A New Longline Survey to Index Inshore Rockfish (*Sebastes spp.*): Summary Report on the Pilot Survey Conducted in Statistical Areas 12 and 13, August 17 - September 6, 2003

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ABSTRACT

Lochead, J.K. and Yamanaka, K.L. 2004. A new longline survey to index inshore rockfish (*Sebastes spp.*): summary report on the pilot survey conducted in Statistical Areas 12 and 13, August 17 – September 6, 2003. Can. Tech. Rep. Fish. Aquat. Sci. 2567: 59p.

A longline survey planned to develop fishery independent indices of abundance and provide spatially representative biological samples was conducted in the northern portion of the Strait of Georgia management region (4B) between August 17 and September 6, 2003. One hundred survey sites were selected using a depth stratified (41 – 70 m and 71 – 100 m) random design and 80 sites were fished with a two skate string of 'snap' longline gear.

Thirty species of marine fish were caught on the survey, including 11 species of rockfish. Quillback rockfish (*Sebastes maliger*) were the most frequently encountered rockfish, followed by yelloweye rockfish (*S. ruberrimus*), with 533 and 173 fish sampled, respectively. Mean fork lengths of quillback and yelloweye rockfishes from SA 12 were significantly larger than those from SA 13. Mean fork length of quillback rockfish was significantly larger in the deep stratum than the shallow stratum. No differences in mean age were detectable between SA 12 and SA 13 for quillback and yelloweye rockfishes. A strong 1985 (age 18) year class is evident in the age frequency data. Male quillback rockfish were significantly older than females and the reverse was found for yelloweye rockfish. Yelloweye rockfish were also found to be significantly older in the deep depth stratum.

There were no significant differences in catch rate (kg/skate) distributions between depth strata for quillback and yelloweye rockfishes. Catch rate distributions of quillback rockfish did not differ significantly between SA12 and SA13, whereas those of yelloweye rockfish did, with the median catch rate from SA 13 significantly higher than in SA 12. A simulation model was used to assess the suitability of the survey's catch rate data to track trends in rockfish populations. It showed that this survey may be useful if continued with a similar sampling effort over the long-term.

RÉSUMÉ

Lochead, J.K. and Yamanaka, K.L. 2004. A new longline survey to index inshore rockfish (*Sebastes spp.*): summary report on the pilot survey conducted in Statistical Areas 12 and 13, August 17 – September 6, 2003. Can. Tech. Rep. Fish. Aquat. Sci. 2567: 59p.

Un relevé à la palangre visant à mettre au point des indices d'abondance indépendants de la pêche et à obtenir des échantillons biologiques représentatifs a été réalisé du 17 août au 6 septembre 2003 dans la partie nord de la région de gestion du détroit de Georgia (4B). Cent sites de relevé ont été choisis suivant un plan aléatoire stratifié selon la profondeur (41 – 70 m et 71 – 100 m), et 80 sites ont été pêchés au moyen d'une palangre à « agrafes » en deux sections.

Durant le relevé, trente espèces de poissons marins ont été capturées, dont 11 espèces de sébastes. Le sébaste à dos épineux, *Sebastes maliger*, était le poisson le plus fréquemment capturé (533 captures), suivi du sébaste aux yeux jaunes, *S. ruberrimus* (173 captures). Les longueurs à la fourche moyennes de ces deux espèces étaient significativement plus grandes dans la zone statistique (ZS) 12 que dans la ZS 13, mais leurs âges moyens ne différaient pas entre les deux zones. La longueur à la fourche moyenne du sébaste à dos épineux était significativement plus grande dans la strate profonde que dans la strate peu profonde. Les données de fréquence d'âges montrent une forte classe d'âge de 1985 (âge de 18 ans). Chez les sébastes à dos épineux, les mâles étaient significativement plus vieux que les femelles, alors que c'était l'inverse chez les sébastes à yeux jaunes. De plus, les sébastes à yeux jaunes étaient significativement plus vieux dans la strate profonde.

Les répartitions des taux de capture (kg par section de palangre) de chacune des deux espèces de sébastes ne différaient pas significativement entre les strates de profondeur. Les répartitions des taux de capture du sébaste à dos épineux ne présentaient aucune différence significative entre la ZS 12 et la ZS 13, contrairement à celles du sébaste à yeux jaunes, dont le taux de capture médian était significativement plus élevé dans la ZS 13 que dans la ZS 12. Nous avons utilisé un modèle de simulation pour évaluer si les données de taux de capture obtenus lors du relevé se prêtent bien au suivi des populations de sébastes. Le modèle montre que le relevé peut être utile si l'on maintient un effort d'échantillonnage semblable à long terme.

1.0 INTRODUCTION

Within British Columbia's Strait of Georgia management region (4B), inshore rockfish (genus *Sebastes*) are estimated to be at low levels of abundance (Yamanaka and Lacko, 2001). The majority of the landed catch from the 4B or 'inside' ZN, directed commercial hook and line fishery for rockfish, has been taken from the most northern Statistical Areas (SA), 12 and 13, since the late 1980's. To improve the assessment of quillback and yelloweye rockfishes, a new longline survey was designed and conducted to provide fishery independent indices of abundance together with biological samples in the northern portion of the 4B management region. The spatial extent and depth coverage of the longline survey overlaps that of the fixed site jig surveys conducted in portions of SA 12 since 1986 (Richards et al., 1988; Richards and Cass, 1987; Richards and Hand, 1987; Yamanaka and Richards, 1993).

The longline survey was conducted in SA 12 and 13 from August 17 to September 6, 2003. This document details the methods, summarizes the catch rate and biological data collected from the survey, and assesses the rockfish catch rate data, through a simulation model, for their potential use as an abundance index.

2.0 METHODS

2.1 Survey Design

To aid in the design of this new longline survey, logbook records from the commercial ZN fishery from 2000 to 2002 were reviewed. The longline catch rate data for quillback and yelloweye rockfishes were used to estimate the number of sets required to reduce catch rate coefficients of variation (CVs) to 20% and also to ensure that a representative age sample could be collected. Simulations were performed on the logbook data and an estimated 100 sets were required to reduce CVs to 20% (R. Haigh pers. comm.). For this survey, 600 quillback rockfish, 150 per depth interval per SA were set as targets for biological sample collection. These sampling targets could be achieved, given catch rates from logbooks in the commercial fishery, by completing 100 sets.

The survey employed a depth stratified, random design to select 2 km by 2 km survey blocks to fish. All waters in SA 12 and 13 with depths from 41 to 100 metres were stratified into two depth intervals, shallow (41 – 70) and deep (71-100). One hundred blocks were randomly selected out of a total of 1247 blocks within SA 12 and 13 (ESRI ® ArcMap™ 8.3).

One longline set was fished within each survey block. The location of the set within each block was determined by bottom type. Hard bottom areas were targeted and the gear was set along contour lines where possible. In situations where strong current, tide or wind conditions combined with close proximity to shore prevented safe gear deployment, the survey block was rejected.

2.2 Survey Vessel

The survey was conducted on board the fisheries research vessel CCGS *Neocaligus*, an 18.8 m, aluminium vessel, originally built to drum seine and longline. The vessel was skippered by Captain Alan Young (August 17 – 25, 2003) and Captain Bob Barker (August 26 – September 6, 2003). The ship's complement consisted of the captain, the chief mate, engineer, deck hand, cook and 3 to 4 scientific staff.

2.3 Fishing Gear and Operations

Snap type longline gear was used for the survey to be consistent with methods used in the commercial ZN fishery. Each longline set or 'string' consisted of two skates of groundline, each ~9 mm (11/32 inch) in diameter, measuring ~600 m (1800 ft) in length and weighing 30 kg (65 pounds), joined using "C" links in the middle and at each end to buoys. Each string of longline gear used 137 m (450 ft) of groundline at each end for buoy line and 225 circle hooks (13/0) were snapped onto the middle of the groundline 3.66 m (12 ft) apart. Perlon gangions, measuring 0.38 m (1.2 ft), were crimped at the snap end and attached to the circle hook with a swivel. Hooks were baited with thawed Argentinean squid, approximately 15 cm long, and cut into fifths.

During gear deployment the groundline was unwound from the drum, fed through a block, and then it travelled back over the setting table and off the stern. The groundline was marked at 137 m (450 ft) where the anchors (34 kg (75 lb) pieces of boom chain) were snapped at each end of the string. Two crewmembers on opposite sides of the setting table snapped the baited hooks onto the middle 823 m (2700 ft) of groundline. Twelve foot spacing was maintained during setting by clipping a hook on the groundline when the previous hook reached the surface of the water. Lead cannonballs weighing 2.27 kg (5 lb) were snapped onto the groundline intermittently, when required to weigh down the line in high relief areas.

The start and end positions and depths of each set were recorded from the vessel's global positioning system (GPS) and depth sounder respectively, when the first and last anchors were set over the stern. Minimum, maximum and modal depths were also recorded.

All survey blocks were fished during daylight hours. The duration, or soak time, of each set was 2 hours and was calculated as the time elapsed between the last anchor over the stern and the first anchor hauled aboard.

2.4 Data Collection

As the gear was retrieved the yield on each hook was recorded. The catch was identified to species and recorded with individual hook numbers. As the gear was retrieved, the catch was sorted to species and set aside for sampling. Once gear retrieval was complete, the catch was weighed by species and biological sampling began.

2.4.1 Biological sampling

Biological sampling consisted of measuring weight (W) in grams (g), length (L) in millimetres (mm) or centimetres (cm), and visually determining the sex (S) and maturity state (M) of the gonads. Rockfish maturity stages are listed in Appendix Table 1. Fork lengths were recorded for rockfish (*Sebastes spp.*), lingcod (*Ophiodon elongatus*), pacific cod (*Gadus macrocephalus*), sablefish (*Anoplopoma fimbria*), and kelp greenling (*Hexagrammos decragrammus*). Total length were recorded for spiny dogfish (*Squalus acanthias*), flatfish (Pleuronectiformes), skates (Rajidae), and irish lords (*Hemilepidotus spp.*). Snout to posterior edge of second dorsal fin lengths were recorded for spotted ratfish (*Hydrolagus colliei*). Both sagittal otoliths (O) were excised from rockfish and fin rays (F) removed from lingcod for subsequent age determination. L/W/S/M/O samples were collected from all rockfish, L/W/S/M/F samples were collected from lingcod, and L/S or L samples were collected from all other vertebrate species.

Sagittal otoliths from quillback and yelloweye rockfishes were aged in the Pacific Biological Station (PBS) Ageing Lab, using the burnt section technique for rockfishes (MacLellan 1997).

2.4.2 Catch Rate Calculations

The catch rate (U) is defined as the total weight in kilograms of fish per set (Wt) divided by the number of intact skates returned (N) from the set.

$$U_{is} = Wt_{is} / N_i$$

where s denotes the species, and i denotes the set.

Catch rates were plotted by set location and are illustrated using sized circles where larger symbols represented larger catch rate values (ESRI ® ArcMap™ 8.3).

Wilcoxon rank sum tests were used to test for differences in median catch rates between statistical areas and depth strata for the two dominant rockfish species, quillback and yelloweye. Modal depths for six fishing sets fell outside of our predetermined depth strata ranges and therefore were omitted from the depth strata analyses (Appendix Table 2). All statistical analyses were performed using SPlus 2000 or Statistix version 7.0.

2.4.3 Simulations

Catch rate data for quillback and yelloweye rockfish were used to estimate the initial parameters for a simulation model (Schnute and Haigh, 2003). This model was then used to investigate the utility of the survey for indexing rockfish abundance. The model is based on the compound binomial-gamma distribution, and uses three key survey parameters:

P = Proportion of sets with zero catch
μ = Mean density of non-zero sets
ρ = Coefficient of variation of non-zero sets

The analysis uses swept area densities to estimate a relative biomass. Distance travelled from the first anchor to the last is obtained from electronic tracking of the vessel during gear deployment (Nobletec™ 6.0). Swept area for each set was estimated by multiplying distance travelled by an assumed effective width (9.14 m or 30 ft). This assumed effective width was decided upon arbitrarily and does not affect interpretation of the simulation results since biomass estimates are discussed in relative terms. Species-specific swept area densities (kg/km^2) were then calculated using set-specific catch rates (kg/set) divided by set-specific swept areas (km^2/set). Biomass was calculated by applying the mean swept area density to the surface area of sea floor in SA 12 and 13 that falls within the 41 – 100 m depth range (ArcMap™ 8.3 Spatial Analyst).

The simulations allowed a known population biomass to increase by 5 % compounded annually and used the survey parameters (P, μ, ρ) to bootstrap biomass estimates expected from similar surveys 20 years into the future. The selection of 5% growth rate was relative and could have also been set to 0 or a negative number. A random process error of 15 % was added to the biomass estimate to account for inter-annual variation (Francis et al., 2003). The total number of sets fished (K) was set at 80, 100, and 120 to observe how sample size affects the variability in the biomass estimates. The simulated annual survey biomass estimates were plotted with the biomass values of the known population, allowing a visual comparison of the simulated and known trajectories.

The utility of the survey catch rates as abundance indices was evaluated quantitatively by comparing the $\log_2$-transformed slopes of the estimated biomass trend lines to the known slope or rate of increase. One thousand simulations were performed and the distribution of the bootstrapped slopes for quillback and yelloweye rockfish were plotted. The percentage of times that the estimated annual rate of change (r) fell within ± 20% of the known annual rate of change is reported.

The quantitative analysis of the survey catch rates (above) was also used to evaluate and optimize the proportion of sets allocated to each statistical area. The proportion of sets allocated to SA 12 versus SA 13 was manipulated by varying the input parameter (N), or number of sets, and the resultant values of (r) ± 20% are reported. By varying set allocation between statistical areas, the percentage of times that the estimated annual rate of change (r) fell within ± 20% of the known annual rate of change was maximized.

3.0 RESULTS AND DISCUSSION

Location, catch and biological data are archived in DFO's GFBio database and can be retrieved by Trip ID 50080.

3.1 Survey set locations, depths and times

Figure 1 presents a map of the study area with the location of the 100 randomly selected sampling blocks, the 80 blocks surveyed as well as the 20 rejected blocks. Fifty-six sets were conducted in SA 12 from August 17 to 30, 2003, and 24 sets in SA 13 from August 31 to September 6, 2003. Across all sets, the minimum depths ranged from 25 to 94 m, the maximum depths ranged from 39 to 145 m, and the modal depths ranged from 35 to 118 m (Appendix Table 2). Gear deployment took place between 0649 h and 1745 h and soak times varied from 107 - 146 minutes. Gear retrieval was complete by 2004 h.

3.2 Catch Summary

3.2.1. Hook by Hook

Forty percent of all hooks retrieved yielded a fish or invertebrate, 30% were empty, and 30% were returned with bait (Table 1). Fish drop offs at the side of the vessel and fish remnants, usually heads returning on the hooks were uncommon, with each making up less than one tenth of a percent of total hooks retrieved.

A total of 38 species and families were caught during the survey, of which 11 were rockfishes and 19 were other marine fish species (Table 2). Spiny dogfish (*Squalus acanthias*) were by far the most ubiquitous species, occurring in 78 of 80 sets. Quillback rockfish were the most prevalent Sebastes species, and were present in 58 of 80 sets. Starfish were the most widespread invertebrate in the catch, occurring in 36 of 80 sets.

The total landed weight for the survey was 12.3 tonnes (t) (Table 2). Spiny dogfish made up the large majority of the catch and represented 74.6% (9.8 t) of the marine fish total weight. Spotted ratfish (*Hydrolagus colliei*) were the second most common species making up 6.1% (0.7 t) of the marine fish total weight. Quillback and yelloweye rockfishes ranked third and fourth most common species with 4.3% (525 kg) and 3.6% (463 kg) of the total marine fish taken, respectively. Tiger (*S. nigrocinctus*), copper (*S. caurinus*), greenstriped (*S. elongatus*) and yellowtail (*S. flavidus*) rockfish were much less common, each with landings of less than 0.2% (~20 kg) of the marine fish total. Canary (*S. pinniger*), rosethorn (*S. helvomaculatus*), redstripe (*S. proriger*), and china (*S. nebulosus*) rockfish were present in the catch, but were rare with landings of 6 kg each or less.

Copper rockfish from this study were more prevalent in the shallow stratum, where 14 individuals were caught, as compared to 2 individuals caught in the deep stratum (Table 3). Numbers of all other rockfish species were evenly distributed between the depth strata. Spiny dogfish numbers exceeded those of all other fish species combined and were evenly distributed between the two depth strata (Table 4). Brown (*Hemilepidotus spinosus)* and red irish lords *(H. hemilepidotus)* were more common in the shallow stratum, whereas Pacific cod (*Gadus macrocephalus)*, Pacific halibut (*Hippoglossus stenolepis)*, sablefish (*Anoplopoma fimbria)*, and spotted ratfish were more common in the deep stratum.

3.2.2 Biological Sampling

A total of 5555 fish were sampled throughout the survey, including 3821 spiny dogfish sampled for L/S and 805 rockfish sampled for L/W/S/M/O (Table 2).

Figure 2 presents length frequency histograms by sex for all marine fish species. Quillback rockfish fork lengths ranged from 270 to 474 mm for males, and 240 to 503 mm for females. The quillback rockfish mean fork length was 363 mm for both sexes combined (Table 5). Yelloweye rockfish fork lengths ranged from 320 mm to 750 mm for males, and 265 to 757 mm for females. With males and females combined, the mean fork length was 492 mm. No significant differences in mean fork lengths were detected between the sexes for quillback and yelloweye rockfishes (Table 6).

The fork length (mm) to weight (g) relationship for rockfish can be expressed as (Figure 3):

$$\text{Weight} = a \text{ Length}^{b}$$

constants are:

quillback rockfish	$a = 0.0529(10^{-5})$	$b = 3.22$
yelloweye rockfish	$a = 0.0712(10^{-5})$	$b = 3.15$

The mean fork length of quillback rockfish caught in the deep depth stratum was significantly larger than that of quillback rockfish caught in the shallow stratum (Table 6). This has been observed for quillback and yelloweye rockfishes in British Columbia (Richards 1986; Yamanaka and Richards, 1993). Mean fork length of yelloweye rockfish caught during this survey was longer in the deep depth stratum but this difference was not significant.

Mean fork lengths of quillback and yelloweye rockfishes from SA 12 were significantly larger than those from SA 13 yet their mean ages were not different (Table 7). This may reflect a difference in environmental or habitat conditions that favour quillback rockfish growth in SA 12.

The sex ratio was close to 1:1 for most species with sample sizes greater than 30 individuals, but there were some notable deviations (Figure 4). Longnose skate (*Raja rhina*) were 30 % female, greenstriped rockfish were 91 % female (n=35), lingcod (*Ophiodon elongates)* were 85 % female (n=33), and the most prominently skewed sex ratio was for spotted ratfish, which were 95 % female (n=526).

The majority of rockfish taken on the survey were sexually mature. Maturity stage data show 57 % of males were 'developing' or 'developed' and 29 % were 'resting' (Table 8). No males were found to be 'running' or 'spent'. Fourteen percent of males were in maturity stages of either 'immature' or 'maturing'. Female maturity data indicate 31 % were 'mature' and 58 % were 'resting'. Very few individuals contained eyed larvae or were 'spent'. Fifteen percent of females were not yet sexually mature.

The mean ages of quillback and yelloweye rockfish overall from this survey were 22.3 and 28.3 years, respectively (Table 9). Male quillback rockfish average age was 23.2 years, which was significantly older than the female average age of 21.1 years (Table 7). The opposite was shown for yelloweye rockfish, where females were significantly older than males. Yelloweye rockfish from the deep depth stratum were also found to be significantly older than those from the shallow stratum (Table 7).

The age frequency distributions for quillback rockfish, pooled and by sex, indicate a strong 1985 year class, age 18 in 2003 (Figure 5). Previous analyses of quillback rockfish age data derived from research survey sites in SA 12, noted the presence of a strong 1985 year class in 1992 and in 2001 (Yamanaka and Richards 1993, Yamanaka and Lacko, 2001). No one year class dominated the age frequencies for yelloweye rockfish (Figure 6).

A truncated age structure may have serious implications for these long-lived species whose recruitment is highly variable and episodic (Palumbi, 2004). Recent evidence shows that rockfish population growth can depend on the presence of older mothers (Berkeley et al., 2004; Berkeley, Hixon, et al., 2004). There is evidence that eggs from older, larger female rockfishes produce larvae that grow faster and are more resistant to starvation than larvae from younger females (Berkeley et al., 2004). Berkeley et al. (2004) suggest that the best and perhaps only way to preserve old-growth age structure is through the creation of marine reserves, such as the Rockfish Conservation Areas recently implemented in British Columbia. (http://www-comm.pac.dfo-mpo.gc.ca/pages/consultations/fisheriesmgmt/rockfish/default_e.htm).

Estimates of von Bertalanffy (1938) growth parameters and length at age curves for quillback and yelloweye males and females were derived from the biological sampling data (Figure 7). A sufficient number of samples allowed the quillback rockfish von Bertalanffy parameter estimates and length at age curves to be further subdivided by statistical area (Figure 8). Because of few very young and very old individuals sampled on this survey, the shape of the von Bertalanffy curves and estimates of the parameters L_∞, k and t_0 may be biased (Smith et al., 1997). Therefore, caution should be used when comparing these parameters to those obtained from other studies. An increase in samples at both ends of the growth curve (<10 and >40 years) will improve the von Bertalanffy parameter estimates.

3.3 Catch Rates

One skate of longline gear with 12 foot hook spacing was chosen to represent a unit of fishing effort rather than a hook because studies have shown that catch per hook varies with hook spacing and that effort is not proportional to the number of hooks (Kurogane 1968, Skud 1972, Karlsen 1977, Skud and Hamley 1978). Although studies have yet to be performed on rockfish, results from halibut, tuna and sablefish experiments show that the effects of hook spacing are similar and suggest that the same basic phenomena occur in longline fisheries in general (Shomura and Murphy 1955, Skud and Hamley 1978, Sigler 1997).

Overall mean rockfish catch rates ranged from 0.0004 kg/skate for harlequin rockfish to 3.25 kg/skate for quillback rockfish (Table 10). Yelloweye rockfish catch rates were the second highest at 2.78 kg/skate. All other rockfish had mean catch rates of less than 0.14 kg/skate. The most frequently observed catch rate for all rockfish species was 0 kg/skate, which occurred in over half of the sets for all rockfish species except quillback whose median catch rate was equal to 1.66 kg/skate.

Since habitat type is an important influence on distribution patterns of rockfishes (Richards 1986, 1987), variation in bottom type was likely a major contributor to the variation in catch rates among sets. Rockfishes tend to inhabit areas with hard, complex substrate and other vertical structure including kelp forests and sponge assemblages (Love et al, 2002). In the Strait of Georgia, visual surveys have shown that inshore rockfish species are associated with bedrock and boulder dominated substrates (Martin and Yamanaka, 2004). Stratifying the survey by habitat or bottom type would likely reduce the variability in catch rates.

The spatial distribution of catch rate (kg/skate) by statistical area is presented for all rockfish species in Figures 9 to 19. Quillback and yelloweye rockfish were caught throughout SA 12 and the northern portion of SA 13. Quillback rockfish catch rates over 15 kg/skate were observed at Nigei Island and Blackney Passage (Figure 14). Yelloweye rockfish were generally less frequently caught than quillback rockfish and catch rates over 15 kg/skate were observed at Gilford Island and in Ramsay Arm (Figure 18).

