BULLETIN OF MARINE SCIENCE, 55(2–3): 1062–1085, 1994

A PILOT STUDY OF THE DISTRIBUTION AND ABUNDANCES OF ROCKFISHES IN RELATION TO NATURAL ENVIRONMENTAL FACTORS AND AN OFFSHORE OIL AND GAS PRODUCTION PLATFORM OFF THE COAST OF SOUTHERN CALIFORNIA

Milton Love, Jeffrey Hyland, Alfred Ebeling,
Timothy Herrlinger, Andrew Brooks and Eiji Imamura

ABSTRACT

Platform Hidalgo is located in 123 m of water, approximately 10 km SW of Pt. Arguello, California. A pilot study was conducted to examine the distribution and abundance of rockfishes around Hidalgo (by scuba and by ROV photosurveys) and at eight adjacent natural reefs (by ROV photosurveys). To test for differences in fish assemblages among reefs using factorial ANOVA, the natural reefs were classified according to two levels each of three factors: "low" (0.2–0.5 m) versus "high" (>1 m) relief height; "nearfield" (<3 km from Hidalgo) versus "farfield" (>3 km from Hidalgo) proximity to the platform; and "shallow" (113–160 m) versus "deep" (195–213 m) reef depth. Fishes were also tagged over natural reefs with breakaway hook tags. Surveys and tagging studies were conducted from July to October 1990. During surveys in July and August, large numbers of young-of-the year (YOY) rockfishes (primarily *Sebastes entomelas, S. flavidus* and *S. hopkinsi*) were found in the surface and midwaters around Hidalgo. At the base of the platform, 1+ yr rockfishes (mainly *S. entomelas* and *S. flavidus*) were very abundant. When the platform was resurveyed in October, following the first gale of the year, nearly all the YOY rockfishes had disappeared, though the 1+ yr fishes were still abundant at the platform's base. While the ultimate fate of the YOY rockfishes is not known, our preliminary data suggest the hypothesis that Platform Hidalgo acts as a producer of fish biomass by providing recruitment habitat for pelagic larvae to settle and grow before dispersing as small juveniles. Both multivariate cluster analysis and univariate ANOVA show that the rockfish assemblage around Hidalgo is different in species composition and abundance from those over the natural reefs, although several species co-occur at the platform and the reefs. Three-way factorial ANOVA (without replication) suggests that among the natural reefs there are no statistically significant differences (at $P \leq 0.05$) in abundances of rockfish populations or in diversity of rockfish assemblages due to the effect of relief height, depth, or proximity to the platform. However, pattern-recognition techniques (cluster analysis) reveal distinct groupings of these fauna that are related foremost to reef depth, followed by proximity to the platform and finally relief height. Fish density differed significantly ($P \leq 0.05$) between sampling times at selected sites. We propose that the factor relief height be dropped in subsequent definitive studies of these offshore reef assemblages. By doing so, the effects of remaining factors, including possible platform effects, on the distribution and abundances of these fishes can be tested with a more powerful replicated factorial design. Sampling also should be conducted on a number of occasions to examine patterns and sources of natural temporal variability.

Currently 29 of 30 oil platforms developed along the southern California coast since 1958 remain in place, most in outer continental shelf (OCS) waters where they extend solid substrate from the ocean's surface to depths exceeding 100 m. Several investigators (Carlisle et al., 1964; Bascom et al., 1976; Allen and Moore, 1976; Love and Westphal, 1990) have studied the assemblages of fishes inhabiting platforms or artificial reefs in shallower California State waters. However, with one exception (Love and Westphal, 1990), little has been published on the ecology of fishes inhabiting such structures in deeper OCS waters.

Yet the potential effects of OCS platforms on hard-bottom fish assemblages,

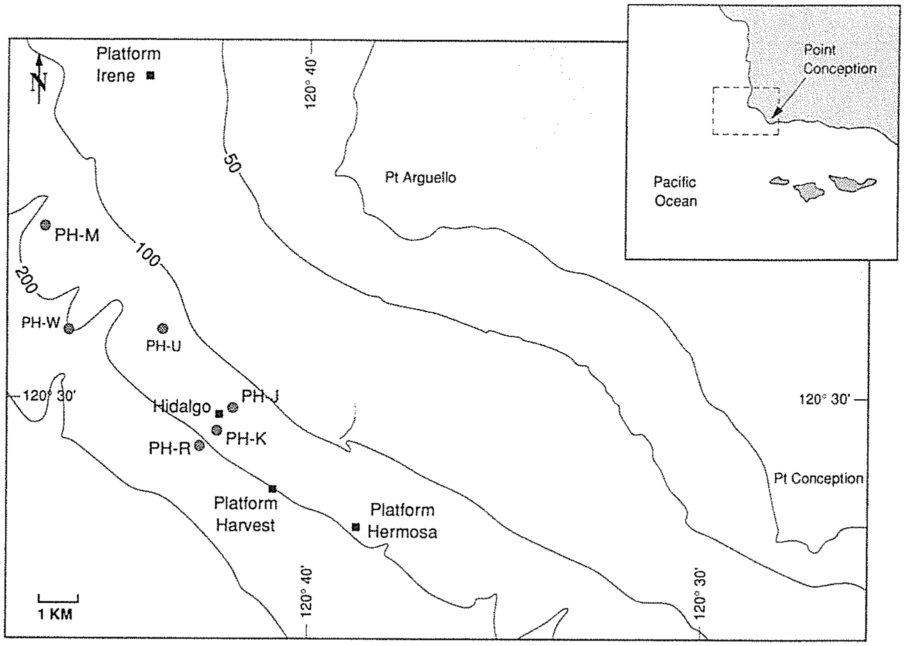


Figure 1. Location of Platform Hidalgo and the eight natural reef sites surveyed in this study. Stations PH-W and PH-R provide both low-relief and high-relief sites. Depth contours are in meters.

primarily rockfishes (genus *Sebastes*) and lingcod (*Ophiodon elongatus*), constitute an important issue. There are concerns that components of operational discharges (e.g., suspended particles and potentially toxic hydrocarbons and trace metals) may adversely affect either the fishes or their prey living on natural reefs near the platforms. In addition, the platform structure itself may attract fishes away from the surrounding natural habitats. A redistribution of fishes to the platforms is of concern to some commercial fishermen because the platforms cannot be accessed by certain types of fishing gear. Alternatively, the platforms may actually enhance overall fish production in the area by, for example, increasing the amount of habitat available for recruitment of juveniles from out of the plankton.

The overall purpose of this pilot study was to provide preliminary data on variations in the distribution and abundances of offshore rocky-reef fish assemblages (emphasizing rockfishes and lingcod) relative to natural environmental factors and to the presence of an OCS platform located nearby. For simplicity of design, we concentrated on two main objectives: (1) to compare rockfish and lingcod assemblages living about the platform with others living on natural rocky reefs located nearby, and (2) to determine if the natural fish assemblages vary with such factors as platform proximity, habitat depth, relief height (substrate complexity) and time.

Materials and Methods

Study Sites.—Installed in July 1986, Platform Hidalgo is located in the southern Santa Maria Basin at 123 m depth approximately 10 km SW of Pt. Arguello, California (Fig. 1). The platform measures 55 m × 31 m at the water surface. Platform Hidalgo was selected as a study site because of its nearness to natural offshore rocky reefs and because it is the site of a comprehensive companion study

Table 1. Station locations, depths, and sampling categories

Station	Latitude Longitude	Depth (m)	Relief type	Platform proximity	Depth category
PH-K	34°29.199′N 120°42.171′W	160	High	Nearfield	Shallow
PH-R(H)	34°29.129′N 120°42.627′W	213	High	Nearfield	Deep
PH-M	34°33.891′N 120°45.974′W	139	High	Farfield	Shallow
PH-W(H)	34°31.641′N 120°45.804′W	195	High	Farfield	Deep
PH-J	34°29.822′N 120°41.824′W	117	Low	Nearfield	Shallow
PH-R(L)	34°29.148′N 120°42.570′W	213	Low	Nearfield	Deep
PH-U	34°31.477′N 120°43.510′W	113	Low	Farfield	Shallow
PH-W(L)	34°31.667′N 120°45.778′W	195	Low	Farfield	Deep

designed to monitor potential platform impacts on hard-bottom benthic invertebrates (Hyland et al., 1990a, 1990b). Possible linkages between these invertebrate assemblages and the feeding habits of fishes occupying these same substrates represent an important question addressed in the present study but will be discussed in a subsequent paper.

At the time of the study, a total of seven development wells (out of a potential 54 well slots) had been drilled, but no production or additional drilling had taken place. Hyland et al. (1990b) report that 7,963 m^3, (3.5×10^6 kg) of drill muds and 2,294 m^3 of cuttings were discharged from Platform Hidalgo during the development of these seven wells, between November 1987 and January 1989. Barite, the primary mud ingredient, accounted for 52% (by weight) of the total mud discharged. While inputs of drilling materials to the surrounding seafloor have been detected (based on excess barium concentrations and diagnostic hydrocarbon parameters in surficial and suspended sediments), levels of potentially toxic chemical contaminants are generally low and characteristic of uncontaminated offshore regions along the California outer continental shelf (Neff and Hyland, 1990).

