Abstract—Between 1995 and 2002, we surveyed fish assemblages at seven oil platforms off southern and central California using the manned research submersible *Delta*. At each platform, there is a large horizontal beam situated at or near the sea floor. In some instances, shells and sediment have buried this beam and in other instances it is partially or completely exposed. We found that fish species responded in various ways to the amount of exposure of the beam. A few species, such as blackeye goby (*Rhinogobiops nicholsii*), greenstriped rockfish (*Sebastes elongatus*), and pink seaperch (*Zalembius rosaceus*) tended to avoid the beam. However, many species that typically associate with natural rocky outcrops, such as bocaccio (*S. paucispinis*), cowcod (*S. levis*), copper (*S. caurinus*), greenblotched (*S. rosenblatti*), pinkrose (*S. simulator*) and vermilion (*S. miniatus*) rockfishes, were found most often where the beam was exposed. In particular, a group of species (e.g., bocaccio, cowcod, blue (*Sebastes mystinus*), and vermilion rockfishes) called here the "sheltering habitat" guild, lived primarily where the beam was exposed and formed a crevice. This work demonstrates that the presence of sheltering sites is important in determining the species composition of man-made reefs and, likely, natural reefs. This research also indicates that adding structures that form sheltering sites in and around decommissioned platforms will likely lead to higher densities of many species typical of hard and complex structure.

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The relationships between fish assemblages and the amount of bottom horizontal beam exposed at California oil platforms: fish habitat preferences at man-made platforms and (by inference) at natural reefs

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Understanding the habitat preferences of deeper-water (below scuba depth) fishes has proven to be elusive. Off the Pacific Coast, several studies (Stein et al., 1992; Yoklavich et al., 2000; Nasby-Lucas et al., 2002) have demonstrated that habitat characteristics play a major role in shaping deeper-water fish assemblages. In those studies it was apparent that, although individuals of many species may be found in a number of habitats, most species showed distinct preferences. These studies clearly showed the role that hard structure plays for many species. How more subtle habitat characteristics, such as the presence of sheltering sites, may influence species composition was still unclear.

Between 1995 and 2002 we surveyed fish assemblages associated with southern California oil and gas platforms. Platforms may serve at least two functions for these fishes. First, the water column around many platforms serves as a nursery ground for a suite of rockfishes (*Sebastes* spp.) and other fish species, often harboring higher densities of these species than do nearby natural outcrops (Love et al., 2003). Second, platform bottoms, where the platform jacket and well pipes meet the sea floor, may harbor high densities of subadult and adult fishes. Most of these fishes are rockfishes, but lingcod (*Ophiodon elongatus*), painted greenling (*Oxylebius pictus*), and various members of the surfperch family (Embiotocidae) may also be abundant (Love et al., 1999; Love et al., 2003).

The platforms we surveyed were designed to have large, circular (1 m in diameter) horizontal beams that connect vertical and diagonal jacket elements at or near the sea floor. In some instances, these beams were buried, either by shells that had fallen from shallow parts of the jacket or by a combination of shells and fine sediment. In other instances, beams were partially exposed (full width of beam or partial width of beam was resting on the sea floor) or completely exposed (thus leaving a gap between the beam and sea floor). During our fish surveys, we noted that fishes appeared to be patchily distributed along the platform bottom and that some species seemed to be responding to the presence or absence of the beam and to the amount of space under the beam. Because the beams are all composed of similarly shaped steel and differ only in the amount of surface exposed, we hypothesized that patterns of fish associations with this structure would present insights into the role that sheltering spaces play in determining species assemblages in both natural and man-made habitats.

Materials and methods

Field sampling

Between 1996 and 2002, we surveyed fish assemblages around seven oil and gas platforms in southern and central California (Table 1, Fig. 1) using the *Delta* research submersible, a 4.6-meter, 2-person vessel, operated by Delta Oceanographics of Oxnard, California. Aboard the *Delta,* we conducted belt transects about two meters from the platform while the submersible maintained a speed of about 0.5 knots. Surveys were conducted in fall, in order to optimize good weather and water clarity.

Submersible surveys were conducted during daylight hours between one hour after sunrise and two hours before sunset. During each transect, a researcher made observations from a viewing port on the starboard side of the submersible. An externally mounted hi-8 mm video camera with lights filmed the same viewing field as seen by the observer. The researcher identified, counted, and estimated the lengths of all fishes and verbally recorded those data on the video. All fishes in a volume two meters from sea floor upwards and two meters from the submersible outwards were counted. Fish lengths were estimated by using a pair of parallel lasers mounted on either side of the external video camera. The projected reference points were 20 centimeters apart and were visible to both the observer and the video camera.

