Chapter 1

INTRODUCTION

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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.

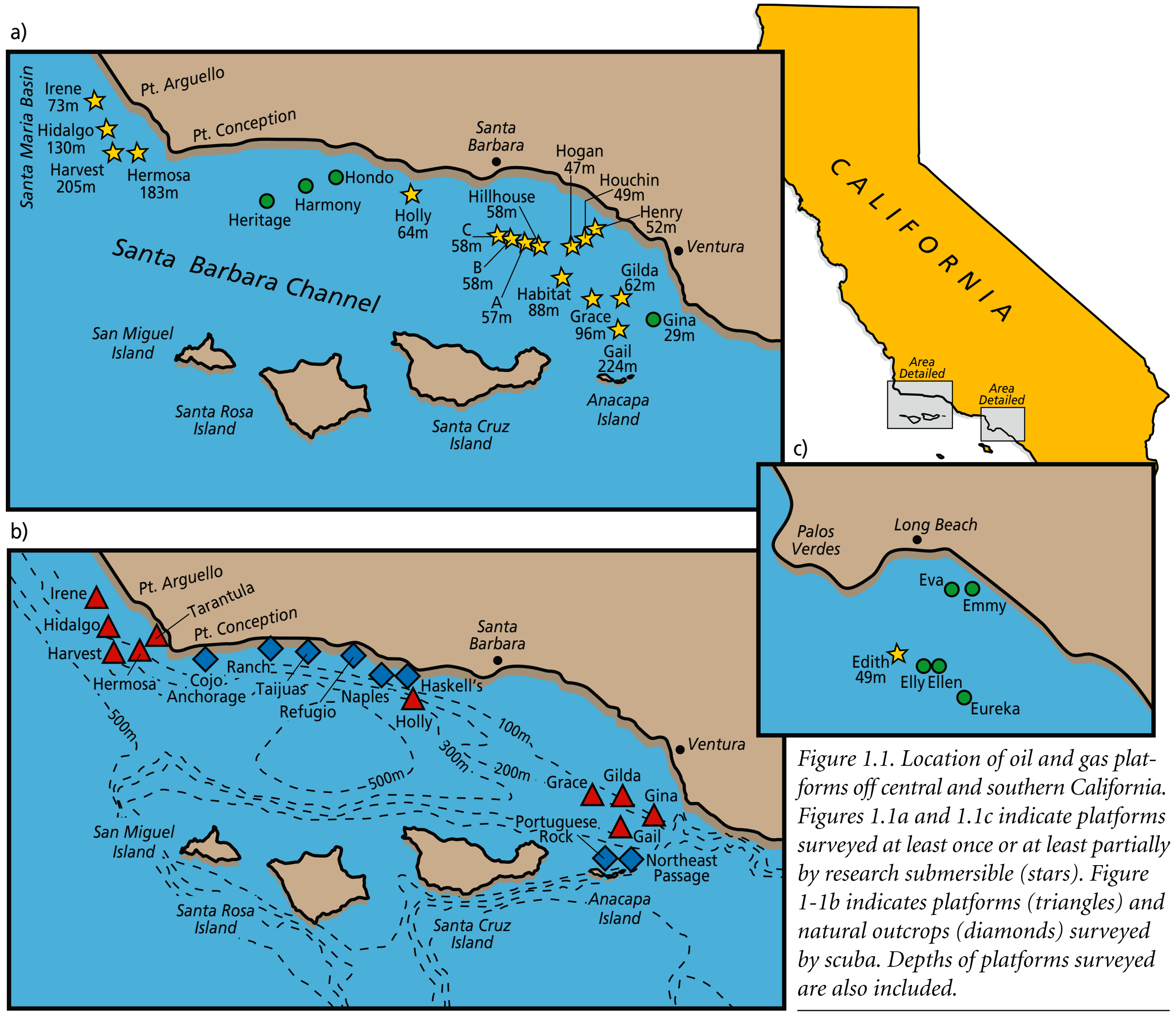


Figure 1.1. Location of oil and gas platforms off central and southern California. Figures 1.1a and 1.1c indicate platforms surveyed at least once or at least partially by research submersible (stars). Figure 1-1b indicates platforms (triangles) and natural outcrops (diamonds) surveyed by scuba. Depths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