Natural Reefs. Eight natural-reef sites in the vicinity of Platform Hidalgo were selected and sampled for this study (Table 1 and Fig. 1). Four sites were classified as "high relief" (with outcroppings more than 1 m high) and four as "low relief" (with sand, cobble, and lower outcroppings, approximately 0.2–0.5 m). Sites within each relief category were further distinguished as either "nearfield" (located <3 km from Hidalgo) or "farfield" (>3 km from Hidalgo). Both high and low-relief classes of sites were sampled at the reef areas labeled PH-R and PH-W. Sites were also grouped into two depth categories: shallow (113–160 m) and deep (195–213 m). Thus, the sampling design among reef sites is a 2^3 factorial of relief height, proximity to the platform, and depth, with two levels per factor. Each of the eight factorial combinations of reefs is unreplicated, although within a reef site replicate photosurvey observations were made to increase sampling precision (see below).

ROV Photosurveys.—Surveys were made during the periods 23 August to 3 September and 15 October to 22 October 1990 from aboard the RV Aloha. All observations were made by viewing photographic slides taken with a Photosea 70-mm still camera mounted on the ROV Recon IV, also outfitted with a video camera, a Photosea 1500S strobe light, a Mesotech color-imaging sonar, two split-beam laser units (used to focus the still camera) and a five-function manipulator. The ship's position was determined with a Motorola Miniranger, which interfaced with an O.R.E. Trackpoint acoustic navigation system on the ROV. On board the Aloha, the ROV operator monitored the vehicle via a videomonitor. Each photograph was taken at a distance of 4.5 m off the bottom to cover a 1-m^2 sampling area.

Photosurveys were conducted at the eight natural-reef sites and at three depth intervals at Platform Hidalgo: top (12–31 m), middle (55–99 m) and bottom (103 m–sea floor). During the October cruise, the uppermost third of the water column around Hidalgo was resurveyed. At each station, approximately 150 70-mm photographs were taken along transects in directions determined at random. A photosurvey was repeated at station PH-K to compare day versus crepuscular (dawn or twilight) samples. At high-relief stations, the 70-mm camera was pointed in a forward direction and maneuvered about the rock features, taking non-overlapping photographs. Once the transect was completed, the ROV was directed on another random heading until the next suitable feature was located. At low-relief sites, non-overlapping photographs were taken with the camera pointed in a downward direction. For each photograph, we noted the time, reef or platform depth, and ROV heading. At every tenth photo, the ROV's position was fixed using the Miniranger navigation.

In the laboratory, the developed transparencies were placed on a light table and those without fishes were separated. These latter images were rechecked for cryptic individuals using a dissecting microscope. Later, photographs containing fish were observed under a dissecting microscope and all fishes were identified to the lowest taxon possible, usually species, although a majority of juvenile rockfishes were identifiable only to genus.

Analysis of Photosurvey Data.—All photosurvey data were coded and entered into a customized data base on a personal computer. Data were analyzed by a combination of pattern-recognition techniques (numerical classification); direct examination of species lists and calculated values of species abundances, diversity, and related community-level variables; and formal hypothesis testing of spatial and temporal patterns by analysis of variance (ANOVA) or *t*-tests. All ANOVAs and *t*-tests were run on SAS (1987).

Normal (Q-mode) numerical classification (Boesch, 1977) was performed on untransformed data as an initial step to exploring patterns of faunal similarity among the various natural-reef sites and between the reefs and the platform. Samples were clustered by group-average sorting (unweighted pair-group method of Sneath and Sokal, 1973), using Bray-Curtis similarity (Bray and Curtis, 1957) as the resemblance measure. The resulting dendrogram ordered samples into groups of increasingly greater similarity based on relative species abundances.

Species diversity was measured by two methods: the Shannon-Wiener information function, H′ (Shannon and Weaver, 1949) and Hurlbert's (1971) modification of Sanders' (1968) rarefaction method. Logarithms to the base 2 were used to calculate values of H′. The second diversity measure predicts the expected number of species, E(Sn), present in increasingly rarefied samples of N individuals selected at random (without replacement) from a finite collection of organisms. Thus "rarefaction" curves relating sample size to expected numbers of species provide estimates of species richness standardized for sample size. Several curves representing different types of samples can be compared visually: the steeper the curves, the greater the species richness independent of sample size.

A 2^3 factorial ANOVA without replication was used to test the null hypothesis of no differences in fish assemblages relative to substrate depth, platform proximity, and relief height. Response variables examined were (1) density of all fishes combined, (2) density of all rockfishes combined, (3) densities of individual dominant species (*Sebastes miniatus* and *Sebastes chlorostictus*), (4) number of all species, (5) number of rockfish species, and (6) H′. Because each cell of this 2^3 factorial design is unreplicated (i.e., represented by a single reef site), F values to test significance of main effects were derived as the ratio of the mean squares due to main effects over that due to the pooled higher-order interactions (Sokal and Rohlf, 1981). In our model, all possible two-way and three-way interactions were pooled as the "error" sum of squares; thus, if main effects were significant, any significant interactions would need to be examined graphically. Each single value of an unreplicated cell in the data matrix is the average over n groups of photographic frames, with group size determined by the procedures described below. To stabilize the variances across cells, data were transformed to $\ln(x + 1)$.

A series of one-way ANOVAs and *t*-tests, using replicate groups of photographs as individual observations within a site, were also performed to examine variability between different sections of the platform (top vs. middle vs. bottom), between the bottom of the platform and nearfield and farfield reefs of comparable depth, or between different sampling times at specific reef and platform sites. Tests were run on the same response variables used in the three-way ANOVAs. The tests were also run on data transformed to $\ln(x + 1)$. Duncan's multiple-range statistic was used as an a posteriori test of differences among means contributing to significant one-way ANOVAs.

To maximize the power of detecting differences among sites, the individual 1.0-m^2 photographs taken within a site were pooled into larger optimum-sized groups, each constituting a new statistical variate. Optimal group size was determined by the criterion of maximizing statistical power as a function both of sample size and variance. The procedure was a modification of a technique applied frequently in agricultural "uniformity trials" to determine optimum plot size (Carlile et al., 1989). In our case, groups were enlarged sequentially until the coefficient of variation among groups was lowered as much as possible while retaining sufficient replicates of groups, and thus degrees of freedom (df), for meaningful statistical analysis. Calculation of power is based on the noncentral F distribution, with 1 and 2n-2 df, at α of 0.05. Thus, we estimated the optimum sample size for all response variables. For every response variable, however, the noncentrality equation indicated increasing power, asymptotic to the value $1 - \beta = 1$, with ever increasing group size. Therefore, the optimum group size was derived in this study by pooling the maximum number of photographs possible among the total taken within a site, without dropping below a minimum of three replicate groups to preserve sufficient degrees of freedom for subsequent statistical testing. Because it is essential to maintain a common group size throughout an analysis, the cell (combination of factor levels) with the least number of

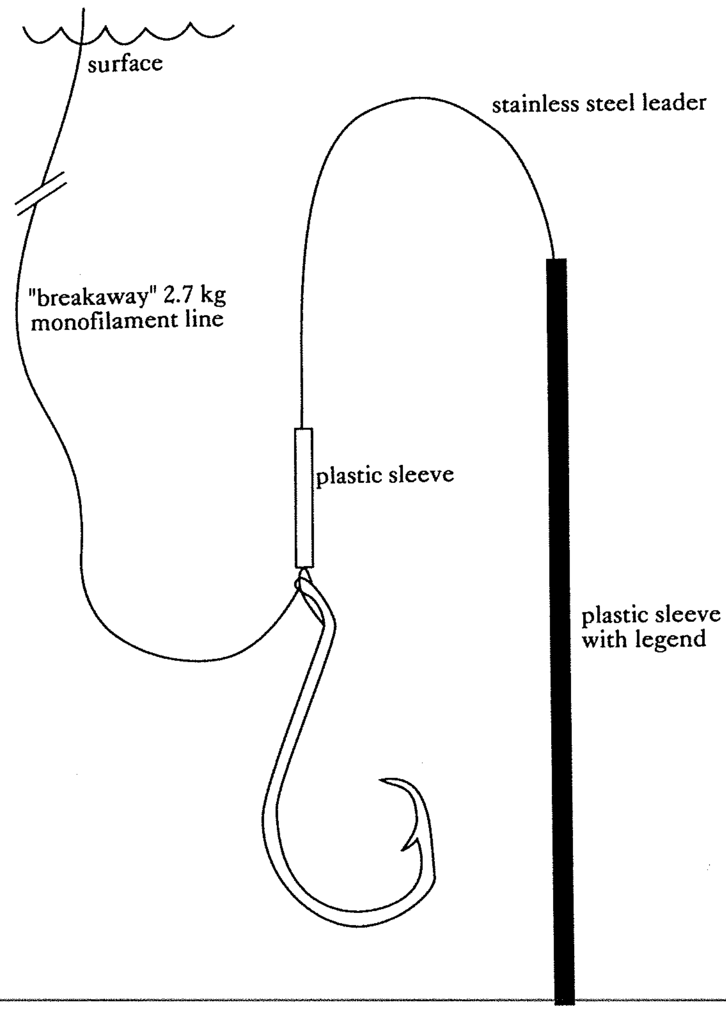


Figure 2. The breakaway hook tag.

photographs to draw upon determines the group size for the remaining cells. All density-related variables were expressed as numbers per m^2.

