Abstract.—A manned submersible was used in the eastern Gulf of Alaska to observe spatial distributions of Pacific ocean perch *Sebastes alutus* and other *Sebastes* spp., and count rockfish for comparison with bottom-trawl catch rates. Twenty submersible dives were completed in 1988 and 1989 at depths of 188–290 m. Approximately 80% of the 5317 rockfish observed from the submersible were Pacific ocean perch. Most adult Pacific ocean perch were in groups of 2–200 over flat, pebble substrate. Fish within a group were 1–4m apart, usually oriented into the current, and 0–7 m above bottom. Most juvenile Pacific ocean perch, and juveniles and adults of other *Sebastes* spp., were associated with rugged habitat (cobble, boulders, pinnacles, and coral). Densities of Pacific ocean perch estimated from bottom-trawl catches were approximately twice those observed from the submersible, indicating that the bridles and otter doors herded fish into the trawl. Bottom-trawl surveys may overestimate Pacific ocean perch abundance because of this possible herding effect and the preference of adult Pacific ocean perch for smooth (trawlable) substrate.

Manuscript accepted 29 September 1992.
Fishery Bulletin, U.S. 91:87-96 (1993).

Distribution and abundance of rockfish determined from a submersible and by bottom trawling

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Pacific ocean perch *Sebastes alutus* is a commercially important rockfish found along the North American coast from southern California to the Bering Sea, and along the Asiatic coast from Cape Navarin to the Kuril Islands (Balsiger et al. 1985). Primarily an offshore species that inhabits the outer continental shelf and upper slope regions, it is caught with bottom trawls at depths of 165–290 m (Hart 1973).

In the Gulf of Alaska, Pacific ocean perch were heavily exploited in the 1960s by the Soviet and Japanese trawl fleets. Foreign catches of rockfish (consisting mainly of Pacific ocean perch) peaked in the Gulf of Alaska in 1965 at 350,000 metric tons (t). By the late 1970s, rockfish catches had declined to less than 10,000 t, and catch-per-unit-effort (CPUE) had decreased by 80% (Balsiger et al. 1985). Domestic trawling replaced foreign trawling in the Gulf of Alaska in the 1980s. Although rockfish stocks remain depressed from overfishing, domestic rockfish catches (mainly Pacific ocean perch) have increased in the Gulf of Alaska from 1000 t in 1985 to 20,000 t in 1990 (Heifetz & Clausen 1990).

Reliable stock assessments are needed for managing depressed stocks of Pacific ocean perch. Current stock assessments, based primarily on catch rates from bottom-trawl surveys, are questionable because (1) the catch efficiency of bottom trawls on Pacific ocean perch is unknown, (2) Pacific ocean perch are not sampled in areas where the habitat is too rugged for bottom trawling, and (3) information is limited on Pacific ocean perch spatial distribution, migration, and off-bottom movement. Leaman & Nagtegaal (1986) noted their dissatisfaction with rockfish bottom-trawl surveys because of wide confidence intervals associated with the biomass estimates, and because alternate assessment techniques indicate that the estimates themselves may be grossly in error. Balsiger et al. (1985) reported that bottom-trawl surveys probably underestimate populations because Pacific ocean perch occupy the water column above the opening of the trawl.

An understanding of both the behavior and habitat of Pacific ocean perch and the catch efficiency of bottom trawls is needed to improve biomass estimates. In this study, a two-man submersible was used for *in situ* observations of rockfish and a bottom trawl to sample rockfish at submersible dive sites. The main objectives were to describe the spatial distribution of rockfish, visually determine their abundance in trawlable and untrawlable habitat, and determine the efficiency of bottom trawls for capturing rockfish. Pacific ocean perch was the target species of this study.

Materials and methods

Study area

This study was conducted in August 1988 and 1989 on the outer continental shelf in the eastern Gulf of Alaska (Fig. 1). Study sites extended over a 300 km range to include a wide range of habitats and population densities of Pacific ocean perch. Dive sites were selected from coordinates of previous trawl and sonar studies: (1) Sites north of lat. 56° N from studies by the Auke Bay Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, in July 1987 and 1988 using bottom trawls, midwater trawls, and sonar to locate high and low densities of rockfish at high-relief (untrawlable) and low-relief (trawlable) sites; and (2) sites south of lat. 56° N from studies by Leaman & Nagtegaal (1986) who used sonar to locate high densities of rockfish at untrawlable sites.

