CALIFORNIA DEPARTMENT OF FISH AND GAME
Nearshore Sport Fish Habitat Enhancement Program

A REPORT OF BIOLOGICAL OBSERVATIONS AT OCEANSIDE #1 AND #2 ARTIFICIAL REEFS CARLSBAD ARTIFICIAL REEF PACIFIC BEACH ARTIFICIAL REEF AND MISSION BAY PARK ARTIFICIAL REEF

Prepared By
Dennis W. Bedford

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Marine Resources Division, 330 Golden Shore Suite 50, Long Beach CA 90802

Introduction

In 1964, the California Department of Fish and Game constructed a quarry rock reef off shore from Oceanside, San Diego County, California (OAR 1). The purpose for constructing OAR 1 was to enhance local sport fishing opportunities. This reef was later augmented in 1987 utilizing surplus concrete dock floats and pier pilings by the Department's newly formed Nearshore Sport Fish Habitat Enhancement Program (NSHEP). During 1987 a second reef was constructed for this same purpose out side the entrance to Mission Bay, San Diego County, California (MBAR). This reef was constructed by sinking two vessels, the "El Rey" and the "Ruby E". Several times since its orginal construction this reef has also been augmented with concrete rubble.

Also during 1987 two other reefs were constructed off southern California. However their purpose and configuration was quite different than the former. A second Oceanside Artificial Reef (OAR 2) and the Pacific Beach Artificial Reef (PBAR), both within San Diego County were designed to (1) provide shelter, forage, nesting, and nursery areas for fishes and invertebrates; (2) offer rocky substrate for the attachment and growth of marine plants, particularly giant kelp (*Macrocystis* sp.); and perhaps most importantly, (3) act as "experimental" reefs for investigating the effect of reef location, depth, height, and rock size on the successional development of the associated biotic communities.

The OAR 2 and PBAR were completed in September and October, respectively, and were designed with similar configurations (Figure 1). Each reef was constructed of 10,000 tons of quarry rock arranged over 128 acres in twenty-four modules. Four pairs of modules were constructed along each of three depth contours: shallow (42 ft), mid-depth (57 ft), and deep (72 ft).

During the spring of 1990 an additional "experimental" reef was constructed at Carlsbad, San Diego County (CAR), in front of the seasonal opening to Batiquitos Lagoon. The configuration of this reef was similar to OAR 2 and PBAR, but consisted of twelve (12), unpaired modules instead of the twenty four (24) paired modules of the former two experimental reefs (Figure 2).

During the late summer of 1992 all five of these reefs (Figure 3) were surveyed by Department divers to fulfill permit conditions as established by the California Coastal Commission.

The experimental reefs OAR 2, CAR and PBAR were surveyed to assess their biological community maturity, or how close they have progressed towards a stable "equilibrium" community.

The fishing reefs, OAR 1 and MBAR were surveyed to assess whether or not they were functioning as designed, i.e.; were they attracting and holding desirable sport fish species?

Due to the young age of the experimental reefs and the rapid successional change still occurring in the associated biotic communities (Carlisle *et al*. 1964; Turner *et al*. 1969; Carter *et al*. 1985; Matthews 1985; Solonsky 1985; Ambrose and Swarbrick 1989; Anderson *et al*. 1989; Hueckel and Buckley 1989; and Wilson *et al*. 1990) combined with the limited need to evaluate only the success or failure of the fishing reefs in attracting and holding sport fish species, only qualitative surveys were conducted.

This report summarizes the results of the surveys conducted by California Department of Fish and Game (CDFG) biologists-divers on OAR 1, OAR 2, CAR, PBAR and MBAR.

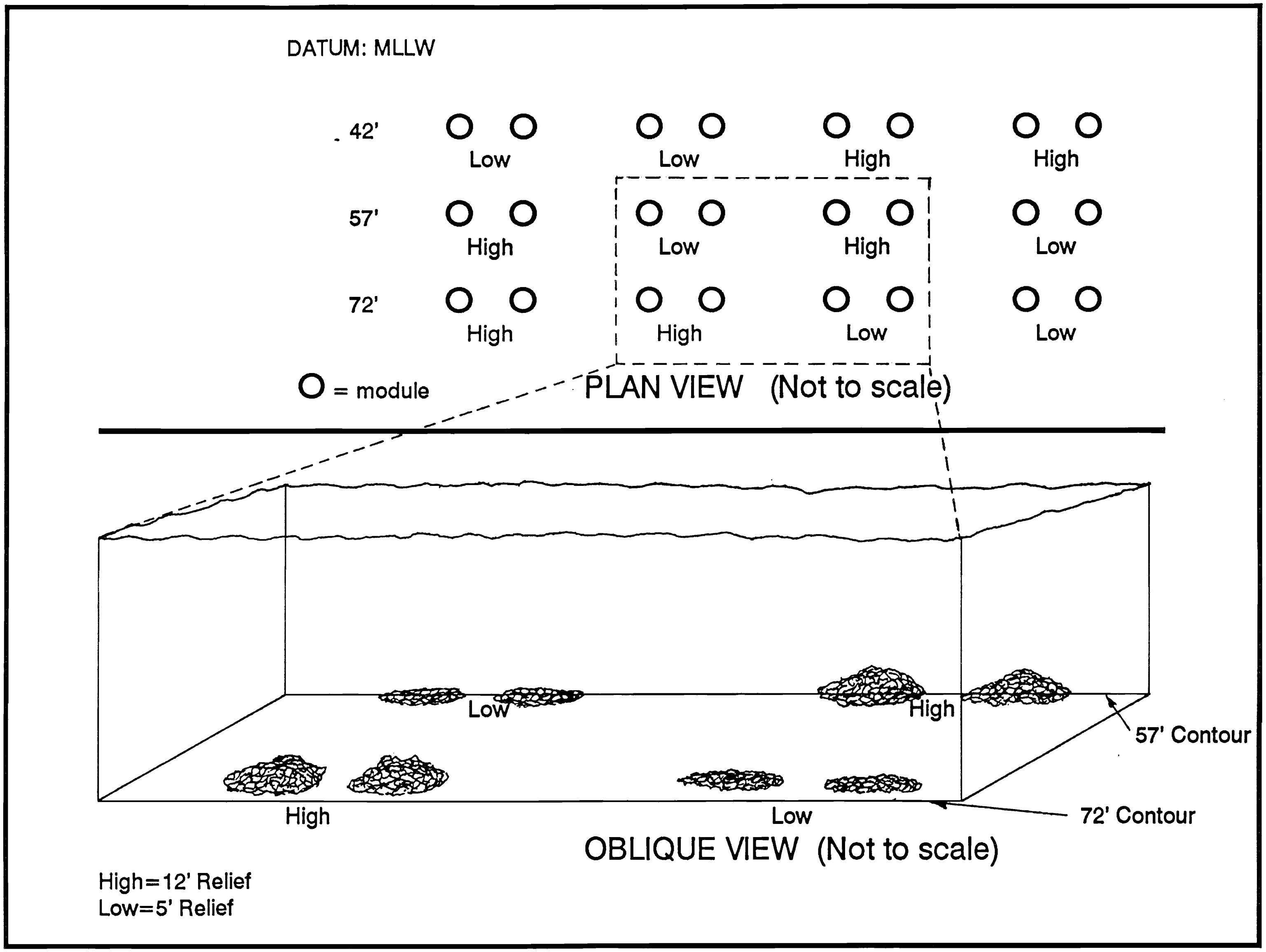

Figure 1. Design of Pacific Beach Artificial Reef and Oceanside No. 2 Artificial Reef.