Dive Surveys on Platform Hidalgo.—On 17–19 July and again on 25 October 1990, SCUBA divers surveyed the fish populations in the upper 30 m around Platform Hidalgo. The divers swam transects at 7, 15 and 25 m around the outside perimeters of the platform and across the middle portion of the platform beneath the superstructure. Fishes were recorded along each transect using an underwater video camera, while abundances were also estimated visually and recorded on a slate. Additional observations of fish abundances and distributions were taken off transect, particularly below the deepest transect depth. Voucher specimens of YOY rockfishes were captured at 15–25 m with a diver-held trawl developed specifically for this purpose. These fishes were identified to species.

Detachable Hook Tagging.—A primary difficulty in estimating deeper-water rockfish movements is in tagging these fishes effectively. Few rockfish survive ascents from depths greater than 100 m, thus precluding conventional tagging methods. To overcome this depth limitation, we experimented with detachable-hook tags (Fig. 2). In this system, fishes strike at baited hooks lightly attached to longlines. The hooks (carrying legends) snap off the longline and lodge in the fishes' mouths. We conducted our experiments using a modification of tags developed in New Zealand (Horn, 1988) on alfonsino (*Beryx splendens*) and bluenose (*Hyperoglyphe antarctica*).

Table 2. Fish species surveyed along three depth intervals (top, 12–31 m; middle, 55–99 m; bottom, 103 m–seafloor) at Platform Hidalgo. A = still-camera photoquadrats during August–September 1990 and October 1990 (Top 1 = August 1990; Top 2 = October 1990); *B = additional species observed by divers in July 1991; †C = additional species seen on ROV videotape during the photosurveys in Aug–Sept and October 1990 (but not recorded in 70-mm photographs).

Scientific/common	PH-Bot (147 photos)	PH-Mid (151 photos)	PH-Top 1 (82 photos)	PH-Top 2 (151 photos)
	A. Photoquadrats			
Oxylebius pictus				
Painted Greenling		10	10	4
Scorpaenichthys marmoratus				
Cabezon		9	11	5
S. caurinus				
Copper Rockfish			1	14
S. chlorostictus				
Greenspotted Rockfish	8			
S. entomelas				
Widow Rockfish	18			
S. flavidus				
Yellowtail Rockfish	886			
S. hopkinsi				
Squarespot Rockfish	55		2	
S. mystinus				
Blue Rockfish				4
S. paucispinis				
Boccacio	15	1		
S. rubrivinctus				
Flag Rockfish	4			
S. semicinctus				
Squarespot Rockfish		1		
Sebastes sp.				
Unidentified Rockfish	1,315	874	33	8
S. entomelas/flavidus				
YOY Widow/Yellowtail Rockfish			224	
Sebastolobus sp.				
Thornyhead	1			

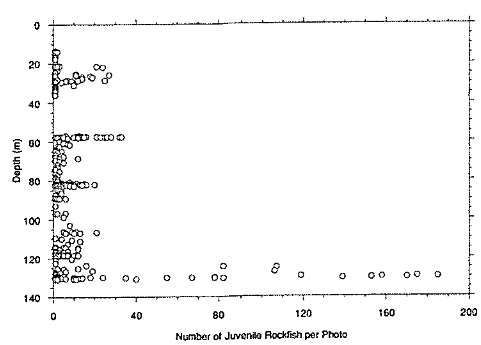
* B. Additional species seen by divers: *Chromis punctipinnis, Engraulis mordax, Mola mola.*
† C. Additional species seen on ROV videotape: *Ophiodon elongatus, Sebastes miniatus.*

Each tag, fabricated by Hallprint Ltd. of Australia, consists of a hollow-point, 6/0 stainless-steel, Mustad hook (92553 S) bent into a circle. A 12-cm piece of stainless-steel wire is fastened to the hook and a 7.5-cm plastic sleeve is fixed around the wire. Each sleeve carries a legend and identification number (Fig. 2). We attached each tag to a longline with a short length of 2.7 kg monofilament line. The longlines, containing either 10 or 20 hooks, were set vertically and were baited with squid or fish. Tags used in the "nearfield" region (3 km or less from Hidalgo) were yellow; those in the "farfield" (over 3 km away) were orange. Tagging fish in situ meant that we did not know exactly what fishes were being tagged and would not know until they were captured. Therefore, to get some initial idea of what fishes were being tagged, we test-fished by hook-and-line at the time tagging was performed.

Results

Fish Assemblages at Platform Hidalgo—A total of 17 fish species representing 6 families (Table 2) were identified from all records (70-mm photographs from ROV, video footage from ROV, direct observations by divers). Rockfishes, almost entirely YOY or 1+ yr old juveniles, dominated the catch.

During the July and August-September surveys we observed extremely large numbers of YOY rockfishes around Platform Hidalgo, primarily at depths of 20–60 m (Fig. 3). Slightly larger juvenile rockfishes, which we believe were 1+ yr,



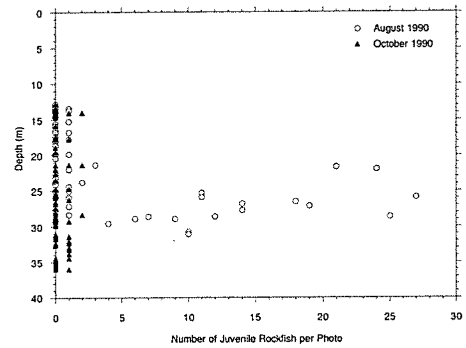


Figure 3 (left). The number of juvenile rockfishes seen per 70-mm still photograph (open circles), by depths, at Platform Hidalgo, August 1990.

Figure 4 (right). A comparison of the number of juvenile rockfishes seen per 70-mm photograph during August (open circles) and October (closed triangles) 1990, by depth, at Platform Hidalgo.

were also abundant near the base of the structure, within about 50 m of the sea bottom, primarily in the lower 10 m (Fig. 3). All of these fishes stayed within a few meters of the platform, either inside or outside the structure. Video footage (bottom and upper portions of platform) and diver observations (upper portion of platform) revealed aggregations of up to thousands of individuals. Most of the YOY were either *Sebastes entomelas* or *S. flavidus* (these two were difficult to distinguish) or *S. hopkinsi.* We also identified lesser numbers of *S. mystinus* and *S. paucispinis* mixed in with the former three species. While these species came within 0.5 m of the substrate, YOY *S. caurinus* tended to hover where two or more platform elements came together or to nestle among attached epifaunal invertebrates (primarily the anemone *Metridium*). Of the 1+ yr fishes at the bottom of the platform, most were *S. entomelas* or *S. flavidus,* although we observed a few *S. rubrivinctus* and *S. chlorostictus* resting on the substrate. We saw almost no adult fishes, except for two mature *S. miniatus* and one *Ophiodon elongatus* as recorded on the video near the bottom. We also observed YOY *Oxylebius pictus* and *Scorpaenichthys marmoratus* along the upper portion of the platform. A few YOY *Chromis punctipinnis,* swimming with the rockfishes, were netted by divers.

When we returned to Hidalgo in October, we found only a few fishes around the upper portion (12–36 m below surface) of the platform (Fig. 4). The remaining few species, including YOY *S. caurinus, S. marmoratus* and *O. pictus,* are commonly found near platform substrates. Cursory inspection with the ROV showed that schools of 1+ yr rockfishes were still abundant near the base of the platform.

Table 3 summarizes results of one-way ANOVAs used to test differences in response-variable means among the three depth intervals down the platform structure. Means differ significantly ($P \leq 0.05$) for all response variables except H′, attributable to significant a posteriori determined differences between the bottom vs. the top intervals (species and density-related variables) or between the bottom vs. both the top and middle intervals among the platform (species-related variables). These differences reflect the unique occurrence of the dense population of 1+ yr. *Sebastes flavidus* in the bottom interval.

Spatial Comparisons among Natural Reefs and the Platform.—Abundances of each species encountered in the three depth intervals along the platform and in the eight natural-reef sites are listed in Tables 2 (see above) and 4, respectively.

Table 3. One-way ANOVA of mean differences in various response variables between three different depth intervals along Platform Hidalgo: PH-Top (T = 12–31 m below sea surface) vs. PH-Mid (M = 55–99 m) vs. PH-Bot (B = 103 m–seafloor). All data were log-transformed (ln[x + 1]).

Response variable	Source	df	F	PR > F	Conclusion*
Ave. ind.·m^{-2}	Error	6			—
(all fishes)	Depth	2	5.66	0.042	TMB
Ave. ind.·m^{-2}	Error	6			—
(rockfishes)	Depth	2	5.95	0.038	TMB
Ave. no. species	Error	7			—
(all fishes)	Depth	2	5.77	0.033	TMB
per sample					
Ave. no.	Error	7			—
rockfishes	Depth	2	8.25	0.014	TMB
per sample					
Ave. H′ per	Error	7			—
sample	Depth	2	2.01	0.2043	TMB

* Depths connected by bars are not significantly different $P \leq 0.05$, based on Duncan's Multiple Range Test.

