simplified approach. We extracted 50 random samples without replacement containing a portion of the original sites (one-half or three-quarters of the data depending on the size of the original data set) and ran these samples through the clustering process. We then combined results into a species by species matrix showing the percentage of times two species were grouped into the same assemblage. From the matrix, we determined the stability of the species assemblages by calculating the average percentage of times all species in a group were placed together. Species that were associated with different groups on different runs were termed “transients.”

To determine where the fish assemblages were being caught, we calculated the average frequency of occurrence for species assemblages within each site group; this analysis is a modified nodal analysis. By analyzing average frequencies of occurrence for species in site groups we were able to determine which species assemblages were influential in forming the site groups. Species groups were considered influential if, on average, species were present in 25% of the sites (CPFV trip/location or trawl). In order to provide a spatial distribution of the site groups, we used GIS to map the site groups over the California coastal area.

Previous studies have shown bathymetry to exert a strong influence on California fish distributions (Gabriel and Tyler 1980, Matthews and Richards 1991, Mason 1995, Williams and Ralston 2002, Allen 2006). Therefore, we calculated a depth distribution for each species assemblage based on its frequency of occurrence in each site group. An assemblage was considered present at a given depth if the average frequency of occurrence was greater than or equal to 25%. We utilized Tukey’s pairwise comparison to test for significant differences in depth distributions among site groups. Other factors besides depth, such as habitat or latitude, can influence fish distributions (Horn and Allen 1978, Monaco et al. 1998, Yoklavich et al. 2000, Clark et al. 2003). Attempts were made to statistically remove the influence of bathymetry from the data sets and then re-analyze the resulting data for assemblage patterns caused by secondary influences. However, two general problems were encountered. First, the standard statistical procedure to remove the influence of bathymetry required a linear relationship between species abundances and bathymetry. However, this relationship remained non-linear even after various transformations were completed. Second, the species abundance data were collected over narrow ranges of other influences, such as bathymetric slope (km scale change in bathymetry) and substrate/sediment size. Again, the problems of non-linearity and zero species abundances prevented further conventional statistical analyses. Therefore, only the influence of bathymetry could be discussed.

