Habitat-specific density of adult yelloweye rockfish *Sebastes ruberrimus* in the eastern Gulf of Alaska*

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Abstract.–Line transects run from a manned submersible were used to estimate the current density of yelloweye rockfish in two areas of the eastern Gulf of Alaska. Yelloweye rockfish were seen in cobble, continuous rock, broken rock, and boulder habitats but were most abundant in broken rock and boulder habitats. The presence of refuge spaces appears to be an important factor affecting occurrence of yelloweye rockfish. Boulder areas in deep water (>108 m) were the most densely-populated habitat, with an estimated density of 9135 adult yelloweye/km^2. Overall density by area and year ranged from 1954 to 2217 adult yelloweye rockfish/km^2. Habitat-specific density estimates were less precise than general area estimates because of smaller sample sizes. For fisheries management, density estimates may be extrapolated to larger areas based on areal estimation of yelloweye habitat from available bathymetric data.

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The yelloweye rockfish *Sebastes ruberrimus* is the target species of the commercial longline fishery for Demersal Shelf Rockfishes (DSR) in the eastern Gulf of Alaska (O'Connell & Fujioka 1991). Rockfishes (*Sebastes* spp.) are managed on an assemblage basis in the Gulf of Alaska under the advice of the North Pacific Fishery Management Council (NPFMC). Demersal Shelf Rockfishes comprise eight species of bottom-dwelling rockfishes inhabiting rocky areas of the continental shelf; yelloweye rockfish account for 96% of the landed catch of targeted DSR.

Traditional stock-assessment methods are difficult to apply to DSR because of a combination of behavioral and physiological factors. The close association of DSR with rugged bottom precludes the use of bottom-trawl surveys used for assessing other groundfish in the Gulf of Alaska. Mark-recapture studies are also ineffective because rockfishes incur high embolism mortality when brought to the surface from depth (O'Connell 1991). Consequently, prior to our research, DSR was one of only two assemblages managed under the Gulf of Alaska Fisheries Management Plan for which no biomass estimates were available.

It has been well documented that rockfish tend to be habitat-specific in their distribution (Love & Ebeling 1978, Larson 1980, Richards 1986, Matthews 1991, Love et al. 1991, Matthews & Richards 1991, Rosenthal et al. 1982). Therefore, to estimate their abundance, we initiated a project designed to take advantage of the preference by DSR for rough, rocky habitat. Our approach was based on the assumption that DSR abundance increases with structural habitat complexity (i.e., increased topographic relief and more interstitial space in and between rocks). Our objective was to estimate density of yelloweye rockfish in the Gulf of Alaska for selected habitat and depth categories. We hope to eventually develop a model predicting the relationship between DSR abundance and habitat complexity and to use this model to indirectly estimate the abundance of DSR. If successful, this approach would allow for expansion of abundance estimates to other areas in the eastern Gulf of Alaska without replicating costly surveys.

Methods

Using the submersible *Delta*, we made 20 dives and covered 47 transects during 17–25 August 1990 in two areas off southeastern Alaska (Fig. 1).