SA 12 had higher rockfish species diversity than SA 13 (Figures 9 to 19). Of the ten Sebastes species encountered on this survey, all were present in catches from SA 12, whereas canary, china, harlequin, redstripe, rosethorn and tiger rockfishes were absent from catches in SA 13.

Statistical comparisons of catch rates between areas and depths were performed for quillback and yelloweye rockfishes (Table 11). Quillback rockfish catch rates did not differ significantly between the two statistical areas, whereas yelloweye rockfish catch rates from SA 13 were significantly higher than those from SA 12. The higher yelloweye catch rates in SA 13 may be attributable to a greater amount of suitable habitat and/or relatively less fishing effort in that area. Quillback and yelloweye rockfish catch rates did not differ significantly between the two depth strata.

Catch rates by species were plotted against modal set depths for the six most frequently encountered rockfish species (Figure 20). These plots illustrate peaks in abundance within species specific depth ranges. Modal set depths at peak catch rates for quillback, yelloweye, greenstriped, copper, tiger and yellowtail rockfishes are 85, 88, 90, 50, 85, and 70 metres, respectively.

3.4 Simulations

The input data for the model's fixed parameters P, μ, and ρ were derived from catch rate data and included all 74 sets that fell within the survey's depth strata (Table 12).

The simulation plots for quillback and yelloweye rockfishes show biomass projections 20 years into the future for three survey sample sizes (K) of 80, 100, and 120 sets (Figures 21 and 22). For both species and each K value, trends in the estimated biomass from the simulations (loess lines) appear to track increases in abundance of the known population over time. However, departures of the estimated biomass from the known population biomass indicate that both under and over estimates are likely. For example, quillback rockfish where K = 100 in 'Sim 2' (Figure 21 centre panel) the relative biomass trend is well tracked; however the biomass is consistently underestimated; and where K = 120 in 'Sim 2' (Figure 21 lower panel) the relative biomass trend is well tracked once again, but the biomass is consistently overestimated.

For quillback rockfish, trends in the estimated biomass from the simulations become more reliable, i.e. give similar increases in abundance as the known population, after about 7 years with K = 80 (Figure 21). Over a shorter period, biomass estimates from the simulations do not consistently track the known population. If, for example, a trend-line were drawn after 7 years for quillback rockfish with K = 80, estimated populations in all three simulation examples would inaccurately show a biomass which is staying relatively constant (Figure 21 top panel).

With K = 80 for yelloweye rockfish, trends in the estimated biomass give similar increases in abundance as the known population after 7 years in 'Sim 1' and 'Sim 3' (Figure 22 top panel). 'Sim 2' estimated populations show a biomass that is decreasing for the first 8 years and illustrates an instance where 10 or more years of data are required to follow the true population trend (Figure 22 top panel).

The utility of the survey catch rates as abundance indices was evaluated quantitatively by plotting the frequency distribution of the $\log_2$-transformed slopes of 1000 estimated (simulated) biomass trend lines. The distributions of bootstrapped slopes for quillback and yelloweye rockfishes (Figure 23 and 24, left and middle panels) are fairly symmetrical about the true slope, with modest improvements by increasing the set budget K from 80 to 120. Ordering the simulations by the corresponding annual rate of increase (r) (Figures 23 and 24, panels C,F,I) show that a r ± 20 % would be detected with this survey 76 %, 79 %, and 79 % of the time for quillback rockfish and 66 %, 73 % and 75 % of the time for yelloweye rockfish at K = 80, 100, and 120 sets, respectively.

Increasing K from 80 to100 and 120 improves the precision of the estimates for both rockfishes.

The proportion of sets allocated to SA 12 versus SA 13 was manipulated to maximize the percentage of time the estimated annual rate of increase (r) fell within ± 20 % of the true r (Table 13). For quillback rockfish with a total survey budget of 80 sets, r ± 20 % is maximized when 67.5 – 87.5 % of sets are allocated to SA 12. To optimize the quillback rockfish catch rate data, future surveys could allocate effort by allocating 65 of 80 sets, 75 of 100 sets and 105 of 120 sets in SA 12. To optimize yelloweye rockfish catch rate data, 50% of sets could be allocated to SA12.

4.0 SUMMARY

This new longline survey in the northern portion of the Strait of Georgia management area (4B) in SA 12 and 13 complements the jig survey that has been conducted in a portion of SA 12 since 1986 and may provide relative abundance indices for some of the marine fish species caught within the 41 – 100 m depth range in hard bottom habitats. A total of 38 species were caught on the survey, of which 11 were rockfishes and 19 were other marine fish species. Quillback and yelloweye rockfishes were the two most commonly caught rockfish and ranked 3rd and 4th in numbers, respectively, overall species.

A total of 5555 fish were sampled on the survey. Analyses of the fork length data show that quillback rockfish fork lengths increased with depth. Mean quillback and yelloweye fork lengths from SA 12 were significantly larger than those from SA 13, however, they are not significantly older. The mean age of quillback and yelloweye rockfish from this survey was 22.3 and 28.3 years, respectively. There was a dominant 1985 year class of age 18 quillback rockfish that was evident in the age frequency data.

Catch rate data indicate that SA 12 had higher rockfish species diversity than SA 13. SA 12 catch rates for yelloweye rockfish were lower than those in SA 13, however no significant difference in catch rates between SAs was found for quillback rockfish.

Simulation results indicate that data from this survey could be effectively used to monitor quillback and yelloweye population trends in the northern portion of BC's Strait of Georgia management region (4B) if the survey was continued with the same level of sampling effort over the long-term (7 – 10 years or more).

Future surveys conducted in a similar manner will be important for estimating the inter-annual variability in the catch rate data. This variability could then be incorporated as process error in the simulation model and would result in a more realistic evaluation of the survey's ability to track population trends.

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Table 1. Summary of hook observations by description, DFO GFBio database code, number of hooks retrieved and percent of total hooks.

Description	GFBio Code	# hooks	% of total
Unknown	0	0	0
Empty hook	1	5030	27
Bait on hook	2	5949	32
Animal on hook (fish or invertebrate)	3	7512	40
Species head on hook	4	109	0.01
Species dropped off hook	5	178	0.01
Total		**18778**	**100**

Table 2. Summary of total catch and biological samples.

Species Name	Taxonomic Name	Total Weight (kg)	% of Marine Fish Total Weight	Total Count (#)	# of Sets with Species Present	Number of fish Sampled	Sample Type
Spiny Dogfish	*Squalus acanthias*	9108.36	74.59	4934	78	3821	TL/S
Spotted Ratfish	*Hydrolagus colliei*	739.39	6.06	619	48	525	DFL/S
Quillback Rockfish	*Sebastes maliger*	519.29	4.25	533	58	533	FL/W/S/M/O
Yelloweye Rockfish	*Sebastes ruberrimus*	444.18	3.64	173	35	173	FL/W/S/M/O
Pacific Halibut	*Hippoglossus stenolepis*	398.71	3.27	59	17	52	TL
Longnose Skate	*Raja rhina*	278.59	2.28	54	27	50	TL/S
Lingcod	*Ophidon elongatus*	237.32	1.94	36	20	35	FL/W/S/M/F
Pacific Cod	*Gadus macrocephalus*	159.54	1.31	125	25	108	FL/W
Big Skate	*Raja binoculata*	107.38	0.88	10	5	10	TL/S
Sunflower Starfish	*Pycnopodia helianthoides*	92.70	-	92	25	0	-
Sablefish	*Anoplopoma fimbria*	80.76	0.66	81	11	77	FL/W/S/M/O
Tiger Rockfish	*Sebastes nigrocinctus*	22.04	0.18	18	5	18	FL/W/S/M/O
Copper Rockfish	*Sebastes caurinus*	19.44	0.16	20	8	20	FL/W/S/M/O
Starfish	Asteriodea	18.68	-	24	12	0	-
Greenstriped Rockfish	*Sebastes elongatus*	18.44	0.15	35	17	35	FL/W/S/M/O
Yellowtail Rockfish	*Sebastes flavidus*	16.02	0.13	16	6	15	FL/W/S/M/O
Arrowtooth Flounder	*Atheresthes stomias*	12.23	0.10	5	2	1	TL/S
Red Irish Lord	*Hemilepidotus hemilepidotus*	11.80	0.10	30	4	30	TL
Pacific sanddab	*Citharichthys sordidus*	10.29	0.08	33	8	24	TL/S
Cabezon	*Scorpaenichthys marmoratus*	7.48	0.06	2	2	0	-
Canary Rockfish	*Sebastes pinniger*	5.76	0.05	2	1	2	FL/W/S/M/O
Brown Irish Lord	*Hemilepidotus spinosus*	4.14	0.03	14	4	13	TL
Kelp Greenling	*Hexagrammos decagrammus*	3.36	0.03	4	3	4	FL/S
Rosethorn Rockfish	*Sebastes helvomaculatus*	2.24	0.02	3	1	3	FL/W/S/M/O
Redstripe Rockfish	*Sebastes proriger*	1.45	0.01	3	3	3	FL/W/S/M/O
Pink Short-Spine Star	*Pisaster brevispinus*	1.18	-	1	1	0	-
China Rockfish	*Sebastes nebulosus*	1.16	0.01	2	2	2	FL/W/S/M/O
Great Sculpin	*M. polyacanthocephalus*	0.62	0.01	1	1	0	-
Anemone	Actiniaria	0.58	-	3	3	0	-
Basket Star	Gorgonocephalidae	0.50	-	2	1	0	-
Pacific Staghorn Sculpin	*Leptocottus armatus*	0.48	0.00	1	1	0	-
Solasteridae	Solasteridae	0.36	-	1	1	0	-
Sea Cucumber	Holothuroidea	0.24	-	1	1	0	-
Spotfin Sculpin	*Icelinus tenuis*	0.10	0.00	1	1	0	-
Slender Sole	*Lyopsetta exilis*	0.06	0.00	1	1	0	-
Harlequin Rockfish	*Sebastes variegatus*	0.06	0.00	1	1	1	FL/W
Sculpin	Cottidae	0.01	0.00	1	1	0	-
Fusitriton oregonensis	*Fusitriton oregonensis*	0.01	-	1	1	0	-
Total		**12324.95**	**100.00**	**6942**	**80**	**5555**	**-**

DFL = snout to posterior edge of second dorsal fin length, FL = fork length, TL = total length
W = weight, S = sex, M = maturity, O = otoliths, F = fins

Table 3. Rockfish counts by set. Squares indicate shallow stratum sets (41-70m), circles indicate deep stratum sets (71-100m), and others are sets whose modal depths did not fall within the survey strata depth ranges.

Set #	Canary Rockfish	China Rockfish	Copper Rockfish	Greenstriped Rockfish	Harlequin Rockfish	Quillback Rockfish	Redstripe Rockfish	Rosethorn Rockfish	Tiger Rockfish	Yelloweye Rockfish	Yellowtail Rockfish
□ 1	-	-	-	2	-	9	-	-	4	6	7
□ 2	-	1	-	-	-	22	-	-	-	-	-
○ 3	-	-	-	-	-	46	-	3	8	3	-
□ 4	-	1	-	-	-	2	-	-	-	-	-
○ 5	-	-	-	3	-	9	-	-	-	-	3
□ 6	-	-	-	3	1	3	1	-	-	2	1
□ 7	-	-	-	2	-	13	1	-	-	1	-
○ 8	-	-	-	1	-	12	-	-	-	1	2
○ 9	-	-	-	1	-	8	-	-	-	1	2
□ 10	-	-	1	-	-	-	-	-	-	-	-
□ 11	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-
□ 13	-	-	-	-	-	7	-	-	3	-	-
14	-	-	5	-	-	-	-	-	-	-	-
□ 15	-	-	-	-	-	6	-	-	-	-	-
□ 16	-	-	-	-	-	2	-	-	-	-	-
○ 17	-	-	-	-	-	6	-	-	-	1	-
□ 18	-	-	-	-	-	15	-	-	-	2	-
□ 19	-	-	-	-	-	1	-	-	-	-	-
□ 20	-	-	-	-	-	6	-	-	-	3	-
□ 21	-	-	-	-	-	-	-	-	-	-	-
○ 22	-	-	-	-	-	27	-	-	-	5	-
□ 23	-	-	-	-	-	-	-	-	-	-	-
○ 24	-	-	-	2	-	11	-	-	-	3	-
□ 25	-	-	1	-	-	1	-	-	-	-	-
○ 26	-	-	-	-	-	8	-	-	-	4	-
○ 27	-	-	-	1	-	14	-	-	-	12	-
○ 28	-	-	-	-	-	1	-	-	-	2	-
□ 29	-	-	-	-	-	2	-	-	-	-	-
○ 30	-	-	-	-	-	6	-	-	-	-	-
□ 31	-	-	-	-	-	8	-	-	-	-	-
○ 32	-	-	-	-	-	-	-	-	-	-	-
□ 33	-	-	-	-	-	11	-	-	-	-	-
□ 34	-	-	-	1	-	32	1	-	-	-	-
□ 35	-	-	-	-	-	-	-	-	-	-	-
□ 36	-	-	-	-	-	1	-	-	-	-	-
○ 37	-	-	-	-	-	19	-	-	-	1	-
○ 38	-	-	-	-	-	-	-	-	-	-	-
○ 39	-	-	-	-	-	6	-	-	-	-	-
□ 40	-	-	-	-	-	-	-	-	-	-	-
○ 41	-	-	-	4	-	8	-	-	-	-	-
□ 42	-	-	1	-	-	-	-	-	-	-	-
○ 43	-	-	-	1	-	3	-	-	-	-	-
□ 44	-	-	-	-	-	-	-	-	-	-	-
45	-	-	-	-	-	-	-	-	-	-	-
○ 46	-	-	-	4	-	6	-	-	-	-	-
47	-	-	-	-	-	2	-	-	-	-	-
○ 48	-	-	-	-	-	5	-	-	-	-	-
○ 49	-	-	-	-	-	3	-	-	-	-	-
50	-	-	-	4	-	-	-	-	-	3	-
○ 51	-	-	1	-	-	-	-	-	-	-	-
52	2	-	-	-	-	1	-	-	2	10	-
○ 53	-	-	-	1	-	6	-	-	-	4	-
□ 54	-	-	-	-	-	-	-	-	-	-	-
○ 55	-	-	-	-	-	20	-	-	1	3	-
○ 56	-	-	-	-	-	-	-	-	-	-	-
○ 57	-	-	-	-	-	5	-	-	-	1	-
○ 58	-	-	-	-	-	-	-	-	-	-	-
□ 59	-	-	-	-	-	-	-	-	-	-	-
○ 60	-	-	-	-	-	14	-	-	-	1	-
○ 61	-	-	-	-	-	1	-	-	-	-	-
□ 62	-	-	8	-	-	3	-	-	-	4	-
□ 63	-	-	2	-	-	-	-	-	-	2	-
□ 64	-	-	-	-	-	-	-	-	-	-	-
□ 65	-	-	1	-	-	1	-	-	-	-	-
○ 66	-	-	-	-	-	8	-	-	-	17	-
○ 67	-	-	-	-	-	4	-	-	-	24	-
○ 68	-	-	-	-	-	19	-	-	-	12	-
○ 69	-	-	-	-	-	-	-	-	-	-	-
□ 70	-	-	-	1	-	24	-	-	-	9	-
□ 71	-	-	-	-	-	9	-	-	-	-	-
○ 72	-	-	-	-	-	6	-	-	-	-	-
□ 73	-	-	-	1	-	5	-	-	-	6	-
□ 74	-	-	-	-	-	3	-	-	-	6	-
□ 75	-	-	-	3	-	10	-	-	-	3	-
□ 76	-	-	-	-	-	21	-	-	-	9	-
□ 77	-	-	-	-	-	10	-	-	-	3	1
□ 78	-	-	-	-	-	18	-	-	-	4	-
□ 79	-	-	-	-	-	3	-	-	-	5	-
□ 80	-	-	-	-	-	1	-	-	-	-	-
Total	**2**	**2**	**20**	**35**	**1**	**533**	**3**	**3**	**18**	**173**	**16**
□ Shallow	**0**	**2**	**14**	**14**	**1**	**252**	**3**	**0**	**7**	**65**	**9**
○ Deep	**0**	**0**	**2**	**17**	**0**	**278**	**0**	**3**	**9**	**95**	**7**

Table 4. Other fish species counts by set. Squares indicate shallow stratum sets (41-70m), circles indicate deep stratum sets (71-100m), and others are sets whose modal depths did not fall within the survey strata depth ranges.

Set #	Arrowtooth Flounder	Big Skate	Brown Irish Lord	Spiny Dogfish	Kelp Greenling	Lingcod	Longnose Skate	Pacific Cod	Pacific Halibut	Pacific Sanddab	Red Irish Lord	Sablefish	Sculpin	Slender Sole	Spotted Ratfish
1	-	-	-	7	-	-	-	-	-	-	-	-	-	-	15
2	-	-	-	-	1	-	2	-	-	1	-	-	-	-	8
3	1	-	1	-	1	2	-	-	-	-	-	-	-	-	32
4	-	-	-	1	2	-	-	1	-	-	27	-	-	-	27
5	-	1	-	15	-	-	3	5	1	-	-	-	-	-	24
6	-	-	-	5	-	-	1	11	1	-	-	-	-	-	15
7	-	-	-	9	-	2	1	11	1	-	-	-	-	-	15
8	-	-	-	22	-	-	5	1	4	-	-	-	-	-	12
9	-	-	-	59	-	1	4	1	2	-	-	6	-	-	13
10	-	-	-	142	-	-	-	-	-	-	-	2	1	-	1
11	-	-	-	118	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	75	-	1	-	-	-	-	-	-	-	-	-
13	-	-	-	78	-	4	-	-	-	-	-	-	-	-	-
14	-	-	-	19	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	6	-	-	1	-	-	-	-	-	-	-	2
16	-	-	-	140	-	-	-	-	-	-	-	-	-	-	1
17	-	-	-	157	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	72	-	-	-	-	-	-	-	-	-	-	8
19	-	-	-	92	-	-	-	-	-	-	-	-	-	-	-
20	-	-	-	8	-	-	-	-	-	-	-	-	-	-	6
21	-	-	3	9	-	1	1	1	-	-	1	-	-	-	-
22	-	-	-	39	-	1	-	2	3	-	-	-	-	-	11
23	-	-	-	69	-	-	-	-	-	-	-	-	1	-	13
24	-	-	-	9	-	1	-	1	-	-	-	-	-	-	12
25	-	-	-	103	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	46	-	-	-	-	-	-	-	-	-	-	4
27	-	-	-	84	-	-	-	3	-	-	-	-	-	-	6
28	-	-	-	98	-	-	-	-	-	-	-	-	-	-	1
29	-	-	-	32	-	-	-	-	-	-	-	-	-	-	-
30	-	-	-	17	-	-	-	-	-	-	-	-	-	-	-
31	-	-	-	39	-	-	-	-	-	4	-	-	-	-	-
32	-	-	-	142	-	-	-	-	-	-	-	-	-	-	1
33	-	-	9	38	-	-	2	5	-	-	1	1	-	-	9
34	4	-	1	18	-	1	2	12	2	-	1	1	-	-	11
35	-	1	-	20	-	1	1	1	5	9	-	27	-	-	4
36	-	-	-	21	-	-	1	-	6	1	-	-	-	-	12
37	-	-	-	71	-	-	3	3	-	-	-	2	-	-	39
38	-	-	-	64	-	-	1	1	5	-	-	7	-	-	19
39	-	-	-	35	-	-	1	-	8	-	-	-	-	-	-
40	-	-	-	29	-	-	1	-	-	-	-	-	-	-	18
41	-	-	-	28	-	2	2	42	12	-	-	-	-	-	28

Set #	Arrowtooth Flounder	Big Skate	Brown Irish Lord	Spiny Dogfish	Kelp Greenling	Lingcod	Longnose Skate	Pacific Cod	Pacific Halibut	Pacific Sanddab	Red Irish Lord	Sablefish	Sculpin	Slender Sole	Spotted Ratfish
42	-	2	-	3	-	-	2	-	-	-	-	-	-	-	3
43	-	-	-	47	-	-	-	1	-	-	-	-	-	-	34
44	-	-	-	28	-	-	3	-	-	3	-	-	-	-	15
45	-	-	-	62	-	-	-	-	1	-	-	-	-	-	7
46	-	-	-	18	-	-	5	9	1	1	-	21	-	-	21
47	-	3	-	64	-	-	-	3	1	-	-	1	-	-	14
48	-	-	-	4	-	-	-	2	5	13	-	12	-	-	1
49	-	3	-	3	-	-	-	-	-	-	-	-	-	-	25
50	-	-	-	28	-	1	2	1	-	-	-	-	-	-	56
51	-	-	-	104	-	-	1	-	-	-	-	1	-	-	1
52	-	-	-	96	-	-	-	1	-	-	-	-	-	-	2
53	-	-	-	62	-	-	-	-	-	-	-	-	1	-	1
54	-	-	-	107	-	1	1	-	1	-	-	-	-	-	10
55	-	-	-	97	-	3	4	4	-	-	-	-	-	-	4
56	-	-	-	141	-	-	1	2	-	-	-	-	-	-	-
57	-	-	-	26	-	4	2	-	-	-	-	-	-	-	30
58	-	-	-	8	-	4	-	-	-	-	-	-	-	-	24
59	-	-	-	159	-	-	-	1	-	-	-	-	-	-	-
60	-	-	-	103	-	-	1	-	-	-	-	-	-	-	-
61	-	-	-	144	-	-	-	-	-	-	-	-	-	-	-
62	-	-	-	158	-	-	-	-	-	-	-	-	1	-	-
63	-	-	-	105	-	-	-	-	-	1	-	-	1	-	-
64	-	-	-	155	-	-	-	-	-	-	-	-	1	-	-
65	-	-	-	112	-	-	-	-	-	-	-	-	-	1	1
66	-	-	-	133	-	-	-	-	-	-	-	-	-	-	-
67	-	-	-	110	-	-	-	-	-	-	-	-	-	-	-
68	-	-	-	69	-	2	-	-	-	-	-	-	-	-	-
69	-	-	-	107	-	-	-	-	-	-	-	-	-	-	-
70	-	-	-	82	-	-	-	-	-	-	-	-	-	-	-
71	-	-	-	57	-	2	-	-	-	-	-	-	-	-	-
72	-	-	-	149	-	-	-	-	-	-	-	-	-	-	-
73	-	-	-	84	-	-	-	-	-	-	-	-	-	-	-
74	-	-	-	32	-	-	-	-	-	-	-	-	-	-	-
75	-	-	-	61	-	-	-	-	-	-	-	-	-	-	-
76	-	-	-	10	-	-	-	-	-	-	-	-	-	-	-
77	-	-	-	13	-	1	-	-	-	-	-	-	-	-	1
78	-	-	-	7	-	1	-	-	-	-	-	-	-	-	-
79	-	-	-	73	-	-	-	-	-	-	-	-	-	-	-
80	-	-	-	133	-	-	-	-	-	-	-	-	-	-	2
Total	5	10	14	4934	4	36	54	125	59	33	30	81	6	1	619
Shallow	4	3	13	2435	3	14	19	43	16	19	30	31	5	1	197
Deep	1	4	1	2211	1	20	33	77	41	14	0	49	1	0	343

Table 5. Rockfish fork length descriptive statistics.