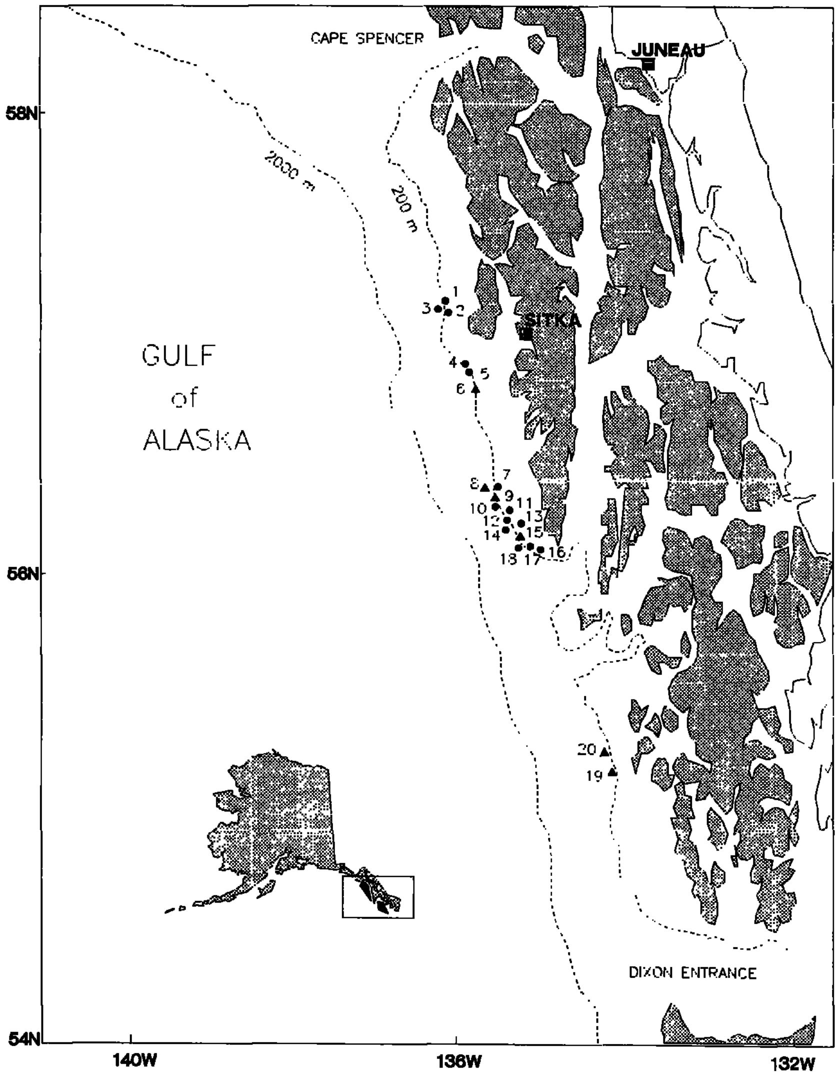

Figure 1
Locations of submersible dive sites in the eastern Gulf of Alaska, 1988 (▲) and 1989 (●).

Submersible

The submersible *Delta* was chartered for all dives. This battery-powered two-man submersible is 4.7 m long, dives to 365 m, and travels 2–6 km/h for 2–4 h. It is equipped with ten 150 W external halogen lights, internal and external video cameras, a 35 mm external camera, magnetic compass, directional gyro compass, underwater telephone, and transponder that allowed tracking of the submersible from the surface vessel *Wm. A. McGaw*.

Submersible transects were charted from the *Wm. A. McGaw*. The surface vessel tracked the submersible and recorded LORAN fixes at the beginning and end of a transect, and every 5–15 min during a transect. In 1988, a transect consisted of a single compass heading followed for 60 min. The transect pattern was changed in 1989 to facilitate trawl comparisons, and consisted of four parallel compass headings followed for 15 min each. The four parallel transects were each separated by 5 min of travel.

A pilot and one of the two observers were aboard the submersible on each dive. The pilot maintained the submersible within 0.5 m of bottom at 3–4 km/h while the observer made observations through a starboard porthole; external cameras were mounted on the starboard side, and the side portholes provided the widest range of view. Observations included rockfish species identification, number, size, grouping behavior, orientation, position relative to the sea bottom, habitat affiliations, and reactions to the submersible. Additional observations included identification and enumeration of other fish species, and estimates of current direction and velocity based on the bending of sea pens and drift of silt. The pilot sat above the observer in a tower with a panoramic view and assisted in counting fish above the observer's view and in monitoring fish behavior completely around the submersible. All observations were audio- and video-recorded for subsequent analysis and verification. All dives were during daylight between 0600 and 1900 h.

