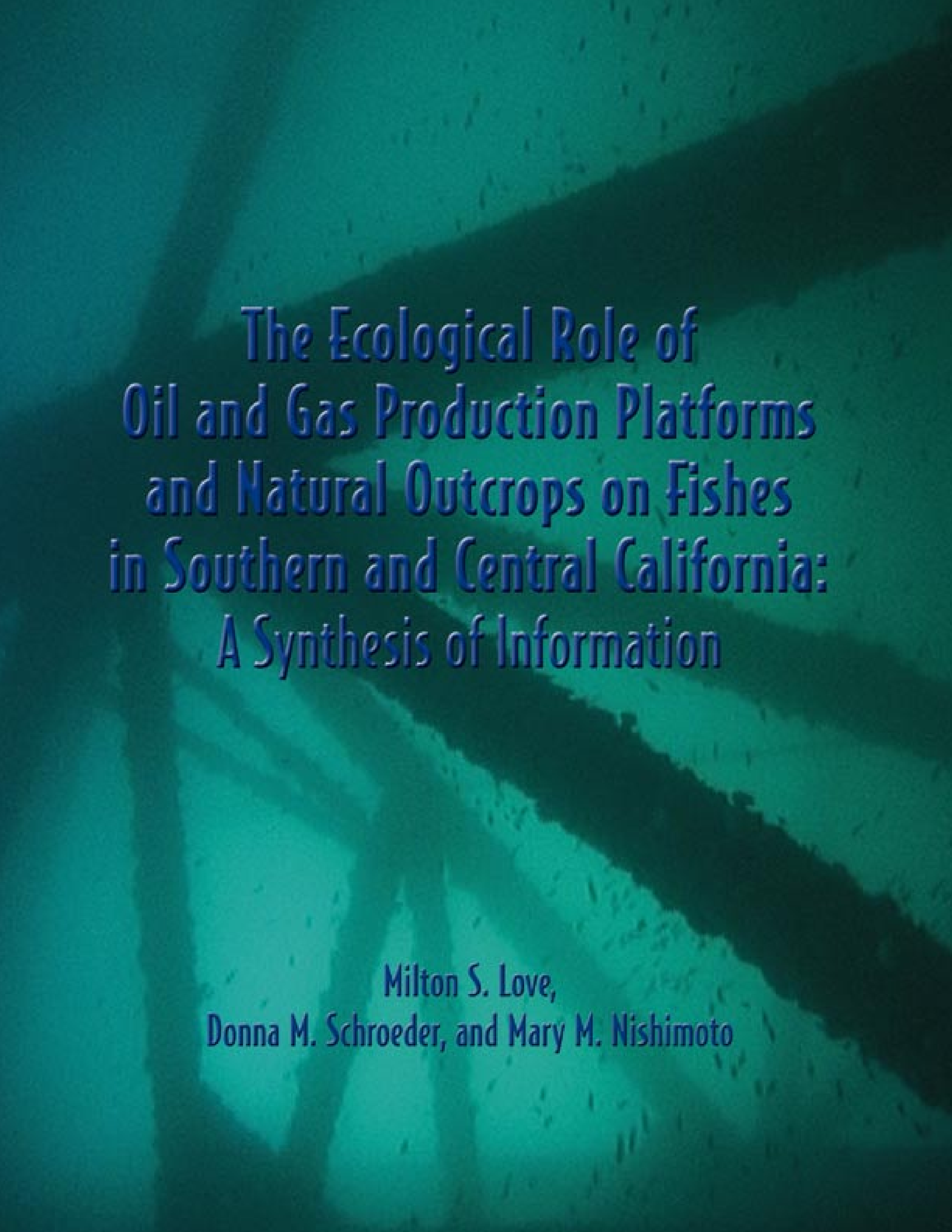

The Ecological Role of Oil and Gas Production Platforms and Natural Outcrops on Fishes in Southern and Central California: A Synthesis of Information

Milton S. Love,
Donna M. Schroeder, and Mary M. Nishimoto

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OCS Study MMS 2003-032

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Front Cover: Background, young-of-the-year rockfishes, Platform Grace (Mary Nishimoto). From upper left: Seastars and mussels, midwater, Platform Holly (Dan Dugan); Platform Irene (Linda Snook); juvenile bocaccio, midwater, Platform Gilda (Donna Schroeder); young-of-the-year yellowtail rockfish, Platform Irene (Rick Starr); flag rockfish, Platform Grace (Donna Schroeder); young-of-the-year cowcod, shell mound, Platform Gail (Milton Love); juvenile vermilion rockfish, bottom, Platform Grace (Donna Schroeder).

Back Cover: Kelp rockfish and club anemones, midwater, Platform Holly (Dan Dugan).

Project Cooperation
This research addressed an information need identified by the U. S. Department of the Interior's Minerals Management Service, Pacific OCS Region, Camarillo, California.

Report Availability
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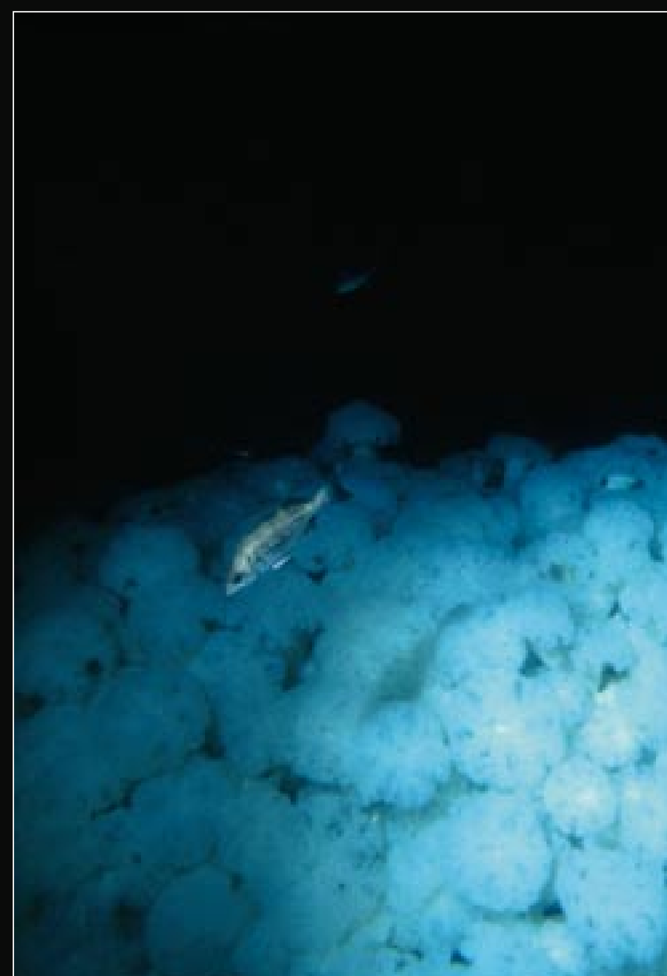
LINDA SNOOK

Mexican rockfish at bottom of Platform Gail.



EXECUTIVE SUMMARY

Information Needed

Production of oil and gas from offshore platforms has been a continual activity along the California coast since 1958. There are 26 oil and gas platforms off California, 23 in federal waters (greater than 3 miles from shore) and 3 in state waters. The platforms are located between 1.2 to 10.5 miles from shore and at depths ranging from 11 to 363 m (35–1,198 ft.). Crossbeams and diagonal beams occur about every 30 m (100 ft.), from near the surface to the seafloor. The beams extend both around the perimeter of the jacket and reach inside and across the platform. The beams and vertical pilings (forming the jacket) and the conductors on all platforms are very heavily encrusted with invertebrates and provide important habitat for fishes. The seafloor surrounding a platform is littered with mussel shells. This "shell mound" (also called "mussel mound" or "shell hash") is created when living mussels, and other invertebrates, are dislodged and fall to the seafloor during platform cleaning or storms.

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*. Platform decommissioning can take a number of forms, from leaving much, or all, of the structure in place to complete removal. Along with the platform operator, many federal and state agencies are involved in the decommissioning process. All oil and gas platforms have finite economic lives and by the beginning of the twenty-first century, seven platforms in southern California had been decommissioned and a number of others appeared to be nearing the end of their economic lives.

Management decisions regarding the decommissioning of an oil and gas platform are based on both biological and socioeconomic information. This study addressed the need for resource information and better understanding of how offshore oil/gas platforms contributed to the fish populations and fishery productivity in the Santa Maria Basin and Santa Barbara Channel. Prior to our studies, there was almost no biological information on Pacific Coast platform fish assemblages. This necessary research involved broad scale sampling at numerous oil/gas platforms and natural reefs. Research objectives included 1) characterizing the fish assemblages around platforms and natural reefs, 2) examining how oceanography affects patterns of recruitment and community structure of reef fishes, and 3) describing the spatial and temporal patterns of fish diversity, abundance and size distribution among habitat types (e. g., platforms and natural outcrops).

Research Summary

Between 1995 and 2001, we studied oil and gas platforms sited over a wide range of bottom depths, ranging between 29 and 224 m (95 and 739 ft.) and sited from north of Point Arguello, central California to off Long Beach, southern California. However, most of the platform research occurred in the Santa Barbara Channel and Santa Maria Basin. The Santa Barbara Channel and Santa Maria Basin are situated in a dynamic marine transition zone between the regional flow patterns of central and southern California. The Santa Barbara Channel is about 100 km long by about 50 km wide (60 x 20 miles) and is bordered on the south by the Northern Channel Islands (San Miguel, Santa Rosa, Santa Cruz, and Anacapa). This area is bathed in a complex hydrographic system of currents and water masses. Generally, cool coastal waters from the California Current enter the Santa Barbara Channel through its west entrance at Point Conception. Warm waters from the Southern California Bight flow in the opposite direction into the channel through its eastern entrance. Surface waters are substantially warmer in the Bight than north of Point Conception due to less wind-induced vertical mixing, the solar heating of surface waters, and currents of subtropical waters entering from the south. The convergence of different water masses in the Santa Barbara Channel results in relatively large scale differences in physical parameters (e.g., temperature, salinity, oxygen, and nutrient concentrations) and biotic assemblages (e. g., flora and fauna).

Scuba surveys were conducted at shallow depths and submersible surveys, using the research submarine *Delta*, at greater depths. We also surveyed shallow-water and deeper-water rock outcrops, many in the vicinity of platforms. Nine nearshore, shallow-water rock outcrops, seven on the mainland and two at Anacapa Island, were monitored annually from 1995 to 2000. These natural outcrops are geographically distributed across the Santa Barbara Channel providing opportunities for spatial comparisons. In addition, we surveyed over 80 deeper-water outcrops, in waters between 30 and 360 m (100

Opposite: Juvenile widow rockfish in platform midwater. (Photograph by Lovelab, UC Santa Barbara) and 1,180 ft.) deep, located throughout the Southern California Bight and off Points Conception and Arguello. These sites included a wide range of such habitats as banks, ridges, and carbonate reefs, ranging in size from a few kilometers in length to less than a hectare in area. On these features, we focussed on hard bottom macrohabitats, including kelp beds, boulder and cobble fields, and bedrock outcrops. Most of these deeper-water sites were visited once, a few were surveyed during as many as four years and one outcrop, North Reef, near Platform Hidalgo, was sampled annually.

Most of our oil and gas platform surveys were conducted at nine structures (Platforms Irene, Hidalgo, Harvest, Hermosa, Holly, Gilda, Grace, Gina, and Gail) located in the Santa Barbara Channel and Santa Maria Basin. Between 1995 and 2000, we conducted annual surveys on the shallow portions of these nine platforms. The shallowest of the nine platforms, Gina, was surveyed from surface to bottom depths using scuba techniques. Deep-water surveys conducted between 1995 and 2001, using the research submersible, *Delta*, studied the same platforms excluding the bottom of Gilda and all of Gina. In 1998, one submersible survey was conducted around Platform Edith, located off Long Beach. In 2000 partial submersible surveys were completed around Platforms C, B, A, Hillhouse, Henry, Houchin, Hogan, and Habitat.

Patterns in Shallow-Water Habitats

Regional and local processes influenced patterns of outcrop fish assemblages in shallow waters. At regional spatial scales, outcrop fish abundance patterns often shifted abruptly as oceanographic patterns changed, roughly defining a cool-temperate assemblage in the western Santa Barbara Channel, and a warm-temperate assemblage in the eastern Santa Barbara Channel. This distinctive spatial pattern was observed in both oil and gas platform and natural outcrop habitats. In shallow waters, there was greater variability in platform species assemblages and population dynamics compared to natural outcrop assemblages, and this was most likely caused by the greater sensitivity of platform habitats to changing oceanographic conditions. Local processes that affected fish distribution and abundance were related to habitat features, where depth, relief height, and presence of giant kelp all played important roles. On platform habitat, we found that the majority of newly settled rockfish juveniles resided at depths greater than 26 m (86 ft.), although there were differences among species.

Characterization of the Deepwater Platform Fish Assemblages

With the exception of the shallow-water Platform Gina, all of the platforms we surveyed were characterized by three distinct fish assemblages: midwater, bottom, and shell mound. Rockfishes, totaling 42 species, dominated these habitats. Fish densities at most platforms were highest in the midwater habitat reflecting the depth preferences of young-of-the-year rockfishes. Young-of-the-year rockfishes represented the most abundant size classes in platform midwaters. Platform midwaters were nursery grounds for rockfishes as well as for a few other species, including cabezon and painted greenling. The young-of-the-year of at least 16 rockfish species inhabited these waters. Settlement success was affected by oceanographic conditions. Densities of young-of-the-year varied greatly between years and platforms. Young-of-the-year rockfish densities often varied by an order of magnitude or greater among survey years and platforms. From 1996 through 1998, rockfish settlement was generally higher around the platforms north of Point Conception as compared to platforms in the Santa Barbara Channel. This finding is reflective of the generally colder, more biologically productive waters in central California during the 1980s and much of the 1990s. Colder waters in 1999 were associated with relatively high levels of rockfish recruitment at all platforms surveyed. In 2000 and 2001, juvenile rockfish recruitment at platforms in the Santa Barbara Channel remained higher than pre-1999 levels, possibly reflecting the oceanographic regime shift to cooler temperatures that may be occurring in southern California.

Subadult and adult rockfishes and several other species dominated the bottom habitats of platforms. The bottom habitat of some platforms is also important nursery habitat as, in some instances, young-of-the-year rockfishes were observed in very large numbers. In general, more than 90% of all the fishes around platform bottoms were rockfishes. Bottom depth strongly influenced the number of species, species diversity, and density of fishes living around platform bases. This is distinctly different than the pattern observed in platform midwaters. The platform base provides habitat for not only fishes but also their prey and predators.

Shell mounds supported a rich and diverse fish assemblage. As at other platform habitats, rockfishes comprised the vast majority of the fishes. The many small sheltering sites created by mussels, anemones, and other invertebrates on the shell mounds created a habitat occupied by small fishes. Many of these fishes were the young-of-the-year and older juveniles of such species as lingcod and copper, flag, greenblotched, and pinkrose rockfishes and cowcod. The adults of these species also inhabited the platform bottom.

Platform versus Reef Fish Assemblages

We compared the species composition of the fish assemblages at Platform Hidalgo and at North Reef, an outcrop located about 1,000 m (3,300 ft.) from the platform. The assemblages were quite similar, both were dominated by rockfishes. In general, the distinctions between the platform and outcrop assemblages were based on differences in species densities, rather than species' presence or absence. Most species were more abundant at Platform Hidalgo. Halfbanded, greenspotted, flag, greenstriped, and canary rockfishes, and all three life stages of lingcod (young-of-the-year, immature, adult) and painted greenling had higher densities around the platform. Five species (pink seaperch, shortspine combfish, pygmy, squarespot, and yellowtail rockfishes) were more abundant at the outcrop. Young-of-the-year rockfishes were found at both Platform Hidalgo (primarily in the midwaters) and at North Reef. Young-of-the-year rockfish densities were higher at the platform than at the outcrop in each of the five years studied. In several years, their densities were more than 100 times greater at Platform Hidalgo compared to North Reef.

Rockfishes numerically dominated the fish assemblages at almost all of the platform and hard seafloor habitats in our study. Overall species richness was greater at the natural outcrops (94) than at the platforms (85). There was a high degree of overlap in species between platforms and outcrops and differences were primarily due to generally higher densities, of more species, at platforms. In general, canary, copper, flag, greenblotched, greenspotted, greenstriped, halfbanded, vermilion rockfishes, bocaccio, cowcod, and widow rockfish young-of-the-year, painted greenling and all life history stages of lingcod were more abundant at platforms than at all or most of the outcrops studied. Yellowtail rockfish and the dwarf species pygmy, squarespot, and swordspine rockfishes were more abundant on natural outcrops.

Findings

Our research demonstrates that some platforms may be important to regional fish production. The higher densities of rockfishes and lingcod at platforms compared to natural outcrops, particularly of larger fishes, support the hypothesis that platforms act as de facto marine refuges. High fishing pressure on most rocky outcrops in central and southern California has led to many habitats almost devoid of large fishes. Fishing pressure around most platforms has been minimal. In some locations, platforms may provide much or all of the adult fishes of some heavily fished species and thus contribute disproportionately to those species' larval production.

Platforms usually harbored higher densities of young-of-the-year rockfishes than natural outcrops and thus may be functionally more important as nurseries. Platforms may be more optimal habitat for juvenile fishes for several reasons. First, because as structure they physically occupy more of the water column than do most natural outcrops; presettlement juvenile or larval fishes, transported in the midwater, are more likely to encounter these tall structures than the relatively low-lying natural rock outcrops. Second, because there are few large fishes in the midwater habitat, predation on young fishes is probably lower. Third, the offshore position and extreme height of platforms may provide greater delivery rates of planktonic food for young fishes. Most of the natural outcrops we found that had high densities of young-of-the-year rockfishes were similar to platforms as they were very high relief structures that thrust their way well into the water column.

Our research, and reviews of existing literature, strongly implies that platforms, like natural outcrops, both produce and attract fishes, depending on species, site, season, and ocean conditions. Platform fish assemblages around many of the deeper and more offshore platforms probably reflect recruitment of larval and pelagic juvenile fishes from both near and distant maternal sources, not from attraction of juvenile or adult fishes from natural outcrops. Annual tracking observations of strong year classes of both flag rockfish and bocaccio imply that fishes may live their entire benthic lives around a single platform. A pilot study showed that young-of-the-year blue rockfish grew faster at a platform than at a natural outcrop indicating that juvenile fishes at platforms are at least as healthy as those around natural outcrops.

Management Applications

In this report, we discuss the ecological and political issues that surround platform decommissioning in California, including the ecological consequences of the four platform decommissioning alternatives: (1) Complete Removal, (2) Partial Removal and Toppling, and (3) Leave-in-Place.

Complete Removal: In complete removal, operators may haul the platform to shore (for recycling, reuse, or disposal) or it can be towed to another site and reefed.

A typical full-removal project begins with well abandonment in which the well bores are filled with cement. The topsides, which contain the crew quarters and the oil and gas processing equipment, are cut from the jacket and removed and the conductors are removed with explosives. Finally, the piles that hold the jacket to the seabed are severed with explosives and the jacket is removed.

Completely removing a platform for disposal on land will kill all attached invertebrates. If some of the platform structure is hauled to a reef area and replaced in the water, some of these animals may survive, depending on water depth and the length of time the structure is exposed to the air. The explosives used to separate the conductor and jacket from the seafloor kill large numbers of fishes. In a study in the Gulf of Mexico, explosives were placed 5 m (15 ft.) below the seafloor to sever the well conductors, platform anchor pilings and support legs, of a platform in about 30 m (100 ft.) of water. All of the fishes on or near the bottom and most of the adult fishes around the entire platform suffered lethal concussions. Marine mammals and sea turtles may also be indirectly killed by damage to the auditory system.

The use of explosives to remove or topple a platform may also complicate fishery-rebuilding programs. Cowcod, a species declared overfished by NOAA Fisheries, provides an example. This species is the subject of a federal rebuilding plan that severely limits catches. In 2001, this was 2.4 metric tons or about 600 fish. Based on our research, there are at least 75 adult cowcod on Platform Gail. If explosives are used to remove Gail, all of these fish will be killed. The loss of at least 75 adult cowcod may be sufficiently large to complicate the rebuilding plan.

Partial Removal and Toppling: Under both partial removal and toppling the topsides are removed. In partial removal, the jacket is severed to a predetermined depth below the surface and the remaining subsurface structure is left standing. In toppling, the conductors and piles are severed with explosives and the jacket is pulled over and allowed to settle to the seafloor. In both partial removal and toppling, conductors need not be completely removed. Retaining conductors would add habitat complexity to a reefed platform.

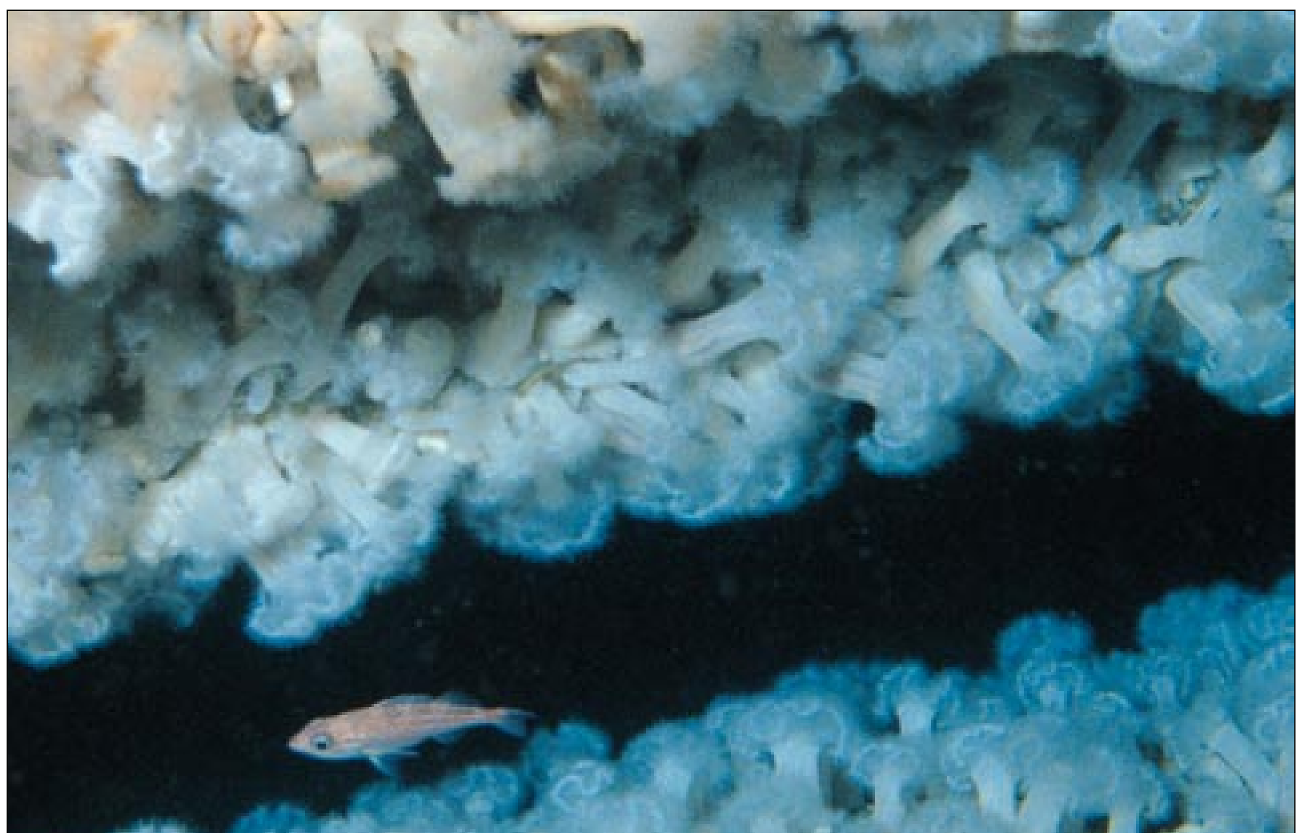
While the immediate mortality impact to attached invertebrates of partial removal is greater than leaving the platform structure in place, mortality risks to both fishes and invertebrates are much lower than in both toppling and total removal. Partial removal causes fewer deaths than does toppling for two reasons. First, because partial removal does not require explosives (as does toppling), there is relatively little fish, marine mammal, sea turtle, and motile invertebrate (such as crab) mortality. In addition, when a platform is partially removed, vertebrate and invertebrate assemblages associated with the remaining structure are likely to be minimally affected. In contrast, when a platform is toppled, the jacket falls to the seafloor, and, depending on bottom depth, many, if not most of the attached invertebrates die.

Both partial removal and toppling would produce reefs with somewhat different fish assemblages than those around intact platforms. With the shallower parts of the platform gone, it is likely that partial removal would result in fewer nearshore reef fishes, such as seaperches, basses, and damselfishes. However, young-of-the-year rockfishes of many species recruit in large numbers to natural outcrops that have crests in about 30 m (100 ft.) of water or deeper. Thus, it is possible that partial removal would result in little or no reduction in young-of-the-year recruitment for many rockfish species. The pelagic stage of some rockfish species, particularly copper, gopher, black-and-yellow and kelp, may recruit only to the shallowest portions of the platform. For these species, both partial removal and toppling would probably decrease juvenile recruitment, depending on the uppermost depth of the remaining structure. Young-of-the-year rockfishes, which make up the bulk of the fish populations in the platform midwater habitat, would probably be less abundant around a toppled platform compared to a partially removed one. Because most California platforms reside in fairly deep water, toppled platforms might reside at depths below much rockfish juvenile settlement. Thus, toppling might result in lowered species composition and fish density. However, depending on the characteristics of the platform, a toppled structure, with twisted and deformed pilings and beams, might have more benthic complexity than one that is partially removed. This might increase the number of such crevice dwelling fishes as pygmy rockfishes.

It is difficult to catch fishes that live inside the vertically standing platform jacket. Our observations demonstrate that many of the rockfishes living at the platform bottom, such as cowcod, bocaccio, flag, greenspotted, and greenblotched rockfishes, dwell in the crevices formed by the bottom-most crossbeam and the seafloor. To a certain extent, these fishes are protected from fishing gear by the vertical mass of the platform, a safeguard that would persist if the platform were partially removed, particularly if the conductors remained in place. It would be much easier to fish over a toppled platform, as more of the substrate would be exposed to fishing gear.

Coast Guard regulations do not require a minimum depth below the ocean surface to which a decommissioned platform must be reduced. The decision on how much of the jacket and conductors is left in place is based on both a Coast Guard assessment and the willingness of the liability holder to pay for the navigational aids required by the Coast Guard. As mussels become rare below about 30 m (100 ft.) on most platforms, the mistaken assumption that all partially removed platforms must be cut to 24–30 m (80–100 ft.) below the surface has led some to conclude that this will inevitably lead to a severe reduction in the amount of mussels that fall to the bottom and, thus, to a change in or end to, the shell mound community. This is not necessarily the case.

Leave-in-Place: A platform could be left in its original location at the time of decommissioning. The topsides would be stripped of oil and gas processing equipment, cleaned, and navigational aids installed. If a platform were left in place, the effect on platform sea life would be minimal.



MARY NISHIMOTO

*Whitespeckled rockfish and white anemones (*Metridium *sp.).*

Pacific Coast Platforms

In this report we have also included a brief summary of information on all of the Pacific Coast platforms (Appendix 1), densities of all fishes observed at each platform during scuba and submersible surveys (Appendix 2 and Appendix 3, respectively), and a list of the 20 most important sites, both platforms and natural outcrops, for the most abundant species in our deepwater study (Appendix 4).

Research Needs

Our research demonstrates that additional biological information is needed in the decommissioning process. These information needs fall into three categories: (1) A comparison of the ecological performance of fishes living at oil platforms and on natural outcrops, (2) A definition of the spatial distribution of economically important species (of all life history stages) within the region of interest and a definition of the connectivity of habitats within this region, and (3) An understanding of how habitat modification of the platform environment (e.g., removal of upper portion or addition of bottom structure) changes associated assemblages of marine life at offshore platforms.

EXECUTIVE SUMMARY

Major questions remaining to be addressed include:

What Fishes Live Around Platforms and Nearby Natural Reefs?

In order to assess the relative importance of a platform to its region, it is essential to conduct basic surveys not only around the platform, but also at nearby reefs. A majority of platforms have not been surveyed.

How Does Fish Production around Platforms Compare to that at Natural Outcrops?

It is possible to compare fish production between habitats by examining (1) fish growth rates, (2) mortality rates, and (3) reproductive output. A pilot study compared the growth rates of young-of-the-year blue rockfish at Platform Gilda and Naples Reef and another examining young-of-the-year mortality rates is planned. Additional work is needed to determine larval dispersal patterns and differences in densities at various study sites. For example, we now have enough data to study the relative larval production per hectare of cowcod and bocaccio at Platform Gail versus that on natural outcrops.

What Is the Relative Contribution of Platforms in Supplying Hard Substrate and Fishes to the Region?

This research would put in perspective the relative contribution of platforms in supplying hard substrate and reef fishes to their environment.

First, this requires knowledge of the rocky outcrops in the vicinity of each platform; this is derived from seafloor mapping. Once the mapping is complete, visual surveys of the outcrops, using a research submersible, will determine the fish assemblages and species densities in these habitats. Knowing the areal extent of both natural and platforms habitats and the densities of each species in both of these habitats, it is then possible to assess the total contribution of each platform to the fish populations and hard substrate in that region.

How Long Do Fishes Reside at Oil/Gas Offshore Platforms?

It is unclear how long fishes are resident to platforms. For instance, does the large number of fishes, particularly such species as the overfished bocaccio and cowcod, remain around the platforms for extended periods? Knowledge of the residence time of these species would allow us to more accurately determine if platforms form optimal habitat for these species.

What are the Effects of Platform Retention or Removal on Fish Populations within a Region?

As an example, what effect would platform retention or removal have on young-of-the-year fish recruitment? Would the young rockfishes that settle out at a platform survive in the absence of that platform? Our surveys demonstrate that planktonic juvenile fishes, particularly rockfishes, often settle to platforms in substantial numbers. If that platform did not exist, would these young fishes have been transported to natural outcrops? Knowing how long it would take rockfish larvae to reach suitable natural outcrops, and what percent of these larvae would likely die before reaching these outcrops, will give a sense of the importance of a platform as a nursery ground.

Similarly, using a synthesis of oceanographic information, it is possible to model the fate of larvae produced by fishes living at a platform.

How Does Habitat Modification of the Platform Environment (e.g., Removal of Upper Portion or Addition of Bottom Structure) Change Associated Assemblages of Marine Life?

All decommissioning options except leave-in-place involve modification of the current physical structure of offshore platforms. Is it possible to increase fish diversity and density by altering the seafloor or the platform itself? For instance, it would be useful to add complexity, in the form of quarry rock or other structure, to the shell mound around a platform, and follow the changes in fish assemblages.

Descriptive information such as depth distribution and life history information is also useful in determining how decommissioning options affect the environment. Experimental research, using a BACI design or similar approach, can aid in predicting how the biotic community will respond to such structural changes.

Chapter 1

INTRODUCTION

Milton S. Love, Donna M. Schroeder, and Mary M. Nishimoto

Goals and Objectives

Production of oil and gas from offshore platforms has been a continual activity along the California coast since 1958. All oil and gas platforms have finite economic lives and at the beginning of the twenty-first century, seven platforms in southern California have been decommissioned and a number of others appear to be nearing the end of their economic lives.

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*. Platform decommissioning can take a number of forms, from leaving much, or all, of the structure in place to complete removal (see Chapter 4, page 4-1). Along with the corporation that owns the platform, federal agencies that are involved in the decommissioning process include the Minerals Management Service (for Outer Continental Shelf platforms), U. S. Coast Guard, U. S. Army Corps of Engineers, National Marine Fisheries Service, U. S. Environmental Protection Agency, U. S. Occupational Safety & Health Administration. California State agencies include the California State Lands Commission (for platforms in State waters), California Regional Water Quality Control Districts (for platforms in State waters), California Coastal Commission, and California Fish and Game Commission. At the local level the County Air Pollution Control Districts and agencies such as the County Energy Division would also play a role.

Off California, three platforms, Harry (in 1974), Helen (in 1978), and Herman (in 1978) were decommissioned through complete removal without a great deal of controversy. Public debate arose over decommissioning of platforms Hilda, Hazel, Hope, and Heidi when a recreational angler's group, desiring to continue fishing on these structures, began to lobby for their retention. Ultimately, the four platforms were removed in 1996. It appears certain that future decommissioning of California platforms will be controversial because of conflicting desires regarding the fate of platforms on the part of various marine stakeholders (see Chapter 4, page 4-1).

Since 1995, our group, first funded by the Biological Resources Division of the U. S. Geological Survey, the Minerals Management Service and most recently by the California Artificial Reef Enhancement Program, has conducted research on the fishes that live around the platforms and on natural rock outcrops. Our goals have been to determine the patterns of fish assemblages around both platforms and outcrops and to identify the processes that may have generated these patterns. In addition, we are attempting to understand the linkages between habitats among different fish life history stages.

Previous Research

Decommissioning decisions in California will have a biological as well as socioeconomic and cultural component. Therefore, it is timely to summarize what is known about the biology and ecology of the fauna of these structures. Our emphasis has been on the fish assemblages.

Our research on platforms and outcrops occurred between 1995 and 2001. Before our research began, only a few fish surveys had been conducted around California platforms. Most of this work was conducted around platforms Hilda and Hazel, two shallow-water platforms off Summerland, just below Santa Barbara (Carlisle et al. 1964; Allen and Moore 1976; Bascom et al. 1976). Both of these structures were removed in 1996. Carlisle et al. (1964) found an average of about 6,000 fish under each platform. Allen and Moore (1976) estimated an average of about 20,000 fishes, occasionally reaching at least 30,000. Rockfishes, particularly young-of-the-year fishes, and sea perches dominated the assemblages, kelp and barred sand bass were also abundant. Large numbers of young bocaccio and widow rockfish living around platforms A, B, and C in the Santa Barbara Channel were tagged by the California Department of Fish and Game (Hartmann 1987). Six bocaccio were recovered as adults. All had traveled to natural outcrops, one 148 km (94 miles) away from the platforms. Love and Westphal (1990) compared fishes captured around oil platforms and at two nearby natural outcrops in the Santa Barbara Channel. Rockfishes were the most commonly taken species. Young rockfishes were most abundant at the platforms, rockfishes on natural outcrops tended to be older. A pilot survey of fishes, using a remotely operated vehicle at Platform Hidalgo and nearby natural outcrops (Love et al. 1994), identified large numbers of young rockfishes at the platform and few at natural outcrops. Benthic rockfishes were more abundant at natural outcrops.

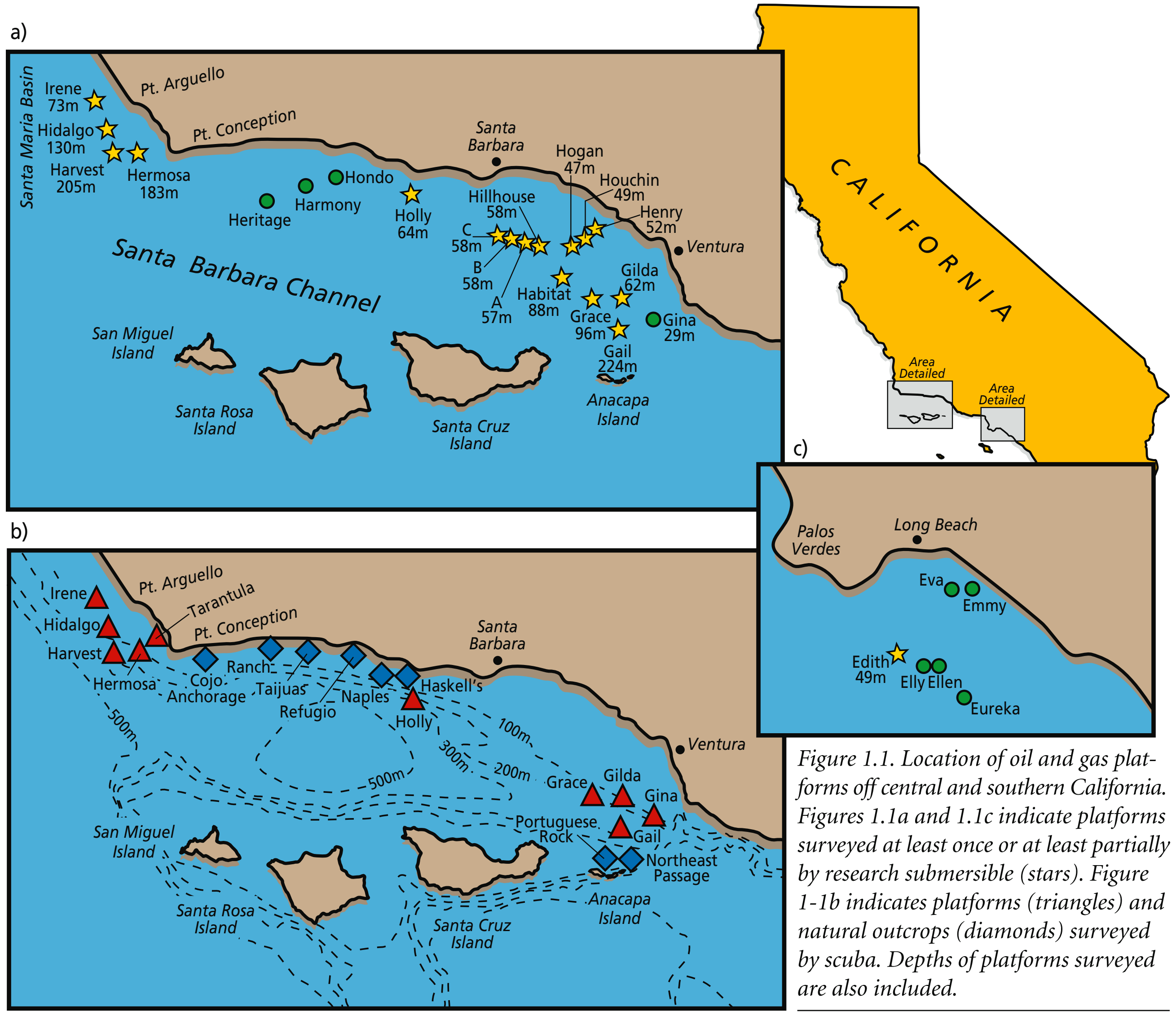


Figure 1.1. Location of oil and gas platforms off central and southern California. Figures 1.1a and 1.1c indicate platforms surveyed at least once or at least partially by research submersible (stars). Figure 1-1b indicates platforms (triangles) and natural outcrops (diamonds) surveyed by scuba. Depths of platforms surveyed are also included.

Our current research began in 1995, preliminary data is found in Love et al. (1999, 2000, 2001) and Schroeder et al. (1999) and we have incorporated that information into this report.

Study Area

Platforms

There are 26 oil and gas platforms off California, 23 in federal waters (greater than 3 miles from shore) and 3 in state waters (Figures 1.1a, b, and c). The platforms are located between 1.2 to 10.5 miles from shore and at depths ranging from 11 to 363 m (35–1,198 ft.). Information regarding location, depth, and other physical features of California's offshore platforms are described in Appendix 1.

All California platforms are similar in design (Figure 1.2); they primarily vary in size. The above-water structures, including oil and gas processing equipment and crew living and working quarters are termed the *topside* (also *topside facilities* and *deck*). The vertical pipes that carry the oil and gas are the *conductors*. The parts of the structure that are embedded in the bottom and protrude through the surface to support the topside structural components form the *jacket* that includes the crossbeams, legs, and the piles inside the legs. In general, the jackets of California platforms are made of carbon steel and the topsides are composed of steel plate and other structural steel components. Platforms also contain a relatively small amount of cement.

Crossbeams and diagonal beams occur about every 30 m (100 ft.), from near the surface to the seafloor. The beams extend both around the perimeter of the jacket and reach inside and across the platform. This web work of cross beams provides a great deal of habitat for both invertebrates

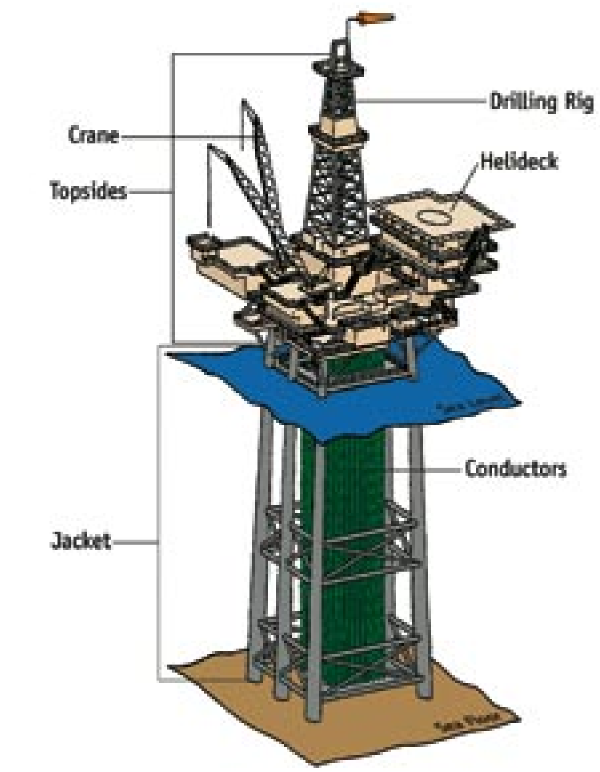


Figure 1.2. A typical oil/gas platform off southern California. Adapted from Manago and Williamson (1998).

and fishes. All of the platforms we studied have a crossbeam on the seafloor, although portions of the beam may be either buried in sediment or undercut by currents.

The seafloor surrounding a platform is littered with mussel shells. This "shell mound" (also called "mussel mound" or "shell hash") is created when living mussels, and other invertebrates, are dislodged during platform cleaning or storms. We observed shell mounds under and around all of the platforms we surveyed. Only a few of the more shallow shell mounds (around platforms Gina, Grace, Henry, and Houchin) have been accurately mapped (Sea Surveyor Inc. 2003). These mounds ranged from 4–6 m (13–19 ft.) high and were either oval or round in shape. Dimensions of these four mounds were: Gina, oval, 45 x 64 m (150 x 210 ft.); Grace, oval, 61 x 118 m (200 x 390 ft.); Henry, round, 76 m (250 ft.) in diameter; Houchin, round, 85 m (280 ft.) in diameter. Current patterns, rate of shell deposition, and age of platform all play a role in the size of shell mounds.

Rock Outcrops

An objective of our research was to compare fish assemblages and fish productivity at platforms and natural outcrops in central and southern California. Understanding spatial variability and trends in fish populations at these sites is important as it aids in understanding the regional importance of platforms as fish habitat. These sites included a wide range of such mesohabitats as banks, ridges, and carbonate buildups, ranging in size from a few kilometers in length to less than a hectare in area. On these features, we focussed on hard bottom macrohabitats, including kelp beds, boulder and cobble fields, and bedrock outcrops following standard, statistically based sampling methods and techniques.

Physical Oceanography and Biogeography of the Platform Study Area

General Description

The study area includes the Santa Barbara Channel and Santa Maria Basin (Figure 1.1). These oceanographic bodies are situated in a dynamic marine transition zone between the regional flow patterns of central and southern California. The Santa Barbara Channel is about 100 km long by about 50 km wide (60 x 20 miles) and is bordered on the south by the Northern Channel Islands (San Miguel, Santa Rosa, Santa Cruz, and Anacapa). Within the Santa

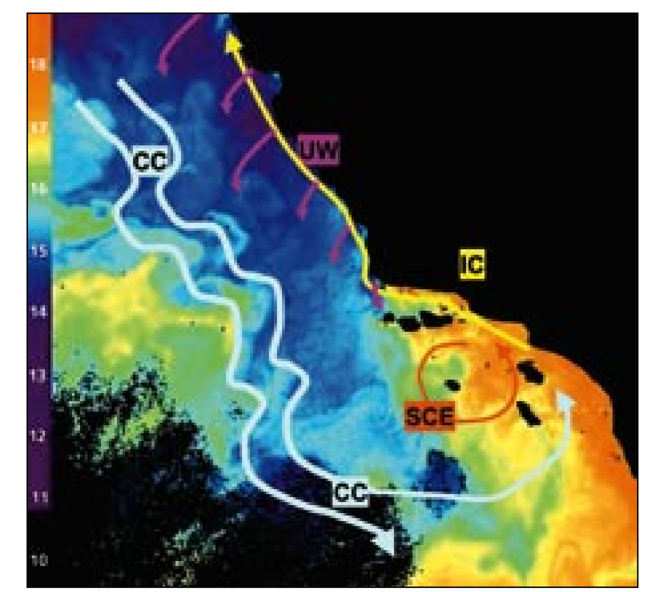


Figure 1.3. Satellite image of sea surface temperature (SST) and a diagram of the large-scale current patterns off the central and southern California coast. This image shows the predominant, large-scale SST pattern along with smaller scale features such as eddies and fronts (temperature scale, degrees Celsius). The generalized flow of the California Current (CC), the Inshore Countercurrent (IC), and Southern California Eddy (SCE) overlay the SST image. Plumes of cold, nutrient-rich, upwelled water (represented by dark blue and purple) originate near the coast and are directed offshore (magenta arrows).

The invertebrate communities of the jacket, conductors and shell mounds

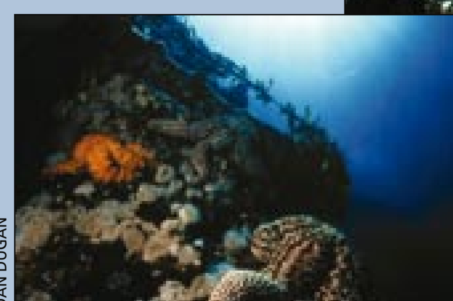
DAN DUGAN

Rock crab

The jackets and conductors of all platforms are very heavily encrusted with invertebrates. Depth zonation of the invertebrate community is evident. An extremely thick layer of mussels extends from the intertidal zone to depths of at least 30 m (100 ft) (and to at least 44 m, 145 ft., on some platforms). Both *Mytilus galloprovincialis* and *M. californianus* occur in these upper depths, although *M. galloprovincialis* is more common in the shallower portions of this zone (J. Dugan, personal communication). Although mussels dominate this habitat, other invertebrate taxa are abundant in this upper layer. Common inhabitants include barnacles, seastars (primarily *Pisaster giganteus*), rock scallops (*Crassadoma gigantea*), rock oysters and jingle shells (*Chama arcana* and *Pododesmus cepio*), sea anemones (*Anthopleura xanthogrammica*, *Metridium* sp.), caprellid amphipods, rock crabs (*Cancer antennarius*), limpets (including *Lottia gigantea*, *Lottia* sp., *Tectura* spp., and *Acmaea mitra*), gooseneck barnacles (*Pollicipes polymerus*), and sessile tunicates. With greater depth, the diverse mussel community wanes and tends to be replaced by a blanket of club anemones (*Corynactis californicus*). At greater depths yet, white anemones (*Metridium* sp.) and sponges begin to dominate these platform structures. These organisms, along with crabs (*Munida* sp.) and sea stars, characterize the deepest parts of the deepwater platforms we surveyed (J. Dugan, personal communication; M. Love, unpublished observations).

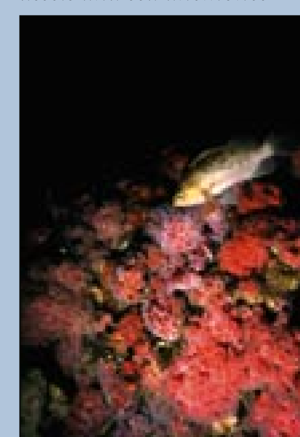
DAN DUGAN

Mussels and sea anemones



DAN DUGAN

Mussels and sea stars



DAN DUGAN

Club anemone and kelp rockfish

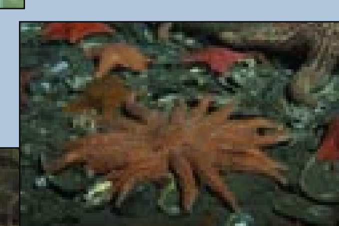
LOVELAB

Metridium sp. and galatheid crab

MILTON LOVE

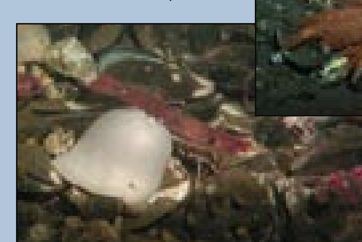
Metridium sp.

Our observations indicate that, depending on bottom depth, a number of invertebrate species are abundant on the shell mounds. Common mound species include three species of seastars (*Pisaster brevispinus, P. giganteus,* and *P. ochraceus*), sunstars (*Pycnopodia helianthoides, Rathbunaster* sp.), bat stars (*Asterina miniata*), brittle stars, rock crabs (*Cancer anthonyi*, *C. antennarius,* and *C. productus*), king crabs (*Paralithodes rathbuni*), opisthobranchs (*Pleurobranchaea californica*), spot prawns (*Pandalus platyceros*), octopi (*Octopus* spp.), and sea anemones (*Metridium* sp.) (M. Love, unpublished observations).



DONNA SCHROEDER

Rathbunaster sp.



LOVELAB

Spot prawn

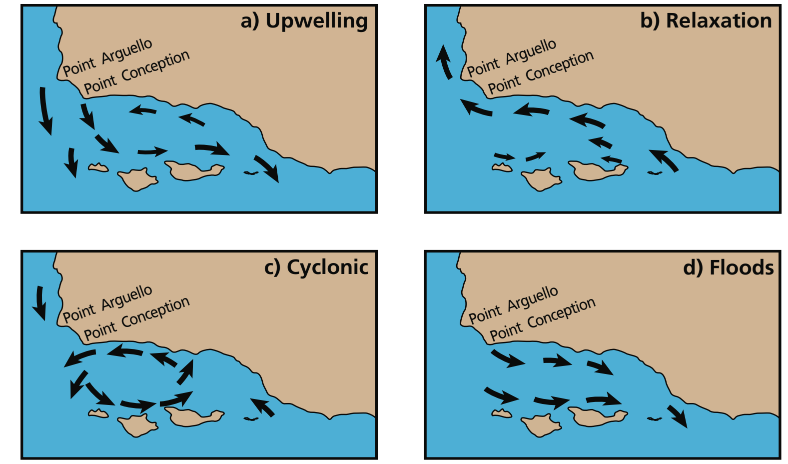


Figure 1.4. Generalized circulation patterns in the Santa Barbara Channel. (a) Upwelling; (b) Relaxation; (c) Cyclonic; (d) Flood east (shown) or west. Westward propagating train of cyclonic and anticyclonic eddies have also been observed (not shown). Adapted from Harms and Winant (1998).

Barbara Channel is a basin that is about 500 m (1,650 ft.) deep. The predominant large-scale patterns of sea surface temperature distributions off California and smaller scale, but persistent, features such as eddies, fronts (strong temperature gradients), and plumes of cold, upwelled water that extend offshore from coastal headlands are depicted in Figure 1.3. The coastal current patterns are embedded in the complex California Current System (CCS) that extends from the Strait of Juan de Fuca at the Canada-US border to the tip of Baja California, Mexico (Hickey 1998). A generalized scheme of the CCS is presented in Figure 1.3. Waters off northern and central California are typically cool because of the southerly flowing California Current offshore the continental shelf and upwelling events generated over the shelf. Upwelling, which is most intense during the spring and summer, is generated by winds that blow toward the south along the coast. Cool coastal waters enter the Santa Barbara Channel through its west entrance at Point Conception. Warm waters from the Southern California Bight flow in the opposite direction into the channel through its eastern entrance. The geographic orientation of the Southern California Bight shelters it from the winds that generate upwelling. Surface waters are substantially warmer in the Bight than north of Point Conception due to less wind-induced vertical mixing, the solar heating of surface waters, and currents of subtropical waters entering from the south (Lynn and Simpson 1987). The convergence of different water masses in the Santa Barbara Channel results in relatively large scale differences in physical parameters (e.g., temperature, salinity, oxygen, and nutrient concentrations) and biotic assemblages (e. g., flora and fauna).

Circulation in the Santa Barbara Channel is complex and highly variable (Hendershott and Winant 1996; Harms and Winant 1998; Winant et al. 1999). Santa Barbara Channel circulation typically is characterized by westward flow along the northern boundary of the Channel and eastward flow along its southern boundary (Figure 1.4). The relative strength of these opposing flows varies on scales of days to weeks and seasonally. Two opposing forces drive channel circulation: a wind gradient that is strongest in the west and a pressure gradient that is caused by higher water temperatures in the east. When these forces are balanced, a singular cyclonic (counter-clockwise rotating) eddy forms in the western channel over its central basin. Cyclonic circulation is observed to be the strongest in the summer and weakest in the winter. Unidirectional currents toward the east or west throughout the Santa Barbara Channel occur predominantly in the winter and tend to be short in duration. Throughout the year, smaller cyclonic and anticyclonic eddies, fronts, and jets are common in the Santa Barbara Channel and may be ephemeral or persistent for days to weeks. Circulation within this channel at any particular time is affected by a tendency for cyclonic flow and by the variability in the alongshelf currents that are of a scale larger than the channel.

