Observations on the distribution and activities of rockfish, *Sebastes* spp., in Saanich Inlet, British Columbia, from the *Pisces IV* submersible

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Abstract.— The distribution and activities of rockfish, *Sebastes* spp., inhabiting depths between 21 and 150 m in the coastal fjord of Saanich Inlet, British Columbia, were assessed by using the *Pisces IV* submersible. Quillback rockfish, *S. maliger*, was the numerically dominant rockfish, attaining a median density of 5.7 fish·100m^{-2} between 21 m and 100 m of depth. Copper rockfish, *S. caurinus*, tiger rockfish, *S. nigrocinctus*, yellowtail rockfish, *S. flavidus*, yelloweye rockfish, *S. ruberrimus*, and greenstriped rockfish, *S. elongatus*, were all observed in consistently low densities (<1 fish·100m^{-2}). The greatest densities of rockfish occurred over complex habitat of broken rock and boulders. The majority (>50%) of rockfish were observed either perched on open substrate, hovering, or swimming. All rockfish species were observed near quillback rockfish (>75% occurrence); and quillback, copper, and yellowtail rockfishes were also found in association with conspecifics.

Manuscript accepted 18 October 1993
Fishery Bulletin 92: 313–323 (1994)

Prior to the advent of submersibles, in situ observations of deep-water demersal fish assemblages were constrained by time-depth limitations of SCUBA, which restrict observations of fish assemblages primarily to depths above 40 m (130 ft) (e.g. Moulton, 1977; Larson, 1980; Hallacher and Roberts, 1985; Richards, 1987; Murie, 1991). Distributional studies of fishes inhabiting waters deeper than 30–40 m have therefore relied on hook-and-line surveys, box trapping, or net trawling, all of which have known biases and limitations (Westrheim, 1970; Uzmann et al., 1977; Krieger, 1993). The recent availability of small submersibles for research purposes has allowed direct visual assessment of the depth distribution, density, and habitat of a variety of deep-water fish species (Uzmann et al., 1977; Carlson and Straty, 1981; Richards, 1986; Dennis and Bright 1988; Pearcy et al., 1989; Stein et al., 1992; Krieger, 1993).

Rockfish (*Sebastes* spp.) are important to nearshore recreational and commercial fisheries along the northeastern Pacific coast (Patten, 1973; Richards, 1987). Many inshore rockfish species are believed to be ecologically and morphologically similar, and are primarily benthic, sedentary fishes (Patten, 1973; Moulton, 1977; Mathews and Barker, 1983; Richards, 1986, 1987; Murie, 1991). Distributions of nearshore rockfish may depend on a variety of factors, including depth, habitat, and the presence of con- and hetero-specifics. Various species are known to segregate bathymetrically (Larson, 1980; Hallacher and Roberts, 1985; Richards, 1986, 1987; Pearcy et al., 1989), reducing or eliminating the potential for competitive interactions between otherwise ecologically similar species (Larson, 1980). Using a submersible, it is possible to observe directly the species-specific depth distributions, as well as to estimate each species' numerical abundance or density with depth. Changes in density with depth within a rockfish species may ultimately be related to fish size because rockfish size is often posi-

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tively correlated with depth (Westrheim, 1970; Boehlert, 1980; Wilkins, 1980; Richards, 1986).

Nearshore rockfish are usually found in close association with the substrate or vertical relief (e.g. kelp beds) and their density may be dependent on the type of habitat available (e.g. boulder fields, shelter holes, etc.) (Patten, 1973; Moulton, 1977; Richards, 1986, 1987; Pearcy et al., 1989; Stein et al., 1992). Depth and density distributions of nearshore rockfish in British Columbia have been assessed primarily by hook-and-line surveys (e.g. Richards et al., 1988) and observations from submersibles are lacking. To date, only one study has assessed the distribution of nearshore rockfish in British Columbia using direct observations from a submersible (Richards and Cass, 1985; Richards, 1986). In their study, the depth and habitat distributions of rockfish were surveyed at depths of 21–140 m in coastal waters of the northeastern Strait of Georgia. In addition to observations on depth and type of habitat frequented by various rockfish species, however, submersibles also provide a unique opportunity to observe the behavioral activities of the fishes and their associations with conspecifics and heterospecifics. To date, there has been a lack of submersible studies that attempt to quantitatively assess the in situ activities of rockfish.

In the present study, we examined the distribution of rockfish observed from a submersible deployed in Saanich Inlet, a coastal fjord in the southern Strait of Georgia, British Columbia (Fig. 1). Fjords in British Columbia differ from open coastal areas, such as those surveyed by Richards (1986), in that they typically rely on estuarine-type circulation for mixing but have submerged sills which restrict mixing of waters below the sill depth (Thomson, 1981). For fjords of Vancouver Island, B.C., limited circulation results in low dissolved oxygen levels in relatively deep water (Pickard, 1963). In Saanich Inlet, restricted mixing at depth results in oxygen-deficient waters (<2.0 $mg \cdot L^{-1}$) below 100 m throughout most of the year and intermittent, seasonal (usually during January–August) anoxia with production of hydrogen sulfide (Herlinveaux, 1962; Liu, 1989), which is toxic to aerobic organisms (Martin et al., 1981). Various studies of invertebrates in Saanich Inlet have shown that the concentration of dissolved oxygen in the water limits their depth distribution (e.g. Burd, 1983; Mackie and Mills, 1983; Jamieson and Pikitch, 1988; Liu, 1989). Field studies have also demonstrated that the vertical or horizontal distribution of fishes is positively correlated with oxygen concentration (reviewed in Kramer, 1987). We therefore speculated that depth distributions for rockfish species in Saanich Inlet would be relatively shallow when compared to their reported maximum depths in open coastal areas.

