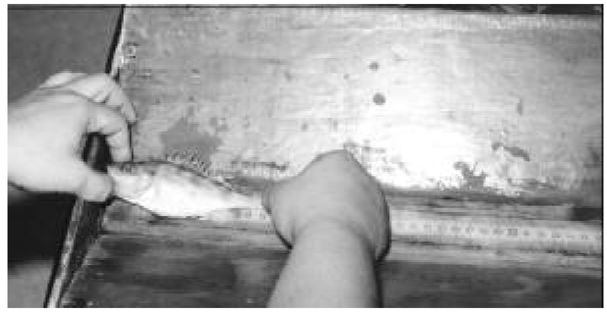
Demersal Fish Assemblages of the Mainland Shelf of Southern California in 1994



M. James Allen, Douglas Diener[1], Jason Mubarak[1], Stephen B. Weisberg, and Shelly L. Moore

ABSTRACT

Although the demersal fish fauna of the southern California shelf has been studied for many years, site assemblages have been described only in small areas and hence reflect local conditions. Because assemblages have not been described for the region as a whole, factors influencing assemblage organization throughout the area are not known. Here we present results of a synoptic trawl survey of the mainland shelf of southern California in July and August 1994. We collected trawl samples at 114 stations selected at random from Point Conception, California, to the United States-Mexico international border at depths of 10 to 200 m. A total of 18,912 fish representing 87 species was collected in this survey. This study describes site and species assemblages of demersal fishes on the mainland shelf of southern California and examines the importance of depth and sediment type on assemblage organization. Site and species assemblages were described using cluster analysis with square-root transformation of abundance data; the Bray-Curtis dissimilarity index; and an agglomerative, hierarchical, flexible sorting method. Five primary site clusters and four primary species clusters of fishes, with secondary clusters, were delineated by cluster analysis. Primary site clusters were the following: (1) Inner Shelf, (2) Sandy Inner/Middle Shelf, (3) Muddy Inner/Middle Shelf, (4) Middle/Outer Shelf, and (5) Outer Shelf. Primary species clusters were (1) White Croaker-California Scorpionfish, (2) Yellowchin Sculpin-Speckled Sanddab, (3) Pacific Sanddab-Plainfin Midshipman, and (4) Slender Sole-Splitnose Rockfish. Overall, depth was more important than geographical area or sediment type in determining the organization of fish assemblages. The assemblages described in this study will provide a baseline for assessing historical changes and the relative health of southern California demersal fish assemblages.

INTRODUCTION

The demersal fish fauna of the mainland shelf of the Southern California Bight (SCB) is diverse, consisting of more than 100 species occupying the soft-bottom habitat at depths of 10 to 200 m (Allen 1982, Allen *et al.* 1998). These species are relatively sedentary and as a result have an increased exposure to accumulated contaminants in sediment and low levels of oxygen in near-bottom waters. Because demersal fishes respond to changes in the benthic environment, they have been monitored for many years to assess impacts resulting from human activities.

Previous studies (Allen 1982, Allen and Moore 1997) have identified different recurrent species groups (based upon species co-ocurrence) in different depth zones on the mainland shelf. Abundance-related assemblages of demersal fishes have only been described for local areas (generally near wastewater outfalls) (e.g., CSDLAC 1990, CLAEMD 1994, CSDMWWD 1995, CSDOC 1996), and hence reflect local conditions. However, without understanding the background distribution of fish assemblages on the shelf, it is difficult to

[1]MEC Analytical Systems, Inc., 2433 Impala Dr., Carlsbad, CA 92009

assess the importance of local changes in fish assemblages. Thus, a description of demersal fish assemblages for the entire mainland shelf of southern California is needed to better understand environmental factors affecting the distribution of fish assemblages. Here we present results of a synoptic trawl survey of the entire southern California coastal shelf.

The objectives of this study were (1) to describe synoptic site and species assemblages of demersal fishes on the mainland shelf of southern California; (2) to describe their distribution with regard to depth, region, and sediment type; and (3) to compare resulting assemblages to previously described recurrent species groups based upon the same synoptic data.

METHODS

Trawl samples were collected at 114 randomly selected stations from Point Conception, California, to the United States-Mexico international border at depths of 9 to 215 m (rounded to 10 to 200 m for the purposes of this report) (Figure 1). A stratified random design was used, with the following depth strata: (1) inner shelf — 10 to 25 m; (2) middle shelf — 25 to 100 m; and (3) outer shelf —100 to 200 m (Bergen 1996, Stevens 1997). These strata were not sampled equally, with 53 samples collected from the middle shelf zone, 31 from the outer shelf zone, and 30 from the inner shelf zone.

Samples were collected from July 12 to August 22, 1994, with 7.6-m head-rope semiballoon otter trawls with 1.25-cm cod-end mesh. Trawls were towed for 10 min at 1 m/sec (2 kn) along isobaths. Fish were identified to species, counted, examined for anomalies, and weighed by species to the nearest 0.1 kg. Fish lengths were reported by centimeter size class.

Sediment samples were collected at each station using a 0.1 m^2 modified Van Veen grab. Sediment grain size was determined using a Horiba Model LA-900 laser scattering particle size distribution analyzer in conjunction with Horiba Data Systems software (Schiff and Gossett 1998).

