p. 253-266. In: The Ecology of Marine Fishes: California and Adjacent Waters. 2006.
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CHAPTER 10

Deep Rock Habitats

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Introduction

In this chapter, we discuss those fishes characteristically found on or over complex seafloor habitats comprising various amounts of cobble, boulders, and rock outcrops in water depths ranging from 30 to 500 m. This depth range encompasses the continental shelf and upper continental slope of California (Greene et al., 1999). We also discuss those fishes associated with such artificial structures as oil platforms off Southern California at similar depths. Because very little is known of fish assemblages associated with deep rock habitats off Baja California, we limit our discussion to California waters. See fig. 10-1 for a general depiction of bathymetry and place names of areas referenced in this chapter.

Fishes that associate with complex benthic habitats below scuba depths (i.e., greater than 30 m) are difficult and expensive to survey. Historically, fishing nets of various types, particularly trawl nets, have been used to make almost all assessments of deep-water fish communities. However, the rugged nature of many of these habitats renders trawl surveys less effective over low-relief structures, such as cobblestone and boulder fields, and virtually useless to assess fish assemblages accurately over high-relief rock outcrops. In addition, surveys conducted remotely from the sea surface using all types of fishing gear yield little or no information on the association among benthic habitats and fish assemblages.

Early California biologists, such as William Ayres, Carl and Rosa Eigenmann, and David Starr Jordan, rarely conducted their own field surveys. Almost all of their information on fishes associated with rock habitats came from specimens purchased in fish markets and from interviews with fishermen regarding their catches. Unfortunately, most of these fishermen spoke little or no English, which often led to only a vague understanding of the substratum type and depth from which the fishes were collected. As an example, Jordan (1884) described the greenspotted rockfish (*Sebastes chlorostictus*) as "Occurring about the rocks in considerable depths of water." In the same publication, he erroneously stated that the nearshore treefish (*Sebastes serriceps*) inhabited "rather deep water."

In contrast to the fine-mesh trawl nets that caught most species occurring on soft substrata, the hook-and-line fisheries operating over rocky outcrops were more selective and did not in any way accurately sample the diverse species assemblages. Even when researchers collected their own specimens from deep waters, as did Carl and Rosa Eigenmann from Cortes Bank in 1889, precise depths of capture rarely were provided (Eigenmann and Eigenmann, 1889). Thus, although this early sampling was useful in establishing the occurrence of a species in a region and something of its general habitat association, it was not possible to characterize complete species assemblages accurately on complex structures.

The first summary of fish assemblages on deep-water rock outcrops off California resulted from collections made aboard commercial passenger fishing vessels (CPFVs) in central and northern California (Miller and Gotshall, 1965). Fishes were measured and identified, and estimates of seafloor depth were recorded. Characterizing this assemblage, Miller and Gotshall noted that most of the fishes taken in water between about 40 and 100 m were rockfishes, although lingcod (*Ophiodon elongatus*), sablefish (*Anoplopoma fimbria*), petrale sole (*Eopsetta jordani*), and cabezon (*Scorpaenichthys marmoratus*) were caught occasionally. Over the entire depth range, yellowtail rockfish (*Sebastes flavidus*) followed by bocaccio (*S. paucispinis*), chilipepper (*S. goodei*), widow (*S. entomelas*), greenspotted, and starry (*S. constellatus*) rockfishes, dominated the catch.

More recently, information regarding fish assemblages off California has come from recreational creel censuses (Reilly et al., 1993; Karpov et al., 1995; Mason, 1995, 1998), commercial fishery data (Pearson and Ralston, 1990), and fishery-independent government surveys (Gunderson and Sample, 1980; Dark and Wilkins, 1994; Shaw et al., 2000; Williams and Ralston, 2002). However, all of these surveys suffered from a lack of habitat specificity because it is not possible to assess fish communities accurately over complex, high-relief seafloor substrata with any of these techniques.

A more comprehensive understanding of fish assemblages associated with deep rock habitats has been the result of quantitative surveys conducted from an occupied research submersible during the past decade at several sites off central and southern California. Such surveys have described

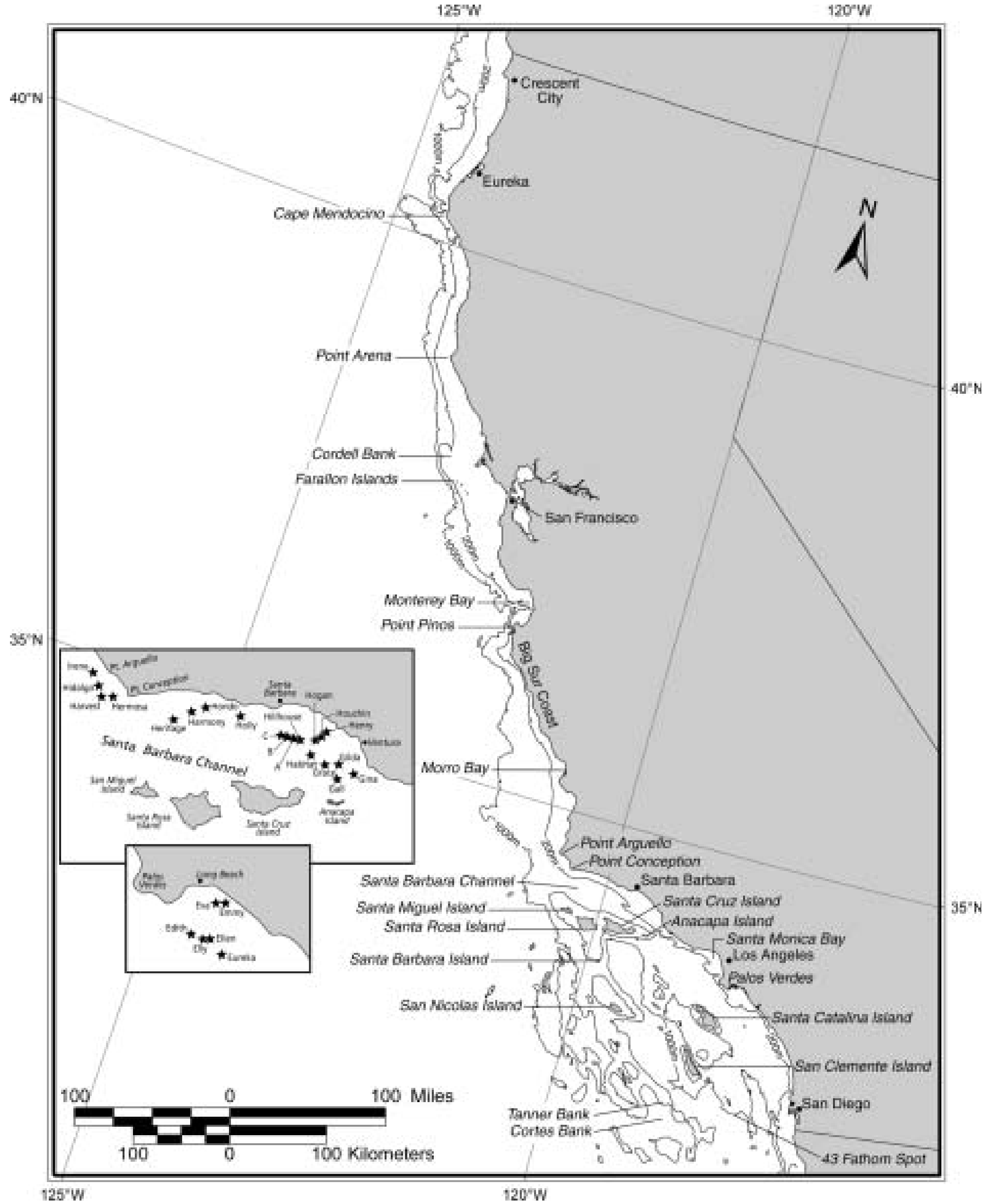

FIGURE 10-1 Locations of place names, including islands, canyons, natural rock outcrops, and oil and gas platforms, referenced in this chapter. Also depicted is general bathymetry (in meters).

the importance of small-scale refugia to deepwater fishes in a submarine canyon in Monterey Bay (Yoklavich et al., 2000), assessed habitats and associated fishes in and out of marine protected areas off central and southern California (Lissner and Dorsey, 1986; Yoklavich et al., 1997, 2002; Love and Yoklavich, unpublished data), and characterized the fish assemblages around offshore oil platforms off southern California (Love et al., 1999; 2000; 2003). These studies form the foundation of our chapter on fish assemblages associated with deep rock habitats.