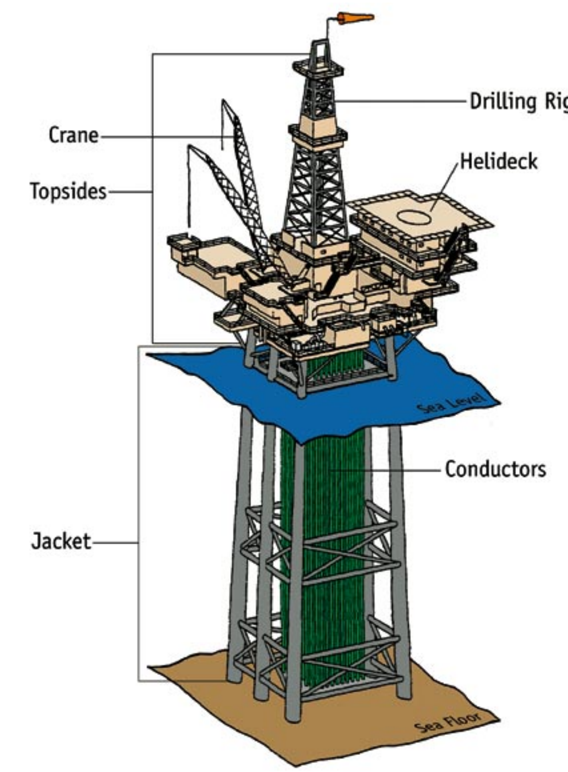


Figure 1.2. A typical oil/gas platform off southern California. Adapted from Manago and Williamson (1998).

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

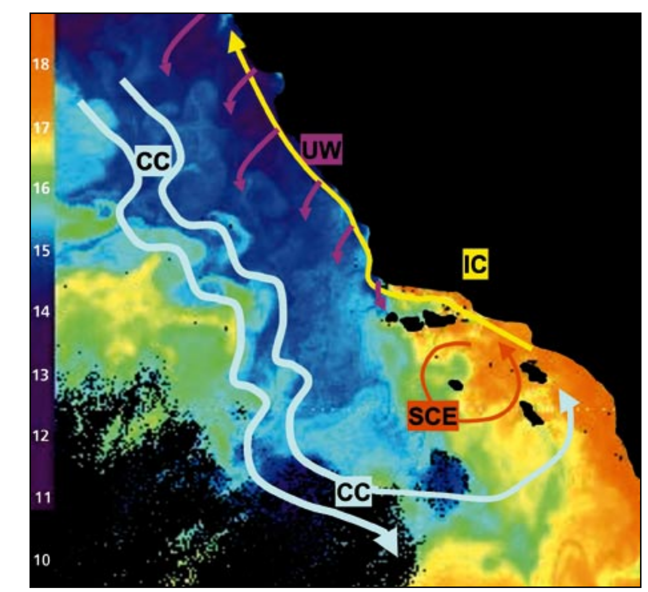


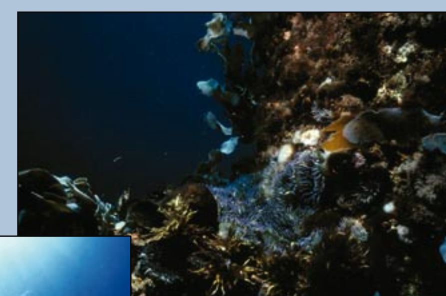
Figure 1.3. Satellite image of sea surface temperature (SST) and a diagram of the large-scale current patterns off the central and southern California coast. This image shows the predominant, large-scale SST pattern along with smaller scale features such as eddies and fronts (temperature scale, degrees 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).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Mussels and sea anemones