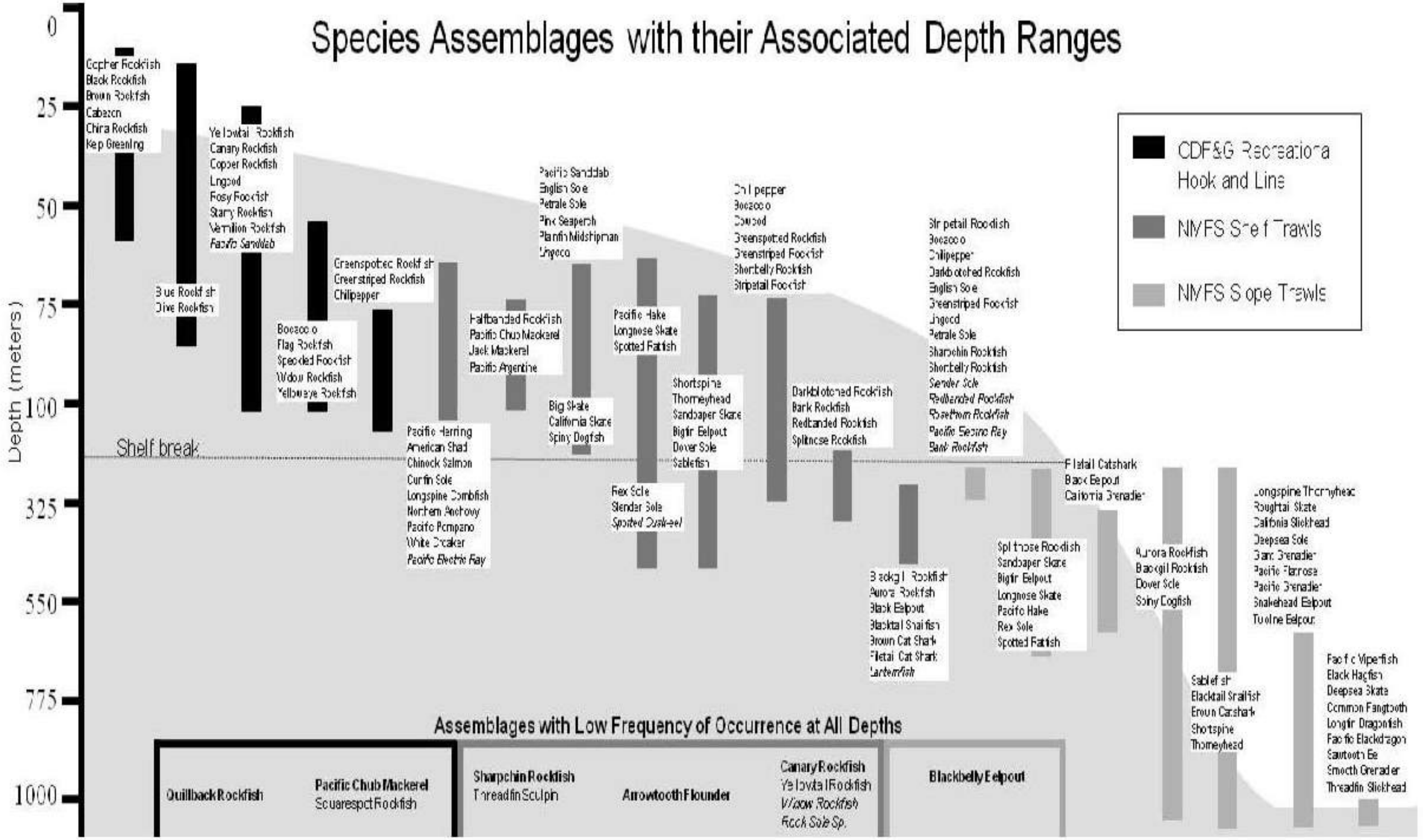


Figure 1. Species assemblage results for the CDFG recreational (black), NMFS shelf (dark gray), and NMFS slope (light gray) data. Assemblages were named for the most influential species in each group. Non-italicized species were consistently placed into the same species assemblage >80% of the time; italicized species were transient, and tended to roam into other assemblages with random sampling. The length of the vertical line depicts the depth interval where species assemblages had an average frequency of occurrence in at least 25% of the trawls. The assemblages listed at the bottom of the figure contained species that were not caught in large enough numbers to be considered "influential" at any depth.

RESULTS AND DISCUSSION

Through these cluster analyses, we condensed 5,694 fishing events (i.e. CPFV trip/ locations or NMFS trawl tows) with 107 species into relevant clusters of events (sites) and species. The separate cluster analysis of each of the three data sets produced 23 site groups and 28 species assemblages (Figure 1). To make interpretation easier, the site groups were named according to depth, and species assemblages were named after the leading species. The 'leading species' was the most abundant species in the assemblage that also accurately represented the occurrence of the fish species across site groups.

Species assemblages delineated for all data sets were tested for robustness with the modified bootstrap procedure which consistently partitioned most of the fish into the same groups for more than 80% of the random samples. This provided confidence in the precision of our fish assemblages, and assured us that the results were not based on a few outlier data points. Species that moved between fish assemblages depending on the subset of sites chosen were referred to as 'transient species' and are distinguished by italics in Figure 1. Species assemblages that were influential (i.e., were present in more than 25% of the trawls) in forming the site groups are identified by bold numbers in Tables 1, 2, and 3. Maps delineating the location of the sites within each site group provided a visual representation of the group distributions with depth (Figure 2, Figure 3, Figure 4). Due to data privacy rights recreational sites were mapped into 2.5 min grids rather than as individual points (Figure 2), which made the grid cell map hard to interpret due to overlap of more than one group within the same cell. For example, within one grid cell on the southern side of Monterey Bay, the maximum depth fished on individual CPV trips ranged between 37 and 660 m, and contained sites from all 8 cluster groups. Therefore, the mean depths fished ± SD are presented (Table 1), which were used in conjunction with Figure 2 to determine the approximate location of the site groups. The maps of shelf and slope trawl tow sites (Figure 3, Figure 4) also had the problem of overlapping site groups. We resolved the problem of the overlapping site groups in the shelf and slope trawl tow site groups (Figure 3, Figure 4) by tiling the maps (i.e., by providing a sub-map for each site group). Comparison of the results from the three data sets showed considerable overlap in species assemblages across depths (Figure 1).

While statistical analyses may be valid, it is important to review the output to determine if the results showed a consistent trend based on knowledge of the region. Therefore, we will discuss each data set individually to determine the spatial patterns in the distribution of site groups and species assemblages before integrating results across data sets.

The CDFG sites (CPFV trip/locations) were divided into eight groups that follow depth (Table 1). Each site group was about 5 to 27 m deeper than the preceding shallower site group. The 40 m and 44 m site groups were not significantly different in depth (Table 1). Figure 2 displays the CDFG recreational data in 2.5 minute grids across five mean depth categories. Because of overlap of members of site groups across a number of grids, only the grids are displayed. The site groups we identified could be placed within the four site groups defined by Sullivan (1995). He analyzed CPFV data for the Monterey Bay area, which was a subset of the same data set that we used. He did separate analyses for midwater species and benthic species. Our eight site groups could be placed into his four site groups based on the benthic species in the following manner: our 26 m, 40 m, and 44 m site groups into his north shallow group (range: 9.1-84.1 m), our 59 m and 64 m site groups into