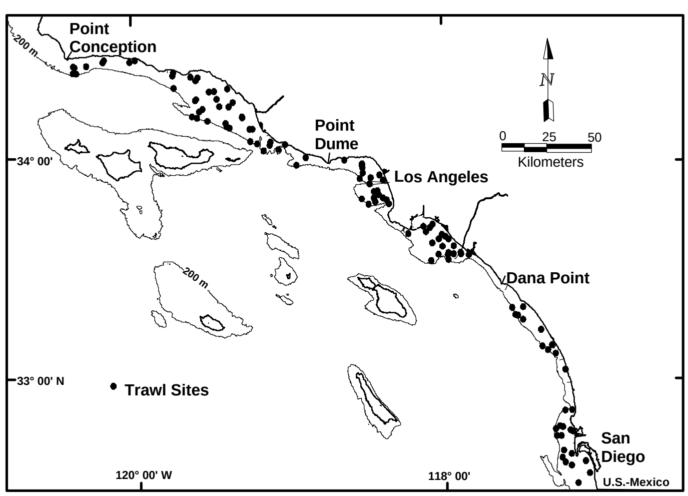
Data Analysis

Abundance-based site and species groups were defined using cluster analysis. Prior to analysis, the data were screened to reduce the confounding effect of rare species and occasional incidental catches of pelagic species. The criteria for inclusion in the analysis were (1) that a species had to have an overall survey abundance of at least 10 individuals and (2) that the species had to occur at a minimum of 5 stations. In addition, the northern anchovy (*Engraulis mordax*) was excluded from the analysis even though it met the selection criteria because its presence was viewed as the incidental catch of a common pelagic species. One station was also dropped from the data since it had fewer than five individuals of any species. Ultimately, 40 species from 113 stations were selected for the cluster analysis.

After selecting the species for analysis, the abundance data were square-root transformed and standardized to mean species abundance. The square-root transformation was applied to moderate the influence of the most abundant taxa (Sokal and Rohlf 1981, Clark and Green 1988). The data were standardized by dividing species abundance at a given station by the mean abundance of that species over all stations. The benefit of standardization is that it effectively equalizes extreme abundance values and facilitates relative comparisons among species (Clark 1993).

The Bray-Curtis measure was used to convert the species composition and abundance data into a dissimilarity matrix (Bray and Curtis 1957, Clifford and Stephenson 1975). Clustering was conducted using agglomerative, hierarchical, flexible sorting method (SAS PROC CLUSTER [SAS Institute 1989]), with *beta* set at -0.25 (Tetra Tech 1985). Both Q-mode cluster analysis (to identify groups of stations that exhibit similar species abundance patterns) and R-mode cluster analysis (to identify complementary groups of species that occur in similar habitats) were conducted and used to produce a two-way coincidence table (Kikkawa 1968, Clifford and Stephenson 1975).

FIGURE 1. Stations sampled by trawl on the mainland shelf of southern California at depths of 10-200 m, July to August 1994.



The relative proportional contribution of species clusters in site clusters was determined by (1) calculating for each species at each site the proportion of its total abundance across all 113 sites, (2) summing these proportions for all species in a given species cluster (e.g., Species Cluster A) within a given site cluster (e.g., Site Cluster 1) to give a species cluster/site cluster total (e.g., sum of Species Cluster A proportions in Site Cluster 1), and (3) dividing each species cluster/site cluster total by the sum of all species cluster/site cluster totals within a site group.

Site clusters were named after depth distribution (i.e., shelf zone) and sediment characteristics (if depth distributions of two site clusters were similar). Primary species clusters were named after their two most abundant species. Secondary species clusters were named after their single most abundant species.

RESULTS

Eighty-seven species of fish, representing 3 classes and 34 families, were collected during the trawl surveys (see Allen *et al*. 1998 for list of species). The survey sampled 80 species of ray-finned fish (Actinopterygii), 6 species of cartilaginous fishes (Chondrichthyes), and 1 species of hagfish (Myxini). The most diverse families were Scorpaenidae (scorpionfishes) with 21 species, Pleuronectidae (righteye flounders) with 9 species, and Paralichthyidae (whiffs) with 7 species.

Twenty-six species accounted for 95% of the total fish abundance in the survey (Table 1). The five most abundant species were Pacific sanddab (*Citharichthys sordidus*), plainfin midshipman (*Porichthys notatus*), slender sole (*Eopsetta exilis*) yellowchin sculpin (*Icelinus quadriseriatus*), and speckled sanddab (*Citharichthys stigmaeus*). These species accounted for approximately 50% of the total fish abundance. In the

TABLE 1. Fish species comprising 95% of the total fish abundance in a regional trawl survey of the mainland shelf of southern California at depths of 10-200 m, July to August 1994.

Scientific Name	Common Name	Abundance (n=18,912)	Percent Total	Percent Cumulative
Citharichthys sordidus	Pacific sanddab	4,125	21.8	21.8
Porichthys notatus	plainfin midshipman	1,996	10.6	32.4
Eopsetta exilis	slender sole	1,569	8.3	40.7
Icelinus quadriseriatus	yellowchin sculpin	1,079	5.7	46.4
Citharichthys stigmaeus	speckled sanddab	1,067	5.6	52.0
Microstomus pacificus	Dover sole	961	5.1	57.1
Citharichthys xanthostigma	longfin sanddab	776	4.1	61.2
Sebastes saxicola	stripetail rockfish	658	3.5	64.7
Symphurus atricauda	California tonguefish	584	3.1	67.8
Sebastes diploproa	splitnose rockfish	522	2.8	70.5
Genyonemus lineatus	white croaker	510	2.7	73.2
Lepidogobius lepidus	bay goby	509	2.7	75.9
Zaniolepis latipinnis	longspine combfish	481	2.5	78.4
Zalembius rosaceus	pink seaperch	466	2.5	80.9
Merluccius productus	Pacific hake	398	2.1	83.0
Zaniolepis frenata	shortspine combfish	316	1.7	84.7
Engraulis mordax	northern anchovy	308	1.6	86.3
Lycodopsis pacifica	blackbelly eelpout	304	1.6	87.9
Pleuronichthys verticalis	hornyhead turbot	221	1.2	89.1
Hippoglossina stomata	bigmouth sole	203	1.1	90.2
Xeneretmus latifrons	blacktip poacher	191	1.0	91.2
Pleuronectes vetulus	English sole	186	1.0	92.2
Sebastes semicinctus	halfbanded rockfish	172	0.9	93.1
Synodus lucioceps	California lizardfish	171	0.9	94.0
Errex zachirus	rex sole	143	0.8	94.7
Argentina sialis	Pacific argentine	136	0.7	95.4

TABLE 2. Frequency of occurrence of fish species in species clusters and site clusters on the mainland shelf of southern California at depths of 10-200 m, July to August 1994. (Spp. Clus = species cluster).