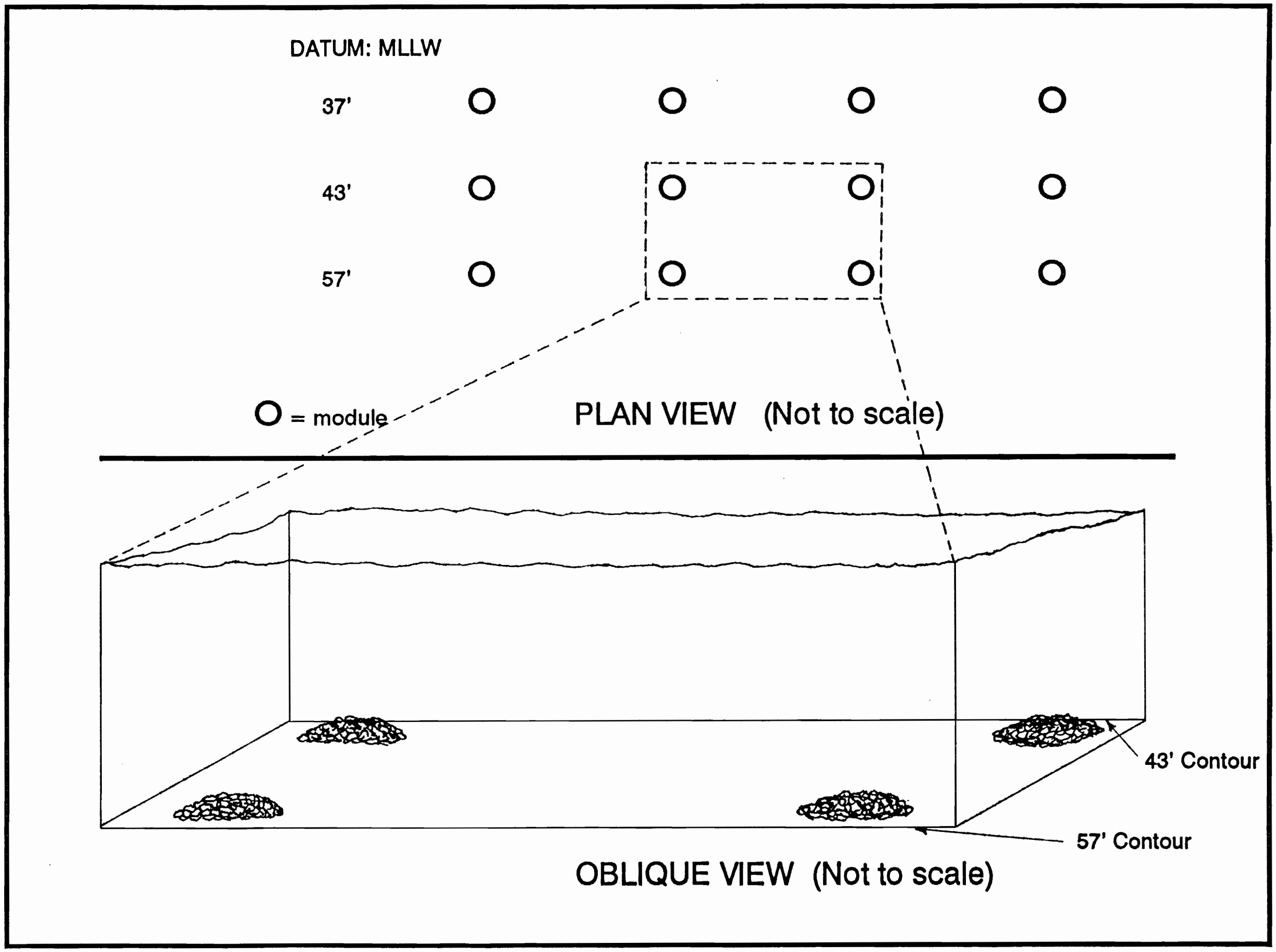

Figure 2. Design of Carlsbad Artificial Reef.

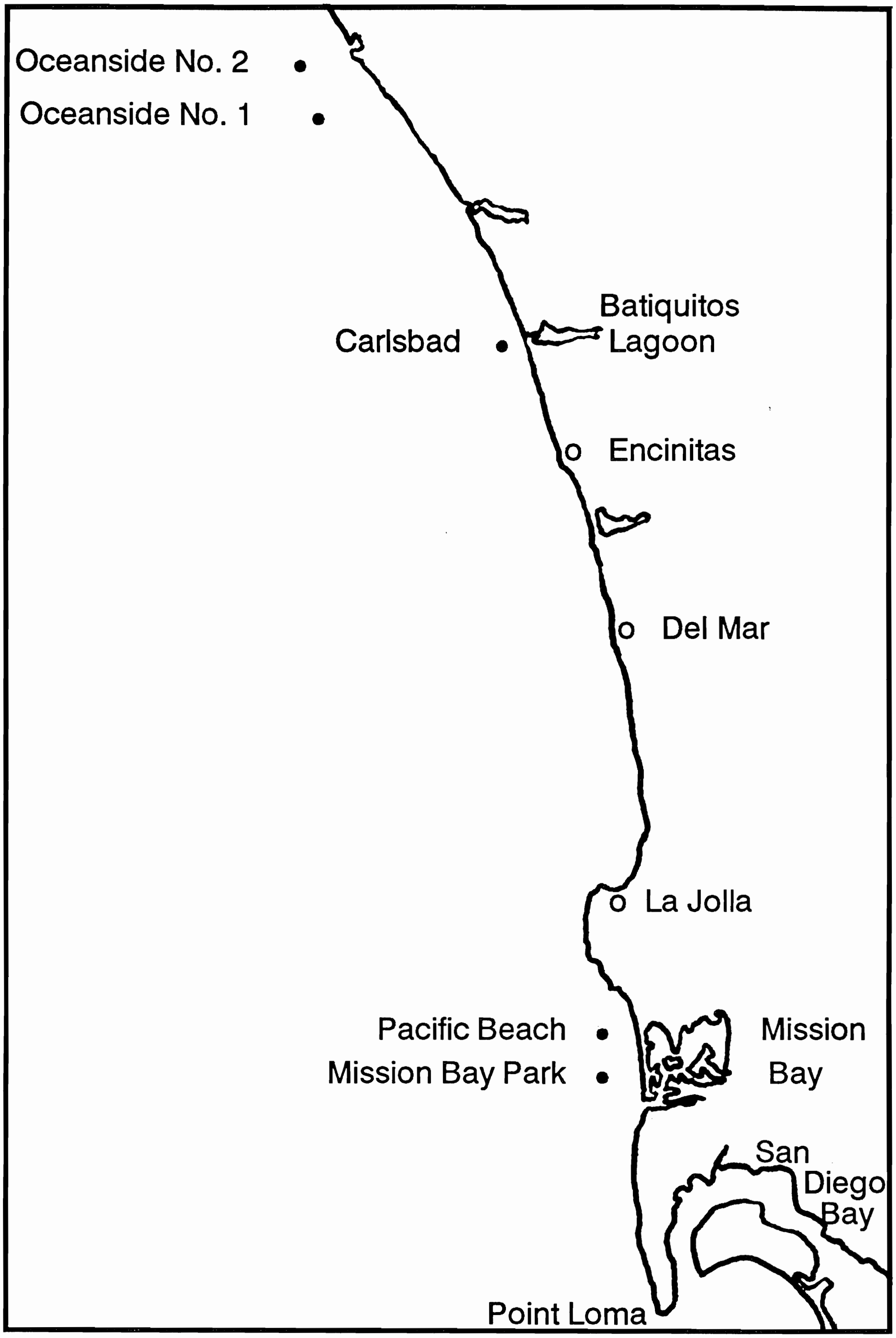

Figure 3. Location of surveyed artificial reefs.