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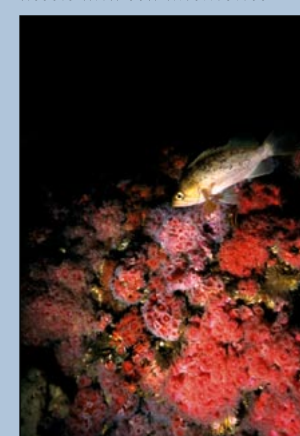
Mussels and sea stars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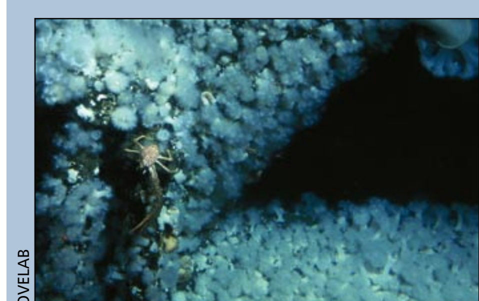
Club anemone and kelp rockfish

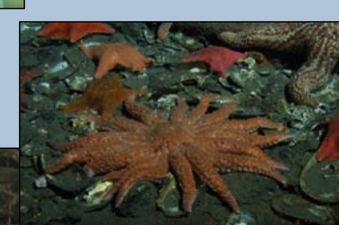

LOVELAB

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

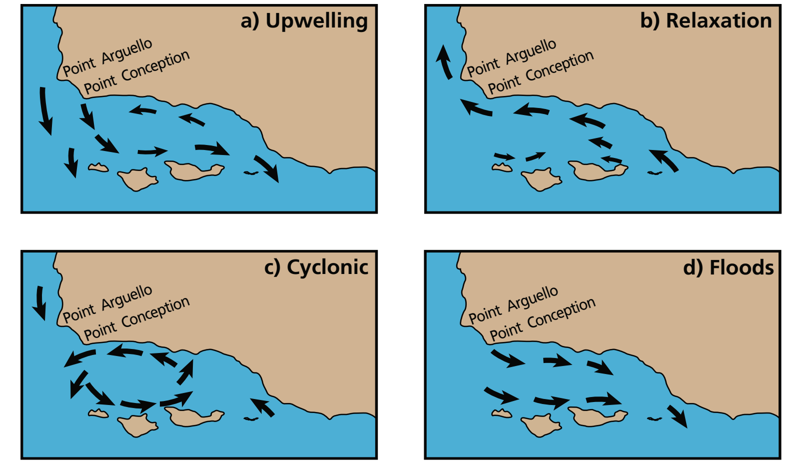


Figure 1.4. Generalized circulation patterns in the Santa Barbara Channel. (a) Upwelling; (b) Relaxation; (c) Cyclonic; (d) Flood east (shown) or west. Westward propagating train of cyclonic and anticyclonic eddies have also been observed (not shown). Adapted from Harms and Winant (1998).