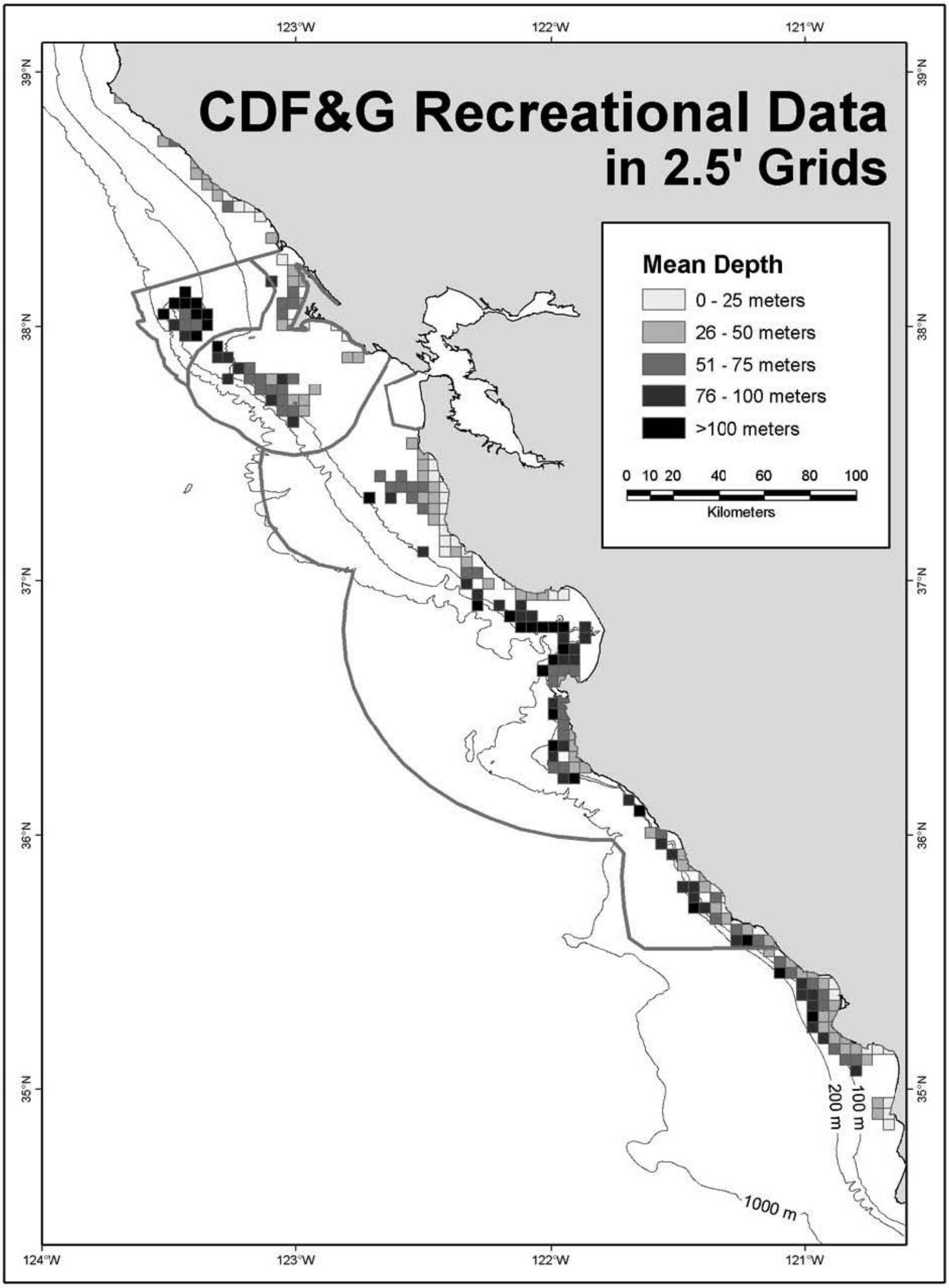


Figure 2. Location of California Department of Fish and Game recreational fishing data in 2.5 min grids which are black-gray shaded according to the mean depth of the fishing trips within the grid cell. The 100, 200, and 1,000 meter depth contours are shown with thin lines. The National Marine Sanctuary boundaries are shown with thicker lines.