Spp. Clus.		Scientific Name	Common Name	Percent Stations by Site Cluster 1 (n=21)	2 (n=20)	3 (n=29)	4 (n=21)	5 (n=22)	Total (n=113)
A	1	*Xystreurys liolepis*	fantail sole	52	40	21	5	-	23
		Pleuronichthys ritteri	spotted turbot	57	15	-	-	-	13
		Paralichthys californicus	California halibut	86	10	10	-	-	20
	2	*Odontopyxis trispinosa*	pygmy poacher	-	30	-	-	-	5
		Chitonotus pugetensis	roughback sculpin	-	60	3	-	-	12
		Scorpaena guttata	California scorpionfish	24	70	14	14	-	23
	3	*Citharichthys fragilis*	gulf sanddab	-	-	7	5	14	5
		Genyonemus lineatus	white croaker	14	-	10	-	-	5
		Sebastes dallii	calico rockfish	-	5	21	5	-	7
		Porichthys myriaster	specklefin midshipman	5	-	41	-	-	12
B	1	*Citharichthys xanthostigma*	longfin sanddab	43	80	69	48	-	49
		Hippoglossina stomata	bigmouth sole	19	75	72	43	32	50
		Symphurus atricauda	California tonguefish	33	70	72	24	9	44
		Icelinus quadriseriatus	yellowchin sculpin	19	85	79	29	5	45
	2	*Pleuronichthys verticalis*	hornyhead turbot	76	85	76	19	5	53
		Citharichthys stigmaeus	speckled sanddab	100	80	34	-	-	42
		Synodus lucioceps	California lizardfish	71	65	66	33	14	51
	3	*Lepidogobius lepidus*	bay goby	-	30	69	48	-	32
		Zalembius rosaceus	pink seaperch	-	30	79	62	9	40
		Zaniolepis latipinnis	longspine combfish	5	35	72	67	5	39
		Raja inornata	California skate	14	45	34	10	5	22
C	1	*Pleuronectes vetulus*	English sole	29	35	62	52	36	44
		Citharichthys sordidus	Pacific sanddab	10	60	76	95	86	66
		Microstomus pacificus	Dover sole	-	35	59	90	100	58
		Sebastes saxicola	stripetail rockfish	-	20	52	67	77	43
		Porichthys notatus	plainfin midshipman	5	35	69	81	55	50
		Argentina sialis	Pacific argentine	-	10	14	62	5	18
	2	*Sebastes rosenblatti*	greenblotched rockfish	-	5	3	29	45	16
		Sebastes elongatus	greenstriped rockfish	-	-	-	19	50	14
		Sebastes chlorostictus	greenspotted rockfish	-	-	-	24	18	7
		Sebastes semicinctus	halfbanded rockfish	-	-	7	52	9	13
		Chilara taylori	spotted cusk-eel	-	10	3	38	32	16
D	1	*Sebastes diploproa*	splitnose rockfish	-	5	-	-	50	12
		Plectobranchus evides	bluebarred prickleback	-	-	-	-	32	6
	2	*Lycodopsis pacifica*	blackbelly eelpout	-	-	-	19	50	13
		Errex zachirus	rex sole	-	-	-	24	68	18
		Eopsetta exilis	slender sole	-	-	21	43	100	33
		Zaniolepis frenata	shortspine combfish	-	5	-	57	86	28
		Xeneretmus latifrons	blacktip poacher	-	-	-	14	77	18
		Merluccius productus	Pacific hake	-	-	-	10	64	14

reduced data set (consisting of 40 species from 113 stations) selected for cluster analysis, the three most frequently occurring species were Pacific sanddab, Dover sole (*Microstomus pacificus*), and hornyhead turbot (*Pleuronichthys verticalis*) (Table 2). The three most abundant species were Pacific sanddab, plainfin midshipman, and slender sole (Table 3).

Site Clusters

Five primary site clusters were delineated after analysis (Figure 2). Site clusters roughly corresponded to water depth with some overlap between site groups (Figure 3). They corresponded to a lesser extent with sediment grain size patterns (Figure 4), which also tend to be correlated with water depth. The site clusters had similar geographic ranges within the SCB study area

TABLE 3. Abundance of fish species in species clusters andfish site clusters on the mainland shelf of southern California at depths of 10-200 m, July to August 1994. (Spp. clus. = Species Cluster).

Spp. Clus.	Scientific Name	Common Name	Number of Individuals by Site Cluster 1 (n=21)	2 (n=20)	3 (n=29)	4 (n=21)	5 (n=22)	Total (n=113)
A 1	*Xystreurys liolepis*	fantail sole	44	11	7	1	-	63
	Pleuronichthys ritteri	spotted turbot	39	4	-	-	-	43
	Paralichthys californicus	California halibut	61	2	39	-	-	102
2	*Odontopyxis trispinosa*	pygmy poacher	-	11	-	-	-	11
	Chitonotus pugetensis	roughback sculpin	-	37	1	-	-	38
	Scorpaena guttata	California scorpionfish	13	84	4	3	-	104
3	*Citharichthys fragilis*	gulf sanddab	-	-	2	4	30	36
	Genyonemus lineatus	white croaker	13	-	497	-	-	510
	Sebastes dallii	calico rockfish	-	13	8	1	-	22
	Porichthys myriaster	specklefin midshipman	1	-	20	-	-	21
B 1	*Citharichthys xanthostigma*	longfin sanddab	50	267	347	112	-	776
	Hippoglossina stomata	bigmouth sole	9	79	91	14	10	203
	Symphurus atricauda	California tonguefish	51	308	198	23	4	584
	Icelinus quadriseriatus	yellowchin sculpin	8	558	471	41	1	1,079
2	*Pleuronichthys verticalis*	hornyhead turbot	89	64	63	4	1	221
	Citharichthys stigmaeus	speckled sanddab	389	528	150	-	-	1,067
	Synodus lucioceps	California lizardfish	39	53	60	13	5	170
3	*Lepidogobius lepidus*	bay goby	-	49	423	37	-	509
	Zalembius rosaceus	pink seaperch	-	104	307	47	8	466
	Zaniolepis latipinnis	longspine combfish	1	75	326	66	13	481
	Raja inornata	California skate	3	11	16	2	1	33
C 1	*Pleuronectes vetulus*	English sole	52	15	53	44	22	186
	Citharichthys sordidus	Pacific sanddab	24	704	792	2,035	570	4,125
	Microstomus pacificus	Dover sole	-	38	118	278	527	961
	Sebastes saxicola	stripetail rockfish	-	12	134	171	341	658
	Porichthys notatus	plainfin midshipman	1	79	138	916	862	1,996
	Argentina sialis	Pacific argentine	-	15	28	91	2	136
2	*Sebastes rosenblatti*	greenblotched rockfish	-	1	3	17	37	58
	Sebastes elongatus	greenstriped rockfish	-	-	-	5	25	30
	Sebastes chlorostictus	greenspotted rockfish	-	-	-	23	5	28
	Sebastes semicinctus	halfbanded rockfish	-	-	6	161	5	172
	Chilara taylori	spotted cusk-eel	-	3	1	16	17	37
D 1	*Sebastes diploproa*	splitnose rockfish	-	1	-	-	521	522
	Plectobranchus evides	bluebarred prickleback	-	-	-	-	19	19
2	*Lycodopsis pacifica*	blackbelly eelpout	-	-	-	5	299	304
	Errex zachirus	rex sole	-	-	-	11	132	143
	Eopsetta exilis	slender sole	-	-	24	68	1,477	1,569
	Zaniolepis frenata	shortspine combfish	-	1	-	91	224	316
	Xeneretmus latifrons	blacktip poacher	-	-	-	4	187	191
	Merluccius productus	Pacific hake	-	-	-	2	396	398