The complex flow patterns and ocean conditions within the Santa Barbara Channel are affected by larger-scale oceanographic and atmospheric processes associated with intra-annual (e.g., storms and seasonal patterns) and inter-annual (e.g., El Niño and La Niña events) variability and interdecadal climate regime shifts. These events are teleconnected to tropical Pacific and Pacific basin-wide atmospheric phenomena. Oceanographic conditions within the Santa Barbara Channel and along the California coast at-large changed dramatically between 1997 and 1999. Strong, warm-water El Niño conditions began late in the summer of 1997 and continued into the summer of 1998. Cool-water La Niña conditions manifested in early 1999 (Lynn et al. 1998; Hayward et al. 1999). El Niño events are linked to delayed and reduced phytoplankton productivity, reduced zooplankton biomass, reduced growth and reproduction of coastal fishes, and increased mortality during their planktonic larval phase (Lenarz et al. 1995; McGowan et al. 1998; Kahru and Mitchell 2000). Our findings indicate that fish populations responded rapidly to the shift from El Niño to La Niña conditions along the coast.

Superimposed on the inter-annual variability, which include the El Niño and La Niña anomalies, are climate-ocean changes that occur throughout the entire North Pacific Basin on decadal scales. A well documented climatic shift occurred rapidly during 1976 to 1977. It was marked by abrupt changes in sea surface temperature patterns and the circulation of a predominant atmospheric feature of the northeast Pacific known as the Aleutian Low. Since that time in the northeast Pacific, macrozooplankton biomass and a number of nearshore fish stocks in the California Current system have declined (Roemmich and McGowan 1995). In 1999, a number of physical and biological changes in the northeast Pacific indicated another shift from a warm to cool regime (Bograd et al. 2000). Recruitment of young-of-the-year rockfishes to platforms in the Santa Barbara Channel was exceptionally high in 1999. The permanence of this shift to cool conditions is uncertain.

Small-Scale Oceanographic Variability within the Santa Barbara Channel

Interesting patterns of fish abundance are related to the complexity and dynamics of the hydrography and circulation within the Santa Barbara Channel. Certain aspects of our research are focussed on the biological significance of fronts and eddies to the transport and survival of early juvenile stages of marine fishes. Typically, these features are generated by local-scale interactions of wind, opposing water mass currents, and tides. This is especially true where the coastline is characterized by irregular topography and bathymetry, as is the case in the Santa Barbara Channel and the Southern California Bight (Owens 1980) (Figure 1.1). As mentioned, fronts and eddies affect how fishes are pelagically distributed in the region and may ultimately affect the timing and location of young-of-the-year settlement. For example, we sampled high densities of pelagic juvenile fishes within an eddy in the Santa Barbara Channel. The location of the eddy was determined by analysis of surface current maps generated from remote-sensing radar (Nishimoto and Washburn 2002). Furthermore, we have discovered that sea surface temperature fronts can be used to identify boundaries that separate reef habitat with high and low levels of juvenile rockfish settlement (Love, Nishimoto, Schroeder, and Caselle 1999). Mesoscale features that are visible in sea surface temperature images and surface current maps potentially can be used along with other oceanographic data to identify areas where benthic recruitment is likely.

The Santa Barbara Channel as a biological transition zone

Marine organisms from distinctively different northern and southern biogeographic communities occur in the Santa Barbara Channel as resident populations or as seasonal or occasional visitors making this a rich, biological transition zone (Horn and Allen 1978). A few examples of warm-temperate and subtropical fishes that are more common in southern California (defined as south of Point Conception) than in central California and that we have observed at platforms in the Santa Barbara Channel are Mexican rockfish, kelp bass, yellowtail, and Pacific barracuda. Examples of cool-temperate fishes that have distributions centered from central California to the Pacific Northwest and may occur at platforms include cabezon, kelp greenling, lingcod, and many rockfishes (e.g., blue, canary, widow, and yelloweye).

Methods

A major research objective of this project was to describe and compare the spatial and temporal patterns of fish assemblages around platforms and natural rock outcrops. Between 1995 and 2001, we surveyed platforms sited over a wide range of bottom depths, ranging between 29 and 224 m (95 and 739 ft.) and sited from north of Point Arguello to off Long Beach. We also surveyed shallow-water and deep-water rock outcrops, many in the vicinity of platforms. Scuba surveys were conducted at shallow depths (< 36 m, 119 ft.), and submersible surveys at deeper depths.

Most of our platform surveys were conducted at nine structures (Platforms Irene, Hidalgo, Harvest, Hermosa, Holly, Gilda, Grace, Gina, and Gail) located in the Santa Barbara Channel and Santa Maria Basin (Figure 1.1). Between 1995 and 2000, we conducted scuba surveys on the shallow portions of these nine platforms (Figure 1.1b). The shallowest of the nine platforms, Gina, was surveyed from top to bottom using scuba. Deeper-water surveys between 1995 and 2001, using a research submersible, surveyed the same platforms excluding the bottom of Gilda and all of Gina (Figure 1.1a). In 1998, we made one submersible survey around Platform Edith, located off Long Beach (Figure 1.1c) and in 2000 we made partial submersible surveys around platforms C, B, A, Hillhouse, Henry, Houchin, Hogan, and Habitat (Figure 1.1a). Poor

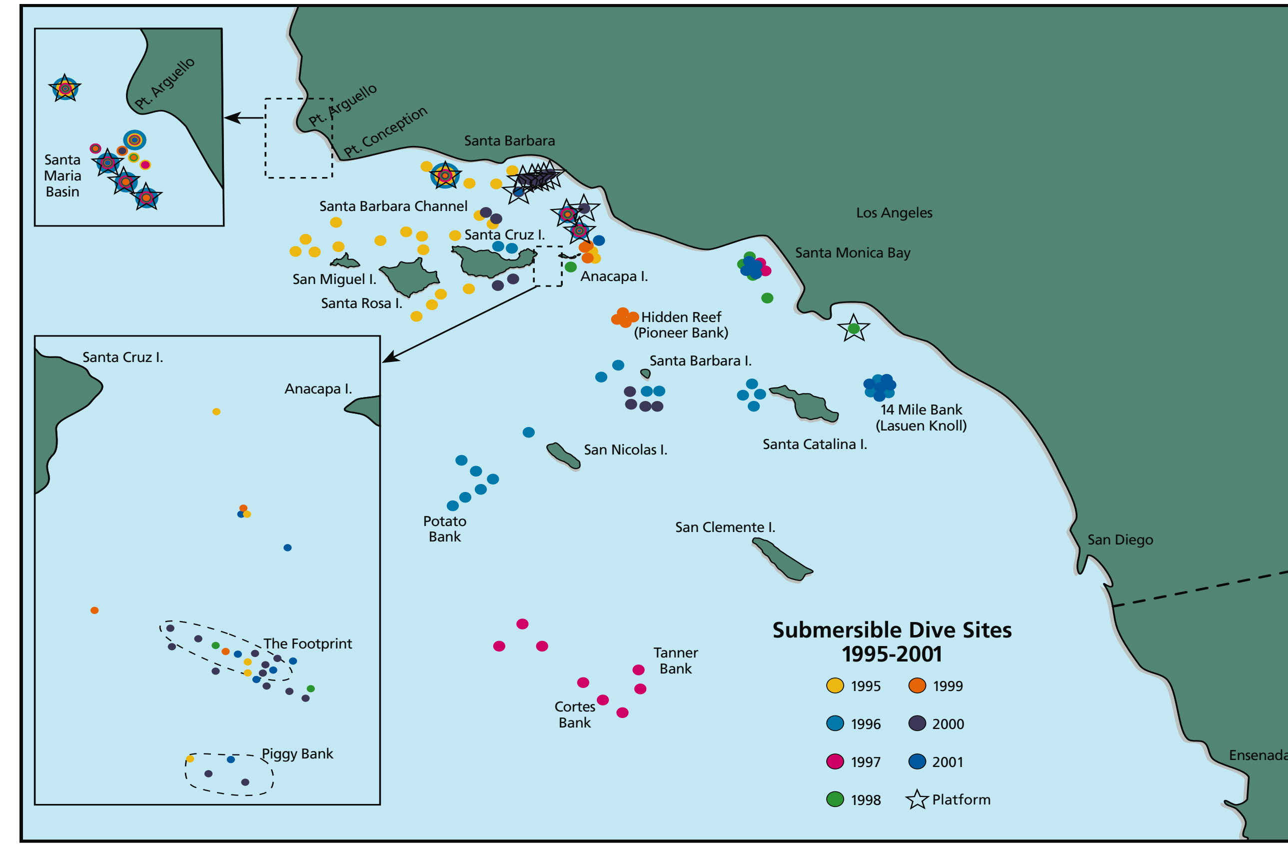


Figure 1.5. Platform and natural outcrops surveyed by Delta submersible, 1995–2001. Concentric rings denote sites surveyed in more than one year. Stars indicate platforms. See Figure 1.1 for names of platforms.

water visibility prevented us from completing the surveys around the latter eight structures. Appendix 1 lists all of the platforms and includes their dimensions, depths, locations, and the years these structures were surveyed.

Nine nearshore, shallow-water rock outcrops, seven on the mainland and two at Anacapa Island were surveyed from 1995 to 2000 by scuba (Figure 1.1b). These surveyed natural outcrops are distributed across the Santa Barbara Channel region and are exposed to water masses similar to that of the surveyed oil platforms. In addition, we surveyed over 80 deeper-water outcrops, in waters between 30 and 360 m (100 and 1,180 ft.) deep (Figure 1.5). Most of these deeper-water sites were visited once, a few were surveyed during as many as four years and one outcrop, North Reef near Platform Hidalgo, was sampled annually.

Shallow Portions of Platforms and Nearshore Natural Outcrops

Scuba surveys estimated density (individuals per hectare), mean size (total length), and species composition of reef fishes in shallow portions of platforms (0–36 m, 0–119 ft. depth) and natural outcrops (6–20 m, 20–66 ft.) (Figure 1.6). Typically, we performed three surveys from July to November of each year during 1995 to 2000, although some platforms were sampled less frequently. Fish enumeration methods consisted of fish counts and fish size estimates using both visual and underwater videography methods. Visual surveys recorded fish density and size (total lengths) using underwater plastic sheets and slates. All divers performing visual counts had received training in size estimation. Additional size estimates were obtained using a Hi-8 mm video camera and laser calibration system. The visual estimates of size and relative abundance were used first in data analyses and video size data were occasionally used to supplement visual estimates.

In each platform survey, scuba divers recorded observations while swimming a pattern which incorporated all four corner legs and the major horizontal crossbeams and portions underneath the platform jacket at three different depths (Level 1 range 6–10 m, 20–33 ft.; Level 2 range 12–21m, 40–70 ft.; Level 3 range 25–36 m, 83–119 ft.) (Figure 1.7). Natural reef surveys consisted of diver observations

Figure 1.6. A scuba diver surveys fishes around Platform Gina.

collected along four haphazardly placed 30 m length x 2 m width x 2 m (100 x 7 x 7 ft.) height belt transects, two transects each at approximately 7 m (23 ft.) and 14 m (46 ft.) bottom depths corresponding to the inshore and offshore portions of the reef. Each transect included sampling of three strata: surface, midwater, and bottom portions of the water column, one above the other. Habitat measures using a random point count method (2 points/m) were taken along the same transects for characterization of physical and biological attributes. Quantified habitat features included relief height (0 to 0.1 m, 0.1 to 1 m, 1 to 2 m, and > 2 m), substrate type (sand/mud, cobble, and rock), and percent cover of sessile invertebrates and fleshy algae. We also measured the percent cover of surface canopy of giant kelp, *Macrocystis pyrifera*, and stipe density of large kelps, especially *M. pyrifera*, *Pterygophora californica*, and *Eisenia arborea*, along the transects.

Deeper Portions of Platforms and Deeper Natural Outcrops

Below scuba depths, we surveyed fish assemblages using the *Delta* submersible, a 4.6 m, 2-person vessel, operated by Delta Oceanographics of Oxnard, California (Figure 1.8). Aboard the *Delta,* we conducted belt transects about two meters from the substrata, while the submarine maintained a speed of about 0.5 knots. At the platforms, transects were made around the bottom of the platform and around each set of cross beams to a minimum depth of 20–30 m (66–100 ft.) below the surface (e. g., midwater habitat). The belt transect was also used to sample the shell mounds and natural rock outcrops. The shell mounds and outcrops were sample in consistently the same fashion as the platform method described above.

Submersible surveys were conducted during daylight hours between one hour after sunrise and two hours 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 video camera with associated lights filmed the same viewing fields as seen by the observer. The observer identified, counted, and estimated the lengths of all fishes and verbally recorded those data on the video. All fishes within 2 m (7 ft.) of the submarine were counted. Densities were calculated as fish per 100 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 (8 in.) apart and were visible both to the observer and the video camera. An environmental monitoring system aboard the submarine continuously recorded date, time, depth, and altitude of the vessel above the seafloor. The environmental data was 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

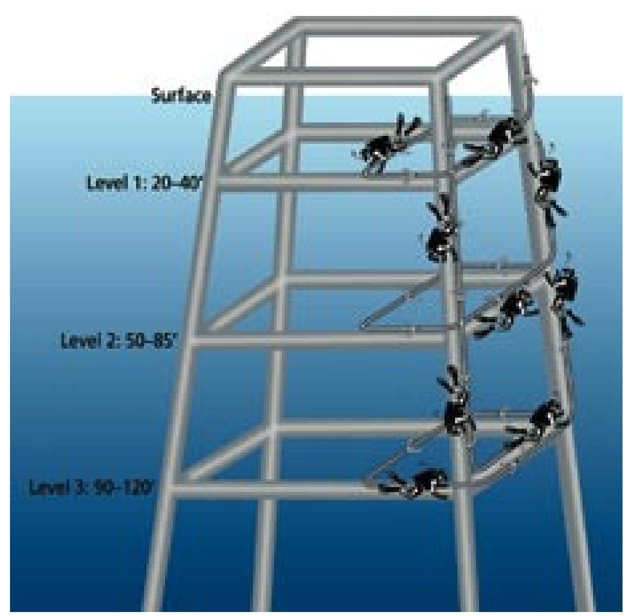


Figure 1.7. A schematic illustration of the diver platform surveys.

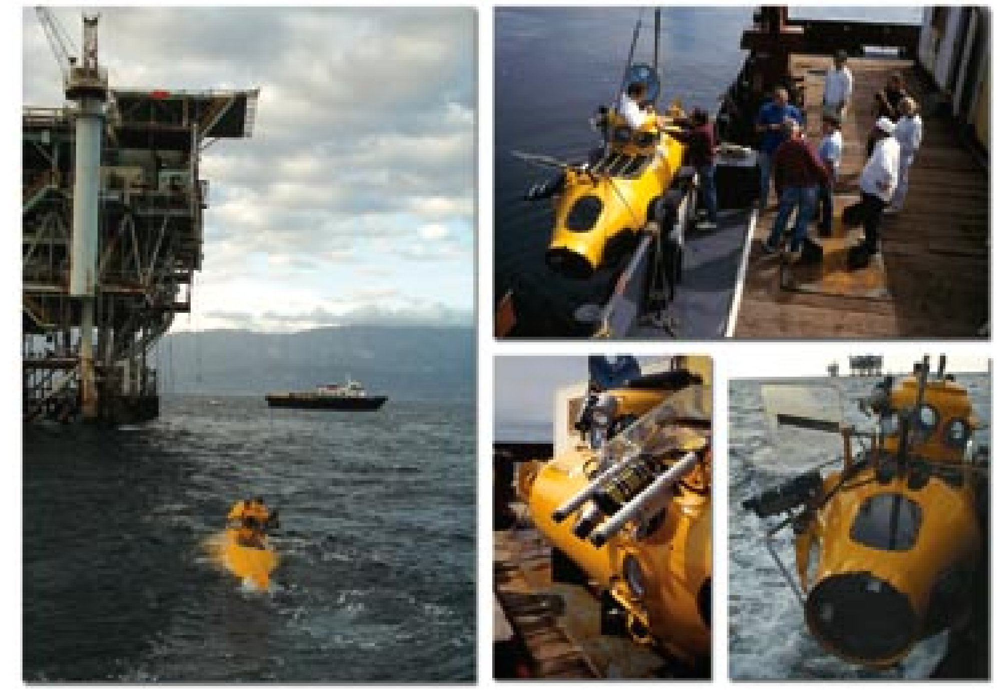


Figure 1.8. The research submersible Delta. Delta *is a 2-person untethered vehicle.*

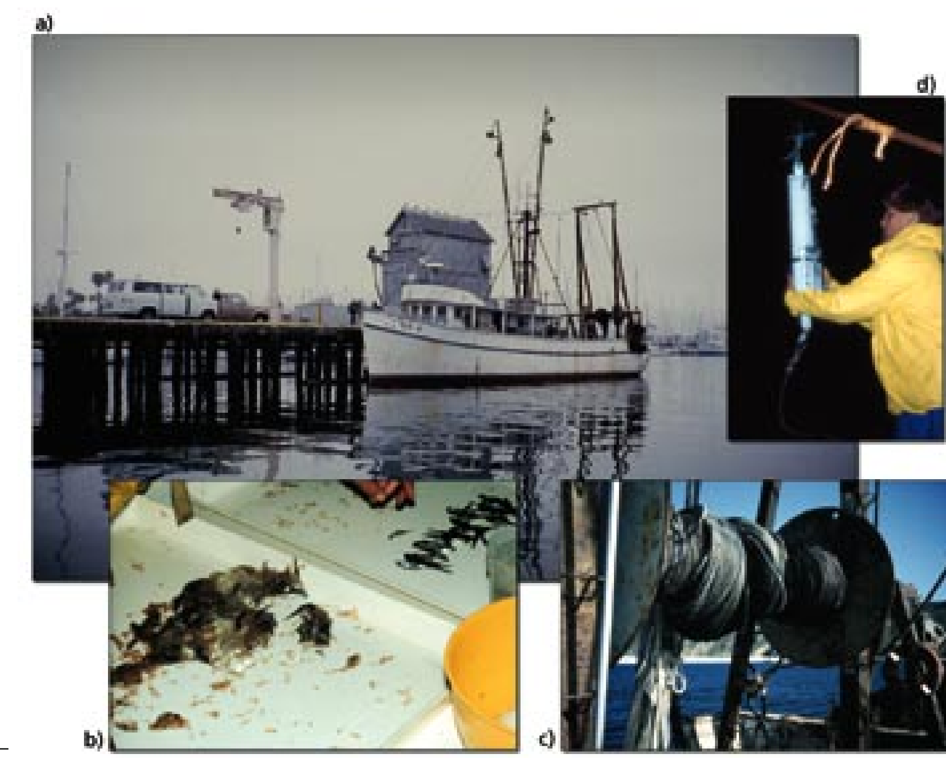


Figure 1.9. Annual midwater trawling and oceanographic surveys, 1995–2000. (a) F/V Gus-D *was chartered for research; (b) pelagic juvenile rockfish and other small fishes were sorted from the catch that included euphausiids and various jellies; (c) modified Cobb trawl rolled around spool; (d) deployment of conductivity-temperature-depth profiler.*

information: (1) species (if known); (2) estimated total length; (3) the habitat it occupied (e.g., rock, sand, mud, cobble, boulder); (4) its position relative to the substrate (e. g., in crevice, on reef crest, on slope, above structure); and (5) the distance of the fish from that substrate.

Midwater Trawling and Oceanographic Surveys

Recruitment, the settlement to a benthic habitat of pelagic juveniles or larvae, is an important process influencing the fish assemblages found on platforms and natural outcrops. To better understand spatial and temporal patterns of recruitment and sources of recruitment variability, we conducted annual midwater trawling and oceanographic surveys in the vicinity of the Santa Barbara Channel and Santa Maria Basin. Our goal was to describe how regional patterns of circulation and distribution of hydrographic features (such as fronts and eddies) influenced the distribution and relative abundance of pelagic juvenile fishes. Our focus on this life stage would allow emphasis on settlement and delineation of nursery habitats, including both platforms and natural outcrops.

Annual midwater trawling and oceanographic surveys were conducted from 1995 through 2000. Sampling was conducted during June to coincide with the time when the most juveniles of the early spring spawning rockfishes would be present in the water column. A modified anchovy trawl with a codend of 9 mm mesh was used to collect samples at depths between 20 m and 55 m (66–182 ft.) below the surface (Figure 1.9). Towing speed was about 2 knots, and trawling time was 15 minutes at the targeted depth. All fishing was conducted at night to minimize net avoidance. Fishes were identified to species if possible and measured in the laboratory. The shipboard surveys included vertical profiling of water properties at all trawling stations so that we could associate patterns of fish abundance with local hydrographic conditions. Salinity, potential temperature, and potential density anomaly, and dynamic height were derived from the data collected using a conductivity-temperature-depth (CTD) profiler (SBE-19, SeaBird Electronics). The CTD was lowered to 200 m (660 ft.) or to about 10 m (33 ft.) above the bottom at shallower stations. Daily satellite imagery, hourly sea surface current maps, and underway sea surface temperature observations were used to direct sampling when it was based on the location of surface circulation features such as fronts and eddies. The specific objective of each survey differed from year to year, see Love et al. (1997, 1999, 2001), Nishimoto (2000), and Nishimoto and Washburn (2002) for details. Surveys were conducted throughout the Santa Barbara Channel, in adjacent waters outside of the channel, and around the Northern Channel Islands (Figure 1.10).

DAN DUGAN

Black-and-Yellow rockfish at Platform Holly.

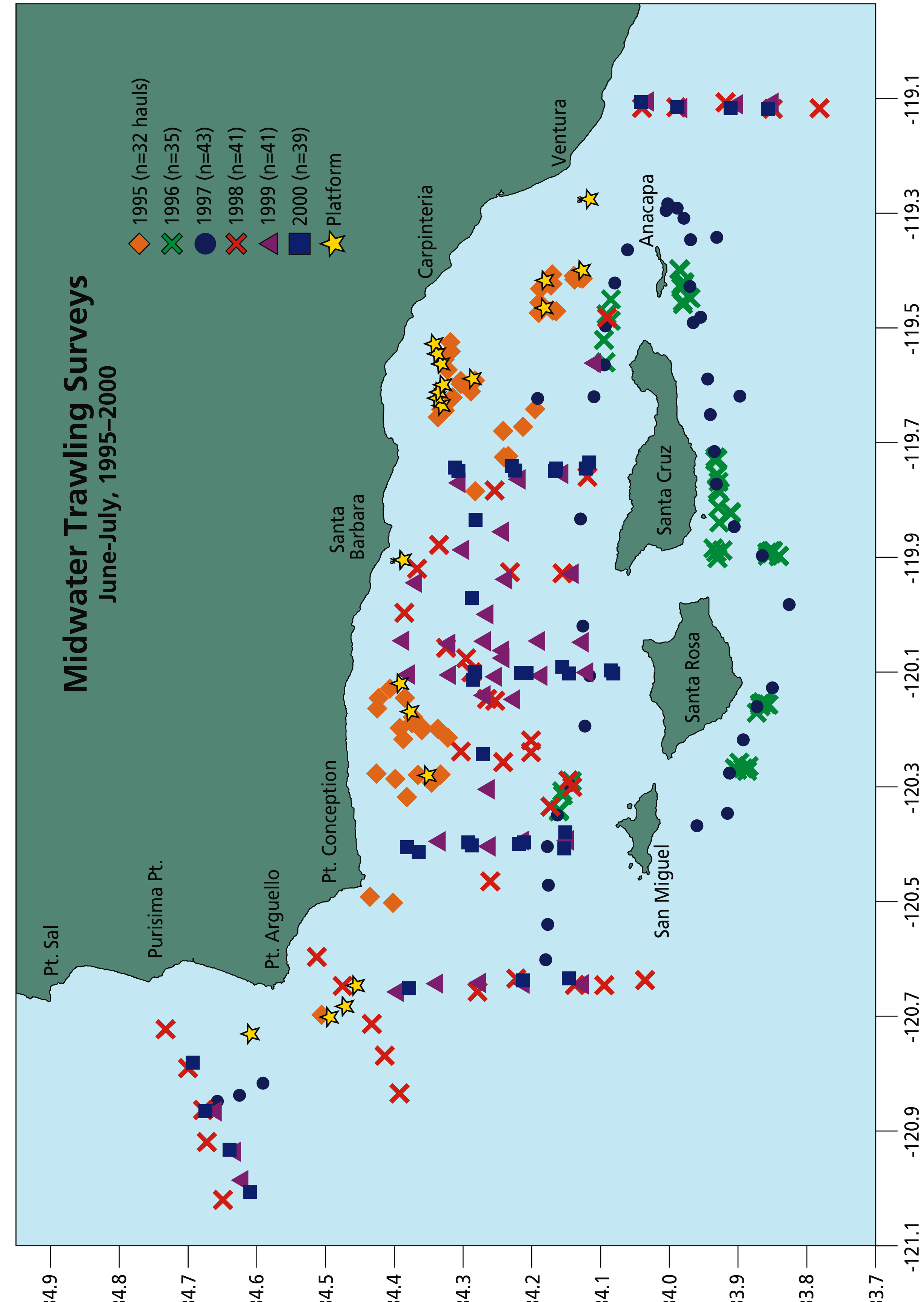
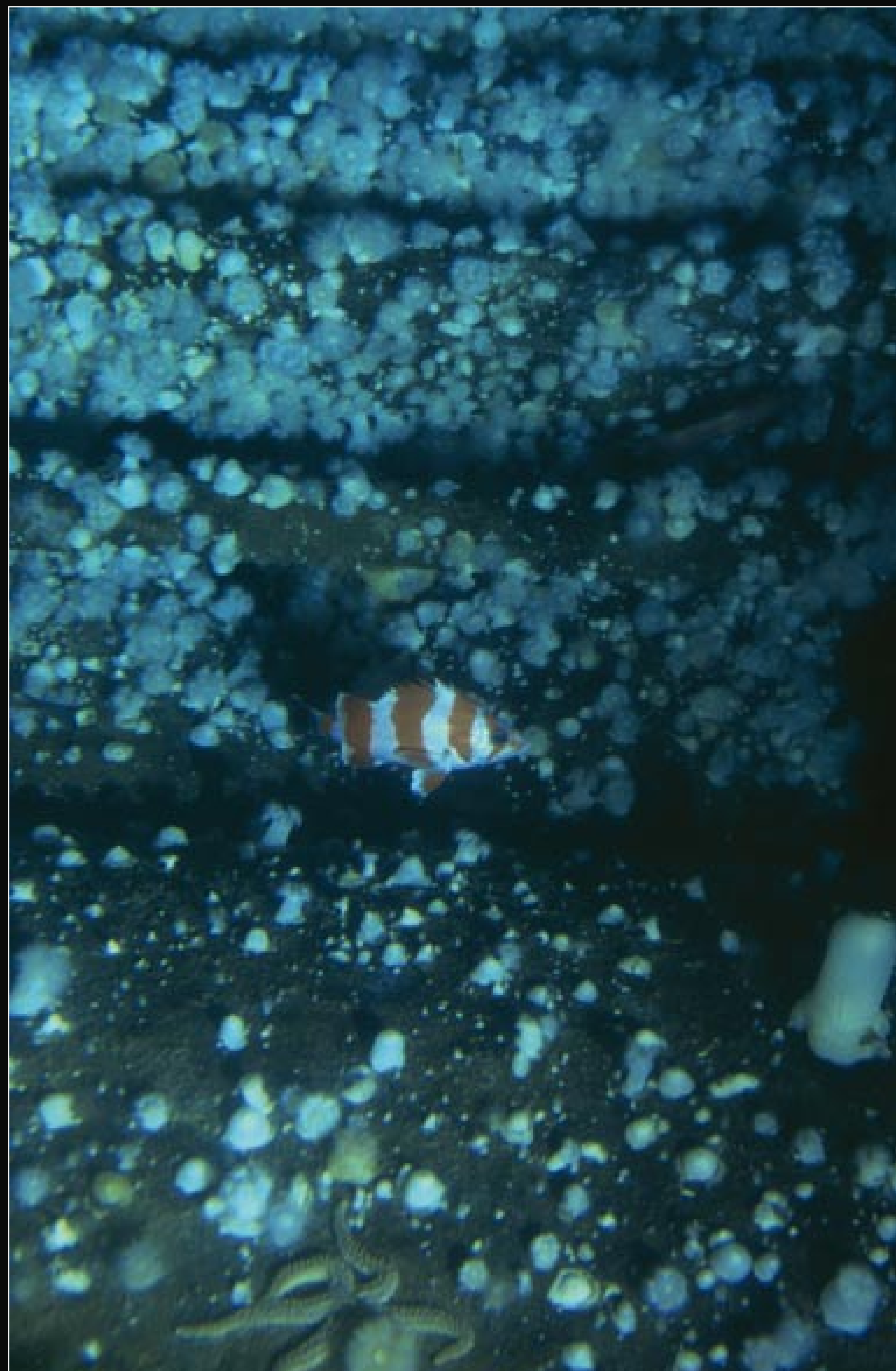


Figure 1.10. Annual midwater trawling surveys, 1995–2000. Map of stations where trawl samples were collected. Surveys typically were conducted in June and included 10 nights of sampling.



Chapter 2

A BRIEF HISTORY OF OIL DEVELOPMENT IN SOUTHERN CALIFORNIA

Milton S. Love

Oil and gas seeps, often the result of geological deformation of the oil-saturated strata, are a common global occurrence. The famous La Brea tarpits, found near downtown Los Angeles, is just one of many seeps found in California. Offshore, seeps are visible on the ocean surface as oil slicks or gas bubbles. As noted by California Resources Agency (1971), "Some [seeps] remain dormant for extended periods of time and then become reactivated, probably by pressure buildup or earth movement. Because of the transient nature of many seeps, an accurate count is difficult to obtain; however, it appears that there are probably 50 to 60 seeps and seep areas on the ocean floor between Point Conception in Santa Barbara County and Huntington Beach in Orange County."

Native Americans in many parts of California, but particularly along the southern California coast, mined those land seeps that contained hard, high-grade asphaltum. The soft tar derived from offshore seeps and diverted to beaches was rarely, if ever, used. California Native Americans used asphaltum in a variety of ways. Baskets and water bottles were made watertight, arrowpoints and hook barbs attached to shafts, broken stone vessels repaired, canoes caulked and sealed and shell decorations were inlaid on various objects. The Chumash of coastal southern California melted asphaltum and mixed it with pine resin to create an effective adhesive for many of these uses.

Early European explorers noted the presence of these seeps. "The Spanish explorer Fages, in 1775, said that 'At a distance of two leagues from this mission [San Luis Obispo] there are as many as eight springs of a bitumen or thick black resin…' Fr. Pedro Font, in 1776, while near Goleta in Santa Barbara County wrote '…much tar which the sea throws up is found on the shores, sticking to the stones and dry. Little balls of fresh tar are also found. Perhaps there are springs of it which flow out into the sea, because yesterday on the way the odor of it was perceptible, and today…the scent was as strong as that perceived in a ship or in a store of tarred ship tackle and rope" (Heizer 1943).

While European settlers in California also utilized asphalt from terrestrial seeps in limited ways, primarily for water proofing and lubrication, there was relatively little interest in oil seeps until about 1850, when it became more widely known that kerosene, an excellent substitute for whale oil in lamps, could be distilled from crude oil. While Dr. Abraham Gesner, a Canadian geologist, is officially credited with inventing this process in 1849, others may also have stumbled onto this idea. In California, the first person known to use partially refined oil for illumination was General Andreas Pico, the brother of Pio Pico, the last Mexican governor of California. In 1850, General Pico distilled kerosene from oil taken from hand dug pits in Pico Canyon (near Newhall, southern California) and used it for lighting a home. By 1854, miners had excavated into Sulphur Mountain in Ventura County (southern California), were hauling out the oil that seeped into their tunnels and had set up stills to produce kerosene. Throughout the 1850 and 1860s, various companies mined seeps for petroleum and produced kerosene or kerosene-like products.

In California, the first well (as opposed to hand-dug pit) that was designed to produce oil was a failure. It was drilled in Humboldt County in 1861 and it, along with others in the same county between 1861 and 1864, came up dry. However, the first productive well, drilled in 1865, came in from this county. This was quickly followed up by successful wells in Ventura and other localities. It was not until 1876 that the first truly commercial well was developed in Pico Canyon, the site of General Pico's first pit mine. The next 20 years saw production rapidly escalate, with new fields explored and developed in a number of locations in central and southern California.

The first oil production from submarine strata in California occurred in Summerland, a sleepy village south of Santa Barbara formally founded in 1889 as a spiritualist colony. For years, Summerland residents had noted both the heavy scent of oil that frequently hung over the community and the numerous seeps that dotted their coastline. In fact, natural gas was so plentiful that when boys wanted to play baseball at night "…they would drive short pieces of pipe into the ground about four or five inches, and would light them, and there would be a gas flame at least a foot high from the top of the pipe. Fifteen or twenty of these pipes along the edge of the road gave plenty of light for them to play after dark. When they got called in to go to bed, each had a flat board, and they would whack the board down over the flame, and out it would go." (Lambert 1975).

In the late 1880s and early 1890s, several Summer-

Opposite: Flag rockfish at Platform Harvest. (Photograph by Donna Schroeder)

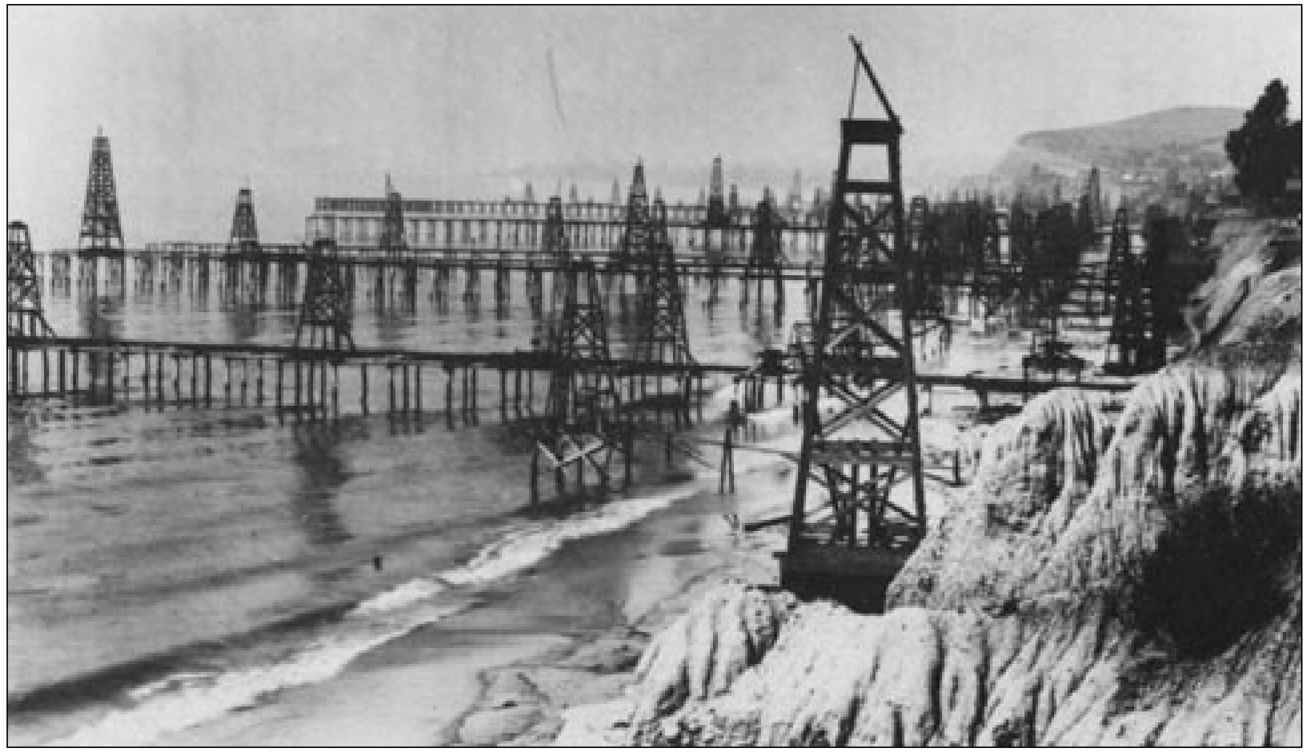


Figure 2.1. Oil piers off Summerland, California, about 1904 (from Rintoul 1990).

land residents had struck oil while digging water wells and at least one would fill barrels from a bucket, haul them by buckboard to Santa Barbara, and sell the oil to laundries. Drilling for oil just back from the ocean commenced shortly after and by 1897 both the beaches and short stretch between ocean and coastal hills were blanketed with drilling rigs. In 1896, W. L. Watts of the California State Mining Bureau reported that "It is also evident that the oil yielding formations extend south into the ocean…At low tide, springs of oil and gas are uncovered on the seashore." (Rintoul 1990).

True to the prediction, the first pier holding a well was built in 1897. This was perhaps the world's first well brought in over water, a record also reportedly claimed for the Baki (formerly Baku) (Republic of Azerbaijan) oil fields in the Caspian Sea and by Pennsylvania for drilling into Lake Erie. Within a few years there were 11 piers (harboring over 200 wells), one of them stretching 1,230 feet offshore (Figure 2.1). The Summerland piers continued to produce oil until 1939, when the last well was destroyed by high tides and high surf.

In the 1920s, a series of discoveries along the Santa Barbara Channel, particularly at Rincon (northwest of Ventura) and Ellwood and Capitan (west of Santa Barbara) led to additional offshore drilling. While all of these discoveries were made on land, development quickly extended onto piers. However, rather than being built of wood, these piers were more heavily constructed of steel pilings and reinforced concrete caissons.

The year 1932 saw the erection of the first oil platform off California and perhaps in the world. In that Depression year, the Indian Petroleum Company was faced with a dilemma. Geological evidence implied that productive oil-bearing strata lay offshore of Rincon (just northwest of Ventura). However, the costs of building a pier out to that formation were prohibitive. The company solved the problem by building part of a pier, located about 1,200 feet beyond the end of the nearest pier. Constructed of steel in 38 feet of water, the aptly named "Steel Island" was eventually home to three wells (Figure 2.2). It lasted until 1 January 1940, when "…mountainous waves battered the platform. The structure went down. There was no loss of life, but equipment was destroyed and wells damaged. Rohl-Connolly Company, marine contractors, removed equipment, derrick and steel pilings from the ocean floor; cut off casing at the floor of the ocean; and placed 6-foot cement plugs in the tops of the water strings" (Rintoul 1990).

Later oil and gas discoveries that were of importance to offshore development included those at Huntington Beach, Wilmington and Seal Beach. However, it was not until 1954, that the next step in offshore production oc-

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Figure 2.2. Built off Rincon, southern California, in 1932, the "Steel Island" was one of the first oil platforms in the world.

curred with the creation of the first man-made drilling island, "Monterey", situated 1.5 miles offshore of Seal Beach in 42 feet of water. Construction on the island commenced in 1952, but a lawsuit by the city of Seal Beach prevented drilling until 1954. The circular island "…75 feet in diameter, had an outer rim formed of interlocking sheet-steel piling driven into the ocean floor to depths of 15 to 20 feet. The interior was filled with rock and sand barged in from Catalina Island" (Rintoul 1990). In succeeding years five other oil islands (Grissom, White, Freeman, Chaffee, and Esther) were built.

Oil islands were only practical in relatively shallow waters and when industry-led seismic surveys and bottom coring discovered potential fields in deeper offshore waters, the stage was set for the development of oil platforms. In June 1958, the California State Lands Commission held its first sale of tidelands leases, ending a freeze that had held up offshore drilling on new sites. The first platform constructed was Platform Hazel, located about two miles offshore of Summerland in 100 feet of water. As noted in Rintoul (1990) regarding Hazel's construction, "In that same month, Standard [Oil] towed an imposing tower a distance of 210 miles… to the Summerland tract. The tower was 75 feet square and 170 feet high. It was a major component of Platform Hazel and was to serve as the foundation on which the 110-foot square deck would be mounted…The tower was floated to the job site on the four big caissons that formed the bottom portion of the tower's legs, each 40 feet high and 27 feet in diameter. Each caisson was pressurized to prevent leakage and also ballasted with 90 tons of sand for stability…Once on bottom, the caissons were sunk 22 feet into the ocean floor by means of high pressure water and air jets that literally hosed away the bottom sands, allowing the caissons to rest on hard ground. The final anchoring was accomplished by filling the caissons with 6,000 tons of sand

and concrete…The cost of building and installing the platform was $4 million." In September 1958, Standard Oil began drilling from the newly constructed platform and within one month the first well, bottoming out at 7,531 feet began producing 865 barrels per day. This was followed two years later by the construction of nearby Platform Hilda.

In subsequent years, a number of platforms were installed in both state and (beginning in 1967 with Platform Hogan) federal waters in southern California. However, expansion of offshore oil drilling came to an abrupt halt in 1969, with the disastrous blowout and subsequent oil spill at Platform A (installed in 1968) in the Santa Barbara Channel. And while discussion of both opposition and support for oil development are beyond the scope of this report (see Beamish et al. 1998, Nevarez et al. 1998, and Paulsen et al. 1998 for more information), it is safe to say that the subsequent environmental concerns about the safety of offshore oil exploration, development, and production delayed further drilling for a number of years. It was not until the late 1970s that installation of new platforms resumed. No new platforms have been erected since 1989 (Nevarez et al. 1998).

How do platforms get their names?

On the Pacific Coast, platform names have to conform to a set of rules promulgated by the U. S. Coast Guard. The Coast Guard created a series of zones ("15-minute quadrangles") along the Pacific Coast beginning at the U. S. – Mexican border. The names of all platforms in a zone must begin with the same letter. Platforms in the first zone, off San Diego, would begin with "A". The southern-most platforms (Emmy, Edith etc.) lie off Long Beach, in the "E" zone.

Industry personnel imply that the choice of names have often been made in a disarmingly casual way. For instance, the project engineer for Hermosa apparently named that structure after the elementary school attended by his daughter. Ellen and Elly are said to honor the wives of the engineers in charge of those platforms' construction. Hondo, meaning "big" in Spanish, was so christened because at the time it was the tallest (measured from the seafloor) of the California platforms. One story has it that, because a nearby platform was later installed to tap the same reservoir as Hondo, it was named Harmony. Hogan and Houchin were the surnames of two presidents of Phillips Petroleum.

Why do Platforms A, B and C, despite their locations in the H zone, not have "H" names? These were installed in the days before the Coast Guard regulations were mandatory.

LINDA SNOOK

Stripetail rockfish on shell mound of Platform Gail.

CHAPTER 3
A REVIEW OF BIOLOGICAL AND OCEANOGRAPHIC SURVEYS: RESULTS AND ANALYSES

Milton S. Love, Donna M. Schroeder, and Mary M. Nishimoto

There was no single characteristic fish assemblage that could be described for the oil platforms and natural outcrops of central and southern California. However, we identified a number of patterns in fish diversity and abundance that corresponded to bottom depth, geographic area, and year. Depth played an important role because, in general, rockfishes numerically dominated fish assemblages around platforms and deep natural reefs, and rockfish species segregate themselves according to habitat depth. We also observed biogeographic partitioning in species composition, where northerly platforms show the influence of the Oregonian province and southerly platforms show the influence of the San Diegan province. These zoogeographic patterns were more conspicuous in shallow water fish assemblages. The large inter-annual fluctuations in juvenile fish recruitment observed during the studies may have been generated by the large inter-annual variability in oceanographic conditions (e.g., upwelling, El Niño-Southern Oscillation events). Since juveniles of many species inhabited shallow and midwater portions of oil platforms, the greatest temporal variability in fish abundance occurred at these depths.

We present more detailed summaries of fish assemblages identified by the two different survey methods (scuba and submersible) in the sections below. The common and scientific names of fishes observed in these studies are listed in Table 1.

1. Shallow Water Fish Assemblages: 0–36 m (119 ft.)

Findings at a Glance

A combination of regional and local processes influenced patterns of reef fish assemblages in shallow water. At regional scales, composition and relative abundance of reef fishes often shifted abruptly as oceanography changed. This shift delineated a cool-temperate assemblage in the western Santa Barbara Channel, and a warm-temperate assemblage in the eastern Santa Barbara Channel. This distinct spatial pattern was reflected in both platform and natural reef habitats. There was greater variability in platform species assemblages and population dynamics compared to natural outcrop assemblages and dynamics, and this was most likely caused by the offshore position and greater sensitivity of platform habitats to changing oceanographic conditions. Local processes which affected fish distribution and abundance were related to habitat features, where depth, relief height, and presence of giant kelp all played important roles. We found that the majority of juvenile rockfish recruits resided at depths greater than 26 m (86 ft.), although there were differences among species.

Except where noted, the following synopsis encompasses platforms Irene, Hidalgo, Harvest, Hermosa, Holly, Grace, Gilda, Gail, and Gina and are based on diver surveys conducted between 1995 and 2000.

1a. General Patterns

The two primary research objectives were to (1) describe the spatial and temporal variability of shallow water (less than 36 m, 119 ft.) fish assemblages residing on oil/gas production platforms and natural outcrops, and (2) describe the relative importance of regional processes (e.g., oceanographic patterns) compared to local processes (e.g., habitat features) in generating observed patterns of reef fish assemblages. An understanding of mechanisms which structure marine populations is necessary to predict the outcome of resource management decisions related to marine fisheries, platform decommissioning, and marine protected areas on fish assemblages within the Santa Barbara Channel region (including the Santa Maria Basin). A list of species observed at each platform is given in Appendix 2.

We find that a combination of regional and local processes influenced patterns of reef fish assemblages in shallow water. At regional scales, composition and relative abundance of reef fishes often shifted abruptly as oceanography changed. This shift delineated a cool-temperate assemblage in the western Santa Barbara Channel, and a warm-temperate assemblage in the eastern Santa Barbara Channel. Rockfishes and surfperches dominated the cool-temperate assemblage, and damselfishes, wrasses, and sea chubs dominated the warm-temperate assemblage. This distinct spatial pattern was reflected in both platform and natural outcrop habitats.

Within each of the cool- and warm-temperate assemblages, local habitat features modified patterns of species abundance and distribution. For example, kelp surfperch and giant kelpfish were only observed on rocky outcrops that possessed stands of giant kelp, *Macrocystis pyrifera*. Other factors likely to have been important were outcrop or platform depth and relief height. These local scale features sufficiently decoupled sites within an oceanographic region (cool- or warm-temperate) to make broad generalizations about fish assemblages difficult, especially within platform habitats.

Temporal dynamics of reef fish assemblages also resulted from a complex, dynamic interaction between regional oceanography and local habitat features. The diverse array of oceanographic conditions that occurred during the six-year survey period appeared to strongly influence regional dynamics of fish assemblages. The 1997–1998 El Niño event corresponded to a large increase in juvenile recruitment of species which dominated the warm-temperate fish assemblage (e.g., blacksmith), while the 1999 La Niña event corresponded to a large increase of juvenile recruitment of species which dominated the cool-temperate fish assemblage (e.g., rockfishes). Severe winter storms that accompany El Niño events propagated into small-scale variability at some sites. For example, the scouring effect of severe storm waves depleted red algal turf (a forage base for small crustaceans and fish) on two shallow natural outcrops. This forage base reduction may have been the primary cause of the observed synchronous decline in surfperch abundance at the same outcrops.

1b. Shallow Water Fish Assemblages Surrounding Oil/Gas Production Platforms

As observed on natural outcrops (see Section 1d), shallow water fish assemblages surrounding oil/gas production platforms show distinct spatial patterns which correspond to oceanographic patterns in the Santa Barbara Channel. Rockfishes are numerically dominant in west channel platform fish communities, although 1999 was a strong recruitment year for juvenile rockfish at all platforms. Blacksmith and halfmoon are numerically dominant in east channel platform assemblages. Platform fish assemblages appeared to respond faster and more dramatically to changing oceanographic conditions than natural reef assemblages, perhaps due to their offshore position and higher proportion of juvenile fishes.

There were notable differences among platforms within an oceanographic region. These differences may be due to water depth in which the platform is positioned, where deeper water can inhibit species such as surfperches from migrating onto platform habitat. Among-platform differences may also be influenced by food availability or other factors. During the 1997–1998 El Niño event, juvenile blacksmith recruited onto all platforms, but did not recruit onto Tarantula Reef, the closest natural reef to west channel platforms surveyed in this study. This observation suggests that platforms may "capture" pelagic stages of some reef fish species that might have otherwise perished.

The fish assemblage observed at Platform Gina (depth 29 m, 95 ft.) is noteworthy because of its very high density of kelp bass and because of the large diversity of rockfishes that recruit to its shell mound habitat. Anecdotal observations at a nearby shipwreck did not record either of these characteristics in its local fish assemblage. High turnover of fish species diversity has also been noted at Platform Gina (Love, Nishimoto, Schroeder, and Caselle 1999).

JAMES FORTE

Kelp bass at a nearshore platform.

1c. Depth Distribution of Juvenile Fish Recruitment on Oil Platforms

For all fishes observed at all Southern California Bight platforms surveyed at shallow depths, approximately 27% were observed in the shallowest portions of platform habitat (6–12 m, 20–40 ft.). Most of these were pelagic fishes, such as anchovy and barracuda. Twenty-seven percent of all fishes were observed at intermediate depths (15–26 m, 50–86 ft.), and 46% were observed at deeper depths (27–36 m, 89–119 ft.). We observed that the majority of juvenile rockfish recruits resided at depths

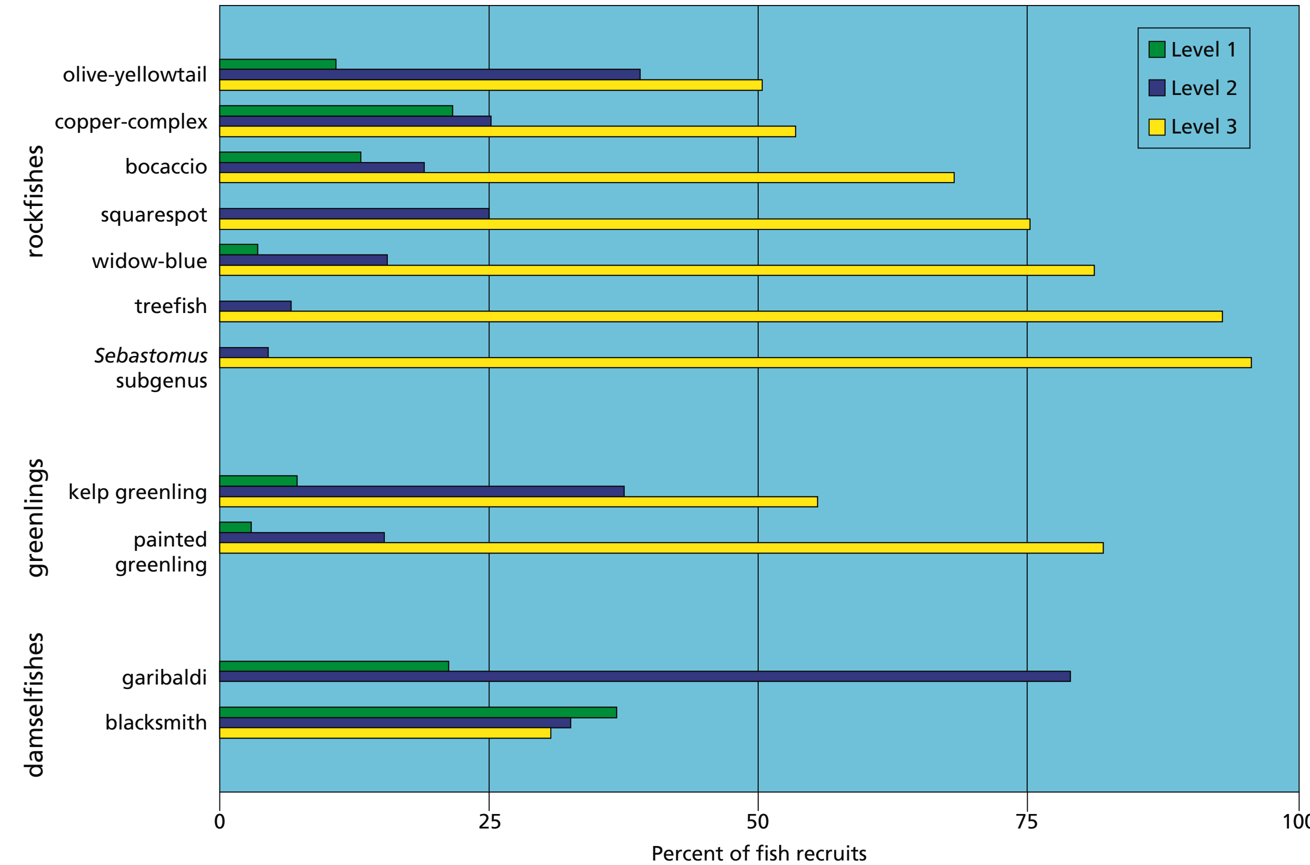


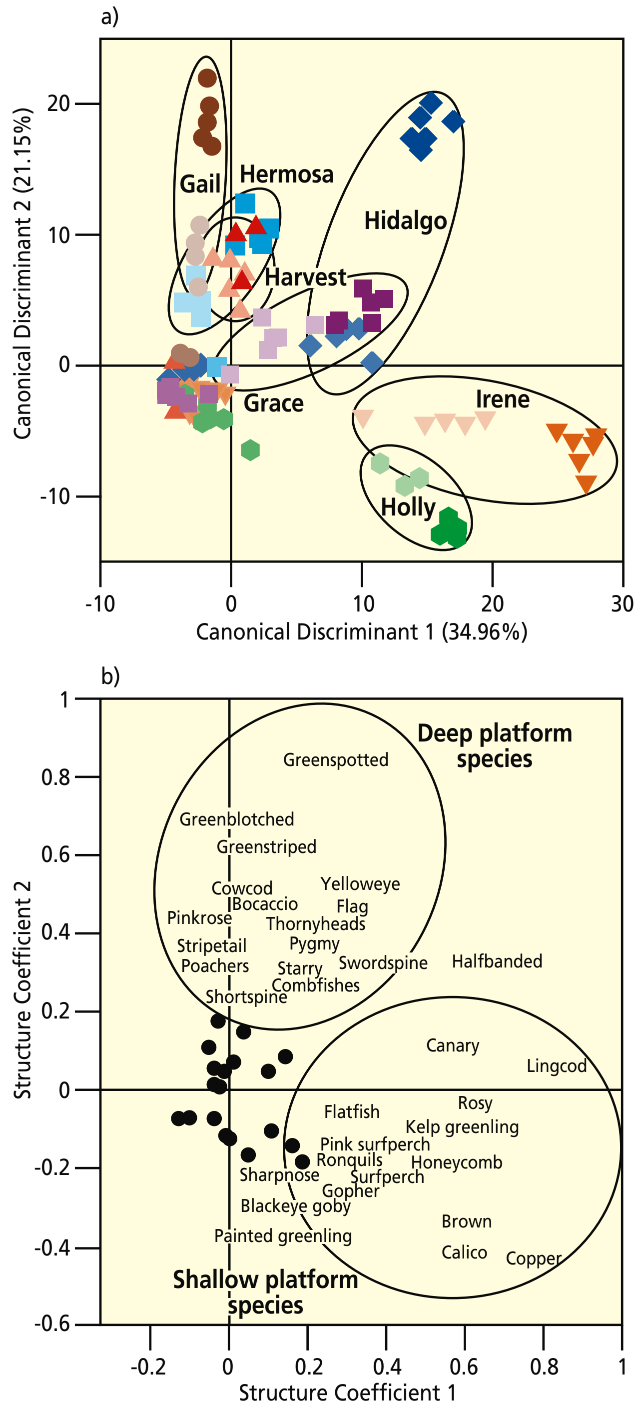
Figure 3.1. Percent of juvenile fish density observed during scuba surveys at different depths on offshore platforms during 1995–2000. Depth ranges for each strata: level 1 (6–12 m), level 2 (15–26 m), level 3 (27–36 m).

greater than 26 m (96 ft.) (Figure 3.1), although there were differences among species. The olive-yellowtail group and copper-complex species group (black-and-yellow, copper, gopher, and kelp rockfishes) had the largest percentages residing at shallower depths. Our observations on copper-complex rockfishes represent a somewhat different vertical distribution than that described by Holbrook et al. (2000). This disparity may be due to differences in surveyed platforms and program duration (6 platforms within one biogeographic area during 1995–7 versus 9 platforms in 3 biogeographic areas during 1995–2000). This difference underscores the importance of evaluating platforms on a case-by-case basis and in developing monitoring programs over multiple years.

