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Stock Assessment Framework For Inshore Rockfish

Cadre d'évaluation des stocks de sébastes côtiers

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Abstract

This working paper is prepared in response to a management request to provide a detailed outline of scientific monitoring and assessment programs required to improve the ability to assess the status of inshore rockfish populations and monitor changes in abundance. This working paper provides a brief background section on biology, fishery management and historic fishery dependent abundance indices for inshore rockfish in B.C., then reviews survey methods and design, trends in relative abundance, biological population parameters and considers these in making recommendations for future surveys. The surveys are grouped into

a) historic research survey programs

- hook and line jig surveys primarily in Statistical Area 12 – 19
- submersible surveys in Statistical Area 15 and 16
- longline surveys with industry on the west coast Queen Charlotte Islands and the west coast of Vancouver Island.

b) new research survey programs aimed at developing fishery independent abundance indices

- observer on the IPHC setline survey
- longline survey in Statistical Areas 12 and 13
- towed camera survey in Statistical Areas 17-19

c) research to develop methods of estimating biomass

- Bowie Seamount and Gwaii Haanas
- lower Strait of Georgia
- genetic tagging in Trincomali Channel

Discussion of research program priority may be developed in concert with the fisheries management framework. Encompassing management goals into a management framework would help to identify specific priorities for monitoring and research programs.

Résumé

Ce document de travail donne suite à une demande des gestionnaires qui souhaitaient obtenir un compte rendu détaillé des programmes de surveillance et d'évaluation scientifiques nécessaires pour améliorer la capacité d'évaluer l'état des populations de sébastes côtiers et d'en surveiller les fluctuations d'abondance. Ce document présente d'abord brièvement de l'information de base sur la biologie et la gestion des pêches de sébastes côtiers de la C.-B., ainsi que sur les indices de leur abondance dépendants des pêches utilisés par le passé. Le document aborde ensuite les méthodes et plans de relevés, ainsi que les tendances de l'abondance relative et des paramètres biologiques des populations, et les examine en vue de relevés futurs. Les relevés sont regroupés dans les trois catégories suivantes :

a) Programmes de relevés scientifiques du passé

- relevés de pêche à la ligne à la turlutte principalement effectués dans les zones statistiques 12 à 19;
- relevés en submersible dans la zone statistique 15 et 16;
- relevés à la palangre réalisés de concert avec l'industrie sur les côtes ouest des îles de la Reine-Charlotte et de l'île de Vancouver.

b) Nouveaux programmes de relevés scientifiques visant à mettre au point des indices d'abondance indépendants des pêches et évaluation, à l'aide de modèles de simulation, de l'utilité du relevé pour estimer l'abondance des sébastes et fournir des données biologiques à des fins d'évaluation des stocks

- observateur du relevé aux lignes fixes de la Commission internationale du flétan du Pacifique;
- relevé à la palangre dans les zones statistiques 12 et 13;
- relevé par caméra remorquée dans les zones statistiques 17 à 19;

c) Recherche pour mettre au point des méthodes d'estimation de la biomasse

- mont sous-marin Bowie Seamount et Gwaii Haanas;
- partie inférieure du détroit de Georgia;
- marquage génétique dans le chenal Trincomali.

Les priorités des programmes de recherche pourraient être établies de concert avec le cadre de gestion des pêches. L'intégration des objectifs de gestion dans un cadre de gestion aiderait à établir les priorités des programmes de surveillance et de recherche.

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1.0 Introduction

Research programs for inshore rockfish began in 1984 with the collection of biological data from the commercial landings in the Strait of Georgia (Cass et al. 1986). The first stock assessment of commercially exploited rockfish stocks in the Strait of Georgia was conducted in 1986 (Richards 1986). The most recent assessment work was presented in 2001 (Yamanaka and Lacko 2002) and recommended accounting for all catch (landed and released), decreasing fishing mortality, establishing areas closed to all fishing and improving stock assessment and monitoring. Subsequent to this advice a multi-disciplinary workshop on inshore rockfish was held and in December 2001, the Minister of Fisheries and Oceans announced a commitment to rebuild and protect rockfish stocks (Appendix A). Four fishery management goals were outlined as guiding principles (Appendix B):

1. significant portions of rockfish habitat closed to all fishing
2. reductions in fishing mortality to less than 2%
3. establish comprehensive catch monitoring programs
4. develop a stock assessment framework

During 2002, stakeholders were consulted, closed area candidates were identified and the first closed areas implemented. Reductions in inshore rockfish catch were implemented for both recreational and commercial fisheries and catch monitoring programs were strengthened. In 2003, research programs were expanded with new funding to address the need for stock monitoring and assessment information.

This working paper is prepared in response to a management request to provide a detailed outline of scientific monitoring and assessment programs required to improve the ability to assess the status of inshore rockfish populations and monitor changes in abundance (Appendix C). Included in the request are the following questions to be addressed for inshore rockfish in B.C.:

1. What is known about their biology and abundance?
2. What methods of monitoring are required to measure changes in relative abundance over time?
3. What research activities are required to support assessment and monitoring?

and the objectives stated for this working paper are:

1. Outline historical fishery and abundance trends of inshore rockfish.
2. Outline current biological information on inshore rockfish.
3. Provide survey methods and considerations for survey design for monitoring and assessing the relative abundance and biological parameters of inshore rockfish.
4. Provide recommendation(s) for survey and research requirements on a priority basis.

Science advice is used to develop fishing plans. Performance measures in the fishing plan, such as, quotas, fishery mortality rates, rockfish protection areas and catch monitoring standards require on-going assessment and support the development of a fisheries management framework (Appendix C). This management framework may include biological reference points, rebuilding targets and associated timeframes.

This working paper attempts to fulfill this request and provides a brief background section on biology, fishery management and historic fishery dependent abundance indices for inshore rockfish in B.C., then reviews a) historic research survey programs and updates, where possible, relative abundance indices b) new research survey programs aimed at developing fishery independent abundance indices and through simulation modeling assesses the utility of the survey to index rockfish abundance and provide biological data for assessment, and c) research to develop methods of estimating biomass in B.C.. Recommendations for survey requirements for inshore rockfish are presented in the final section of the working paper.

Discussion of research program priority may be developed in concert with the fisheries management framework. Encompassing the four management goals (Appendix C) into this management framework would help to identify specific priorities for monitoring and research programs

2.0 Background

2.1 Biology

Rockfishes are in the genus *Sebastes* and together with the thornyheads, *Sebastolobus,* comprise the Scorpaenidae family in B.C.. The rockfishes are a diverse group of fish which occupy a wide range of habitats and exhibit great diversity in behaviour and ecology. There are over 60 species of rockfishes in the N.E. Pacific (Love et al. 2002) and 35 species in B.C. (Hart 1973) of which about 28 species are caught in commercial fisheries (Table 1.)

Rockfishes are viviparous with internal fertilization of eggs and maternal nourishment of the developing embryos (Boehlert and Yoklavich 1983). Females are highly fecund and after insemination are able to store sperm for several weeks before fertilizing the eggs (Haldorson and Love 1991). Fertilized eggs develop and hatch over a period of 4-5 weeks prior to parturition, or the extrusion of larvae (Wyllie Echeverria 1987).

Larvae and juveniles of nearshore rockfish species are found in the upper mixed layer of the ocean and are dispersed by physical transport processes before settlement to nearshore rocky habitats (Loeb et al. 1995, Kokita and Omori 1999). In B.C., copper rockfish begin to settle in shallow water reef habitats in August (Haldorsen and Richards 1987). Typically, rockfishes move bathymetrically with age, with the larger, older fish occupying the deeper habitats within their depth range (Lea et al. 1999).

Yelloweye *(Sebastes ruberrimus)*, quillback *(S. maliger)*, copper *(S. caurinus)*, china *(S. nebulosus)*, tiger *(S. nigrocinctus)* and black *(S. melanops)* rockfishes, are referred to as inshore rockfish. In contrast to other B.C. rockfish, inshore rockfish are generally solitary, benthic dwellers that aggregate over rocky reef habitat subtidally to about 200 m in depth (Table 1). These characteristics vary within the group with black rockfish being the most pelagic and schooling species, copper rockfish inhabiting shallow water kelp forests and yelloweye rockfish occupying deep rugged rock habitats.

In B.C., the age at which 50% of the fish are sexually mature is about 7 years for copper rockfish, 11 for quillback rockfish and 17 to 20 for yelloweye rockfish (Yamanaka and Richards 1993, Kronlund and Yamanaka 2001). The maximum known age for rockfish in B.C. is 41 for copper, 95 for quillback and 115 for yelloweye (DFO GFBio databases). Copper rockfish and yelloweye rockfish outside of B.C. have been aged to 50 and 120 years, respectively but the quillback rockfish in B.C. is the oldest known (Love et al. 2002). Maximum known ages for china, tiger and black rockfishes are 79, 116 and 50 years, respectively.

Genetic population analyses of 2520 yelloweye rockfish at 13 microsatellite loci revealed that the 25 samples from nine sites from north western Vancouver Island to southeast Alaska, including Bowie Seamount, were derived from one panmictic population (Yamanaka et al. 2000). Allelic diversity and observed heterozygosity levels at microsatellite loci were high, indicating that effective population size was large. Low level of genetic differentiation among yelloweye rockfish is likely due to larval dispersal by ocean currents.

Similar analyses of 19 quillback rockfish samples from the Georgia Strait, Puget Sound, west coast of Vancouver Island to Prince Rupert in northern B.C. showed that 99.5% of the observed genetic variation occurred within samples (Yamanaka and Lacko 2001). Less than 0.5% of the variation was accounted for by the differentiation of B.C. and U.S. samples. There are high levels of genetic variation within quillback rockfish aggregations and very low levels of differentiation among the B.C. samples. Samples collected from Puget Sound and the U.S. portion of the Strait of Georgia were slightly differentiated from those from B.C. but also displayed high level of genetic variation.

2.2 Fishery management

The hook and line groundfish fishery involves the use of either longline, troll or handline gear to catch rockfish, lingcod, dogfish, skate, pacific cod, sole and flounder. Rockfish is caught by hook and line under the authority of a ZN license. Incidental catch of rockfish is also permitted in the salmon troll, halibut, dogfish, sablefish (seamount only) and groundfish trawl fisheries.

The Category ZN license was created in 1986. Prior to 1986, rockfish could be harvested commercially by hook and line gear by any vessel with a vessel based license allowing the fisher to catch Schedule II – Other species. In 1987, 1,935 ZN licenses were issued. The number of ZN licenses issued increased to a high of 2, 395 in 1990. ZN licenses are not vessel based licenses but personal licenses that must be designated to a fishing vessel each year upon license issuance.

In 1990, the Groundfish Hook and Line Advisory Committee (GHLAC) was established to advise DFO about issues concerning the groundfish hook and line fisheries. This committee is comprised of representatives of fishers, processors, the UFAWU, First Nations and the Province of BC.

Rockfish area licensing (inside/outside) was implemented in 1991 with 2,183 ZN licenses issued: 592 Inside (Strait of Georgia) and 1591 Outside (remainder of the coast) (Table. 2.). Industry expressed concern that continued growth of the rockfish fleet would be detrimental to both the long term health of the resource and to the economic viability of fishing operations. Limited entry was implemented in the inside fishery in 1992, resulting in 74 eligible licenses, and the outside fishery in 1993, resulting in 183 eligible licenses. Maximum vessel length restrictions were included with the limited entry program.

Management measures for rockfish have been increasingly restrictive and complex to ensure resource conservation and address marketing, incidental catch and enforcement concerns. Management measures presently in place for the Inside and/or Outside rockfish fisheries include: area TACs, trip or fishing period limits, incidental catch allowances, relinquishment of limit overages, area/time closures (including RCAs), option selection, seabird avoidance measures, at-sea monitoring and 100% dockside monitoring.

The inside rockfish fishery in 2003/04 season had 65 active licenses. Unlimited stacking of licenses is permitted for Georgia Strait resulting in a total of 26 vessels fishing in the 2003/04 season. The TAC is split evenly between all the eligible licenses (74). Fishers are able to fish their amendment any time between April 1 and March 31 every year.

The outside rockfish fishery is divided into several Options: Option A targets quillback, copper, china and tiger rockfish to serve the live rockfish market, Option B is primarily a yelloweye fishery that delivers iced fish to the fresh market, Option C lands primarily deep water species such as shortraker, rougheye and redbanded rockfish primarily on ice but some frozen at sea and Option D is a combination fishing program for vessels licensed for both halibut and outside rockfish. Fishers must select their options prior to the season commencing and are locked into that Option for the fishing season. Only one license is permitted per vessel. For 2004/05 fishing season, of the 191 eligible licenses 43 chose Option A, 16 Option B, 21 Option C and 111 Option D.

Inshore rockfish are caught in hook and line fisheries coastwide (Table 3.). Historically, the largest component of the catch has been taken by the commercial sector, however, the recreational sector has taken large portions of the catch from the Strait of Georgia management region. Catch records from the commercial fishery are the most complete with logbook reporting, dockside monitoring and onboard observer programs. Recreational fisheries are monitored in various locations on the coast through creel surveys and logbook programs.

2.3 Fishery dependent catch indices

Commercial fishery catch and effort data are available from sale slip records (DFO PacHarv3 database) between 1956 and 1995 for aggregated species of rockfish. Sale slips did not record species information for many rockfish and inshore rockfish are likely accounted for in two categories, ‘red snapper’ and ‘other rockfish’. Catch per effort indices were derived for the years 1982 to 1995 and presented in Yamanaka and Kronlund (1997). Without information on the species composition of the catch in the two rockfish catch categories, it is not possible to reconstruct relative abundance indices for individual species from these early catch data.

The ZN logbook data remain the only source of coastwide commercial catch data available to construct species specific abundance indices. ZN fishery logbook records are available from 1986 to the present in the DFO PacHarvHL database (see Hand et al. 1990, Haigh and Richards 1997 for early descriptions of the data) and have been used to construct abundance indices (Kronlund and Yamanaka 1997, Yamanaka and Kronlund 1997, Yamanaka and Lacko 2001). Updated indices are presented for quillback rockfish by gear type (handline and longline) for the inside (SG) management region (Figure 1.) and the outside (WCVI, CC, NC, and the QCI) management regions (Figure 2.). Yelloweye rockfish indices are presented for longline gear in the inside and outside management regions (Figure 3). Catch per unit of effort (CPUE) is derived from the total kilograms of fish caught per hour of fishing time for individual logbook records. Annual catch indices are determined from the mean and median CPUE by species, gear type and area. Any year, species, gear type and area with less than 50 records to determine the mean and median is not plotted. Local regression lines are then fit to the annual CPUEs where enough data exists.

Interpreting the data is difficult, due to the unknown influence of fishery management actions on the CPUE indices. Changes in fishing behaviour in response to limited entry licensing, a change to aggregated species TACs and declining annual quotas has resulted in low confidence that fishery dependant CPUE indices reflect fish abundance (Yamanaka and Lacko 2001). A decreasing proportion of the total catch removed by the ZN fishery also influences CPUE, likely leading to declines due to the non-targeting of some species by portions of the fishing fleet. In 2003, the ZN fishery accounts for about 30% of the coastwide yelloweye rockfish catch (Table 3).

3.0 Historic research surveys

3.1 Hook and line jig research surveys

Hook and line jig fishing methods were developed in 1984 by Richards and Cass to index abundance and collect biological data for the assessment of nearshore reef-fishes. Once survey methods were standardized, jig surveys were conducted throughout the Strait of Georgia management region (Figure 4.). Surveys were conducted in Statistical Area 12 in 1986 (Richards and Cass 1987), 1987 (Richards and Hand 1987), 1988 (Richards et al 1988) and 1992 (Yamanaka and Richards 1993) and in statistical areas 13 and 15 to 19, intermittently between 1984 and 2003 (Richards et al. 1985a, Richards and Cass 1985b, Richards and Cass 1987, Richards and Hand 1987, Richards et al. 1988, Hand and Richards 1989, Yamanaka and Murie 1995, King et al. 2003, Haggerty and King 2004)(Table 5.).

3.1.1 Survey methods

Research hook and line jig fishing is conducted using trolling rods and level wind reels, weights, swivels, leaders and hooks baited with 12 cm frozen herring (Richards and Cass 1985). Small vessels (5-7 m) are used as fishing platforms for two to three fishers. Once in the fishing site, baited hooks are lowered to the bottom and jigged while the vessel drifts or maintains its position by using the engine. Fishing effort is defined as the sum of the fishing times of each angler from the time that the line was in position on the bottom until a fish was hooked or the line retrieved. All catch is identified and fork lengths measured. Rockfish and lingcod are retained for biological sampling. Although fishers and vessels have changed over the years, the jig survey gear and methods have remained the same as those standardized in late 1984.

3.1.2 Survey design

In planning the initial survey for statistical area 12 in 1986, the shoreline accessible by boat within ¾ hour from Telegraph Cove was divided into a grid measuring one minute latitude by one minute longitude (Richards and Cass 1987). Ten grid squares were then randomly selected for the survey. Three depth strata, 5-40 m, 41-70 m and 71-100 m were fished within each index survey site. Survey design in the other statistical areas was similar to that in statistical area 12. A stratified random design was used to select the initial fishing blocks then these same blocks were fished in every year that surveys were conducted (see references in section 3.1).

3.1.3 Trends in relative abundance and biological population parameters

Research jig fishing surveys provide data for fishery independent catch indices as well as biological population parameters. Surveys were compared by statistical area for common sites and depths by year. Catch indices for quillback rockfish by area surveyed are presented in Table 6. For most statistical areas, surveys were not continuous over time, however, over all statistical areas catch rates do show a general declining trend (Figure.5). Median CPUE is lower in the late 1990's to early 2000's than the mid to late 1980's.

Research jig fishing catch per effort (CPUE) often have a skewed distribution and zero catches when abundance is low. In this situation, changes in the proportion of zero catches are more sensitive to changes in abundance than the mean value of the overall distribution of CPUE (Bannerot and Austin 1983). The proportion of zero catches in the statistical area 17 surveys were plotted to determine whether the decline in rockfish abundance over time is significant. For copper and quillback rockfish, the regression of the square root of the proportion of zero catches by year is linear and the slope is significantly different from zero for quillback rockfish but not for copper rockfish (Figure 7.). This suggests that there is a significant decline in abundance for quillback rockfish over the 1984 to 2003 surveys in statistical area 17.

3.1.4 Biological population parameters

As many as 39 species of fish are caught on the jig surveys (Table 4.) The most common species include quillback, copper and yellowtail (*Sebastes flavidus*) rockfishes, kelp greenling (*Hexagrammos decagrammus*) and lingcod (*Ophiodon elongatus*). Biological data, including ageing structures on all rockfish and lingcod are collected during the surveys.

Unlike the CPUE index, median catch age for quillback rockfish is similar among the years 1986 to 1988 in statistical areas 12 and 13 (Figure 6.). The decrease in median age in statistical area 12 in 1992 maybe due to the recruitment of a strong 1985 year class (Yamanaka and Richards 1993).

3.1.5 Considerations for survey design

Because of the affinity of inshore rockfish with rocky reef habitats and the small home ranges of some species, index site fishing surveys run the risk of depleting local populations within the index site. Particularly in small sites, in areas of low stock abundance and where survey fishing effort is high relative to the regular fishery. Index site surveys may not index the population overall, but only the populations within the index sites. When surveys are intermittent and relatively small in comparison with the fishery, as they have been in the past, local depletion from index site surveys is less of a concern.

The small size and number of index sites for the survey in the Strait of Georgia make extrapolations to larger areas difficult. The spatial frame for the statistical area 12 jig survey was the shorelines accessible from Telegraph Cove by ¾ hr boat ride. Extrapolations of stock status for areas outside of this spatial frame may not be appropriate if assumptions of similar habitat, fish densities and fishing pressure are not met. Even within the survey spatial frame, those areas initially chosen at random as index sites may in fact not be representative of the entire area.

The surveys have been intermittent snapshots of stock abundance and no consistent time series exists for any statistical area. Updating surveys in statistical areas 12, 13, 15 and 16 would allow a comparison of catch rate and age data from the late 1980's to the early 2000's.

3.2 Submersible surveys

A *PISCES IV* submersible survey was conducted in the Strait of Georgia in 1984 (Richards and Cass 1985) and provided part of the design for a similar *Aquarius* submersible survey conducted in 2003 (see New research surveys 4.3 for additional submersible research). The 2003 survey attempted to repeat the dive transects conducted in 1984 to estimate the change in stock abundance over the 19 years.

3.2.1 Survey methods

The surveys used manned submersibles, carrying a pilot and two scientific observers. Observers identified and counted fish on the port and starboard sides of the submersible path or dive transect. In 1984, audio was recorded during the dives and in 2003 both audio and video was recorded (Richards and Cass 1985). General site locations were drawn on nautical charts and the depth at which fish were observed were recorded for the 1984 surveys. By 2003, sophisticated technology and instrumentation was used to collect positional, as well as, data for velocity, heading, depth, temperature and salinity.

Dive transects were conducted in the *PISCES IV submersible* in 1984. Dives were started at a maximum depth of about 150 m, traveled upslope, usually perpendicular to the shoreline, and ended at 20 m. At each survey site, attempts were made to dive the exact transects that were conducted in 1984. Dives started in deeper depths in 2003 to ensure that all the depths from 1984 were surveyed. Once on the bottom, the *Aquarius* was directed from the surface to retrace the 1984 transects. For the comparison between surveys, only data from the sites and depths that were common in both years were used to estimate fish abundance by transect.

