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research paper

An analysis of the fish assemblages around 23 oil and gas platforms off California with comparisons with natural habitats

[1] *Marine Science Institute, University of California, Santa Barbara, California 93106.*

[2] *Department of Biological Sciences, California State Polytechnic University, Pomona, California 91786.*

[3] *Vantuna Research Group, Occidental College, Los Angeles, California 90041.*

* *Corresponding author email: <love@lifesci.ucsb.edu>.*

Fishes and invertebrates of oil and gas platforms off California

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Milton S Love [1*]
Jeremy T Claisse [2,3]
Alexa Roeper [2]

ABSTRACT.—Between 1995 and 2013, we surveyed fishes living around 23 California offshore oil and gas platforms (midwaters, bases, and shell mounds) and 70 natural habitats. These platforms were distributed between about Point Arguello, central California, and Huntington Beach, southern California, had seafloor depths between 49 and 363 m, and were surveyed between one and 16 times. A total of 1,526,437 fishes were observed. Fish densities were highest around platform bases, followed by platform midwaters, shell mounds, and natural habitats. Of all fishes observed, 90.4% were in the genus *Sebastes*. Water depth was the strongest driver of the fish species assemblages, although habitat type and geographic location were also important. Most of the fishes living around platforms and natural habitats were relatively small, primarily ≤20 cm in length. Many of these individuals were the juveniles of larger taxa or the juveniles and adults of dwarf species. Larger fishes were less common and these were most often found around platform bases and on natural habitats. Most young-of-the-year (YOY) fishes occurred at water depths of ≤150 m at all four habitats. At platforms, YOY densities were highest in platform midwaters and bases. On average, densities of these young fishes were somewhat higher compared to natural habitats and it is likely that many, although not all, California platforms play a significant role as nursery grounds for a variety of fishes, particularly for a number of *Sebastes* species.

Petroleum and natural gas production began in the 19th century in California. While production first took place on land, by the early 20th century, drilling had expanded offshore of southern California with dozens of well-bearing piers lining mainland shores. The first offshore oil platforms (Hazel and Hilda) were constructed in the nearshore off Summerland, Santa Barbara Channel (at a seafloor depth of about 30 m) in 1958 and 1960, respectively (Carlisle et al. 1964). The number of platforms off California peaked in the 1980s with 30 platforms operating in southern and central California (Love et al. 2000). Four platforms were removed in 1996 and there are currently 26 platforms off California (Fig. 1). The remaining platforms off California were installed between 1968 and 1989, lie in waters with seafloor depths

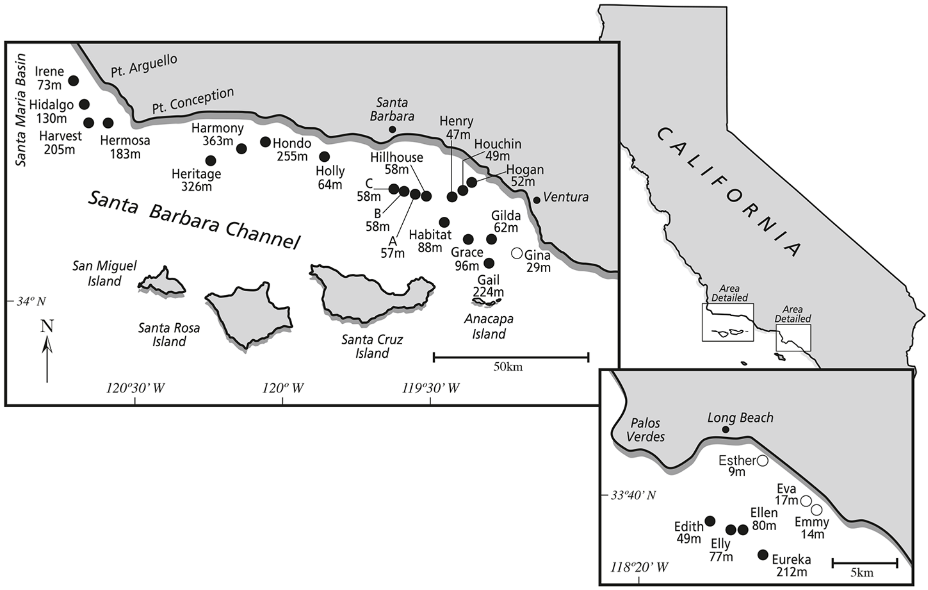

Figure 1. Geographic locations and seafloor depths of all platforms off California. Platforms marked with close circles were surveyed for this study. The location, year of installation, and number of years each platform was surveyed are found in Table 1.

between 14 and 363 m, and are situated from just north of Point Arguello, central California, to off Huntington Beach, southern California, with the majority of sites within the Santa Barbara Channel (Fig. 1, Online Fig. 1, Table 1).

There is some evidence that a number of California platforms are nearing the end of their economic lives. Once an industrial decision is made to cease oil and gas production, managers go through a decommissioning process to decide what to do with that platform. In California, the decommissioning process will be at least partially governed by the California Marine Resources Legacy Act (CMRLA; *see* CMRLA 2010). The CMRLA lists a number of specific factors that will be considered when making a determination regarding a platform's ultimate disposition. One of these is that a structure's net environmental benefit (NEB) be assessed. While NEB remains undefined in this document, the act goes on to state that "The contribution of the proposed structure to protection and productivity of fish and other marine life" must be determined.

The first studies surveying the organisms living in the vicinity of California platforms were conducted via scuba around Hilda and Hazel from 1958 to 1960, and again in 1975 (Carlisle et al. 1964, Bascom et al. 1976). This research demonstrated that platform jackets—the cross beams and vertical pilings—were covered with a variety of sessile and motile invertebrates (e.g., mussels, sea anemones, barnacles, and sea stars) and documented that the fish assemblages were dominated by rockfishes (genus *Sebastes*, family Scorpaenidae), sea perches (family Embiotocidae), and basses (family Serranidae). It was estimated that between 6000 and 30,000 fishes (of at least 40 species) inhabited each platform. In particular, these early surveys noted high densities of young-of-the-year (YOY) *Sebastes* spp. that had apparently recruited from the plankton in the platform midwaters. In addition, by the time of the 1975

Table 1. Number of years that transects were conducted by habitat type at each of 23 oil and gas platforms off southern and central California, including location, bottom depth, and year of installation of each platform. Three of the shallowest-water platforms, Emmy, Eva, and Gina, were not surveyed. Platforms are listed in alphabetical order. Note that in some years, at some platforms, some of the habitats were not surveyed. The asterisk (*) indicates a partial transect.

Platform	Location	Bottom depth (m)	Midwater	Base	Shell mound	Year installed
A	34°19′N, 119°36′W	57	9	2	2	1968
B	34°19′N, 119°37′W	58	7	2	2	1968
C	34°19′N, 119°37′W	58	7	2	3	1977
Edith	33°35′N, 118°08′W	49	7	8	8	1983
Ellen	33°34′N, 118°07′W	80	7	7	7	1980
Elly	33°35′N, 118°07′W	77	7	7	7	1980
Eureka	33°33′N, 118°06′W	212	7	3	3	1984
Gail	34°07′N, 119°24′W	224	16	15	14	1987
Gilda	34°10′N, 119°25′W	62	7	5	5	1981
Grace	34°10′N, 119°28′W	97	15	13	14	1979
Habitat	34°17′N, 119°35′W	88	7	2	2	1981
Harmony	34°22′N, 120°10′W	363	1	1	1	1989
Harvest	34°28′N, 120°40′W	202	6	5	5	1985
Henry	34°19′N, 119°33′W	52	4	2	2	1979
Heritage	34°21′N, 120°16′W	326	1*	1	0	1989
Hermosa	34°27′N, 120°38′W	179	6	7	6	1985
Hidalgo	34°29′N, 120°42′W	129	10	10	9	1986
Hillhouse	34°19′N, 119°36′W	58	7	2	2	1969
Hogan	34°20′N, 119°32′W	47	4	2	2	1967
Holly	34°22′N, 119°52′W	60	13	11	6	1966
Hondo	34°23′N, 120°07′W	255	3	3	2	1976
Houchin	34°20′N, 119°33′W	49	3	2	2	1968
Irene	34°36′N, 120°43′W	72	11	11	10	1985

surveys an extensive shell mound, composed of the invertebrates formerly living on the jackets (e.g., mussels, sea anemones, crabs, and sea stars) and dislodged through platform cleaning or water turbulence, had developed around both platforms.

Beginning in the 1990s, a series of studies focused on the role of California platforms as fish habitats. Among the preliminary results were that, regarding fishes, most California platforms were composed of three habitats: midwaters, bases, and shell mounds. Fish assemblages observed associated with the platform structure in the midwaters (from the surface down to 2 m above the seafloor) were significantly different from those at the other two habitats. Midwater assemblages on many platforms were characterized by YOY and older juvenile reef-oriented fishes, primarily *Sebastes* spp. and *Chromis punctipinnis* (for all species authorities, *see* Online Table 1), but also included juveniles and adults of a suite of other nearshore reef fishes [e.g., *Semicossyphus pulcher*, *Hypsypops rubicunda*, and *Girella nigricans* (Love et al. 1994, 2000, Martin and Lowe 2010)]. The density of YOY fishes varied interannually (likely reflecting oceanographic conditions); however, in some years, some platforms harbored hundreds of thousands of young fishes and densities of these fishes were sometimes large enough to contribute to the rebuilding of overfished stocks (Love et al. 2006).

By comparison, platform base (bottom 2 m of platform structure at the seafloor) and shell mound assemblages were most similar to each other. YOY and juvenile *Sebastes* spp. (often of different species than found in midwaters) tended to be abundant at shallow platforms bases and shell mounds, while these habitats in deeper water tended to be dominated by a suite of subadult and adult *Sebastes* spp., *Ophiodon elongatus*, *Oxylebius pictus*, and other reef-oriented species (Love et al. 1999, 2000). In southern California, the densities of the adults of some economically important species (e.g., *Sebastes paucispinis* and *Sebastes levis*) were significantly higher at some platforms than at any natural reef surveyed and thus estimated larval production of these species was also higher at these platforms than at natural habitats (Love et al. 2005). Species living around shallow platforms may exhibit less site fidelity than those living around deeper ones (Lowe et al. 2009) and at least some benthic fishes that were displaced from platforms homed back to their original habitats (Anthony et al. 2012). Claisse et al. (2014) estimated that (among other factors) the high densities of quickly growing juvenile *Sebastes* spp. led California platforms to have some of the highest levels of secondary fish production of any aquatic system.

However, the broad-scale platform surveys cited above (i.e., Love et al. 1999, 2000) were based on data that were limited in both time and geographic range, and following their publication we continued our survey work for >10 yrs. In addition, no comparisons between California platform and natural reef fish assemblages have been published. Thus, for this study, and based on preliminary studies, we formulated the following hypotheses: (1) water depth is a major factor determining species composition; (2) there are different fish assemblages associated with the platform midwater habitat and the platform habitats at the sea floor (base and shell mound); (3) the fish assemblages at platforms vary geographically; and (4) in terms of fish densities, platform fish assemblages resemble, but are distinct from, those on natural reefs.

Methods

We surveyed fishes around platforms and natural habitats (natural sites were comprised of both high and low rocky habitats) between September and November from 1995 to 2013. From 1995 to 2009, we used the Delta research submersible, a 4.6-m long, two-person vessel, operated by Delta Oceanographics of Oxnard, California. In 2010 and 2011, we used the Dual Deepworker, a 7.2-m long, two-person vessel, operated by Nuytco Research, North Vancouver, British Columbia. During each transect, the researcher made observations from a viewing port on the starboard side of the submersible. An externally mounted video camera (Delta: Sony Hi8; Dual Deepworker: Cannon HF-S1 Vixia, HDV) with associated lights filmed the same viewing fields as seen by the observer. As each fish passed before the porthole, the observer identified, counted, and estimated its length to the nearest 5 cm of all fishes and verbally recorded those data. If the submersible passed through aggregations of fishes, the observer would make their best effort to identify each individual and its length, but this would be later verified and refined by a review of the footage in the laboratory.

Over these years, poor water visibility around eight platforms (A, B, C, Hillhouse, Henry, Houchin, Hogan, and Habitat) prevented surveys around these structures' bases and shell mounds. In response, in 2012 and 2013, we conducted fish surveys at these platforms using a remotely operated vehicle (ROV) operated by Haaland

Diving, of Goleta, California. The ROV mimicked the movements of the manned submersible, maintaining a similar height above the bottom and distance from the platform. This vehicle used a video camera that was pointed in the same direction, laterally, as the camera on the submersibles and these images were transmitted to an external hard drive aboard the research vessel. Footage on this hard drive was later analyzed in the laboratory.