Natural Outcrops

Overview of Habitats

The distribution of fishes off California is influenced by depth, substratum type, temperature, and ocean currents, which when integrated produce fish habitat. We have divided deep rock habitats into two categories based on water depth: (1) shelf (30–200 m) and (2) upper slope (201–500 m). The extent of the continental shelf ranges from about 0.5 km (off the Big Sur coast) to 180 km (around Cortes Bank) offshore of California. The offshore continental slope extends to more than 1000 m water depth.

There are a variety of deep rock habitat types off California. The shelf habitats comprise bedrock outcrops, isolated pinnacles and large rock banks, boulder fields, mixtures of low-relief sand or mud and cobble fields, and a few offshore islands. Examples include extensive rock and boulder fields off headlands such as Point Sur; isolated bedrock that can be several meters high and surrounded by a flat, sandy seafloor of Monterey Bay; Cordell Bank off central California, and Tanner and Cortes Banks in the offshore water of the Southern California Bight. The offshore upper slope habitats are largely composed of expansive mud fields interspersed with rock outcrop and scattered boulders. Several submarine canyons containing slumps of rock talus piles, scarps, and ledges are part of the shelf and slope systems. A prominent example is the Monterey Bay Canyon system, which cuts into the shelf less than 1 km from shore and extends down the continental slope to depths greater than 1000 m off central California. Megafaunal invertebrates, such as sea anemones, sponges, black coral, crinoids, and basket stars, provide substantial structure on deep rock habitats.

In broad terms, the ocean off California can be divided into two water masses (see fig. 10-2 for reference). Waters to the north and west of Point Conception typically are cool because (1) the California Current flows equatorward from high latitudes year-round and (2) frequent upwelling of cold deep water occurs at several headlands along this stretch of coast during spring and summer. On the other hand, year-round cyclonic circulation in the Southern California Bight entraps water, which results in warm water flowing poleward along the coast to the south and east of Point Conception as far as the Santa Barbara Channel. Reflecting these temperature regimes, fishes in central and northern California generally are more tolerant of cold water than those in southern California, which are more temperate or subtropical. Interestingly, San Miguel Island and part of Santa Rosa Island are located farthest north and west of all the Channel Islands and are therefore bathed in California Current water; fish assemblages of these two islands more closely resemble those off central California than those around other of the Channel Islands (Hubbs, 1974; Love et al., 1985).

Overview of Fish Assemblages

Rockfishes dominate the fish assemblages on deep rock habitats off California. Half of the 52 species and 77% of the total number of fishes identified in a submarine canyon in Monterey Bay at 94–305 m water depth were rockfishes (Yoklavich et al., 2000). At least 36 species of the 82 species of fishes identified in one study off the central California coast were rockfishes; 95% of all fishes surveyed at water depths of 35–100 m were rockfishes, and 64% of fishes at depths of 100–250 m were rockfishes (Yoklavich et al., 2002). Similarly, 42 rockfish species comprised 92.5% of all fishes surveyed at depths of 35–300 m off southern California (Love et al., 2003). In general, species diversity (that is, the number of rockfish species) is greatest off southern California and diminishes to the north and south (fig. 10-3). Rockfish diversity also increased in mixed habitats of complex rock and mud (Yoklavich et al., 2000) and generally with water depth (Yoklavich et al., 2002).

Reflecting differences in water masses, a number of more temperate or subtropical species, particularly freckled (*Sebastes lentiginosus*), honeycomb (*S. umbrosus*), pinkrose (*S. simulator*), and whitespeckled (*S. moseri*) rockfishes, treefish, California scorpionfish (*Scorpaena guttata*), and threadfin bass (*Pronotogrammus multifasciatus*) are either absent or less common north of Point Conception. Flag (*Sebastes rubrivinctus*), greenblotched (*S. rosenblatti*), rosy (*S. rosaceus*), speckled (*S. ovalis*), squarespot (*S. hopkinsi*), and starry rockfishes, chilipepper and cowcod (*S. levis*) are common on mid- and deep-shelf rock habitats off southern and central California but become less abundant or are absent altogether off northern California. A number of species, including black (*Sebastes melanops*), China (*S. nebulosus*), quillback (*S. maliger*), rosethorn (*S. helvomaculatus*), redbanded (*S. babcocki*), yelloweye (*S. ruberrimus*), and yellowtail rockfishes, and wolf-eel (*Anarrhichthys ocellatus*) are relatively abundant in northern and even central California but rare in much of southern California (Reilly et al., 1993; Love et al., 2002; Love, unpubl. data; Yoklavich unpubl. data; Yoklavich et al., 2000). Some of these species, such as yelloweye rockfish, have a center of distribution to the north and occur in southern California only in deep water (i.e., about 200 m) around those offshore banks (e.g., Tanner and Cortes Banks) that are influenced by the California Current (Eigenmann and Eigenmann, 1889; MacGregor, 1970). In addition, adults of some species, such as copper (*Sebastes caurinus*) and vermilion (*S. miniatus*) rockfishes and lingcod, live in shallower water (e.g., 10 m) north of Point Conception than they do off southern California (Burge and Schultz, 1973; Love et al., 2002).

Fishes living on rock outcrops can be placed into one of three behavioral categories: (1) midwater aggregators, (2) demersal aggregators, and (3) demersal nonaggregators or solitary individuals. Midwater aggregators, though loosely associated with rock structure, spend time as many as 30 m or more above the seafloor in large schools. Many, if not most, of these species descend to the seafloor during part of the day, most often at dusk, but sometimes at dawn. Black, blue (*Sebastes mystinus*), canary (*S. pinniger*), chilipepper, shortbelly (*S. jordani*), widow, and yellowtail rockfishes, juvenile and young-adult bocaccio, and blacksmith (*Chromis punctipinnis*) are examples of species in this category. Demersal aggregators rarely ascend more than a few meters from the bottom; these include squarespot, halfbanded (*S. semicinctus*), pygmy (*S. wilsoni*), young vermilion, and copper rockfishes. Demersal nonaggregators usually occur on the seafloor, often sheltering in or near complex habitat such as caves, crevices, and overhangs. These species are either solitary or found in small groups and include adult brown (*S. auriculatus*), copper, flag, greenspotted (*S. chlorostictus*), greenstriped (*S. elongatus*), pinkrose, rosethorn, rosy, swordspine (*S. ensifer*), and yelloweye rockfishes, as well as cowcod, large adult bocaccio, blackeye goby (*Rhinogobiops nicholsii*), combfishes (*Zaniolepis* spp.), lingcod, wolf-eel, and cabezon. A few species are not so easily categorized. Individual splitnose

