Submersible Observations of Deep-Reef Fishes of Heceta Bank, Oregon

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ABSTRACT: Rockfishes, *Sebastes* spp., were the most numerous and speciose fishes seen during 16 submersible dives from 64 to 305 m depth in the vicinity of Heceta Bank off the coast of Oregon. Dense schools of juvenile rockfishes and large yellowtail rockfish, *S. flavidus*, were observed only over rocky, high relief areas near the top of the bank, and highest densities of small benthic rockfishes (up to 5–10/m^2) on the flanks of the bank. These observations suggest that shallow, rocky portions of Heceta Bank are a nursery area for juvenile rockfishes. Two species groups of nonschooling fishes were identified based on transects over the diverse seafloor habitats around the bank: one comprised primarily of rockfishes in shallow water on rock and cobble, and the other comprised of flatfishes, agonids, sablefish, and some rockfishes in deep water over mud and cobble. Species composition of fishes observed from submersible dives differed from species composition of fishes taken from trawl catches in the same general areas.

Prominent offshore submarine banks of exposed bedrock, formed by subduction of oceanic plates, occur along the continental shelf of western North America (Kulm and Fowler 1974), providing a specialized habitat for marine fauna. Large aggregations of rockfishes (Scorpaenidae: *Sebastes*) and other fishes are often associated with these banks (Isaacs and Schwartzlose 1965), just as concentrations of fishes are found on or over seamounts in the North Pacific Ocean (Uda and Ishino 1958; Uchida and Tagami 1985; Uchida et al. 1986).

Heceta Bank, located about 55 km off the central Oregon coast, rises abruptly from depths of over 1,000 m on its seaward face to depths of <60 m (Figs. 1, 2). Trawlable areas around Heceta Bank support a large portion of Oregon's commercial fishery production. The bank itself is thought to be a nursery for juvenile fishes. Several surveys of near-bottom fishery resources of the region have been attempted using bottom trawls (Gunderson and Sample 1980; Barss et al. 1982; Weinberg et al. 1984). However much of the bank is too rugged for bottom trawling, and until our study, no submersible surveys of this area had been made. Thus, species composition, abundances, and distributions of fishes on Heceta Bank itself are largely unknown.

We used a manned submersible to conduct surveys of fishes on and around Heceta Bank. Our goals were to assess visually the abundances of fishes on Heceta Bank, to relate distributions and species assemblages with habitat type and depth, and to evaluate the importance of the bank as a nursery and refugium for commercially important fishes.

METHODS

We dove 16 times in the vicinity of Heceta Bank (Fig. 2) during daylight on 23–31 August 1987, using the submersible *Mermaid II*. Bottom depths ranged from 64 to 305 m. Usually two or three visual belt transects were made during each dive. During each transect the position of the submersible and the distance traversed in 30 minutes at speeds of 1.5–2.0 km/h were determined from Loran C fixes by the surface vessel *Aloha* as it followed a surface buoy towed by the submersible. In this paper we report on 21 transects from 10 dives in which the submersible attempted to follow a compass course parallel to isobaths. Two scientists and a pilot were on each dive. Scientists switched positions from the bow window to a stern jump seat between 30 min transects. Seven scientists made dives.

All fishes seen between two fixed points on the submersible's bumper (a path about 3.5 m wide

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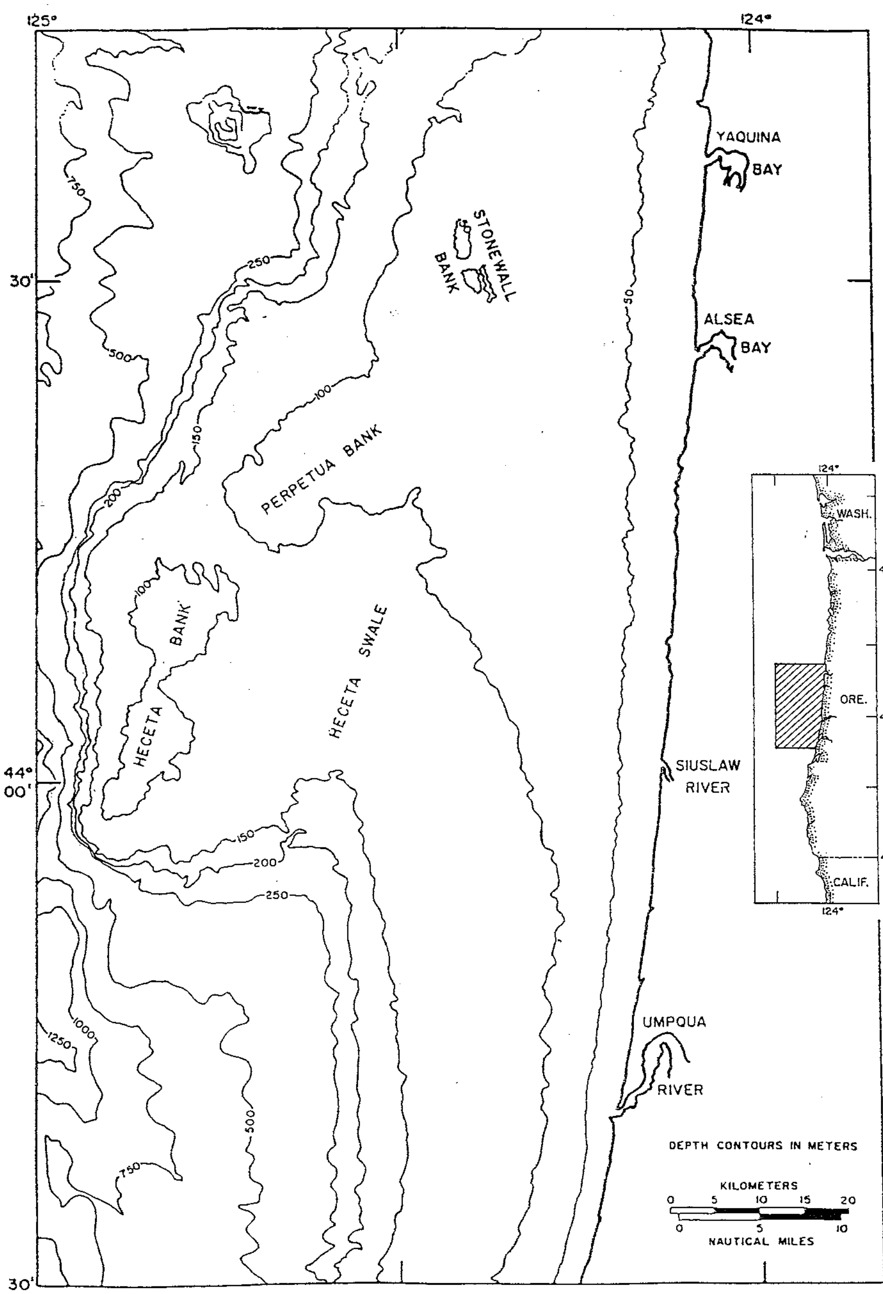

