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ARTICLE

Sampling Efficiency of Longlines for Shortraker and Rougheye Rockfish Using Observations from a Manned Submersible

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Abstract
Populations of demersal rockfish of the genus *Sebastes* are challenging to assess because they inhabit rocky areas that are difficult to sample with trawl gear. In contrast, longline gear can sample rocky areas, but several factors besides fish density can affect the relationship between catch rates and density. In this study, longline catch rates of shortraker rockfish *Sebastes borealis* and rougheye rockfish *S. aleutianus* were compared with observations of density from a manned submersible to evaluate the species' catchability on longline gear. On separate occasions, rockfish behavior in the presence of longline gear was observed from the submersible. Densities averaged 3.0 shortraker and rougheye rockfish (combined) per 330 m^2 of bottom (the effectively sampled area of a 100-m transect). Longline catch rates averaged 2.7 shortraker and rougheye rockfish per skate of 45 hooks. Longline catch rates were not statistically affected by submersible observations. There was a positive trend between density and longline catch rates, but the relationship was not significant. As observed from the submersible, the proportion of fish free-swimming near the longline increased through the duration of the set, indicating that rockfish were attracted to the line faster than they were caught. The catching process for shortraker and rougheye rockfish lasts longer than for more mobile species such as sablefish *Anoplopoma fimbria*.

Populations of rockfish *Sebastes* spp. can be difficult to assess with bottom-trawl survey gear (O'Connell and Carlile 1993; Love and Yoklavich 2006) because they often inhabit untrawlable rocky habitats (Zimmerman 2003). Conversely, longline gear can be set in most bottom habitats and is used to assess abundance of several benthic fish species (e.g., Kohler et al. 1998; Clark and Hare 2006; Cook 2007; Hanselman et al. 2009). The relationship between longline catch rate and abundance is linear for some species when the gear is not near saturation (Sigler 2000). When the relationship between density and catch rate is known, catch rates can be used as an index of abundance. Several factors besides abundance, however, can affect catch rate, including competition for hooks (Rodgveller et al. 2008), reduced scent of bait with soak time (Løkkeborg and Johannessen 1992), water currents (Løkkeborg et al. 1989), time of day (Løkkeborg 1994), feeding history (Løkkeborg et al. 1995; Stoner and Strum 2004), water temperature (Sogard and Olla 1998a, 1998b; Stoner and Strum 2004), and behavioral responses of fish (Løkkeborg 1994). These factors can blur the relationship between catch rate and density and

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make catch rates a less reliable tool for assessing abundance trends.

The Alaska Fisheries Science Center of the National Marine Fisheries Service (NMFS) performs an annual longline survey of fixed stations throughout Alaskan waters (Sigler 2000). The survey targets sablefish *Anoplopoma fimbria*, but several other species are caught, including shortraker rockfish *S. borealis* and rougheye rockfish *S. aleutianus*. Currently, longline catch rates for shortraker and rougheye rockfish are assumed to be linearly related to fish density. However, studies have tested this assumption only for sablefish (Sigler 2000). A linear relationship between density and catch rate on the longline survey would indicate that survey catch rates are a reliable index of abundance for shortraker and rougheye rockfish.

Our first objective was to determine the sampling efficiencies of longline and submersible observations by testing whether a relationship exists between longline catch rates and the densities of shortraker and rougheye rockfish at the same sites, as estimated in situ via a manned submersible. Our second objective was to observe the behavior of shortraker and rougheye rockfish in the presence of longline gear and to determine whether their behavior should influence our interpretation of longline catch rates for abundance estimation.

METHODS

Study Area

The study sites were located near Kruzof Island, Alaska (≤40 km from 57°N, 136°W), at the shelf break along the depth contour from 280 to 365 m, an area where rougheye and shortraker rockfish commonly are caught during the NMFS longline survey. Nearby areas are known to have good visibility (average 7 m) and minimal currents (≤1 km/h), which makes this area a good choice for submersible observations (Krieger 1992, 1993). Shortraker and rougheye rockfish are less patchy in their distribution than other species. For example, NMFS trawl survey biomass estimates are less variable for rougheye (CV = 11–23%; Shotwell et al. 2009) and shortraker rockfish (CV = 16–31%; Clausen 2009) than for northern rockfish *S. polyspinis* (CV = 27–61%; Heifetz et al. 2009).