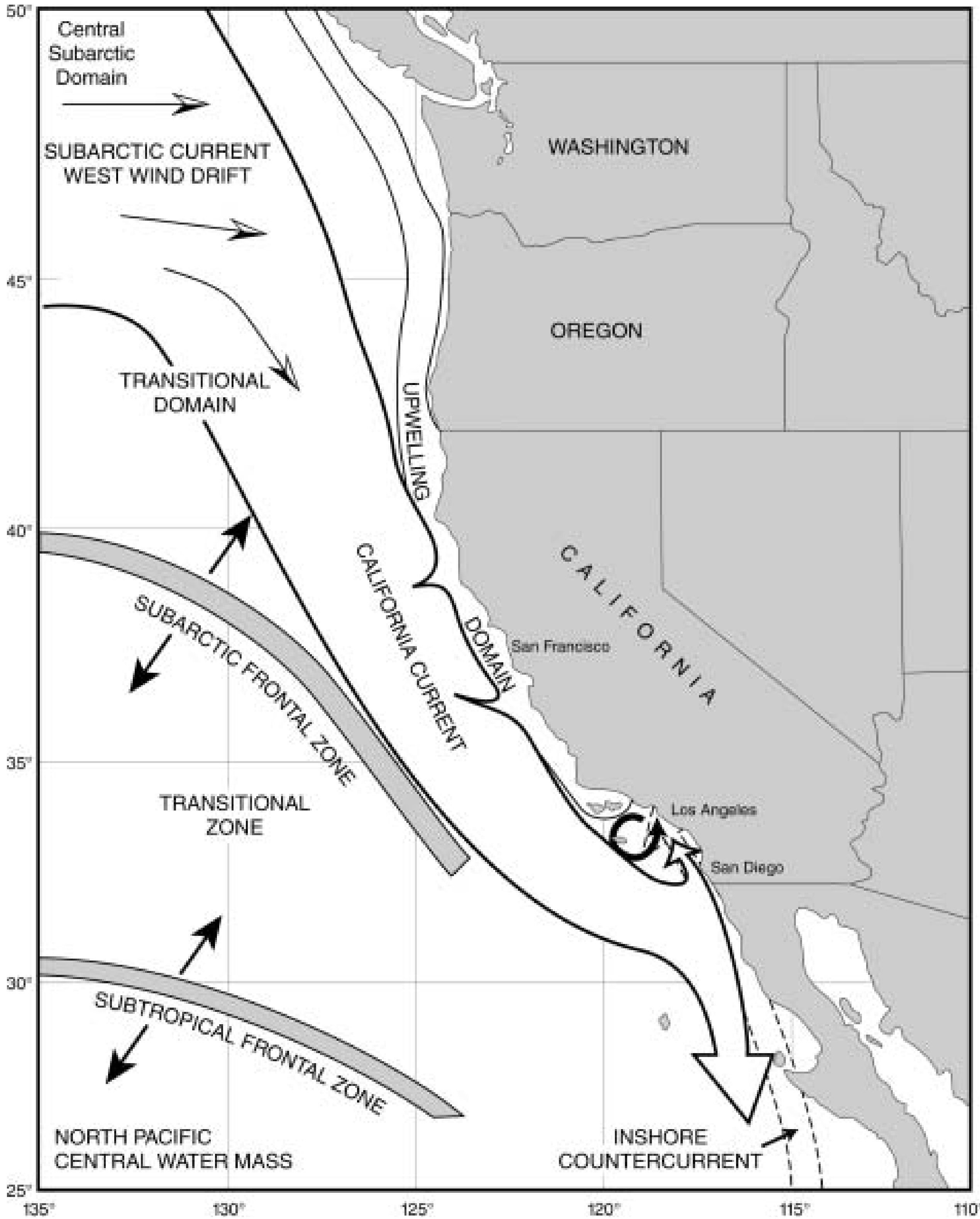

FIGURE 10-2 A schematic of the primary ocean currents off California, modified from PFMC (2003).

rockfish, for instance, often rest in shallow depressions in soft mud or next to rock on the seafloor; each fish is well separated from one another. However, occasionally they form large schools tens of meters above the seafloor. In addition, some species change behavior as they mature. Young bocaccio are midwater aggregators whereas older individuals become reclusive, solitary individuals residing in caves and crevices (Love et al., 2002; Yoklavich et al., 2000).

In this chapter, we attempt to portray representative fish assemblages as they exist today, covering a relatively broad depth and geographic range (table 10-1). These characterizations do not dwell on the rare fish visitor or the unusual unfished

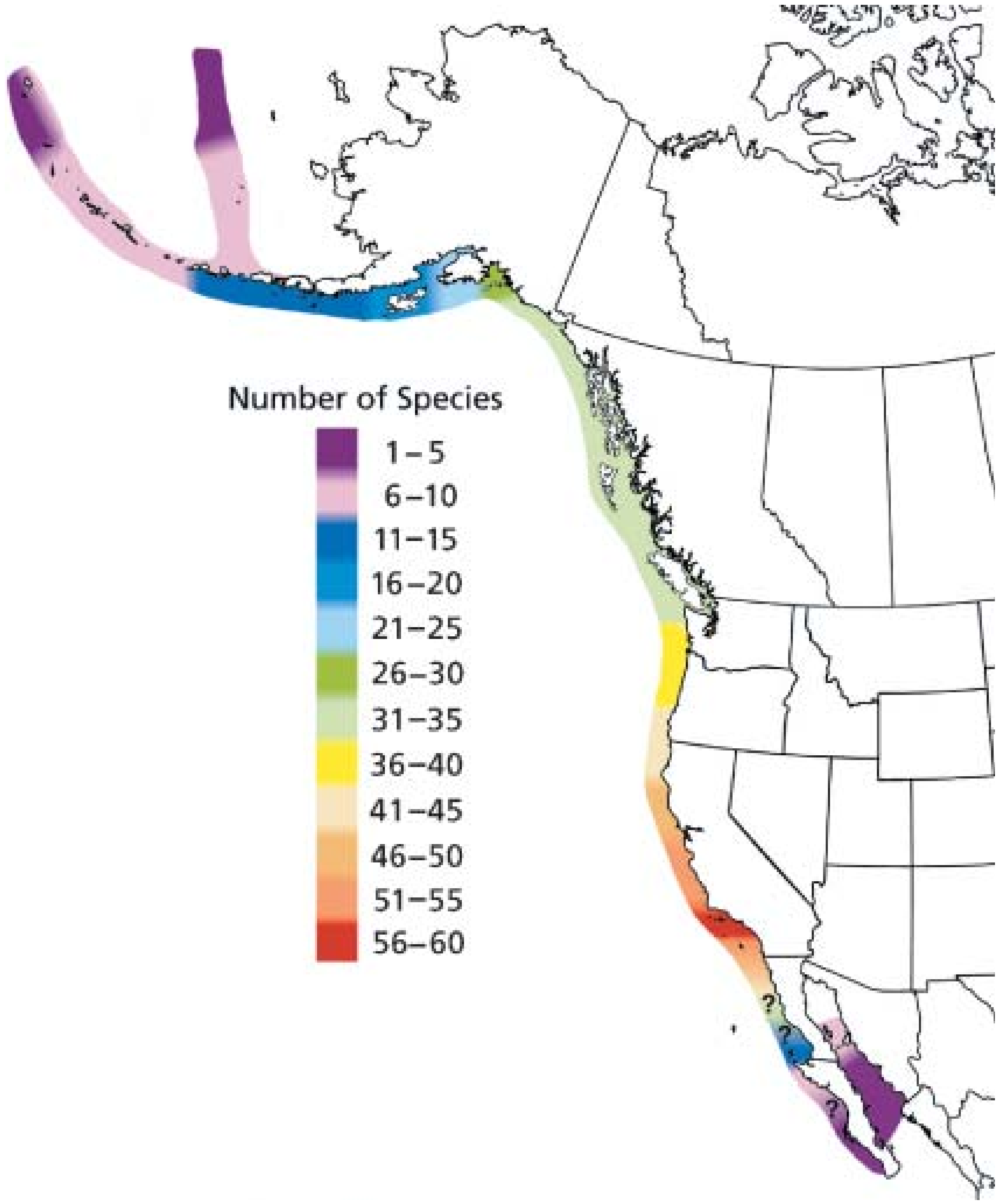

FIGURE 10-3 Distribution of the number of species of rockfishes along the west coast of North America (from Love et al., 2002).

outcrop. In addition, some species occupy more than one community. As an example, juveniles of several species often occur in waters shallower than that of the adults, and therefore these species will be included in several depth categories.

These should be considered only as generalized divisions because fish assemblages vary considerably on multiple scales of time and space. For instance, the long-term ocean warming of the 1980s and 1990s has drastically altered the midshelf rockfish communities off southern California. Juvenile and adult blue and olive (*Sebastes serranoides*) rockfishes and juvenile copper rockfish and bocaccio, once important members of the midshelf community, were absent for most of that period (Stephens et al., 1984).

