RELATIVE HABITAT VALUE OF OIL AND GAS PRODUCTION PLATFORMS AND NATURAL REEFS TO SHALLOW WATER FISH ASSEMBLAGES IN THE SANTA MARIA BASIN AND SANTA BARBARA CHANNEL, CALIFORNIA

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ABSTRACT

A number of oil and gas production platforms off California are reaching the end of their economic life. To assess the validity of a rigs-to-reef program for decommissioned platforms, resource managers need a comparison of shallow water fish assemblages between platforms and nearby natural reefs. Bond and his colleagues (In press) developed an index that estimates the "value" of various marine habitats. We modified and used this index to analyze data collected from visual fish surveys around nine platforms and nine reefs located in the Santa Maria Basin and Santa Barbara Channel off southern California. For each site-specific fish assemblage, the modified index sums the square root transformation of the product of each species' density, mean size (total length) and fidelity. Average habitat value for platforms was 42% lower than that for natural reefs. Mean species richness was 24% lower on platforms than natural reefs, but platforms did support a greater abundance and diversity of rockfish (*Sebastes* spp.) juveniles. Variability in platform habitat values and species richness was large compared to natural reef values, suggesting that decommissioned platforms should be evaluated individually in a rigs-to-reef program.

Keywords: Artificial reefs, habitat value, oil platforms, reef fishes, Santa Barbara Channel, Santa Maria Basin, *Sebastes*.

INTRODUCTION

The structure provided by offshore oil and gas production platforms often hosts a large and diverse fish assemblage (Allen and Moore 1976; Bascom et al. 1976; Picken and McIntyre 1989; Seaman et al. 1989; Love et al. 1994; Rooker et al. 1997). For this reason, many platforms provide a recreational opportunity for both sport diving and fishing communities (Stanley and Wilson 1989; Love and Westphal 1990). A number of platforms in the Southern California Bight are reaching the end of their economic life, and many have suggested that decommissioned platforms be used as artificial reefs. To determine the utility of a rigs-to-reefs program resource managers need, among other things, a comparison of fish assemblages associated with platforms to those associated with natural reefs.

In California, previous studies of artificial reefs composed of concrete rubble, quarry rock, and other materials show fish abundance, biomass, and species richness to be similar to or even greater than that of natural reefs (Matthews 1985; Ambrose and Swarbrick 1989; DeMartini et al. 1989; Danner et al. 1994; Stephens et al. 1994). But in many of these cases, substrate complexity of artificial reefs was comparable to or greater than the complexity of nearby natural reefs. Metal jackets of platforms provide few fish-sized refuges and crevices and therefore may be of poor quality for many fish species. Further, platforms do not support large stands of macroalgae that characterize most temperate reefs off California (Dayton 1985). Because they are positioned offshore, platform habitat generally has increased exposure to wave swell and storms, and vastly greater vertical profiles than natural reefs. In spite of these differences, structure from decommissioned platforms may still possess sufficient habitat value to warrant consideration for conversion into artificial reefs.

The purpose of this study is to compare the habitat value for shallow water (0 to 39 m depth) fish assemblages of nine platforms located in the Santa Maria Basin and Santa Barbara Channel, California, with nine natural reefs distributed in the same area. There are many methods to measure habitat value, especially in the literature concerning mitigation (e.g., Barnett et al. 1991). We chose to use a modified index developed by Bond et al. (In press) because, unlike many other indices, it is based on parameters that are objective and simple to measure (fish density, mean size and fidelity).

METHODS

We surveyed nine oil and gas production platforms and nine natural reefs in the Santa Maria Basin and Santa

Barbara Channel, California (Figure 1). At each habitat type (platforms and natural reefs), density (individuals per hectare), mean size (total length) and species composition of reef fishes were estimated in shallow portions of platforms (0 to 39 m depth) and natural reefs (6 to 20 m). Typically, we performed three surveys during July to November of each year during 1995 to 1997, although some platforms had different sample sizes (Table 1). Surveys consisted of fish counts and fish size estimation using both visual and underwater videography methods. Visual surveys recorded fish density and size estimates of fish total lengths on underwater plastic sheets and slates. All divers performing visual counts had completed previous training in size estimation. Additional size estimates were obtained using a Hi8 video camera and laser calibration system. In analyses, visual estimates were used first and video size data were occasionally used to supplement visual estimates.