The present study is the first to examine in situ species composition and density of rockfish in a coastal fjord in British Columbia. In addition, in situ behavioral activities and species associations of nearshore rockfish at depths greater than 30 m in coastal waters of British Columbia have been described for the first time.

Methods

The *Pisces IV* submersible (Department of Fisheries and Oceans, Canada) was used to survey rockfish populations in Saanich Inlet on 9–10 December 1986. A comprehensive description of the *Pisces IV* submersible was given by Mackie and Mills (1983). The inlet has a steep, rocky slope bottom interspersed with sand-shell valleys and is 7.2 km at its

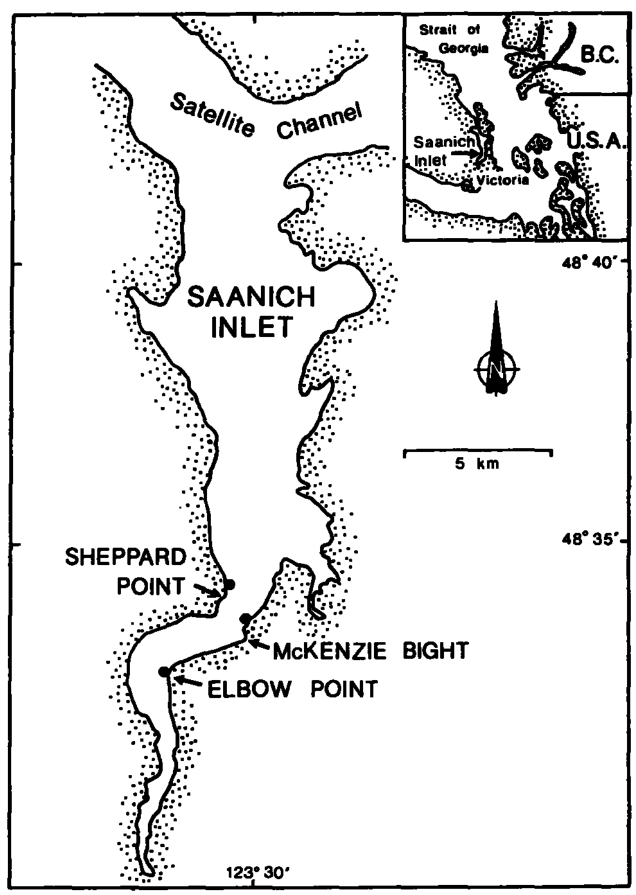

Figure 1
Location of transect sites (•) in Saanich Inlet, Vancouver Island, British Columbia. Inset: Location of Saanich Inlet in relation to the mainland of B.C.

widest. Specifics of the oceanographic characteristics of Saanich Inlet are detailed elsewhere (Herlinveaux, 1962; Anderson and Devol, 1973). Of relevance is that the basin of the inlet reaches a maximum depth of 234 m, but a submerged sill at 75 m at its mouth in Satellite Channel restricts the renewal of deep-water into the inlet. The resulting oxygen deficiency, anoxia, and production of hydrogen sulfide is offset in some years when well-oxygenated, dense bottom-water intrudes over the sill (Herlinveaux, 1962; Anderson and Devol, 1973). We therefore did a hydrocast at depths of 0–225 m to determine the depth of the oxycline in the inlet and whether hydrogen sulfide was present at the time of the surveys. The sampling station was located at lat. 48°37.80'N and long. 123°30.00'W (Liu, 1989).

Three sites within Saanich Inlet were surveyed: five transects were traversed at Elbow Point, eight in an area north of McKenzie Bight, and three in an area north of Sheppard Point (Fig. 1). These areas were known from preliminary SCUBA dive surveys to have rockfish present in >30 m water depth (Murie et al., pers. obs.). All surveys were conducted during daylight hours (09:30 hours to 16:00 hours) and were also restricted to a depth range between 20 and 150 m because the buoyancy of the *Pisces IV* is not finely controlled above 20 m, and bottom time restrictions precluded the transects starting at the basin floor (~200 m). Depth at which each transect started therefore varied among sites owing to slope and positioning of the submersible, with starting depths of 95–109 m at Elbow Point, 92–154 m at McKenzie Bight, and 67–74 m at Sheppard Point.

At the start of each transect, the *Pisces IV* submerged in open water and on reaching depth the external floodlights were lit and the submersible was manoeuvred horizontally, slowly, toward the cliff face. Once the bottom substrate (cliff) was located, the submersible began a slow vertical ascent (~5 m·min^{-1}), keeping the viewing ports (port, pilot, and starboard) directed perpendicular to and approximately 3 m from the substrate. Underwater visibility at the time of the surveys was ~5–6 m with external illumination.