In addition and almost without exception, these are impacted fish assemblages. Decades of overfishing, together with over 20 years of warm ocean conditions since the mid-1970s, has in many cases significantly changed these communities. Many of the previously dominant species, such as canary, darkblotched (*Sebastes crameri*), and widow rockfishes, bocaccio, cowcod, and lingcod, are now classified as overfished and in some instances are almost absent from important habitats (Love et al., 1998, 2002; M. Love and M. Yoklavich, unpubl. data; Yoklavich et al., 2000). Today, the fishes that dominate most rock outcrops in deep water are dwarf species such as pinkrose (southern California only), halfbanded, pygmy, squarespot, and swordspine rockfishes. These fishes

TABLE 10-1

Typical Adult Fish Assemblages over Rock Substrata off California

Southern California

Midshelf

Scorpaenidae: Blue, bocaccio, California scorpionfish, canary, calico, chilipepper, copper, cowcod, flag, freckled, greenblotched, greenspotted, halfbanded, honeycomb, olive, pygmy, rosy, speckled, squarespot, starry, vermilion, widow, whitespeckled
Gobiidae: Blackeye goby
Labridae: Senorita, sheephead
Pomacentridae: Blacksmith
Serranidae: Threadfin bass
Embiotocidae: Pile perch, sharpnose seaperch, white seaperch (*Phanerodon furcatus*)
Hexagrammidae: Lingcod, painted greenling

Deep Shelf

Scorpaenidae: Bocaccio, bank, canary, chameleon (*Sebastes phillipsi*), chilipepper, cowcod, dwarf-red (*S. rufinanus*), flag, halfbanded, greenblotched, greenspotted, Mexican (S. *macdonaldi*), pink (*S. eos*), pygmy, pinkrose, semaphore (*S. melanosema*), shortbelly, speckled, swordspine, vermilion, whitespeckled, widow, yellowtail
Hexagrammidae: Lingcod

Slope

Scorpaenidae: Aurora (*Sebastes aurora*), bank, blackgill, bocaccio, bronzespotted (*S. gilli*), chameleon, chilipepper, cowcod, greenblotched, pink, pinkrose, shortbelly, splitnose
Cottidae: Threadfin sculpin (*Icelinus filamentosus*)
Hexagrammidae: Lingcod

Central California and Northern California

Midshelf

Scorpaenidae: Black, blue, bocaccio, canary, chilipepper, china, copper, cowcod, flag, halfbanded, olive, pygmy, quillback, rosy, squarespot, starry, vermilion, widow, yellowtail, yelloweye
Hexagrammidae: Lingcod, kelp greenling, painted greenling
Cottidae Cabezon
Gobiidae: Blackeye goby
Embiotocidae: Pile perch, sharpnose seaperch, white seaperch
Anarhichadidae: Wolf-eel

Deep Shelf

Scorpaenidae: Bocaccio, bank, canary, chilipepper, cowcod, darkblotched, halfbanded, greenblotched, greenspotted, pygmy, redbanded, rosethorn, sharpchin, swordspine, splitnose, vermilion, widow, yelloweye, yellowtail
Hexagrammidae: Lingcod

Slope

Scorpaenidae: Aurora, bank, blackgill, bocaccio, chilipepper, cowcod, darkblotched, greenblotched, greenspotted, Pacific Ocean perch (*Sebastes alutus*), rosethorn, sharpchin, splitnose (*S. diploproa*)
Hexagrammidae: Lingcod

NOTE: Midshelf-30–100 m, deep shelf-101–200 m, and upper slope-201–500 m. From Miller and Geibel (1973); Gotshall et al. (1974); Gabriel and Tyler (1980); Gunderson and Sample (1980); Allen and Smith (1988); Dark and Wilkins (1994); Mason (1995); Love et al. (2002); Williams and Ralston (2002); Yoklavich et al. (2000, 2002).

either are too small to take a hook or are small enough to pass through a net. Release from competition and from predation by the larger, overfished species likely has resulted in the dominance of these weed-like species on deep rock habitats.

Many fish species associated with deep-water habitats are distributed on a macroscale (up to tens of meters) in response to specific types of seafloor sediments and water depth (Pearcy et al., 1989; Stein et al., 1992). From an example of benthic fish and habitat surveys conducted off the Big Sur coast, four distinct fish assemblages or guilds were separated primarily by depth (ranging from 30 to 250 m) and secondarily by a combination of sediment type and slope of the seafloor (fig. 10-4; Yoklavich et al., 2002). The two midshelf groups were associated primarily either with sand waves, ripples, and shell hash (dominated by speckled, *Citharichthys stigmaeus*, and Pacific sanddabs, *C. sordidus*) or with high-relief boulders and rock outcrops sometimes overlaid with kelp and understory algae (members of this group included blue, gopher (*Sebastes carnatus*), olive, rosy, and vermilion rockfishes, painted greenling (*Oxylebius pictus*), lingcod, and sharpnose seaperch (*Phanerodon atripes*).

Fish assemblages associated with various types of rock habitats on the midshelf are dominated by similar species off southern and central California (table 10-1; fig. 10-5; Yoklavich et al., 2002; Love et al., 2003). Juvenile greenstriped and stripetail (*Sebastes saxicola*) rockfishes, young-of-the-year cowcod, longspine (*Zaniolepis latipinnis*) and shortspine (*Z. frenata*) combfishes, pink seaperch (*Zalembius rosaceus*), and blackeye gobies position themselves on the sand and mud surrounding rock outcrops. Blackeye gobies also commonly rest on boulders and rocks of all sizes. Schools of young halfbanded and pygmy rockfishes swarm over cobblestones and low-lying broken rock; the halfbandeds often are distributed as much as 10 m into the water column, whereas the pygmies are much closer to the bottom. Young-of-the-year widow, squarespot, and other rockfish species also school with each other over rocks, usually in areas devoid of larger fishes. Larger juvenile and subadult greenspotted and swordspine rockfishes

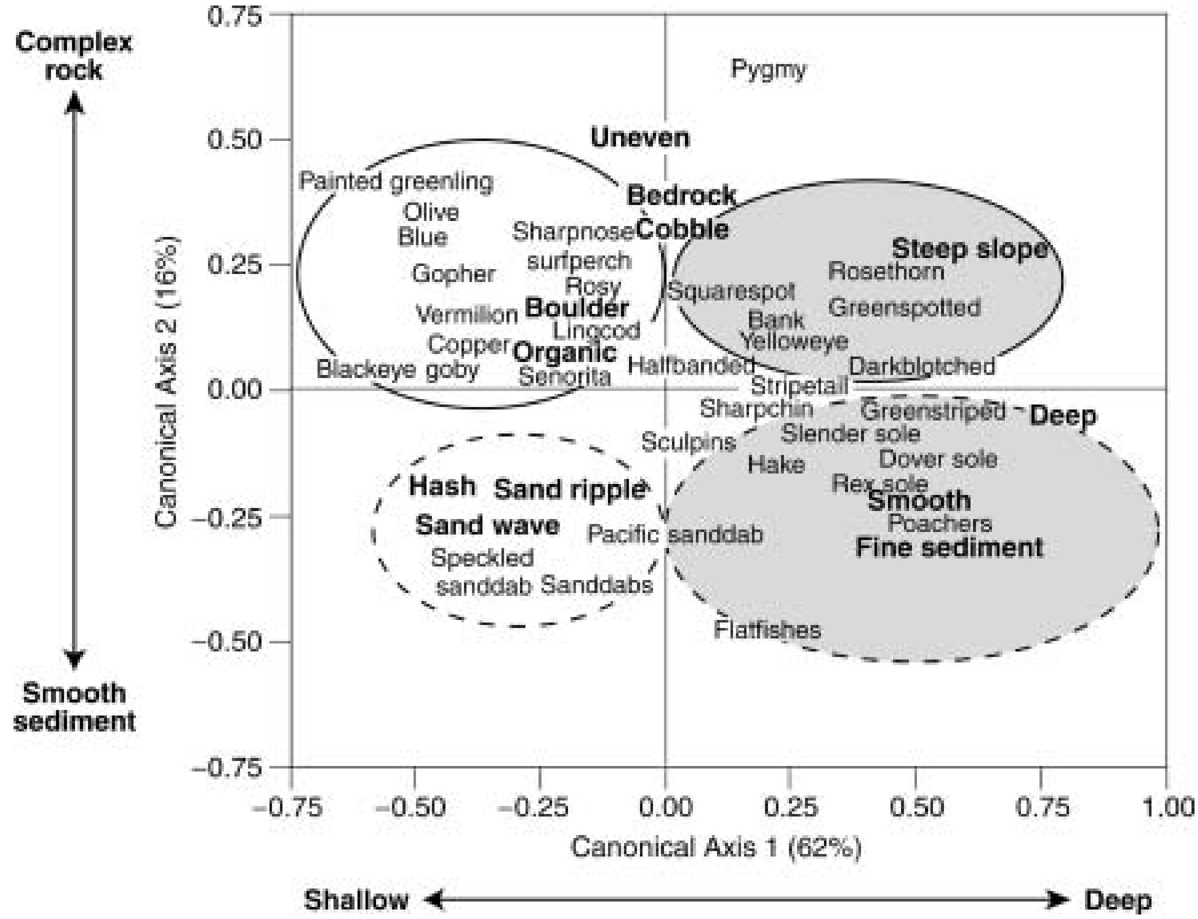

FIGURE 10-4 Fish assemblages characterized primarily by depth and secondarily by sediment and slope of the seafloor off Big Creek Marine Ecological Reserve, central California (from Yoklavich et al., 2002).