In each platform survey, scuba divers swam a pattern which incorporated all four corner legs as well as major horizontal crossbeams and portions underneath the platform jacket at three different depths (Level 1 range 6 to 10 m; Level 2 range 12 to 21; Level 3 range 25 to 39 m). Natural reef surveys consisted of divers recording observations along four haphazardly placed 30 m length x 2 m width x 2 m height belt transects, two each at approximately 7 m and 14 m bottom depths which correspond to the inshore and offshore portions of the reef. Each transect included sampling of three strata: surface, midwater, and bottom portions of the water column, one above the other. On the same transects used for fish surveys, other divers measured habitat features using a random point count method (2 points/m). Quantified habitat features included relief height (0 to 0.1 m, 0.1 to 1 m, 1 to 2 m, and > 2 m), substrate type (sand/mud, cobble, and rock), and percent cover of sessile invertebrates and fleshy algae. We also measured the percent cover of surface canopy of giant kelp, *Macrocystis pyrifera*, and stipe density of large kelps, especially *M. pyrifera*, *Pterygophora californica*, and *Eisenia arborea*, along the transects.

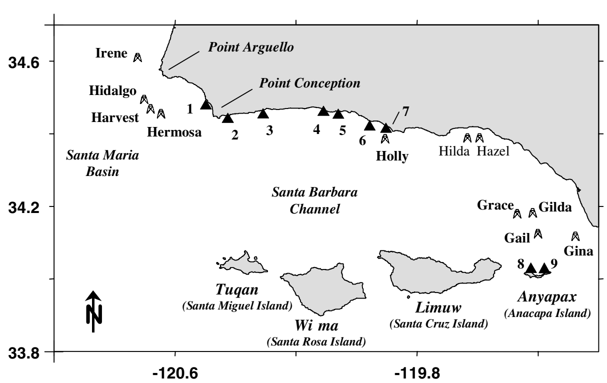

Figure 1. Location of oil and gas platforms and natural reefs referred to in this study. Platforms Hilda and Hazel were decommissioned and removed in 1996. Triangles represent natural reefs (1, Tarantula Reef; 2, Cojo Anchorage; 3, Ranch Reef; 4, Tajiguas Reef; 5, Refugio Reef; 6, Naples' Reef; 7, Haskell's Reef; 8, Portuguese Rock, Anyapax; 9, Northeast Passage, Anyapax).

Table 1. Number of surveys, area surveyed, and platform water depth of sites in this study.

Site	No. samples	Area surveyed for each sample (m2)	Platform water depth (m)
Irene	9	981	74
Hidalgo	4	1493	131
Harvest	3	1308	183
Hermosa	9	1386	204
Holly	9	644	64
Grace	4	1096	97
Gilda	9	864	64
Gail	4	1041	225
Gina	24	561	29
All natural reefs	9	240	-

We estimated habitat value using a modified form of an index developed by Bond et al. (In press). For each site-specific fish assemblage, the modified index sums the square root transformation of the product of each species' density (no./ hectare), mean size (total length in mm) and fidelity. We converted our estimates of fish density from no./volume to no./area (Table 1). Fidelity is calculated as the number of times a species is observed in all surveys divided by the total number of surveys. For example, if black surfperch were seen four times in eight surveys, the fidelity value would be 0.5. The original Bond index assigned each species into an ecological guild and then summed for each guild the square root transformation of the product of the three population parameters (density, size and fidelity). We choose to group our data according to species instead of guilds because there is less subjectivity involved with the former. Since habitat value varies among individual platforms and reefs, we standardized the relative contribution of each species to a site's habitat value by using the equation

$$HV_i \% = (HV_i / \Sigma HV_i) * 100 \qquad (1)$$

where HV_i is the habitat value contributed by species *i* and ΣHV_i is the habitat value of the entire site (platform or reef).

Species richness is simply the cumulative number of species observed during all surveys; we did not correct for the unequal number of surveys among sites. There are several taxon categories that we counted as one species which may consist of several similar species. They are: unidentified species of rockfish juveniles, canopy rockfish juveniles (*Sebastes atrovirens, S. carnatus, S. caurinus* and *S. chrysomelas*), olive or yellowtail juvenile rockfish (*Sebastes flavidus* and *S. serranoides*), shallow water rockfish juveniles of the subgenus *Sebastomus* (*Sebastes rosaceus* and *S. umbrosus*), Family Atherinidae (*Atherinops affinis*, *A. californiensis*, *Leuresthes tenuis*), kelpfishes of the genus *Gibbonsia*, (*Gibbonsia evides, G. metzi,* and *G. montereyensis*), unidentified flatfishes, unidentified poachers, unidentified sculpins, and unidentified surfperch juveniles.