3.2.2 Survey design

Originally, the submersible survey was designed as an experiment to test the assumption that catch per unit effort is an index of stock abundance (Richards and Schnute 1986). Sites in statistical areas 15 and 16 which had been fished during the jig surveys in 1984 were again surveyed for stock abundance using the *PISCES IV s*ubmersible. Four index sites in statistical area 15 and five sites in area 16 were resurveyed in 2003 (Figure.8).

3.2.3 Trends in relative abundance

Fifty-eight species of marine fish were observed during the submersible survey in 2003 (Table 4). Boxplots of numbers of fish per transect are shown in Figure 9. for the four most commonly seen fish. Rank transformed ANCOVAs were performed on fish per transect with fishing site as co-variate with the statistic computed around the median rank. The difference in quillback rockfish counts per transect between 1984 and 2003 were highly significant. No differences were detected between years for greenstriped rockfish, yelloweye rockfish and lingcod.

For quillback rockfish the mean number of fish observed per transect was compared by 20 m depth interval between the surveys (Figure 10). Significant differences in the number of quillback rockfish are apparent in the shallowest depth intervals between 21 and 60 m.

3.2.4 Biological population parameters

Submersible surveys collect in-situ fish observations and therefore there is no opportunity to obtain biological samples for estimating population parameters. Fish lengths can be estimated through the use of parallel lasers mounted externally on the submersible. The size of quillback rockfish observed per transect by 20 m depth intervals is shown in Figure 11 for the 2003 survey. The relative proportions of the small (<20 cm) quillback rockfish are higher in the 21 – 40 m depth interval and lower in the 41 – 80 m depth interval than the 1984 survey (Richards 1986).

3.2.5 Considerations for survey design

Visual surveys allow the direct estimation of fish distribution, abundance and habitat associations. These in-situ surveys are the only means to assess inshore rockfish stock status in areas closed to fishing or in areas of low stock abundance where a fishing survey is at risk of depleting of stocks.

Submersibles are not commonly used to index abundance on an annual basis, however, the repeatability of fish counts between submersibles and years should be assessed.

3.3 Chartered industry vessel longline surveys

In 1997, the Groundfish Hook and Line Advisory Committee (GHLAC) began allocating 5% of the coastwide ZN (hook and line rockfish) total allowable catch (TAC) of rockfish to conduct research surveys. This TAC was required to cover costs of the vessel charter as well as the fish taken during the survey. In collaboration with representatives from GHLAC, yelloweye rockfish surveys were planned in the spring and initiated in September 1997.

The purpose of this survey was to determine whether differences in catch rates and biological data could be detected between areas with contrasting fishing histories (Kronlund and Yamanaka 2001) and to directly estimate Z, total mortality and infer F, fishing mortality for all the areas (Yamanaka and Lacko 2001).

To determine whether the survey could index abundance over time, catch rates from the 2002 and 2003 surveys were used to derive population parameters for a simulation model developed to assist in the planning and design of trawl surveys (Schnute and Haigh 2003).

3.3.1 Survey methods

In each year of the survey, two commercial longline vessels were chartered to conduct research fishing for yelloweye at four index sites. Standardized fishing gear used for each longline set consisted of 500 hooks spaced 8 feet apart onto halibut groundline.

14/0 circle hooks were attached to a swivel and perlon and baited with whole California squid. Each string soaked for two hours, with the start and end times of fishing recorded as the last anchor overboard and first anchor aboard, respectively.

3.3.2 Survey design

Representatives from industry were consulted to identify heavily fished and lightly fished sites off the lower west coast of the Queen Charlotte Islands and the upper west coast of Vancouver Island. Four index sites were identified, Tasu, Flamingo, Triangle and Top Knot (Figure.12.). The Tasu and Triangle sites were considered lightly fished relative to the Flamingo and Top Knot sites. Catch rates were thought to vary seasonally therefore two opposing months of the year, September and May, were chosen to conduct surveys. These seasonal surveys together would then represent an annual survey. Within these index sites, two depth strata were selected, 40–120 and 121–200 metres to target yelloweye rockfish. At least 200 fish from each depth strata per vessel and site were targeted to obtain a representative age frequency sample.

Surveys were scheduled at a five year periodicity primarily due to the amount of fish available in the research TAC but also due to the unknown level of population change that could be detected in yelloweye density and demographics. Yelloweye rockfish are slow growing and long-lived. With the error in ageing yelloweye rockfish, it could take five years before an increase in yelloweye age modes could be detected. Surveys were then conducted in September of 2002 and May of 2003.

3.3.3 Trends in relative abundance

Catch rates and biological samples from the 1997 and 1998 surveys were assessed to determine whether past fishing history could be detected in yelloweye rockfish catch rates and age compositions. Catch rates for yelloweye rockfish were lower and less variable at the heavily fished Top Knot site than the other sites (Kronlund and Yamanaka 2001). No differences among catch rate distributions could be detected for the Flamingo, Tasu and Triangle sites and the Top Knot catch rate distribution differed from the other sites. The highest catch rates peaked at a depth of 150 metres. Depths of only 100 metres were fished at the Top Knot site and may explain the differences in catch rates.

Trends in relative abundance over the four survey years and combined seasons for two annual surveys are shown in Figure 13. There are no significant differences in catch rates between seasons in each of the paired surveys so the data for fall and spring were combined to produce annual surveys in 1997/98 and 2002/03. Comparing the two annual surveys, catch rates for the annual surveys are significantly higher for the 2002/03 survey (Anova, F=6.3, p=0.0131, df=1,165). The heavily fished sites, Top Knot and Flamingo were closed to commercial hook and line fishing in 2000.

To investigate the utility of conducting surveys every five years or annually to index abundance of yelloweye rockfish over time, the 2003 catch data was used to derive population parameters (p, μ, ρ) used in a simulation model to assist in the planning and design of surveys (Schnute and Haigh 2003). The population parameters represent the proportion of zero catches, the mean of the non-zero catches and the coefficient of variation of the non-zero catches. Based on the population parameters (p, μ, ρ) computed for a single survey stratum (combined depths of the survey from 40-200 m), bootstrapped biomass estimates $\hat{B}_i$ can be generated for hypothetical surveys performed at time intervals $(i = 1 \ldots I)$. In this case, the time period was varied between 5 years (Figure 14) and annually (Figure 15.) for 20 y. The estimates $\hat{B}_i$ suggest a trend that can be summarized by the slope $\hat{b}$ after $\log_2$-transformation of $\hat{B}_i$ (Schnute et al. 2004, Section 5.6) and compared with the known slope $b = \log_2(r+1) = 0.07$, assuming an annual rate of increase $r = 0.05$ and random process error of 15% added to the biomass estimate.

For the 5 year survey period (Figure 14.), the distributions of bootstrapped slopes (panels A, B, D, E, G, and H) are fairly symmetrical about the true slope, with modest improvement by increasing the set budget K from 32 to 178. The corresponding $\hat{r} = 2^{\hat{b}} - 1$ (panels C, F, and I) suggest that $r \pm 20\%$ would be achieved 56%, 63%, and 66% of the time at $K = 32$, 89, and 178 sets, respectively. For an annual survey period (Figure 15.), $r \pm 20\%$ would be achieved 84%, 89%, and 90% of the time at $K = 32$, 89, and 178 sets, respectively.

3.3.4 Biological population parameters

Fourty-four marine species of fish were caught on the longline surveys (Table 4). Biological samples were collected for rockfish species caught on the surveys and are available for analyses. Estimates of Z and F were derived from catch curve analysis (Ricker 1975) and age data collected at Bowie Seamount (Z) and the 1997 and 1998 surveys (Yamanaka and Lacko 2001). Fishing mortality at the heavily fished sites was greater than that estimated from the lightly fished sites. Age data from the 2002 and 2003 surveys are not yet available.

3.3.5 Considerations for survey design

Using the catch rate data from the longline surveys, other survey designs could be further explored with the simulation model (Schnute and Haigh 2003). Set allocation between two depth strata could be investigated, as well as, two and three year periods between surveys.

The longline index site surveys for the southern QCI and northern WCVI, conducted for yelloweye rockfish were specifically designed to detect expected extremes in fishing mortality through catch rate and biological population parameters. This survey design is useful to assess stock status and could be used in other management areas to refine stock assessments on a smaller spatial scale. The selection of the index sites is critical to this survey design. Consensus on the heavily and lightly fished sites may not be easily achieved on a smaller spatial scale than these first experimental surveys.

4.0 New research surveys conducted in 2003

4.1 IPHC chartered industry vessel longline survey

The International Pacific Halibut Commission (IPHC) has conducted a standardized stock assessment (SSA) survey for Pacific halibut (*Hippoglossus stenolepis*) since 1963. This survey provides distribution, biomass, age, growth and maturity data that are used in the annual assessment of Pacific halibut.

In 2003, the Department of Fisheries and Oceans, Pacific Halibut Management Association and the Canadian Sablefish Association, jointly funded a third technician on the Canadian portion of the IPHC SSA survey (Yamanaka et al. 2004). The third technician determined species composition of the total catch and collected biological samples from the rockfish and sablefish catch. The purpose of collecting data on the non-halibut catch during the IPHC survey was to determine whether 1.) catch rate and biological data could be used to derive a relative abundance index for the rockfish caught during the survey and 2.) sufficient biological data could be collected for the assessment of yelloweye rockfish.

4.1.1 Survey methods

Two industry vessels were chartered to fish the 170 IPHC SSA survey stations located in B.C. waters (Yamanaka et al. 2004). Fixed or 'conventional' fishing gear was used and standardized fishing operations were maintained, as required in the IPHC Charter Bid Specifications (http://www.iphc.washington.edu). In 2003, each set of fishing gear consisted of eight skates of halibut groundline. Each skate of groundline measured 549 m and contained approximately 100, size 16/0 circle hooks spaced 5.5 m apart. The hooks were baited with frozen chum salmon (*Onchoryncus keta*) cut into 0.11 – 0.15 kg pieces. Fishing gear was left to soak for a minimum of 5 hours and maximum of 24 hours.

4.1.2 Survey Design

The SSA survey consists of a regular distribution of stations from the southern Oregon border to the north Bering Sea including the Aleutian Islands. The survey is divided into ten IPHC regulatory areas, however, all areas have not been surveyed annually. In B.C., annual surveys were reinstated in 1993 after a seven year gap.

The fixed-stations on the SSA survey are distributed on a 10 nmi by 10 nmi grid and one set of longline gear is deployed at each of the 170 Canadian stations (Figure. 16.). SSA surveys previous to 2003, with the exception of 1993 and 1995, did not identify the total non-halibut catch to species.

4.1.3 Trends in relative abundance

To assess whether a relative abundance index could be constructed from the IPHC SSA survey over time, the 2003 catch data was used to derive population parameters (p, μ, ρ) (Schnute and Haigh 2003) (Table 8) for a simulation model used in survey planning and design. Quillback, redbanded and yelloweye rockfish densities (kg/km^2) were calculated using catch rate data and an estimate of area swept by the gear based on the length, and an assumed effective width of a skate of longline gear (Yamanaka et al. 2004). Model simulations were conducted under fixed survey budgets (number of sets) identical to the IPHC survey with an assumed population growth rate of 5% and random process errors of 15% added to the biomass estimates. Model outputs were examined qualitatively to investigate whether the surveys could track trends in relative abundance over time for quillback, redbanded and yelloweye rockfishes (Figure 17.). The total model coefficients of variation (CV_t), are lowest for yelloweye rockfish as catch rates were relatively high and less variable than the other rockfish species encountered on the survey. Results indicate that, at worst reliable trends in population biomass will be detected two times out of three and at best may yield reliable trends in abundance after about 7 years of annual IPHC surveys.

Species specific catch rates and associated variances were calculated for all rockfish and sablefish caught during the 2003, area 2B survey (Table.7.). Relative species proportions derived from this data could be used to reconstruct a relative rockfish abundance index for previous IPHC SSA surveys in area 2B. There are no data to validate the assumption of fixed species proportions over time and these data are not presented.

4.1.4 Biological population parameters

A total of 37 fish species were encountered on the 2003 survey and 1,967 rockfish including 835 yelloweye rockfish were sampled for ageing structures (Yamanaka et al. 2004, Table 4.). Although ages are not yet available for analysis, previous work indicates that at least 200 ages are required to reliably detect modes in age distributions for yelloweye rockfish. Biological data collections on the IPHC survey are probably sufficient to estimate total mortality (Z) and infer fishing mortality (F) for the yelloweye population over the whole of the outside management region.

4.1.5 Considerations for survey design

DFO has no input to the IPHC SSA survey design. The integration of the hook-by-hook species identification into the IPHC survey design would create an opportunity for sampling of catch at dockside. Species of interest for biological sampling could be marked by set and set aside for easy access when offloading. The collection of complete species composition data in other jurisdictions may shed light on the relative stock status of rockfish in B.C. Species composition data from the IPHC SSA survey, together with fishery data from onboard observers, provided that the observer data is representative of the fishery as a whole, may provide estimates of the overall rockfish catch in the halibut fishery.

4.2 Longline survey in statistical areas 12 and 13

This survey was initiated, in August of 2003, to provide a fishery independent index of inshore rockfish abundance and provide biological data for the assessment of population parameters (Lochead and Yamanaka *in review*). Similar to the IPHC survey, inshore rockfish catch rates were used to derive population parameters as input data to a simulation model (Schnute and Haigh 2003). The simulation model was then used to examine the number of sets required in the survey to reliably index quillback and yelloweye rockfish.

4.2.1 Survey methods

A longline survey was conducted using the *CCGS Neocaligus* in statistical areas 12 and 13 (Figure. 18.). ‘Snap’ gear was used to be consistent with the commercial fishery. Each set of longline gear consisted of two ‘skates’ of groundline, each 8.73 mm in diameter, measuring 548.6 m in length and weighing 29.48 kg. Skates contained approximately 112, size 13/0, circle hooks spaced 3.66 m apart. Perlon gangions measuring 0.61 m were attached to the hook and snap by swivels. Hooks were baited with thawed Argentinean squid, approximately 15 cm long and cut into eighths. Each longline set was left to soak for 2 hours, timed from the last anchor overboard to the first anchor aboard.

4.2.2 Survey design

A depth stratified, random design was applied in the survey. The majority of the inside ZN fishery fishing activity in the Strait of Georgia management region takes place within statistical areas 12 and 13 therefore the survey sampling frame encompassed this whole area. Fishery logbook data was then used to determine the extent of the fishery and delineated the upper extent of the survey in the mainland inlets. A two kilometre by two kilometre grid was drawn over the remaining areas and 100 grid blocks within the 40 to 100 metre depth interval were randomly selected for fishing. One fishing set was conducted in each block and targeted for either the shallow (40 – 70 m) or the deep (71-100 m) strata so that approximately half the blocks were fished shallow and the other half deep. The location of the fishing set within the randomly selected block was determined by depth strata and bottom type. Hard bottom substrates were targeted in the survey.

4.2.3 Trends in relative abundance

Between August 17 and September 6, 2003, longline sets were made in 80 random blocks (Lochead and Yamanaka *in review*). Mean catch rates and CVs for inshore rockfish species are presented in Table 7. Rockfish densities (kg/km2) were calculated using the species specific catch rates, skate length (834 m), and an assumed effective skate width (9.44 m). Catch data from the survey sets were used to derive population parameters (p, μ, ρ) (Schnute and Haigh 2003) (Table 8.). A single stratum of Areas 12 and 13 combined over depths of 40 to 100 m was used with the population parameters (p, μ, ρ) to bootstrap biomass estimates $\hat{B}_i$ generated for hypothetical surveys performed annually for 20 years. The estimates $\hat{B}_i$ suggest a trend that can be summarised by the slope $\hat{b}$ after $\log_2$-transformation of $\hat{B}_i$ (Schnute et al. 2004, Section 5.6) and compared with the known slope $b = \log_2(r+1) = 0.07$, assuming an annual rate of increase $r = 0.05$ and random process error of 15% added to the biomass estimate.

The distributions of bootstrapped slopes for quillback and yelloweye rockfishes (Figure 18 and 19, left and middle panels) are fairly symmetrical about the true slope, with modest improvement by increasing the set budget K from 80 to 120. The corresponding $\hat{r} = 2^{\hat{b}} - 1$ (panels C, F, I) suggest that $r \pm 20\%$ would be achieved 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.

4.2.4 Biological population parameters

Thirty species of fish were encountered on the survey and 5555 biological samples, including 805 rockfish age samples were collected (Lochead and Yamanaka *in review,* Table 4.). Ages are not yet available for analysis but there are sufficient samples to derive total mortality estimates (Z) and infer fishing mortality (F) for quillback and yelloweye rockfishes in statistical areas 12 and 13.

4.2.5 Considerations for survey design

The design of the survey could be expanded to deeper depths which may improve the index for yelloweye rockfish. The calibration of this survey with the historic jig survey in statistical areas 12 and 13 should be done by conducting both surveys in the same year. An assessment of the between year variability of the depth stratified random block longline survey should also be conducted by surveying the same statistical area for two to three years, selecting new random sites to fish in each year.

4.3 Towed camera survey

An underwater video camera was deployed from the *CCGS Neocaligus,* in June of 2003 and used to survey shallow (< 65m) water reef fishes and their habitats on the Vancouver Island side of the lower Strait of Georgia (Figure. 20.). This survey was conducted to develop in-situ visual monitoring methods and assess the feasibility of this technology for inshore rockfish assessment.

4.3.1 Survey methods

The towed camera platforms used for this survey comprises a metal frame to which are attached a video camera, lighting modules, instrumentation for recording temperature and depth and a pair of parallel lasers for estimating measurements (Martin and Yamanaka *in review*). Video is recorded on the research vessel along with synoptic GPS data and the streaming data from the temperature and depth sensors. Video is reviewed for fish and invertebrate selection, as well as classification of habitat.

Transect width is determined by using calibration values obtained empirically with a measured grid in a large seawater tank to enable the measured separation of the laser dots on the video screen to be translated into a maximum field of view. The measurement of the laser dots, taken every 30 seconds during the video review, allow a mean field-of-view to be estimated for each transect conducted. Transect length is estimated by plotting the GPS data in ESRI ArcMap™, and measuring the portions of the track composed of each primary substrate type. Total transect length is the sum of the measured lengths of all segments of varying primary substrate types.

4.3.2 Survey design

The survey used a depth-stratified random design, where 20, one kilometre by one kilometre survey blocks were selected at random from two depth strata of 10-50 m and 50-100 m. Transect locations were chosen within those grids to target rock substrates with vertical relief in the southern Strait of Georgia and ranged from Newcastle Island south to Darcy Island.

4.3.3 Trends in relative abundance

The video survey was conducted from June 4th – 8th, 2003 (Martin and Yamanaka *in review*) (Figure 21). Habitat specific densities and coefficients of variation (CV) for fish enumerated over the survey are shown in Table 9. The highest abundance of quillback, copper and tiger rockfishes is over the bedrock and boulder habitats (Figure 22). Mud, sand and gravel substrate types had very low rockfish abundance but other species were seen in abundance in these habitats (Figure 23).

4.3.4 Biological population parameters

There were no biological samples, other than estimated lengths, collected during the survey. Twenty species of marine fish were observed during the camera survey (Table 4.).

4.3.5 Considerations for survey design

As with all visual surveys, it is difficult to count fish when they are cryptic and closely associated with rugged rock habitats. Some rockfish may be obscured from view and go undetected and therefore absolute abundance would be underestimated. However, cryptic rockfish and shy behavior would remain constant over time and will not affect a relative abundance estimate.

To mitigate visual impediments, the camera surveys could be conducted during the late fall or winter when kelp and plankton blooms are at a minimum. Surveys could also be confined to hard bottom, high relief and complex substrates such as bedrock and boulder habitats for monitoring stock abundance of inshore rockfish.

The towed camera would be able to survey deeper depths and thus more area with a longer cable and possibly some design modifications. Copper rockfish and other shallow water reef fish such as kelp greenling are surveyed throughout their depth range with the towed camera depths to <60 m but quillback rockfish are not.

The towed camera is a useful tool, in the shallow depths, primarily to conduct frequent surveys in areas closed to fishing and where fishing surveys may deplete existing stocks. Where jig surveys in the shallow water are being conducted, calibration surveys could be done with the towed camera to enable a comparison between survey methods and abundance indices.

5.0 Estimating biomass

5.1 Bowie Seamount and Gwaii Haanas

This program is designed to develop non-intrusive stock monitoring methods to estimate habitat specific densities of rockfish at Bowie Seamount and on the southwest coast of the Queen Charlotte Islands and to compare this abundance index with traditional fishery dependent indices. Specific objectives are to:

1. Use 'line' and 'belt' transect methods to visually estimate rockfish densities by habitat type then apply these densities to their respective habitat area to estimate total rockfish biomass.
2. Compare the visual index with a traditional fishing index to determine the relationship between stock abundance and catch per unit of effort (CPUE) and estimate the catchability of the longline gear.

5.1.1 Survey methods

The *Delta* submersible was used to conduct 25 minute transects that began at depth and traversed upslope. Two external video cameras were mounted on the *Delta,* one directed forward and the other directed to starboard. Both cameras were mounted with parallel lasers, set a fixed distance, to enable the measurement of fish in the field of view. Fish were counted visually by looking out the starboard side ports of the submersible. When fish were encountered they were identified to species and an estimate of their distance from the submersible was recorded on the videotapes. Two transects were conducted on each dive with a 10 minute break between transects to relocate to the next starting position.

Fish densities were estimated using 'line' and 'strip' transect methods (Buckland et al. 1993, O'Connell and Carlile 1993, O'Connell et al. 1998). Videotapes were reviewed for fish counts and distances, as well as, habitat types for all transects. In line transects, the forward looking video camera was used to 'guard' the transect line and allow fish that were displaced by the movement of the submersible to be counted. The forward camera was also used to demark a strip transect, over relatively flat substrates (Steiner et al. 1983, Jagielo et al. 2003).