Recently, rougheye rockfish were separated into two species, rougheye and blackspotted rockfish *S. melanostictus* (Orr and Hawkins 2008). However, they are notoriously difficult to tell apart, even in hand, and the two species are still being managed as a species complex. No studies have yet described the differences in their biology and distribution. For simplicity, we will use the name rougheye rockfish to refer to both species.

The study was conducted during May 24–June 6, 1994, and August 7–20, 1997. To observe rougheye and shortraker rockfish near the seafloor, we used the *Delta*, a two-person, battery-powered submersible that is 4.7 m long and dives to 365 m. To deploy and retrieve the longline gear, we used the National Oceanic and Atmospheric Administration ship *John N. Cobb* (28 m long) in 1994 and the fishing vessel *Ocean Prowler* (47 m long) in 1997.

Study Design and Sampling

Study design.—The study was designed to collect and compare three types of data: (1) the density of fish as observed from a submersible, (2) the longline catch rate, and (3) the behavior of fish nearby the longline as observed from a submersible. We attempted to collect all three data types at each sample site to reduce the chance that spatial differences in fish abundance obscured these comparisons, although weather and logistic constraints sometimes prevented collection of all three sample types at all locations. For the first data type, the site was transited by the submersible to estimate the density of fish. For the second data type, the longline was set at the site to measure the longline catch rate. For the third data type, the longline was set and then observed from the submersible while on-bottom to observe the pattern of arrivals to the longline. The first two data types were designed to meet our first objective of determining the sampling efficiencies of submersible and longline observations. The third data type was designed to meet our second objective of examining rougheye and shortraker rockfish behavior near longline gear. In addition, the longline catch rates with and without submersible observation were compared to determine whether there was a submersible effect on the catching process. The order of collecting each data type (i.e., treatment) at a site was systematically varied to compensate for possible treatment effects. It took three or more days to sample one location three times because it was impractical to visit a site more than once per day.

Sampling gear and data collection.—Study planning was based on the operational criteria of three submersible dives per 24-h period, each dive lasting 2 h and covering 2 km along the bottom. The *Delta* conducted one-sided line transects. On each dive, the pilot maintained the submersible 0.5 m off the seafloor at a speed of approximately 0.33 m/s. The seafloor was illuminated for fish counting by the submersible lights. A scientist counted all fish seen out of the starboard porthole. A starboard-mounted video camera captured this view and recorded the scientist's audio counts. Current speed and direction were measured with a current meter on the submersible. Anchors with surface buoys, deployed and retrieved by the longline vessel, marked the start and end of the transect. To estimate rockfish density, the submersible descended along the buoy line and transited between the anchors. The position of the submersible was recorded at each anchor by global positioning system (GPS) and LORAN fixes from the support vessel. The submersible transited the same transect one to four times; each transect lasted about 15 min.

Three skates of longline gear (total of 300 m of line with 135 Mustad circle hooks [13/0] spaced 2 m apart) were baited with squid *Illex* spp. (Zenger and Sigler 1992). Each end of the set started with a flag or buoy array, followed by buoy line, an 18-kg anchor, 300 m of line without hooks ("running line"), and then the line with hooks. The line was weighted with 3-kg weights at the end of each skate and on the running line every 200 m to ensure the gear was on the bottom. A time-depth recorder was attached to determine when the gear reached the bottom. The *John N. Cobb* deployed sets of three skates each, and the *Ocean*

Prowler deployed sets of 30 skates each. The *Ocean Prowler* deployed more longline gear because their charter allowed them to sell the catch, but only data from the first three skates are included in our study. A scientist recorded the status of each hook (bait present or absent, species of fish caught) when the longline gear was retrieved. The number of fish per skate was computed by dividing the number of fish caught by the number of skates deployed.