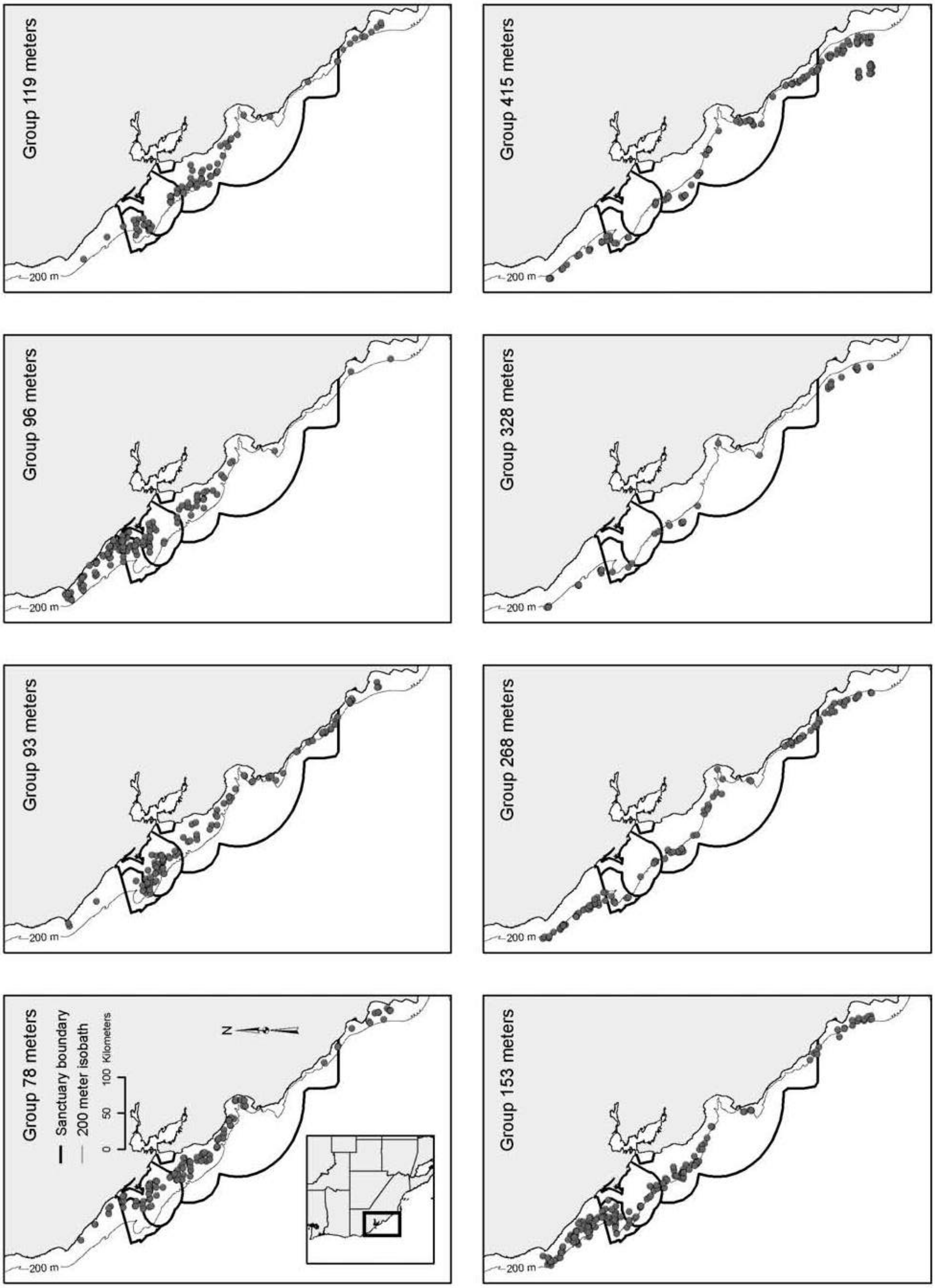


Figure 3. Location of site groups for National Marine Fisheries Service shelf trawls. The 200-m contour line is shown with a thin line. The National Marine Sanctuary boundaries are shown with thicker lines.

his south shallow group (range: 14.6-146.3 m), our 77 m and 98 m site groups into his shelf flats group (range: 23.8-274.3 m), and our 125 m group into his canyon ledge group (range: 73.2-219.5 m).

One of our site groups (44 m) did not appear to be associated with any fish assemblage (Table 1). The mean catch for this group was much lower (12 fish/trip) compared to the rest of the trips (68 fish/trip), suggesting that either this site group represents biologically poor areas, or some outside factor (such as poor weather, low effort, etc.) was influencing catch at these sites.

The CDFG fish species were divided into seven groups (Figure 1, Table 1). Five of these assemblages follow depth. These five assemblages were designated as the gopher rockfish (*Sebastes carnatus*) (15-55 m), blue rockfish (*Sebastes mystinus*) (15-80 m), yellowtail rockfish (*Sebastes flavidus*) (25-100 m), bocaccio rockfish (*Sebastes paucispinis*) (50-100 m), and greenspotted rockfish (*Sebastes chlorostictus*) (75-110 m) assemblages.

Our gopher rockfish assemblage (15-55 m) was similar in composition to Love et al.'s (2002) nearshore group (subtidal to about 30 m) if we exclude the juvenile fish in their group. Similarly, our blue rockfish assemblage (15-80 m) and yellowtail rockfish assemblage (25-100 m) corresponded to Love et al.'s (2002) shallow shelf group (30-100 m) if we exclude the juvenile fish in their group. Our gopher rockfish and blue rockfish assemblages contained many of the rockfish in Mason's (1995) Monterey Bay sport fisheries shallow group assemblage (less than 70 m). Her deep water group assemblage (greater than 70 meters) corresponds to our bocaccio rockfish and greenspotted rockfish assemblages. Our results differ with respect to placement of the species in our yellow rockfish assemblage. Mason (1995) included the yellowtail rockfish in her deep water group, and placed many of the species in our yellowtail rockfish assemblage in her "other rockfish" category. She noted that the rockfish in her "other rockfish" category occur in shallow water as young fish and deeper water as larger adults.

Our Pacific chub mackerel and quillback rockfish assemblages contained species that were not caught in large enough numbers to be considered "influential" at any depth (Table 1). Depth associations were probably present, just not discernable given that we defined influential as being present in greater than 25% of the CDFG sites (CPFV trip/locations) within a site group.

The shelf trawls were divided into eight site groups divided by depth (Figure 3, Table 2). Only two groups (Group 93 m, and Group 96 m) did not contain sites that were significantly different in depth. In addition, similar species were caught in these two groups, leaving the mechanism behind the separation of these groups uncertain. Each site group was about 15 to 115 m deeper than the preceding shallower site group.

The shelf trawl fish species were separated into thirteen assemblages according to depth (Figure 1, Table 2). Ten of these assemblages have clear depth associations. These assemblages were designated as the Pacific Herring (*Clupea pallasii*) (60-110 m), halfbanded rockfish (*Sebastes semicinctus*) (70-110 m), Pacific sandab (*Citharichyhys sordidus*) (60-200 m), big skate (*Raja binoculata*) (60-200 m), Pacific hake (*Merluccius productus*) (60-400 m), rex sole (*Glyptocephalus zachirus*) (60-400 m), shortspine thornyhead (*Sebastolobus alascanus*) (60-400 m), chilipepper rockfish (*Sebastes goodel*) (60-300 m), darkblotched rockfish (*Sebastes crameri*) (220-330 m), and blackgill rockfish (*Sebastes melanostomus*) (320-420 m) assemblages. We note that many of the pelagic species were clustered together in the Pacific herring assemblage.