We defined the amount of beam exposure on a scale of 0–4: 0=the beam was completely covered by shells and soft sediment and it was not visible; 1=only the top of the beam (usually encrusted with invertebrates) was visible; 2=the beam was partially exposed (top and sides)—the bottom of the beam remaining in contact with the sea floor; 3=the beam was completely exposed and formed an open crevice less than 0.5 m high; and 4=the beam was completely exposed and formed an open crevice more than 0.5 m high (Fig. 2). For each fish we recorded the size of the gap with which the fish associated.

An environmental monitoring system aboard the submersible continuously recorded date, time, depth, and altitude above the sea floor of the vessel. These environmental data were overlaid on the original videotape upon completion of each survey. Transect videos were reviewed aboard the research vessel or in the laboratory and observations transcribed into a database.

Statistical analysis

We were interested in broad patterns of species' distribution among small-scale habitats. Because rare species may prefer some (nonmeasured) extreme habitat and thus potentially would have skewed a general picture, we did not use those species where fewer than 40 fish were seen or those that were not seen on at least five dives. This left us with 27 species (of the original

Table 1

Platforms, bottom depths, crossbeam exposure parameters, and numbers of fishes surveyed in this study. Beam exposure scale: 0=beam was completely covered and not visible; 1=only the top of the beam was visible; 2=the beam was partially exposed—the bottom of the beam remaining in contact with the sea floor; 3=the beam was completely exposed and formed an open crevice less than 0.5 m high; 4=the beam was completely exposed and formed an open crevice more than 0.5 m high.

Platform	Years	Depth (meters)	Amount of platform covered (0) or exposed (1–4) (length in meters, percent of total in parentheses) 0	1	2	3	4	Total amount of beam (covered and exposed, in meters)	Mean gap size (and standard deviation)	Number of fishes
Irene	1996–2001	73	422 (33.9)	142.2(11.4)	449.9(36.2)	229.5(18.5)	0	1243.6	1.4(0.8)	10,591
Hidalgo	1996–2001	130	146.9(9.3)	458.9(29.2)	478.1(30.2)	499.8(31.6)	0	1583.8	1.8(0.9)	11,509
Harvest	1996–2000	205	934.8(73.9)	172.9(13.7)	80.8(6.4)	76.9(6.1)	0	1265.5	0.5(0.4)	775
Hermosa	1996–2000	183	235.5(18.4)	721.3(56.4)	299(23.4)	24.2(1.9)	0	1279.9	1.1(0.6)	7195
Holly	1996–1999, 2001	64	744.4(71.0)	82.2(7.8)	82.8(7.9)	126.6(12.1)	12.7(1.2)	1048.7	0.7(0.6)	4196
Grace	1996, 1997, 1999–2002	96	512.2(32.4)	17.7(1.1)	81.3(5.1)	484.5(30.6)	486.9(30.8)	1583.1	2.3(1.3)	16,688
Gail	1996, 1997, 1999–2002	224	68.8(3.8)	4.8(0.3)	774.4(43.0)	951.4(52.9)	0	1799.5	2.5(1.1)	2045
Total			3064.5	1600.1	2246.9	2393.0	499.5	9804.1		52,999

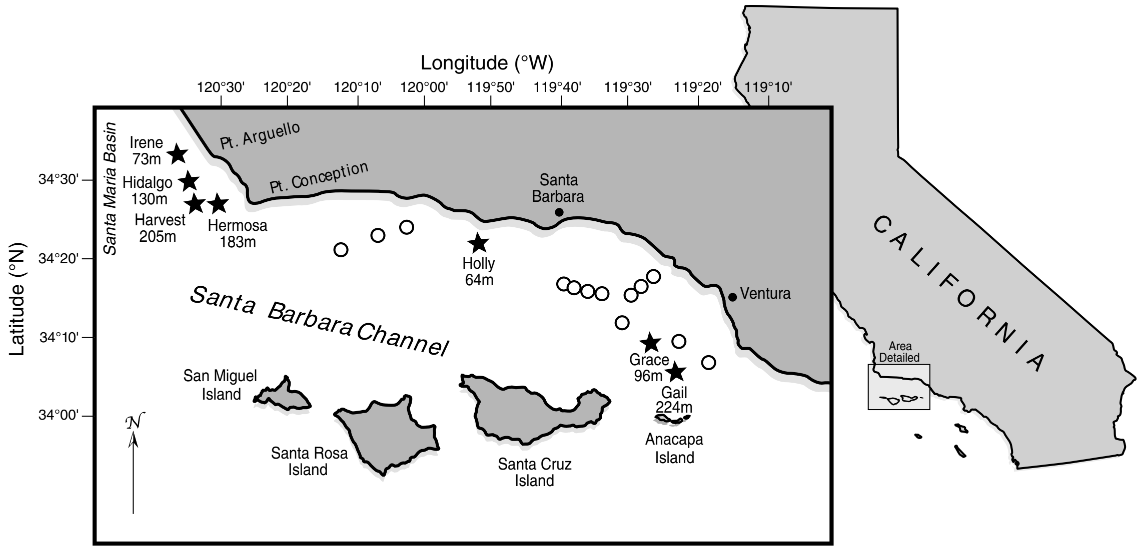

Figure 1

Location of platforms in the Santa Barbara Channel and Santa Maria Basin. Platforms discussed in this paper are shown as black stars and their bottom depths are indicated. The open circles indicate other platforms.

