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Using Line Transects and Habitat-based Assessment Techniques to Estimate the Density of Yelloweye Rockfish (Scorpaenidae: *Sebastes*) in the Eastern Gulf of Alaska

O'Connell, V.M., D.C. Carlile, and W. W. Wakefield

ABSTRACT
Yelloweye rockfish (*Sebastes ruberrimus)* are the target of a commercial longline fishery in the Eastern Gulf of Alaska. The Alaska Department of Fish and Game has been using a submersible to conduct line transects for estimating the density of yelloweye rockfish since 1990. Prior to this study no biomass estimates were available for this species, as they inhabit complex rocky habitats inaccessible to trawl surveys. Biomass of adult yelloweye rockfish is derived as the product of line transect density (for all rock habitats), the estimate of area of suitable habitat, and average weight of fish from port samples by management area. Line transects require distance and angle to each fish on or adjacent to the transect line, and line length. These data are fit to a probability detection function. Although not used directly in management, habitat-specific densities are also estimated. Yelloweye rockfish are more abundant in areas with refuge spaces (i.e. caves, large cracks, overhangs or in boulder fields where the boulders are large and the void to clast ratio is also large). Density estimates vary significantly by management area ranging from 839 adult yelloweye/km^2 in Northern Southeast East Outside (NSEO) to 4,176/km^2 Fairweather Ground. The estimated density of adult yelloweye rockfish in Central Southeast Outside (CSEO), the primary fishing ground and the only management area surveyed in all years, has ranged from 1,683/km^2 in 1994 to 2,929/km^2 in 1995. The differences are largely explained by changes in survey techniques including the use of a second video camera in 1995 to "guard" the transect line. The inclusion of the camera ensures that 100% of the fish on the transect line are detected, an important assumption in line transect theory. The 1997 survey yielded a density estimate of 2,534/km^2 for the CSEO area. In 1994, we conducted a pilot study using sidescan sonar to help delineate available habitat and identify areas of key habitat types. We expanded this study in 1996 and collected sidescan and bathymetric data for 563 km^2 of fishing ground in the CSEO area. In the summer of 1998, we will continue using geophysical techniques to survey the Fairweather Ground, a very productive offshore bank. Although this method is used for management, difficulties remain including precision of line length estimates, accurate quantification of available habitat, and the high cost of the survey.

Key words: Gulf of Alaska, habitat, line transects, submersible, yelloweye rockfish

Victoria M. O'Connell, Alaska Department of Fish and Game, 304 Lake Street, Room 103, Sitka, Alaska 99835, (907) 747-6688, FAX (907) 747-6239,
Email: toryo@fishgame.state.ak.us
David W. Carlile, Alaska Department of Fish and Game, Box 240020,Douglas, Alaska 99824 (907) 465-4126 FAX:(907) 465-4944, email:davec@fishgame.state.ak.us
Waldo Wakefield, Rutgers University, Institute of Marine and Coastal Sciences, College Farm and Dudley Rd, New Brunswick, NJ 08903-0231, (908) 932-6555, email: waldo@ahab.rutgers.edu

INTRODUCTION
The yelloweye rockfish (*Sebastes ruberrimus*) is the target species of the commercial longline fishery for Demersal Shelf Rockfish (DSR) in the eastern Gulf of Alaska (O'Connell and Fujioka 1991). Rockfishes 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 seven species of bottom-dwelling rockfishes inhabiting rocky areas of the continental shelf; yelloweye rockfish account for 96% of the landed catch of targeted DSR.

The life history parameters of the yelloweye rockfish make this species particularly susceptible to overexploitation. They exhibit extreme longevity (in excess of 115 year) and do not reach sexual maturity until 20 –25 years (O'Connell and Funk 1987). They are a large fish, reaching a maximum length of 96 cm and have a very low natural mortality rate M, estimated at 0.02.

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 have a physoclistic swim bladder and 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 objectives are to estimate the density of yelloweye rockfish in the Gulf of Alaska for selected habitat and depth categories and quantify the area of available habitat. We hope to 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 will allow for expansion of abundance estimate to other areas in the eastern Gulf of Alaska without replicating costly surveys.

