

DISTRIBUTION OF BOCACCIO (*SEBASTES PAUCISPINIS*) AND COWCOD (*SEBASTES LEVIS*) AROUND OIL PLATFORMS AND NATURAL OUTCROPS OFF CALIFORNIA WITH IMPLICATIONS FOR LARVAL PRODUCTION

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ABSTRACT

There is increasing evidence that some California oil platforms form important habitats for a number of economically important fishes. We asked to what extent might platforms be important as producers of larvae of several overfished species (bocaccio, *Sebastes paucispinis* Ayres, 1854 and cowcod, *Sebastes levis* Eigenmann and Eigenmann, 1889) on a local or regional basis. We compared adult densities and potential larval production of these species at platforms and natural outcrops in California. Densities of mature bocaccio and cowcod were highly variable among survey sites, but were generally very low at both natural reefs and platforms. However, the mean densities for both species were higher around platforms than at natural reefs. Two of the three platforms (Gail and Hidalgo) that harbored mature bocaccio had larger mature individuals than did any natural reef. Platform Gail had by far the highest densities of both mature bocaccio and cowcod of any natural or human-made habitat and the potential larval production of both species at Platform Gail was much higher than at any other site surveyed. We estimated the removal of Platform Gail would be the equivalent of removing 12.57 ha of average-producing natural habitat in southern California for cowcod or 29.24 ha of average-producing natural habitat for bocaccio. These results may have implications for the platform decommissioning process.

There are 27 oil and gas platforms off the coast of southern and central California. Located in both state and federal waters, these structures are situated in bottom depths ranging from 11 to 363 m and can have footprints as large as 10,606 m² (Love et al., 2003). While all of these platforms are currently either pumping oil or gas, or are being used as transfer stations for these products, platforms have a finite economic life span. Once an industrial decision is made to cease oil and gas production, managers must decide what to do with the structure, a process known as decommissioning. Decommissioning is a complex process, involving state and federal agencies, corporate entities, and such stakeholders as recreational and commercial fishermen, and non-consumptive users (Schroeder and Love, 2004). Ultimately, a decommissioned platform could be left in place, removed to some point below the sea surface, toppled to lie on the sea floor, or totally removed (Schroeder and Love, 2004).

One issue in the decommissioning process is the role that platforms may play as fish habitat. There is increasing evidence that some California platforms form important habitats for many economically important fishes. This is particularly true of the rockfishes (genus *Sebastes*) that often comprise over 90% of all fishes observed around platforms in southern and central California waters (Love et al., 2003). Platform habitat may serve at least two functions for these fishes. First, the midwaters of many platforms serve as nursery habitat for a suite of rockfishes and other fish species, often harboring higher densities of these species than do nearby natural outcrops (Love et al., 1999; Carr et al., 2003; Love et al., 2003). Compared to most natural reefs, a platform's size, structural complexity, and high vertical profile probably

provide pelagic juvenile rockfishes and larvae of other species with a relatively strong stimulus to trigger settlement. In addition, most platforms have few large fishes in the midwaters and thus predation on young fishes is likely to be low (Schroeder et al., 2000; Love et al., 2003). Platform bottoms, where the jacket and conductor pipes meet the seafloor, may harbor high densities of subadult and adult fishes, again usually comprised primarily of rockfishes (Love et al., 1999; Carr et al., 2003; Love et al., 2003). The high densities of larger fishes at the platform bottoms are due to both acceptable habitat and because some platforms are rarely fished and thus act as de facto marine reserves (Schroeder and Love, 2002; Love et al., 2003).

Off southern California, fishing pressure by both recreational and commercial fishermen on natural outcrop species has been very heavy for many decades (Love et al., 1998, 2002). In particular, the adults of economically important species such as bocaccio (*Sebastes paucispinis* Ayres, 1854) and cowcod (*Sebastes levis* Eigenmann and Eigenmann, 1889) are now uncommon or even absent on many natural outcrops in southern California (Love et al., 1998b, 2003; Love and Yoklavich, unpubl. data).