FIGURE 1.—Chart of the central Oregon coast showing Heceta Bank (depth in meters), and insert showing area covered by chart.

on the bottom at an altitude of 2 m) were identified when possible, counted, and lengths estimated to the nearest 10 cm. These data were simultaneously recorded on tape recorders and/or an event recorder by one of the two scientists on each dive. Altitude above the bottom was determined by observing a length of chain marked in decimeters suspended below the submersible and visible from the port. Altitude was fairly constant, about 2 m, on dives over uniform bottom. A fiberglass "T"-shaped rod, protruding 2.5 m from the bow of the submersible with black and white bands at 10 cm intervals, and a similar 50 cm bar with 10 cm bands attached to the bottom of the chain were used to estimate fish lengths.

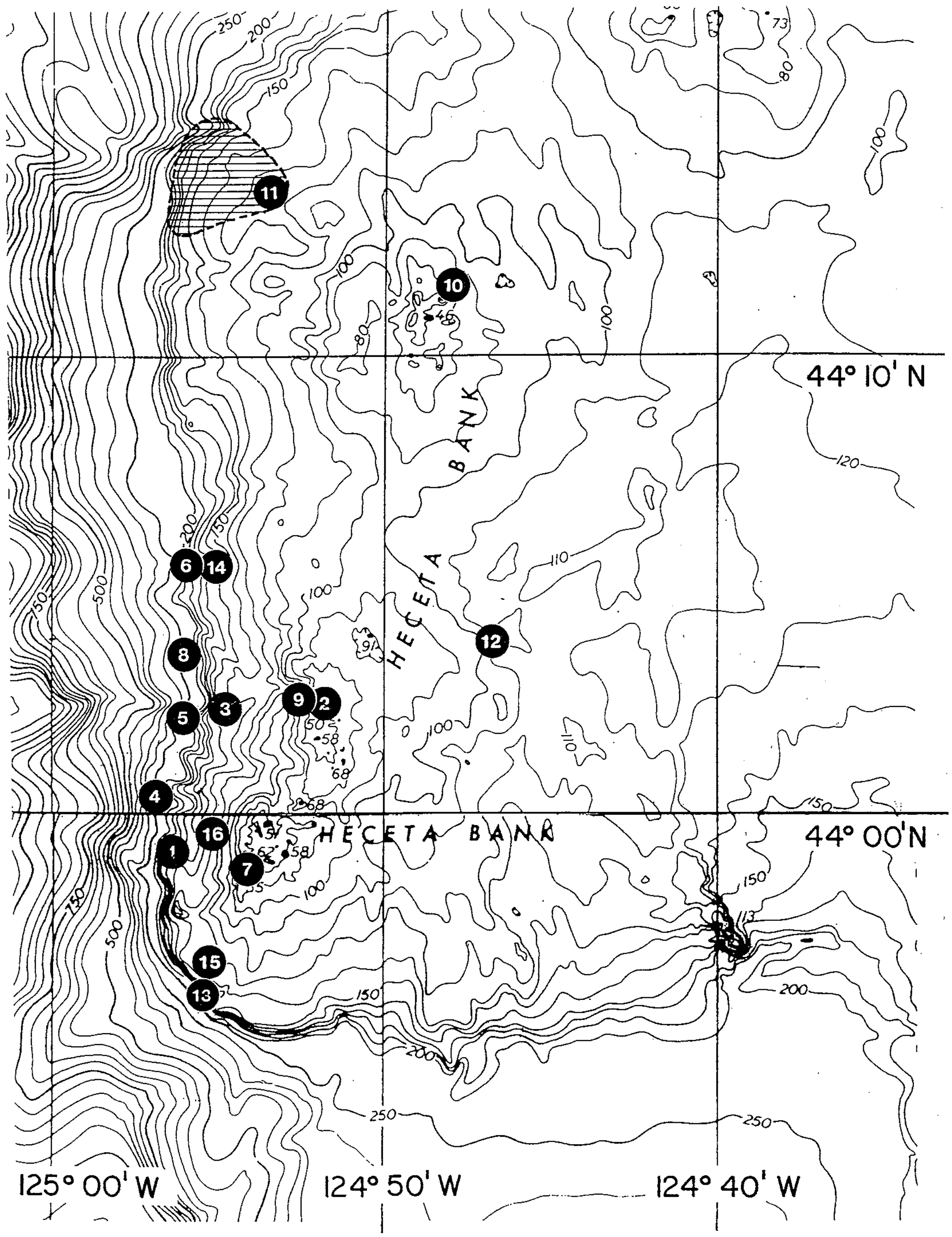

FIGURE 2.—Location of the 16 dives on Heceta Bank. Hatched areas indicate locations of bottom trawling.

External lighting consisted of two 500 W and two 150 W iodide lamps. A Photo-Sea 1000[1] 35 mm camera with strobe and a CM-55 Underwater Television Camera were used on every dive to assist in identification of fishes after the dives. We used a slurp gun and rotenone dispenser (Straty 1987) to collect voucher specimens. Between transects on some dives the submersible rested on the bottom with lights and

[1]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

thrusters off for about 10 minutes. The lights were then turned on to determine their effects on fish behavior. Although "marine snow" was sometimes dense, visibility near the bottom was 3–5 m on all dives. Observations were sometimes made with ambient light from the submersible's conning tower at shallow depths.

A hierarchical cluster analysis (see Pimentel 1979), using presence or absence of species, was used to determine the similarity of nonschooling fish assemblages among transects. Schooling fishes were not included because most were small and could not be accurately enumerated or identified to species.

RESULTS

We encountered diverse and patchy substrates. Bottom types ranged from soft mud to rock walls and pinnacles. The bottom was often mud at depths below about 150 m, and cobble or rock at shallower depths. Massive rock formations, often sculptured into ridges and valleys, existed at depths of 75 m or less. Although habitats were generally stratified by depth, bottom type typically varied within a dive.