Surveys were conducted during daylight, between 1 hr after sunrise and 1 hr before sunset. At each platform, we conducted surveys (1) on the shell mound, (2) platform base, and (3) platform midwaters. We conducted belt transects (2 × 2 × 2 m) at a distance of approximately 2 m from the platform, while the vehicles maintained a speed of about 0.5 knots. During dives on both shell mounds and natural sites, we attempted to maintain a constant distance within 1 m off the seafloor. For the natural sites, we have included in the analysis a range of hard habitats, including rock ridges, boulders, and cobbles (Love et al. 2009); transects composed primarily of sand or mud were excluded from the analyses. Thus, we surveyed four broad habitat categories: (1) platform midwaters, (2) platform bases, (3) platform shell mounds, and (4) natural habitats.

Fish lengths were estimated using a pair of parallel lasers mounted on either side of the external video camera (Yoklavich et al. 2000). The projected points were 20 cm apart and were projected onto the sea floor or platform jacket (not onto fishes) and were visible both to the observer and in the video recorded image. We made measurements by comparing the size of a fish to the known spacing of the two red laser spots when the object was perpendicular to the camera and lasers. Thus, the laser points did not have to pass along a fish for length estimates to be made. This system has been used in many other Pacific Coast submersible fish studies (e.g., Love et al. 2000, Love and York 2006, Yoklavich et al. 2007, Laidig and Yoklavich 2016). Many years of experience along the Pacific Coast indicated that if either the Delta or Dual Deepworker is moving at a constant and slow rate of speed, as in these surveys, there is very little obvious effect on most fishes, particularly rockfishes (Laidig and Yoklavich 2016). However, we do note that a study off California (Laidig and Yoklavich 2016) demonstrated that ROV surveys of reef fishes produced densities that were less than those observed with a manned submersible. Therefore, it is likely that densities at the bases and shell mounds of those platforms surveyed with the ROV are likely conservative compared with data from the manned submersibles. Unless hidden in complex substrate, fishes as small as about 5 cm in length were readily visible within 2 m of the vehicle.

Fish Data Processing.—With the exception of listings Appendix 1, we excluded transient and highly mobile species from the data set, such as jack mackerel, *Trachurus symmetricus,* and Pacific sardine, *Sardinops sagax*. YOY were defined for each taxon as individuals with a total length less than the average length at 1 yr, as predicted by the von Bertalanffy growth function using taxon-specific parameters following Claisse et al. (2014).

For the community structure analyses [e.g., nonmetric multidimensional scaling (nMDS) ordination, cluster analyses], because not all taxa could be identified to species, related taxa needed to be combined or, in some instances, removed to ensure that individuals of the same species would not be present in the data set under two or more taxonomic levels. In cases where a higher-level taxa designation was more abundant in the data set (e.g., more individuals identified to a genus than a species), densities were summed to the higher taxonomic level. If lower level taxa designations were more abundant in the data set, the individuals identified at the higher taxonomic level were excluded from the data set. Thus, for example, if more fishes were identified as within the family Agonidae than those identified as either genera or species within that family, we combined all of these under Agonidae. For rockfishes, as there were more individuals identified to the species level than identified to genus, fishes that we could only identify to genus (*Sebastes* spp.) were removed from the community analyses.

Fish Community Analyses (Influence of Depth, Habitat Type, and Geographic Proximity).—To examine the relationships among fish assemblages, transects were categorized into 50-m depth zones (range 0–400 m) for each of the four habitat types (platform midwater, platform base, platform shell mound, and natural reef). For base, shell mound, and natural reef transects, depth zone categorizations were based on transect seafloor depths, while for platform midwater transects, categorizations were based on the water depths of the horizontal crossbeams surveyed. We constructed a similarity matrix using averaged (across years), fourth root–transformed, fish taxa–specific densities, as well as the Bray-Curtis similarity coefficient for each site-specific habitat type and depth zone combination that were sampled. To visualize these relationships, we created a two-dimensional nMDS ordination plot using the metaMDS function in the vegan package (Oksanen et al. 2017) in R (R Core Team 2017). We tested for significant effects of depth zone, habitat type, and their interaction (depth zone × habitat type) on fish community structure using permutational multivariate analysis of variance (PERMANOVA) using the adonis function (R vegan package; Oksanen et al. 2017). This was followed by pairwise adonis PERMANOVA tests for significant differences in community structure between pairs of fish assemblages in depth zone and habitat type combinations where at least four sites were sampled in each. With sample sizes smaller than four sites, these permutation tests had low power to resolve significant differences.

Based on clear separation between the fish assemblages in platform midwater and platform seafloor habitats (i.e., base and shell mound; *see* Results), we then used two separate cluster analyses to more closely examine the effects of depth zone and geographic proximity on the fish assemblages living associated with platform midwater or seafloor habitats. In each case, we created a similarity matrix using averaged (across years), fourth root–transformed, fish taxa–specific densities, as well as the Bray-Curtis similarity coefficient for each site-specific habitat type and depth zone combination. We then produced a dendrogram and ran a similarity profile (SIMPROF) test (alpha = 0.001) using the simprof function in the clustsig package (Clarke et al. 2008, Whitaker and Christman 2014) in R (R Core Team 2017) to group the assemblages into significantly different fish community clusters.

We also examined interannual variation in the fish assembles at individaul platform sites by habitat type (midwater, base, shell mound) and depth zone. We constructed similarity matrices using fourth root–transformed, fish taxa–specific annual densities, and the Bray-Curtis similarity coefficient for each year-specific habitat type and depth zone combination for platforms that were sampled for at least 3 yrs. Platform-specific nMDS ordination plots were produced using the metaMDS function in the vegan package (Oksanen et al. 2017) in R (R Core Team 2017). We then quantified

Table 2. A summary of platform and natural habitat surveys conducted 1995–2013. In some years, not all habitats around a specific platform were surveyed (*see* Table 1). In most instances, the midwater, base, and shell mound habitats at a specific platform were surveyed on a single dive. For base, shell mound, and natural reef transects, depths are sea floor depths, while for platform midwater transects depths are the water depths of the horizontal crossbeams surveyed.

Habitat	Area surveyed (m^2)	Transect length (m)	Number of dives	Number of transects	Minimum depth (m)	Maximum depth (m)
Platform midwaters	196,474	98,237	186	618	5	328
Platform bases	56,796	28,398	137	138	42	365
Platform shell mounds	64,810	32,405	128	128	44	365
Natural habitats	926,262	463,131	412	1,206	22	400

the interannual variation (relative spread in points for a given habitat type and depth zone combination at a platform) by calculating the average distance to the spatial median of each group of points using the betadisper function in the vegan package in R.

Results

All data used in these analyses can be accessed through the Santa Barbara Channel Marine Biodiversity Observation Network (*see* Love et al. 2017 for data).

Between 1995 and 2013, we surveyed the fishes living around 23 California oil and gas platforms (midwaters, bases, and shell mounds) and 70 natural habitats (*see* Online Table 2 for years that each platform and each platform habitat was surveyed). The platforms surveyed were installed between 1968 and 1989, were distributed between about Point Arguello (central California) and Long Beach (southern California), had seafloor depths ranging 49–363 m, and were surveyed 1–16 times (Fig. 1, Table 1). Total area surveyed, transect length, transect number, and minimum and maximum depths of these transects for each habitat are given in Table 2. We note that between 5 and 16 times more natural habitat was surveyed than at any of the three platform habitats.

A total of 1,526,437 fishes were observed. Fish densities were highest around the platform bases, followed by platform midwaters, platform shell mounds, and natural habitats (Appendix 1). Of all fishes observed, 90.4% were in the genus *Sebastes,* ranging from 86.1% (midwaters) to 96.1% (base). Total number of species observed ranged from 144 (natural habitats) to 79 (platform midwaters). A list of all species observed, by platform and habitat type, is found in Online Table 3.

Depth, Habitat Type, and Geographic Proximity.—Depth zone was the strongest driver of the fish species assemblages, although both habitat type and geographic location were also important. A clear depth gradient in the fish assemblages across all habitat types is evident in the nMDS plot (Fig. 2). Depth zone and habitat type had significant effects on fish community structure, with depth zone having the largest partial R^2 value [PERMANOVA: depth zone partial R^2 = 0.31, P = 0.001; habitat type partial R^2 = 0.11, P = 0.001; depth zone × habitat type interaction partial R^2 = 0.08, P = 0.001; because the sampling design was unbalanced and Type I sums-of-squares are used by this function, the partial R^2 values reported are from when each main effect (depth zone or habitat type) is ordered second in the model]. The influence of habitat is most evident in the almost complete separation between the

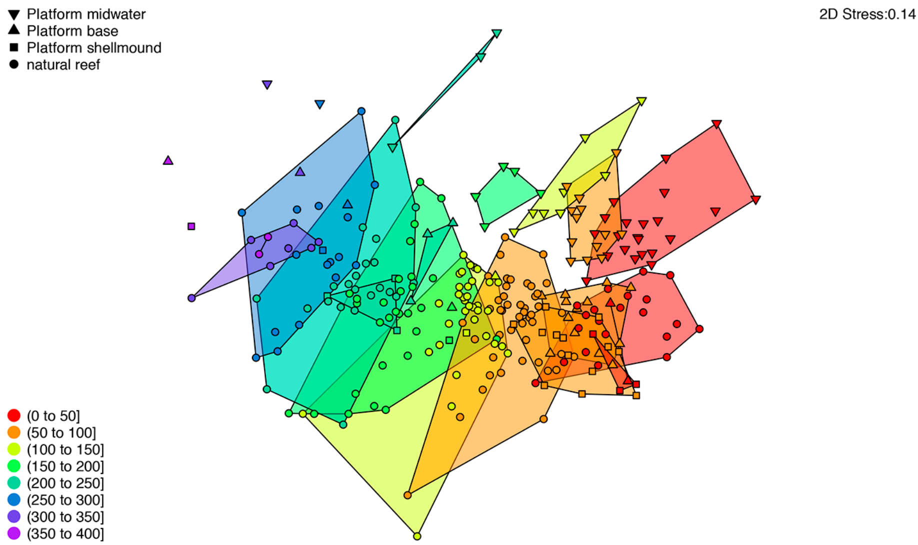

Figure 2. Variation in fish assemblages across all sites sampled by habitat type (point shape) and depth zone (color; depths in meters). Nonmetric multidimensional ordination of fish assemblages using Bray-Curtis similarity based on the fourth root–transformed, fish taxa–specific densities averaged over all years sampled at a site-specific habitat type and depth zone combination. Minimum convex polygons were drawn around all points in each habitat type and depth zone combination and color filled according to depth zone. *See* Table 3 for pairwise tests of significant differences in community structure between fish assemblages in depth zone and habitat type combinations.

points representing fish assemblages in platform midwater habitats from those in all seafloor habitat types (i.e., platform bases, platform shell mounds, and natural habitats). There was relatively more overlap in the minimum convex polygons (MCPs) of depth zone and habitat type combinations for the seafloor habitat types, although for cases where there were at least four sites sampled in a depth zone and habitat type combination, pairwise comparisons of their average fish assemblages were significantly different in all cases except for two: (1) relatively deep adjacent platform midwater depth zones (>100 to 150 m and >150 to 200 m) and (2) the two deepest natural reef depth zones where at least 4 sites were sampled (>250 to 300 m and >300 to 350 m; Table 3). Natural reef fish assemblages typically had the most variable habitat-specific fish assemblages for sites within a depth zone (i.e., largest MCPs, Fig. 2), although they covered the largest geographic area (Fig. 1) and also had the largest number of sites sampled.

Platform midwater habitat fish assemblages tended to be more similar among different platforms in the same depth zones, compared to assemblages from different depth zones on the same platform. The cluster analysis of platform midwater habitats by depth zone resulted in nine significant clusters (Fig. 3A) that indicated effects of both depth zone and relative geographic proximity. Four significant midwater clusters contained fish assemblages from similar depth zones (clusters 1, 3, 4, 5 in Fig. 3A) on platforms geographically located in very close proximity to one another (Fig. 1). For example, midwater cluster 5 contained the shallowest depth zone (>0 to 50 m) from the four "E" platforms located just offshore of Huntington Beach, and midwater cluster 1 contained the deepest midwater depth zones from each of three "H"

Table 3. Permutational analysis of variance (PERMANOVA) R^2 statistics from pairwise tests of significant differences in community structure (using the adonis PERMANOVA function in R; Oksanen et al. 2017, R Core Team 2017) between fish assemblages sampled in depth zone and habitat type combinations where at least four sites were sampled in each. Statistically significant values are indicated by * ($P < 0.05$) and ** ($P < 0.005$).