METHODS

We used the manned submersible *Delta* to conduct 305 line transects (Buckland et al. 1993, Burnham et al. 1980) in four fishery management areas in the Eastern Gulf of Alaska (figure 1). We surveyed the Fairweather Ground in the EYKT section and the CSEO section during 1990, 1991, 1994, 1995, and 1997 and NSEO and SSEO in 1994. Although line transect data is collected for four of the seven DSR species (yelloweye, quillback, tiger, rosethorn), and for juvenile as well as adult yelloweye, included here are density estimates for adult yelloweye rockfish only. Density estimates are limited to adult yelloweye, because it is the principal species targeted and caught in the fishery, and therefore our allowable biological catch (ABC) recommendations for the entire assemblage are keyed to adult yelloweye. In a typical dive, two transects were run per dive with each transect lasting 45 minutes. During each transect, the submersible's pilot attempted to maintain a constant speed of 0.5 kn and to remain within 1 m of the bottom, terrain permitting. A predetermined compass heading was used to orient each transect line.

The usual procedure for line transect sampling entails counting objects on both sides of a transect line. Due to the configuration of the submersible, with primary view ports and imaging equipment on the starboard side, we only counted fish on the right side of the 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 transect recorded (Buckland 1985). An externally mounted video camera was used on the starboard side to record both habitat and audio observations. In 1995, a second video camera was mounted in a forward-facing position. This camera was used to "guard" the transect line promoting 100% detectability of yelloweye on the transect line, a critical assumption when employing line transects. The forward camera also enabled counts of fish that avoided the sub as the sub approached. Yelloweye rockfish have distinct coloration differences between juveniles and adults, so observations of the two were recorded separately.

A PISCES data logger overlaid depth of the submersible and its distance from the bottom, time of day, and temperature onto the videotape at 1 intervals. In addition to the video system we used a Photosea 35-mm camera with strobe to photograph habitat and fish.

Hand-held sonar guns were used to calibrate observer estimates of perpendicular distances. It was not practical, and can be deleterious to accurate counts and distance estimates, to take a sonar gun confirmation to every fish. We therefore calibrated observer distance estimates using the sonar gun at the beginning of each dive, prior to running the transect. The sonar gun was also used during the transect when necessary to reconfirm distances. To verify the accuracy of this method, we confirmed sonar readings by positioning a scuba diver at intervals along a marked transect line.

Six habitat categories were used for initial analysis: soft, gravel, cobble, continuous rock, broken rock, and boulder. Other descriptions of habitat were also recorded, including rock type (e.g. basalt), invertebrate