We observed a total of 42 taxa of fishes, including 31 identified species (Table 1). Rockfishes (Scorpaenidae) were by far the most abundant and speciose group: 12 species of *Sebastes* were identified. Of the nonschooling fishes, small "blotched" rockfishes, tentatively identified as sharpchin rockfish, *S. zacentrus*, were seen more frequently on transects of contour dives than all other fishes combined (Table 1). Rockfishes ranked first in abundance on 15 transects and second in abundance on 10 of the 21 transects (Table 2). The most numerous of the identified nonschooling species was the rosethorn rockfish, *Sebastes helvomaculatus*. The most numerous of the identified schooling species was yellowtail rockfish, *S. flavidus*; sometimes nonschooling individuals of this species were seen.

TABLE 1.—Rank order of abundances of nonschooling fishes seen on the 21 transects on Heceta Bank.

Nonschooling fishes	Total no. observed
Sharpchin rockfish, *Sebastes zacentrus?*	949
Unidentified small rockfish	902
Rosethorn rockfish, *Sebastes helvomaculatus*	409
Zoarcidae	164
Sablefish, *Anoplopoma fimbria*	140
Pygmy rockfish, *Sebastes wilsoni?*	132
Slender sole, *Lyopsetta exilis*	99
Dover sole, *Microstomus pacificus*	97
Unidentified large rockfish	71
Agonidae	67
Greenstriped rockfish, *Sebastes elongatus*	55
Unidentified flatfish	52
Cottidae	51
Hagfish	40
Shortspine thornyhead, *Sebastolobus alascanus*	33
Slim sculpin, *Radulinus asprellus*	33
Rex sole, *Glyptocephalus zachirus*	33
Splitnose rockfish, *Sebastes diploproa*	32
Yelloweye rockfish, *Sebastes ruberrimus*	25
Canary rockfish, *Sebastes pinniger*	25
Kelp greenling, *Hexagrammos decagrammus*	23
Unknown fish	21
Darkblotched rockfish, *Sebastes crameri*	19
Yellowtail rockfish, *Sebastes flavidus*	16
Lingcod, *Ophiodon elongatus*	14
Spotted ratfish, *Hydrolagus colliei*	12
Longnose skate, *Raja rhina*	10
Blenniidae	8
Bathymasteridae	8
Rajidae	7
English sole, *Parophrys vetulus*	7
Redbanded rockfish, *Sebastes babcocki*	7
Arrowtooth flounder, *Atheresthes stomias*	6
Big skate, *Raja binoculata*	4
Pacific hake, *Merluccius productus*	4
Tiger rockfish, *Sebastes nigrocinctus*	2
Wolf-eel, *Anarrhichthys ocellatus*	2
Sand sole, *Psettichthys melanostictus*	2
Stripetail rockfish, *Sebastes saxicola*	1
Ragfish, *Icosteus aenigmaticus*	1
Sand dab, *Citharichthys* sp.	1
Threadfin sculpin, *Icelinus filamentosus*	1
Osmeridae	1
Greenspotted rockfish, *Sebastes chlorostictus*	1