A dive on the longline gear to observe rockfish behavior began by following the buoy line to the bottom. The submersible then transited the 300-m running line to the beginning of the line with hooks. Visibility was measured by counting how many strands of survey tape (attached to the line 1-m apart) were visible. Sites where the visibility was at least 7 m were included in the analyses. One site was excluded because of poor visibility. Observations started about 50 min after the longline reached bottom. A transect consisted of one 300-m transit of three skates and took about 15 min. The submersible then turned and transited the same three skates again. At 6 sites the submersible transited the skates four times, and at 12 sites it transited only two times. On each transect of the longline gear, the status of each hook was documented (bait present or absent, species of fish caught) and free-swimming fish were enumerated. The position of the submersible at the end of each transect was recorded by GPS and LORAN fixes from the support vessel.

We planned each transect to last about 15 min, the time scale on which we expected changes in fish arrival times to occur. We used arrival times observed for sablefish (Sigler 2000) because no observations were available for rougheye and shortraker rockfish. During test fishing prior to the submersible–longline comparison, we attempted to collect arrival-time data for rougheye and shortraker rockfish to test this assumption. Hook timers, an electromechanical device used to measure arrival times, were attached to one of the three skates during test fishing. Although successfully used to measure arrival times for sablefish (Sigler 2000), rougheye and shortraker rockfish typically did not trip the timers and signal their capture, presumably because sablefish are more active swimmers than rougheye and shortraker rockfish. As a result, we abandoned this effort to measure arrival times.

The detection function for submersible observations of rougheye and shortraker rockfish was estimated from perpendicular distance measurements from the submersible to observed rougheye and shortraker rockfish. Unfortunately, too few distance measurements were taken during the 1994 and 1997 experiments to estimate the detection function. Instead, we used perpendicular distance measurements from a later submersible study of rougheye and shortraker rockfish. These measurements were collected during a 2005 *Delta* submersible study in areas of high rougheye and shortraker rockfish abundance: Albatross Bank, near Kodiak, Alaska (within 30 km of 55.928N, −153.615W). Following the method of O'Connell and Carlile (1993), fish distances were calibrated using a handheld sonar device to measure distance to large stationary objects, such as boulders, for training. Dives for rockfish catchability followed several training dives where distances to objects were frequently checked. All observations were collected by one observer to eliminate variability between observers. We assumed that the detection probability is the same for both areas because these rockfish species are brightly colored, not easily hidden by benthic habitat, usually motionless, distributed near the seafloor, and have minimal response to submersibles (Krieger and Sigler 1996; Krieger and Ito 1998; Yoklavich et al. 2007; Videos 1, 2) and because both areas had the same range of visibility (7–10 m). A total of 224 measurements during eight transects, totaling 18,030 m, were collected during the Albatross Bank study.

Data Analysis

Sampling efficiency objective.—We used Distance 5.0 software (Thomas et al. 2006) to choose a detection function and calculate fish densities at each site for shortraker and rougheye rockfish using the following function:

$$\hat{D}_i = \frac{\hat{f}(0)n_i}{L_i},$$

where $\hat{D}_i$ is the density at the ith site, n_i is the number of fish counted on all transects at the ith site, L_i is the total length of all transects at the ith site, and $\hat{f}(0)$ is the probability density function evaluated at 0 perpendicular distance (Buckland et al. 1993).

We compared longline catch rates with and without submersible observations and found no significant effect of the submersible on the catching process (two-tailed paired t-test; $P = 0.96$, df $= 23$). Having no significant effect let us use the average longline catch rate for each site (from sets both with and without submersible observations) when comparing longline and submersible sampling efficiencies. The catchability coefficient (q) was computed as the ratio of the average catch per unit effort (CPUE; number of fish per skate of gear with 45 hooks on 100 m of groundline) to the average density (i.e., count totals for 100-m-long transects) for all sampled stations, given the assumption that the line transect density was the true underlying density. Shortraker and rougheye rockfish were pooled together for this analysis because (1) rougheye and shortraker rockfish are similar in their depth preferences, benthic, usually motionless, distributed near the seafloor, and have minimal response to submersibles (Kreiger and Sigler 1996; Krieger and Ito 1998), and (2) not all shortraker and rougheye rockfish were identified to species.