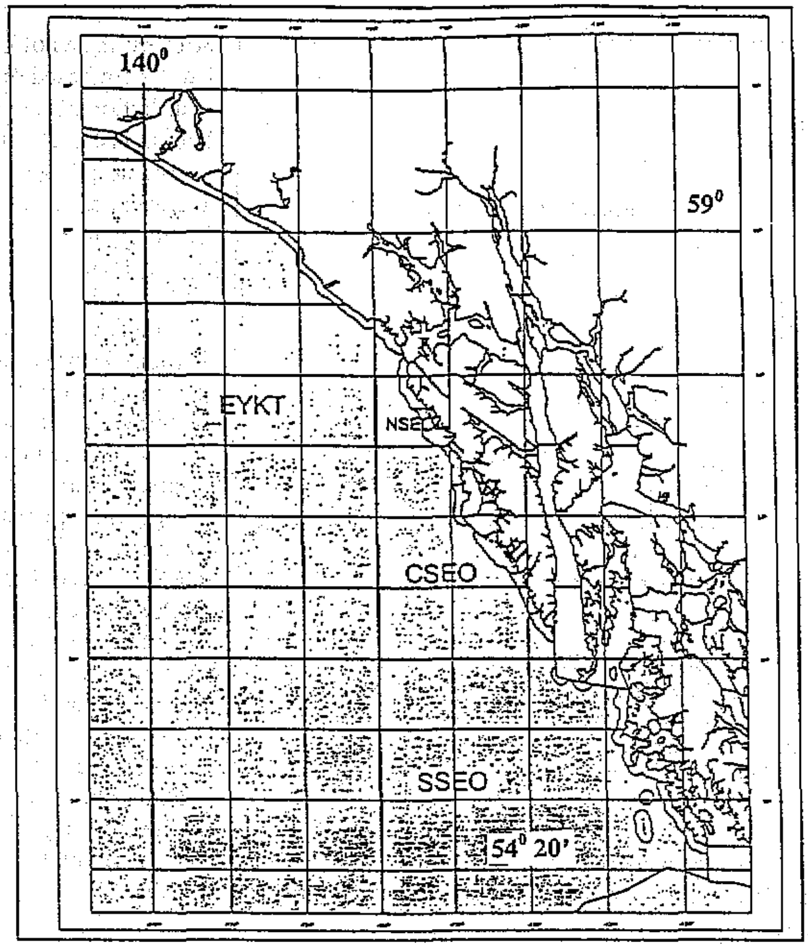

Figure 1. Management areas for yelloweye rockfish in the Eastern Gulf of Alaska east of 140° W longitude and between the latitudes of 54° 20' and 59° 40' N.

cover, and vertical relief. To analyze depth differences, two depth intervals were defined: shallow < 108 m, and deep ≥ 108 m.

Density estimation

A line transect estimator (Buckland et al 1993) was calculated and the best fit model selected from several detection functions using version 2.01 of the software program DISTANCE (Laake et al 1993). A principal function of the DISTANCE software is to estimate f(0) (figure 2).

For each area yelloweye density was estimated as

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

Where:

n = total number yelloweye rockfish adults observed
f (0) = probability density function of distance from a transect line, evaluated at zero distance
L = total line length in meters

An ORE International, Inc., Track-point II underwater tracking and navigation system was used to track the submersible. Methods for estimation of line length have varied between surveys. In 1997 we positioned the support ship directly over the submersible at 5-minute time intervals, and used the corresponding Differential Global Positioning (DPGS) fixes to determine line length.

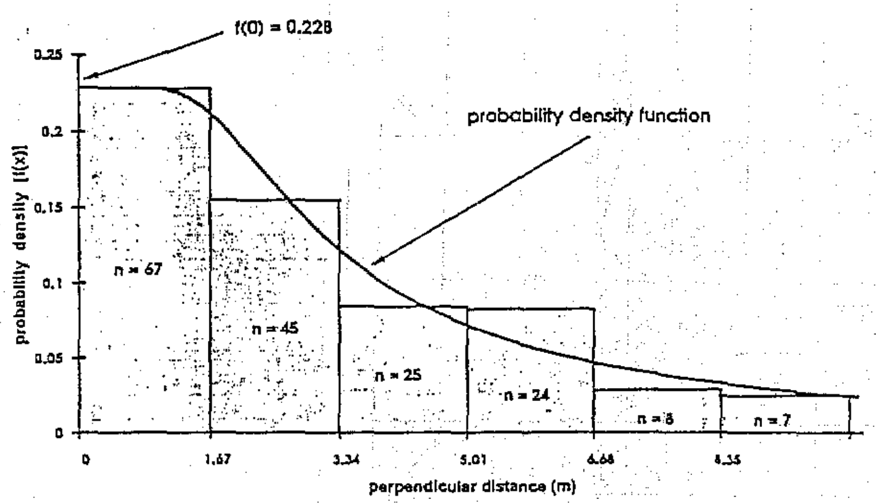

Figure 2

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).

Area estimates of DSR habitat are based on the distribution of rocky habitat inshore of the 100-fathom edge. Inclusion of areas was based on nautical charts, NOS bathymetric data, and commercial longline logbook information detailing DSR set locations. An overlay grid was placed on the nautical charts for each region and squares within the grid were classified as either rocky or not rocky based on the above information. Area estimates for the Fairweather Portion of the East Yakutat Subdistrict were refined during the 1997 survey. The support ship transected the bank in several sections using a paper-recording fathometer to determine gross bottom type. The "Delta" submersible was then used to groundtruth habitat characterization in several areas.