On ascent, an audio-record was made of the species, time, depth, estimated size (whenever possible), activity, and habitat for each rockfish observed. Each observer (port and starboard) recorded all rockfish encountered within a plane bisecting the pilot's viewport and extending outward at an angle of approximately 45°, corresponding to approximately 3 m of horizontal distance across the substrate (i.e. viewing width). To avoid counting the same fish twice, any rockfish swimming across the path of the submersible or positioned close to the pilot's viewing area was pointed out to the other observer. Size was visually estimated (±5 cm) by comparing the fish with an externally mounted graduated rod. Rockfish were designated as small (≤20 cm total length [TL]) and large (>20 cm TL); large referring to the size at which they enter recreational and commercial fisheries (Richards, 1986). Activity of each fish was scored according to whether the fish was perched in the open, positioned in a crevice, occupying a shelter hole, hovering off the substrate, or swimming. Habitat was categorized as vertical wall (may have cracks, small crevices, or ledges; score=1), complex (comprising broken rock and boulder fields; score=2), or sand-mud (score=3). Any change in the habitat or slope of the substrate (±10°) was recorded and the depth noted.

Rockfish density was estimated for each habitat type over 20–m depth intervals. The total number of fish recorded by both observers within each habitat type over a 20–m depth interval was divided by the total area of that habitat type viewed over the depth interval. The area viewed was calculated by multiplying the viewing width of both observers (i.e. 6 m) by the ratio of the change in depth to the sine of the slope.

Median densities of small and large fish were calculated for each habitat type and 20–m depth interval, with transects pooled for increased sample size. Density distributions for rockfish were skewed so densities were calculated as medians with 25% and 75% quartiles. Densities of quillback rockfish, *S. maliger*, among depth intervals and habitats were analyzed by using Kruskal-Wallis tests (SAS, 1985), as this species had an adequate median density (>1 fish·100m^{-2}). Statistical significance was indicated by $P \leq 0.05$. Analyses for the other rockfish species (median densities <1 fish·100m^{-2}) were limited to qualitative comparisons of their depth distributions and numerical abundances.

Activity of each species of rockfish was analyzed using percent occurrence, which was calculated by dividing the sum of all individuals observed in each activity by the total number of individuals of the species for which activities were recorded, and multiplying by 100%. Species associations were determined for individual fish of each species by scoring the presence of a conspecific or a heterospecific within 3 m. The sum of the number of individuals which were observed in the presence of a con- or hetero-specific was then expressed as a percentage of the total number of individuals of the species. Individual rockfish with no other rockfish within 3 m were considered to be 'alone' (solitary).

Results

Physical habitat

An area of approximately 10,521 m^2 was surveyed from the submersible, of which 38% was wall, 47% complex, and 15% sand-mud habitat. Area of coverage among habitat types differed with depth (Fig. 2). The area of complex and sand-mud habitat covered in the surveys decreased with depth whereas that of wall habitat increased. Sand-mud habitat was encountered only at depths of <60 m and the median area surveyed among transects was zero. Wall habitat was the only habitat type observed at depths greater than 120 m. The slope of the substrate was correlated with depth (Spearman rank correlation: r_s=0.37, P<0.001) and habitat (r_s =-0.71, P<0.001). This was evident in that wall habitat found primarily in deep water provided vertical or near-vertical relief (~70–90° slope), whereas complex and sand-mud habitats in shallower depths provided a graded substrate (~20–70° slope).

The area of each type of habitat surveyed differed among survey sites (Kruskal-Wallis: P=<0.001, 0.03, and <0.001 for wall, complex, and sand-mud habitat respectively). Elbow Point and McKenzie Bight had similar habitats whereas Sheppard Point had less wall and complex habitat and more sand-mud habitat than the Elbow Point and McKenzie Bight sites.

At the time of the surveys, Saanich Inlet was not anoxic although waters below 100 m were deficient in dissolved oxygen (Liu, 1989) (Table 1). Hydrogen sulfide was not present at any depths sampled in the inlet. Temperature and salinity were relatively stable below depths of 100 m.

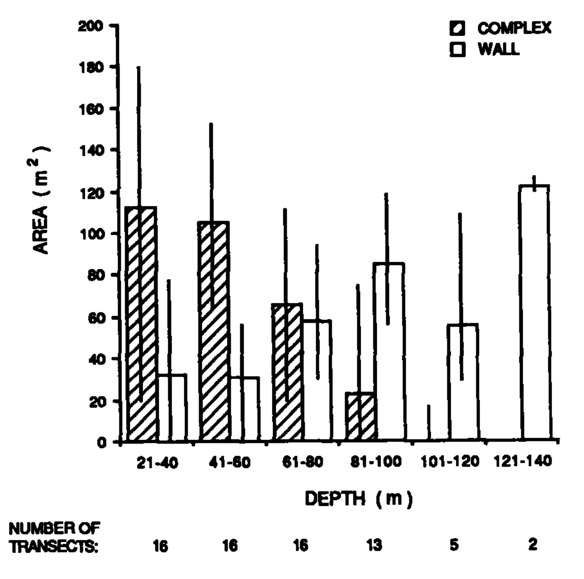

Figure 2

Overall median area of survey coverage for complex and wall habitat in relation to depth. Vertical bars represent the interquartile ranges ($Q_{0.25}$ to $Q_{0.75}$). Median area of sand-mud habitat surveyed was zero.