Given the depleted state of many rockfish species on natural reefs (seven species have been declared overfished by NOAA Fisheries), and the relative abundance of some of these species on some platforms, we asked to what extent might platforms be important as producers of larvae on a local, or even regional, basis. That is, how important are adult populations of rockfishes on platforms? To help answer that question, we conducted a pilot study that focused on cowcod and bocaccio (Fig. 1), two species declared overfished by NOAA Fisheries and the two overfished species that are most abundant as adults around California platforms. We compared adult densities and potential larval export of these species at both offshore platforms and natural outcrops in central and southern California. A knowledge of the relative importance of these human-made structures as fish habitat could play a role in decommissioning decisions.

MATERIALS AND METHODS

FISH SURVEYS.—Between 1995 and 2002, we surveyed platforms sited over a wide range of bottom depths, ranging between 29 and 224 m, and sited from north of Point Arguello to off Long Beach, southern California. Most of our platform surveys were conducted at seven structures (Platforms Irene, Hidalgo, Harvest, Hermosa, Holly, Grace, and Gail) located in the Santa Barbara Channel and Santa Maria Basin. In addition, we surveyed over 80 deeper-water outcrops (many in the vicinity of platforms) in waters between 30 and 360 m deep. Most of these deeper-water natural sites were visited once, a few were surveyed during as many as 4 yrs and, one outcrop, North Reef near Platform Hidalgo, was sampled annually.

We surveyed fish assemblages using the DELTA submersible, a 4.6-m, two-person vessel, operated by Delta Oceanographics of Oxnard, California. Aboard the DELTA, we conducted belt transects about 2 m from the substrata, while the submersible maintained a speed of about 0.5 kts. At the platforms, transects were made around the bottom of the platform and around each set of crossbeams to a minimum depth of 20–30 m below the surface (e.g., mid-water habitat). The belt transect was also used to sample the shell mounds surrounding the platforms and natural rock outcrops. The shell mounds and outcrops were sampled in consistently the same fashion as the platform method described above.

Submersible surveys were conducted during daylight hours between 1 hr after sunrise and 2 hrs before sunset. During each transect, observations were taken from one viewing port on the starboard side of the submersible. An externally mounted hi-8 mm or digital video camera with associated lights filmed the same viewing fields as seen by the observers. The

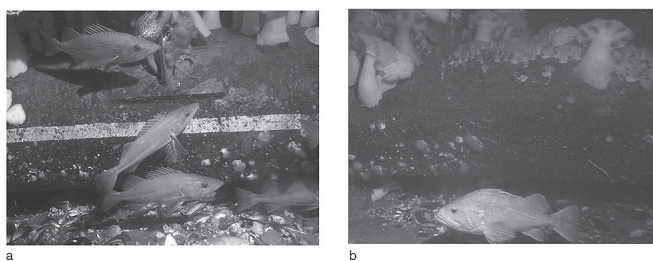


Figure 1. A) Adult bocaccio (*Sebastes paucispinis*) and B) cowcod (*Sebastes levis*) at the bottom of Platform Gail, eastern Santa Barbara Channel. Note the undercut area below the bottom-most cross beam, which provides shelter for both species.

observer identified, counted, and estimated the lengths of all fishes and verbally recorded those data on the video. All fishes within 2 m of the submarine were counted. All fish larger than the size of first maturity were observed within 2 m of the bottom (none were seen in midwater transects). Thus, densities were calculated as fish m^{-2} . Fish lengths were estimated using a pair of parallel lasers mounted on either side of the external video camera. The projected reference points were 20 cm apart and were visible both to the observer and the video camera. An environmental monitoring system aboard the submarine continuously recorded date and time, depth, and altitude of the vessel above the sea floor. The 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. Field observations were transcribed into a database. For each fish, we recorded the following information: 1) species (if known), 2) its estimated total length (TL), and 3) in the surveys over natural reefs, the habitat it occupied (e.g., rock, sand, mud, cobble, or boulder).

Many years of experience along the Pacific Coast have shown that if the Delta is moving at a constant and slow rate of speed, as in these surveys, there is very little obvious effect on demersal rockfishes (M. Love, V. O'Connell, Alaska Department of Fish and Game, and M. Yoklavich, NOAA Fisheries, pers. obs.). Certainly, we noticed virtually no movement at all from most of the fishes in this study as the research submersible passed by.