Assemblages of Nonschooling Fishes

Cluster analysis grouped the nonschooling fishes into two major groups associated with two major habitat types and two depth zones—bottoms where rock and cobble predominated at depths of 67–145 m (Habitat I:13 transects) and mud and cobble bottoms at depths of 140–299 m (Habitat II:8 transects) (Fig. 3, Table 2). Two subclusters occurred within each habitat group at a Euclidian distance of <0.4. The distance (dissimilarity) between the two major habitat types was almost twice as great as among the four subclusters. As can be seen in Table 2, differences in species compositions among clusters were not large. Many species were found in several habitat/depth types. Distinct species assemblages were not obvious. The four habitat groups were as follows:

IA-Shallow Rock Habitat. Six transects near the top of the bank (67–76 m) were over a seafloor predominated by high-relief, massive rock walls often separated by eroded valleys filled with cobble or sand. Four transects were over cobble and flat rock interspersed with patches of mud at depths of 104–149 m. Crinoids (*Florometra serratissima*), sponges, anemones (*Metridium* sp.), hydrocorals, and bryozoans were abundant on exposed rock faces. Basket stars (*Gorgonocephalus* sp.) were obvious on ridge tops. Rockfishes were the most frequently observed fishes, especially rosethorn, small sharpchin rockfishes, and large yelloweye (*S. ruberrimus*), and yellowtail rockfishes.

IB-Shallow Cobble Habitat. Three of the transects were at 122–145 m over cobble and lower relief rocks interspersed with soft sediments on the northern portion of the bank (Fig. 1). Rosethorn, yelloweye, canary (*S. pinniger*), and large sharpchin rockfishes occurred near rocks, and zoarcids and longnose skates (*Raja rhina*) were seen in muddier areas.

IIA-Deep Mud-Cobble Habitat. Two of the transects were over mud and cobble substrates in deeper water (185–220 m and 140–148 m, respectively). Rosethorn, greenstriped (*S. elongatus*), canary, and yellowtail rockfishes occurred in these two transects but were absent in deeper transects over mud bottoms. However, the fishes seen on these transects were similar to mud bottom assemblages because of the occurrence of several species of flatfishes. Greenstriped rockfish and Dover sole, *Microstomus pacificus*, occupied soft bottom areas between rocks.

IIB-Deep Mud Habitat. Six transects were over mud, which was the predominant substrate at the deepest depths, 164–300 m, although occasional small rock outcrops or boulders were evident there. Sea urchins, *Allocentrotus fragilis*; sea stars, *Pycnopodia helianthoides*; sea cucumbers, *Parastichopus californicus*; and crabs *Lopholithodes foraminatus* were common in this habitat. All these invertebrates had very patchy distributions. We saw zoarcids, Dover sole, and unidentified flatfishes on all six of these transects, and hagfish (*Eptatretus* sp.); rex sole, *Glyptocephalus zachirus*; slender sole, *Lyopsetta exilis*; sablefish, *Anoplopoma fimbria*; poachers (Agonidae); and skates (Rajidae) on most transects. The deep mud habitat included some species also seen over shallow rock and cobble as well as species only observed over deep mud and cobble (Table 2).

The two cobble subgroups (IB and IIA) are probably transitional habitats between shallow rock (IA) and deep mud (IIB). As such they allow comparisons of the occurrence of fishes on similar bottom types at different depths. Yelloweye and canary rockfish appeared to be more common at shallow than deep cobble, whereas splitnose and greenstriped rockfish, cottids, Dover sole, and other flatfishes were more frequently seen over deep than over shallow cobble. Rosethorn rockfish were common in both subgroups (Table 2).

Six to 22 different species of nonschooling fishes were identified on individual transects. Interestingly, the fewest species of fishes (6–12) were seen on the shallowest dives, over rocky and cobble bottoms (67–149 m; Habitat I), while the greatest number (10–22) were seen on deeper dives over mud and cobble bottoms (164–299 m; Habitat II) (Table 2; Mann-Whitney U–test, $P < 0.01$). This difference would be reduced if the unidentified schooling rockfishes seen in shallow water (see below) could have been included. Average density of nonschooling fishes observed varied greatly (0.02–1.3/m^2) within and among habitat types. No difference was found in the densities between Habitat I and Habitat II (Mann-Whitney U-test, $P > 0.2$). Fish density was highest on dives over slabs of flat rock at 149 m (15A) where large numbers of juvenile rockfishes were seen.

Rockfishes

Because rockfishes were the most numerous and diverse family of fishes seen on our dives (Tables 1, 2) and because they are taxonomically a cohesive group with distinct behavioral patterns, they merit special consideration. Most individuals could be categorized into one of four distinct size groups and behavior patterns: 1) schools of small or juvenile fishes, 2) solitary benthic fishes of intermediate size, 3) pelagic schools of large fishes, and 4) large solitary rockfish near the bottom.