A multibeam acoustic survey was conducted at Bowie Seamount on the *NOAA Rainer* after the submersible survey. Bathymetry data was made available through the Canadian Hydrographic service (CHS) however backscatter data is unavailable for habitat analysis.

5.1.2 Survey design

The seamount was divided into three sections and three depth intervals (<100 m, 100-200 m and 201-300 m) and transect locations were selected at random within each of the 9 grid blocks. A similar design was used off the lower west side of the Queen Charlotte Islands.

5.1.3 Biomass estimation

Biomass estimates are to be estimated by applying the fish densities by habitat type to the size of the respective habitats at both locations. Habitat maps would enhance the development of the biomass estimate. This work is ongoing.

5.1.4 Considerations for survey design

As more bathymetric data is collected in these areas, survey designs could be depth and possibly habitat stratified with randomly chosen dive start points.

5.2 Lower Strait of Georgia

In addition to resurveying sites visited in 1984, the *Aquarius* submersible was used in 2003 to develop methods for estimating biomass within the Strait of Georgia. With similar methods to the habitat based biomass estimate in the seamount study, habitat specific densities of fish were determined from submersible observations and by using habitat maps, fish biomass may be estimated.

5.2.1 Survey methods

The *Aquarius* submersible was used to conduct transects up-slope from a predetermined start point. Two observers dictated notes into microphones, with the audio track being recorded to a digital video deck which recorded the video from either the port or starboard side of the submersible. Each observer attempted to make observations from the port or starboard sides, but the large field of view and movement of fish, led to both sets of observations being pooled with to ensure that each fish was recorded only once. Data describing species (or lowest possible taxonomic identification), size (cm), distance from the centerline (m) and side (port or starboard) was recorded on the audiotape. Habitat was classified according to substrate type, relief, complexity, biocover type and biocover thickness using a coding system outlined in Pacunski and Palsson (2001).

During dives, the position of the vehicle was tracked from the surface ship using an acoustic beacon system and recorded using WinFog™ Integrated Navigation System software. Spatial tracking of the vehicle was interpolated using velocity and heading data from the submersible-mounted Doppler Velocity Logger (RDI Inc.). The interpolated track of the submersible dive is plotted in ESRI ArcMap™ and each primary substrate type colour-coded. The length of the portions of each transect with a given primary substrate type is measured in ArcMap, and the total lengths of each summed to give total length for each transect.

Counts of each species per primary substrate type per transect are then divided by the length of that substrate type over the transect to yield a number of fish per linear distance over each type of primary substrate. This enabled mean relative densities and CVs to be calculated for each species and primary substrate type over all transects of the survey.

5.2.2 Survey design

Data from marine geophysical surveys such as multibeam bathymetry, side scan sonar, seismic profiles, and bottom grabs were used to construct habitat maps in two areas of the southern Strait of Georgia, Gabriola Pass (Figure 25 and 26) and Active Pass. These habitat maps were divided into 500 m by 500 m blocks. Blocks were stratified by habitat type and survey blocks were selected at random from the bedrock, bedrock scarp and till/glacial marine sediment habitat types in proportion to the number of blocks of each habitat type. Sand and mud blocks were not surveyed.

5.2.3 Biomass estimation

Habitat-specific densities of fish were estimated initially as numbers of fish per linear meter of transect length (Table 10.). Quillback rockfish were seen in the highest densities over the bedrock and boulder habitats (Figure 24). Habitat maps are being revised with new seismic data and visual data collected during this survey.

Using line transect techniques, to estimate fish density over the submersible transects, fish observations and distances of each fish from the transect line are used to construct a probability of detection function for each species and habitat type (Buckland *et al* 1993). The detection function for quillback rockfish using preliminary data from the 2003 survey is shown in Figure 27. When the revised maps are available from the Pacific Geosciences Center, these habitat-dependant estimates of density can be used to estimate the biomass of these species over the area covered by the habitat map, in the southern Strait of Georgia.

5.2.4 Considerations for survey design

As more physical data is compiled and refined for other areas within the Strait of Georgia and coastwide, estimates of rockfish specific densities and biomass can be extrapolated using a similar survey design.

5.3 Genetic tagging

In cooperation with Simon Fraser University (SFU, Dr. S. Cox) and the DFO genetics lab (Kristi Miller), a pilot study to develop methods for tagging rockfish was initiated in 2003. The concept of genetic tagging is to obtain a tissue sample from a rockfish at depth, without having to retrieve it to the surface, and through microsatellite DNA analyses of the retrieved tissue, identify (tag) individual rockfish. Through repeated sampling, matches of individual rockfish would constitute tag returns. Traditional tag/recovery analyses for the estimation of biomass, movement rates, catchability and fishing mortality rates could then be applied to rockfish.

5.3.1 Survey methods

In 2003, methods to develop a non-lethal sampling hook, and the microsatellite DNA genetic analysis to screen species, quillback and copper rockfishes, and then 'fingerprint' individual rockfish were investigated. Prototype sampling hooks developed in Australia (Rik Buckworth) were modified and tested on quillback rockfish in a Rockfish Conservation Area (RCA) closed to fishing, in Trincomali Channel, between Wallace and Galiano Island in the southern Strait of Georgia. Successful species screens and the identification of individual rockfish were developed and 373 samples were analyzed. Six microsatellite loci were run on 2 gels for the analysis but it may be possible to identify individual rockfish with only 4 loci.

5.3.2 Survey design

Genetagging within the Trincomali Channel RCA will be conducted on a larger scale in 2004. Habitat maps developed by the Pacific Geoscience Centre will be used to allocate genetags by habitat type to investigate the movement of rockfish among habitats and estimate biomass.

5.3.3 Considerations for future surveys

Out of the 373 samples analysed, 58% were quillback rockfish, 30% were copper rockfish, 1% were yelloweye rockfish and 1% were other species (Kristi Miller *pers comm*). All blind tests for quillback recaptures, mixed rockfish species and invertebrates were correctly identified and one fish was recaptured on a different sampling date demonstrating the potential for this tagging technique.

This tagging technique could be used to estimate biomass in other areas for quillback rockfish and if modified for longline gear could be used to tag deeper water rockfishes. Tagging rockfish within the RCA allows the analysis of rockfish movement rates and will provide some guidance for estimating a minimum size of RCAs for the protection of rockfish.

6.0 Recommendations for survey requirements

Surveys provide data that are used to monitor and assess fish populations. Traditional abundance indices based on commercial fishery data have been uninformative due to fisher behaviour tied to changes in management and economics. Surveys to monitor fish populations ideally were started prior to fishery exploitation and are conducted at some useful periodicity, in perpetuity. Under the Species at Risk Act, surveys would also monitor all species, not only those of commercial value. Long-term monitoring surveys will provide data that is sufficient to determine trends in population abundance and estimate biomass for marine fish species. This document provides a review of species specific surveys for inshore rockfish. What is now required is an optimization of the monitoring goals for inshore rockfish within an overall strategic approach to groundfish surveys in all habitats coastwide.

Recommend that inshore rockfish monitoring goals be addressed within a strategic plan for groundfish surveys. This would involve the development of a survey strategy to monitor all hard bottom habitats coastwide between the depths of 5 and 200 meters.

Aside from this strategic groundfish survey plan, the following are recommended to direct survey activity in the short term.

6.1 Monitoring surveys

6.1.1 Index site surveys

1. ***Recommend*** the integration of index site surveys into surveys with a depth/habitat stratified random design.

a) The jig survey in statistical area 12 and 13 could be conducted to update the current catch rate indices to determine the trend in stock abundance from the late 1980's to the present. In the same year, longline surveys could be conducted so that the two indices may be calibrated to allow the continued use of the index after the transition to the new survey design.

b) For other jig surveys in statistical areas where stock abundance is low, camera surveys could be conducted in the same manner as a) with a calibration and transition period to integrate the new survey design.

c) The yelloweye longline index site survey design could be rotated through the various management regions, in the short term, to assess stock status on a smaller spatial scale than the whole of the outside fishery area. Over a period of 5 years, all management areas could be assessed in this way. Where it is not possible to identify heavily and lightly fished areas within a management region, depth/habitat stratified random surveys could be conducted. In the long term, in the same manner as above, with a calibration and transition period, the new survey design could be integrated.

6.1.2 IPHC survey

1. ***Recommend*** the continued collection of complete species composition and biological data for inshore rockfish.
2. ***Recommend*** the ageing of yelloweye rockfish from the surveys.

6.1.3 Visual surveys

1. ***Recommend*** the reassessment of the towed camera survey techniques during the winter when plankton blooms will not interfere with visabilty.
2. ***Recommend*** the towed camera system be reassessed in deeper water using a longer cable, if available.
3. ***Recommend*** the calibration of visual towed camera surveys with shallow water jig surveys.
3. ***Recommend*** the development of visual surveys for stock monitoring within RCAs where stock abundance is low and where fishing surveys risk further stock decline.

6.2 Biomass surveys

1. ***Recommend*** developing methods to estimate habitat specific densities of rockfish and extrapolating biomass based on habitat.
2. ***Recommend*** the use of submersibles for similar work on biomass estimation and catchability in other areas.
3. ***Recommend*** the use of genetagging methods for biomass estimation, movement rate information and the direct assessment of fishing mortality.
4. ***Recommend*** the development of genetagging methods for the monitoring and assessment of RCAs.

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Table 1. Rockfish caught in commercial fisheries in B.C. by depth and type of fishery, hook and line (H), trawl (T) or both (O). Inshore rockfish species are denoted by an asterisk.

SEBASTES				DEPTH IN METRES								
COMMON			10	15	20	25	30	35	40	45	50	55
NAMES	0	50	0	0	0	0	0	0	0	0	0	0
copper*	H	O										
black*	H	O	O									
china*	H	O	O	T								
quillback*		O	O									
tiger*		H	H	H	T	T						
yelloweye*		H	H	O	O							
widow		H	O	O	O							
vermilion		H	H	H	T	T	T					
greenstriped		H	H	O	O	T						
yellowtail			O	O	O							
dusky			H	O	T							
canary			O	O	T							
bocaccio			O	O	O	T						
silvergray			T	O	O	O						
harlequin			T	O	O	O						
blue				T	T	T						
shortbelly				T	T	T						
chilipepper				T	T							
redstripe					O	O	O					
yellowmouth					O	O	O					
redbanded					H	O	O					
rosethorn					H	O	O					
sharpchin					T	T						
darkblotched						T	T					
splitnose						T	T					
POP						O	O	O				
shortraker					H	O	O	O	O	T		
rougheye						H	O	O	T	T	T	T

Table 2. British Columbia fishery management regions and corresponding statistical areas.

Area	Management region	statistical area
Inside	Strait of Georgia (SG)	12 - 20, 28 and 29
Outside	west coast Vancouver Island (WCVI) central coast (CC) north coast (NC) Queen Charlotte Islands (QCI)	21 - 27, 11, 121 - 127 and 111 6 - 10, 106 - 110 3 - 5, 103 - 105 1, 2, 101 and 102

Table. 3. Estimates of coastwide catch of yelloweye rockfish and aggregates 1 & 2 (quillback, copper, china and tiger rockfishes) by fishing year and fishery.

		2001/02 fishing season		2002/03 fishing season		2003/04 fishing season	
Licence Category	Description of Fishery	Yelloweye (t)	Aggs 1&2 (t)	Yelloweye (t)	Aggs 1&2 (t)	Yelloweye (t)	Aggs 1&2 (t)
L	Halibut	239.4	12.7	172.4	16.9	156.0	16.2
ZN	H&L rockfish	245.4	315.8	84.6[a]	141.7[a]	67.7	134.0
T	Groundfish trawl	6.9	1.6	6.2	2	4.8	3.9
C	Lingcod & dogfish	0.5	0.1	0	0.1	1.8	0
K	Sablefish	n/a	n/a	n/a	n/a	n/a	n/a
S	Shrimp trawl	n/a	n/a	n/a	n/a	n/a	n/a
W	Prawn trap[b]	n/a	n/a	n/a	1	n/a	n/a
A	Salmon troll	0.6	0.3	0.7	0.2	0.05	0.3
REC	Individual fishers[c]	14.6	46.5	10.3	49.5	4.9	18.1
	Lodges[d]	0.1	0.0	0.2	0.4	0.0	0.2
	Guides	n/a	n/a	n/a	n/a	n/a	n/a
FN	Allocations	n/a	n/a	n/a	n/a	n/a	n/a
	Food Fish	n/a	n/a	n/a	n/a	n/a	n/a
TOTAL Landed Catch		507.5	377.0	274.4	211.8	235.3	172.7

[a] Option I fishery extended fishing season
[b] estimate (t) by conversion from pieces using average weight of 0.44 lbs
[c] estimate based on encounters which includes landed catch and releases, estimated weight (t) converted from pieces using average weight of 1.54 lbs
[d] estimated weight (t) converted from pieces using average weight of 1.54 lbs

Table 4. Summary of taxon encountered during inshore rockfish surveys. An ‘x’ indicates that the taxon was observed.

Common Name	**Taxonomic Name**	**Area 12/13 Longline 2003**	**IPHC SSA 2003**	**YE Charters 1997 - 98 2002 - 03**	**Jig Surveys 85,86,87,88 92,93,98,03**	**Subermisble Survey 2003**	**Towed Camera 2003**
ANEMONE	*ACTINIARIA*	x	x	x		x	x
ANTHOZOA	*ANTHOZOA*	x	x	x			
ARROWTOOTH FLOUNDER	*ATHERESTHES STOMIAS*	x	x	x	x		
BASKET STARS	*EURYALAE*	x	x				
BIG SKATE	*RAJA BINOCULATA*	x	x	x			
BIVALVE MOLLUSCS	*BIVALVIA*		x			x	
BLACKFIN POACHER	*BATHYAGONUS NIGRIPINNIS*					x	
BLACKFIN SCULPIN	*MALACOCOTTUS KINKAIDI*					x	
BLACK ROCKFISH	*SEBASTES MELANOPS*			x	x		
BLUESPOTTED POACHER	*XENERETMUS TRICANTHUS*					x	
BLOOD STAR	*HENRICIA SPP.*					x	x
BLUE SHARK	*PRIONACE GLAUCA*		x	x			
BOCACCIO	*SEBASTES PAUCISPINIS*		x	x		x	
BROWN IRISH LORD	*HEMILEPIDOTUS SPINOSUS*	x			x		
BUFFALO SCULPIN	*ENOPHRYS BISON*				x		
BURROWING SEA CUCUMBER	*LEPTOSYNAPTA CLARKI*						x
BUTTER SOLE	*ISOPSETTA ISOLEPIS*		x		x		
CABEZON	*SCORPAENICHTHYS MARMORATUS*	x			x		
CANARY ROCKFISH	*SEBASTES PINNIGER*	x	x	x	x	x	
CANCER CRABS	*CANCERIDAE*					x	x
CERIANTHID ANEMONES	*CERIANTHARIA*					x	
CEPHALOPODS	*CEPHALOPODA*					x	
CHINA ROCKFISH	*SEBASTES NEBULOSUS*	x	x	x			
CHINOOK SALMON	*ONCORHYNCHUS TSHAWYTSCHA*				x		
CODFISHES	*GADIDAE*					x	
COELENTERATES	*COELENTERATES*	x	x	x			
COHO SALMON	*ONCORHYNCHUS KISUTCH*		x		x		
COOKIE STAR	CERAMASTER PATAGONICUS					x	
COPPER ROCKFISH	*SEBASTES CAURINUS*	x			x	x	x
CUSHION STAR	*PTERASTER TESSELATUS*					x	x
DARKBLOTCHED ROCKFISH	*SEBASTES CRAMERI*			x			
DOVER SOLE	*MICROSTOMUS PACIFICUS*		x	x		x	x
DUNGEONESS CRAB	*CANCER MAGISTER*					x	x
DUSKY ROCKFISH	*SEBASTES CILIATUS*			x	x		
EELPOUTS	*ZOOARCIDAE*					x	x
ENGLISH SOLE	*PLEURONECTES VETULUS*					x	x
FISH-EATING STAR	*STYLASTERIAS FORRERI*		x				
FLATFISHES	*PLEURONECTIFORMES*					x	x
FLATHEAD SOLE	*HIPPOGLOSSOIDES ELASSODON*		x		x	x	
OREGON TRITON	*FUSITRITON OREGONENSIS*	x		x			

Table 4 continued

Common Name	Taxonomic Name	Area 12/13 Longline 2003	IPHC SSA 2003	YE Charters 1997 - 98 2002 - 03	Jig Surveys 85,86,87,88 92,93,98,03	Submermisble Survey 2003	Towed Camera 2003
GASTROPODS	*GASTROPODA*			x			
GIANT PACIFIC OCTOPUS	*ENTEROCTOPUS DOFLEINI*					x	x
GIANT RED SEA CUCUMBER	*PARASTICHOPUS CALIFORNICUS*					x	x
GOBIES	*GOBIIDAE*					x	
GORGONIAN CORALS	*GORGONACEA*			x		x	
GREAT SCULPIN	*MYOXOCEPHALUS POLYACANTHOCEPHALUS*	x			x		
GREENLINGS	*HEXAGRAMMOS SP.*			x		x	x
GREENSTRIPED ROCKFISH	*SEBASTES ELONGATUS*	x		x	x	x	
GRENADIERS	*MACROURIDAE*					x	
GUNNELS	*PHOLIDAE*					x	x
HAKES AND BURBOTS	*LOTIDAE*					x	
HARBOUR SEAL	*PHOCA VITULINA*					x	
HARLEQUIN ROCKFISH	*SEBASTES VARIEGATUS*	x		x	x		
HERMIT CRAB	*PAGURIDAE*					x	
HYDROID	*HYDROZOA*		x				
JACK MACKEREL	*TRACHURUS SYMMETRICUS*			x			
JAPANESE ANCHOVY	*ENGRAULIS JAPONICUS*						x
KELP GREENLING	*HEXAGRAMMOS DECAGRAMMUS*	x		x	x	x	x
KELP POACHER	*AGONOMALUS MOZINOI*					x	
LINGCOD	*OPHIODON ELONGATUS*	x	x	x	x	x	x
LITHODES CRAB	*LITHODES*		x			x	
LONGNOSE SKATE	*RAJA RHINA*	x	x	x		x	
METRIDIUM	*METRIDIUM*					x	x
MOLLUSCS	*MOLLUSCA*			x			
MYSIDA	*MYSIDA*						x
OCTOPUS	*OCTOPODA*		x	x		x	
OPHIUROIDS	*OPHIUROIDEA*	x	x	x			
PACIFIC COD	*GADUS MACROCEPHALUS*	x	x	x	x	x	
PACIFIC GEODUCK	*PANOPEA ABRUPTA*					x	
PACIFIC HAKE	*MERLUCCIUS PRODUCTUS*					x	
PACIFIC HALIBUT	*HIPPOGLOSSUS STENOLEPIS*	x	x	x		x	
PACIFIC HERRING	*CLUPEA PALLASI*					x	
PACIFIC LAMPREY	*LAMPETRA TRIDENTATA*					x	
PACIFIC OCEAN PERCH	*SEBASTES ALUTUS*			x			
PACIFIC SANDDAB	*CITHARICHTHYS SORDIDUS*	x	x		x	x	
PACIFIC SLEEPER SHARK	*SOMNIOSUS PACIFICUS*		x	x			
PACIFIC STAGHORN SCULPIN	*LEPTOCOTTUS ARMATUS*	x			x		
PAINTED GREENLING	*OXYLEBIUS PICTUS*					x	
PALAEOTAXODONTA	*PALAEOTAXODONTA*						x
PARAGORGIA PACIFICA CORAL	*PARAGORGIA PACIFICA*		x				

Table 4 continued

Common Name	Taxonomic Name	Area 12/13 Longline 2003	IPHC SSA 2003	YE Charters 1997 - 98 2002 - 03	Jig Surveys 85,86,87,88 92,93,98,03	Subermisble Survey 2003	Towed Camera 2003
PETRALE SOLE	*EOPSETTA JORDANI*		x	x			
PINK SHORT-SPINE STAR	*PISASTER BREVISPINUS*	x					
PLAINFIN MIDSHIPMAN	*PORICHTHYS NOTATUS*					x	
POACHERS	*AGONIDAE*					x	x
PRAWNS	*PANDALUS PLATYCEROS*					x	x
PRICKLEBACKS	*STICHAEIDAE*					x	
PSOLIDAE	*PSOLIDAE*						x
PUGET SOUND ROCKFISH	*SEBASTES EMPHAEUS*						x
PURPLE SEA URCHINS	*STRONGYLOCENTROTUS PURPURATUS*					x	x
QUILLBACK ROCKFISH	*SEBASTES MALIGER*	x	x	x	x	x	x
RATFISHES	*CHIMAERIDAE*					x	
REDBANDED ROCKFISH	*SEBASTES BABCOCKI*		x	x			
RED IRISH LORD	*HEMILEPIDOTUS HEMILEPIDOTUS*	x			x		x
RED ROCK CRAB	*CANCER PRODUCTUS*					x	
REDSTRIPE ROCKFISH	*SEBASTES PRORIGER*	x		x	x		
RED URCHIN	*STRONGYLOCENTROTUS FRANCISCANUS*					x	x
REX SOLE	*ERREX ZACHIRUS*					x	
RIGHTEYE FLOUNDERS	*RIGHTEYE FLOUNDERS*				x		
ROCKFISHES	*SEBASTES SPP.*					x	x
ROCK SOLE	*PLEURONECTES BILINEATUS*			x		x	x
ROSETHORN ROCKFISH	*SEBASTES HELVOMACULATUS*	x		x			
ROUGHEYE ROCKFISH	*SEBASTES ALEUTIANUS*		x	x			
SABLEFISH	*ANOPLOPOMA FIMBRIA*	x	x	x	x	x	
SAILFIN SCULPIN	*NAUTICHTHYS OCULOFASCIATUS*					x	
SALMONIDS	*SALMONIDAE*					x	
SANDPAPER SKATE	*BATHYRAJA INTERRUPTA*		x	x			
SCALLOP	*PECTINIDAE*		x				x
SCULPIN	*COTTIDAE*	x		x	x	x	x
SEA CUCUMBER	*HOLOTHUROIDEA*	x	x			x	x
SEA LILLIES AND FEATHER STARS	*CRINOIDEA*					x	x
SEA PENS	*PENNATULACEA*		x			x	x
SEA SLUGS	*NUDIBRANCHIATA*					x	
SEA URCHINS	*ECHINACEA*			x		x	x
SEA WHIP	*OSTEOCELLA SEPTENTRIONALIS*		x			x	x
SHARPCHIN ROCKFISH	*SEBASTES ZACENTRUS*			x	x		
SHINER PERCH	*CYMATOGASTER AGGREGATA*					x	
SHORTRAKER ROCKFISH	*SEBASTES BOREALIS*		x	x			
SHORTSPINE THORNYHEAD	*SEBASTOLOBUS ALASCANUS*		x	x		x	
SHRIMP	*NANTANTIA*					x	x
SKATES	*RAJIDAE*					x	