Structure (depth)	Platform midwaters (0–50]	Platform midwaters (50–100]	Platform midwaters (100–150]	Platform midwaters (150–200]	Platform bases (50–100]	Platform shell mound (50–100]	Natural habitats (0–50]	Natural habitats (50–100]	Natural habitats (100–150]	Natural habitats (150–200]	Natural habitats (200–250]	Natural habitats (250–300]
Platform midwaters (50–100]	0.13**											
Platform midwaters (100–150]	0.21**	0.13*										
Platform midwaters (150–200]	0.24**	0.22**	0.14									
Platform bases (50–100]	0.30**	0.32**	0.42**	0.46**								
Platform shell mound (50–100]	0.35**	0.38**	0.42**	0.46**	0.08*							
Natural habitats (0–50]	0.24**	0.30**	0.33**	0.35**	0.28**	0.27**						
Natural habitats (50–100]	0.35**	0.24**	0.20**	0.17**	0.20**	0.17**	0.19**					
Natural habitats (100–150]	0.44**	0.34**	0.26**	0.20**	0.33**	0.30**	0.35**	0.08**				
Natural habitats (150–200]	0.44**	0.39**	0.29**	0.20**	0.39**	0.36**	0.42**	0.25**	0.14**			
Natural habitats (200–250]	0.50**	0.48**	0.40**	0.28**	0.50**	0.48**	0.50**	0.35**	0.26**	0.05*		
Natural habitats (250–300]	0.47**	0.48**	0.41**	0.31**	0.50**	0.49**	0.47**	0.37**	0.32**	0.15**	0.08**	
Natural habitats (300–350]	0.48**	0.58**	0.57**	0.55**	0.63**	0.61**	0.50**	0.34**	0.35**	0.21**	0.19**	0.07

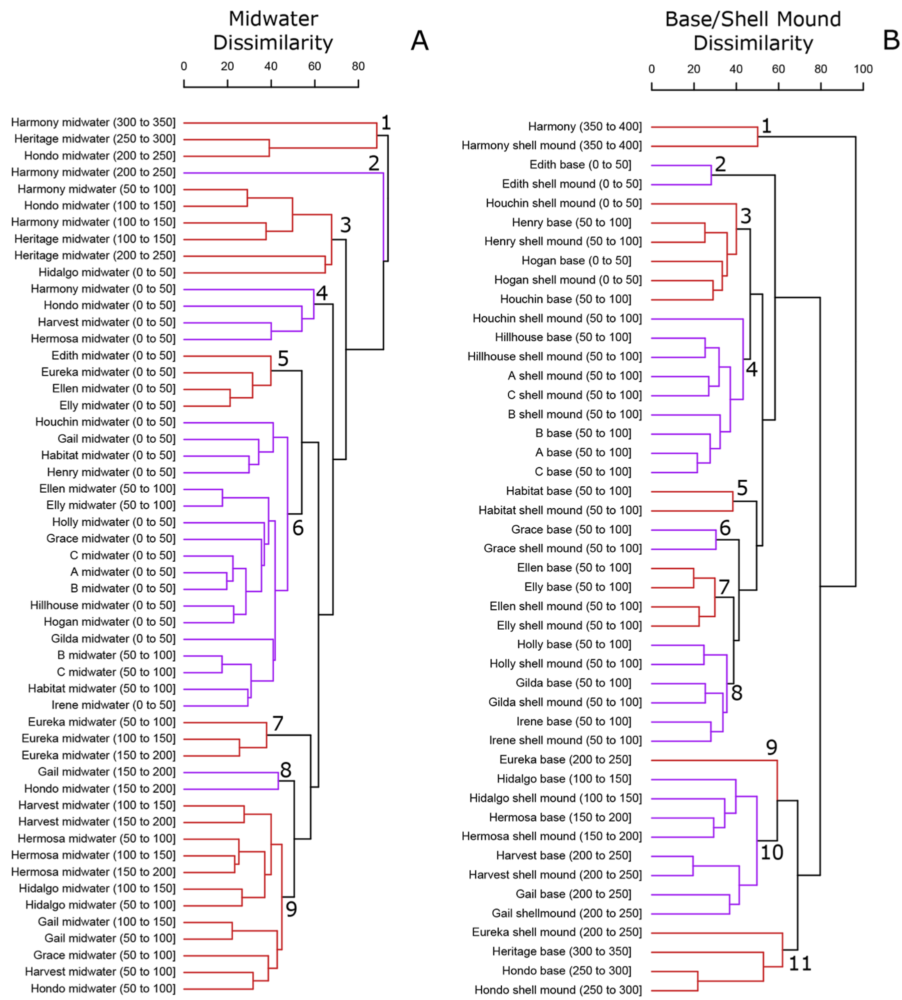

Figure 3. Dendrogram of dissimilarity between fish assemblages using Bray-Curtis similarity based on the fourth root–transformed, fish taxa–specific densities averaged over all years sampled at a site-specific depth zone (m) for (A) midwater portions of platform structures and (B) platform seafloor habitats (i.e., platform bases and shell mounds). Numbers and alternating colors indicate significantly different clusters based on similarity profile tests (alpha = 0.001).

platforms located offshore north of Santa Barbara (Figs. 1, 3A). Midwater cluster 6 contained fish assemblages from shallow depth zones (mostly 0–50 m) on platforms spanning the entire region. Interestingly, within this cluster the >50 to 100 m depth zones from two of the "E" platforms located farther south, where the surface waters tend to be somewhat warmer, were most similar to >0 to 50 m depth zone fish assemblages from platforms located farther north in relatively colder water. Midwater clusters 8 and 9 (Fig. 3A) contained fish assemblages from somewhat deeper depth zones on "H" and "G" platforms spanning relatively large distances across most of the northern and central parts of the region (Fig. 1). Finally, three of platform Eureka's midwater depth zones (from 50 to 200 m) formed their own significant cluster (midwater cluster 7).

For platform seafloor habitats (i.e., platform bases and associated shell mounds) depth zone appears to be the most important factor in structuring their associated fish communities, followed by geographic proximity, with habitat type (base or shell mound) only becoming important at the smallest spatial scales. The cluster analysis of platform seafloor habitats by depth zone resulted in 11 significant clusters. Very importantly, in most cases, fish assemblages at the base of a platform were most similar (i.e., least dissimilar) to the fish assemblage observed at the associated shell mound habitat (cluster 1, 2, 5, 6, within cluster 8, 10; Fig. 3B). Alternatively, in cases where platforms are located in close proximity to each other at the same depths (i.e., platforms Ellen and Elly, or the ABC platforms; Fig. 1), the fish assemblages on the same habitat types (i.e., bases or shell mounds) were more similar to each other (within clusters 4 or 7, Fig. 3B). The significant clusters together also form larger clusters with those containing similar depth zones, with seafloor clusters 2–8 forming a shallow "super-cluster" (depth zones from >0 to 100 m), and clusters 9–11 forming a deeper "super-cluster" (depth zones from >100 to 300 m; Fig. 3B).

The depth zone and habitat type variation in these fish assemblages can be characterized by the related distribution and abundance patterns of their individual taxa. Common taxa had depth distributions across all habitat types that tended to be shallower (top two rows of plots in Fig. 4), mid-depths only (middle rows of plots in Fig. 4), or deeper (bottom row of plots in Fig. 4). Interestingly though, in almost all cases, these common taxa were observed across a larger range of depths in natural habitats compared to platform habitats (Fig. 4). These common species that contributed to the fish assemblage differentiation included high-relief specialists (i.e., *Sebastes entomelas*, *Sebastes hopkinsi*, *C. punctipinnis*, and *S. paucispinis*), lower relief or habitat generalists (i.e., *Sebastes semicinctus*, *Sebastes elongatus*, and Agonidae), and soft seafloor taxa (i.e., Zoarcidae, *Sebastolobus* sp., and *Sebastes diploproa*; Fig 4.). Dominant fishes in platform midwaters (not including transient pelagic species) included *S. hopkinsi*, unidentified YOY *Sebastes*, *S. entomelas*, *C. punctipinnis*, *Sebastes jordani*, *S. paucispinis*, *Oxylebius pictus*, *Sebastes mystinus*, *Sebastes rufus*, and *Sebastes serranoides* (Appendix 1). Midwater depth zones were then further separated by depth-specific patterns of abundance. For example, *S. hopkinsi* density peaked at 50–100 m, while *S. rufus* density increased with water depth, peaking at 250–300 m (Fig. 4). In common with platform midwaters, the platform bases harbored high densities of *S. hopkinsi*, unidentified YOY *Sebastes*, *S. jordani*, *S. paucispinis,* and *S. entomelas*. However, unlike in midwaters, *S. semicinctus*, *Sebastes dalli*, *Sebastes miniatus*, *Ophiodon elongatus*, and *Sebastes caurinus* were also important (Appendix 1). The most abundant species at platform bases, *S. semicinctus*, also exhibited a large increase in abundance with seafloor depth, peaking at platform bases located in the 150–200 m depth zone (Fig. 4). The shell mound assemblage was similar to that of the platform base, with only *S. jordani*, *S. entomelas*, *S. caurinus*, and *Rhinogobiops nicholsii* not held in common among the top 10 highest density species (Appendix 1). Further, many common species in a given shell mound depth zone were at lower densities than in platform base habitat in the same depth zone (Fig. 4). The fish assemblages of the natural habitats had much in common with that of the overall platform assemblages as *S. hopkinsi*, *S. semicinctus*, *S. jordani*, *R. nicholsii*, *C. punctipinnis*, and *S. entomelas* were all important. Among the most important species on the natural habitats that were not commonly observed at platforms were *Sebastes wilsoni*, *Sebastes ensifer*, and *Zalembius rosaceus*

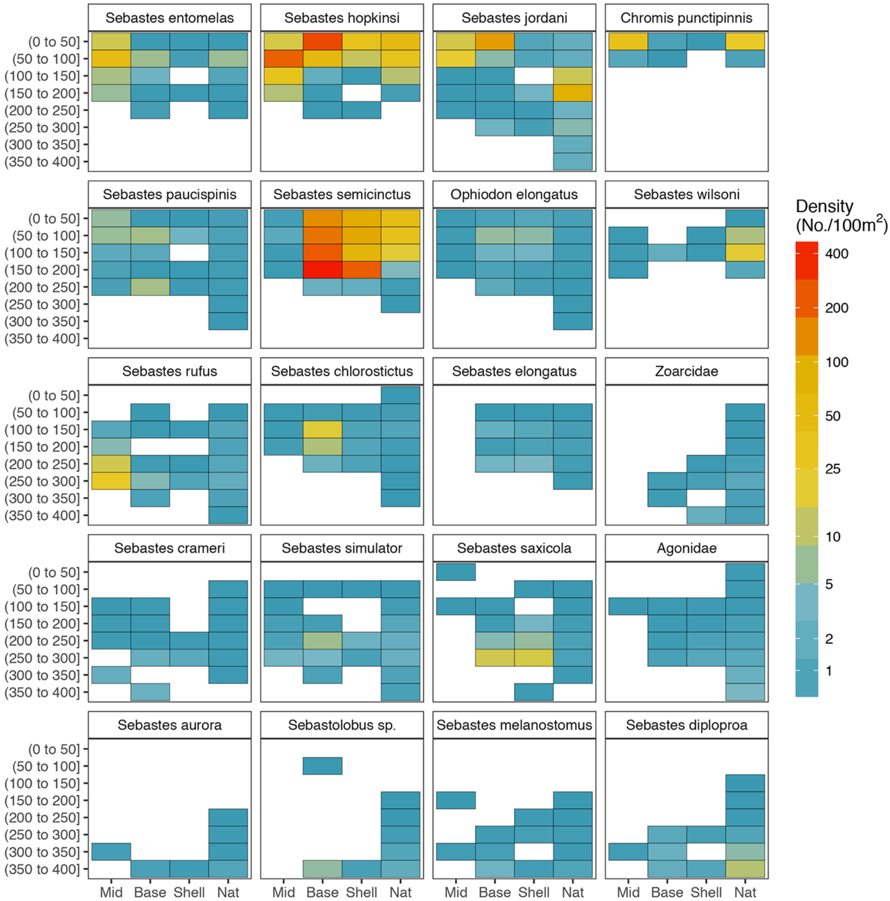

Figure 4. Heatmap plot showing depth zone (m) and habitat type (platform midwaters, platform bases, platform shell mounds, and natural reefs) density distribution for individual fish taxa. The taxa presented here include the two taxa with the highest densities in each habitat type and depth zone combination. Taxa-specific densities were calculated by first averaging over years, then across sites, for each habitat type and depth zone combination. The density color scale was log (x+1) transformed for visibility of the lower values given the skew towards extremely high densities in some cases.

(Appendix 1). In general, while the common species had considerable differences in abundance across the four habitats, they were still present in all of them (with the exception of *S. elongatus, Sebastolobus* sp., and Zoarcidae; Fig. 4).

