Distribution and abundance of shortraker rockfish, *Sebastes borealis*, and rougheye rockfish, *S. aleutianus*, determined from a manned submersible

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Abstract.–A manned submersible was used in the eastern Gulf of Alaska in 1992 to observe spatial distributions and habitats of shortraker rockfish, *Sebastes borealis*, and rougheye rockfish, *S. aleutianus*, on the continental slope at 262–365 m depths. Observations of these two species were combined because distinguishing between them was not always possible from the submersible. A seafloor area of 104,900 m^2 was surveyed at 15 dive sites, and 646 shortraker and rougheye rockfish were observed. Densities were 0.0 to 14.8 rockfish/1000 m^2 (mean, 5.8 rockfish/1000 m^2). Of the 646 rockfish, 115 were observed above bottom and 531 were on the bottom. The above-bottom rockfish were descending slowly to the seafloor and became sedentary when they contacted the seafloor. Approximately two-thirds of the rockfish were in groups; 82 of the 113 groups contained 2 or 3 rockfish, and only 2 groups had more than 12 rockfish. Rockfish were associated with 20 of the 22 substrates encountered. Soft substrates of sand or mud usually had the greatest densities of rockfish, whereas hard substrates of bedrock, cobble, or pebble usually had the least densities. Habitats containing steep slopes and numerous boulders had greater densities of rockfish than habitats with gradual slopes and few boulders; 52 rockfish lay against boulders. According to catch rates from bottom-trawl surveys, populations of shortraker and rougheye rockfish may be underestimated because of the above-bottom distribution of these rockfish and their use of steep-slope boulder habitats.

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Shortraker rockfish, *Sebastes borealis*, and rougheye rockfish, *S. aleutianus*, occur in commercial quantities from northern Washington throughout Alaska (Allen and Smith, 1988). Both species are similar in appearance and share similar life-history patterns. These rockfish attain maximum total lengths of about 100 cm (Kramer and O'Connell, 1986) and have been aged at more than 120 years (Chilton and Beamish, 1982). Their bathymetric range is 25–875 m (Allen and Smith, 1988), and their lengths at 50% maturity are 43.97 cm for rougheye rockfish and 44.90 cm for shortraker rockfish (McDermott, 1994). They apparently share similar habitats. During the 1996 Gulf of Alaska triennial survey, 89% of the trawl hauls containing shortraker rockfish also contained rougheye rockfish.

Shortraker and rougheye rockfish are harvested with bottom trawls and longlines in the Gulf of Alaska. Until the mid 1980s, they were mainly bycatch species caught during longlining for halibut, *Hippoglossus stenolepis*, and sablefish, *Anoplopoma fimbria*, and during bottom trawling for more abundant rockfish species. Before 1991, shortraker and rougheye rockfish were combined with 18 other rockfish species and managed as "slope rockfish." Since 1991, shortraker and rougheye rockfish have been managed as a separate subgroup because fishermen target these highly valued species. For example, shortraker and rougheye rockfish made up 33% of the commercial rockfish catch in the eastern Gulf of Alaska in 1990 but made up only 14% of the estimated rockfish biomass (Heifetz and Clausen, 1991). Catch quotas of shortraker and rougheye rockfish are based primarily on population estimates derived from catch rates of bottom-trawl surveys (Heifetz et al., 1996). These estimates are suspect because the catch efficiency of bottom trawls on these species is unknown and only certain types of habitats can be sampled with bottom trawls.

Catch rates from bottom-trawl surveys are converted to biomass estimates by assuming a 100% sampling efficiency for the area swept by the trawl. The area that is swept is determined as the distance between the wingtips of the net and the distance the net is towed. The sampling efficiency could be less than 100% if fish are distributed above the headrope, protected by structures such as boulders, swim out of the path of the net, or escape under the net. Conversely, if fish are herded into the trawl by the bridles and doors and do not escape above or under the net, the sampling efficiency may be greater than 100%. Typically, smooth (trawlable) substrates are sampled during trawl surveys. Catch rates from trawlable substrates are then applied to all substrates for estimating biomass. Bottom-trawl surveys may not provide reliable biomass estimates of shortraker and rougheye rockfish because 1) the sampling efficiency may not be 100% for the distance between the wingtips of the net, 2) these species may use untrawlable substrates at a different rate than they do trawlable substrates, and 3) the sampling frequency may not be sufficient, depending on the distribution patterns of the target species.