Methods

During September and October 1992, NSHEP biologist-divers surveyed OAR 1, OAR 2, CAR, PBAR and MBAR to evaluate the assemblage of fishes, macroinvertebrates, turf communities (small sessile invertebrates and plants), and macroalgae on randomly selected modules at each depth contour. The modules were located by using Loran-C, GPS, side-scanning sonar, and echosound. The small size of the modules, coupled with favorable visibility, allowed qualitative observations of the biotic communities to be made.

The quantities of fishes were estimated using four categories: abundant (>50 individuals), common (11-50 individuals), occasional (2-11 individuals), and one (1 individual). Fish size was estimated using two categories: adult (Ad) and subadult (Sad).

A distinction is made between invertebrates and algae which are large enough or rare enough that individuals can be counted and those whose numbers are so great that they blanket large areas of a reef. As a matter of convenience the former are labeled macroinvertebrates and macroalgae, while the latter are categorized as the "turf" community. It is recognized that there is no clear biological distinction between these groupings, such as macroinvertebrates and turf invertebrates, but the categorization greatly eases our task of quantifying the species.

The quantities of macroinvertebrates and macroalgae were estimated by counting all individuals, within one meter on either side of a transect line, run from the base of a module over the crest and down to the base on the opposite side. The numbers are reported as the average number of individuals per square meter. Macroalgae size was estimated using four categories of height: A1 (≤1 in.), A2 (1 in.- 1 ft.), A3 (1 ft. to the subsurface), and A4 (surface canopy).

Estimated percent cover for turf community organisms was averaged for ten randomly selected quarter square meter quadrats.

Physical data collected included information about module depth and height (relief), water visibility, and sediment type. Measurements of scouring around the base of modules were also taken. Module depth and height were determined by averaging numerous depth gauge readings taken along the module base and crest (surface), respectively.

Results

Physical Data

Some variability existed among the heights of the modules. Although OAR 2, CAR and PBAR were constructed with similar configurations, height among modules varied between 10 and 21 ft.

The height of OAR 1 never exceeded 5 feet, while the sunken vessels present at MBAR stood as much as 20 feet above the bottom.

The OAR 1 was surrounded by a fine grain sand. There was very little sedimentation and no evidence of scouring around the base of the single concrete dock float module examined. The entire reef lies at a minimum depth of 70 feet.

The OAR 2 was surrounded by a combination of sand and cobble (small rocks). Differences in the sediment did exist between the shallow, mid-depth and deep modules. Fine gray sand surrounded the deep and mid-depth modules. A mixture of sand and cobble was noted around the entire base of the shallow module. The cobble at this module was similar to that on southern Oceanside and Carlsbad beaches, which resulted from the construction of the Oceanside Harbor and breakwater. Scouring occurred (1 ft deep) at the shallow module, creating a 3 ft wide band around its base. Scouring was not observed at the mid-depth or deep module. Underwater visibility ranged from 6 to 25 feet.

The CAR is entirely surrounded by clean, medium to course grain sand. Some scouring does exist at the bases of the shallow and mid depth modules. One of the shallow modules at CAR is the highest relief rock module yet observed at any southern California artificial reef. It sits at a depth of 37 feet (MLLW) and rises 21 feet above the bottom. Visibility ranged between 10 to 25 feet.

The PBAR was surrounded by clean multi-sized sand; grain size varied among modules but no pattern was observed with change in module depth. Scouring around a module base was greatest (3 ft deep) at the shallow module; scouring, if any, was slight at mid-depth and deep modules. Module height varied between 8 and 12 feet. Underwater visibility ranged from 10 to 15 feet.

Mission Bay Park Artificial Reef consists of two sunken vessels and scattered rubble, all at depths between 70 - 80 feet. The wrecks are surrounded by coarse grain sand. No scouring was noted. The wrecks present a fairly high relief structure, rising to as much as 20 feet above the bottom. Visibility ranged from 10 to 20 feet.

Biological Data (Biotic Communities)

Fishes

Many of the fish species common on nearshore reefs in southern California (Wilson *et al.* 1990) were observed on each of the modules surveyed (Tables 1, 2, 3, 4, and 5). Blacksmith (*Chromis punctipinnis*) was the most numerous at all five reefs. Adult and subadult (juvenile) blacksmith were observed in abundant numbers at nearly all modules surveyed, particularly on shallow and mid-depth modules at OAR 2, CAR and PBAR. Other fish observed in abundant numbers on some, but not all modules include kelp bass (*Paralabrax clathratus*), barred sand bass (*P. nebulifer*), sheephead (*Semicossyphus pulcher*), blackeye goby (*Coryphopterus nicholsii*), black surfperch (*Embiotoca jacksoni*), senorita (*Oxyjulis californica*), white surfperch (*Phanerodon furcatus*), jack mackerel (*Trachurus symmetricus*), black croaker (*Cheilotrema saturnum*), salema (*Xenistius californiensis*), pile surfperch (*Damalichthys vacca*), kelp surfperch (*Brachyistius frenatus*) and halfmoon (*Medialuna californiensis*).

Eleven (11) fish species were observed on the dock float module of OAR 1. Of these only blacksmith and jack mackerel were abundant. The blacksmith hovered just above and around the structures. The jack mackerel schooled at about 30 to 40 feet from the surface, or about mid way between the module and the surface.

Seventeen (17) fish species were observed on the modules at OAR 2. Eleven (11) species were observed on the deep and mid-depth modules. Fourteen (14) fish species were observed on the shallow module. Only blacksmith was abundant at all three depths. At the deepest site blacksmith shared its dominance with blackeye gobies clinging to the rock surfaces and halfmoons hovering above the crest of the module. The dominant species changed as we moved inshore. On the shallow module, halfmoon were not present at all and blackeye goby were seen only occasionally. Sheephead became far more abundant inshore as did black surfperch, black croaker, senorita wrasse and jack mackerel. The last four species were absent at the deepest site.

Although CAR is the most recent of the experimental type artificial reefs, it held nearly as many fish species as any other reef system. (Only PBAR held more). A total of twenty two (22) species were observed. The mid depth module held the greatest number of fish species by depth, with twenty (20) observed. The deepest and shallowest modules each held fourteen (14) species, although once again dominance of any particular species tended to shift with depth. Rubberlip surfperch were common on the deep module and entirely absent on the shallow module. On the other hand, halfmoon, which were observed only occasionally at deep modules, were a dominant member of the shallow module community. This distribution pattern the reverse of that observed at OAR 2.

PBAR held a total of twenty five (25) species of fish. By depth the shallow module held the greatest number, twenty (20), although the other depths were not significantly different. The deep and mid-depth modules held eighteen (18) and seventeen (17) species respectively. It does not appear that there are any obvious patterns of species dominance with depth at this reef.

A total of seventeen (17) fish species were observed at MBAR. All modules are deep at this reef. The low relief rubble piles held a slightly greater number of species, fourteen (14), than the sunken wrecks, with twelve (12) and thirteen (13) species. White surfperch were abundant on the wrecks, absent on the rubble piles. Senorita wrasse were abundant on the rubble piles, while only observed occasionally of the wrecks.

Macroinvertebrates

The number of macroinvertebrates species observed at the five reefs ranged from one to nine (Tables 1, 2, 3, 4, and 5). Only the giant spined sea star (*Pisaster giganteus*) was observed on all modules.

Only one species, the giant spined sea star was observed on the dock float module of OAR 1.