Patterns of Fish Densities and Size Structures.—Most of the fishes living around platforms and natural habitats were relatively small, primarily 20 cm or less in length (Fig. 5). Many of these individuals were the juveniles of larger taxa (e.g., *O. elongatus, S. entomelas,* and *S. paucispinis*) or the juveniles and adults of dwarf species (e.g., *O. pictus, R. nicholsii, S. hopkinsi,* and *S. semicinctus*). Larger fishes were less common, and these were most often found around platform bases and on natural habitats (Figs. 5, 6, 7). Most YOY fishes occurred in depth zones of 150 m or less at all four habitats (Fig. 6). At platforms, YOY densities were highest in platform midwaters

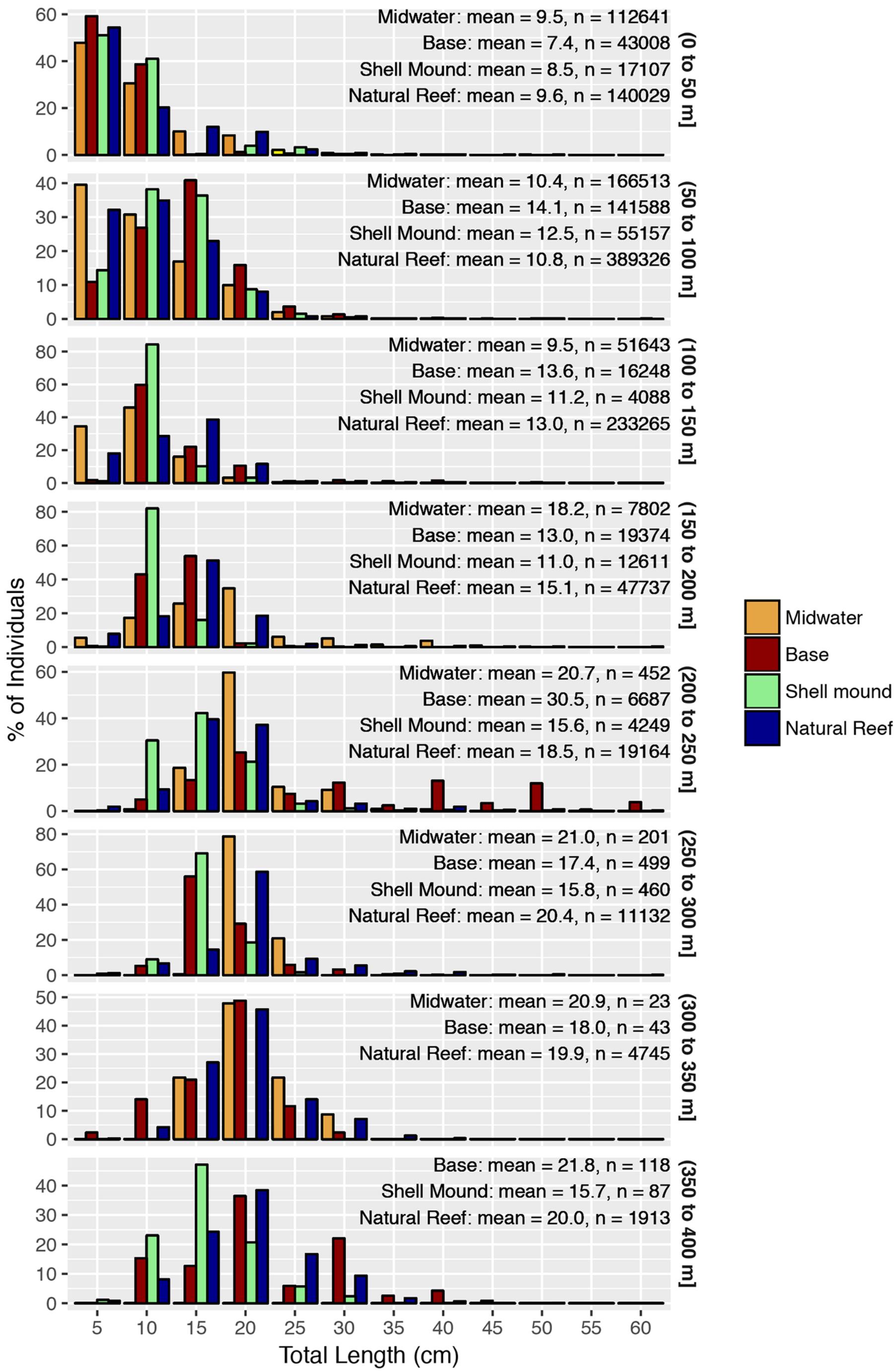

Figure 5. Length distributions by habitat type and depth zone (m) of all fishes observed across all platforms and natural habitats, 1995–2013. Mean total length (cm) and total number of fishes observed are reported for each habitat type and depth zone combination. Note that within and between depth zones, numbers of fishes observed vary greatly among the four habitats. Between 5–16 times more natural reef habitat was surveyed than at any of the three platform habitats (Table 2) and this contributed to higher numbers of fish being observed in natural reef habitats.

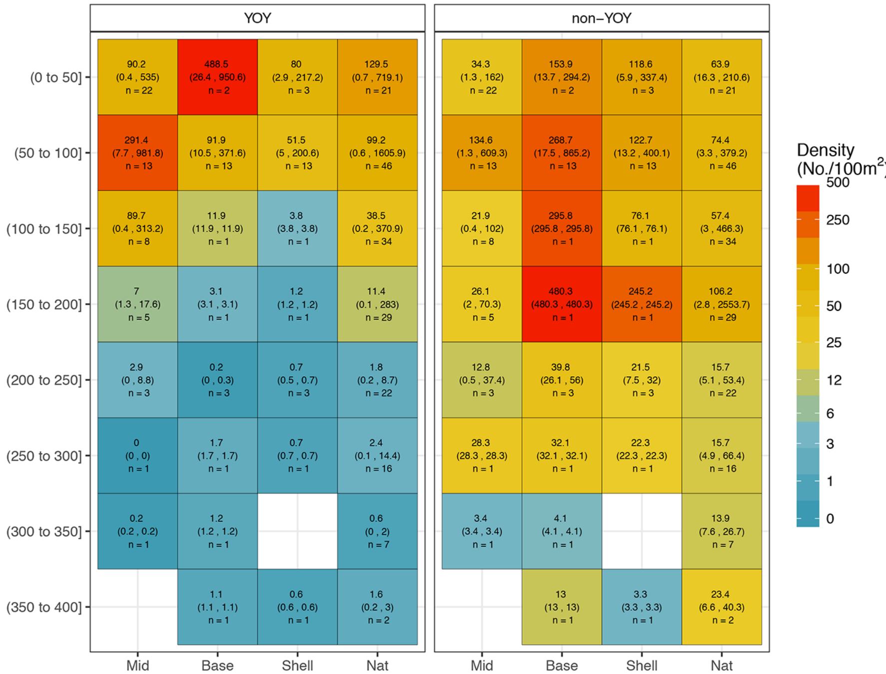

Figure 6. Heatmap plot showing depth zone (m) and habitat type (platform midwaters, platform bases, platform shell mounds, and natural reefs) density distribution of all young-of-the-year (YOY) fishes and non-YOY fishes (larger than YOY). For each taxa, YOY was defined as individuals with a total length less than the average length at 1 y as predicted by the von Bertalanffy growth function using taxa-specific parameters following Claisse et al. (2014). Densities were calculated by first averaging over years, then across sites, for each habitat type and depth zone combination. The density color scale was log (x+1) transformed for visibility of the lower values given the skew towards extremely high densities in some cases. The values reported in each heatmap tile include: (1) mean density (number per 100 m^2), (2) the range of densities across sites (in parentheses), and (3) the number of sites sampled for that habitat type and depth zone combination.

and bases. Densities of these very young fishes were somewhat lower, on average, over natural habitats. Densities of fishes older than YOYs also decreased in deeper depth zone, but at a rate slower than that observed with young fishes and densities of these older fishes peaked in depth zones of 0–200 m at all four habitats (Fig. 6). In general, to depths of 300 m, the highest densities of older fishes were observed at platform bases (Fig. 6). At almost all platforms, densities of non-YOY fishes were highest at the base compared to their midwaters and shell mound habitats (Online Fig. 2). In all four habitat types, mean lengths of fishes tended to increase with depth peaking in the >200 to 250 m depth zone, or in the >250 to 300 m depth zone for natural habitats (Fig. 5). This pattern was due to (1) most fishes ≤10 cm TL lived in <150 m depth and (2) an increase in the densities of larger individuals with depth. Fish size structures at all three platform habitats at each platform are found in Online Figure 3.

Fishes utilized platforms and natural habitats at a variety of life stages (Fig. 7). First, there were species for which platform habitats acted primarily as nursery grounds. For instance, during some years and around some platforms, juvenile *S. entomelas* were extremely abundant in platform midwaters (and to a lesser extent at bases and

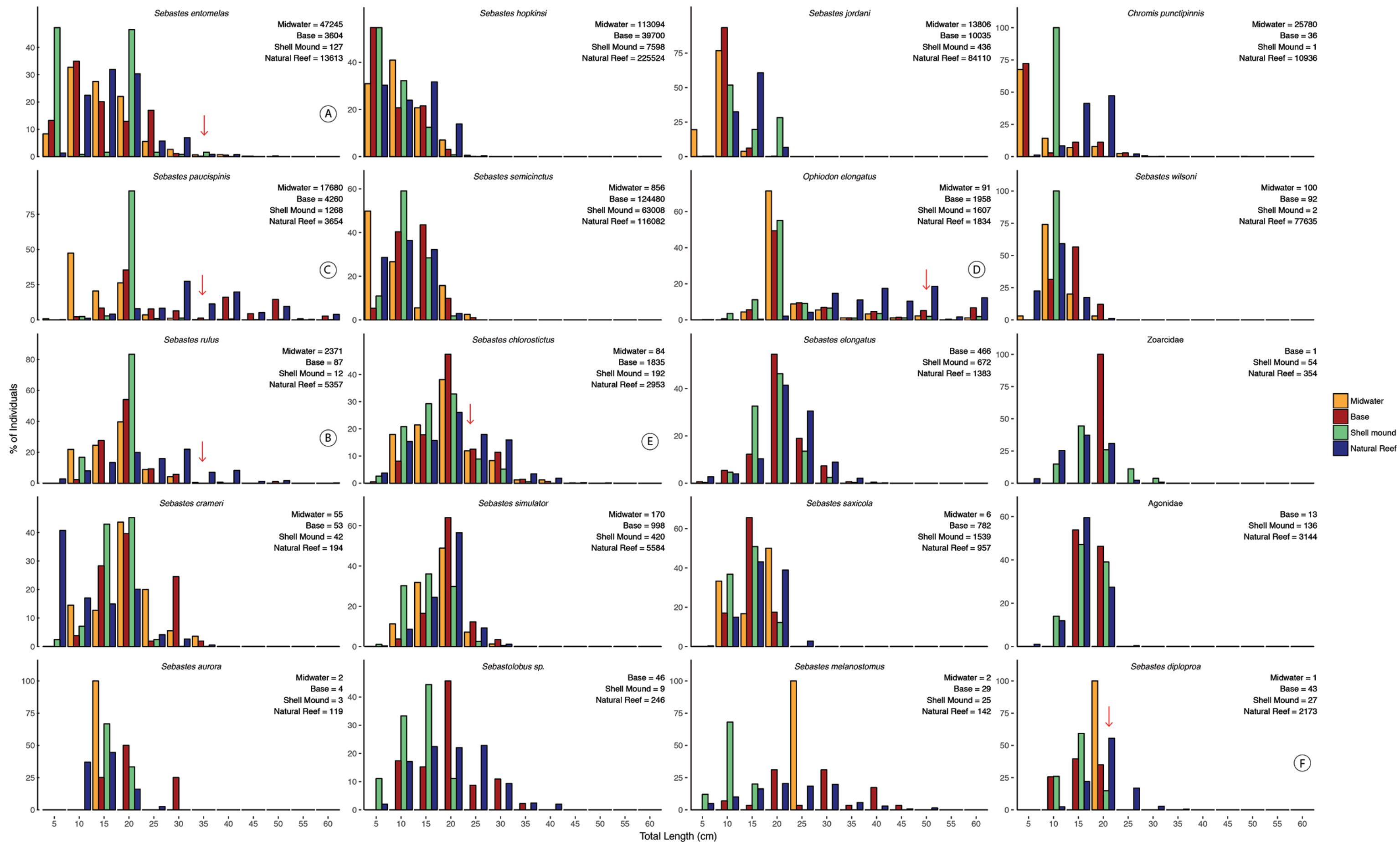

Figure 7. Length distributions of selected species observed at all platforms and natural habitats, 1995–2013, including number of each species observed at each of four habitats (platform midwaters, bases, shell mounds, and natural reefs). Arrows designate length at 50% maturity, data from Love (2011). Note that between 5–16 times more natural reef habitat was surveyed than at any of the three platform habitats (Table 2) which would contribute to increased numbers of fish being observed in natural reef habitats.