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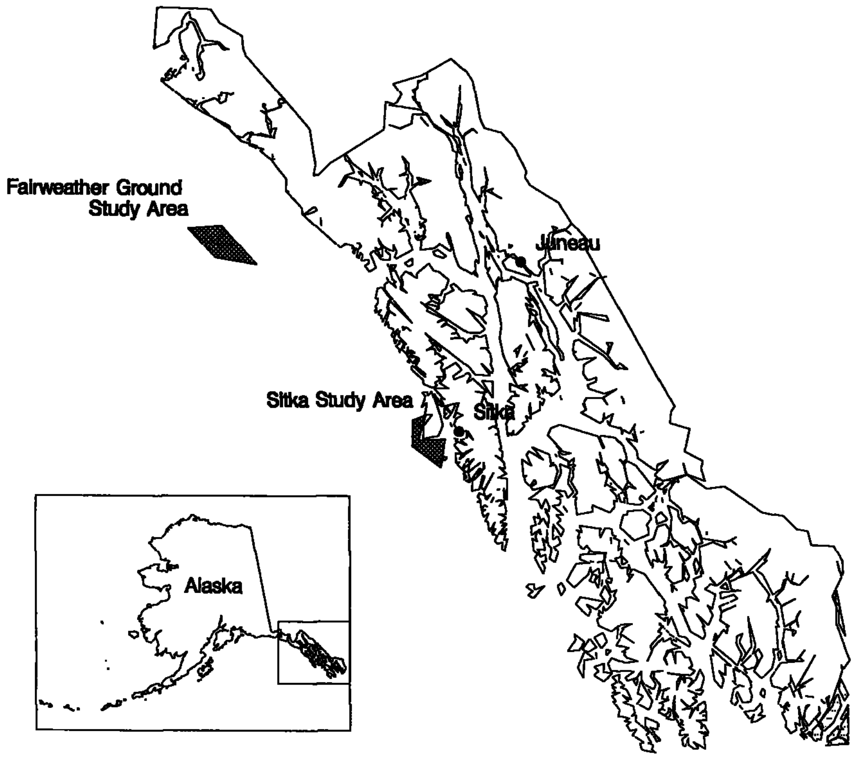

Figure 1
Study sites for submersible survey of yelloweye rockfish, eastern Gulf of Alaska, 1990–1991.

Eleven dives were made on the Fairweather Ground and nine dives were made off Sitka Sound. Eighteen dives and 30 transects were completed off Sitka Sound during 27 May–3 June 1991. One transect was replicated at night to compare day and night effects. Transect locations were chosen systematically to include sites with a range of topographical relief. Bathymetric data from the National Ocean Service Hydrographic and Marine Geophysical databases were used as an aid in site location.

In a typical dive in 1990, three transects were run per dive with each transect lasting 30 min. In 1991, transect durations were extended to 1 h with two transects run per dive. *Delta's* pilot attempted to maintain a constant speed of 0.5 kn and to remain within 1m of the bottom, terrain permitting. A predetermined compass heading was used to maintain position along a transect line. Periodic locational fixes of *Delta* along each transect were recorded using a TRAK-POINT navigation system aboard the support vessel, in combination with a Loran (1990) or a global positioning system (1991). The length of each transect (l_i) was measured as the sum of distances between locational fixes.

The usual procedure for line-transect sampling entails counting objects on both sides of a transect line. Due to the configuration of the submersible, we only counted fish on the right side of each line. Horizontal visibility was usually good, 5–15 m. All fish observed from the starboard port were individually counted and their perpendicular distance from the line recorded (Buckland 1985). The observer used the lower and middle starboard ports for viewing. An externally-mounted video camera was used to record both habitat and audio observations of species encountered and perpendicular distances to fish. Yelloweye rockfish have distinct coloration differences between juveniles and adults, so observations of the two were recorded separately, and also on a back-up tape recorder. A Pisces Box data-logger recorded depth of the submersible and its distance from the bottom, time of day, and temperature onto the videotape at 1s intervals. These data were later downloaded onto a microcomputer spreadsheet. In addition to the video system, we used a Photosea 35 mm camera with strobe to photograph habitat and fish. Two lamps were mounted externally to provide lighting for the camera systems.

Hand-held sonars were modified to obtain perpendicular distance recordings. Two sonar models were used: Manta and Scubapro. The end of each gun was fit with a tight (rubber) reservoir cinched to the sonar barrel. The reservoir was filled with water, and a syringe used to remove air bubbles. The end of the reservoir was kept damp by resting it on a wet sponge. A digital read-out of the distance from the submersible to its target was obtained by pressing the reservoir end of the gun against the port, aiming the gun, and pressing the trigger. To verify the accuracy of this method, we confirmed readings by positioning a scuba diver at intervals along a marked transect line.