NUMERICAL CLASSIFICATION. Numerical classification of samples among these various reef and platform sites results in four major and three minor clusters, reflecting among-reef and platform-vs.-reef differences in the relative abundances of component fish species (Fig. 5). The strongest differences distinguish fish assemblages associated with the platform bottom (Cluster Groups 1 and 2) and with the middle and upper portions of the platform (Cluster Group 4) from assemblages inhabiting the natural-reef sites (Cluster Group 3). The natural-reef cluster is made up of three distinct subcomponents consisting of all samples from shallow sites except Station PH-M (Cluster Group 3A); all samples from deep sites (Cluster Group 3B); and the three samples representing the shallow, farfield, high-relief Station PH-M (Cluster Group 3C). At lower orders of resolution, the shallow and deep clusters are further subdivided by platform proximity and finally by relief type. These results suggest that assemblages of fish species at Platform Hidalgo differ fundamentally in structure from those inhabiting the adjacent natural reefs, and that among-reef differences are related foremost to water depth. These results also confirm the noticeable difference in assemblage structures between the bottom and two upper portions of the oil platform itself.

ABUNDANCES OF DOMINANT SPECIES AND COMMUNITY-LEVEL VARIABLES. Table 5 summarizes densities of the three most abundant rockfish species and other community-level variables among the eight reef sites and three platform depths. Several patterns emerge from these data. First, the platform, regardless of depth, had higher densities of fishes (all species combined and all rockfishes combined) than the adjacent natural-reef sites. The highest densities (ave. of 15.67·m^{-2} for all species; 15.65·m^{-2} for rockfishes) occurred at the platform bottom, due largely to a dense population of *Sebastes flavidus* (ave. density of 6.03·m^{-2}). This species was not found at any other platform depth or natural-reef location. Two other bottom-assemblage dominants, *S. miniatus* and *S. chlorostictus,* were not found along the middle and upper portions of the platform, but did occur at most natural-reef sites. In contrast to species abundances, species numbers and diversity were generally lower at the platform than at reef sites.

Among the natural-reef sites, Station PH-M had the highest densities of fishes (ave. of 2.73·m^{-2} for all species combined, ave. of 2.71·m^{-2} for rockfishes). Both *Sebastes miniatus* and *S. chlorostictus* were most abundant at this site. In contrast, Station PH-M had relatively few species and, consequently, the lowest diversity (H′ of 1.11). The relatively high abundances and low diversity of species at this

Table 4. Abundances of fishes surveyed along the eight natural reefs during Aug–Sept. 1990 and October 1990

Scientific/common	PH-J (150 photos)	PH-K1* (148 photos)	PH-K2† (75 photos)	PH-M (148 photos)	PH-R(H) (147 photos)	PH-R(L) (128 photos)	PH-U (148 photos)	PH-W(H)1‡ (142 photos)	PH-W(H)2§ (77 photos)	PH-W(L) (125 photos)
Coryphopterus nicholsi										
Blackeye Goby	1									
Eptatretus stouti										
Pacific Hagfish		4	1		2	2		11	7	22
Hydrolagus colliei										
Spotted Ratfish	2		1		1					
Merluccius productus										
Pacific Hake				2						
Ophiodon elongatus										
Lingcod	2	1	1		1	2				1
Porichthys notatus										
Plainfin Midshipman		10					5			
Raja sp.										
Skate										1
Sebastes auriculatus										
Brown Rockfish	1									
S. caurinus										
Copper Rockfish	1						4			
S. chlorostictus										
Greenspotted Rockfish	28	17	4	107	3		10	8		1
S. constellatus										
Starry Rockfish	4									
S. elongatus										
Greenstriped Rockfish		3	2	1		3	11			1
S. ensifer										
Swordspine Rockfish	21	4	4		4	1	2	3	1	3
S. entomelas										
Widow Rockfish	2	3			1		1	4	23	33
S. hopkinsi										
Squarespot Rockfish	40						4			

Table 4. Continued

Scientific/common	PH-J (150 photos)	PH-K1* (148 photos)	PH-K2† (75 photos)	PH-M (148 photos)	PH-R(H) (147 photos)	PH-R(L) (128 photos)	PH-U (148 photos)	PH-W(H)1‡ (142 photos)	PH-W(H)2§ (77 photos)	PH-W(L) (125 photos)
S. levis										
Cow Rockfish	1							1	1	
S. miniatus										
Vermilion Rockfish	16	34	1	271	1			2	2	5
S. ovalis										
Speckled Rockfish	1									
S. paucispinis										
Bocaccio			4	4				1		
S. rosaceus										
Rosy Rockfish	3									
S. rosenblatti										
Greenblotched Rockfish			1		8	4				
S. ruberrimus										
Yelloweye Rockfish				5						1
S. rubrivinctus										
Flag Rockfish	3		1							1
S. rufus										
Bank Rockfish		1	1		11	8		1	3	4
S. saxicola										
Stripetail Rockfish	2									1
S. semicinctus										
Halfbanded Rockfish							10			
Sebastes sp.										
Unidentified Rockfish	25	1	2	13	11	1	8	4	4	7
Sebastolobus sp.										
Thornyhead	8	3	2		18	6	2	2	1	7
Zaniolepis sp.										
Combfish	1									

* K1 = night (ave. time = 9:35 PM), 10/16/90.
† K2 = twilight (ave. time = 6:34 PM) 10/24/90.
‡ W1 = 8/27/90 (dawn and night).
§ W2 = 10/24/90 (night).

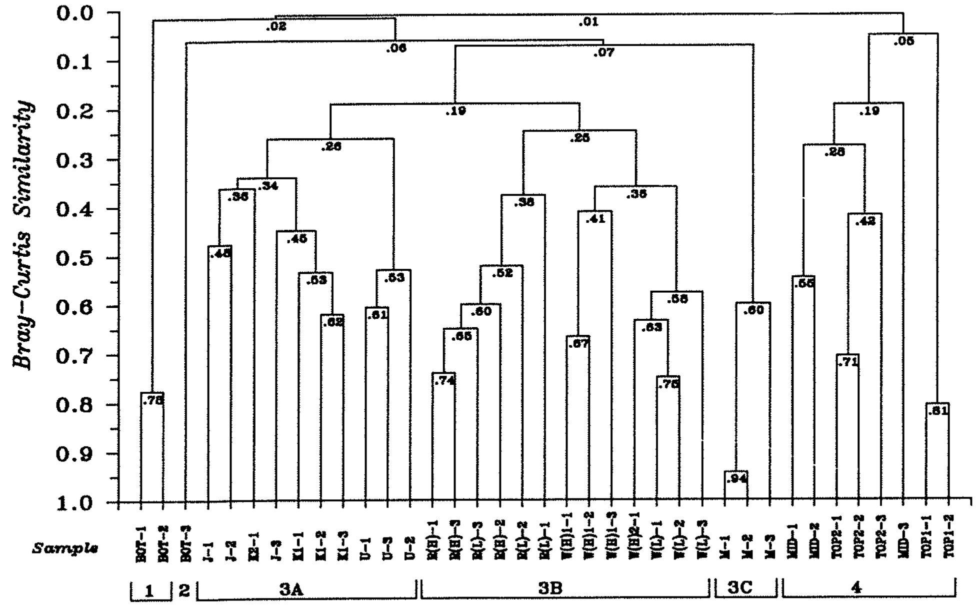


Figure 5. The dendogram resulting from clustering (Group-Average Sorting) of Bray-Curtis Similarity between fish species composition of individual samples (41 combined 1.0-m² photographs) at the eight natural reef sites and three depth intervals along Platform Hidalgo.

natural-reef site are also clearly seen in the rarefaction analysis (Fig. 6), where all reef sites except PH-M form one large envelope of the steepest curves denoting highest diversity. In contrast, the curve for Station PH-M is both shallowest and longest, denoting lowest species diversity and highest abundances, respectively. Thus the assemblage structure at Station PH-M appears to be unique among those of the natural-reef sites.

Among natural-reef sites, species richness and diversity were highest at Station PH-J, a nearfield location (Table 5). A total of 17 species, including 12 species of rockfishes, were recorded from this site (among 123, 1.0-m² photographs). The average number of species per sample (41 combined photographs) was 10.7, and the average H′ value 2.69. Most other nearfield reef sites (with one exception) also showed greater species richness and diversity than corresponding farfield reefs of similar relief height and depth.