Our results correspond with Holbrook et al. (2000) regarding vertical distribution of midwater juvenile rockfishes (e.g., bocaccio, blue, and widow) where the vast majority of individuals recruited to depths greater than 26 m (86 ft.). The majority of individuals of other rockfish species such as squarespot, treefish, and the *Sebastomus* subgenus (e.g., rosy, greenspotted, starry rockfishes, and others) are also found below 26 m (86 ft.). Kelp and painted greenling recruits, two species associated with the cool-temperate fish fauna, mimic the vertical distribution of rockfish recruits, preferring deeper portions. In contrast, garibaldi and blacksmith recruits, two species associated with the warm-temperate fish fauna, favor upper portions of platforms, suggesting temperature may play a role in determining depth distribution of juvenile fishes at platforms.

1d. Fish Assemblages on Nearshore Natural Outcrops

The relative importance of spatial versus temporal variability in structuring fish assemblages on shallow natural outcrops differed among sites. Ordination analysis revealed that natural outcrops in the west channel tended to be more sensitive to temporal variability than those outcrops positioned in the east channel. This seems intuitive since west channel outcrops are closer to areas of intense and temporally variable upwelling processes which affect mean water temperature, primary production, and dispersal processes of larvae.



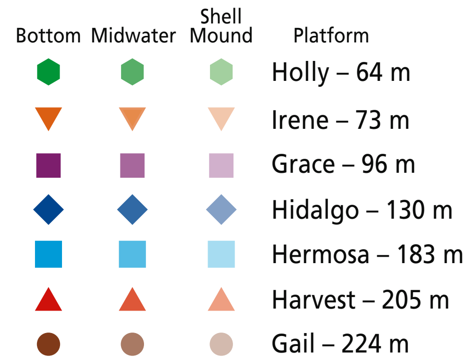


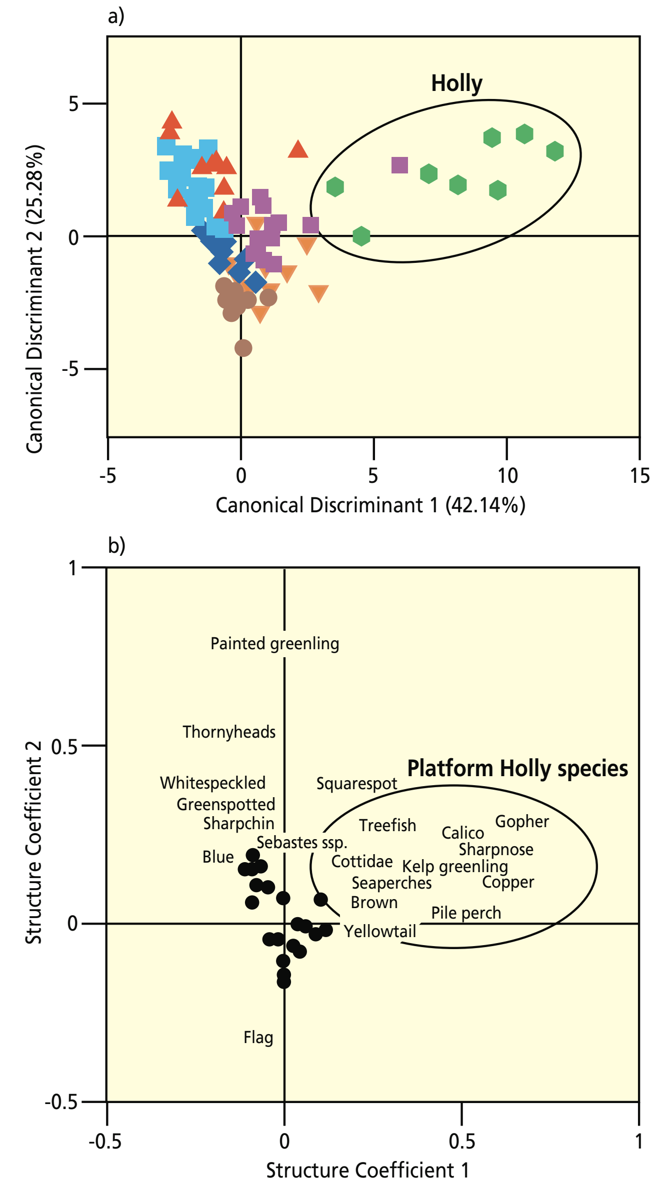
Figure 3.2. 3.2a. Canonical Discriminant Analysis of the bottom and shell mound fish assemblages at seven platforms, 1996–2001. 3.2b. Canonical Discriminant Analysis of the bottom and shell mound species found around seven platforms, 1996–2001. Two groups, one characteristic of shallow platforms, the other of deeper structures are apparent. Black dots represent species that were not strongly associated with either axis.

Similar to platform habitats, the fish assemblages on natural outcrops showed distinct spatial patterns that seemed to correspond to regional oceanographic patterns in the Santa Barbara Channel. Rockfishes and surfperches were important species in west channel fish communities, although 1999 was a strong recruitment year for juvenile rockfishes at most natural outcrops. Blacksmith, garibaldi, sheephead, opaleye, and rock wrasse were important species in east channel fish communities. Kelp bass, black surfperch, and senorita were abundant at all sites. Because we observed abrupt spatial changes in abundance for many species in the Santa Barbara Channel, it is tempting to attribute these patterns solely to oceanographic processes. However, habitat features may covary with oceanography, and we are currently unable to distinguish between these processes.

Dispersal of pelagic stages does not appear to be the primary factor in structuring fish assemblages. For the eight common species in the warm-temperate assemblage that have pelagic larvae, six species exhibited very low or no juvenile recruitment onto shallow rocky outcrops in the Santa Barbara Channel. This suggests that dispersal of benthic stages plays a critical role in the dynamics of reef fish communities and local temperature may be an important criterion in habitat selection. Some species important in the warm-temperate fish assemblage (e.g., kelp bass and opaleye) declined in abundance during the cold La Niña year of 1999. The response of reef fish communities to oceanographic regime shifts may be faster and less persistent than previously thought.

2. Deeper-water Platform Fish Assemblages: 31–224 m (103–739 ft.)

Except where noted, the following synopsis encompasses platforms Irene, Hidalgo, Harvest, Hermosa, Holly,



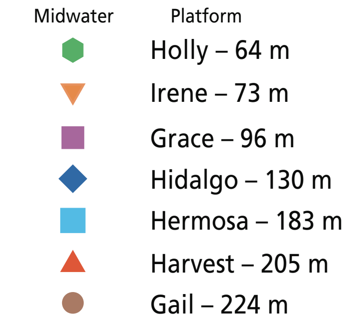


Figure 3.3. 3.3a. Canonical Discriminant Analysis of midwater fish assemblages at seven platforms, 1996–2001. Note that the Platform Holly fish assemblage is distinct from the others. 3.3b. Canonical Discriminant Analysis of the midwater species found around seven platforms, 1996–2001. Note that a group of species tends to be more characteristic of Platform Holly than other platforms. Dots represent species that were not strongly associated with either axis.

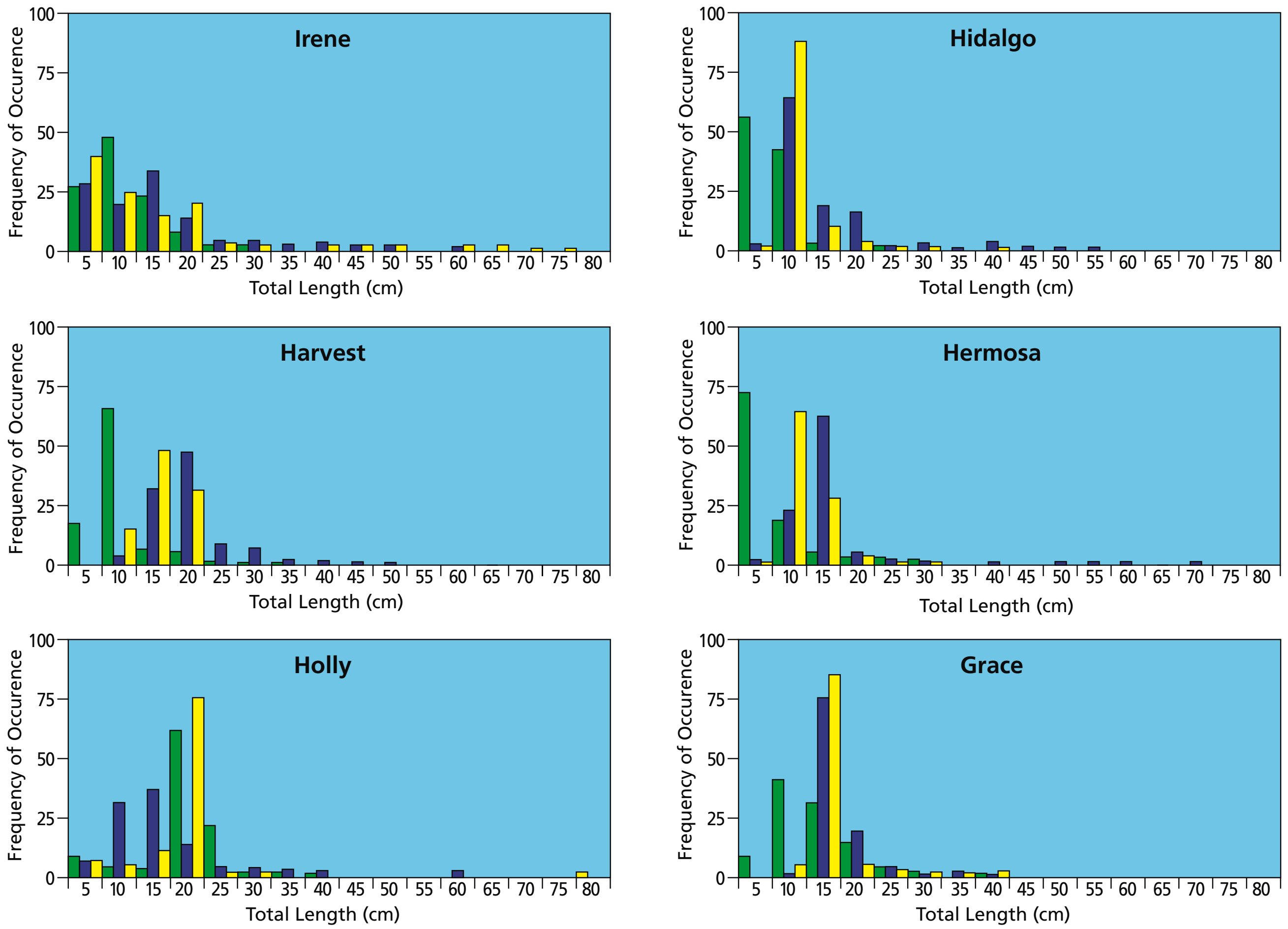
Grace, and Gail, based on surveys conducted between 1995 and 2001 from the research submersible *Delta*.

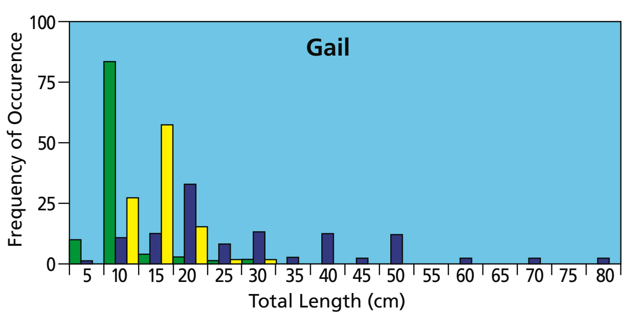
2a. General Patterns

All of the platforms studied by submersible had three distinct fish assemblages, midwater, bottom, and shell mound (Figure 3.2a). Rockfishes, totaling about 35 species, dominated all three fish assemblages. Fish densities at most platforms tended to be highest in the midwater reflecting the depth preferences of young-of-the-year rockfishes that represented the most abundant size class of fishes.

Midwater assemblages were more similar to each other regardless of platform location and bottom depth. The assemblage at Platform Holly had the only distinct midwater assemblage (Figure 3.3a). A suite of species (e.g., calico, copper, and gopher rockfishes, pile, and sharpnose seaperches) characterized this particular assemblage (Figure 3.3b). Holly has the shallowest bottom depth (standing in 64 m, 211 ft.), and it might be that these shallow demersal species were able to occupy these shallow midwater crossbeams. The midwater fish assemblages around the other platforms showed no systematic depth or geographic relationships.

The composition of platform bottom and shell mound fish assemblages was dependent on the bottom depth of the platform (Figure 3.2a) and certain species are characteristic of either shallow or deep benthic habitats (Figure 3.2b). Platforms Holly and Irene (64 m and 73 m; 211 and 241 ft., respectively) were dominated by brown, calico, copper, and vermilion rockfishes and lingcod. In deeper waters, Platforms Hermosa, Harvest, and Gail (183 m, 205 m, and 224 m; 604, 677, and 739 ft., respectively) were dominated by greenblotched, greenspotted, and greenstriped rockfishes. Platform Hidalgo, and to a certain extent Platform Grace, both at intermediate depths (130 m and 96 m, 429 and 317 ft., respectively), were inhabited by species common to both the shallower and deeper platforms. In general, our data suggests that shell mound fish assemblages most closely resemble the fish assemblages of their adjacent platform bottoms (Figure 3.2a). Fishes living on the shell mounds are generally smaller, and presumably younger, than the same species living around the platform bottom.





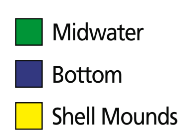


Figure 3.4. Frequency of occurrence of fishes in 5 cm size classes in midwater, bottom and shell mounds at seven platforms, 1996–2001.

The size distribution of fishes differed by habitat type. The midwater assemblages harbored few fishes over 20 cm (8 in.) long (Figure 3.4). Immature, mostly young-of-the-year rockfishes and young painted greenling dominated midwater depths. In addition, seaperches, blacksmith, and several less abundant species inhabited this zone. In contrast, older and larger rockfishes, lingcod, and several other benthic species, occupied the platform bottom habitat. Rockfishes also dominated the shell mounds. The size frequency of shell mound fishes tended to be intermediate between the two other habitats (Figure 3.4). This apparent partitioning of different size modes was most evident in the deepest platforms. Around shallow platforms, there was significant settlement of young-of-the-year rockfishes both in the midwater and at the bottom. This common feature blurred the distinctions between these two habitats.

Young-of-the-year rockfishes showed strong depth preferences around platforms (Figure 3.5). Young-of-the-year were often very abundant in the shallowest portions (above 30 m, 100 ft., depths) of the platform but were also abundant between 31 and 120 m depths (102–396 ft.). They were most abundant at depths between 61 and 90 m (201–297 ft.).

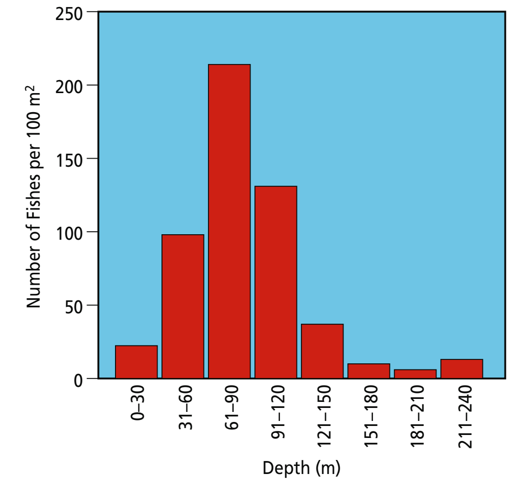


Figure 3.5. Density of young-of-the-year rockfishes observed from the Delta *submersible, by depth, at all platforms surveyed, 1995–2001. Note that large numbers of these fishes were also observed by scuba divers in the shallower sections of the platforms.*

Among platforms, total fish densities typically fell within a relatively small range (Figure 3.6). In general, platforms furthest offshore and in deepest waters had somewhat lower fish densities than did those closer to shore in shallower waters. However, the absolute number of fishes around deeper water platforms may be greater than those in shallower waters, as deeper platforms are much larger than shallower water structures.

2b. Midwater Assemblages

Findings at a Glance

Platform midwaters are nursery grounds for rockfishes as well as for other marine fish species such as cabezon and painted greenling. The young-of-the-year of at least 15 rockfish species inhabit these midwater habitats.

Benthic settlement success is greatly influenced by oceanographic conditions. During our study, densities of young fishes varied greatly between years and platforms. Young-of-the-year rockfish densities often varied

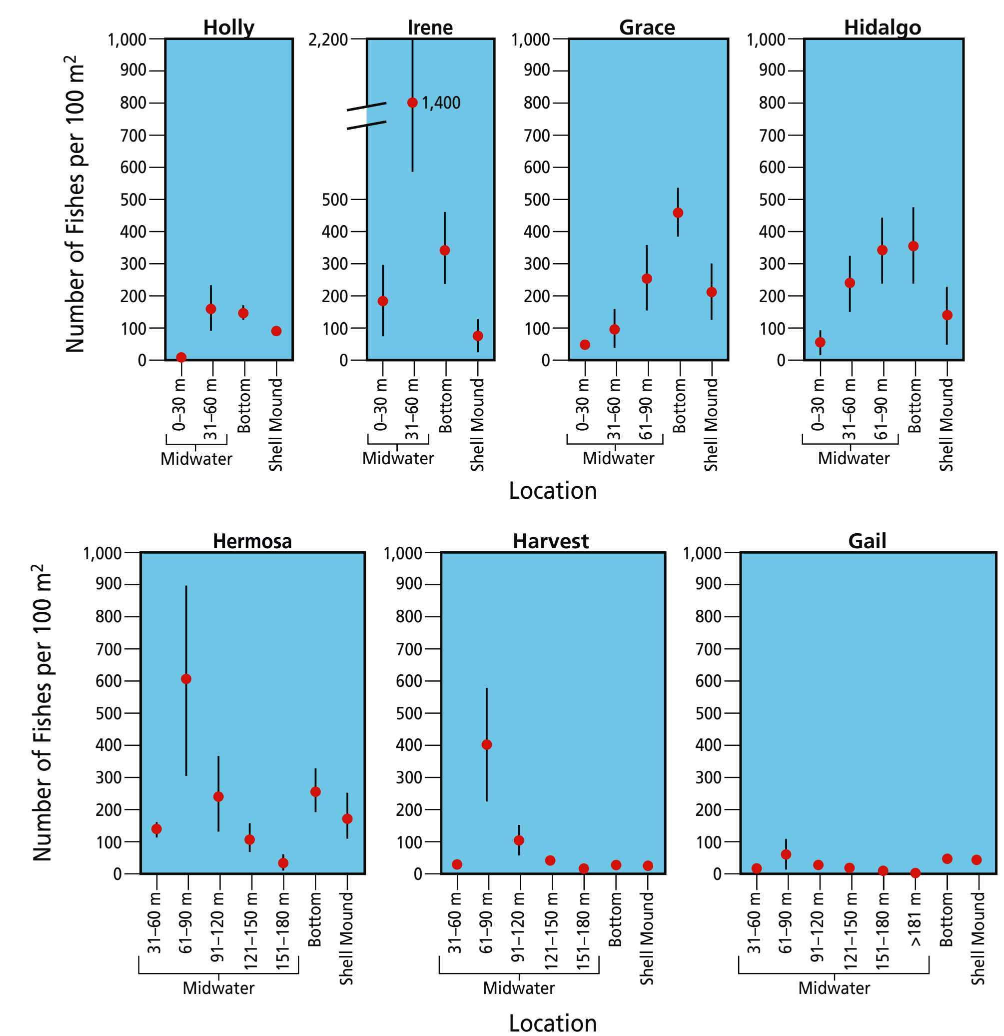


Figure 3.6. Density, with standard error bars, of all fishes in midwater (by 30 m depth zones), bottom and shell mounds, at seven platforms, 1996–2001.

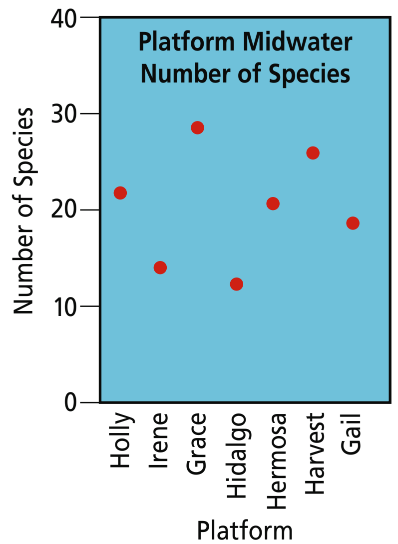


Figure 3.7. Number of species observed in the midwaters of seven platforms, 1996–2001. Platforms are listed from left to right, from shallowest to deepest.

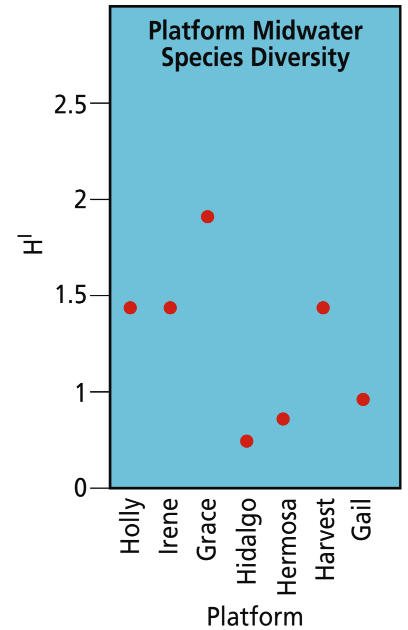


Figure 3.8. Species diversity of fishes in the midwaters of seven platforms, 1996–2001. Platforms are listed from left to right, from shallowest to deepest.

by a factor of 10 or even 100 among survey years at some platforms. From 1996 through 1998, rockfish settlement was generally higher around the platforms north of Point Conception compared to those structures in the Santa Barbara Channel, reflective of generally colder, more productive waters in central California. Colder waters in 1999 were associated with relatively high densities of young-of-the-year rockfish recruitment at all of the platforms surveyed. In 2000 and 2001, rockfish recruitment at platforms in the Santa Barbara Channel remained higher than pre-1999 levels. We hypothesize that this was related to the oceanographic regime shift to cooler temperatures that may be occurring in southern California.

Depending on platform location, we observed between 13 and 29 fish species in the midwater habitats below 31 m (102 ft.) depths (Appendix 3). There was no relationship between platform bottom depth and either the number of species or species diversity in the midwater habitat (Figures 3.7 and 3.8). Relatively abundant non-rockfish species included blacksmith, sharpnose seaperch, and juvenile painted greenling. Occasionally, we observed influxes of migratory species such as Pacific sardine, jack mackerel, and Pacific mackerel. However, because our surveys are snapshots in time, they do not adequately capture the importance of platform habitats to these and other pelagic species. The most abundant fishes were young-of-the-year and older juvenile rockfishes and blacksmith. These are planktivorous and thus are not dependent on the platform for food. They utilize these structures for orientation in the water column and as refuge from predation. Less common species, such as seaperches, painted greenling, opaleye, and cabezon do feed on animals or algae living on the platform jacket or conductors.

Our research shows that oil and gas platforms off California provide important nursery grounds for many species of rockfishes. The most conspicuous faunal characteristic of the platform midwaters below scuba depth is the dominance of young rockfishes. Over the course of the study, young-of-the-year and older juvenile rockfishes almost always comprised more than 90% of all fishes observed in this habitat (Appendix 3). In some years, young-of-the-year rockfishes were virtually the only fishes present at some platform midwaters (Appendix 3).

The young-of-the-year of at least 16 rockfish species (bank, blue, copper, darkblotched, flag, gopher, kelp, olive, pygmy, shortbelly, squarespot, widow, yellowtail rockfishes, bocaccio, cowcod, and one or more members of the subgenus *Sebastomus*) recruited to the midwater habitat. Many of the species that were most abundant (e.g., blue, olive, pygmy, squarespot, widow, and yellowtail rockfishes and bocaccio) are those that are epibenthic or semipelagic as adults. Of these diverse young rockfishes, widow rockfishes were consistently the most abundant species at platforms. Among adult rockfishes, kelp and whitespeckled rockfishes were commonly observed.

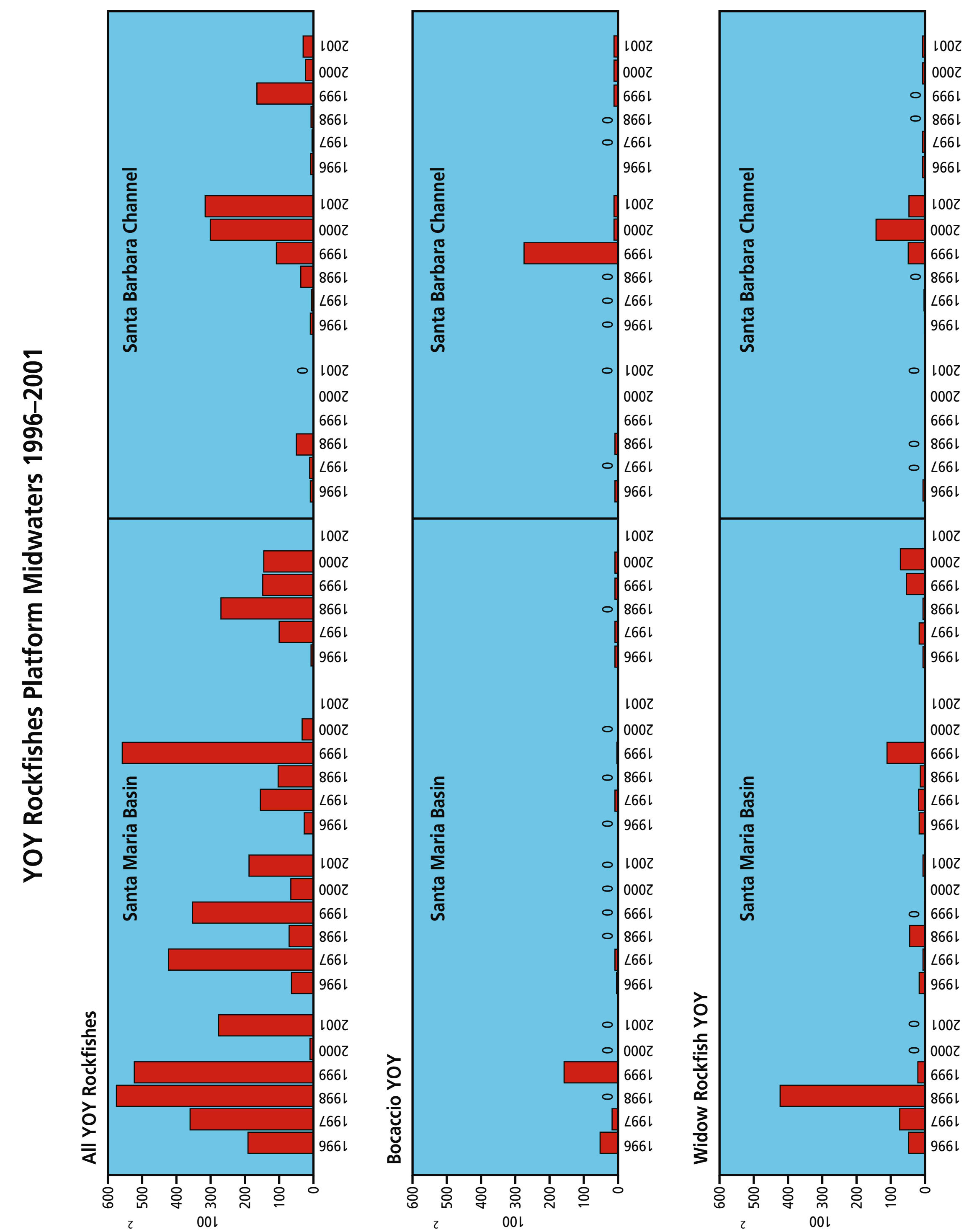


Figure 3.9. Density of all young-of-the-year bocaccio and widow rockfish and all YOY rockfishes combined in platform midwaters, by year and platform, 1996–2001.


DAN DUGAN

Pacific sardines, midwaters of Plaform Holly.


RICK STARR

Young-of-the-year yellowtail rockfish, midwaters of Platform Irene.


MARY NISHIMOTO

Juvenile bocaccio and widow rockfish, midwaters of Platform Grace.

Young-of-the-year and 1-yr old rockfishes of many species (e.g., bank, blue, olive, pygmy, shortbelly, squarespot, widow, and yellowtail rockfishes, and bocaccio) often formed highly mobile schools in the midwater habitat. During years of high abundance, these schools contained many thousands of individuals. Our experience suggests that these schools remained either inside the platform or ventured only a few meters outside it. Schools of young rockfishes tended to more closely associate with the jacket substrate during years of low recruitment or when water visibility was poor. However, when their numbers were high or water clarity was good, young rockfishes, while still living within the platform structure, only loosely associated with the crossbeams and vertical structure. In general, the schools occurred throughout 50 to 100 m or more (150–300 ft.) of the water column. Young copper, gopher, kelp, and flag rockfishes, treefish, and cowcod, as well as cabezon and painted greenling were generally observed either as solitary individuals or in small groups, usually intimately associated with the platform jacket.

Young-of-the-year rockfish settlement (recruitment) to midwater habitats is also strongly influenced by oceanographic conditions. The density of these fishes varied greatly inter-annually by location and among platforms (Figure 3.9). Spatial and temporal differences in young-of-the-year rockfish densities often varied by a factor of 10 or even 100. In several instances, a species that was entirely absent from a platform midwater in one year would recruit in great numbers in the following year. Between 1996 and 1998, young-of-the-year rockfish recruitment was generally higher around the platforms north of Point Conception in the Santa Maria Basin (Irene, Hidalgo, Harvest, and Hermosa) than at the structures in the Santa Barbara Channel (Holly, Grace, and Gail) (Figure 3.9). In contrast, these three years were a period of low rockfish recruitment for many species south of Point Conception both at platforms (Holly, Grace, and Gail) and natural outcrops. The colder water conditions of 1999 brought with it widespread recruitment for a number of rockfish species in California compared to the previous decades. This was reflected at all of the platforms surveyed (Figure 3.9). We should note that the 2000 data at Platforms A, B, C, Hillhouse, Hogan, Houchin, and Henry (see sidebar) strongly suggest that recruitment for some rockfish species, particularly blue and widow rockfishes, had been very successful in 1999. In 2000 and 2001, recruitment of some rockfish at Platforms Gail and Grace remained higher than pre-1999 levels (Figure 3.9). We hypothesize that this represents a successful response to the oceanographic regime shift to cooler temperatures that may be occurring in southern California and the greater northeast Pacific.

The population dynamics of bocaccio exemplifies the annual and geographic variability that occurs in rockfish recruitment at both platforms (Figure 3.9) and natural

Figure 3.10. Patterns of young-of-the-year (YOY) bocaccio settlement in 1999, as observed from the Delta *submersible surveys.*

outcrops (Figure 3.10). Prior to 1999, young-of-the-year bocaccio were absent at the platforms we surveyed (except Irene in 1996 and 1997). During 1999, large densities of young-of-the-year bocaccio were observed at Platforms Irene and Grace; small numbers of at least a few individuals were observed at most other platforms. Platform Grace provided the most striking example of inter-annual variability. Almost no young-of-the-year bocaccio were observed at Platform Grace prior to 1999. In contrast, during 1999, the platform harbored the third highest densities (after 1996 and 1999 at Platform Irene) of young bocaccio we observed around either platforms or natural outcrops during the six years of research. It is important to realize that even in years of relatively high rockfish recruitment, the actual process of settlement may result in a patchy distribution of young-of-the-year benthic recruits. Such patchiness was observed in the bocaccio recruitment pattern in 1999 at Platforms Grace and Gail, which are located only 8 km (5 miles) apart. While Platform Grace harbored large numbers of young bocaccio, they were much less abundant at nearby Platform Gail. Furthermore, our research has shown that successful rockfish recruitment at platforms does not always translate to similar high densities of these species at nearby natural outcrops. Using the *Delta*, in 1999 we also surveyed 12 natural outcrops located in depths suitable for bocaccio recruitment and found little evidence of bocaccio recruitment over any of these structures (Figure 3.10).

In 2000, we studied the midwater habitats of Platforms C, B, A, Hillhouse, Henry, Houchin, Hogan, and Habitat. These platforms, located off Summerland east of Santa Barbara (Figure 1.1), were home to many typical midwater reef fishes, including juvenile blue, olive, and widow rockfishes (of the 1999 year class), blacksmith, kelp rockfish, kelp bass, painted greenling, halfmoon, and sharpnose seaperch. Unlike the species assemblage of the further offshore and the more northerly platforms, both garibaldi and California sheephead were common. In 1998, we surveyed Platform Edith and again found a typical mix of reef fishes, including blacksmith, halfmoon, opaleye, sheephead, and garibaldi. Complete species assemblages for all of these platforms are found in Appendix 3.

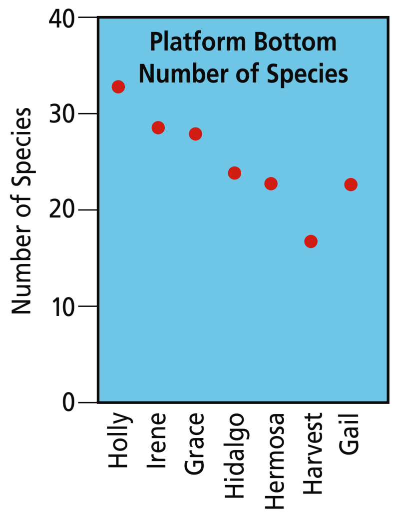


Figure 3.11. Number of species observed at the bottom of seven platforms, 1996–2001. Platforms are listed from left to right, from shallowest to deepest.

2c. Bottom Assemblages

Findings at a Glance

The bottom habitat of platforms is dominated by subadult and adult rockfishes. Young-of-the-year rockfishes were also abundant around some platform bottoms, occasionally in large numbers. In general, more than 90% of all the fishes found around platform bottoms were rockfishes. The numbers and estimated densities of all fishes in the bottom habitats are shown by platform in Appendix 3. Bottom depth strongly influenced the number of species, species diversity, and density of fishes living around platform bases. This is in direct contrast to the midwater habitat. The presence of young-of-the-year and older aged juveniles indicates that the bottom habitat of some platforms may be important nursery habitat for some species. The platform base appears to be important to many marine species, as it provides both refuge and prey.

Depth strongly influences fish assemblages in platform bottom habitat. Species richness varied widely from about 33 species at Platform Holly to 17 species at Platform Harvest. Generally, the shallower-water platforms harbored more species than platforms in deeper depths although this trend may have begun to reverse at Gail, the deepest platform (Figure 3.11). Species diversity was high at the shallowest and deepest platforms and lowest among the mid-depth structures (Figure 3.12). Conversely, overall fish densities were much higher at the mid-depth platforms than at the deepest platforms (Figure 3.13).

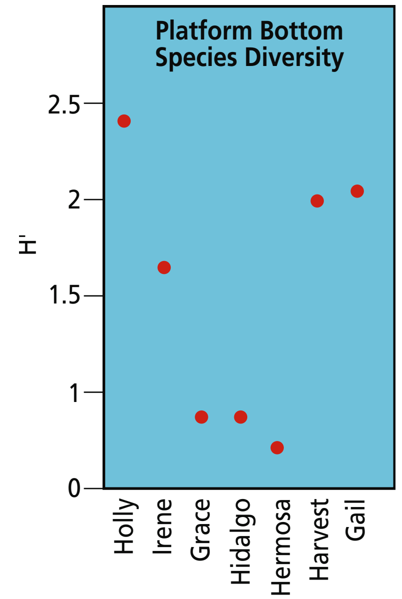


Figure 3.12. Diversity of fishes at the bottom of seven platforms, 1996–2001. Platforms are listed from left to right, from shallowest to deepest.

Diversity and abundance patterns were driven by the depth preferences of a suite of rockfishes that dominate the bottom habitats. For instance, brown, calico, copper, and vermilion rockfishes were most abundant around the shallower structures but were absent from the deepest platforms (Figure 3.13). Pile perch, painted greenling, and young-of-the-year lingcod displayed the same pattern. Juvenile lingcod were also abundant at the shallowest platforms, particularly at Platform Irene, but these were also occasional around even the deepest structures surveyed. Halfbanded rockfish and flag rockfish were typically found at the intermediate-depth platforms. Greenblotched, greenspotted, greenstriped, pinkrose, and stripetail rockfishes were most abundant around the deeper structures (Figure 3.13). The juveniles of many of these species were found in shallower water or on the shell mounds.

Platform structure in the bottom habitats may influence the distribution of fishes. This habitat encompasses that area where the platform jacket and conductors physically meet the seafloor. At all of the platforms surveyed, there is a crossbeam that rests on, or is close to, the bottom. Some portions of this crossbeam may be completely buried by sediment or undercut by currents. The platform jacket and, in particular, the undercut crossbeam, appears to provide many of the attributes of a natural outcrop, providing high relief and large crevices. Many species, such as canary, flag, vermilion, and widow rock-

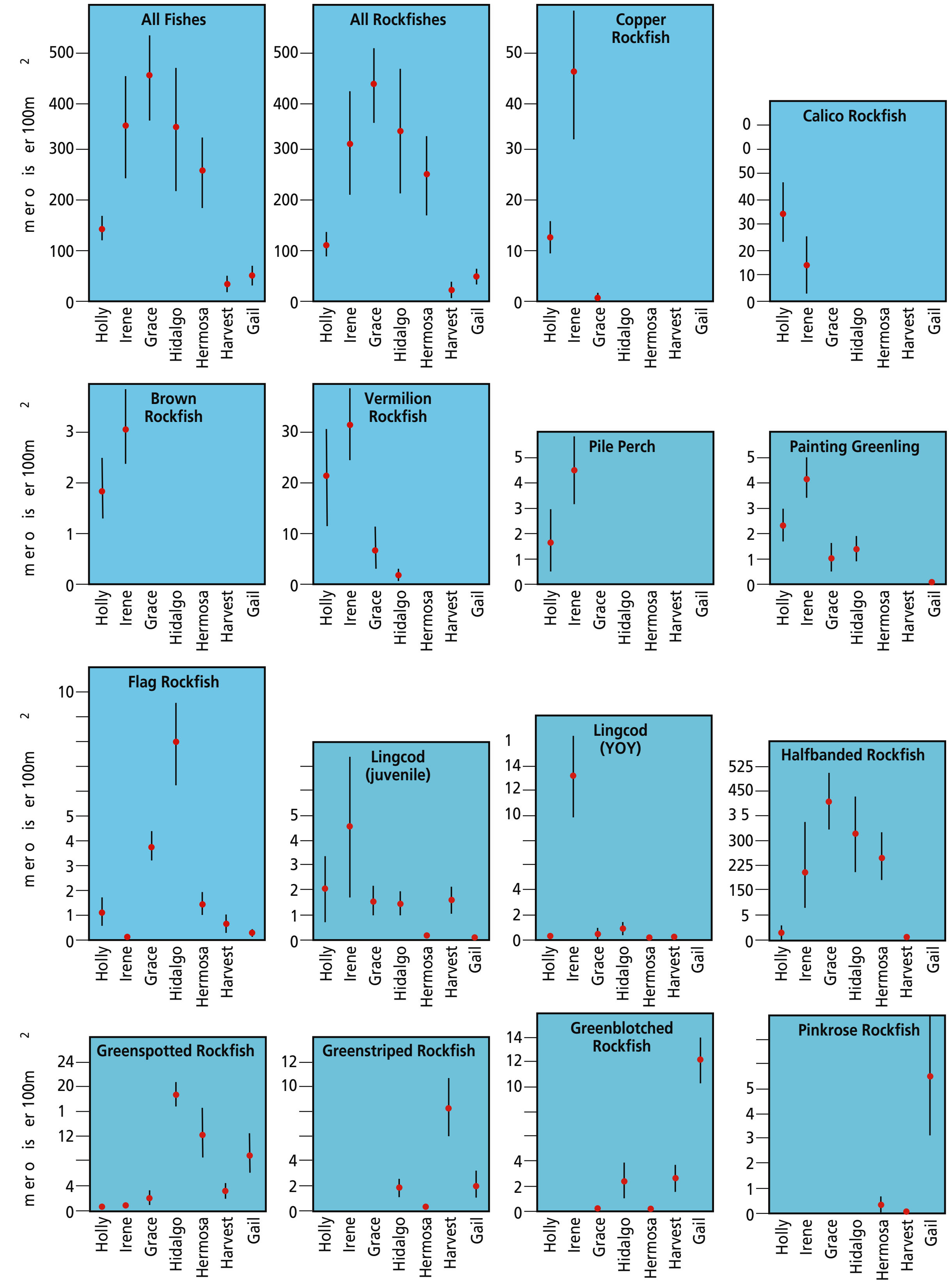


Figure 3.13. Densities (with standard error bars) of all fishes, all rockfishes and the most important species at the bottom of seven platforms, years combined, 1996–2001.

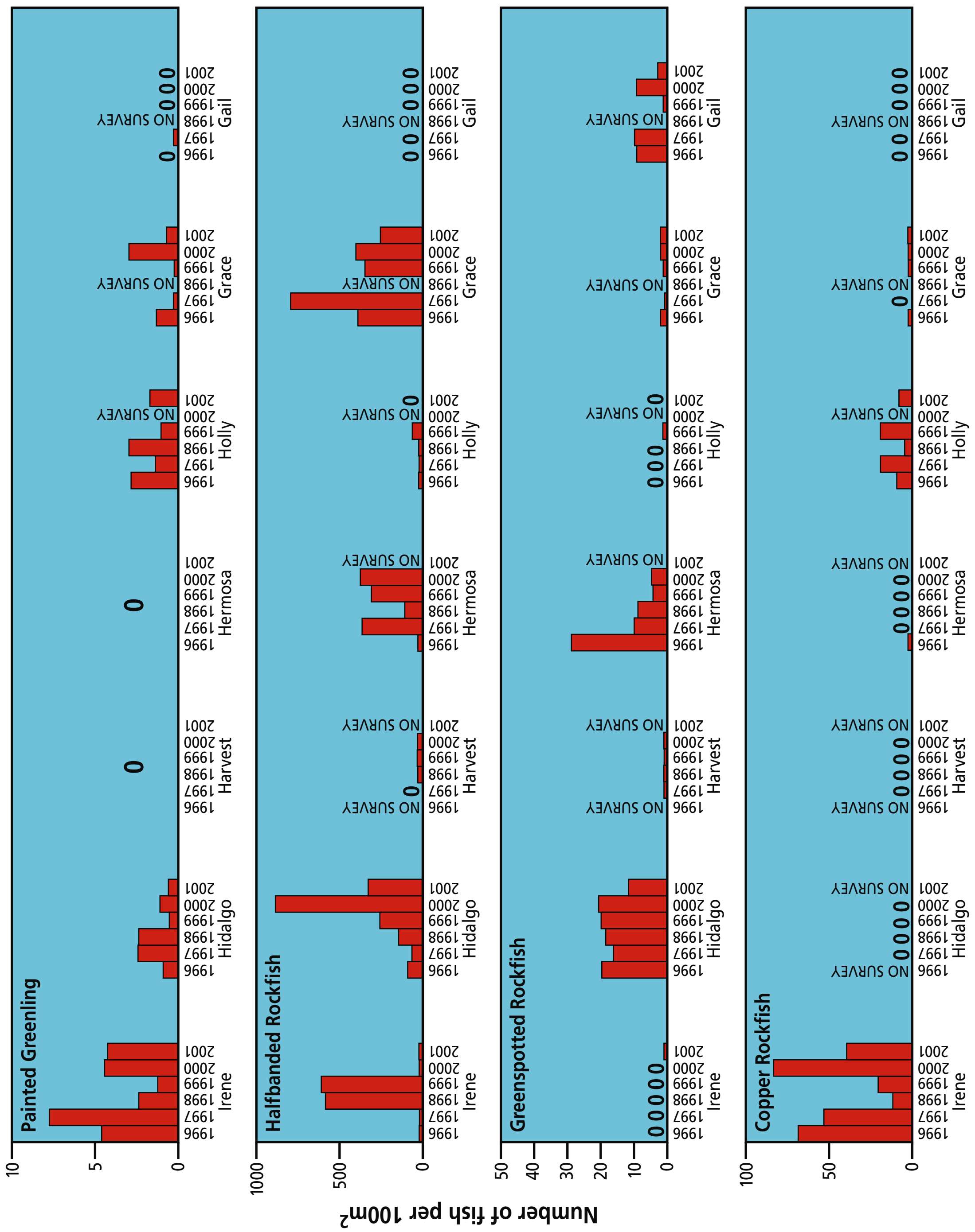


Figure 3.14a. Densities of selected species at the bottom of seven platforms, by platform, by year, 1996–2001.

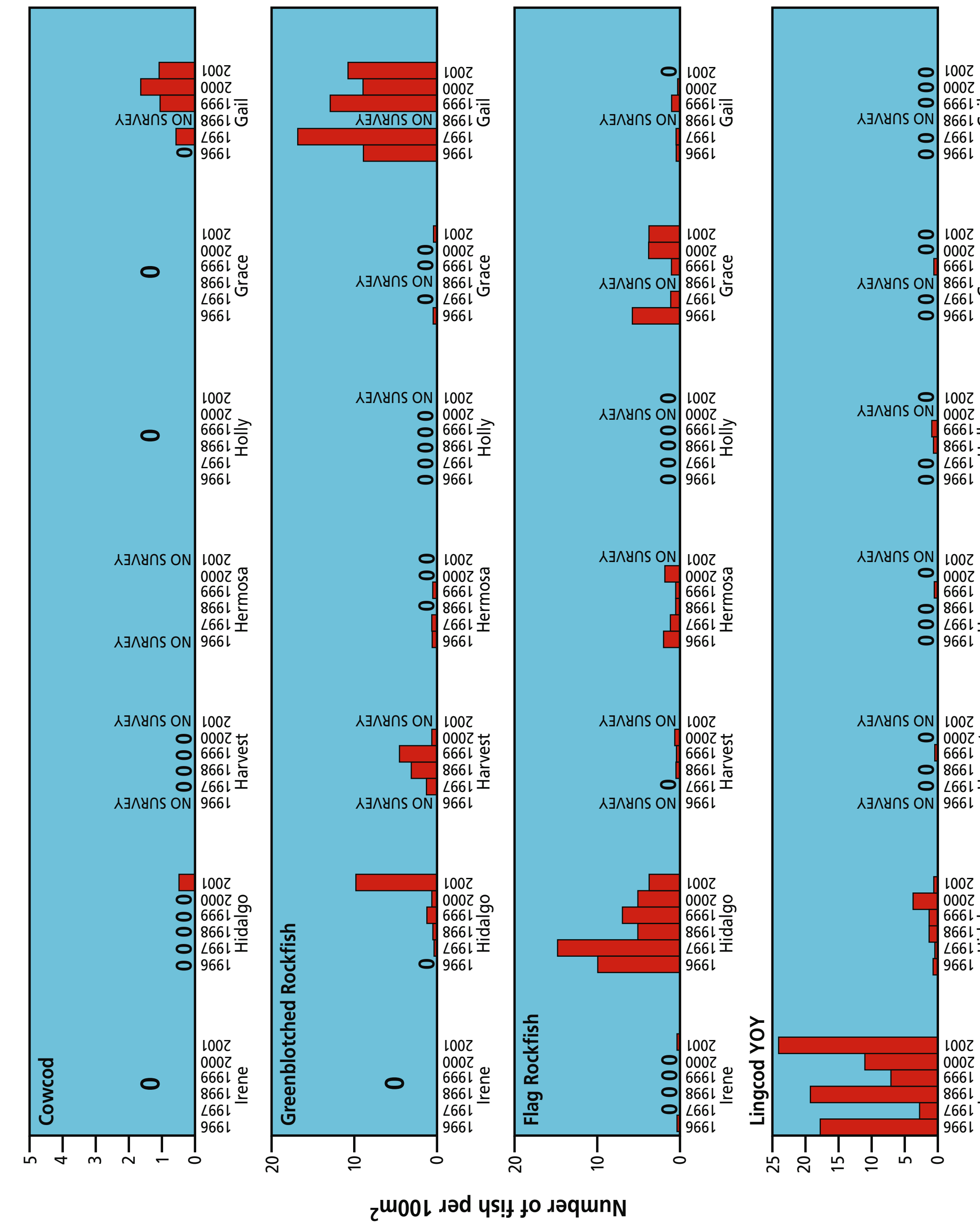


Figure 3.14b. Densities of selected species at the bottom of seven platforms, by platform, by year, 1996–2001.


MILTON LOVE

Bocaccio, bottom of Platform Gail.


DONNA SCHROEDER

Subadult vermilion rockfish, bottom of Platform Grace.


LINDA SNOOK

Cowcod, bottom of Platform Gail.


MILTON LOVE

Lingcod, bottom of Platform Gail.

fishes, bocaccio, pile perch, and painted greenling closely associate themselves with the platform jacket, particularly with the crossbeam. Similarly, larger copper, greenspotted, greenblotched, and pinkrose rockfishes and cowcod tend to shelter inside or immediately next to the platform. These fishes were particularly abundant where a space formed between the lowest crossbeam and the seafloor. Calico and greenstriped rockfishes and various life stages of lingcod were less closely associated with the structure. While most species rarely ascend more than a meter or two above the seafloor, bocaccio and halfbanded rockfish often rose as much as 5 m (17 ft.) above the bottom.


LINDA SNOOK

Mexican and greenspotted rockfishes, bottom of Platform Gail.

Most platform bottom species are either solitary or shelter in small groups. The exceptions are young-of-the-year rockfishes, juvenile and subadult brown, copper, halfbanded, and vermilion rockfishes, and bocaccio. On a number of occasions, we observed aggregations of tens and hundreds of brown, copper, and vermilion rockfishes and bocaccio and large schools of halfbanded rockfish comprised of thousands of individuals.

Compared to midwater habitats, the fish species compositions at platform bottoms were relatively stable over time (Figures 3.14a, b). The dominant species varied little between years at any platform. Thus a platform, such as Gail, that was dominated by adult greenspotted and greenblotched rockfishes, bocaccio, and cowcod in one year tended to be inhabited by these same species in all years in about the same abundances. Similar patterns were observed for such common species as painted greenling (Platforms Irene and Holly), greenspotted rockfish (Platforms Hidalgo and Hermosa), copper rockfish (Platforms Irene and Holly), and flag rockfish (Platform Hidalgo). It is likely that we were observing some of the same individuals each year. This constancy would be expected as these assemblages are at least partially composed of subadult and adult stages of relatively sedentary and long-lived rockfishes. Thus, the composition of the bottom assemblages is not determined by the year-to-year fluctuations in year-class success that is characteristic of the platform midwaters. However, the densities of a few important species, particularly halfbanded rockfish, varied annually. In some years halfbanded rockfish were essentially absent from a platform bottom, only to be extremely abundant the following year. Schools of this species are highly mobile and may have been present but not in the vicinity of the submersible when the survey was made.