65) and 50,048 fish of the original 52,999 observations, or 95.1% of fish observed on all dives. In our analyses, we separated bocaccio (*Sebastes paucispinis*) and lingcod into two categories, YOY and older fishes, based on length-at-age and length-at-first-maturity data (Miller and Geibel, 1973; Cass et al., 1990; Love et al., 2002).

We used chi-square goodness-of-fit tests to determine which species tended to avoid or favor certain beam habitats. Species tend to be associated with particular depth ranges, platforms are placed at fixed depths, and some species may or may not have ever been observed on some platforms. Thus, the proportion of a particular beam habitat available to a given species was determined as the proportion of that habitat occurring only on those platforms where the species was observed. We hypothesized that if a particular species does not favor or avoids certain habitats, the expected number of those fish seen in particular habitats would be proportional to the amount of available habitat. In equation form: Let $u_{j,i}$ be the proportion of gap j (j=0, 1, 2, 3, or 4) available to species i (i=1, 2..., 27) and T_i be the total number individuals of species i observed. Then, the expected number of fish i at gap j, $E_{j,i} = u_{j,i}$ ¥ T_i. Under the null hypothesis for species i,

$$X_i^2 = \sum_{j=0}^{4} \frac{(O_{j,i} - E_{j,i})^2}{E_{j,i}}$$

is distributed as a chi-square random variable with n_i–1 degrees of freedom, where n_i is the number of u_{ij}>0. The asymptotic assumptions for the chi-square test are not valid if the expected value of many cells is small. Cochran (1954) developed a conservative rule of thumb that the test not be used if more than 20% of the expected cell frequencies are less than five. Koehler and Larntz (1980) suggested that the chi-square test is reasonable if the total number of observations is greater than 10, the number of categories is at least 3, and the square of the number of observations is greater than 10 times the number of categories.

If the goodness-of-fit hypothesis was rejected, we examined the individual deviations, $X_{ji} = (O_{ji} - E_{ji})/(E_{ji})^{.5}$, which are approximately distributed as normal (0,1) random variables under the null hypothesis. Small values of X_{ji} indicate that the species is found less often than predicted, whereas large values indicate it is found more often.

Results

All species satisfied both the Cochran (1954) and Koehler and Larntz (1980) criteria for the validity of the chi-square test (Table 2). The null hypothesis that species are randomly distributed among the crevice habitats was rejected (P<0.0001) for all but one species, kelp greenling (*Hexagrammos decagrammus*) (Table 2).

We surveyed a total of 9804.1 m^2 of sea floor. Platforms varied both in the amount of horizontal beam exposed and, when exposed, the degree of gap between beam and sea floor. At each platform, there was relatively little annual variability in the amount of beam exposed or the size and type of gap (Fig. 3). Mean size of gap per platform over the entire study ranged from 2.5 (SD=1.1) to 0.5 m (SD=0.4). (Fig. 3, Table 1). Platforms Gail and Grace, in the east Santa Barbara Channel, had the greatest amount of gap. In particular, almost none of the bottommost beam at Gail was completely buried and most of it was at least partially exposed. At the

