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FISH ASSEMBLAGES ON MUSSEL MOUNDS SURROUNDING SEVEN OIL PLATFORMS IN THE SANTA BARBARA CHANNEL AND SANTA MARIA BASIN

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ABSTRACT

Mussel shell mounds surround all offshore oil and gas platforms in California. These biotic reefs are formed when large clumps of mussels are dislodged from the superstructure. In 1997, we surveyed the fish assemblages on the mussel mounds surrounding seven platforms in the Santa Barbara Channel and in the Santa Maria Basin, California. The objectives of this study were (1) to document the fish assemblages on the mussel reefs, (2) to investigate the spatial patterns of use of parts of mussel reefs by various fish species and (3) to compare species assemblages, population densities and fish sizes on the mussel reefs with those on adjacent platform bottoms. We observed at least 35 species on the mussel mounds, 18 of which were rockfishes (genus *Sebastes*). Most of the species that were found both in large numbers and were encountered at a number of mussel mounds were solitary, benthic forms. Most species appeared to be non-randomly distributed among parts of the mussel mounds with different percent shell cover. All species combined and all rockfish species tended to be slightly but significantly over-represented on areas of 80–100% cover (all species: $\chi^2 = 227$, n = 5, P < 0.001, all rockfishes: $\chi^2 = 211$, n = 5, P < 0.001). Species richness, density (fish 100 m^{-2}) and mean lengths of fishes were all less on the mussel mounds than on the platform bottoms. However, cluster analysis revealed that the species composition on each mussel mound is more similar to its adjacent platform bottom than to other mounds. There did not appear to be a distinct "mussel mound community", instead the mussel mounds should be considered as an integral part of the oil platform system.

Since 1958, offshore oil platforms have been a part of the southern California marine ecosystem. Currently, there are 19 platforms in operation in the Santa Barbara Channel and off central California (Fig. 1). While some of these platforms are as small as 23 m on the side at the surface, the newer structures are over 100 m long (MBC, 1987).

These platforms have a finite economic lifespan and, as they become uneconomical, questions have arisen as to their final disposition. Through 1997, all uneconomical structures have been removed. However, today there is considerable debate regarding the fate of oil platforms. In particular, questions have arisen as to the potential ecological and economic importance of the platforms as artificial reef systems (Seaman and Sprague, 1991). Therefore, understanding the biological communities on and around the platforms is one crucial element to deciding whether to remove or convert obsolete structures into permanent fish habitat.

A major feature of these platforms is the large number of sessile invertebrates (primarily mussels, barnacles and anemones) that encrust the pilings, crossbeams and well pipes. Among animals encrusting these surfaces, mussels (*Mytilus californianus* and *M. galloprovincialis*) are the dominant animals in about the first 15 m of the water column and are occasionally found down to at least 24 m (Carlisle et al., 1964). In shallow waters, thick layers of mussels tend to cover all available surfaces. These bivalves are held to the platform and to each other by byssal threads. Eventually, the weight of these mussel masses is sufficiently large that the holding strength of the byssal threads is approached or surpassed. When this occurs, wave action or storm surge loosens and then dislodges mussel clumps and they fall to the bottom. The amount of mussels dislodged can be substantial; on one platform an estimated 70 kg wet weight of mussels fell to the seafloor each day (Wolfson et al., 1979).

As these invertebrates cover the bottom, they form an extensive, low-relief reef, called a "mussel mound", that may cover a fairly extensive area. Current estimates are that these mounds rise above the sea floor an average of 6–8 m and are on average 60 m in diameter (C. Fusaro, pers. comm.). While mussels form the bulk of the mussel mounds, a large variety of invertebrates, including various species of crabs, seastars, sea cucumbers, anemones and other organisms are also common (Simpson, 1977).

However, while there have been some surveys of the invertebrates on these mounds, there has been no directed research on the fishes inhabiting these communities. In 1997, as part of a survey of the fishes living on offshore platforms of southern and central California, we conducted a survey of the fishes living on these mussel reefs. The objectives of this study were (1) to document the fish assemblages on the mussel reefs adjacent to seven oil platforms, (2) to investigate the spatial patterns of use of parts of mussel reefs by various fish species and (3) to compare species assemblages, population densities and fish sizes on the mussel reefs with those on adjacent platform bottoms.

METHODS

Using the submersible DELTA, we surveyed fish assemblages on mussel mounds surrounding seven oil platforms situated in the Santa Barbara Channel and Santa Maria Basin (Fig. 1). These surveys were part of a larger study investigating fish communities on the oil platforms (Love et al., in press). Surveys were conducted between 10–14 October 1997. Late fall is the optimal time to conduct surveys of this type because of generally good weather and water clarity. In addition, many species have completed their seasonal juvenile recruitment by this time. We conducted belt transects on the mussel mounds. The submarine maintained a speed of approximately 0.5 kt and stayed approximately 1m above the bottom. Dives were conducted during daylight hours, between 1 hr after sunrise and 2 hr before sunset. For a discussion of the oceanography around the survey areas see Love et al., (in press).

During the transects, researchers made their observations from the central starboard side viewing port. An externally mounted Hi-8 mm video camera with associated lights filmed the same viewing field as seen by the observers. Observers identified, counted and estimated the lengths of all fishes and verbally recorded those data on the video. All fishes within 2 m of the submarine were counted. Fish lengths were estimated during the survey using a pair of dual-beam lasers mounted on either side of the external video camera. The projected reference spots were 20 cm apart and were visible both to the observer and the video camera. An environmental monitoring system aboard the submarine continuously recorded date and time, depth and altitude of the vessel above the sea floor.

After the dive, the environmental data was overlaid on the original videotape. Either aboard the research vessel or in the laboratory, we then reviewed the transect videos. For each fish, we recorded: (1) species to lowest identifiable taxa; (2) estimated total length to the nearest cm; and (3) percent shell coverage of the substrata under each individual.