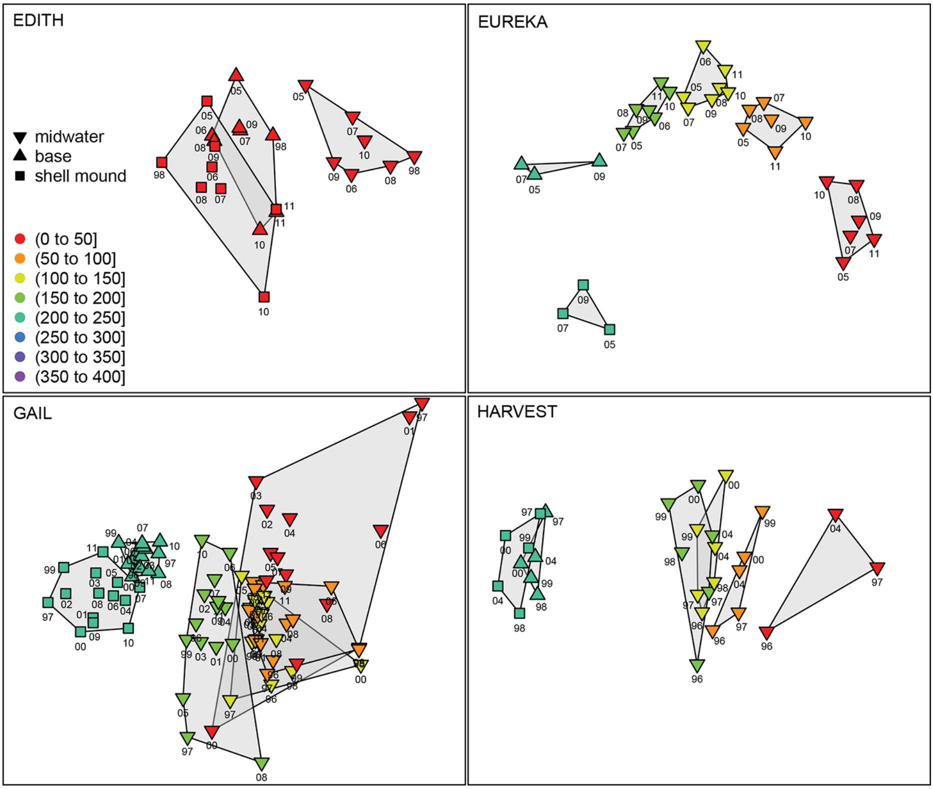

Figure 8. Inter-annual variation in fish assemblages at four platforms by habitat type (point shape) and depth zone in meters (color). Non-metric multidimensional ordination of fish assemblages using Bray-Curtis similarity based on the fourth-root transformed fish taxa-specific densities for each year sampled at a platform-specific habitat type and depth zone combination. Minimum convex polygons are drawn around all points in each habitat type and depth zone combination. The interannual variation (relative spread in points for each habitat type and depth zone combination) was also quantified and reported in Online Table 4.

at natural habitats; Fig. 7A). However, we observed few mature individuals at the platforms or at natural reefs in our study area.

Similarly, juvenile *S. rufus* were occasionally abundant in platform midwaters, but adult fish were generally absent at platforms; almost all mature *S. rufus* were observed in natural habitats (Fig. 7B). Second, some species were found as both recruiting juveniles and adults at platforms (Fig. 7C). As an example, during some years, high densities of YOY *S. paucispinis* were found in the midwaters of many platforms (densities higher than at other parts of the platforms and at natural habitats) where they remained for at most 1–2 yrs. We did observe older juveniles at platform bases and shell mounds, and adults at platform bases. YOYs were mostly missing from natural reefs, where we observed primarily older juveniles and adults (Fig. 7C). Third, there were species, such as *O. elongatus*, whose YOYs or older juveniles were rare or absent from platform midwaters, but for whom bases or shell mounds were important nursery grounds (Fig. 7D). For this species, almost all fish in the smallest size classes (between 10 and 20 cm) lived at platform bases and shell mounds; relatively few individuals <30 cm were observed in natural habitats. *Sebastes chlorostictus* also follows this pattern, except that, unlike *O. elongatus*, all size classes were found at both base and natural habitats (Fig. 7E).

Table 4. The top 20 sites, in any given year and habitat, for young-of-the-year fish densities. Although all species are included in this analysis, most of these fishes are rockfishes, genus *Sebastes*. Density is in fish per 100 m^2. Depths are in meters.

Site	Habitat	Depth zone	Year	Density
Platform Edith	Base	0–50	2005	3,821
Platform Elly	Midwaters	50–100	2010	3,121
Platform Irene	Midwaters	0–50	2001	2,892
Platform Ellen	Midwaters	50–100	2009	2,653
Platform Ellen	Midwaters	50–100	2010	2,485
Platform Hermosa	Midwaters	50–100	1999	2,140
Hidden Reef	Natural Habitat	50–100	1999	1,606
Platform Elly	Midwaters	50–100	2009	1,578
Platform Edith	Base	0–50	2009	1,571
Platform Irene	Midwaters	0–50	2009	1,270
Platform Eureka	Midwaters	50–100	2009	1,004
Platform Edith	Midwaters	0–50	2009	999
Platform Ellen	Midwaters	50–100	2008	994
Platform Hidalgo	Midwaters	100–150	2009	943
Platform Eureka	Midwaters	0–50	2010	876
Platform Eureka	Midwaters	50–100	2010	870
Platform Elly	Base	50–100	2005	854
Platform Hidalgo	Midwaters	50–100	2009	829
Platform Eureka	Midwaters	100–150	2011	767
Platform C	Midwaters	50–100	2012	761

Platform Fish Assemblage Continuity.—In general, the patterns observed in fish assemblages associated with habitat type and depth zone (e.g., Fig. 2) were similar, and consistent year-to-year, when we examined the interannual variability in the fish assemblages at individual platforms (Fig. 8). Clear separation in the fish assemblages were evident between the midwater habitats and seafloor (base and shell mound) habitats, and among midwater habitats in different depth zones. Additionally, midwater habitat fish assemblages were on average 1.53 times more variable over time than the assemblage associated with their respective base habitat at a given platform, and shell mound assemblages were 1.29 times more variable than those associated with their bases (Fig. 2, Online Table 4).

Discussion

Around the California platforms that we surveyed, fish assemblages were differentiated along a depth gradient, and there were clear distinctions between the assemblages in the platform midwaters, and those allied with platform bases and their associated shell mounds. Interplatform variability in these assemblages was also driven by habitat characteristics and, to a lesser extent, platform geography. The most common species had depth distribution ranges across all habitat types that were limited to only a portion of water or seafloor depths surveyed in the study, and this contributed to the differences in fish assemblages across depth zones. Additionally, depth also plays a large role in the life history of many California fish species. For instance, the YOYs of many species recruit at depths shallower than those occupied by adults (Love et al. 2009). This is reflected in the high densities of YOY fishes in depths shallower than 150 m at both platforms and natural habitats (Fig. 6). While a number of fish species recruit as YOYs to platforms, only a subset of these taxa were abundant at platforms during our surveys. In particular, the YOYs of *S. entomelas*, *S. hopkinsi*, *S. jordani*, and *S. paucispinis*, along with *C. punctipinnis* and *O. elongatus*, were among the species found at highest densities (Fig. 7, Online Table 3). On average, densities of at least *S. entomelas*, *S. hopkinsi*, *S. paucispinis*, *C. punctipinnis*, and *O. elongatus* were higher at platforms than at natural habitats.

It is likely that many, although not all, California platforms play a significant role as nursery grounds for a variety of fishes, particularly for a number of *Sebastes* species.

In midwaters, YOYs comprised 64.8% of all fishes observed, compared to 31.8% at bases, 18.5% over shell mounds, and 43.5% over natural habitats. Abundances of YOYs at platforms can be very high; in years with successful recruitment, there can be hundreds of thousands of YOY *Sebastes* around a single platform (Love et al. 2006b). YOY densities around platforms tend to be higher than at many natural habitats. As an example, over the course of this survey, among the sites having the top 20 highest YOY densities, 16 were platform midwaters, 3 platform bases, and 1 a natural habitat (Table 4). Highest YOY densities were not limited to a few platforms, but rather were spread out among eight structures, although a large proportion occurred at some of the southernmost structures (Edith, Ellen, Elly, and Eureka).

Because successful YOY recruitment is dependent on annually fluctuating oceanographic conditions, interannual densities of YOYs at any given platform, or even between nearby platforms within a year, vary considerably. For instance, in 2003, abundances of *S. paucispinis* YOYs at eight platforms within the Santa Barbara Channel ranged from about 350,000 to about 800 (Love et al. 2006b). In addition, in at least some years, YOY recruitment to platforms may be significantly higher than at nearby natural habitats. As an example, almost all YOY *S. paucispinis* recruitment in 2003 in much of southern California (platforms and natural habitat) appeared to take place around Santa Barbara Channel platforms (Love et al. 2006b). During that year, platform recruitment was sufficiently large that it was estimated that the minimum 430,000 YOYs found at eight platforms comprised about 20% of the average number of juvenile *S. paucispinis* that survive annually within the species' geographic range and would contribute about 1% of the addition fish needed to rebuild that species' stock (Love et al. 2006b). However, we emphasize that platforms, like natural habitats, do not harbor high densities of YOYs every year and some platforms may not serve this function at all. For instance, a study conducted during 2006–2007 around the very nearshore platforms Esther and Eva off Huntington Beach (platforms we did not survey) observed no recruitment of YOY *Sebastes* (Martin and Lowe 2010).

Why might platforms, and particularly platform midwaters, tend to harbor higher densities of YOY fishes than do most natural habitats? First, off California, the majority of larvae and pelagic juveniles (in the case of *Sebastes*) of nearshore fishes occupies the upper 100 m of the water column (Ahlstrom 1959, Lenarz et al. 1991, Moser and Pommeranz 1999, Love et al. 2009, 2012; a similar trend was observed in the Gulf of Mexico Hernandez et al. 2003). Thus, these pelagic stages are more likely to encounter platform jackets (encompassing the entire water column) than to nearby, and lower, natural habitats. This is particularly true of platforms and reefs sited in relatively deep waters where, off southern California, natural reefs tend to be only a few meters tall. Second, predation on YOYs may often be lower in platform midwaters than on natural habitats as California platform midwaters tend to harbor lower densities of large (e.g., more predatory) reef fishes than natural habitats (Fig. 5). This is likely partially a function of the midwaters having less habitat complexity than natural habitats and, in addition, large semipelagic and pelagic taxa (i.e., jacks, sharks, and barracuda) are relatively rare around California platforms. Thus, platform midwaters may function as spatial refuges for young fishes.

Similar to conspecifics living on natural habitats (Love et al. 2009), many platform species exhibit ontogenetic shifts; they recruit to relatively shallow waters around platforms and migrate deeper as they mature. As these species mature, they either migrate away from platforms (if the platform base is too shallow; i.e., *S. entomelas*) or remain around the jacket, but move down into deeper waters (i.e., *S. caurinus* and *S. hopkinsi*). Thus, the behavior of fishes that recruit to platforms sited in relatively shallow water is different from those in deeper water and can be demonstrated by comparing the size frequencies within depth zones of *S. paucispinis* at Platform Grace (seafloor depth 98 m) with Platform Gail (seafloor depth 204 m; Fig. 9). At Grace, almost all *S. paucispinis* leave the platform by about 30 cm (when immature). By contrast, at Gail, while *S. paucispinis* also leave the midwaters by about 30 cm, they then take up residence at the platform base (Fig. 9). The juveniles of some species leave platform waters for reasons other than depth-related ontogeny. For instance, *S. mystinus* and *S. serranoides*, whose adults live in shallow waters, recruit as YOY to the midwaters of many California platforms. However, rarely do these fish remain at platforms as adults, despite the presence of the availability of water and seafloor depths preferred by adults.