Six habitat categories were used: soft, gravel, cobble, continuous rock, boulder, and broken rock. Other descriptions of habitat were also recorded, including rock type (e.g., basalt), invertebrate cover, and vertical relief. To analyze depth differences, two depth intervals were defined: shallow <108 m, and deep ≥108 m.

Density estimates were obtained for combinations of species, area, depth, and habitat type using the density estimator advanced by Burnham et al. (1980), except that length of transect (l_i) as used in the denominator was not doubled, since we were able to count fishes only on one side of each line transect. Data from all transects were combined, and yelloweye rockfish density was estimated as

$$\hat{D}_{YE} = \frac{n\hat{f}(0)}{L},$$

where n = total yelloweye rockfish adults observed (from all transects), and L = total line length (all transects combined) in meters.

We used the indirect method of estimating variance in density (Burnham et al. 1980:54), and *f(0)* was estimated from detection functions based on the hazard-rate perpendicular distance model of Hayes & Buckland (1983).

Results

Density estimates

No discernable difference was noted in the occurrence of yelloweye rockfish between day and night replicate transects, and all density estimates are calculated from daytime dives. Estimated densities of yelloweye rockfish in 1990 and 1991 varied from 1954/km^2 to 2531/km^2 (Table 1). Estimated probability density functions (pdf) generally exhibited the "shoulder" (i.e., an inflection and asymptote in the pdf for perpendicular distances near 0) that Burnham et al. (1980) discuss as a desirable attribute of the pdf for estimation of f(0) (Fig. 2).

Habitat effects

Boulder fields were the most densely populated habitat type, followed by broken rock (Table 2). Although density was greater in boulder cover regions, the occurrence of this habitat type was relatively infrequent, accounting for only 16% of the total bottom surveyed.

Surveyed habitat ranged from low-relief mud to high-relief pinnacles and cliff faces. The predominant rock type was volcanic, including folded lava flats and columnar basalt. Adult yelloweye rockfish were encountered over all habitats surveyed, but occurred most frequently over broken rock and boulder fields, often observed resting in refuge spaces such as cracks, caves, or overhangs (Fig. 3). They were also observed hovering off cliff faces above cobble or pavement bottoms. Generally, only one yelloweye rockfish was observed per refuge space, but often the hole was cooccupied by a tiger rockfish *Sebastes nigrocinctus*. Frequency-of-occurrence of yelloweye rockfish over soft, cobble, and continuous rock bottom was too low to provide acceptable line-transect density estimates. In both the Sitka Sound and Fairweather areas, there are infrequent abrupt pinnacles overlaid with massive boulders and overhangs. Density of yelloweye and other species was extremely high in these habitats. In the Sitka area we surveyed two adjacent pinnacles: one pinnacle highly dissected with many boulders and overhangs, the other comparatively smooth. Occurrence of yelloweye rockfish on the complex habitat pinnacle was clearly higher than on the smoother pinnacle. Alhough gross vertical relief is similar between the two pinnacles, the number of refuge spaces differed and appeared to be important in the occurrence of yelloweye rockfish.

Depth effects

Depth effects on abundance were difficult to interpret because of the confounding influence of habitat. Depth-related density differences were evaluated by combining the 1990 and 1991 Sitka data and examining two depth zones within the two preferred habitat types: broken rock and boulder. In both habitats, deep zones had higher abundances than shallow zones within the same habitat type. Boulder areas differed the most between shallow and deep zones: The highest estimated density in boulder areas was in the deep zone where 9135 yelloweye rockfish/km^2 were counted, compared with 6122 yelloweye rockfish/km^2 in the shallow zone. The deep-zone broken-rock habitat had 2831 yelloweye rockfish/km^2. compared with 2748/km^2 for the shallow zone.

Table 1

Density estimates, CV(D), and 95% CL for adult yelloweye rockfish by area and year.