RESULTS

There were a number of differences in fish assemblages and habitat value between oil and gas production platforms and natural reefs. On average, platform habitat values were 42% lower than natural reef habitat values (platform mean = 2240, 1SD = 1331; natural reef mean = 3854, 1SD = 797). There was a distinct pattern of lower habitat value for platforms located in the Santa Maria Basin compared to those located in the central and eastern Santa Barbara Channel (Figure 2). This regional pattern was not apparent in natural reef habitat values (Figure 2). Platform values were more variable than natural reef values, having a coefficient of variation (CV) of 58%. For natural reefs, the habitat value CV was 21%. Platform habitat values were negatively correlated with increasing seafloor depth ($r = -0.67$, $p < 0.05$). Natural reef habitat values were positively correlated with mean relief height ($r = 0.67$, $p < 0.05$).

Mean species richness also differed among habitat types. Platforms possessed lower values than natural reefs, with an average of 22 species (range 12 to 42) while natural reefs averaged 29 species (range 23 to 37). Species richness was more variable among platforms (CV = 42%) than among natural reefs (CV = 19%). Platforms with the highest richness were located in the Santa Barbara Channel (Figure 2). A regional pattern in species richness was not apparent among natural reefs (Figure 2).

The twenty most important species contributing to habitat value of all platforms and reefs are listed in Table 2. On platforms, the two dominant species were blacksmith and halfmoon, together contributing about a third of mean habitat value (Table 2). The two dominant species on natural reefs were senorita and kelp bass, together contributing about one quarter of mean total value (Table 2). Half of the twenty species important to platform habitat value were also important to natural reef habitat value (Table 2).

There are several notable differences between the top twenty species of each habitat type (Table 2). Whereas two wrasses (Family Labridae), California sheephead and senorita, were important to natural reefs, there were no wrasses important in platform habitat. Platform fish assemblages lacked many surfperch species (Family Embiotocidae), having only two in the top twenty, pile and sharpnose surfperch. Natural reefs had six surfperches in the top twenty: black, kelp, pile, rainbow, rubberlip and white surfperch. Kelp surfperch and giant kelpfish, two species important in natural reef assemblages which have strong affinities to giant kelp (Holbrook et al. 1990, Anderson 1994), were not present in platform assemblages. Rockfishes (Family Scorpaenidae) were a more important component to platform habitat value, constituting eight of the top twenty species. Kelp rockfish and the species suite of juveniles that recruit to giant kelp canopy were the only scorpaenids important to habitat value of natural reefs. Species which primarily inhabit the pelagic environment (e.g. anchovy, jack mackerel, and sardine) were more important in platform habitat value (Table 2; Figure 2).

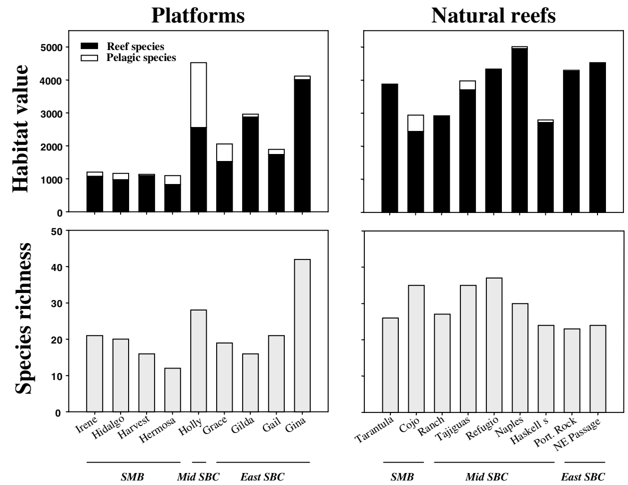

Figure 2. Habitat value and species richness for each oil and gas production platform and natural reef surveyed in this study.

DISCUSSION

The purpose of this study was to compare the relative importance of oil and gas production platforms and natural reefs to shallow water fish assemblages in the Santa Maria Basin and Santa Barbara Channel. We found notable differences in the mean and variance of habitat value and species richness between platforms and natural reefs. Although platforms should not be considered analogous to natural reefs, platform structure is of considerable value to reef fishes. We also present several points for resource managers to consider when determining platform decommissioning strategy.