Rockfish densities were derived from the number of fish counted and the seafloor area searched. The seafloor area searched was the distance traveled (1.7–2.2 km/dive) times estimates of the lateral distance from the submersible at which rockfish were visible. Lateral distance estimates varied between 5 and 6 m because of changes in water clarity; illumination was provided entirely by the submersible lights and remained constant. Estimated distances were compared with true distances using three methods: (1) A length of pipe marked at meter intervals was laid on the seafloor on two dives, (2) a hand-held sonar gun provided distance readouts to rock formations on six dives, and (3) the submersible's sonar provided distance readouts to the seafloor during descent and ascent. Estimates of distance were consistently within 1m of true distances. About 10 m was monitored above the submersible: 5–6 m by the observer and an additional 4–5 m by the pilot.

Dive sites were classified as trawlable, marginally trawlable, or untrawlable based on bottom type and extent of relief. Trawlable sites contained pebble substrate interspersed with cobble <0.5 m in diameter on flat bottom; marginally trawlable sites contained pebble substrate interspersed with cobble and boulders of 0.5–5.0 m in diameter on low-relief bottom; untrawlable sites contained mainly bedrock substrate with a variety of rugged habitats including boulders, coral, ledges, rocky outcroppings, and pinnacles on high-relief bottom.

Bottom trawling

Bottom trawling was used in 1989 to identify fish species at submersible dive sites and to derive population densities from catch rates. Trawling was conducted from the NOAA ship RV *Townsend Cromwell*, using a 400-mesh Eastern otter trawl equipped with 1.5×2.1 m doors, each weighing 386 kg. Trawling was during daylight, usually within 4h after completion of a submersible dive. The time between dives and trawls depended on ship's operations, including how long it took to process the catch. The sampling strategy was to trawl at 6.0 km/h, intersecting the four parallel submersible transects at each dive site.

Trawl catches were processed for total number and weight by species. The fork lengths of rockfish were measured to the nearest centimeter. Fish density estimates were derived from the number of fish captured and the seafloor area swept by the net. The seafloor area swept was the distance trawled (0.93–1.35 km/haul) times the horizontal opening of the net (14 m, based on measurements between the wing tips, 12.2–14.3 m for the 400-mesh Eastern otter trawl; NMFS 1990). Measured vertical openings were 1.4–1.8 m.

Data analysis

The off-bottom distance monitored from the submersible was about 10 m, whereas the trawl sampled to about 2 m off bottom. Correlation between the percent composition of fish species observed from the submersible and captured with bottom trawls was determined using correlation analysis (Sokal & Rohlf 1981). Correlations were determined for rockfish, flatfish, shortspine thornyhead *Sebastolobus alascanus*, and walleye pollock *Theragra chalcogramma*.

Correlation analysis also was used to examine the correlation between densities of rockfish observed from the submersible and densities derived from trawl catch rates. Ratio estimates (Cochran 1977) of observed and trawl densities were then used to determine the catch efficiency of bottom trawls for rockfish. For these analyses, Pacific ocean perch, sharpchin rockfish *S. zacentrus*, redstripe rockfish *S. proriger*, and harlequin rockfish *S. variegatus* >25 cm long were categorized as "large"; whereas those ≤25 cm were categorized as "small." Most "large" rockfish observed from the submersible were identified as adult Pacific ocean perch (based on symphyseal knob and body shape), whereas "small" rockfish could not be consistently identified. Rockfish were visually categorized as either large or small from the submersible, whereas trawl-caught fish were measured. Other rockfish species observed from the submersible included redbanded *S. babcocki*, rosethorn *S. helvomaculatus*, dusky *S. ciliatus*, silvergray *S. brevispinis*, yelloweye *S. ruberrimus*, and greenstriped *S. elongatus*. These solitary, demersal rockfish were identified from the submersible by their distinct color patterns, and categorized as "other" rockfish.

Results and discussion

Submersible dives

Six submersible dives were completed in 1988 and fourteen in 1989 at 188–290 m depths. Thirteen of the dive sites were classified as trawlable, three as marginally trawlable, and four as untrawlable. Of the 9278 fish observed from the submersible, 5317 were rockfish (Table 1). Rockfish were the most abundant fish on 11 dives and second in abundance on 9 dives. Of the rockfish, 76% were large, 21% small, and 3% other. Other commonly observed fish were shortspine thornyhead, flatfish, and walleye pollock (Table 1).

Distribution of large rockfish

Large rockfish were solitary or in groups of 2–200 fish. Of the 4020 large rockfish observed, 998 (25%) were solitary and 3022 (75%) were divided about equally among groups of 2–10, 11–50, and 51–200 (Table 2). Although 53% of the rockfish were in groups of more than 10 fish, the number of these groups were few: 56 groups of 11–50 fish and 9 groups of 51–200 fish, compared with 303 groups of 2–10 fish (Table 2). The infrequent occurrence of large groups probably contributes to the high variability of trawl catch rates encountered during rockfish surveys.