Depth, size, and density distributions

Quillback rockfish represented 88% (681/770) of all rockfish sighted and were observed at a median depth of 54 m (Table 2). Density of quillback rockfish did not differ among depth intervals between 21–100 m (P=0.35) (Fig. 3A). Only three quillback rockfish were seen at depths >100 m. In total, the median size of 460 quillback rockfish was 23 cm (Table 2). Quillback rockfish size was positively correlated with depth (r^2=0.23, P<0.001, n=460) and the density of small and large quillback rockfish varied among depth intervals (P=0.01 and P=0.02 respectively) (Fig. 3B). Density of small quillback rockfish was similar to that of large quillback rockfish in the 21–40 m depth interval (P=0.66), but it was less at depth intervals greater than 40 m (all P<0.05) (Fig. 3B). In contrast, the median density of large quillback rockfish at depth intervals between 41–100 m was greater than their density in the 21–40 m depth interval (Fig. 3B).

Tiger rockfish, *S. nigrocinctus*, copper rockfish, *S. caurinus*, yellowtail rockfish, *S. flavidus*, greenstriped rockfish, *S. elongatus*, and yelloweye rockfish, *S. ruberrimus*, all had median densities of zero in 21–150 m depths in Saanich Inlet (Table 2).

Table 1

Temperature, salinity, and dissolved oxygen measured throughout depths in Saanich Inlet on 12 December 1986. Hydrogen sulfide was not present at any of the depths sampled.

Depth (m)	Temperature (°C)	Salinity (‰)	Dissolved oxygen ($mg \cdot L^{-1}$)
0	6.24	26.68	7.01
10	8.70	30.18	5.83
30	8.94	30.31	4.50
50	9.40	30.56	3.80
75	9.19	30.96	2.80
100	9.19	31.25	1.39
125	9.23	—	0.41
150	9.28	31.44	0.50
175	9.27	—	0.87
200	9.29	31.47	1.70
225	9.29	—	1.75

Table 2

Numerical abundance, median density, median depth, and median estimated size of *Sebastes* species observed at depths of 21–150 m in Saanich Inlet from the *Pisces IV* submersible.

Species	Number	Density (fish·100m^{-2}) Median	Range	Depth (m) Median	Range	Size (cm) Median	Range
S. maliger	681	5	(0–31)	54	(21–115)	23	(5–41)
S. nigrocinctus	28	0	(0– 2)	55	(33– 97)	28	(20–46)
S. caurinus	24	0	(0– 4)	44	(21– 65)	25	(5–36)
S. flavidus	23	0	(0– 7)	49	(41– 65)	35	(20–40)
S. elongatus	8	0	(0– 1)	65	(52–114)	18	(15–23)
S. ruberrimus	5	0	(0– 4)	89	(76–103)	28	(18–46)
Unidentified sp.	1			42		—	

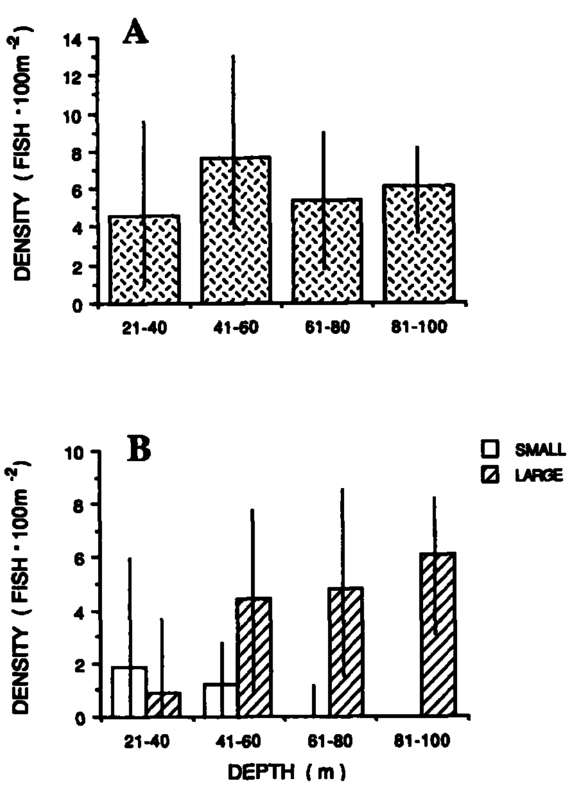

Figure 3

(**A**) Overall median densities of all quillback rockfish, *Sebastes maliger*, over depth; and (**B**) median densities of small and large quillback rockfish over depth. Vertical bars represent the interquartile ranges ($Q_{0.25}$ to $Q_{0.75}$). Median density of quillback rockfish in depths >100 m was zero.