We estimated transect length by first determining the submersible speed. This was done by evaluating a 10 s segment for every one minute of transect. The video was manually forwarded frame by frame and the number of 20 cm segments passing the lasers in a 10 s section was counted. To obtain speed in cm s^{-1}, the number of 20 cm segments per 10 s was divided by 2. All subsamples were then

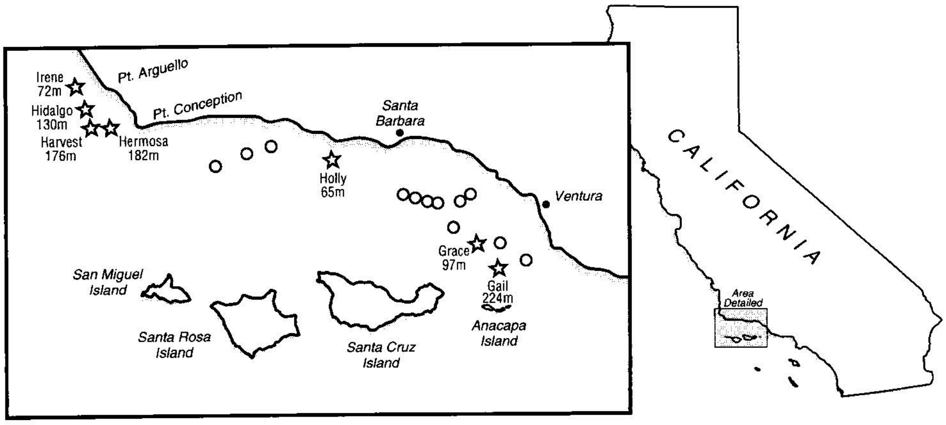

Figure 1. Locations of oil platforms and mussel mounds in the Santa Barbara Channel and Santa Maria Basin.

averaged to obtain mean transect speed (cm^{-s}). The mean speed was then multiplied by the number of seconds in the transect and divided by 100 to obtain transect length in meters. The length was then multiplied by 2 m (the transect width) to obtain transect area, allowing us to estimate fish densities. All densities are presented in fish 100 m^{-2}.

Compared to carbonate reefs, mussel mounds are fairly homogeneous in terms of relief and complexity. Even at the edges of the mounds, we saw no abrupt changes in vertical relief, but rather a slow diminishment of shell cover. In general, the mounds contain few crevices larger than the largest mussel shell. At this time, the spatial extent of the mounds around these platforms is unknown.

Mussel mounds vary in the percentage of mussel cover, ranging from sandy patches with no shells to 100% coverage. Percent cover was categorized as 0–20, 21–40, 41–60, 61–80 and 81–100%. We assessed the patterns of use of the mounds by comparing the number of fishes observed over each area of differing percentage cover with the number of fishes expected according to the proportional availability of that percentage cover. We did this for all mounds combined. For example, if 50% of the area of all the mussel mounds is 100% cover, than assuming no preference for mussel cover, 50% of all fishes observed should be over the 100% cover. We plotted frequency histograms of the observed and expected numbers of fishes for all of the common species in the survey. To test for non-random mound use we used chi-square goodness-of-fit tests. Since calculated values of chi-square are biased when expected frequencies are small, and we observed low numbers of individuals of most species, we only performed the test on species that had zero or one expected frequency less than 5 (Siegel and Castellan, 1988).

Mean lengths of fishes on the mussel mounds and adjacent platforms were compared using Students t-tests in all cases where the variances were equal. When variances were found to be unequal, we used Welch approximate t-test.

To compare the assemblage structure on the mussel mounds with that on the platform bottoms, species abundance data were converted to a triangular matrix of similarity between every pair of samples using the Bray-Curtis similarity coefficient (Bray and Curtis, 1957). Densities (fish 100 m^{-2}) were log (x+1) transformed to decrease the importance of the abundant species. Species present on only one mussel mound or one platform were dropped from the analysis. Samples were clustered using group-average sorting on the Bray-Curtis similarities. The resulting dendrogram ordered samples into groups of increasingly greater similarity based on relative species abundance.

RESULTS

MUSSEL MOUND ASSEMBLAGES.—Thirty-four identifiable fish species (or groups) were found associated with the mussel mounds of the seven platforms (Table 1). Rockfishes were the most speciose group; a minimum of 18 species was seen. While no species was found on every mound, several species or species groups (Pacific sanddab, lingcod, halfbanded rockfish and *Sebastomus* group) were found on six. Other commonly seen species included greenspotted and rosy rockfishes (five mussel mounds), and painted greenling, shortspine combfish, greenstriped and flag rockfishes, and young-of-the-year (YOY) rockfish (four mounds).

Most of the species that were both abundant (found in large numbers) and common (encountered at a number of mussel mounds) were solitary, benthic forms. Typical of this group were greenspotted, greenstriped and rosy rockfishes, lingcod and Pacific sanddab. The first four species were usually found resting on the bottom and were often sheltered among the mussel shells. We often saw Pacific sanddab swimming slightly above the bottom, although they were also commonly encountered resting either on soft substrata or occasionally on the shells. The only commonly encountered schooling forms were the halfbanded rockfish and YOY rockfishes. Halfbanded rockfish were very abundant on a number of the mounds. They were almost always seen in large, active schools that often numbered in the hundreds of individuals. These schools were usually positioned from less than 1 m to approximately 3 m above the substrata. The small numbers of YOY rockfishes observed on the mounds relative to the platforms were in small groups and usually very close to the shell-covered substratum.

Several other species of schooling fishes were found in large numbers at only single platforms. At Platform Grace, thousands of shiner surfperch were encountered over the mussel mound and adjacent to the platform (Table 1). Pacific sardines were seen over the mussels at Holly and northern anchovies were observed over the mussels at Gail. It is likely that the sardines and anchovies, and perhaps the shiner surfperches, are highly motile and not representative mussel mound fauna.