and cowcod hide in cracks and between stones or hover just over the seafloor. As the relief in habitat increases and becomes more complex, adult flag, greenspotted, pygmy, rosy, starry, and swordspine rockfishes, kelp (*Hexagrammos decagrammus*) and painted greenlings, senorita (*Oxyjulis californica*), and sheephead (*Semicossyphus pulcher*) and blacksmith (both southern California) are relatively abundant on or very near the seafloor, often alone but occasionally in small groups. At the same time, schools of late juvenile or young adult bocaccio, blue, speckled, squarespot, pygmy, vermilion, and whitespeckled (southern California only) rockfishes and sharpnose seaperch swim from near the seafloor to several meters above it. These species can occur together or in segregated aggregations. A few large cowcod (southern California), vermilion, and yelloweye rockfishes reside deep within caves and crevices in this depth category. Juvenile and adult lingcod are found from the edge of the rock outcrop to its crest.

With a few exceptions, little has been published on the habitat associations of fishes on deep-shelf (101–200 m) and upper slope (201–500 m) rock habitats. The two deep water (100–250 m) groups that were delineated from fish and habitat surveys off the Big Creek Marine Ecological Reserve (central California; Yoklavich et al., 2002) were associated either with smooth, fine sediment (members included rex [*Glyptocephalus zachirus*], slender [*Lyopsetta exilis*], and Dover [*Microstomus pacificus*] soles, Pacific hake [*Merluccius productus*], poachers [Family Agonidae], and sculpins [Family Cottidae]) or with steeply sloping bedrock and some cobbles (primarily bank [*Sebastes rufus*], greenspotted, darkblotched, rosethorn, squarespot, and yelloweye rockfishes; fig. 10-4). Five of the six guilds of benthic fishes that were described based on their associations with sediment types in deep water (75–305 m) of Soquel submarine canyon in Monterey Bay, comprised various combinations of high relief rock outcrop and boulders, low-relief cobble and pebbles, and fine muds (fig. 10-6; Yoklavich et al., 2000). Assemblages in the two guilds that were defined by low-lying habitats of cobble, pebble, and mud were diverse and included either relatively small species (greenstriped, halfbanded, rosethorn, stripetail, and, to a lesser degree, pygmy rockfishes) or small individuals of a large species (greenspotted rockfish). Two other guilds were defined by high-relief structures of large boulders and rock outcrops interspersed with fine mud on the canyon's steep walls. Some of the largest species (e.g., cowcod and yelloweye rockfishes up to 1 meter long, greenblotched and redbanded rockfishes, and bocaccio) were closely associated with rock ledges, caves, and overhangs in the canyon's rock walls. One isolated rock outcrop surrounded by a field of soft mud served as a natural refuge to the highest densities and largest members of these species that have been documented off California. The fifth guild, defined by rock and boulder habitat of moderate relief at 75–175 m depth, was dominated by pygmy rockfish; this type of habitat is typical for this species elsewhere off Southern (Love et al. et al., 2003) and central California (Yoklavich et al., 2002; Yoklavich, unpublished data) (fig. 10-7).

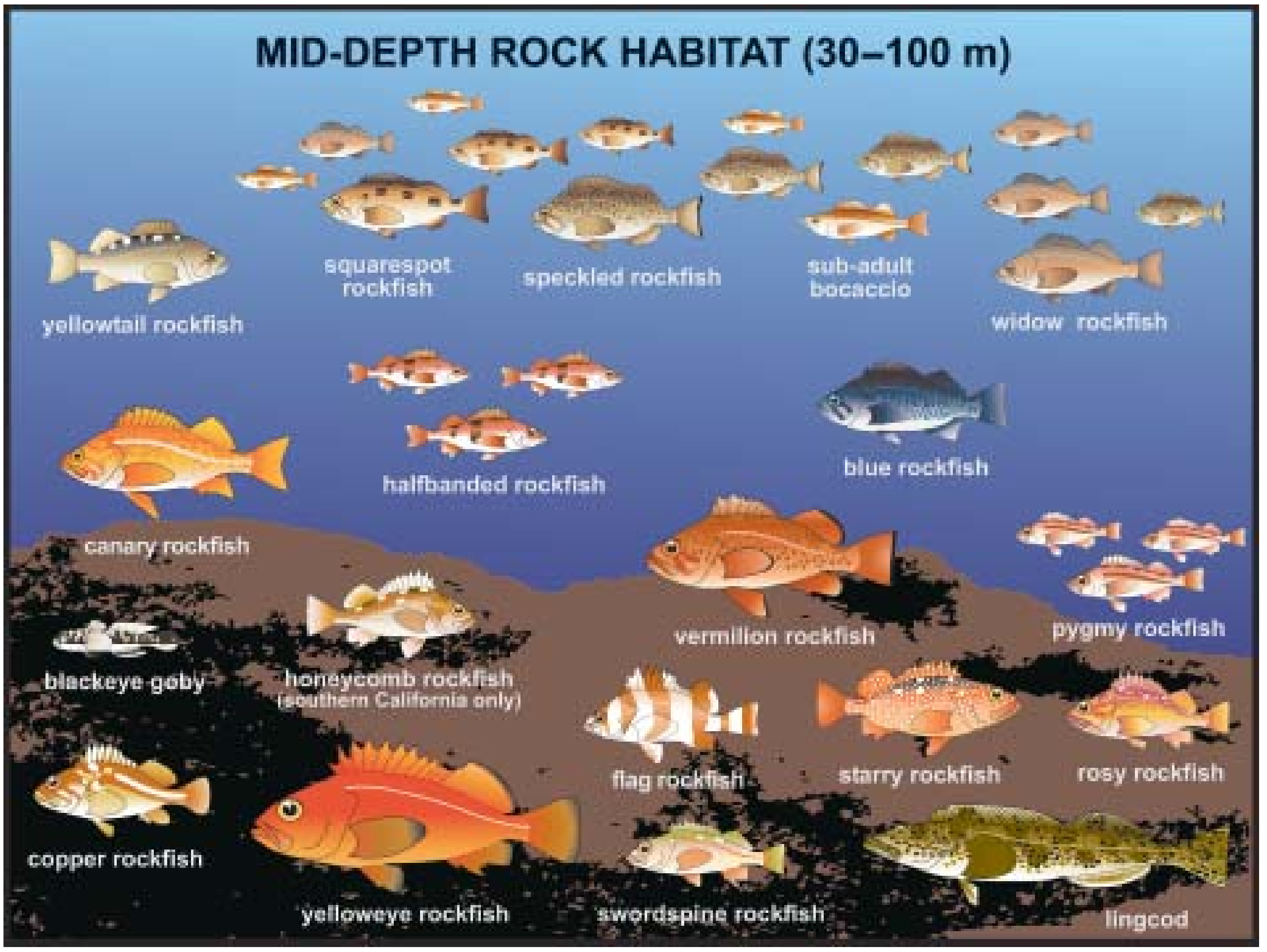

FIGURE 10-5 Representative fishes on midshelf rock habitats off southern and central California.

Anthropogenic Structures: Oil and Gas Platforms, Shell Mounds, and Pipelines

There are two types of artificial structures in the ocean off California. The first of these, artificial reefs, was created under the direction of the California Department of Fish and Game to enhance recreational fishing by providing marine habitat (Wilson et al., 1990). Because almost all of these artificial reefs are in water less than 30 m deep, these structures are not discussed in this chapter. A second group of artificial structures include offshore oil and gas platforms and various pipelines. These were created for other obvious purposes but also provide habitat for fishes. Almost all of the research on these structures has been directed toward offshore platforms (Carlisle et al., 1964; Allen and Moore, 1976; Bascom et al., 1976; Simpson, 1977; Love and Westphal, 1990; Love et al., 1999, 2000, 2003; Love, 2001).