The macroinvertebrate community was well developed at OAR 2 with nine (9) species observed. Sea cucumbers (*Parastichopus sp.*) and scallops (*Hinnites giganteus*) were abundant, particularly on the deepest module. The short spinned sea star (*Pisaster brevispinus*), a predator of bivalve species and also present in large numbers, may be the principle benefactor of the abundant scallop population.

The macroinvertebrate community was also beginning to develop on CAR, however the data was inadvertantly lost and so are unavailable for analysis.

As with other species groupings the macroinvertebrate community at PBAR is well developed with a total of eight (8) species observed. In excess of one bat star (*Asterina miniata*) per square meter was observed on the deepest module, while kellet's whelk (*Kelletia kelletii*) occurred on the shallow module at just under one per square meter. PBAR was also host to a number of spiny lobsters, (*Panulirus interruptus*).

The macroinvertebrate community was best developed on the rubble module at MBAR rather than the wrecks. This is due to the increased complexity of the habitat provided by the holes and crevices at the rubble site, as opposed to the broad flat surfaces of the wrecks. Eight (8) species were observed at the rubble module compared to four (4) and five (5) at the two wreck sites. The abundance of bat stars at both the "El Rey" and the rubble module were quite high, indicating some very abundant food source. This was probably a clam species in the reef/sand interface as evidenced by the presents of shells around the base of the wrecks.

Turf Community

In the turf community (Tables 1, 2, 3, 4, and 5), foliose red algae, dominated by *Rhodymenia sp.* and filamentous red algae were observed on nearly all modules.

Invertebrate turf communities are dominated by erect ectoprocts, hydroids and barnacles. On all but the newest reef, CAR, reef crests and vertical faces are adorned by colonies of strawberry anemones (*Corynactis californica*). Such colonies are an indication of a fairly advanced stage of development (Vance, 1988; Palmer and Aseltine, In press).

Macroalgae

Giant kelp (*Macrocystis pyrifera*) occurred at all the experimental reefs on the shallow and mid-depth modules (Tables 1, 3, and 4). At CAR giant kelp also grew on the deepest module at 57 feet. On the shallow modules giant kelp was so well established that it created a barrier to divers running transect lines. The modules at both fishing reefs, OAR 1 and MBAR are generally considered too deep to support giant kelp. However a few very small plants were observed at both OAR 1 and the wreck "Ruby E" at MBAR. *Pterygophera*, *Desmarestia*, *Agarum*, *Cystoseira* and *Eisenia* also grew on most reef modules observed, with the exception of the wrecks at MBAR. Of these only *Agarum* also grew on the "Ruby E". On shallow modules of OAR 2, CAR and PBAR several other genera were established including *Pelagophycus*, *Egregia* and *Farlowia*.

Table 1. Abundance and size estimates of organisms observed on Oceanside Artificial Reef #2, September 1992.

Deep Module – 75 ft (MLLW)

FISHES	Abundance Estimate[•]	Size Estimate[1]
Blackeye goby	abundant	Ad
Blacksmith	abundant	Ad/SAd
Halfmoon	abundant	Ad
Sheephead	common	Ad/SAd
Kelp bass	common	Ad
Black surfperch	common	Ad
Sculpin	common	Ad
Barred sand bass	occas.	Ad
Rock wrasse	occas.	Ad
Painted greenling	one	Ad
Lingcod	one	Ad

MACROINVERTEBRATES	Avg. #/m^2	SE
Sea cucumber	0.100	
Short–spined sea star	0.100	
Scallops	*	

* – abundant, but not counted

TURF COMMUNITY	Avg. % Cover	SE
Invertebrates:		
Hydroids	26.8	6.64
White sponge	19.5	3.91
Erect ectoprocts	14.1	3.04
Strawberry anemone	8.2	4.50
Orange sponge	0.5	0.42
Tunicates	0.3	0.18
Live barnacles	0.3	0.13
Urn sponge	0.1	0.08
Algae:		
Rhodymenia	1.7	0.62
Diatoms	1.5	0.59

MACROALGAE	Avg. #/m^2	Size Estimate[2]
Giant kelp (A2)	0.050	A2
Giant kelp (A1)	*	A1
Desmarestia	*	A1

* – present but not counted

Mid–depth Module – 58 ft (MLLW)

FISHES	Abundance Estimate[•]	Size Estimate[1]
Blackeye goby	abundant	Ad
Blacksmith	abundant	Ad/SAd
Black surfperch	abundant	Ad
Sheephead	common	Ad/SAd
Pile surfperch	occas.	Ad
Rock wrasse	occas.	Ad
Kelp bass	occas.	Ad/SAd
Barred sand bass	occas.	Ad
Garibaldi	occas.	Ad
Painted greenling	one	Ad
Olive rockfish	one	Ad

MACROINVERTEBRATES	Avg. #/m^2	SE
Giant–spined sea star	0.150	
Short–spined sea star	0.075	
Ochre sea star	0.025	
Purple urchin	0.025	
Lobster	*	

* – present but not in transect

TURF COMMUNITY	Avg. % Cover	SE
Invertebrates:		
Erect ectoprocts	50.0	8.06
Barnacles	23.1	6.74
Hydroids	20.6	4.84
Tunicates	13.5	4.31
Strawberry anemone	5.2	2.50
Gorgonians	2.0	0.71
Feather–duster worm	2.0	0.94
Encrusting ectoprocts	1.6	0.80
Rock Scallops (#/m^2)	1.2	1.20
Algae:		
Diatoms	7.3	2.32
Red Filaments	6.7	1.39
Rhodymenia	2.7	0.71

MACROALGAE	Avg. #/m^2	Size Estimate[2]
Giant kelp	*	A1

* – 1 present but not in transect

Shallow Module – 42 ft (MLLW)

FISHES	Abundance Estimate[•]	Size Estimate[1]
Sheephead	abundant	Ad/SAd
Black surfperch	abundant	Ad
Black croaker	abundant	Ad
Señorita	abundant	SAd
Jack mackerel	abundant	Ad
Blacksmith	abundant	Ad/SAd
Sculpin	common	Ad
Kelp bass	common	Ad/SAd
Painted greenling	occas.	Ad
Blackeye goby	occas.	Ad
Barred sand bass	occas.	Ad
Pile surfperch	occas.	Ad
Opaleye	occas.	Ad
Rock wrasse	occas.	Ad

MACROINVERTEBRATES	Avg. #/m^2	SE
Giant keyhole limpet	0.100	
Lobster	0.075	
Short–spined sea star	0.075	
Giant–spined sea star	0.025	
Three–winged murex	*	

* – present

TURF COMMUNITY	Avg. % Cover	SE
Invertebrates:		
Erect ectoprocts	42.5	7.29
Hydroids	21.1	5.08
Gorgonians	18.5	3.61
Tube worms	18.5	6.11
Other hydroids	18.5	5.02
Fluted Bryzoan	4.0	3.33
Tunicates	0.9	0.49
Encrusting Ectoprocts	0.9	0.41
Strawberry anemone	0.5	0.42
Scaled worm mollusk	0.5	0.42
Mussels	0.1	0.08
Algae:		
Acrosorium	2.5	0.74
Diatoms	2.2	1.27
Red filaments	1.1	0.56
Dictyota	0.6	0.42
Gelidium	0.1	0.08

MACROALGAE	Avg. #/m^2	Size Estimate[2]
Feather–boa kelp	0.050	
Pterogophora	0.025	
Desmarestia	0.025	
Giant kelp	*	

* – one small plant off reef, also in drift

[•] – Categories for estimating fish abundance are: abundant = >50; common = 11–50; occasional = 2–11; and one = 1.