Habitat composition (i.e., hard vs soft) and complexity (i.e., relief, presence of sheltering sites) also influence midwater platform fish species assemblages as many species may broadly be categorized as habitat specialists or habitat generalists (Anderson and Yoklavich 2006, Love et al. 2006a, Love and York 2006). An example of how habitat complexity helps define platform species assemblages can be seen in the fish assemblages inhabiting the midwaters of Eureka, a structurally unique California platform. The jackets of California platforms, with the exception of Eureka, are composed of cylindrical crossbeams, pilings, and conductors without significant horizontal or vertical relief. The effect of this habitat uniformity is that fish assemblages in midwaters tend to be similar across different platforms at a given depth zone (Figs. 2, 3). In contrast, the midwater jacket of Eureka is studded with large, circular piling guides that provide substantial vertical and horizontal complexity to this otherwise relatively simple habitat. The effect of this structural complexity is that most of the midwater fish assemblages at Eureka are significantly different from other platform midwaters (Fig. 3; Love et al. 2019a). As an example, compare the size frequencies of *S. paucispinis* at Platform Gail to that of Platform Eureka (Fig. 9). In both instances, juveniles leave the shallower midwaters within a few years. However, while all mature fish migrate to the base of Gail, some mature individuals remain in the deepest midwaters (150–200 m) of Eureka. This is likely the result of the additional habitat complexity in Eureka's midwaters. Mature *S. paucispinis* are habitat specialists, associated with caves, crevices, or, at platforms, undercut seafloor crossbeams (Love and York 2006, Love et al. 2006b, 2009). Juveniles (and particularly YOYs), while they always associate with hard structure, do not require particularly complex substrate (i.e., pier pilings, eelgrass, or platforms; Miller and Gotshall 1965, Love et al. 2002). Comparing the fish assemblages of the relatively complex midwaters

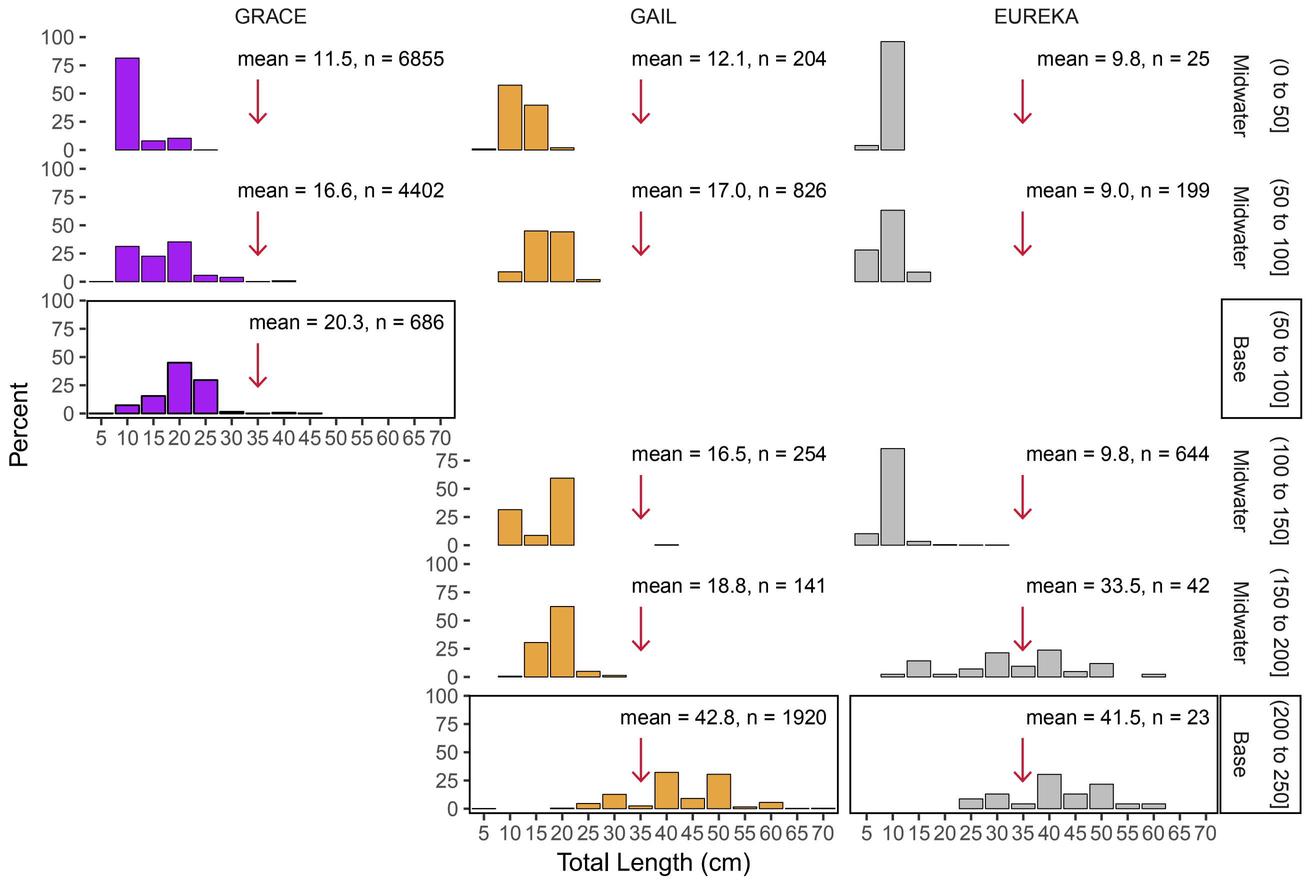

Figure 9. Length distributions of *Sebastes paucispinis* observed at Platforms Grace, Gail, and Eureka in midwaters and bases. Depth zones are in meters. Mean total length (cm) and total number of fishes observed are reported. Arrows designated length at 50% maturity, data from Love (2011).

of Eureka with that of the less complex Gail: Eureka has (1) higher densities of fishes, (2) higher densities of mature individuals, (3) greater species richness, (4) and higher densities of species typical of complex high relief (i.e., *S. caurinus*, *S. paucispinis*, *Sebastes rosaceus*, and *S. rufus*; Love et al. 2019a).

Habitat complexity is also an integral factor in determining both platform base and shell mound fish assemblages. Regarding the platform base assemblage: all California platforms were designed to have a cross beam near the sea floor. Over time, the sea floor under some of these crossbeams has either been scoured out by currents (leading to a gap of varying sizes between sea floor and cross beam) or covered in shells (burying or partially burying the beam). In contrast to the robust and sometimes complex habitat that platform bases provide, the shell mounds are of only moderate relief and complexity, and are characterized by (1) small crevices formed from the random fall of large mussel shells and (2) intermittent patches of soft seafloor. Our study demonstrates that, in a majority of instances, the fish assemblages around the platform base and its associated shell mound are similar in composition (Fig. 4). However, there can be substantial differences in the densities of some of the species that are held in common (Online Tables 3, 4). Species that are present in similar densities between the bases and shell mounds tend to be habitat generalists (i.e., *O. elongatus*, *S. hopkinsi*, *Sebastes saxicola*, and *S. semicinctus*) that frequently move between platform base and shell mound. While some of these species are solitary (i.e., *O. elongatus* and S. *saxicola*), others (i.e., *S. hopkinsi* and *S. semicinctus*) form large schools. The differences that do occur between the base and shell mound are likely related to the differences in the structural complexity of the two habitats. As an example, the suite of fishes of the "sheltering habitat" guild (Love and York 2006), such as *S. paucispinis*, *S. caurinus*, *Sebastes rubrivinctus*, *S. chlorosticus*, and *S. rosaceus*, are found at much higher densities at the platform base, particularly where the crossbeam is undercut, than at the associated shell mound. This pattern appears to break down somewhat in deeper waters, where a few larger and solitary rockfishes, such as *S. chlorostictus* and *Sebastes rosenblatti*, occupy both the platform bases and shell mounds. On the other hand, the relatively high densities of the smallest size classes of YOY *O. elongatus* on shell mounds—densities higher than at other platform or natural habitats—implies that the low rugosity of the shell mounds is an attractive feature to these newly settled fish. Lastly, benthic habitat complexity around platforms may also differentially impact fishes at different life stages. As an example, at platforms adult *S. levis* only live in close association with platform bases, while YOY *S. levis* live only on those shell mounds associated these platforms. In addition, small *S. paucispinis* tend to be found over the shell mounds, while larger individuals are characteristic of platform bases.

What are the sources of the fishes that live at California platforms? YOY, often a major proportion of the fish assemblages, recruit from the plankton to midwaters, bases, and shell mounds depending on species. It is likely that most of the fishes that make up platform assemblages recruit directly from the plankton. Rockfishes, in particular, but also such taxa as *O. pictus* and *C. punctipinnis*, recruit at a size commensurate with first settlement from the plankton. By comparison, some species do not recruit at the earliest benthic stages and these have to come from other structures. For instance, we did not observe the young of live-bearing Embiotocidae (i.e., *Damalichthys vacca*, *Phanerodon atripes*, and *Phanerodon furcatus*) at platforms although older fishes were characteristic of some platforms. Although YOY *S.*

miniatus/*Sebastes crocotulus* (these two species cannot be separated by appearance at a young age) recruit to very shallow inshore waters, high densities of older juveniles live around the bases of some platforms; these fish must have migrated to these jackets. Similarly, while *G. nigricans* recruit to tide pools (Norris 1963), adults were sometimes seen in platform midwaters.

The fish assemblages of platform midwaters and shell mounds tended to be more variable among years than those at platform bases. This variability reflects (1) the midwaters (and to a lesser extent shell mound) dependence on highly variable larval and pelagic juvenile recruitment success and (2) the greater importance of older fishes at platform bases compared to midwaters and shell mounds. In our study, the midwater exception was Eureka, whose midwaters are structurally more similar to typical platform bases and whose assemblages were very consistent across years (Fig. 8). In particular, deeper-water platform base assemblages, much less dependent on annual recruitment from the plankton and containing higher densities of older individuals, were more stable than their midwater assemblages (e.g., Gail, Harvest; Fig. 8). We note that at some deeper platform bases, we predictably observed high densities of the adults of some species (i.e., *S. chlorostictus*, *S. levis*, and *S. rubrivinctus*) year after year along the same section of jacket, and it is likely we observed some of the same individuals over the years.

With the California decommissioning process in mind, we wish to emphasize that, while there may be substantial similarities between the fish assemblages associated with a given habitat type in a given depth zone, the densities of individual species, particularly economically important taxa, at an individual platform need to be considered individually regardless of how similar two platforms are in seafloor depth, jacket topography, or geography. As an example, we compared the densities of five economically important taxa at the bases of four platforms, all of which lie within a relatively narrow seafloor depth range (179–212 m; Table 5). Harvest and Hermosa lie near each other, while Gail and Eureka lie well to the south (Fig. 1). Densities of the five species vary widely among the platforms, even between nearby Harvest and Hermosa. At the extreme, *S. paucispinis* were abundant at Gail, but absent from Harvest and Hermosa. Some of these differences may be linked to platform base complexity, as the base crossbeams at Harvest and Hermosa are mostly covered or barely exposed (and thus the bases are relatively simple), while those at Gail and Eureka are primarily undercut (Love and York 2006; M Love unpubl data). However, while this might explain the absence of the complex-habitat *S. paucispinis* from Harvest and Hermosa, it does not explain the substantial differences in densities of S. *chlorosticus* and *S. rosenblatti* between the two platforms. Ultimately, much of these intraspecific density differences may be due to stochastic processes.

Table 5. Densities (number per 100 m^2) of five economically important fish species from four platforms off southern California. Platforms are listed alphabetically. Bottom depths of these are platforms are: Eureka = 212 m, Gail = 224 m, Harvest = 202 m, and Hermosa = 179 m.

Platform	Eureka	Gail	Harvest	Hermosa
Ophidon elongatus	0.6	2.2	1.2	0.0
Sebastes chlorostictus	0.4	4.1	2.7	8.8
Sebastes levis	0.5	2.4	0.1	0.0
Sebastes paucispinis	1.4	21.2	0.0	0.0
Sebastes rosenblatti	4.9	8.1	2.2	0.1

While a detailed analysis is outside the scope of this work, it is useful to make some comparisons regarding fish assemblages around California platforms and those residing around Gulf of Mexico (GOM) structures. It is important to note that both the abiotic and biotic environments associated with GOM platforms are substantially different from those off California. All of the 26 California platforms reside on the narrow continental shelf, arguably within similar water masses, or at least in waters that are seasonally affected by some level of coastal upwelling. In contrast, the thousands of GOM platforms are situated from very nearshore waters to those far offshore and from eutrophic to oligotrophic waters, and with ambient water temperatures that are generally higher than those off California (Stanley and Wilson 2000). In addition, the fouling communities vary between these regions. While mussels predominate in the upper parts of all California platforms, and anemones and sponges dominate deeper waters (Continental Shelf Associates 2005), the platform biofouling community in the GOM tends to reflect each platform's location and may be dominated by algae, barnacles, hydroids, bivalves, and, in some instances, scleractinian corals (Gallaway and Lewbel 1982, Lewbel et al. 1987, Carney 2005, Atchison et al. 2008). In response, the sea floors associated with most California platforms are covered in thick layers of shells that are absent from GOM platforms.