There are 23 platforms off California in greater than 40 m water depth. Of these, 19 are located in the Santa Barbara Channel and Santa Maria Basin (fig. 10-1). Almost no research has been conducted on the three platforms to the south of the Santa Barbara Channel. Seven platforms, located 3 to 12 miles from shore and based in 65 to 224 m water depth, have been most extensively surveyed (fig. 10-1).

In general, there are three distinct fish assemblages around these deep-water platforms: (1) those in the midwater around the platform (defined as between the surface and about 10 m above the seafloor); (2) those on the bottom, adjacent to and within the platforms; and (3) those on the shell mound surrounding the platform. Rockfishes, including about 36 species, dominate all of these assemblages in both density and biomass (Love et al., 1999, 2000, 2003; Love, 2001).

Midwater Assemblage

Young-of-the-year (YOY) and 1-year-old rockfishes dominated surveys conducted during a 6-year period from July to November in midwater, particularly at platforms north of Point Conception. YOY rockfishes are virtually the only fishes seen around many platforms. Most of these are midwater or epibenthic species, primarily blue, olive, pygmy, squarespot, widow, and yellowtail rockfishes and bocaccio. These species form large schools that rarely leave the cover of the platform. Young-of-the-year copper and flag rockfishes and painted and kelp greenlings also may be common, but they are closely associated with the crossbeams and vertical framework of the platforms. Typical shallow-water outcrop species, such as blacksmith, kelp bass (*Paralabrax clathratus*), pile perch (*Rhachochilus vacca*) and sheephead, are found in the midwater around platforms close to shore. The midwater around platforms also hosts a number of transient pelagic visitors, such as northern anchovy (*Engraulis mordax*), Pacific sardine

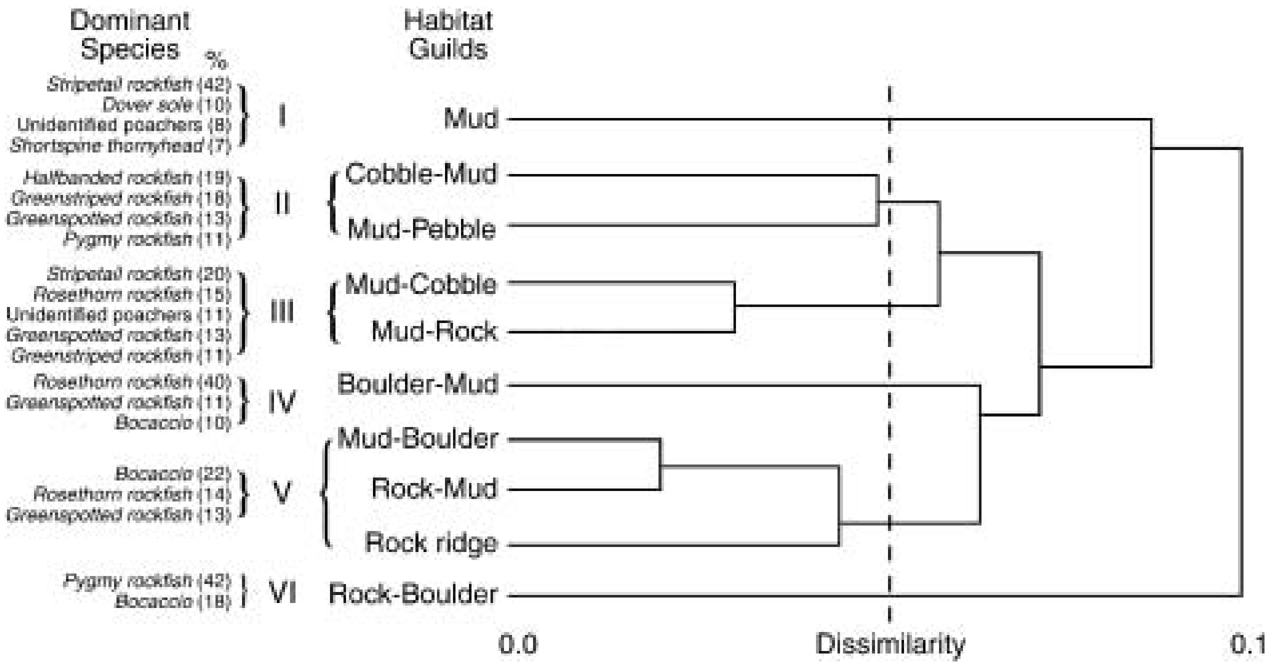

FIGURE 10-6 Cluster analysis of nonschooling benthic fish species in Soquel Canyon, Monterey Bay, based on associated type of seafloor sediments (from Yoklavich et al., 2000).

(*Sardinops sagax*), Pacific chub mackerel (*Scomber japonicus*), and mola (*Mola mola*). On offshore platforms, only a few species, such as blue and widow rockfishes, remain in the midwater after their first year. After about 1 year, many species, such as copper, flag, and yellowtail rockfishes, bocaccio, and kelp and painted greenlings, either move down to the platform bottom or off the platform all together.

Because oceanographic conditions strongly affect fish recruitment success, the density of YOY rockfishes may vary interannually by a factor of 10 or more (fig. 10-8a). Similarly, densities may vary by that much between adjacent platforms within a year. During the mid-to-late 1990s, platforms north of Point Conception (Irene, Hidalgo, Harvest, and Hermosa) had higher densities of YOYs than those in the Santa Barbara Channel (figure 10-8a). This is most clearly seen between 1995 and 1998, when there was little fish recruitment at Santa Barbara Channel platforms. However, the fortuitously timed upwelling of 1999 brought with it an exceptionally good year for rockfish recruitment, reflected at all of the platforms, including those within the Santa Barbara Channel. Rockfishes even recruited to Platform Gail, which had not supported YOY rockfish during the previous 4 years. Bocaccio most clearly exemplifies extremes in annual and geographic variability in rockfish recruitment (fig. 10-8b). Between 1995 and 1998, YOY bocaccio were uncommon or absent from the platforms. In 1999, high densities of bocaccio were observed at Platforms Irene and Grace, and at least a few individuals occurred at other platforms. Platform Grace, in particular, provides a striking example of interannual variability; almost no YOY bocaccio were observed prior to 1999.

On average, the midwater platform habitat harbors higher densities of juvenile rockfishes than nearby natural rock piles. Between 1996 and 1999, fishes were surveyed at Platform Hidalgo and at five nearby rock piles in about the same water depth (112–140 m). In all 4 years, there were higher densities of YOY rockfishes around the platform midwater than on the rocks (fig. 10-9). The occurrence of consistently high densities of YOY rockfish at Platform Hidalgo depends partially on the depth of these habitats. Four rock piles (North, B, C, and D) are in water shallower than 120 m, whereas the platform and A Reef are located in somewhat deeper water. However, because Platform Hidalgo covers the entire water column, it is much more likely to be encountered and colonized by shallow-dwelling pelagic juvenile rockfishes than the relatively low-lying rocks that have a vertical dimension of only a few meters.

Bottom Assemblage

Bottom habitat is the area where the seafloor meets the platform framework. At every platform, there is a crossbeam that rests either on or close to the seafloor. However, some or all of the crossbeams may be buried by sediment.

Subadult and adult rockfishes and lingcod dominate bottom assemblages that are either very close to or within the crossbeams, pilings, and wellheads of the platforms. An exception is the mobile, schooling halfbanded rockfish, which is found near the bottom and some distance outside the platform structure, perhaps avoiding large predators. Common hiding or resting spaces for many individuals are the crevices formed by near-bottom currents that erode sediments from beneath the crossbeams.

The bottom depth of the platforms strongly influences the species composition of associated fish assemblages (Love, 2001). Relatively shallow-water platforms (i.e., 50–130 m depth) are often habitat to halfbanded, copper, vermilion, flag, brown, and calico (*Sebastes dalli*) rockfishes and adult and juvenile lingcod. Painted and kelp greenlings and some seaperches also are common. Only rarely are YOY rockfishes abundant on the bottoms of these structures. Pinkrose, greenspotted, greenblotched, greenstriped, and stripetail rockfishes, bocaccio, cowcod, and combfishes commonly occur on platform bottom habitats in deep water.