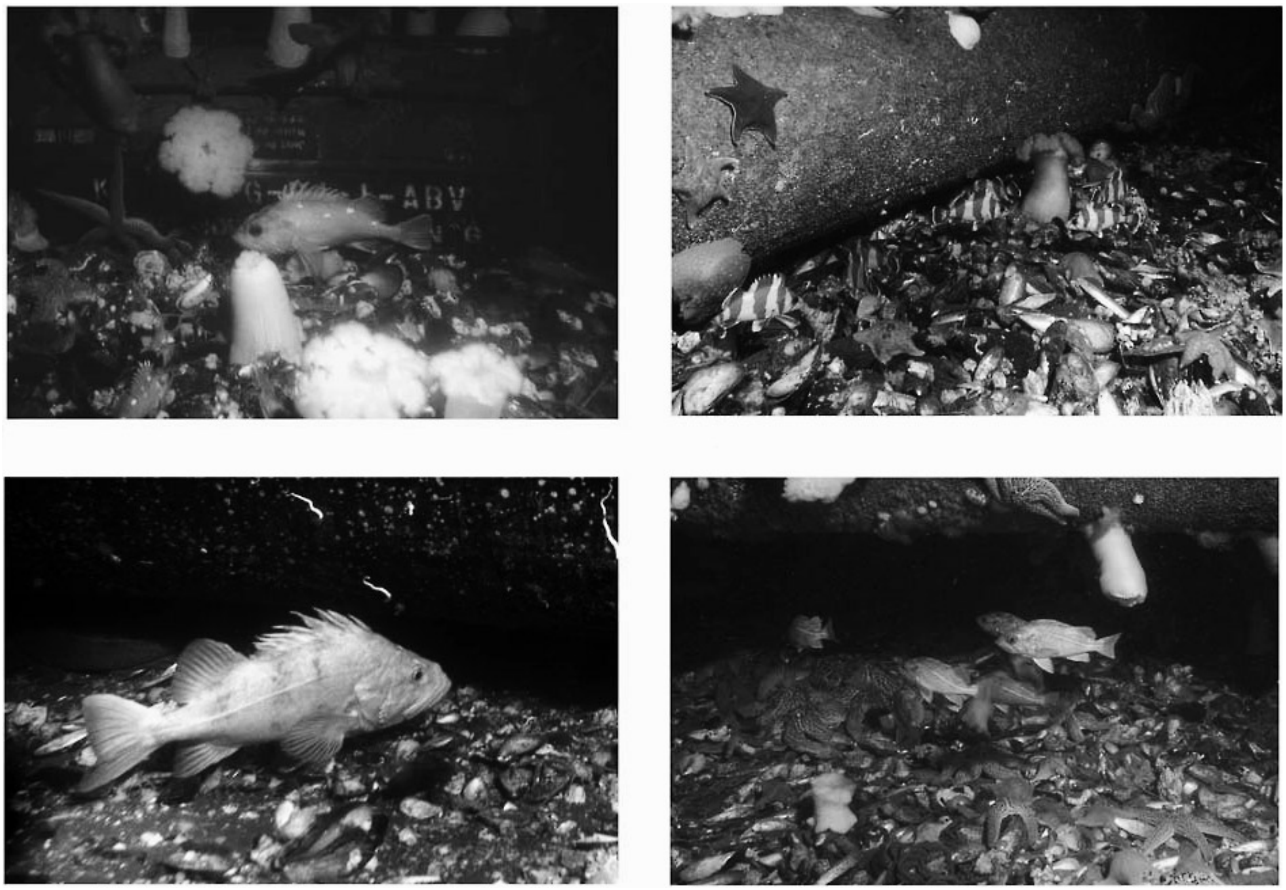

Figure 2

Examples of four types of bottom beam structure: (**A**) at least some of the beam was visible, but the full width of the beam rested on the sea floor (greenspotted rockfish, *Sebastes chlorostictus*); (**B**) the beam was partially exposed, remaining in contact with the sea floor at its bottom, not its sides (flag rockfish, *S. rubrivinctus*); (**C**) the beam was completely exposed and formed an open crevice less than 0.5 m high (cowcod, *S. levis*); (**D**) the beam was completely exposed and formed an open crevice more than 0.5 m high (vermilion rockfish, *S. miniatus*).

other extreme, most of the bottom beam at both Platforms Holly in the central Santa Barbara Channel and Harvest, off Point Conception, was completely buried. We saw little relationship between geographic location (or platform depth) and mean gap size. For instance, Platforms Hidalgo and Harvest are located within 4.6 km of each other, yet have very different beam exposures, as do Platforms Holly and Irene that are sited at almost the same depth. A lack of relationship probably reflects differences in oceanographic conditions, because some of these structures are found in areas where strong currents scour the bottom, whereas others are found in areas where sediments have not been disturbed.

Except for kelp greenling, all species exhibited some beam habitat preference (Table 2). Species found more often where the beam was completely buried (gap 0) included greenstriped (*S. elongatus*), non-YOY lingcod, rosy (*S. rosaceus*), sharpchin (*S. zacentrus*), and stripetail (*S. saxicola*) rockfishes, painted greenling, pink seaperch (*Zalembius rosaceus*), and sanddabs (*Citharichthys* spp.). Those that favored the presence of the beam or some amount of exposure (exposures 1 and 2) included calico (*S. dallii*), copper (*S. caurinus*), flag (*S. rubrivinctus*), and pinkrose (*S. simulator*) rockfishes, pile perch (*Rhacochilus vacca*), and sharpnose seaperch (*Phanerodon atripes*). Species that tended to inhabit areas where there was a gap between beam and sea floor (exposures 3 and 4) were blue (*S. mystinus*), brown (*S. auriculatus*), canary (*S. pinniger*), greenblotched (*S. rosenblatti*), halfbanded (*S. semicinctus*), squarespot (*S. hopkinsi*) and vermilion (*S. miniatus*) rockfishes, and both size classes of bocaccio (*S. paucispinis*). The vast majority of cowcod (*S. levis*) were found at beams that were scored as exposures 2 and 3. Both greenspotted rockfish (*S. chlorosticus*) and YOY lingcod appeared to prefer either soft bottom without beam exposure or beam exposure without a deep gap (exposures 1 and 2).