FORK LENGTH (MM)	Canary	China	Copper	Greenstriped	Harlequin	Quillback	Redstripe	Rosethorn	Tiger	Yelloweye	Yellowtail
Mean	565	332	374	326	165	363	321	346	391	492	405
Standard Error	3.00	26.50	13.33	9.79	0.00	1.83	9.70	5.81	10.93	7.19	12.71
Median	565	331.5	374	332.5	165	361	325	347	400	490	414
Standard Deviation	4.24	37.48	54.97	57.08	-	41.68	16.80	10.07	45.08	97.80	49.22
Sample Variance	18.00	1404.50	3021.51	3258.32	-	1737.37	282.33	101.33	2031.97	9564.64	2422.41
Minimum	562	305	270	225	165	240	303	335	280	265	312
Maximum	568	358	471	526	165	503	336	355	469	757	479
Total Count	2	2	17	34	1	519	3	3	17	185	15
Confidence Level (95.0%	38.12	336.71	28.26	19.92	-	3.59	41.74	25.01	23.18	14.19	27.26

Table 6. Results of two sample t-tests for differences in fork length (mm) between statistical areas, depth strata, and sexes for quillback and yelloweye rockfish.

Quillback Rockfish	Mean	Min	Max	SD	CV	N	T Statistic	p
stat area 12	373	240	503	44.794	0.1200	367	10.38	<0.0001*
stat area 13	337	252	403	30.196	0.0896	152		
shallow (41-70m)	350	240	503	45.509	0.1301	245	-6.09	<0.0001*
deep (71-100m)	373	265	474	39.958	0.1072	271		
female	358	240	503	45.701	0.1276	246	-1.82	0.069
male	365	270	474	42.299	0.1158	273		

Yelloweye Rockfish	Mean	Min	Max	SD	CV	N	T Statistic	p
stat area 12	520	320	757	117.72	0.2265	84	3.45	0.0008*
stat area 13	469	265	612	70.232	0.1496	101		
shallow (41-70m)	477	296	757	98.233	0.2060	79	-1.75	0.0821
deep (71-100m)	503	265	750	98.522	0.1958	93		
female	483	265	757	96.815	0.2003	108	-1.49	0.1385
male	505	320	750	98.404	0.1949	77		

Table 7. Results of two sample t-tests for differences in age (years) between statistical areas, depth strata, and sexes for quillback and yelloweye rockfish.

Quillback Rockfish	Mean	Min	Max	SD	CV	N	T Statistic	p
stat area 12	22.4	6	80	12.225	0.5446	367	0.7541	0.4511
stat area 13	21.6	6	46	8.414	0.3890	152		
shallow (41 - 70m)	21.7	6	61	10.866	0.5009	245	-1.0477	0.2953
deep (71 - 100m)	22.7	6	80	11.614	0.5109	271		
female	21.1	6	58	10.585	0.5016	246	2.1395	0.03286*
male	23.2	6	80	11.732	0.5055	273		

Yelloweye Rockfish	Mean	Min	Max	SD	CV	N	T Statistic	p
stat area 12	29.3	7	101	21.044	0.7180	84	0.9361	0.3504
stat area 13	27.0	7	56	11.410	0.4221	101		
shallow (41 - 70m)	25.4	7	95	16.507	0.6507	79	-2.1185	0.03558*
deep (71 - 100m)	30.7	7	101	16.214	0.5287	93		
female	30.4	7	101	18.912	0.6214	108	-2.3440	0.02015*
male	24.7	7	56	11.633	0.4702	77		

Table 8. Male and female rockfish maturity stages.

ROCKFISH MALE	Number (Proportion) of Individuals in Each Maturity Stage							Total N
	Immature	Maturing	Developing	Developed	Running	Spent	Resting	
Canary	0	0	0	2 (1.00)	0	0	0	2
China	0	0	0	0	0	0	0	0
Copper	0	2 (0.22)	6 (0.66)	0	0	0	1 (0.11)	9
Greenstripe	0	0	1 (0.33)	1 (0.33)	0	0	1 (0.33)	3
Quillback	2 (0.01)	22 (0.08)	101 (0.36)	81 (0.29)	0	0	73 (0.26)	279
Redstriped	0	0	0	0	0	0	0	0
Rosethorn	0	0	0	0	0	0	3 (1.00)	3
Tiger	1 (0.07)	1 (0.07)	0	0	0	0	12 (0.86)	14
Yelloweye	9 (0.11)	14 (0.17)	28 (0.34)	4 (0.05)	0	0	27 (0.33)	82
Yellowtail	1 (0.20)	3 (0.60)	1 (0.20)	0	0	0	0	5
Total	**13 (0.03)**	**42 (0.11)**	**137 (0.35)**	**88 (0.22)**	**0**	**0**	**117 (0.29)**	**397**

ROCKFISH FEMALE	Number (Proportion) of Individuals in Each Maturity Stage							Total N
	Immature	Maturing	Mature	Fertilized	Larvae	Spent	Resting	
Canary	0	0	0	0	0	0	0	0
China	0	0	0	0	0	0	2 (1.00)	2
Copper	0	0	1 (0.125)	0	0	0	7 (0.875)	8
Greenstripe	0	1 (0.03)	4 (0.13)	0	0	0	26 (0.84)	31
Quillback	3 (0.01)	36 (0.15)	64 (0.26)	0	0	0	145 (0.58)	248
Redstriped	0	0	1 (0.33)	0	0	0	2 (0.66)	3
Rosethorn	0	0	0	0	0	0	0	0
Tiger	0	0	0	0	0	2 (0..50)	2 (0.50)	4
Yelloweye	4 (0.04)	13 (0.11)	1 (0.01)	0	2 (0.02)	4 (0.04)	58 (0.51)	114
Yellowtail	0	7 (0.70)	3 (0.30)	0	0	0	0	10
Total	**7 (0.02)**	**57 (0.14)**	**74 (0.18)**	**0**	**2 (0.005)**	**6 (0.01)**	**242 (0.58)**	**420**

Table 9. Age summary statistics for quillback and yelloweye rockfish.

Age (years)	Quillback	Yelloweye
Mean	22.26	28.25
Standard Error	0.49	1.16
Median	19	23
Standard Deviation	11.24	16.40
Sample Variance	126.33	269.12
Minimum	6	7
Maximum	80	101
Total Count	532	199
Confidence Level(95.0%)	0.96	2.29

Table 10. Rockfish catch rate (kg/skate) summary statistics by statistical area.

Areas 12 and 13	*Canary*	*China*	*Copper*	*Greenstripe*	*Harlequin*	*Quillback*	*Redstriped*	*Rosethorn*	*Tiger*	*Yelloweye*	*Yellowtail*
Mean	0.0360	0.0073	0.1215	0.1153	0.0004	3.2456	0.0090	0.0140	0.1378	2.7761	0.1001
Standard Error	0.0360	0.0063	0.0582	0.0318	0.0004	0.5470	0.0052	0.0140	0.0828	0.5627	0.0517
Median	0	0	0	0	0	1.655	0	0	0	0	0
Standard Deviation	0.3220	0.0565	0.5210	0.2844	0.0034	4.8928	0.0461	0.1252	0.7409	5.0330	0.4624
Sample Variance	0.1037	0.0032	0.2714	0.0809	0.0000	23.9398	0.0021	0.0157	0.5489	25.3307	0.2138
Minimum	0	0	0	0	0	0	0	0	0	0	0
Maximum	2.8800	0.5000	4.1000	1.5100	0.0300	33.6000	0.2525	1.1200	6.1500	26.7500	3.6400
Total Number of Skates	160	160	160	160	160	160	160	160	160	160	160
Confidence Level (95.0%)	0.0717	0.0126	0.1159	0.0633	0.0007	1.0888	0.0103	0.0279	0.1649	1.1200	0.1029

Area 12	*Canary*	*China*	*Copper*	*Greenstripe*	*Harlequin*	*Quillback*	*Redstriped*	*Rosethorn*	*Tiger*	*Yelloweye*	*Yellowtail*
Mean	0.0514	0.0104	0.0732	0.1488	0.0005	3.5087	0.0129	0.0200	0.1968	2.0957	0.1309
Standard Error	0.0514	0.0090	0.0373	0.0439	0.0005	0.7412	0.0073	0.0200	0.1178	0.5514	0.0727
Median	0	0	0	0	0	1.97	0	0	0	0	0
Standard Deviation	0.3849	0.0675	0.2788	0.3285	0.0040	5.5467	0.0548	0.1497	0.8813	4.1259	0.5439
Sample Variance	0.1481	0.0046	0.0777	0.1079	0.0000	30.7659	0.0030	0.0224	0.7767	17.0234	0.2958
Minimum	0	0	0	0	0	0	0	0	0	0	0
Maximum	2.8800	0.5000	1.6500	1.5100	0.0300	33.6000	0.2525	1.1200	6.1500	22.3100	3.6400
Total Number of Skates	112	112	112	112	112	112	112	112	112	112	112
Confidence Level (95.0%)	0.1031	0.0181	0.0747	0.0880	0.0011	1.4854	0.0147	0.0401	0.2360	1.1049	0.1457

Area 13	*Canary*	*China*	*Copper*	*Greenstripe*	*Harlequin*	*Quillback*	*Redstriped*	*Rosethorn*	*Tiger*	*Yelloweye*	*Yellowtail*
Mean	0	0	0.2342	0.0371	0	2.6317	0	0	0	4.3638	0.0283
Standard Error	0	0	0.1741	0.0212	0	0.5808	0	0	0	1.3314	0.0283
Median	0	0	0	0	0	1.655	0	0	0	2.14	0
Standard Deviation	0	0	0.8529	0.1036	0	2.8453	0	0	0	6.5223	0.1388
Sample Variance	0	0	0.7274	0.0107	0	8.0955	0	0	0	42.5399	0.0193
Minimum	0	0	0	0	0	0	0	0	0	0	0
Maximum	0	0	4.1000	0.4000	0	9.6600	0	0	0	26.7500	0.6800
Total Number of Skates	48	48	48	48	48	48	48	48	48	48	48
Confidence Level (95.0%)	0	0	0.3601	0.0438	0	1.2014	0	0	0	2.7541	0.0586

Table 11. Results of Wilcoxon rank sum tests for differences in catch rates between statistical areas and between depth strata for quillback and yelloweye rockfish.

QUILLBACK ROCKFISH:

Stat Area	Mean	Min	Max	SD	CV	N	U Statistic	two-tailed p-value
12	3.51	0	33.60	5.5467	1.5809	56	671.50	1.0000
13	2.63	0	9.66	2.8453	1.0812	24	672.50	
Depth strata	**Mean**	**Min**	**Max**	**SD**	**CV**	**N**	**U Statistic**	**two-tailed p-value**
41-70m	2.68	0	15.56	3.6982	1.3814	41	508.50	0.0665
71-100m	4.50	0	33.60	6.1827	1.3733	33	844.50	

YELLOWEYE ROCKFISH:

Stat Area	Mean	Min	Max	SD	CV	N	U Statistic	two-tailed p-value
12	2.10	0	22.31	4.1259	1.9688	56	503.00	* 0.0493
13	4.36	0	26.75	6.5223	1.4946	24	841.00	
Depth strata	**Mean**	**Min**	**Max**	**SD**	**CV**	**N**	**U Statistic**	**two-tailed p-value**
41-70m	1.89	0	11.86	3.3347	1.7669	41	559.00	0.1593
71-100m	3.71	0	26.75	6.2616	1.6875	33	794.00	

Table 12. Summary of the three key survey parameters used in the simulation model. Parameters: P = proportion of sets with zero catch, μ = mean density of fish in non-zero sets (kg/km^2), ρ = CV of μ in non-zero sets; Constants: N= number of sets used to derive parameters, A = bottom area (km^2).

Species	**Stat Area**	**P**	**μ**	**ρ**	**N**	**A**
Quillback rockfish	12/13	0.2432	1049.1334	1.1096	74	1605
Quillback rockfish	12	0.2400	1138.3111	1.168923	50	1119
Quillback rockfish	13	0.2500	860.86946	0.801275	24	486
Yelloweye rockfish	12/13	0.5676	1519.5949	0.955749	74	1605
Yelloweye rockfish	12	0.6400	1300.397	0.948733	50	1119
Yelloweye rockfish	13	0.4167	1801.4207	0.943282	24	486

Table 13. Simulation results for quillback and yelloweye rockfish showing the effect of varied set allocations between statistical areas 12 and 13 on the percentage of times the estimated annual rate of change for simulated surveys falls within ± 20% of the true annual rate of change. 'K' represents the total number of sets completed on the hypothetical survey. The shaded cells indicate the set allocation that was employed on the 2003 survey. The bold percentages indicate where r±20% is maximized.

Quillback Rockfish

Area 12 % of total sets	Area 13 % of total sets	K = 80 r ± 20%	K = 100 r ± 20%	K = 120 r ± 20%
93.8%	6.2%	74.6%	74.7%	**79.7%**
87.5%	12.5%	**75.5%**	77.9%	**80.1%**
81.3%	18.7%	**76.2%**	**78.9%**	**79.8%**
75.0%	25.0%	**75.7%**	**79.1%**	**79.9%**
67.5%	32.5%	**75.5%**	**78.8%**	79.0%
50.0%	50.0%	74.2%	75.1%	79.4%
37.5%	62.5%	69.2%	72.2%	74.6%
25.0%	75.0%	63.8%	66.3%	70.2%

Yelloweye Rockfish

Area 12 % of total sets	Area 13 % of total sets	K = 80 r ± 20%	K = 100 r ± 20%	K = 120 r ± 20%
93.8%	6.2%	49.8%	54.9%	59.1%
87.5%	12.5%	60.7%	63.3%	64.3%
81.3%	18.7%	62.7%	67.3%	71.5%
75.0%	25.0%	64.8%	67.6%	74.2%
67.5%	32.5%	65.7%	73.0%	74.7%
50.0%	50.0%	**68.8%**	**73.9%**	**75.8%**
37.5%	62.5%	67.5%	69.9%	72.7%
25.0%	75.0%	62.5%	64.3%	69.6%

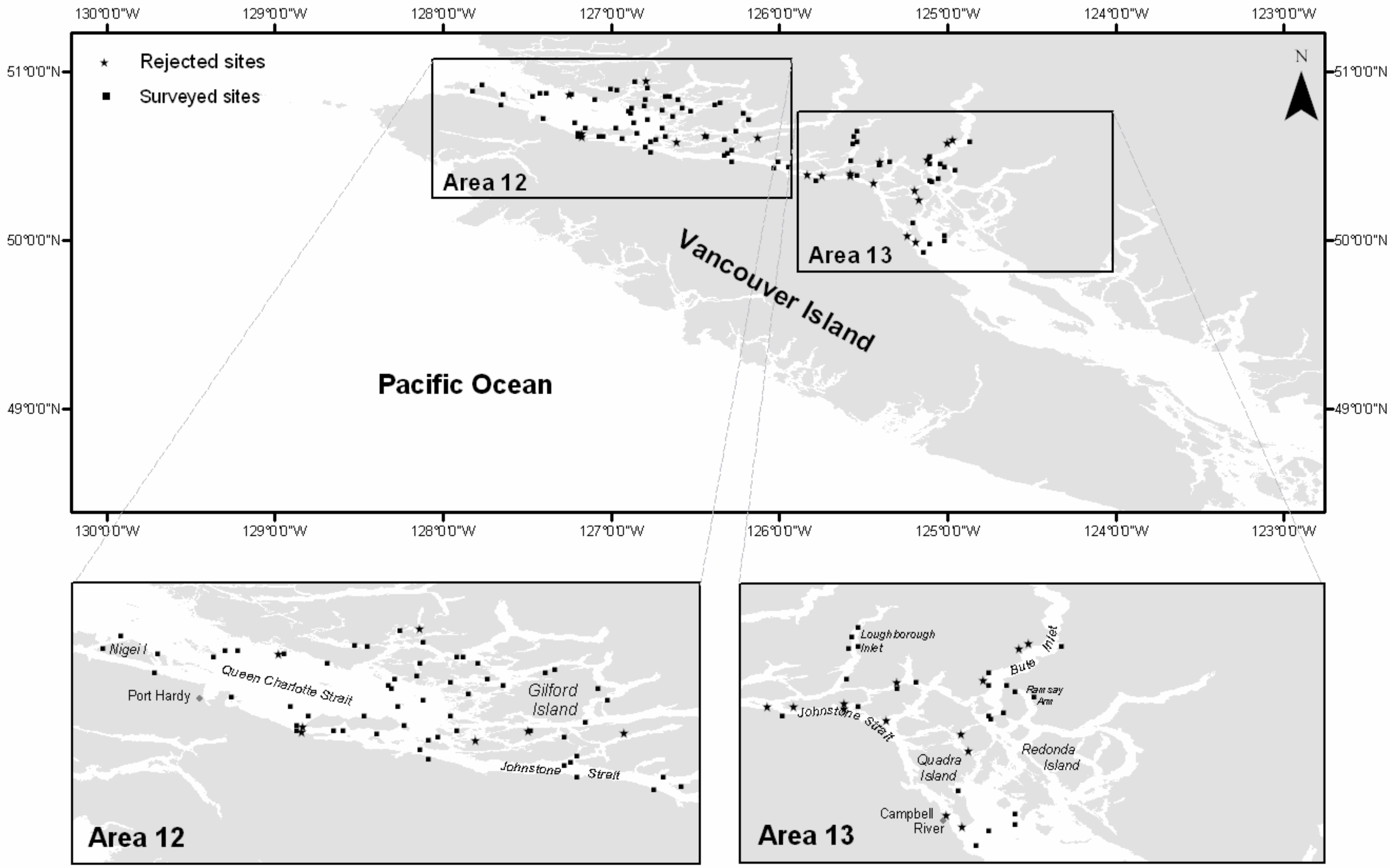


Figure 1. Location of the 80 surveyed sites and the 20 rejected sites. The lower left panel shows a close-up of SA 12 and the lower right panel shows a close-up of SA 13.

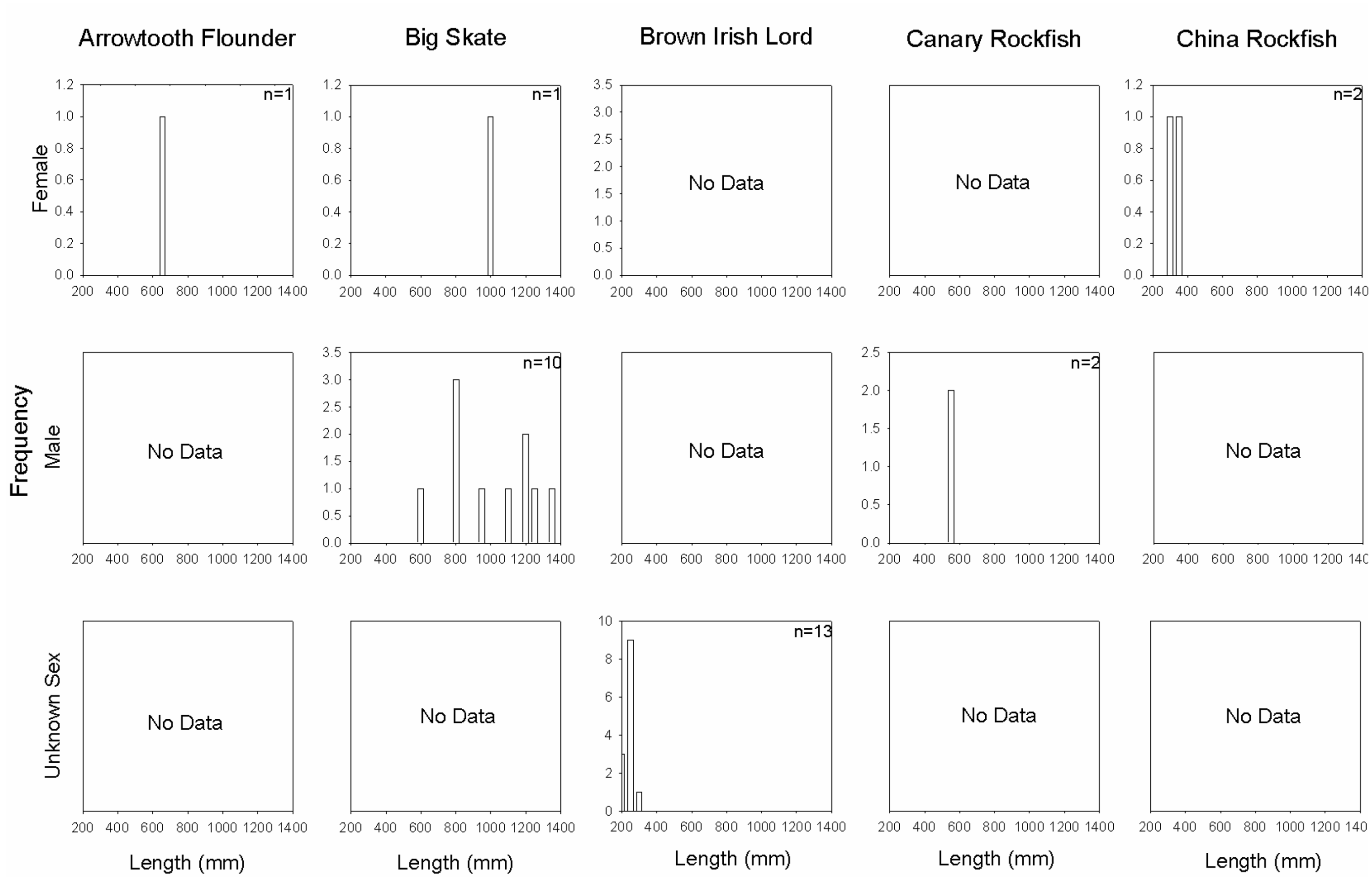


Figure 2. Length frequency histograms for males, females, and unknown sexes of all marine fish species.

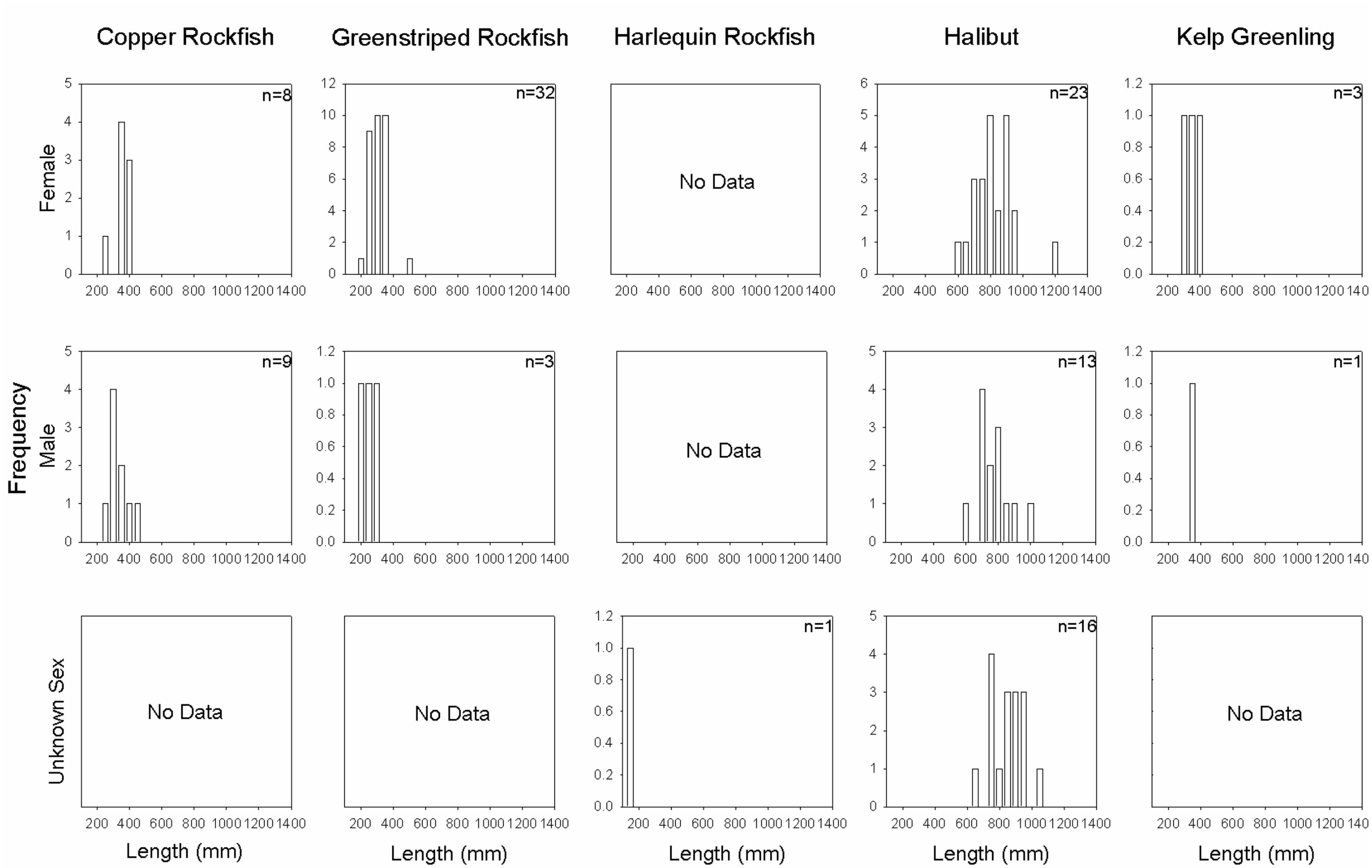


Figure 2. (continued) Length frequency histograms for males, females, and unknown sexes of all marine fish species.