Table 4 continued

Common Name	Taxonomic Name	Area 12/13 Longline 2003	IPHC SSA 2003	YE Charters 1997 - 98 2002 - 03	Jig Surveys 85,86,87,88 92,93,98,03	Subermisble Survey 2003	Towed Camera 2003
SILVERGRAY ROCKFISH	*SEBASTES BREVISPINIS*		x	x	x		
SIXGILL SHARK	*HEXANCHUS GRISEUS*		x				
SKATES	*RAJIDAE*		x	x		x	
SLENDER SOLE	*LYOPSETTA EXILIS*	x				x	
SNAILFISHES	*LIPARINAE*					x	
SNAKE PRICKLEBACK	*LUMPENUS SAGITTA*					x	
SOFT CORALS	*ALCYONACEA*		x				
SOLASTERIDAE	*SOLASTERIDAE*	x			x	x	
SOUPFIN SHARK	*GALEORHINUS ZYOPTERUS*		x				
SOUTHERN ROCK SOLE	*LEPIDOPSETTA BILINEATA*		x		x		
SPECKLED SANDDAB	*CITHARICHTHYS STIGMAEUS*				x		
SPINY DOGFISH	*SQUALUS ACANTHIAS*	x	x	x	x	x	
SPINY RED SEA STAR	*HIPPASTERIA SPINOSA*					x	
SPLITNOSE ROCKFISH	*SEBASTES DIPLOPROA*					x	
SPONGES	*PORIFERA*		x	x		x	x
SPOTFIN SCULPIN	*ICELINUS TENUIS*	x					
SPOTTED RATFISH	*HYDROLAGUS COLLIEI*	x	x	x	x	x	
SQUID	*TEUTHOIDEA*					x	
STARFISH	*ASTERIODEA*	x	x	x		x	x
STELLER SEA LION	*EUMETOPIAS JUBATUS*		x				
STONY CORALS	*MADREPORIA*			x		x	
STURGEON POACHER	*PODATHECUS ACIPENSERINUS*					x	
SUNFLOWER STARTFISH	*PYCNOPODIA HELIANTHOIDES*	x				x	x
THORNYHEADS	*SEBASTOLOBINAE*					x	
TIGER ROCKFISH	*SEBASTES NIGROCINCTUS*	x		x	x	x	x
TOAD CRAB	*HYAS LYRATUS*						x
TUBE WORMS	*SEDENTARIA*					x	x
UNIDENTIFIED SHARK	*ELASMOBRANCHI*		x				
VERMILION ROCKFISH	*SEBASTES MINIATUS*			x			
VERMILLION STARFISH	*MEDIASTER AEQUALIS*					x	
WALLEYE POLLOCK	*THERAGRA CHALCOGRAMMA*		x		x	x	
WARTY POACHER	*OCCELLA VERRUCOSA*					x	
WHITESPOTTED GREENLING	*HEXAGRAMMOS STELLERI*				x		
WIDOW ROCKFISH	*SEBASTES ENTOMELAS*				x		
WOLF EEL	*ANARRHICHTHYS OCELLATUS*		x	x			x
YELLOWEYE ROCKFISH	*SEBASTES RUBERRIMUS*	x	x	x	x	x	x
YELLOWMOUTH ROCKFISH	*SEBASTES REEDI*		x	x			
YELLOWFIN SOLE	*LIMANDA ASPERA*				x		
YELLOWTAIL ROCKFISH	*SEBASTES FLAVIDUS*	x	x	x	x	x	
TOTAL NUMBER OF MARINE FISH SPECIES		**30**	**37**	**44**	**39**	**58**	**20**
TOTAL OF ALL SPECIES AND TAXONOMIC GROUPS		**41**	**56**	**57**	**39**	**95**	**47**

Table. 5. Total number of sites surveyed by year and statistical area using hook and line jig gear.

Year	Statistical Area						
	12	13	15	16	17	18	19
1984	-	-	13	17	-	-	-
1985	-	-	7	10	10	-	-
1986	10	6	-	10	-	-	-
1987	10	6	-	-	10	-	-
1988	10	11	-	-	10	-	-
1992	10	-	-	-	-	-	-
1993	-	-	-	-	-	14	6
1998	-	-	-	-	-	4	4
2003	-	-	-	-	19	12	5
Number of common sites	10	6	-	8[a]	4	3[b]	3[b]

[a] does not include survey year 1984
[b] does not include survey year 2003

Table 6. Summary of jig survey catch rates (kg/hr), median, mean and CV's by statistical area.

Statistical Area	Year	Quillback rockfish		
		median	mean	CV
Area 12	1986	151.3	181.89	0.82
	1987	58.56	72.2	0.72
	1988	104.88	121.34	0.85
	1992	64.17	89.32	1.14
Area 13	1986	136	153.63	0.63
	1987	28.74	40.35	0.88
	1988	81.33	90.03	0.63
Area 16	1985	36	72.45	1.45
	1986	47.54	59.47	0.79
Area 17	1985	60.94	93.18	1.1
	1987	48.78	69.28	0.78
	1988	31.53	37.8	0.78
	2003	13.26	21.9	1.24
Area 18	1993	16.8	28.88	0.73
	1998	4.14	6.47	0.83
Area 19	1993	34.19	48.44	0.69
	1998	23.16	27.24	0.8

Table 7. Summary of catch rates (kg/skate) and coefficients of variation (CV %) by fishing survey.

Survey	Quillback rockfish		Copper rockfish		Redbanded rockfish		Yelloweye rockfish	
	mean	CV %	mean	CV %	mean	CV %	mean	CV %
Area 12/13 Longline	3.25	151	0.12	429	-	-	2.78	181
IPHC Survey 2003	0.11	302	-	-	0.96	284	0.90	275
YE Charter 1997-98	0.23	447	-	-	2.07	248	26.82	70
YE Charter 2002-03	0.37	400	-	-	1.12	336	34.56	60

Table 8. Summary of simulation parameters by dominant rockfish species for each survey. 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).

Survey	Species	P	μ	ρ	N	A
2003 Area 12/13 Longline Survey	Quillback rockfish	0.2432	1049.13	1.1096	74	1605
2003 IPHC Survey	Quillback rockfish	0.8235	17.71	0.8484	170	146992
2003 IPHC Survey	Redbanded rockfish	0.5824	146.76	1.7881	170	146992
2003 IPHC Survey	Yelloweye rockfish	0.5824	188.60	1.4492	170	146992
2002-2003 Yelloweye Charters	Yelloweye rockfish	0	15501.76	0.6025	89	567

Table 9. Mean fish densities (number km^{-2}) and coefficients of variation (CV %) by substrate type for the 2003 towed camera survey

	Hardpan		**Bedrock**		**Boulder**		**Cobble**		**Mixed Coarse**		**Sand**		**Mud**	
	Mean (km^{-2})	**CV%**	**Mean (km^{-2})**	**CV%**	**Mean (km^{-2})**	**CV%**	**Mean (km^{-2})**	**CV%**	**Mean (km^{-2})**	**CV%**	**Mean (km^{-2})**	**CV%**	**Mean (km^{-2})**	**CV%**
Puget Sound Rockfish	—	—	9676.31	349	26279.66	252	3033.48	300	3398.90	539	—	—	1152.39	424
Quillback Rockfish	—	—	12283.06	197	7632.21	184	252.79	300	405.05	147	5506.94	332	—	—
Copper Rockfish	156.21	316	6186.16	177	7333.57	415	—	—	984.80	489	4951.28	203	942.87	291
Tiger Rockfish	—	—	424.17	387	365.60	375	—	—	—		—	—	0.00	—
Eelpout	468.62	316	—	—	—	—	—	—	131.61	375	1515.41	259	35584.62	108
Kelp Greenling	14033.68	303	3636.21	201	27389.67	418	—	—	2340.36	221	2916.80	206	1162.26	318
Lingcod	1624.34	316	5123.13	217	1374.91	231	252.79	300	397.04	340	3177.00	286	2450.49	245
Rock Sole	13494.77	316	—	—	—	—	—	—	260.89	358	1862.69	231	1772.26	226

Table 10. Marine fish species observed on the camera survey in 2003 with the total observed, the number of transects that each species were observed in and their overall proportions.

Species	Total Number Observed	# transect s	% of Total
Puget Sound Rockfish	285	10	38.26
Eelpouts	88	14	11.81
Quillback Rockfish	85	16	11.41
Unidentified Fish	59	25	7.92
Kelp Greenling	52	26	6.98
Lingcod	38	15	5.10
Copper Rockfish	35	13	4.70
Unidentified Rockfish	29	14	3.89
Unidentified Flatfish	26	10	3.49
Rock Sole	13	9	1.74
Unidentified Greenlings	9	7	1.21
Poachers	6	4	0.81
Gunnels	5	2	0.67
Tiger Rockfish	4	3	0.54
Sculpins	4	4	0.54
Wolf Eel	2	2	0.27
Red Irish Lord	1	1	0.13
English Sole	1	1	0.13
Dover Sole	1	1	0.13
Yelloweye Rockfish	1	1	0.13
Dogfish	1	1	0.13

Table 11. Habitat specific mean number of fish per linear meter of transect and coefficients of variation (CV%) for quillback rockfish, yelloweye rockfish, greenstriped rockfish and lingcod for the 2003 *Aquarius* submersible survey.

	Bedrock		Boulder		Cobble		Mixed Coarse		Gravel		Sand		Mud	
	Mean per meter	**CV%**	**Mean per meter**	**CV%**	**Mean per meter**	**CV%**	**Mean per meter**	**CV%**	**Mean per meter**	**CV%**	**Mean per meter**	**CV%**	**Mean per meter**	**CV%**
Quillback Rockfish	0.0703	177	0.0577	113	0.1356	190	0.0334	200	0.0000	—	0.0288	155	0.0123	193
Yelloweye Rockfish	0.0190	93	0.0174	230	0.0072	192	0.0000	—	0.0000	—	0.0000	—	0.0030	331
Greenstriped Rockfish	0.0100	167	0.0103	175	0.1061	280	0.0066	119	0.0000	—	0.0092	245	0.0114	143
Lingcod	0.0040	141	0.0341	198	0.0031	197	0.0020	200	—	—	—	—	0.0008	328

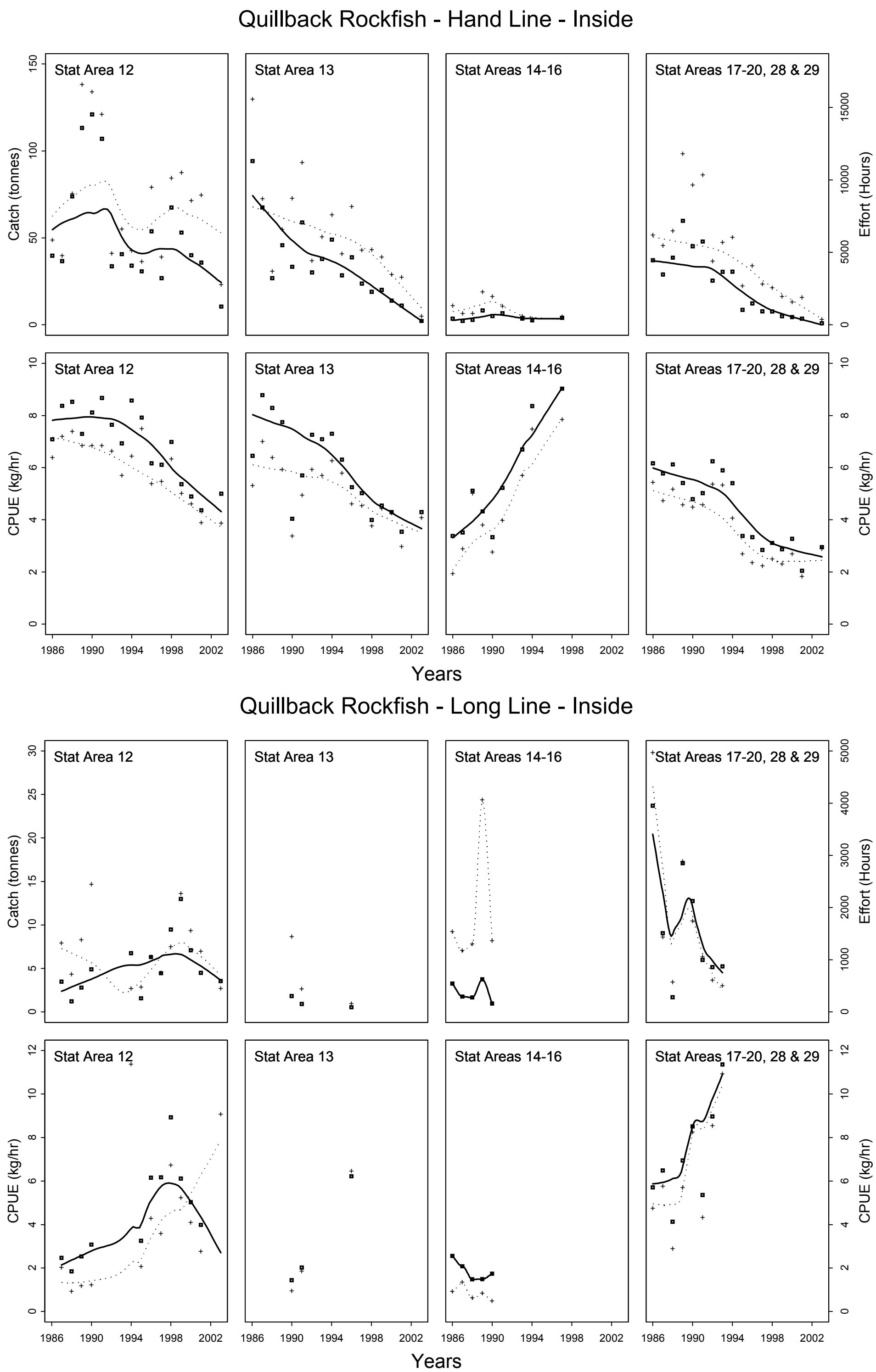


Figure 1. Catch, effort and CPUE plots for quillback rockfish by gear type for the inside fishery by statistical area(s) (panel labels). The plots consist of 8 panels each; top 4 panels are catch in kilograms (squares) and effort in hours (pluses) with the solid bold line is local regression fit of catch, dotted line is local regression fit of effort, bottom 4 panels are mean CPUE (squares) and median (pluses) CPUE, Solid bold line is local regression fit of mean CPUEs, dotted line is local regression fit of median CPUEs.

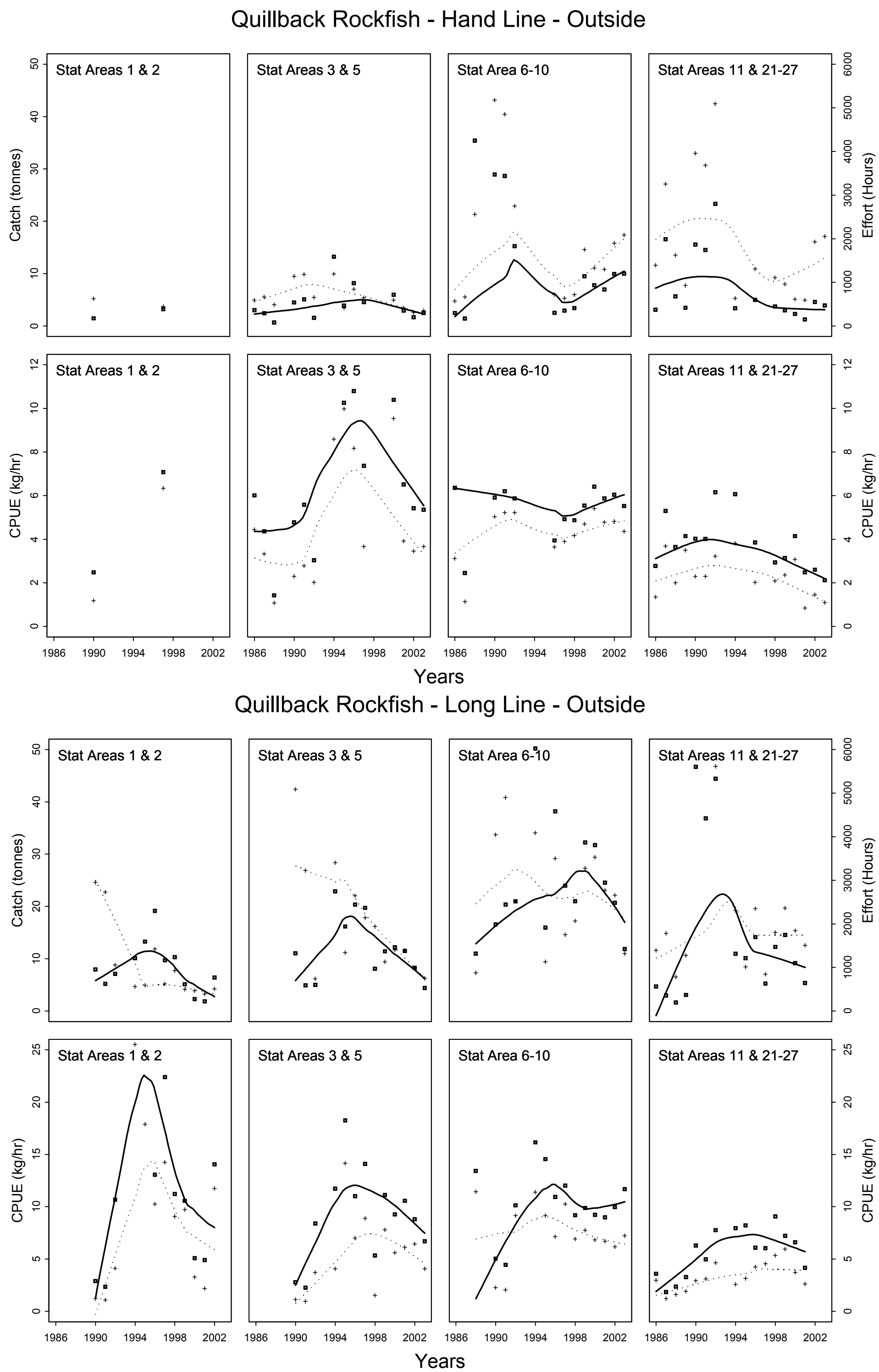


Figure 2. Catch, effort and CPUE plots for quillback rockfish by gear type for the outside fishery by statistical area(s) (panel labels). The plots consist of 8 panels each; top 4 panels are catch in kilograms (squares) and effort in hours (pluses) with the solid bold line is local regression fit of catch, dotted line is local regression fit of effort, bottom 4 panels are mean CPUE (squares) and median (pluses) CPUE, Solid bold line is local regression fit of mean CPUEs, dotted line is local regression fit of median CPUEs

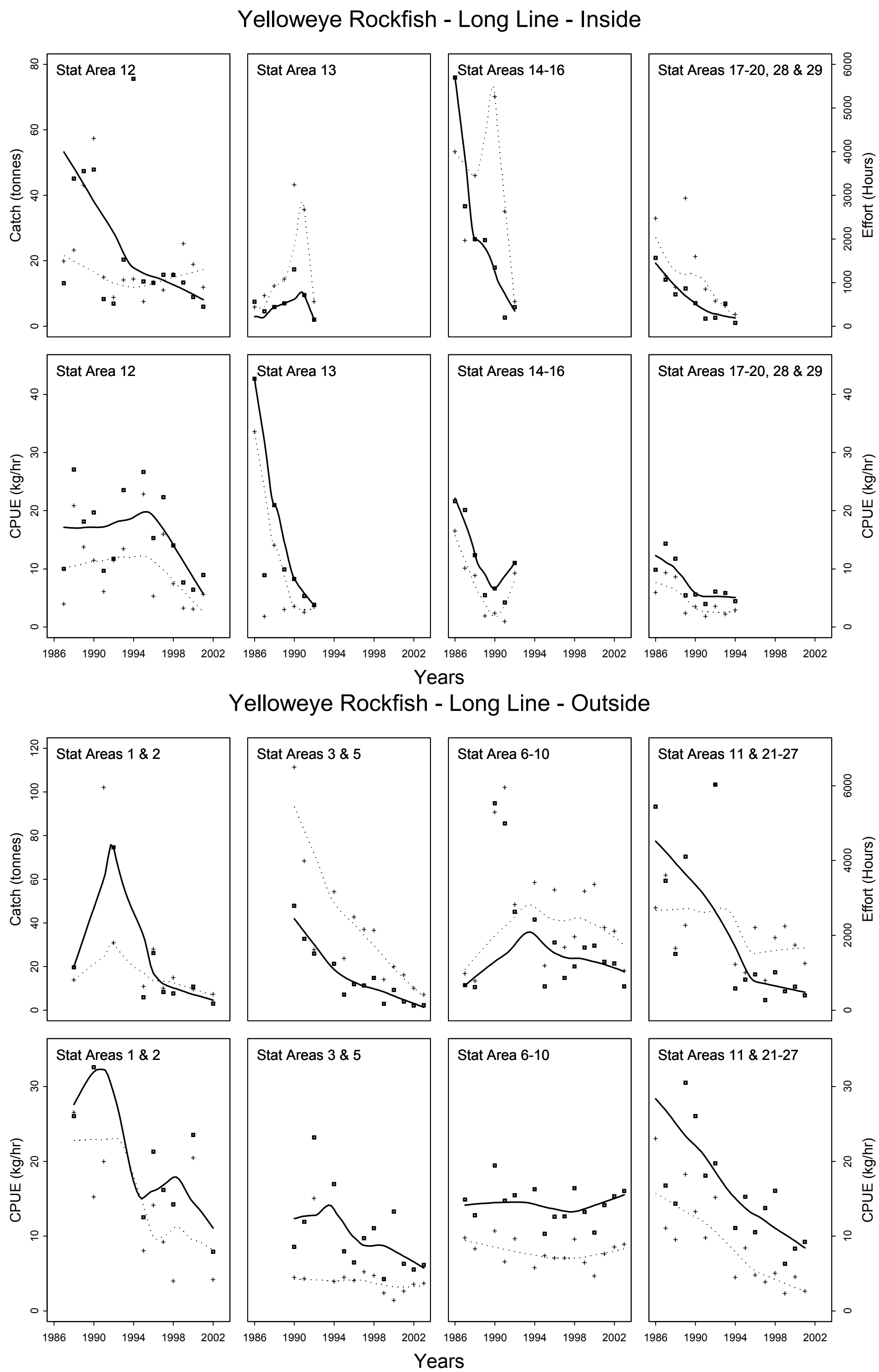


Figure 3. Catch, effort and CPUE plots for yelloweye rockfish for longline gear for inside (top plots) and the outside (bottom plots) fishery by statistical area(s) (panel labels). The plots consist of 8 panels each; top 4 panels are catch in kilograms (squares) and effort in hours (pluses) with the solid bold line is local regression fit of catch, dotted line is local regression fit of effort, bottom 4 panels are mean CPUE (squares) and median (pluses) CPUE, Solid bold line is local regression fit of mean CPUEs, dotted line is local regression fit of median CPUEs.