Minimal information is available on the distribution of shortraker and rougheye rockfish. Fishermen report that rockfish school above bottom in steep-slope areas. From a manned submersible Krieger (1992) observed 20 shortraker rockfish on the continental shelf; these fish were in contact with the seafloor and were distributed as solitary individuals on shallow-sloped, smooth habitat. Shortraker rockfish were observed only at sites where boulders were common, and six of the fish were found next to boulders 0.5–1.5 m in diameter (Krieger, 1992). Catches of shortraker and rougheye rockfish during longline surveys indicate they are most abundant on the upper continental slope at 300–400 m depths (Sigler and Zenger, 1994), but most of this substrate is considered untrawlable and is seldom sampled during bottom-trawl surveys. For example, only eight trawl hauls were completed along the 500-km continental slope in southeastern Alaska during the last four bottom-trawl surveys (1987, 1990, 1993, 1996).

We need to understand the distribution and habitats of shortraker and rougheye rockfish to assess them effectively with bottom trawls or other sampling gear. In this study, a manned submersible was used to observe their spatial distributions and habitat associations. These species were also quantified from the submersible for comparison with abundance estimates from bottom-trawl surveys. The two species were combined and are referred to as rockfish in this paper because distinguishing between them was not always possible from the submersible.

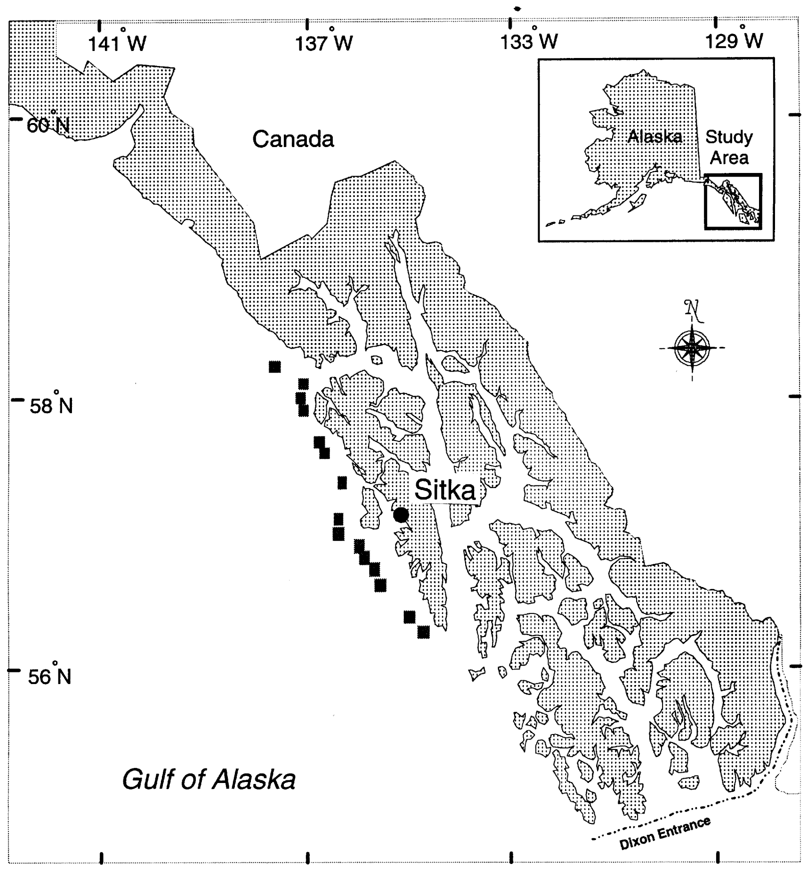

Figure 1

Submersible survey sites for shortraker and rougheye rockfish in the eastern Gulf of Alaska in May 1992.