DATA ANALYSES.—While our surveys estimated size for most observed fish, we were not able to estimate sex ratios. Cowcod are not sexually dimorphic and it seemed reasonable to assume an equal female to male ratio. Bocaccio are sexually dimorphic and sex ratios of commercial catches are not 1:1 and are related to size. We obtained data to estimate length-specific sex ratios for bocaccio from Mark Wilkins (NOAA Fisheries, AFSC, Seattle) in the form of length compositions by sex from the triennial bottom trawl survey conducted by the AFSC. The trawl survey uses finer meshed nets than commercial operations and all captured fish are sampled for length compositions. Commercial operations also discard some fish due to market demand or regulations.

Our submersible survey estimated fish size to the nearest 5 cm. Observers were not able to estimate size for a small proportion of fish (0.006 for bocaccio and 0.048 for cowcod). These fish were assumed to be smaller than the size-at-maturity and not included in the estimates. The trawl survey measured size to the nearest 2 cm. We converted the trawl survey length compositions to 5 cm intervals. NOAA Fisheries estimated the total abundance of bocaccio off southern and central California in numbers of fish by size and sex for each year of the survey. The estimates of total numbers of fish varied considerably among years. Since growth is sexually dimorphic for bocaccio and there is considerable variation in year-class strength, we decided it would be best to calculate the ratios of females to total fish at each year and then average the ratios, in order to give equal weight to each year's estimates. The results indicated that ratios varied without trend through 60 cm and then rapidly increased to one (all females) at 70 cm. We concluded that because females grow faster and to larger sizes than males, it

would be reasonable to apply the average female to total fish ratio, 0.44, between 25 and 60 cm, the observed value, 0.82, for 65 cm, and 1.00 for larger fish (Table 1).

We used estimates of maturity schedules for bocaccio and cowcod obtained from the study area (M. Love, unpubl. data). We believe it was more appropriate to use these data than other published results from fish that were collected from more northern waters. These data are summarized in Love et al. (1990), but the published results were not in sufficient detail for the purpose of the present study. We converted to maturity data in 1–5 cm intervals. We estimated maturity schedules for combined sexes by sum for each sex of proportion mature weighted by proportion for that sex (Table 2).

We used the size fecundity estimates of Love et al. (1990) to estimate number of eggs of mature females, as these were derived from fishes collected from the study area. The bocaccio estimates are similar to those estimated by Phillips (1964) from fish that were collected from more northern waters.

For bocaccio, $Fecundity = 1.15 (L^{3.2696})$, and for cowcod, $Fecundity = 1.702(L^{3.1542})$, where L is TL in cm.

To calculate the number of larvae that could be produced by resident bocaccio and cowcod at a given area, we first segregated all observed fish during a survey into size classes. For bocaccio, we estimated the number of females in each size class using the sex ratio data in Table 1 (cowcod are assumed to have a 1:1 ratio). Next, for each species in each size class, we used maturity schedules (Table 2) to estimate the proportion of mature females in each class. Length-fecundity equations were then used to determine the number of larvae each female could produce. Larval production is therefore linked to fish density and rates are scaled appropriately across sites.

We estimated area surveyed by multiplying transect distance by two, because survey width was 2 m, and then calculated densities per area for each species and size. Transect lengths were estimated using a pair of parallel lasers mounted on either side of the external video camera. The projected reference points were 20 cm apart and were visible both to the observer and the video camera. Transect lengths were computed by counting the number of 20 cm laser segments in 15 s subsamples (1 min^{-1}) throughout the transect, calculating speed based on those counts and averaging them over the whole transect, and multiplying that average speed by the transect duration. The 15 s subsamples were made during the first 15 s of each minute of the transect in which the laser points were visible. We first summed all data for a dive. Sometimes there was more than one dive for a station in a year. In this case, we averaged the results of the dives for estimates of the station-year. In many cases a station was surveyed in more than 1 yr and we averaged the results over years for each of those stations. We also grouped stations that were adjacent to each other.

Table 1. Estimated ratio of female to total bocaccio, in 5 cm length intervals, in southern California.