Table 2

The observed number of fish at each exposure value, the expected number under the null hypothesis, and the chi-square statistics of goodness of fit. Observed values are coded in the following manner: 1) "– –" if X_{ij} <–4; indicating that the observed value is much smaller than predicted (P=0.0001), 2) "–" if –2 <X_{ij} <–4; indicating that the observed value is smaller than predicted, (P=0.05), 3) "+" if 4 <X_{ji} <2; indicating that the observed value is larger than predicted, (P=0.05), 4) "+ +" if X_{ji} >4; indicating that the observed value is much larger than predicted, P = 0.0001. Beam exposure scale: 0=beam was completely covered and not visible; 1=only the top of the beam was visible; 2=the beam was partially exposed—the bottom of the beam remaining in contact with the sea floor; 3=the beam was completely exposed and formed an open crevice less than 0.5 m high; 4=the beam was completely exposed and formed an open crevice more than 0.5 m high.

	Observed number of fish at each exposure scale value						Expected number of fish at each exposure scale level					χ^2 test of null hypothesis		
Species	0	1	2	3	4	Total	0	1	2	3	4	df	χ^2	P
Blackeye goby	64 +	1	0 –	2 –	0	67	47.6	5.2	5.3	8.1	0.8	4	19.81	<0.001
Blue rockfish	13 – –	0 – –	8 –	29	55 + +	105	45.5	6.6	16.6	22.8	13.5	4	162.99	<0.001
Bocaccio (>20 cm)	16 – –	2 – –	210 – –	458 + +	138 + +	824	229.8	87.8	205.6	247.2	53.7	4	595.27	<0.001
Bocaccio (yoy)	11 – –	5 – –	8 – –	205 + +	0	229	57.1	38.3	58.1	62.1	13.4	4	451.43	<0.001
Brown rockfish	23	6	30	57 + +	0	116	59.0	11.4	27.0	18.0	0.6	4	109.81	<0.001
Calico rockfish	444 – –	168 + +	379 + +	112 – –	4	1107	563.3	108.4	257.2	172.0	6.1	4	137.34	<0.001
Canary rockfish	9 –	15	24	42 + +	4	94	28.7	19.8	19.4	19.0	7.0	4	44.80	<0.001
Copper rockfish	460 – –	192 + +	530 + +	296	3 – –	1481	641.5	92.5	234.8	321.3	190.9	4	716.18	<0.001
Cowcod	9 –	0 –	26 +	31 +	0	66	20.2	13.6	16.2	15.9	0.0	4	40.2	<0.001
Flag rockfish	88 – –	42 –	195 + +	134	12	471	147.2	76.9	107.9	115.0	24.0	4	119.00	<0.001
Greenblotched rockfish	49 – –	23 – –	304 + +	181 +	0	557	140.7	102.0	127.1	151.0	36.1	4	409.20	<0.001
Greenspotted rockfish	120 + +	329 + +	656 + +	243 – –	13 – –	1361	425.4	222.1	311.9	332.2	69.3	4	719.98	<0.001
Greenstriped rockfish	130 + +	67	84	54 –	0	335	78.3	76.7	92.2	87.7	0.0	3	49.04	<0.001
Halfbanded rockfish	4457 – –	7338	3142 – –	15,838 + +	5593 + +	36,368	13,610.8	7247.9	6690.1	6549.6	2269.6	4	26,078.39	<0.001
Kelp greenling	14	8	8	8	4	42	14.0	5.4	8.4	10.3	3.8	4	1.80	0.772
Lingcod (>20 cm)	128 +	26 –	91	88	8	341	106.6	55.7	78.2	83.2	17.4	4	27.54	<0.001
Lingcod (yoy)	201 + +	54	111 + +	16 – –	2 – –	384	143.7	76.5	70.6	69.2	24.0	4	113.52	<0.001
Painted greenling	104 + +	38 +	50	37 – –	5 –	234	61.1	22.8	60.2	73.9	16.1	4	68.19	<0.001
Pile perch	29 – –	45 + +	41	37 +	0	152	77.3	14.9	35.3	23.6	0.8	3	100.52	<0.001
Pinkrose rockfish	5 – –	11 – –	182 + +	47	0	245	69.9	50.7	65.1	59.3	0.0	3	303.86	<0.001
Pink seaperch	60 + +	1 –	6	4 –	3 –	74	28.2	15.5	8.8	12.0	9.4	4	59.99	<0.001
Rosy rockfish	61 +	12	19	29	3 –	124	41.5	15.9	24.8	30.4	11.3	4	17.74	<0.001
Sharpchin rockfish	42 + +	14	5 –	0 –	0	61	14.3	14.0	16.8	16.0	0.0	3	78.22	<0.001
Sharpnose seaperch	7 – –	205 + +	168 + +	31 – –	0	411	209.1	40.2	95.5	63.8	2.3	4	944.19	<0.001
Squarespot rockfish	186	4 – –	54 – –	237 + +	21 –	502	167.9	64.5	100.5	123.3	45.9	4	198.65	<0.001
Stripetail rockfish	197 + +	37 –	65 + +	152	0	451	111.6	61.8	129.4	148.3	0.0	3	107.37	<0.001
Unidentified sanddab	76 + +	0 –	0 –	2 – –	2 –	80	26.4	4.5	15.0	20.2	13.8	4	138.96	<0.001
Vermilion rockfish	230 – –	162 – –	525 + +	582 + +	437 + +	1936	647.4	248.6	387.5	475.4	177.2	4	753.15	<0.001
Widow rockfish	1295	53 – –	68 – –	466 –	87 –	1969	491.1	329.1	499.5	534.1	115.2	4	1935.80	<0.001