[1] – Size estimates for fishes are based upon adult (Ad)/subadult (SAd) categories used in CDFG fish studies at Pendleton Artificial Reef.

[2] – Categories for estimating algal size are: A1 = 1in – 1ft; A2 = 1ft to subsurface; and A3 = surface canopy.

Table 2. Abundance and size estimates of organisms observed on Oceanside Artificial Reef #1, September 1992.

Module – Dock floats

FISHES	Abundance Estimate°	Size Estimate[1]
Jack mackerel	abundant	Ad
Blacksmith	abundant	Ad
Black surfperch	common	Ad
Kelp bass	common	Ad
Señorita	common	SAd
Blackeye goby	occas.	Ad
Barred sand bass	occas.	Ad
Sheephead	occas.	Ad/SAd
Sculpin	occas.	Ad
Cabezon	one	Ad
Rubberlip perch	one	Ad

INVERTEBRATES	Avg. #/m²	SE
Giant-spined sea star	0.050	

TURF COMMUNITY	Avg. % Cover	SE
Invertebrates:		
Strawberry anemone	15.1	7.88
Encrusting mud ectoproct	8.0	6.67
Erect ectoprocts	8.0	2.33
Hydroids	6.1	1.07
Sponges	4.0	1.28
Barnacles	0.7	0.42
Stalked tunicate	0.2	0.17
Algae:		
Diatoms	27.0	7.08
Gigartina corymbifera	4.1	1.87
Foliose reds	2.3	0.67
Filamentous reds	1.3	0.54
Dictyota	0.5	0.42

MACROALGAE	Avg. #/m²	Size Estimate[2]
Giant kelp	0.925	A1
Desmarestia	0.150	A1
Desmarestia	0.075	A2
Pterogophora	*	

* – 1 present but not in transect

° – Categories for estimating fish abundance are: abundant = >50; common = 11–50; occasional = 2–11; and one = 1.

[1] – Size estimates for fishes are based upon adult (Ad)/subadult (SAd) categories used in CDFG fish studies at Pendleton Artificial Reef.

[2] – Categories for estimating algal size are: A1 = 1in – 1ft; A2 = 1ft to subsurface; and A3 = surface canopy.

Table 3. Abundance and size estimates of organisms observed on Carlsbad Artificial Reef, September 1992.

Deep Module – 57 ft (MLLW)

FISHES	Abundance Estimate*	Size Estimate[1]
Señorita	abundant	Ad/SAd
Blacksmith	abundant	Ad/SAd
White surfperch	abundant	Ad
Sheephead	common	Ad/SAd
Kelp bass	common	Ad
Black surfperch	common	Ad/SAd
Kelp surfperch	common	Ad
Rubberlip perch	common	Ad
Blackeye goby	common	Ad/SAd
Halfmoon	occas.	Ad
Sculpin	occas.	Ad
Rock wrasse	occas.	Ad
Brown rockfish	occas.	Ad
Barred sand bass	occas.	Ad

MACROINVERTEBRATES	Avg. #/m²	SE
DATA LOST		

TURF COMMUNITY	Avg. % Cover	SE
Invertebrates:		
Hydroids	14.7	3.20
Dead barnacles	7.5	3.40
Erect ectoprocts	3.4	1.10
Live barnacles	2.8	0.92
Tunicates	2.5	2.50
Ectoprocts	1.3	0.65
Mussels	0.6	0.42
Stalked tunicate	0.1	0.08
Fragile tube worm	*	
Algae:		
Rhodymenia	40.4	8.47
Diatoms	2.6	1.79
Botryocladia	1.8	0.68

* – present, but not sampled

MACROALGAE	Avg. #/m²	Size Estimate[2]
Giant kelp	4.3	0.97

Mid–depth Module – 43 ft (MLLW)

FISHES	Abundance Estimate*	Size Estimate[1]
Salema	abundant	Ad
Blacksmith	abundant	Ad/SAd
Jack mackerel	abundant	Ad
Señorita	abundant	Ad/SAd
Halfmoon	abundant	Ad
Rubberlip perch	common	Ad
Sheephead	common	Ad/SAd
White surfperch	common	Ad/SAd
Kelp bass	common	Ad/SAd
Barred sand bass	common	Ad
Walleye surfperch	common	Ad
Pile surfperch	common	Ad/SAd
Kelp surfperch	common	Ad
Black surfperch	common	Ad/SAd
Rock wrasse	common	Ad
Sargo	occas.	Ad
Sculpin	occas.	Ad
Blackeye goby	occas.	Ad
Cabezon	occas.	Ad
Garibaldi	occas.	SAd

MACROINVERTEBRATES	Avg. #/m²	SE
DATA LOST		

TURF COMMUNITY	Avg. % Cover	SE
Invertebrates:		
Erect ectoprocts	23.3	7.54
Hydroids	4.3	1.66
Mussels	4.2	1.42
Live barnacles	0.9	0.43
Dead barnacles	0.4	0.15
Algae:		
Rhodymenia	18.9	4.38
Corallines	5.2	4.11
Diatoms	4.2	1.20

MACROALGAE	Avg. #/m²	Size Estimate[2]
Giant kelp	2.8	0.60

Shallow Module – 37 ft (MLLW)

FISHES	Abundance Estimate*	Size Estimate[1]
Halfmoon	abundant	Ad
Blacksmith	abundant	SAd
White surfperch	abundant	Ad/SAd
Kelp perch	abundant	Ad
Señorita	abundant	Ad/SAd
Sheephead	common	Ad
Black surfperch	common	Ad
Pile surfperch	common	Ad/SAd
Kelp bass	common	Ad/SAd
Sargo	occas.	Ad
Barred sand bass	occas.	Ad
Kelpfish	one	Ad
Rock wrasse	one	Ad
Halibut	one	Ad

MACROINVERTEBRATES	Avg. #/m²	SE
DATA LOST		

TURF COMMUNITY	Avg. % Cover	SE
Invertebrates:		
Erect ectoprocts	30.2	7.82
Mussels	19.8	7.51
Live barnacles	1.0	0.83
Hydroids	0.4	0.29
Tube worms	0.2	0.17
Algae:		
Rhodymenia	10.4	4.28
Corallines	5.9	2.90
Gelidium	0.3	0.18
Gigartina	0.3	0.13
Colpomenia	0.1	0.08

MACROALGAE	Avg. #/m²	Size Estimate[2]
Giant kelp	1.7	0.54

* – Categories for estimating fish abundance are: abundant = >50; common = 11–50; occasional = 2–11; and one = 1.

[1] – Size estimates for fishes are based upon adult (Ad)/subadult (SAd) categories used in CDFG fish studies at Pendleton Artificial Reef.

[2] – Categories for estimating algal size are: A1 = 1in – 1ft; A2 = 1ft to subsurface; and A3 = surface canopy.

Table 4. Abundance and size estimates of organisms observed on Pacific Beach Artificial Reef, September 1992.