We recorded 11 identifiable fish species around Platform Irene (Table 1). Halfbanded rockfish were by far the most common species. Pacific sanddab, lingcod (primarily juveniles), copper rockfish (juveniles) and painted greenling were also frequently encountered. The high density of juvenile lingcod on the Irene mussel mounds is particularly noteworthy, as we have never observed this species in such high density on any other artificial or natural structure in southern or central California (Love, unpubl. data). Halfbanded rockfish were also the most abundant species on the Hidalgo mussel mound, where we found 13 species. Young greenspotted rockfish, lingcod, YOY rockfish, rosy rockfish and painted greenling were also quite abundant. Relatively few species (10) were seen at Harvest and it also had the lowest fish densities overall. Sharpchin rockfish, greenstriped rockfish, greenspotted rockfish and poachers were most common. As with a number of other sites, halfbanded rockfish were the most abundant species on the Hermosa mound, where 13 species were noted. Greenspotted rockfish, shortspine combfish and greenstriped rockfish were also fairly common. A school of Pacific sardines dominated the mound at Holly, where 10 species were seen. As noted above, it is likely that this was a transient event, as sardines are highly mobile. Among the more typical species, young copper rockfish were the most abundant, followed by calico rockfish, pink surfperch, rosy rockfish and halfbanded rockfish. While a very large school of shiner surfperch

Table 1. Densities (number fish 100 m^{-2}) of all species observed on each platform (P) and its corresponding mussel mound (MM). Dots indicate zero density values. Platforms and mounds are ordered by depth from shallow to deep with bottom depths given. The minimum number of species was calculated by not including any unidentified species that could be confused with an identifiable species.

		Holly 49 m		Irene 72 m		Grace 97 m		Hildago 130 m		Harvest 176 m		Hermosa 182 m		Gail 224 m		Total	
Name	Common Name	MM	P	MM	P	MM	P	MM	P	MM	P	MM	P	MM	P	MM	P
SCORPAENIDAE																	
S. auriculatus	Brown rockfish	·	2.75	·	1.52	·	·	·	·	·	·	·	·	·	·	·	4.28
S. caurinus	Copper rockfish	9.34	21.83	5.25	48.33	·	·	·	·	·	·	·	·	·	·	14.59	70.16
S. carnatus	Gopher rockfish	·	0.21	·	0.44	·	·	·	·	·	·	·	·	·	·	·	0.65
S. chlorostictus	Greenspotted rockfish	·	·	·	·	0.73	0.97	3.75	16.80	3.05	3.46	3.36	9.27	0.16	10.16	11.05	40.67
S. constellatus	Starry rockfish	·	·	·	·	·	·	·	0.54	·	·	·	·	·	·	·	0.54
S. crameri	Darkblotched rockfish	·	·	·	·	·	·	·	·	·	·	·	0.15	1.61	·	1.61	0.15
S. dalli	Calico rockfish	4.87	30.94	·	1.31	·	·	·	·	·	·	·	·	·	·	4.87	32.25
S. elongatus	Greenstriped rockfish	·	·	·	·	·	·	0.72	·	6.71	5.69	1.68	0.15	2.57	0.31	11.68	6.15
S. ensifer	Swordspine rockfish	·	·	·	·	0.36	·	0.54	·	·	·	·	·	3.85	·	4.75	·
S. entomelas	Widow rockfish	·	·	·	0.22	·	72.82	·	0.36	·	·	·	·	·	·	·	73.39
S. flavidus	Yellowtail rockfish	·	0.21	·	0.22	·		·	·	·	·	·	·	·	·	·	0.43
S. goodei	Chilipepper	·	·	·	·	·	0.24	·	·	·	·	·	·	0.64	0.78	0.64	1.02
S. hopkinsi	Squarespot rockfish	·	1.70	·	·	·	·	·	·	·	·	·	·	·	·	·	1.70
S. levis	Cowcod	·	·	·	·	·	·	·	·	·	·	0.34	·	·	0.47	0.34	0.47
S. miniatus	Vermilion rockfish	·	4.45	0.75	29.61	·	1.94	0.18	2.17	·	·	·	·	·	·	0.93	38.17
S. paucispinis	Bocaccio	·	·	0.19	1.31	·	·		1.63	·	·	·	0.15		17.67	0.19	20.75
S. pinniger	Canary rockfish	·	0.21	·	1.09	·	0.24	0.18	1.08	·	·	·	0.15	·	·	0.18	2.78
S. rosaceus	Rosy rockfish	1.22	2.33	1.12	3.48	0.36	0.49	2.68	0.90	·	·	0.34		·	·	5.72	7.20

Table 1. Continued.

		Holly 49 m		Irene 72 m		Grace 97 m		Hildago 130 m		Harvest 176 m		Hermosa 182 m		Gail 224 m		Total	
Name	Common Name	MM	P	MM	P	MM	P	MM	P	MM	P	MM	P	MM	P	MM	P
S. rosenblatti	Greenblotched rockfish	·	·	·	·	·	·	·	0.18	0.41	2.47	0.50	0.45	5.94	16.57	6.85	19.67
S. ruberrimus	Yelloweye rockfish	·	·	·	0.22	·	0.24		0.54	·	·	·	·	·	·	·	1.00
S. rubrivinctus	Flag rockfish	0.41	1.48	·	·	1.46	1.70	0.36	14.82	·	·	0.17	0.90	·	0.16	2.39	19.05
S. rufus	Bank rockfish	·	·	·	·	·	·	·	·	0.20	·	·	·	·	·	0.20	·
S. saxicola	Stripetail rockfish	·	·	·	·	·	·	·	·	·	·	·	·	26.17	29.55	26.17	29.55
S. semicinctus	Halfbanded rockfish	1.22	6.99	119.73	9.14	48.08	878.88	38.62	74.62	0.20	·	68.16	333.60	·	·	276.01	1303.24
S. serriceps	Treefish rockfish	·	0.64	·	·	·	0.24	·	·	·	·	·	·	·	·	·	0.88
S. wilsoni	Pygmy rockfish	·	·	·	·	·	·	·	0.36	·	·	·	·	·	·	·	0.36
S. zacentrus	Sharpchin rockfish	·	·	·	·	·	·	·	·	18.11	10.88	·	·	2.41	0.16	20.51	11.04
Scorpaena guttata	Spotted scorpionfish	·	0.42	·	·	0.36	·	·	·	·	·	·	·	·	·	0.36	0.42
Sebastes spp.	Rockfish YOY*	·	0.42	·	302.81	·	·	2.86	16.80	1.02	0.49	0.17	·	1.44	0.63	5.49	321.16
Sebastomus group		·	·	0.19	0.44	0.36	1.70	0.18	0.72	0.61	0.74	0.34	0.75	0.64	2.03	2.32	6.38
HEXAGRAMMIDAE																	
Hexagrammos decagrammus	Kelp greenling	·	0.21	·	0.22	·	·	·	·	·	·	·	·	·	·	·	0.43
Ophiodon elongatus	Lingcod	0.81	0.85	14.24	5.44	0.36	·	3.40	3.07	1.02	1.48	0.67	0.90	·	0.63	20.50	12.37
ZANIOLEPIDIDAE																	
Oxylebius pictus	Painted greenling	0.81	1.27	5.25	7.18	0.36	0.24	1.43	2.35	·	·	·	·	·	0.16	7.85	11.20
Zaniolepis frenata	Shortspine combfish	·	0.21	·	·	1.46	·	0.72	·	0.41	0.25	1.85	0.30	·	·	4.43	0.76
Zaniolepis sp.	Combfish sp.	0.81	·	·	·	1.82	0.49	·	0.18	·	·	·	·	1.61	·	4.24	0.67