Regardless of group size, large rockfish were separated by 1–4 m, were similar in size within each group,

Table 1

Numbers of rockfish and other fish observed at 20 submersible dive sites in the eastern Gulf of Alaska, 1988 and 1989.

Site	Site type*	Distance between sites (km)	Depth (m)	Surveyed area ($10^3 m^2$)	Number of fish: Rockfish	Thornyheads	Flatfish	Pollock	Other	Total
1	MT		204–208	13.3	80	96	59	3	34	272
		2.6								
2	MT		204–209	13.8	304	221	7	0	16	548
		3.5								
3	MT		188–211	15.2	151	319	49	1	106	626
		44.1								
4	T		196–198	14.5	104	129	24	48	17	322
		0.6								
5	T		190–193	13.7	124	79	45	47	10	305
		9.3								
6	T		202–207	10.0	42	135	19	3	0	199
		55.2								
7	T		203–207	15.3	198	178	42	9	5	432
		2.8								
8	U		226–290	9.0	44	86	2	0	5	137
		1.7								
9	T		220–227	13.2	47	89	12	0	4	152
		0.7								
10	T		210–213	13.6	83	121	40	0	15	259
		3.2								
11	T		204–210	13.9	376	88	50	35	6	555
		1.1								
12	T		207–210	12.1	234	122	58	53	2	469
		8.2								
13	T		192–192	12.0	1015	37	60	60	10	1182
		3.2								
14	T		195–200	12.3	760	58	53	42	4	917
		8.0								
15	T		213–221	10.5	98	92	20	0	6	216
		24.6								
16	T		197–208	14.8	863	45	40	15	4	967
		2.8								
17	T		192–207	12.9	136	23	96	37	4	296
		4.8								
18	U		192–211	11.8	298	188	10	0	10	506
		128.0								
19	U		201–259	12.0	248	260	12	0	9	529
		9.1								
20	U		195–259	13.2	112	250	13	0	14	389
				Totals	5317	2616	711	353	281	9278

*MT = marginally-trawlable site; T = trawlable site; U = untrawlable site.

Table 2

Numbers of solitary and grouped rockfish and distribution by group size of large and small rockfish observed at 20 submersible dives sites in the eastern Gulf of Alaska, 1988 and 1989.

	Solitary	Grouped							
		2–10		11–50		51–200		Total	
Site	No. fish	No. groups	No. fish	No. groups	No. fish	No. groups	No. fish	No. groups	No. fish
				Large rockfish					
1	38	4	9					4	9
2	71	13	35	2	32			15	67
3	77	15	33					15	33
4	33	7	20					7	20
5	90	9	20					9	20
6	20								
7	71	33	116					33	116
8	11	4	9					4	9
9	18	8	24					8	24
10	57	7	21					7	21
11	75	28	80	1	36	1	160	30	276
12	34	14	57	5	98			19	155
13	172	48	90	17	283	3	300	68	673
14	114	40	131	10	197	2	233	52	561
15	17	10	50	2	27			12	77
16	38	29	93	17	373	3	325	49	791
17	24	12	41	1	41			13	82
18	14	8	21	1	20			9	41
19	10	8	31					8	31
20	14	6	16					6	16
Totals	998	303	897	56	1107	9	1018	368	3022
				Small rockfish					
1	16	3	14					3	14
2	51	3	9	3	69			6	78
3	13	6	17					6	17
4	16	7	30					7	30
5	5	2	5					2	5
6	18	2	4					2	4
7	1	1	3					1	3
8	17	2	7					2	7
9	4								
10	0	1	3					1	3
11	16	3	6					3	6
12	2	1	4	1	35			2	39
13	49	14	58	3	56			17	114
14	26	8	19	2	33			10	52
15	0	1	2					1	2
16	12	1	2	1	18			2	20
17	12	3	18					3	18
18	1	10	40	5	144			15	184
19	50	14	47	1	49	1	60	16	156
20	51	8	29					8	29
Totals	360	90	317	16	404	1	60	107	781

and were usually motionless and facing the current (Fig. 2). Their vertical distribution ranged 0–7 m above bottom. Rockfish in groups of 1–5 rockfish were usually 0–1 m above bottom, whereas rockfish in larger groups were 0–7 m above bottom. No large rockfish were seen above 7 m, either by the observer while ascending, descending, or traveling off the bottom, or by the pilot who searched to 10 m above bottom. This