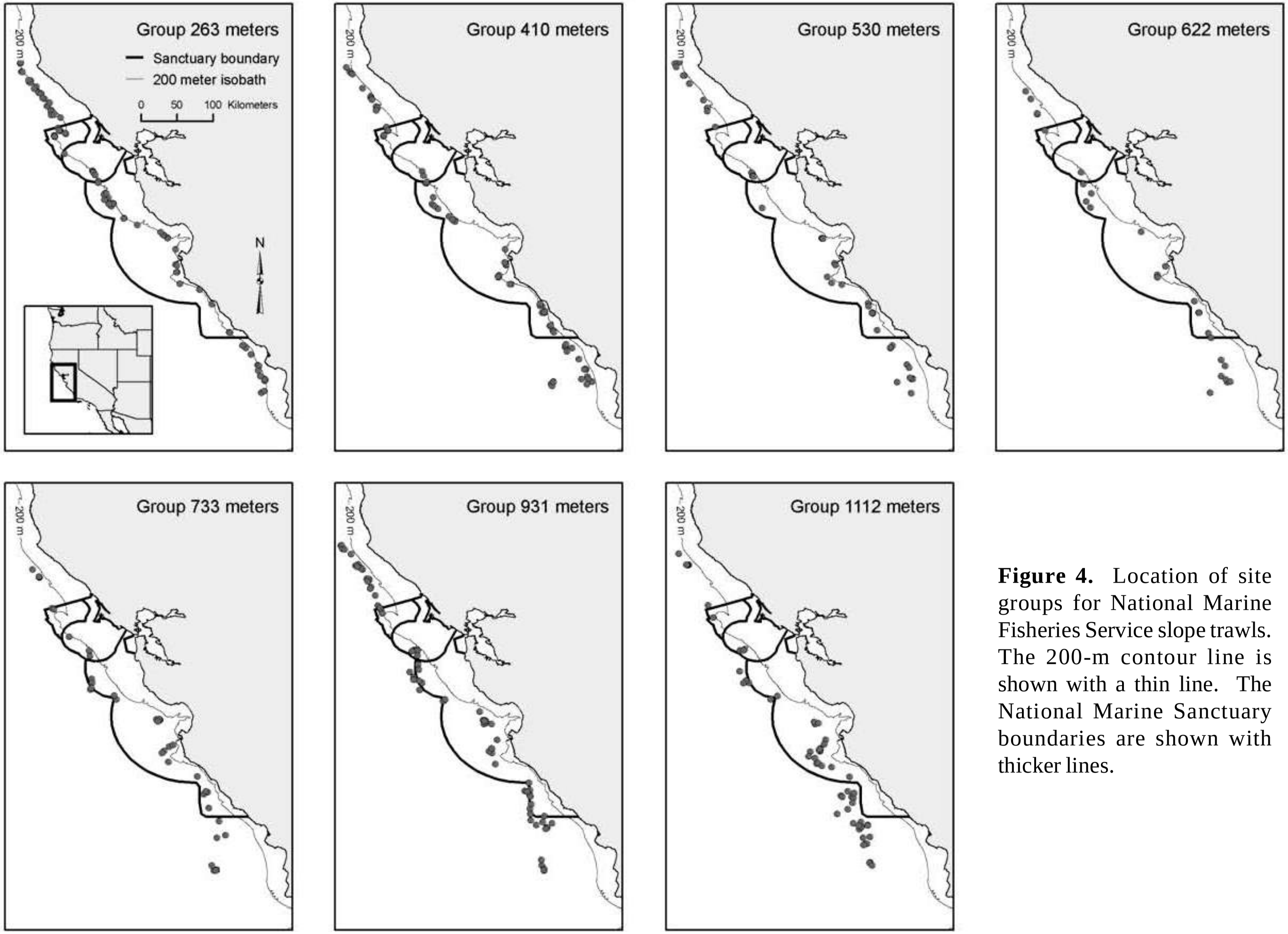
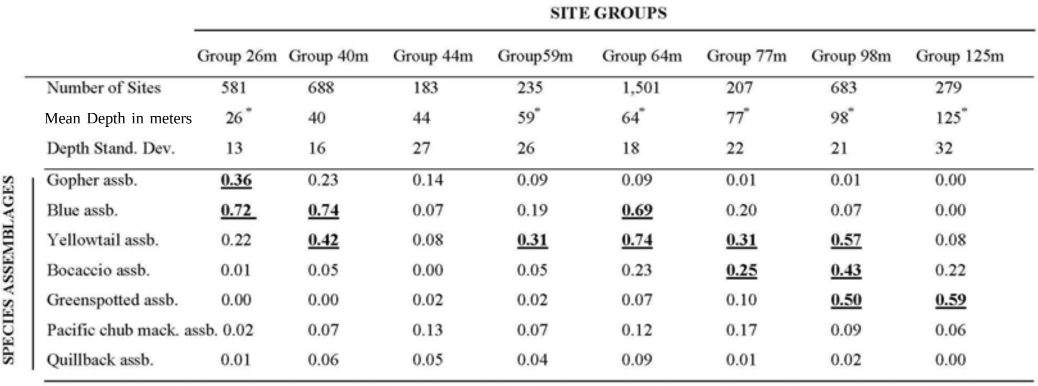


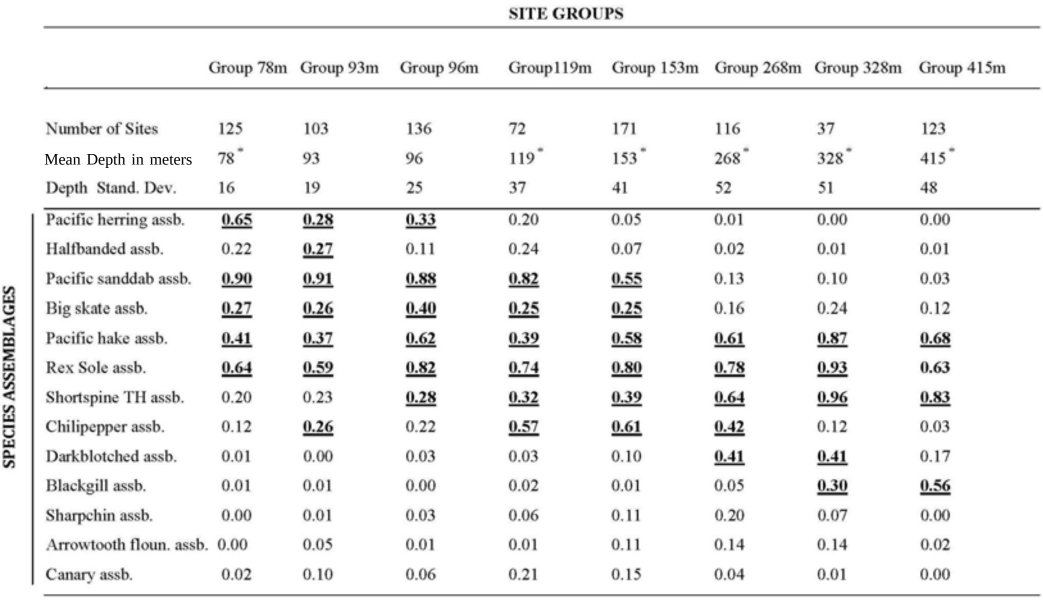
Figure 4. Location of site groups for National Marine Fisheries Service slope trawls. The 200-m contour line is shown with a thin line. The National Marine Sanctuary boundaries are shown with thicker lines.