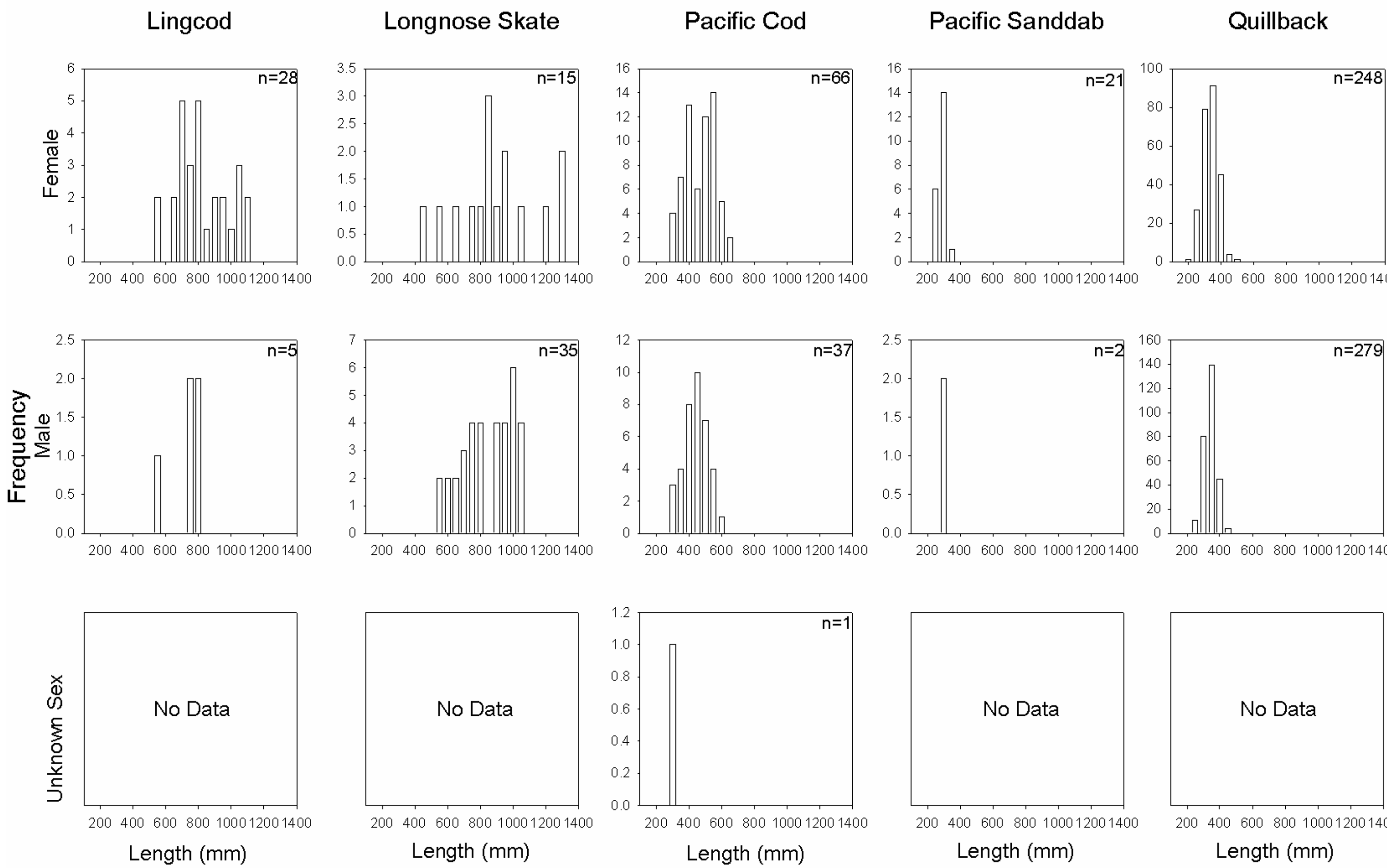


Figure 2. (continued) Length frequency histograms for males, females, and unknown sexes of all marine fish species.

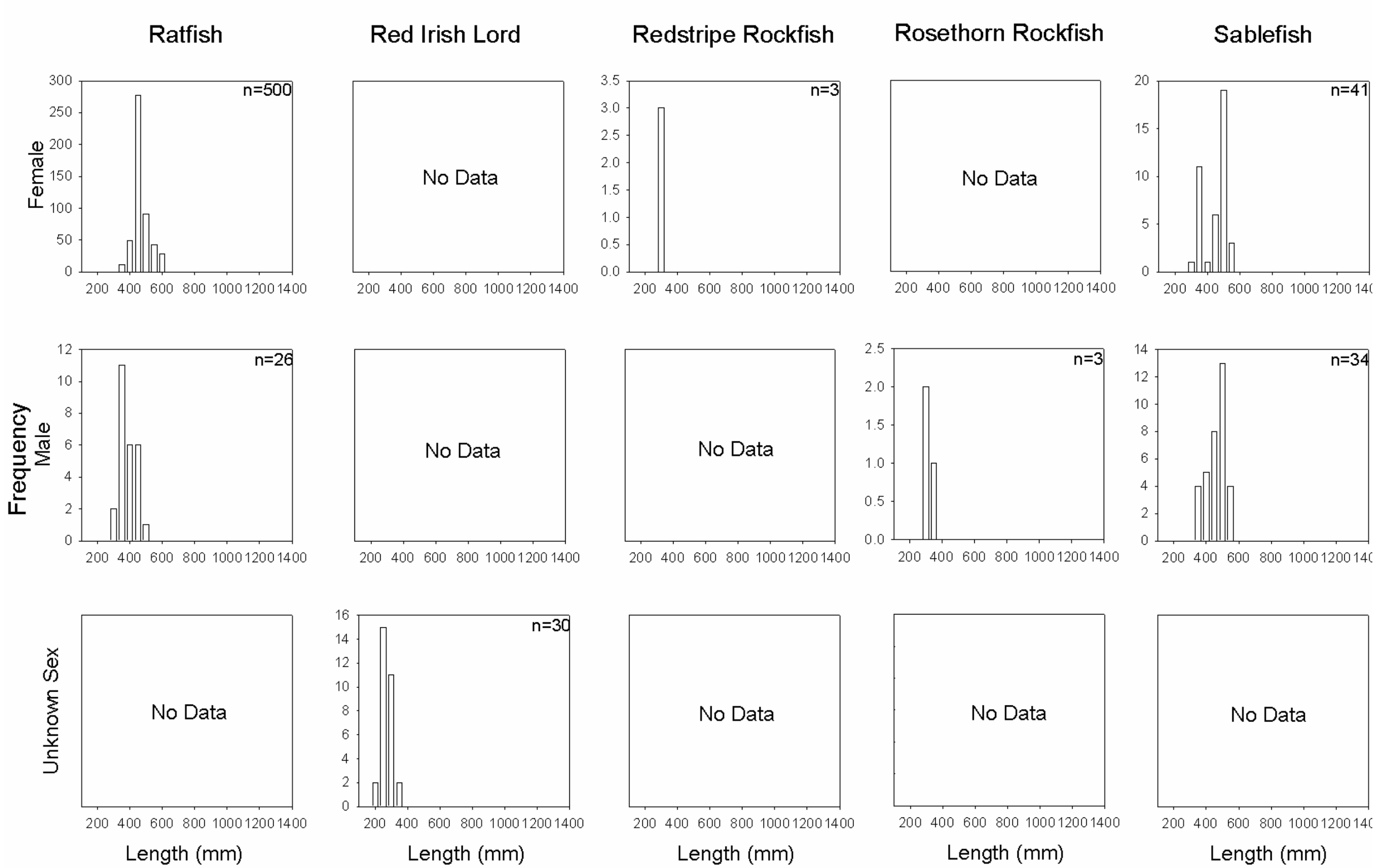


Figure 2. (continued) Length frequency histograms for males, females, and unknown sexes of all marine fish species.

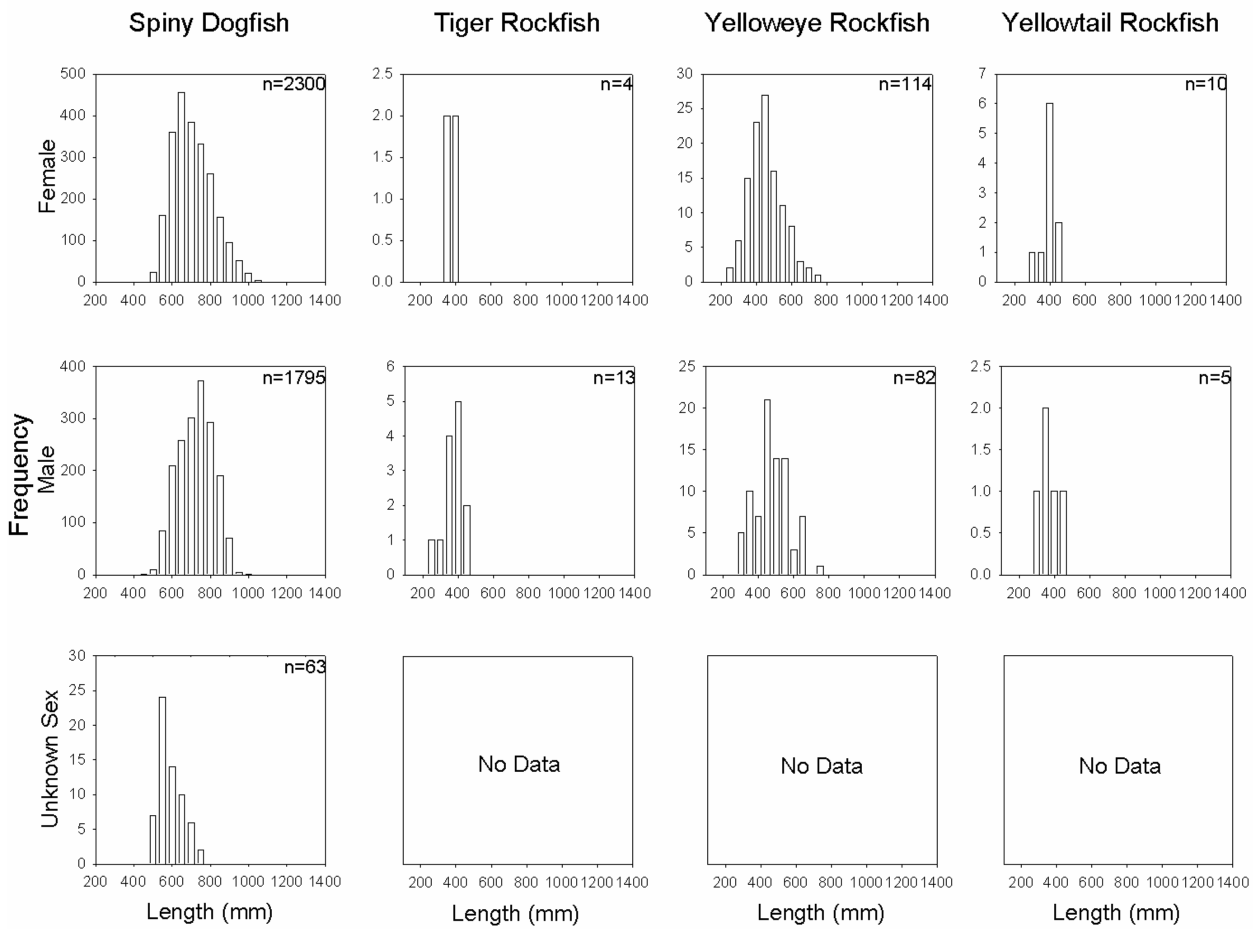


Figure 2. (continued) Length frequency histograms for males, females, and unknown sexes of all marine fish species.

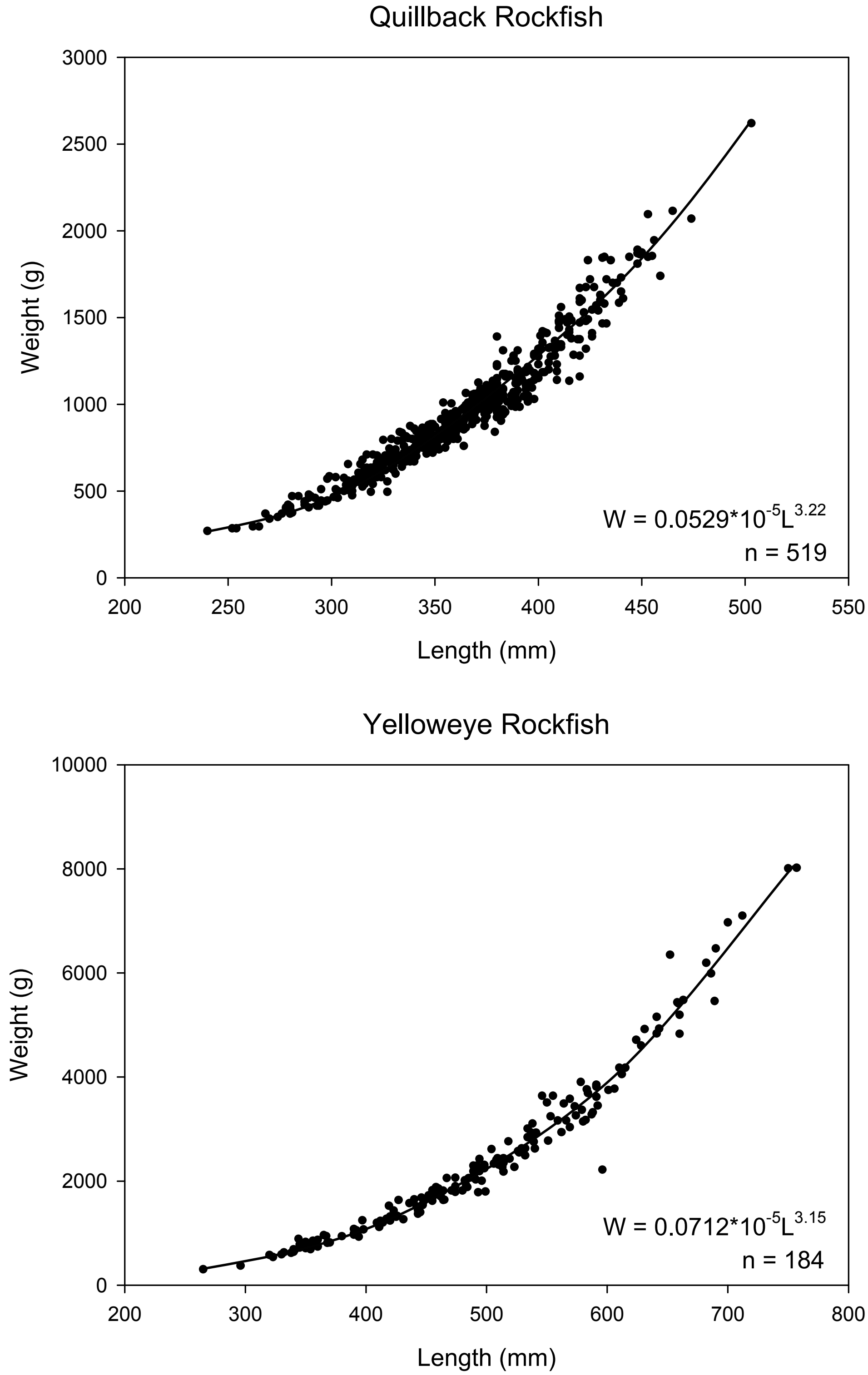


Figure 3. Length – weight relationship for quillback and yelloweye rockfish. Line equations are shown where 'W' equals weight in grams, 'L' equals fork length in millimetres and 'n' equals sample size.

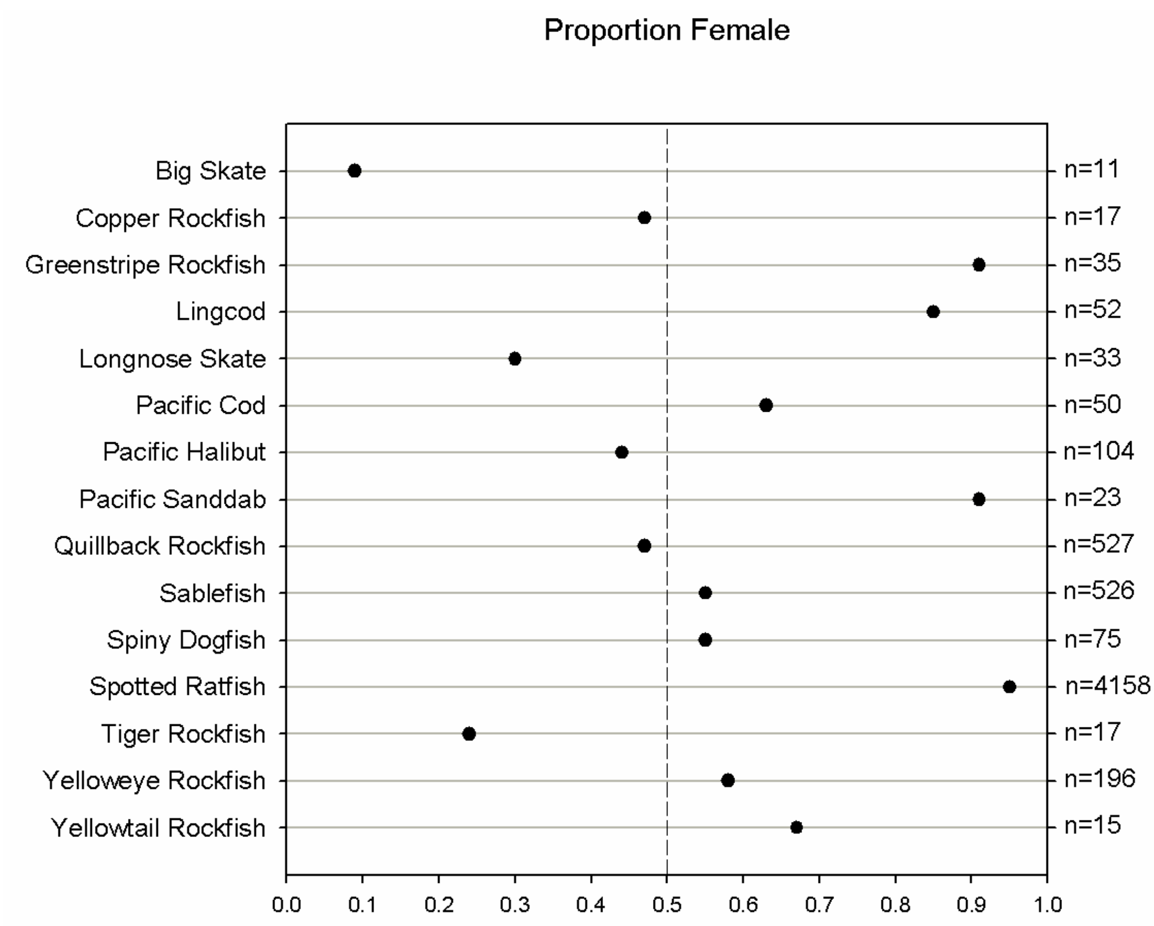
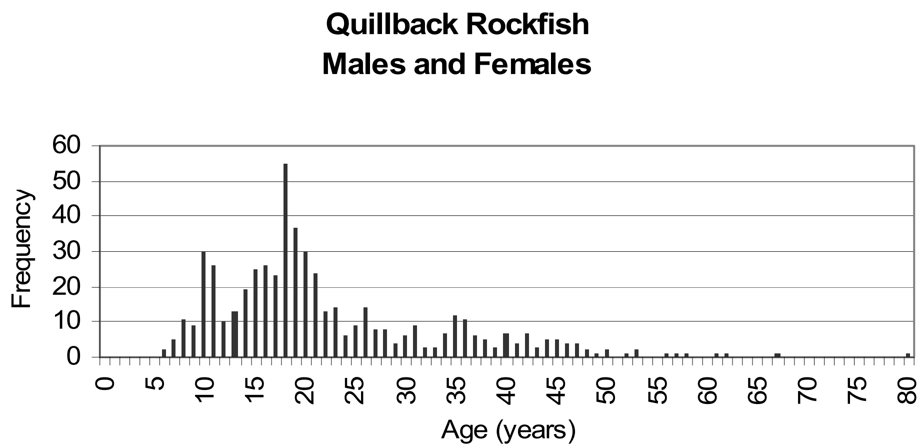
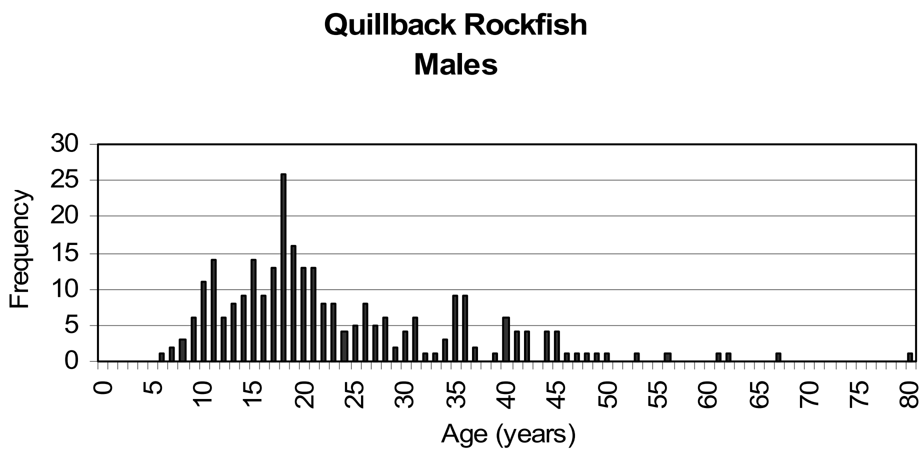


Figure 4. Proportion female for species where sample size (n) was greater than 10.