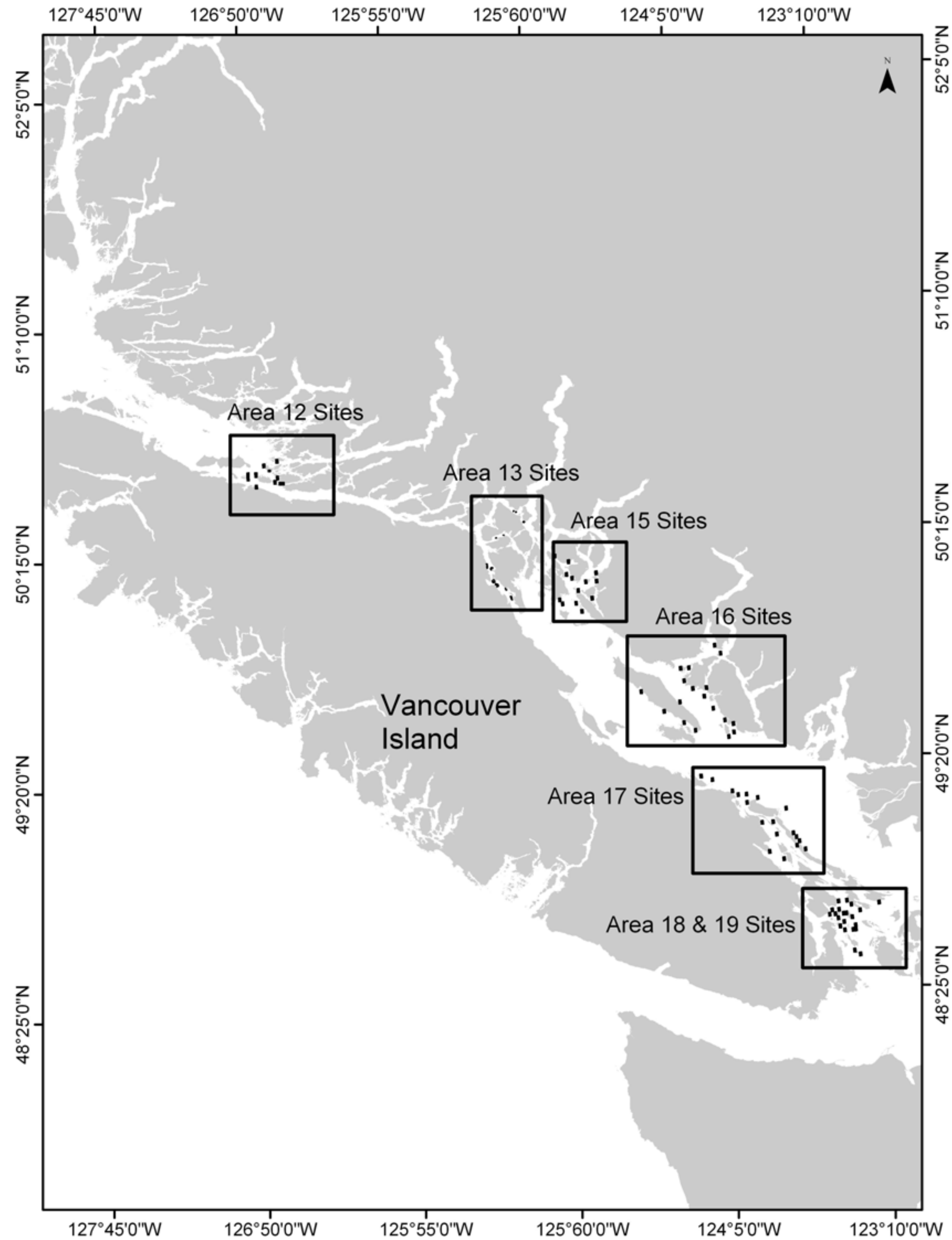


Figure 4. Location of the hook and line jig surveys, by statistical area, conducted in various years from 1984 and 2002.

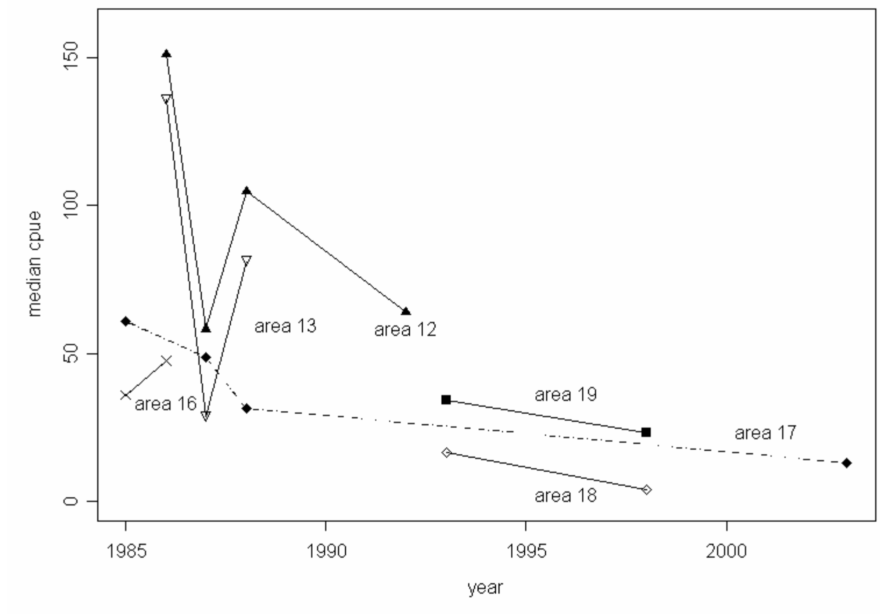


Figure 5. Jig survey median CPUE index for quillback rockfish. Median CPUE (kg/hr) by year for all common research sites and depths by statistical area.

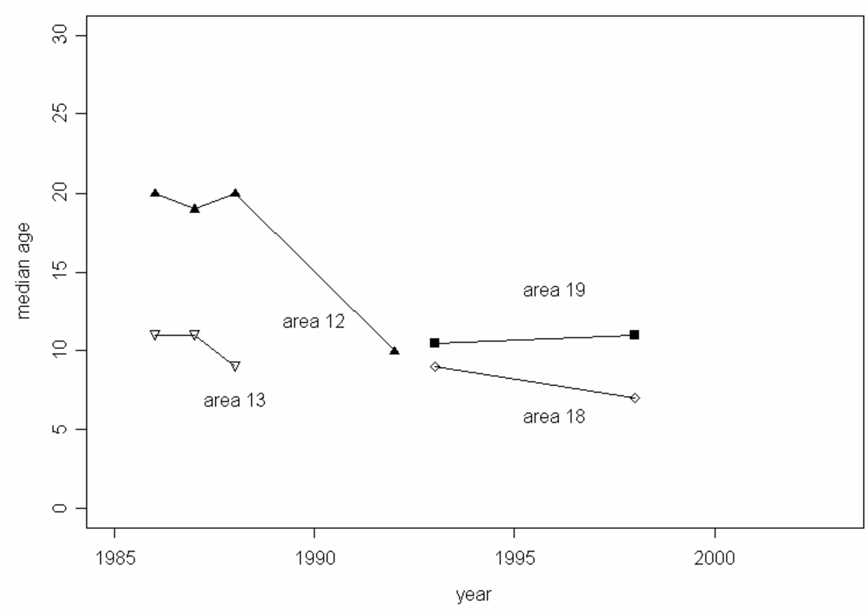


Figure 6. Median quillback rockfish age by year for all common research sites and depths by statistical area. Some quillback rockfish age data is not available.

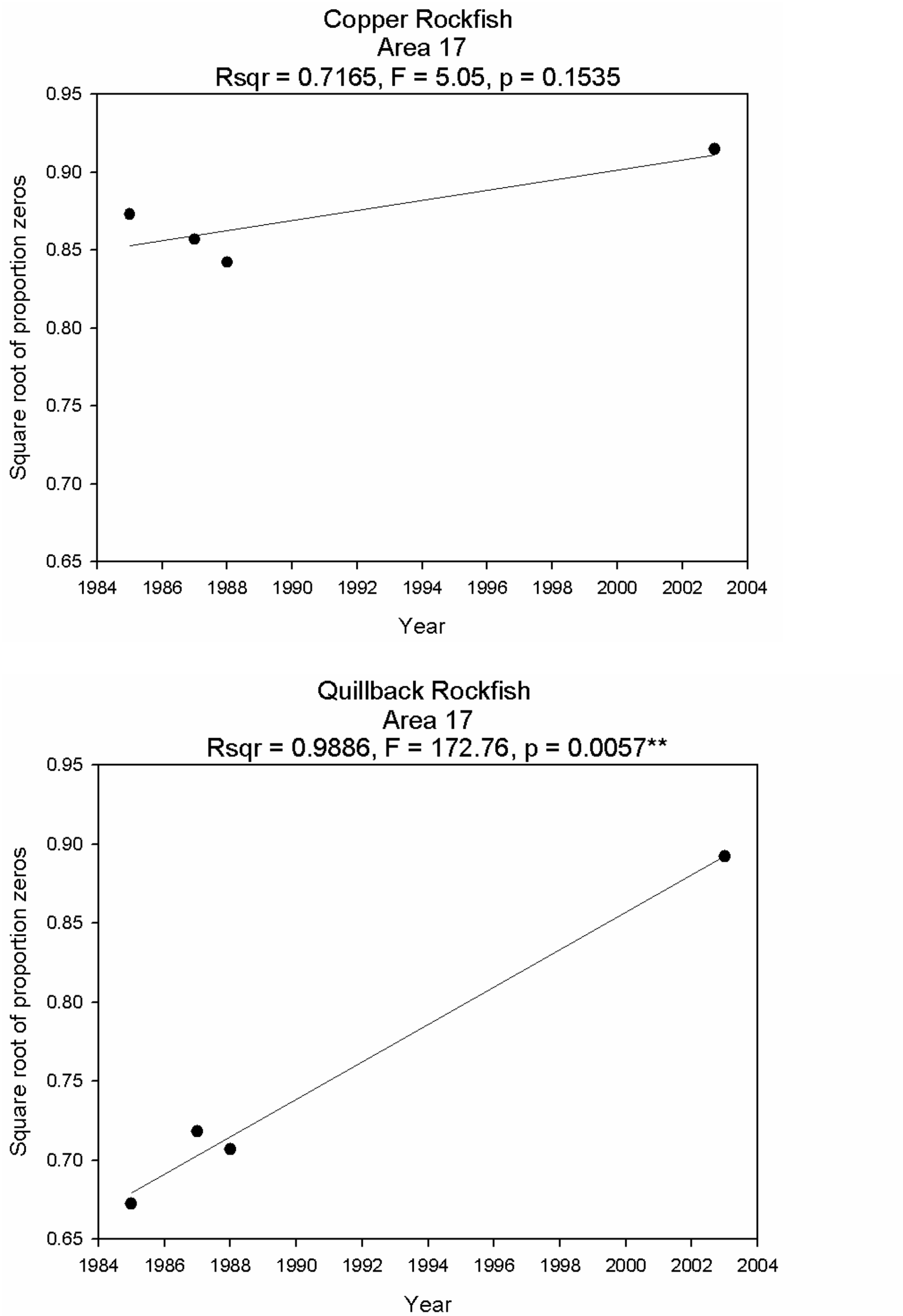


Figure 7. Square root of the proportion of zero catches occurring during the jig surveys in Statistical Area 17 by survey year. An increase in the proportion of zero catches is evident from 1985 to 2003. When the slope of the regression line is significantly different from zero, there is a significant decrease in abundance. Data for copper rockfish are shown in the upper panel and for quillback rockfish in the lower panel.

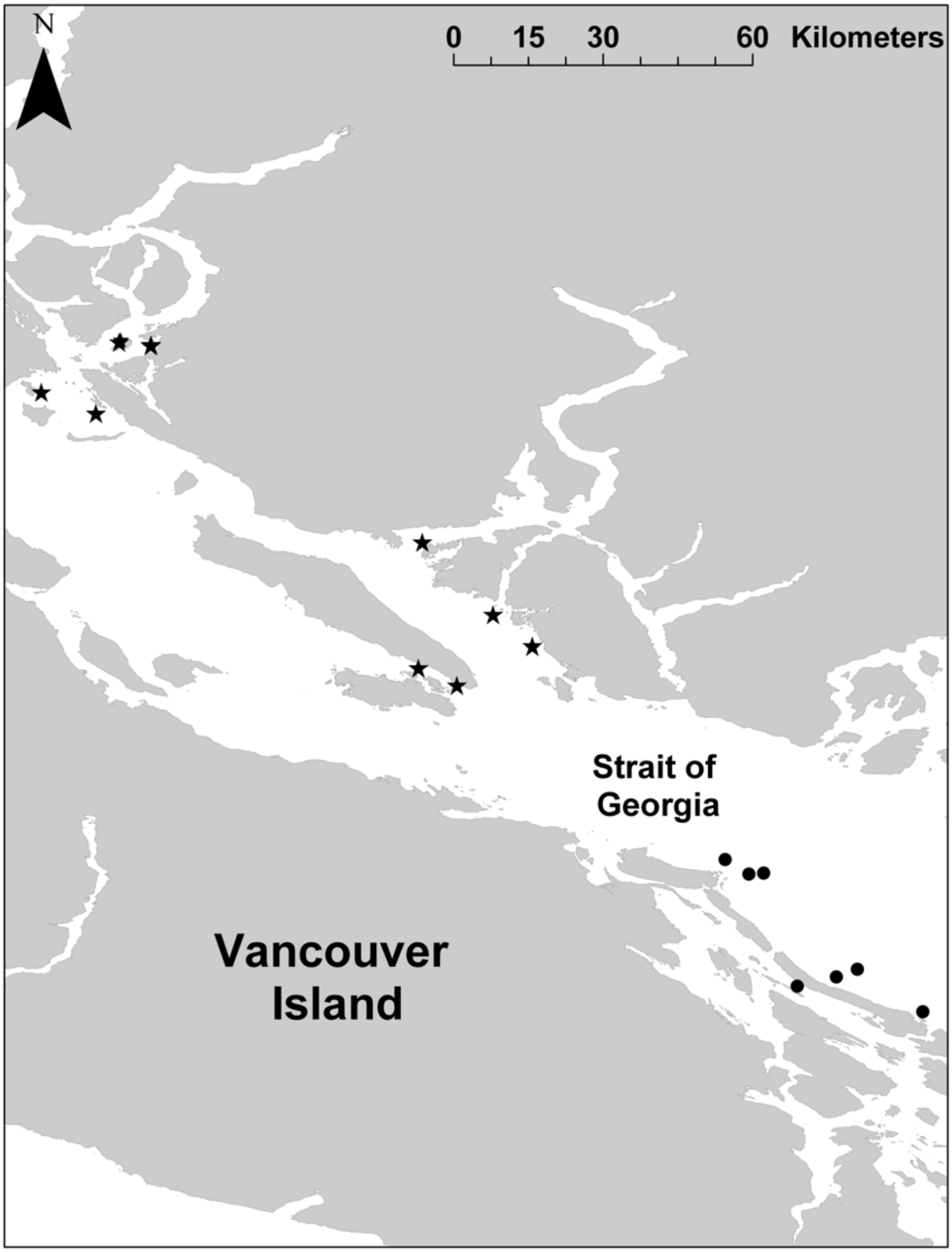


Figure 8. Location of the *Aquarius* submersible dives in 2003. Locations that were surveyed by the *Pisces* submersible in 1984 are shown as stars.

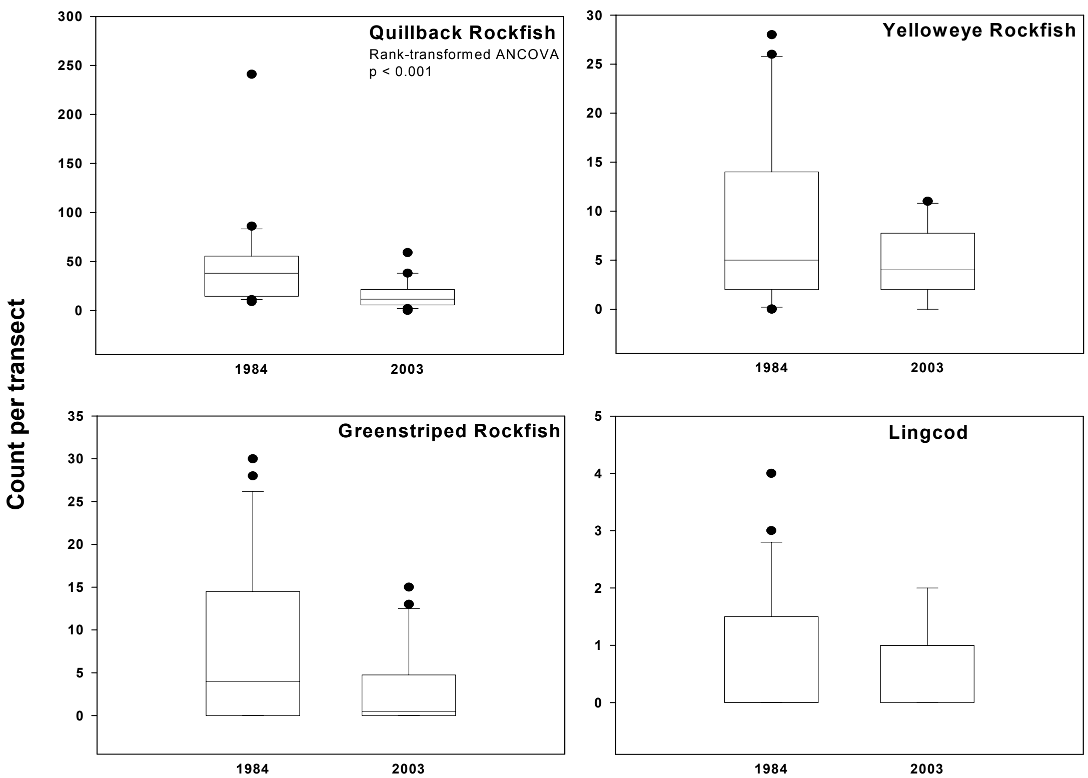


Figure 9. Comparison of the number of fish per transect between 1984 and 2003 submersible surveys. Only data for sites and depths common to both surveys were included in the analysis. The center line through each box represents the median value while the 1nd and 3rd quartiles delineate the box. Whiskers indicate the 10th and 90th percentiles, with individual outliers plotted. Rank-transformed ANCOVAs were performed with 'site' as co-variable, and the statistic is computed around the median rank.