Year/Area	Density no./km^2	n	CV(D)	95% CL Lower	95% CL Upper
1990 Fairweather	2217	221	19.5	1184	3250
1990 Sitka	1954	236	25.3	813	3054
1991 Sitka	2065	352	14.9	1347	3165

Juvenile yelloweye

Abundance of juvenile yelloweye rockfish was too low to obtain reliable habitat-specific density es-

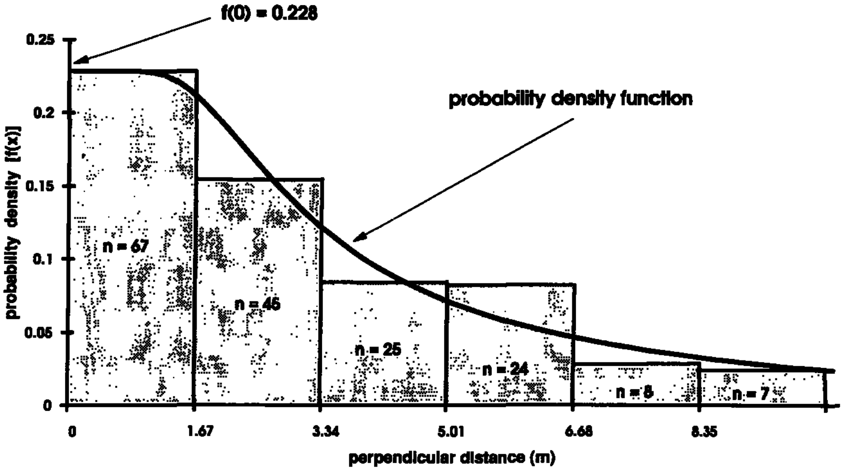

Figure 2

Representative probability density function (pdf) and histogram of relative frequencies $(n_i/(\Delta_i n))$ of yelloweye rockfish observed for 5 distance intervals over boulder habitat in the Sitka study area, 1990. For relative frequencies, n_i = number of fish observed in interval i, Δ_i = size of class interval (in this case, 1.67m), and n = total number of yelloweye observed (in this case, 176).

timates; hence they varied considerably (Table 3). Data on frequency-of-occurrence/meter traversed suggested preference by juvenile yelloweye rockfish for the shallow-zone broken-rock habitat.

Discussion

In addition to confirming the strong association of yelloweye rockfish with rocky habitat noted by Richards (1986), we were able to estimate overall and habitat-specific densities for yelloweye rockfish. The only previously published estimates of yelloweye rockfish densities are from the Strait of Georgia, British Columbia. Richards (1986) used strip transects conducted from the submersible *Pisces VI* to describe spatial distribution patterns of rockfish. Although our results were not directly comparable to hers because of differences in habitat categorization and because juvenile yelloweye rockfish were included in her density estimates, our results were similar. For two depth categories, 21–80 m and 81–140 m, Richards (1986) estimated yelloweye rockfish densities of ~10,000 and 14,000 yelloweye/km^2 in her complex habitat category, including high-relief areas of cobble with large rock, broken rock, and boulder, a category that may encompass our broken-rock and boulder habitat types. In our study, estimated densities in boulder and broken-rock habitats varied from 2405 to 9135 yelloweye rockfish/km^2, depending on depth. Comparison of estimated densities from roughly similar habitat types in the two studies suggests that yelloweye densities in the Strait of Georgia, BC were greater than we estimated for the coast of southeast Alaska.

Table 2

Density estimates for adult yelloweye rockfish by habitat category, area, and year.

Habitat	Year/Area	*n*	Density no./km^2	CV(D)	95% CL Lower	95% CL Upper
Boulder	1990 Fairweather	59	3660	36.60	792.2	6527.1
	1990 Sitka	52	3712	53.70	0	8015.8
	1991 Sitka	82	5026	30.99	1693.0	8358.9
Broken rock	1990 Fairweather	143	3312	24.50	1575.1	5048.8
	1990 Sitka	175	2515	20.80	1393.2	3637.6
	1991 Sitka	253	2405	40.81	304.84	4505.16