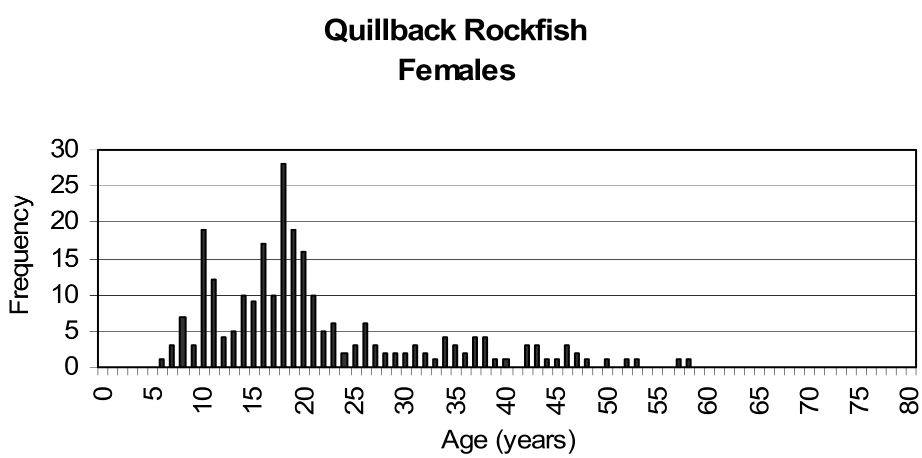


Figure 5. Age frequency distribution of quillback rockfish plotted with sexes combined (top), with males only (middle), and females only (bottom).

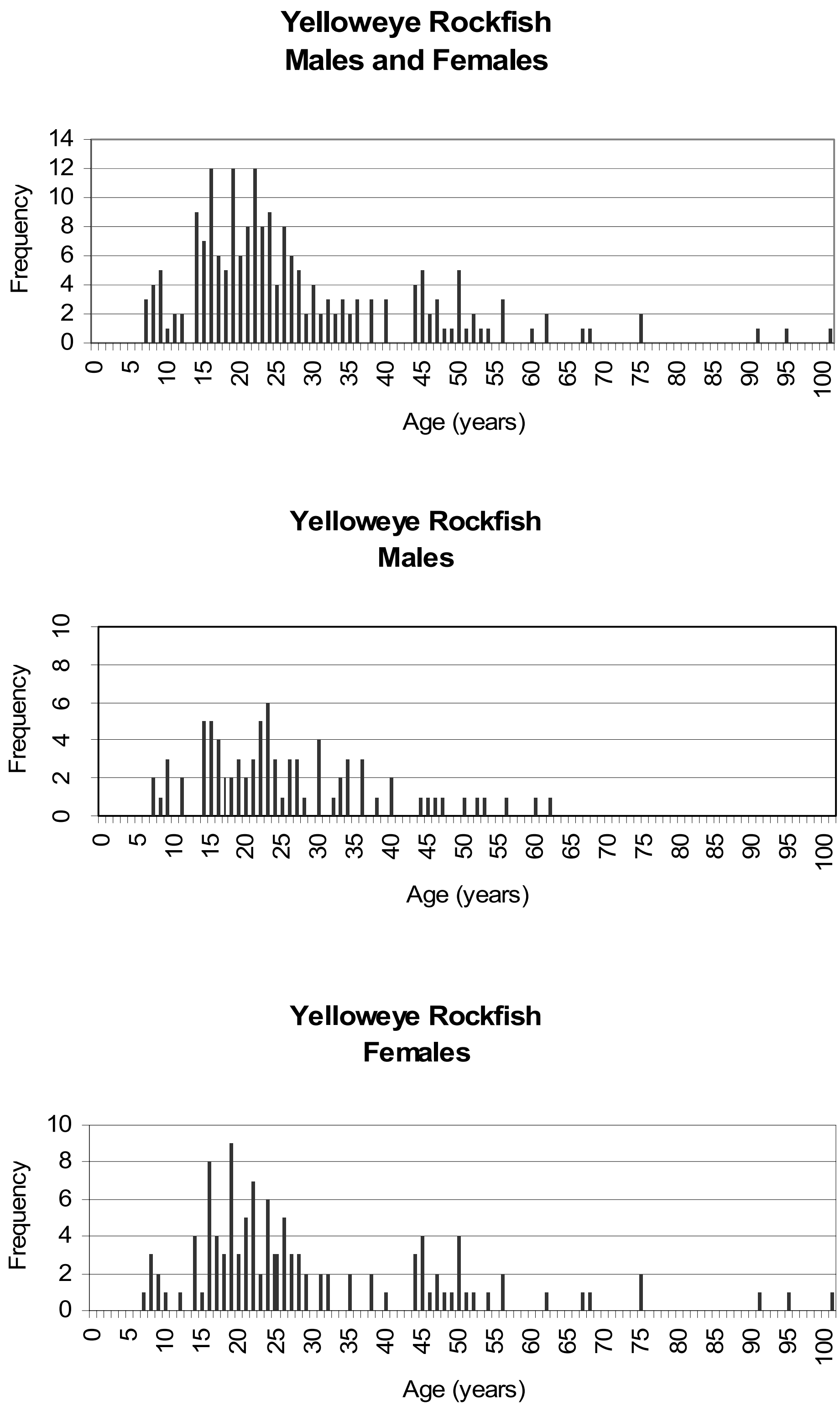


Figure 6. Age frequency distribution of yelloweye rockfish plotted with sexes combined (top), with males only (middle), and females only (bottom).

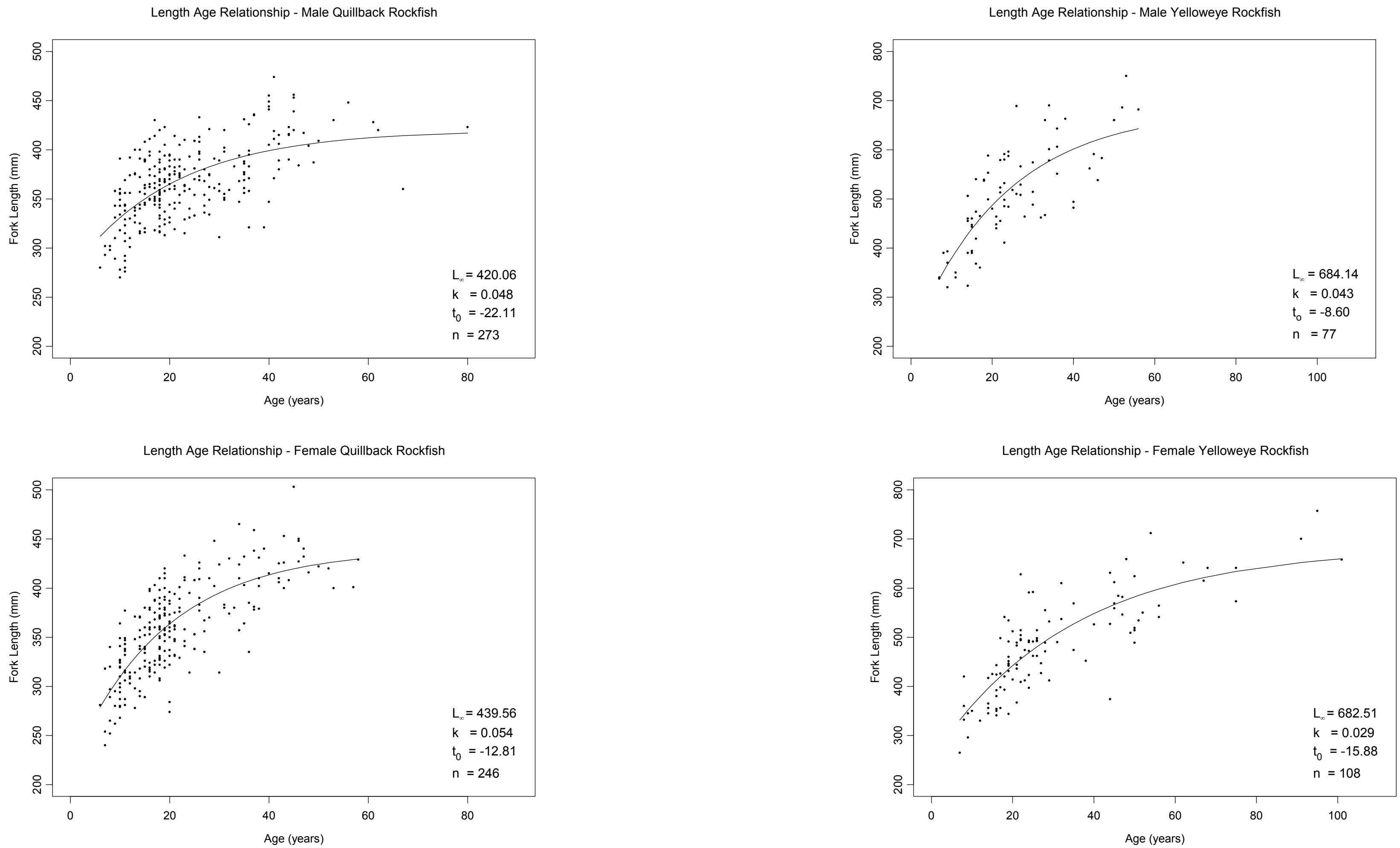


Figure 7. von Bertalanffy growth curves and parameters for male and female quillback and yelloweye rockfish.

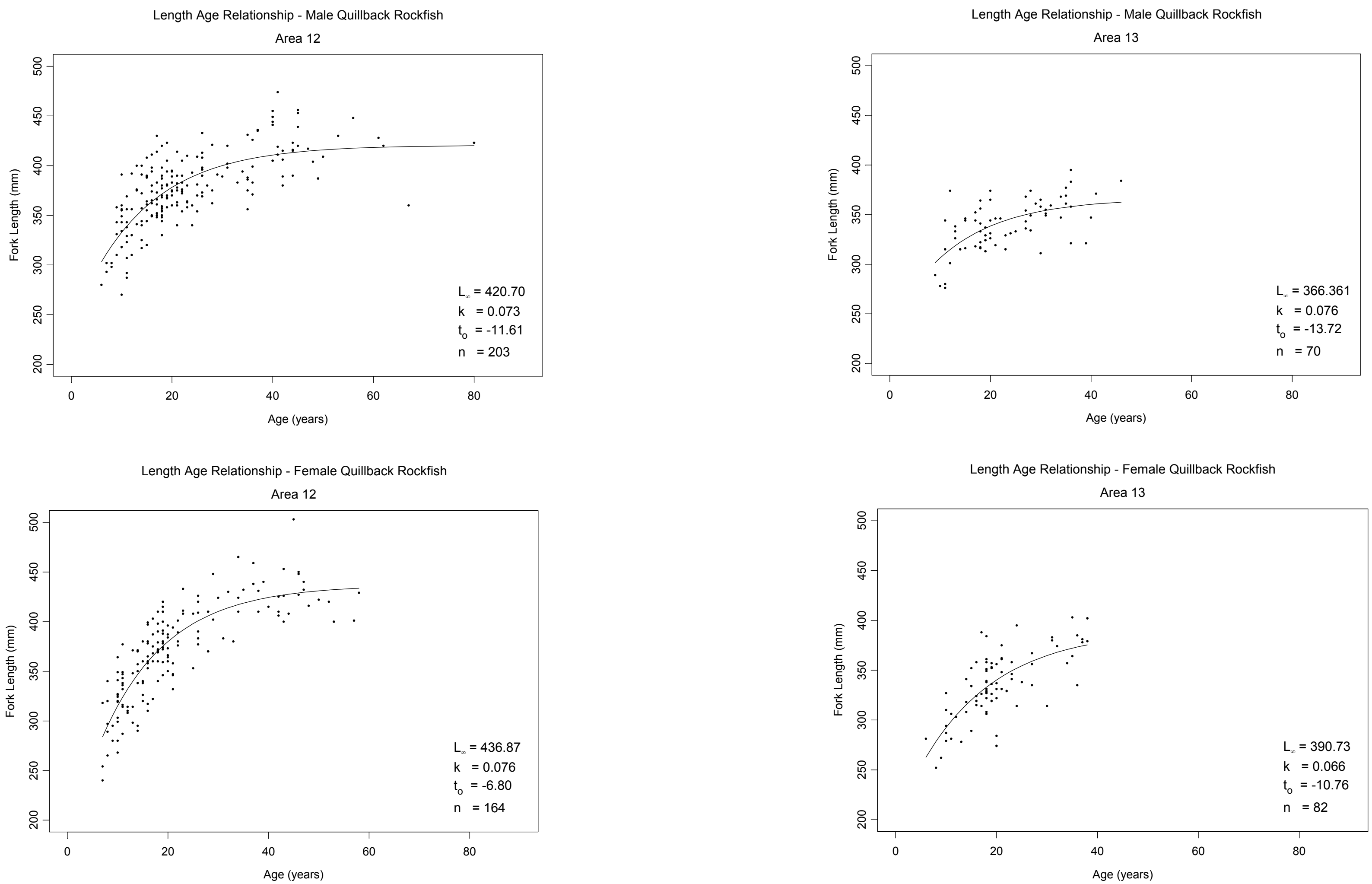
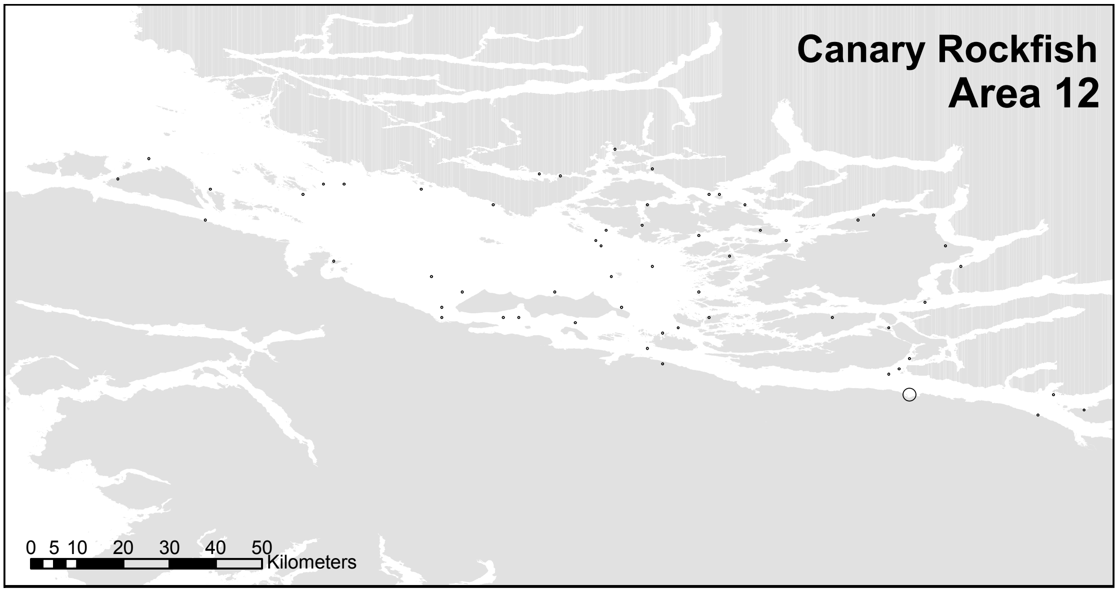


Figure 8. von Bertalanffy growth curves and parameters for male and female quillback rockfish, by statistical area.



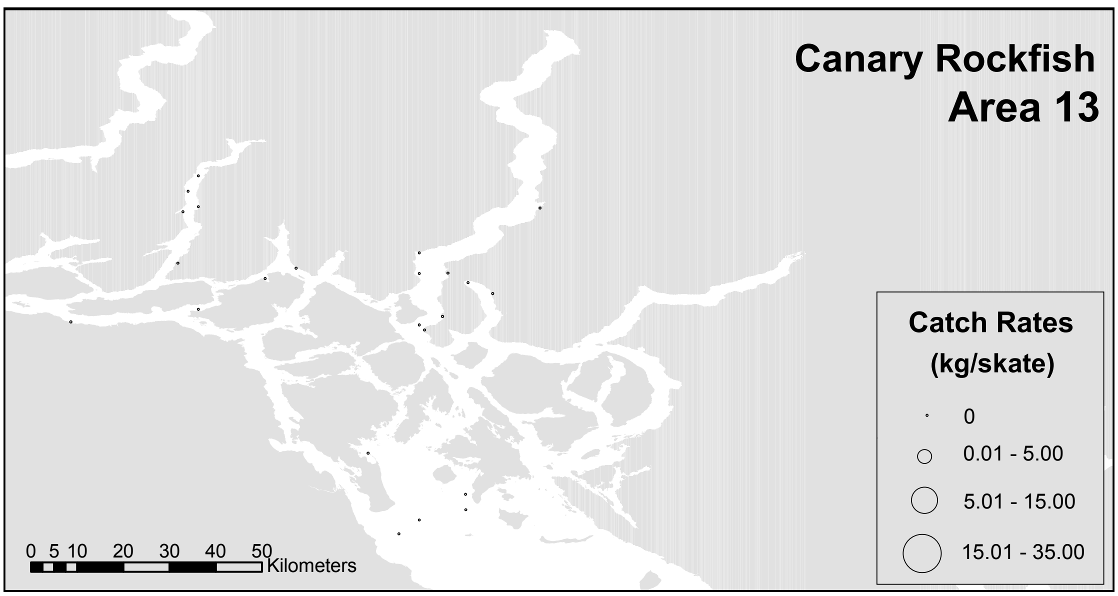


Figure 9. Spatial distribution of canary rockfish catch rates in units of kilograms per skate for survey sites in SA 12 (top panel) and SA 13 (lower panel).

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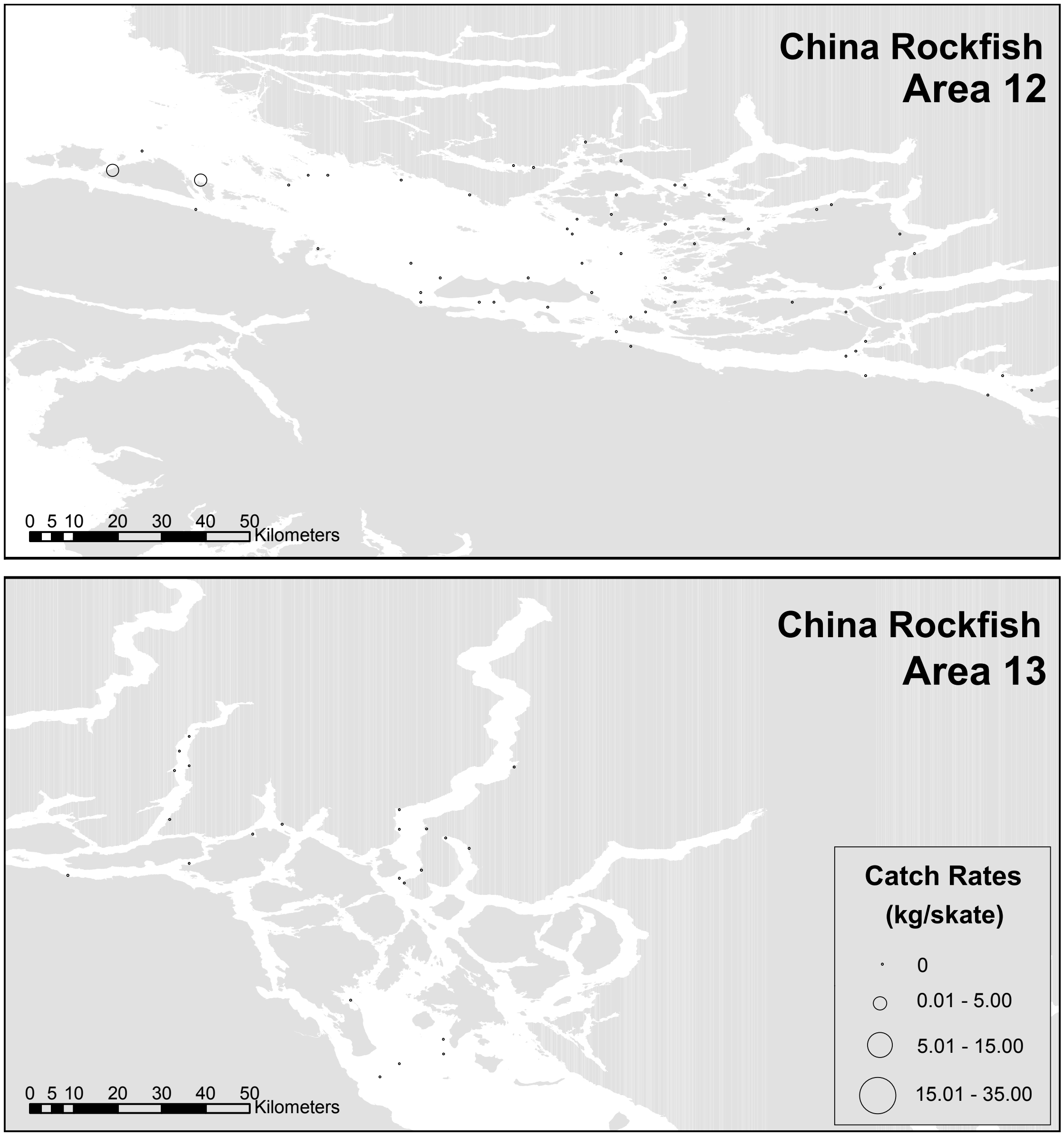


Figure 10. Spatial distribution of china rockfish catch rates in units of kilograms per skate for survey sites in SA 12 (top panel) and SA 13 (lower panel).