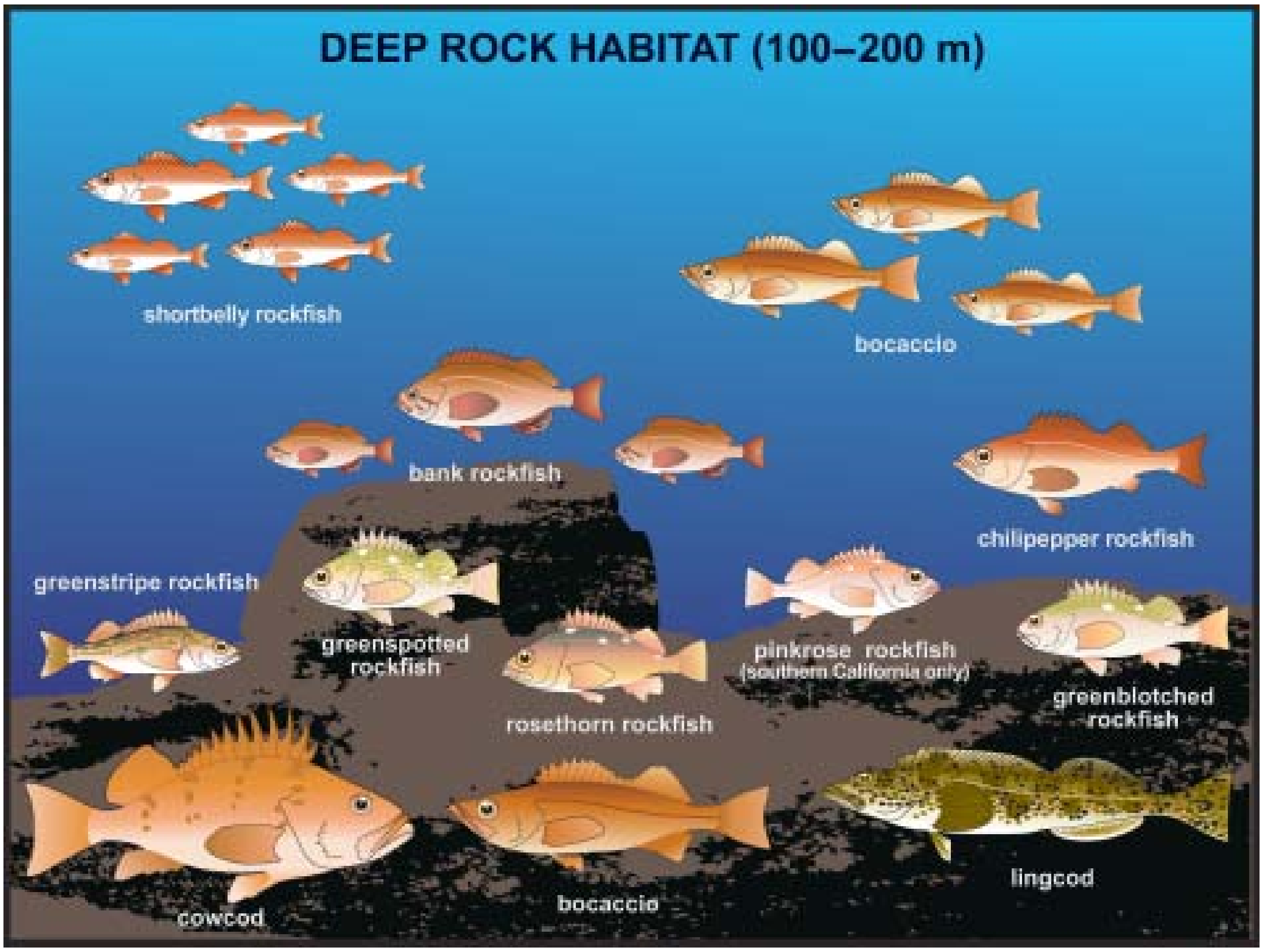

FIGURE 10-7 Representative fishes on deep-shelf and upper slope rock habitats off central and southern California

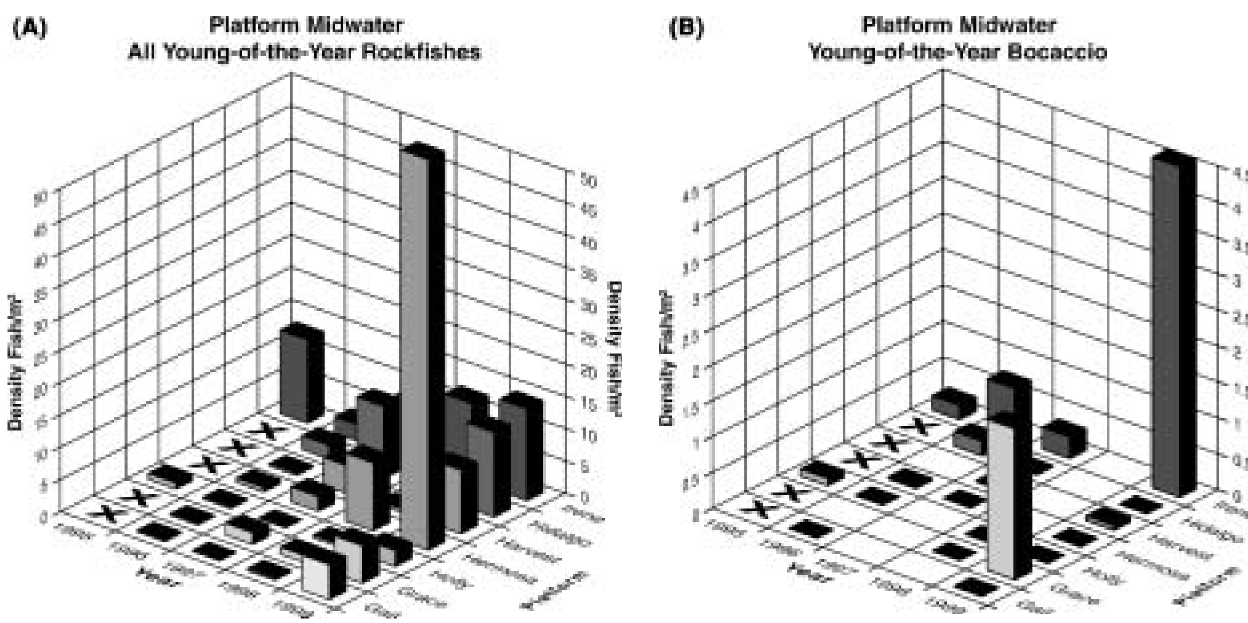

FIGURE 10-8 (a) Densities of young-of-the-year rockfishes by year and platform and (b) densities of young-of-the-year bocaccio by year and platform.

TABLE 10-2

Densities of All Species Found in Bottom and Midwater Habitats Around Platform Hidalgo and on North Reef

Family	*Common Name*	*1998 Platform Midwater*	*1998 Platform Bottom*	*1998 North Reef*	*1999 Platform Midwater*	*1999 Platform Bottom*	*1999 North Reef*
Scorpaenidae	Bocaccio		1.8				1.6
	Canary rockfish		3.3	0.7		3.9	7.2
	Cowcod					0.4	1.7
	Flag rockfish		10.7	0.4	0.5	15	0.5
	Greenblotched rockfish		0.4			2.8	2.6
	Greenspotted rockfish		37.2	32.2		41.5	10.9
	Greenstriped rockfish		6.6	12.3		1.9	0.8
	Halfbanded rockfish		284.7	52.8		574.7	10.6
	Pygmy rockfish		1.1	0.4		0.4	52.9
	Rockfish YOY	206.2	2.2	14.3	2622.6	81.3	333.4
	Rosy rockfish			0.4		1.2	5.8
	Sebastomus sp.		1.5	10.6		1.2	13.7
	Sharpchin rockfish		1.8				
	Squarespot rockfish			0.7		4.7	
	Starry rockfish			0.4			0.6
	Swordspine rockfish		2.6	0.4		0.8	1
	Vermilion rockfish		2.2	0.4		0.4	3.9
	Widow rockfish	308.6	1.1			13.8	276.7
	Yelloweye rockfish		1.1			0.8	0.6
	Yellowtail rockfish			0.4			3.8
Hexagrammidae	Kelp greenling				3.8		
	Lingcod		3.3	4.3		2.8	0.6
	Painted greenling	9.3	4.4		19.4	1.2	0.3
	Shortspine combfish			7.4			4.6
	Longspine combfish			0.4			
	Unid. combfish		1.1	2.1			
Embiotocidae	Pink seaperch			5.3			2.3
Gobiidae	Blackeye goby			5.4			2.8
Agonidae	Poachers						0.3
Unidentified fishes				7.5	1.6		