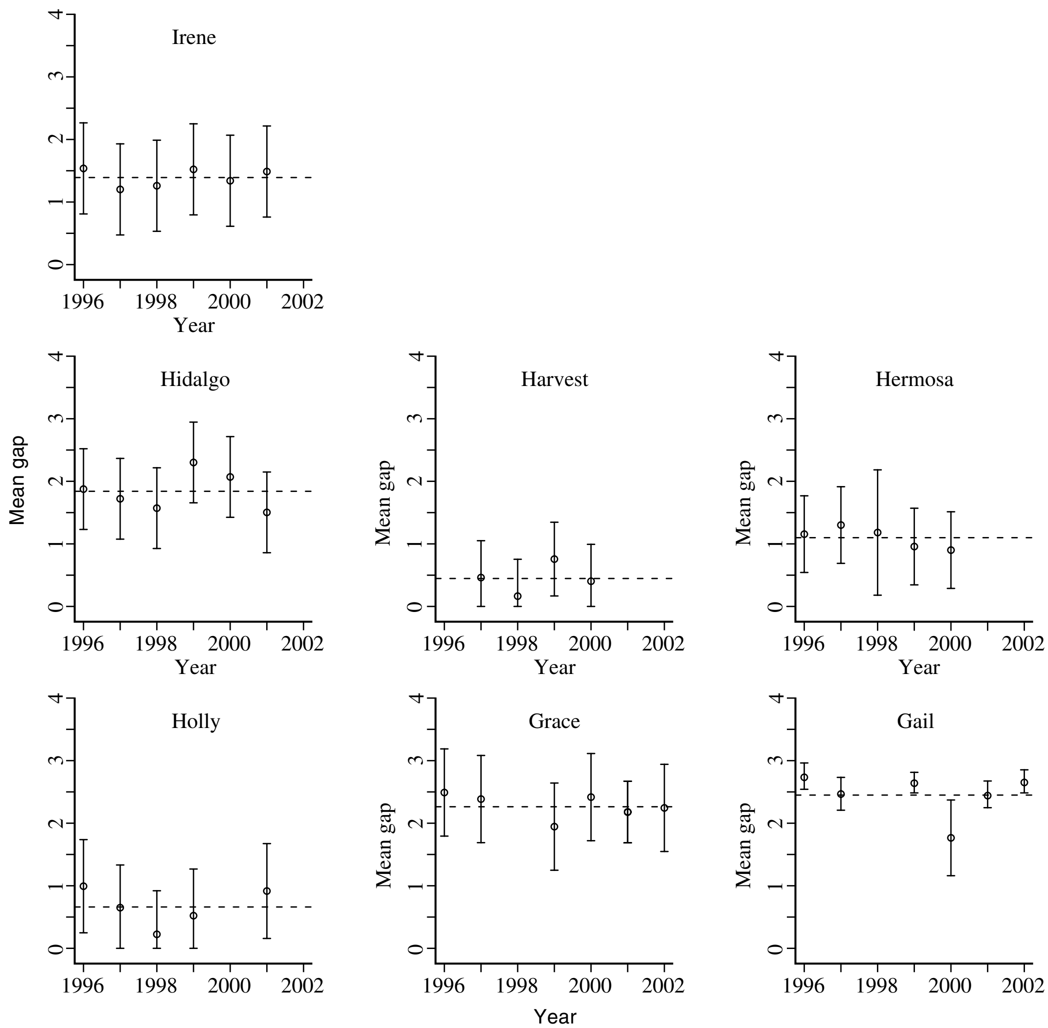

Figure 3

Mean size of gap between beam and sea floor on a scale of 0–4 at each platform, by year. Platforms are ordered from northernmost to southernmost. 0=beam was completely covered and not visible; 1=only the top of the beam was visible; 2=the beam was partially exposed—the bottom of the beam remaining in contact with the sea floor; 3=the beam was completely exposed and formed an open crevice less than 0.5 m high; 4=the beam was completely exposed and formed an open crevice more than 0.5 m high.