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

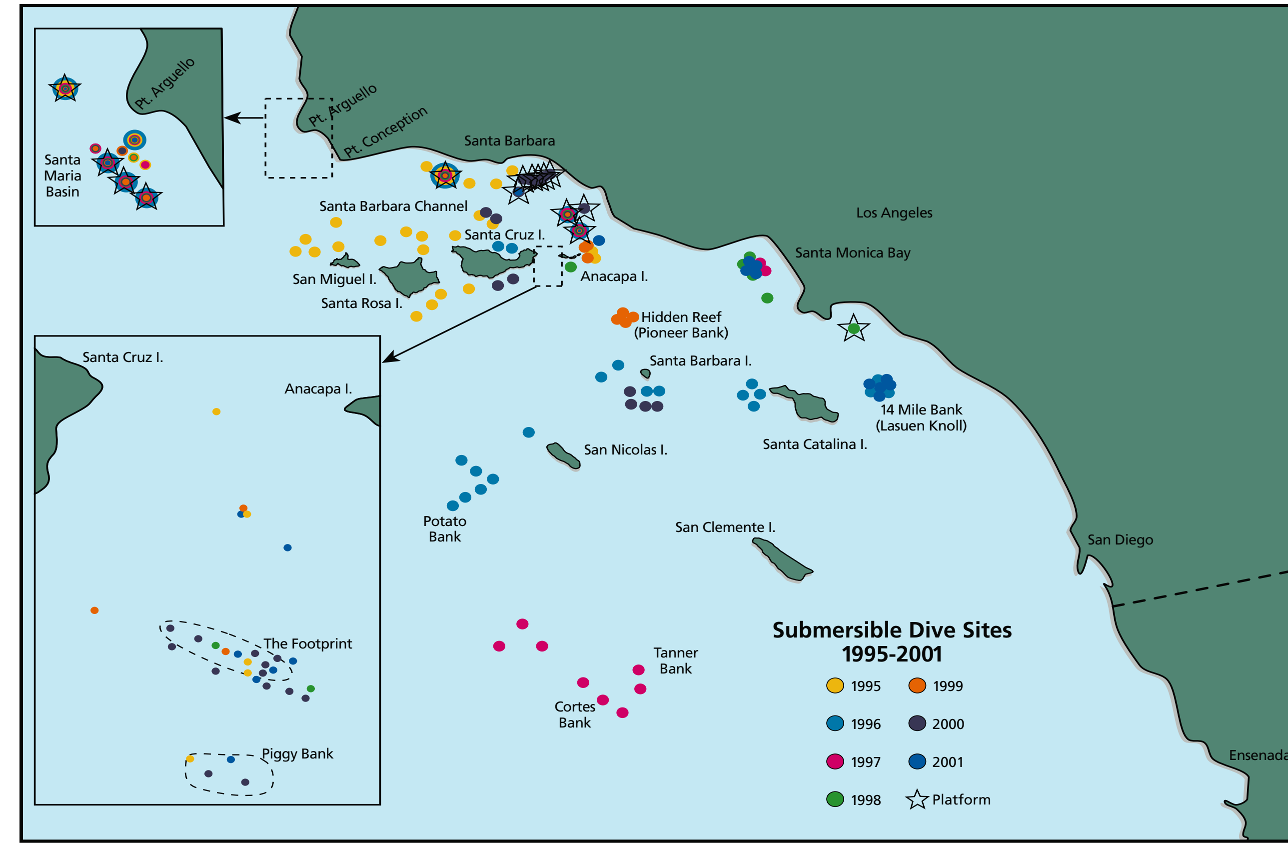


Figure 1.5. Platform and natural outcrops surveyed by Delta submersible, 1995–2001. Concentric rings denote sites surveyed in more than one year. Stars indicate platforms. See Figure 1.1 for names of platforms.

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

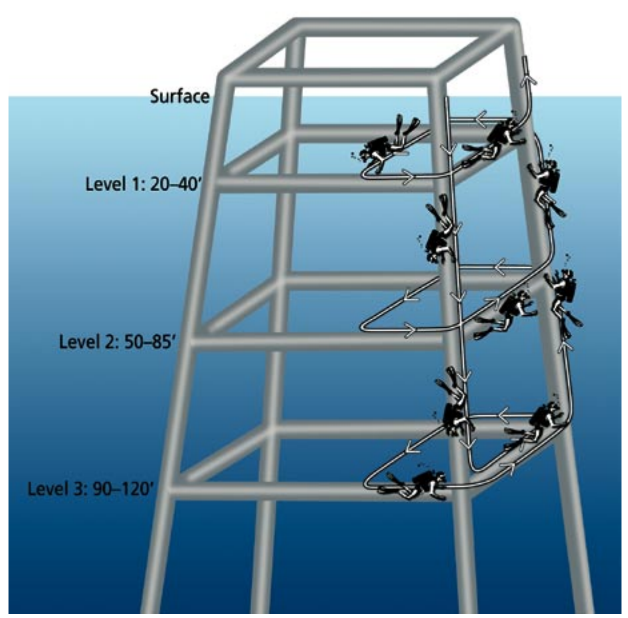


Figure 1.7. A schematic illustration of the diver platform surveys.