Tiger rockfish accounted for 4%, and copper rockfish 3%, of the rockfish encountered; both were most abundant in 41–60 m (0.6 fish·100m^{-2}). Yellowtail rockfish also represented 3% of all rockfish observed with their density reaching a maximum of 6.3–6.6 fish·100m^{-2} in the 41–80 m depth intervals. Greenstriped rockfish (n=8), yelloweye rockfish (n =5), and one unidentified rockfish each represented less than 1% of all observed rockfish. Greenstriped and yelloweye rockfish both occurred in relatively deeper waters (Table 2).

The size of tiger rockfish was not correlated with depth (P=0.27, n=15) and only relatively large fish were seen from the submersible (Table 2). Copper rockfish size was positively correlated with depth (r^2=0.36, P=0.02, n=15), and no small copper rockfish were seen at depths greater than 40 m. Yellowtail rockfish seen were all relatively large fish (Table 2) and their size was not correlated with depth (P=0.46, n=21). All greenstriped rockfish observed were small (Table 2). Two juvenile yelloweye rockfish (18–20 cm TL) were observed at depths greater than 95 m and three subadult and adult yelloweye rockfish (36–46 cm TL) occurred between 80 and 90 m.

Habitat distribution

Density of quillback rockfish differed among survey sites (P=0.001). Densities observed at the Elbow Point and McKenzie Bight sites were similar (P=0.236), with a pooled median density of 5.7 fish·100m^{-2}. In contrast, the median density of quillback rockfish at Sheppard Point was zero.

Overall, quillback rockfish density was highest in areas of complex habitat (5.8 fish·100m^{-2}), followed by wall habitat (3.5 fish·100m^{-2}) (Fig. 4). Only four quillback rockfish were observed over sand-mud habitat. Quillback rockfish densities, whether in complex or wall habitat, did not differ among depth intervals ≤100 m (P=0.52 and P=0.64 respectively) (Fig. 4).

Tiger, copper, yellowtail, and yelloweye rockfish were observed only over complex or wall habitats, whereas greenstriped rockfish occurred mostly over sand-mud habitat (Table 3). Tiger rockfish tended to occur in both complex and wall habitats, whereas copper, yellowtail, and yelloweye rockfish were seen mostly in complex habitat.

Activities

Quillback, copper, and greenstriped rockfish did not appear to be attracted to or obviously repelled by the presence of the submersible and its lights. At times, rockfish actively finned to maintain station after the submersible had produced currents. Any observed movements away from or towards the submersible were always relatively slow and, at times, hovering quillback rockfish would move slightly away from the path of the submersible, stop, and then resume hovering. Tiger and yelloweye rockfish appeared to have a delayed response to the submersible, in that it was possible to observe them prior to their actually moving into a shelter hole or crevice. In contrast, some spotted ratfish, *Hydrolagus colliei*, and a sixgill shark, *Hexanchus griseus*, were obviously attracted to the *Pisces*. These fish swam back-and-forth around the front of the submersible, repeatedly approaching the viewing ports near the external lights.

Activities were determined for a total of 662 quillback rockfish and the majority were observed hovering or perched on substrate in the open (Fig. 5), regardless of depth interval (all P>0.10). Copper rockfish were also observed primarily hovering and perched in the open, but were seen swimming more frequently than quillback rockfish. Both species were observed infrequently in crevices and rarely in shelter holes. Tiger rockfish were also observed most frequently perched in the open or occupying crevices. Yellowtail rockfish were all observed either hovering or swimming close to the substrate. All eight greenstriped rockfish were observed perched on the substrate. Of the five yelloweye rockfish observed, one was in a shelter hole, three were in crevices, and one was hovering.

Table 3

Numerical abundance of rockfish (*Sebastes* spp.) observed in densities of ≤1 fish·100m^{-2} over complex, wall, and sand-mud habitat in Saanich Inlet.

Species	Complex	Wall	Sand-Mud
S. nigrocinctus	13	15	0
S. caurinus	20	4	0
S. flavidus	21	2	0
S. elongatus	0	1	7
S. ruberrimus	4	1	0

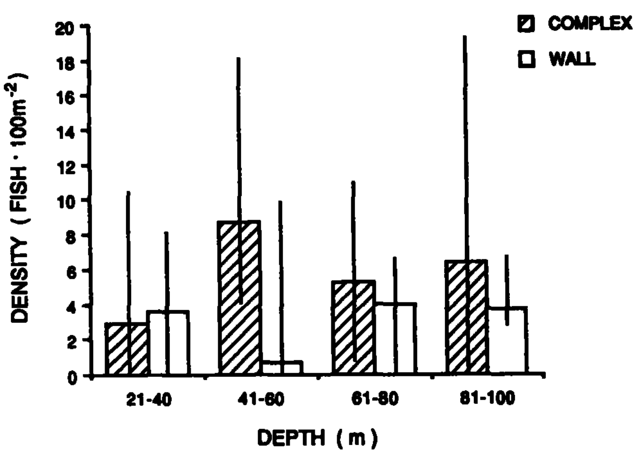

Figure 4

Median densities of quillback rockfish, *Sebastes maliger*, in complex and wall habitats among depths. Vertical bars represent interquartile ranges ($Q_{0.25}$ to $Q_{0.75}$). Median densities of quillback rockfish over sand-mud habitat were zero.