Biomass estimation

For the 1993 stock assessment report (based on 1990 and 1991 data), we assumed a Poisson distribution for the sample size, n to estimate the variance in biomass. The variance of n provides one component of the overall variance estimate of density. We used this approach because of the relatively small number of transects conducted in 1990 and 1991. In 1994, 1995, and 1997, we substantially increased the numbers of transects conducted and therefore used an actual empirical estimate of the variance of n (see p. 88, Buckland et al. 1993). Total biomass for yelloweye rockfish is estimated for each management subdistrict as the product of density, mean weight and areal estimates of DSR habitat (O'Connell and Carlile, 1993). For estimating variability in yelloweye biomass, we used log-based confidence limits because the distribution of density tends to be positively skewed and we assume density is log-normally distributed (Buckland et al 1993). Biomass was also calculated differently for the EYKT area in 1997 compared to previous assessments. Within the EYKT area, Fairweather and non-Fairweather sub-areas were designated. The biomass was calculated for Fairweather based on the density estimates from the Fairweather transects, the average weight from EYKT, and the estimate of rocky habitat in Fairweather. The biomass for the non-Fairweather portion of EYKT was estimated using the density estimate from the CSEO transect, the average weight from EYKT, and the estimated area of the Non-Fairweather portion of EYKT. The overall estimate for EYKT was based on the combined biomass and variance estimates from the area as a whole. This was done because there were no transect data from the Non-Fairweather portion of EYKT and commercial logbook data strongly indicates that yelloweye abundance on Fairweather is far greater than in other areas of EYKT. Past estimates of biomass for EYKT were revised using this procedure. No new surveys were conducted in NSEO and SSEO. The biomass estimates from 1995 for these areas were revised using 1997 average weight data for the 1998 estimate.

Biomass estimates were made for each management subdistrict then the results summed to determine total exploitable biomass. Exploitable biomass is expressed as the sum of the lower 90% confidence limits for each management area. Past estimates of exploitable biomass have been revised based on the new habitat estimate for EYKT and the new method for determining biomass in the EYKT area.

RESULTS AND DISCUSSION

Estimated probability detection 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) advocate as a desirable attribute of the pdf for estimation of f(0) (Fig. 2). Densities, CVs, average weights, units of habitat, and biomass estimates are listed in Table 1. Estimated densities of yelloweye rockfish varied from 839 adult yelloweye/km^2 in the NSEO area during 1994 to 4,176/km^2 in Fairweather during 1997. The Fairweather Ground of the EYKT management area consistently had higher densities than the other areas. The estimated density of adult yelloweye rockfish in Central Southeast Outside (CSEO), the primary fishing ground and the only management area surveyed in all years, has ranged from 1,683/km^2 in 1994 to 2,929/km^2 in 1995. The differences are in part due to changes in survey techniques including the use of a second video camera in 1995 to "guard" the transect line. The inclusion of the camera ensures that 100% of the fish on the transect line are detected, an important assumption in line transect theory. Fish counts that included fish seen only with the forward looking camera increased counts by 8% overall, and 12% on average. However, because of the influence of these observations on the PDF, the associated density estimate is 40% greater than without the forward camera observations. The 1997 survey yielded a density estimate of 2,534/km^2 for the CSEO area.

Table 1. Density estimates of yelloweye rockfish by year and management area with associated CV (coefficient of variation), average fish weights, estimated area of habitat, and biomass estimates.