Materials and methods

Study area

This study was conducted in May 1992 on the upper continental slope in the eastern Gulf of Alaska between lat. 56°10' and 58°10'N (Fig. 1). This region has consistently produced high catch rates of shortraker and rougheye rockfish during the annual longline surveys in the Gulf of Alaska (Rutecki et al., 1997). The study area spanned more than 200 km to include a variety of habitats. Distances separating adjacent sites ranged from 0.2 to 84.2 km. Dives were conducted during daylight, between 0600 and 1900 hours.

Submersible

The two-man submersible *Delta* was chartered for all dives. This battery-powered submersible is 4.7 m long, dives to 365 m, and travels 2–6 km/h for 2–4 h. It is equipped with halogen lights, internal and external video cameras, magnetic compass, directional gyro compass, underwater telephone, and transponder that allow tracking of the submersible from a surface vessel. On each dive, the submersible descended to 265–365 m and then usually traveled parallel to the shelf break, followed by up-slope travel to less than 300 m before it ascended. The surface vessel recorded LORAN fixes at the beginning and end of a dive, and every 1–5 min during a dive. The submersible traveled 1.0–2.5 km/h, depending on the slope and ruggedness of the terrain and the magnitude and direction of the current. The degree of slope determined how observations were made from the submersible. When the slope was less than 60°, the submersible remained in contact with the seafloor while the scientist viewed the water column parallel to the seafloor through a starboard porthole 0.5 m above the base of the submersible. When the slope was greater than 60°, the submersible traveled 2–3 m away from the seafloor while the scientist viewed the water column almost perpendicular to the seafloor through portholes on the starboard side and bow. The pilot sat above the observer in a tower with a panoramic view and assisted in locating fish, especially above the submersible. The submersible lights provided constant illumination.

Data analysis

Observations of rockfish and their habitat were audiotape- and videotape-recorded for subsequent analysis and verification. The senior author reviewed all video tapes by 1-min segments (16–42 m travel distances), and four habitat parameters were estimated: 1) main substrate, 2) secondary substrate, 3) slope, and 4) boulder abundance. The main substrate made up 50–100% of the substrate, whereas the secondary substrate made up 10–50% of the substrate. Substrates consisted of mud, sand, pebble, cobble, and bedrock. Granular size used to separate pebble and cobble was 2.5 inches (64 mm), and to separate cobble and boulders was 10 inches (256 mm). Mud would stay suspended when disturbed by the submersible, whereas sand would not. Size references for classifying pebble, cobble, and boulders included the known length and width of a video frame as well as the known, uniform size of invertebrates such as sea stars and shrimp. The slope was classified into four categories: 1 = 0–5°, 2 = 6–20°, 3 = 21–45°, and 4 = 46–90°. Slope classification was based on estimates by the pilot and on the view from a downward-aimed, mounted video camera. Boulder abundance was classified into five categories: 0 = absent, 1 = scarce, 2 = scattered patches, 3 = common (usually in view), and 4 = abundant (always in view). For each site, we calculated the average slope, average boulder abundance, and the densities of rockfish associated with each substrate. For all sites combined, we calculated rockfish densities associated with each substrate, and the percentage of rockfish associated with each slope category and each boulder category.

Rockfish observations included number, size, grouping behavior, above-bottom distribution, and movements. Three sizes of rockfish were estimated visually: small (<30 cm), medium (30–60 cm), and large (>60 cm). The observers had used laser beams to measure rockfish lengths from submersibles and were, therefore, experienced in sizing them. Rockfish were considered grouped if they were within 5 m of each other. Densities were estimated from counts of rockfish and the total seafloor area surveyed. The surveyed area was the distance the submersible traveled (0.3–1.8 km/dive) multiplied by the estimated viewing distance from the submersible (4–10 m, depending on water clarity). These estimates were calibrated against sonar readouts when the seafloor became visible during descents and when the seafloor disappeared from view during ascents. Estimated distances were within 1 m of true distances according to sonar readouts and distance calibrations in previous studies (Krieger, 1993). Rockfish movement rates were based on the estimated distance moved during a specific time period.

Results

Submersible dives

Fifteen submersible dives were completed and 104,900 m^2 of seafloor was surveyed at 262–365 m depths (Table 1). Rockfish densities ranged from 1.2 to 14.8 rockfish/1000 m^2 (mean, 5.8/1000 m^2) at the 14 sites where they were observed. Of the 646 rockfish observed, 188 were small, 289 medium, and 169 large.