(Figure 5). Site Cluster 1 generally included the shallowest and sandiest stations sampled while Site Cluster 5 included the deepest stations sampled (Figures 3 and 4). All five site clusters were broadly distributed throughout the study area except for Site Cluster 1, which was not represented in the western portion of the Santa Barbara Channel, and Site Cluster 3, which predominantly represented the middle shelf area of the northern SCB (Figure 5).

Site Cluster 1 (Inner Shelf Cluster) included 21 of the shallowest stations and ranged in depth from 9 to 24 m (mean = 17.2 m). This site cluster occupied an inner shelf habitat characterized by shallow water and mostly sandy sediments (mean = 84.1% sand) (Figures 2 and 3). Site Cluster 1 included all members (i.e., the complete set) of Species Clusters A1, B1, and B2 (Tables 2 and 3). Six species occurred in 50% or more of the stations in this cluster (Table 2). Three species (speckled sanddab;

California halibut, *Paralichthys californicus*; and hornyhead turbot) occurred in more than 75% of the stations in this cluster, with speckled sanddab occurring at all (100%) of the stations. Speckled sanddab was the most abundant species in this cluster, followed by hornyhead turbot and California halibut (Table 3).

Site Cluster 2 (Sandy Inner/Middle Shelf Cluster) included 20 stations ranging in depth from 18 to 97 m (mean = 42.9 m), defining an inner/middle shelf habitat characterized by sandy-silt sediments (mean = 68.3% sand). Station 1418, at 97 m, was located at the head of the San Gabriel Submarine Canyon and was an outlier by depth for this cluster. All other stations in this group were found within the 18 to 66 m depth range. However, Station 1418 had unusually sandy sediments (70.4% sand), which may have contributed to its inclusion in Site Cluster 2. This site cluster included complete Species Clusters A1, A2, B1, B2, B3, and C1 (Tables 2 and 3). Ten species occurred in 50% or more of the stations in this cluster (Table 2). Five species (hornyhead turbot; yellowchin sculpin; speckled sanddab; longfin sanddab, *Citharichthys xanthostigma*; and bigmouth sole, *Hippoglossina stomata*) occurred in at least 75% of the stations. Hornyhead turbot and yellowchin sculpin were most common, occurring in 85% of the stations. Pacific sanddab, yellowchin sculpin, and speckled sanddab were the most abundant species in this cluster (Table 3).

Site Cluster 3 (Muddy Inner/Middle Shelf Cluster), the largest site cluster group, contained 30 stations ranging in depth from 13 to 86 m (mean = 43.6 m). Although the depth range of Site Cluster 3 overlapped with Site Cluster 2, Site Cluster 3 was associated with finer sediments (mean = 50.4% silt/clay). Thus, Site Clusters 2 and 3 characterize an inner/middle shelf habitat distinguished by somewhat different sediment types. Site Cluster 3 included all members of Species Clusters A3, B1, B2, B3, and C1 (Tables 2 and 3) and thus differs from Site Cluster 2 in which of the secondary clusters of Species Cluster A were present. Fourteen species occurred in 50% or more of the stations in this cluster (Table 2). Four species (yellowchin sculpin; pink seaperch, *Zalembius rosaceus*; hornyhead turbot; and Pacific sanddab) occurred in at least 75% of the stations. Yellowchin sculpin and pink seaperch occurred in 79% of the stations. Pacific sanddab, yellowchin sculpin, and bay goby (*Lepidogobius lepidus*) were the most abundant species in this cluster (Table 3).

Site Cluster 4 (Middle/Outer Shelf Cluster) included 20 stations ranging in depth from 72 to 160 m (mean = 101.2 m) characterizing a middle/outer shelf habitat with approximately equal portions of sand and fine sediments (mean = 53.0% sand). This site cluster included complete Species Clusters B1, B3, C1, C2, and D2 (Tables 2 and 3). Ten species occurred in 50% or more of the stations in this cluster (Table 2). Three species (Pacific sanddab, Dover sole, and plainfin midshipman) occurred in at least 75% of the stations. Pacific sanddab was the most common species in this cluster, occurring in 95% of the stations. It was also by far the most abundant species, followed by plainfin midshipman and Dover sole (Table 3).

Site Cluster 5 (Outer Shelf Cluster) included 22 stations ranging in depth from

FIGURE 2. Summary of two-way table and dendrogram for species and site clusters of demersal fishes on the mainland shelf of southern California at depths of 10-200 m, July to August 1994. Cell dot sizes represent relative proportional contribution of species clusters within site clusters.