Table 1. Continued.

		Holly 49 m		Irene 72 m		Grace 97 m		Hildago 130 m		Harvest 176 m		Hermosa 182 m		Gail 224 m		Total	
Name	Common Name	MM	P	MM	P	MM	P	MM	P	MM	P	MM	P	MM	P	MM	P
EMBIOTOCIDAE																	
Cymatogaster aggregata	Shiner surfperch	·	·	·	·	375.17	31.55	·	·	·	·	·	·	·	·	375.17	31.55
Phanerodon atripes	Sharpnose surfperch	·	83.92	·	·	·	·	·	·	·	·	·	·	·	·	·	83.92
Rhacochilus toxotes	Rubberlip surfperch	·	1.27	·	1.74	·	·	·	·	·	·	·	·	·	·	·	3.01
Rhacochilus vacca	Pile perch	·	0.85	0.94	9.58	·	·	·	·	·	·	·	·	·	·	0.94	10.43
Zalembius rosaceus	Pink seaperch	1.22	1.27	0.19	·	2.91	2.91	·	·	·	·	0.17	0.15	·	·	4.49	4.33
COTTIDAE																	
	Unident. sculpins	·	·	·	·	·	·	·	·	·	·	·	·	0.16	·	0.16	·
GOBIIDAE																	
Coryphopterus nicholsi	Blackeye goby	·	1.48	·	·	·	·	·	·	·	·	·	·	·	·	·	1.48
BATHYMASTERIDAE																	
	Unident. Ronquil	·	1.48	0.19	0.22	·	·	·	·	·	·	·	·	0.16	·	0.35	1.70
Rathbunella sp.	Ronquil	·	·	·	·	0.36	·	0.18	·	·	·	·	·	·	·	0.54	·
AGONIDAE																	
	Unident. Poachers	·	·	·	·	·	·	·	·	1.83	0.49	0.50	·	0.96	·	3.30	0.49
BOTHIDAE																	
Citharichthys sordidus	Pacific sanddab	1.62	2.75	17.80	20.90	2.91	1.21	1.07	·	0.20	0.25	1.51	·	·	·	25.13	25.11
PLEURONECTIDAE																	
Microstomus pacificus	Dover sole	·	·	·	·	·	·	·	·	·	·	·	·	0.16	·	0.16	·

Table 1. Continued.

		Holly 49 m		Irene 72 m		Grace 97 m		Hildago 130 m		Harvest 176 m		Hermosa 182 m		Gail 224 m		Total	
Name	Common Name	MM	P	MM	P	MM	P	MM	P	MM	P	MM	P	MM	P	MM	P
ENGRAULIDAE																	
Engraulis mordax	Northern anchovy	·	·	·	·	·	·	·	·	·	·	·	·	25.36	0.16	25.36	0.16
CLUPEIDAE																	
Sardinops sagax	Pacific sardine	81.21	·	·	·	·	·	·	·	·	·	·	·	·	·	81.21	·
TORPEDINIDAE																	
Torpedo californica	Pacific electric ray	·	·	·	·	·	·	·	·	·	·	·	·	0.32	·	0.32	·
CARANGIDAE																	
Trachurus symmetricus	Jackmackerel	·	·	·	·	·	·	·	·	·	·	·	·	1.12	·	1.12	·
UNIDENT. FISH	Unidentified fish	0.81	·		0.65	·	0.24	·	·	·	·	0.17	·	0.32	0.16	1.30	1.05
	Total Density	104.4	170.17	165.8	446.1	437.1	996.1	56.9	137.1	33.8	26.2	79.9	347.0	75.6	79.7	953.6	2202.3
	Total min. # of spp.	10	24	11	19	14	15	13	15	10	7	13	11	16	12	34	40