Table 1. Site groups and species assemblages for CDFG recreational data. Except for site groups 40 m and 44 m, all site groups were significantly different based on the Tukey's pairwise comparison test on log adjusted depth with an overall *alpha* set at 0.001. Average frequency of occurrence of fish species assemblage (percent occurrence calculated for each species and then averaged for each fish assemblage) for each shelf site group is listed in lower part of the table. Underlined bold numbers represent influential species assemblages in that column's site group. NOTE 1: assb stands for assemblage. NOTE 2: an asterisk to the upper right of the depth indicates that the site group's depth is significantly different from preceding and following site groups' depths.



		SITE GROUPS							
		Group 26m	Group 40m	Group 44m	Group59m	Group 64m	Group 77m	Group 98m	Group 125m
	Number of Sites	581	688	183	235	1,501	207	683	279
	Mean Depth in meters	26^{*}	40	44	59^{*}	64^{*}	77^{*}	98^{*}	125^{*}
	Depth Stand. Dev.	13	16	27	26	18	22	21	32
SPECIES ASSEMBLAGES	Gopher assb.	**0.36**	0.23	0.14	0.09	0.09	0.01	0.01	0.00
	Blue assb.	**0.72**	**0.74**	0.07	0.19	**0.69**	0.20	0.07	0.00
	Yellowtail assb.	0.22	**0.42**	0.08	**0.31**	**0.74**	**0.31**	**0.57**	0.08
	Bocaccio assb.	0.01	0.05	0.00	0.05	0.23	**0.25**	**0.43**	0.22
	Greenspotted assb.	0.00	0.00	0.02	0.02	0.07	0.10	**0.50**	**0.59**
	Pacific chub mack. assb.	0.02	0.07	0.13	0.07	0.12	0.17	0.09	0.06
	Quillback assb.	0.01	0.06	0.05	0.04	0.09	0.01	0.02	0.00

Table 2. Site groups and species assemblages for NMFS trawls along the continental shelf. Except for site groups 93m and 96m, all site groups were significantly different based on the Tukey's pairwise comparison test on log adjusted depth with an overall *alpha* set at 0.001. Average frequency of occurrence of fish species assemblage (percent occurrence calculated for each species and then averaged for each fish assemblage) for each shelf site group is listed in lower part of the table. Underlined bold numbers represent influential species assemblages in that column's site group. NOTE 1: assb stands for assemblage. NOTE 2: an asterisk to the upper right of the depth indicates that the site group's depth is significantly different from preceding and following site groups' depths.



		SITE GROUPS							
		Group 78m	Group 93m	Group 96m	Group119m	Group 153m	Group 268m	Group 328m	Group 415m
	Number of Sites	125	103	136	72	171	116	37	123
	Mean Depth in meters	78^{*}	93	96	119^{*}	153^{*}	268^{*}	328^{*}	415^{*}
	Depth Stand. Dev.	16	19	25	37	41	52	51	48
SPECIES ASSEMBLAGES	Pacific herring assb.	**0.65**	**0.28**	**0.33**	0.20	0.05	0.01	0.00	0.00
	Halfbanded assb.	0.22	**0.27**	0.11	0.24	0.07	0.02	0.01	0.01
	Pacific sanddab assb.	**0.90**	**0.91**	**0.88**	**0.82**	**0.55**	0.13	0.10	0.03
	Big skate assb.	**0.27**	**0.26**	**0.40**	**0.25**	**0.25**	0.16	0.24	0.12
	Pacific hake assb.	**0.41**	**0.37**	**0.62**	**0.39**	**0.58**	**0.61**	**0.87**	**0.68**
	Rex Sole assb.	**0.64**	**0.59**	**0.82**	**0.74**	**0.80**	**0.78**	**0.93**	**0.63**
	Shortspine TH assb.	0.20	0.23	**0.28**	**0.32**	**0.39**	**0.64**	**0.96**	**0.83**
	Chilipepper assb.	0.12	**0.26**	0.22	**0.57**	**0.61**	**0.42**	0.12	0.03
	Darkblotched assb.	0.01	0.00	0.03	0.03	0.10	**0.41**	**0.41**	0.17
	Blackgill assb.	0.01	0.01	0.00	0.02	0.01	0.05	**0.30**	**0.56**
	Sharpchin assb.	0.00	0.01	0.03	0.06	0.11	0.20	0.07	0.00
	Arrowtooth floun. assb.	0.00	0.05	0.01	0.01	0.11	0.14	0.14	0.02
	Canary assb.	0.02	0.10	0.06	0.21	0.15	0.04	0.01	0.00

Our sharpchin rockfish (*Sebastes zacentrus*), arrowhead flounder (*Atheresthes stomias*), and canary rockfish (*Sebastes pinniger*) assemblages contained species that were not caught in large enough numbers to be considered "influential" at any depth (Table 2). Their depth associations were probably present, but they were not present in greater than 25% of the shelf trawls for one or more site groups.