Our observations indicate that the bottom habitat of some platforms may be particularly important for certain species. For example, young-of-the-year lingcod densities were much higher at Platform Irene and Hidalgo than at any natural outcrop during any year of the survey (Appendix 4).

Unlike most of the fishes living in the platform midwater, it is likely that the majority of the platform bottom-dwelling species feed on platform-associated prey. Many of these species, such as brown, copper, and flag rockfishes, eat a variety of crustaceans, molluscs, and small fishes, many of which live in and around the jacket, conductors, and shell mound. Other species, such as lingcod, cowcod, and bocaccio are opportunistic feeders, preying on a very wide range of organisms, including benthic and water column fishes, molluscs, and crustaceans (Love et al. 2002). Thus, for many benthic fishes, the platform base provides not only shelter but also an abundant source of food.

We conducted one survey, in 1998, around the base of Platform Edith. We found that California scorpionfish, sharpnose seaperch, blacksmith, and blackeye goby were the most abundant species. See Appendix 3 for a complete species list.

2d. Shell Mound Assemblages

Findings at a Glance

Shell mounds support a rich and diverse fish assemblage. As at other platform habitats, rockfishes comprise the vast majority of the fishes. The many small sheltering sites created by mussels, anemones, and other invertebrates on the shell mounds provided structure in a habitat dominated by small fishes. Many of these fishes are the young-of-the-year and older-aged juveniles of lingcod and copper, flag, greenblotched, and pinkrose rockfishes and cowcod. The adults of these species inhabit the platform bottom.

Depending on platform, we observed between 17 and 30 species living on this habitat. In the shell mound habitat, the patterns of species numbers, diversity, and fish densities were similar to those observed around the platform bottoms. Species numbers generally decreased with increasing depth (Figure 3.15) although it increased sharply at the Platform Gail, the deepest structure. This increase was due to the occurrence of a number of deeper water species (e. g., rex sole, blackgill rockfish, and California smoothtongue) that were absent from other platforms. As in the platform bottom habitat, species diversity was highest at the shallowest and deepest platforms compared to shell mounds in intermediate depths (Figure 3.16).

The shell mounds surrounding all platforms provided habitat and refuge for a diverse assemblage of fishes. Fish densities were highest on the intermediate-depth platform shell mounds (Figure 3.17). However, as in the platform midwater and bottom, a majority of these fishes are rockfishes; between 53% and 98% of all fishes living on the shell mounds are rockfishes (Appendix 3). Furthermore, when highly migratory and non-resident species, such as Pacific hake and Pacific sardine, are eliminated from the analysis, rockfishes comprise more than 80% of the shell mound fauna at each of the seven platforms surveyed. Those species most characteristic of the shell mounds exhibited distinct depth preferences (Figure 3.17) and the abundance of some of these fishes was responsible for the higher densities in the intermediate bottom depths. The dominant species of the shallow water shell mounds were vermilion, copper, and calico rockfishes, young-of-the-year and immature lingcod, and painted greenling. A few species, such as greenspotted and halfbanded rockfishes, were most common in the intermediate bottom depths. It was primarily the very high densities of halfbanded rockfish that were responsible for the overall high densities at intermediate-depth shell mounds. Greenstriped, pinkrose, and stripetail rockfishes

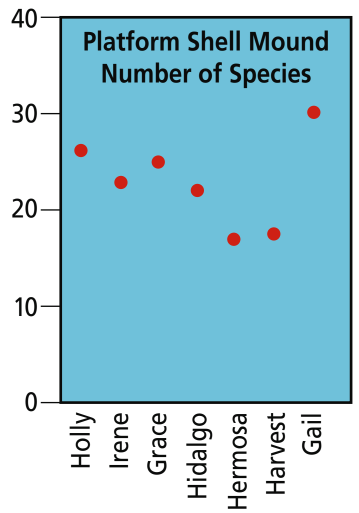


Figure 3.15. Number of fish species observed on the shell mounds of seven platforms, 1996–2001. Platforms listed left to right from shallowest to deepest.

were most abundant at the deepest platforms surveyed.

The mosaic of small refuge sites created by mussels, anemones, and other invertebrates are occupied by small fishes. Many of these fishes are the juveniles of such species as lingcod and copper, flag, greenblotched, and pinkrose rockfishes and cowcod, whose adults inhabit the adjacent platform bottom. Small sheltering sites are rarely found at the platform bottom. In part, this explains why fishes tend to be smaller on a shell mound than on the associated platform bottom (Table 2). This also explains why the shell mound assemblage so closely resembles its counterpart around the adjacent platform bottom. Painted greenling, calico, and halfbanded rockfishes, shortspine combfish, blackeye goby, and the poachers are among the dwarf species occupying the shell mound. Juveniles of the species characteristic of platform midwaters, such as blue and widow rockfishes, are rare over the shell mounds.

Most shell mound species are solitary fishes, living just above the seafloor or nestled among the shell debris or around anemones, seastars, and other large invertebrates. The only schooling species is the halfbanded rockfish that often forms highly mobile schools of 100 to 1,000 or more individuals.

It is likely that many of the fishes, including most of the rockfishes, combfishes, painted greenling, and other benthic species are resident to the shell mound habitat. Highly mobile and migratory species, such as northern anchovy, Pacific sardine, and juvenile Pacific hake, that were observed over the shell mounds probably spend only a relatively short period associated with this habitat.

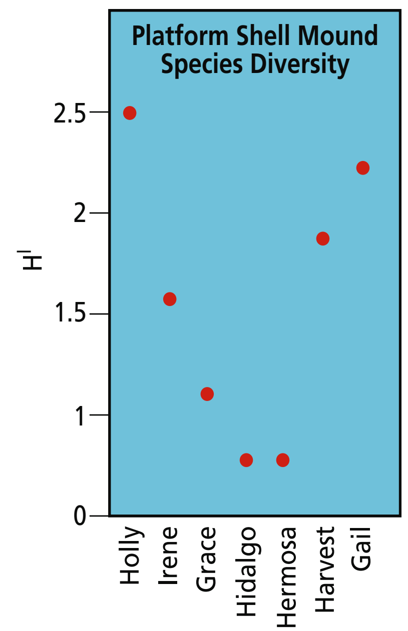


Figure 3.16. Diversity of all fishes observed on the shell mounds of seven platforms, 1996–2001. Platforms are listed left to right from shallowest to deepest.

Shell mound surveys were conducted around Platform Edith in 1998 and around Platform C in 2000. Young vermilion rockfish, as well as halfbanded and calico rockfish, were the most abundant species around Platform C. These species were also characteristic of the shell mound at Platform Holly, which lies in a similar depth. California scorpionfish and blackeye goby dominated the shell mound around platform Edith. Edith lies a few miles southeast of Long Beach and near a known California scorpionfish spawning grounds (Love et al. 1987). California scorpionfish are relatively uncommon in the Santa Barbara Channel and are rare north of Point Conception. This distribution explains the near absence of this species from other shell mounds we surveyed.

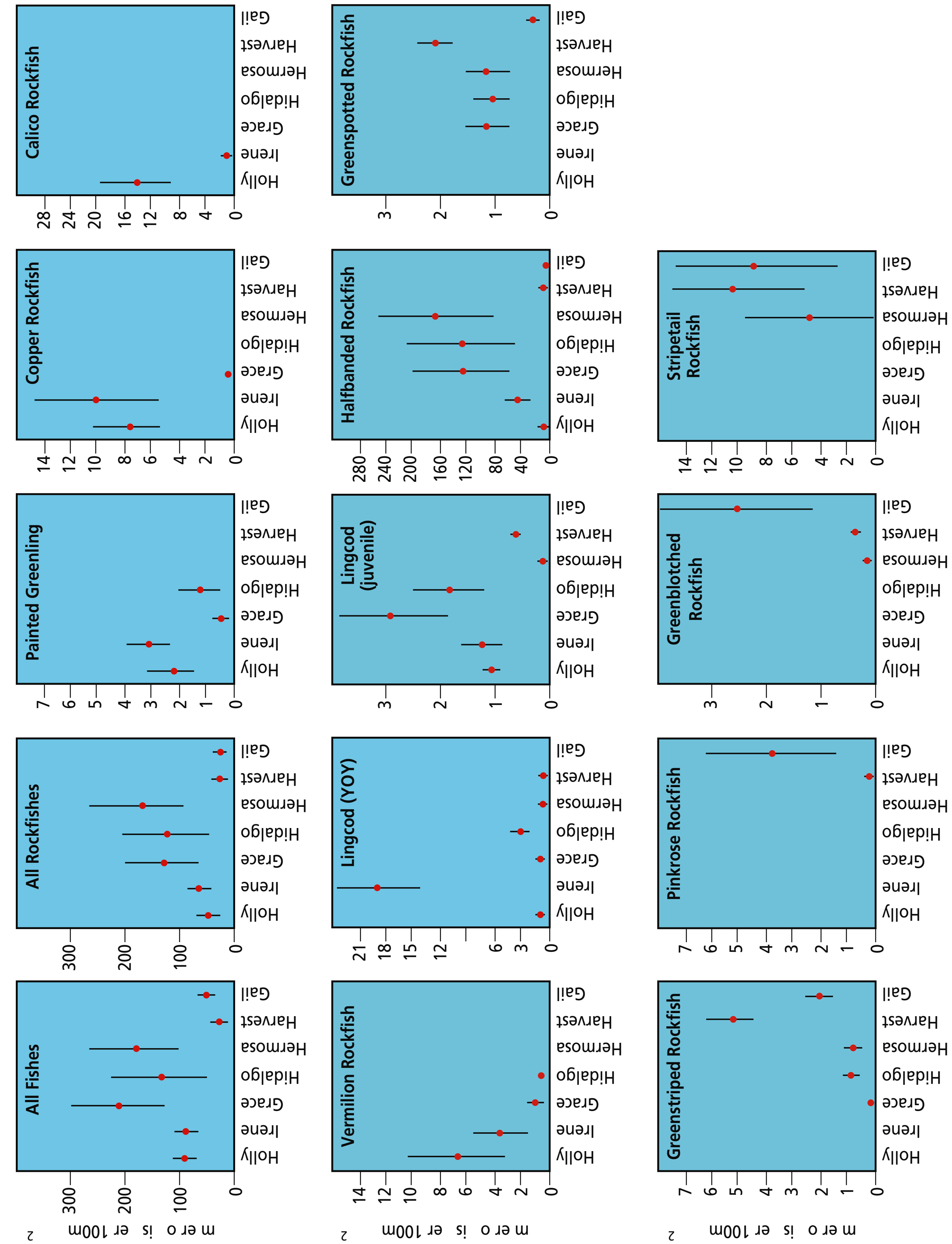


Figure 3.17. Density (with standard error bars) of all fishes, all rockfishes, and the most abundant shell mound fish species found around seven platforms, 1996–2001. Platforms are listed left to right from shallowest to deepest.

Pinkrose rockfish, shell mound of Platform Gail.

Greenspotted and flag rockfishes, shell mound of Platform Gail.

Young-of-the-year cowcod on shell mound of Platform Gail.

Halfbanded rockfish, shell mound of Platform Hidalgo.

3. A Comparison of Fish Assemblages at a Deeper Platform and a Nearby Natural Outcrop: Hidalgo and North Reef

Findings at a Glance

The species composition at Platform Hidalgo and North Reef are quite similar as both structures are dominated by rockfishes. In general, the distinctions between the platform and reef assemblages were based on differences in species densities (rather than species presence or absence). Most species were more abundant at Platform Hidalgo than at North Reef. Halfbanded, greenspotted, flag, greenstriped, and canary rockfishes, all three life stages of lingcod (young-of-the-year, immature, adult), and painted greenling all had higher densities around the platform. Five species (i. e., pink seaperch, shortspine combfish, pygmy, squarespot, and yellowtail rockfishes) were more abundant at the reef. The dominance of small fishes at North Reef probably reflects fishing pressure that has cropped larger individuals. Young-of-the-year rockfishes were found at both Platform Hidalgo (primarily in the midwaters) and at North Reef. In each of five years, young-of-the-year rockfish density was higher at the platform than at the reef. In several years, densities of these young fishes were more than 100 times greater at Platform Hidalgo than at North Reef.

We surveyed the fish assemblages at Platform Hidalgo and a nearby natural outcrop, North Reef, for the period 1996–2001. North Reef was compared with Platform Hidalgo because it is close to the platform (about 1,000 m, 3,300 ft., north of the platform) (Figure 3.18), and its depth (112 m, 370 ft.) is comparable to the platform's 130 m (430 ft.). North Reef is a hard carbonate scarp, which is 1–4 m (3–13 ft.) high, 3,353 m^2 in area and contains numerous boulders, caves, and crevices.

The species composition at Platform Hidalgo and North Reef are very similar (Table 3). Both habitats are dominated by rockfishes; they comprised 98.3% and

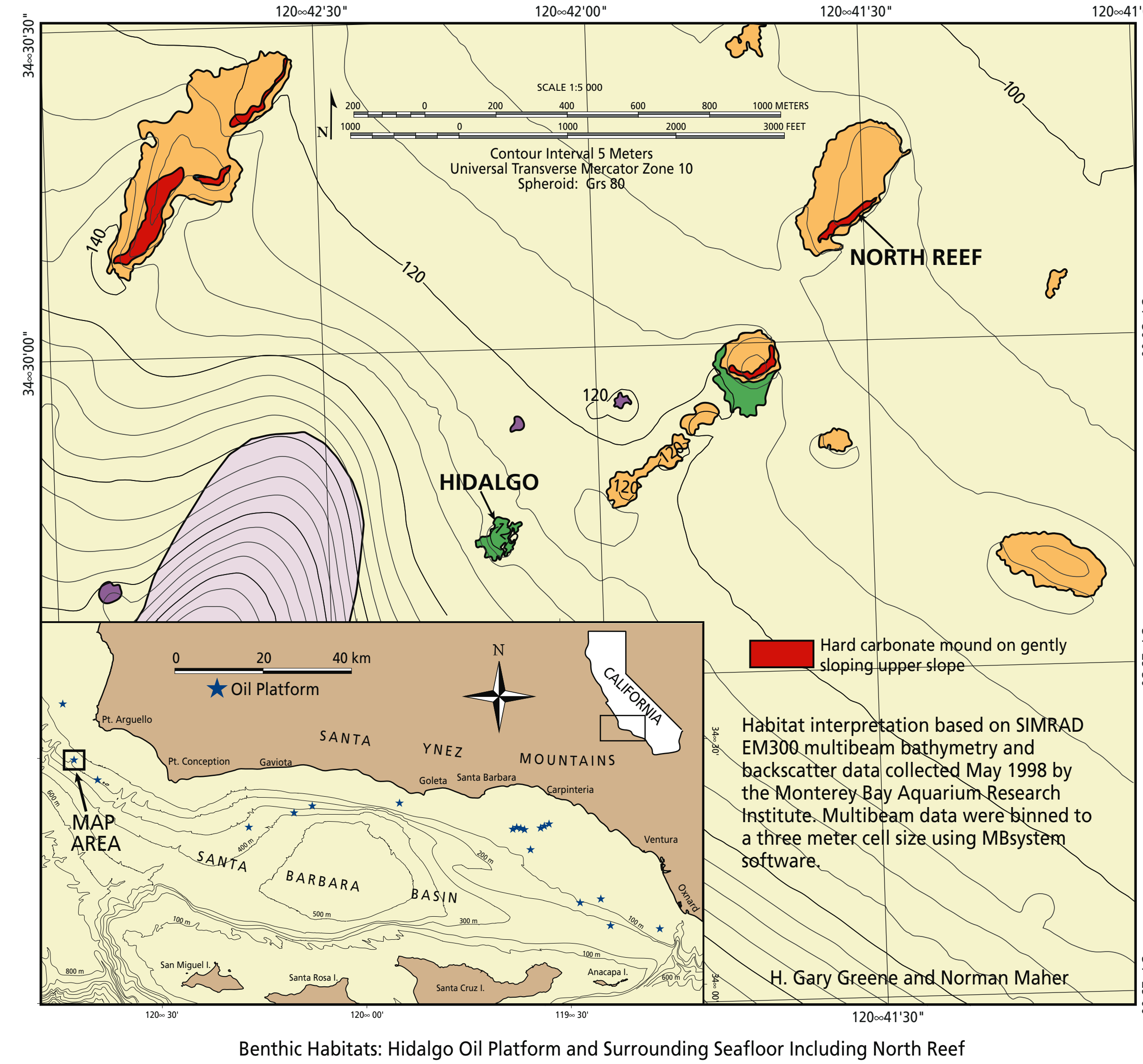


Figure 3.18. Locations of Platform Hidalgo and North Reef. Seafloor characterization by Gary Greene, Moss Landing Marine Laboratory.

96.6% of all fishes at Platform Hidalgo and North Reef, respectively. We observed a minimum of 34 fish species at each location. A few species were unique to each structure. Copper and stripetail rockfishes and California scorpionfish were found only at Platform Hidalgo, while blackeye goby, bluebarred prickleback, Pacific argentine, speckled sanddab, and an unidentified cuskeel were present only at North Reef. None of these species were major constituents of their respective fish communities.

However, when taking into consideration the fish assemblages of the three habitats (midwater, bottom, and shell mounds) at Platform Hidalgo, each was somewhat distinct from that of North Reef (Figure 3.19). To characterize and distinguish between the species assemblages at Platform Hidalgo and North Reef, we compared only the benthic assemblages of the platform bottom and shell mound and North Reef. Canonical discriminant analysis showed that species assemblages at the bottom of Platform Hidalgo and its shell mound were somewhat different from each other and from the North Reef assemblages (Figure 3.20a). The platform bottom assemblage was characterized by a suite of rockfishes, including bocaccio and cowcod, flag, vermilion, and widow rockfishes and lingcod. The shell mound assemblage was similar to and overlapped with the platform bottom, but was characterized by smaller fishes, such as swordspine,

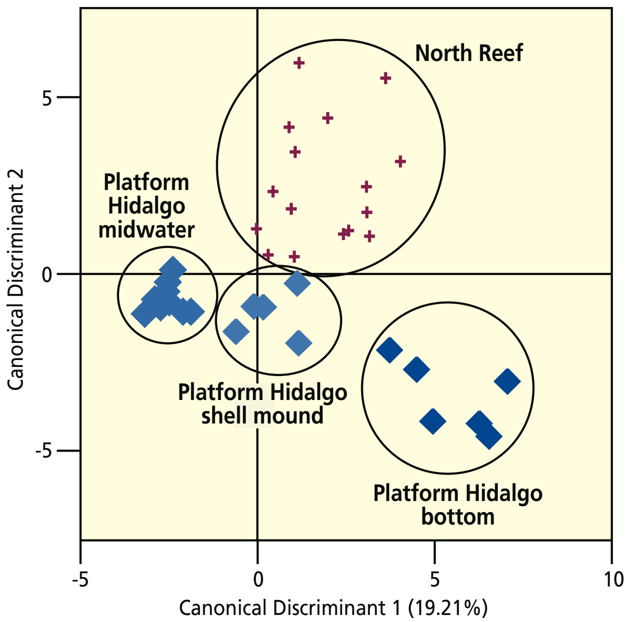


Figure 3.19. Canonical Discriminant Analysis of fish assemblages at Platform Hidalgo, midwater, bottom, and shell mound habitats and North Reef, 1996–2001.

greenstriped and halfbanded rockfishes, painted greenling, and juvenile lingcod (Figure 3.20b).

In general, the distinctions between the platform and reef assemblages were based on differences in species densities rather than species presence and absence. The densities of a range of species varied between the two sites (Figure 3.21) and most exhibited higher densities at Platform Hidalgo than at North Reef (Figure 3.21). Halfbanded, greenspotted, flag, greenstriped, canary rockfishes, all three life stages of lingcod (young-of-the-year, immature, adult), and painted greenling were among the species that were more abundant around the platform. Five species (pink seaperch, shortspine combfish, pygmy, squarespot, and yellowtail rockfishes) were more abundant at the reef.

Young-of-the-year rockfishes were common at both Platform Hidalgo (primarily in the midwaters) and at North Reef, although species differences were observed. From our submersible surveys, we identified at least seven species of young-of-the-year rockfishes at Hidalgo (e.g., blue, bocaccio, olive, pygmy, squarespot, widow, and yellowtail). Our scuba surveys around that platform also noted young-of-the-year of the "copper complex," composed of black-and-yellow, copper, gopher, and kelp rockfishes. Most of the young-of-the-year rockfishes at North Reef appeared to be pygmy, squarespot, and widow rockfishes.

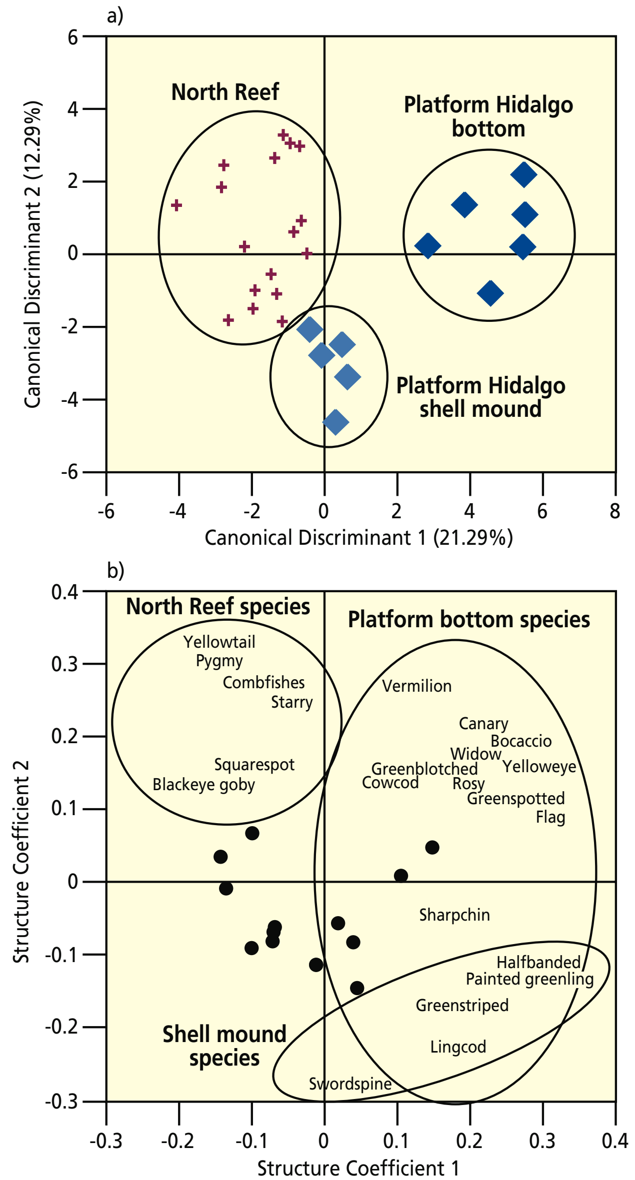


Figure 3.20. 3.20a. Canonical Discriminant Analysis of fish assemblages at Platform Hidalgo bottom and shell mound habitats and North Reef, 1996–2001. Each yearly survey at North Reef was comprised of 2–3 transects and thus each year's survey is represented by more than one cross. 3.20b. Canonical Discriminant Analysis of the species found around Platform Hidalgo, bottom and shell mound and North Reef, 1996–2001. Dots represent species that were not strongly associated with either axis.

The mean density of young-of-the-year rockfishes in the midwater habitat of Platform Hidalgo was higher than at North Reef (Figure 3.21). This probably reflects greater rockfish recruitment to the platform. This has important implications with respect to platform habitat values regarding settlement and fish production around

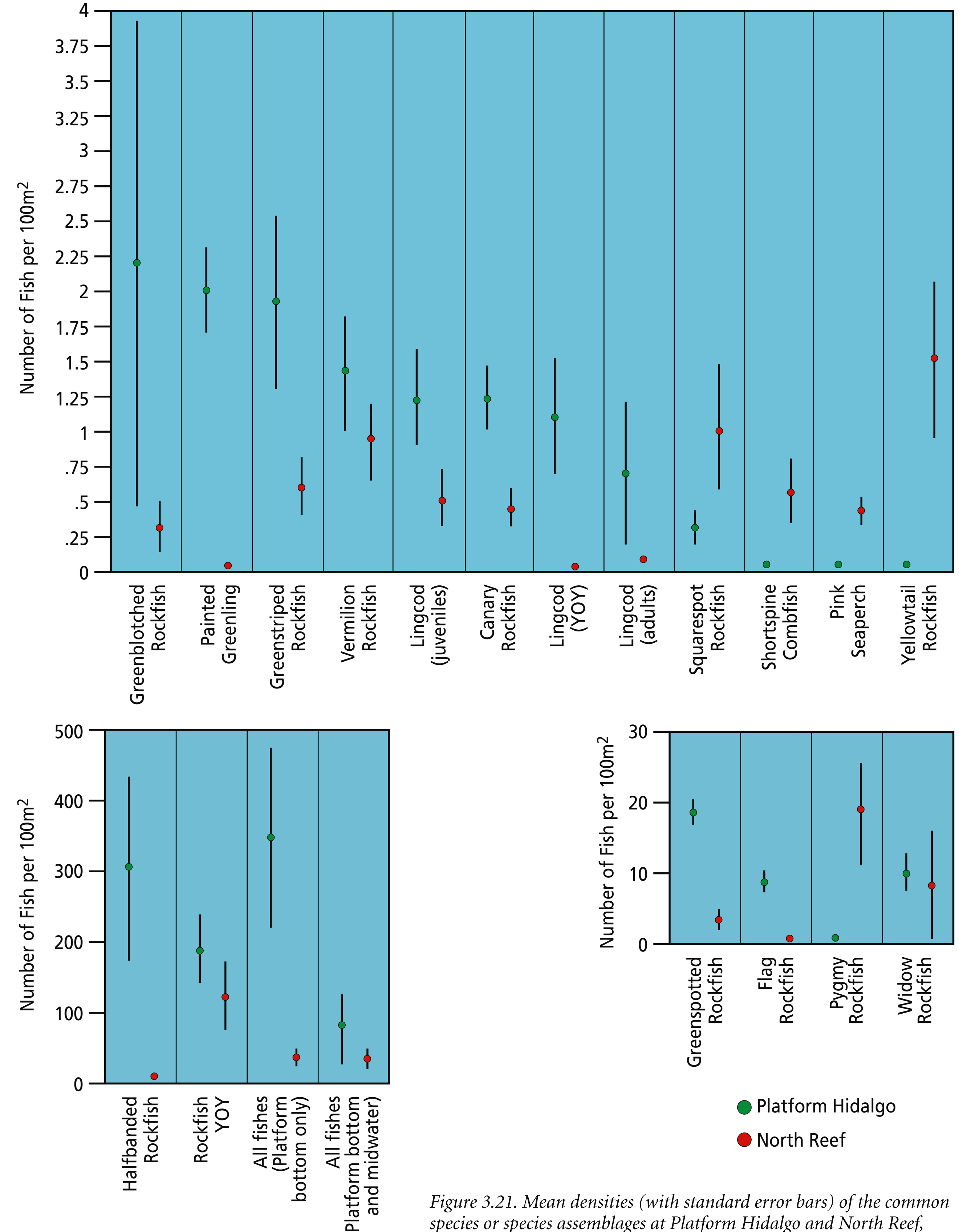


Figure 3.21. Mean densities (with standard error bars) of the common species or species assemblages at Platform Hidalgo and North Reef, 1996–2001. Species or species assemblages are grouped by abundance.

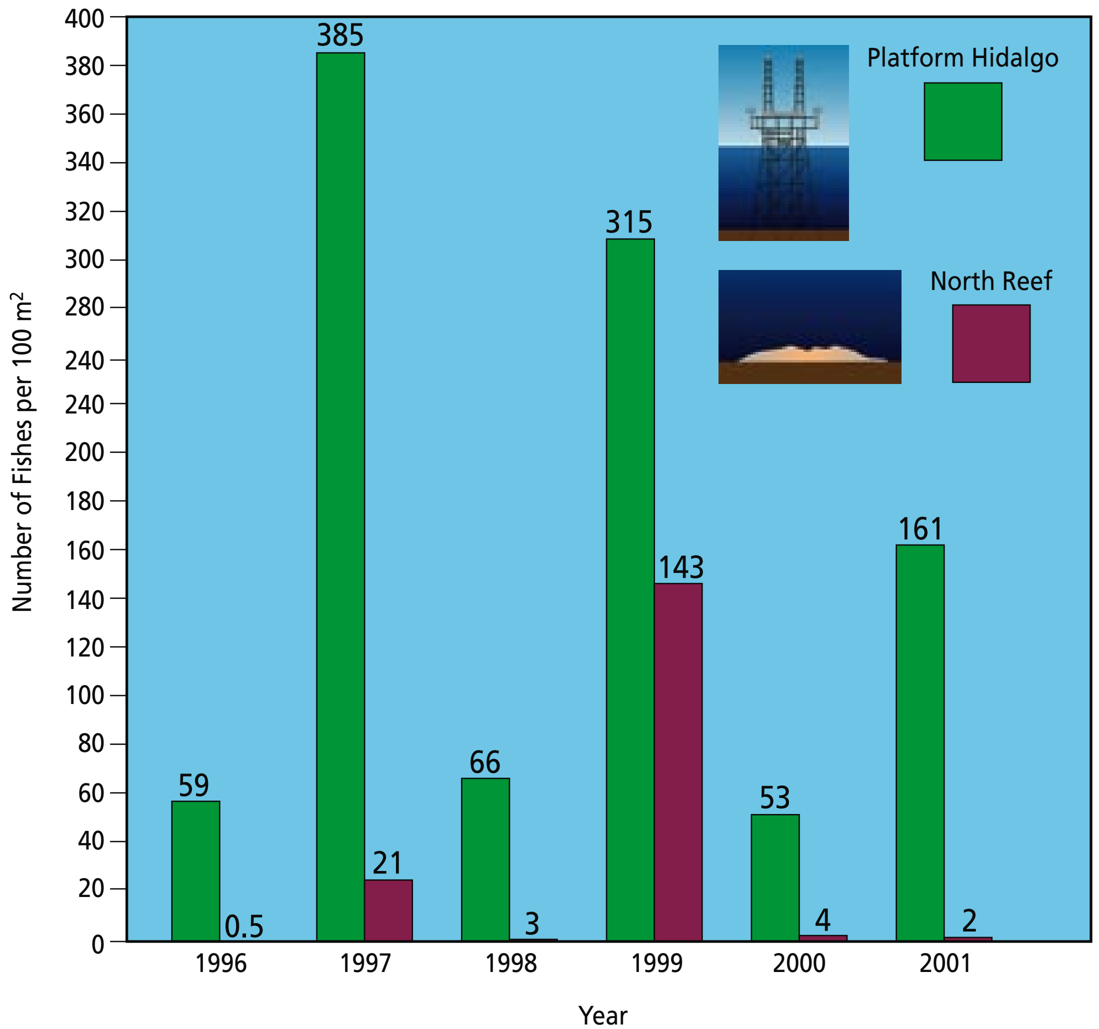


Figure 3.22. Mean densities of young-of-the-year rockfishes, all species combined, at Platform Hidalgo midwater and North Reef, 1996–2001.

these structures. This recruitment pattern was repeated in each year of our surveys as young-of-the-year rockfish densities were always greater at the platform than at the outcrop (Figure 3.22). In some years, densities were more than 100 times greater at the platform.

4. A Comparison of Fish Assemblages of Platforms and Natural Outcrops off Central and Southern California

Findings at a Glance

Based on surveys of seven platforms and over 80 natural outcrops, rockfishes dominate almost all of the platform and hard seafloor habitats. A greater number of species was observed at the natural outcrops (94) than at the platforms (85). There is a high degree of overlap in species composition and differences are primarily due to generally higher densities for more species at platforms. In particular, widow rockfish young-of-the-year, canary, copper, flag, greenblotched, greenspotted, greenstriped, halfbanded, and vermilion rockfishes, bocaccio, painted greenling and all life history stages of lingcod were more abundant at platforms. Yellowtail rockfish and the dwarf species pygmy, squarespot, and swordspine rockfishes were more abundant on natural outcrops. Some of these differences can be explained by recruitment (settlement) processes and the greater chance for survival at the platform habitats. We believe that as fish size increases with age the platforms act as de facto marine reserves because fishing pressure is light or nonexistent. Platforms can be characterized as having higher densities of young-of-the-year rockfishes than natural outcrops.

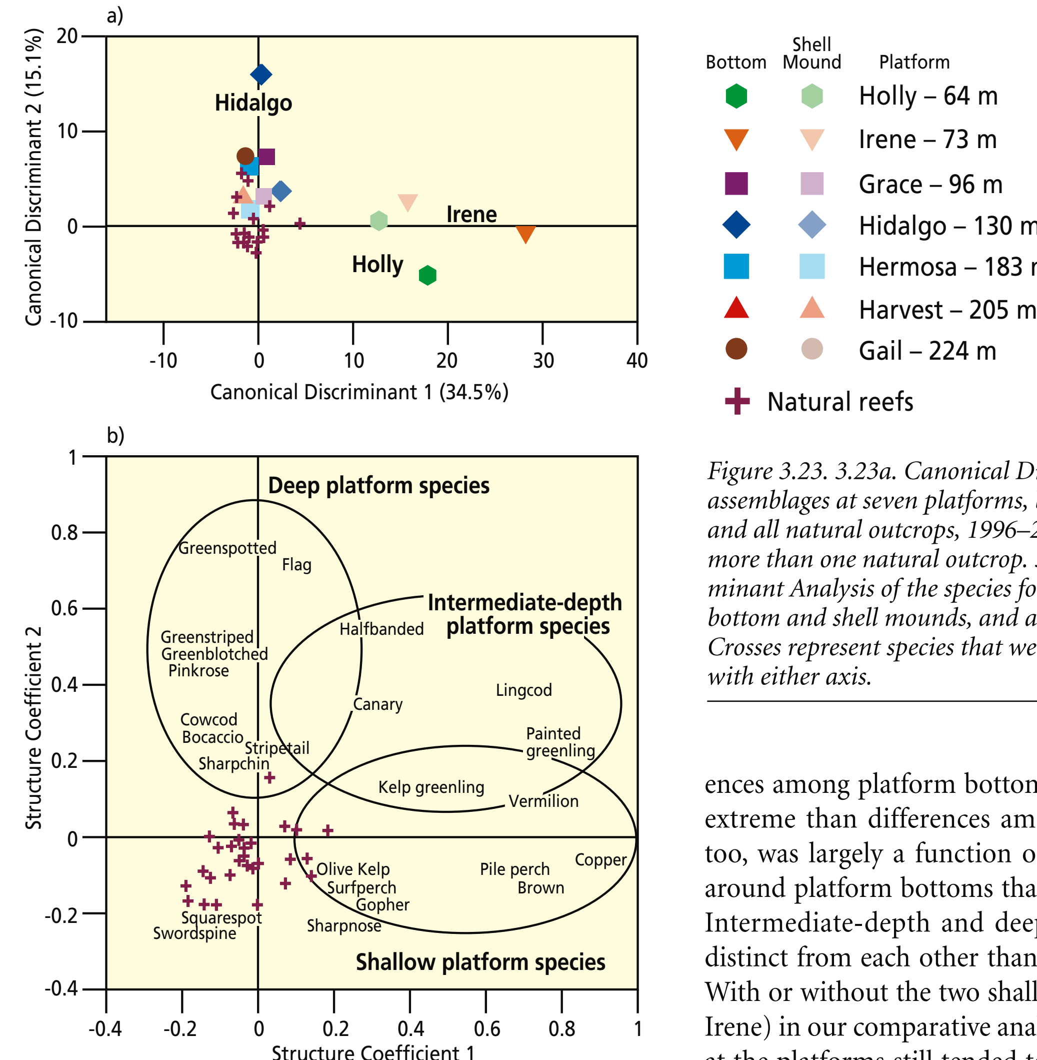


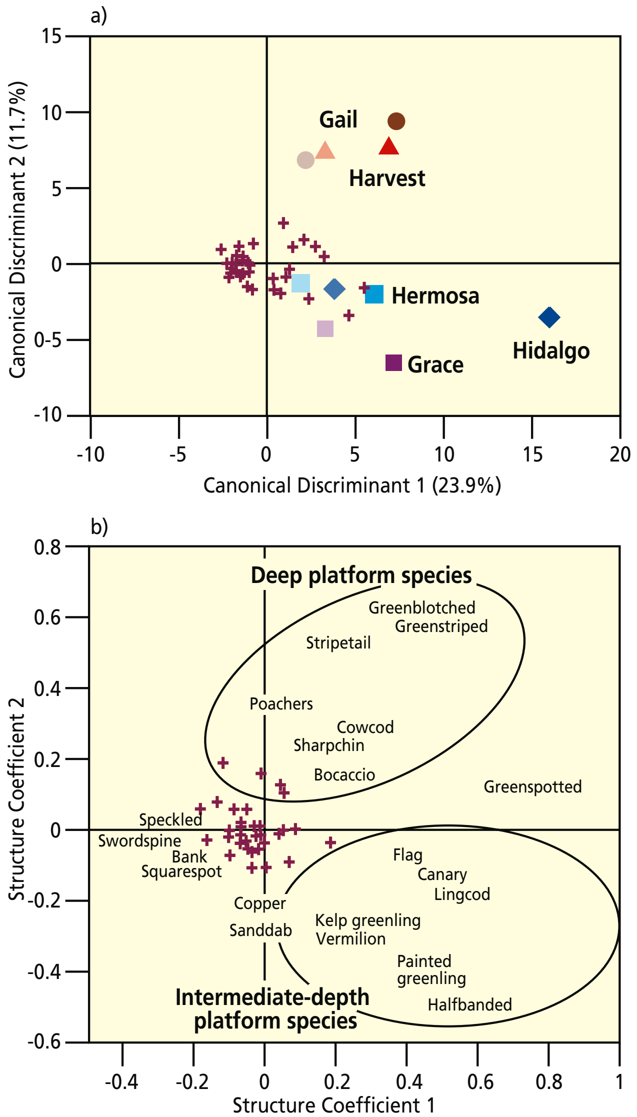
Figure 3.23. 3.23a. Canonical Discriminant Analysis of fish assemblages at seven platforms, bottom and shell mound, and all natural outcrops, 1996–2001. Each cross represents more than one natural outcrop. 3.23b. Canonical Discriminant Analysis of the species found at seven platforms, bottom and shell mounds, and all natural reefs, 1996–2001. Crosses represent species that were not strongly associated with either axis.

We compared the fish assemblages from the deeper parts of seven platforms (below about 30 m, 100 ft.) with those of similar depth natural outcrops. Analyses were based on platform surveys and on 133 dives at over 80 natural outcrops throughout southern California and off Point Conception and Point Arguello (Figure 1.5).

We observed at least 85 species at platforms and 94 species at outcrops (Table 4). Rockfishes dominated both habitats, comprising 89.7% of all fishes at platforms and 92.5% at outcrops. Platform fish assemblages were somewhat different from those of natural outcrops (Figures 3.23a, b). However, these differences were due almost entirely to the generally greater numbers, of more species, of fishes around platforms, rather than differences in species composition between platforms and outcrops.

There was a distinct assemblage of fishes at the two shallow platforms, Holly and Irene, and another composed of species occupying the deeper platforms. Differences among platform bottom assemblages were more extreme than differences among shell mounds. This, too, was largely a function of greater fish abundance around platform bottoms than over the shell mounds. Intermediate-depth and deepest platforms were less distinct from each other than from shallow platforms. With or without the two shallow platforms (Holly and Irene) in our comparative analysis, the fish assemblages at the platforms still tended to be different from those at the natural outcrops (Figures 3.24a, b). These differences were primarily due to most fish species being more abundant at platforms than at outcrops (Figure 3.25). Widow rockfish young-of-the-year, canary, copper, flag, greenblotched, greenspotted, greenstriped, halfbanded, and vermilion rockfishes, bocaccio, painted greenling, and all life history stages of lingcod were more abundant at platforms. Species that were more abundant at natural outcrops than platforms included pygmy, squarespot, swordspine, and yellowtail rockfishes.

Platforms tended to harbor higher densities of young-of-the-year rockfishes than did natural outcrops. Young-of-the-year rockfishes primarily occurred in the platform midwaters. Thirteen of the 20 highest young-of-the-year rockfish densities were observed at Platforms Grace, Harvest, Hermosa, Hidalgo, Holly, and Irene (Table 5). The highest young-of-the-year rockfish densities over natural outcrops were usually at high relief sites well away from the mainland. The California Current, which is centered



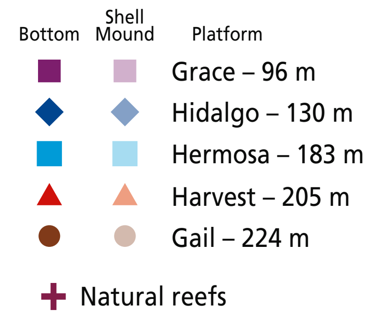


Figure 3.24. 3.24a. Canonical Discriminant Analysis of fish assemblages at five platforms (shallower platforms Holly and Irene deleted), bottom and shell mound, and all natural outcrops, 1996–2001. Each cross represents more than one natural outcrop. 3.24b. Canonical Discriminant Analysis of the species found at five platforms (shallower platforms Holly and Irene deleted), bottom and shell mound, and all natural outcrops, 1996–2001. Crosses represent species that were not strongly associated with either axis.

offshore of the coastal shelf, influences these locations (e.g., San Nicolas and San Miguel islands) more than the mainland sites we surveyed. Furthermore, our observations strongly imply that the midwaters of many platforms bear a striking resemblance to some of the relatively shallow and steep-sided outcrops (such as those on Hidden Reef) that dot the outer continental shelf of southern California. In both cases, the assemblages are dominated by young rockfishes and larger fish predators are relatively uncommon. Thus, survivorship of young fishes may be higher in both habitats due to lowered predation rates.

The role that some platforms play as defacto marine refuges is supported by evidence of greater densities of rockfishes, particularly the larger size classes, at platforms compared to natural outcrops. As an example, densities tended to be higher at some platforms than at natural outcrops for: (1) all rockfishes regardless of size, (2) all rockfishes greater than or equal to 30 cm (12 in.), (3) adult bocaccio, and (4) adult cowcod (Figures 3.26–3.29). Our experience is that rockfishes are most susceptible to being caught by both recreational and commercial gear when they reach about 30 cm (12 in.); thus, densities of fishes of this or larger sizes would be an indication of fishing pressure. Adult bocaccio and cowcod are overfished species with population sizes at levels less than 10% of unfished stock. These fishes at one time were abundant in southern California.

Rockfishes were observed at all of the platforms and outcrops we surveyed, with the exception of two sites on Piggy Bank (Figure 3.26). The highest rockfish densities (500 rockfishes or more per 100 m^2) occurred at four platforms and at five natural outcrops; all of these structures were nursery grounds for young-of-the-year rockfishes. The assemblages of most of the other platforms and outcrops that harbored relatively high rockfish densities also were primarily composed of small rockfishes, both immature individuals and dwarf species. This can be clearly seen when we focussed on rockfishes 30 cm (12 in.) or larger (Figure 3.27). The paucity of rockfishes 30 cm (12 in.) or larger is evident even at the most productive sites (Figure 3.27). Highest densities of large rockfishes (10 rockfishes or more per 100 m^2) occurred at three platforms and two natural outcrops. Many sites harbored no or only a few larger rockfishes.

Almost all of the natural outcrops we studied should have harbored large numbers of larger rockfishes. Their absence or rarity is almost certainly attributable at least

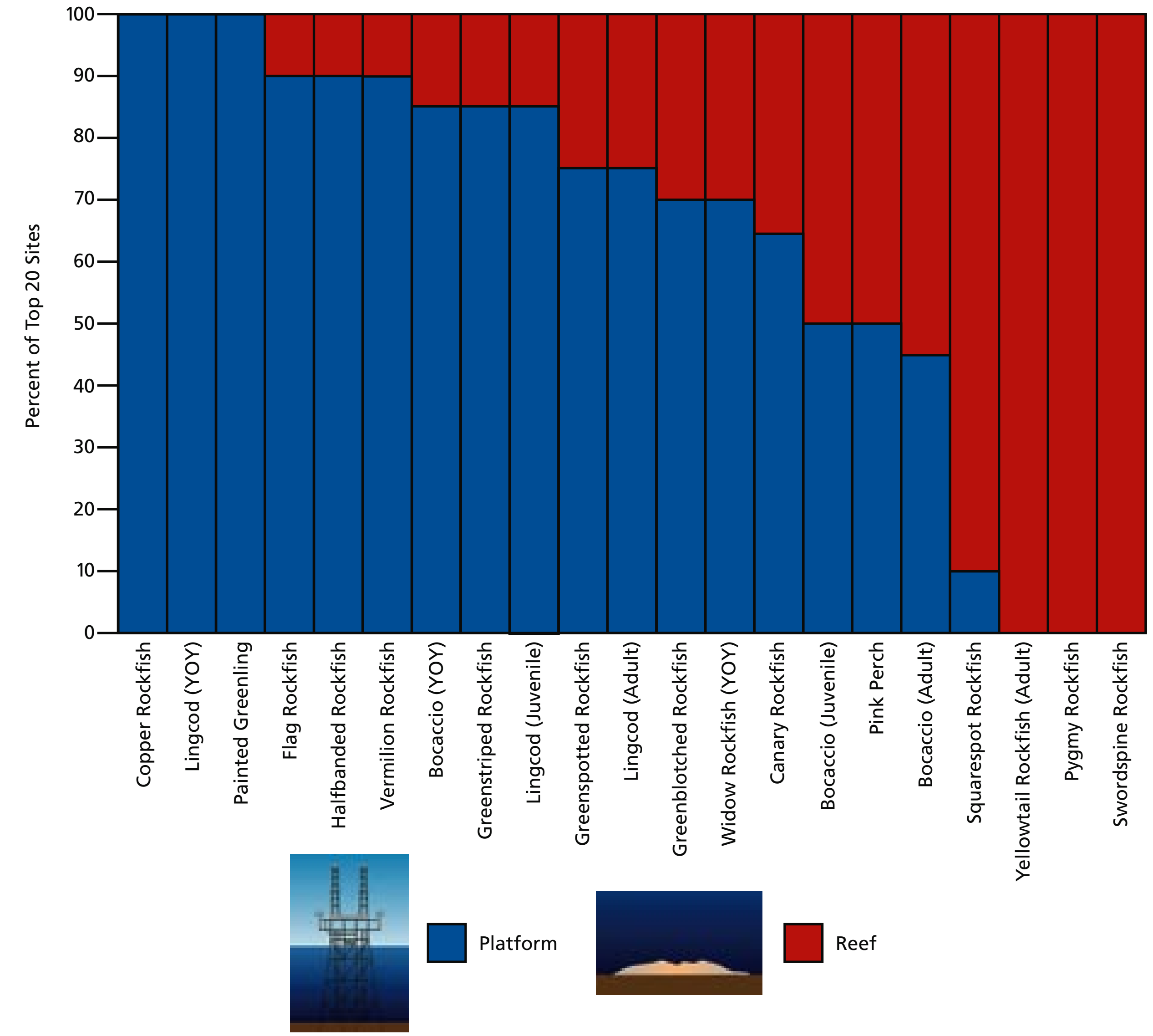


Figure 3.25. The relative importance of seven platforms (Irene, Hidalgo, Harvest, Hermosa, Holly, Grace, and Gail) and about 80 natural outcrops off central and southern California as habitat for common reef fish species. Densities of these species were computed for each year, at each location (platform midwater, bottom and shell mound, and natural outcrops) and ranked from highest to lowest. This figure displays the percentage that platforms or natural outcrops comprised of the top 20 densities for each species (or species' life history stage). For example, of all sites where copper rockfish were observed, the highest 20 densities were at various platforms, in a number of years. Similarly, the highest 20 densities of swordspine rockfish were all at natural outcrops. See Appendix 4 for underlying data.

in part to fishing pressure. These sites were comprised of boulders or other structures that were suitable shelter sites for larger sized rockfishes. A few outcrops, such as sites near the Potato and Osborn Banks, were composed of cobble, a habitat that is less likely to harbor large rockfishes. Adult bocaccio were only abundant around Platform Gail and were relatively common at Platform Hidalgo, Reef "D" near that platform and a few sites around the northern Channel Islands (Figure 3.28). Even at these natural outcrops, many shelter structures contained no or few adult bocaccio. Cowcod densities were also depressed (Figure 3.29). Relatively few rock outcrops surveyed contained adults, and platform Gail harbored the highest densities, although even here numbers were low. In general, the highest densities of adult bocaccio and cowcod occurred at platforms or at those outcrops that were protected from harvest by distance from ports or by being situated in areas susceptible to poor weather conditions.