* YOY means young-of-the-year

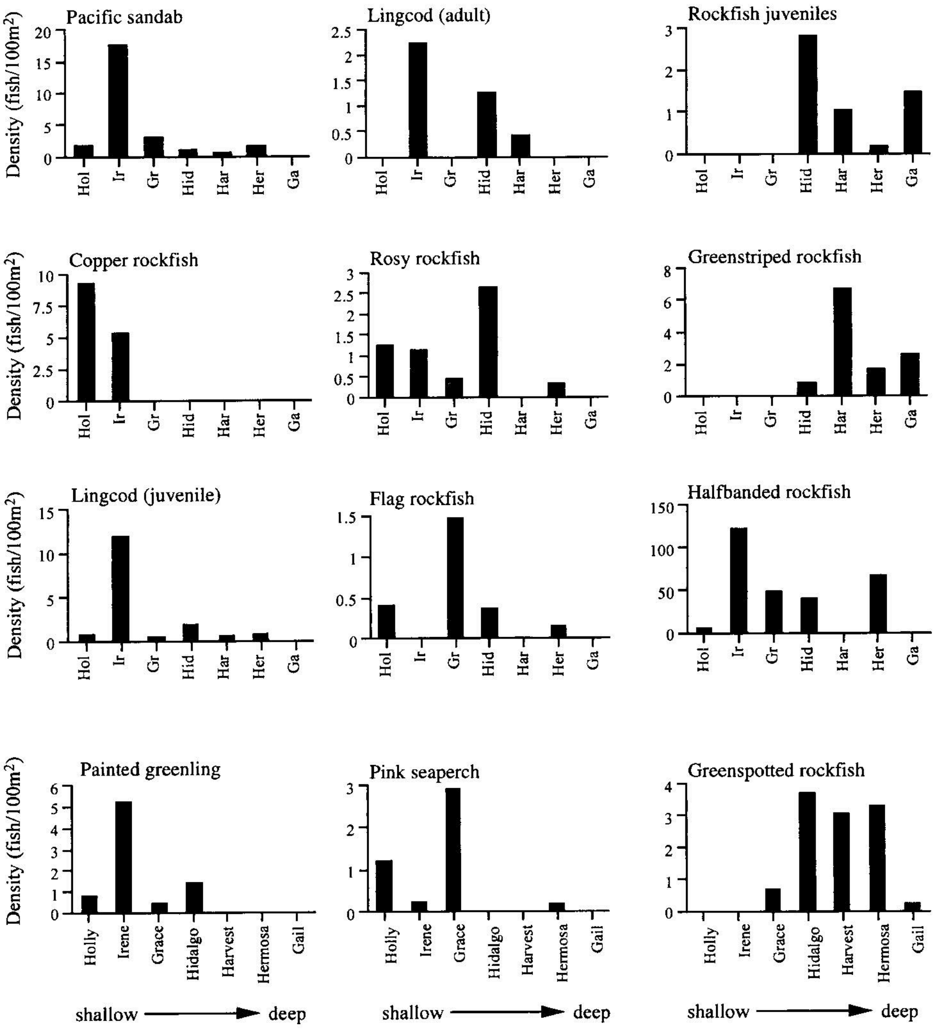

Figure 2. Densities of common mussel mound species on each mound. Mounds arranged by depth from shallow (Holly) to deep (Gail).

dominated the mussel mound around Grace (14 species observed), halfbanded rockfish, pink seaperch, combfish and young flag rockfish were also often seen. Sixteen species were noted around Gail, the greatest species richness among the mounds. Around Gail, a single, large school of northern anchovy was present, which caused it to be the most dense species here. Other common species at Gail included stripetail, greenblotched, swordspine, sharpchin and greenstriped rockfishes.

Some of these differences among mussel mound species assemblages appear to be related to bottom depth (Table 1, Fig. 2). Among the rockfishes, coppers tended to found on the shallowest mounds while rosies, halfbandeds, flags and greenspotteds were most common in midrange (Fig. 2). Sharpchins, darkblotched, greenblotched, greenstriped and rockfish YOY tended to be found on the deepest mussel mounds (Table 1, Fig. 2). Painted

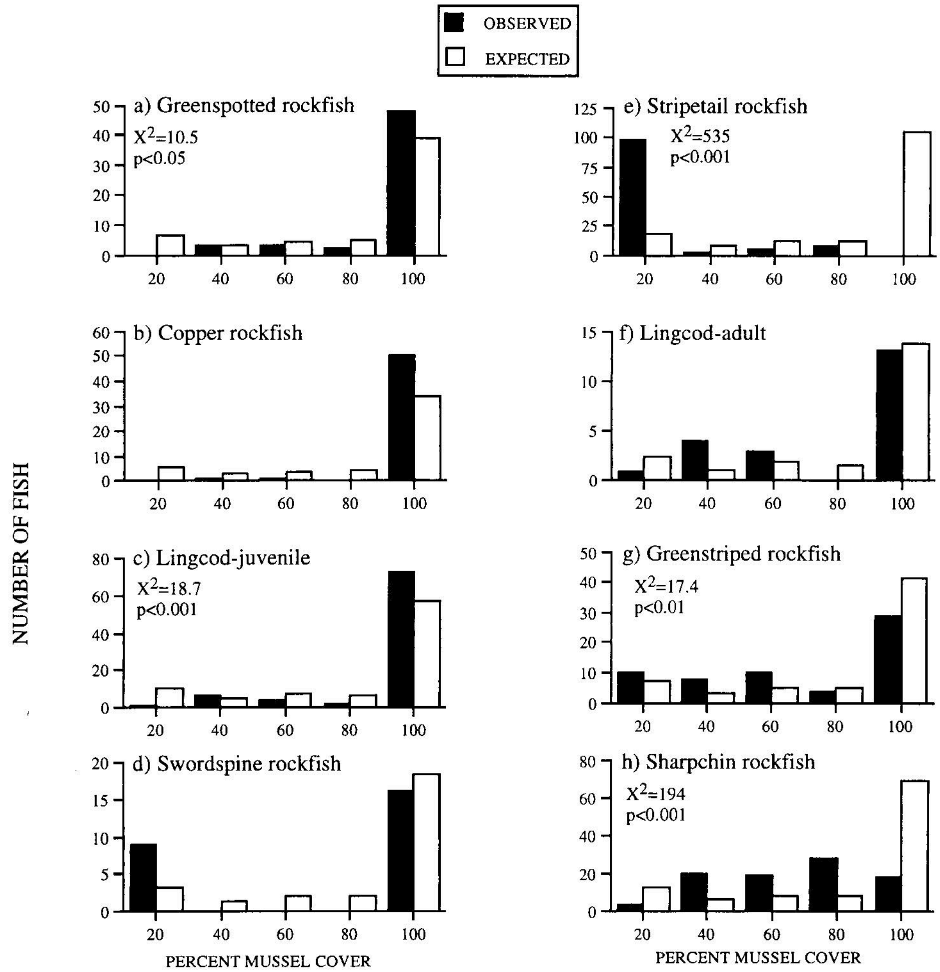

Figure 3. Observed and expected numbers of individuals of various species on mussel mounds. Expected numbers were calculated based on the availability of the different percentage classes of mussel cover. Chi-square goodness-of-fit tests were performed on species with zero or one expected frequency less than 5 (Siegel and Castellan, 1988).

greenling, juvenile lingcod, pink seaperch and Pacific sanddab also were found in shallow waters (Fig. 2).