Species associations

The majority of quillback rockfish (94% occurrence) were observed within 3 m of at least one other quillback rockfish (Fig. 6). Quillback rockfish were almost never observed alone (2%) and were observed in the presence of other species relatively infrequently (~20% occurrence or less). Quillback rockfish formed loose conspecific aggregations that were distinctly different from the conspecific schools of yellowtail rockfish observed from the *Pisces*. When schooling, yellowtail rockfish formed tight groups of fish that orientated and moved together in the same direction, whereas in the aggregations of quillback rockfish, individual fish were orientated in various directions and engaged in various activities. Small groups of quillback rockfish (2–5 fish) observed from the submersible were interspersed between larger aggregations of more than 15 fish. Copper rockfish occurred within 3 m of quillback rockfish 92% of the time (Fig. 6), but also tended to occur near other copper rockfish

(64% occurrence) and tiger rockfish (32%). Copper rockfish, while usually near quillback rockfish, were also observed in conspecific aggregations and they were seldom seen alone (4%). Tiger rockfish were almost always observed near quillback rockfish (96% occurrence) and, to a much lesser extent, near other tiger rockfish (21%) (Fig. 6). The majority of yellowtail rockfish were observed in proximity to quillback rockfish (96%) and other yellowtail rockfish (91%). All five of the yelloweye rockfish seen were near quillback rockfish. Six greenstriped rockfish were observed near quillback rockfish whereas two were alone.

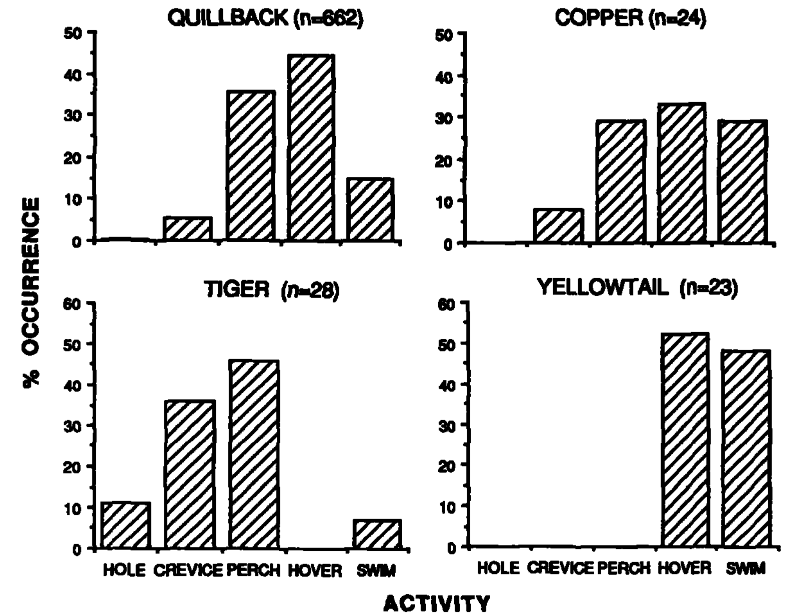

Figure 5

Percent occurrence of behavioral activities for quillback rockfish, *Sebastes maliger*; copper rockfish, *S. caurinus*; tiger rockfish, *S. nigrocinctus*; and yellowtail rockfish, *S. flavidus*, observed in Saanich Inlet from the *Pisces* submersible.

Discussion

Quillback rockfish are the numerically dominant rockfish species at depths of 21–100 m in nearshore areas of southern British Columbia, based on submersible observations in a fjord (this study) and in relatively open coastal areas (Richards, 1986). Based on both of these submersible studies, the main depth distribution of quillback rockfish is between 41 and 60 m, and their density at this depth is more than eight times greater than that of any other rockfish species observed at 41–60 m (Fig. 3A; Richards, 1986). As in Saanich Inlet, greenstriped and yelloweye rockfish were also observed in relatively low densities in the northeastern Strait of Georgia (means of ≤ 2 fish$\cdot$100m^{-2} in various habitat types) (Richards, 1986), as well as tiger and copper rockfish (Richards and Cass, 1985). Yellowtail rockfish were not seen during submersible dives in the northeastern Strait of Georgia (Richards and Cass, 1985). In Saanich Inlet, complex habitat dominated by broken rock and boulder fields appears to be a common feature for the occurrence of the majority of these rockfish species. Based on *Pisces* surveys in the northeastern Strait of Georgia, Richards (1986) also observed that quillback and yelloweye rockfish were most abundant in complex habitat. Similarly, densities of copper and quillback rockfish were highest in complex habitat or in areas of highly irregular relief in Saanich Inlet in <40 m depth (Murie, 1991) and in the northern Strait of Georgia in <18 m depth (Richards, 1987). In SCUBA surveys, Matthews (1990) found the greatest densities of large copper and large quillback rockfish on high-relief rocky reefs in Puget Sound, Washington. Additionally, submersible observations in the vicinity of Heceta Bank, Oregon (Pearcy et al., 1989), suggested that tiger, yelloweye, and yellowtail rockfish were most frequently encountered over rock and rubble habitat. The densities of these near-bottom species may be greatest in this type of habitat because of increased protection from predators or increased density of prey due to the increase in microhabitat and vertical structure.