Size cm	Female: Total	
	Observed	Estimated
25	0.40	0.44
30	0.45	0.44
35	0.48	0.44
40	0.45	0.44
45	0.55	0.44
50	0.34	0.44
55	0.40	0.44
60	0.48	0.44
65	0.82	0.82
70	1.00	1.00
75	1.00	1.00

Table 2. Maturity schedules, in 5 cm length intervals, estimated for bocaccio and cowcod in southern California.

Size (cm)	Bocaccio			Cowcod		
	Female	Male	Combined	Female	Male	Combined
30	0.00	0.00	0.00	0.00	0.00	0.00
35	0.22	0.33	0.29	0.00	0.07	0.03
40	0.78	0.92	0.86	0.02	0.35	0.19
45	0.99	1.00	1.00	0.64	0.70	0.67
50	1.00	1.00	1.00	0.95	1.00	0.97
55	1.00	1.00	1.00	1.00	1.00	1.00

Estimates of footprint areas for the platforms come from Love et al. (2003). We estimated area of natural reefs needed to produce the same amount of larvae as an average platform by multiplying the average area of a platform by the ratio of average platform production to average reef production.

RESULTS

In comparing larval production, fish densities, and ultimately habitat equivalence between platforms and natural outcrops, we restricted our analyses to habitats and depths most likely to harbor adult cowcod and bocaccio (based on data from Yoklavich et al., 2000 and Love et al., 2002). A site was considered to be appropriate habitat and retained for analyses if any starting depth was ≥ 60 m for bocaccio or ≥ 80 m for cowcod and if any patch bottom in that site was classified as "rocky high relief," "rocky low relief," or "boulders." Based on these parameters, 63 reefs and seven platforms (Gail, Grace, Harvest, Hermosa, Hidalgo, Holly, and Irene) were used in the bocaccio dataset and 52 reefs and five platforms (Gail, Grace, Harvest, Hermosa, and Hidalgo) in the cowcod dataset.

Overall, we observed 1054 bocaccio of all sizes at platforms and 976 at reefs, and 125 cowcod at platforms and 134 at reefs. Among bocaccio estimated to be mature, we observed 313 individuals around platforms and 313 at reefs, and 38 mature cowcod at platforms and 61 at reefs. Adult fishes were patchily distributed among both platforms and natural reefs. Fifty-seven percent of surveyed natural reefs (36 out of 63) with appropriate habitat (as defined above) had mature bocaccio on them and 42% (23 out of 54) of surveyed natural reefs with appropriate habitat had adult cowcod on them. Platforms had nearly identical ratios as natural reefs, as 57% (4 out of 7) had adult bocaccio and 40% (2 out of 5) had adult cowcod.

Densities of mature bocaccio and cowcod were highly variable among survey sites, but were generally very low at both natural reefs and platform habitats (Figs. 2, 3). The mean density on natural reefs for bocaccio and cowcod was 0.15 per 100 m² (SE 0.03) and 0.04 per 100 m² (SE 0.01) respectively. Higher densities of mature fishes on natural reefs tended to occur in more remote areas (Figs. 2, 3). The mean density around platforms for bocaccio and cowcod was higher, 1.25 per 100 m² (SE 1.16) and 0.21 per 100 m² (SE 0.19), respectively. While densities were much lower on reefs than on platforms at most sizes, relative numbers of medium-size fish tended to be higher on reefs than on platforms (Fig. 4).

For both species, the larger average adult size at platform habitat proportionally increased the potential larval production at platforms compared to natural reefs,