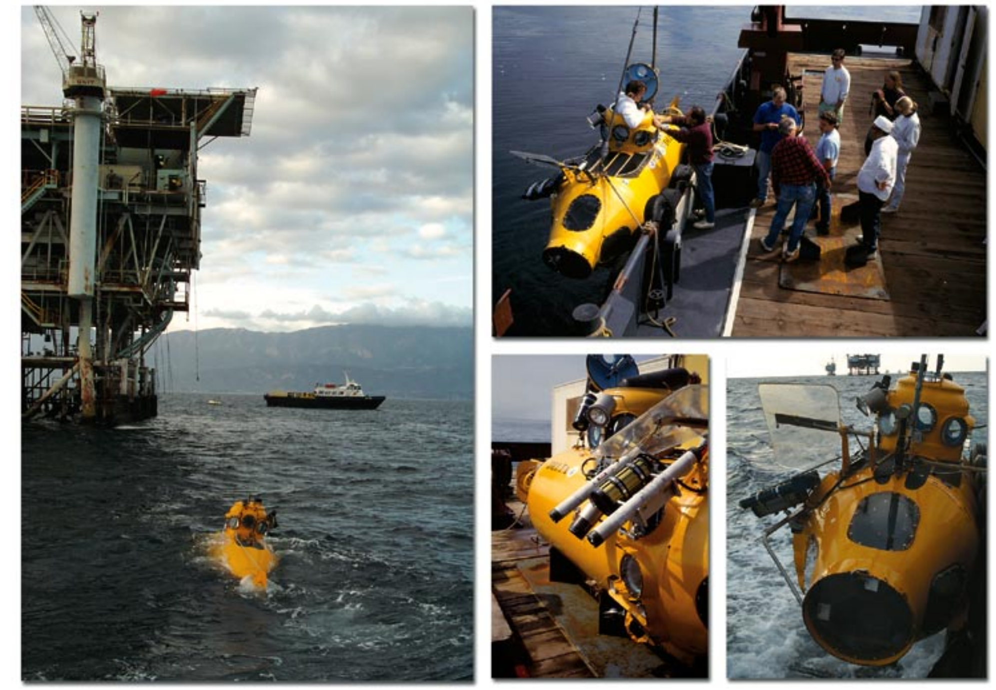


Figure 1.8. The research submersible Delta. Delta *is a 2-person untethered vehicle.*

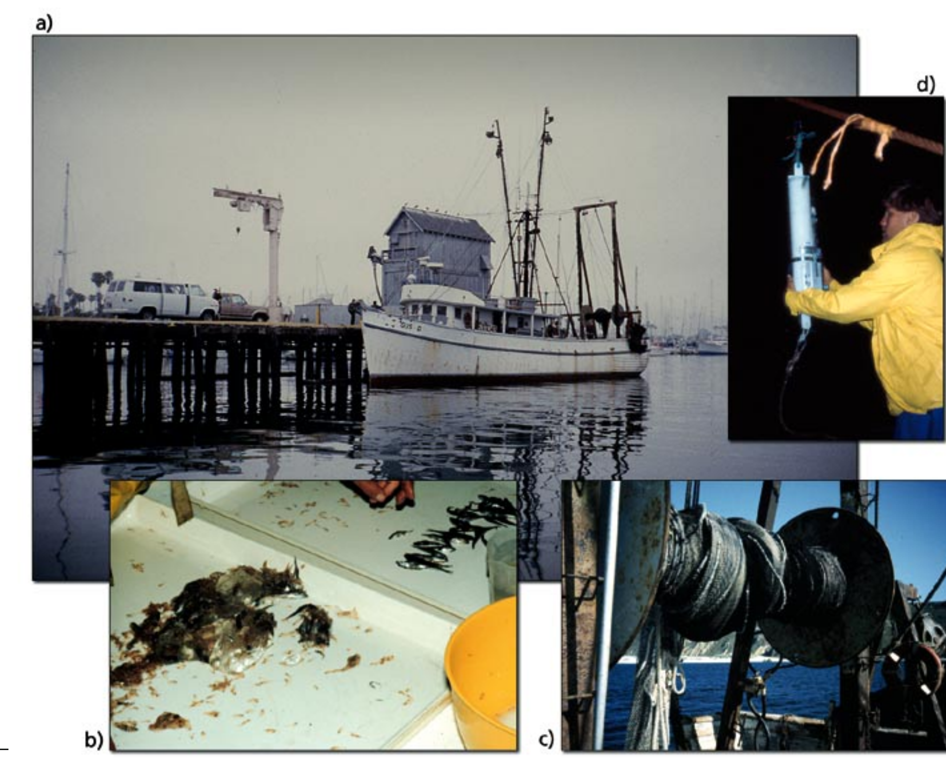


Figure 1.9. Annual midwater trawling and oceanographic surveys, 1995–2000. (a) F/V Gus-D *was chartered for research; (b) pelagic juvenile rockfish and other small fishes were sorted from the catch that included euphausiids and various jellies; (c) modified Cobb trawl rolled around spool; (d) deployment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