The slope trawls were divided into seven site groups divided by depth (Figure 4, Table 3). All eight of these site groups were significantly different in depth. Each site group was about 100 to 200 m deeper than the preceding shallower site group.

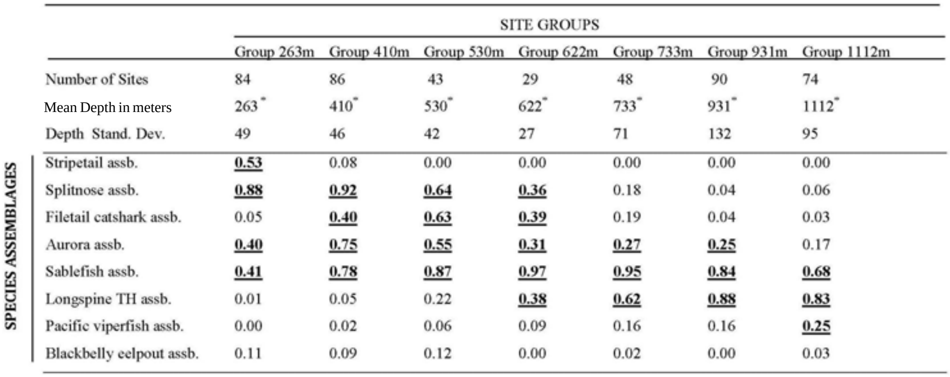
The deepwater slope species assemblages all contain meso-and bathy-benthal species (Figure 1, Table 3). These slope trawl fish species were separated into eight assemblages (Figure 1). Generally, seven of these assemblages have clear depth associations. These seven assemblages were designated as the stripetail rockfish (*Sebastes saxicola*) (200-300 m), splitnose rockfish (*Sebastes diploproa*) (300-500 m), filetail catshark (*Parmaturus xaniurus*) (320-640 m), aurora rockfish (*Sebastes aurora*) (250-1100 m), sablefish (*Anoplopoma fimbria*) (250-1100 m), longspine thornyhead (*Sebastolobus altivelis*) (550-1100 m), and Pacific viperfish (*Chauliodus macouni*) (900-110 m).

Sablefish and aurora rockfish assemblages were found across all depths, while the blackbelly eelpout (*Lycodes pacificus*) assemblage was not influential at any depth. The stripetail assemblage was only found in the shallowest group, and consists of species that were placed into separate groups when analyzed with the shallower shelf trawls. The Pacific viperfish assemblage has a high occurrence only in the deepest site group, suggesting that these species were deeper than the bathy-benthal species. Little information is available on these exclusively slope species. Despite this lack of understanding, the species cluster results from the NMFS slope trawls seem much less intuitive than those from the NMFS shelf trawls.

The results from all three datasets support the NMFS characterization of rockfish species into three broad groups: nearshore, shelf, and slope species (based on Gabriel and Tyler 1980). Tolimieri and Levin (2006) clustered slope species into five assemblages based on depth and latitude. Their deepwater group corresponds directly to our longspine thorneyhead assemblage, while their mid-depth group corresponds to our sablefish and aurora rockfish assemblages. They divide the rest of their species into three shallow water groups distinguished by latitude. As our study covered a smaller geographic range there was not a strong latitudinal component to our results, and their three shallow water groups correspond to our stripetail and splitnose rockfish groups. The one interesting discrepancy between our results and those of Tolimieri and Levin (2006) involves the placement of spiny dogfish (*Squalus acanthias*). They place spiny dogfish in with shallow species such as longnose skate (*Raja rhina*) and Pacific hake, while we place the spiny dogfish in with deeper species such as the aurora rockfish, blackgill rockfish, and Dover sole (*Microstomus pacificus*). Allen and Pondella (2006), also place the dogfish in with Pacific hake and longnose skate (their species group 42) corroborating Tolimieri and Levin's placement with the shallow slope species.

Williams and Ralston (2002) grouped rockfish from the NMFS shelf trawl data into eight groups which were similar to our results. Their group A1 corresponded to the rockfish in our blackgill and darkblotched rockfish assemblages, while their group C4 matches our chilipepper assemblage. Their D7 corresponds to our canary rockfish assemblage, except that they include greenspotted rockfish in with this assemblage while our analysis placed greenspotted rockfish in with our chilipepper assemblage. Similarly, they grouped cowcod

Table 3. Site groups and species assemblage for NMFS trawls on the continental slope. All site groups were significantly different based on the Tukey's pairwise comparison test on log adjusted depth with an overall *alpha* set at 0.001. Average frequency of occurrence of fish species assemblage (percent occurrence calculated for each species and then averaged for each fish assemblage) for each shelf site group is listed in lower part of the table. Underlined bold numbers represent influential species assemblages in that column's site group. NOTE 1: assb stands for assemblage. NOTE 2: an asterisk to the upper right of the depth indicates that the site group's depth is significantly different from preceding and following site groups' depths.