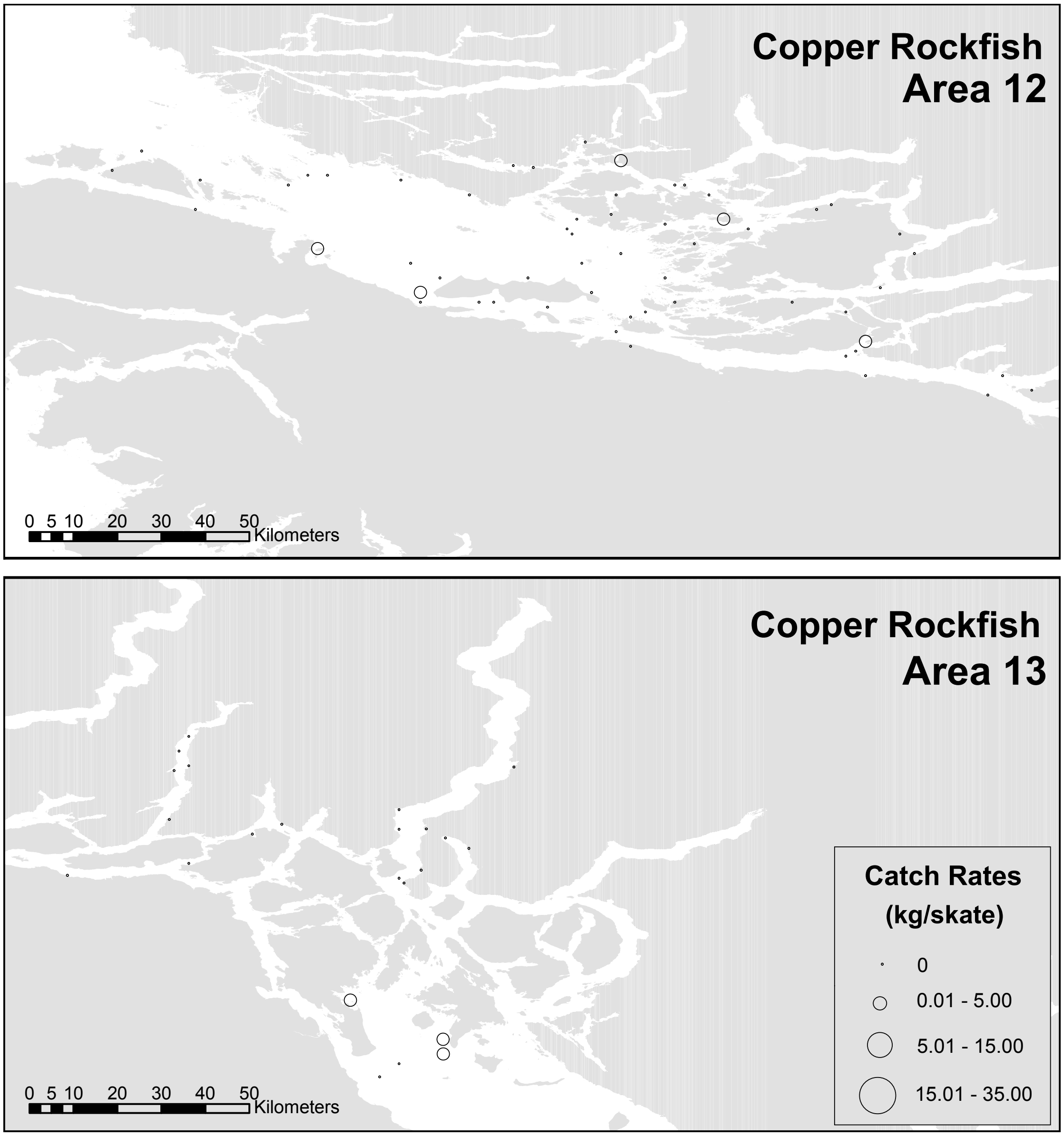


Figure 11. Spatial distribution of copper rockfish catch rates in units of kilograms per skate for survey sites in SA 12 (top panel) and SA 13 (lower panel).

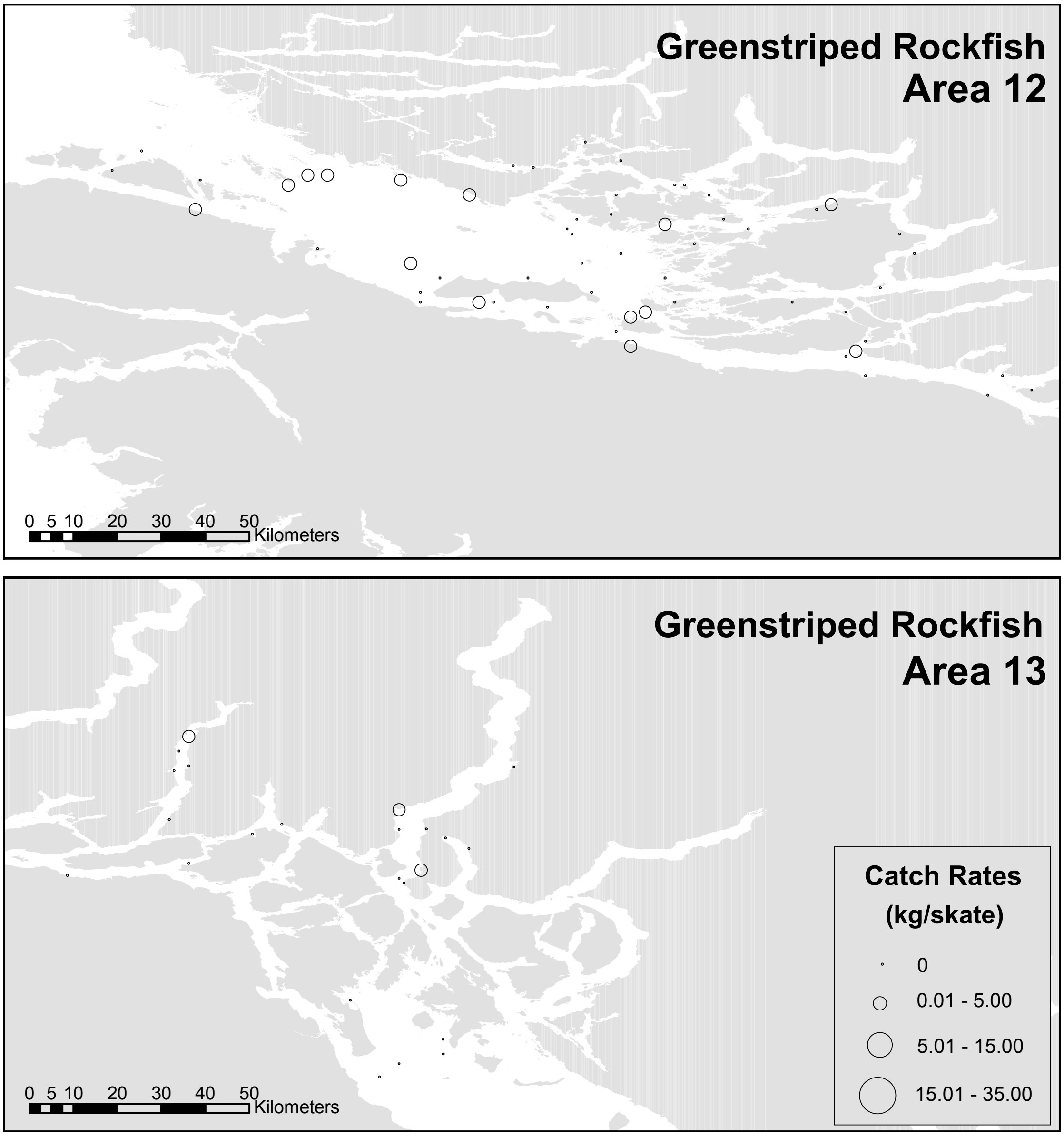
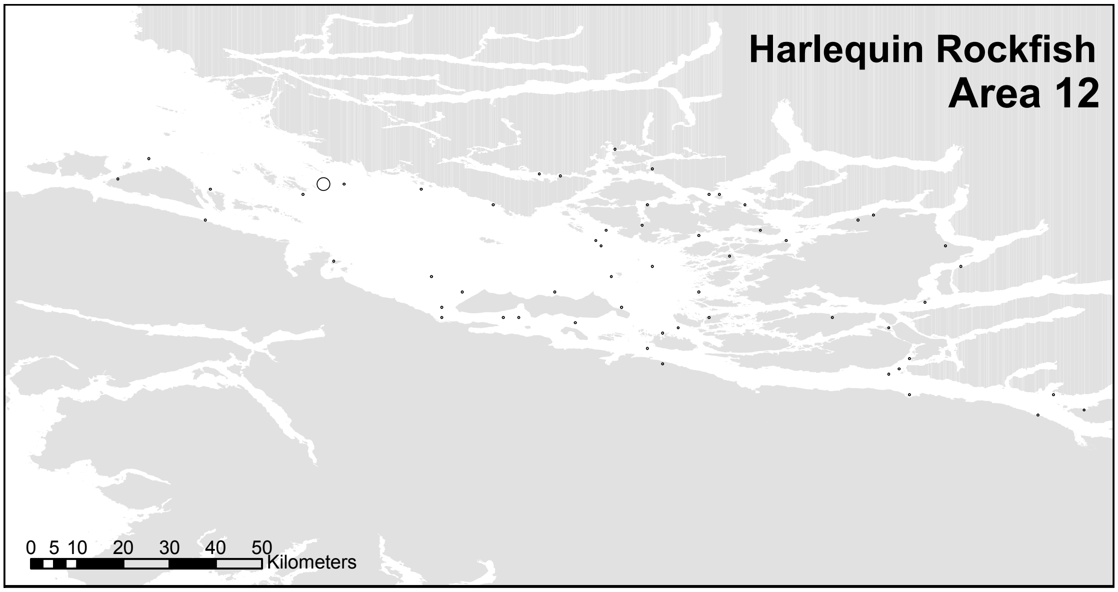


Figure 12. Spatial distribution of greenstriped rockfish catch rates in units of kilograms per skate for survey sites in SA 12 (top panel) and SA 13 (lower panel).



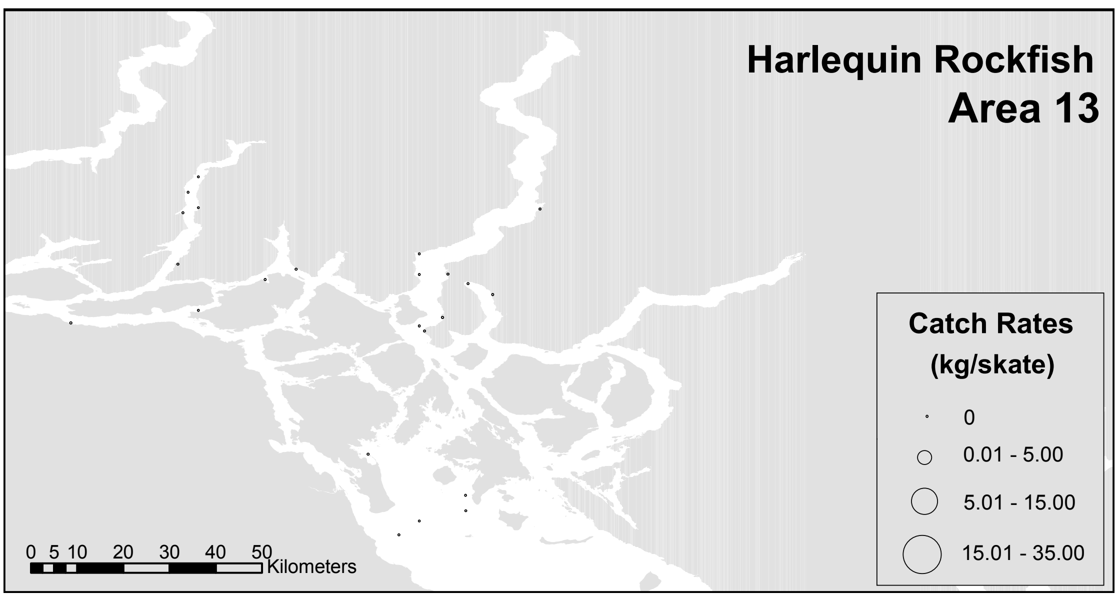


Figure 13. Spatial distribution of harlequin rockfish catch rates in units of kilograms per skate for survey sites in SA 12 (top panel) and SA 13 (lower panel).

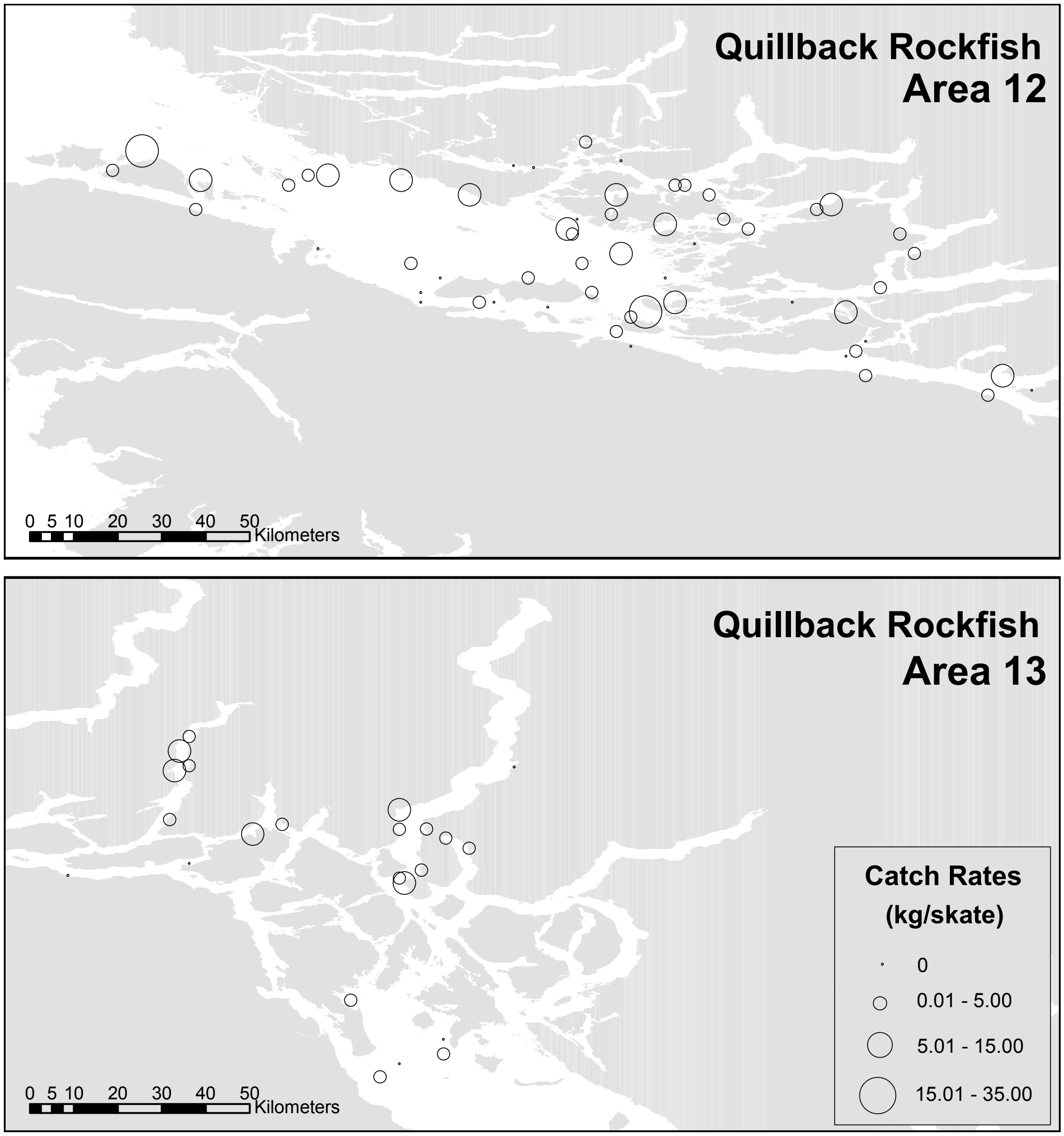
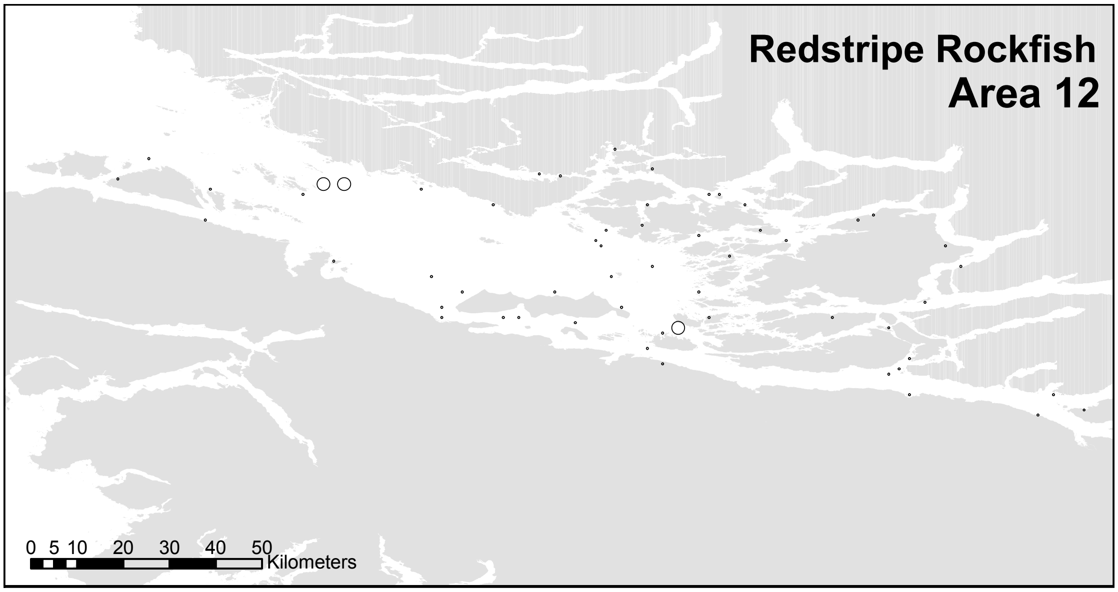


Figure 14. Spatial distribution of quillback rockfish catch rates in units of kilograms per skate for survey sites in SA 12 (top panel) and SA 13 (lower panel).



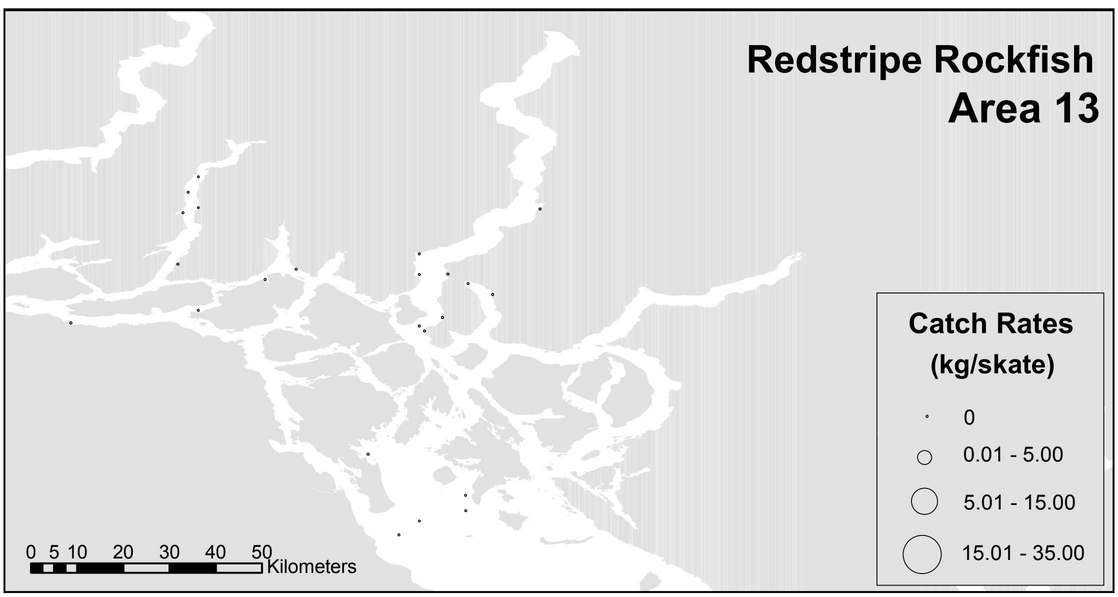


Figure 15. Spatial distribution of redstripe rockfish catch rates in units of kilograms per skate for survey sites in SA 12 (top panel) and SA 13 (lower panel).

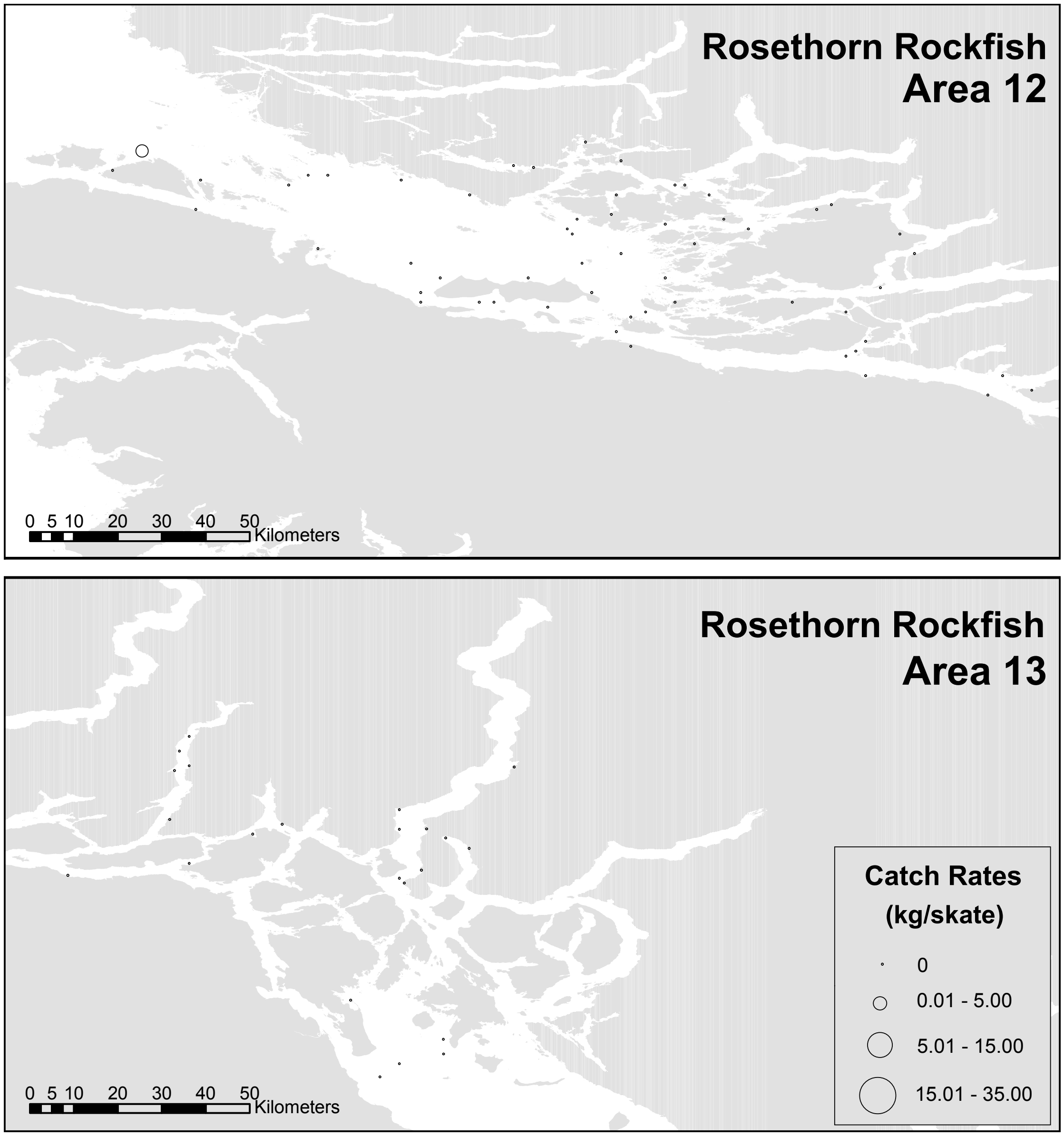


Figure 16. Spatial distribution of rosethorn rockfish catch rates in units of kilograms per skate for survey sites in SA 12 (top panel) and SA 13 (lower panel).