Differential Use of Parts of Mussel Mounds.—Most species appeared to be nonrandomly distributed among parts of the mussel mounds. We compared the distributions of individuals across areas with different percent mussel cover with the expected distributions based on the availability of areas of different percent cover (Fig. 3A–H). We did this graphically or with chi-square goodness-of-fit tests (see Methods).

Among the more abundant species, greenspotted and copper rockfishes, as well as juvenile lingcod, were all disproportionately present over areas with 80–100% mussel cover (Fig. 3A–C). Greenspotted rockfish and lingcod juveniles showed a significant deviation from the expected based on the availability of different percent covers (Fig. 3A,C). At the other extreme, swordspine, stripetail and greenstriped rockfishes and adult

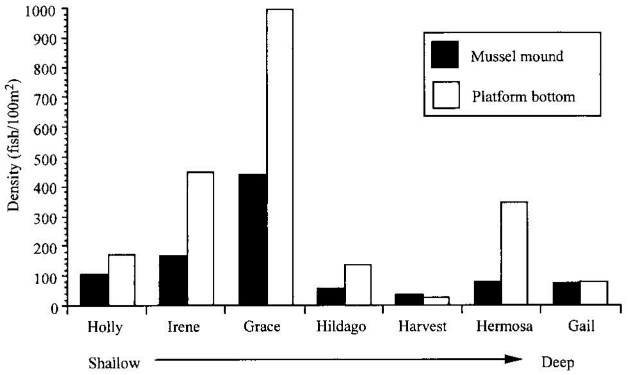

Figure 4. Density (fish 100 m^{-2}) of all species of fishes per platform and mound. Platforms ordered by depth.

lingcod were over-represented on bottoms with relatively little shell cover, with stripetail and greenstriped significantly so (Fig. 3D–G). Sharpchin rockfish were significantly non-randomly distributed and were most abundant over a mixed shell-mud bottom (Fig. 3H).

COMPARISONS WITH PLATFORM BOTTOMS.—*Species Richness and Diversity.*—Species richness was slightly greater on the platform bottoms (40 species) than on the mussel mounds (34 species). Mean number of species on a platform bottom was 14.7 (range 7–24) compared to an average of 12.6 species per mussel mound (range 10–16) (Table 1). This difference was not significant ($t = -0.88$, $df = 6$, $P = 0.4$).

Density.—The mean density of all species combined was 136.2 fish 100 m^{-2} on the mussel mounds compared to 314.6 fish 100 m^{-2} on the platform bottoms and the difference was significant ($t = -2.3$, $df = 6$, $P = 0.03$). At five of the seven sites, the total density of all species on the mussel mounds was approximately half that on the adjacent platform bottom (Fig. 4). The exceptions were around Platforms Harvest and Gail, where densities were very similar. In no case was total fish density substantially greater on the mound compared to the adjacent platform bottom. However, the large-scale spatial pattern of densities among platform bottoms and adjacent mussel mounds was similar. That is, there was a significant correlation between the density of fishes on a platform and on the adjacent mound (Spearmans rank correlation, $Rs = 0.93$, $n = 7$, $P < 0.005$). However, there was no relationship between total fish density on the mussel mounds and either bottom depth ($Rs = 0.057$, $n = 7$, $P > 0.05$) or geography (measured as the ranking of the platforms from north to south) ($Rs = 0.18$, $n = 7$, $P > 0.05$). We have also previously shown that the densities of fishes around platform bottoms also show no relationship with either bottom depth or geography (Love et al., in press).

Fish Lengths.—In general, the mean lengths (TL) of fishes inhabiting the mussel mounds were significantly smaller than fishes on the platforms (Table 2). For the 14 species that were present in relatively large numbers on both types of habitat, 10 were significantly smaller on the mussel mounds, one was significantly larger and three showed no significant length differences. The size differences were particularly large for copper, greenblotched, flag and halfbanded rockfishes and lingcod, all of which were larger on the platforms. Only stripetail rockfish were, in general, larger on the mounds than on the platforms.

Table 2. Mean total length (cm) and 1 SE and sample size for species of fish inhabiting both mussel mounds and platform bottoms. P-values are for student t-tests except in cases where variances are unequal. Welch approximate t-test's were substituted in these cases and are noted with *.

		Platforms		Mussel mounds		
	Common name	Mean ln (SE)	N	Mean ln (SE)	N	p-value
Platform >Mound	Copper rockfish*	19.8 (0.4)	325	14.9 (0.6)	51	<0.001
	Greenspotted rockfish	17.3 (0.3)	238	13.6 (0.6)	58	<0.001
	Greenstriped rockfish*	21.9 (1.3)	26	18.6 (0.5)	63	<0.05
	Rosy rockfish*	13.9 (0.8)	32	11.0 (0.4)	27	<0.01
	Greenblotched rockfish*	21.7 (0.6)	120	16.7 (0.8)	42	<0.001
	Halfbanded rockfish*	14.5 (0.0)	6,341	9.8 (0.1)	1,397	<0.001
	Flag rockfish	19.8 (0.5)	102	12.5 (1.1)	6	<0.001
	Lingcod	37.3 (2.0)	59	24.7 (1.2)	107	<0.001
	Painted greenling	13.6 (0.7)	53	11.5 (0.7)	39	<0.05
	Pink seaperch	16.1 (0.8)	19	13.5 (0.9)	13	<0.05
No Difference	Pacific sanddab	12.9 (0.4)	96	13.6 (0.4)	92	NS
	Shiner surfperch	15.0 (0.0)	130	15.0 (0.0)	1,030	NS
	Sharpchin rockfish	14.4 (0.4)	45	13.5 (0.3)	104	NS
Mound >Platform	Stripetail rockfish	13.4 (0.3)	191	15.0 (0.3)	163	<0.001

Community Composition.—We asked whether species compositions were more similar among the various mussel mounds or between each mussel mound and adjacent platform bottom. That is, is there a mussel mound fish community that differs from a platform bottom community? Numerical classification revealed that, in general, each mussel mound is more similar to its adjacent platform bottom than to other mounds (Fig. 5). The only exception to this pattern is the Hidalgo mussel mound, which is more similar to the Hermosa platform/mound pair than to the Hidalgo platform. Overall, the mean similarity (average Bray-Curtis coefficient on log (x+1) transformed densities) was lower among all platforms (0.27, n = 21 platform-platform pairs) and among all mussel mounds (0.28, n = 21 mound-mound pairs) than among each adjacent mussel mound-platform pair (0.61, n = 7).