Deep Module – 69 ft (MLLW)

FISHES	Abundance Estimate[*]	Size Estimate[1]
Blacksmith	abundant	Ad/SAd
White surfperch	abundant	Ad
Señorita	abundant	Ad/SAd
Sheephead	common	Ad/SAd
Pile surfperch	common	Ad
Blackeye goby	common	Ad/SAd
Rainbow perch	common	Ad
Kelp bass	common	Ad
Black surfperch	common	Ad/SAd
Painted greenling	occas.	Ad
Barred sand bass	occas.	Ad
Rock wrasse	occas.	Ad
Treefish	occas.	Ad
Olive rockfish	occas.	SAd
Brown rockfish	one	SAd
Rubberlip perch	one	SAd
Lingcod	one	Ad
Cabezon	one	Ad
MACROINVERTEBRATES	**Avg. #/m²**	**SE**
Bat star	1.167	
Lobster	0.383	
Giant–spined sea star	0.133	
Kellet's whelk	0.033	
Short–spined sea star	0.033	
Sea cucumber	0.017	
TURF COMMUNITY	**Avg. % Cover**	**SE**
Invertebrates:		
Hydroids	6.0	1.38
Erect ectoprocts	3.6	0.95
Tunicates	0.2	0.11
Algae:		
Filamentous reds	69.5	8.31
Rhodymenia	12.0	2.75
Foliose reds	5.0	1.93
MACROALGAE	**Avg. #/m²**	**Size Estimate[2]**
Agarum	0.050	

Mid–depth Module – 55 ft (MLLW)

FISHES	Abundance Estimate[*]	Size Estimate[1]
Barred sand bass	abundant	Ad
Blacksmith	abundant	Ad
Señorita	abundant	Ad/SAd
Kelp bass	abundant	Ad
Black surfperch	abundant	Ad
Pile surfperch	abundant	Ad
Blackeye goby	common	Ad
Rainbow perch	common	Ad
Rock wrasse	common	Ad
Rubberlip perch	common	Ad
Sheephead	common	Ad/SAd
Cabezon	occas.	Ad
Halfmoon	occas.	Ad
Opaleye	occas.	Ad
Garibaldi	occas.	Ad
Brown rockfish	one	Ad
Lingcod	one	Ad
MACROINVERTEBRATES	**Avg. #/m²**	**SE**
Bat star	0.583	
Giant–spined sea star	0.417	
Lobster	0.100	
Kellet's whelk	0.100	
Short–spined sea star	0.050	
Sea cucumber	0.017	
Giant keyhole limpet	0.017	
TURF COMMUNITY	**Avg. % Cover**	**SE**
Invertebrates:		
Strawberry anemone	5.7	3.08
Hydroids	4.5	2.55
Encrusting bryozoans	4.5	1.75
Erect ectoprocts	4.5	1.86
Tunicates	0.2	0.11
Algae:		
Filamentous reds	73.0	10.02
Foliose reds	1.8	0.87
Rhodymenia	1.5	0.65
Brown blade	0.1	0.08
MACROALGAE	**Avg. #/m²**	**Size Estimate[2]**
Cystoseira	0.267	
Farlowia	0.133	
Pterogophora	0.050	
Pelagophycus	0.017	
Macrocystis	0.017	

Shallow Module – 40 ft (MLLW)

FISHES	Abundance Estimate[*]	Size Estimate[1]
Blacksmith	abundant	Ad/SAd
Kelp bass	abundant	Ad
Señorita	abundant	Ad/SAd
Black surfperch	common	Ad
Blackeye goby	common	Ad
Painted greenling	occas.	Ad
Brown rockfish	occas.	Ad
Sargo	occas.	Ad
Cabezon	occas.	Ad
Garibaldi	occas.	Ad
Barred sand bass	occas.	Ad
White surfperch	occas.	Ad
Black croaker	occas.	Ad
Sculpin	occas.	Ad
Rubberlip perch	occas.	Ad
Halfmoon	occas.	Ad
Rock wrasse	occas.	Ad
Rainbow perch	occas.	Ad
Sheephead	occas.	Ad/SAd
Opaleye	occas.	Ad
MACROINVERTEBRATES	**Avg. #/m²**	**SE**
Kellet's whelk	0.750	
Giant–spined sea star	0.400	
Lobster	0.333	
Short–spined sea star	0.033	
Bat star	0.017	
Octopus	present but not in transect	
TURF COMMUNITY	**Avg. % Cover**	**SE**
Invertebrates:		
Cryptoarachnidium	50.5	12.57
Erect ectoprocts	4.6	1.74
Scaled worm mollusk	2.5	2.08
Strawberry anemone	2.2	1.27
Encrusting bryozoans	2.2	0.68
Hydroids	1.5	0.65
Algae:		
Filamentous reds	46.0	7.19
Dictyota flabellata	3.2	1.28
Rhodymenia	2.5	0.96
Gelidium	2.0	1.12
Foliose reds	1.6	0.64
Brown blade	1.5	0.65
MACROALGAE	**Avg. #/m²**	**Size Estimate[2]**
Cystoseira	0.300	
Pterogophora	0.083	
Macrocystis	0.017	
Egregia	0.017	
Agarum	0.017	
Farlowia	0.017	

[*] – Categories for estimating fish abundance are: abundant = >50; common = 11–50; occasional = 2–11; and one = 1.

[1] – Size estimates for fishes are based upon adult (Ad)/subadult (SAd) categories used in CDFG fish studies at Pendleton Artificial Reef.

[2] – Categories for estimating algal size are: A1 = 1in – 1ft; A2 = 1ft to subsurface; and A3 = surface canopy.

Table 5. Abundance and size estimates of organisms observed on Mission Bay Artificial Reef, September 1992.

Module – RUBY E (sunken ship)

FISHES	Abundance Estimate°	Size Estimate[1]
White surfperch	abundant	Ad
Blacksmith	abundant	Ad/SAd
Painted greenling	common	Ad
Pile surfperch	common	Ad
Kelp bass	common	Ad
Blackeye goby	occas.	Ad
Señorita	occas.	SAd
Black surfperch	occas.	Ad
Sheephead	occas.	SAd
Cabezon	one	Ad
Olive rockfish	one	Ad
Smooth Ronquil	one	Ad

MACROINVERTEBRATES	Avg. #/m²	SE
Bat star	0.100	
Sea cucumber	0.025	
Kellet's whelk	0.025	
Giant–spined sea star	*	
Short–spined sea star	*	

* – present, but not in transect

TURF COMMUNITY	Avg. % Cover	SE
Invertebrates:		
Erect ectoprocts	16.8	7.69
Hydroids	3.8	1.95
Strawberry anemone	3.3	1.98
Encrusting bryozoan	0.4	0.42
Tunicates	0.3	0.26
Algae:		
Filamentous reds	17.1	6.58
Rhodymenia	11.3	4.91
Foliose reds	7.3	1.73
Crustose corallines	1.7	0.86

MACROALGAE	Avg. #/m²	Size Estimate[2]
Macrocystis	0.200	A1
Agarum	0.125	A2

Module – EL REY (sunken ship)

FISHES	Abundance Estimate°	Size Estimate[1]
White surfperch	abundant	Ad
Blacksmith	abundant	Ad/SAd
Painted greenling	common	Ad
Barred sand bass	common	Ad
Kelp bass	common	Ad
Rubberlip perch	common	Ad
Black surfperch	occas.	Ad
Blackeye goby	occas.	Ad
Sheephead	occas.	Ad/SAd
Pile surfperch	occas.	Ad
Rock wrasse	one	Ad
Cabezon	one	Ad
Copper rockfish	one	Ad

MACROINVERTEBRATES	Avg. #/m²	SE
Bat star	0.850	
Giant–spined sea star	0.100	
White urchin	many	
Kellet's whelk	*	

* – present but not in transect

TURF COMMUNITY	Avg. % Cover	SE
Invertebrates:		
Strawberry anemone	20.1	8.92
Erect ectoprocts	9.6	3.91
Red gorgonian	0.2	0.11
Algae:		
Rhodymenia	0.2	0.11

MACROALGAE	Avg. #/m²	Size Estimate[2]