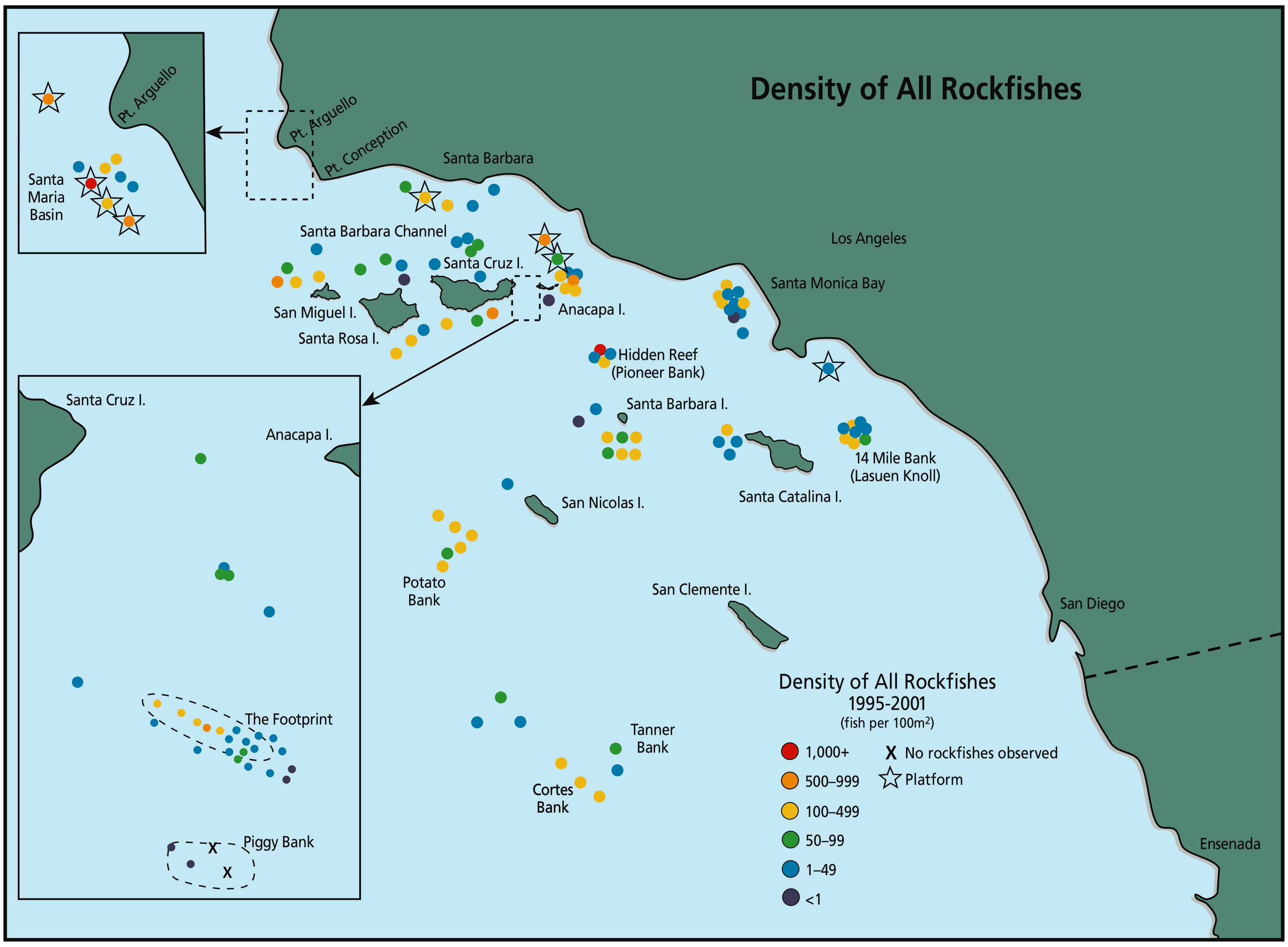


Figure 3.26 . Density of all rockfishes, regardless of size, as observed from the Delta *submersible on platforms and natural outcrops, 1995–2001. Fish densities for Platforms Irene, Hidalgo, Harvest, Hermosa, Holly, Grace and Gail, North Reef and reefs "A", "B", "C" and "D" in the vicinity of Platform Hidalgo represent means of years.*

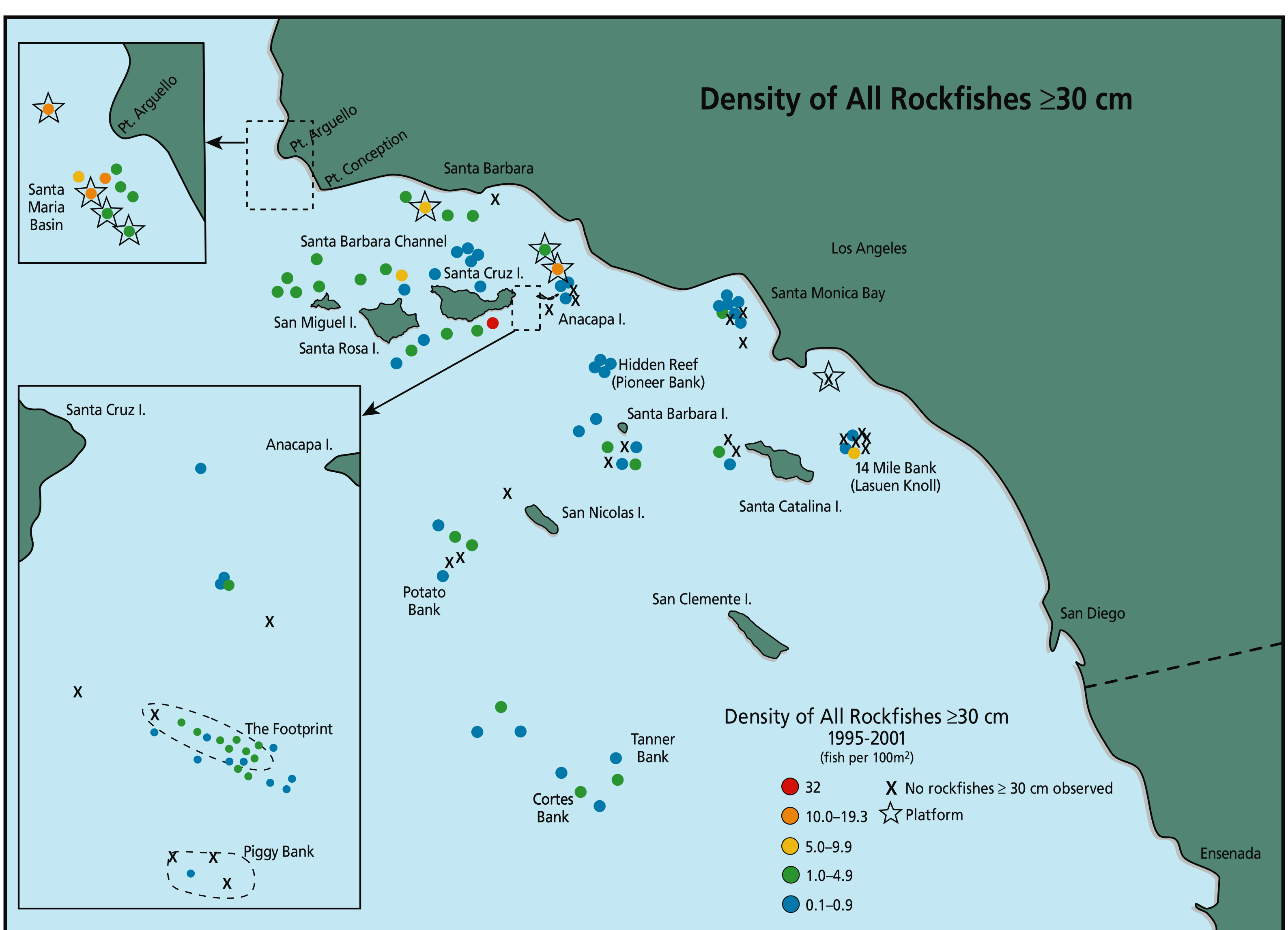


Figure 3.27. Density of all rockfishes larger than or equal to 30 cm as observed from the Delta *submersible on platforms and natural outcrops, 1995–2001. Fish densities for Platforms Irene, Hidalgo, Harvest, Hermosa, Holly, Grace and Gail are from platform bottoms and densities for these seven platforms and for North Reef and reefs "A", "B", "C" and "D" in the vicinity of Platform Hidalgo represent means of years. Platforms C, B, A, Hillhouse, Hogan, Houchin, and Henry were not included because they were not completely surveyed.*

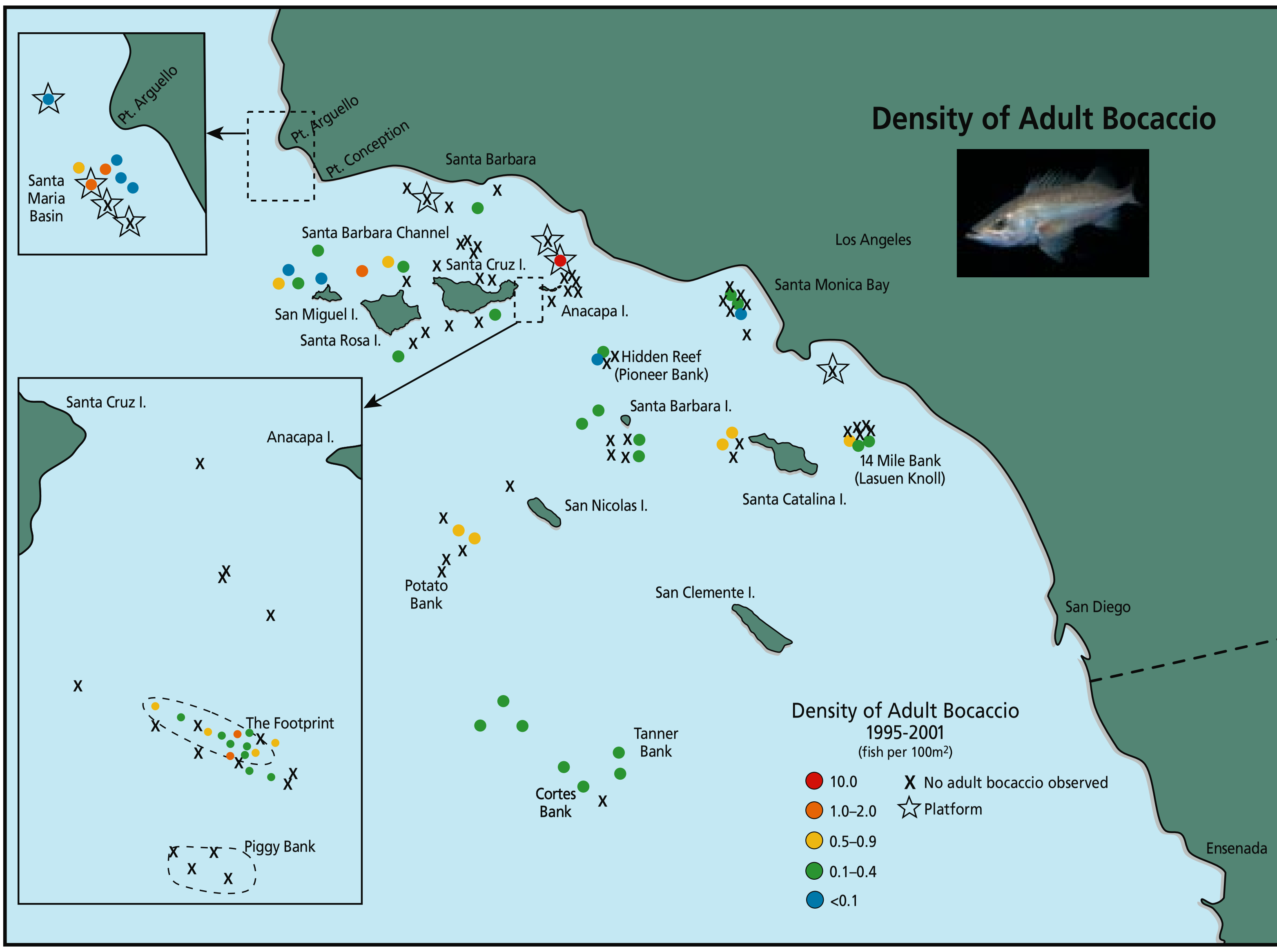


Figure 3.28. Density of adult bocaccio (defined as fish larger than 35 cm total length) as observed from the Delta submersible on platforms and natural outcrops, 1995–2001. Bocaccio densities for Platforms Irene, Hidalgo, Harvest, Hermosa, Holly, Grace and Gail are from platform bottoms and densities for these seven platforms and for North Reef and reefs "A", "B", "C" and "D" in the vicinity of Platform Hidalgo represent means of years. Platforms C, B, A, Hillhouse, Hogan, Houchin, and Henry were not included because they were not completely surveyed.

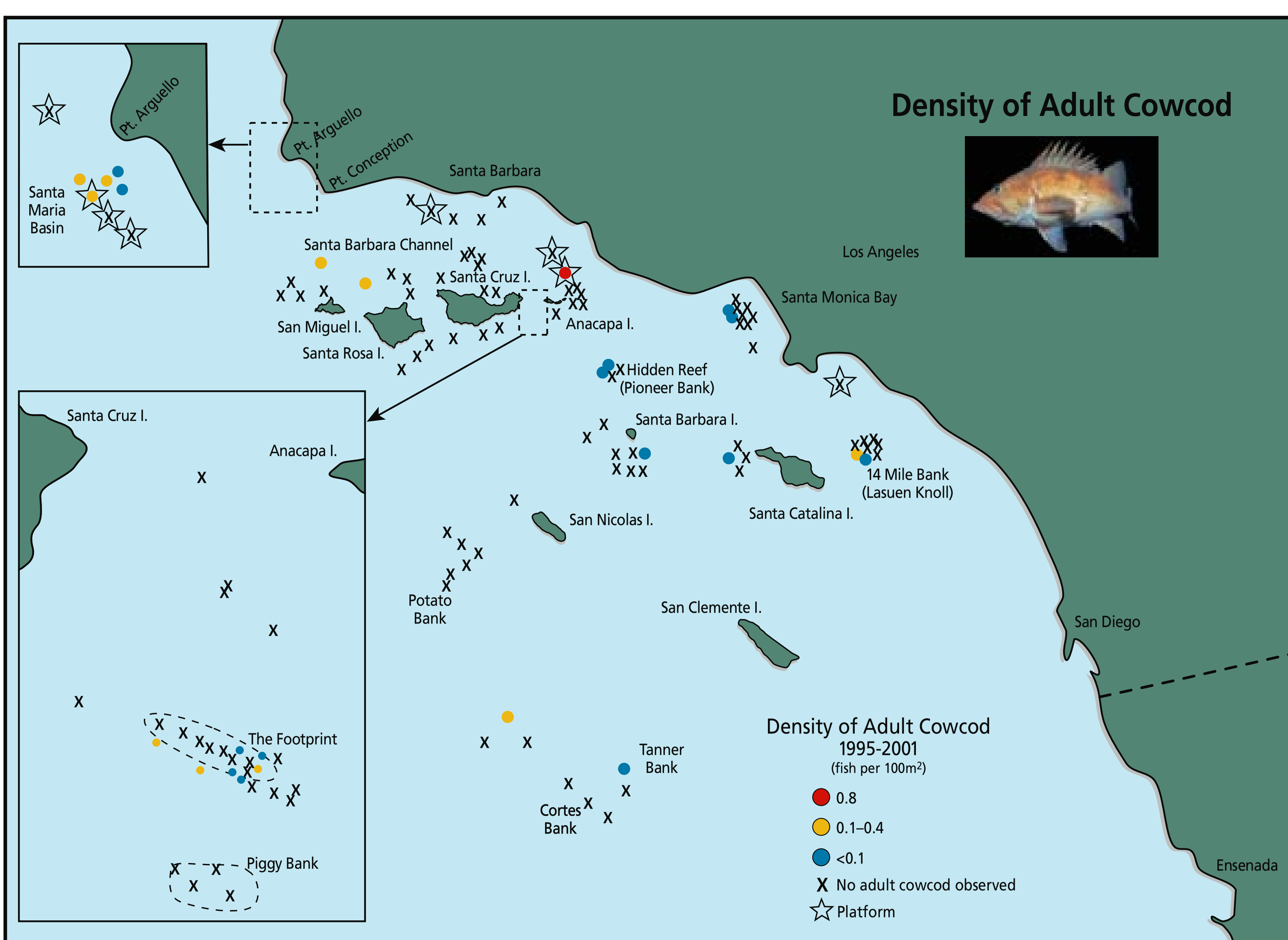


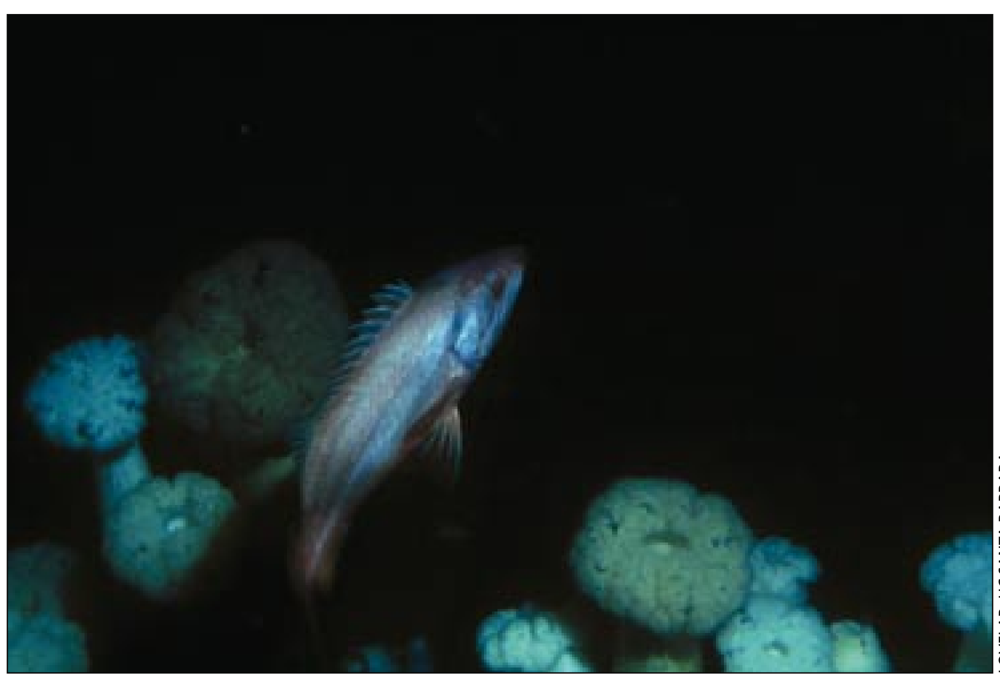
Figure 3.29. Density of adult cowcod (defined as fish larger than 45 cm TL) as observed from the Delta *submersible on platforms and natural outcrops, 1995–2001. Cowcod densities for Platforms Irene, Hidalgo, Harvest, Hermosa, Holly, Grace and Gai are from platform bottoms and densities for these seven platforms and for North Reef and reefs "A", "B", "C" and "D" in the vicinity of Platform Hidalgo represent means of years. Platforms C, B, A, Hillhouse, Hogan, Houchin, and Henry were not included because they were not completely surveyed.*

Why platforms support higher densities of young rockfishes than do nearby natural outcrops.

Platforms are important nursery habitat for many species of rockfishes. This research demonstrates that, in general, platforms may be more important nursery habitats than nearby natural outcrops or, indeed, most other outcrops surveyed in central and southern California. Why is this? First, platforms occupy more of the water column than do most natural outcrops. Presettlement juvenile rockfishes, swimming in the midwater, are much more likely to encounter these tall structures than the relatively low-lying natural rock outcrops. It is interesting to note that most of the natural outcrops we found that had high densities of young-of-the-year rockfishes (e.g., Hidden Reef and outcrops around islands) were very high relief features that thrust their way well into the water column.

In addition, there are also relatively fewer large predators in the platform midwaters. By comparison, even on heavily fished outcrops there tend to be at least a few larger fishes. Many of the major predators of young rockfishes are species that live close to the bottom, such as lingcod, copper and vermilion rockfishes, cowcod and large bocaccio. In general, these species do not ascend the platform jacket. Thus, even when they are abundant at the bottom of a platform, they are absent from the platform midwaters. In this respect, platforms are similar to some of the offshore pinnacles on the southern California continental shelf. Predatory species, such as cowcod, lingcod, and greenblotched rockfishes are also not abundant around the steep, smooth sides of offshore outcrops.

At most of the platforms, we observed both harbor seals and California sea lions, both resting on the platforms and swimming in the water column among the jackets and conductors. Based on the known food habits of these animals, it is likely that they feed on platform fishes, but their low numbers probably have little effect on the abundance of young rockfishes. We also observed both harbor seals and California sea lions swimming over natural outcrops and it likely that here, too, predation on young rockfishes occurs.



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Bocaccio.

Platforms as defacto marine refuges

The role that some platforms play as defacto marine refuges is supported by evidence of greater densities of rockfishes, particularly the larger size classes, at platforms than at natural outcrops. The role that platforms may play as de facto reserves should not be underestimated at a time when many fish populations are in decline on natural outcrops. A number of benthic fishes, including such economically important species as bocaccio, cowcod, copper, and vermilion rockfishes and lingcod find refuge within the platforms and this is probably a factor in their relatively high densities compared to most natural outcrops. Schroeder and Love (2002) compared the rockfish assemblages at three deeper-water areas subjected to variable fishing pressures. Two were natural outcrops, one outcrop open to all fishing and one open only to recreational fishing, and the third was Platform Gail, acting as a de facto marine refuge. The outcrop allowing open fishing had the highest densities of rockfishes (7,212 fish/ha); however, the assemblage was dominated by dwarf species. The recreational fishing area had the lowest rockfish density (423 fish/ha) and this assemblage was also dominated by small fishes. Platform Gail possessed a relatively high density (5,635 fish/ha), and the fishes tended to be larger than individuals at either of the fished sites. Two federally listed overfished species, cowcod and bocaccio, had 32- and 408-fold higher densities, respectively, at Platform Gail than the recreational site, and 8- and 18-fold higher densities, respectively, than the all-fishing area.

There is some fishing effort around most platforms in the Southern California Bight and Santa Maria Basin. The relative amount of fish pressure among platforms is dependent on ease of access and local ocean conditions. Platforms in the Santa Maria Basin are located in an area that is far from ports, usually windy, and unprotected from weather. It is difficult to fish around the bottom of platforms, especially the deeper ones, because of the threat to gear imposed by the large number of crossbeams, other platform structural elements, conductors, and strong currents. Many anglers also believe that operators do not welcome fishing near their platforms.

Some platforms are important fishing areas for recreational anglers. Historically, commercial passenger fishing vessels and small private vessels fished around some of the shallower platforms in the Santa Barbara Channel (Love and Westphal 1990). Platforms Hilda and Hazel were targeted for kelp bass. During years with strong rockfish recruitment, large numbers of juvenile bocaccio, blue, olive, and widow rockfishes were caught at Platforms Holly, A, B, C and Hillhouse. In all of these instances, fishing effort was directed at surface or midwaters, rather than at the platform bottom. The removal of Hilda and Hazel and the poor rockfish recruitment of the 1980s and much of the 1990s reduced the overall fishing effort at oil/gas platforms. Some recreational fishing continues around Platform Gina, and there is minimal effort around a few other structures in the Santa Barbara Channel.

Overfishing has drastically altered the species composition of many outcrops off central and southern California (Yoklavich et al. 2000; M. Love, unpublished data). Over most moderate-depth and deep outcrops in central and southern California, many, or sometimes all, of the larger predatory fishes, such as lingcod, cowcod, bocaccio, yelloweye, and canary rockfishes are gone. In contrast, surveys made over an unfished outcrop in central California showed very high densities of large predatory fishes, including lingcod, cowcod, bocaccio, and yelloweye rockfish (Yoklavich et al. 2000). At many natural outcrops, these larger individuals have been replaced by very large numbers of dwarf species, particularly pygmy, swordspine, and squarespot rockfishes. Fish assemblages at platforms, such as Gail, Hidalgo, and Irene, with relatively high densities of many economically important species and low numbers of dwarf species, may more closely resemble unfished assemblages than those at many natural outcrops.

5. The Origins of Platform Fishes: Production and Attraction

Finding at a Glance

Our research suggests that platforms, like natural outcrops, both produce and attract fishes, depending on species and location. Platform fish assemblages around the deeper and further offshore platforms may be generated primarily from the recruitment of larval and pelagic juvenile fishes, not from attraction of fishes from natural outcrops. Some fishes may live their entire lives around a single platform but their movement patterns are poorly known. A pilot study comparing growth rates showed that young-of-the-year blue rockfish grew faster at a platform than at a natural outcrop.

In recent years, public attention has been drawn to artificial reefs and their function in the marine environment. While a variety of issues have been raised, much of the discussion has centered around the question of whether artificial reefs are producers or attractors of marine life (Carr and Hixon 1997; Lindberg 1997). Some researchers suggest this question is biologically simplistic, because it "imposes an unrealistic either-or-dichotomy…" (Lindberg 1997). Nevertheless, this issue continues to arise in the context of the importance of platforms as fish habitat off California (Carr and Stephens 1998; Krop 1998).

Attraction suggests the net movement of juvenile and adult fishes away from natural outcrops to platforms. While there is not complete agreement on the definition of production, most researchers agree that it involves larval or pelagic juvenile settlement at a structure and the survival and growth of these organisms in this habitat (Carr and Hixon 1997).The attraction/production debate is framed around three questions (Carr and Stephens 1998; Krop 1998): (1) Do larval and juvenile fishes settle onto platforms from the plankton, or do fishes move from other structures to platforms as older juveniles or adults? (2) If a species does settle onto a platform, are growth and survivorship at least as good as on a natural outcrop? (3) If a species does grow and survive well around a platform, did the structure take away larvae or pelagic juveniles that would have settled onto natural outcrops?

5a. Do Fishes Settle from the Plankton onto Platforms or Do They Swim There from Other Structures as Juveniles or Adults?

A large number of fish species settled out of the plankton and took up residence around platforms. We observed young-of-the-year of about 46 fish species at these structures (Table 6) and, including species observed by other researchers (Carlisle et al. 1964), at least 50 fish settle on to platforms from the plankton. During some years, the midwaters of many platforms had very high densities of juvenile rockfishes. Young-of-the-year blacksmith, kelp and painted greenlings, and cabezon also were abundant in this habitat at times. Young-of-the-year rockfishes, lingcod, and other species were abundant around platform bottoms and shell mounds. With a few exceptions, species that settled on the bottom and shell mound were different from those found in the midwaters.

Juveniles of some species were rarely or never observed around platforms. For instance, young-of-the-year kelp bass were rarely seen around any platform, although adults were very abundant at one platform. Young seaperches also were rare or absent. In these cases, older juveniles or adults immigrated to the platforms or juveniles settled there at times other than our surveys.

5b. The Biological Influence of Oceanographic Conditions on Recruitment Success at Platforms and Natural Outcrops in the Santa Barbara Channel and Santa Maria Basin

Most coastal fishes and invertebrates, including those inhabiting platforms, are planktonic during early stages of their life histories. These life stages, which may last from weeks to months, can begin as fertilized eggs (e.g., lingcod, cabezon, and garibaldi) or larvae (e.g., rockfishes). Some fishes, including rockfishes, continue to develop in the pelagic environment until they transform to the juvenile stage (Figure 3.30).

Pelagic life stages are at risk from starvation and predation and transport away from the specific habitats required for their growth and survival. Therefore, the type of water mass an animal finds itself may have a profound effect on its survival. There are a number of water masses in our study area, including waters from the Southern California Bight, the central California coast, upwelling from Point Conception, and from more distant places such as Baja California. How these waters enter, circulate and mix in the Santa Barbara Channel and Santa Maria Basin affects marine populations and community diversity on both platforms and natural habitats.

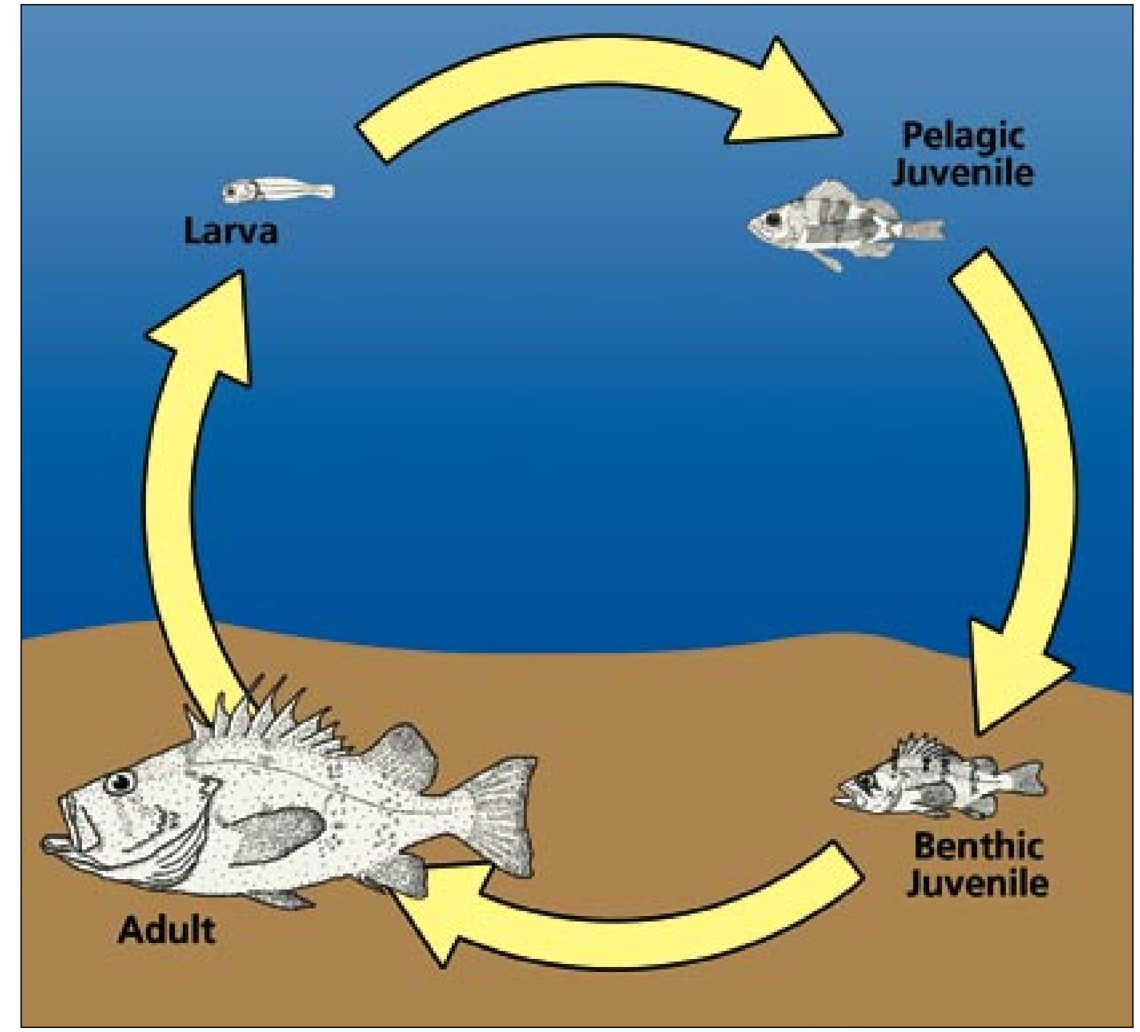

Figure 3.30. A typical rockfish life history cycle using the cowcod as an example.

Upwelling processes, the wind-induced pulling of deeper, colder water to the surface and displacement of warmer waters offshore, is a major factor in larval and pelagic juvenile survival. During years when upwelling coincides with larval fish production, fish survival may be enhanced. Because deep waters are nutrient-rich, upwelling increases reproduction of phytoplankton and encourages the growth of zooplankton, providing food for larval and pelagic juvenile fishes. Upwelling may also increase survivorship of some species by moving larvae and pelagic juveniles somewhat offshore, away from high densities of nearshore predators. Conversely, the offshore transport that accompanies upwelling can be detrimental to the survival of larvae and pelagic juveniles. Wind-induced turbulence in surface waters can make it difficult for larvae to come into contact with prey. Larvae risk being swept well offshore by strong upwelling and far removed from suitable habitat. Spatial and temporal variability in circulation, however, can provide some larvae and pelagic juveniles with conditions that enhance survivorship including delivery to optimum settlement.

The timing, location, intensity, and duration of upwelling events may have a large effect on rockfish settlement. For instance, recruitment may be hampered at sites constantly exposed to newly upwelled water. Through much of the late-spring and summer when presettlement-stage rockfishes are in the pelagic environment, upwelling from the mainland at Point Conception impacts the west channel. Our summer oceanographic data confirm that the upwelling plume can extend across the western portion of the Northern Channel Islands (Love et al. 1999). We found that pelagic juvenile rockfishes were relatively rare in this newly upwelled water (Figure 3.31) (Nishimoto 2000). As an example, when cool upwelled waters moved into an area off the south side

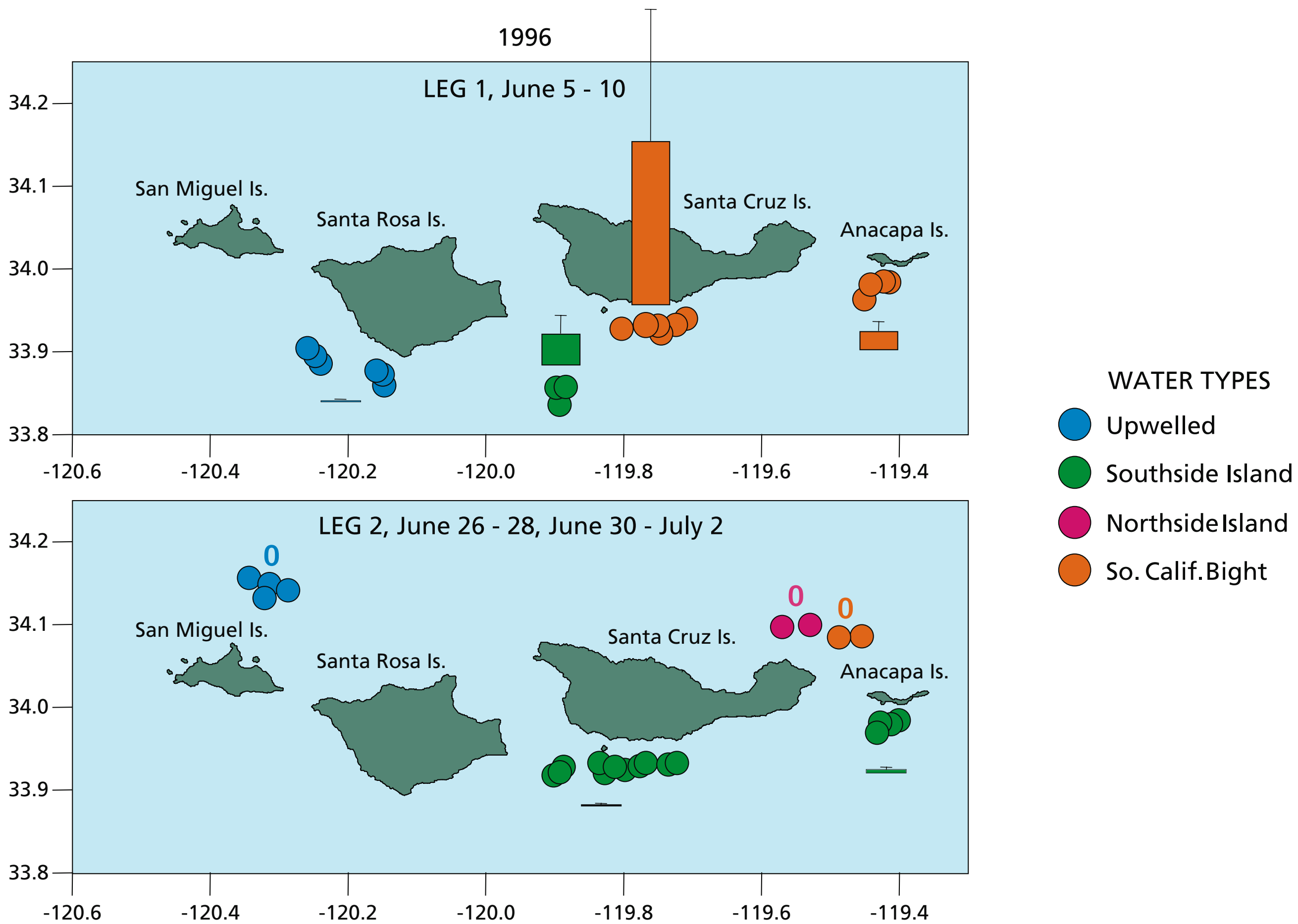

Figure 3.31. The abundance of late-larval stage and pelagic juvenile rockfishes decreases off the south side of Santa Cruz Island when one water mass replaced another between two sampling periods, June–July 1996. Temperature and salinity properties were used to identify four water masses: Upwelled water, Southside Island water, Northside Island water, and Southern California Bight water. Hauls are represented by colored circles. Fish abundance was estimated using the mean collected in midwater trawl hauls within a water mass. Bars illustrate the relative abundances among the water masses. Zeros indicate that no rockfishes were collected in the hauls within a water mass.

of Santa Cruz Island, the fish assemblage changed from one with relatively abundant pelagic juvenile rockfishes to one where these fishes were almost absent. We suspect that the upwelled water, the coldest and most saline water mass that we identified, was recently brought to the surface from depths where few larval and juvenile rockfishes reside**.**

Inter-annual oceanographic conditions, including the intensity of seasonal, coastal upwelling, are highly variable and this affects year class success and population variability. A shift from El Niño to La Niña conditions between 1998 and 1999 was marked by abrupt changes in the marine ecosystem off southern and central California. Our survey data of young-of-the-year rockfishes in 1999 indicates an increase in rockfish recruitment. The number of several juvenile rockfishes and other fish species observed on oil/gas production platforms and rocky outcrops in 1999 far exceeded those of 1998 and previous years. This increased recruitment coincided with intense coastal upwelling off Central California (among the strongest events in 50 years) in spring 1999 followed by high phyto- and zooplankton production (Lynn et al. 1998; Hayward et al. 1999). High productivity in the region likely contributed to the increased survivorship of the fishes including those that recruited to the platforms and natural outcrops.

Relatively transitory phenomena, such as fronts and eddies, may also play an important role in fish settlement and year-class success. Fronts, the zones where different water masses collide and mix, may prevent weak-swimming planktonic animals from swimming between these masses (Moser and Smith 1993; Wing et al. 1998). The strength of recruitment to a platform or outcrop may be determined in part by the habitat's exposure to those fronts carrying ready-to-settle fish larvae and juveniles. Our research at Santa Cruz and Anacapa islands indicates that the recruitment of nearshore rockfishes was sparse on outcrops separated from cool, fish-rich waters by a frontal boundary (Figure 3.32) (Love, Nishimoto, Schroeder, and Caselle 1999).

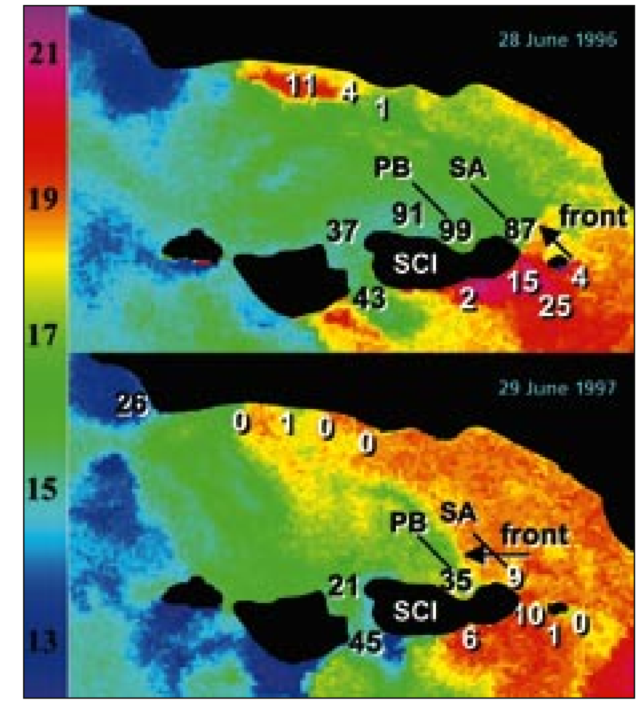

Figure 3.32. The strong correspondence between exposure to cool water and young-of-the-year rockfish density. A shift in position of the thermal front on the north shore of Santa Cruz Island (SCI) in 1996 and 1997 corresponded with a striking spatial shift in juvenile rockfish densities (see sampling sites, Pelican Bay (PB) and Scorpion Anchorage (SA)). Numbers overlaid on images represent mean densities of juvenile rockfishes (number/60 m²) that recruited to giant kelp canopy at sites within the survey area.

Eddies, cyclonic currents that can concentrate and retain plankton, may retain fishes and affect the dispersal of larval and juvenile fishes to outcrops and platforms. For instance, in summer 1998 we sampled a stationary and persistent cold-core cyclonic eddy in the western Santa Barbara Channel. In this feature, we found very high concentrations of small fishes, including late-stage larval and pelagic juvenile rockfishes (Figure 3.33). Eddies may also be very transitory. During the summer of 1999, we observed a much different circulation pattern of shorter-lived, propagating eddies and collected few young rockfishes.

We suspect that the high levels of recruitment of young-of-the-year rockfishes at some platforms were associated, in part, with eddies and fronts retaining larvae that had been locally produced at either platforms or natural outcrops. For instance, Platform Irene is located to the north of the frontal boundary of the upwelling plume that extends off Point Conception. The platform is also situated in an area where a semi-persistent eddy is frequently observed during spring and summer (L.Washburn, personal communication). Similarly, both fronts and eddies were observed at Platforms Gail and Grace in the eastern channel north of Anacapa. As noted previously, Platform Gail harbors important habitat for adult bocaccio in the Santa Barbara Channel. Local retention of bocaccio larvae produced at Platform Gail would explain the high levels of bocaccio settlement at nearby platform Grace and Gilda.

The variability of oceanographic conditions in the Santa Barbara Channel between 1995 and 2001 appears to have strongly influenced settlement as young-of-the-year recruitment to platforms and natural outcrops was highly variable both temporally and spatially. For instance, while the 1997–1998 El Niño corresponded with a large increase in juvenile recruitment of species that dominate the warm-temperate fish assemblage (such as blacksmith), the 1999 La Niña corresponded to a strong settlement of cool-temperate species, such as rockfishes. While settlement of many rockfish species to platforms was generally higher north of Point Conception than in

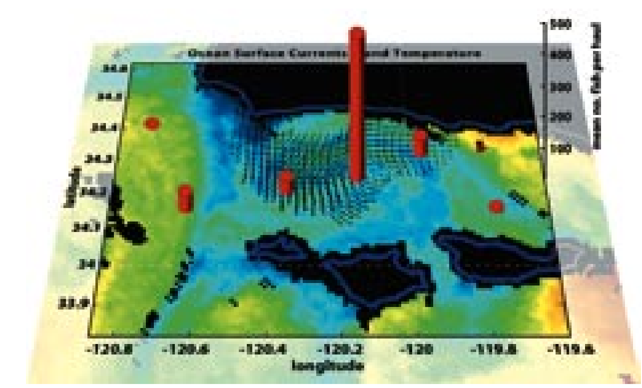

Figure 3.33. The strong link between eddy circulation and the distribution of pelagic young-of-year rockfishes. A persistent eddy about 30 km (19 mi.) wide was evident in satellite sea surface temperature imagery and in surface current mapping generated from coastal-based high frequency radar observations. The abundance of fishes were extraordinarily high in the center of the eddy (red bars represent the mean number of late-stage larval and pelagic juvenile rockfishes in midwater trawl samples from different areas).

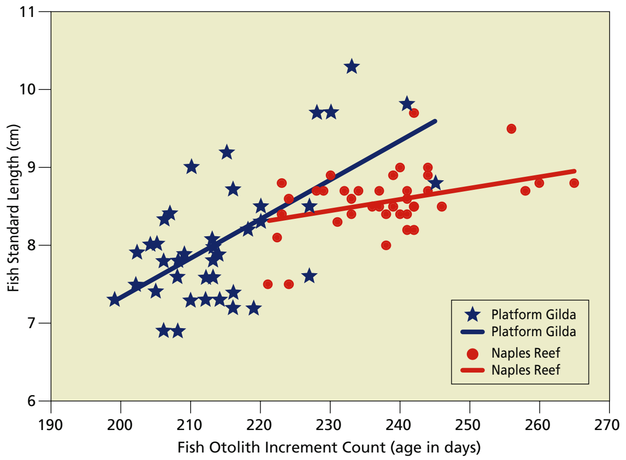

Figure 3.34. A comparison of daily growth rates of young-of-the-year blue rockfish collected at Platform Gilda and Naples Reef in 1999. Fish from Platform Gilda grew at a statistically faster rate than did those from the natural outcrop.

the Santa Barbara Channel during 1996 through 1998, the cooler waters of 1999 brought with it a relatively good year for cool-temperate rockfish recruitment throughout the channel.

The timing of this upsurge in young-of-the-year rockfish settlement in the Santa Barbara Channel also coincided with what may have been a Northeast Pacific oceanographic regime shift from warm to cool waters that overlaid the El Niño and La Niña events. This may have been reflected in the 2000 and 2001 rockfish recruitment at platforms in the eastern channel, which remained higher than pre-1999 levels. We should note that the last cold water regime off southern California occurred in the 1970s, a period that saw heavy settlement of young-of-the-year blue, olive, and widow rockfishes and bocaccio to some of the platforms near Santa Barbara (Love and Westphal 1990).

5c. If a Species Does Settle around a Platform, How Well Does It Grow and Survive, Particularly Compared to the Same Species on a Natural Outcrop?

While our studies in this area are preliminary, they are sufficiently compelling that we can begin to draw some conclusion regarding production of fishes at platforms. On many platforms, we believe that larval and pelagic juvenile recruitment is a major force in shaping platform fish assemblages. We have observed young-of-the-year of about 46 species at the platforms. Of these species, at least 35 were observed as adults at the same structures (Table 7). Adults of some species, such as pygmy, widow, and yellowtail rockfishes, are relatively uncommon around platforms suggesting different habitat requirements. Conversely, adults of many more species, including blacksmith, bocaccio, cabezon, cowcod, lingcod, painted greenling, shortspine and longspine combfishes, and calico, copper, flag, greenblotched, greenspotted, greenstriped, halfbanded, kelp, and pinkrose rockfishes are abundant at the platforms.

Pilot research suggests that at least some juvenile fishes may be growing as well or better at the platforms than at natural outcrops. In 1999, we collected young-of-the-year blue rockfish from Platform Gilda and from Naples Reef (Figure 1.1). Daily growth rates derived from these fishes from otoliths (ear bones) indicated that the platform fish grew at a statistically faster rate than did those from the natural outcrop (F-test, $F = 2.96$, $p = 0.0006$) (Figure 3.34).

Recruitment patterns of flag rockfish at Platform Grace and bocaccio at Platform Gail in 1999 and subsequent annual monitoring of year classes at these sites is providing important new information about the production value of platform habitats. In 2000, and again in 2001, we observed the 1999 year classes of these species at the bottoms of the platforms (Figures 3.35 and 3.36). Length-frequency data indicate substantial survival of the 1999 year classes at the platforms (Figure 3.36). Flag rockfish mature at about six years of age (M. Love and M. Yoklavich, unpublished data) and bocaccio at four or five years (A. MacCall, personal communication). Thus,

DONNA SCHROEDER

Figure 3.35. Flag rockfish at the bottom of Platform Grace, 2001. These fish recruited to the platform as pelagic juveniles in 1999 and moved to the bottom in 2000.

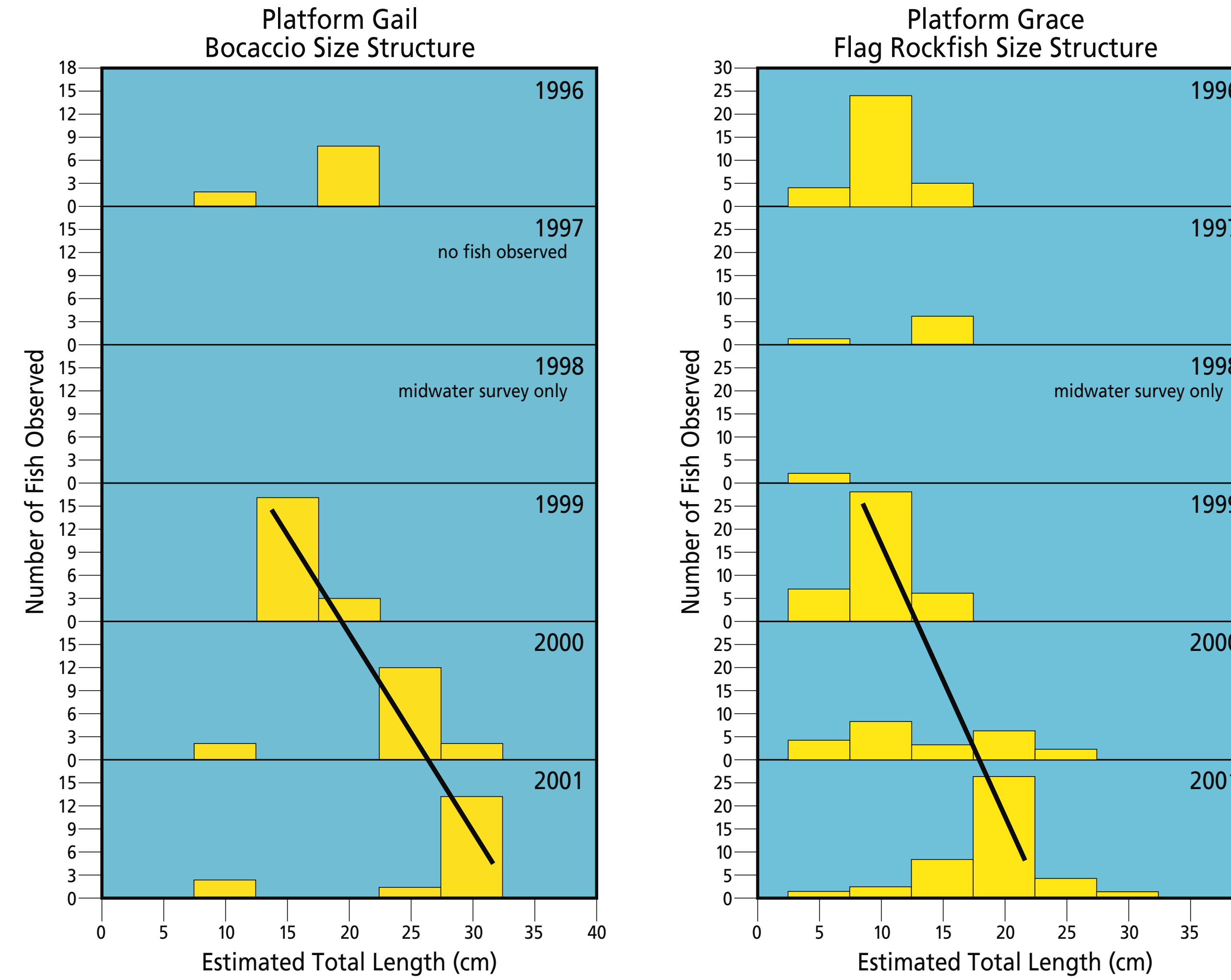

Figure 3.36. Size structure of young bocaccio observed at Platform Gail and flag rockfish observed at Platform Grace, 1996 to 2001. Black line denotes persistence of the successful 1999 year class.

it is conceivable that these fishes will mature at the platforms. This would be strong evidence of production at these structures. [Added in proof: We again observed these fishes during our 2002 surveys of Platforms Gail and Grace.]

5d. Both Attraction and Production Play Important Roles in Shaping Fish Assemblages at Platforms

Our research suggests that populations of fishes at platforms far removed from natural outcrops, as is true for Platforms Gail and Grace, are most likely dependent on larval and juvenile recruitment from the plankton. Our research is developing information about recruitment and residence of fishes at platforms and we have provided evidence of fishes not only settling out at platforms but also maturing there. Recruitment process is highly variable at all habitats from year to year. Adult abundance, at least for some species, is dependent on the strength of recruitment in previous years. Furthermore, recruitment variability may contribute to the year class success (i.e., demographics) of platform and outcrop species such as flag rockfish and bocaccio.

While the movement patterns of some deeper-water rockfishes are unknown, it is likely that many benthic species, such as greenspotted, greenblotched, pinkrose, and cowcod are residential (Starr et al. 2001; Love et al. 2002). Certainly many are restricted to hard substrata seafloors and probably rarely traverse large expanses of soft sediment (Love et al. 2002). Thus, it is likely that the high densities of many platform rockfishes, as well as such species as combfishes, painted greenling, and perhaps lingcod, are due to successful settlement from the plankton and subsequent survival.

The shallow-water species that do inhabit offshore platforms are further evidence that larval and juvenile recruitment play a dominant role in these structures' assemblages. Shallow species that do occur on Gail and/or Grace include kelp bass, garibaldi, and grass and kelp rockfishes. All of these fishes have pelagic larvae. Pile perch and rubberlip seaperch, species without a pelagic life stage, while found on the shallower platforms, are not present on Gail and Grace. This reflects the difficulty these species have in crossing deep waters along the seafloor.

Thus, there is growing evidence that individuals of a number of species, particularly those that are relatively resident and benthic, not only settle out at platforms but also mature there. Such species include, but are not limited to, blacksmith, bocaccio, cowcod, flag, grass, greenblotched, greenspotted, kelp, pinkrose rockfishes, painted greenling, and combfishes.

A dependence on pelagic juvenile recruitment, rather than attraction of older fishes from other structures, explains some of the differences in species composition we observed among the platforms. For instance, until 1999, we observed high densities of adult flag rockfish only at Platform Hidalgo. These densities were far higher than at other platforms or natural outcrops. In 1999, there was a strong recruitment of pelagic juvenile flag rockfish to Platform Grace, and as noted above, these fish remained there at least through 2001. [Added in proof: We observed these fish in 2002.] Annual recruitment of rockfish is highly variable. Thus, the large numbers of flag rockfish observed at Platform Hidalgo are almost certainly the result of a previous successful recruitment, similar to that at Platform Grace. Spatial variability is indicated by the paucity of this species at the other platforms. Similarly, the high densities of adult bocaccio at Platform Gail, and their absence at Platform Harvest (which is located in about the same depth), also suggests spatial variability in the recruitment process.

In contrast, the fish assemblages at platforms that are closer to shore, and in shallow waters, are probably derived both from larval/pelagic juvenile settlement and movements of juveniles and adults from other structures. Carlisle et al. (1964) clearly demonstrated that inshore reef species, such as kelp bass and sheephead, are very mobile and able to traverse shallow, soft seafloors from outcrop to artificial reef. Platform Gina, for instance, is a shallow water platform that seasonally harbors very large numbers of kelp bass, halfmoon, opaleye, pile perch, and other reef species. Fishes are abundant around that platform during summer and fall, but move elsewhere in late winter and spring.

MARY NISHIMOTO

Adult canary rockfish at bottom of Platform Hidalgo.

CHAPTER 4

A GUIDE TO ECOLOGICAL AND POLITICAL ISSUES SURROUNDING OIL PLATFORM DECOMMISSIONING IN CALIFORNIA

Donna M. Schroeder and Milton S. Love

Decommissioning Alternatives

Within one year of an OCS lease termination, the Minerals Management Service (MMS) requires that the lessee remove the oil platform structure to a depth of fifteen feet below the mud line, and the leased area must be cleared of obstructions (*see generally*, 30 C.F.R. Part 250, subpart Q, § 250.1700 *et seq.*). However, the MMS may waive these requirements to accommodate conversion of a platform structure to an artificial reef provided that (1) the remaining structure does not inhibit future oil or other mineral development, (2) the resulting artificial reef complies with the Army Corps of Engineers permit requirements and procedures outlined in the National Artificial Reef Plan, and (3) a state fishing management agency accepts liability for the remaining structure (30 C.F.R. §§ 250.1703, 250.1730). In addition, the National Fishing Enhancement Act of 1984 (NFEA), which authorizes the Corps of Engineers' permit program and the National Artificial Reef Plan (33 U.S.C. § 2101 *et seq.*), allows other organizations or agencies (such as the operator) to assume liability for the artificial reef, although MMS policy to date has required a state agency to accept liability.

The timing of future decommissioning activities is not fixed. It depends on the length of the lease, the rate of reservoir depletion, the market value of oil or gas, and whether the platform might serve an extended use for the operator, such as a gathering system for the production of other platforms. There are three stages in the decommissioning process: planning, permitting, and implementation. Platform decommissioning alternatives fall into four general categories: complete removal (the default option), partial removal, toppling, and leave-in-place (Figure 4.1). The suite of decommissioning alternatives that proposes to leave part or all of the abandoned platform structure in the marine environment is often collectively referred to as "rigs-to-reefs".

Alternative 1: COMPLETE REMOVAL

A typical full-removal project begins with well abandonment in which the well bores are filled with cement. The conductors are then separated from below the seafloor by being pulled, cut-off, or removed using explosives. Next the topsides, which contain the crew quarters and the oil and gas processing equipment, are cut from the jacket and removed. Finally, the piles that hold the jacket to the seabed are severed with explosives and the jacket is removed. Other typical decommissioning requirements include the removal or abandonment of pipelines and electrical cables and the removal of any debris from the seafloor.