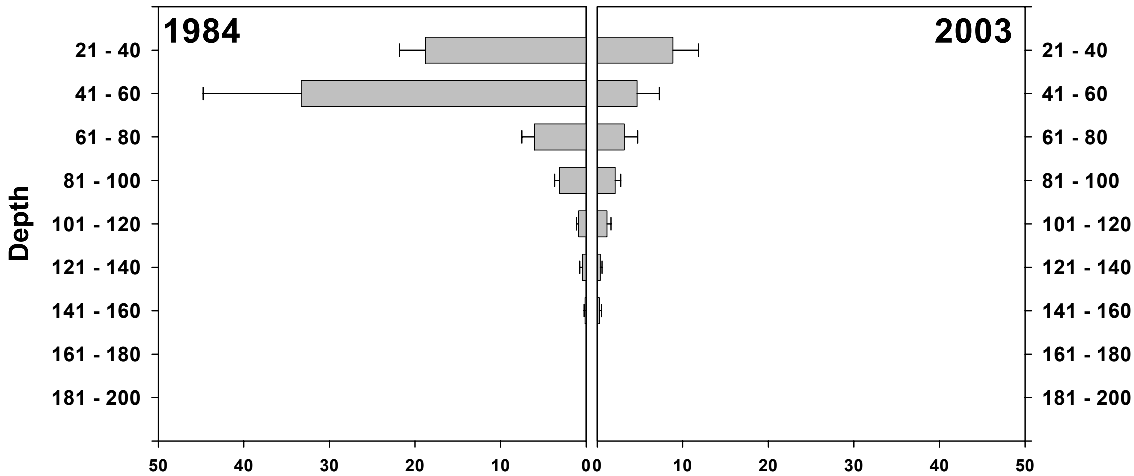


Figure 10. Comparison of the mean number (± 1 standard error) of individuals observed per transect by 20m depth intervals for quillback rockfish (*S. maliger*) between 1984 and 2003 submersible surveys. Only sites and depths common to both years are included in the analysis.

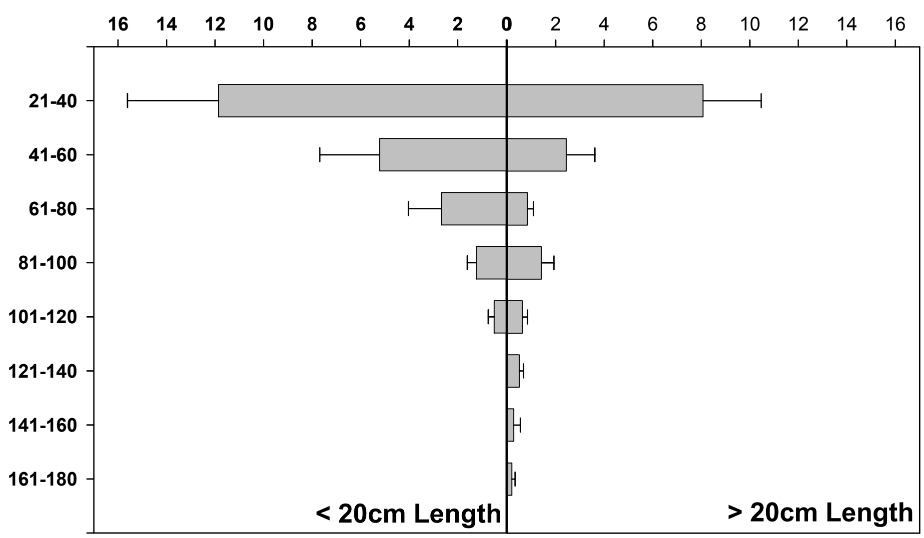


Figure 11. Mean number (± 1 standard error) of individuals observed per transect by 20m depth intervals for quillback rockfish (*S. maliger*) of two size classes in 2003. The distributions are similar to comparable site and depth data in 1984.

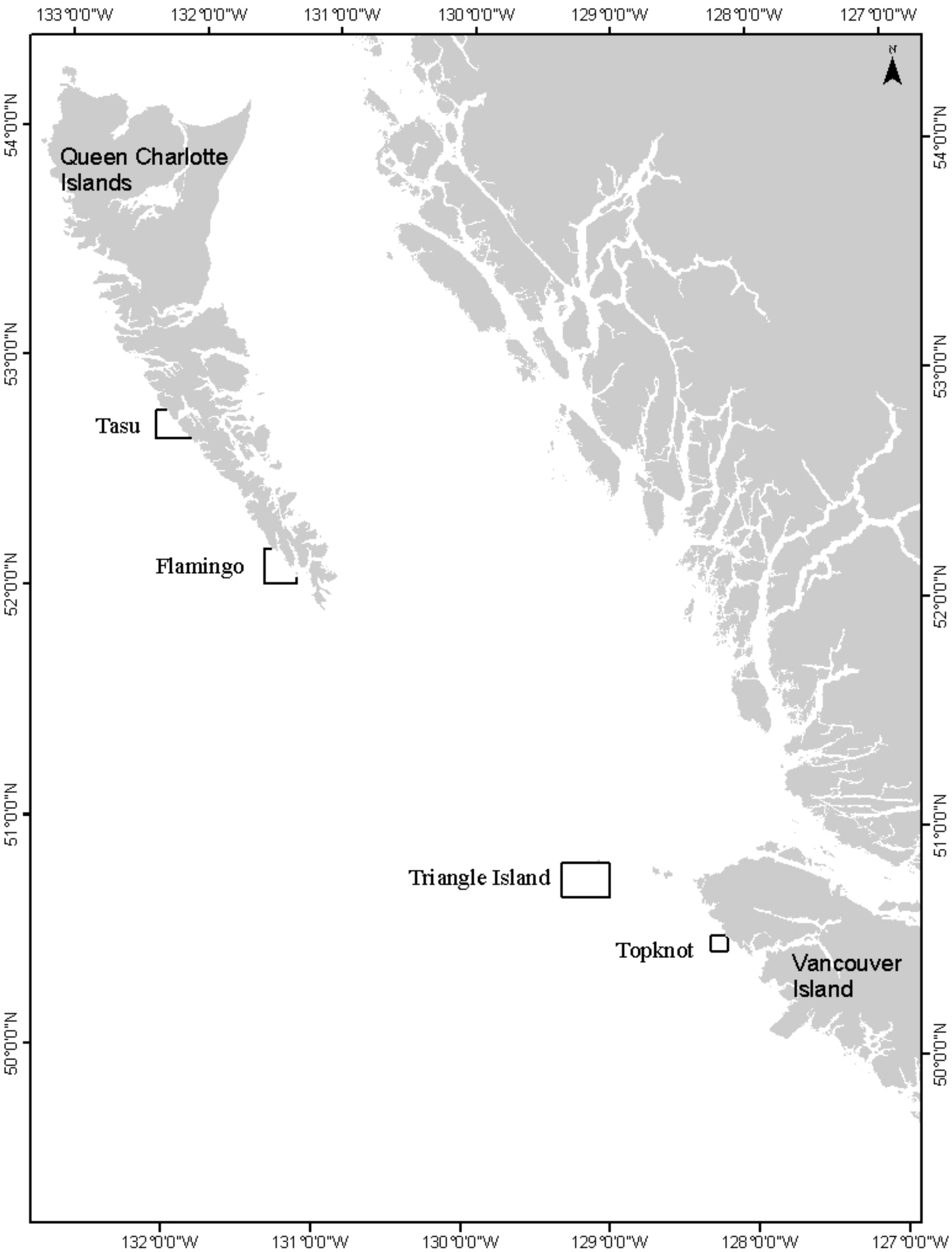
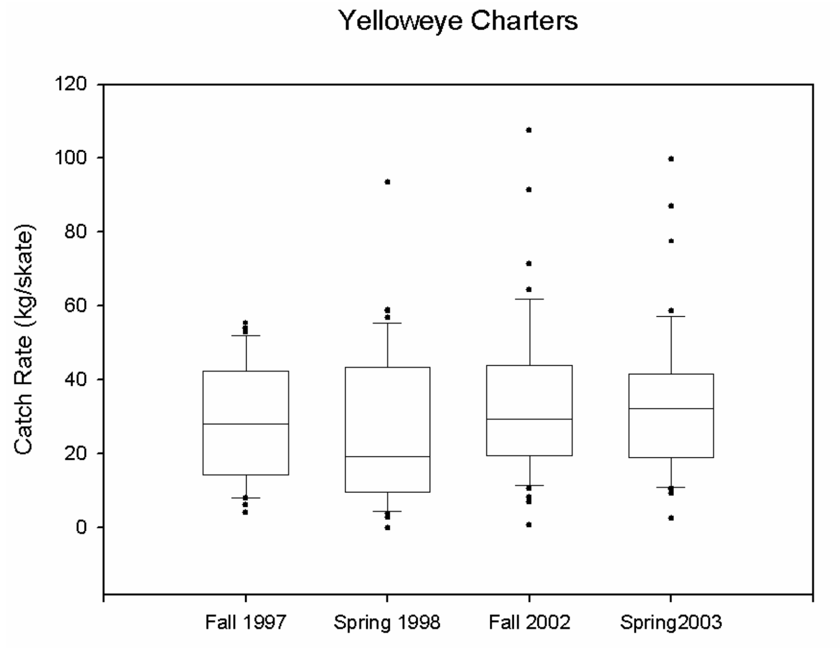


Figure 12. Location of the yelloweye rockfish index sites surveyed in 1997, 1998, 2002 and 2003 by chartered industry vessels.



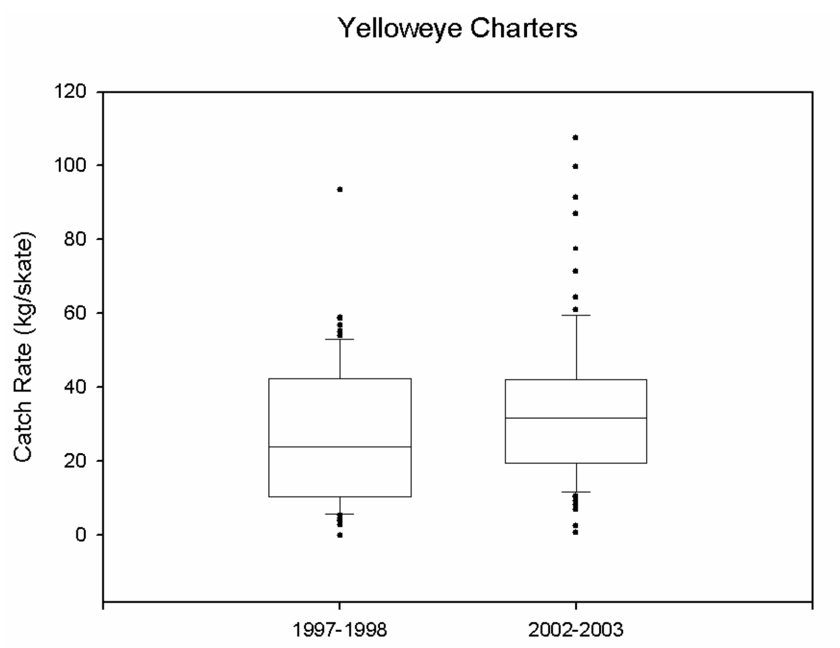


Figure 13. Yelloweye catch per effort (kg/skate) from the index site surveys by year (upper panel) and combined as two annual surveys (lower panel).

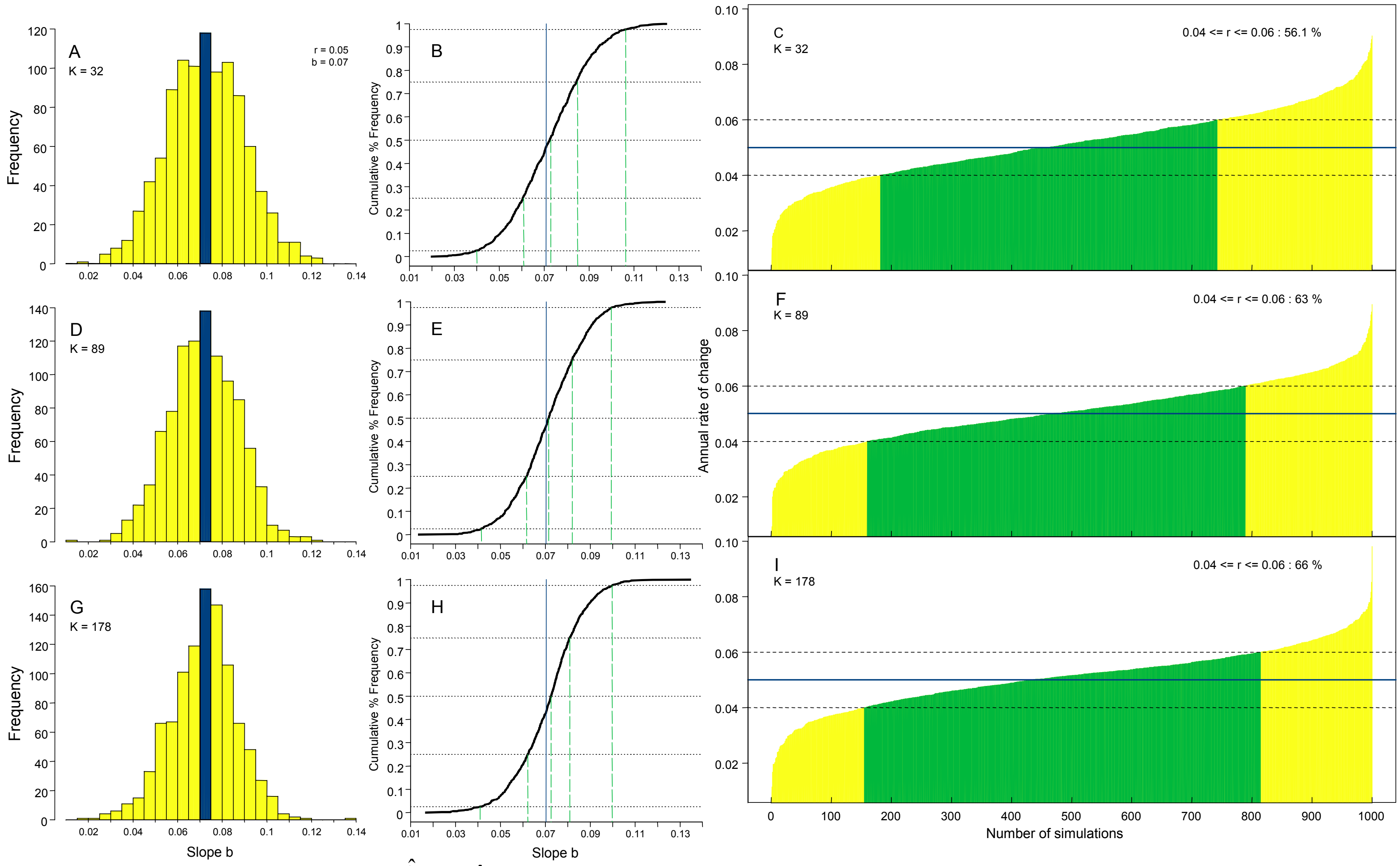


Figure 14. Distribution of bootstrapped $\hat{b}$ and $\hat{r}$ (Schnute et al. 2004, Section 5.6) for yelloweye rockfish. Figure rows correspond to tow budgets $K =$ 32, 89, and 178 sets. (A,D,G) Histogram of $\hat{b}$; blue bar indicates interval that contains the true slope $b = 0.07$. (B,D,H) Cumulative percent frequency of $\hat{b}$; solid blue vertical line indicates true slope $b = 0.07$; dashed green vertical lines indicate 2.5%, 25%, 50%, 75%, and 97.5% quantiles. (C,D,I) High-density line plots of $\hat{r}$; solid blue horizontal line indicates the true annual rate of increase $r = 0.05$; dashed horizontal lines indicate $r \pm 20\%$; green shading denotes simulated surveys where $\hat{r}$ falls in the range $r \pm 20\%$.

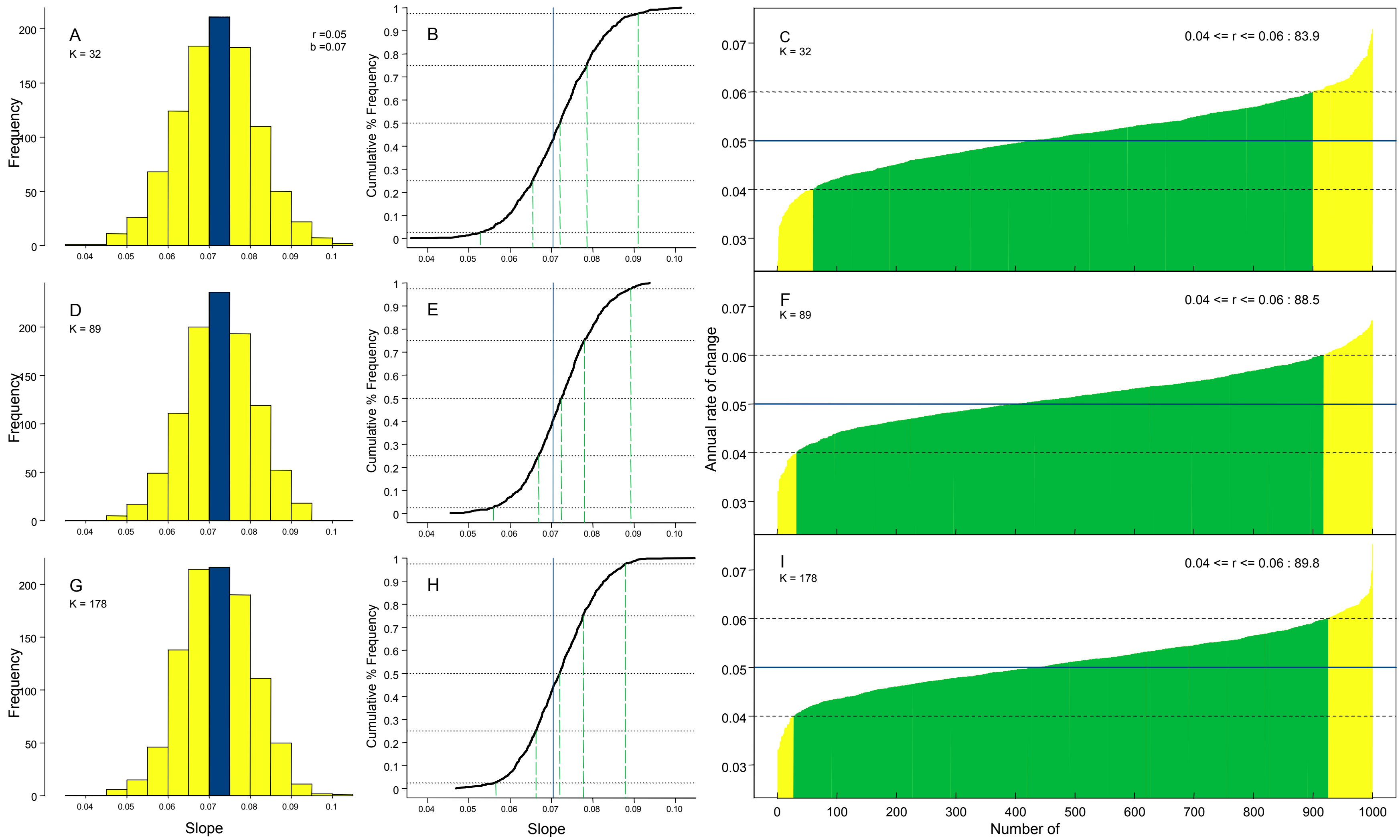


Figure 15. Distribution of bootstrapped $\hat{b}$ and $\hat{r}$ (Schnute et al. 2004, Section 5.6) for quillback rockfish. Figure rows correspond to tow budgets $K =$ 32, 89, and 178 sets. (A,D,G) Histogram of $\hat{b}$; blue bar indicates interval that contains the true slope $b = 0.07$. (B,D,H) Cumulative percent frequency of $\hat{b}$; solid blue vertical line indicates true slope $b = 0.07$; dashed green vertical lines indicate 2.5%, 25%, 50%, 75%, and 97.5% quantiles. (C,D,I) High-density line plots of $\hat{r}$; solid blue horizontal line indicates the true annual rate of increase $r = 0.05$; dashed horizontal lines indicate $r \pm 20\%$; green shading denotes simulated surveys where $\hat{r}$ falls in the range $r \pm 20\%$..