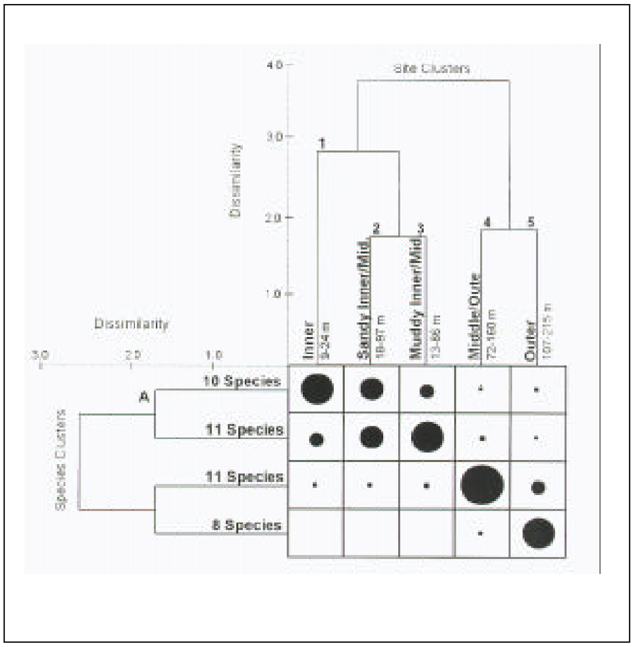
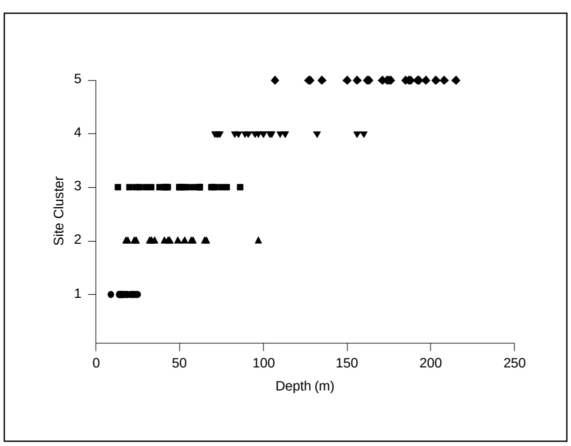
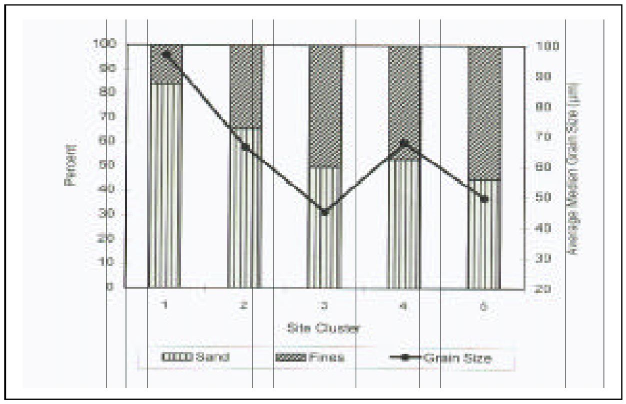


FIGURE 3. Bathymetric distribution of demersal fish site clusters on the mainland shelf of southern California at depths of 10-200 m, July to August 1994.



107 to 215 m (mean = 172.5 m), characterizing an outer shelf group with the finest sediments (mean = 55.3% silt/clay). This site cluster included all members of Species Clusters C1, C2, D1, and D2 (Tables 2 and 3). Twelve species occurred in 50% or more of the stations in this cluster (Table 2). Six species (Dover sole; slender sole; Pacific sanddab; shortspine combfish, *Zaniolepis frenata*; stripetail rockfish, *Sebastes saxicola*; and blacktip poacher, *Xeneretmus latifrons*) occurred in at least 75% of the stations; Dover sole and slender sole occurred at all stations. Slender sole, plainfin midshipman, and Pacific sanddab were the most abundant species in this cluster (Table 3).

FIGURE 4. Relationship of demersal fish site clusters to sediment characteristics (percent of sediment type and average median grain size) on the mainland shelf of southern California at depths of 10-200 m, July to August 1994.

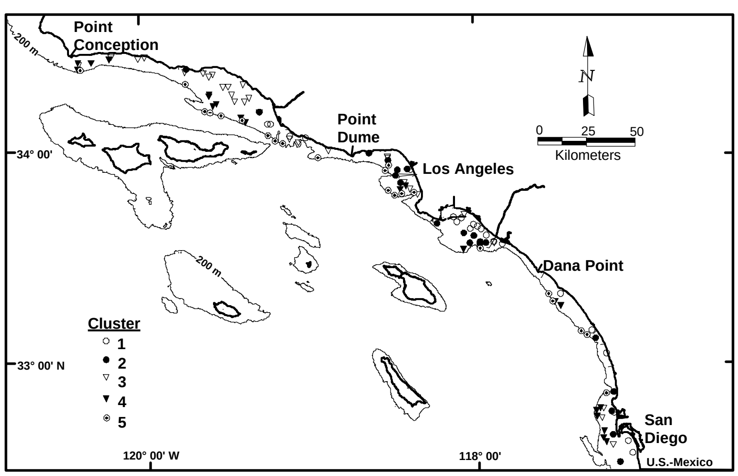


Species Clusters

Four primary species clusters were delineated after analysis (Figure 2). Species Clusters A through D occupied successively deeper depth zones. The correlation of site clusters with water depth results from depth distribution patterns of fish species found in the four species clusters. All site clusters included representatives of three or more species groups. Species Cluster B was dominant in Site Clusters 1, 2, and 3; Species Cluster C was dominant in Site Cluster 4; and Species Cluster D was dominant in Site Cluster 5 (Figure 6).