Stein et al. (1992) observed fish from a submersible at Heceta Bank and determined that the occurrence of fish species was related to specific substrates. Given the propensity of quillback rockfish to aggregate over complex habitat, differences in their density among sites surveyed in our study was not surprising. Sheppard Point, which had more sand-mud areas and a shallower slope, was noticeably different from Elbow Point and McKenzie Bight. It was also the only site where greenstriped rockfish were observed, which is consistent with the apparent habitat distribution of this species (Richards, 1986; Pearcy et al., 1989; Stein et al., 1992).

The overlap in the depth ranges, as well as the similarity in the median depths and the occurrence of fish over complex and wall habitats, suggested that quillback, copper, tiger, and yellowtail rockfish do not segregate in Saanich Inlet within the range of bathymetry or habitat surveyed from the submersible. Yellowtail rockfish may be segregated spatially from tiger rockfish and, to some degree, copper and quillback rockfish, because the activities of yellowtail rockfish consistently placed them in the water column near the substrate but never in direct contact with the bottom. The appearance of quillback and copper rockfish near to one another (Fig. 6) was consistent with observations from SCUBA dive surveys at Saanich Inlet in 20–40 m. Sympatric aggregations of quillback and copper rockfish over complex habitat in Saanich Inlet can be dense (~25–50 fish·100m^{-2}) (Murie, 1991).

Published information on in situ behavioral activity, species associations, and density of tiger rockfish is scarce, no doubt in part due to the consistently low densities in which this species is encountered. Tiger rockfish have been observed in low densities, and primarily as only a single fish encountered at any one time, in waters <30 m deep in Puget Sound (Moulton, 1977), in 21–140 m in the northeastern Strait of Georgia (Richards and Cass, 1985), in 64–305 m depths off Oregon (Pearcy et al., 1989), and in <30 m in Saanich Inlet (Murie, 1991). As 21% (6/28) of *S. nigrocinctus* were observed within 3 m of another tiger rockfish in our study (Fig. 6), this species may not be as 'solitary' as indicated by the previous studies. Density of tiger rockfish may be limited by the availability and defense of suitably large shelter holes, which the fish retreat into upon approach by a SCUBA diver (Murie, pers. obs.).

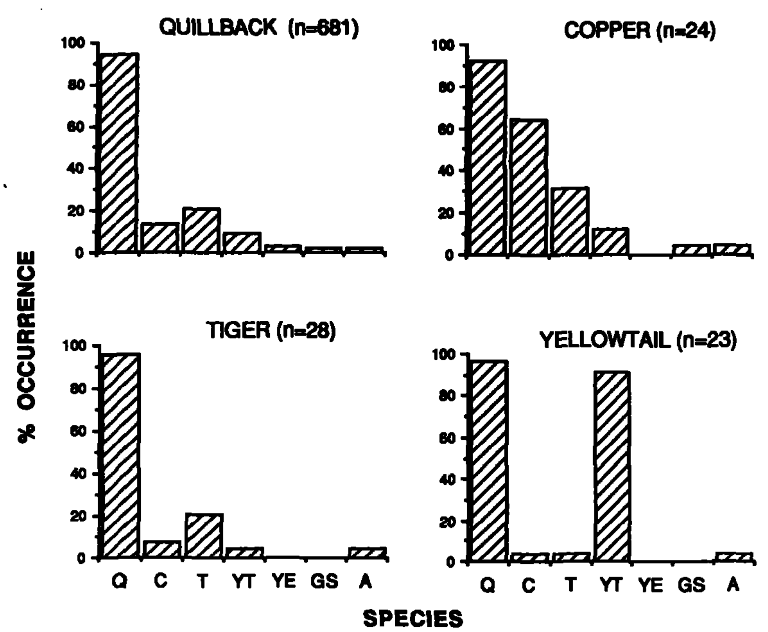

Figure 6

Percent occurrence of conspecific and heterospecific rockfish in association with quillback rockfish, *Sebastes maliger*; copper rockfish, *S. caurinus*; tiger rockfish, *S. nigrocinctus*; and yellowtail rockfish, *S. flavidus*; Species key: Quillback rockfish (Q), copper rockfish (C), tiger rockfish (T), yellowtail rockfish (YT), yelloweye rockfish (YE), greenstriped rockfish (GS), and alone (A).