Many species appeared to avoid certain beam configurations; that is, they were found in numbers far less than expected by chance. For instance, blue, flag, greenblotched, halfbanded, pinkrose, squarespot, and vermilion rockfishes, and bocaccio were all significantly less abundant in areas with either no horizontal beam or where that structure was not well exposed (exposures 0 and 1). On the other hand, a variety of taxa, such as greenspotted rockfish, YOY lingcod, painted greenling, and sanddabs were relatively uncommon where there was a large gap between the bottom of the beam and the sea floor (exposure 4). Widow rockfish (*S. entomelas*), in our study comprising almost entirely YOY individuals, tended to avoid areas where the beam was exposed. Calico and copper rockfish, along with sharpnose seaperch, tended to avoid both sea floors with no beam present and sea floors where the beam structure was completely exposed (and the gap was significant).

Discussion

Species generally occupied those parts of the beams that appear to be most similar to their natural habitats (Feder et al., 1974; Yoklavich et al., 2000, 2002; Love et al., 2002). In our system, there was a suite of species that were less abundant or nearly absent when the beam was exposed. These species included blackeye goby

(*Rhinogobiops nicholsii*), greenstriped, sharpchin, and stripetail rockfishes, painted greenling, pink seaperch, and sanddabs. These species are usually referred to as "soft substrata" or "mixed substrata" fishes. Other taxa were associated more often or almost exclusively with the exposed beam and these are species often categorized in the literature as "reef" species. These included blue, brown, calico, canary, copper, flag, greenblotched, halfbanded, pinkrose, squarespot, and vermilion rockfishes, cowcod, bocaccio, pile perch, and sharpnose seaperch. As in natural systems, to a great extent greenspotted rockfishes and non-YOY lingcod inhabited several different habitats.

There is evidence that the crevices, cracks, and caves on both natural and human-made structures, may influence fish species assemblages because they form shelters for fishes (Luckhurst and Luckhurst, 1978; Kellison and Sedberry, 1998; Rilov and Benayahu, 1998). In many instances, overall fish abundances are positively correlated with these openings that enhance habitat complexity. On the Pacific Coast, there are only a few observations specifically addressing shelter sites and deeper-water fishes. Caselle et al. (2002), surveying oilfield debris off southern California, examined the influence that structural complexity may exert on fish assemblages. They found that the presence of shelter was one of the most important determinants for high densities of both copper and vermilion rockfishes and played some role in the abundance of a number of other species. Yoklavich et al. (2000) noted that the "rock habitat guild," composed of such species as cowcod, pygmy (*S. wilsoni*), and yelloweye rockfishes, were "closely associated with ledges, caves, crevices, and overhangs." Discussing yelloweye rockfish habitat off southeastern Alaska, O'Connell and Carlile (1993) stated that the "occurrence of refuge spaces may be one key to the presence of yelloweye rockfish, which were normally found in areas where refuge spaces were available, even if the surrounding habitat was not their preferred habitat of boulder or broken rock."

From our research, it was apparent that, among the reef species, there is a "sheltering" guild. These are species (i.e., blue, canary, flag, greenblotched, halfbanded, pinkrose, and vermilion rockfishes, cowcod, and bocaccio) for which an exposed beam alone is not sufficient. These taxa tend to be associated with the spaces that provide shelter under that structure. Blue, brown, canary, halfbanded, and vermillion rockfishes and bocaccio were found in particularly large numbers where the gap between beam and sea floor was largest (exposures 3 and 4). A few species, such as calico, copper, greenspotted, and pinkrose rockfishes, YOY lingcod, and sharpnose seaperch, although often found along the beams, seemed to avoid the most exposed sections.

Fishes that either avoided the beam, or at least that part that formed a gap between the beam and the sea floor, tended to be small in size and to fall into several categories. One group, the sanddabs, is adapted to living on soft substrata. Other species, including blackeye goby, greenstriped, rosy, and sharpchin rockfishes, painted greenling, and pink seaperch, are diminutive and solitary. Although pink seaperch are found in schools over natural outcrops, we did not see them schooling around platforms. All of these diminutive forms will live in high relief, complex substrata when larger predators have been removed from the system, as occurs on most of the rocky outcrops off southern and central California (M. Love, unpubl. data). However, it is likely they avoid exposed beams because of the presence in the area of high densities of large fishes.

Variability in habitat complexity, caused by variation in the amount of beam exposure and the size of gap between beam and sea floor, may explain at least one of the between-platform differences we have observed in fish assemblages. In general, platforms occupying similar depths harbor similar fish assemblages (Love et al., 2003). However, an exception was found when comparing fish species at Platform Gail (224 m) and at Platform Harvest (205 m) (Love et al., 2003). In order of density, greenblotched rockfish, bocaccio, greenspotted, stripetail, and pinkrose rockfishes dominated the bottom fish assemblage at Platform Gail. Cowcod, although not among the top five most abundant fish, were found at higher densities at this platform than at any natural outcrops or other platform that we surveyed in southern California. By contrast, at Platform Harvest, stripetail, greenstriped, greenspotted, greenblotched, and sharpchin rockfishes were most commonly seen. Cowcod were considerably less abundant at this platform and we observed almost no bocaccio. Platform Gail contains, on average, the highest mean exposure value (about 2.5 m) and Harvest the lowest (slightly more than 1.0 m). Most of the common fishes at Gail are representative of complex habitat, those at Harvest of lower relief and softer substrata.