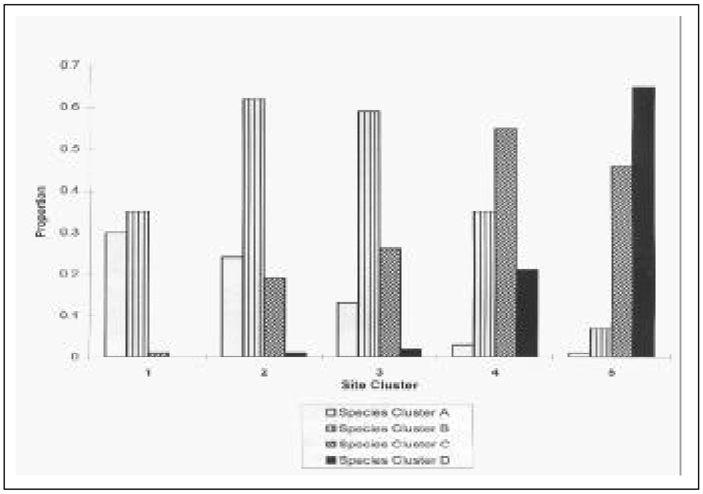
Species Cluster A (White Croaker-California Scorpionfish Cluster) included 10 species and 3 secondary clusters (Tables 2 and 3). Although Species Cluster A was not the dominant species cluster in any of the site clusters (Figure 6), it was relatively more abundant in Site Cluster 1 and thus represents an inner shelf assemblage. None of the site clusters included all members of this species cluster (Tables 2 and 3). The most frequently occurring species were fantail sole (*Xystreurys liolepis*), California scorpionfish (*Scorpaena guttata*), and California halibut. The most abundant species were white croaker (*Genyonemus lineatus*), California scorpionfish, and California halibut. The first secondary cluster (Species Cluster A1, California Halibut Cluster) included fantail sole, spotted turbot (*Pleuronichthys ritteri*), and California halibut. This cluster characterized the inner shelf fish assemblage. All species occurred together in Site Clusters 1 and 2, but all were most frequent and abundant in Site Cluster 1. The next secondary cluster (Species Cluster A2, California Scorpionfish Cluster) included the pygmy poacher (*Odontopyxis trispinosus*), roughback sculpin (*Chitonotus pugetensis*), and California scorpionfish. This cluster characterizes an inner/middle shelf assemblage. All species were found together in Site Cluster 2 and had a broader depth range (18-66 m) than Species Cluster A1 (9-24 m). The last secondary cluster (Species Cluster A3, White Croaker Cluster) included the remaining four species — gulf sanddab (*Citharichthys fragilis*), white croaker, calico rockfish (*Sebastes dallii*), and specklefin midshipman (*Porichthys myriaster*). These species had little similarity to each other and to other groupings. All were found together in Site Cluster 3 and hence represent a middle shelf assemblage with finer sediments.

FIGURE 5. Spatial distribution of demersal fish site clusters on the mainland shelf of southern California at depths of 10-200 m, July to August 1994.



Species Cluster B (Yellowchin Sculpin-Speckled Sanddab Cluster) included 11 species and 3 secondary clusters (Tables 2 and 3). This species cluster was dominant in Site Clusters 1, 2, and 3 (Figure 6), and thus represents an inner/middle shelf assemblage. All species in this cluster occurred together in Site Clusters 2 and 3 (Tables 2 and 3). The most frequently occurring species in this group were hornyhead turbot, California lizardfish (*Synodus lucioceps*), and bigmouth sole; the most abundant species were yellowchin sculpin, speckled sanddab, and longfin sanddab. The first secondary cluster (Species Cluster B1, Yellowchin Sculpin Cluster) included four species (longfin sanddab; bigmouth sole; California tonguefish, *Symphurus atricauda*; and yellowchin sculpin) that occurred together in Site Clusters 1 through 4. They were most abundant at stations in Site Clusters 2 and 3, and hence represent a broad inner/middle shelf assemblage. The next secondary cluster (Species Cluster B2, Speckled Sanddab Cluster) consisted of hornyhead turbot, speckled sanddab, and California lizardfish. These species occurred together in Site Clusters 1 through 3, and hence represent a somewhat narrower inner/middle shelf assemblage, extending to the inner shelf. The final secondary cluster (Species Cluster B3, Bay Goby Cluster) included four species (bay goby; pink seaperch; longspine combfish, *Zaniolepis latipinnis*; and California skate, *Raja inornata*) that were found together in Site Clusters 2 through 4 and hence represent a broad middle shelf assemblage.

FIGURE 6. Relative proportion of possible occurrences of fish species cluster members in site cluster stations on the mainland shelf of southern California at depths of 10-200 m, July to August 1994.



Species Cluster C (Pacific Sanddab-Plainfin Midshipman Cluster) included 11 species and 2 secondary clusters (Tables 2 and 3). This species cluster was dominant in Site Cluster 4 (Figure 6) and represents a middle/outer shelf assemblage. All species in this cluster occurred in Site Clusters 4 and 5 (Tables 2 and 3). The most frequently occurring species in this group were Pacific sanddab, Dover sole, and plainfin midshipman; the most abundant species were Pacific sanddab, plainfin midshipman, and Dover sole. The first secondary cluster (Species Cluster C1, Pacific Sanddab Cluster) comprised six species: English sole (*Pleuronectes vetulus*), Pacific sanddab, Dover sole, stripetail rockfish, plainfin midshipman, and Pacific argentine (*Argentina sialis*). All of these species occurred together in Site Clusters 2 through 5, with peak abundances in Site Cluster 4. Species Cluster C1 characterizes a broad middle/outer shelf assemblage. The next secondary cluster (Species Cluster C2, Halfbanded Rockfish Cluster) consisted of five species: greenstriped rockfish (*Sebastes elongatus*), greenblotched rockfish (*Sebastes rosenblatti*), greenspotted rockfish (*Sebastes chlorostictus*), halfbanded rockfish (*Sebastes semicinctus*), and spotted cusk-eel (*Chilara taylori*). These species were all found together in Site Clusters 4 and 5 and characterize a more narrow middle/outer shelf assemblage.