We compared the q estimated from this study with a comparable estimate of q from the rougheye rockfish population model in the Gulf of Alaska stock assessment (Shotwell et al. 2009). The stock assessment uses a population model to estimate abundance and set catch quotas. The population model assumes that there is a linear relationship between survey longline CPUE and fish density, that is,

$$\hat{I} = \hat{q}N,$$

where I is the survey abundance index, q is the catchability coefficient, and N is the true underlying abundance. The longline survey sampled the shelf break throughout the Gulf of Alaska, so the data used for the population model is geographically more extensive than the data collected in this study. However, the gear is identical and the depths sampled on the longline survey intersect the depths that were sampled in this study. No population model has been developed for shortraker rockfish. While the rougheye rockfish population model is more complicated, includes other indices of abundance, and estimates gear selectivity and availability, the q estimated in the model is a reasonable approximation of the ratio of longline CPUE and density. To compare these values directly, we computed an estimate of q for this study and converted the values to the same scale. The variance of the estimate was computed using the typical ratio estimate of variance,

$$\text{var}(\hat{q}) = \left(\frac{N-n}{nN\bar{\hat{D}}^2}\right)\left(\frac{1}{(n-1)}\right)\sum_{1}^{n}(\text{CPUE}_i - \hat{q}\,\hat{D}_i)^2$$

(equation 7.7 in Thompson 2002), where n is the sample size of the study and N is the number of possible samples in the Gulf of Alaska based on the amount of area used to compute the longline survey abundance index, $\hat{D}$ is the average density of all sites, and $\hat{D}_i$ is the density of each site. We also computed the variance using the delta method (Zhou 2002), which yielded the same variance.

Behavior objective.—Fish behavior at sites where the longline was transited two times were analyzed separately from that at sites where the line was transited four times. Shortraker and rougheye rockfish were also analyzed separately because, for these longline sets, these rockfish species were differentiated during submersible observation and longline retrieval. The normalized number of fish caught, normalized free-swimming fish observed, and normalized percent fish hooked (computed as the number of fish hooked/[number free-swimming + number hooked]) were computed as

$$\frac{F_i - F_{\text{avg}}}{F_{\text{avg}}},$$

where F_i is either the number of fish caught, the number of free-swimming fish, or the percentage of fish that were hooked on the ith transect and F_{avg} is the average number of fish caught, number of free-swimming fish, or percentage of fish hooked for all transects at a site. This enabled trends in caught, free-swimming, and percent hooked fish to be examined at all sites together on a relative scale. A linear regression was performed on the normalized values for each category versus the transect number (one-two or one-four). The regression tested for trends in the timing of fish attraction to the line and capture.

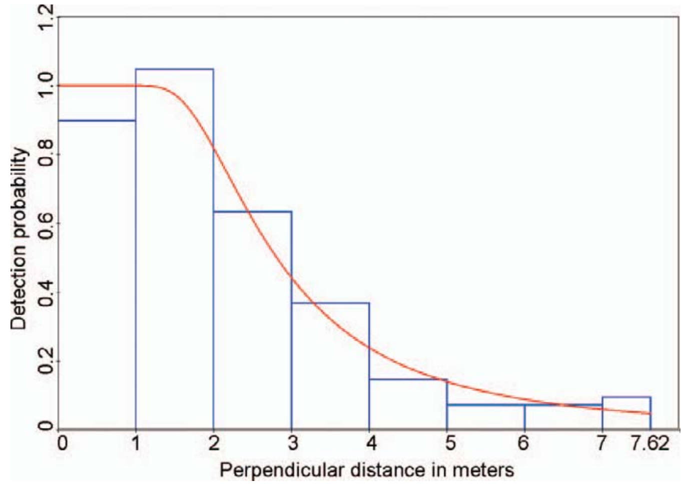

FIGURE 1. Histogram of distances of shortraker and rougheye rockfish observed from the *Delta* submersible from sites on Albatross Bank near Kodiak, Alaska in 2005 and the hazard-rate probability density function fit in Distance 5.0 (red line).