STATISTICAL TESTS OF SPATIAL VARIABILITY. The 2^3 factorial ANOVA without replication revealed no significant (at $P \leq 0.05$) main effects of natural-reef depth (shallow vs. deep), relief height (high vs. low), and proximity to the platform (nearfield vs. farfield) on densities of two of the three most abundant species of rockfish and the five other community-level response variables (Table 6). Because the highest-ranked dominant, *Sebastes flavidus,* occurred only at the bottom of the platform, this species was omitted from the analysis. Based on our limited sampling effort for this pilot study, therefore, results suggest that none of the three environmental factors have a major and clearly noticeable effect on the structure of fish assemblages on natural reefs about the oil platform. Type I error probabilities associated with F values are very large, ranging from $P = 0.144$ to 0.918. The only noticeable emergent pattern is that significance levels associated with the depth factor tend to be lowest, suggesting that reef depth may exert the greatest

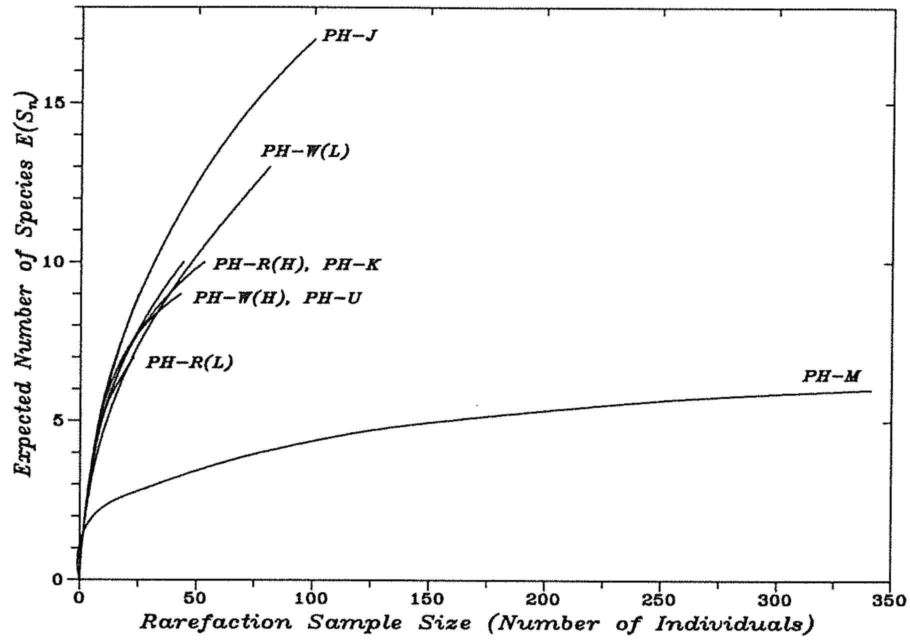


Figure 6. Hurlburt rarefaction plots of expected number of species [$E(S_n)$] per increasing sample size for the eight natural reef sites (all samples combined within stations).

influence on fish assemblage structure, a pattern also indicated by the cluster analysis.

One-way ANOVAs, based on replicate groups of photographs within a site, revealed highly significant differences in species abundances (all fishes combined and all rockfishes combined) between the platform and nearfield (PH-K) or farfield (PH-M) reef sites (Table 7). These differences are due largely to the presence of the dense population of *Sebastes flavidus* at the bottom of the platform and nowhere else. The two natural-reef sites did not differ significantly (at $P \leq 0.05$) in any response variables, except densities of *Sebastes miniatus* and *Sebastes chlorostictus,* both of which occurred at significantly higher densities at farfield Station PH-M. Rockfish species richness did not differ significantly among the three sites (at $P \leq 0.05$), although the difference in H′ diversity between the platform and farfield Station PH-M was marginally significant.

Short-Term Temporal Comparisons.—Samples obtained at different times within a 2-month period at three locations (PH-K, PH-W(H), and the top of Platform Hidalgo) provided an opportunity to examine short-term temporal variability in rockfish assemblages. Table 8 lists average values of seven response variables for two different periods each at Station PH-K and the top of the platform (PH-Top) and three different periods at Station PH-W(H). Periods for Station PH-K represent different times of day on separate days (T1 = night conditions on 10/16/90 vs. T2 = twilight conditions on 10/24/90). Periods for Station PH-W(H) are different times on the same day (T1 = dawn vs. T2 = night, both sampled on 8/27/90) as well as the same time on separate days (T2 = 8/27/90 vs. T3 = 10/24/90, both sampled during the night). The two periods for Station PH-Top also represent different times on separate days (T1 = day conditions on 8/26/90 vs. T2 = twilight/night conditions on 10/21/90).

Table 5. Average species abundances (all species combined, all rockfishes combined, and top three dominant rockfishes) and other community variables at eight natural reef sites and three depth intervals along Platform Hidalgo (species numbers and diversity are minimum values, based on identifiable taxa only)

Station	Station type	Ind.·m^{-2} (all fishes)	Ind.·m^{-2} (rockfishes)	Ind.·m^{-2} (*Sebastes flavidus*)	Ind.·m^{-2} (*Sebastes miniatus*)	Ind.·m^{-2} (*Sebastes chlorostictus*)	Tot. no. species (all fishes) per station	Tot. no. rockfishes per station	No. spec. (all fishes) per sample[1]	No. rockfishes per sample[1]	H′ per sample*
Natural Reefs											
PH-K	Shallow, high relief, Nearfield	0.58	0.43	0	0.23	0.11	10	6	6.7	4.0	2.27
PH-M	Shallow, high relief, Farfield	2.73	2.71	0	1.83	0.72	6	5	5.0	4.3	1.11
PH-J	Shallow, low relief Nearfield	1.17	0.99	0	0.11	0.19	17	12	10.7	8.0	2.69
PH-U	Shallow, low relief, Farfield	0.53	0.34	0	0	0.07	9	7	6.7	5.0	2.50
PH-R(H)	Deep, high relief, Nearfield	0.42	0.27	0	0.01	0.02	10	6	6.3	4.0	2.38
PH-W(H)	Deep, high relief, Farfield	0.27	0.17	0	0.01	0.06	9	7	5.0	3.7	2.15
PH-R(L)	Deep, low relief, Nearfield	0.22	0.13	0	0	0	7	4	4.3	2.6	1.99
PH-W(L)	Deep, low relief, Farfield	0.74	0.46	0	0.04	0.01	13	9	7.7	5.0	2.29

Table 5. Continued

Station	Station type	Ind.·m^{-2} (all fishes)	Ind.·m^{-2} (rockfishes)	Ind.·m^{-2} (*Sebastes flavidus*)	Ind.·m^{-2} (*Sebastes miniatus*)	Ind.·m^{-2} (*Sebastes chlorostictus*)	Tot. no. species (all fishes) per station	Tot. no. rockfishes per station	No. spec. (all fishes) per sample[1]	No. rockfishes per sample[1]	H′ per sample*
Platform											
PH-Top	Upper Platform (12–31 m)	3.45	3.17	0	0	0	4	2	3.0	1.7	1.37
PH-Mid	Middle Platform (55–99 m)	5.99	5.85	0	0	0	5	3	3.0	1.0	1.24
PH-Bot	Lower Platform (103 m–seafloor)	15.67	15.65	6.03	0	0.05	7	6	5.3	5.0	0.76

* Sample size = 41 combined photographs (1.0 m^2 each).

Table 6. Results of 2^3 factorial ANOVA of mean differences in various response variables due to main effects of depth (shallow vs. deep); relief (high vs. low); and platform proximity (nearfield vs. farfield). Each factorial combination is represented by a single value (without replication), derived as the average of N groups of 41 individual photographic observations taken at the same site. Error mean squares, used for calculating F values, are derived from pooled variances associated with two-way and three-way interactions (see text). All data were log-transformed (ln[x + 1]).

Response variable	Source	df	F	PR > F	Conclusion*	Power†
Ave. ind.·m^{-2}	Error	4	—	—	—	—
(all species)	Depth	1	2.41	0.196	NS	0.23
	Relief	1	0.13	0.736	NS	0.05
	Proximity	1	0.61	0.480	NS	0.07
Ave. ind.·m^{-2}	Error	4	—	—	—	—
(rockfishes)	Depth	1	2.43	0.194	NS	0.23
	Relief	1	0.24	0.649	NS	0.07
	Proximity	1	0.49	0.522	NS	0.08
Ave. ind.·m^{-2}	Error	4	—	—	—	—
(*S. miniatus*)	Depth	1	1.60	0.275	NS	0.17
	Relief	1	1.22	0.331	NS	0.14
	Proximity	1	0.76	0.432	NS	0.10
Ave. ind.·m^{-2}	Error	4	—	—	—	—
(*S. chlorostictus*)	Depth	1	3.29	0.144	NS	0.28
	Relief	1	1.18	0.338	NS	0.13
	Proximity	1	0.70	0.450	NS	0.10
Ave. no. species	Error	4	—	—	—	—
(all fishes)	Depth	1	0.87	0.404	NS	0.11
per sample	Relief	1	0.89	0.398	NS	0.11
	Proximity	1	0.25	0.641	NS	0.07
Ave. no. species	Error	4	—	—	—	—
(rockfishes)	Depth	1	1.90	0.240	NS	0.20
per sample	Relief	1	0.75	0.436	NS	0.11
	Proximity	1	0.01	0.918	NS	<0.05
Ave. H′	Error	4	—	—	—	—
per sample	Depth	1	0.10	0.768	NS	0.06
	Relief	1	1.09	0.356	NS	0.13
	Proximity	1	0.78	0.427	NS	0.11

* NS = not significant at $P \leq 0.05$ for Type I error probability (two-tailed).
† Power = 1 − β; where β = Type II error probability, given α = 0.05 (two-tailed).

At Station PH-K, differences between time periods were not significant (at $P \leq 0.05$) for all response variables except density of *Sebastes chlorostictus* ($P = 0.015$) (Table 9), which was more abundant during the night on the first sampling than during twilight hours eight days later (Table 8). *S. miniatus* showed a similar, though non-significant, pattern of higher mean abundance during the night on the first sampling period, although variability among individual observations was quite large (Table 8).

At Station PH-W(H), differences between time periods were marginally significant ($P = 0.057$) for density of all fishes combined and highly significant ($P = 0.019$) for density of all rockfishes (Table 10). Both samples taken on the same day were similar, regardless of time (T1 vs. T2). Density of all fishes combined was also similar for the same time between different days (T2 vs. T3). The combined effect of different day and time (T1 vs. T3) was significant (or marginally significant) for densities of rockfishes and all fishes, both of which were greater at night than dawn (Table 8). No further differences attributable to sampling times were evident (error probabilities are large for remaining variables in Table 10).