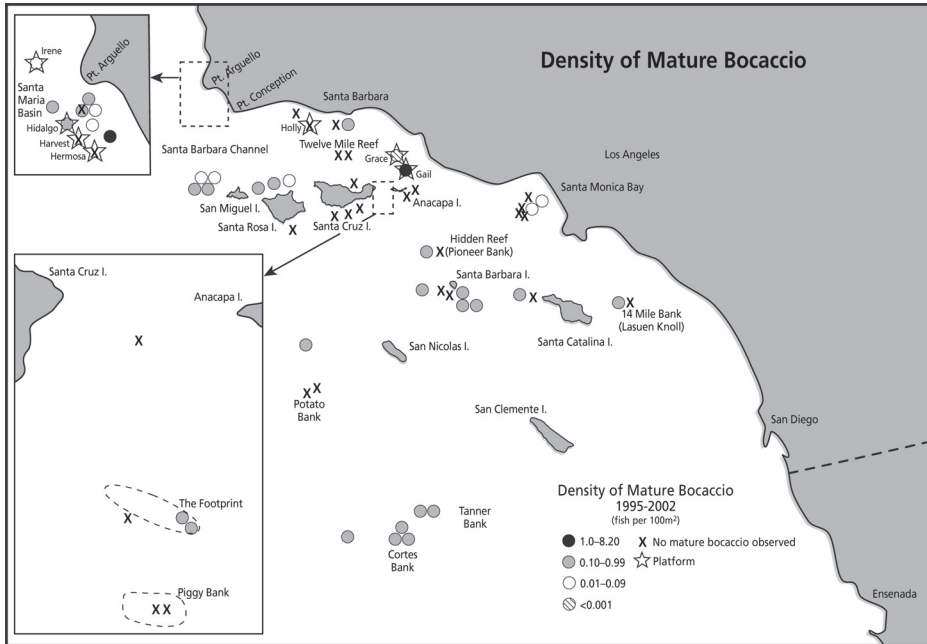


Figure 2. Densities of mature bocaccio at seven platforms and 63 natural reefs in the southern California Bight and off central California, 1995–2002. Included are sites that were classified as “rocky high relief,” “rocky low relief,” or “boulders,” and in depths of ≥ 60 m.

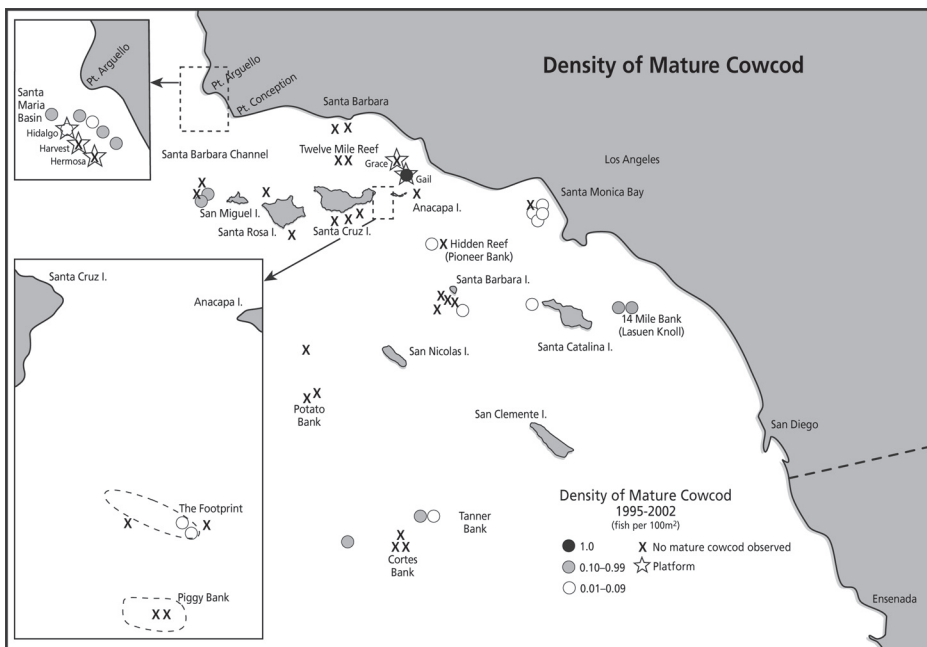


Figure 3. Densities of mature cowcod at five platforms and 52 natural reefs in the southern California Bight and off central California, 1995–2002. Included are sites that were classified as “rocky high relief,” “rocky low relief,” or “boulders,” and in depths of ≥ 80 m.

especially for bocaccio (Fig. 5). Mean (± 1 SE) larval production (no. eggs m^{-2}) at platform sites was 2883 (2597) for bocaccio and 743 (676) for cowcod, while mean production for natural outcrop sites was much less, 254 (58) for bocaccio and 132 (34) for cowcod.