The strongest differences distinguish fish assemblages from platform/mound pairs at different depths. Three major clusters arose (Fig. 5). Cluster 1 contains the shallowest sites (Holly mound/platform and Irene mound/platform). Cluster 2 generally contains the mid-depth sites, while cluster 3 contains the deepest sites. The exception to this pattern is that Hermosa (platform and mound at 182 m) clustered with Hidalgo (130 m) and Grace (97 m), while Harvest (176 m) clustered with Gail (the deepest at 224 m).

Despite the similarities in assemblage structure between a mussel mound and its adjacent platform bottom, there were also some notable differences in term of species presence and absence. This was particularly true among the rockfishes. Widow and canary rockfishes and bocaccio were found either entirely or primarily on the platforms whereas swordspine rockfish were observed solely on the mussel mounds (Table 1). Greenstriped rockfish and shortspine combfish were both more abundant on the mussel mounds than on the platform bottoms.

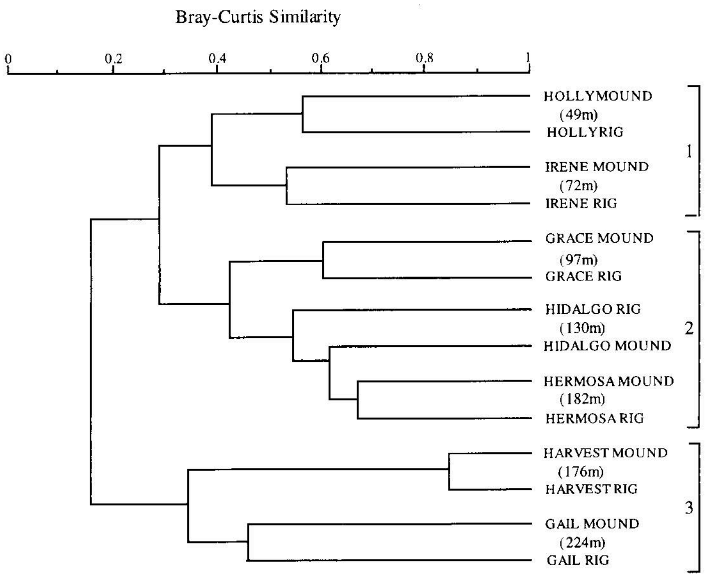

Figure 5. The dendrogram resulting from clustering (Group-Average sorting) of Bray-Curtis similarities on fish species composition between samples at all platform bottoms and mussel mounds. Three major clusters were found and numbered 1 through 3. The depth of each platform and mussel mound is shown in parentheses between each pair.

Discussion

A major objective of this study was to document the fish assemblages on mussel mounds and to compare the mussel mounds to nearby oil platforms. One significant finding is that there does not appear to be a unique "mussel mound assemblage" that differs from assemblages found on nearby platforms. Instead, each mussel mound is more similar in terms of relative species abundance to its adjacent rig than it is to other mounds. A pilot study comparing the fish assemblage on one oil platform to several natural reefs in the vicinity showed that there were distinct differences in species composition and abundance between the platform and the natural reefs (Love et al., 1994). Several of the natural reefs in that study were located within 3 km of the platform. Thus it appears that the mussel reefs which are directly below and adjacent to the platforms could be considered more as a part of one "platform system" than even relatively close-by natural reefs. Natural reefs, mussel reefs and oil platforms all differ in habitat. That the species composition between a mussel reef and adjacent platform is more similar than among all mussel reefs is likely due simply to close proximity. Movement from a mussel reef to the adjacent platform must be more easily accomplished than movements among platforms surrounded by large expanses of sand or mud bottom. Thus, there is likely to be a greater flux of individuals between a platform and the adjacent mussel mound than between various platforms.

This study cannot address the issue of movement between platforms and mussel mounds. It should be noted that the surveys discussed here are a "snapshot" in time. Whether the assemblages at the various platforms/mussel reefs are stable over time remains to be seen. Longer-term surveys of the fish fauna on two platforms in the Gulf of Mexico as well as one in the Santa Barbara Channel showed considerable diel and seasonal variation in the number of species present (Carlisle et al., 1964; Hastings et al., 1975). In addition, monthly SCUBA observations on one shallow-water platform indicate that there may be large temporal changes in assemblage structure (D. Schroeder, unpub data). Despite this, no obvious differences were detected between the mussel mound and platform assemblages.

Although there are similar species assemblages on a platform and adjacent mussel mound, there are depth-related differences among the platform/mussel mound pairs (hereafter referred to as "sites"). Cluster analysis showed differences in the fish assemblages between sites in shallow, moderate and deep waters. It is widely accepted that fish have depth preferences and there was a large range of depths surveyed in this study (49 to 224 m). We have previously shown that fish assemblages differ between the midwater portions and the bottoms of the platforms (Love et al., in press). We related those differences to both depth preferences and to habitat structure. The strongest differences in this study were between the two shallowest sites (Holly and Irene at 49 and 72 m, respectively) and the others. Both Holly and Irene are located in relatively nearshore, shallow waters compared to all the other platforms that are situated farther from shore and in deeper water. Several rockfish and surfperch species were only present at these two shallow sites. These included brown, gopher, yellowtail, calico, and squarespot rockfishes and sharpnose, rubberlip and pile surfperches. Surfperches are livebearers and tend to live in shallow water. As livebearers, this family has no pelagic phase; thus juvenile dispersal across deep water is probably extremely limited. Surfperches, by swimming along the bottom, may only be able to reach the shallower of the sites. The moderate and deepest sites were less distinctive. There may be a threshold depth and/or distance from shore that once exceeded, determines which species can colonize or survive at a site. Only one species, the stripetail rockfish, was present only at the deepest site (Gail, 224 m). Thus, bottom depth may be more important in determining differences in species composition among widely separated sites than specific features of microhabitat. That is, species will only occupy or disperse between platforms within a certain depth range. Within the preferred depth ranges, fish may distribute themselves randomly or based on other characteristics such as habitat structure (e.g., mussel mound or platform members), presence or absence of competitors or predators, or food availability.