Use of the submersible allowed collection of qualitative data for assessment of factors contributing to the distribution and abundance of fishes. Occurrence of refuge spaces may be one key to the presence of yelloweye rockfish, which were normally in areas where refuge spaces were available, even if the surrounding habitat was not the preferred habitat of boulder or broken rock. For example, we often encountered yelloweye rockfish under overhangs of large, solitary boulders in cobble flats. Continuous rock bottom was not particularly good habitat in terms of yelloweye density. Additional transects will be needed to increase the precision of habitat-specific estimates and narrow the associated confidence limits. Further refinement of habitat categories (e.g., subcategories of boulders based on average size of boulders and/or interstitial spaces) may also yield more precise habitat-specific estimates for yelloweye.

Differences in density estimates for juvenile yelloweye between the Fairweather and Sitka sites are interesting. The higher density on the Fairweather site may be due to terrain: the Fairweather Ground is a well-defined bank surrounded by large ex-

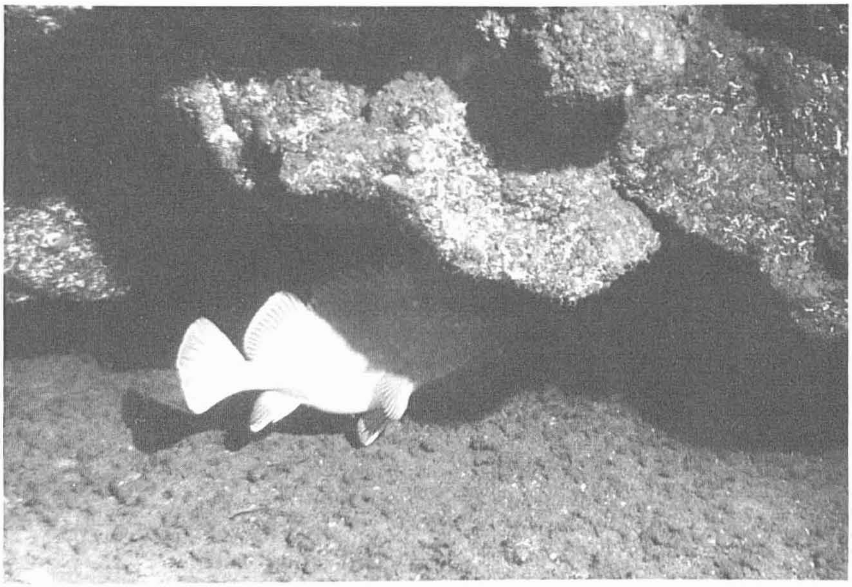

Figure 3

An adult yelloweye rockfish in a typical "refuge space."

Table 3

Density estimates for juvenile yelloweye rockfish by area, eastern Gulf of Alaska, 1990.

Area	n	Density no./km^2	CV(D)	95% CL Lower	95% CL Upper
Fairweather	140	1766	21.34	959.2	2572.7
Sitka	48	497	40.77	63.3	929.7

panses of soft bottom. This topography may cause juveniles to be more closely aggregated than in the Sitka area, where reefs and pinnacles are often linked by hard bottom, e.g., continuous lava flats. Although hard bottom is not ideal habitat, it may promote movement of fish between reefs.

Our ultimate goal is to develop a quantitative predictive model to estimate density of yelloweye rockfish and other DSR species based on one or more parameters reflective of structural habitat complexity. In the interim, the use of line transect-derived density estimates can be directly applied in fisheries management. In the absence of a fishery-independent biomass estimate, the total allowable catch (TAC) currently in use for demersal shelf rockfish had previously been based on historical catch information. In contrast, the transect data allowed us to estimate biomass/km^2 and to expand this estimate to a larger area using an estimate of area of rocky habitat inside the 180 m deep edge of the continental shelf. Allowable biological catch (ABC) and TAC can then be set, using known life-history information including estimates of natural mortality. In 1991, the Gulf of Alaska Plan Team of the NPFMC used this approach in recommending an ABC for the demersal shelf rockfish assemblage in the East Yakutat District (O'Connell et al. 1991).

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