Species Cluster D (Slender Sole-Splitnose Rockfish Cluster) included eight species and two secondary clusters (Tables 2 and 3). This species group was dominant in Site Group 5 (Figure 6) and thus represents an outer shelf assemblage. All species in this cluster occurred in Site Cluster 5 (Tables 2 and 3). The most frequently occurring species in this group were slender sole, shortspine combfish, rex sole (*Errex zachirus*), and blacktip poacher; the most abundant species were slender sole, splitnose rockfish (*Sebastes diploproa*), and Pacific hake (*Merluccius productus*). The first secondary cluster (Species Cluster D1, Splitnose Rockfish Cluster) consisted of splitnose rockfish and bluebarred prickleback (*Plectobranchus evides*) and represents an outer shelf assemblage; both species were found together in Site Cluster 5. The next secondary cluster (Species Cluster D2, Slender Sole Cluster) consisted of six species (blackbelly eelpout, *Lycodopsis pacifica*; rex sole; slender sole; shortspine combfish; blacktip poacher; and Pacific hake) that were found together in Site Clusters 4 and 5, being most abundant in Site Cluster 5. These species represent a more broadly distributed outer shelf assemblage than the first secondary cluster.

DISCUSSION

Most of the five site and four species clusters of demersal fishes appear to be natural groups in that they consist of relatively tight clusters of stations or species. Almost all of the species included in the analysis typically inhabit the soft-bottom habitat although some (e.g., greenspotted rockfish and greenstriped rockfish) are associated with the low-relief rocky bottom (Allen 1982). However, Species Cluster A1 (White Croaker Cluster) is probably an artificial grouping. Of the four species in this cluster, one (gulf sanddab) is typically a middle/outer shelf species, two (white croaker, calico rockfish) are typically inner/middle shelf species, and one (specklefin midshipman) is typically an inner shelf species (Allen 1982). The occurrence of specklefin midshipman and gulf sanddab together at two stations is unusual; however, some specklefin midshipmen were taken at greater depths than normal (Allen 1982, Allen *et al*. 1998).

Site and species clusters were generally related to water depth, a pattern found for other demersal fish population and assemblage attributes in the area (e.g., SCCWRP 1973, Allen 1982, Stull 1995, Stull and Tang 1996, CSDOC 1996, Allen and Moore 1997, Allen *et al*. 1998). Although site clusters typically differed by depth, considerable overlap of site clusters was often found in the predefined depth subpopulations of the survey (Figure 3). Site Cluster 1 (Inner Shelf Cluster) was found only in the inner shelf depth zone (10-25 m) of all three regions and Site Cluster 5 (Outer Shelf Cluster) was exclusively associated with the outer shelf depth zone (100-200 m). However, the intermediate depth site clusters overlapped with these categories and the middle shelf zone (25-100 m). For example, five stations from Site Cluster 2 (Sandy Inner/Middle Shelf Cluster) and three stations from Site Cluster 3 (Muddy Inner/Middle Shelf Cluster) occurred on the inner shelf zone; and nine stations from Site Cluster 4 (Middle/Outer Shelf Cluster) fell within the outer shelf category.

Although site clusters suggest that demersal fish assemblages are generally organized around depth, other factors (e.g., grain size, geographic subregion, substrate type, or proximity to hard structure) also influence the distribution of fish assemblages. For example, the middle shelf depth category included stations from Site Clusters 2, 3, and 4; however, stations in Site Cluster 2 were absent from the northern area, which was dominated by stations in Site Cluster 3. This distribution may, in part, be due to the muddy (>50% silt/clay) sediments associated with some of the stations (particularly in the Santa Barbara Channel) in Site Cluster 3. Site Cluster 4 was found on sandier bottoms than were Site Clusters 3 and 5 (Figure 4).

All site clusters had unique combinations of complete species clusters (Tables 2 and 3). Similarly, complete species clusters were generally found in different combinations of site groups. However, all members of Species Clusters C2 and D2 occurred only at Site Clusters 4 and 5. These two clusters differ in habitat type with Species Cluster C2 characteristic of coarse sediments and Species Cluster D2 associated with fine sediments.

No pollution effects were found in the study area. Twenty of the trawl stations were identified as being near potential anthropogenic sources of contamination (e.g., wastewater outfalls, river discharges, oil platforms) (Allen *et al*. 1998). These stations were found in all fish site clusters and did not form unique cluster groups.

Comparison of Recurrent Groups and Site/Species Clusters

Fish assemblages based upon cluster analysis have been described in southern California for local areas, generally in the vicinity of ocean outfalls (e.g., CSDLAC 1990, CLAEMD 1994, CSDMWWD 1995, CSDOC 1996), but not for the entire mainland shelf. However, fish assemblages have been defined by recurrent group analysis for this region using the same data set (Allen and Moore 1997). Recurrent group analysis differs from cluster analysis in that species groups are defined based upon co-occurrence of species (using presence/absence data), rather than similarity in relative abundance patterns. In addition, site groups are not defined by recurrent group analysis. Nevertheless, the two methods generally, but not always, produce similar results.

A comparison of the fish cluster results with recurrent group analysis on the same data found many similarities in species associations (Table 4). The four major recurrent groups (excluding an artifactual Group 5) defined in Allen and Moore (1997) generally followed the site cluster pattern. Two recurrent groups were confined to single site clusters, two groups extended across two site clusters, and one site cluster included two recurrent groups. Recurrent Group 2 (Middle Shelf Group) and Recurrent Group 4 (Outer Shelf Group) were restricted to single clusters (Site Clusters 3 and 5, respectively). Recurrent Group 1 (Inner/Middle Shelf Group) and Recurrent Group 3 (Middle/Outer Shelf Group) extended across Site Clusters 1 and 2 and Site Clusters 3 and 4, respectively. Site Cluster 3 included Recurrent Groups 2 and 3.