Given these caveats, what comparisons can be made between the two regions? (1) Water depth is a major driver of fish community structure at both California and GOM platforms (Ajemian et al. 2015). (2) At both California and GOM platforms, juvenile fishes tend to be most abundant in shallow and mid-depths, declining in deeper waters (Hernandez et al. 2003). (3) From near-surface waters to the platform bottom, fish densities are relatively high at California platforms to depths of at least 300 m. In the GOM, fish densities around platforms vary greatly with depth and there does not appear to be a consistent pattern among platforms (Stanley and Wilson 1997, 1998, Reynolds et al. 2018). At the extreme, Stanley and Wilson (1998) documented almost no fishes in waters deeper than 100 m at a platform (GC 18) on the continental slope with a bottom depth of 219 m. Stanley and Wilson (2000) speculate that platforms situated in the oligotrophic waters of the continental slope (such as GC 18) will, in general, harbor lower densities of fishes than platforms on the more eutrophic, nearshore waters of the continental shelf. (4) Unlike off California, in the GOM the dominant fish species tend to vary with distance from shore (Bedinger 1981, Stanley and Wilson 1991). (5) The vast majority of California platform taxa are reef dependent as pelagic or semi-pelagic taxa (i.e., jacks, tunas, clupeids, engraulids, and pelagic elasmobranchs), and are either absent or, with a few exceptions, very transient. On the other hand, of the 246 fish species observed on Gulf of Mexico platforms, >50% (132) were not reef associated (Cowan and Rose 2016). Rather, pelagic species, such as tunas, jacks, and various elasmobranchs, routinely occupy GOM platform waters, particularly those associated with more offshore structures (Dugas et al. 1979, Gallaway and Lewbel 1982, Childs 2002, Edwards and Sulak 2003, Brown et al. 2010, Reynolds and Cowan 2015). However, with the exception of taxa like *Seriola rivoliana* Valenciennes, 1833, *Caranx crysos* (Mitchill, 1815), *Rachycentron canadum* (Linnaeus, 1766), and *Sphyrna* spp., many of these taxa are transitory visitors (Gallaway and Lewbel 1982, Brown et al. 2010). Keenan et al. (2003) hypothesize that GOM platforms accumulate zooplankton resulting in increased densities for prey for pelagic predators such as *C. crysos*. (6) Similarly, while one group, the rockfishes, dominate many California platform assemblages, a very wide range of both reef-associated and pelagic taxa are found in the GOM (Cowan and Rose 2016). (7) Most California platforms serve as nursery grounds for a number of species (primarily *Sebastes* spp. and *C. punctipinnis*) and during some years, hundreds of thousands of YOYs may recruit to a single platform. In contrast, while young fishes are found around GOM platforms, they do not appear to occur in the high densities routinely observed off California (Boland 2002, Hernandez and Shaw 2002).

Conclusions

Regarding the four hypotheses we formulated, depth zone, habitat complexity, and habitat geography all influenced platform fish assemblages. Depth zone was a primary driver of differences in fish assemblages across all habitat types. Most common taxa were found only in part of the 400 m depth range that was surveyed, either having a more shallow, mid-depth, or a deeper distribution. The densities of many individual species then varied dramatically among habitat types and across depth zones in a single habitat type, which could often be attributed to habitat and depth preferences of specific life history stages. This resulted in clear distinctions between the fish assemblages in platform midwater habitats and all other habitat types. Habitat complexity, particularly as it related to the availability of refuge sites, also had a major influence. Complex habitats, found at the base of many platforms, and in the jacket midwaters of platform Eureka, harbored higher densities of fishes, particularly larger fishes, than did less-rugose structures.

Platform midwaters tended to harbor (1) YOYs of a suite of shallow- and deep-water species, primarily *Sebastes* spp. and *C. punctipinnis*, and (2) the older juveniles and adults of shallow-water reef taxa. Densities of individual species showed consistent patterns across depth zones in midwater habitats resulting in midwater habitat fish assemblages in the same depth zones being more similar among different platforms, compared to assemblages from different depth zones on the same platform. Platform bases and shell mounds might also harbor YOYs, but on average these were occupied by older and larger individuals than those found in midwaters. This dichotomy likely has two causes. First, midwater jackets of most platforms are relatively simple and do not provide extensive refuge sites for larger fishes. Second, most larval and pelagic juveniles recruit to waters shallower than 150 m, thus precluding most recruitment to those deeper water platform bases and shell mounds. The greatest overlap between these two assemblages occurred around relatively shallow platforms, where YOYs recruited both to midwaters and sea floor habitats and at Platform Eureka, where the structure of the midwater jacket was uniquely complex and may have mimicked sea floor habitat.

Our data supported the hypothesis that California platform fish assemblages (when summed over all three habitats) are similar to, but distinct from, those of natural structures. Importantly, these distinctions are due more to differences in species' densities rather than to the presence or absence of certain taxa.

In addition, because midwater assemblages in particular depend on annual juvenile recruitment, they are unpredictable from year to year. By contrast, platform bases and shell mounds, occupied to a greater extent by older individuals, tended to be less-variable assemblages over time.

The platforms we surveyed served as nursery grounds for a variety of *Sebastes* and other taxa and, in many instances, platform habitats harbored higher densities of young fishes than did many natural sites. It is likely that this was primarily due to platforms encompassing the entire water column; settling pelagic larvae and juveniles are more likely to encounter these tall structures than natural habitats that have relatively little relief above the seafloor, and perhaps secondarily to comparatively reduced predation in midwaters compared to natural sites. We found that the nursery function of both platforms and natural reefs occurs primarily in waters less than about 150 m deep, correlating to the depths at which pelagic larvae and pelagic juveniles recruit to hard structures.

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Appendix 1. Densities and numbers of all fishes, and total number of species by habitat, observed around 23 oil and gas platforms and 70 natural habitats off central and southern California, 2005–2013. YOY = young-of-the-year. Unid. = unidentified. A list and densities of all species observed, by platform and by platform habitat, is found in Online Table 2.

Species	Densities (number per 100 m^2)	Numbers
Platform midwaters		
Sebastes hopkinsi	59.2	113,094
Unid. *Sebastes* (YOY)	33.7	73,544
Sebastes entomelas	25.8	47,245
Chromis punctipinnis	23.5	25,780
Sebastes jordani	16.5	13,806
Unid. *Sebastes*	12.9	26,613
Sebastes paucispinis	5.5	17,680
Trachurus symmetricus	5.0	12,628
Sardinops sagax	2.6	3,108
Oxylebius pictus	2.2	3,336
Sebastes mystinus	1.9	3,802
Sebastes rufus	1.3	2,371
Sebastes serranoides	1.1	1,266
Sebastes atrovirens	0.5	683
Sebastes semicinctus	0.5	856
Unid. *Sebastomus*	0.4	943
Phanerodon atripes	0.4	549
Engraulis mordax	0.4	528
Semicossyphus pulcher	0.4	469
Medialuna californiensis	0.3	428
Sebastes flavidus	0.3	246
Damalichthys vacca	0.3	249
Unid. Embiotocidae	0.3	230
Sebastes caurinus	0.2	429
Sebastes ovalis	0.2	1,174
Hypsypops rubicundus	0.2	249
Scorpaenichthys marmoratus	0.2	236
Sebastes zacentrus	0.1	357
Phanerodon furcatus	0.1	161
Sebastes rubrivinctus	0.1	483
Sebastes simulator	0.1	170
Sebastes moseri	0.1	193
Ophiodon elongatus	0.1	91
Sebastes dalli	0.1	129
Girella nigricans	0.1	41
Paralabrax clathratus	0.1	72
Sebastes rosaceus	<0.1	160
Sebastes crameri	<0.1	55
Rathbunella alleni	<0.1	35
Sebastes constellatus	<0.1	98
Sebastes auriculatus	<0.1	38
Sebastes rufianus	<0.1	151
Hexagrammos decagrammus	<0.1	40
Sebastes carnatus	<0.1	58

Appendix 1. *Continued.*

Species	Densities (number per 100 m^2)	Numbers
Platform midwaters		
Sebastes chlorostictus	<0.1	84
Sebastes goodei	<0.1	79
Sebastes miniatus	<0.1	29
Oxyjulis californica	<0.1	27
Rhinogobiops nicholsii	<0.1	59
Sebastes wilsoni	<0.1	100
Sebastes rosenblatti	<0.1	75
Unid. Cottidae	<0.1	26
Sebastes umbrosus	<0.1	27
Scomber japonicus	<0.1	30
Sebastes serriceps	<0.1	23
Sebastes rastrelliger	<0.1	10
Merluccius productus	<0.1	23
Sebastes melanops	<0.1	7
Sebastes ruberrimus	<0.1	10
Rhacochilus toxotes	<0.1	6
Sebastes saxicola	<0.1	6
Rathbunella hypoplecta	<0.1	8
Sebastes aurora	<0.1	2
Sebastes ensifer	<0.1	17
Anarrhichthys ocellatus	<0.1	3
Unid. Pleuronectidae	<0.1	1
Sebastes diploproa	<0.1	1
Sebastes lentiginosus	<0.1	10
Sebastes levis	<0.1	6
Sebastes melanostomus	<0.1	2
Halichoeres semicinctus	<0.1	1
Unid. *Icelinus*	<0.1	2
Lythrypnus dalli	<0.1	1
Mola mola	<0.1	1
Unid. *Rathbunella*	<0.1	2
Sebastes helvomaculatus	<0.1	4
Sebastes pinniger	<0.1	1
Zaniolepis frenata	<0.1	2
Argentina sialis	<0.1	2
Citharichthys sordidus	<0.1	1
Unid. *Citharichthys*	<0.1	1
Odontopyxis trispinosa	<0.1	2
Pristigenys serrula	<0.1	1
Sebastes eos	<0.1	1
Zalembius rosaceus	<0.1	1
Zaniolepis latipinnis	<0.1	1
Unid. *Zaniolepis*	<0.1	1
Total	196.7	355,570
Minimum number of species	79	
Percent *Sebastes*	86.1	

Appendix 1. *Continued.*

Species	Densities (number per 100 m^2)	Numbers
Platform base		
Sebastes semicinctus	147.9	124,480
Sebastes hopkinsi	58.3	39,700
Unid. *Sebastes* (YOY)	13.5	10,682
Sebastes jordani	13.5	10,035
Sebastes dalli	12.5	5,309
Engraulis mordax	10.3	1,573
Sebastes miniatus	9.9	5,848
Sebastes paucispinis	5.2	4,260
Sebastes entomelas	4.1	3,604
Ophiodon elongatus	3.9	1,958
Sebastes caurinus	3.5	2,461
Oxylebius pictus	2.7	1,297
Unid. *Sebastomus*	2.2	1,866
Unid. *Sebastes*	2.2	750
Sebastes rubrivinctus	1.7	1,486
Sebastes chlorostictus	1.6	1,835
Sebastes rosaceus	1.5	1,131
Zaniolepis frenata	1.5	240
Rhinogobiops nicholsii	1.4	1,056
Sebastes serranoides	1.3	293
Sebastes umbrosus	1.2	849
Sebastes saxicola	1.2	782
Sebastes simulator	1.1	998
Sebastes mystinus	1.1	295
Sebastes rosenblatti	0.8	1,008
Scorpaena guttata	0.8	609
Sebastes auriculatus	0.8	371
Damalichthys vacca	0.7	340
Phanerodon atripes	0.5	505
Sebastes elongatus	0.5	466
Unid. Embiotocidae	0.3	124
Sebastes pinniger	0.3	292
Sebastes atrovirens	0.3	88
Unid. *Sebastolobus*	0.2	46
Sebastes rufus	0.2	87
Sebastes diploproa	0.2	43
Sebastes flavidus	0.2	110
Unid. *Citharichthys*	0.2	150
Hexagrammos decagrammus	0.2	93
Sebastes serriceps	0.2	132
Sebastes crameri	0.2	53
Unid. Pleuronectidae	0.2	104
Zalembius rosaceus	0.2	154
Sebastes levis	0.2	261
Scorpaenichthys marmoratus	0.1	99
Sebastes melanostomus	0.1	29

Appendix 1. *Continued.*

Species	Densities (number per 100 m^2)	Numbers
Platform base		
Phanerodon furcatus	0.1	51
Sebastes carnatus	0.1	43
Synodus lucioceps	0.1	19
Citharichthys sordidus	0.1	105
Sebastes constellatus	0.1	87
Unid. *Rathbunella*	0.1	86
Sebastes zacentrus	0.1	84
Cymatogaster aggregatus	0.1	130
Sebastes wilsoni	0.1	92
Sebastes macdonaldi	0.1	152
Rhacochilus toxotes	0.1	40
Chromis punctipinnis	0.1	36
Unid. *Zaniolepis*	<0.1	29
Sebastes ensifer	<0.1	36
Sebastes ruberrimus	<0.1	29
Unid. Agonidae	<0.1	13
Semicossyphus pulcher	<0.1	22
Sebastes lentiginosus	<0.1	17
Rathbunella alleni	<0.1	18
Sebastes goodei	<0.1	18
Sebastes aurora	<0.1	4
Rathbunella hypoplecta	<0.1	15
Unid. Cottidae	<0.1	5
Anarrhichthys ocellatus	<0.1	7
Sebastes rastrelliger	<0.1	2
Careproctus melanurus	<0.1	2
Unid. Nettastomatidae	<0.1	2
Sebastes ovalis	<0.1	4
Unid. Zoarcidae	<0.1	1
Microstomus pacificus	<0.1	4
Chilara taylori	<0.1	1
Lyconema barbatum	<0.1	1
Unid. Ophidiidae	<0.1	1
Enophrys taurina	<0.1	3
Hydrolagus colliei	<0.1	5
Sebastes eos	<0.1	7
Sebastes helvomaculatus	<0.1	2
Sebastes moseri	<0.1	3
Merluccius productus	<0.1	2
Paralichthys californicus	<0.1	1
Pronotogrammus multifasciatus	<0.1	1
Zaniolepis latipinnis	<0.1	2
Cryptotrema corallinum	<0.1	1
Leuroglossus stilbius	<0.1	1
Sebastes babcocki	<0.1	1