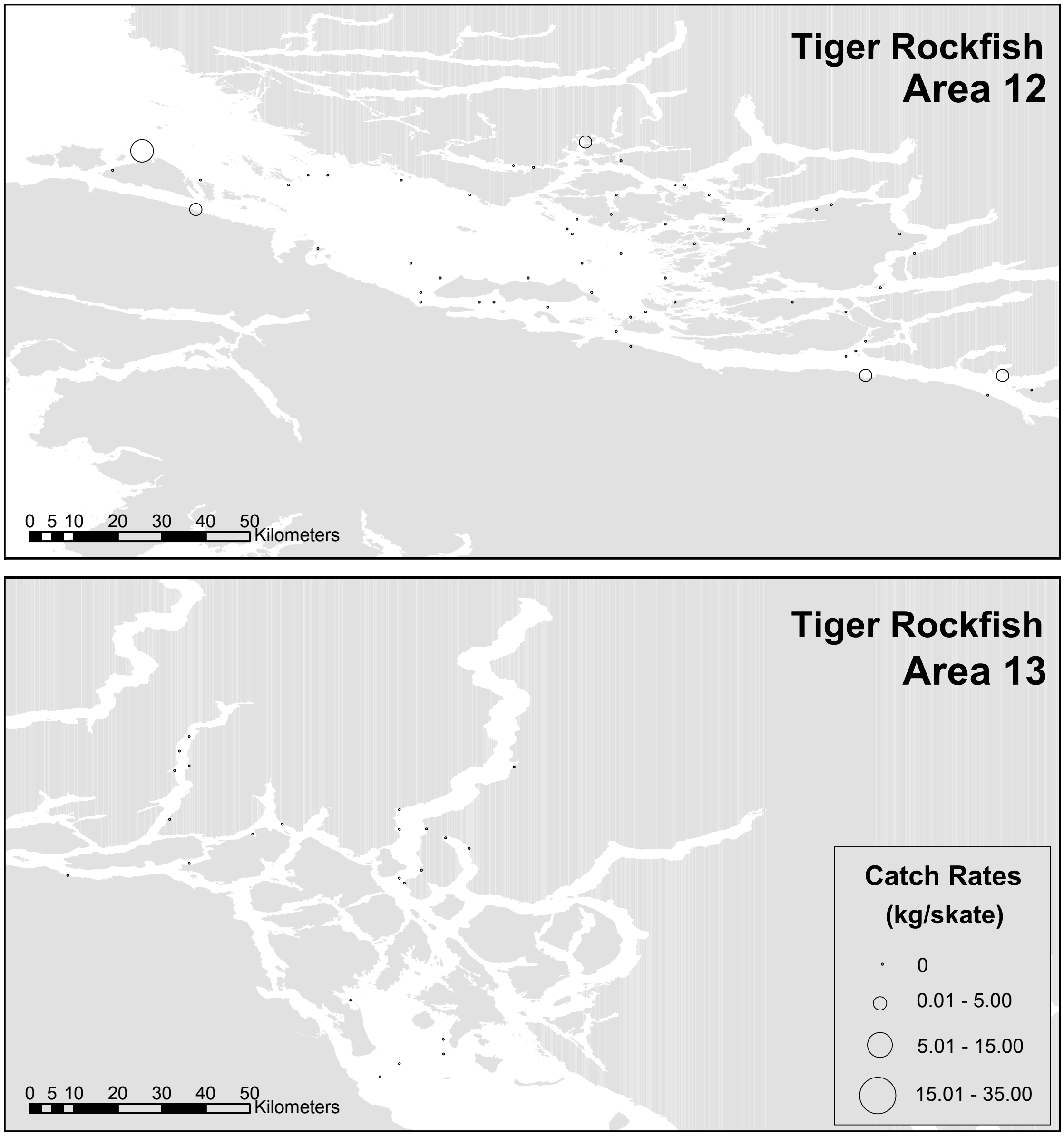


Figure 17. Spatial distribution of tiger rockfish catch rates in units of kilograms per skate for survey sites in SA 12 (top panel) and SA 13 (lower panel).

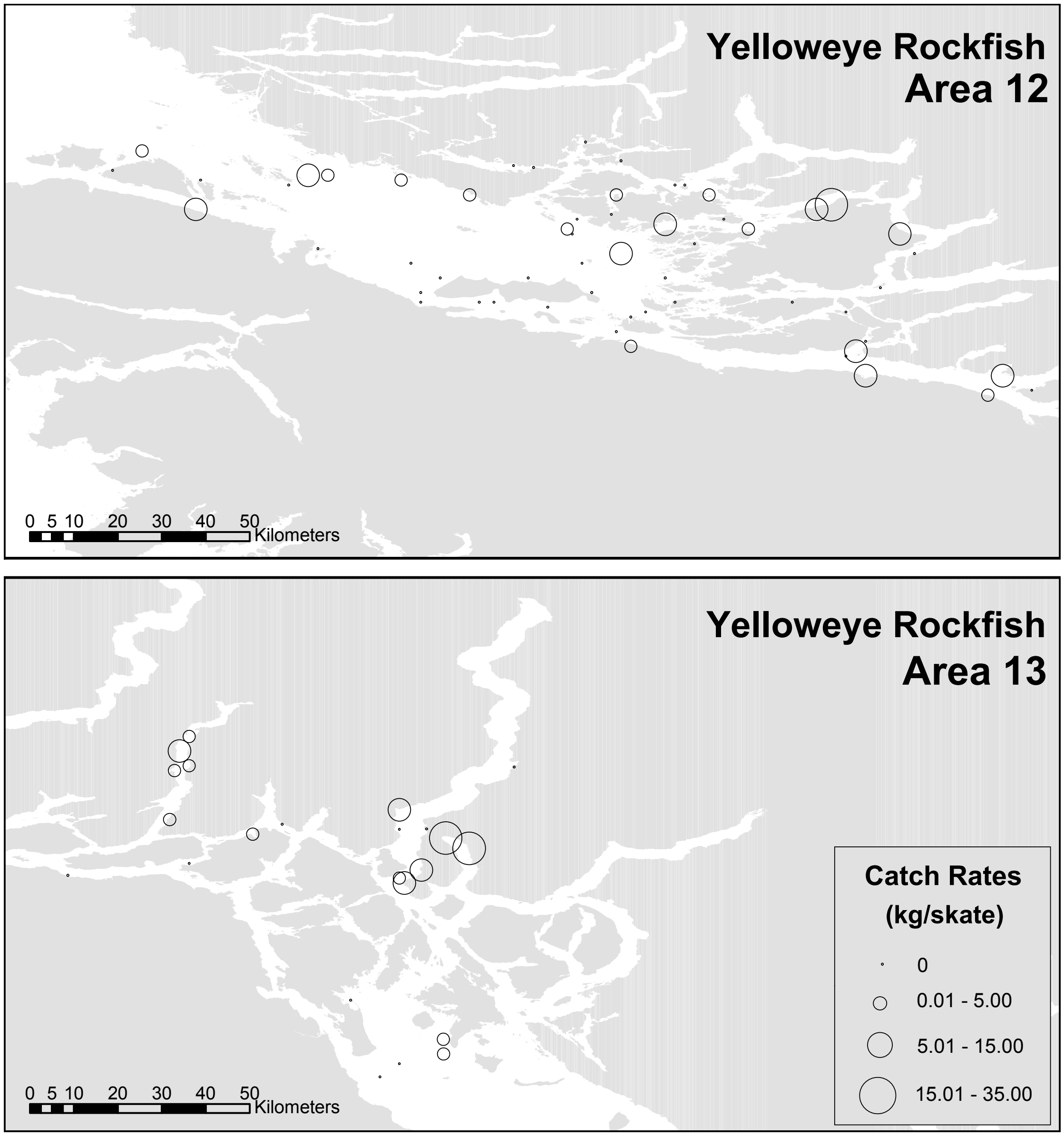


Figure 18. Spatial distribution of yelloweye rockfish catch rates in units of kilograms per skate for survey sites in SA 12 (top panel) and SA 13 (lower panel).

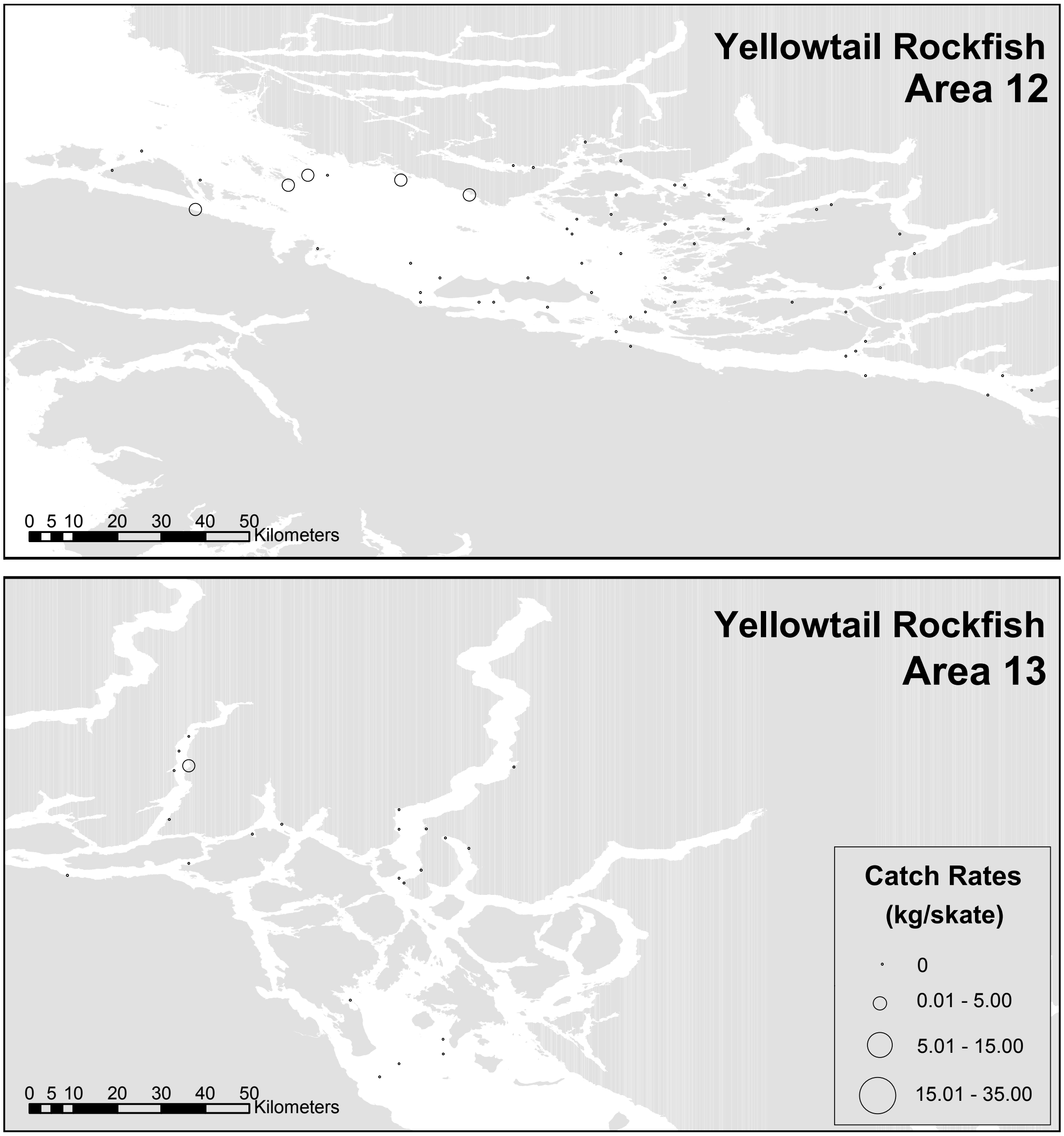


Figure 19. Spatial distribution of yellowtail rockfish catch rates in units of kilograms per skate for survey sites in SA 12 (top panel) and SA 13 (lower panel).

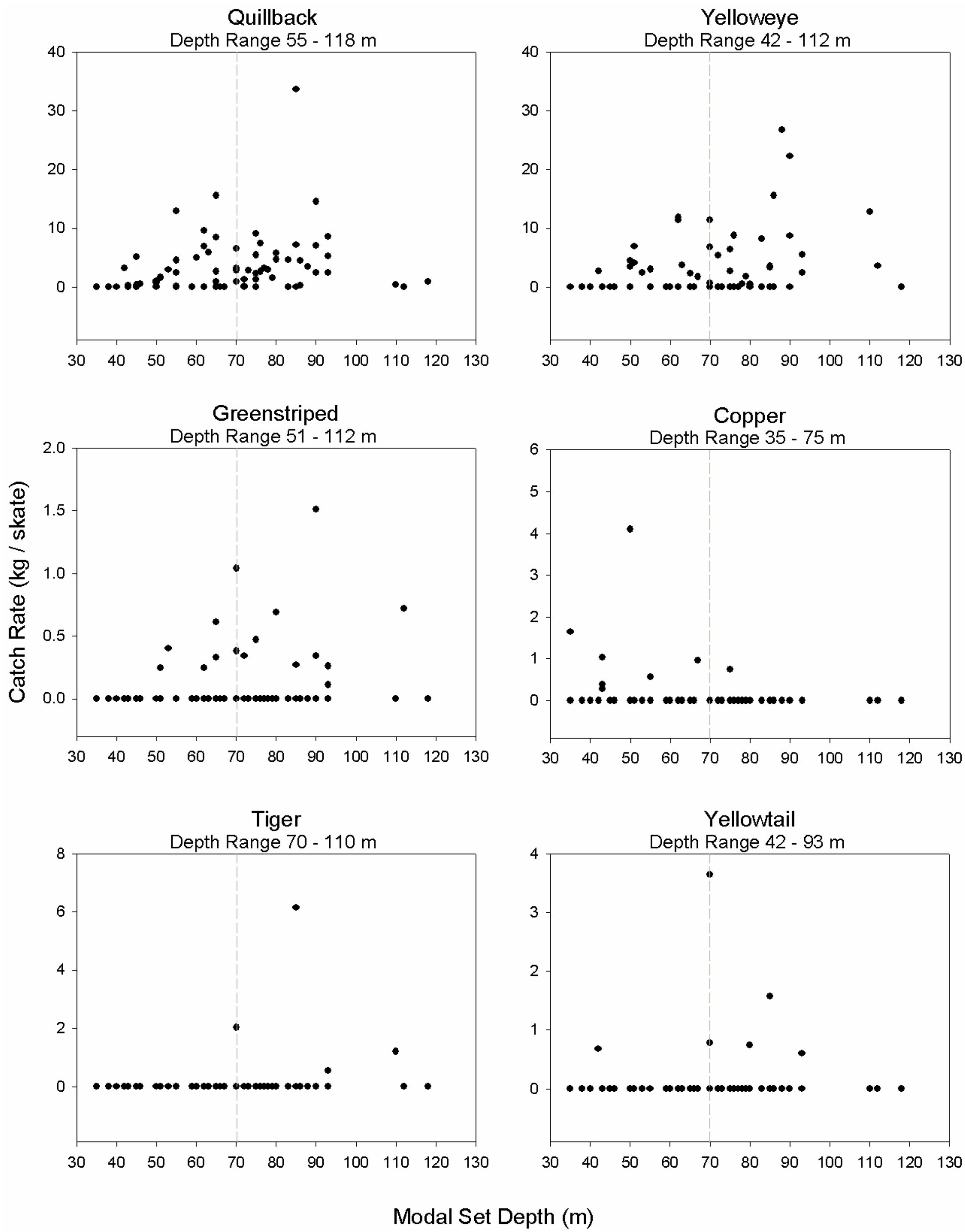


Figure 20. Relationships between catch rates (kg/skate) and modal set depth (m) for the six most frequently encountered rockfish on the survey. Depth ranges are for non-zero catch rates. The grey dotted line represents the boundary between the shallow stratum (41-70m) and the deep stratum (71-100m).

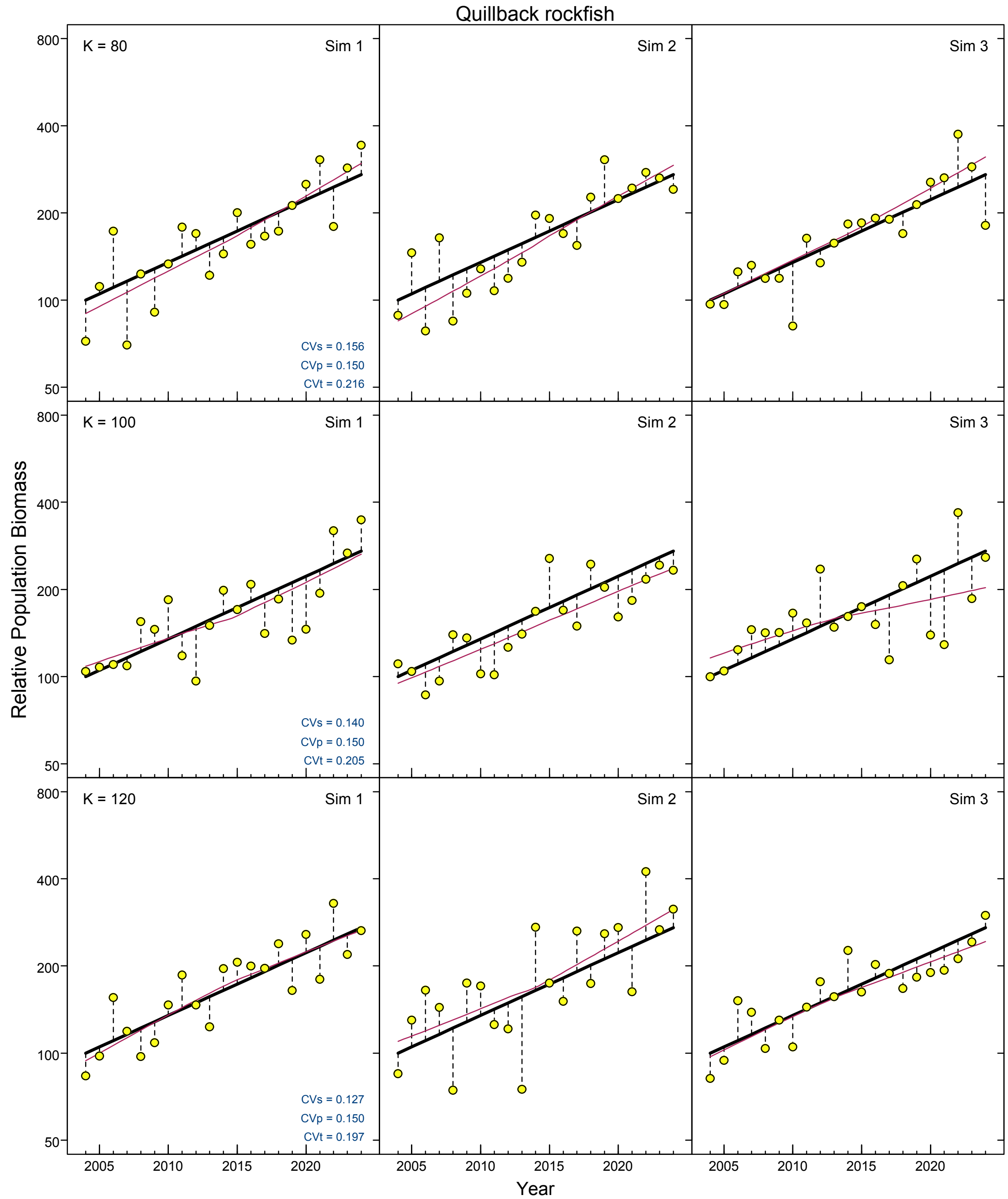


Figure 21. Quillback rockfish simulation results showing a 20 year projection of the relative population biomass. The known population density increases at 5% compounded per year and is shown as a thick black line. Biomass estimates are adjusted with a 15% random process error and are shown as circles. Departure of the biomass estimates are shown as a vertical dashed line and the loess fit of the simulated biomass estimates is shown as a thin black line. 'K' indicates the number of hypothetical sets fished per year.

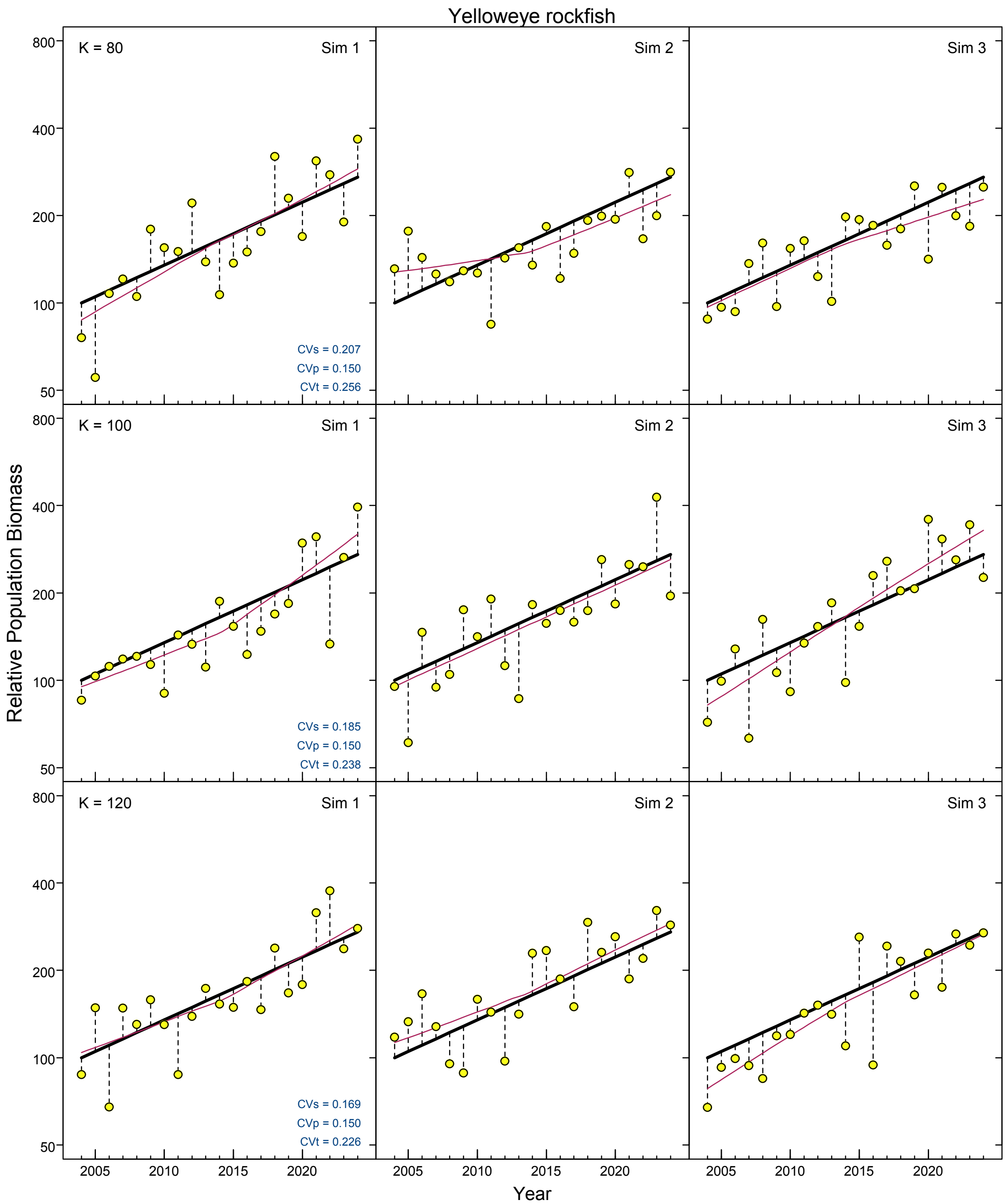


Figure 22. Yelloweye rockfish simulation results showing a 20 year projection of the relative population biomass. The known population density increases at 5% compounded per year and is shown as a thick black line. Biomass estimates are adjusted with a 15% random process error and are shown as circles. Departure of the biomass estimates are shown as a vertical dashed line and the loess fit of the simulated biomass estimates is shown as a thin black line. 'K' indicates the number of hypothetical sets fished per year.