Module – Rubble pile

FISHES	Abundance Estimate°	Size Estimate[1]
Blacksmith	abundant	Ad/SAd
Señorita	abundant	Ad/SAd
Black surfperch	common	Ad
Sheephead	common	Ad/SAd
Blackeye goby	common	Ad
Painted greenling	occas.	Ad
Rainbow perch	occas.	Ad
Barred sand bass	occas.	Ad
Kelp bass	occas.	Ad
Smooth ronquil	one	Ad
Garibaldi	one	Ad
Treefish	one	Ad
C–O turbot	one	Ad
Copper rockfish	one	SAd

MACROINVERTEBRATES	Avg. #/m²	SE
Bat star	1.075	
Sea cucumber	0.525	
Red urchin	0.400	
Kellet's whelk	0.400	
Giant keyhole limpet	0.100	
Giant–spined sea star	0.025	
Orange puffball sponge	*	
Chestnut cowry	*	

* – present but not counted

TURF COMMUNITY	Avg. % Cover	SE
Invertebrates:		
Cup corals	4.2	1.39
Erect ectoprocts	2.5	1.14
Sponges	1.5	0.90
Tunicates	1.1	0.56
Red gorgonian	1.0	0.56
Strawberry anemone	0.6	0.42
Algae:		
Crustose corallines	20.5	8.40
Filamentous reds	7.0	3.07
Foliose reds	6.0	1.74
Articulated corallines	5.5	1.99
Rhodymenia	0.5	0.42

MACROALGAE	Avg. #/m²	Size Estimate[2]
Agarum	0.375	A2
Cystoseira	0.050	A2
Eisenia	0.025	A2

° – Categories for estimating fish abundance are: abundant = >50; common = 11–50; occasional = 2–11; and one = 1.

[1] – Size estimates for fishes are based upon adult (Ad)/subadult (SAd) categories used in CDFG fish studies at Pendleton Artificial Reef.

[2] – Categories for estimating algal size are: A1 = 1in – 1ft; A2 = 1ft to subsurface; and A3 = surface canopy.

Discussion

These were only the second scheduled observations of OAR 2 and PBAR since their construction in 1987. CAR, although relatively new has been monitored frequently since its construction in 1990. Thus, for CAR 2 and PBAR little previous data exists for long term comparisons of community development. Comparisons are limited to observations made two years ago and the observations listed in this report. CAR, although well monitored is still in its early stage of development. As might be expected CAR's biolgical community is changing rapidly during this early stage of development.

The biota on OAR 2, PBAR and CAR appears to be following typical developmental patterns observed on similar artificial reefs in southern California (Wilson *et al.* 1990). Comparing the observations of OAR 2 and PBAR two years ago to these 1992 observations indicates an increasing biological diversity, a trend which is expected to continue for the next few years. We anticipate that the biotic communities at OAR 2 and PBAR will approach biological equilibrium within the next five years, especially if forests of giant kelp continue to become established and persistant. The newest reef, CAR is probably still 8 to 9 years from a equilibrium state. It is encouraging to see the rapid early development of giant kelp on this reef (Photo 1).

While a rocky substrate is of first importance, the presence of giant kelp greatly increases the recruitment of kelp bass (Quast 1968). Kelp bass tend to shift in response to site preference and a lowered population density at preferred sites. Accordingly the shallow and mid-depth modules at the experimental reefs may play a major role in supporting local kelp bass populations.

Fish communities on all three experimental reefs are diverse and abundant. The large number of important sport fish species such as kelp bass, barred sand bass, sculpin, and sheephead suggest that the reefs will support substantial sport fishing. Success has been reported by Commercial Passenger Fishing Vessels targeting sculpin and California halibut (*Paralichthys californicus*) at some of these reefs.

The experimental reefs, OAR 2 and PBAR both have diverse and abundant macroinvertebrate and turf communities (Photos 2 and 3). The third experimental reef, CAR is becoming well established but is still too new to compare with the former two sites (Photo 4).

Virtually no prior recorded data exists for the fishing reefs, OAR 1 and MBAR, so as a practical matter these may be considered their first biological observations. Future observations may reveal whether or not these sites are still undergoing successional change, or if they have already reached their potential for biological community development.

Although less diverse, the fish communities at OAR 1 and MBAR were still well established and fairly abundant. Fish production was suggested at all sites by the large number of juvenile blacksmith as well as juveniles of sheephead and kelp bass.

The macroinvertebrate and turf communities were not very diverse at OAR 1 or the wrecks of MBAR. However the abundance of some species such as the strawberry anemone colonies on the vertical surfaces of both MBAR wrecks was very impressive (Photo 5).

In general, it appears that the holes and crevices created by piling quarry rock or concrete rubble support a much more diverse community than the broad flat surfaces of the dock floats of OAR 1 or the wrecks of MBAR. The rubble piles of MBAR, although concrete were more similar to the quarry rock experimental reefs than the wrecks.

The fishing reefs, OAR 1 and MBAR while not ideal reefs for production of a broad range of species, are functioning well for their original purpose, as they support large numbers of important sport fish species. They can and will be improved though, as information gathered from the earlier modules at these sites and new information gained from observation of the experimental reefs is used to increase their productive potential through future augmentations.

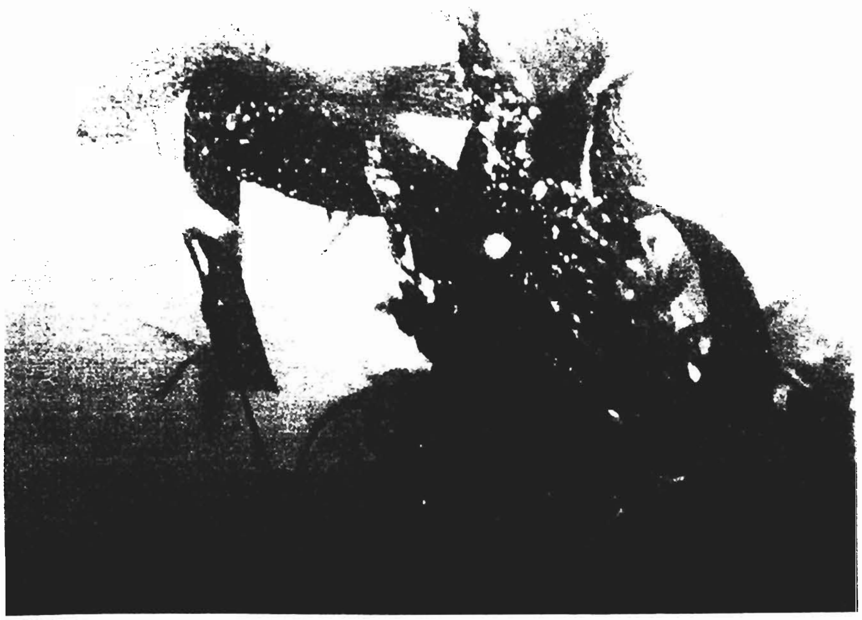

Photo 1.

The shallow and mid-depth modules of CAR are host to a thick growth of giant kelp, *Macrocytis pyrifera*. During the fall of 1992 these plants fell just short of forming a surface canopy.