Small Schooling Rockfishes

We saw 24 schools, comprised of 10 to several thousand small (<10 cm) unidentified reddish juvenile rockfishes, during 5 of the 16 dives.

TABLE 2.—Number of nonschooling fishes observed on 21 transects on Heceta Bank, groupings and Table 1 for scientific names. (Because transect lengths

	I: Shallow rock and cobble												
Habitat:	IA: Rock										IB: Cobble		
Depth (m):	67-85	67-85	67-85	72-76	72-76	72-76	104-107	104-107	149	149	145	122-145	122-145
Species / Drive-transect:	2A	2B	2C	9A	9B	9C	12A	12B	15A	15B	11B	11C	11A
Rosethorn RF	25	5	2	37	16	44	24	31	31	12	37	12	28
Yelloweye RF	6				1	3			1		5	3	3
Lingcod	5			1	1	4	1					1	
Small RF	3	2		7		11	12	3	825	30	1	1	
Pigmey RF									126				
Ratfish	2						4						
Sanddab	1												
Cottidae		12	6	3			4	10			1		
Greenstriped RF		3	8				15	4		2			1
Zoarcidae		2	1	19	1		1				2	5	4
Canary RF		2		2					1		3	2	7
Yellowtail RF		2		2	5	5							
Kelp greenling	8	2		1	6	3					1	1	
Wolf-eel		1											
Large RF						2	1	2	4	3	21	5	
Longnose skate						1			1		1	1	1
Sharpchin RF							3	2	751	85	4	6	9
Hagfish							3	4	3				1
Dover sole			1				7	3	1	2			
Redbanded RF									1				
Darkblotched RF				7								4	
Splitnose RF				1							3		
Tiger RF				1								1	
Big skate			1										2
Bathymasteridae								8					
Blenniidae							8						
Stripetail RF											1		
Agonidae												1	
Rajidae													3
Rex sole													1
Flatfish													
Thornyhead													
Arrowtooth Fl													
English sole													
Slender sole													
Pacific hake													
Sablefish													
Ragfish													
Sand sole													
No. fish types	7	9	6	11	6	8	12	9	11	6	12	13	11
No. fish/100 m^2	3.0	4.4	2.2	4.8	3.4	3.6	4.6	6.2	130	14	9.5	5.6	1.5

These schools frequently occurred at the shallowest depths (<85 m) over rugged, rocky topography. Including transects where no schools were seen, the median and mean numbers, respectively, of small schooling rockfishes observed were 750 and 831 at depths <85 m, and 0 and 9.4 at depths >85 m. These schools, usually encountered about a meter off the bottom, often dove toward the bottom when alarmed by the submersible, with individuals dispersing into crevices, rubble, or among the stalks of large anemones.

23-31 August 1987. See Figure 3 for cluster analysis of habitat varied, we compared relative abundances among dives.)

	II: Deep mud and cobble							
Habitat:	IIA: Cobble		IIB: Mud					
Depth (m):	185-220	140-148	244	244	164-222	164-222	290-299	290-299
Species / Drive-transect:	3C	14	5A	5B	6B	6A	8A	8B
Rosethorn RF	27	21						
Yelloweye RF	1					1		
Lingcod			1					
Small RF		3	1		2			
Pigmey RF								
Ratfish			1			1	1	3
Sanddab								
Cottidae	16	17	5				3	
Greenstriped RF	1	21						
Zoarcidae	9	14	14	20	53	8	4	6
Canary RF		1						1
Yellowtail RF	2							
Kelp greenling								
Wolf-eel								
Large RF	5	4			2			
Longnose skate		2			1			1
Sharpchin RF	9		9		1	8	1	
Hagfish			1	1	1	14	7	5
Dover sole	11	29	8	3	10	4	6	12
Redbanded RF	1	1	4					
Darkblotched RF	1							
Splitnose RF		21	1	6				
Tiger RF								
Big skate			1					
Bathymasteridae								
Blenniidae								
Stripetail RF								
Agonidae	1	1	6	51	4	2	1	
Rajidae			1	1		1	1	3
Rex sole	4	2	8	9	4			2
Flatfish	10	3	8	13	2	5	1	1
Thornyhead	1		22				6	4
Arrowtooth Fl	1		1		4			
English sole		4				1	2	
Slender sole		2	2	13	16	65		1
Pacific hake			4					
Sablefish			4	1	2	1	65	67
Ragfish			1					
Sand sole			1					
No. fish types	16	16	22	10	13	12	12	12
No. fish/100 m^2	1.0	6.8	58	5.2	2.6	4.4	7.3	5.5

Solitary Benthic Rockfishes

We saw solitary benthic rockfishes on all dives. The rosethorn rockfish (10–15 cm in length) was the most ubiquitous of all fishes observed on our dives. They were seen on all dives between 67 and 305 m, except the two dives over mud bottom, and ranked first in abundance on 10 of 21 transects (Table 2). They usually occurred singly, resting on soft sediments near rocks, on flat rocks, and occasionally in the depressions of vase sponges. Shortspine thornyheads, *Sebasto-*