Above-bottom and on-the-bottom behavior

We observed 115 rockfish 1–10 m above bottom and 531 on the bottom (Table 2). Sites 5 (80 above-bottom rockfish) and 13 (19 above-bottom rockfish) accounted for 86% of the above-bottom rockfish. Above-bottom rockfish were medium-size (108 rockfish) or large (7 rockfish), and they were observed descending at less than 10 m/min without detectable movements of fins or body. They would contact the seafloor without disturbing sediments and would orient broadside to the current, which would tilt them 10–45° (Fig. 2). Currents were less than 1.0 km/h at all sites.

Table 1

Number and density of shortraker and rougheye rockfish at 15 submersible dive sites in the eastern Gulf of Alaska, 1992. Small = <30 cm; Medium = 30–60 cm; Large = >60 cm.

Site	Depth (m)	Surveyed area (1000 m^2)	Number of rockfish				Density of rockfish (no./1000 m^2)
			Total	Small	Medium	Large	
1	365–262	8.1	25	16	7	2	3.1
2	323–270	1.8	0	0	0	0	0.0
3	346–285	3.5	21	10	6	5	6.0
4	362–262	10.1	60	30	26	4	5.9
5	365–292	13.0	192	24	165	3	14.8
6	365–270	7.9	43	16	19	8	5.4
7	365–270	4.0	5	3	0	2	1.2
8	365–275	7.5	45	7	9	29	6.0
9	365–300	13.5	16	0	3	13	1.2
10	365–270	1.7	21	10	6	5	12.4
11	365–304	7.3	64	28	15	21	8.8
12	365–280	2.0	17	3	3	11	8.5
13	365–320	16.3	98	29	23	46	6.0
14	365–288	5.8	34	9	5	20	5.9
15	365–285	2.4	5	3	2	0	2.1
Totals		104.9	646	188	289	169	

Table 2

The number of shortraker and rougheye rockfish observed on the bottom, above bottom, solitary, and grouped, and their distribution by group size at 15 submersible dive sites in the eastern Gulf of Alaska, 1992.

Site	Fish on bottom	Fish above bottom	Solitary fish	No. of fish in groups	No. of groups	Group size													
						2	3	4	5	6	7	8	9	10	11	12	—	15	32
1	24	1	15	10	4	2	2												
2	0	0	0	0	0														
3	21	0	14	7	2	1			1										
4	59	1	30	30	11	6	3	1	1										
5	112	80	35	157	27	9	6	2	3	1				1	1	2		1	1
6	42	1	19	24	9	6	2			1									
7	5	0	5	0	0														
8	39	6	10	35	10	4	4			1			1						
9	15	1	9	7	3	2	1												
10	21	0	6	15	6	3	3												
11	62	2	37	27	11	8	1	2											
12	17	0	7	10	3	1		2											
13	79	19	21	77	22	13	1	3	1	1		2	1						
14	30	4	22	12	5	4		1											
15	5	0	5	0	0														
Totals	531	115	235	411	113	59	23	11	6	4	0	2	2	1	1	2		1	1

Of the 531 rockfish on the bottom, only 21 moved when passed or approached by the submersible; 5 moved 0.5–1.0 m above the seafloor and swam less than 5 m away at a speed of less than 1 km/h, and 16 moved less than 2 m along the seafloor by drifting or by slight movements of fins. The submersible drifted against several large rockfish, which did not respond as they were pushed along the seafloor.

Figure 2

Shortraker or rougheye rockfish tilted with the current while lying on the seafloor in the eastern Gulf of Alaska in May 1992. Observed from a submersible.

Spatial distribution

Of the 115 above-bottom rockfish, 106 were grouped with at least one other rockfish as they descended together to the seafloor. They contacted the seafloor within 5 m of at least one other rockfish in the group. Because these fish maintained a <5-m spacing from each other, all rockfish within 5 m of other rockfish on the seafloor were considered grouped. Twelve sites had 411 grouped fish, and 14 sites had 235 solitary fish (Table 2). Most groups were small; 82 of the 113 groups contained only 2 or 3 rockfish, whereas only two groups contained more than 12 rockfish. Twenty-six pairs of rockfish consisted of a small and medium-size fish separated by less than 0.5 m.