This research may have a bearing on the ultimate disposition of California platforms. The possibility of enhancing fish habitats and fish populations at platforms is an important issue in the decommissioning process. In particular, the California Department of Fish and Game has suggested increasing habitat complexity around the bottom of platform jackets by placing quarry rock or other materials around the jacket (Schroeder and Love, 2004). However, to date, augmentation has not been attempted. With the results from our study, we predict that increasing the habitat complexity at platforms will, in some instances, increase the densities of a number of rock or boulder-oriented species, those species that are preferentially found where there is a gap below the bottom beam.

In addition, the results of this research may also be applied to natural reef studies, particularly those involving marine protected areas (MPAs). This research clearly demonstrates that, in terms of habitat preferences of many fish species, not all hard habitat is the same. In fact, this research indicates that it may be possible to predict which species are found around different types of hard structure by the presence of different types of shelters at the hard structure. This would be particularly important when deciding on what habitats to set aside for MPAs designed to protect and enhance the populations of specific fish species.

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Literature cited

Cass, A. J., R. J. Beamish, and G. A. McFarlane.
1990. Lingcod (*Ophiodon elongatus*). Can. Spec. Publ. Fish. Aquat. Sci. 109, 40 p.

Caselle, J. E., M. S. Love, C. Fusaro, and D. Schroeder.
2002. Trash or habitat? Fish assemblages on offshore oilfield seafloor debris in the Santa Barbara Channel, California. ICES J. Mar. Sci. 59:S258–S265.

Cochran, W. G.
1954. Some methods of strengthening the common chi-square tests. Biometrics 10:417–451.

Feder, H. M., C. H. Turner, and C. Limbaugh.
1974. Observations on fishes associated with kelp beds in southern California. Calif. Fish Game, Fish. Bull. 160, 144 p.

Kellison, G. T., and G. R. Sedberry.
1998. The effects of artificial reef vertical profiles and hole diameter on fishes off South Carolina. Bull. Mar. Sci. 62:763–780.

Koehler, K. J., and K. Larntz.
1980. An empirical investigation of goodness-of-fit statistics for sparse multinomials. J. Am. Statist. Assoc. 66:755–759.

Love, M. S., J. Caselle, and L. Snook.
1999. Fish assemblages around seven oil platforms in the Santa Barbara Channel area. Fish. Bull. 98:96–117.

Love, M. S., Schroeder, D. M., and M. M. Nishimoto.
2003. The ecological role of oil and gas production platforms and natural outcrops on fishes in southern and central California: a synthesis of information. Minerals Management Service OCS Study MMS 2003-032. [Available at http://www.id.ucsb.edu/lovelab.]

Love, M. S., M. M. Yoklavich, and L. Thorsteinson.
2002. The rockfishes of the northeast Pacific, 405 p. Univ. California Press, Berkeley, CA.

Luckhurst, B. E., and K. Luckhurst.
1978. Analysis of the influence of substrate variables on coral reef fish communities. Mar. Biol. 49:317–323.

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

Nasby-Lucas N. B., W. Embley, M. A. Hixon, S. G. Merle, B. N. Tissot, and D. N. Wright.
2002. Integration of submersible transect data and high-resolution multibeam sonar imagery for a habitat-based groundfish assessment of Heceta Bank, Oregon. Fish. Bull. 100:739–751.

O'Connell, V. M., and D. W. Carlile.
1993. Habitat-specific density of adult yelloweye rockfish *Sebastes ruberrimus* in the eastern Gulf of Alaska. Fish. Bull. 91:304–309.

Rilov, G., and Y. Benayahu.
1998. Vertical artificial structures as an alternative habitat for coral reef fishes in disturbed environments. Mar. Environ. Res. 45:431–451.

Schroeder, D. M., and M. S. Love.
2004. Ecological and political issues surrounding decommissioning of offshore oil facilities in the Southern California Bight. Ocean Coastal Manag. 47:21–48.

Stein, D. L., B. N. Tissot, M. A. Hixon, and W. Barss.
1992. Fish-habitat associations on a deep reef at the edge of the Oregon continental shelf. Fish. Bull. 90:540–551.

Yoklavich, M., G. Cailliet, R. N. Lea, H. G. Greene, R. Starr, J. De Marignac, and J. Field.
2002. Deepwater habitat and fish resources associated with the Big Creek Marine Ecological Reserve. CalCOFI Rep. 43:120–140.

Yoklavich, M. M., H. G. Greene, G. M. Cailliet, D. E. Sullivan, R. N. Lea, and M. S. Love.
2000. Habitat associations of deep-water rockfishes in a submarine canyon: an example of a natural refuge. Fish. Bull. 98:625–641.