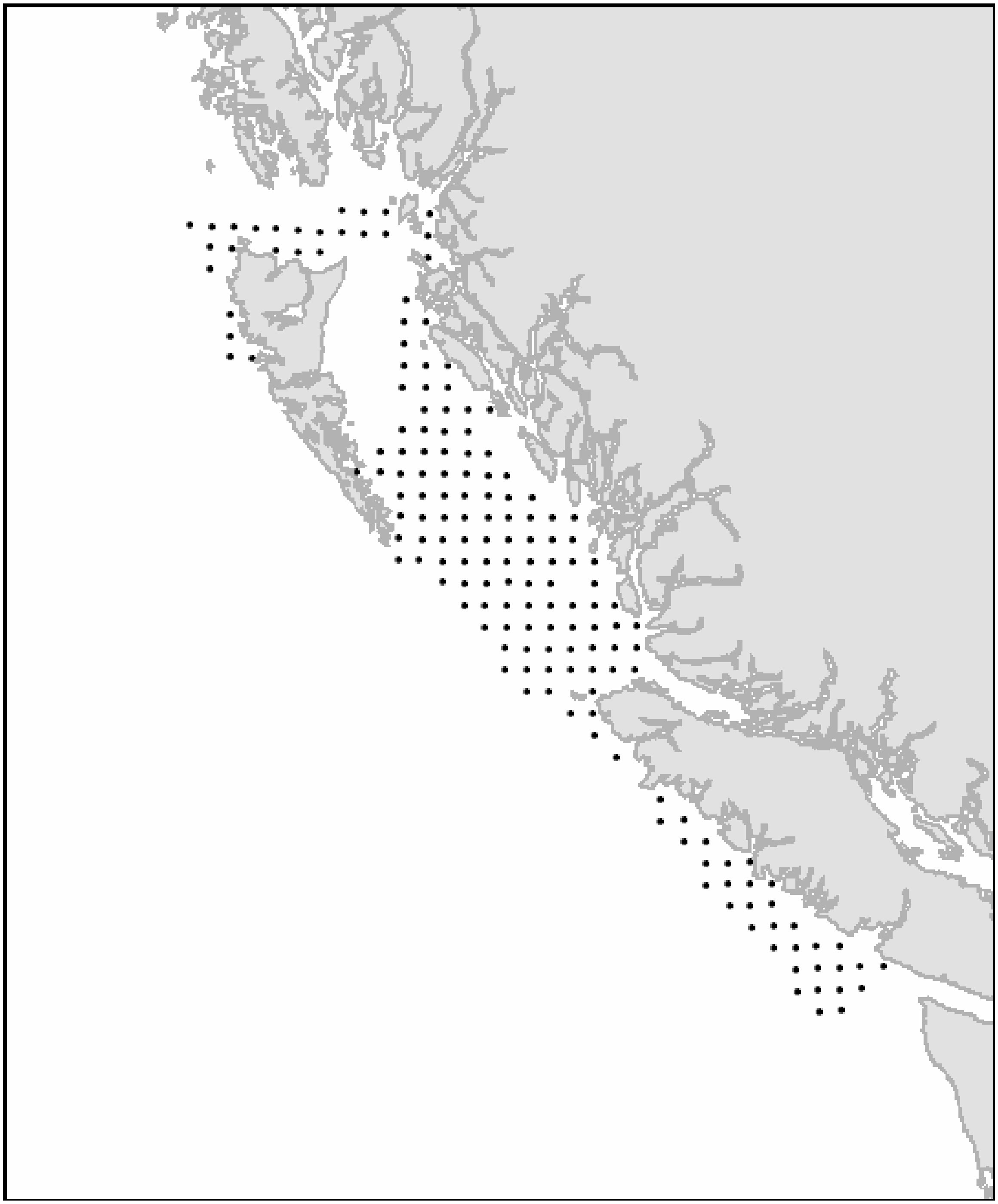


Figure 16. Location of the International Pacific Halibut Commission (IPHC) Setline Stock Assessment (SSA) fixed stations surveyed from May to August in 2003.

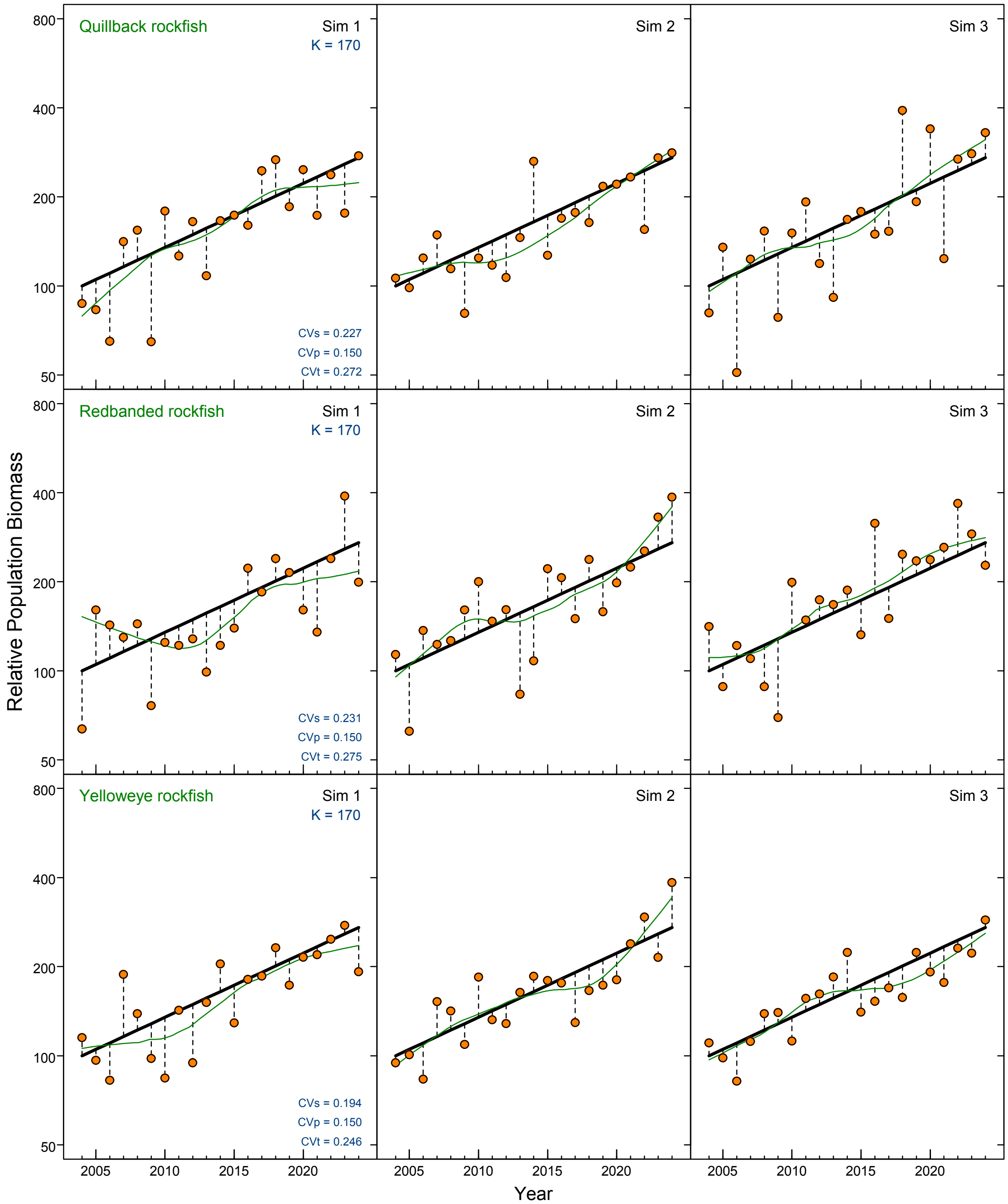


Figure 17. Simulations with the known population growth rate of 5% compounded per year (solid line) and biomass estimates (circles) including process error of 15%. Departures of the biomass estimates from the known population (vertical dashed lines) are shown with a loess line (thin lines). Coefficients of variation are shown for the survey (CVs), process (CV_p) and total (CV_t).

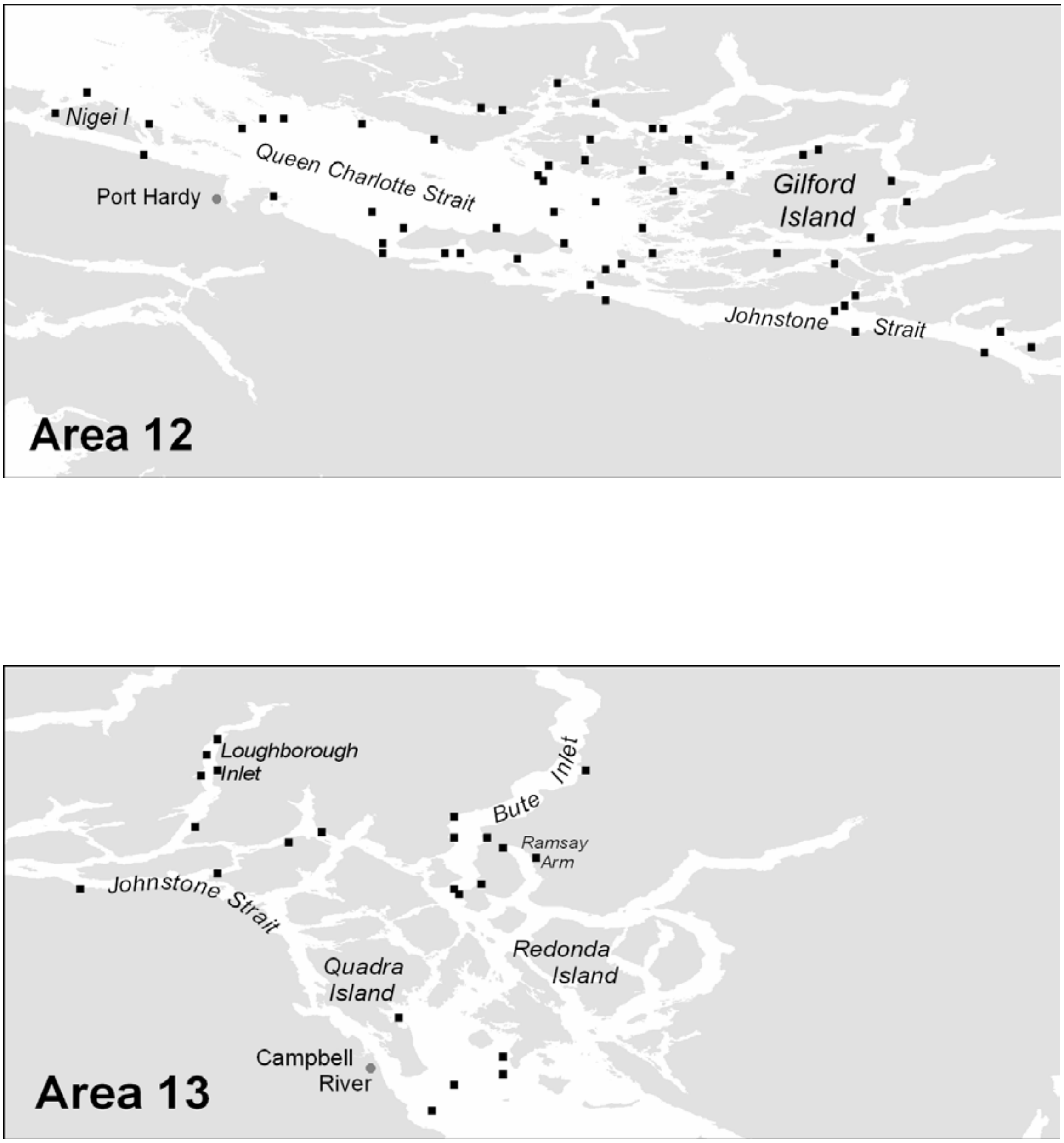


Figure 18. Locations of the *CCGS Neocaligus* longline survey random set locations fished from August to September in 2003.

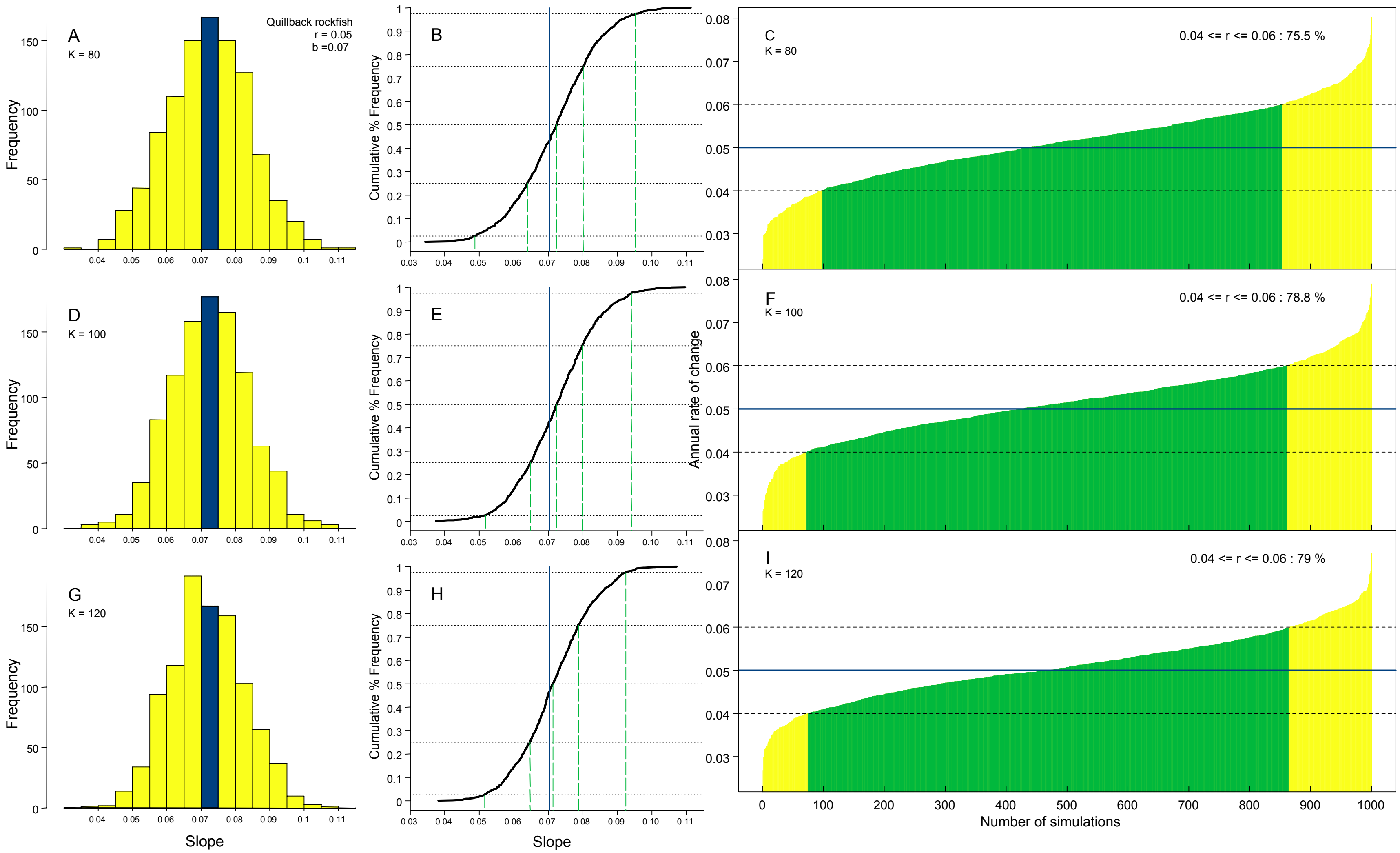


Figure 19. Distribution of bootstrapped $\hat{b}$ and $\hat{r}$ (Schnute et al. 2004, Section 5.6) for quillback rockfish. Figure rows correspond to tow budgets $K =$ 80, 100, and 120 sets. (A,D,G) Histogram of $\hat{b}$; blue bar indicates interval that contains the true slope $b = 0.07$. (B,D,H) Cumulative percent frequency of $\hat{b}$; solid blue vertical line indicates true slope $b = 0.07$; dashed green vertical lines indicate 2.5%, 25%, 50%, 75%, and 97.5% quantiles. (C,D,I) High-density line plots of $\hat{r}$; solid blue horizontal line indicates the true annual rate of increase $r = 0.05$; dashed horizontal lines indicate $r \pm 20\%$; green shading denotes simulated surveys where $\hat{r}$ falls in the range $r \pm 20\%$.

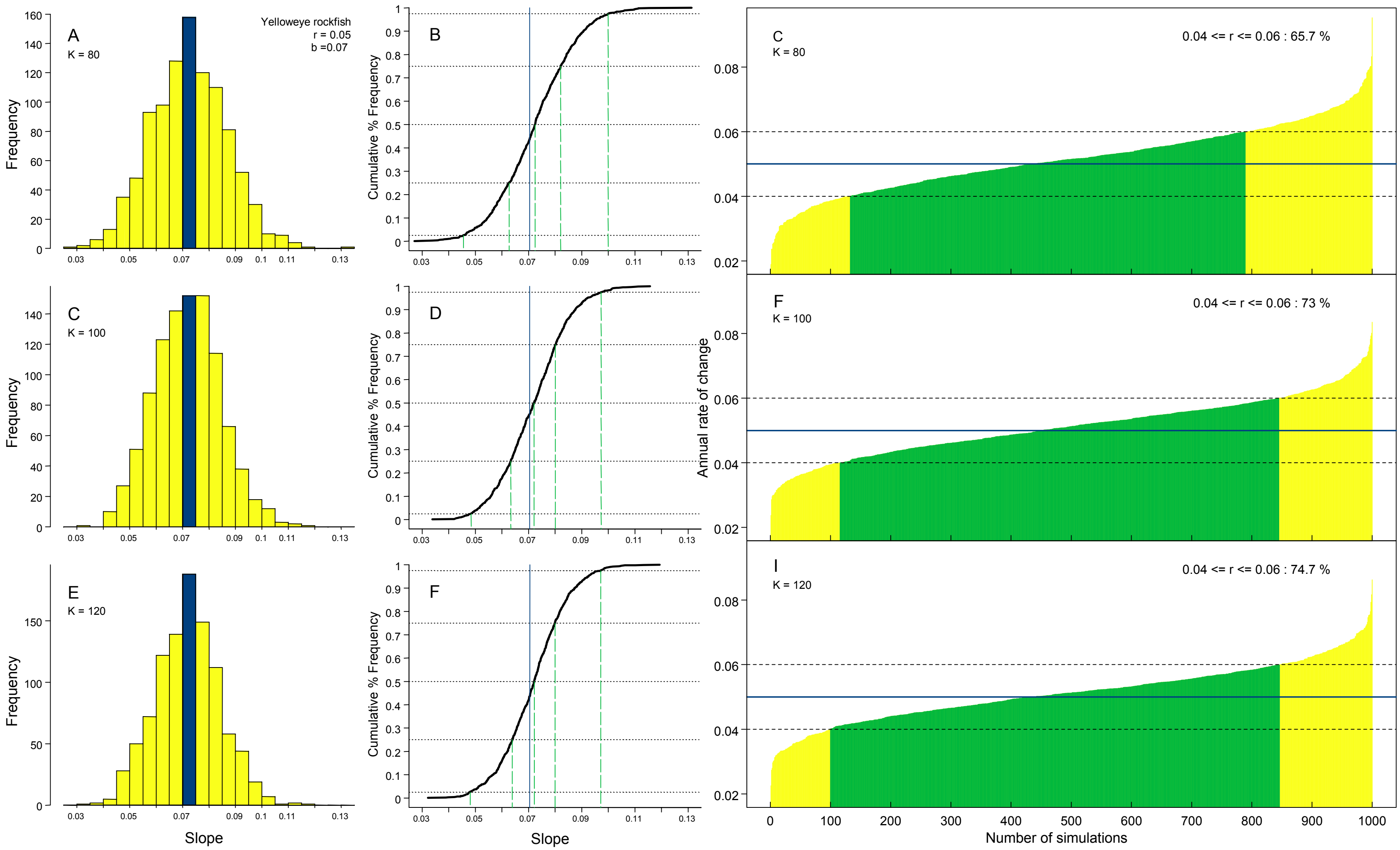


Figure 20. Distribution of bootstrapped $\hat{b}$ and $\hat{r}$ (Schnute et al. 2004, Section 5.6) for yelloweye rockfish. Figure rows correspond to tow budgets $K =$ 80, 100, and 120 sets. (A,D,G) Histogram of $\hat{b}$; blue bar indicates interval that contains the true slope $b = 0.07$. (B,D,H) Cumulative percent frequency of $\hat{b}$; solid blue vertical line indicates true slope $b = 0.07$; dashed green vertical lines indicate 2.5%, 25%, 50%, 75%, and 97.5% quantiles. (C,E,I) High-density line plots of $\hat{r}$; solid blue horizontal line indicates the true annual rate of increase $r = 0.05$; dashed horizontal lines indicate $r \pm 20\%$; green shading denotes simulated surveys where $\hat{r}$ falls in the range $r \pm 20\%$.

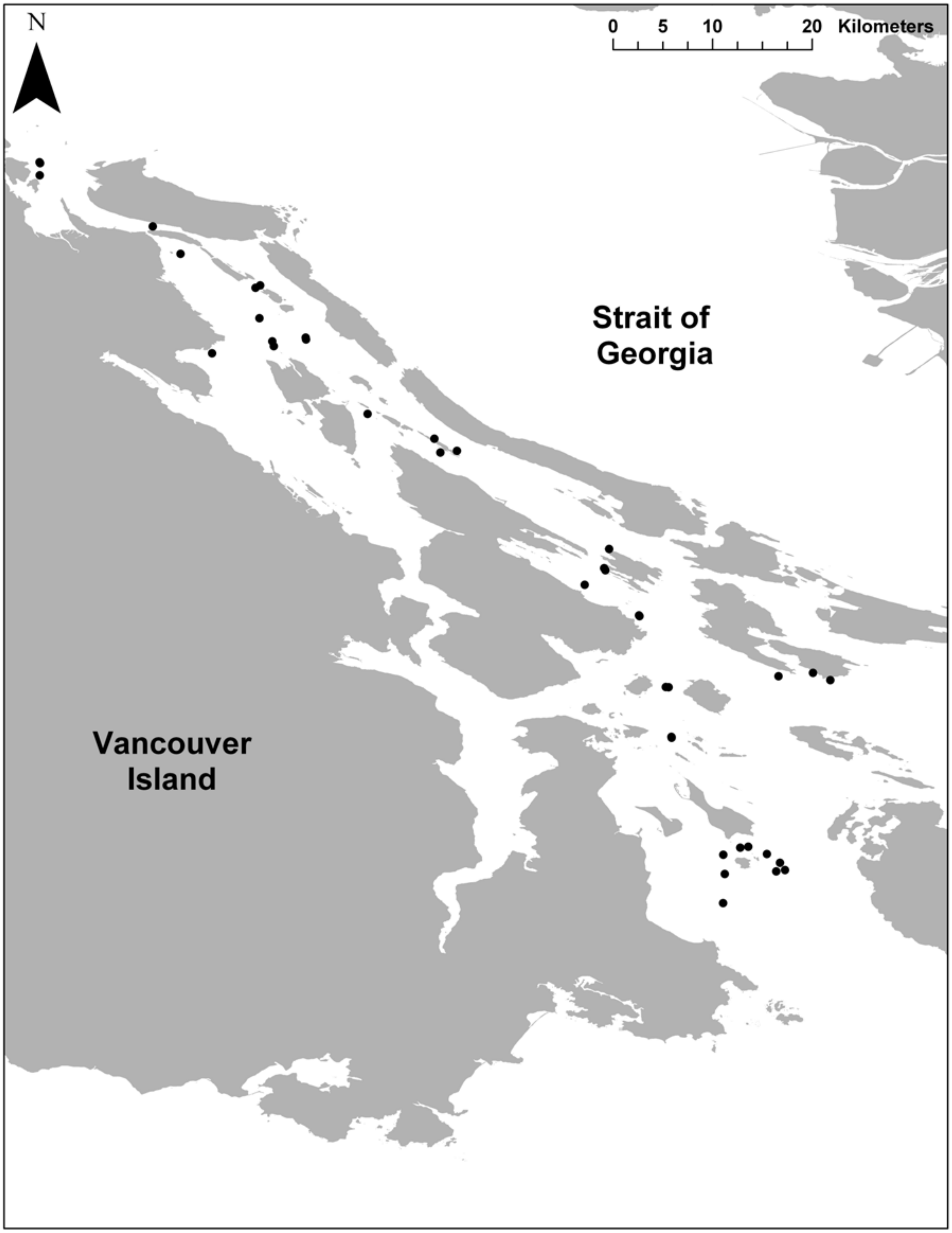


Figure 21. Locations of the *CCGS Neocaligus* towed camera transects surveyed in June 2003.