Similarity in species composition might indicate random and frequent movements between mounds and platforms. Although we could not distinguish a "mussel mound community" from a "platform community", there were several important differences between the mounds and platforms that suggest that movements may not be frequent or random. First, mussel reefs are inhabited almost entirely by small individuals. Fishes greater than about 20 cm in TL were relatively rare at all of the mounds. In the case of rockfishes, the smaller fishes on the mussel mounds were either juveniles or dwarf species that do not grow large (e.g., swordspine and halfbanded). A number of the other common mussel mound species, such as Pacific sanddab, painted greenling and shortspine combfish, are also small taxa.

On the other hand, the fishes observed at the bottom of the platforms are, in general, larger than those found on the mounds. What might account for this size difference? Both the type and amount of habitat structure have been shown to influence the species composition and abundance of fishes (Choat and Ayling, 1987; Anderson et al., 1989; Caselle and Warner, 1996; Light and Jones, 1997; Friedlander and Parrish, 1998). Although we did not measure characteristics of the habitats in this study, there were easily observable differences. First, the platform superstructure, particularly the crossbeam usually found near the bottom, provide large crevices that tend to harbor large rockfishes and lingcod. These crossbeams appear to provide shelter to these larger fishes (Love et. al., in prep). Smaller individuals may be avoiding this predator-filled habitat. By the same token, many larger fishes may avoid the relatively low relief mussel mounds, because of a lack of sheltering caves and crevices. This allows small fishes the opportunity to inhabit a mound habitat relatively free of predators. The only large individuals commonly seen on the mounds were lingcod. Lingcod are known to inhabit a wide range of habitats, from relatively smooth bottom to high, rocky relief (Miller and Geibel, 1973). Lingcod are also predatory on small fishes and may make periodic forays to the mussel mound to forage.

There were also differences in the density of fishes between the mounds and the platforms. The total density of all species on the platform bottoms was almost twice as high as on the mounds. Given that the fishes are larger on the platform bottoms, estimates of biomass density are even higher on the platforms compared to the mussel mounds. The density differences observed in this study support the notion that there may be competition for the higher structural complexity space offered by the platforms. Younger individuals and smaller individuals tend to be found on the mounds, but in most cases can also be found on the platforms. The similarities in assemblage structure but differences in individual sizes and densities suggest that younger and smaller fish may be using the mussel mounds instead of the platforms due to competition with larger or older individuals for space or predator avoidance. These alternatives could be tested in the future with field manipulations and measurement of survival and growth rates in the two habitats. The patterns observed do suggest that if there are movements between the two habitats, they are probably uni-directional, with younger fish settling or colonizing the mound and later moving to the platforms. Clearly, the differences in habitat structure between the mussel mounds and the platform bottoms influence the distribution of various size classes and the abundance of fishes. Whether these distributions are formed in response to predation, competition for space or other factors such as food availability or food preference remains to be seen.

While it might be expected that dwarf or small rockfishes would preferentially inhabit those parts of the mussel mounds with the highest mussel concentrations, thus affording themselves maximum protection from predation, this was not the case. To some extent, the affinity exhibited by some species for certain degrees of mussel cover, reflects their preferences in natural habitats. Both greenstripe and stripetail rockfishes are most often found over a substrata composed of both mud and rock (Yoklavich et al., submitted for publication) and over the mussel mounds both species were more prevalent over a substrata with relatively low mussel density. Similarly, copper rockfish were always found over the heaviest mussel cover, which would be expected from this high-relief outcrop dweller. However, some of the mussel mound data does not neatly fit expected patterns. Greenspotted rockfish are, relative to many rockfish, habitat generalists, and thus are frequently found over virtually all habitat types (Yoklavich et al., submitted for publication). Yet over the mussel mounds, they were most likely to live over the highest mussel cover. Just as we do not know for certain the extent of fish movements from the mussel mound to platform bottom at a site, we also do not know the extent to which there is temporal variation in use of parts of the mussel mounds. However, the analyses investigating differential use of the mounds were all performed on data from all mounds combined. The fact that there were significant patterns in mussel mound use, indicates that the preferences shown by some species for different parts of the mounds, may be consistent.

The entire mussel mound-platform system is characterized by high levels of spatial variability in fish assemblage structure. Although each mussel mound is more similar to its platform than to other mounds, the overall levels of similarity were quite low (Fig. 5). The differences in assemblage structure appear to reflect different habitat requirements for at least several species. Species that appear to need large shelter areas, such as bocaccio and vermilion, canary and flag rockfishes are common around some platforms and are rare or absent on the adjacent mounds. However, a number of species seem equally abundant (though with differences in size compositions) both near and away from the platforms. Only a few taxa appear to prefer the low relief afforded by the mussel mounds; these include the greenstripe rockfish and the shortspine combfish. On our surveys of natural reefs, these two species are usually found on reef edges and other low relief habitats.

In summary, mussel mounds harbor lower densities, fewer species, smaller species and smaller individuals than platform bottoms. Larger spatial scale patterns of species composition appear to be determined by depth with the two, nearshore shallow mounds having different species composition than the offshore deeper sites. Based on our first-year survey, it appears that these mussel mounds may provide a nursery function for some species, particularly for some of the rockfishes. We found a few YOY rockfishes and large numbers of somewhat older juveniles, particularly of copper and greenspotted rockfishes, on some of the mussel mounds. However, based on only 1 yr of work, we cannot determine the stability of the patterns we observed. For instance, it is quite possible that 1997, an El Niño year, was a poor one for recruitment of many rockfish species. Our surveys of the adjacent platforms showed 1997 rockfish recruitment to be very low compared to past years. It is quite possible that recruitment on these mounds might be considerably greater during more favorable years. At this point, it appears that there is not a unique mussel mound community. We suggest that the mussel mounds adjacent to the oil platforms in the Santa Barbara Channel be considered an integral part of the "platform system".

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