Table 7. One-way ANOVA of mean differences in various response variables between three different locations: bottom of Platform Hidalgo (P = PH-Bot), a nearfield high relief reef of similar depth (N = PH-K), and a farfield high-relief reef of similar depth (F = PH-M). Data were log-transformed (ln[x + 1]).

Response variable	Source	df	F	PR > F	Conclusion*
Ave. ind.·m^{-2}	Error	6			
(all fishes	Location	2	11.7	0.009	$P\ \overline{N\ F}$
Ave. ind.·m^{-2}	Error	6			
(rockfishes)	Location	2	12.5	0.007	$P\ \overline{N\ F}$
Ave. ind.·m^{-2}	Error	6			
(*S. miniatus*)	Location	2	25.4	0.001	$\overline{P\ N}\ F$
Ave. ind.·m^{-2}	Error	6			
(*S. chlorostictus*)	Location	2	38.6	0.004	$\overline{P\ N}\ F$
Ave. no. species	Error	7			
(all fishes)	Location	2	1.12	0.378	$\overline{P\ N\ F}$
per sample					
Ave. no. species	Error	7			
(rockfishes)	Location	2	0.54	0.604	$\overline{P\ N\ F}$
per sample					
Ave. H′	Error	7			
per sample	Location	2	4.63	0.052	$\overline{P\ N}$, $\overline{N\ F}$

* Locations connected by bars are not significantly different at $P \leq 0.05$, based on Duncan's Multiple Range Test.

Along the upper portion of Platform Hidalgo (PH-Top), no response variable differed significantly ($P \leq 0.05$) between daytime vs. twilight-to-nighttime periods sampled approximately two months apart (Table 11). Mean densities of all fishes and all rockfishes, however, were much higher during the day than at night (Table 8) and the large error probabilities given in Table 11 are probably the result of the large amounts of variance among photographs for a given time interval.

Detachable Hook Tagging.—The detachable-hook system seemed to be an effective method of tagging deep-water fishes. When the fish were biting, we tagged large numbers very quickly, sometimes losing all 10 or 20 tags per longline to fishes within a few minutes. The slowest part of the operation was tallying what tags were lost (if only a few had been snapped off) and in replacing lost tags.

We tagged a total of 566 fish (Fig. 7), most in the nearfield area at depths of 105–200 m. Considerable tagging occurred over discrete pinnacles (such as PH-J). However, we found larger aggregations of fish that were more willing to bite, along the edges of dropoffs and in expanses of low relief. Based on the fishes taken in our test-fishing, we tagged primarily *S. flavidus, S. goodei, S. miniatus* and *S. paucispinis*.

At this writing, 9 months after our experiments, we have been notified of two recoveries (Fig. 7). Both are *S. miniatus,* tagged at station PH-J, and both travelled a few kilometers to the north to another prominent rocky outcrop.

Discussion

Unique Features of the Fish Assemblage at Platform Hidalgo.—The fish assemblage at Platform Hidalgo contained far fewer species than assemblages reported typically at Gulf of Mexico platforms (Hastings et al., 1976; Sonnier et al., 1976) or other shallower southern California structures (Carlisle et al., 1964). For example, Carlisle et al. (1964) found 20 families and 46 species at Platform Hazel,

Table 8. Temporal comparisons of species abundances and other community variables at two natural reefs and the upper portion of Platform Hidalgo

Station	Time	Av. ind.·m^{-2} (*S. miniatus*)	Av. ind.·m^{-2} (*S. chlorostictus*)	Av. ind.·m^{-2} (all fishes)	Av. ind.·m^{-2} (rockfishes)	Ave. no. species per sample*	Ave. no. rockfishes per sample*	Ave. H′ per sample*
PH-K	T1: Night (Ave. T = 9:35 PM, 10/16/90)	0.23	0.28	0.58	0.43	4.5	3.0	1.88
	T2: Twilight (Ave. T = 6:34 PM, 10/24/90)	0.01	0.05	0.36	0.27	5.7	4.0	2.32
PH-W(H)	T1: Dawn (Ave. T = 8:22 AM, 8/27/90)	0	0.05	0.24	0.15	1.6	1.1	0.68
	T2: Night (Ave. T = 9:51 PM, 8/27/90)	0.07	0.07	0.35	0.26	2.3	1.3	1.11
	T3: Night (Ave. T = 1:30 AM, 10/24/90)	0.03	0	0.57	0.44	1.9	1.6	0.68
PH-Top (12–31 m below sea surface)	T1: Day (Ave. T = 1:15 PM, 8/26/90)	0	0	3.45	3.17	3.3	1.7	0.65
	T2: Twilight (Ave. T = 7:36 PM, 10/21/90)	0	0	0.23	0.17	2.0	1.2	0.73

* Sample size = 25 combined photographs (1.0 m^2 each) for Station PH-K, 10 combined photographs for Station PH-W(H), 27 combined photographs for Station PH-Top.

located about 3 km off Summerland, California in about 30 m of water. Even when pelagic (nonresident) and cryptic species are removed from the list, Hazel harbored 13 families and 38 species, considerably more than found at Hidalgo (Table 12). What factors might be responsible for the differences between the two platforms?

Platform Hidalgo's relative isolation from the mainland (located about 10 km offshore, at a depth of 123 m) may be one factor. For example, whereas the live-bearing, shallow-water seaperches (family Embiotocidae), comprising nine species and a majority of the biomass, were a major component of Platform Hazel's fish community (Carlisle et al., 1964), they were absent from Platform Hidalgo. Newly-born seaperches are fully-formed and the family does not have a pelagic phase; thus juvenile dispersal across deep water is probably extremely limited, and juveniles may not be able to reach Hidalgo. Most of the seaperches around Hazel probably arrive by swimming along the bottom from nearby shallow natural reefs; the depths (up to 30-m) and short distances encountered in reaching this platform would not be a barrier to most species. In contrast, the greater depths and distances from shore that must be traversed to reach Hidalgo probably block the immigration of almost all species of seaperch.

Table 9. *t*-tests of mean differences in various response variables between two different times, Night/Day 1 (Ave. time = 9:35 PM, 10/16/90) vs. Twilight/Day 2 (Ave. time = 6:34 PM, 10/24/90), at Station PH-K. *t*-tests were made using log-transformed data (ln[x + 1]).

Response variable	df	t	PR > t	Conclusion*
Ave. ind.·m^{-2} (all fishes)	4	1.63	0.178	NS
Ave. ind.·m^{-2} (rockfishes)	4	0.892	0.423	NS
Ave. ind.·m^{-2} (*S. miniatus*)	2	1.43	0.287	NS
Ave. ind.·m^{-2} (*S. chlorostictus*)	4	4.12	0.015	S
Ave. no. species (all fishes) per sample	6	0.943	0.382	NS
Ave. no. species (rockfishes) per sample	6	1.61	0.158	NS
Ave. H′ per sample	6	1.22	0.267	NS

* S = significant at $P \leq 0.05$; NS = not significant.

Hidalgo is also situated in a different water mass than Hazel. Hazel is located in an area influenced by both the cold California Current and warmer southern California Gyre, a condition which brings a mixture of cooler and warmer-water species. Typical warmer-water species, such as basses (*Paralabrax clathratus, P. nebulifer*) and grunts (*Anisotremus davidsoni*), as well as temperate-water fishes, such as *Hexagrammos decagrammus* and *Ophiodon elongatus,* are found in abun-

Table 10. One-way ANOVA of mean differences in various response variables between three different times, Dawn/Day 1 (T1: Ave. time = 8:22 AM, 8/27/90) vs. Night/Day 1 (T2: Ave. time = 9:51 AM, 8/27/90) vs. Night/Day 2 (T3: Ave. time = 1:30 AM, 10/24/90), at Station PH-W(H). Data were log-transformed (ln[x + 1]).

Response variable	Source	df	F	PR > F	Conclusion*
Ave. ind.·m^{-2}	Error	6	—	—	
(all fishes)	Time	2	4.79	0.057	$\overline{\text{T1 T2}}$, $\overline{\text{T2 T3}}$ (T1 T2 T3)
Ave. ind.·m^{-2}	Error	6	—	—	
(rockfishes)	Time	2	8.18	0.019	$\overline{\text{T1 T2}}$ T3
Ave. ind.·m^{-2}	Error	6	—	—	
(*S. miniatus*)	Time	2	0.72	0.524	$\overline{\text{T1 T2 T3}}$
Ave. ind.·m^{-2}	Error	6	—	—	
(*S. chlorostictus*)	Time	2	0.83	0.480	$\overline{\text{T1 T2 T3}}$
Ave. no. species	Error	18	—	—	
(all fishes) per sample	Time	2	0.87	0.437	$\overline{\text{T1 T2 T3}}$
Ave. no. species	Error	18	—	—	
(rockfishes) per sample	Time	2	1.00	0.388	$\overline{\text{T1 T2 T3}}$
Ave. H′	Error	18	—	—	
per sample	Time	2	0.77	0.480	$\overline{\text{T1 T2 T3}}$

* Times connected by bars are not significantly different at $P \leq 0.05$, based on Duncan's Multiple Range Test.