Substrate associations

Twenty-two combinations of primary and secondary substrates were encountered at the 15 sites (Table 3). Substrates changed frequently within each site, averaging 6.9 substrates/site. Rockfish were associated with 20 of the substrates, but no consistent pattern of association was observed within a site. For example, the 8 greatest densities (>16 rockfish/1000 m^2) included 7 different substrates, the 23 lowest densities (no rockfish) included 13 different substrates, and 3 substrates had both more than 16 rockfish/1000 m^2 and no rockfish.

For all sites combined, the most abundant substrate was cobble with sand (17.3%), whereas 7 of the 22 substrates made up 1.0% or less each of the total substrate (Table 4). The greatest densities of rockfish were usually associated with soft substrates. Sand with mud had the greatest average density (9.1 rockfish/1000 m^2), and 7 of the 10 greatest densities were associated with primary substrates of sand or mud. Nine of the 12 lowest densities of rockfish were associated with primary substrates of cobble, rock, or pebble.

Boulder and slope associations

Average boulder indices ranged from 0.0 to 2.1 (Table 3) and were not highly correlated (r=0.30) with rockfish densities. For all sites combined, high-abundance boulder habitat contained greater densities of rockfish than did low-abundance boulder habitat (Fig. 3). Habitats where boulders were absent (index=1) or rare (index=2) were encountered 67% of the time and had 56% of the rockfish, whereas habitats where boulders were more abundant (index=3, 4, or 5) were encountered 33% of the time and had 44% of the rockfish; 52 rockfish were found lying against boulders (Fig. 4). The only site without boulders (site 2) was the only site not containing rockfish.

Average slope indices ranged from 0.9 to 3.7 and were not highly correlated (r=0.56) with rockfish

Table 3

Densities of shortraker and rougheye rockfish associated with specific substrates at 15 submersible dive sites in southeastern Alaska, 1992, and indexes of boulder abundance and topography (slope). Indexes are averages of 1-min video segments, where boulders were absent (0), rare (1), scattered patches (2), common (3), or abundant (4), and slopes were 0–5° (1), 5–20° (2), 20–45° (3), or 45–90° (4). M = mud; S = sand; C = cobble; P = pebble; R = rock; M-S = mud and sand; M-C = mud and cobble, etc.

	Boul-der	Slope	Rockfish densities (no./1000 m^2) and associated substrates																					
Site	index	index	M	M-S	M-C	M-P	M-R	S	S-M	S-C	S-P	S-R	P-S	P-M	P-C	C	C-S	C-M	C-P	C-R	R	R-S	R-M	R/P
1	1.1	2.0						3.1		3.1	2.1		4.1		3.1	3.1	2.1		2.2					
2	0.0	2.0								0.0			0.0		0.0		0.0		0.0					
3	0.7	3.0			4.0	12.8				12.0	8.0				0.0		1.0		0.0					
4	1.1	3.0	0.0	11.8		12.8	0.8		3.0	5.9	8.9		7.9	9.6			4.9							
5	1.7	2.9		5.1				22.3	70.9	9.7							16.9							
6	1.2	3.5	0.0		8.7	4.0				1.9			13.0		5.8		5.8	0.0	0.0			17.3	6.7	2.9
7	1.6	2.0									0.8		3.2	1.1					0.8					
8	2.1	2.0	3.0			0.0		6.5	6.0	6.0	7.4						0.0							
9	0.8	0.9	1.0		1.3	3.9							1.6	0.0	0.5		1.1	0.0	0.0	0.0				
10	0.4	3.7		13.7						25.1							0.0							
11	0.7	3.7		6.5	25.8	12.9				0.0	6.5		9.0		3.2		17.7		6.5					
12	1.1	3.0															11.7		7.6					
13	1.7	3.2						14.0		3.0	5.4		6.0		5.5		9.5		7.5		3.0	3.0		3.0
14	1.9	2.9								11.7	28.0	1.7				0.0	4.9					5.9		
15	1.2	2.4						0.0		4.5		0.0					4.5			0.0		4.5		

densities (Table 3). For all sites combined, habitats with slopes greater than 20° contained greater densities of rockfish than those with slopes less than 20° (Fig. 5). Slopes less than 20° were encountered 37% of the time and had 24% of the rockfish, whereas slopes greater than 20° were encountered 63% of the time and had 76% of the rockfish.