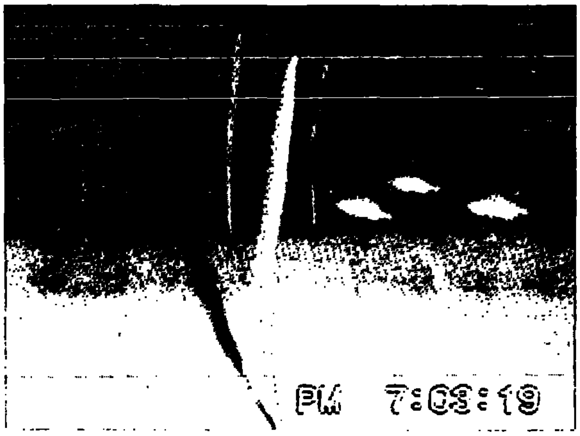

Figure 2
Photograph from the submersible of adult Pacific ocean perch *Sebastes alutus* spaced about 1 m apart and facing into the current. Current direction is indicated by the bend in the sea pens.

observation is supported by results of previous studies that used echosounding equipment to locate off-bottom rockfish, and midwater and bottom trawls to capture fish. In Queen Charlotte Sound, British Columbia in 1976, Pacific ocean perch were the dominant species in bottom-trawl catches, but were not a significant component of midwater-trawl catches targeting off-bottom fish echosignals (Gunderson & Nelson 1977). In the Gulf of Alaska in 1987 and 1988, Pacific ocean perch were not captured in midwater-trawl hauls that targeted fish echosignals 10–30 m off bottom, but Pacific ocean perch were abundant in bottom-trawl hauls (NMFS Auke Bay Lab., Juneau, unpubl. cruise reps. JC 87-04 and JC 88-03).

Table 3
Densities (no./1000 m^2) of large and small rockfish at trawlable (T), marginally-trawlable (MT), and untrawlable (U) sites observed from a submersible.

	Large rockfish			Small rockfish		
Site	T	MT	U	T	MT	U
1		3.5			2.3	
2		10.0			9.3	
3		7.2			2.0	
4	3.6			3.2		
5	8.0			0.7		
6	2.0			2.2		
7	12.2			0.3		
8			2.2			2.7
9	3.2			0.3		
10	5.7			0.2		
11	25.3			1.6		
12	15.6			3.4		
13	70.4			13.6		
14	54.9			6.3		
15	9.0			0.2		
16	56.0			2.2		
17	8.2			2.3		
18			4.7			15.7
19			3.4			17.2
20			2.3			6.1
Mean densities	21.1	6.9	3.2	2.8	4.5	10.4

The highest densities of large rockfish observed from the submersible were at trawlable sites. Densities averaged 21.1 rockfish/1000 m^2 of seafloor area at the 13 trawlable sites compared with 6.9 rockfish/1000 m^2 at the 3 marginally-trawlable sites and 3.2 rockfish/1000 m^2 at the 4 untrawlable sites (Table 3). About 90% (3565) of the large rockfish were associated with pebble substrate on flat or low-relief bottom. The remaining 455 large rockfish were among a variety of rugged habitats: 226 (6%) over cobble at trawlable sites, 138 (47%) over cobble and boulders at marginally-trawlable sites, and 91 (62%) among ledges, coral, etc., at untrawlable sites (Table 4). The preference of trawlable substrate by Pacific ocean perch is supported by two other studies: Westrheim (1970) mentions that best trawl catches of Pacific ocean perch were on "good bottom"; and Matthews et al. (1989) used sunken gill nets and caught 231 Pacific ocean perch (38% of the rockfish catch) on trawlable bottom, but only 25 (2% of the rockfish catch) on untrawlable bottom.

Only trawlable sites contained high densities of large rockfish, but densities varied considerably among trawlable sites. For example, sites 6 and 7 were 55.2 km apart and had a sixfold difference in large-rockfish densities; adjacent sites 16 and 17, only 2.8 km apart, had a sevenfold difference in large-rockfish densities (Table 3). These variations in abundance may have been related to the distribution of cobble habitat: All groups of more than 30 large rockfish were within 20 m of cobble habitat, although cobble averaged only 10% of the habitat at trawlable sites. The cobble was in patches <30 m^2 and the cobble size was <0.5 m in diameter.

Distribution of small rockfish

Of the small rockfish, 68% (781) were in groups of 2–60 individuals and 32% (360) were solitary (Table 2). Distribution by group size of 2–10, 11–50, and 51–200 rockfish was 41%, 52%, and 7%, respectively. Individuals within a group were usually separated by <1 m; small rockfish, in contrast to large, did not seem to orient with the current.

The highest densities of small rockfish were at untrawlable sites. Their densities averaged 10.4 rock-

Table 4

Percent rugged habitat, and proportions of large and small rockfish using rugged habitat at 20 submersible dive sites in the eastern Gulf of Alaska. Rugged habitat consisted of cobble at trawlable sites (T), cobble and boulders at marginally-trawlable sites (MT), and ledges, coral, etc., at untrawlable sites (U).