Of particular interest, Platform Gail had by far the highest densities of mature bocaccio (8.17 per 100 m^2 compared to 1.46 for the highest density on a natural reef) and cowcod (1.00 per 100 m^2 compared to a maximum of 0.23 for natural reefs) of any natural or human-made habitat in this study (Figs. 2, 3). Platform Gail also had the highest potential larval production values, topping out at 18,397 eggs m^{-2} for bocaccio and 3440 eggs m^{-2} for cowcod (Fig. 5). This means that if Platform Gail (whose footprint is 0.5337 ha) were removed during decommissioning, it would be the equivalent of removing 12.57 ha of average-producing natural habitat in southern California for cowcod, or equivalent to removing 29.24 ha of average-producing natural habitat in southern California for bocaccio.

DISCUSSION

Our study provides the first published evidence, based on direct underwater observations, for intense depletion of both adult bocaccio and cowcod on many natural structures in southern California (previous evidence came from fishery-dependent data; e.g., Love et al., 1998 and Butler et al., 2003; and larval or juvenile surveys, e.g., Love et al., 1998b; Moser et al., 2000; Butler et al., 2003). It is likely that these low densities were due both to overfishing and to poor larval and pelagic juvenile survivorship (Love et al., 2002, 2003). With the exception of Platforms Gail and Hidalgo, densities were also low for adults of both species at platforms.

Platform Gail harbored unusually high densities of adult bocaccio and cowcod. The high densities of both species at Platform Gail are likely due to its status as a *de facto* marine protected area (Schroeder and Love, 2002), a bottom depth that is commonly occupied by adult bocaccio and cowcod, and the presence of a bottom crossbeam that provides a sheltering area for both species (Fig. 1). It is probable that the adult bocaccio and cowcod living at Platform Gail were derived from young-of-the-year (YOY) that had recruited from the plankton to that platform's jacket, shell mound, or pipeline. During nine years of surveys, we have on several occasions observed relatively high densities of YOY bocaccio recruiting to the midwaters of Platform Gail and YOY cowcod to its shell mound and pipeline (Love et al., 2003; Love and York, 2005). In addition, our research indicates that both species not only have recruited as YOYs to the jacket or surrounding structures, these year classes also have remained at the platform over succeeding years (Love et al., 2003; Love, unpubl. data).

The densities of bocaccio and cowcod we observed at Platform Gail were not only far higher than those of any other platform or natural reef in southern California, they were higher than four of five deeper-water sites surveyed in Soquel Canyon in central California and were surpassed only by an outcrop that likely has never been fished (Yoklavich et al., 2000). This natural refuge provides a comparison from deeper waters off central California, as most of the abundant species at the Soquel Submarine Canyon site (e.g., bocaccio, cowcod, lingcod, greenspotted, and greenblotched rockfishes) are also those most characteristic of the jacket bottom at Platform Gail (Love et al., 2003). Yoklavich et al. (2000) make the point that the Soquel Canyon site may be an important site for larval production, noting that "These areas appear to