Submersible counts versus trawl catch rates

During the last four bottom-trawl surveys (1987, 1990, 1993, 1996), eight trawl hauls were completed on the continental slope in southeastern Alaska and 234,100 m^2 of seafloor was sampled. The mean catch rate was 3.2 rockfish/1000 m^2 for the 8 trawl hauls, compared with the mean observation rate of 5.8 rockfish/1000 m^2 at the 15 dive sites. Catch rates exceeded 5.0 rockfish/1000 m^2 at only 2 of the 8 trawl sites, whereas observation rates exceeded 5.0 rockfish/1000 m^2 at 10 of the 15 dive sites.

Discussion

Because the two rockfish species were combined in this study, we did not determine whether shortraker rockfish behavior differs from rougheye rockfish behavior. They appear to share the same habitats, based on bottom-trawl sampling and observations from the submersible, but differences may exist in

Table 4

The percentage of each seafloor substrate and density of shortraker and rougheye rockfish associated with each substrate observed during 15 submersible dives in southeastern Alaska, 1992.

Substrate type	Substrate (%)	Rockfish (no./1000 m^2)
sand-mud	1.0	19.1
cobble-sand	17.3	9.7
mud-cobble	1.7	9.3
sand	6.5	8.4
mud-pebble	5.0	7.0
sand-cobble	10.0	6.7
rock-mud	2.0	6.7
mud-sand	7.5	6.1
rock-sand	3.6	6.0
sand-pebble	10.5	5.5
pebble-mud	2.4	5.5
pebble-sand	11.5	3.7
cobble-pebble	7.7	3.5
rock	0.6	3.0
rock-pebble	1.0	3.0
pebble-cobble	6.0	2.5
cobble-rock	0.5	2.1
sand-rock	0.6	1.5
mud	2.1	0.9
mud-rock	1.1	0.8
cobble-mud	0.8	0.0
cobble	0.4	0.0

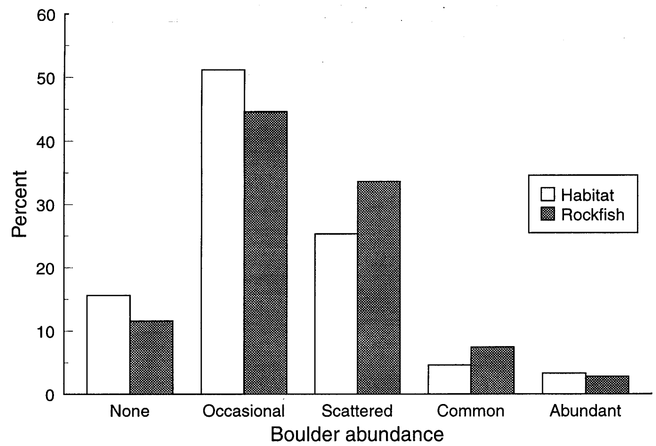

Figure 3

Five levels of boulder abundance observed on the seafloor, and the percent occurrence of habitat and percent occurrence of shortraker and rougheye rockfish associated with each level. Observations are from a submersible in the eastern Gulf of Alaska, 1992.

their above-bottom distributions, grouping behavior, and use of boulders.

The 150 rockfish observed above bottom were at nine different dive sites and all were descending, indicating they were reacting to the submersible. They were probably seeking the seafloor in response to the submersible. A diving response to trawl and vessel disturbances has been noted for other species of offshore rockfish (Kieser et al., 1992). The protection provided by the seafloor may explain their reluctance to move when they are on the seafloor and approached by the submersible. Assuming rockfish were descending in response to the submersible, the proportion of rockfish observed above bottom is probably a minimum estimate because some had probably reached the seafloor before they were viewed from the submersible. The 80 rockfish above bottom at site 5 indicate that a high percentage of rockfish move above the seafloor, although the frequency and duration of their movements are unknown. Rockfish may move above bottom to capture prey such as the squid and lantern fish (Myctophidae) on which they are known to feed (Yang, 1993, 1996). About two-thirds of the rockfish were in groups of 2–6 fish; only two groups contained more than 12 fish. The reason for the close pairing of a small and medium rockfish is unknown; it is probably not related to mating because female shortraker and rougheye rockfish shorter than 30 cm are not mature (McDermott, 1994).