RESULTS

Sampling Efficiency

A hazard-rate model was chosen for the detection function for submersible observations based on the minimum Akaike information criterion value (Buckland et al. 1993), which was generated in Distance 5.0 (Thomas et al. 2006). A chi-square test showed that 1-m binning of data were adequate and preferable to 0.5-m, 1.5-m, and 2-m bins (P-values < 0.05; Thomas et al. 2006). The $f(0)$ for this model was 0.303, and the effective strip width was 3.3 m. The chosen probability density function closely fit the distance histogram (Figure 1). The hazard rate function represents the probability an object is detected given its distance from the viewer; it takes the form

$$g(y) = 1 - \exp\left\{-\left(\frac{y}{\sigma}\right)^{-b}\right\},$$

where y is the perpendicular distance, σ and b are estimable parameters, and $g(0) = 1$ (Buckland et al. 2001).

Densities observed during submersible dives without a longline present averaged 3.0 shortraker and rougheye rockfish (combined) per 330 m^2 (SE = 0.45, n = 25; Table 1). The 330-m^2 value is based on the transect length (100 m) multiplied by the effective strip width estimated in Distance 5.0 (3.3 m). Using this value standardizes the density to the number of shortraker and rougheye rockfish expected during one submersible transect.

Longline catch rates averaged 2.7 shortraker and rougheye rockfish (combined) per skate (SE = 0.41, N = 25; Table 1). Because there was no significant effect of treatment order at each site on catch rates (paired t-test; P = 0.96, df = 23), the catch rate used for each site was the average catch rate from

TABLE 1. Catch of shortraker and rougheye rockfish (combined) on longline gear (1) when a manned submersible observed the set gear (Sub) and (2) when no submersible was present (No sub). Catch per unit effort (CPUE, i.e., the number of fish per skate of gear with 45 hooks) is the average for sets under both conditions. Also included are counts of shortraker and rougheye rockfish from the submersible and calculated densities (number of fish/330 m^2 along a 100-m-long transect with an effective strip width of 3.3 m). The sites visited in 1994 differed from those visited in 1997.

		No sub		Sub			Sub without longline		
Year	Site	Number of skates	Catch	Number of skates	Catch	CPUE	Transect length (m)	Count	Density
1994	1	3	1	3	14	2.5	300	23	7.7
	2	3	0	3	0	0.0	900	13	1.1
	3	3	0	3	1	0.2	900	10	1.0
	6	3	12	3	0	2.0	1,200	85	7.1
	7	3	2	3	3	0.8	300	1	0.3
	8	3	1	3	0	0.2	1,200	45	3.7
	9	3	6	3	8	2.3	1,200	106	8.8
1997	1	6	65	3	13	8.7	1,200	76	6.3
	2	3	3			1.0	900	10	1.1
	3	3	5			1.7	600	3	0.5
	4	2	3			1.5	1,200	12	1.0
	5	3	2	3	18	3.3	1,200	20	1.7
	6	2	4	3	5	1.8	1,200	38	3.2
	7	3	14	3	15	4.8	1,200	36	3.0
	8	2	12	3	10	4.4	1,200	27	2.2
	9	3	8	3	5	2.2	1,200	39	3.2
	10	3	10	3	26	6.0	1,200	30	2.5
	11	3	4	2	9	2.6	900	32	3.6
	12	3	3	3	6	1.5	1,200	18	1.5
	13	3	11	3	7	3.0	1,200	26	2.2
	14	3	10	3	4	2.3	1,200	26	2.2
	15	3	4	3	14	3.0	1,200	15	1.2
	16	3	4	3	8	2.0	1,200	48	4.0
	18	3	19	3	3	3.7	1,200	35	2.9
	19			3	18	6.0	1,200	26	2.2

both the longline sets that were observed and unobserved when they were both available (Table 1).