NOTE: Density = fish/100 m^2. From Love 2001

Because the species assemblages around the platform bottom include primarily subadult and adult fishes, their densities are less reflective of annual recruitment processes and perhaps more stable than densities of midwater assemblages. The extent to which individual fish move on and off the platform is unknown. However, it is likely that relatively sedentary species, such as greenspotted and greenblotched rockfishes, rarely leave the platform environment. More mobile species, such as halfbanded rockfish and young widow rockfish and bocaccio, may move extensively.

Some platforms serve as de facto reserves because there is little fishing pressure in their vicinity. For instance, there are higher densities of adult bocaccio and cowcod (both species declared "overfished" by the National Marine Fisheries Service) at Platform Gail, located in the eastern end of the Santa Barbara Channel, than at any of the 50 natural rock habitats surveyed throughout southern California (Love, 2001; Love, unpubl. data).

Love (2001) compared the species compositions of fish assemblages surveyed in midwater and bottom habitats at Platform Hidalgo and at the nearby North Reef in 1998 and 1999 (see fig. 10-1 for locations). Although there was almost complete overlap in species composition, the densities of the dominant species varied between the two sites (table 10-2). Higher densities of young-of-the-year rockfishes (YOY) and adult halfbanded and flag rockfishes, painted greenling, and lingcod occurred at Platform Hidalgo, whereas pygmy, rosy, and yellowtail rockfishes and cowcod were more abundant at North Reef.

As previously noted, the higher densities of YOY rockfish in Platform Hidalgo's midwater habitat compared to those associated with North Reef are likely to reflect the greater vertical relief of the platform. The high densities of flag rockfish at Platform Hidalgo also may be linked to increased facilitation of juvenile recruitment at the platform. On natural outcrops, flag rockfish usually are found as solitary animals. However, 10 or more individuals were found crowded together under the bottom crossbeam at Platform Hidalgo. Pelagic juvenile flag rockfishes are abundant in surface waters (Love et al., 2002) and therefore are more likely to encounter platforms than natural outcrops. During years of good recruitment, large numbers of YOY flag rockfish occupy the midwater habitat of some platforms. From surveys of fishes at Platform Grace between 1999 and 2002, flag rockfish that had recruited to the midwater in 1999 remained at the platform through the succeeding 3 years. By 2002, large numbers of flag rockfish, with densities similar to those at Platform Hidalgo, were observed in the bottom habitat of Platform Grace (Love et al., 2003).

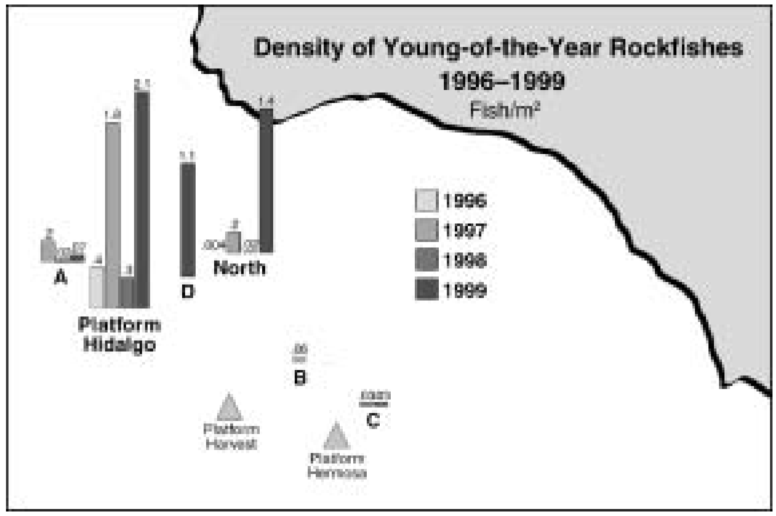

FIGURE 10-9 Mean annual densities of young-of-the-year rockfishes at Platform Hidalgo and at five natural rock outcrops, 1996–1999.

Shell Mound Assemblage

The seafloor surrounding platforms is covered by living and dead mussel shells that have fallen from the platforms during storms or cleaning operations. These shell mounds harbor a rich invertebrate fauna, including large numbers of anemones, seastars, brittlestars, crabs, and shrimps. They also are home to YOY rockfishes (primarily benthic species such as cowcod, copper, brown, stripetail, blackgill [*Sebastes melanostomus*], greenspotted), other small rockfishes (e.g., halfbanded, pinkrose, greenblotched, rosy), juvenile and occasionally adult lingcod, both longspine and shortspine combfishes, Pacific sanddab, and poachers. The rugose substratum formed by mussels and other invertebrates provides refuge from predation for these small fishes. In general, the fish assemblage on shell mounds is an extension of the bottom assemblage adjacent to the platform (Love et al., 2003).

Pipeline Assemblage

Most of the pipelines in deep water off California release treated sewage or are associated with oil and gas platforms. These pipes range from 0.3–3.7 m in diameter. Only two studies have examined the fish assemblages on these structures: a sewer line in Santa Monica Bay (Allen et al., 1976) and a gas line located between Platforms Gail and Grace in the Santa Barbara Channel (M. Love, unpubl. obs). In both surveys, pipelines harbored relatively high numbers of fishes of those species (particularly rockfishes, as well as painted greenling, sculpins, and poachers) common to rock habitats, along with high densities of large invertebrates such as anemones and sea stars. The relatively shallow (60–100 m) Santa Monica Bay pipe was home to high densities of blue, olive, flag, shortbelly, and vermilion rockfishes, as well as young bocaccio and cowcod. Some of these species were noted on a section of the oil and gas pipeline at about 100 m water depth. The deep sections (to 220 m) of this pipeline were occupied by juvenile cowcod, stripetail, pinkrose, splitnose, and blackgill rockfishes and poachers. Fishes were particularly abundant where there was dense invertebrate cover on the pipe.

A Final Comment

It is important to reiterate that the fish communities we have discussed are not "natural." As noted in Jackson (2001) and Jackson et al. (2001), coastal ecosystems worldwide have been dramatically altered by human activity. It is clear that the fish assemblages on deep rock habitats off California have been substantially changed. This alteration has occurred both from intense, continuous recreational and commercial fishing at least as far back as the 1940s and, beginning in the mid-1970s, from more than two decades of a warm and plankton-depleted oceanographic regime, which was at least partially responsible for the poor reproductive success of many fish species. This has led to fish assemblages dominated by dwarf species that perhaps are more productive and able to avoid capture.

We have almost no data on prefishery fish assemblages on deep rock habitat, and we can only speculate on the structure of unfished communities and on the significance and magnitude of subsequent impacts. However, based on observations by Yoklavich et al. (2000) of an unfished outcrop on a canyon wall in Monterey Bay, it is likely that the optimal high-relief habitat was occupied by high densities of the adults of larger species, such as greenspotted, greenblotched, and yelloweye rockfishes, boccacio, cowcod, and lingcod. In the past, the young of these species and the dwarf species that now dominate these outcrops were probably relegated to suboptimal habitats, such as cobble.

On the Pacific Coast, mapping and subsequent characterization of deep rock habitats and their faunal assemblages are only just beginning and are critical when trying to understand and protect essential fish habitats. In addition, those surveys of deep rock habitats that evaluate the role of oil platforms as fish habitat or of submarine canyons as marine refuges have been narrowly focused. With additional seafloor mapping and broadly based community studies, it will be possible to fill in the gaps in our knowledge. However, it is unfortunate that we will not be able to reconstruct these vanished ecosystems completely.

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