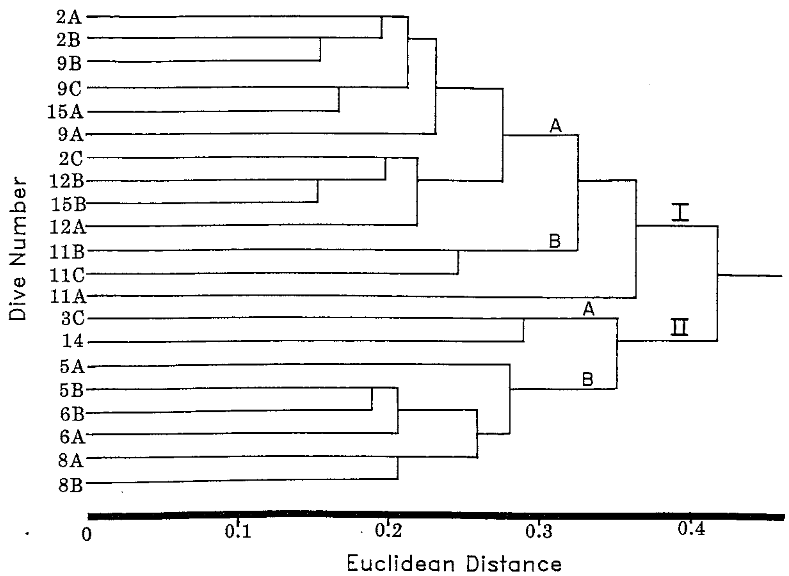

FIGURE 3.—Dendogram showing results of cluster analysis based on presence/absence of fish species from 21 transects. Dive numbers are shown along Y-axis and Euclidian distance along the X-axis. Roman numerals indicate the two major habitat groups and letters indicate subgroups (see Table 2).

lobus alascanus, and greenstriped rockfishes were usually in deep water on mud bottoms and in shallow water on mud or rocky bottoms, respectively (Tables 2, 3). Often thornyheads rested in shallow depressions in the bottom.

Largest concentrations of small- and intermediate-sized benthic rockfishes were seen during a dive at 149 m over rock (15A). Most of these were tentatively identified as sharpchin and pygmy, *S. wilsoni*, rockfishes. Their mean density on this transect was about 1.3/m^2 (Table 2). Pygmy; sharpchin; and Puget Sound, *S. emphaeus*, rockfishes were collected on this dive (Table 3). On another dive (not shown in Table 2), the densities of these small benthic rockfishes in areas of flat rocks, ledges, and cobble were as high as 5–10/m^2 at depths of 120–140 m. These fishes rested among rocks and ledges on the bottom but also swam one or two meters off the bottom. When frightened they often retreated into crevices and under rocks.

Large Schooling Rockfishes

Schools of large (30–50 cm) rockfishes were seen on five of the dives where bottom depths were less than 150 m. No schools of large rockfishes were seen in deeper water. These shallow-water schools were predominantly of yellowtail rockfish and occasionally of canary rockfishes. Other than an occasional canary or

TABLE 3.—List of fishes (standard lengths in mm) collected with the slurp gun during five Mermaid dives onto Heceta Bank in August 1987.

Dive 3	
Slender sole	*Lyopsetta exilis* (186, 129)
Smootheye poacher	*Xeneretmus leiops* (170)
Dive 4	
Splitnose rockfish	*Sebastes diploproa* (181)
Bigeye starsnout poacher	*Bathyagonus pentacantha* (186)
Dive 6	
Rosethorn rockfish	*Sebastes helvomaculatus* (162)
Sharpchin rockfish	*Sebastes zacentrus* (132)
Dive 8	
Blacktail snailfish	*Careproctus melanurus* (227)
Dive 15	
Threadfin sculpin	*Icelinus filamentosus* (162)
Spotted cusk-eel	*Chilara taylori* (263)
Thornback sculpin	*Paricelinus hopliticus* (156)
Pygmy rockfish	*Sebastes wilsoni* (179, 148, 141, 136, 129, 117)
Sharpchin rockfish	*Sebastes zacentrus* (132, 92, 82)
Puget Sound rockfish	*Sebastes emphaeus* (101)

[2]These fish had two white stripes, one above and one below the lateral line, with reddish pigmentation over the rest of the body.

yellowtail rockfish in a school of similar-sized yellowtail rockfish, all schools were comprised of fish of one species, all about the same size. Observers in the submersible sometimes located schools where echo-groups, probably caused by aggregations of large schooling rockfishes, were recorded by the surface vessel's echosounder. The sound scatterers were often prominent as spires close to topographic pinnacles or elevated rocky outcrops.

Yellowtail rockfish schools were attracted to and followed the submersible on several dives. On one dive, a school of 500–1000 fish stayed near the submersible for over an hour. The school either followed the submersible, or circled when it stopped, before abruptly turning away. Individual fish were usually 3–4 body lengths apart and could be clearly seen with ambient light at a depth of about 100 m. When the submersible lights were turned on, fish sometimes "flinched" but did not swim away. On another dive, a school of several hundred yellowtail rockfish were encountered while the submersible descended; they remained in view most of the way to the bottom. At first they actively swam downward, but at 100 m they passively sank, oriented head-down. When the thrusters were turned on, this school disappeared, but once the submersible was on the bottom, the school approached and swam around the submersible.