The q estimated by the rougheye rockfish stock assessment population model was 3.5 times larger than the q we estimated from the ratio of CPUE and density (Table 2; Figure 2). The model implies that the longline is more effective at sampling than is the experiment. For example, for a density of 2 fish/330 m^2 (or a 100 m long transect), the model predicts a catch rate of 6.3 fish/skate (100-m-long set), whereas the experiment predicts a catch rate of 1.8 fish/skate (Figure 2). However, the confidence intervals for both q estimates overlapped and both intersected the CPUE and density data from the study sites (Figure 2).

Behavior

Submersible observations of shortraker and rougheye rockfish during longline sets demonstrated that the number of free-swimming fish in the vicinity of the line increased more quickly than the number of caught fish. The regression of normalized shortraker and rougheye rockfish catch versus transect number (a proxy for time) was significantly positive for the two-transect analysis ($P = 0.002$ and 0.025, respectively), but not significant for the four-transect analysis ($P = 0.080$ and 0.221, respectively; Table 3). The two-transect analysis indicates that catch increased early in the set, while the four-transect analysis indicates that the upward trend eventually slows. Normalized counts of free-swimming shortraker and

TABLE 2. Catchability coefficients (q), from the present study computed as the ratio of the average CPUE (number of shortraker and rougheye rockfish per skate of longline gear with 45 hooks) to the average density (per 330 m^2 over a 100-m transect with an effective width of 3.3 m) and from the Gulf of Alaska rougheye rockfish stock assessment model (Shotwell et al 2009).

Source	q	SD	Confidence interval
Study	0.91	0.17	0.57–1.24
Assessment	3.14	1.01	1.12–5.16

TABLE 3. Correlations (r), associated P-values, sample sizes (N), and slopes of the linear regressions between the transect number, a proxy for time, and (1) the normalized number of shortraker and rougheye rockfish caught, (2) the number of free-swimming fish, and (3) the hook fraction (number caught/[number caught + number free-swimming]), as observed from a manned submersible.

Species	Variable	r	N	Slope	P
		Sites visited two times			
Shortraker	Catch	0.61	24	1.27	0.002
	Free-swimming	0.55	24	0.74	0.009
	Hook fraction	0.02	24	0.01	0.938
Rougheye	Catch	0.46	22	0.43	0.025
	Free-swimming	0.54	22	0.65	0.007
	Hook fraction	0.50	22	0.44	0.013
		Sites visited four times			
Shortraker	Catch	0.36	24	0.04	0.080
	Free-swimming	0.53	24	0.60	0.008
	Hook fraction	−0.45	24	−0.15	0.027
Rougheye	Catch	0.24	24	0.03	0.221
	Free-swimming	0.51	24	0.45	0.006
	Hook fraction	−0.40	24	−0.01	0.054

rougheye rockfish around the longline were significantly positive for analyses of two and four transects, indicating that the number of fish swimming around the longline increased through time. The four-transect analysis of the fraction of hooked fish demonstrated that the percentages of fish that were caught decreased through time because free fish increased faster than fish were caught. The normalized fraction of fish hooked was significantly negative in the four-transect analysis for shortraker rockfish ($P = 0.027$) and nearly significant for rougheye rockfish ($P = 0.054$), was significantly positive in the two-transect analysis for rougheye rockfish ($P = 0.013$), and was not different from zero in the two-transect analysis for shortraker rockfish ($P = 0.938$; Table 3).