Both large and small scale processes affect the development of fish assemblages and habitat value. Among-site variation in fish assemblages may occur due to 1) spatial and temporal differences in oceanography which may affect larval settlement rates, and 2) due to local habitat features which may affect fish survivorship and migration rates. We assume that over the entire study region access to pelagic larvae is likely to be similar between natural reefs and platforms. If true, this implies that local features determine the difference between mean habitat values of platforms and natural reefs. Decreasing habitat value with increasing platform depth suggests that depth is a barrier to fish migration. The maximum depth recorded for many reef fishes in southern California is 46 m or less (Eschmeyer et al. 1983). The only platform which has a depth shallower than 46 m is Platform Gina, and this site has the highest habitat value of reef fishes of all platforms, and exceeds the habitat value of five surveyed natural reefs. Platform Holly, which is at a depth of 60 m, had the largest habitat value of all platforms, but about half the value is from pelagic species which would not be migration-limited by seafloor depth. Another migration barrier might be the distance a platform is from other reefs (natural or artificial). But, since depth is often confounded with distance, it will be difficult to discriminate between these two factors without experimental manipulation.

Table 2. Twenty most important fish species contributing to habitat value on oil and gas production platforms and natural reefs.

Species		Platforms			Natural reefs		
Common name	Scientific name	Mean relative habitat value (% of total)	Rank	% of sites with species	Mean relative habitat value (% of total)	Rank	% of sites with species
Blacksmith	*Chromis punctipinnis*	17.44	1	100	5.65	6	78
Halfmoon	*Medialuna californiensis*	14.72	2	100	1.47	20	78
Sardine	*Sardinops sagax*	7.57	3	67	1.88	15	11
Painted greenling	*Oxylebius pictus*	6.20	4	100	1.76	16	100
Kelp Bass	*Paralabrax clathratus*	5.27	5	56	10.99	2	100
Jack mackerel	*Trachurus symmetricus*	5.11	6	67	-	-	-
Kelp Rockfish	*Sebastes atrovirens*	3.77	7	89	3.59	9	89
Unidentified *Sebastes* juveniles	*Sebastes* spp.	3.76	8	78	-	-	-
"Canopy rockfish" juveniles	*Sebastes atrovirens, S. carnatus, S. caurinus, S. chrysomelas*	3.74	9	100	4.01	8	100
Bocaccio	*Sebastes paucispinis*	3.55	10	78	-	-	-
Cabezon	*Scorpaenichthys marmoratus*	3.14	11	100	-	-	-
Widow rockfish	*Sebastes entomelas*	3.08	12	44	-	-	-
Blue rockfish	*Sebastes mystinus*	2.39	13	78	-	-	-
Opaleye	*Girella nigricans*	2.19	14	33	2.91	12	56
Treefish	*Sebastes serriceps*	1.93	15	100	-	-	-
Sharpnose surfperch	*Phanerodon atripes*	1.86	16	33	-	-	-
Anchovy	*Engraulis mordax*	1.80	17	11	-	-	-
Pile surfperch	*Rhacochilus vacca*	1.65	18	44	3.25	10	100
Copper rockfish	*Sebastes caurinus*	1.46	19	89	-	-	-
Silversides	Family Atherinidae	1.25	20	11	6.51	4	100
Senorita wrasse	*Oxyjulis californica*	-	-	-	15.55	1	100
Kelp surfperch	*Brachyistius frenatus*	-	-	-	6.89	3	100
Black surfperch	*Embiotoca jacksoni*	-	-	-	5.93	5	100
Rainbow surfperch	*Hypsurus caryi*	-	-	-	4.13	7	78
Giant kelpfish	*Heterostichus rostratus*	-	-	-	3.23	11	89
California sheephead	*Semicossyphus pulcher*	-	-	-	2.68	13	56
White surfperch	*Phanerodon furcatus*	-	-	-	2.63	14	67
Rubberlip surfperch	*Rhacochilus toxotes*	-	-	-	1.72	17	89
Garibaldi	*Hypsypops rubicundus*	-	-	-	1.56	18	44
Barred sandbass	*Paralabrax nebulifer*	-	-	-	1.51	19	56
Other species	-	8.10	-	-	12.88	-	-
	Total	100%		Tot	100%		

Local supply of food and shelter may be insufficient to sustain some species of fish on platform habitat. This seems the likely explanation for the absence of kelp surfperch and giant kelpfish on platforms because both species possess a strong affinity for macroalgae, especially giant kelp (Holbrook et al. 1990; Anderson 1994). Except for occasional impingement by drifting kelp mats, giant kelp is not present on platforms (D. Schroeder, pers. obs. 1995 to 1998). Other fish species that are not found on platforms but are found on natural reefs are various surfperches (black, rainbow, and white) and wrasses (California sheephead and senorita). However, these species have been observed in fish assemblages on other platforms not included in this study. The fish assemblage associated with Platform Edith which lies in 49 m water depth off Huntington Beach, has numerous individuals of California sheephead and senorita (D. Schroeder, pers. obs. 1998). Carlisle et al. (1964) and Mearns and Moore (1976) have documented black, rainbow and white surfperches on Platforms Hilda (30 m depth) and Hazel (32 m depth) southeast of Santa Barbara (Figure 1). Although a formal comparison of invertebrate fouling communities has not been performed, it would seem that food and shelter characteristics of Platforms Edith, Hazel, and Hilda would be similar to other platforms and so food and shelter would not be the limiting factor to the missing surfperch and wrasse species.