The depth distribution of rockfish in Saanich Inlet, and hence any size or species associations, may be influenced by a number of factors, including a) the physical regime of the inlet; b) the paucity of observations for relatively uncommon species; and c) the actual depth range and total number of transects surveyed with the submersible. The year-round oxygen deficiency in waters >100 m in Saanich Inlet, and the intermittent anoxia that occurs in waters of 125–234 m depth during January to August (Liu, 1989), may act to compress or shift the depth distribution of rockfish compared to open coastal waters where relatively deep water is not limiting in dissolved oxygen. In Saanich Inlet, squat lobsters, *Munida quadrispina,* migrate vertically en masse to avoid decreasing oxygen levels (Burd, 1983) although catastrophic mortality of spot prawns, *Pandalus platyceros,* in 85–90 m depth has been attributed to a sudden intrusion of displaced anoxic bottom-water into midwater depths (Jamieson and Pikitch, 1988). For mobile organisms (such as rockfish) decreasing oxygen levels may elicit a behavioral response involving a vertical or horizontal habitat shift (Kramer, 1987). Of three transects in Saanich Inlet that started at 150 m, no rockfish were observed at depths >115 m, and only three quillback rockfish were seen at depths >100 m (note: one of these transects was not used in the overall analysis owing to loss of the audio-track at <80 m). With the exception of copper rockfish, Hart (1973) reports maximum depths of >250 m for the other rockfish species. In addition, quillback, tiger, greenstriped, and yellowtail rockfish have been observed from submersibles at depths >120 m (Richards and Cass, 1985; Pearcy et al., 1989).

The scarcity of observations on relatively low density species of rockfish, especially in combination with time limitations of the submersible, could also affect our interpretation of rockfish depth distribution. In Saanich Inlet, few rockfish other than quillback rockfish were observed during the submersible dives. The depth range and density of the relatively uncommon species of rockfish may have been improved if we had been able to do more transects and, in the instance of maximum depths, by doing deeper transects. Bias in using submersible transects was exemplified by the downward bias (i.e. deeper) in the observed minimum depth ranges for tiger, yellowtail, and yelloweye rockfish in Saanich Inlet (Table 2). These rockfish species have been observed during SCUBA dives in Saanich Inlet in water as shallow as 15–25 m (Murie, pers. obs.). The density estimate and depth range for copper rockfish was probably also biased because of the reduced ability to maintain fine control of the *Pisces* buoyancy as it approaches shallower depths (~20 m). We know that copper rockfish in Saanich Inlet occur from near-surface waters (~2 m) and their distribution extends visibly below 40 m depth (Murie, 1991). The density of copper rockfish on rocky reefs in 20–30 m of water, however, can approach 50 fish$\cdot$100m^{-2} (Murie, 1991), far in excess of any density observed for copper rockfish from the submersible (Table 2). In general, however, copper rockfish do occur in shallower water than quillback rockfish (Moulton, 1977; Richards, 1987; Murie, 1991), as was observed from the submersible transects in Saanich Inlet.

Another potentially important bias in the use of the *Pisces IV* to observe densities and activities of rockfish is whether the fish are attracted or noticeably repelled by the size, noise, and lights of the submersible. Similar to our study, Carlson and Straty (1981) noted that most of the rockfish were neither repelled nor attracted to the submersible while they observed them in southeastern Alaska. In addition, Richards (1986) observed that none of the common fish species seen in the northeastern Strait of Georgia seemed disturbed by the *Pisces IV* submersible. A notable exception in Carlson and Straty's (1981) study was large (7–10 kg) yelloweye rockfish that were obviously attracted to the submersible and actually followed it, similar to the ratfish and sixgill shark in our study. Pearcy et al. (1989) also noted that large schools of yellowtail rockfish were attracted to their submersible and followed it over substantial periods of time and depth; there was no visible evidence, however, of schools of yellowtail rockfish following the *Pisces* in our study.

The occurrence of perching and hovering activities observed for the majority of rockfish in Saanich Inlet from the *Pisces* was consistent with behavioral activities of quillback and copper rockfish observed with SCUBA in Saanich Inlet (Murie, 1991). Observations from the submersible were limited in this respect because it was impossible to look into all crevices or into shelter holes under rocks for the presence of fish. Tiger and yelloweye rockfish could be seen in shelter holes and crevices but their size could not always be estimated. Although the *Pisces* approaches shelter holes from below (during its ascent), fish in deep shelter holes and crevices may not be detected. The presence of fish in crevices and shelter holes was therefore probably underestimated. Nevertheless, at present, submersibles and remotely-operated vehicles (ROVs) provide the best means of observing the activities of rockfish occupying complex habitat in deep water.

Although it is evident from submersible observations that estimates of abundance and activities of rockfish involve a variety of biases, these direct visual assessments can provide quantitative information on the densities and depth distributions of rockfish species in habitats that cannot be surveyed adequately using bottom trawls. In addition, submersibles allow direct observation of the behavioral activities and associations of individual fish in relation to specific habitat types. This type of information has not been attainable using conventional survey techniques of fisheries.

Acknowledgments

We are especially grateful to T. Fitch and the pilots and crew of the *Pisces IV* (Institute of Ocean Sciences, Department of Fisheries and Oceans, Sidney, B.C.) who provided the opportunity and expertise to work efficiently with the submersible. We thank Q. Liu for analyzing the hydrocast samples, and J. Gilbert and C. Steinhoff for rockfish observations. Constructive comments by F. Matthews, L. Richards, J. McInerney, N. Wilimovsky, P. Gregory, V. Tunnicliffe, D. Mitchell, C. Tolman, and two anonymous reviewers improved the manuscript. Financial support was provided by a Postgraduate Scholarship from the Natural Sciences and Engineering Research Council of Canada (DJM) and by the Biology Department, University of Victoria.

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