Appendix 1. *Continued.*

Species	Densities (number per 100 m^2)	Numbers
Platform base		
Sebastolobus alascanus	<0.1	1
Total	311.9	229,139
Minimum Number of Species	80	
Percent *Sebastes*	96.1	
Platform shell mounds		
Sebastes semicinctus	90.3	63,008
Sebastes hopkinsi	11.9	7,598
Sebastes dalli	5.6	1,338
Unid. *Sebastes* (YOY)	5.5	3,164
Sebastes miniatus	4.0	974
Ophiodon elongatus	3.2	1,607
Rhinogobiops nicholsii	2.8	2,179
Sebastes paucispinis	1.7	1,268
Sebastes saxicola	1.6	1,539
Oxylebius pictus	1.6	694
Scorpaena guttata	1.5	1,199
Unid. *Sebastes*	1.5	402
Citharichthys spp.	1.4	580
Unid. *Sebastomus*	1.2	1,019
Cymatogaster aggregata	1.2	1,031
Sebastes caurinus	0.9	382
Sebastes jordani	0.8	436
Sebastes mystinus	0.6	58
Sardinops sagax	0.6	200
Sebastes elongatus	0.6	672
Unid. Pleuronectiformes	0.6	167
Sebastes auriculatus	0.5	56
Zalembius rosaceus	0.4	370
Sebastes rosaceus	0.4	314
Sebastes umbrosus	0.4	296
Sebastes simulator	0.4	420
Damalichthys vacca	0.4	120
Sebastes serranoides	0.3	46
Synodus lucioceps	0.3	37
Sebastes rubrivinctus	0.3	213
Merluccius productus	0.3	474
Sebastes atrovirens	0.3	16
Citharichthys sordidus	0.2	149
Zaniolepis frenata	0.2	215
Sebastes chlorostictus	0.2	192
Sebastes zacentrus	0.2	123
Sebastes entomelas	0.2	127
Unid. Embiotocidae	0.2	55
Unid. *Zaniolepis*	0.2	134
Sebastes rosenblatti	0.1	172
Unid. *Rathbunella*	0.1	89

Appendix 1. *Continued.*

Species	Densities (number per 100 m^2)	Numbers
Platform shell mounds		
Unid. Agonidae	0.1	136
Engraulis mordax	0.1	188
Unid. Zoarcidae	0.1	54
Hexagrammos decagrammus	0.1	30
Sebastes crameri	0.1	42
Zaniolepis latipinnis	0.1	38
Scorpaenichthys marmoratus	0.1	38
Sebastes diploproa	0.1	27
Phanerodon atripes	0.1	15
Sebastes ensifer	0.1	63
Microstomus pacificus	<0.1	47
Sebastes goodei	<0.1	12
Sebastes pinnifer	<0.1	35
Sebastes rufus	<0.1	12
Sebastes levis	<0.1	39
Sebastes melanostomus	<0.1	25
Anarrhichthys ocellatus	<0.1	15
Rathbunella alleni	<0.1	25
Sebastes flavidus	<0.1	15
Unid. Cottidae	<0.1	15
Sebastes carnatus	<0.1	2
Rhacochilus toxotes	<0.1	4
Rathbunella hypoplecta	<0.1	16
Unid. *Sebastolobus*	<0.1	9
Sebastes constellatus	<0.1	11
Phanerodon furcatus	<0.1	11
Unid. Stichaeidae	<0.1	8
Semicossyphus pulcher	<0.1	7
Paralabrax nebulifer	<0.1	2
Sebastes serriceps	<0.1	6
Leuroglossus stilbius	<0.1	3
Plectobranchus evides	<0.1	3
Sebastes helvomaculatus	<0.1	4
Hydrolagus colliei	<0.1	9
Icelinus filamentosus	<0.1	1
Sebastes aurora	<0.1	3
Pleuronichthys coenosus	<0.1	15
Lyconema barbatum	<0.1	2
Sebastes lentiginosus	<0.1	3
Torpedo californica	<0.1	4
Trachurus symmetricus	<0.1	7
Cryptotrema corallinum	<0.1	2
Enophrys taurina	<0.1	2
Careproctus melanurus	<0.1	1
Lycodes pacificus	<0.1	1
Paralichthys californicus	<0.1	1
Parophrys vetulus	<0.1	1

Appendix 1. *Continued.*

Species	Densities (number per 100 m^2)	Numbers
Platform shell mounds		
Unid. Scyliorhinidae	<0.1	1
Sebastes macdonaldi	<0.1	4
Sebastes wilsoni	<0.1	2
Squalus suckleyi	<0.1	1
Chromis punctipinnis	<0.1	1
Glyptocephalus zachirus	<0.1	2
Unid. *Icelinus*	<0.1	1
Oxyjulis californica	<0.1	1
Platichthys stellatus	<0.1	1
Pleuronichthys verticalis	<0.1	1
Sebastes babcocki	<0.1	1
Sebastes nigrocinctus	<0.1	1
Unid. Ophidiidae	<0.1	1
Symphurus atricaudus	<0.1	1
Total	145.7	94,162
Total number of species	88	
Percent *Sebastes*	89.4	
Natural habitats		
Sebastes hopkinsi	26.0	225,524
Sebastes semicinctus	25.8	116,082
Unid. *Sebastes* (YOY)	14.9	114,869
Sebastes jordani	7.5	84,110
Sebastes wilsoni	6.3	77,635
Unid. *Sebastes*	3.6	22,437
Unid. *Sebastomus*	2.5	30,976
Rhinogobiops nicholsii	2.3	21,169
Sebastes entomelas	2.3	13,613
Sebastes ensifer	1.8	31,083
Chromis punctipinnis	0.4	10,936
Zalembius rosaceus	0.7	6,205
Sebastes rosaceus	0.7	5,492
Sebastes mystinus	0.7	6,701
Sebastes rufus	0.6	5,357
Sebastes miniatus	0.6	3,279
Zaniolepis frenata	0.6	7,167
Sebastes simulator	0.4	5,584
Sebastes paucispinis	0.4	3,654
Sebastes rufinanus	0.4	4,338
Sebastes chlorostictus	0.4	2,953
Oxyjulis californica	0.3	4,066
Unid. *Zaniolepis*	0.3	2,764
Unid. Pleuronectiformes	0.3	4,047
Ophiodon elongatus	0.3	1,834
Sebastes constellatus	0.2	2,188
Sebastes rubrivinctus	0.2	933
Sebastes ovalis	0.2	2,439
Sebastes elongatus	0.2	1,383

Appendix 1. *Continued.*

Species	Densities (number per 100 m^2)	Numbers
Natural habitats		
Unid. *Citharichthys*	0.2	1,194
Sebastes diploproa	0.2	2,173
Sebastes moseri	0.2	1,594
Sebastes flavidus	0.2	724
Sebastes dalli	0.1	200
Unid. Agonidae	0.1	3,144
Sebastes caurinus	0.1	546
Sebastes auriculatus	0.1	90
Sebastes serranoides	0.1	730
Hydrolagus colliei	0.1	1,173
Cryptotrema corallinum	0.1	945
Semicossyphus pulcher	0.1	818
Sebastes goodei	0.1	426
Zaniolepis latipinnis	0.1	662
Scorpaena guttata	0.1	304
Unid. Cottidae	0.1	407
Oxylebius pictus	0.1	583
Unid. *Rathbunella*	0.1	406
Damalichthys vacca	0.1	408
Sebastes rosenblatti	0.1	605
Sebastes saxicola	0.1	957
Sebastes umbrosus	0.1	322
Sebastes pinniger	0.1	132
Icelinus tenuis	<0.1	139
Sebastes levis	<0.1	519
Phanerodon atripes	<0.1	748
Unid. Embiotocidae	<0.1	420
Microstomus pacificus	<0.1	853
Argentina sialis	<0.1	170
Lyopsetta exilis	<0.1	169
Plectobranchus evides	<0.1	387
Unid. Stichaeidae	<0.1	305
Citharichthys sordidus	<0.1	160
Unid. Zoarcidae	<0.1	354
Phanerodon furcatus	<0.1	534
Sebastes serriceps	<0.1	232
Sebastes zacentrus	<0.1	132
Sebastolobus alascanus	<0.1	76
Lycodes cortezianus	<0.1	128
Sebastes carnatus	<0.1	202
Sebastes crameri	<0.1	194
Sebastes melanostomus	<0.1	142
Merluccius productus	<0.1	1,279
Rathbunella alleni	<0.1	78
Unidentified *Sebastolobus*	<0.1	246
Sebastes lentiginosus	<0.1	114
Sebastes ruberrimus	<0.1	75

Appendix 1. *Continued.*

Species	Densities (number per 100 m^2)	Numbers
Natural habitats		
Leuroglossus stilbius	<0.1	51
Rhocochilus toxotes	<0.1	214
Lyconema barbatum	<0.1	276
Unid. *Icelinus*	<0.1	170
Sebastes helvomaculatus	<0.1	236
Torpedo californica	<0.1	43
Unid. *Raja*	<0.1	42
Sebastes atrovirens	<0.1	19
Rathbunella hypoplecta	<0.1	74
Sebastes eos	<0.1	77
Caulolatilus princeps	<0.1	53
Icelinus filamentosus	<0.1	76
Pronotogrammus multifasciatus	<0.1	43
Unid. Ophidiidae	<0.1	46
Synodus lucioceps	<0.1	25
Hypsurus caryi	<0.1	164
Parophrys vetulus	<0.1	67
Raja rhina	<0.1	51
Sebastes aurora	<0.1	119
Sebastes gilli	<0.1	52
Alloclinus holderi	<0.1	21
Glyptocephalus zachirus	<0.1	78
Sebastes melanops	<0.1	15
Trachurus symmetricus	<0.1	94
Anarrhichthys ocellatus	<0.1	10
Cymatogaster aggregata	<0.1	5
Embiotoca jacksoni	<0.1	25
Embiotoca lateralis	<0.1	10
Enophrys taurina	<0.1	1
Eopsetta jordani	<0.1	32
Unid. *Eptatretus*	<0.1	30
Eptatretus stouti	<0.1	11
Girella nigricans	<0.1	4
Lumpenopsis clitella	<0.1	10
Lycodes pacificus	<0.1	59
Macroramphosus gracilis	<0.1	6
Nezumia stelgidolepis	<0.1	4
Paralichthys californicus	<0.1	2
Pleuronichthys verticalis	<0.1	11
Porichthys notatus	<0.1	11
Raja binoculata	<0.1	18
Scomber japonicus	<0.1	1
Sebastes macdonaldi	<0.1	4
Xeneretmus latifrons	<0.1	9
Xystreurys liolepis	<0.1	8
Anoplopoma fimbria	<0.1	14
Atractoscion nobilis	<0.1	2

Appendix 1. *Continued.*

Species	Densities (number per 100 m^2)	Numbers
Natural habitats		
Bathyraja interrupta	<0.1	9
Brosmophycis marginata	<0.1	3
Careproctus melanurus	<0.1	4
Cephaloscyllium ventriosum	<0.1	5
Chilara taylori	<0.1	4
Chitonotus pugetensis	<0.1	3
Citharichthys stigmaeus	<0.1	1
Embassichthys bathybius	<0.1	5
Engraulis mordax	<0.1	2
Halichoeres semicinctus	<0.1	1
Hexanchus griseus	<0.1	4
Icelinus burchami	<0.1	1
Kathetostoma averruncus	<0.1	1
Lepidogobius lepidus	<0.1	4
Lythrypnus dalli	<0.1	1
Mola mola	<0.1	2
Unid. Myctophidae	<0.1	10
Myliobatis californica	<0.1	3
Nautichthys oculofasciatus	<0.1	1
Unid. Nemichthyidae	<0.1	1
Paralabrax clathratus	<0.1	2
Paralabrax nebulifer	<0.1	1
Unid. Pholidae	<0.1	2
Unid. Pleuronectidae	<0.1	2
Pleuronichthys coenosus	<0.1	4
Psettichthys melanostictus	<0.1	1
Raja inornata	<0.1	9
Raja stellulata	<0.1	3
Rhamphocottus richardsonii	<0.1	1
Scorpaenichthys marmoratus	<0.1	1
Unid. Scyliorhinidae	<0.1	3
Sebastes babcocki	<0.1	3
Sebastes maliger	<0.1	2
Sebastes melanosema	<0.1	3
Sebastes nigrocinctus	<0.1	1
Sebastes phillipsi	<0.1	32
Squalus suckleyi	<0.1	1
Squatina californica	<0.1	2
Stereolepis gigas	<0.1	1
Symphurus atricaudus	<0.1	1
Unid. Trichiuridae	<0.1	1
Xeneretmus triacanthus	<0.1	1
Total	104.6	847,566
Total number of species	144	
Percent *Sebastes*	90.8	