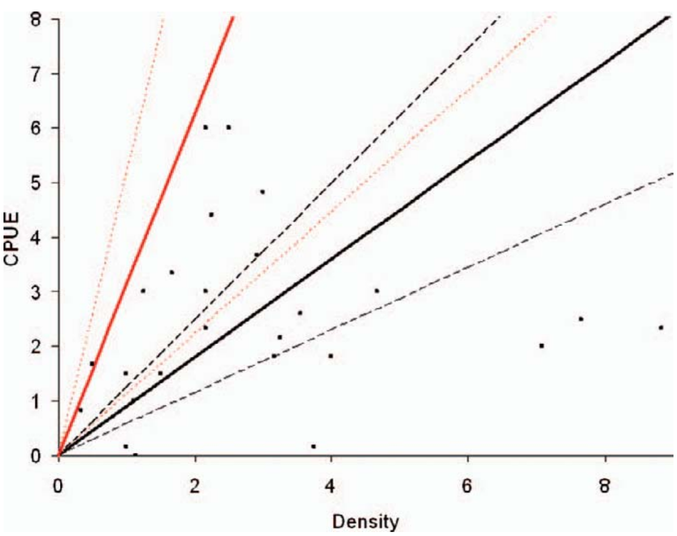

FIGURE 2. Observed shortraker and rougheye rockfish (combined) longline catch and density, estimated via counts from a manned submersible, from 25 sites in Southeast Alaska (black dots). The study catchability coefficient (q), computed as the ratio of the average CPUE (i.e., the number of shortraker and rougheye rockfish per skate of longline gear with 45 hooks) to the average density (fish/330 m^2, i.e., a 100-m transect with an effective width of 3.3 m), is represented by a solid black line; the black dashed lines are 95% confidence intervals calculated using the standard error of the mean of the density estimates, not including the intradensity variance. The q from the Gulf of Alaska rougheye rockfish stock assessment model (Shotwell et al. 2009) is represented by a solid red line; the red dashed lines are 95% confidence intervals calculated from the Hessian matrix.

Many fish were observed mouthing the bait during the set but were not actually caught. Out of 191 hooks with a shortraker rockfish on the hook at some time during the set, 30% were empty when the gear was retrieved; 19% appeared to have caught a shortraker rockfish at an earlier transect, did not during later transects, and then had a shortraker rockfish on at haul back; and 51% caught shortraker rockfish that remained on the hook. Out of 224 hooks with a rougheye rockfish on the hook at sometime during the set, 9% were empty when the gear was retrieved; 8% appeared to have caught a rougheye rockfish on an earlier transect, did not at later transects, and then had a rougheye rockfish on at haul back; and 83% caught fish that never came off the hook during the set. Overall shortraker rockfish were less likely than rougheye rockfish to be caught at retrieval after appearing to be hooked during transects of the set gear.

DISCUSSION

Both experiment-based and model-based values of longline catchability appear reasonable given plausible examples of the longline catching process. While the study predicts that for every 2 fish nearby the line, 1.8 will be caught, the population model implies that 6.3 rockfish will be caught. This may occur if the bait attracts rockfish farther from the line than we observed. The catchability coefficient estimated from the regression relationship is about 29% of the value estimated from the rougheye rockfish population model. However, simply obtaining a comparable value (the same order of magnitude) lends credence to both estimates. The line representing model-based catchability lies on the upper edge of the cloud of data points from the experiment (Figure 2). The model-based value also is affected by other model parameters, such as the assumed value of natural mortality and gear selectivity.

The lower study q implies that rougheye rockfish abundance is higher than estimated by the population model. Rougheye rockfish abundance has changed little during the last 20–25 years (Shotwell et al. 2009). For population models, historical variation in stock size and fishing pressure is needed to estimate model parameters (including abundance) with any reliability (Hilborn and Walters 1992). Incorporating the experiment-based estimate of longline catchability as a prior distribution into the population model probably is worth exploring and may improve the reliability of abundance estimates.

The relationship between longline CPUE and submersible-based density was not significant. However, catch rate tended to be lower when density was lower, and catch rate tended to be higher when density was higher, indicating that with more samples, a significant relationship might be detected. A power analysis estimated that, given the amount of variability in our observations, 58 samples were needed to reliably test whether the relationship is significant at $\alpha = 0.05$ (about 2.5 times the number of samples available). There was high variability in the relationship between CPUE and density, so with more samples the study-based q could potentially change.