Table 11. *t*-tests of mean differences in various response variables between two different times, Daytime/Day 1 (Ave. time = 1:15 PM, 8/26/90) vs. Twilight-Nightime/Day 2 (Ave. time = 7:36 PM, 10/21/90), at Station PH-Top (12-31 m below sea surface along Platform Hidalgo). *t*-tests were made on log-transformed data (ln[x + 1]).

Response variable	df	t	PR > t	Conclusion*
Ave. ind.·m^{-2} (all fishes)	2	2.21	0.157	NS
Ave. ind.·m^{-2} (rockfishes)	2	1.90	0.197	NS
Ave. no. species (all fishes) per sample	6	1.60	0.160	NS
Ave. no. species (rockfishes) per sample	6	0.273	0.794	NS
Ave. H' per sample	6	0.001	0.999	NS

* NS = not significant.

dance at Hazel (Carlisle et al., 1964). The waters off Pt. Arguello (near Hidalgo) are colder, thus basses, grunts and other warm-water species are rare or absent.

Furthermore, ocean conditions around Hidalgo are much more variable than they are around Platform Hazel. Platform Hidalgo lies off an open coast, unpro-

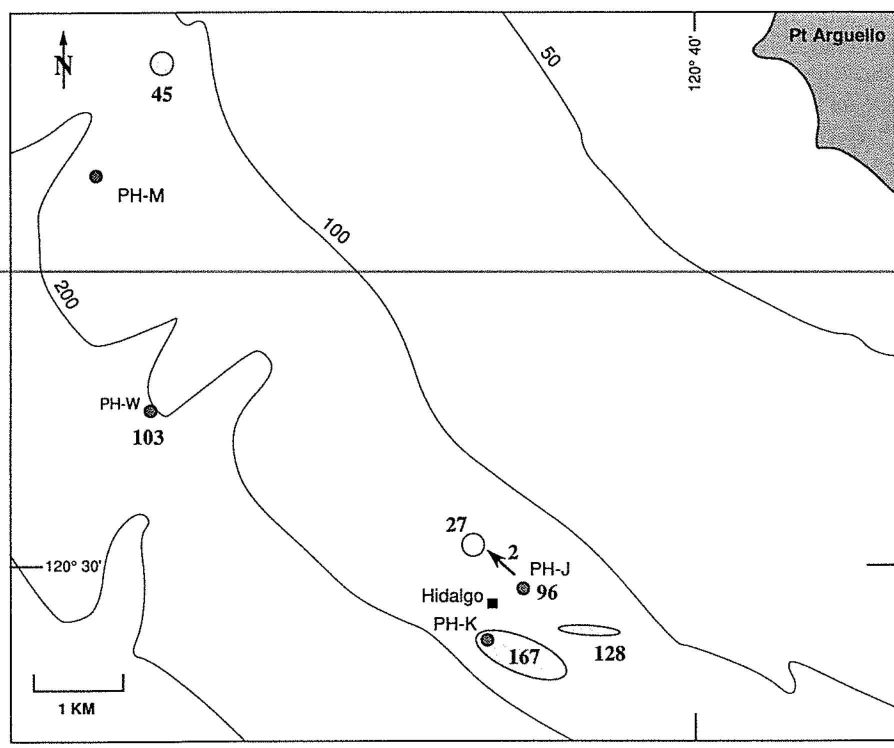


Figure 7. Breakaway hook tagging sites and numbers of fishes tagged at each site. Arrow indicates movement of fishes from two returned tags. Depth contours are in meters.

Table 12. Comparison of the numbers of fish families and species found at Platforms Hidalgo (this paper) and Hazel (Carlisle et al., 1964)

Taxon	Hidalgo	Hazel
All families	6	20
All families, pelagic and cryptic species subtracted	4	13
All species	17	46
All species, pelagic and cryptic species subtracted	15	38

tected from winter storms originating from the north. Platform Hazel is set in the Santa Barbara Channel, more sheltered from severe wave action by four offshore islands. It is possible that many species develop a temporary foothold around Hidalgo (through larval settlement or juvenile/adult migration) only to be driven off the platform during periods of severe storm conditions.

Another unusual observation was that Platform Hidalgo was inhabited almost exclusively by juveniles. In contrast, mature individuals of various species have been found at platforms in the Gulf of Mexico (Hastings et al., 1976; Sonnier et al., 1976) and off southern California (Carlisle et al., 1964; Love and Westphal, 1990). There are at least two reasons for the occurrence of large numbers of juvenile rockfishes at Hidalgo. Work by Carr (pers. comm.) on rockfishes and kelp bass suggests that larval fish settle out of the plankton on the first suitable habitat they encounter. Platform Hidalgo and the two neighboring platforms Harvest and Hermosa, isolated from other nearshore habitats, are the only structures in the area that offer mid-water to nearsurface habitat suitable for recruitment. Moreover, these rockfishes tend to be concentrated because the structure that they are occupying represents a relatively small area (e.g., compared to a mainland kelp forest) and individuals cannot spread out as they might on larger reefs. Second, the absence of larger fishes implies there is little predation on these juveniles, particularly in comparison to inshore reefs, where larger rockfishes, lingcods etc. prey heavily on YOY and older juvenile rockfishes (Miller and Geibel, 1973).

Given the abundance of adult rockfishes on nearby natural reefs, it is difficult to explain the dearth of mature fishes at Hidalgo. Certainly the platform is not spatially isolated from the reefs (some are only a few hundred meters away) and associated rockfish populations. There is evidence (Love, 1980, 1981) that many of the rockfish species found on these reefs can move far greater distances than what exists between Hidalgo and the reefs. Hidalgo's pipes, pilings and cross-beams should also form suitable habitat for mature rockfishes to use. Many species (such as *S. flavidus, S. goodei, S. levis, S. miniatus* and *S. paucispinis*) seem to utilize reefs for shelter and/or as orientation points, and not necessarily as a source of prey. The maze of structures comprising Hidalgo would seem to provide an abundance of shelter and orientation sites. Morever, the wealth of small rockfishes (a prime prey of many mature rockfishes) would provide an abundance of food.

It is remotely possible that Hidalgo emits something, either sounds or substances, which keep most mature fishes away from the platform. However, this seems unlikely, as Hidalgo was neither producing oil nor drilling new wells at the time of the study. Moreover, it is not understood what mechanism would cause only adults to be driven away.

Platform Hidalgo: An Aggregator or Producer of Fish Populations?—There is considerable debate over the role of offshore artificial structures in attracting and aggregating fishes versus actually producing additional fish biomass to the surrounding ecosystem (Bohnsack and Sutherland, 1985; National Academy Press, 1988; Bohnsack, 1989). Structures that aggregate simply draw fishes from surrounding areas, while producers tend to increase survivorship and thus generate a net sustainable increase in overall fish biomass. Bohnsack (1989) listed five ways structures can enhance fish biomass: "(1) providing additional food, (2) increasing feeding efficiency, (3) providing shelter from predation, (4) providing recruitment habitat for settling individuals that would otherwise have been lost to the population, and (5) indirectly, because fishes moving to artificial reefs increase vacated space in the natural environment that allows replacement from outside the system." While some artificial habitats appear to be primarily fish aggregators (Moffitt et al., 1989), others may also produce fishes (Beets, 1989). Thus "attractors only" and "producers only" represent the extremes of a functional continuum: different species respond differently to artificial habitat in that populations of some species are aggregated, while others are enhanced.

With respect to rockfishes, it is possible that Platform Hidalgo acts as a producer. We found large numbers of YOY and 1+ yr fish of a number of species at the platform. Given the absence of these juveniles on surrounding natural reefs and their limited movements (Love et al., 1991), it is very likely that these fishes recruited to the platform as pelagic larvae (or small pelagic juveniles). Thus Hidalgo probably acts to produce rockfishes through mechanism (4) above. Had the pelagic larvae of these fishes not encountered the platform, it is possible that many would have been lost to the population through predation, starvation or advection away from suitable natural reefs by currents.

Because we do not know the exact fate of the YOY and 1+ yr olds, however, the question remains open as to whether the platform has generated a net increase in rockfish biomass to the offshore ecosystem over any extended period of time. We know that following a Fall gale, almost all of the YOY disappeared from the upper part of the platform. Many of these individuals may have migrated or been swept away from the platform. There is some possible evidence that once these fishes have dispersed from the platform, they settle out on the nearest reefs. For example, our data show a weak trend of greater species numbers and diversity of adult fishes at nearfield than at farfield reefs. A conflicting result is that intermediate-size juveniles were not seen in photographs among the reefs, although this may have occurred simply because these individuals typically are much rarer compared to YOY and adults and thus would be harder to detect with a limited sample size. Furthermore, 1989–1990 were poor recruitment years for several species of rockfishes along the central California coast (Whipple, 1991).

Our preliminary data suggest the hypothesis that Platform Hidalgo acts as a producer by providing recruitment habitat for pelagic larvae to settle and grow before dispersing as small juveniles. However, further study with a longer sampling record is needed to determine the ultimate fate of these juveniles once they have left the platform. If these fishes do not find nearby suitable habitat and die in the move, they have added only transitory biomass to the offshore fish community.