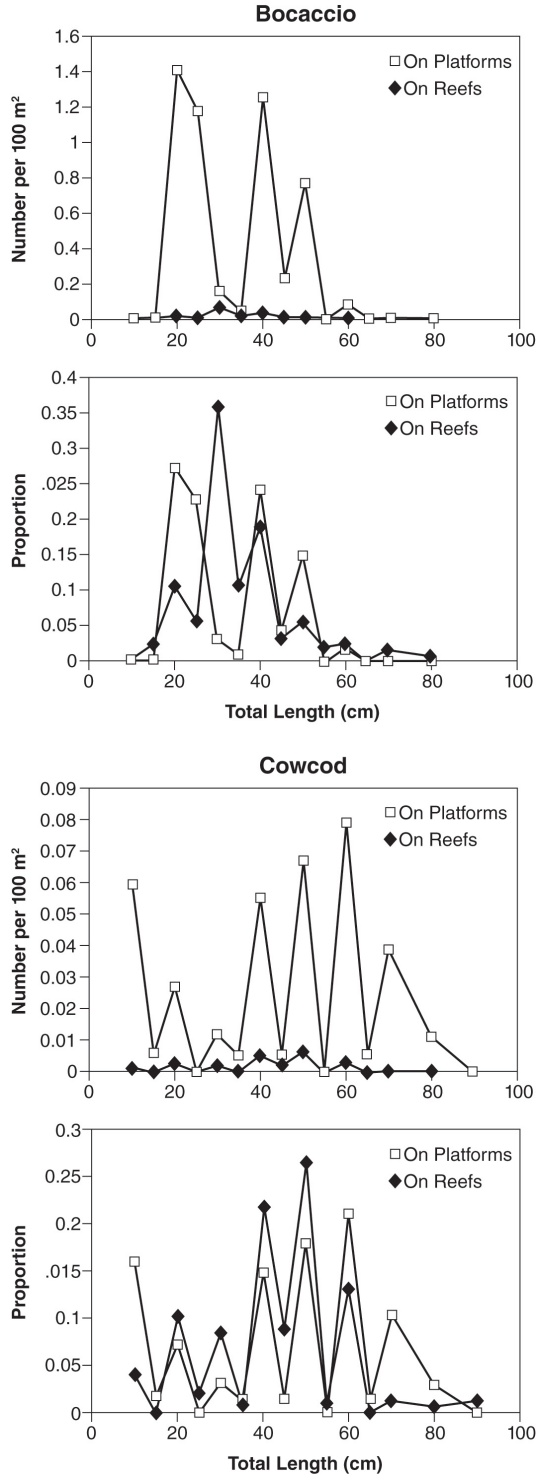


Figure 4. Average densities by size of bocaccio and cowcod observed at natural reefs and platforms. Data from all dives in suitable habitat and all fish sizes are included.

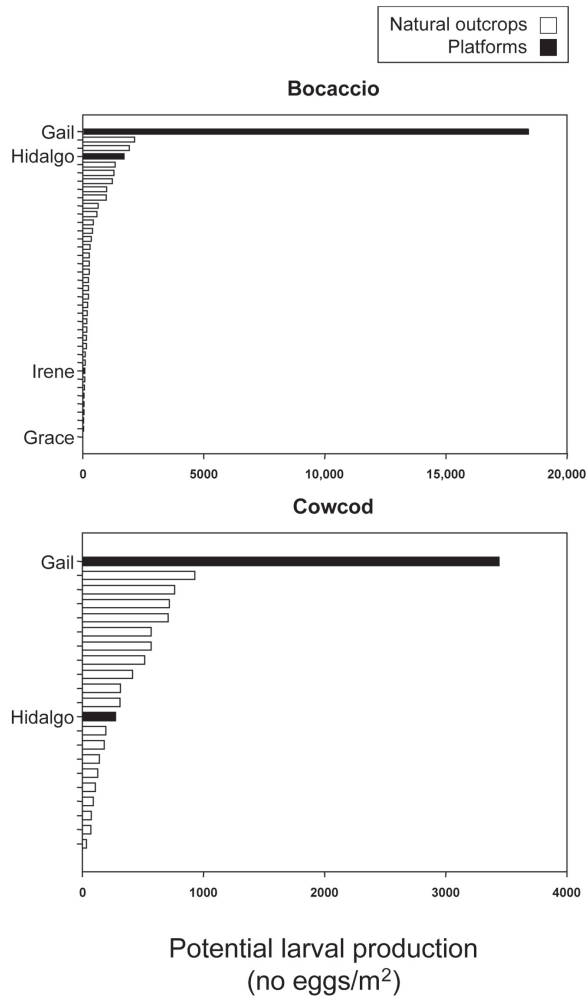


Figure 5. Comparison of potential larval production (no. eggs m⁻²) of sites that had at least one mature bocaccio (40 natural reefs and four platforms) or one mature cowcod (25 natural reefs and two platforms). Bars representing platforms are darkened. Platforms in the appropriate depth range that did not harbor mature cowcod included Grace, Harvest, Hermosa, and for bocaccio, Harvest, Hermosa, and Holly.

function as a natural harvest refugium, potentially contributing new recruits to adjacent fished areas” through larval export. The high densities and relatively large size of fishes at Platform Gail translate into substantially higher potential larval export per unit area for that platform than for any other site surveyed in our study.