		Rockfish using rugged habitat/Rockfish total (N)					
	% rugged	Large			Small		
Site	habitat	T	MT	U	T	MT	U
1	6		5/47			18/30	
2	33		64/138			95/129	
3	31		69/110			22/30	
4	38	12/53			39/46		
5	10	33/110			4/10		
6	9	1/20			15/22		
7	3	11/187			4/4		
8	21			16/20			17/24
9	4	2/42			1/4		
10	2	2/78			3/3		
11	4	40/351			16/22		
12	6	0/189			39/41		
13	25	92/845			158/163		
14	12	13/675			77/78		
15	1	0/94			0/2		
16	18	19/829			32/32		
17	5	1/106			15/30		
18	76			26/55			153/185
19	49			36/41			193/206
20	74			13/30			64/80
Total numbers		226/3579	138/295	91/146	403/457	135/189	427/495
Percentages		6%	47%	62%	88%	71%	86%

fish/1000 m^2 of seafloor area at the four untrawlable sites, compared with 4.5 rockfish/1000 m^2 at the three marginally-trawlable sites and 2.8 rockfish/1000 m^2 at the thirteen trawlable sites (Table 3). Most small rockfish were over rugged habitat: 88% (403) over cobble at trawlable sites, 71% (135) over cobble and boulders at marginally-trawlable sites, and 86% (427) among ledges, coral, etc., at untrawlable sites (Table 4). Small-rockfish densities were minimal estimates because rugged habitat blocked some fish from the observer's view. Three other submersible studies noted use of rugged habitat by small rockfish: Carlson & Straty (1981), Straty (1987), and Pearcy et al. (1989).

Trawl catches

Seven trawlable sites and two marginally-trawlable sites were sampled with bottom trawls. Trawl speed ranged from 5.5 to 6.5 km/h, and the trawl intersected at least three of the four submersible transect paths at each of the nine sites (Fig. 3). Total number of fish captured was 11,089; 65% (7162) were rockfish (Table 5). Of the rockfish, 81% were Pacific ocean perch: 5587 adults (>25 cm) and 219 juveniles (≤25 cm). After trawl-caught rockfish were standardized to the submersible rockfish categories, large rockfish, small rockfish, and other rockfish comprised 90%, 9%, and 1% of the trawl-caught rockfish, respectively. Other commonly occurring fish in the trawl hauls were shortspine thornyhead (17%), flatfish (13%), and walleye pollock (3%) (Table 5).

The composition of fish captured in trawls and observed from the submersible were highly correlated; correlation coefficients (r) for all rockfish combined, shortspine thornyhead, flatfish, and walleye pollock were 0.93, 0.86, 0.79, and 0.72, respectively (Fig. 4). These high correlations indicate that bottom trawls sampled the same fish species observed from the submersible.

Catch efficiency on rockfish

Catch densities of large rockfish were highly correlated with observed densities from the submersible (r=0.88). Catch densities were

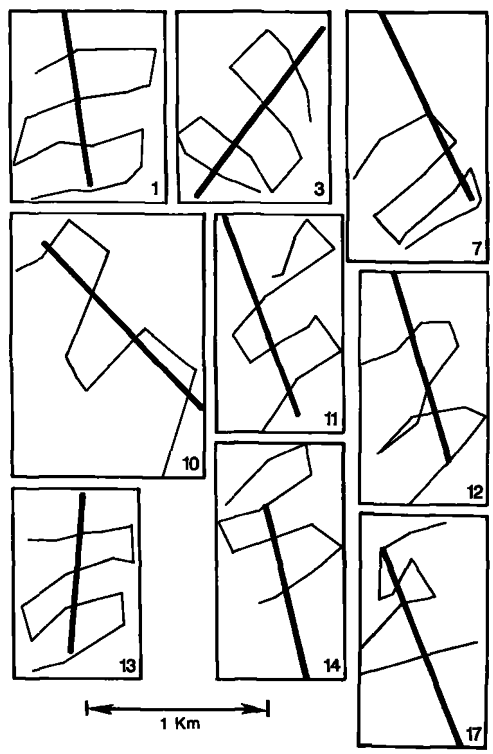

Figure 3

Submersible transect courses (—) and trawl paths (–) at nine submersible sites where rockfish counts made from a submersible were compared with CPUE of bottom-trawl hauls, August 1989. Numbers refer to sites in Figure 1.

Table 5
Numbers of rockfish and other fish captured with bottom trawls at nine submersible dive sites in the eastern Gulf of Alaska.