Large Near-Bottom Rockfishes

The best example of this category is the yelloweye rockfish. Large individuals of this species were seen in shallow water swimming above rock or cobble. Canary and yellowtail rockfishes, though more pelagic, sometimes were seen singly near the bottom. Although large rockfish usually were not resting on the bottom, yellowtail, splitnose (*S. diploproa* >30 cm), yelloweye, greenspotted (*S. chlorostictus*), and tiger (*S. nigrocinctus*) were observed doing so occasionally.

Rockfish Coloration. Splitnose rockfish sometimes changed color dramatically during and after collection. In situ, most individuals had strikingly red and white vertical bars extending almost to the ventral surface, but one that was chased blanched to almost all white. Another (181 mm SL) that was captured had lost its prominent white bars at the surface, appearing a dull red overall as shown in Eschmeyer et al. (1983). Straty (1987) also noted dramatic changes in the coloration of juvenile rockfishes in sita and after they were examined at the surface.

The yellowtail rockfish we observed had 3–5 very vivid large white spots above the lateral line. These spots faded to indistinct pale spots on live yellowtail brought to the surface by hook and line. The white spots on rosethorn rockfish were also less prominent on fish captured and brought to the surface than on those seen in situ.

Fishes Collected

In addition to several large benthic invertebrates, we collected 21 individuals and 12 species of fishes using the slurp gun (Table 3). Six species of rockfishes were also captured using hook and line from the support vessel: yellowtail, canary, yelloweye, rosethorn, greenspotted, and the bank (*S. rufus*) rockfishes. The last fish was not identified from the submersible. The liparidid *Careproctus melanurus* was also seen on several dives (but not during transects) and was collected by slurp gun.

DISCUSSION

The diverse physical habitats encountered during our dives correlated with differences in the species composition and abundances of fishes. Two species groups were identified: one primarily comprised of rockfishes in shallow water on rock and cobble, and one that included zoarcids, several species of flatfishes, agonids, and sablefish in deep water mostly over soft substrates. Greenstriped and splitnose rockfishes and shortspine thornyheads were most common over soft substrates, whereas most other scorpaenids were seen most frequently in rocky habitats in shallow water. Richards (1986) also noted that greenstriped rockfish were most abundant over fine-sediment habitats in the Strait of Georgia, British Columbia, whereas yelloweye rockfish preferred rock wall and more complex habitats at shallower depths.

Most species were broadly distributed (Table 2). There was much overlap in species distributions, and species associations were indistinct. Habitat type and depth varied together, however, with rock habitat occurring predominantly in shallow water and mud in deep water. Although cobble habitats were identified at two depths, these data were inadequate for examining bathymetric segregation of rockfish species within habitat types, as has been documented for certain shallow-water species (Larson 1980; Hallacher and Roberts 1985).

Heceta Bank, and probably other rocky banks off the Pacific Northwest and Southeast Alaska, appear to be important juvenile nursery areas for rockfishes. Dense schools of pelagic juveniles and adult yellowtail rockfishes were observed only over the rocky, high-relief areas on the top of the bank, and high densities of benthic juveniles were found only on the flanks of the bank and not in deeper waters of the bank (Table 2). Straty (1987) and Carlson and Straty (1981) observed large schools of young rockfish near rocky pinnacles and boulder fields at depths <171 m off southeastern Alaska, and concluded that these areas were nursery grounds for rockfish. They collected specimens of Pacific ocean perch, *S. alutus*; sharpchin, pygmy, and Puget Sound rockfishes; and shortspine thornyheads on the bottom, species (with the exception of *S. alutus*) that we captured on Heceta Bank (Table 3).

Some of our submersible dives were close to locations previously sampled by trawl surveys of the Oregon Department of Fish and Wildlife (ODFW) (Barss et al. 1982). In the ODFW surveys, commercial trawls designed for catching rockfishes on rough terrain (Atlantic Western and Box Mystic trawls) were used with roller gear to keep the footrope off the bottom. The cod end of these nets was usually made of 11.4 cm mesh. During 1980–81, a total of 27 tows were made between 132 and 210 m, within about 4 km of Dive Site 11 (145 m) (Fig. 2).

Fish assemblages in trawl catches and in submersible observations from adjacent areas differed. Only 8 of the 25 trawl-caught species were seen from the submersible on Dive 11, and 7 of the species observed during the dive were not caught in trawls (Table 4). Five species of rockfishes, however, were among the most numerous 11 species by both methods. *Sebastes pinniger* dominated trawl catches by number and weight (comprising 88% of the total weight of the catches), but it was not seen many times from the submersible.

TABLE 4.—Composition of fishes by percentage calculated from numbers during submersible dives and caught in trawls from the same general area near Heceta Bank. The weight of individual species caught in trawl catches were converted to numbers of a species by dividing by the average weight of individuals.