Year	Mgt Area	Survey data used in estimates	Density (adults/km^2)	CV(D)	avg wt (kg.)	Habitat (km^2)	Point Est (mt)	Biomass *L 90% CL (mt)*
1998	Fairweather	1997	4176	0.18	3.87	448	7369	5443
	Other EYKT	CSEO '97	2534	0.20	3.87	268	2669	1921
	Total EYKT	1997			3.87	716	10039	7899
	CSEO	1997	2534	0.20	2.87	1997	14520	10453
	NSEO	'94	839	0.28	2.98	896	2239	1428
	SSEO	94 density, '96 avg wt	1173	0.28	3.27	2149	8243	5253
	TOTAL SEO					5757	35041	25031
1996 and 1997	Fairweather	95 with 97 habitat	4805	0.16	3.74	448	8046	5759
	Other EYKT	CSEO 95	2929	0.19	3.74	268	2689	2158
	EYKT total	1995				716	11014	8492
	CSEO	1995	2929	0.19	3.10	1997	18117	13168
	NSEO	1994	839	0.28	2.98	896	2239	1426
	SSEO	1994	1173	0.28	3.88	2149	9781	6222
	TOTAL SEO					5757	41151	29285
1995	Fairweather	90 density, 97 habitat	2283	0.10	4.05	448	4143	2947
	Other EYKT	CSEO 1994	1683	0.10	4.05	268	1686	1414
	EYKT total				4.05	716	5829	4957
	CSEO	1994	1683	0.10	2.70	1997	9076	7583
	NSEO	1994	839	0.28	2.98	896	2239	1426
	SSEO	1994	1173	0.29	3.88	2149	9781	6222
	TOTAL SEO					5757	26925	20188
1994	Fairweather	90 density, 97 habitat	2283	0.10	4.05	448	4143	2947
	Other EYKT	1991 CSEO	2030	0.09	4.05	268	2199	1564
	EYKT total					716	6342	4924
	CSEO	1991	2030	0.09	2.93	1997	11892	15608
	NSEO	1991 CSEO	2030		3.73	896	6779	5124
	SSEO	1991 CSEO	2030		3.43	2149	14964	11344
	TOTAL SEO					5757	39976	30453

Surveyed habitat ranged from low-relief mud to high-relief pinnacles and cliff faces. Yelloweye rockfish are most abundant in areas with refuge spaces (i.e. cave, large cracks, overhangs, or in boulder fields where the boulders are large and the void-to-clast ratio is also large) (Fig. 3). Habitat-specific densities have not been estimated since 1992 and given the improvements in survey technology these estimates do not reflect actual densities. However, the relative trends in densities are reflective of the relationships between habitat, depth and density. Boulder fields were the most densely populated habitat type followed by broken rock. The 1990 and 1991 CSEO data were combined and examined for two depth zones within broken rock and boulder habitats. The highest estimated density was in deep water boulder fields with a density more than 3 times greater than the shallow water broken rock habitat.

Because this is a developing method for stock assessment, we have made some changes in techniques each year in an attempt to improve the survey. Estimation of both line length for the transects, and total area of rocky habitat, are problematic and result in some uncertainty in the biomass estimates. For example, based on the 1997 survey, the estimate of total area of rocky habitat on the Fairweather Ground was reduced from 1132 sq. km to 448 sq. km. In 1994, we conducted a pilot study using sidescan sonar to help delineate available habitat and identify areas of key habitat types. We expanded this study in 1996 and collected sidescan and bathymetric data for 563 km^2 of fishing ground in the CSEO area. In the summer of 1998, we will continue using geophysical techniques to survey the Fairweather Ground, a very productive offshore bank. These mapping surveys will allow us to greatly improve the quantification of rocky habitat for use in fisheries stock assessment. While uncertainties remain, the use of DGPS has improved the ability to measure line transect length, and the use of sidescan sonar data and/or groundtruthing with the "Delta" submersible have improved the accuracy of habitat delineation

The biomass estimates presented here are used by the North Pacific Fishery Management Council for setting Allowable Biological Catch (ABC) levels and commercial fishery harvest quotas. Because of the continued uncertainty in estimation of biomass for yelloweye rockfish, we continue to advocate using the sum of the lower 90% confidence limits of biomass, by area, as the reference number for setting ABC. This results in a biomass estimate of 25,031 mt. By applying a fishing rate (F) equivalent to estimated natural mortality (M), in this case 0.02, to this biomass and adjusting for the 10% of other DSR species landed in the fishery, the recommend 1998 ABC is 560 mt. Continued conservatism in managing this fishery is warranted given the life history of the species and the uncertainty of the biomass estimates.

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