Site	Site type*	Area trawled ($10^3 m^2$)	Rockfish	Thorny-heads	Flatfish	Pollock	Other	Total
1	MT	13.7	75	32	94	4	6	211
3	MT	15.3	138	239	43	0	52	472
7	T	16.1	342	112	53	6	16	529
10	T	18.9	358	448	58	6	20	890
11	T	16.4	1148	321	139	66	15	1689
12	T	16.4	863	355	210	24	22	1474
13	T	13.0	2918	188	320	90	50	3566
14	T	14.0	893	90	183	20	20	1206
17	T	15.5	427	87	391	142	5	1052
		Totals	7162	1872	1491	358	206	11,089

*MT = marginally-trawlable site; T = trawlable site.

higher than observed densities at the seven trawlable sites (Fig. 5) and lower at the two marginally-trawlable sites; the ratio estimate of catch to observed densities was 2.2:1 (SE=0.4). This high ratio estimate indicates that bottom trawls are very efficient for capturing large rockfish, resulting in density estimates approximately twice those observed from the submersible.

Herding of large rockfish toward the net opening may explain the high catch rates of large rockfish. Submersible counts included rockfish to 7 m off bottom, whereas the trawl sampled to only 2 m off bottom. Rockfish apparently moved downward in response to the trawl gear. Downward movements alone would have resulted in a catch-to-observed ratio of about 1:1. The ratio of 2.2:1 indicates large rockfish also moved inward toward the net opening to avoid the bridles and otter doors. The bridles and doors extend approximately 7 m on each side of the 14m horizontal net opening, increasing by twofold the seafloor area swept by the trawl gear. Downward and inward movements in response to trawling have been reported for other semi-demersal fish species (Wardle 1983 and 1986, Ona & Godo 1990). The low catch rates at the two marginally-trawlable sites may reflect decreased trawl efficiency in rugged habitat.

Catch densities of small rockfish were also highly correlated with observed densities from the submersible (r=0.89). Catch densities were similar to observed densities at all nine sites (Fig. 5); the ratio estimate of catch-to-observed densities was 1.3:1 (SE=0.3). Two possible reasons that ratio estimates were lower for small rockfish than for large rockfish are that (1) small rockfish escape through net meshes at a greater

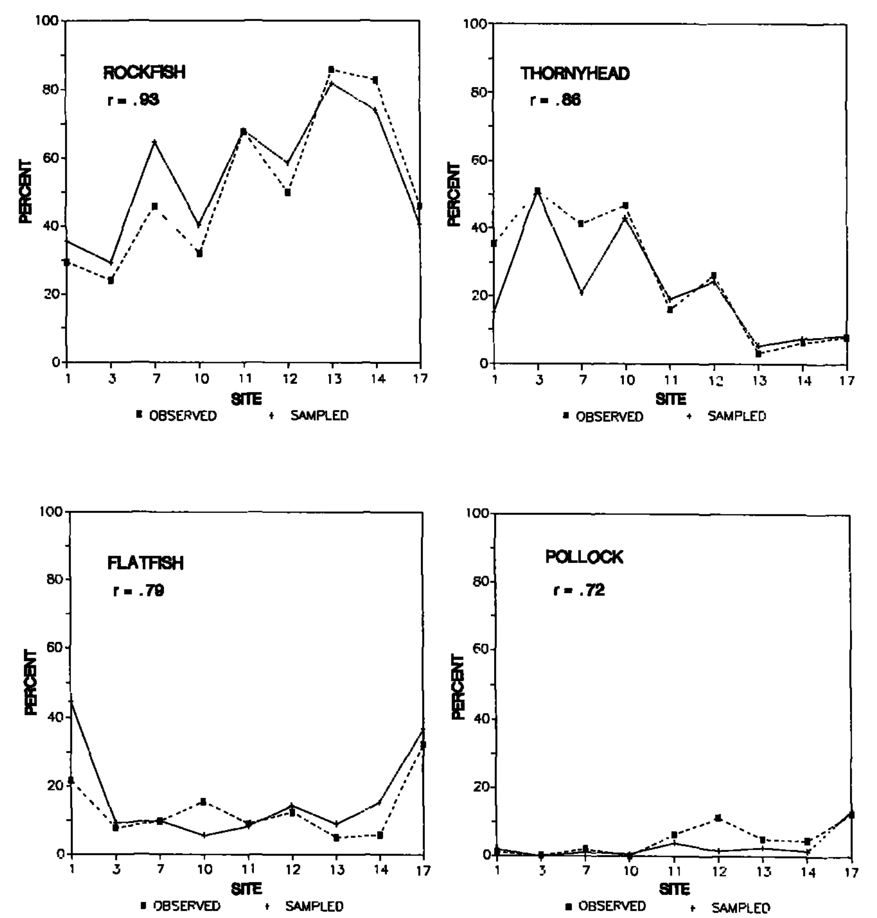

Figure 4
Percent composition of fish groups observed from a submersible and sampled with bottom trawls, and correlation coefficients (r) at nine sites in the eastern Gulf of Alaska.