Fish Distributions in Relation to Natural Factors.—Pattern recognition techniques (cluster analysis) and formal hypothesis testing (ANOVA) both show distinct differences in the fish assemblages between Platform Hidalgo and nearby natural reefs (Fig. 5, Table 7). Hidalgo harbored a large number of midwater rockfishes (i.e., *S. entomelas, S. flavidus* and *S. hopkinsi*) and few of the more bottom-associated species (*S. chlorostictus, S. ensifer. S. miniatus* and *S. rosaceus*) found over nearby natural reefs. This same pattern was noted by Love and Westphal (1990), who compared rockfish populations around OCS platforms to natural reefs off Santa Barbara, California. The substrate around Hidalgo, composed of mud and shells, is not optimal habitat for species that shelter within structure. While one might expect that the platform itself, composed of a myriad of pilings and girders, would be a very attractive habitat for these benthic species, this was not the case in the present study.

Among the natural reefs, no statistical differences (at $P \leq 0.05$) could be found in rockfish population densities or community-level variables due to the effect of relief-height, depth, or proximity to the platform, based on the conservative 2^3 factorial ANOVA without replication. However, this result may be due to our inability to detect such differences because of our small sampling effort, limited to a single survey and unreplicated reef design. The power ($1 - \beta$; $\alpha = 0.05$, two-tailed) to detect actual observed differences in the various response variables due to each main effect is low (<0.28) in all cases (Table 6). Thus differences in relation to natural factors may actually exist though they cannot be detected with high statistical confidence at the present sample sizes. Results of cluster analysis, in fact, suggest possible among-reef patterns (Fig. 5). Differences in species composition, for example, are most closely related to reef depth, followed by proximity to the platform. Samples from all deep sites cluster together and samples from most shallow sites cluster together with the exception of those from Station PH-M. Station M is somewhat of an anomaly, as it harbored a large population of *S. miniatus,* a schooling, mobile species, which was much less abundant on the other survey reefs.

Reef height seems to have the least effect on species composition. Our definition of "high" (1 + m) and "low" (0.2–0.5 m) relief is based on prior observations of invertebrate populations in the Pt. Arguello area (Hyland et al., 1990a). This earlier study showed that there is a distinct invertebrate faunal break at a reef height of about 1 m. It is likely that many strongly thigmotaxic rockfish species, particularly midwater ones, use relief for orientation, rather than shelter or as a source of food. Thus even relatively low relief may provide enough structure to lure and hold these species. Based on these preliminary results, we propose that the factor relief height be dropped in subsequent definitive studies of these reef assemblages. By doing so, the effects of remaining factors, including possible platform effects, on the distributions of these assemblages can be tested with a more powerful replicated factorial design. Time-series sampling also should be incorporated to examine patterns and sources of natural temporal variability.

ACKNOWLEDGMENTS

This research (Contract Number 14-35-0001-30489, to Marine Research Specialists) was carried out for the Minerals Management Service, Pacific OCS office. G. Brewer was the MMS project coordinator for the contract and we gratefully acknowledge his continuing interest in this research.

We thank M. Carr, D. Canestro and D. Schroeder for their assistance in the Hidalgo dive surveys and J. Campbell for coordinating field operations aboard the RV ALOHA. D. Hardin, J. Shrake and T. Parr helped design the field program and D. Hardin was a valued member of the ROV survey scientific team. We also extend our appreciation to J. Skalski for statistical advice, to D. Coats for production of computer-assisted graphics, and to Chevron USA for their coordination of sampling at Platform Hidalgo. Lastly, we thank D. G. Higbee for typing this manuscript.

Literature Cited

Allen, M. J. and M. D. Moore. 1976. Fauna of offshore structures. South. Calif. Coast. Water Res. Proj. Annu. Rep., Long Beach, California, pp. 179–186.

Bascom, W., A. J. Mearns and M. D. Moore. 1976. A biological survey of oil platforms in the Santa Barbara Channel. J. Petrol. Technol. 28: 1280–1284.

Beets, J. 1989. Experimental evaluation of fish recruitment to combinations of fish aggregating devices and benthic artificial reefs. Bull. Mar. Sci. 44: 973–983.

Boesch, D. F. 1977. Application of numerical classification in ecological investigations of water pollution. U.S. Environmental Protection Agency Ecol. Res. Ser., EPA-600/3-77033. 115 pp.

Bohnsack, J. A. 1989. Are high densities of fishes at artificial reefs the result of habitat limitation or behavioral preference? Bull. Mar. Sci. 44: 631–645.

——— and D. L. Sutherland. 1985. Artificial reef research: a review with recommendations for future priorities. Bull. Mar. Sci. 38: 11–39.

Bray, J. R. and J. T. Curtis. 1957. An ordination of the upland forest communities of southern Wisconsin. Ecol. Monogr. 27: 325–349.

Carlile, D. W., J. R. Skalski, J. E. Bother, J. M. Thomas and V. I. Cullivan. 1989. Determination of ecological scale. Landscape Ecol. 2: 203–213.

Carlisle, J. G., Jr., C. H. Turner and E. E. Ebert. 1964. Artificial habitat in the marine environment. Calif. Dept. Fish Game, Fish Bull. 124. 93 pp.

Hastings, R. W., L. H. Ogren and M. T. Mabry. 1976. Observations on the fish fauna associated with offshore platforms in the northeastern Gulf of Mexico. Fish Bull. 74: 387–402.

Horn, P. 1988. Tagging bluenose and alfonsino with detachable hooks. Catch 15: 17–18.

Hurlbert, S. H. 1971. The nonconcept of species diversity: a critique and alternative parameters. Ecology 52: 577–586.

Hyland, J., E. Imamura and J. Neff. 1990a. Chapter 1, Introduction. Pages 1-1–1-12 *in* M. Steinhauer and E. Imamura, eds. The California OCS Phase II Monitoring Program, Year-Three Annual Report (Vol. 1). MMS 90-0055. U.S. Dept. of Interior, Minerals Management Service, Pacific OCS Region, Camarillo, California.

———, D. Hardin, E. Crecelius, D. Drake, P. Montagna, and M. Steinhauer. 1990b. Monitoring long-term effects of offshore oil and gas development along the southern California outer continental shelf and slope: background environmental conditions in the Santa Maria Basin. Oil Chemical Pollut. 6: 195–240.

Love, M. S. 1980. Isolation of olive rockfish, *Sebastes serranoides,* populations off southern California. Fish Bull. U.S. 77: 975–983.

———. 1981. Evidence of movements of some deepwater rockfishes (Scorpaenidae: genus *Sebastes*) off southern California. Calif. Fish Game 67: 246–249.

——— and W. Westphal. 1990. Comparison of fishes taken by a sportfishing party vessel around oil platforms and adjacent natural reefs near Santa Barbara, California. Fish. Bull. U.S. 88: 599–605.

———, M. H. Carr and L. J. Haldorson. 1991. The ecology of substrate-associated juveniles of the genus *Sebastes*. Env. Biol. Fish. 30: 225–243.

Miller, D. J. and J. J. Geibel. 1973. Summary of blue rockfish and lingcod life histories; a reef ecology study; and giant kelp, *Macrocystis pyrifera,* experiments in Monterey Bay, California. Calif. Dept. Fish Game, Fish Bull. 158. 137 pp.

Moffitt, R. B., F. A. Parrish, and J. J. Polovina. 1989. Community structure, biomass and productivity of deepwater artificial reefs in Hawaii. Bull. Mar. Sci. 44: 616–630.

National Academy Press. 1988. Artificial reefs and fish aggregating devices. Pages 85–114 *in* Fisheries technologies for developing countries. Report of an Ad Hoc Panel of the Board on Science and Technology for International Development, Office of International Affairs, National Research Council, National Academic Press, Washington, D.C. pp. 85–114.

Neff, J. and J. Hyland. 1990. Chapter 13, Program synthesis and recommendations. Pages 13-1–13-62 *in* M. Steinhauer and E. Imamura, eds. The California OCS Phase II Monitoring Program, Year-Three Annual Report (Vol. 1). MMS 90-0055. U.S. Dept. of Interior, Minerals Management Service, Pacific OCS Region, Camarillo, California.

Sanders, H. L. 1968. Marine benthic diversity: a comparative study. Am Nat. 102: 243–282.

SAS Institute, Inc. 1987. SAS/STAT guide for personal computers, version 6. 1,028 pp.

Shannon, C. E. and W. Weaver. 1949. The mathematical theory of communication. Univ. Illinois Press, Urbana, Illinois. 117 pp.

Sneath, P. H. A. and R. R. Sokal. 1973. Numerical taxonomy. The principles and practice of numerical classification. W. H. Freeman and Co., San Francisco, California, 573 pp.

Sokal, R. R. and F. J. Rohlf. 1981. Biometry, 2nd ed. W. H. Freeman and Company, New York. 859 pp.

Sonnier, F., J. Teerling and H. D. Hoese. 1976. Observations on the offshore reef and platform fish fauna of Louisiana. Copeia 1976: 105–111.

Whipple, J., ed. 1991. Progress in rockfish recruitment studies. NMFS Southwest Fisheries Science Center, Tiburon, California. Administrative Report No. T-91-01.

DATE ACCEPTED: October 7, 1993.

ADDRESSES: *(M.L., A.E., T.H., A.B.) Marine Science Institute, University of California, Santa Barbara, California 93106; (J.H.) Arthur D. Little, Inc., Earth and Marine Sciences, Acorn Park, Cambridge, Massachusetts 02140; (E.I.) Marine Research Specialists, 3639 E. Harbor Blvd., Suite 208, Ventura, California 93001.*