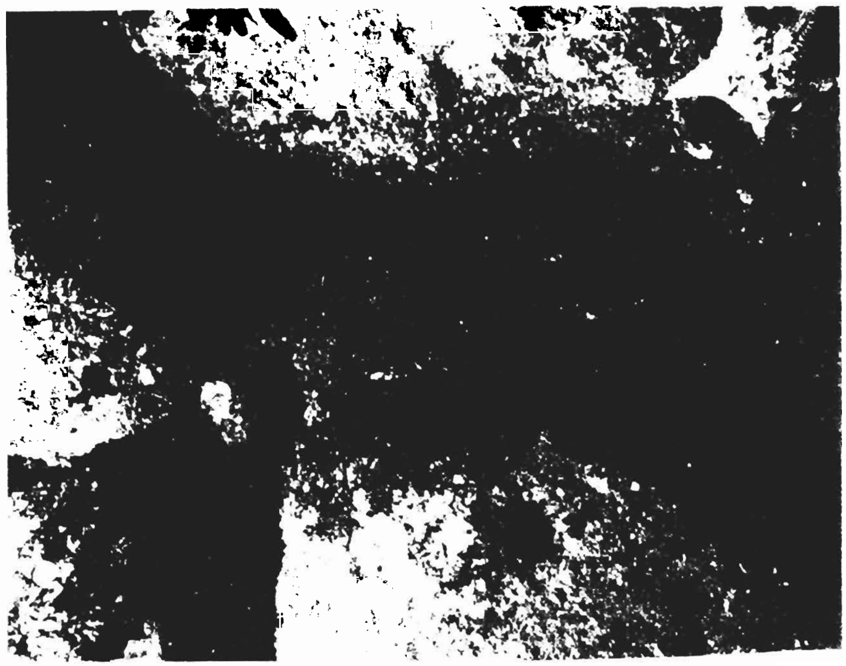

Photo 2.

The shallow modules of PBAR were host to large numbers of sub-legal spiny lobster, *Panulirus interruptus*.

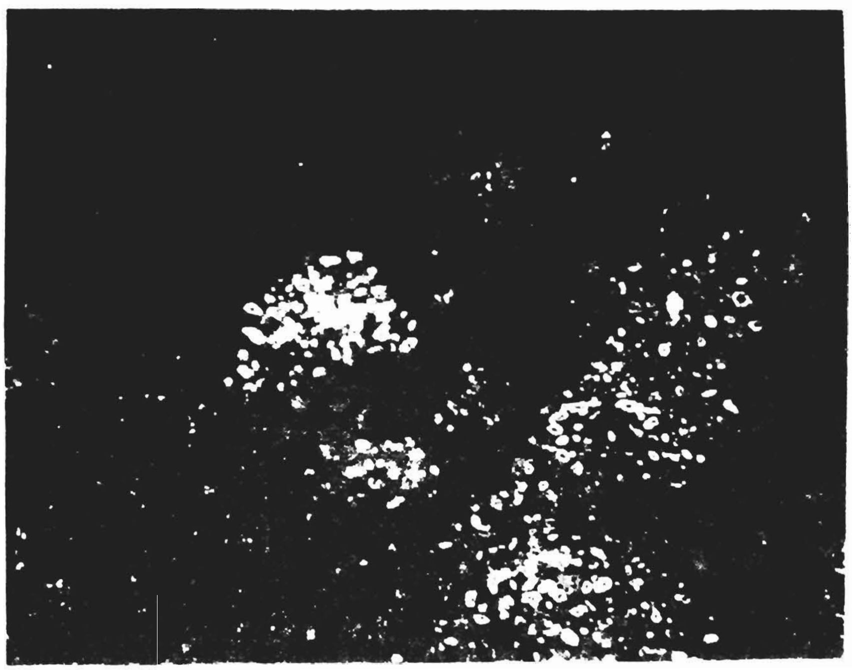

Photo 3.

The crests of all modules at CAR 2 and PBAR are covered by colonies of the strawberry anemone, *Corynactis californica*.

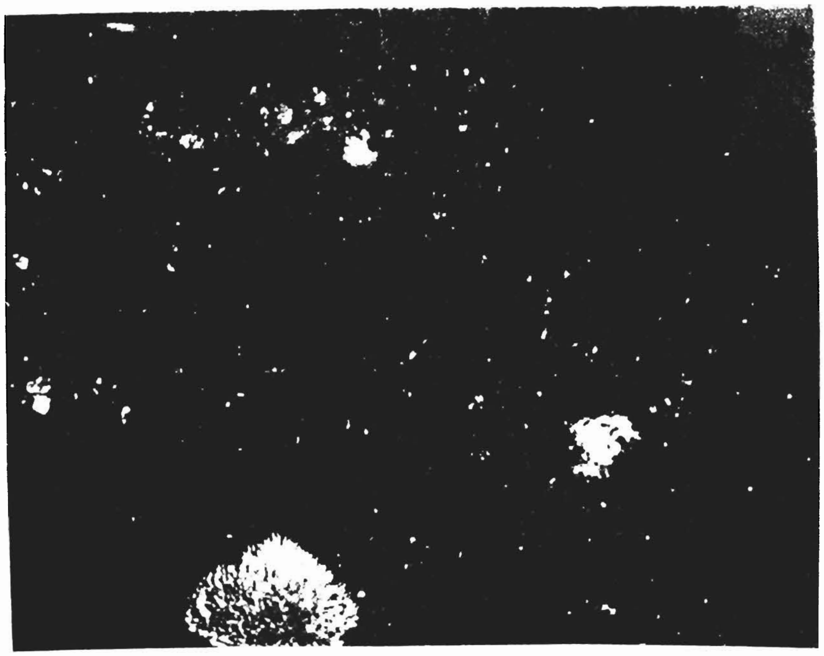

Photo 4.

The encrusting turf community on CAR is characterized by early colonizers such as barnacles, hydroids and ectoprocts. However on the deepest modules we found unusual colonies of the fragile tube worm, *Salmacina tribranchiata.*

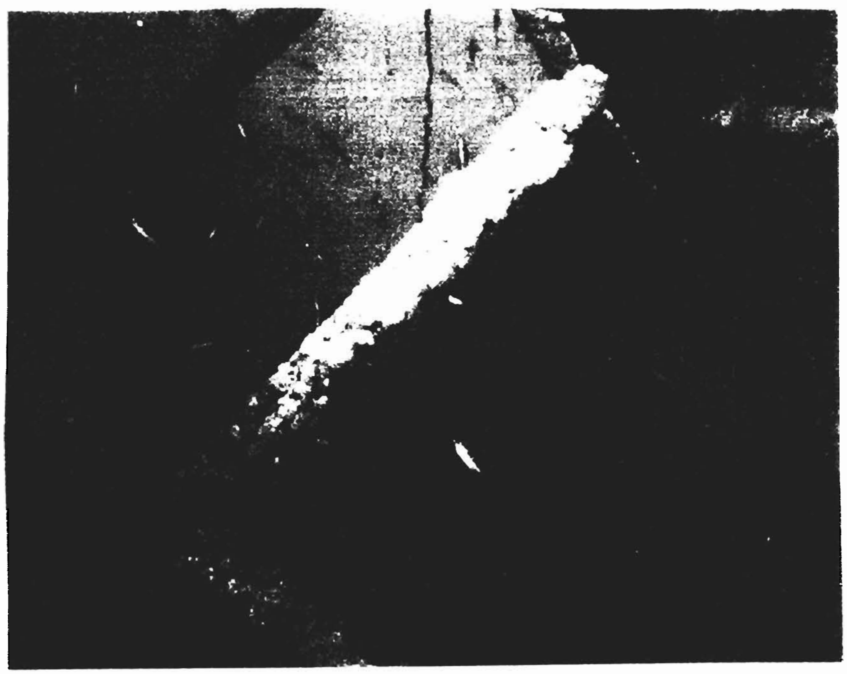

Photo 5.

While generally lacking diversity, the wrecks of MBAR show their maturity by the presence of large colonies of the strawberry anemone, *Corynactis californica* on vertually all the vertical surfaces.

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