Density measurements of rockfish by the submersible appear reliable. Longline catch rates in our study probably were minimally affected by submersible presence. There may have been some movement from the 0–1-m distance bin to the 1–2-m distance (Figure 1). Buckland et al. (1993) explains that when there is avoidance behavior, it is important that the function be monotone (i.e., not increasing to a peak away from 0 distance). They suggest fixing the peak so that it remains monotone to decrease bias. For our data, this was not necessary because all functions we tried to fit were monotone. The increase in counts at the 1–2-m distance was minimal. In fact, if we assumed that the counts should have been equal in the 0–1-m and 1–2-m distance categories, then there would have been 7.5% movement away from the transect line into the 1–2-m category. Buckland et al. (1993) explains that small movement away from the transect line, of around 5%, is “trivial.” Therefore, it is unlikely that any movement away from the transect line in this study had much effect on the probability density function. Other studies have also found that rockfish are not easily disturbed. For example Yoklavich et al. (2007) reviewed the literature and found that, based on 30 years of collective experience, demersal rockfish do not exhibit avoidance or attraction behavior to the *Delta* submersible (Yoklavich et al. 2007).

The catching process for shortraker and rougheye rockfish lasts at least a few hours; exactly when the catching process slows is indeterminate from our results. The number of free-swimming shortraker and rougheye rockfish increased faster than the number of caught fish, so these species are attracted to the line but often are not caught during the first 2 h of a set. On average, twice as many shortraker and rougheye were caught after approximately 5 h of soak than were observed from the submersible within the first 2 h. This indicates that the catching process was still occurring after the longline was observed. Catch rates from a range of soak times need to be tested, both shorter and longer, to determine the curvature of the relationship between catch rate and soak time. When the catch rate per hour slows, the soak time is adequate.

Typically, fish captures eventually slow because of local depletion, gear saturation (Rodgveller et al. 2008), or decreased bait scent (Løkkeborg and Johannessen 1992). For example, Sigler (2000) found that sablefish, which are more aggressive and mobile than shortraker and rougheye rockfish, were caught mostly in the first 3 h of a longline set (their catch was only 15% higher after 7 versus 3 h). Sigler (2000) concluded that 3 h is an adequate soak time for this species. On the NMFS longline survey, soak time for longline sets in shortraker and rougheye rockfish habitat is approximately 4 h, which may be before rockfish captures have substantially slowed. Again, more data are needed to better estimate the relationship between rockfish catch rates and soak time.

Even though sablefish may sometimes outcompete rockfish for baited hooks on the longline survey in some habitats (Rodgveller et al. 2008), it is not likely that there was competition for hooks in this study (even though sablefish were caught at most sites) because there were many baited hooks remaining (on average, 59%). Because sablefish and other more mobile species like Pacific halibut avoid the submersible, these species were seldom observed free-swimming. Therefore, densities could not be computed for comparison to rockfish.

The docile nature of shortraker and rougheye rockfish may explain why their catching process lasts longer. Løkkeborg et al. (1989) observed haddock *Melanogrammus aeglefinus* and Atlantic cod *Gadus morhua* in the North Sea. They found Atlantic cod were hooked more often than haddock on their first bite attempt, and haddock made a sequence of attempts lasting up to 15 min. Løkkeborg et al. (1989) suggested that haddock prefer slow, benthic prey, have less intense responses to prey, and therefore are not successfully hooked on the first strike; Atlantic cod were more aggressive and swallowed the whole bait, increasing their hooking probability. Shortraker and rougheye rockfish are slow-growing and often motionless. Many shortraker rockfish and some rougheye rockfish held the bait in their mouth but were not hooked. They may be less aggressive feeders, like haddock, and take longer to first be attracted to the bait, attack the bait, and then become hooked.

We found that the assessment q was about three times the study q estimate. If the rockfish catching process is longer than the time allowed during the study, more rockfish may be hooked after greater soak times, thereby increasing the study q. Because rockfish are more docile and probably less aggressive predators, the soak time needed to accurately assess these species may be longer than the soak time observed in this study. Future research should aim to describe the catching process for rockfish to determine the soak time necessary to accurately index their abundance.

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