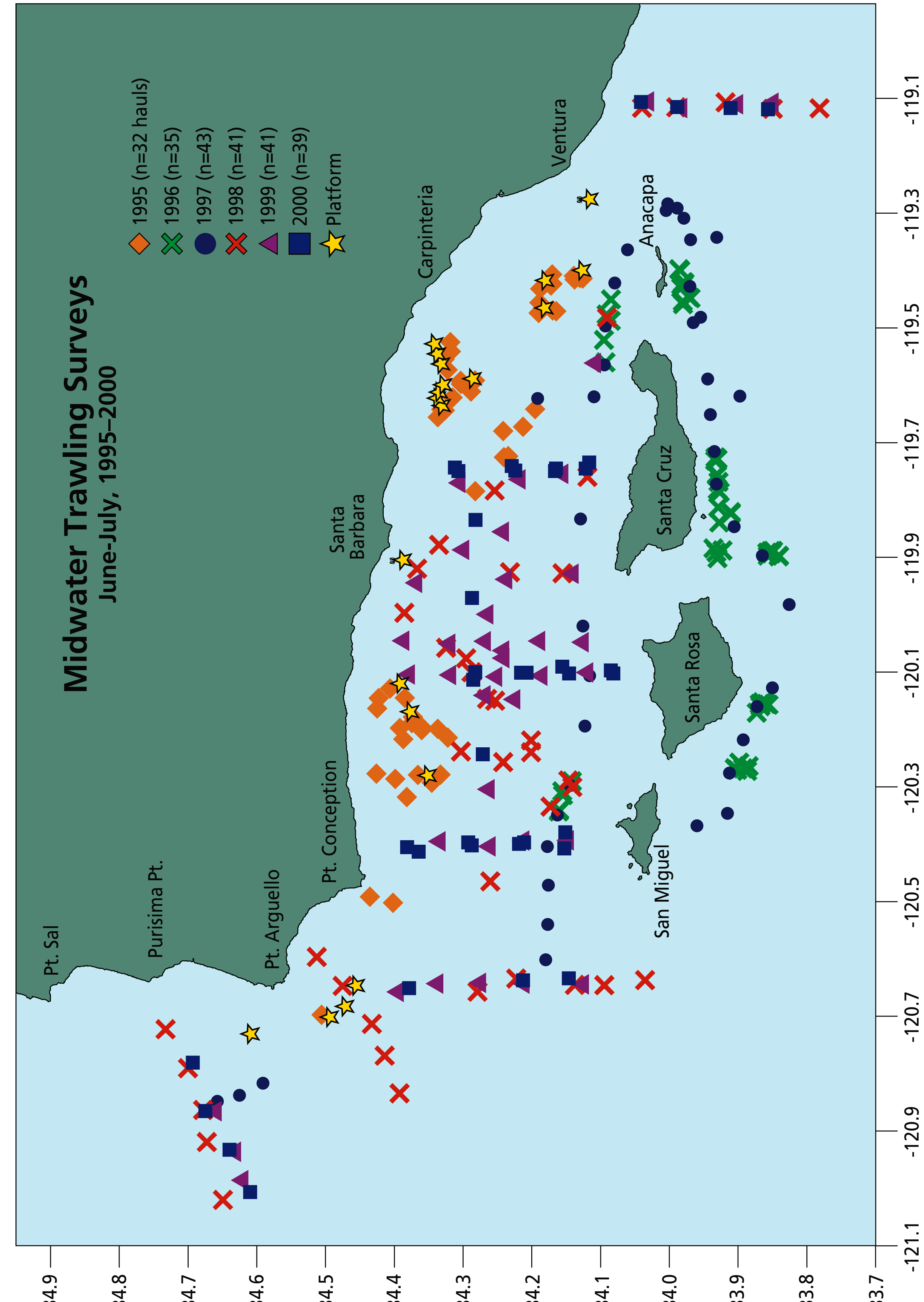


Figure 1.10. Annual midwater trawling surveys, 1995–2000. Map of stations where trawl samples were collected. Surveys typically were conducted in June and included 10 nights of sampling.