After deciding to totally remove a platform from the seafloor, operators have several options (O'Connor 1999; van Voorst 1999; Gibbs 2000; Terdre 2000). (1) The platform can be taken to shore, where it is disassembled and the components either recycled, sold as scrap, or discarded in landfills or other depositories. To date, managers have selected this option for most decommissioned platforms. (2) The structure can be reconditioned and reused. As an example, in 1997 a platform was removed from the North Sea, taken to shore and cleaned, refurbished, shortened by 10 m (33 ft.), and installed in another North Sea location. A few small platforms have also been reused in the Gulf of Mexico. (3) A platform can be towed to another site and reefed. This has occurred a number of times in the Gulf of Mexico, with the most zealous example towing structures of two Tenneco platforms over 1480 km (920 mi) from offshore Louisiana to a site 1.5 miles off Dade County, Florida (Wilson et al. 1987).

Alternative 2: PARTIAL REMOVAL

In this scenario, the wells are abandoned, the topsides are removed, and the remaining jacket and possibly the shell mound are left in place to continue to function as an artificial reef. Navigation aids are added.

Despite what has been implied in other reports, conductors need not be completely removed. Dauterive (2000) notes "Recognizing the preservation of environmental values associated with the method of partial removal of the platform, the MMS in 1997 established a policy to allow the industry the option to partially remove

DECOMMISSIONING OPTIONS AND ISSUES

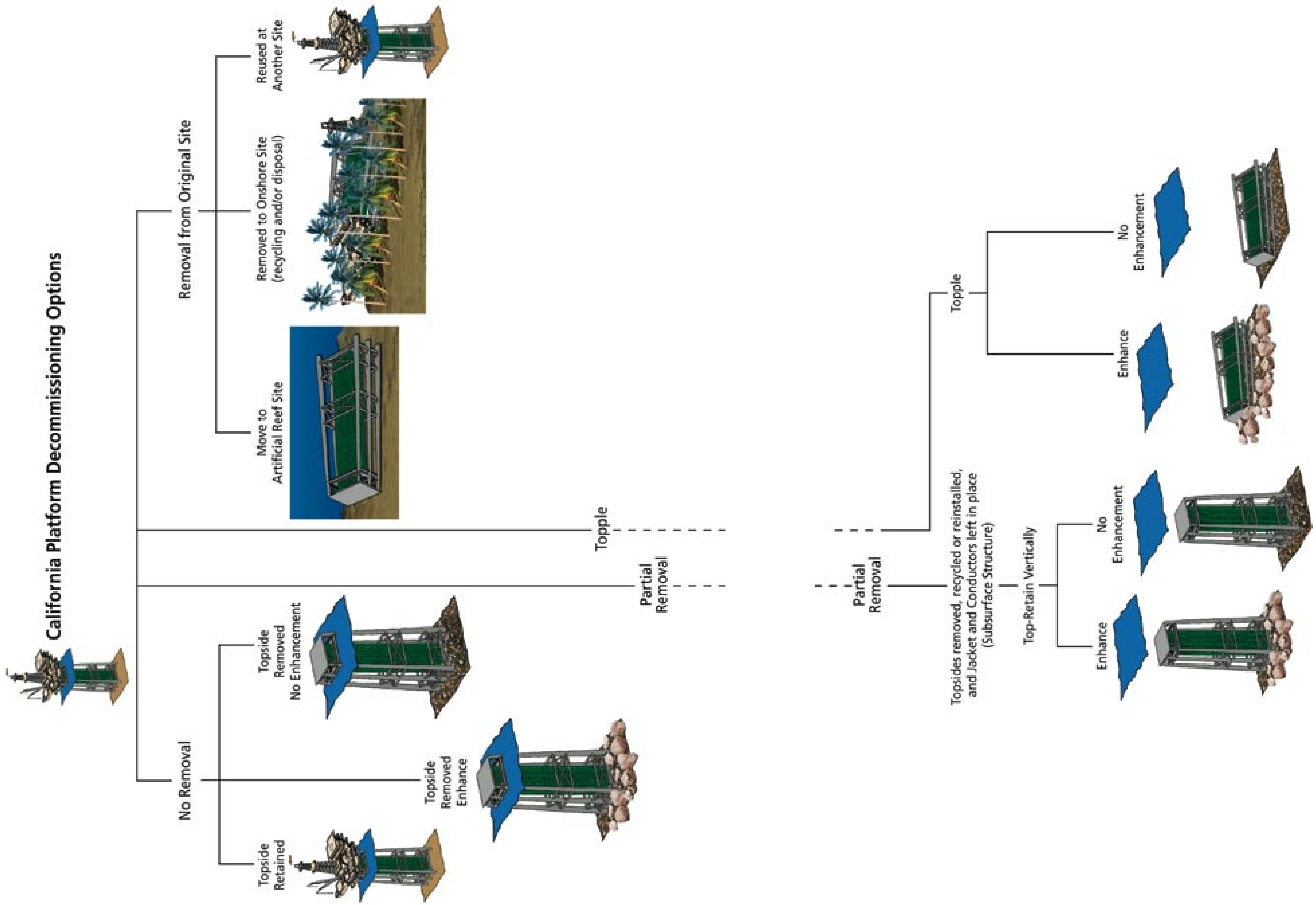

Figure 4.1. Platform decommissioning options.

the well conductors at the same depth below the water line (WL) at which the industry had proposed to remove the platform jacket." Retaining platform conductors has two consequences. First, it adds additional complexity to remaining structure. Second, explosives are usually used to remove the conductors and retaining these pipes eliminates the need for explosives (Dauterive 2000).

After cleaning, disposition of topsides may be handled in a couple of ways. It can be moved to a new platform and reinstalled, or it can be taken onshore, where the steel and other valuable components are recycled and other material sent to landfills. Certain parts of the topsides, such as the cleaned deck, have occasionally be used in forming artificial reefs.

Alternative 3: TOPPLING

As in partial removal, the wells are abandoned and the topsides are removed. The shell mounds may be either removed or left in place. The primary difference between partial removal and toppling is that, in toppling, explosives are used to sever the jacket from the seabed and then a derrick barge or pull barge drags the jacket over and it is allowed to settle to the seafloor (Twachtman 1997). Navigational aids, if necessary, are then put in place.

Alternative 4: NO REMOVAL (LEAVE-IN-PLACE)

A platform and its surrounding shell mound could be left in its original location at the time of decommissioning. The topside would be stripped and cleaned and navigational aids installed.

In the Gulf of Mexico this scenario has been discussed on a number of occasions, although it has not been attempted. For instance, a platform in the Flower Garden Banks National Marine Sanctuary was studied as a possible research laboratory. However, the cost of maintaining cathodic protection and navigational aids (together running to $300,000 per year) proved too high (L. Dauterive, personal communication). Other creative suggestions offered by stakeholders for decommissioned, left-in-place platforms include wind and aquaculture farms, meteorological stations, hospitals, hotels, gambling casinos, and penal institutions.

Agencies Responsible for the Decommissioning Process

By law, various coastal states and the federal government share the administration of submerged lands, subsoils and seabeds off the United States. Thus, depending on where platforms are positioned, responsibility for mineral extraction, including oil and gas development, is either under state or federal jurisdiction. Similarly, decisions regarding the decommissioning of platforms fall under either state or federal control, although the final decisions are based on consultation and mutual agreements among a number of agencies.

Responsibility for the fate of platforms in federal waters rests with the MMS (33 U.S.C. § 1331 *et seq.*) Federal agencies that are consulted in the decommissioning process include the Environmental Protection Agency (33 U.S.C. §§ 1311(a), 1342), Army Corps of Engineers (33 U.S.C. §§ 403,1344), National Oceanic and Atmospheric Administration (NOAA) Fisheries (16 U.S.C. § 1801 *et seq.*), and Coast Guard (14 U.S.C. § 85: 43 U.S.C. § 1333(d)). State agencies, such as the California Department of Fish and Game do not have jurisdiction in federal waters but may comment in the decision making process. Under the federal Coastal Zone Management Act (16 U.S.C. § 1451 *et seq.*), MMS decisions on platform decommissioning that will affect coastal resources are also reviewed by the appropriate state agency for consistency with the state's coastal zone management program. In California, the California Coastal Commission conducts review for consistency with the state program. In turn, state agency consistency decisions can be appealed to the U. S. Department of Commerce (16 U.S.C. § 1456(c)(3)(A), (c)(3)(B)(iii); 15 C.F.R. Part 930, subpart H).

Decisions regarding the decommissioning of platforms in California state waters are the province of the State Lands Commission (Cal. Pub. Res. Code § 6216), along with such agencies as the California Coastal Commission (Cal. Pub. Res. Code § 30330), Department of Fish and Game (Cal. Fish & Game Code § 1602), local Air Pollution Control Districts (Cal. Health & Safety Code 40000), U. S. Army Corps of Engineers (33 U.S.C. §§ 403, 1344), and the U. S. Coast Guard (14 U.S.C. § 85).

Jacket and conductor removal: the role of the U. S. Coast Guard in decommissioning

Local United States Coast Guard districts are responsible for the safety of vessel traffic in their respective geographic areas and have the authority to dictate aids to navigation for obstacles in the water (14 U.S.C. §85; 43 U.S.C. § 1333(d); 33 C.F.R. Part 67). Therefore, in instances where some part or all of a platform is to be reefed, the Coast Guard will specify the necessary navigational aids. Discussions regarding decommissioning of platforms off California have often erroneously assumed that the Coast Guard will require that the jacket be removed to about 26 m (85 ft.) below the surface. However, decommissioning experience in the Gulf of Mexico demonstrates that there is no set removal depth. Indeed, the Coast Guard decision-making process appears to be quite flexible; it reviews each decommissioning on a case-by-case basis. For instance, in the decommissioning of the mile-long Freeport-McMoRan sulfur mine platform and bridge off Louisiana, the Coast Guard required piles to be cut 9 m (30 ft.) beneath the surface (Kasprzak 1999).

Generally, the requirements for aids to navigation become more restrictive (and therefore more expensive) the closer to the surface the obstacle lies. As an example, here is a generic set of conditions for decommissioned platforms in the Gulf of Mexico based on recent Coast Guard decisions (G. Steinbach, personal communication):

- If the obstacle is greater than 61 m (200 ft.) in depth: no requirement for aids to navigation
- If the obstacle is from 61 m to 26 m (200 ft. to 85 ft.) in depth: unlighted buoys are required
- If the obstacle is 26 m to 11 m (85 ft. to 35 ft.) in depth: lighted buoys are required
- If the obstacle is from 11 m (35 ft.) to protruding through the surface: lights or lighted buoys and foghorns are required.

In the rigs-to-reefs programs in the Gulf of Mexico, the states are responsible for aids to navigation on reefed platforms. The costs of these aids are paid for from the funds created by the industry's donations. As a cost savings measure, these states generally have selected greater water clearances. The requirements for California waters may be different from those in the Gulf of Mexico. The local Coast Guard District will determine these requirements based on vessel traffic and other local conditions.

The question of liability for a reefed platform off California

Liability, who retains responsibility for a reefed platform, is a major issue in the decommissioning process. MMS policy states the "The MMS supports and encourages the reuse of obsolete offshore petroleum structures as artificial reefs in U. S. Waters." Current MMS regulations provide that a platform operator may be released from removal obligations in the federal lease instrument if a state agency responsible for managing fisheries resources will accept liability (30 C.F.R. § 250.1730). However, in situations where reefs are not managed by a state agency, another organization or agency must assume liability, as provided in the National Fishing Enhancement Act of 1984 (Stone 1985). In such cases, liability could possibly be retained by the oil company, transferred to a private entity, or handled in some other manner as long as MMS approval is received (G. Steinbach, personal communication).

An extensive body of policy and research outlines proper procedures for siting and deploying artificial reefs, and this information bears upon liability of such structures. The National Artificial Reef Plan (NARP) states "When a reef has been properly located, marked on navigation charts if necessary, and any required surface markers affixed, there should be very little potential for liability" (Stone 1985). Regarding accidents, which may occur during recreational activities near artificial reefs, the NARP further declares, "Diving accidents may occur with use by recreational divers. In this respect, an artificial reef is like a public park — there are dangers in those parks, guardrails and fences cannot be placed everywhere, and everyone who visits the park assumes some risk of injury. A warning could be placed on nautical charts and posted in local dive shops to warn of these dangers. However, each case would probably involve determination of comparative negligence" (Stone 1985). Parker (1999) notes that no lawsuits have ever been filed against the California Department of Fish and Game with respect to their artificial reef program.

Regardless of which decommissioning alternative is selected, the federal government cannot be held liable. Regarding State liability, the NARP notes, "If the permit holder is a State government, it may have sovereign immunity from liability. It is unclear whether the National Fishing Enhancement Act affects any State's claim of sovereign immunity." (Stone 1985)

National Artificial Reef Plan

Decommissioning options other than complete removal must be consistent with the National Artificial Reef Plan (33 U.S.C. § 2104(a)(4)). The National Fishing Enhancement Act of 1984 directed the development of a long-term National Artificial Reef Plan (NARP) to provide guidance and criteria on planning, construction, and evaluating artificial reef use, as well as introducing liability and mitigation issues (33 U.S.C. § 2103). Goals of the NARP seek to enhance fishing and fishery resources and minimize user conflicts and environmental risks without creating unreasonable obstruction to navigation (33 U.S.C. § 2102). In 1998, the NARP was supplemented by the Coastal Artificial Reef Planning Guide, which incorporates new language from relevant federal and state agencies, fishing interests, and the general public.

California Department of Fish and Game Rigs-to-Reef Guidelines

"These guidelines stipulate that the project must benefit living marine resources, habitat, and user groups; that disposal or use of contaminated materials is not permitted; that wherever possible the subsurface structure of the platform should remain in place; that where possible subsurface structure that must be removed could be relocated to the base of the rig or other appropriate sites; and that the remaining structure be augmented by rocks or other materials to assure that the site functions as a diverse and productive reef habitat. To replace the biotic productivity from that part of the platform removed for navigational purposes, rock or concrete reefs should be placed in nearshore locations. A rigs-to-reef project sponsor must provide sufficient funds to the Department to evaluate the benefits to biotic productivity, user groups, and the overall management of fishery resources." (Holbrook et al. 2000)

Social Values in Platform Decommissioning

Defining the social and ecological goals of decommissioned platforms as artificial reefs will be critical in evaluating the efficacy of any potential rigs-to-reef program and the current and future performance of any artificial reef. Therefore, it is likely that various stakeholder groups will vie in defining the goals (and therefore the usefulness) of decommissioned platforms as artificial reefs. In this report, we sort the multitude of stakeholder viewpoints regarding a rigs-to-reef program into three groups, each of which is primarily defined by one concern: community membership, resource accessibility and environmental (marine life) issues. Of course, an individual may be influenced by more than one social value, and others may use arguments from multiple categories to promote a desired decommissioning outcome.

The first group consists of stakeholders who are concerned about community membership, and either oppose or support local presence of the oil industry. Those that wish to promote a community without the oil industry often view reefing alternatives as bundled together with all oil industry activities (e.g., continued exploration and production), the whole of which should be locally opposed (although they may not be opposed to oil industry activities in the Gulf of Mexico). For example, Camozzi (1998a) states that complete removal should be the preferred alternative in decommissioning because, after decades of fighting oil development on the California Coast, it acts as a "catharsis" for the local community. Camozzi (1998b) reiterates this point by stating that, in regard to mussel mound removal, "Sending a message to oil companies that they must clean up our coast when they are done extracting their profits is the most vital issue in this case." Individuals who wish to encourage or maintain the presence of the oil industry in the local community, presumably for economic reasons, favor some sort of reefing option because reefing is less expensive than complete removal (Pulsipher et al. 2000). Further information regarding local community views on the oil industry in California can be found in Lima (1994) and Smith and Garcia (1995).

The second group of stakeholders is primarily concerned with resource accessibility. A heterogeneous group, these citizens will either favor or oppose decommissioning alternatives depending on how these alternatives aid or inhibit their ability to access a particular resource. For example, commercial trawlers in the Southern California Bight favor complete removal because fishing gear may snag on platform structure or shell mounds (Southern California Trawlers Association 1998; McCorkle 1999). Other commercial fishers benefit from oil industry activities. Shrimp trawlers in the Gulf of Mexico drag within 0.4 km (0.25 mi) of platform structures, reporting that these fishing grounds tend to be more productive (Wilson et al. 1987). The rocky habitat associated with Rincon Oil Island in California provides excellent lobster fishing grounds and trap fishers would oppose seeing this habitat removed (Miller

1999). Recreational fishers often dominate the debate surrounding platform decommissioning, and they have driven the formation of artificial reef policy at both state and federal levels (Stone 1985; Wilson et al. 1987). Many recreational fishers favor a reefing alternative in decommissioning because catch per unit effort is often high at offshore platforms for targeted fish species such as kelp bass (Love and Westphal 1990; McCrea 1998). In the Gulf of Mexico, Reggio (1987) estimates that 70% of fishing excursions target oil platform habitats. Citizens participating in non-consumptive activities also possess a variety of viewpoints regarding decommissioning alternatives. Many scuba divers find that underwater portions of oil platforms provide outstanding diving and underwater photographic opportunities, and favor decommissioning alternatives that preserve such opportunities, (Vallette 1999). Other members of the public may view the topside structure of platforms as denying them access to unobstructed, scenic ocean views, and consequently they oppose the leave-in-place decommissioning option (Wiseman 1999).

The third stakeholder group makes decisions regarding decommissioning based on their perception of how certain marine populations or environmental ideals fare under the various decommissioning alternatives. It is this last group that is most likely to use ecological information in making decisions regarding platform decommissioning. A decommissioning option that involves reefing may be supported if a substantial net benefit to the marine environment can be demonstrated (Chabot 1999). Others support complete removal because this option is the only one which promotes a wilderness ideal, that is, a marine environment which fails to retain a visible mark of human activities. If there is a lack of scientific evidence regarding ecological consequences, or if they are unaware of such consequences, these stakeholders may use another social value, such as community membership, in choosing a preferred decommissioning alternative (Chabot 1999).

Economic incentives interact and overlap with social values. In past rigs-to-reefs activities, industry and state entities have equally shared the cost-savings resulting from partial removal or toppling alternatives. Partial removal of deep water platforms will generate estimated savings of one to two orders of magnitude greater than the amount saved in decommissioning smaller platforms. The cost of maintaining navigational equipment (if any is needed) at these reefed platforms will not increase in the same proportion as the increase in cost-savings, and may actually decrease. These additional financial resources may be used to develop or enhance projects of interest to stakeholders, and may be a sufficient incentive to alter the preferred decommissioning option for some groups.

The Interaction of Science, Scale, and Social Values

State and federal regulatory agencies involved in the decommissioning process are required to protect the public interest when managing natural resources. In the face of strongly conflicting viewpoints among stakeholder groups, resource managers may try to convert a controversial issue into a technical one. For instance, they may give preference to the protection of marine life resources, thereby avoiding the appearance of favoring one group's economic concerns over another's. Additionally, legislation such as the Endangered Species Act and the Marine Mammal Protection Act, among others, often give environmental concerns priority over social and economic concerns. In combination, these issues give ecological information a prominent role in the decommissioning process.

Impacts to the environment may be measured at short or long time scales, or within a local or regional context. As time and space scales increase, so does scientific uncertainty about predicting consequences of various management alternatives (due to an increasing number of unknown variables and propagation of error associated with imprecise assumptions or model parameters). When there is greater scientific uncertainty, social values and political or economic factors often become more important in the decision-making process. This phenomenon may result in stakeholders advocating that ecological performance of reefed platforms be evaluated at scales which enhance the possibility of their preferred decommissioning alternative, even if ecological data are irrelevant to their concerns.

For example, proponents of regional ecological assessment at long time intervals may be individuals who oppose the local presence of the oil industry. Since regional assessment is difficult and expensive to accomplish, social values (e.g., antagonistic views of oil industry) will increase in importance. Significantly, these same individuals have not stipulated that other artificial reefs which are similar to reefed platforms, such as steel hulled ships, undergo the same rigorous ecological assessment. Further, the assured instantaneous and lethal effects of explosives are not considered in arguments about marine life effects.

Proponents of small scale ecological assessment tend to be recreational anglers, who often state their support for rigs-to-reef programs in terms of benefits to the environment. They maintain that the local presence of abundant marine life at a platform is sufficient evidence of satisfactory ecological performance. But this support for a rigs-to-reef alternative often evaporates if artificial reefs are designated no-take areas.

Ecological information greatly aids the decision-making process if explicit management goals are specified. The rebuilding of depleted fish stocks might be one goal, the preservation and expansion of marine wilderness might be another. Determination and ranking of ecological goals reflects cultural values. Thus, controversies surrounding platform decommissioning cannot easily be translated into technical issues by giving priority to ecological goals because we lack agreement on the space and time scales in which ecological impacts should be measured. Therefore, the scale at which ecological impacts are measured (local or regional) and considered (short or long term) becomes paramount in the decommissioning process. To date, such specific space and time scales have not been designated by any state or federal government agency.

MILTON LOVE

Juvenile cowcod on pipeline.

Decommissioning Activities in the Gulf of Mexico

To date, almost all platform decommissioning and reefing in the world has occurred in the Gulf of Mexico. Because large-scale offshore drilling first took place in the Gulf of Mexico, it was in this region that the issue of what to do with unwanted platforms first arose. Below, we give a brief summary of the history of decommissioning in the Gulf of Mexico; additional details are found in Lukens (1997), Kasprzak (1998), and Dauterive (2000).

Kerr-McGee erected the first offshore oil and gas platform in the Gulf of Mexico off Louisiana in 1947. Despite its primitive structure and placement in waters only 6 m (18 ft.) deep, oil was struck 22 days after drilling began, presaging a veritable tidal wave of offshore drilling. In 2001, there were over 4,000 platforms in the Gulf of Mexico, the vast majority occurring off Louisiana, followed by Texas, Mississippi and Alabama (Lukens 1997; Moritis 1997; Kasprzak 1998, 1999; Dauterive 2000). Platforms provide a considerable amount of the hard substrate in the north-central Gulf of Mexico, and surveys indicate that 20%–50% more fish live around platforms than on surrounding soft seafloors (Gallaway and Lewbel 1982; Driesen 1985). Because recreational and commercial fishers target fish residing near these structures, they are of considerable economic value (Dimitroff 1982; Reggio 1987; Kasprzak 1998).

By the late 1970s, it was apparent that the economic life span of many of these structures was nearing an end. During that decade, about 150 platforms were removed to shore and scrapped. The first reefing of an oil and gas structure occurred in 1979 when a subsea production system was towed from Louisiana to an artificial reef site off the Panhandle of Florida. In 1982, an obsolete platform jacket was moved from Louisiana to a Dade County, Florida site and over the next few years several additional structures were moved to various artificial reef sites.

Responding to this new activity, Congress passed the National Fishing Enhancement Act (NFEA) in 1984 (33 U.S.C. § 2101 *et seq.*). The NFEA mandated the creation of a "long-term plan for siting, constructing, permitting, installing, monitoring, managing, and maintaining artificial reefs within and seaward of state jurisdictions" (Kasprzak 1998). This document, later called the National Artificial Reef Plan, was published in 1985. In response to NFEA, several Gulf of Mexico states have now passed laws to take advantage of platform decommissioning to help preserve complex habitat in the northern Gulf of Mexico, for example, the Louisiana Fishing Enhancement Act of 1986 (La. Rev. Stat. § 56:639.1 *et seq.*) [Act 100] and the Texas Artificial Reef Act of 1989 (Tex. Parks & Wildlife Code § 89.001 *et seq.*). As an example, Act 100 created a process by which ownership of and liability for uneconomical platforms could be transferred from operators to the state of Louisiana. As noted by Kasprzak (1998), "Act 100 established the State of Louisiana as the permittee for artificial reefs developed under the program's jurisdiction and appointed the Department of Wildlife and Fisheries as agent for the state. The state assumes responsibility for the reefs upon placement within the established reef permit area…Act 100 does not authorize state general funds for the artificial reef program but does establish the Louisiana Artificial Reef Trust Fund. Oil and gas companies that donate structures to the program are asked to contribute half of the disposal savings realized through program participation to the trust fund." A similar program exists in Texas (Texas Parks and Recreation 1999).

A significant amount of money has been collected in rigs-to-reef programs in both Louisiana and Texas. As of 2001, there was about $15 million in the Louisiana fund and at least $4 million in Texas. Contrary to what has been reported (McGinnis et al. 2001), major artificial reef programs of several states, including Louisiana and Texas, receive neither state nor federal funding, they are fully underwritten by the interest paid on their respective rigs-to-reef accounts (J. Culbertson, personal communication; R. Kasprzak, personal communication). The Louisiana Department of Wildlife and Fisheries and Texas Parks and Wildlife Department describe their rigs-to-reefs programs at http://www.wlf.state.la.us (under "Marine Fisheries") and http://www.tpwd.state.tx.us/fish/reef/artreef.htm, respectively.

Since 1942, over 188 Gulf of Mexico platforms have been reefed, primarily off Louisiana and Texas. This represents about 8.4% of all decommissioned platforms (L. Dauterive, personal communication). The reasons for this early low reefing rate were economic. Most of the platforms thus far decommissioned were in shallow water, and it was more cost effective to haul them onshore for salvage or reuse rather then tow them to reefing sites. In the future, it is likely that a higher proportion of platforms will be reefed as more offshore structures become obsolete. Of the platforms that have been reefed, about 60% have been removed from a site and towed to a new location. Contrary to what was stated by Krop (1998), some decommissioned platform structures have been left in place. Thus far, 30% have been toppled in place and the remainder have been partially removed and left standing (Dauterive 2000). As larger platforms in deeper waters are decommissioned, L. Dauterive (personal communication) has noted a trend towards partial removal, rather than towing or toppling. In all but a few instances, only the platform jacket has been used as reef material.

The Future: Ecological Consequences of Offshore Platform Decommissioning in California

Complete Removal (Total Removal) of Platform

The immediate impact of removing and hauling an entire platform to shore is that all attached animals die. If some of the platform structure is hauled to a reef area and replaced in the water, some of these animals may survive, depending on water depth and the length of time the structure is exposed to the air.

Using explosives to separate the jacket from the seafloor kills large numbers of fishes, although limited research makes it difficult to predict how many deaths will occur. Marine mammals and sea turtles may also be indirectly killed by damage to the auditory system. In a study in the Gulf of Mexico (Bull and Kendall 1994), explosives were placed 5 m (15 ft.) below the seafloor to sever the well conductors, platform anchor pilings and support legs, of a platform in about 30 m (100 ft.) of water. All of the fishes on or near the bottom and most of the adult fishes around the entire platform suffered lethal concussion.

Some shallow-water platforms can be removed without explosives. However, "The oil and gas industry has attempted to find alternatives to the use of explosives, such as cryogenic cutting, hydraulic abrasive cutting, mechanical cutting, and torch cutting. Most of these techniques either have proven to be ineffective or are successful only in limited situations. At present, the industry maintains that the use of explosives is by far the safest, most reliable, and most cost-effective method of platform removal" (Kasprzak 1998). A recent assessment of techniques for removing platforms (NRC 1996) found that it is unlikely that any techniques or devices now known will significantly reduce fish kills during removal operations that use explosives.

Shell Mounds at the Base of Platform

The jackets and conductors of all platforms off southern and central California are heavily encrusted with invertebrates, including mussels, barnacles, seastars, rock scallops, rock oysters and jingle shells, sea anemones, caprellid amphipods, rock crabs, limpets, gooseneck barnacles, and sessile tunicates. An extremely thick layer of mussels extends from the intertidal zone to depths of at least 30 m (100 ft.) (and deeper on some platforms). The seafloor surrounding the platforms is covered with mussel shells. This "shell mound" or "mussel mound" is created when mussels, and other invertebrates, are dislodged during platform cleaning or heavy swells. Our observations show that, depending on bottom depth, a number of species of invertebrates, including many species of seastars, brittle stars, and rock crabs, as well as king crabs, opisthobranchs, shrimps, octopi, and sea anemones are abundant on the shell mounds. Substantial number of fishes, primarily the juvenile stages of various rockfishes, adult stages of dwarf rockfish species, as well as lingcod, poachers, painted greenling, and other benthic species also inhabit shell mounds.

Around four platforms in shallow water locations (+/- about 33 m, 109 ft., water depth), the shell mounds were found to be many meters thick, and were found to cover accumulations of drilling muds and cuttings. Investigations of the shell mounds around deep-water platforms have not been completed. Nevertheless, because of the potential for environmental harm, this issue must be addressed for all platforms regardless of the decommissioning option pursued. The level of contamination, while localized, has been shown to vary from platform to platform. Therefore, any remedial actions taken during the decommissioning process will likely be determined on a case-by-case basis. Although the regulatory requirements are still evolving, the alternatives being discussed include leaving the shell mounds undisturbed, smoothing and shaping them to allow for trawling, capping the shell mounds with an impervious material, adding material to the mounds for enhancement, or completely removing the shell mounds.

The removal of shell mounds may have a number of consequences to marine life by (1) removing habitat and (2) the potential for releasing toxins into the water column during the removal process. The biological consequences of either removing, altering, or leaving the shell mounds in-place must be given appropriate attention in the decommissioning process.

Partial Removal of Platform

Since partial removal reduces or eliminates shallow water habitat from the platform structure, this alternative would likely result in lower species composition and diversity than at the start of decommissioning process. Response of biotic communities will depend upon how much of the upper portion is removed. Depending on the platform, fewer nearshore reef fishes, such as surfperches, basses, and damselfishes may occur. Invertebrates that only reside or recruit to shallow water habitat would also be absent. Since the majority of mussels are located at shallow depths, shell mound replenishment will be reduced or absent, and affect the persistence of that community.

Since partial removal does not require the use of explosives, there is relatively little marine mammal, sea turtle, fish and invertebrate mortality compared to complete removal. Vertebrate and invertebrate assemblages associated with the remaining platform structure are assumed to be minimally affected.

A number of misunderstandings surround predictions regarding the potential ecological consequences of partial removal.

(1) Some stakeholders and policy analysts have erroneously assumed that Coast Guard regulations require a minimum depth below the ocean surface to which a reefed platform must be reduced. However, as noted earlier, the decision on how much of the jacket and conductors is left in place is based on both a Coast Guard assessment and the willingness of the liability holder to pay for the requisite navigational aids. As mussels become rare below 30 m (100 ft.) on most platforms, the mistaken assumption that all topped platforms must be cut to 24–30 m (80–100 ft.) below the surface has led some to conclude that partial removal will inevitably lead to a severe reduction in the amount of mussels that fall to the bottom and, thus, to a change in or end to the shell mound community. This is not necessarily the case.

(2) Some reports suggest that partial removal will lead to a large decrease in juvenile rockfish densities; our research does not support this supposition. On the offshore platforms in the Santa Barbara Channel region, the juveniles of most rockfish species (particularly blue, bocaccio, halfbanded, olive, pygmy, squarespot, starry, widow, and yellowtail) are uncommon in waters shallower than 26 m (85 ft.). Partial removal could reduce fish densities if pelagic juvenile stages of these rockfishes first encounter a platform in shallow surface waters, then swim downwards below the 26 m range, causing pelagic juveniles to "miss" a platform. However, young-of-the-year rockfishes of many of these species recruit from the plankton in large numbers both to natural outcrops in nearshore waters and to those coming out of deeper waters that have crests in about 30 m (100 ft.) of water. This indicates that emergent structure is not necessary for these juveniles to locate suitable habitat.

On the other hand, the pelagic stage of a few rockfish species, particularly copper, gopher, black-and-yellow, and kelp may prefer to recruit shallower portions of the platform than other rockfish species (Holbrook et al. 2000; this report). These species recruit to nearshore rocky outcrops and kelp beds and do not appear to settle in deeper waters (Larson 2002a,b). For these species, partial removal of a platform would probably decrease juvenile recruitment, depending on the uppermost depth of the remaining structure.

(3) Errors regarding factors affecting juvenile fish mortality have also lead to confusion. McGinnis et al. (2001), in describing the history of artificial reef research in California, states that "Research has shown that high relief, open structures serve best to attract fish, and better enable fishery exploitation, while low relief, complex structured reefs provide better nurseries and afford more diverse assemblages of fish and other organisms". McGinnis et al. (2001) also cite an anonymous California Department of Fish and Game biologist who notes that "a drawback to rigs as reefs is that they are high relief, which works against survival of young-of-the-year fish, suggesting they may not be a source of production but rather simply an attraction site."

We know of no research that can support the above claims, and the authors do not cite any specific studies. Predators are the main source of juvenile fish mortality in marine systems; death due to starvation or exposure is rare. Thus, variation in habitat structure would modify juvenile fish survivorship by modifying the success rate of predators. Presently, no studies have assessed comparative performance in survivorship rates between platforms and natural habitats. Alternatively, we may begin to infer potential predator vulnerability between habitats by examining the ratio of juvenile fishes to piscivorous fishes. In the shallow portion of Platform Irene, the ratio of juvenile rockfishes to piscivorous fish is about 25:1 and at nearby Tarantula Reef it is 3:1 (Appendix 2; Schroeder, unpublished data). Conversely, in the east Santa Barbara Channel, at Platform Gina the ratio is 1:5, and at Portuguese Rock, Anacapa Island it is 1:1.4.

Toppling of Platform

Toppling would produce reefs with somewhat different fish assemblages than what has been observed around intact platforms. Consequences of removal of shallow water habitat would be similar to that of partial removal. In California, because most platforms reside in fairly deep water, toppled platforms would also harbor fewer young-of-the-year rockfishes, just as the reefs adjacent to Platform Hidalgo harbor fewer of these animals. Depending on the characteristics of the platform, a toppled structure, with twisted and deformed pilings and beams, might have more complexity than an upright one. This might increase the number of such crevice dwelling fishes as pygmy rockfishes.

No Removal (Leave-in-Place) of Platform

The no-removal option would allow the platform and shell mound to continue to function as they had when the structure was occupied. Decommissioning activities would result in small mortality impacts to resident marine populations.

What is the Life Span of a Reefed Platform?

How long can a decommissioned steel platform survive in the marine environment before rusting away? Operating steel platforms are protected by sacrificial anodes, often made of aluminum or zinc, which preferentially corrode before steel, thus preserving the jackets' integrity. This cathodic protection lasts as long as the anodes are intact, usually for a number of decades. It is assumed that, once a platform is reefed, there will be no additional replacement of the sacrificial anodes, although the issue has yet to be addressed for platforms off California. While corrosion rates vary in seawater, depending on water temperature, biofouling and other factors, it is estimated that the life span of a cathodically unprotected platform will range from a minimum of 100 to more than 300 years (Quigle and Thorton 1989; Mishael 1997; Voskanian and Byrd 1998).

Pipelines Associated with Platforms

Pipelines run from all platforms either to shore or to other platforms that collect the oil or gas and then ship it to shore. McGinnis et al. (2001), note that "Both Federal and California regulations allow decommissioned OCS pipelines to be abandoned in place so long as they do not constitute a hazard to navigation, commercial fishing or unduly interfere with other uses of the OCS." (See also 30 C.F.R. § 250.1750; Ca. Pub. Res. Code § 6873.) In the Gulf of Mexico, few pipelines have been completely removed in the course of decommissioning (Breaux et al. 1997).

In 2001, using the research submersible *Delta*, we conducted pilot surveys of a pipeline between Platforms Gail and Grace. We found this pipe to be heavily encrusted with such invertebrates as anemones, crinoids, basket stars, and seastars. We also noted relatively large numbers of fishes, particularly juvenile or dwarf fishes, including cowcod, flag, blackgill, striped, and vermilion rockfishes, along with poachers and flatfishes. Both fish and invertebrate densities were much higher than found on the surrounding mud bottom.

Resource Management Issues Associated with Decommissioning

Habitat Enhancement of Reefed Platform Structure

The California Department of Fish and Game has issued guidelines for rigs-to-reef projects that call for enhancing the remaining structure using quarry rocks or other material (Parker 1998). Adding such material would increase the number of crevices and hiding places suitable for smaller sized fish. Thus, species which are rare or absent from observed platform fish assemblages, such as pygmy rockfish, may then occur. The ecological community response may depend on the type of habitat enhancement and has not been examined.

Marine Protected Areas

To a certain extent, the platforms in the Santa Barbara Channel and Santa Maria Basin currently act as de facto marine protected areas (Schroeder and Love 2002). Fishing pressure around many of these platforms is relatively low because (1) some platforms are relatively far from harbors and thus from fishing vessels, (2) four platforms (Irene, Hidalgo, Harvest, and Hermosa) are located near Point Conception in waters that are extremely rough for much of the year, and (3) it is difficult to fish close to operating platforms because tying up to these structures is discouraged by platform operators.

Clearly, many reefed platforms would be a target for recreational anglers or commercial fishermen because platforms often host sizable local populations of sought-after fish species. Off Florida, Shinn and Wicklund (1989) suggest that patterns of large fish at Tenneco platforms may be in part determined by fishing activities. Thus, in California, it has been proposed that reefed structures be designated as no-take areas (California senate bill introduced by D. Alpert). In addition, it may be possible to modify the architecture of reefed platforms to make them difficult to fish. For instance, because most of the target species are found inside the bottom of platform any structure above the bottom would prevent gear from reaching the seafloor, thus inhibiting the capture of many fishes.

Decommissioning Alternatives in Relation to National Marine Fishery Service's Fishery Rebuilding Plans

The use of explosives to remove or topple a platform may compromise fishery-rebuilding programs. Cowcod provide one example. This species has been declared overfished by NOAA Fisheries (formerly known as the National Marine Fisheries Service) and is the subject of a federal rebuilding plan. The Pacific Fisheries Management Council has approved a cowcod rebuilding plan that limits fishery impacts to 1% per year (about 2.4 metric tons for 2001), as part of a 95-year rebuilding period, and the use of spatial closures south of Point Conception to reduce bycatch mortality. As noted earlier, our observations around Platform Gail indicate it has the highest density of adult cowcod and bocaccio of any natural or artificial structure surveyed. We can make an estimate of the number of cowcod at the bottom of Gail by multiplying the density of cowcod observed by the area of the platform's footprint (the area underneath the platform). For instance, in the last two years of the survey, 1999 and 2000, observed cowcod densities were 0.015 and 0.0183 fish per m^2, respectively. As Gail's footprint is 5,327 m^2 (Holbrook et al. 2000), extrapolation for 1999 and 2000 gives estimates of 79 and 97 individuals respectively. This conservative estimate does not include juveniles we have observed living on the shell mound or on the adjacent pipeline. The current rebuilding plan calls for both a quota on commercial and recreational fisheries combined of 2.4 metric tons, equal to about 600 fish (T. Barnes, personal communication). Assuming that Platform Gail has 75 or more cowcod living under it, and if, as seems likely from all known research, explosives used to remove or topple a platform will kill all of them, that loss may be sufficiently large to complicate the rebuilding plan (T. Barnes, personal communication).

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Spotted ratfish on shell mound at Platform Gail.

CHAPTER 5

RESEARCH AND MONITORING RECOMMENDATIONS

When Governor Davis vetoed SB 1, a bill that would have allotted some of the savings derived from reefing platforms to California, he wrote, "There is no conclusive evidence that converted platforms enhance marine species or produce net benefits to the environment…it is premature to establish this program until the environmental benefits of such conversions are widely accepted by the scientific and environmental communities." And, with respect to assessing the effect of different decommissioning options on marine populations, Holbrook et al. (2000) state that the key marine ecological question is, "What is the effect of each decommissioning alternative on regional stocks of reef-associated species in general, or of particular targeted species?" Clearly, in the decommissioning process, there is a need for additional information.

Below we list examples of research that would be useful in addressing these issues. Many of these examples have been suggested by various resource managers. The first two tasks are necessary to resolve issues regarding attraction or production of platform and natural habitats as well as helping to define essential fish habitat. In addition to aiding in the platform decommissioning process, these three tasks will also aid in future coastal zoning and mapping that would occur in any future boundary expansion of the Channel Islands Marine Sanctuary.

Compare ecological performance between oil platforms and natural outcrops and determine if any oil platforms serve as Essential Fish Habitat for focal species.

What fishes live around platforms and nearby natural reefs?

In order to assess the relative importance of a platform to its region, it is essential to conduct basic surveys not only around the platform, but also at nearby reefs. A majority of platforms have not been well surveyed or have not been surveyed at all. Both scuba and submersible surveys must be conducted.

How does fish production around platforms compare to that at natural outcrops?

Fish production can be assessed and compared between habitats by examining a number of ecological yardsticks. These include (1) fish growth rates, (2) mortality rates, and (3) reproductive output. As an example, we conducted a pilot study comparing the growth rates of young-of-the-year blue rockfish at Platform Gilda and Naples Reef. More research needs to be conducted in all of these areas. For instance, mortality rates can be estimated by sequential surveys of the densities of young fishes at a specific platform or natural outcrop. Reproductive output (larval production in the case of rockfishes) can be quantified by first estimating the size frequency and density of a species at a platform or natural outcrop. Then, using size-fecundity relationships from the literature, the potential annual larval production for that species can be calculated.

How does trophic structure around platforms compare to that at natural outcrops?

How do platforms and natural outcrops compare in terms of habitat value?

A relatively new measure called Habitat Value (HV) allows comparisons between habitats, incorporating fish density, fish length, and fish regularity of occurrence. In Stephens et al. (1999), we presented a preliminary analysis of nine platforms and found that platform HVs tended to be much higher than those for open coastal soft substrate, higher than low relief deep rock outcrop and in the same range as wetlands and kelp/rock natural outcrops. An analysis of all of the platforms and as many outcrops as possible should be conducted.

Can we identify areas that are Essential Fish Habitat?

All of the above studies contribute to answering this question.

Define the spatial distribution of economically important species (all life history stages) within the region of interest and define connectivity of habitats within this region.

What is the relative contribution of platforms in supplying hard substrate and fishes to the region?

This research would put in perspective the relative contribution of platforms in supplying hard substrate and reef fishes to their environment.

First, this requires an assessment of the rocky outcrops in the vicinity of each platform; this is derived from seafloor mapping. Much of the seafloor in the vicinity of platforms remains to be characterized. Once the mapping is complete, visual surveys of the outcrops, using a research submersible, will determine the fish assemblages and species densities in these habitats. Knowing the areal extent of both natural and platforms habitats and the densities of each species in both of these habitats, it is then possible to assess the total contribution of each platform to the fish populations and hard substrate in that region.

How long do fishes reside at platforms?

It remains unclear how long fishes are resident around a platform. For instance, do the large numbers of fishes, such as the overfished bocaccio and cowcod, remain around the platforms for extended periods? One settled on a platform, how long do young-of-the-year fishes remain there? A knowledge of the residence time of these species would allow for a more accurate determination if platforms form optimal habitat for these species and if they are indeed acting as long-term marine reserves. Residence time can be determined through the use of both tagging studies and observations of a year class through time.

Acoustic tags are one way to determine fish residency. In a pilot study, Dr. Christopher Lowe, at California State University, Long Beach, captured and acoustically tagged rockfishes at Platform Gail and, after one year has determined that all have remained around the platform. Broader studies, covering additional platforms, outcrops, and species are needed.

What are the effects of platform retention or removal on fish populations within a region?

As an example, what effect would platform retention or removal have on fish recruitment? For instance, would the young rockfishes that settle out at a platform survive in the absence of that platform? Our surveys demonstrate that planktonic juvenile fishes, particularly rockfishes, often settle out of the plankton to a platform in substantial numbers. If that platform did not exist, would these young fishes have found, and settled upon, natural outcrops? In a pilot project, we are using radar-derived (CODAR) current data to estimate where the young rockfishes that settled at Platform Irene would have gone if Irene had not existed. We identify the direction and distance of pathways from the platform to natural outcrops. A directional histogram of radar-derived trajectories will show the degree to which surface currents potentially carry larvae in any given direction from the platform site. Knowing how long it would take rockfish larvae to reach suitable natural outcrops, and what percent of these larvae would likely die before reaching these outcrops, will give a sense of the importance of a platform as a nursery ground. Similarly, using a synthesis of oceanographic information, it is possible to model the drift direction of larvae produced by fishes living at a platform.

It would be useful to understand the natal origins of fishes residing at platforms and natural outcrops. Both genetic and otolith microchemistry techniques might aid in determining the degree of dispersal of fishes produced at platforms and natural outcrops.

Understand how habitat modification of platform environment (e.g., removal of upper portion or addition of bottom structure) changes associated assemblages of marine life at offshore platforms.

All decommissioning options except leave-in-place involve modification of the current physical structure of offshore platforms. Is it possible to increase fish diversity and density by altering the seafloor or the platform itself? For instance, it would be useful to add complexity, in the form of quarry rock or other structure, to the shell mound around a platform, and follow the changes in fish assemblages.

Descriptive information such as depth distribution and life history information is also useful in determining how decommissioning options affect the environment. Experimental research, using a BACI design or similar approach, can aid in predicting how the biotic community will respond to such structural changes.

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Opposite: Tons o'invertebrates on the Gail-Grace pipeline. (Photograph by Milton Love)

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TABLES

TABLE 1. Common and scientific names of fishes observed in these studies.

Common Name	Scientific Name
Bank rockfish	*Sebastes rufus*
Barred sand bass	*Paralabrax nebulifer*
Barred surfperch	*Amphistichus argenteus*
Bat ray	*Myliobatis californica*
Bearded eelpout	*Lyconema barbatum*
Big skate	*Raja binoculata*
Black-and-yellow rockfish	*Sebastes chrysomelas*
Blackeye goby	*Rhinogobius nicholsi*
Blackgill rockfish	*Sebastes melanostomus*
Black rockfish	*Sebastes melanops*
Blacksmith	*Chromis punctipinnis*
Black perch	*Embiotoca jacksoni*
Bluebanded goby	*Lythrypnus dalli*
Bluebarred prickleback	*Plectobranchus evides*
Blue rockfish	*Sebastes mystinus*
Bluntnose sixgill shark	*Hexanchus griseus*
Bocaccio	*Sebastes paucispinis*
Brown rockfish	*Sebastes auriculatus*
Bull sculpin	*Enophrys taurina*
Cabezon	*Scorpaenichthys marmoratus*
Calico rockfish	*Sebastes dalli*
California halibut	*Paralichthys californicus*
California lizardfish	*Synodus lucioceps*
California scorpionfish	*Scorpaena guttata*
California sheephead	*Semicossyphus pulcher*
California smoothtongue	*Leuroglossus stilbius*
California tonguefish	*Symphurus atricauda*
Canary rockfish	*Sebastes pinniger*
Chilipepper	*Sebastes goodei*
C-O turbot	*Pleuronichthys coenosus*
Copper rockfish	*Sebastes caurinus*
Cowcod	*Sebastes levis*
Darkblotched rockfish	*Sebastes crameri*
Dover sole	*Microstomus pacificus*
Dwarf perch	*Micrometrus minimus*
Embiotoca sp.	Black perch, *Embiotoca jacksoni* or striped perch, *E. lateralis*
Fantail sole	*Xystreurys liolepis*
Flag rockfish	*Sebastes rubrivinctus*
Freckled rockfish	*Sebastes lentiginosus*
Garibaldi	*Hypsypops rubicunda*
Giant kelpfish	*Heterostichus rostratus*
Gopher rockfish	*Sebastes carnatus*
Grass rockfish	*Sebastes rastrelliger*
Gray smoothhound	*Mustelus californicus*
Greenblotched rockfish	*Sebastes rosenblatti*
Greenspotted rockfish	*Sebastes chlorostictus*
Greenstriped rockfish	*Sebastes elongatus*
Halfbanded rockfish	*Sebastes semicinctus*
Halfblind goby	*Lethops connectens*
Halfmoon	*Medialuna californiensis*
Honeycomb rockfish	*Sebastes umbrosus*
Hornshark	*Heterodontus francisci*
Hornyhead turbot	*Pleuronicthys verticalis*
Island kelpfish	*Alloclinus holderi*
Jack mackerel	*Trachurus symmetricus*
Kelp bass	*Paralabrax clathratus*
Kelp goby	*Lethops connectens*
Kelp greenling	*Hexagrammos decagrammus*
Kelp gunnel	*Ulvicola sanctaerosae*
Kelp rockfish	*Sebastes atrovirens*
Kelp perch	*Brachyistius frenatus*
Lavender sculpin	*Leiocottus hirundo*
Leopard shark	*Triakis semifasciata*
Lingcod	*Ophiodon elongatus*
Longnose skate	*Raja rhina*
Mexican rockfish	*Sebastes macdonaldi*
Mola	*Mola mola*
Mussel blenny	*Hypsoblennius jenkinsi*
Northern anchovy	*Engraulis mordax*
Ocean sunfish	*Mola mola*
Ocean whitefish	*Caulolatilus princeps*
Olive rockfish	*Sebastes serranoides*
Opaleye	*Girella nigricans*
Pacific argentine	*Argentina sialis*
Pacific barracuda	*Sphyraena argentea*
Pacific electric ray	*Torpedo californica*
Pacific hagfish	*Eptatretus stouti*
Pacific hake	*Merluccius productus*
Pacific mackerel	*Scomber japonicus*
Pacific pompano	*Peprilus simillimus*
Pacific sanddab	*Citharichthys pacificus*
Pacific sardine	*Sardinops sagax*
Painted greenling	*Oxylebius pictus*
Phanerodon sp.	White seaperch, *Phanerodon furcatus* or sharpnose seaperch, *P. atripes*
Pile perch	*Rhacochilus vaca*
Pink rockfish	*Sebastes eos*
Pink seaperch	*Zalembius rosaceus*
Pinkrose rockfish	*Sebastes simulator*
Plainfin midshipman	*Porichthys notatus*
Pygmy rockfish	*Sebastes wilsoni*

TABLE 1. (cont.) Common and scientific names of fishes observed in these studies.

Common Name	Scientific Name
Rainbow surfperch	*Hypsurus caryi*
Rathbunella sp.	Unidentified ronquil
Redbanded rockfish	*Sebastes babcocki*
Rex sole	*Glyptocephalus zachirus*
Rock wrasse	*Halichoeres semicinctus*
Rosy rockfish	*Sebastes rosaceus*
Roughback sculpin	*Chitonotus pugetensis*
Rubberlip seaperch	*Rhacochilus toxotes*
Sarcastic fringehead	*Neoclinus blanchardi*
Sargo	*Anisotremus davidsoni*
Sebastomus sp.	Unidentified member of rockfish subgenus *Sebastomus*
Senorita	*Oxyjulis californica*
Sharpchin rockfish	*Sebastes zacentrus*
Sharpnose seaperch	*Phanerodon atripes*
Shiner perch	*Cymatogaster aggregata*
Shortbelly rockfish	*Sebastes jordani*
Shortspine combfish	*Zaniolepis frenata*
Shortspine thornyhead	*Sebastolobus alascanus*
Silver surfperch	*Hyperprosopon ellipticum*
Slender sole	*Eopsetta exilis*
Speckled sanddab	*Citharichthys stigmaeus*
Spotted cuskeel	*Chilara taylori*
Spotted ratfish	*Hydrolagus colliei*
Spotted sand bass	*Paralabrax maculatofasciatus*
Squarespot rockfish	*Sebastes hopkinsi*
Starry rockfish	*Sebastes constellatus*
Striped seaperch	*Embiotoca lateralis*
Stripetail rockfish	*Sebastes saxicola*
Swell shark	*Cephaloscyllium ventriosum*
Swordspine rockfish	*Sebastes ensifer*
Thornback	*Platyrhinoidis triseriata*
Threadfin bass	*Pronotogrammus multifasciatus*
Treefish	*Sebastes serriceps*
Tube-snout	*Aulorhynchus flavidus*
Vermilion rockfish	*Sebastes miniatus*
Walleye surfperch	*Hyperprosopon argenteum*
White seabass	*Atractoscion nobilis*
White surfperch	*Phanerodon furcatus*
Whitespeckled rockfish	*Sebastes moseri*
Widow rockfish	*Sebastes entomelas*
Wolf-eel	*Anarrhichthys ocellatus*
Yelloweye rockfish	*Sebastes ruberrimus*
Yellowtail	*Seriola lalandi*
Yellowtail rockfish	*Sebastes flavidus*
Zebra goby	*Lythrypnus zebra*
Zebraperch	*Hermosilla azurea*
Unidentified blennies	Family Blenniidae
Unidentified gunnel	Family Pholidae
Unidentified kelpfishes	Family Clinidae
Unidentified pipefishes	*Syngnathus* spp.
Unidentified poachers	Family Agonidae
Unidentified rockfish juveniles	*Sebastes* spp.
Unidentified ronquils	Family Bathymasteridae
Unidentified sanddabs	*Citharichthys* spp.
Unidentified sculpins	Family Cottidae
Unidentified silversides	Family Atherinidae
Unidentified fish species	

TABLE 2. Mean length of selected species at platform bottoms and shell mounds, 1996–2001.