Dive 11		Bottom trawl	
%	Species	%	Species
30.1	Schooling *Sebastes* spp.	76.2	*Sebaster pinniger*
29.4	*Sebastes helvomaculatus*	10.1	*Sebastes zacentrus*
10.7	*Sebastes* unidentified	2.5	*Sebastes flavidus*
7.2	*Sebastes zacentrus*	2.1	*Sebastes helvomaculatus*
4.6	*Sebastes pinniger*	1.5	*Merluccius productus*
4.2	*Sebastes ruberrimus*	1.2	*Ophiodon elongatus*
4.2	Zoarcidae	1.2	*Sebastes jordani*
1.5	*Sebastes crameri*	1.0	*Sebastes elongatus*
1.1	Rajidae	1.0	*Sebastes proriger*
1.1	*Sebastes diploproa*	0.6	*Sebastes brevispinnis*
1.1	*Raja rhina*	0.4	*Squalus acanthias*
0.8	*Hexagrammos decagrammus*	0.4	*Anoplopoma fimbria*
0.8	*Raja binoculata*	0.4	*Trachurus symmetricus*
0.4	*Sebastes elongatus*	0.3	*Hydrolagus colliei*
0.4	*Ophiodon elongatus*	0.2	*Sebastes ruberrimus*
0.4	Cottidae	0.2	*Sebastes paucispinis*
0.4	*Sebastes nigrocinctus*	0.2	*Microstopmus pacificus*
0.4	*Sebastes saxicola*	0.1	*Hippoglossus stenolepis*
0.4	*Eptatretus stouti*	0.1	*Parophrys vetulus*
0.4	Agonidae	0.1	*Glyptocephalus zachirus*
0.4	*Glyptocephalus zachirus*	0.1	*Sebastes entomelas*
		<0.1	*Oncorhynchus tshawytscha*
		<0.1	*Eopsetta jordani*
		<0.1	*Raja rhina*
		<0.1	*Atheresthes stomias*

Both of the assessment methods have biases, and differences between them are to be expected. The trawls were designed to avoid contact with the bottom and sampled a large volume of water at a greater distance above the seafloor and retained mostly large fishes, whereas the submersible was most effective for surveying small fishes on or close to the seafloor. Most large pelagic fishes probably avoided the submersible. Although yellowtail rockfish were attracted to the submersible, only a small fraction of the individuals in schools were visible from the viewing port. Differences in sampling locations and times undoubtedly contributed to differences in species composition. Thus quantitative surveys from submersibles appear to be most useful for assessing fishes closely associated with the sea floor, for comparing relative abundances among habitats, and for studying fine-scale distributions of fishes.

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LITERATURE CITED

Barss, W. H., S. L. Johnson, and R. L. Demory.
1982. Biological studies on rockfish and associated species from Heceta Bank off Oregon, 1980–1981. Oreg. Dep. Fish Wildl. Completion Rep. Project 1-151-R2, 28 p. Contract 81-ABD-ORAC, NMFS, NOAA, U.S. Dep. Commer. Fish. Res. Devel. Act.

Carlson, H. R., and R. R. Straty.
1981. Habitat and nursery grounds of Pacific rockfish, *Sebastes* spp., in rocky coastal areas of southeastern Alaska. Mar. Fish. Rev. 43(7):13–19.

Eschmeyer, W. N., E. S. Herald, and H. Hammann.
1983. A field guide to Pacific coast fishes of North America. Houghton Mifflin Co., Boston, 336 p.

Gunderson, D. R., and T. M. Sample.
1980. Distribution and abundance of rockfish off Washington, Oregon and California during 1977. Mar. Fish. Rev. 42(3–4):2–16.

Hallacher, L. E., and D. A. Roberts.
1985. Differential utilization of space and food by the inshore rockfishes (Scorpaenidae: *Sebastes*) of Carmel Bay, California. Environ. Biol. Fishes 12:91–110.

Isaacs, J. D., and R. A. Schwartzlose.
1965. Migrant sound scatterers: Interaction with sea floor. Science 150:1810–1813.

Kulm, L. D., and G. A. Fowler.
1974. Oregon continental margin structural and stratigraphy: a test of the imbricate thrust model. *In* C. A. Burk and C. L. Drake (editors), The geology of continental margins, p. 261–283. Springer-Verlag, N.Y.

Larson, R. J.
1980. Competition, habitat selection, and bathymetric segregation of two rockfish (*Sebastes*) species. Ecol. Monogr. 50:221–239.

Pimentel, R. A.
1979. Morphometrics, the multivariate analysis of biological data. Kendall-Hunt, Dubuque, IA, 276 p.

Richards, L. J.
1986. Depth and habitat distribution of three species of rockfish (*Sebastes*) in British Columbia: observations from the submersible PISCES IV. Environ. Biol. Fishes 17:13–21.

Straty, R. R.
1987. Habitat and behavior of juvenile Pacific rockfish (*Sebastes* spp. and *Sebastolobus alascanus*) off southeastern Alaska. NOAA Symp. Ser. Undersea Res. 2(2):111–125.

Uchida, R. N., and D. T. Tagami.
1985. Groundfish fisheries and research in the vicinity of seamounts in the North Pacific Ocean. Mar. Fish. Rev. 46(2):1–17.

Uchida, R. N., S. Hayasi, and G. W. Boehlert.
1986. Environment and resources of seamounts in the North Pacific. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 43, 105 p.

Uda, M., and M. Ishino.
1958. Enrichment pattern resulting from eddy systems in relations to fishing grounds. J. Tokyo Univ. Fish. 44:105–109.

Weinberg, K. L., M. E. Wilkins, and T. A. Dark.
1984. The 1983 Pacific west coast bottom trawl survey of groundfish resources: estimates of distribution, abundance, age and length composition. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/NWC-70, 376 p.