		SITE GROUPS						
		Group 263m	Group 410m	Group 530m	Group 622m	Group 733m	Group 931m	Group 1112m
	Number of Sites	84	86	43	29	48	90	74
	Mean Depth in meters	263*	410*	530*	622*	733*	931*	1112*
	Depth Stand. Dev.	49	46	42	27	71	132	95
SPECIES ASSEMBLAGES	Stripetail assb.	**0.53**	0.08	0.00	0.00	0.00	0.00	0.00
	Splitnose assb.	**0.88**	**0.92**	**0.64**	**0.36**	0.18	0.04	0.06
	Filetail catshark assb.	0.05	**0.40**	**0.63**	**0.39**	0.19	0.04	0.03
	Aurora assb.	**0.40**	**0.75**	**0.55**	**0.31**	**0.27**	**0.25**	0.17
	Sablefish assb.	**0.41**	**0.78**	**0.87**	**0.97**	**0.95**	**0.84**	**0.68**
	Longspine TH assb.	0.01	0.05	0.22	**0.38**	**0.62**	**0.88**	**0.83**
	Pacific viperfish assb.	0.00	0.02	0.06	0.09	0.16	0.16	**0.25**
	Blackbelly eelpout assb.	0.11	0.09	0.12	0.00	0.02	0.00	0.03

(*Sebastes levis*) by itself (their group C5), while we grouped it with chilipepper, shortbelly (*Sebastes jordani*) bocaccio, stripetail, and greenstriped rockfish. We both grouped halfbanded rockfish in its own group (their B3). The rest of their groups contain species not included in our analyses, highlighting one difficulty in comparing studies. Other details also make comparisons between studies difficult such as differences in habitats targeted and differences in the scale of the results. It is important to remember the spatial extent of our analyses. Since recreational boats drift over multiple habitats during a set, and trawls cover a distance of 1-4 km (Helser et al. 2004), fish from multiple habitats can be present in one site. In addition, species assemblage results could also be confounded by ontogenetic habitat shifts because the sizes of the fish captured were not considered.

For the recreational and shelf datasets, all but two groups were significantly different in depth (using Tukey's pairwise comparisons with overall á adjusted to 0.05) (Tables 1 and 2), while all NMFS slope site groups were significantly different in depth (Table 3). Even though the importance of depth has been recorded previously (Gabriel and Tyler 1980, Matthews and Richards 1991, Mason 1995, Williams and Ralston 2002, Allen 2006), the over-riding effect of depth in this study was remarkable. These results can be partially explained by the type of collection completed. Both fishing methods may cover multiple habitats in one "site" as they actively trawl or drift across an area. Therefore, fish were collected in a fairly similar depth profile, but one that may cover multiple habitats, emphasizing depth over habitat. Correlations between species assemblages and latitude or habitat were attempted; however, because all of these factors vary with depth, it was impossible to separate these effects from those of depth. For example, the width of the continental shelf diminishes around 37° N Latitude, consequently diminishing the amount of shallow and soft bottom habitat present, and influencing the species assemblages present. Obviously latitude and habitat may have an effect on species assemblages, but were inextricably tied to depth within this dataset and cannot be distinguished independently.

Species included with the three data sets differed, especially after species caught in less than 5% of the trawls/trips were discarded. Therefore, while the NMFS shelf and slope trawls may have overlapped for the 200-500 m depth range, the species included in the analyses differed. Thirty-three species were included in both the shelf and slope analyses. It is interesting to note that the shallow slope species included in the NMFS slope trawl analysis were all placed in one assemblage, the stripetail rockfish assemblage. The same species included in this stripetail rockfish assemblage were found in five different NMFS shelf assemblages. This does not imply that species co-occurrences changed between the shelf and slope trawls, but that cluster results were sensitive to the depth range covered by the data set.

Only 10 species overlapped between the recreational data and the shelf trawl data. Generally, these fish species were associated with a shallower depth in the recreational hook-and-line analysis than in the shelf trawl analysis. This could be due to differences in habitats fished or size selectivity of the fishing methods. Some rockfish species settle as juveniles in shallow water, and slowly shift to deeper water as they mature (Love et al. 2002). Fish sizes were not provided with all data sets, so no comparison was undertaken.

In summary, the results from this study reduced a large data matrix into smaller, easily comprehended groups of species and sites. Incorporating GIS into the analyses enables visualization of the data and quick interpretations. Understanding which species were caught together could lead to further studies analyzing what biotic or abiotic characteristics or ecological relationships most influence their location, or what habitats were most important for a diverse group of species. This study is an important step in looking beyond single-species attributes while incorporating a spatial context to aid in interpreting the biostatistical analyses.

MANAGEMENT IMPLICATIONS

This assessment study provides information relevant to fisheries management. It was completed to define the distribution of species assemblages within and outside the boundaries of the three Central California National Marine Sanctuary sites. The fish assemblage analyses have been integrated to facilitate discussions on potential modification of national marine sanctuary boundaries or alternative management strategies implemented within the existing boundaries of the three sites (NOAA 2003). The results of this investigation have been particularly useful in evaluating the ecological relevancy of the current shared boundary for the southern extent of the Gulf of the Farallones National Marine Sanctuary and the northern edge of the Monterey Bay National Marine Sanctuary. Results from this study have also been incorporated into regional reports such as the “Analysis of Biophysical Features in the Marine Life Protection Act Central Coast Study Region” (S. Aramie, University of California, Santa Barbara, personal communication).

Substantial declines in the standing stock biomass of some economically important rockfish species across the entire west coast (Ralston 1998) prompted NMFS to organize a symposium to discuss the implications of no-take areas for rockfish in September, 1997. Starr (1998) expressed a management need for the identification of species assemblages so that management can provide for adequate protection of each species assemblage. The results from this study provide information on these assemblages for nearshore, shelf, and slope ecosystems.

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