Species	Location	Holly	Irene	Grace	Hidalgo	Hermosa	Harvest	Gail
LINGCOD	bottom	—	22.6	30.4	34.7	—	32.7	—
	shell mound	—	19.1	30.2	22.2	—	28.8	—
	t	—	7.04	0.15	7.57	—	2.24	—
	d.f.	—	869	124	222	—	49	—
	significant@α=.05	—	*	—	*	—	*	—
PAINTED GREENLING	bottom	—	15.6	—	12.7	—	—	—
	shell mound	—	13.5	—	11.9	—	—	—
	t	—	3.35	—	0.93	—	—	—
	d.f.	—	175	—	80	—	—	—
	significant@α=.05	—	*	—	—	—	—	—
STRIPED ROCKFISH	bottom	—	—	—	17.8	—	22.1	21.3
	shell mound	—	—	—	14.4	—	21.3	17.4
	t	—	—	—	3.11	—	1.75	5.08
	d.f.	—	—	—	82	—	341	119
	significant@α=.05	—	—	—	*	—	—	*
COPPER ROCKFISH	bottom	22.2	20.7	—	—	—	—	—
	shell mound	20	18.4	—	—	—	—	—
	t	22.23	5.95	—	—	—	—	—
	d.f.	327	1,400	—	—	—	—	—
	significant@α=.05	*	*	—	—	—	—	—
PINKROSE ROCKFISH	bottom	—	—	—	—	—	—	20.2
	shell mound	—	—	—	—	—	—	14.2
	t	—	—	—	—	—	—	141.2
	d.f.	—	—	—	—	—	—	278
	significant@α=.05	—	—	—	—	—	—	*
GREENBLOTCHED ROCKFISH	bottom	—	—	—	—	—	—	26.0
	shell mound	—	—	—	—	—	—	17.5
	t	—	—	—	—	—	—	8.86
	d.f.	—	—	—	—	—	—	432
	significant@α=.05	—	—	—	—	—	—	*
FLAG ROCKFISH	bottom	—	—	17.4	—	—	—	—
	shell mound	—	—	13.7	—	—	—	—
	t	—	—	3.23	—	—	—	—
	d.f.	—	—	136	—	—	—	—
	significant@α=.05	—	—	*	—	—	—	—
HALFBANDED ROCKFISH	bottom	12.5	11.6	16.2	12.3	13.5	—	—
	shell mound	7.0	7.0	14.9	10.4	11.7	—	—
	t	7.23	35.6	32.8	32.33	31.37	—	—
	d.f.	438	6,356	15,230	13,158	10,288	—	—
	significant@α=.05	*	*	*	*	*	*	*

TABLE 3. Total numbers and densities (fishes per 100m²) of all fishes observed at Platform Hidalgo and North Reef, 1996–2001.

PLATFORM HIDALGO

Species	Total	Density
Unidentified rockfish YOY	13,462	103
Halfbanded rockfish	13,194	101
Widow rockfish YOY	828	6
Greenspotted rockfish	617	5
Flag rockfish	266	2
Lingcod	224	2
Painted greenling	218	2
Widow rockfish	95	<1
Bocaccio YOY	91	<1
Greenstriped rockfish	84	<1
Greenblotched rockfish	69	<1
Bocaccio	56	<1
Rosy rockfish	56	<1
Vermilion rockfish	44	<1
Canary rockfish	41	<1
Squarespot rockfish	33	<1
Swordspine rockfish	27	<1
Sebastomus sp.	27	<1
Pacific sanddab	17	<1
Pygmy rockfish	16	<1
Sharpchin rockfish	16	<1
Unidentified combfish	14	<1
Cowcod	12	<1
Yelloweye rockfish	12	<1
Kelp greenling	10	<1
Unidentified rockfish	9	<1
Unidentified sanddab	7	<1
Starry rockfish	7	<1
Shortspine combfish	6	<1
Unidentified poacher	5	<1
Yellowtail rockfish	5	<1
Unidentified fishes	5	<1
Pink surfperch	4	<1
Bank rockfish	2	<1
Unidentified ronquil	2	<1
Unidentified sculpin	1	<1
Ratfish	1	<1
Copper rockfish	1	<1
Stripetail rockfish	1	<1
California scorpionfish	1	<1
Longspine combfish	1	<1
TOTAL	29,587	226
Minimum number of species	34	
Total rockfish YOY	14,381	109
Total rockfishes	29,071	217

Rockfish YOY comprised 48.6% of all fishes surveyed.
All rockfishes comprised 98.3% of all fishes surveyed.

NORTH REEF

Species	Total	Density
Unidentified rockfish YOY	4,786	54
Pygmy rockfish	1,684	19
Widow rockfish YOY	886	10
Halfbanded rockfish	575	7
Greenspotted rockfish	370	4
Sebastomus group	187	2
Yellowtail rockfish	118	1
Vermilion rockfish	100	1
Squarespot rockfish	72	<1
Shortspine combfish	69	<1
Greenstriped rockfish	61	<1
Unidentified rockfish	52	<1
Lingcod	49	<1
Blackeye goby	43	<1
Unidentified fish	40	<1
Pink surfperch	39	<1
Starry rockfish	38	<1
Canary rockfish	38	<1
Greenblotched rockfish	38	<1
Rosy rockfish	34	<1
Unidentified combfish	27	<1
Pacific argentine	23	<1
Swordspine rockfish	19	<1
Flag rockfish	18	<1
Bocaccio	16	<1
Cowcod	12	<1
Widow rockfish	10	<1
Unidentified flatfishes	10	<1
Unidentified ronquils	5	<1
Speckled rockfish	4	<1
Yelloweye rockfish	4	<1
Unidentified sanddab	3	<1
Bank rockfish	3	<1
Unidentified poacher	2	<1
Ratfish	2	<1
Olive rockfish	2	<1
Unidentified Cusk-eel	1	<1
Kelp greenling	1	<1
Painted greenling	1	<1
Bluebarred prickleback	1	<1
Sharpchin rockfish	1	<1
Longspine combfish	1	<1
TOTAL	9,445	108
Minimum number of species	34	
Total rockfish YOY	5,672	65
Total rockfishes	9,128	99

Rockfish YOY comprised 60% of all fishes surveyed.
All rockfishes comprised 96.6% of all fishes surveyed.

Species observed only at Platform Hidalgo: California scorpionfish, copper and stripetail rockfishes.
Species observed only at North Reef: Blackeye goby, bluebarred prickleback Pacific argentine, speckled sanddab.

TABLE 4. Total numbers of all fishes observed at the deeper, below 30 m, depths at seven platforms and 80 natural outcrops, 1996–2001.

ALL PLATFORMS

Species	Total	Species	Total	Species	Total
Unident. rockfish YOY	47,973	Pile perch	235	Splitnose rockfish	22
Halfbanded rockfish	46,831	Blackeye goby	222	Gopher rockfish	19
Widow rockfish YOY	10,902	Pacific sanddab	215	Pygmy rockfish	17
Shortbelly rockfish	7,443	Unidentified combfish	210	Yelloweye rockfish	16
Squarespot rockfish	3,834	Yellowtail rockfish	198	C-O turbot	15
Pacific sardine	3,308	Whitespeckled rockfish	196	Senorita	14
Blacksmith	2,796	Halfmoon	189	Darkblotched rockfish	14
Widow rockfish	2,540	Unidentified rockfish	184	Unidentified *Rathbunella*	12
Vermilion rockfish	2,288	Kelp rockfish	171	Cabezon	12
Blue rockfish	2,063	Rosy rockfish	167	California smoothtongue	11
Stripetail rockfish	2,037	Northern anchovy	159	Starry rockfish	11
Bocaccio YOY	1,910	Brown rockfish	142	Bank rockfish	11
Copper rockfish	1,836	Unidentified fishes	131	Speckled rockfish	7
Painted greenling	1,738	Chilipepper	122	Spotted ratfish	6
Greenspotted rockfish	1,595	Canary rockfish	113	Hornyhead turbot	5
Widow/squarespot rockfish	1,575	Unidentified flatfish	103	Unidentified cuskeel	4
Lingcod	1,486	Cowcod	98	*Phanerodon* sp.	4
Calico rockfish	1,311	Unidentified seaperch	95	Unidentified skate	4
Shiner perch	1,161	Swordspine rockfish	73	Wolf-eel	3
Bocaccio	742	Kelp greenling	66	Unidentied eelpout	3
Flag rockfish	735	Kelp bass	55	Rex sole	2
Sharpnose seaperch	621	California sheephead	53	Bluebanded goby	2
Greenblotched rockfish	600	Longspine combfish	43	California halibut	2
Unidentified sanddab	576	Dover sole	41	Redbanded rockfish	2
Greenstriped rockfish	572	Opaleye	38	Pink rockfish	2
California scorpionfish	560	Garibaldi	36	Pacific electric ray	2
Pacific hake	531	Honeycomb rockfish	35	Mola	1
Sebastomus sp.	371	Spotted cuskeel	33	White seaperch	1
Jack mackerel	348	Treefish	33	Whitespeckled rockfish/	
Sharpchin rockfish	346	Unidentified ronquil	30	Chilipepper	1
Pinkrose rockfish	331	Rubberlip seaperch	30	Bocaccio/chilipepper	1
Olive rockfish	312	Pacific mackerel	30	Shortspine thornyhead	1
Pink seaperch	308	Blackgill rockfish	28	California tonguefish	1
Unidentified poacher	296	Unidentified sculpin	26		
Shortspine combfish	245	Mexican rockfish	25		

TOTAL 155,973
Minimum number of species 85
Total rockfishes 139,855
All rockfishes comprised 89.7% of all fishes surveyed.

TABLE 4. (cont.) Total numbers of all fishes observed at the deeper, below 30 m, depths at seven platforms and 80 natural outcrops, 1996–2001.

ALL NATURAL OUTCROPS

Species	Total	Species	Total	Species	Total
Widow rockfish YOY	87,238	Splitnose rockfish	214	Black perch	12
Squarespot rockfish	41,344	Pile perch	202	Calico rockfish	12
Pygmy rockfish	36,036	Greenblotched rockfish	167	Pacific hake	9
Shortbelly rockfish	35,439	Cowcod	146	Rubberlip seaperch	9
Halfbanded rockfish	26,169	Bocaccio YOY	146	Kelp rockfish	9
Swordspine rockfish	11,733	White seaperch	137	California halibut	7
Sebastomus spp.	7,648	*Rathbunella* sp	128	Unidentified prickleback	6
Widow rockfish YOY	6,635	Canary rockfish	127	Spotted cuskeel	4
Widow rockfish	6,245	Painted greenling	125	Dover sole	4
Blacksmith	4,744	Unidentified flatfish	123	Redbanded rockfish	4
Pink seaperch	4,495	Honeycomb rockfish	118	California lizardfish	4
Senorita	3,831	Copper rockfish	112	Jack mackerel	4
Rosy rockfish	2,459	Unidentified seaperch	111	Wolf-eel	3
Blue rockfish	2,274	Stripetail rockfish	106	Slender sole	3
Blackeye goby	2,123	Unidentified poacher	104	Bluntnose sixgill shark	3
Pacific sardine	2,070	Pacific argentine	104	Hornyhead turbot	3
Bank rockfish	1,781	Unidentified sanddab	104	Longnose skate	3
Pinkrose rockfish	1,433	Unidentified ronquil	85	White seabass	2
Speckled rockfish	1,285	Olive rockfish	85	Roughback sculpin	2
Greenspotted rockfish	1,094	Unidentified sculpin	73	Northern anchovy	2
Vermilion rockfish	945	Freckled rockfish	65	Rex sole	2
Unidentified rockfish	863	Yelloweye rockfish	65	Kelp greenling	2
Bocaccio	861	Treefish	64	Halfmoon	2
Unidentified combfish	728	Sharpchin rockfish	59	Unidentified pholid	2
Shortspine combfish	663	Shortspine thornyhead	49	English sole	2
Pinkrose rockfish	585	Swell shark	48	Unidentified turbot	2
Lingcod	580	Brown rockfish	40	Unidentified skate	2
Yellowtail rockfish	494	Darkblotched rockfish	38	Pacific electric ray	2
Greenspotted rockfish	462	Unidentified eelpout	36	Pacific sanddab	1
Starry rockfish	440	Gopher rockfish	35	Rainbow surfperch	1
Unidentified fish	381	Longspine combfish	31	California smoothtongue	1
Chilipepper	373	Island kelpfish	27	Bearded eelpout	1
Sharpnose seaperch	325	Blackgill rockfish	26	Unidentified cuskeel	1
Flag rockfish	309	Ocean whitefish	23	*Phanerodon* sp	1
Spotted ratfish	296	Threadfin bass	21	Bluebarred prickleback	1
California sheephead	237	Pink rockfish	17	C-O turbot	1
California scorpionfish	222	Pacific hagfish	14	Big skate	1
Whitespeckled rockfish	221	Bronzespotted rockfish	13		

GRAND TOTAL 298,379
Minimum number of species 94
Total rockfishes 276,034
All rockfishes comprised 92.5% of all fishes surveyed.

TABLE 5. Twenty highest densities of rockfish young-of-the-year juveniles, 1996–2001 as observed from the *Delta* submersible. Platforms are listed in blue, natural outcrops in red.

Site	Year	Habitat Type	Density of Rockfish YOY (fish per 100m²)
Hidden Reef	1999	Natural	1249.2
Platform Hermosa	1999	Midwater	993. 6
Platform Irene	1998	Midwater	935.4
Platform Harvest	1999	Midwater	555.1
Platform Irene	1999	Midwater	524.3
San Miguel Island	1995	Natural	520.5
Platform Grace	2001	Midwater	486.5
Platform Hidalgo	1997	Midwater	385.2
Potato Bank	1996	Natural	367.7
Platform Irene	1997	Bottom	363.8
Platform Grace	2000	Midwater	346.2
Platform Irene	1997	Midwater	344.1
North Reef	1995	Natural	338.7
Platform Holly	1999	Bottom	326.1
Platform Hidalgo	1999	Midwater	314.6
Platform Irene	2001	Midwater	306.2
San Nicolas Island	1996	Natural	302.9
San Miguel Island	1995	Natural	262.1
Santa Rosa Island	1995	Natural	227.1
Platform Harvest	1997	Midwater	225.6

TABLE 6. Fish species observed as young-of-the-year juveniles at California oil/gas platforms.

Common Name	Common Name
Bank rockfish	Kelp bass*
Black rockfish	Kelp greenling*
Blackeye goby*	Kelp rockfish*
Blackgill rockfish	Lingcod*
Blacksmith*	Olive rockfish
Blue rockfish*	Pacific hake
Bluebanded goby*	Painted greenling*
Bocaccio*	Pinkrose rockfish*
Brown rockfish*	Pygmy rockfish*
Cabezon*	Rosy rockfish*
Calico rockfish*	Sharpchin rockfish
Canary rockfish*	Shortbelly rockfish*
Copper rockfish*	Splitnose rockfish
Cowcod*	Squarespot rockfish*
Flag rockfish*	Starry rockfish*
Garibaldi*	Stripetail rockfish*
Gopher/Black-and-Yellow rockfish*	Treefish
Greenblotched rockfish*	Vermilion rockfish*
Greenspotted rockfish*	Widow rockfish*
Greenstriped rockfish*	Yelloweye rockfish*
Halfbanded rockfish*	Yellowtail rockfish
Halfmoon*	Unidentified combfishes (*Zaniolepis* spp.)*

We also observed adult sarcastic fringehead, as well as unidentified blennies (*Hypsoblennius* spp.) and sculpins. Given the cryptic and sedentary nature of these species, we believe they arrived at platforms via larval recruitment.

In addition, Carlisle et al. (1964) observed young-of-the-year black perch, pile perch, rubberlip seaperch, and white surfperch at Platform Hazel (removed in 1996).

*These species were observed as both newly settled juveniles and adults at platforms.

APPENDICES

APPENDIX 1. Platform Synopses

In this section, we give a brief summary of each of the California platforms. The platforms are listed from the most northwest, Irene, off Point Arguello, to Emmy in the southeast off Long Beach.

Wherever possible, we have included the following information on each platform: (1) the original operator; (2) the current operator of record; (3) the date the platform was installed; (4) the first production date; (5) the platform's distance from shore (including whether it is in state or outer continental shelf [OCS] waters); (6) the bottom depth of the platform; (7) the number of wells; (8) what the platform produces (oil and/or gas); (9) the platform jacket dimensions (generally at the seafloor [bottom]); (10) the size of the shell mound surrounding the platform; (11) the size of the platform's footprint. This data was taken from California Resources Agency (1971), Manago and Williamson (1998), Holbrook et al. (2000), and Sea Surveyor Inc. (2001). We have also included a photograph of most of the platforms and their locations including latitude and longitude.

We follow this with a synopsis of the fish assemblages around each platform. When these summaries are based on our scuba and submersible surveys we include the years these surveys were conducted. Scuba surveys are midwater surveys except at the shallow water Platform Gina. Because of funding limitations, a number of platforms were surveyed only once and in a number of instances poor water visibility prevented complete coverage. Neither ExxonMobil nor Aera gave us permission to survey their platforms. In some instances, we were able to review videos that were taken during mandatory platform inspections. From these, we made a qualitative estimate of platform bottom fish assemblages for those platforms we were unable to survey.

IRENE

Original operator: Union; current operator of record: Nuevo Energy; date installed: 1985; first production: 1987; distance from shore (miles): 4.7 (OCS); water depth: 73 m (242 ft.); number of well slots 72; produces: oil and gas; platform jacket dimensions: 47 x 56 m (155 x 185 ft.) (bottom); platform footprint (m^2): 2,633; location: 120°43.45'N, 34°36.37'W.

Dates and types of surveys:

Scuba: 1995–2000

Submersible:

	Midwater	Bottom	Shell Mound
1995	x		
1996	x	x	x
1997	x	x	x
1998	x	x	x
1999	x	x	x
2000	x	x	x
2001	x	x	x

Platform Irene's midwaters consistently harbored large numbers of YOY (young-of-the-year) and older juvenile rockfishes. Bocaccio, blue, shortbelly, squarespot, treefish, and widow rockfishes, and the complex comprised of young black-and-yellow, copper, gopher, and kelp rockfishes, were abundant. Densities of these fishes were usually among the highest we observed around either platforms or natural outcrops. Young painted greenling, living on the jacket, were also quite abundant. During the 1998 El Niño, YOY blacksmith settled on the platform in large numbers. However, they were gone by the following year. Kelp greenling recruited as young-of-the-year in 1999; they swam to the platform bottom during the next year and were there through 2001. Two pelagic species, jack mackerel and Pacific sardine, were also occasionally seen in high numbers. The platform bottom had particularly high densities of halfbanded rockfish and YOY rockfishes, as well as subadult and adult copper, vermilion, calico, and brown rockfishes. Juvenile lingcod, pile perch and painted greenling were also very abundant and Pacific sanddab, canary and yellowtail rockfishes were frequently seen. On the shell mound, halfbanded and copper rockfish, as well as young lingcod were very common. Platform Irene is particularly noteworthy as it harbored far higher densities of young lingcod than did any other site (platform or natural outcrop) that we surveyed.

Opposite: Vermilion rockfish and assorted invertebrates at the bottom of Platform Grace. (Photograph by Donna Schroeder)

HIDALGO

Original operator: Chevron; current operator of record: Arguello Inc.; date installed: 1986; first production: 1991; distance from shore (miles): 5.9 (OCS); water depth: 130 m (430 ft.); number of well slots: 56; produces: oil and gas; platform jacket dimensions: 78 x 53 m (257 x 176 ft.) (bottom); platform footprint (m^2): 4,154; location: 34°29'N, 120°42'W.

Dates and types of surveys:
Scuba: 1996–2000
Submersible:

	Midwater	Bottom	Shell Mound
1996	x	x	x
1997	x	x	x
1998	x	x	x
1999	x	x	x
2000	x	x	x
2001	x	x	x

We observed high densities of YOY and older juvenile rockfishes in the midwaters of Platform Hidalgo. A number of rockfishes, including blue, copper, gopher, kelp, olive, rosy, squarespot, and widow rockfishes and bocaccio were abundant. Halfmoon and young painted greenling were also common. Large numbers of YOY blacksmith recruited to the platform during 1998 and remained there through 2001. Similarly, kelp greenling young settled during 1999, and some remained through 2001. Jack mackerel and northern anchovy were occasional visitors. The bottom of this platform was dominated by halfbanded, greenspotted, and flag rockfishes, YOY rockfishes, and lingcod. Flag rockfish density was higher than at any natural outcrop or other platform. Other important species included canary, greenstriped, vermilion, and widow rockfishes and painted greenling. On the shell mounds, we noted extremely large numbers of halfbanded rockfish. Both juvenile and adult lingcod were also abundant.

HARVEST

Original operator: Texaco; current operator of record: Arguello Inc.; date installed: 1985; first production: 1991; distance from shore (miles): 6.7 (OCS); water depth: 205 m (675 ft.); number of well slots: 50; produces: oil and gas; platform jacket dimensions: 61 x 97 m (200 x 319 ft.) (bottom); platform footprint (m^2): 5,859; location: 34°28'N, 120°40'W.

Dates and types of surveys:
Scuba: 1996–2000
Submersible:

	Midwater	Bottom	Shell Mound
1996	x		
1997	x	x	x
1998	x	x	x
1999	x	x	x
2000	x	x	x
2001			

As on most of the other platforms we surveyed, YOY and somewhat older rockfishes characterized the midwaters of Platform Harvest. Of these, bocaccio, as well as blue, olive, squarespot, and widow rockfishes were most abundant. Young painted greenling , as well as halfmoon, also were seen frequently. Blacksmith were abundant, they had recruited in 1998 as YOY and remained at the platform through 2001. Large numbers of kelp greenling settled from the plankton in 1999. Pelagic species, such as northern anchovy and Pacific sardine, were occasional visitors. In the deeper midwaters, we saw many sharpchin and whitespeckled rockfishes. Stripetail, greenstriped, greenspotted, and greenblotched rockfishes and lingcod were commonly seen on the bottom. Stripetail, greenstriped and sharpchin rockfishes were most abundant on the shell mounds.

HERMOSA

Original operator: Chevron; current operator of record: Arguello Inc.; date installed: 1985; first production: 1991; distance from shore (miles): 6.8 (OCS); water depth: 183 m (603 ft.); number of well slots: 48; produces: oil and gas; platform jacket dimensions: 61 x 85 m (200 x 280 ft.) (bottom); platform footprint (m^2): 5,142; location: 34°27'N, 120°38'W.

Dates and types of surveys:
Scuba: 1996–2000
Submersible:

	Midwater	Bottom	Shell Mound
1996	x	x	
1997	x	x	x
1998	x	x	x
1999	x	x	x
2000	x	x	x
2001			

Platform Hermosa's midwaters are noteworthy as rockfish nursery grounds. They harbored the second highest densities of YOY rockfishes of any site we surveyed (second only to Hidden Reef) (Table 5). Bocaccio, blue, olive, squarespot, widow, and whitespeckled rockfishes, as well as painted greenling were very abundant. Blacksmith and halfmoon were also typical species. As at many other platforms, in 1999 kelp greenling settled out of the plankton at Platform Hermosa. Jack mackerel and northern anchovy were also common. While halfbanded rockfish dominated the bottom assemblage, greenspotted rockfish were also abundant. Halfbanded rockfish also were the most abundant species on the shell mound.

HONDO

Original operator: Exxon; current operator of record: ExxonMobil; date installed: 1976; first production: 1981; distance from shore (miles): 5.1 (OCS); water depth: 255 m (842 ft.); number of well slots: 28; produces: oil and gas; platform jacket dimensions: 68 x 68 m (225 x 225 ft.) (bottom); platform footprint (m^2): 4,649; location: 34°23'N, 120°07'W.

Exxon and ExxonMobil did not allow us to survey this platform. However, we were able to review part of an inspection tape made at and near the bottom of Platform Hondo (Divecon International, 3 August 2002). Based on this, a number of rockfishes, including bank, darkblotched, pinkrose, widow and probably blackgill, live around the bottom of Platform Hondo. Darkblotched rockfish appeared to be particularly abundant.

HARMONY

Original operator: Exxon; current operator of record: ExxonMobil; date installed: 1989; first production: 1993; distance from shore (miles): 6.4 (OCS); water depth: 363 m (1,198 ft.); number of well slots: 60; produces: oil and gas; platform jacket dimensions: 91 x 117 m (300 x 385 ft.) (bottom); platform footprint (m^2): 10,606; location: 34°22'N, 120°10'W.

Exxon and ExxonMobil did not allow us to survey this platform.

HERITAGE

Original operator: Exxon; current operator of record: ExxonMobil; distance from shore (miles): 8.2 (OCS); water depth: 326 m (1,075 ft.); number of well slots: 60; produces: oil and gas; location: 34°21'N, 120°16'W.

Exxon and ExxonMobil did not allow us to survey this platform. We reviewed part of an ROV inspection of this platform (Divecon International, 2 August 2002) and noted blackgill, darkblotch, pinkrose, and widow rockfish at or near the bottom.

HOLLY

Original operator: Atlantic Richfield, current operator of record: Venoco, date installed: 1966; first production: 1966; distance from shore (miles): 1.8 (state); water depth: 64 m (211 ft.); number of well slots: 30; produces: oil and gas; platform jacket dimensions: 18 x 30 m (60 by 100 ft.) (surface), 36 x 48 m (119 by 158 ft.) (bottom); location: 34°22'N, 119° 52'W.

Dates and types of surveys:
Scuba: 1995–2000
Submersible:

	Midwater	Bottom	Shell Mound
1995	x		
1996	x	x	
1997	x	x	x
1998	x	x	x
1999		x	
2000			
2001	x	x	x

The midwaters around Platform Holly were populated by large numbers of blue, copper, kelp, olive, squarespot, and widow rockfishes and bocaccio. With the exception of kelp rockfishes, most of these fishes were juveniles. Blacksmith, halfmoon, kelp bass, painted greenling, pile perch, and sharpnose seaperch were also abundant. Schools of jack mackerel and Pacific sardines were also noted. The platform bottom fish assemblage was characterized by YOY widow rockfish, calico, vermilion, halfbanded, and copper rockfishes, sharpnose seaperch and blackeye goby. Most of the vermilion and copper rockfishes were juveniles and subadults. Calico, vermilion, and copper rockfishes were the most abundant species on the shell mound.

C

Original operator: Union Oil; current operator of record: Nuevo Energy; date installed: 1977; first production: 1977; distance from shore (miles): 5.7 (OCS); water depth: 58 m (192 ft); number of well slots: 60; produces: oil and gas; platform jacket dimensions: 40 x 48 m (133 x 158 ft.) (bottom); platform footprint (m^2): 1,930; location: 34°19'N, 119°37'W.

Dates and types of surveys:
Submersible:

	Midwater	Bottom	Shell Mound
2000	x (partial)		x

Only part of the platform midwater was surveyed and olive rockfish were most abundant. On the shell mound, vermilion, halfbanded, and calico rockfishes were most common, and blackeye goby, copper rockfish and painted greenling were also frequently encountered. A platform inspection video made on 23 September 1999 (Stolt Comex Seaway) around the platform bottom showed large numbers of juvenile blue, brown, copper, olive, vermilion, and widow rockfishes and lingcod. Both juvenile and adult calico, gopher, halfbanded and kelp rockfishes and painted greenling were also present.

B

Original operator: Union Oil; current operator of record: Nuevo Energy; date installed: 1968; first production: 1969; distance from shore (miles): 5.7 (OCS); water depth: 58 m (190 ft.); number of well slots: 63; produces: oil and gas; platform jacket dimensions: 40 x 48 m (133 x 158 ft.) (bottom); platform footprint (m^2): 1,930; location: 34°19'N, 119°37'W.

Dates and types of surveys:
Submersible:

	Midwater	Bottom	Shell Mound
2000	x		

Juvenile widow rockfish, which had probably settled from the plankton in 1999, were abundant in the platform midwaters in 2000. Blacksmith, young blue, olive and kelp rockfishes, senorita and painted greenling were also common. We reviewed a video of a platform inspection (Stolt Comex Seaway, 21 September 1999) and noted large numbers of juvenile lingcod, blue, flag, and vermilion rockfishes as well as many juvenile and adult calico, gopher, halfbanded, kelp and rosy rockfishes and painted greenling.

A

Original operator: Union Oil; current operator of record: Nuevo Energy; date installed: 1968; first production: 1969; distance from shore (miles): 5.8 (OCS); water depth: 57 m (188 ft.); number of well slots: 57; produces: oil and gas; platform jacket dimensions: 40 x 48 m (133 x 158 ft.) (bottom); platform footprint (m^2): 1,930; location: 34°19'N, 119°36'W.

Dates and types of surveys:
Submersible:

	Midwater	Bottom	Shell Mound
2000	x		

Blacksmith, blue and olive rockfishes were most abundant in the platform midwaters during 2000. Halfmoon, kelp bass and painted greenling were also common. Due to poor visibility, we were unable to survey the bottom and shell mound of Platform A during 2000. However, we reviewed a 2001 platform inspection video tape (Divecon International 2001) conducted with a remotely operated vehicle. That tape showed that there were large numbers of fishes, primarily rockfishes, around the platform bottom. These included many subadult vermilion and copper rockfishes, as well as blue, calico, gopher, kelp, and juvenile widow rockfishes, lingcod and painted greenling.

HILLHOUSE

Original operator: Sun Oil; current operator of record: Nuevo Energy; date installed: 1969; first production: 1970; distance from shore (miles): 5.5 (OCS); water depth: 58 m (190 ft.); number of well slots: 60; produces: oil and gas; platform jacket dimensions: 49 x 40 m (163 x 133 ft.) (bottom); location: 34°19'N, 119°36'W.

Dates and types of surveys:
Submersible:

	Midwater	Bottom	Shell Mound
2000	x		

Blacksmith and painted greenling were the most abundant species in the platform midwaters. Poor water visibility prevented us from surveying the platform bottom and shell mound. We reviewed a videotape made during an ROV platform inspection survey (Divecon International, 26 August 2001) and, although this too was conducted during poor visibility, noted juvenile copper, flag, and vermilion rockfishes, as well as painted greenling and pile perch.

HENRY

Current operator of record: Nuevo Energy; date installed: 1979; first production: 1980; distance from shore (miles): 4.3 (OCS); water depth: 52 m (173 ft.); number of well slots: 24; produces: oil and gas; platform jacket dimensions: 45 x 33 m (149 x 110 ft.) (bottom); size of shell mound: 9 m (19 ft) high, circular and 76 m (250 ft.) in diameter; platform footprint (m^2): 1,505; location: 34°19'N, 119°33'W.

Dates and types of surveys:

Submersible:

	Midwater	Bottom	Shell Mound
2000	x		

Halfmoon, blacksmith and kelp bass were common in the midwaters of Platform Henry.

HOUCHIN

Original operator: Phillips Petroleum/Continental Oil/Cities Services Oil; current operator of record: Pacific Operators Offshore; date installed: 1968; first production: 1969; distance from shore (miles): 4.1 (OCS); water depth: 49 m (163 ft.); number of well slots: 60; produces: oil and gas; platform jacket dimensions: 38 x 38 m (125 x 125 ft.) (bottom); size of shell mound: 6 m (21 ft.) high, circular and 85 m (280 ft.) in diameter; 1,435; location: 34°20'N, 119°33'W.

Dates and types of surveys:

Submersible:

	Midwater	Bottom	Shell Mound
2000	x		

Painted greenling and halfmoon were the most abundant species in the platform midwaters.

HOGAN

Original operator: Phillips Petroleum/Continental Oil/Cities Services Oil; current operator of record: Pacific Operators Offshore; date installed: 1967; first production: 1968; distance from shore (miles): 3.7 (OCS); water depth: 47 m (154 ft.); number of well slots: 66; produces: oil and gas; platform jacket dimensions: 38 x 38 m (125 x 125 ft.) (bottom); platform footprint (m^2): 1,435; location: 34°20'N, 119°32'W.

Dates and types of surveys:

Submersible:

	Midwater	Bottom	Shell Mound
2000	x		

The midwaters around Platform Hogan were important habitat for a diverse fish assemblage. Blacksmith, blue and olive rockfishes, painted greenling, sharpnose seaperch, pile perch and California sheephead were all common species.

HABITAT

Original operator: Texaco; current operator of record: Nuevo Energy; date installed: 1981; first production: 1993; distance from shore (miles): 7.8 (OCS); water depth: 88 m (290 ft.); number of well slots: 24; produces: gas; platform jacket dimensions: 60 x 38 m (199 x 125 ft.) (bottom); platform footprint (m^2): 2,284; location: 34°17'N, 119°35'W.

Dates and types of surveys:

Submersible:

	Midwater	Bottom	Shell Mound
1995	x (partial)		
2000	x		

YOY widow rockfish, blacksmith, and one-year-old widow rockfish dominated the midwater at Platform Habitat. Blue and kelp rockfishes and painted greenling were also common species.

GRACE

Original operator: Standard Oil; current operator of record: Venoco; date installed: 1979; first production: 1980; distance from shore (miles): 10.5 (OCS); water depth: 96 m (318 ft.); number of well slots: 48; produces: Grace is a non-producing platform; platform jacket dimensions (at surface and at bottom): 27 x 44 m (90 by 145 ft.) (surface), 48 x 65 m (158 x 213 ft.) (bottom); size of shell mound: 4 m (13 ft.) high, oval, 61 x 118 m (200 x 390 ft.), oriented in a northwest-southeast direction; platform footprint (m^2): 3,090; location: 34°10'N, 119°28'W.

Dates and types of surveys:

Scuba: 1996–2000

Submersible:

	Midwater	Bottom	Shell Mound
1996	x	x	
1997	x	x	x
1998	x		x
1999	x	x	x
2000	x	x	x
2001	x	x	x

The midwaters around Platform Grace contained very large numbers of young rockfishes. Most of these rockfishes recruited between 1999 and 2001. YOY widow rockfish and bocaccio, juvenile squarespot, blue and widow rockfishes, bocaccio and juvenile and adult blacksmith were very common. Painted greenling, sharpnose seaperch, jack mackerel and young flag rockfish were also frequently encountered. Halfbanded rockfish were the most abundant species around the platform bottom. Juvenile widow, vermilion, and flag rockfishes and bocaccio were also abundant. Many of these individuals had settled out of the plankton at the platform in 1999 and had remained there. Squarespot and greenspotted rockfishes, young lingcod, and sanddabs were also common. Over the shell mounds, halfbanded rockfish and shiner perch were the most abundant species. Pink seaperch, sanddabs, YOY bocaccio, young lingcod, juvenile greenspotted, flag and vermilion rockfishes were also characteristic species.

GILDA

Original operator: Union Oil; Current operator of record: Nuevo Energy; date installed: 1981; first production: 1981; distance from shore (miles): 8.8 (OCS); water depth: 62 m (205 ft.); number of well slots: 96; produces: oil and gas; platform jacket dimensions: 45 x 52 m (150 x 170 ft.) (bottom); platform footprint (m²): 2,342.location: 34°10'N, 119°25'W.

Dates and types of surveys:
Scuba: 1995–2000
Submersible:

	Midwater	Bottom	Shell Mound
2000	x		

Blacksmith, halfmoon, kelp bass, opaleye, senorita, as well as YOY and juvenile blue, olive, squarespot and widow rockfishes and bocaccio were abundant in the midwater of this platform. Many of these rockfishes recruited from the plankton as YOYs during 1999. Due to poor visibility, we were unable to survey the bottom and shell mound of Platform Gilda during 2000. However, we reviewed a 2001 platform inspection video tape (Divecon International 2001) conducted with a remotely operated vehicle. That tape showed high densities of calico and juvenile vermilion rockfishes, as well as blue, brown, copper, halfbanded, olive, and widow rockfishes. Kelp greenling, lingcod, Pacific sanddab, and painted greenling were also noted.

GAIL

Original operator: Standard Oil; current operator of record: Venoco; date installed: 1987; first production: 1988; distance from shore (miles): 9.9 (OCS); water depth: 224 m (739 ft.); number of well slots: 36; produces: oil and gas; platform jacket dimensions: 21 x 52 m (70 x 170 ft.) (surface), 60 x 90 m (197 x 297 ft.) (bottom); platform footprint (m²): 5,327; location: 34°07'N, 119°24'W.

Dates and types of surveys:
Scuba: 1996–2000
Submersible:

	Midwater	Bottom	Shell Mound
1996	x	x	
1997	x	x	x
1998	x		
1999	x	x	x
2000	x	x	x
2001	x	x	x

Blacksmith, halfmoon, kelp bass and a variety of young rockfishes, including bocaccio, blue, flag, olive, and widow, characterized the midwaters of this platform. Most of the young rockfishes settled from the plankton in 1999. The platform bottom fish assemblage was dominated by adult bocaccio, greenblotched, greenspotted, stripetail and pinkrose rockfishes. Of particular interest, we observed higher densities of both adult cowcod and bocaccio at the bottom of Platform Gail than at any natural outcrop or other platform. The shell mound at Platform Gail was characterized by stripetail, pinkrose, greenblotched and greenstriped rockfishes. On one occasion, large numbers of juvenile hake were observed, on another northern anchovies were abundant.

GINA

Original operator: Union Oil; current operator of record: Nuevo Energy; date installed:1980; first production: 1982; distance from shore (miles): 3.7 (OCS); water depth: 29 m (95 ft.); number of well slots: 15; produces: oil and gas; platform jacket dimensions: 28 x 20 m (94 x 65 ft.) (bottom); shell mound: 4 m (13 ft.) high, oval, 45 x 64 m (150 x 210 ft.), oriented in a northwest-southeast direction; platform footprint (m²): 561; location: 34°07'N, 119°16'W.

Dates and types of surveys:
Scuba: 1995–2000

Platform Gina had the highest species richness (47) of any platform surveyed using scuba. Blacksmith dominated the assemblage, comprising 38% of all fishes observed. A close second was kelp bass, which counted for 31% of all fishes observed. Platform Gina had the highest number and density of surfperches of any platform, and was the only site where rubberlip surfperch formed part of the assemblage. The shell mound habitat at this platform provided excellent habitat for many species of recruiting rockfishes, where 13 species were observed. However, despite being present at every other surveyed platform, no widow or bocaccio juveniles were observed at Platform Gina. Pelagic species that characterized this assemblage include yellowtail, barracuda, and jackmackerel.

EDITH

Original operator: Standard Oil; current operator of record: Nuevo Energy; date installed: 1983; first production: 1984; distance from shore (miles): 8.5 (OCS); water depth: 49 m (161 ft.); number of well slots: 72; produces: oil and gas; platform jacket dimensions: 58 x 50 m (190 x 165 ft.) (bottom); platform footprint (m²): 2,879; location: 33°35'N, 118°08'W.

Dates and types of surveys:
Submersible:

	Midwater	Bottom	Shell Mound
1998	x	x	x

Blacksmith, halfmoon, opaleye, sheephead and garibaldi characterized the midwater fish assemblage at Platform Edith. Very high densities of California scorpionfish, along with sharpnose seaperch, blacksmith and blackeye goby were found at the platform bottom. California scorpionfish were also extremely abundant on the shell mound.

ELLEN

Original operator: Shell Oil; current operator of record: Aera Energy; date installed: 1980; first production: 1981; distance from shore (miles): 8.6 (OCS); water depth: 80 m (265 ft.); number of well slots: 80; produces: oil and gas; platform jacket dimensions: 45 x 56 m (147 x 186 ft.) (bottom); platform footprint (m²): 2,511; location: 33°34'N, 118°07'W.

Aera did not allow us to survey this platform. We reviewed a tape of a platform inspection carried out with a remotely operated vehicle (Divecon International, 7 September 2001) and observed very high densities of flag, halfbanded, squarespot and honeycomb rockfishes. We also saw a number of young vermilion rockfish. In the platform midwater, from about 61 m (200 ft) and deeper, there were very large numbers of young rockfishes, including both squarespots and widows.

ELLY

Original operator: Shell Oil; current operator of record: Aera Energy; date installed: 1980; first production: n/a; distance from shore (miles): 8.6 (OCS); water depth: 77 m (255 ft.); number of well slots: n/a; produces: Elly is a processing facility for Ellen and Eureka; platform jacket dimensions: 48 x 61 m (159 x 202 ft.) (bottom); platform footprint (m^2): 2,949; location: 33°35'N, 118°07'W.

Aera did not allow us to survey this platform. We reviewed a tape of a platform inspection carried out with a remotely operated vehicle (Divecon International, 9 September 2001) and observed high densities of young vermilion and young widow rockfishes, as well as many flag, honeycomb, olive, and squarespot rockfishes, and lingcod.

EUREKA

Original operator: Shell Oil; current operator of record: Aera Energy; date installed: 1984; first production: 1985; distance from shore (miles): 9.0 (OCS); water depth: 212 m (700 ft.); number of well slots: 60; produces: oil and gas; platform jacket dimensions: 54 x 85 m (179 x 282 ft.) (bottom); platform footprint (m^2): 4,635; location: 33°33'N, 118°06'W.

Aera did not allow us to survey this platform. We reviewed a tape of a platform inspection carried out with a remotely operated vehicle (Divecon International, 5 September 2001) and observed large numbers of pinkrose and juvenile darkblotched rockfishes, as well as juvenile and subadult bocaccio and widow rockfish. Also present were flag, greenblotched and greenspotted, and perhaps speckled, rockfishes and lingcod.

EVA

Original operator: Union Oil Company; current operator of record: Nuevo Energy; date installed: 1964; first production: 1966; distance from shore (miles): 1.8 (state); water depth: 17 m (57 ft.); number of well slots: 39; produces: oil and gas; location: 33°39'N, 118°03'W.

EMMY

Original operator: Signal Oil and Gas Company; current operator of record: Aera Energy; date installed: 1963; first production: 1963; distance from shore (miles): 1.2 (state); water depth: 14 m (47 ft.); number of well slots: 53; produces: oil and gas; location: 33°39N, 118°02'W.

Aera did not allow us to survey this platform.

APPENDIX 2

Density of fishes observed during the oil/gas platform scuba surveys off central and southern California. Platforms are listed from northwest to southeast. Density is in fish per 100 m^2, "<" means "less than."

Common name	Irene	Hidalgo	Harvest	Hermosa	Holly	Grace	Gilda	Gail	Gina
Barred sand bass					0.8				
Black rockfish		<0.1		<0.1		<0.1			<0.1
Black-and-yellow rockfish			<0.1	<0.1		<0.1			
Blackeye goby		<0.1	<0.1			<0.1		0.2	4.0
Blacksmith	1.6	16.2	20.0	8.5	20.9	71.3	57.4	77.4	51.3
Blue rockfish	32.3	3.8	18.9	7.5	36.3	5.3	9.8	3.9	1.3
Bluebanded goby									<0.1
Bocaccio	9.5	0.1	3.7	0.8	36.6	2.7	5.0	5.9	
Brown rockfish		<0.1			<0.1		<0.1		<0.1
Bull sculpin							<0.1		
Cabezon	0.1	0.1	0.2	0.2	0.1	<0.1	0.1	<0.1	1.1
Calico rockfish							<0.1		0.6
California barracuda						0.4	<0.1		0.8
California scorpionfish	<0.1				<0.1				0.1
California sheephead			<0.1			<0.1	0.1	<0.1	0.3
C-O turbot									<0.1
Copper rockfish	0.2	0.2	0.1	0.1	0.8	0.1	<0.1	<0.1	<0.1
Copper -complex juv. rockfishes	6.1	4.7	3.1	1.5	0.7	0.8	0.4	0.1	0.2
Garibaldi						<0.1	0.1	<0.1	0.1
Giant kelpfish					<0.1				
Gopher rockfish	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1
Grass rockfish					<0.1	<0.1	<0.1	0.2	<0.1
Halfbanded rockfish									0.6
Halfmoon	<0.1	1.3	0.3	0.9	3.1	2.2	16.7	13.7	2.4
Jackmackerel	69.3	22.1		8.0	34.5	6.1	6.3	0.2	9.6
Kelp bass					<0.1	0.5	6.1	1.8	42.9
Kelp greenling	0.1	0.4	0.6	0.4	0.1	0.1	0.1	0.1	<0.1
Kelp rockfish	<0.1	0.7	0.2	0.1	3.7	1.5	0.6	0.4	0.4
Lingcod	<0.1				0.1		<0.1		0.2
Mussel blenny							<0.1		
Northern anchovy		6.3	7.4	7.4					
Ocean sunfish	<0.1								
Ocean whitefish				0.0					0.8
Olive rockfish	0.6	0.7	4.5	3.8	2.5	0.3	1.6	0.9	0.2
Opaleye						<0.1	2.4	0.1	2.5
Pacific butterfish	<0.1								
Pacific mackerel						<0.1			
Painted greenling	3.4	1.6	1.5	2.9	1.9	1.0	0.5		1.7
Pile perch	0.1				0.7		0.2		3.4
Rock wrasse							0.1		0.1
Rosy rockfish	<0.1	0.5	<0.1		<0.1			<0.1	0.1
Rubberlip seaperch									0.6
Sarcastic fringehead						<0.1			
Sardine	7.1		0.2		169.3	36.4	1.2	6.8	
Senorita							3.6	0.2	
Sharpnose seaperch					1.9		0.7		2.3

Common name	Irene	Hidalgo	Harvest	Hermosa	Holly	Grace	Gilda	Gail	Gina
Shortbelly rockfish	57.0								
Spotted sand bass									<0.1
Squarespot rockfish	4.7	8.4	3.3		49.0	5.4	13.3	0.2	4.2
Starry rockfish									<0.1
Stripetail rockfish									1.2
Treefish	0.4	0.1	0.2	<0.1	0.1	0.2	0.1	0.1	0.1
Unidentified Atherinidae					12.3				
Unidentified Blenniidae					<0.1	<0.1		<0.1	
Unidentified Bothidae									<0.1
Unidentified Clinidae					<0.1				
Unidentified Cottidae	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1
Unidentified fish species	<0.1	<0.1	<0.1		<0.1		<0.1	<0.1	<0.1
Unidentified rockfish juveniles	4.9	8.6	1.2	0.1	1.6	0.5	0.2	0.1	0.6
Vermilion rockfish									0.1
White seaperch	<0.1				<0.1		<0.1		1.5
Widow rockfish	141.4	10.8	46.9	15.5	54.9	2.7	1.5	<0.1	
Wolf eel	<0.1								<0.1
Yellowtail									0.1


DAN DUGAN

Cabezon in the midwater of Platform Holly.

APPENDIX 3

Number and density of fishes observed in the midwaters, bottoms and shell mounds of oil/gas platforms off central and southern California. Platforms are listed geographically, from northwest to southeast. Species are ranked by number observed. YOY means "young-of-the-year", those are fish that are less than one year old. Density is in fish per 100 m^2, "<" means "less than".

PLATFORM MIDWATERS

Because we could not estimate the lengths of the transects around Platforms Habitat and Gilda, no fish densities are presented.

PLATFORM IRENE (Surveyed 1995–2001)

Species	Number	Density
Shortbelly rockfish YOY	7,300	378
Unidentified rockfish YOY	4,133	214
Widow rockfish YOY	2,310	120
Pacific sardine	1,600	83
Bocaccio YOY	989	51
Widow rockfish	372	19
Yellowtail rockfish	133	7
Blacksmith	120	6
Painted greenling	26	1
Copper rockfish	24	1
Pile surfperch	11	<1
Blue rockfish	5	<1
Unidentified rockfish	2	<1
Kelp greenling	1	<1
Lingcod	1	<1
Olive rockfish	1	<1
TOTAL	**17,028**	**880**
Minimum number of species	14	
Total rockfish YOY	14,732	763
Total rockfishes	15,269	790

Rockfish YOY comprised 86.5% of all fishes surveyed.
All rockfishes comprised 89.7% of all fishes surveyed.

PLATFORM HIDALGO (Surveyed 1996–2001)

Species	Number	Density
Unidentified rockfish YOY	13,134	186
Widow rockfish YOY	794	11
Painted greenling	136	2
Bocaccio YOY	87	1
Halfbanded rockfish	34	<1
Widow rockfish	26	<1
Flag rockfish	6	<1
Kelp greenling	5	<1
Yellowtail rockfish	5	<1
Squarespot rockfish	5	<1
Pygmy rockfish	3	<1
Unidentified fish	3	<1
Greenspotted rockfish	2	<1
Unidentified sculpin	1	<1
Copper rockfish	1	<1
Cabezon	1	<1
TOTAL	**14,243**	**200**
Minimum number of species	13	
Total rockfish YOY	14,015	198
Total rockfishes	14, 097	198

Rockfish YOY comprised 98.3% of all fishes surveyed.
All rockfishes comprised 98.9% of all fishes surveyed.

PLATFORM MIDWATERS, cont.

PLATFORM HARVEST (Surveyed 1996–2000)

Species	Number	Density
Unidentified rockfish YOY	5,000	54
Widow rockfish YOY	1,474	16
Squarespot rockfish	1,246	14
Painted greenling	289	3
Sharpchin rockfish	171	2
Whitespeckled rockfish	134	1
Widow rockfish	113	1
Chilipepper	50	<1
Sebastomus sp.	47	<1
Bocaccio YOY	43	<1
Flag rockfish	26	<1
Unidentified rockfish	23	<1
Unidentified fish	22	<1
Greenspotted rockfish	21	<1
Blue rockfish	18	<1
Blacksmith	13	<1
Kelp rockfish	5	<1
Cabezon	2	<1
Kelp greenling	2	<1
Pacific sardine	2	<1
Rosy rockfish	2	<1
Shortbelly rockfish	2	<1
Blackeye goby	1	<1
Bocaccio	1	<1
Calico rockfish	1	<1
Halfbanded rockfish	1	<1
Pygmy rockfish	1	<1
Shortspine combfish	1	<1
Starry rockfish	1	<1
Treefish	1	<1
Wolf-eel	1	<1
Yellowtail rockfish	1	<1
TOTAL	**8,715**	**91**
Minimum number of species	26	
Total rockfish YOY	6,517	70
Total rockfishes	8,382	88

Rockfish YOY comprised 74.8% of all fishes surveyed.
All rockfishes comprised 96.2% of all fishes surveyed.

PLATFORM HERMOSA (Surveyed 1996–2000)

Species	Number	Density
Unidentified rockfish YOY	17,242	199
Widow rockfish YOY	1,140	16
Painted greenling	480	7
Blue rockfish	436	5
Widow rockfish	256	3
Squarespot rockfish	148	2
Whitespeckled rockfish	47	<1
Sebastomus sp.	42	<1
Blacksmith	30	<1
Bocaccio YOY	29	<1
Unidentified rockfish	22	<1
Pacific hake	19	<1
Greenspotted rockfish	12	<1
Halfbanded rockfish	10	<1
Flag rockfish	8	<1
Copper rockfish	5	<1
Cowcod	5	<1
Unidentified fish	4	<1
Unidentified sculpin	3	<1
Cabezon	3	<1
Lingcod	3	<1
Sharpchin rockfish	3	<1
Chilipepper	2	<1
Stripetail rockfish	2	<1
Treefish	2	<1
Yelloweye rockfish	2	<1
TOTAL	**19,955**	**232**
Minimum number of species	21	
Total rockfish YOY	18,411	215
Total rockfishes	19,413	225

Rockfish YOY comprised 92.2% of all fishes surveyed.
All rockfishes comprised 97.3% of all fishes surveyed.

PLATFORM MIDWATERS, cont.

PLATFORM HOLLY (Surveyed 1995–1998, 2001)

Species	Number	Density
Pacific sardine	1,506	78
Squarespot rockfish	315	16
Jack mackerel	287	15
Unidentified rockfish YOY	129	6
Painted greenling	120	6
Kelp rockfish	43	2
Copper rockfish	31	2
Sharpnose seaperch	31	1
Yellowtail rockfish	22	1
Blacksmith	8	<1
Pile perch	7	<1
Brown rockfish	7	<1
Calico rockfish	6	<1
Gopher rockfish	6	<1
Unidentified rockfish	6	<1
Sebastomus sp.	4	<1
Treefish	3	<1
Unidentified sculpin	2	<1
Widow rockfish	2	<1
Blue rockfish	2	<1
Bocaccio YOY	2	<1
Unidentified fish	2	<1
Lingcod	1	<1
Olive rockfish	1	<1
Rubberlip seaperch	1	<1
Widow rockfish YOY	1	<1
Unidentified seaperch	1	<1
TOTAL	**2,546**	**127**
Minimum number of species	22	
Total rockfish YOY	122	6
Total rockfishes	580	27

Including the one time occurrence of Pacific sardine, YOY rockfishes comprised 4.8%, and all rockfishes comprised 22.8% of all fishes surveyed.

Excluding Pacific sardines, YOY rockfishes comprised 11.7%, and all rockfishes comprised 55.8% of all fishes surveyed.

PLATFORM A (Surveyed 2000)

Species	Number	Density
Blacksmith	421	28
Blue rockfish	336	22
Olive rockfish	126	8
Halfmoon	25	2
Kelp bass	17	1
Painted greenling	11	<1
Unidentified seaperch	9	<1
Sharpnose seaperch	9	<1
Kelp rockfish	8	<1
Garibaldi	7	<1
Unidentified rockfish YOY	6	<1
Pile perch	5	<1
California sheephead	4	<1
Blackeye goby	3	<1
Unidentified fish	1	<1
Unidentified rockfish	1	<1
TOTAL	**989**	**61**
Minimum number of species	13	
Total rockfish YOY	6	<1
Total rockfishes.	477	30

Rockfish YOY comprised <1% of all fishes surveyed.
All rockfishes comprised 48.2% of all fishes surveyed.

PLATFORM MIDWATERS, cont.

PLATFORM B (Surveyed 2000)

Species	Number	Density
Widow rockfish	180	12
Blacksmith	124	8
Blue rockfish	44	3
Olive rockfish	26	2
Kelp rockfish	16	1
Senorita	13	<1
Painted greenling	13	<1
California sheephead	9	<1
Kelp bass	6	<1
Sharpnose seaperch	6	<1
Halfmoon	5	<1
Pile perch	4	<1
Bluebanded goby	2	<1
Cabezon	1	<1
Copper rockfish	1	<1
Gopher rockfish	1	<1
Lingcod	1	<1
Unidentified rockfish YOY	1	<1
TOTAL	**453**	**26**
Minimum number of species	17	
Total rockfish YOY	1	<1
Total rockfishes	269	18

Rockfish YOY comprised <1.0% of all fishes surveyed.
All rockfishes comprised 59.4% of all fishes surveyed.