Because the metal structure is similar among platforms, we suggest that the large among-platform variability in habitat value is due to oceanographic processes. Although local circulation is complex, platforms may be divided into two groups based on prevailing oceanography: 1) those located in the Santa Maria Basin which are more exposed to the California Current and frequently encounter upwelled water from Points Arguello and Conception, and 2) those platforms located in the eastern Santa Barbara Channel which generally bathe in warm water of the southern California countercurrent (Brink and Muench 1986; Harms and Winant 1998). If larval encounter rates or thermal preferences are important in structuring fish assemblages, local hydrographic differences should generate differences between fish assemblages of the two platform groups. Certain species of juvenile rockfishes that are abundant off Central California are observed in large numbers at Santa Maria Basin platforms and not at Santa Barbara Channel platforms. This is consistent with the larval encounter prediction. The distribution of kelp bass, a sub-tropical serranid, is limited to the five Santa

Barbara Channel platforms, which supports the thermal preference prediction. Natural reefs, which are exposed to the same range of oceanographic conditions as platforms, do not have such distinct patterns in fish assemblages as platforms. Variability in local features among natural reefs may be responsible for blurring patterns cause by oceanography.

The high variability of habitat value among oil and gas production platforms has an obvious spatial component. Therefore, we suggest that in a rigs-to-reef program, platforms should be evaluated on a case-by-case basis. Suggested decommissioning strategies include: 1) leaving platforms in place, 2) leaving in place but "topped off" to 30 m, and 3) removing the entire platform structure or topped off portion to a designated area (H. Leedy, pers. comm. 1999). Fish assemblages and habitat value described here are only valid if platforms are left in place; it is not known whether topping off will cause a decline in shallow-water fish abundance. If platform structure is removed to a designated area, the resulting fish assemblage and habitat value would vary according to depth and spatial position. Management objectives should determine the optimal placement for decommissioned platform structure. If the primary goal is to provide habitat for shallow water species, it would be worthwhile to consider placing platform structure into shallower depths than they presently occupy. Managers should also prioritize species to be targeted in artificial reef programs, and consider regional patterns of oceanography. Although platforms in the Santa Maria Basin possess lower habitat values, they host a greater abundance of rockfish juveniles. Santa Maria Basin platforms may therefore be valuable to fisheries managers since rockfishes, which are highly prized in both sport and commercial fisheries, show dramatic declines in abundance in southern California (Love et al. 1998).

Our observation of a positive relationship between relief height and habitat value on shallow natural reefs is in agreement with other southern California studies of kelp bed fish assemblages (Quast 1968; Feder et al. 1974; Ebeling et al. 1980). Relief height is often a proxy for the abundance of shelter interstices (fish refuges) which has also been shown to affect density, biomass, and species composition of kelp bed and coral reef fish assemblages (Hixon and Beets 1989, 1993; Nemeth 1998; Ohman and Rajasuriya 1998; Steele 1999). Submersible and scuba surveys of platform structure reveal that fishes aggregate in crevices and corners at the bottom of platforms (D. Schroeder, pers. obs. 1995 to 1998). Therefore, we suggest that an increase of substrate complexity, perhaps by the addition of quarry rock, will enhance the attractiveness of relatively simple platform structure to fishes.

Habitat value indices must be employed with caution since much ecological information is lost in the reduction process to provide a single measurement value. It is important to carefully define the "value" of habitat to be sure to include all appropriate ecological characteristics in a value index. The Bond Index, in either its modified or unmodified form, does not include several measurements which may be considered to be meaningful indicators of habitat quality, including species richness, species evenness, weighted value for presence of rare species, diversity of trophic levels, primary productivity, and absolute size of habitat.

This study does not address the most important question surrounding the debate on the utility of artificial reefs. Namely, whether artificial reefs enhance or merely redistribute fish populations. In order to show a benefit to fish populations, some aspect of production (growth, survivorship, or fecundity) must be increased at the regional scale with the addition of artificial reefs (Grossman et al. 1997). To date, no studies have unequivocally demonstrated this effect.

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