This comparison helps to identify groups of species that contribute to the uniqueness of each site cluster. Site Cluster 1 differs from Site Cluster 2 in having inner shelf species (California halibut, fantail sole, and spotted turbot) that did not co-occur with sufficient frequency to form a recurrent group. In contrast, in Cluster 2, these species were less important (or absent), and more middle shelf species were present. Cluster 3 had the most diverse assemblage (from the recurrent group perspec-

TABLE 4. Distribution of demersal fish recurrent groups (Allen and Moore 1997) in site clusters on the mainland shelf of southern California at depths of 10-200 m, July to August 1994. (n = no. stations, blocks designate recurrent groups, listed species occur in at least 50% of stations in site cluster).

		Relative Abundance (Percent Total in Site Cluster)				
Scientific Name	Common Name	1 (n=21)	2 (n=20	3 (n=29)	4 (n=21)	5 (n=22)
Paralichthys californicus	California halibut	7	-	-	-	-
Xystreurys liolepis	fantail sole	5	-	-	-	-
Pleuronichthys ritteri	spotted turbot	4	-	-	-	-
Recurrent Group 1						
Citharichthys stigmaeus	speckled sanddab	42	17	-	-	-
Pleuronichthys verticalis	hornyhead turbot	10	2	1	-	-
Synodus lucioceps	California lizardfish	4	2	1	-	-
Symphurus atricauda	California tonguefish	-	10	5	-	-
Scorpaena guttata	California scorpionfish	-	3	-	-	-
Recurrent Group 2						
Citharichthys sordidus	Pacific sanddab	-	22	18	47	9
Icelinus quadriseriatus	yellowchin sculpin	-	18	11	-	-
Citharichthys xanthostigma	longfin sanddab	-	8	8	-	-
Hippoglossina stomata	bigmouth sole	-	3	2	-	-
Lepidogobius lepidus	bay goby	-	-	10	-	-
Zaniolepis latipinnis	longspine combfish	-	-	7	2	-
Zalembius rosaceus	pink seaperch	-	-	7	1	-
Porichthys notatus	plainfin midshipman	-	-	3	21	14
Chitonotus pugetensis	roughback sculpin	-	1	-	-	-
Recurrent Group 3						
Sebastes saxicola	stripetail rockfish	-	-	3	4	6
Microstomus pacificus	Dover sole	-	-	3	6	9
Pleuronectes vetulus	English sole	-	-	1	1	-
Sebastes semicinctus	halfbanded rockfish	-	-	-	4	-
Argentina sialis	Pacific argentine	-	-	-	2	-
Recurrent Group 4						
Zaniolepis frenata	shortspine combfish	-	-	-	2	4
Eopsetta exilis	slender sole	-	-	-	-	24
Errex zachirus	rex sole	-	-	-	-	2
Merluccius productus	Pacific hake	-	-	-	-	6
Lycodopsis pacifica	blackbelly eelpout	-	-	-	-	5
Xeneretmus latifrons	blacktip poacher	-	-	-	-	3
Sebastes elongatus	greenstriped rockfish	-	-	-	-	0
Sebastes diploproa	splitnose rockfish	-	-	-	-	9
Total Abundance of Species		936	3,150	4,369	4,344	6,110

tive) with two groups; whereas in Cluster 4, Recurrent Group 2 breaks down while Recurrent Group 3 remains. Cluster 5 is clearly distinct as a site cluster with a distinct recurrent group, both indicative of an outer shelf assemblage.

Comparison of recurrent groups in Allen and Moore (1997) to species clusters (Table 2) gave a less distinct relationship. No recurrent group occurred in Species Cluster A. However, the Recurrent Group 1 species (speckled sanddab, hornyhead turbot, and California lizardfish) all occurred in Species Cluster B2. Recurrent Group 2 species (Pacific sanddab, plainfin midshipman, yellowchin sculpin, longfin sanddab, bay goby, longspine combfish, pink seaperch, and bigmouth sole) appeared in the Species Clusters B1, B3, and C1. Recurrent Group Species 3 (Dover sole, stripetail rockfish, and English sole) also occurred in Species Cluster C1. All Recurrent Group 4 species (slender sole, Pacific hake, shortspine combfish, blacktip poacher, and rex sole) occurred in Species Cluster D1.

Comparison of all three types of associations (recurrent groups, site clusters, and species clusters) clearly shows that the outer shelf association is most distinct. Recurrent groups appear to reflect site clusters more closely than species clusters. Differences between the two analyses were due to the different analytical methods utilized and the number of species included in each analysis. However, the fact that many of the species groups were similar between the two analyses when the data were similar supports the premise that these species assemblages are natural features of communities within specific habitats rather than artifacts of a particular analytical method.

Recurrent group analysis and site cluster analysis describe assemblages from two perspectives of the community (Allen 1982). Recurrent group analysis describes groups of species that occur together frequently. When applied to a large area, these groups can approximate the biogeographic community (a set of species that live together over a large area and in the same biogeographic province, life zone, and habitat). Members of the biogeographic community often form core elements of the local assemblage (a set of species found at a local site). However, the local assemblage also includes a number of incidental species with centers of distribution in other biogeographic communities found in other biogeographic provinces, life zones, or habitats. While recurrent group analysis can define core species groups (and hence basic components) in the community, it is not appropriate for defining the local assemblage at a given site. However, the assemblage at a given site can be described by site clustering. Site clustering is also appropriate for defining altered sites and ecotone areas (i.e., where different species assemblages overlap).

Species clusters define species groups based upon similar abundance patterns among species, whereas recurrent groups describe species that simply occur together. Species abundance patterns can be influenced by food availability; if this occurs, species that cluster together may feed in a similar, rather than a different, manner. Recurrent group analysis may include species that vary in their abundance patterns and yet occur in the same area. Recurrent groups of demersal fishes in southern California typically consist of species that feed differently and represent different feeding niches (Allen 1982). Species clusters may differ from recurrent groups if the abundance patterns of species that occur together differ, as might be the case if co-occurring species fed on different prey with different abundance patterns. However, over a large area such as the mainland shelf of southern California, both approaches converge on descriptions of assemblages with similar species composition.

The results of this study indicate that depth is more important than sediment type or geographic region in determining the demersal fish assemblage found in an area. The assemblages described in this study will provide a baseline for assessing historical changes and the relative health of southern California demersal fish assemblages.

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