On a regional basis, how important is larval bocaccio and cowcod production at Platform Gail? First, from our research submersible surveys it is clear that there is little larval production from bocaccio and cowcod that live on natural outcrops in the Santa Barbara Channel. With the exception of the carbonate feature Twelve Mile Reef (Fig. 2), located in the center of the Santa Barbara Channel, much of the sea floor in the channel (at depths frequented by adult bocaccio and cowcod) is composed of soft substrata (G. Cochrane, U.S. Geological Survey, pers. comm.). The Twelve Mile

Reef was at one time the major Santa Barbara Channel fishing ground for a number of rockfish species, including both cowcod and bocaccio (M. Kronman, Santa Barbara Harbor Department, pers. comm.; M. Love, unpubl. data). However, during our surveys we observed no adult bocaccio and cowcod on that outcrop. Other, and smaller, Santa Barbara Channel features (Fig. 2) also harbored few or no adults of these species.

Rockfish larvae may be partially retained in the east Santa Barbara Channel, where Platform Gail is sited, through oceanographic fronts and eddies (Nishimoto, 2000). Under certain conditions, larvae generated within the Santa Barbara Channel may also be entrained in seasonal gyres located in the western Channel (Nishimoto and Washburn, 2002). Thus, local sources of larvae may be critical to the maintenance of Santa Barbara Channel rockfish populations and Platform Gail, apparently one of the major producers of bocaccio and cowcod larvae in the Channel, may be quite important. It is interesting to note that some of the highest densities of YOY bocaccio we have observed anywhere in our studies were found at platforms Gilda and Grace, which are located within a few kilometers of Platform Gail (M. Love, unpubl. data). Thus, there is a possibility that these young fishes were generated as larvae at the latter structure.

While platform fish assemblages vary with platform bottom depth, it is clear that many of the platforms off southern California, regardless of bottom depth, act as de facto marine reserves. At these platforms, fish species in addition to bocaccio and cowcod have also responded to protection from fishing as densities of other economically important species (e.g., brown, *Sebastes auriculatus* Girard, 1854, copper, *Sebastes caurinus* Richardson, 1844, flag, *Sebastes rubrivinctus* (Jordan and Gilbert, 1880), greenblotched, *Sebastes rosenblatti* Chen, 1971, and greenspotted, *Sebastes chlorostictus* (Jordan and Gilbert, 1880), rockfishes, and lingcod, *Ophiodon elongatus* Girard, 1854) are higher at platforms than at most or all southern California natural reefs (Schroeder and Love, 2002; Love et al., 2003). It is likely that larval production of these species, per unit area, will also be higher at platforms than at most natural habitats. Thus, the potential importance of platforms as marine refugia may be large given the generally very low densities of adults of a number of rockfish species on natural reefs in southern California. If future platform decommissioning involves retaining some of the platform jacket in place, it is important to note that the high fish densities we observed would only be maintained if the platforms remained protected from fishing.

Clearly, southern and central California platforms vary widely in size, bottom depth, and fish assemblages. For instance, of the platforms we surveyed, Platform Gail, and to a lesser extent, Hidalgo, were unique in having high densities of mature bocaccio and cowcod. Given these variables, it would be premature to judge the importance of all of these structures as fish habitat. In addition, all of our surveys were conducted in the fall and we do not know whether adult cowcod and bocaccio remain at any of these structures throughout the year, although the interannual persistence of high densities of large bocaccio and cowcod at Platform Gail lends credence to this hypothesis. However, it is clear from our analysis that platforms can be important habitat for adult fishes, particularly of species that have been heavily exploited. Given the high densities of adults of many species of economically important rockfishes and lingcod around platforms and the low densities of these same species on many or most natural reefs in southern California, it is quite possible that some platforms are

of regional significance as sources of larval production and export for some species. The extent of this significance should play an important role in determining the preferred option of future decommissioning activities (removal or leave-in-place) once oil and gas production ceases.

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