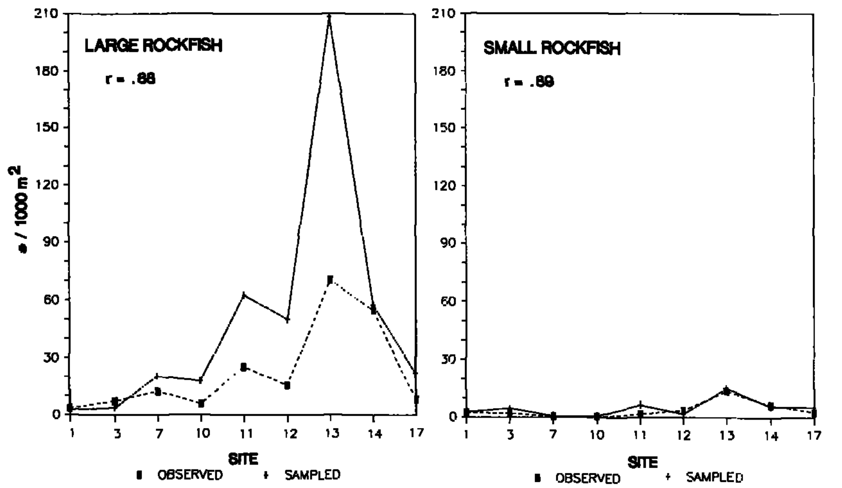

Figure 5
Densities of rockfish observed from a submersible and estimated from bottom-trawl catch rates, and correlation coefficients (r) at nine sites in the eastern Gulf of Alaska, August 1989.

rate than large rockfish, and (2) most small rockfish use rugged habitat, which bottom trawls do not sample as effectively as smooth habitat.

The 2.2:1 ratio for large rockfish and 1.3:1 for small rockfish should be considered preliminary, because these are based on only nine comparisons and the area sampled by the trawl may be underestimated. If rockfish were captured during trawl retrieval, the area sampled was underestimated and the ratios would be less. Studies are planned to determine the sampling capabilities of the trawl during retrieval, and to increase the number of trawl-to-submersible comparisons.

Reliability of fish counts

Fish densities were determined from the submersible by counting fish within an estimated distance. Estimates to within 1 m were possible because of uniform illumination and minimal change in water clarity between sites. Large rockfish were ideal for counting within the illuminated area because they were brightly colored, solitary or loosely grouped, not obstructed by rugged habitat, and usually motionless. The only movements were by individuals moving out of the direct path of the submersible, and a few larger groups moving toward the submersible. These fish swam slowly and maintained their spacing and orientation. The pilot observed similar rockfish behavior completely around the submersible. The species and size of rockfish captured in the trawls confirmed that most large rockfish observed from the submersible were adult Pacific ocean perch; 81% of the rockfish catch were Pacific ocean perch, of which 92% were >30 cm long.

Besides large rockfish, shortspine thornyhead were ideal for counting because they were motionless on the bottom and not obstructed by rugged habitat. Counts were biased for other fish species observed from the submersible. Small rockfish and "other" rockfish were underestimated because some were blocked from view by rugged habitat. Flatfish were underestimated because they blended into the bottom and were difficult to see more than about 3 m from the submersible. Walleye pollock and sablefish *Anoplopoma fimbria* reacted both positively and negatively to the submersible, and the accuracy of their counts could not be determined.

Application to bottom trawl assessments

Estimates of rockfish abundance derived from bottom trawl assessments are based on the assumptions that rockfish densities at untrawlable sites are similar to their densities at trawlable sites, and that the seafloor area sampled is determined from the horizontal opening of the net. Results from this study indicate these assumptions are incorrect for Pacific ocean perch. High densities of adult Pacific ocean perch were observed only at trawlable sites; hence, extrapolation of catch rates from trawlable substrate to untrawlable substrate would overestimate their abundance. Also, seafloor area sampled may include area swept by the bridles and otter doors, resulting in additional overestimates of abundance.

Acknowledgments

I thank the crews of the submersible *Delta* and the support vessel *Wm. A. McGaw* for completing safe and successful dives under adverse weather conditions. I thank the crew and scientists aboard the NOAA RV *Townsend Cromwell* for their detailed sampling that allowed comparisons of bottom-trawl catches to submersible observations. I also thank Victoria O'Connell of the Alaska Department of Fish and Game and John Karinen for participating in the submersible diving, and Dr. Richard Carlson and Nancy Maloney for their advice and assistance in writing this paper. The *Delta* was chartered by NOAA's National Undersea Research Program (NURP).

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