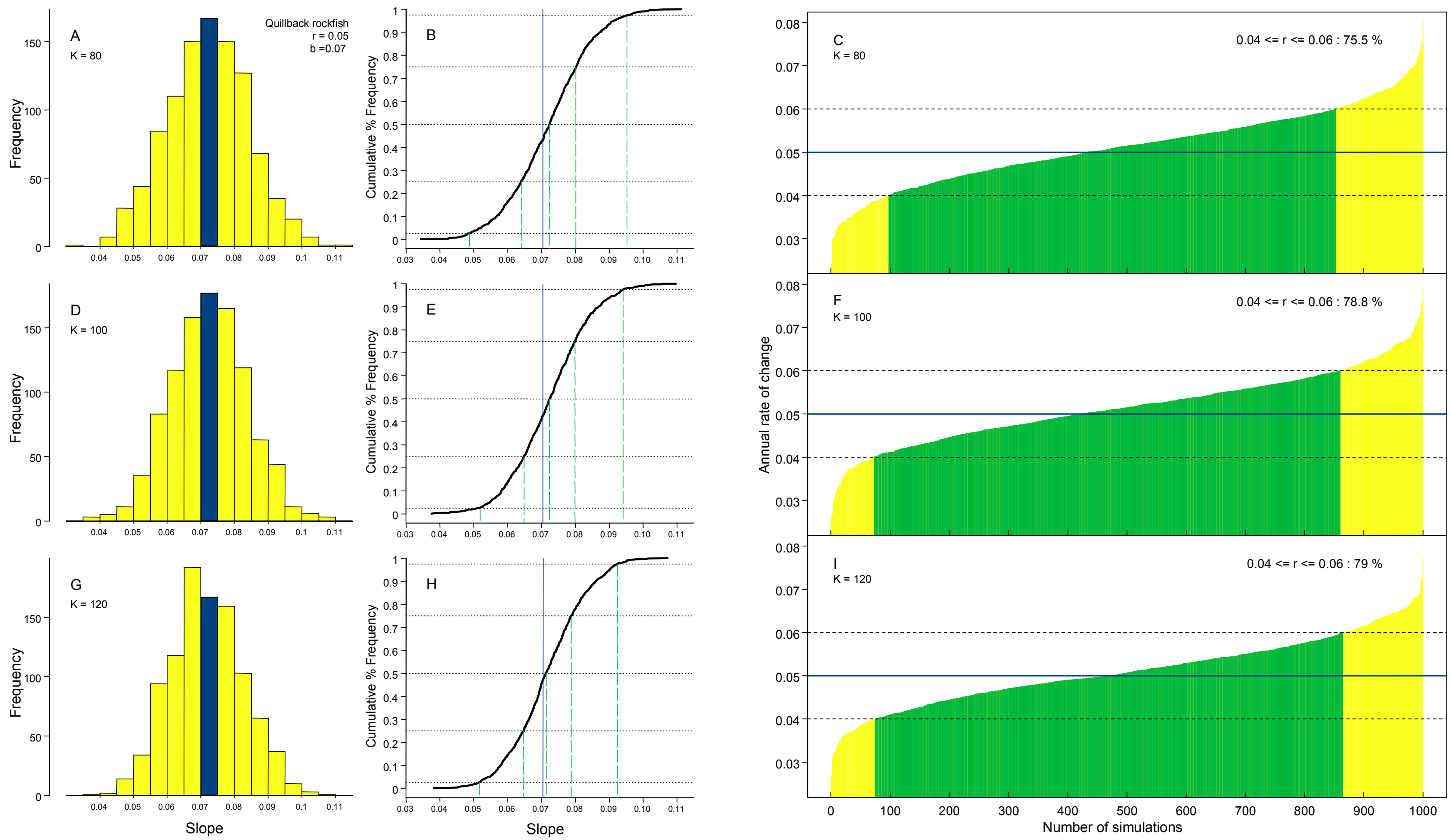


Figure 23. Distribution of bootstrapped slopes and annual rates of change for quillback rockfish. Figure rows correspond to the number of hypothetical sets fished per year, or ‘K’, which is set at 80, 100, and 120. Histogram panels A, D and G illustrate the frequency distribution of slopes obtained from 1000 simulations and the black bar indicates the interval that contains the true slope b = 0.07. Dashed vertical lines in panels B,E, and H indicate 2.5%, 25%, 50%, 75%, and 97.5% quantiles. Panels C, F, and I are high-density line plots of annual rate of change, where the solid horizontal line indicates the true annual rate of increase r = 0.05; dashed horizontal lines indicate r±20%; dark shading denotes simulated surveys where estimated annual rate of change falls in the range r±20%.

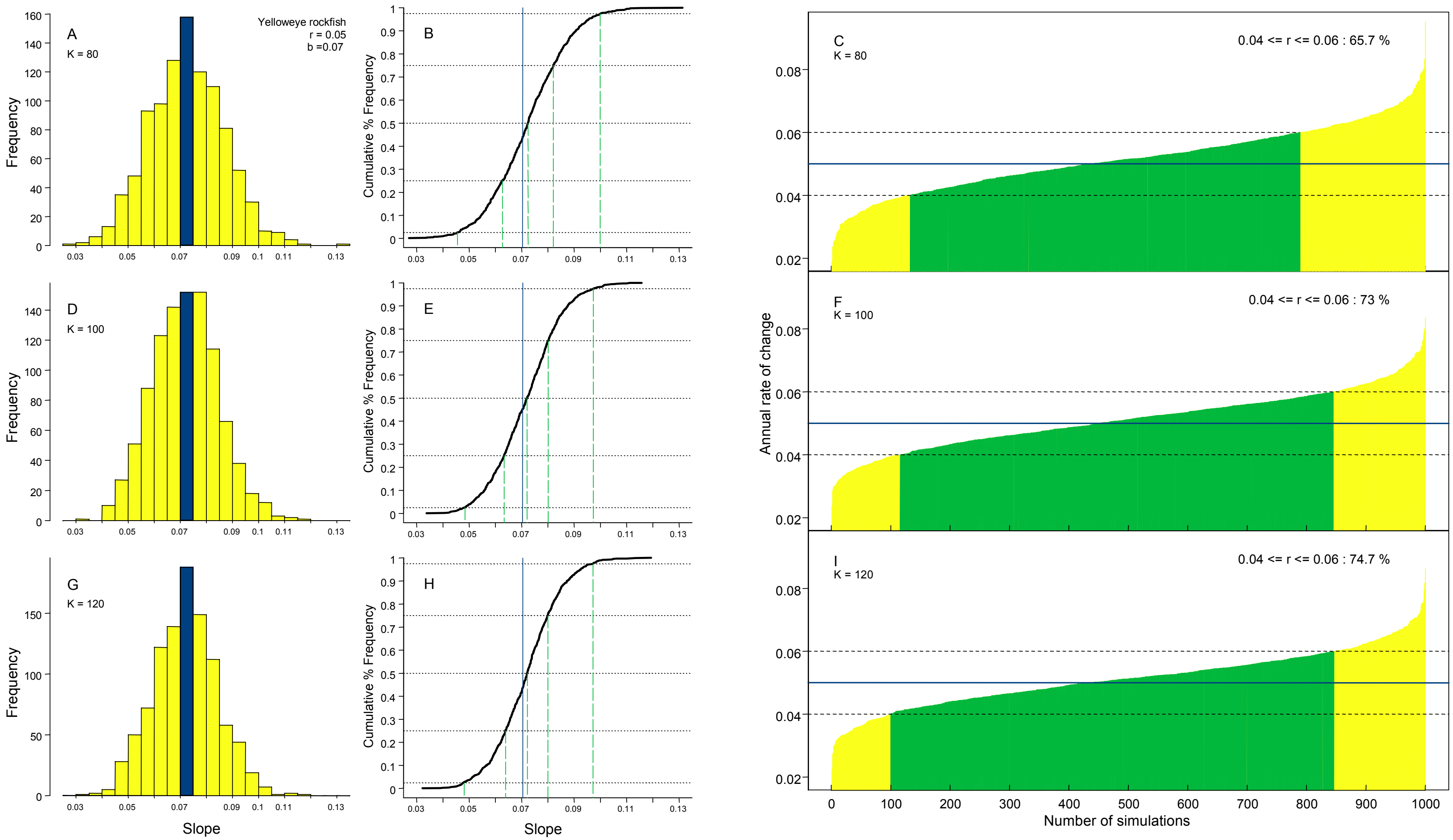


Figure 24. Distribution of bootstrapped slopes and annual rates of change for yelloweye rockfish. Figure rows correspond to the number of hypothetical sets fished per year (K) which is set at 80, 100, and 120. Histogram panels A, D and G illustrate the frequency distribution of slopes obtained from 1000 simulations and the black bar indicates the interval that contains the true slope b = 0.07. Dashed vertical lines in panels B,E, and H indicate 2.5%, 25%, 50%, 75%, and 97.5% quantiles. Panels C, F, and I are high-density line plots of annual rate of change, where the solid horizontal line indicates the true annual rate of increase r = 0.05; dashed horizontal lines indicate r±20%; dark shading denotes simulated surveys where estimated annual rate of change falls in the range r±20%.

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Appendix Table 1. Description of sexual maturity stages for rockfish, based on Westrheim (1975).

Maturity Stage	**Males**
Immature	translucent pink, threadlike
Maturing	stringlike, slight swelling, translucent
Developing	swelling, brown-white
Developed	large, white; easily broken
Running	running sperm
Spent	white-brown; sperm still in duct
Resting	triangluar in cross-section; small, brown

Maturity Stage	**Females**
Immature	translucent pink, small
Maturing	small, yellow eggs, translucent or opaque;
Mature	large, yellow or orange eggs; opaque
Fertilized	large, orange-yellow eggs; translucent
Embryos or Larvae	include eyed eggs; translucent
Spent	large, flaccid, red ovaries; a few larvae may be present
Resting	moderate size, firm, orange-grey ovaries, some with dark blotches

Appendix Table 2. Set Specifications.

Set #	Start Latiutde	Start Longitude	End Latitude	End Longitude	Distance Travelled (km)	Modal Depth (meters)	Min Depth (meters)	Max Depth (meters)	Begin Deployment	End Deployment	Begin Retrieval	End Retrieval	Soak Time (minutes)
1	50 48.80	127 39.46	50 48.48	127 38.76	0.985	70	48	92	7:17 AM	7:28 AM	9:35 AM	9:57 AM	127
2	50 52.66	127 38.55	50 52.29	127 37.77	1.178	55	42	72	8:10 AM	8:23 AM	10:31 AM	10:54 AM	128
3	50 55.96	127 46.17	50 55.62	127 45.52	1.002	85	67	92	11:38 AM	11:49 AM	1:56 PM	2:19 PM	127
4	50 53.77	127 49.64	50 54.02	127 48.56	1.202	46	32	52	12:40 PM	12:53 PM	3:00 PM	3:22 PM	127
5	50 51.91	127 27.64	50 51.87	127 28.44	1.063	80	68	92	7:00 AM	7:10 AM	9:12 AM	9:35 AM	122
6	50 53.33	127 25.41	50 52.9	127 25.02	0.930	70	54	100	7:46 AM	7:57 AM	10:11 AM	10:29 AM	134
7	50 52.80	127 23.25	50 53.24	127 23.8	1.187	65	50	92	11:14 AM	11:25 AM	1:26 PM	1:49 PM	121
8	50 52.58	127 14.15	50 52.80	127 14.93	1.028	85	80	102	12:25 PM	12:36 PM	2:36 PM	2:58 PM	120
9	50 50.52	127 05.57	50 50.88	127 06.10	0.907	93	84	98	3:58 PM	4:09 PM	6:10 PM	6:30 PM	121
10	50 43.81	127 24.55	50 43.11	127 24.94	0.969	43	37	59	6:52 AM	7:04 AM	9:08 AM	9:29 AM	124
11	50 54.19	127 00.33	50 54.13	127 01.19	1.011	45	38	75	3:12 PM	3:25 PM	5:31 PM	5:49 PM	126
12	50 53.84	127 56.96	50 53.85	127 57.86	1.124	35 *	28	42	7:44 AM	7:58 AM	10:00 AM	10:18 AM	122
13	50 56.79	127 50.93	50 56.90	127 50.08	1.009	shallow **	-	-	8:41 AM	8:53 AM	11:06 AM	11:21 AM	133
14	50 54.85	126 47.15	50 55.41	126 47.04	1.032	35 *	31	40	12:21 PM	12:34 PM	2:38 PM	2:53 PM	124
15	50 52.09	126 40.73	50 52.28	126 41.49	0.959	65	38	98	4:23 PM	4:34 PM	6:41 PM	6:55 PM	127
16	50 52.14	126 39.19	50 51.89	126 39.87	1.009	65	38	77	6:53 AM	7:06 AM	8:57 AM	9:12 AM	111
17	50 50.87	126 36.53	50 50.99	126 37.31	1.006	78	70	80	7:27 AM	7:41 AM	9:44 AM	9:55 AM	123
18	50 50.85	126 47.43	50 50.69	126 48.24	1.004	70	40	80	10:48 AM	11:00 AM	1:06 PM	1:27 PM	126
19	50 48.16	126 48.31	50 48.5	126 48.62	0.841	45	33	51	11:25 AM	11:35 AM	1:53 PM	2:07 PM	138
20	50 46.23	126 31.63	50 46.23	126 30.83	0.974	55	28	82	3:44 PM	3:54 PM	5:56 PM	6:12 PM	122
21	50 40.45	126 41.53	50 40.41	126 41.35	0.980	55	40	63	7:16 AM	7:26 AM	9:30 AM	9:53 AM	124
22	50 43.48	126 46.84	50 43.5	126 47.67	1.030	90	80	103	7:54 AM	8:04 AM	10:30 AM	10:48 AM	146
23	50 44.77	126 38.18	50 44.63	126 38.95	0.978	59	45	69	11:31 AM	11:41 AM	1:44 PM	2:00 PM	123
24	50 47.08	126 41.54	50 46.78	126 42.19	0.963	75	58	115	12:46 PM	12:57 PM	2:57 PM	3:10 PM	120
25	50 47.90	126 34.40	50 47.87	126 35.06	0.920	43	25	52	3:46 PM	3:57 PM	5:59 PM	6:14 PM	122
26	50 49.06	126 22.88	50 49.20	126 22.15	0.896	83	47	90	7:10 AM	7:19 AM	9:19 AM	9:33 AM	120
27	50 49.30	126 21.36	50 49.65	126 20.63	0.896	90	42	102	7:28 AM	7:37 AM	9:46 AM	10:01 AM	129
28	50 45.98	126 12.63	50 45.72	126 11.39	0.895	72	50	80	11:00 AM	11:10 AM	1:11 PM	1:25 PM	121
29	50 43.43	126 10.97	50 43.21	126 10.62	0.867	70	48	103	12:17 PM	12:27 PM	2:29 PM	2:42 PM	122
30	50 39.02	126 15.14	50 39.20	126 14.48	0.863	73	68	107	3:26 PM	3:36 PM	5:39 PM	5:54 PM	123
31	50 36.31	126 19.70	50 36.34	126 20.43	0.880	45	30	60	7:01 AM	7:09 AM	9:15 AM	9:29 AM	126
32	50 37.70	126 26.06	50 37.76	126 26.86	0.957	75	68	92	7:45 AM	7:52 AM	10:07 AM	10:22 AM	135
33	50 37.70	126 40.67	50 37.97	126 41.30	0.900	60	44	76	12:08 PM	12:16 PM	2:03 PM	2:18 PM	107
34	50 36.51	126 43.84	50 36.25	126 43.18	0.906	65	-	-	12:42 PM	12:50 PM	2:50 PM	3:10 PM	120
35	50 40.40	127 09.14	50 40.64	127 08.49	0.913	65	49	67	7:37 AM	7:46 AM	9:48 AM	10:08 AM	122
36	50 40.30	126 58.43	50 40.27	126 57.63	0.935	shallow **	-	-	8:30 AM	8:39 AM	11:01 AM	11:18 AM	142
37	50 46.73	126 53.90	50 47.24	126 54.19	0.996	75	66	102	12:07 PM	12:16 PM	2:16 PM	2:31 PM	120
38	50 47.91	126 52.58	50 47.71	126 51.9	0.867	72	68	74	1:05 PM	1:17 PM	3:17 PM	3:32 PM	120
39	50 45.71	126 53.05	50 46.12	126 53.55	0.961	77	77	100	3:52 PM	4:01 PM	6:04 PM	6:23 PM	123
40	50 37.73	127 11.47	50 38.49	127 12.37	1.746	40	27	49	7:46 AM	7:58 AM	9:58 AM	10:24 AM	120

Appendix Table 2. Set Specifications (continued).

Set #	Start Latiutde	Start Longitude	End Latitude	End Longitude	Distance Travelled (km)	Modal Depth (meters)	Min Depth (meters)	Max Depth (meters)	Begin Deployment	End Deployment	Begin Retrieval	End Retrieval	Soak Time (minutes)
41	50 42.34	127 12.84	50 42.72	127 11.91	1.313	100	65	104	8:23 AM	8:35 AM	10:55 AM	11:21 AM	140
42	50 38.66	127 11.79	50 39.03	127 12.34	0.935	43	40	43	12:04 PM	12:15 PM	2:17 PM	2:47 PM	122
43	50 37.52	127 04.45	50 37.48	127 05.24	0.939	72	68	72	1:29 PM	1:43 PM	3:49 PM	4:15 PM	126
44	50 37.65	127 02.86	50 37.66	127 03.89	1.222	50	41	60	3:29 PM	3:43 PM	5:46 PM	6:08 PM	123
45	50 36.80	126 55.87	50 36.74	126 55.01	1.013	38 *	33	39	7:53 AM	8:08 AM	10:10 AM	10:34 AM	122
46	50 35.65	126 45.77	50 36.07	126 46.45	1.137	90	66	105	8:48 AM	9:00 AM	11:16 AM	11:43 AM	136
47	50 42.09	126 51.79	50 42.18	126 52.56	0.945	118 *	87	120	1:08 PM	1:23 PM	3:23 PM	3:48 PM	120
48	50 38.63	126 50.73	50 39.12	126 50.95	0.907	75	65	85	2:33 PM	2:47 PM	4:49 PM	5:11 PM	122
49	50 33.79	126 47.92	50 33.61	126 46.36	0.741	75	52	97	9:10 AM	9:20 AM	11:20 AM	11:49 AM	120
50	50 32.39	126 46.05	50 32.18	126 45.3	0.987	112 *	67	121	10:37 AM	10:48 AM	12:54 PM	1:16 PM	126
51	50 32.79	126 16.98	50 32.41	126 17.3	0.796	75	67	86	6:49 AM	6:59 AM	8:59 AM	9:19 AM	120
52	50 28.42	126 17.36	50 28.69	126 18.09	1.017	110 *	94	135	7:55 AM	8:08 AM	10:08 AM	10:38 AM	120
53	50 31.23	126 18.11	50 31.85	126 18.48	0.839	93	71	100	9:33 AM	9:44 AM	11:44 AM	12:03 PM	120
54	50 31.19	126 19.35	50 31.10	126 20.14	1.033	62	54	78	12:13 PM	12:26 PM	2:26 PM	2:45 PM	120
55	50 28.64	126 00.42	50 28.43	126 01.17	0.948	93	70	97	4:03 PM	4:19 PM	6:19 PM	6:38 PM	120
56	50 26.79	125 56.96	50 26.87	125 57.79	1.002	83	78	88	7:06 AM	7:19 AM	9:20 AM	9:39 AM	121
57	50 26.04	126 01.99	50 26.41	126 02.58	1.002	79	73	94	8:26 AM	8:39 AM	10:39 AM	11:05 AM	120
58	50 22.05	125 46.84	50 22.40	125 47.48	0.991	75	61	78	12:59 PM	1:09 PM	2:59 PM	3:12 PM	110
59	50 23.42	125 32.30	50 23.25	125 33.03	0.937	66	56	75	4:23 PM	4:37 PM	6:38 PM	7:03 PM	121
60	50 27.33	125 24.29	50 26.99	125 24.84	0.930	80	68	102	7:06 AM	7:19 AM	9:22 AM	9:49 AM	123
61	50 28.52	125 20.91	50 28.90	125 21.33	0.867	86	86	88	8:12 AM	8:23 AM	10:23 AM	10:48 AM	120
62	50 00.37	125 00.96	50 00.89	125 01.04	0.976	50	43	59	7:36 AM	7:48 AM	9:48 AM	10:15 AM	120
63	50 02.19	125 02.99	50 02.65	125 01.71	0.922	67	53	69	8:33 AM	8:46 AM	10:48 AM	11:10 AM	122
64	49 59.13	125 06.39	49 59.54	125 06.92	0.967	55	47	57	12:01 PM	12:14 PM	2:16 PM	2:38 PM	122
65	50 06.65	125 12.57	50 07.08	125 12.99	0.948	55	40	61	3:41 PM	3:53 PM	5:52 PM	6:11 PM	119
66	50 25.74	124 57.08	50 25.86	124 58.34	0.896	86	68	106	8:19 AM	8:31 AM	10:33 AM	10:58 AM	122
67	50 26.47	125 00.66	50 26.06	125 00.22	0.935	88	66	120	9:18 AM	9:30 AM	11:32 AM	11:56 AM	122
68	50 21.31	125 05.46	50 21.59	125 04.90	0.848	76	59	86	1:18 PM	1:31 PM	3:31 PM	3:50 PM	120
69	50 35.63	124 51.93	50 35.93	124 52.58	0.965	85	45	145	5:35 PM	5:45 PM	7:44 PM	8:04 PM	119
70	50 30.03	125 06.34	50 29.53	125 6.31	0.935	62	57	92	6:58 AM	7:11 AM	9:11 AM	9:31 AM	120
71	50 27.90	125 06.43	50 27.44	125 6.32	0.919	55	45	88	8:20 AM	8:32 AM	10:30 AM	10:50 AM	118
72	50 28.05	125 02.97	50 28.51	125 03.18	0.895	76	64	111	9:56 AM	10:07 AM	12:06 PM	12:28 PM	119
73	50 22.75	125 03.56	50 23.24	125 03.37	1.006	51	30	89	1:43 PM	1:55 PM	3:56 PM	4:17 PM	121
74	50 22.15	125 06.38	50 21.79	125 06.87	1.089	50	44	66	2:52 PM	3:05 PM	5:06 PM	5:20 PM	121
75	50 39.49	125 31.96	50 39.04	125 32.26	0.920	53	30	95	7:03 AM	7:14 AM	9:15 AM	9:34 AM	121
76	50 37.22	125 33.25	50 36.80	125 33.34	0.802	62	36	71	7:41 AM	7:51 AM	9:51 AM	10:10 AM	120
77	50 35.81	125 31.82	50 36.25	125 31.89	0.830	42	29	74	10:24 AM	10:35 AM	12:36 PM	12:52 PM	121
78	50 34.86	125 33.89	50 34.49	125 33.53	0.891	63	45	91	11:31 AM	11:42 AM	1:41 PM	1:55 PM	119
79	50 29.02	125 34.29	50 29.47	125 34.08	0.885	51	40	64	2:34 PM	2:45 PM	4:44 PM	5:02 PM	119
80	49 56.33	125 08.94	49 56.52	125 09.38	0.635	45	43	53	2:09 PM	2:18 PM	4:18 PM	4:38 PM	120

* modal depths fell outside the predetermined depth strata ranges; these sets were omitted from simulations and catch rate by depth analyses

** minimum, maximum and modal depths not recorded; depth strata determined using start and end depths