The spatial distribution of rockfish varied within dive sites. This variability can be partially explained by their grouping behavior and by their habitat associations. Rockfish were associated with most of the habitats encountered, but the greatest densities were associated with soft substrates, frequent boulders, and slopes greater than 20°. Their association with soft substrates may be prey related. Pandalid shrimp and hippolytid shrimp, which concentrate on soft substrates, were the main prey of rougheye rockfish examined from the Gulf of Alaska (Yang, 1993, 1996) and from the Aleutian Islands (Yang, 1996). The association of rockfish with boulders in this study and on the continental shelf (Krieger, 1992) indicates that boulders are important for these species. Perhaps boulders are a necessary habitat feature, because shortraker and rougheye rockfish were absent at the one site without boulders in this study and at the three sites without boulders in a previous study (Krieger, 1992). These species may use boulders as territorial markers, to avoid currents, or to capture prey. Rockfish were least abundant on shallow-slope habitat (<5°) in this study, and Krieger (1992) observed shortraker rockfish at three sites where the slope was 3–12° but none at six sites with slopes less than 2°. Steep slopes may provide relief from currents.

The mean observation rate from the submersible was about twice the mean catch rate from bottom-trawl surveys, probably because of the limited habitats sampled during trawl surveys. Bottom trawling may be effective for sampling shortraker and rougheye rockfish on low-relief habitats because these rockfish descended and remained on the sea-

Figure 4

Observation from a submersible of a shortraker or rougheye rockfish lying against a boulder in the eastern Gulf of Alaska in May 1992.

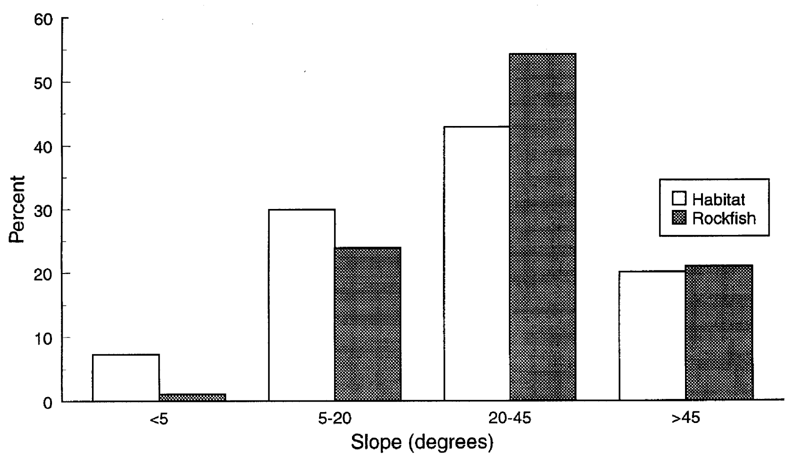

Figure 5

Four levels of slope observed on the seafloor, and the percent occurrence of habitat and percent occurrence of shortraker and rougheye rockfish associated with each level. Observations are from a submersible in the eastern Gulf of Alaska, 1992.

floor in response to the submersible. However, some above-bottom rockfish may not be captured because of their slow rates of descent. Bottom-trawl assessment gear is not designed to sample the steep-slope, boulder habitats occupied by these species, and the few trawl hauls that are completed in boulder habitat likely do not sample rockfish associated with boulders. An assessment method is needed that addresses the wide range of habitats, above-bottom distribution, and grouping behavior of shortraker and rougheye rockfish. Longline gear and bottom trawls with large rollers can sample rugged habitat, and studies are currently underway to determine the efficiency of these gears for sampling shortraker and rougheye rockfish.

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