PLATFORM C (Partially Surveyed 2000)

Species	Number	Density
Olive rockfish	13	3
Kelp rockfish	7	2
Pile perch	4	<1
Blue rockfish	4	<1
Phanerodon sp.	3	<1
Vermilion rockfish	2	<1
Unidentified rockfish	2	<1
Lingcod	1	<1
Unidentified fish	1	<1
Unidentified rockfish YOY	1	<1
TOTAL	**38**	**5**
Minimum number of species	7	
Total rockfish YOY	1	<1
Total rockfishes	27	5

All rockfishes comprised 71.1% of all fishes surveyed.

PLATFORM HILLHOUSE (Surveyed 2000)

Species	Number	Density
Blacksmith	23	2
Painted greenling	22	2
Kelp bass	7	<1
Olive rockfish	7	<1
Pile perch	3	<1
Kelp rockfish	1	<1
Lingcod	1	<1
Phanerodon sp.	1	<1
Unidentified rockfish	1	<1
TOTAL	**66**	**4**
Minimum number of species	8	
Total rockfishes	9	<1

PLATFORM HENRY (Surveyed 2000)

Species	Number	Density
Halfmoon	57	6
Blacksmith	20	2
Kelp bass	12	1
Painted greenling	8	<1
Kelp rockfish	1	<1
Unidentified rockfish YOY	1	<1
TOTAL	**99**	**9**
Minimum number of species	5	
Total rockfish YOY	1	<1
Total rockfishes	2	<1

Rockfish YOY comprised 1% of all fishes surveyed.
All rockfishes comprised 2% of all fishes surveyed.
All rockfishes comprised 13.6% of all fishes surveyed.

PLATFORM MIDWATERS, cont.

PLATFORM HOUCHIN (Surveyed 2000)

Species	Number	Density
Painted greenling	41	4
Halfmoon	12	1
Kelp rockfish	9	<1
Blacksmith	4	<1
Unidentified rockfish YOY	4	<1
Garibaldi	3	<1
Pile perch	2	<1
California sheephead	1	<1
Olive rockfish	1	<1
Sharpnose seaperch	1	<1
Unidentified sculpin	1	<1
TOTAL	**99**	**6**
Minimum number of species	10	
Total rockfish YOY	4	<1
Total rockfishes	14	<1

Rockfish YOY comprised 4% of all fishes surveyed.
All rockfishes comprised 14% of all fishes surveyed.

PLATFORM HOGAN (Surveyed 2000)

Species	Number	Density
Blacksmith	75	7
Blue rockfish	72	6
Olive rockfish	41	3
Painted greenling	28	3
Sharpnose seaperch	26	2
Pile perch	16	1
California sheephead	15	1
Kelp rockfish	4	<1
Unidentified rockfish YOY	4	<1
Garibaldi	1	<1
Kelp bass	1	<1
Rubberlip seaperch	1	<1
TOTAL	**293**	**23**
Minimum number of species	11	
Total rockfish YOY	4	<1
Total rockfishes	121	9

Rockfish YOY comprised 1.4% of all fishes surveyede
All rockfishes comprised 41.3% of all fishes surveyed.

PLATFORM HABITAT (Partially Surveyed 1995, Surveyed 2000)

Species	Number	Density
Widow rockfish YOY	470	
Blacksmith	122	
Widow rockfish	111	
Unidentified rockfish YOY	41	
Blue rockfish	25	
Painted greenling	14	
Kelp rockfish	14	
Bocaccio YOY	12	
Flag rockfish	7	
Halfmoon	5	
Olive rockfish	5	
Copper rockfish	4	
Garibaldi	4	
Kelp bass	1	
Sebastomus sp.	1	
TOTAL	**836**	
Minimum number of species	13	
Total rockfish YOY	523	
Total rockfishes	690	

Rockfish YOY comprised 62.6% of all fishes surveyed.
All rockfishes comprised 82.5% of all fishes surveyed.

PLATFORM MIDWATERS, cont.

PLATFORM GRACE (Surveyed 1996–2001)

Species	Number	Density
Unidentified rockfish YOY	5,454	79
Widow rockfish YOY	2,768	40
Squarespot rockfish	1,554	22
Blue rockfish	1,029	15
Widow rockfish	633	9
Bocaccio YOY	396	6
Blacksmith	313	4
Bocaccio	142	2
Painted greenling	86	1
Sharpnose seaperch	54	<1
Jack mackerel	54	<1
Flag rockfish	46	<1
Kelp rockfish	35	<1
Olive rockfish	30	<1
Pacific mackerel	30	<1
Unidentified rockfish	28	<1
Halfmoon	26	<1
Chilipepper	25	<1
Sebastomus sp.	15	<1
Brown rockfish	10	<1
Copper rockfish	10	<1
Lingcod	7	<1
Whitespeckled rockfish	5	<1
Unknown fish	4	<1
Unknown sculpin	3	<1
Greenspotted rockfish	3	<1
Rosy rockfish	2	<1
Swordspine rockfish	2	<1
Treefish	2	<1
Calico rockfish	1	<1
Cowcod	1	<1
Kelp greenling	1	<1
Pink seaperch	1	<1
Vermilion rockfish	1	<1
White seaperch	1	<1
Unidentified seaperch	1	<1
TOTAL	**12,773**	**178**
Minimum number of species	29	
Total rockfish YOY	8,618	125
Total rockfishes	12,192	173

Rockfish YOY comprised 67.5% of all fishes surveyed.
All rockfishes comprised 95.5% of all fishes surveyed.

PLATFORM GILDA (Surveyed 2000)

Species	Number	Density
Widow rockfish	650	
Blue rockfish	23	
Olive rockfish	15	
Kelp bass	6	
Kelp rockfish	6	
Painted greenling	5	
Squarespot rockfish	3	
Blacksmith	2	
Bocaccio	2	
Lingcod	1	
Mola	1	
Opaleye	1	
Pile perch	1	
Senorita	1	
Sharpnose seaperch	1	
TOTAL	**718**	
Minimum number of species	15	
Total rockfishes	699	

All rockfishes comprised 97.4% of all fishes surveyed.

PLATFORM MIDWATERS, cont.

PLATFORM GAIL (Surveyed 1996–2001)

Species	Number	Density
Unidentified rockfish YOY	2,371	24
Blacksmith	241	2
Flag rockfish YOY	102	1
Widow rockfish YOY	93	<1
Painted greenling	46	<1
Bocaccio YOY	28	<1
Unidentified fish	23	<1
Pinkrose rockfish	12	<1
Widow rockfish	8	<1
Squarespot rockfish	7	<1
Whitespeckled rockfish	6	<1
Bank rockfish	4	<1
Unidentified rockfish	4	<1
Greenblotched rockfish	3	<1
Blue rockfish	2	<1
Cabezon	2	<1
Greenspotted rockfish	2	<1
Olive rockfish	2	<1
Bocaccio	1	<1
Chilipepper	1	<1
Kelp greenling	1	<1
Pacific hake	1	<1
Sebastomus sp.	1	<1
Swordspine rockfish	1	<1
TOTAL	**2,962**	**26**
Minimum number of species	19	
Total rockfish YOY	2,593	25
Total rockfishes	2,648	25

Rockfish YOY comprised 87.5% of all fishes surveyed.
All rockfishes comprised 89.4% of all fishes surveyed.

PLATFORM EDITH (Surveyed 1998)

Species	Number	Density
Blacksmith	1,241	265
Halfmoon	59	13
Opaleye	37	8
Sheephead	23	5
Garibaldi	20	4
Sharpnose seaperch	8	1
Kelp bass	5	1
Painted greenling	4	1
TOTAL	**1,397**	**298**
Minimum number of species	8	

No rockfishes observed.

PLATFORM BOTTOMS

PLATFORM IRENE (Surveyed 1996–2001)

Species	Number	Density
Halfbanded rockfish	5,393	217
Unidentified rockfish YOY	1,411	57
Copper rockfish	1,187	47
Vermilion rockfish	799	40
Lingcod	468	19
Calico rockfish	381	15
Widow rockfish YOY	335	13
Pile perch	115	5
Painted greenling	105	4
Pacific sanddab	96	4
Brown rockfish	78	3
Yellowtail rockfish	30	1
Canary rockfish	28	1
Blue rockfish	25	1
Rosy rockfish	21	<1
Kelp greenling	20	<1
Rubberlip seaperch	19	<1
Bocaccio YOY	17	<1
Sebastomus sp.	12	<1
Olive rockfish	8	<1
Unidentified seaperch	5	<1
Gopher rockfish	5	<1
Sharpnose seaperch	4	<1
Squarespot rockfish	4	<1
Widow rockfish	4	<1
Unidentified fish	4	<1
Greenspotted rockfish	3	<1
Unidentified rockfish	3	<1
Bocaccio	2	<1
Flag rockfish	2	<1
Kelp rockfish	2	<1
Honeycomb rockfish	1	<1
Yelloweye rockfish	1	<1
Unidentified ronquil	1	<1
Unidentified sanddab	1	<1
Unidentified flatfish	1	<1
TOTAL	**10,591**	**427**
Minimum number of species	29	
Total rockfish YOY	1,766	70
Total rockfishes	9,748	395

Rockfish YOY comprised 16.7% of all fishes surveyed.
All rockfishes comprised 92% of all fishes surveyed.

PLATFORM HIDALGO (Surveyed 1996–2001)

Species	Number	Density
Halfbanded rockfish	9,664	305
Greenspotted rockfish	587	19
Unidentified rockfish YOY	307	10
Flag rockfish	256	8
Lingcod	97	3
Greenblotched rockfish	69	2
Widow rockfish	69	2
Greenstriped rockfish	60	2
Bocaccio	56	2
Painted greenling	47	1
Vermilion rockfish	43	1
Canary rockfish	39	1
Rosy rockfish	36	1
Widow rockfish YOY	34	1
Squarespot rockfish	28	<1
Sebastomus sp.	26	<1
Sharpchin rockfish	15	<1
Pygmy rockfish	12	<1
Yelloweye rockfish	12	<1
Swordspine rockfish	10	<1
Cowcod	8	<1
Unidentified rockfish	8	<1
Starry rockfish	6	<1
Unidentified combfish	6	<1
Kelp greenling	5	<1
Bocaccio YOY	4	<1
Shortspine combfish	2	<1
Bank rockfish	1	<1
Stripetail rockfish	1	<1
Unidentified poacher	1	<1
TOTAL	**11,509**	**358**
Minimum number of species	24	
Total rockfish YOY	345	11
Total rockfishes	11, 351	354

Rockfish YOY comprised 3.0% of all fishes surveyed.
All rockfishes comprised 98.6% of all fishes surveyed.

PLATFORM BOTTOMS, cont.

PLATFORM HARVEST (Surveyed 1997–2000)

Species	Number	Density
Stripetail rockfish	250	10
Greenstriped rockfish	207	8
Greenspotted rockfish	78	3
Greenblotched rockfish	67	3
Sharpchin rockfish	44	2
Lingcod	35	1
Sebastomus sp.	24	<1
Flag rockfish	17	<1
Unidentified rockfish	12	<1
Unidentified combfish	10	<1
Unidentified rockfish YOY	6	<1
Chilipepper	5	<1
Halfbanded rockfish	4	<1
Shortspine combfish	4	<1
Unidentified flatfish	3	<1
Cowcod	2	<1
Pinkrose rockfish	2	<1
Unidentified poacher	2	<1
Bank rockfish	1	<1
Bocaccio	1	<1
Swordspine rockfish	1	<1
TOTAL	**775**	**27**
Minimum number of species	17	
Total rockfish YOY	6	<1
Total rockfishes	721	26

Rockfish YOY comprised <1% of all fishes surveyed.
All rockfishes comprised 93.0% of all fishes surveyed.

PLATFORM HERMOSA (Surveyed 1996–2000)

Species	Number	Density
Halfbanded rockfish	6,718	262
Greenspotted rockfish	321	13
Flag rockfish	42	2
Sebastomus sp.	26	1
Lingcod	24	1
Unidentified rockfish YOY	9	<1
Pinkrose rockfish	7	<1
Shortspine combfish	7	<1
Cowcod	6	<1
Greenstriped rockfish	6	<1
Greenblotched rockfish	5	<1
Shortbelly rockfish	4	<1
Unidentified rockfish YOY	4	<1
Pacific hake	2	<1
Ratfish	2	<1
Swordspine rockfish	2	<1
Unidentified rockfish	2	<1
Bocaccio YOY	1	<1
Canary rockfish	1	<1
Darkblotched rockfish	1	<1
Pink seaperch	1	<1
Sharpchin rockfish	1	<1
Starry rockfish	1	<1
Whitespeckled rockfish	1	<1
Widow rockfish	1	<1
Unidentified combfish	1	<1
Unidentified fish	1	<1
Unidentified flatfish	1	<1
Unidentified poacher	1	<1
TOTAL	**7,195**	**279**
Minimum number of species	23	
Total rockfish YOY	14	<1
Total rockfishes	7,159	278

Rockfish YOY comprised <1% of all fishes surveyed.
All rockfishes comprised 99.5% of all fishes surveyed.

PLATFORM BOTTOMS, cont.

PLATFORM HOLLY (Surveyed 1996–1999, 2001)

Species	Number	Density
Widow rockfish YOY	1,028	49
Calico rockfish	726	35
Vermilion rockfish	444	21
Sharpnose seaperch	407	19
Halfbanded rockfish	405	19
Copper rockfish	285	13
Squarespot rockfish	221	10
Blackeye goby	67	3
Unidentified seaperch	66	3
Unidentified rockfish YOY	54	3
Pink seaperch	53	3
Painted greenling	51	2
Rosy rockfish	43	2
Brown rockfish	38	2
Pile perch	37	2
Lingcod	36	2
Widow rockfish	29	1
Flag rockfish	24	1
Sebastomus sp.	24	1
Unidentified flatfish	20	<1
Honeycomb rockfish	19	<1
Canary rockfish	18	<1
Unidentified rockfish	13	<1
Blue rockfish	12	<1
Unidentified ronquil	10	<1
Rubberlip seaperch	9	<1
Treefish	9	<1
Kelp rockfish	8	<1
Olive rockfish	8	<1
Gopher rockfish	7	<1
Kelp greenling	5	<1
Unidentified fish	4	<1
California scorpionfish	3	<1
Bocaccio YOY	2	<1
Rathbunella sp.	2	<1
Yellowtail rockfish	2	<1
Unidentified combfish	2	<1
Cowcod	1	<1
Greenspotted rockfish	1	<1
Shortspine combfish	1	<1
Shortspine thornyhead	1	<1
TOTAL	**4,195**	**191**
Minimum number of species	33	
Total rockfish YOY	1,084	52
Total rockfishes	3,421	157

Rockfish YOY comprised 25.8% of all fishes surveyed.
All rockfishes comprised 81.5% of all fishes surveyed.

PLATFORM GRACE (Surveyed 1996, 1997, 1999–2001)

Species	Number	Density
Halfbanded rockfish	11,078	408
Widow rockfish	413	15
Squarespot rockfish	220	8
Vermilion rockfish	205	8
Bocaccio YOY	203	7
Bocaccio	183	7
Shiner perch	130	5
Flag rockfish	103	4
Unidentified sanddab	79	3
Greenspotted rockfish	66	2
Lingcod	41	2
Painted greenling	29	1
Unidentified rockfish YOY	28	1
Chilipepper	26	<1
Sebastomus sp.	24	<1
Rosy rockfish	21	<1
Pink seaperch	19	<1
Unidentified flatfish	12	<1
Blue rockfish	9	<1
Kelp greenling	9	<1
Copper rockfish	8	<1
Unidentified rockfish	8	<1
Canary rockfish	7	<1
Unidentified fish	6	<1
Treefish	5	<1
Greenblotched rockfish	4	<1
Unidentified combfish	4	<1
Whitespeckled rockfish	3	<1
Widow rockfish	3	<1
Shortspine combfish	3	<1
Yellowtail rockfish	2	<1
Pink rockfish	1	<1
Rathbunella sp.	1	<1
Yelloweye rockfish	1	<1
Unidentified sculpin	1	<1
TOTAL	**12,955**	**471**
Minimum number of species	28	
Total rockfish YOY	231	8
Total rockfishes	12,621	460

Rockfish YOY comprised 1.8% of all fishes surveyed.
All rockfishes comprised 97.4% of all fishes surveyed.

PLATFORM BOTTOMS, cont.

PLATFORM GAIL (Surveyed 1996, 1997, 1999–2001)

Species	Number	Density
Greenblotched rockfish	369	12
Bocaccio	328	11
Greenspotted rockfish	278	9
Stripetail rockfish	200	7
Pinkrose rockfish	168	6
Sebastomus sp.	63	2
Greenstriped rockfish	61	2
Cowcod	34	1
Mexican rockfish	22	<1
Lingcod	17	<1
Unidentified rockfish	14	<1
Flag rockfish	11	<1
Chilipepper	7	<1
Unidentified rockfish YOY	5	<1
Unidentified poachers	4	<1
Swordspine rockfish	3	<1
Dover sole	2	<1
Unidentified fish	2	<1
Unidentified flatfish	2	<1
Bank rockfish	1	<1
Bocaccio YOY	1	<1
Darkblotched rockfish	1	<1
surveyed.		
Northern anchovy	1	<1
Painted greenling	1	<1
Pink rockfish	1	<1
Redbanded rockfish	1	<1
Sharpchin rockfish	1	<1
Widow rockfish	1	<1
Unidentified combfish	1	<1
TOTAL	**1,600**	**50**
Minimum number of species	23	
Total rockfish YOY	5	<1
Total rockfishes	1,570	50

Rockfish YOY comprised <1% of all fishes surveyed.
All rockfishes comprised 98.2% of all fishes surveyed.

PLATFORM EDITH (Surveyed 1998)

Species	Number	Density
California scorpionfish	274	63
Sharpnose seaperch	71	16
Blacksmith	35	8
Blackeye goby	22	5
Treefish	9	2
Unidentified seaperch	8	2
Painted greenling	6	1
Unidentified rockfish YOY	5	1
Pile perch	3	<1
Cabezon	3	<1
Unidentified fish	3	<1
Honeycomb rockfish	2	<1
Squarespot rockfish	1	<1
Sebastomus sp.	1	<1
California sheephead	1	<1
Unidentified rockfish	1	<1
TOTAL	**445**	**98**
Minimum number of species	12	
Total rockfish YOY	5	<1
Total rockfishes	19	

Rockfish YOY comprised 1.1% of all fishes

All rockfishes comprised 1% of all fishes surveyed.

PLATFORM SHELL MOUNDS

PLATFORM IRENE (SURVEYED 1996–2001)

Species	Number	Density
Halfbanded rockfish	965	45
Lingcod	404	19
Copper rockfish	215	10
Pacific sanddab	92	4
Vermilion rockfish	76	4
Painted greenling	72	3
Calico rockfish	32	2
Pile perch	18	<1
Rosy rockfish	9	<1
Kelp greenling	8	<1
Unidentified rockfish YOY	8	<1
Olive rockfish	5	<1
Unidentified fish	5	<1
Canary rockfish	3	<1
Unidentified flatfish	3	<1
Unidentified sanddab	3	<1
Bocaccio YOY	2	<1
Brown rockfish	2	<1
Sebastomus sp.	2	<1
Widow rockfish	2	<1
Wolf-eel	2	<1
Yellowtail rockfish	2	<1
Unidentified ronquil	2	<1
Flag rockfish	1	<1
Pink seaperch	1	<1
Unidentified rockfish	1	<1
Unidentified sculpin	1	<1
TOTAL	**1,936**	**87**
Minimum number of species	23	
Total rockfish YOY	8	<1
Total rockfishes	1,341	61

Rockfish YOY comprised <1% of all fishes surveyed.
All rockfishes comprised 69.3% of all fishes surveyed.

PLATFORM HIDALGO (SURVEYED 1996–2001)

Species	Number	Density
Halfbanded rockfish	3,496	124
Lingcod	127	4
Painted greenling	35	1
Greenspotted rockfish	28	<1
Greenstriped rockfish	24	<1
Unidentified rockfish YOY	21	<1
Rosy rockfish	20	<1
Pacific sanddab	17	<1
Swordspine rockfish	17	<1
Unidentified combfish	8	<1
Unidentified sanddab	7	<1
Cowcod	4	<1
Flag rockfish	4	<1
Pink seaperch	4	<1
Shortspine combfish	4	<1
Unidentified poacher	4	<1
Canary rockfish	2	<1
Unidentified fish	2	<1
Bank rockfish	1	<1
Longspine combfish	1	<1
Pygmy rockfish	1	<1
Ratfish	1	<1
Rathbunella sp.	1	<1
Sebastomus sp.	1	<1
Sharpchin rockfish	1	<1
Starry rockfish	1	<1
Vermilion rockfish	1	<1
Unidentified rockfish	1	<1
Unidentified ronquil	1	<1
TOTAL	**3,835**	**129**
Minimum number of species	22	
Total rockfish YOY	21	<1
Total rockfishes	3,623	124

Rockfish YOY comprised <1% of all fishes surveyed.
All rockfishes comprised 94.5% of all fishes surveyed.

PLATFORM SHELL MOUNDS, cont.

PLATFORM HARVEST (Surveyed 1997–2000)

Species	Number	Density
Stripetail rockfish	373	14
Greenstriped rockfish	136	5
Sharpchin rockfish	91	3
Greenspotted rockfish	41	2
Unidentified poacher	18	<1
Sebastomus sp.	17	<1
Lingcod	16	<1
Greenblotched rockfish	9	<1
Unidentified rockfish	8	<1
Unidentified flatfish	7	<1
Shortspine combfish	7	<1
Unidentified combfish	6	<1
Pinkrose rockfish	5	<1
Unidentified rockfish YOY	5	<1
Halfbanded rockfish	4	<1
Unidentified fish	3	<1
Chilipepper	2	<1
Bank rockfish	1	<1
Cowcod	1	<1
Flag rockfish	1	<1
Pacific hake	1	<1
Ratfish	1	<1
Rathbunella sp.	1	<1
Swordspine rockfish	1	<1
Unidentified sanddab	1	<1
TOTAL	**756**	**24**
Minimum number of species	18	
Total rockfish YOY	5	<1
Total rockfishes	695	24

surveyed.
Rockfish YOY comprised <1% of all fishes surveyed.
All rockfishes comprised 91.9% of all fishes surveyed.

PLATFORM HERMOSA (Surveyed 1997–2000)

Species	Number	Density
Halfbanded rockfish	3,572	188
Shortbelly rockfish	114	6
Stripetail rockfish	64	3
Shortspine combfish	38	2
Greenspotted rockfish	27	1
Greenstriped rockfish	14	<1
Unidentified sanddab	11	<1
Lingcod	9	<1
Unidentified combfish	9	<1
Flag rockfish	6	<1
Sebastomus sp.	6	<1
Cowcod	4	<1
Unidentified poacher	3	<1
Greenblotched rockfish	3	<1
Unidentified fish	3	<1
Longspine combfish	2	<1
Pink seaperch	2	<1
Rosy rockfish	2	<1
Unidentified rockfish YOY	2	<1
Blackeye goby	1	<1
Ratfish	1	<1
Widow rockfish	1	<1
Unidentified rockfish	1	<1
TOTAL	**3,895**	**200**
Minimum number of species	17	
Total rockfish YOY	2	<1
Total rockfishes	3,814	

Rockfish YOY comprised <1% of all fishes surveyed.
All rockfishes comprised 97.9% of all fishes

PLATFORM SHELL MOUNDS, cont.

PLATFORM HOLLY (Surveyed 1997, 1998, 2001)

Species	Number	Density
Pacific sardine	200	25
Calico rockfish	129	16
Vermilion rockfish	64	8
Copper rockfish	44	5
Halfbanded rockfish	35	4
Blackeye goby	31	4
Squarespot rockfish	21	3
Pink seaperch	18	2
Lingcod	14	2
Honeycomb rockfish	13	2
Painted greenling	13	2
Flag rockfish	11	1
Rosy rockfish	9	1
Canary rockfish	8	<1
Brown rockfish	6	<1
Kelp greenling	6	<1
Pile perch	6	<1
Unidentified fish	6	<1
Rathbunella sp.	5	<1
Sebastomus sp.	5	<1
Unidentified flatfish	4	<1
Unidentified ronquil	4	<1
Olive rockfish	3	<1
Pacific hake	3	<1
Unidentified combfish	3	<1
Unidentified rockfish	2	<1
California halibut	1	<1
California scorpionfish	1	<1
Sharpnose seaperch	1	<1
Treefish	1	<1
Widow rockfish	1	<1
Sebastomus sp.	1	<1
Unidentified seaperch	1	<1
Unidentified rockfish YOY	1	<1
TOTAL	**670**	**75**
Minimum number of species	26	
Total rockfish YOY	1	<1
Total rockfishes	354	40

Including the one-time observation of Pacific sardine, YOY rockfishes comprised <1%, and all rockfishes comprised 52.8% of all fishes surveyed.
Excluding sardines, YOY rockfishes comprised <1%, and all rockfish comprised 75.3% of all fishes.

PLATFORM C (Surveyed 2000)

Species	Number	Density
Vermilion rockfish	153	74
Halfbanded rockfish	59	29
Calico rockfish	33	16
Olive rockfish	19	9
Blackeye goby	16	8
Copper rockfish	15	7
Painted greenling	10	5
Kelp rockfish	9	4
Lingcod	8	4
Brown rockfish	1	<1
Canary rockfish	1	<1
Widow rockfish	1	<1
Yellowtail rockfish	1	<1
TOTAL	**326**	**156**
Minimum number of species	13	
Total rockfishes	292	139

All rockfishes comprised 89.5% of all fishes surveyed.

APPENDIIX 3

PLATFORM SHELL MOUNDS, cont.

PLATFORM GRACE (Surveyed 1997–2001)

Species	Number	Density
Halfbanded rockfish	4,154	144
Shiner perch	1,031	36
Pink seaperch	171	6
Unidentified sanddab	148	5
Bocaccio YOY	91	3
Lingcod	88	3
Unidentified rockfish YOY	80	3
Greenspotted rockfish	38	1
Flag rockfish	35	1
Vermilion rockfish	34	1
Shortspine combfish	27	<1
Unidentified combfish	26	<1
Hornyhead turbot	15	<1
Painted greenling	10	<1
Blue rockfish	8	<1
Sebastomus sp.	5	<1
Bocaccio	4	<1
Canary rockfish	4	<1
Swordspine rockfish	4	<1
California scorpionfish	2	<1
Copper rockfish	2	<1
Kelp greenling	2	<1
Rathbunella sp.	2	<1
Rosy rockfish	2	<1
Unidentified flatfish	2	<1
Greenstriped rockfish	1	<1
Hornyhead turbot	1	<1
Squarespot rockfish	1	<1
Treefish	1	<1
Unidentified fish	1	<1
Unidentified rockfish	1	<1
Unidentified seaperch	1	<1
TOTAL	**5,992**	**203**
Minimum number of species	25	
Total rockfish YOY	171	6
Total rockfishes	4,464	153

Rockfish YOY comprised <1% of all fishes surveyed.
All rockfishes comprised 74.5% of all fishes surveyed.

PLATFORM GAIL (Surveyed 1997, 1999–2001)

Species	Number	Density
Pacific hake	470	15
Stripetail rockfish	242	8
Northern anchovy	158	5
Pinkrose rockfish	112	4
Greenblotched rockfish	65	2
Greenstriped rockfish	60	2
Unidentified poacher	46	2
Unidentified combfish	29	<1
Swordspine rockfish	25	<1
Shortbelly rockfish	23	<1
Sharpchin rockfish	18	<1
Darkblotched rockfish	12	<1
Dover sole	11	<1
Unidentified fish	11	<1
Sebastomus sp.	9	<1
Unidentified rockfish	9	<1
Pacific sanddab	8	<1
Unidentified rockfish YOY	8	<1
Unidentified sculpin	8	<1
Greenspotted rockfish	8	<1
Jack mackerel	7	<1
Blackgill rockfish	5	<1
Chilipepper	4	<1
Unidentified flatfish	4	<1
Cowcod	3	<1
Flag rockfish	3	<1
Mexican rockfish	3	<1
Pacific electric ray	2	<1
Unidentified ronquil	2	<1
Bocaccio	1	<1
California smoothtongue	1	<1
California tonguefish	1	<1
Halfbanded rockfish	1	<1
Redbanded rockfish	1	<1
Rex sole	1	<1
TOTAL	**1,371**	**38**
Minimum number of species	30	
Total rockfish YOY	8	<1
Total rockfishes	603	16

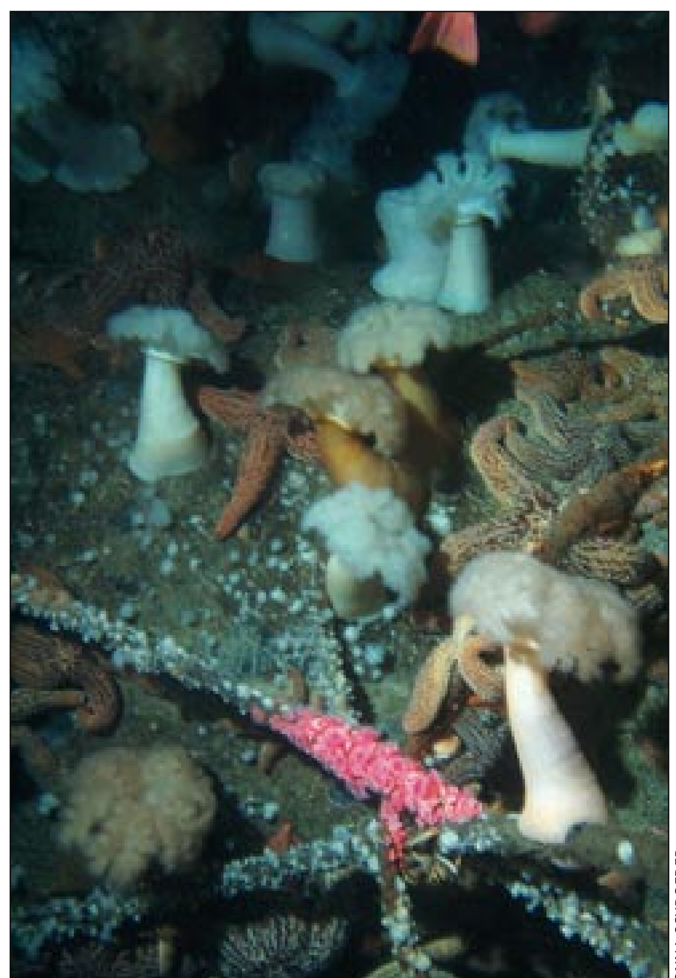
Rockfish YOY comprised <1% of all fishes surveyed.
All rockfishes comprised 44.0% of all fishes surveyed.

PLATFORM SHELL MOUNDS, cont.

PLATFORM EDITH (Surveyed 1998)

Species	Number	Density
California scorpionfish	280	67
Blackeye goby	81	19
Unidentified fish	3	<1
Unidentified rockfish YOY	3	<1
Unidentified seaperch	3	<1
Calico rockfish	2	<1
Sharpnose seaperch	2	<1
Painted greenling	1	<1
Pile seaperch	1	<1
Unidentified flatfish	1	<1
TOTAL	377	**0.86**
Minimum number of species	8	
Total rockfish YOY	3	<1
Total rockfishes	5	<1

Rockfish YOY comprised <1% of all fishes surveyed.
All rockfishes comprised <1% of all fishes surveyed.



An invertebrate tossed salad at the bottom of Platform Grace.

APPENDIX 4

Densities, at the top 20 sites, of some of the most abundant species in our deepwater surveys. Platforms are listed in blue, natural outcrops in red.

Species	Site	Year	Habitat Type	Density(Fish per 100 m^2)
Lingcod (adult)	Hidalgo	1996	Bottom	3.2
	Irene	1997	Bottom	1.7
	Irene	1997	Shell Mound	1.5
	Hermosa	1996	Bottom	1.0
	Footprint	2001	Natural	1.0
	Hermosa	1997	Bottom	0.9
	Reef “A”	1997	Natural	0.8
	Reef “A”	1998	Natural	0.7
	Hermosa	1999	Bottom	0.7
	Gail	2001	Bottom	0.7
	Santa Monica Bay	2001	Natural	0.7
	Santa Cruz I.	2000	Natural	0.6
	Santa Monica Bay	2001	Natural	0.5
	Hermosa	2000	Bottom	0.5
	Gail	1996	Bottom	0.5
	Gail	1997	Bottom	0.5
	Gail	1999	Bottom	0.5
	GAIL	2000	Bottom	0.5
	Irene	1998	Bottom	0.5
	Irene	2000	Bottom	0.5
	Irene	2001	Bottom	0.5
Lingcod (juvenile)	Irene	1996	Bottom	18.8
	Holly	1999	Bottom	6.1
	Grace	2000	Shell Mound	5.4
	Grace	2001	Platform pipe	4.6
	14 Mile Bank	2001	Natural	4.5
	Grace	2000	Bottom	3.8
	Hidalgo	1999	Shell mound	3.6
	Platform “C”	2000	Shell mound	3.4
	Grace	2001	Shell mound	3.2
	Irene	2001	Bottom	2.7
	Hidalgo	1997	Bottom	2.7
	Grace	1999	Shell Mound	2.3
	Harvest	2000	Bottom	2.2
	Grace	2001	Bottom	2.2
	Irene	1999	Bottom	2.2
	Hidalgo	2000	Bottom	2.1
	Harvest	1999	Bottom	1.9
	More Mesa	1995	Natural	1.9
	Irene	1997	Shell Mound	1.9
	12 Mile Reef	2000	Natural	1.8
Lingcod YOY	Irene	1998	Shell Mound	31.5
	Irene	2001	Shell Mound	29.2
	Irene	2001	Bottom	24.1
	Irene	1998	Bottom	19.6
	Irene	1996	Bottom	17.9
	Irene	2000	Shell Mound	12.0
	Irene	1997	Shell Mound	10.9
	Irene	2000	Bottom	10.6

Species	Site	Year	Habitat Type	Density(Fish per 100 m²)
Lingcod YOY (cont.)	Irene	1999	Shell Mound	9.7
	Irene	1999	Bottom	7.5
	Hidalgo	1999	Shell Mound	4.6
	Hidalgo	2000	Shell Mound	4.3
	Hidalgo	2000	Bottom	3.0
	Irene	1997	Bottom	2.9
	Hidalgo	2001	Shell Mound	2.6
	Hidalgo	1998	Shell Mound	1.9
	Hidalgo	1997	Shell Mound	1.8
	Grace	1999	Shell Mound	1.2
	Hidalgo	1998	Bottom	1.1
	Hidalgo	1999	Bottom	1.1
Painted greenling	Holly	1998	Midwater	18.0
	Harvest	1999	Midwater	9.9
	Harvest	1997	Midwater	9.9
	Holly	2001	Midwater	8.2
	Hermosa	1997	Midwater	8.1
	Irene	1997	Bottom	8.0
	Hermosa	1998	Midwater	6.9
	Hermosa	1999	Midwater	5.5
	Houchin	2000	Midwater	5.3
	Irene	1997	Shell Mound	5.3
	Irene	2000	Shell Mound	5.1
	Irene	1996	Bottom	4.8
	Harvest	1999	Midwater	4.7
	Holly	1998	Shell Mound	4.6
	Irene	2000	Bottom	4.6
	Irene	2000	Midwater	4.5
	Platform "C"	2000	Shell Mound	4.4
	Hermosa	2000	Midwater	4.4
	Irene	2001	Bottom	4.4
	Hidalgo	2000	Midwater	4.2
Greenspotted rockfish	Hermosa	1996	Bottom	30.3
	Hidalgo	2000	Bottom	21.8
	Gail	1996	Bottom	21.3
	Hidalgo	1996	Bottom	20.6
	Hidalgo	1999	Bottom	19.9
	Hidalgo	1998	Bottom	19.1
	Hidalgo	1997	Bottom	17.6
	Hidalgo	2001	Bottom	12.1
	Gail	1997	Bottom	10.8
	Hermosa	1997	Bottom	10.6
	North Reef	1997	Natural	9.8
	Gail	2000	Bottom	9.3
	Hermosa	1998	Bottom	9.1
	Hermosa	2000	Bottom	5.8
	Reef "A"	1997	Natural	5.0
	North Reef	1998	Natural	5.0
	Reef "C"	1999	Natural	4.9

Species	Site	Year	Habitat Type	Density(Fish per 100 m²)
Greenspotted rockfish (cont.)	Reef "A"	2000	Natural	4.8
	Hermosa	1999	Bottom	4.3
	Grace	1996	Bottom	4.0
Copper rockfish	Irene	2000	Bottom	88.5
	Irene	1996	Bottom	71.6
	Irene	1997	Bottom	53.6
	Irene	2001	Bottom	40.8
	Irene	2000	Shell Mound	27.1
	Holly	1997	Bottom	21.8
	Holly	1999	Bottom	21.5
	Irene	1999	Bottom	21.5
	Holly	1998	Shell Mound	12.0
	Holly	1996	Bottom	11.4
	Irene	2001	Shell Mound	10.4
	Irene	1998	Bottom	10.4
	Holly	1997	Shell Mound	9.3
	Holly	2001	Bottom	8.4
	Platform "C"	2000	Shell Mound	7.3
	Irene	1997	Shell Mound	5.2
	Irene	1999	Shell Mound	4.5
	Holly	1998	Bottom	4.4
	Irene	2001	Midwater	3.9
	Irene	2000	Midwater	3.7
Swordspine rockfish	14 Mile Bank	1996	Natural	94.4
	14 Mile Bank	1996	Natural	47.4
	14 Mile Bank	2001	Natural	45.8
	Footprint	2000	Natural	41.0
	Footprint	2000	Natural	39.6
	Footprint	1999	Natural	29.7
	Osborn Bank	2000	Natural	27.5
	Footprint	2001	Natural	24.9
	Catalina I.	1996	Natural	22.4
	Santa Monica Bay	2001	Natural	21.9
	Tanner Bank	1997	Natural	20.1
	Footprint	2000	Natural	20.1
	Santa Barbara I.	2000	Natural	18.3
	Footprint	2001	Natural	15.3
	Footprint	2000	Natural	14.2
	Cortes Bank	1997	Natural	12.8
	Santa Monica Bay	1998	Natural	10.6
	Footprint	2001	Natural	9.9
	Footprint	2000	Natural	8.3
	Footprint	1999	Natural	8.2
Greenstriped rockfish	Harvest	2000	Bottom	14.7
	Harvest	1999	Bottom	9.2
	Gail	2000	Bottom	7.5
	Harvest	1997	Shell Mound	7.1
	Harvest	1997	Shell Mound	6.1
	Harvest	2000	Shell Mound	5.9

Species	Site	Year	Habitat Type	Density(Fish per 100 m²)
Greenstriped rockfish (cont.)	Harvest	1998	Bottom	5.2
	Harvest	1999	Shell Mound	4.3
	Harvest	1997	Bottom	3.6
	Harvest	1998	Shell Mound	3.5
	Hidalgo	1998	Bottom	3.4
	Hidalgo	2000	Bottom	3.4
	Reef "A"	2000	Natural	3.3
	Gail	1997	Shell Mound	2.6
	Reef "A"	1997	Natural	2.5
	Gail	1999	Shell Mound	2.4
	Hidalgo	2001	Bottom	2.3
	Gail	2000	Shell Mound	2.2
	Santa Rosa Passage	1995	Natural	2.2
	Hidalgo	1998	Shell Mound	2.1
Widow rockfish (YOY)	Irene	1998	Midwater	344.0
	Irene	1996	Midwater	253.3
	Holly	1999	Bottom	252.9
	Harvest	1999	Midwater	188.9
	Grace	2000	Midwater	175.7
	Irene	1997	Midwater	173.6
	San Nicholas I.	1996	Natural	173.5
	Catalina I.	1996	Natural	116.8
	Irene	1998	Bottom	79.1
	Grace	2001	Midwater	73.8
	San Nicolas I.	1996	Natural	68.1
	Grace	1997	Bottom	66.3
	Cortes Bank	1997	Natural	66.0
	Santa Cruz I.	2000	Natural	65.4
	North Reef	1999	Natural	63.6
	Hidalgo	1998	Midwater	52.9
	Footprint	1995	Natural	45.9
	Hermosa	2000	Midwater	44.4
	Footprint	2001	Natural	40.3
	Grace	1999	Midwater	39.6
Squarespot rockfish	Santa Cruz I.	2000	Natural	282.5
	Santa Barbara I.	2000	Natural	263.0
	Santa Monica Bay	1998	Natural	196.4
	Harvest	1999	Midwater	180.0
	Cortes Bank	1997	Natural	149.6
	Grace	2001	Midwater	130.6
	San Miguel I.	1995	Natural	122.1
	Footprint	1998	Natural	94.6
	San Nicolas I.	1996	Natural	93.9
	Anacapa Passage	1999	Natural	88.8
	Santa Monica Bay	1998	Natural	85.0
	Hidden Reef	1999	Natural	72.6
	San Nicolas I.	1996	Natural	69.7
	Guano Bank	1995	Natural	69.6
	Footprint	2000	Natural	61.8

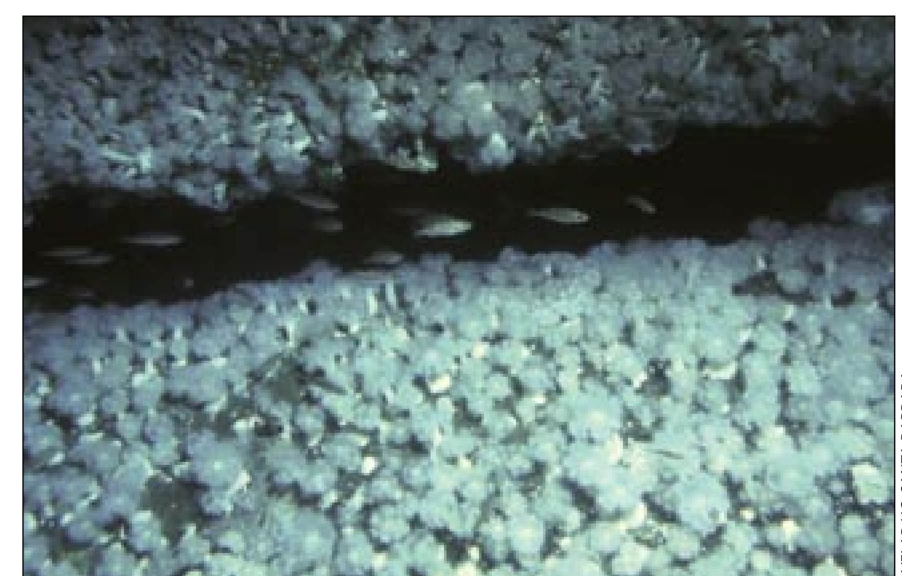
Species	Site	Year	Habitat Type	Density(Fish per 100 m²)
Squarespot rockfish (cont.)	Osborn Bank	2000	Natural	54.9
	Osborn Bank	2000	Natural	51.9
	Anacapa Passage	1995	Natural	50.5
	Santa Monica Bay	2001	Natural	44.3
	Santa Rosa I.	1995	Natural	43.4
Vermilion rockfish	Platform "C"	2000	Shell Mound	74.5
	Holly	2001	Bottom	58.1
	Irene	2000	Bottom	55.2
	Irene	1996	Bottom	47.8
	Irene	1997	Bottom	32.8
	Grace	2001	Platform pipe	30.8
	Irene	1999	Bottom	30.4
	Anacapa Passage	1995	Natural	30.1
	Grace	2001	Bottom	29.9
	Holly	1999	Bottom	23.8
	Holly	1996	Bottom	22.0
	Irene	2001	Bottom	14.0
	Irene	1998	Bottom	12.5
	Holly	2001	Shell Mound	11.9
	Irene	2000	Shell Mound	10.6
	Grace	2001	Bottom	8.8
	Holly	1998	Shell Mound	8.3
	Irene	2001	Shell Mound	6.1
	Santa Cruz I.	2000	Natural	5.2
	Holly	1997	Bottom	4.5
Bocaccio (adult)	Gail	1997	Bottom	18.2
	Gail	1999	Bottom	11.0
	Gail	1996	Bottom	10.8
	Gail	2000	Bottom	6.2
	Gail	2001	Bottom	3.5
	Hidalgo	2001	Bottom	3.0
	Hidalgo	1996	Bottom	2.7
	Reef "A"	1997	Natural	1.9
	Reef "D"	1999	Natural	1.6
	Hidalgo	1997	Bottom	1.3
	Santa Rosa Passage	1995	Natural	1.2
	Footprint	1995	Natural	1.1
	Hidalgo	1998	Bottom	0.9
	Footprint	2001	Natural	0.9
	Footprint	2001	Natural	0.9
	Footprint	2000	Natural	0.8
	Footprint	2000	Natural	0.7
	Catalina I.	1996	Natural	0.6
	Footprint	1999	Natural	0.6
	San Nicolas I.	1996	Natural	0.6
Bocaccio (juvenile)	Grace	2000	Bottom	39.6
	Grace	2000	Midwater	13.0
	Santa Cruz I.	2000	Natural	5.6
	14 Mile Bank	2001	Natural	5.1

Species	Site	Year	Habitat Type	Density(Fish per 100 m²)
Bocaccio (juvenile) (cont.)	Santa Barbara I.	2000	Natural	2.5
	Santa Monica Bay	2001	Natural	2.4
	Gail	2001	Bottom	2.3
	Osborn Bank	2000	Natural	2.3
	12 Mile Reef	2000	Natural	2.0
	Gail	2000	Bottom	1.8
	Footprint	2000	Natural	1.2
	Grace	2001	Platform pipe	0.9
	Reef“A”	1997	Natural	0.9
	Footprint	2000	Natural	0.8
	Hidalgo	2000	Bottom	0.8
	Gail	1997	Bottom	0.7
	Footprint	2000	Natural	0.6
	Grace	2000	Shell Mound	0.6
	Hidalgo	1996	Bottom	0.6
	Hidalgo	2001	Bottom	0.6
Bocaccio (YOY)	Irene	1999	Midwater	166.4
	Irene	1996	Midwater	91.8
	Grace	1999	Bottom	44.9
	Grace	1999	Midwater	24.1
	Irene	1997	Midwater	17.2
	Grace	1999	Shell Mound	15.9
	Hidalgo	1996	Midwater	5.6
	Harvest	1999	Midwater	4.0
	Grace	2001	Midwater	3.0
	Hidden Reef	1999	Natural	2.3
	Irene	1999	Bottom	2.2
	Grace	2001	Midwater	1.5
	Harvest	1999	Midwater	1.3
	Santa Barbara I.	1996	Natural	1.3
	Irene	1997	Bottom	1.2
	Harvest	1997	Midwater	1.1
	Grace	2000	Midwater	1.0
	Hidalgo	1997	Midwater	0.9
	Santa Monica Bay	2001	Natural	0.9
	Hidalgo	2000	Bottom	0.8
Canary rockfish	Irene	2001	Bottom	5.5
	Holly	2001	Bottom	3.4
	Hidalgo	1999	Bottom	1.9
	Holly	2001	Shell Mound	1.7
	Hidalgo	1998	Bottom	1.7
	North Reef	1999	Natural	1.7
	Reef “D”	1999	Natural	1.6
	Hidalgo	1996	Bottom	1.3
	Reef “A”	1999	Natural	1.2
	Irene	1997	Bottom	1.2
	Reef “B”	1997	Natural	1.1
	Hidalgo	1997	Bottom	0.9
	Hidalgo	2001	Bottom	0.9

Species	Site	Year	Habitat Type	Density(Fish per 100 m²)
	Grace	2000	Bottom	0.9
	Holly	1996	Bottom	0.8
	North Reef	2000	Natural	0.7
	Reef “C”	1998	Natural	0.7
	Irene	2001	Shell Mound	0.7
	Reef “A”	1998	Natural	0.5
	Grace	1998	Shell Mound	0.5
Greenblotched rockfish	Gail	1997	Bottom	17.7
	Gail	1999	Bottom	13.7
	Gail	2001	Bottom	11.3
	Hidalgo	2001	Bottom	10.6
	Gail	1996	Bottom	9.7
	Gail	2000	Bottom	9.2
	Gail	1997	Shell Mound	5.9
	Harvest	1999	Bottom	4.6
	Harvest	1998	Bottom	3.8
	Gail	1999	Shell Mound	3.3
	Harvest	1997	Bottom	1.6
	San Miguel I.	1995	Natural	1.4
	Hidalgo	1999	Bottom	1.3
	North Reef	1997	Natural	1.0
	Footprint	2001	Natural	1.0
	Reef “A”	1999	Natural	0.9
	Reef “B”	1997	Natural	0.8
	Hidalgo	2000	Bottom	0.8
	North Reef	2001	Natural	0.7
	Gail	2001	Shell Mound	0.7
Flag rockfish	Hidalgo	1997	Bottom	15.5
	Hidalgo	1996	Bottom	11.0
	Hidalgo	1999	Bottom	7.2
	Grace	1996	Bottom	6.6
	Grace	2001	Bottom	5.7
	Hidalgo	1998	Bottom	5.5
	Hidalgo	2000	Bottom	5.1
	Grace	2000	Bottom	4.4
	Hidalgo	2001	Bottom	3.8
	Holly	2001	Bottom	3.1
	Grace	2001	Bottom	3.1
	Santa Barbara Point	1995	Natural	3.0
	Hermosa	1996	Bottom	2.7
	Grace	1999	Midwater	2.6
	Gail	1999	Midwater	2.5
	Hermosa	2000	Bottom	2.2
	Grace	2001	Shell Mound	2.2
	Santa Rosa Passage	1995	Natural	2.0
	Holly	1998	Shell Mound	1.8
	Holly	2001	Shell Mound	1.7

Species	Site	Year	Habitat Type	Density(Fish per 100 m²)
Halfbanded rockfish	Hidalgo	2000	Bottom	907.1
	Grace	1997	Bottom	800.5
	Anacapa I.	1999	Natural	703.1
	Irene	1999	Bottom	621.2
	Irene	1998	Bottom	595.9
	Hidalgo	2000	Shell Mound	461.0
	Grace	1999	Shell Mound	415.1
	Hermosa	2000	Shell Mound	406.9
	Grace	2000	Bottom	405.2
	Hermosa	2000	Bottom	398.1
	Grace	1996	Bottom	395.1
	Hermosa	1997	Bottom	381.4
	Grace	1999	Bottom	344.2
	Hidalgo	2001	Bottom	318.4
	Hermosa	1999	Bottom	313.2
	E. End Anacapa I.	1995	Natural	284.9
	Hidalgo	1999	Bottom	275.8
	Grace	2001	Bottom	266.4
	Grace	2001	Shell Mound	259.1
	Grace	2001	Bottom	237.7
Pygmy rockfish	Hidden Reef	1999	Natural	263.7
	San Nicolas I.	1996	Natural	236.9
	Footprint	2001	Natural	125.7
	Cortes Bank	1997	Natural	119.7
	North Reef	2000	Natural	93.8
	Santa Monica Bay	1998	Natural	93.7
	San Miguel I.	1995	Natural	87.3
	Santa Monica Bay	2001	Natural	84.1
	Cortes Bank	1997	Natural	76.7
	Footprint	2000	Natural	72.2
	Santa Cruz I.	2000	Natural	71.9
	Osborn Bank	2000	Natural	71.2
	San Nicolas I.	1996	Natural	64.6
	14 Mile Bank	2001	Natural	64.5
	San Nicolas I.	1996	Natural	64.2
	Santa Rosa I.	1995	Natural	60.6
	Footprint	2000	Natural	54.6
	Reef "D"	1999	Natural	47.0
	Footprint	1999	Natural	42.3
	Santa Monica Bay	2001	Natural	38.3
Pink seaperch	Santa Monica Bay	1998	Natural	304.5
	Grace	1998	Shell Mound	39.2
	Holly	1998	Shell Mound	11.1
	Holly	1999	Bottom	9.1
	Catalina I.	1996	Natural	4.0
	Grace	1997	Shell Mound	2.9
	Grace	1997	Bottom	2.7
	Holly	1996	Bottom	1.8

Species	Site	Year	Habitat Type	Density(Fish per 100 m²)
Pink seaperch (cont.	Reef "D"	1999	Natural	1.7
	Santa Monica Bay	1997	Natural	1.3
	Holly	1997	Bottom	1.3
	Catalina I.	1996	Natural	1.2
	Holly	1997	Shell Mound	1.2
	Santa Monica Bay	1997	Natural	1.2
	Santa Rosa I.	1995	Natural	1.2
	Grace	2000	Bottom	1.1
	Grace	2001	Platform pipe	1.0
	Reef"A"	1997	Natural	0.9
	Santa Cruz I.	1996	Natural	0.8
	North Reef	1998	Natural	0.8
Yellowtail rockfish (adult)	Reef "B"	1995	Natural	3.9
	San Miguel I.	1995	Natural	3.5
	North Reef	1996	Natural	2.8
	North Reef	1995	Natural	2.1
	Santa Rosa I.	1995	Natural	2.1
	San Miguel I.	1995	Natural	1.9
	San Miguel I.	1995	Natural	1.7
	Reef "D"	1999	Natural	1.6
	North Reef	2000	Natural	1.5
	Reef "A"	2000	Natural	1.0
	San Miguel I.	1995	Natural	0.7
	Reef "A"	1998	Natural	0.7
	Reef "B"	1997	Natural	0.5
	North Reef	1999	Natural	0.5
	Santa Rosa I.	1995	Natural	0.4
	Reef "A"	1997	Natural	0.3
	North Reef	1997	Natural	0.3
	Santa Rosa I.	1995	Natural	0.2
	North Reef	1998	Natural	0.2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Young-of-the-year rockfish in the platform midwater.