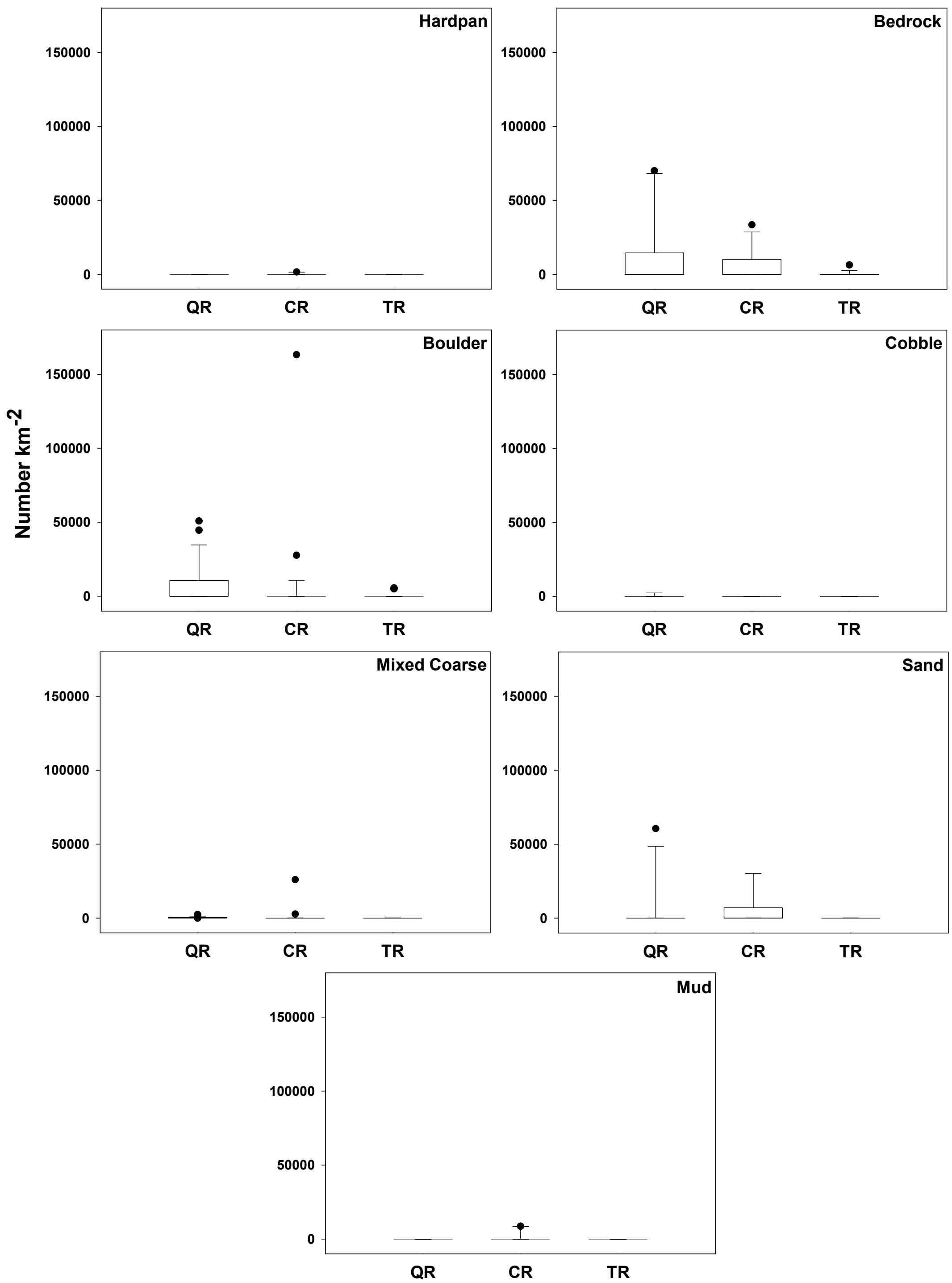


Figure 22. Mean densities by primary substrate type for quillback, copper and tiger rockfish. Yelloweye rockfish were not included as only one individual was observed over all transects. The center line through each box represents the median calue while the 1st and 3rd quartiles are indicated by the upper and lower limits of each box. Whiskers above and below each box indicate the 10th and 90th percentiles and individual outliers are plotted.

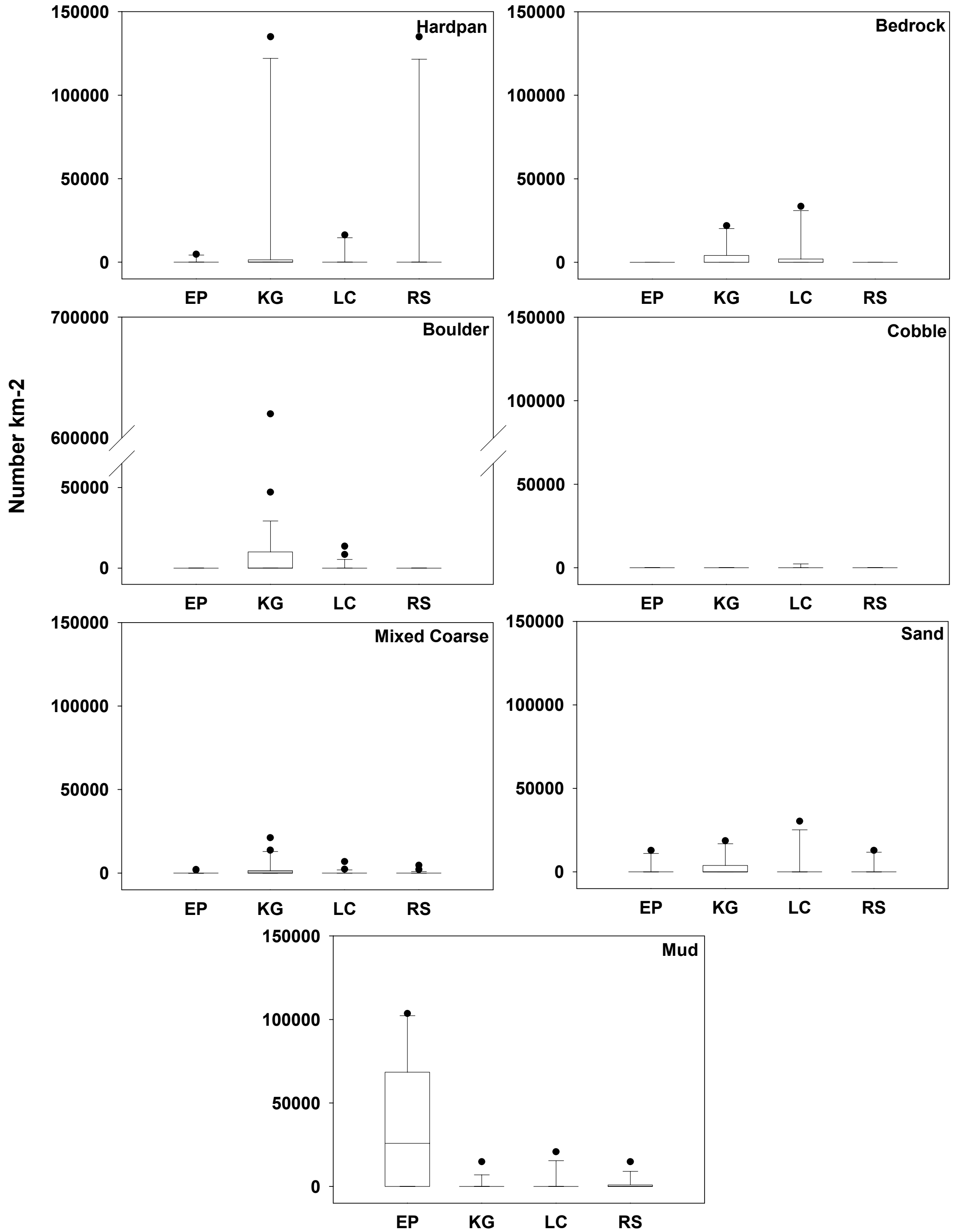


Figure 23. Mean densities by primary substrtate type for the four most common non-rockfish taxa encountered. Gravel is not included as no fish were observed over that substrate. The center line through each box represents the median cpue while the 1^{nd} and 3^{rd} quartiles are indicated by the upper and lower limits of each box. Whiskers above and below each box indicate the 10^{th} and 90^{th} percentiles and individual outliers are plotted.

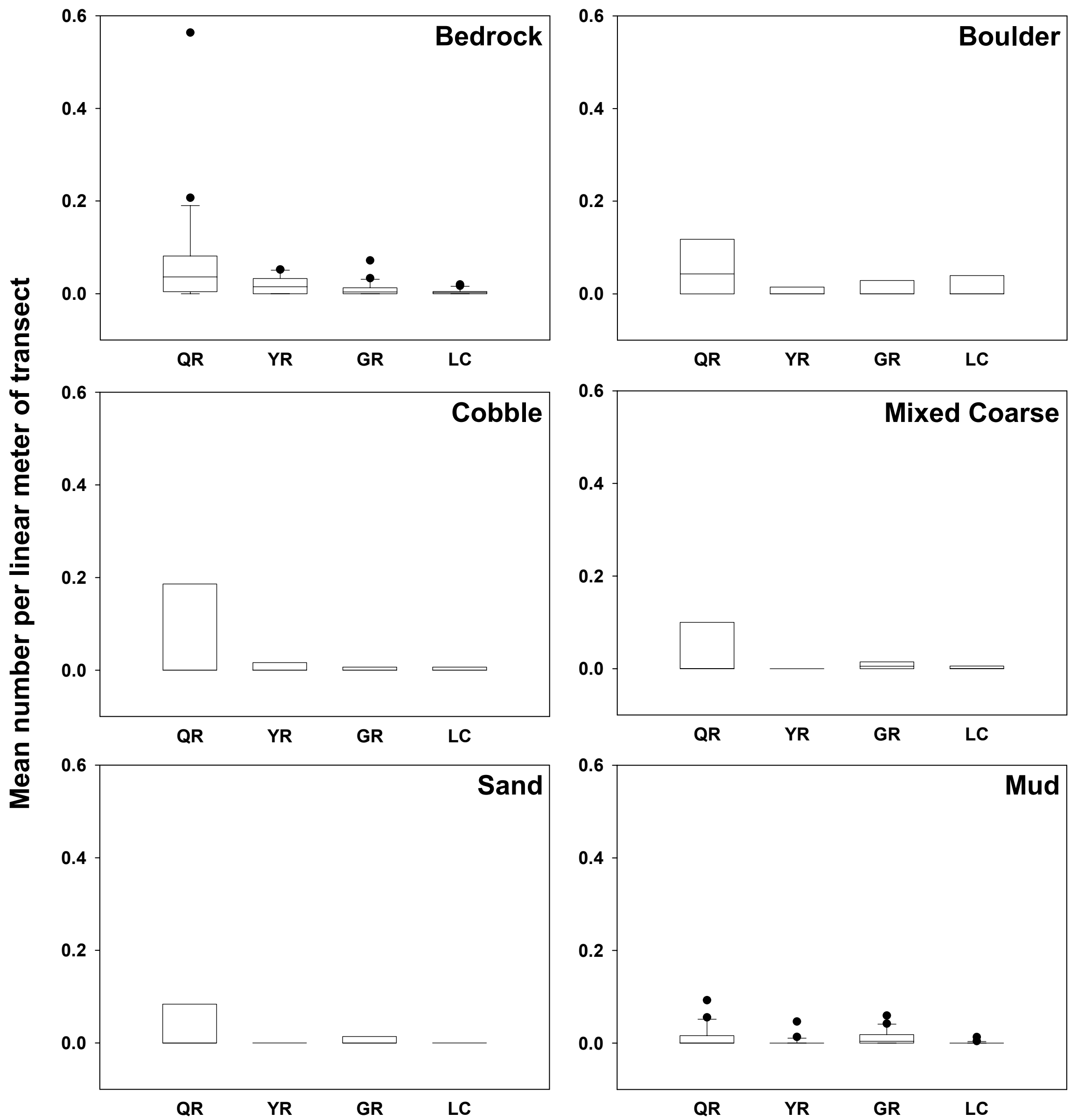


Figure 24. Mean number of quillback (QR), yelloweye (YE) and greenstriped (GR) rockfishes and lingcod (LC) per linear meter of transect by primary substrate type for the 2003 *Aquarius* submersible survey. The center line through each box represents the median value while the 1st and 3rd quartiles are indicated by the upper and lower limits of each box. Whiskers indicate the 10th and 90th percentiles (where sufficient observations allow calculation) and each individual outlier is plotted. Hardpan and gravel substrates were not included as no fish of these species were observed over these substrates.

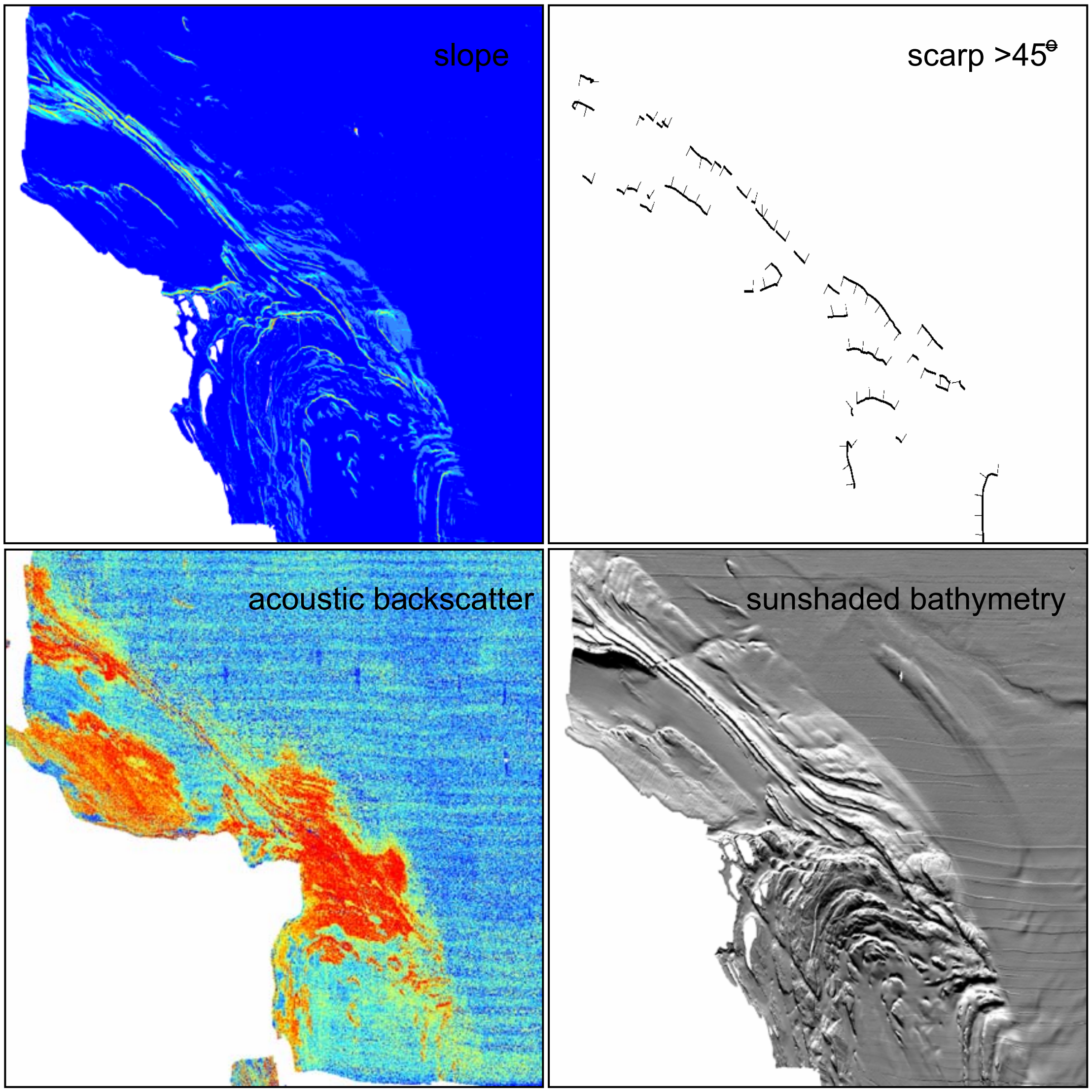


Figure 25. Multibeam acoustic bathymetry and backscatter data used to construct a habitat map for the Gabriola Pass area of the Strait of Georgia. Slope analysis is used to identify scarps (high relief areas), backscatter data shows highly reflective rock areas in red.

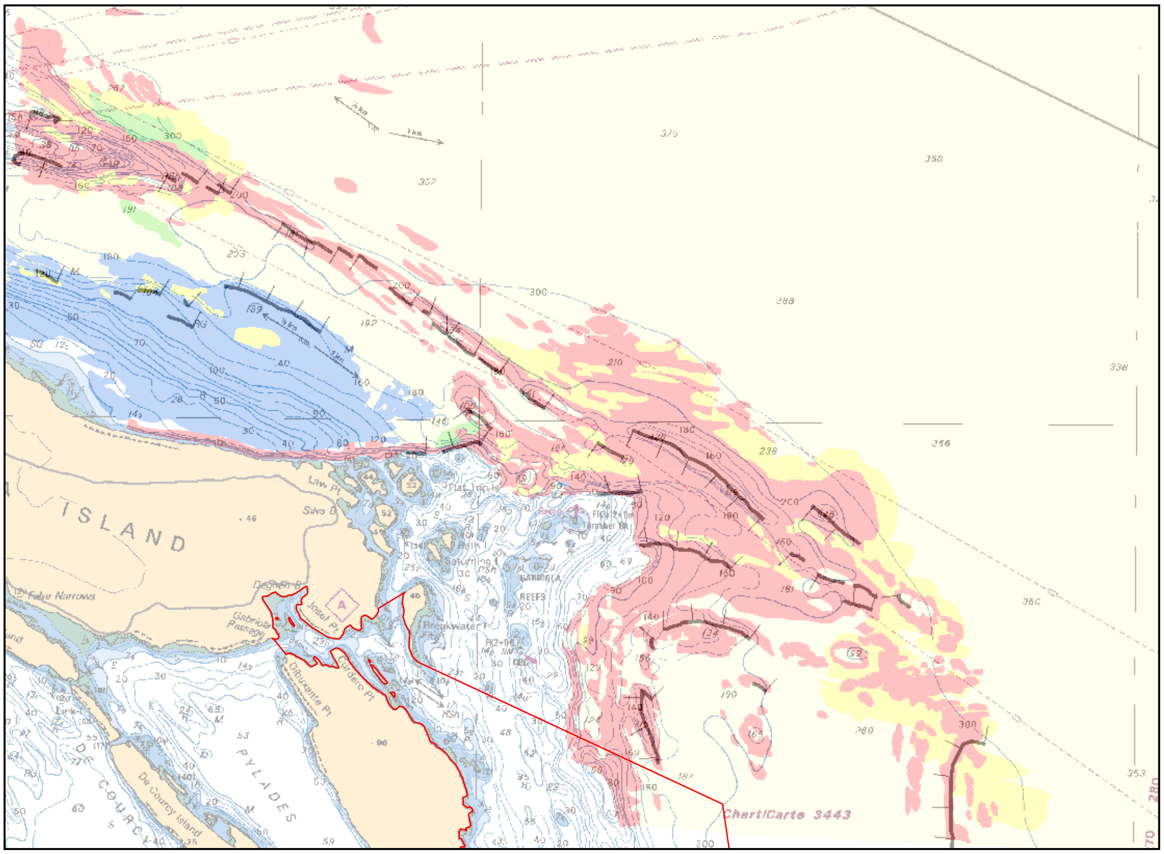


Figure 26. Habitat map for the Gabriola Pass area overlain on the nautical chart, showing scarps (black lines), bedrock areas in red, till and glacial marine sediment areas in blue, sponge areas in purple and sand and mud areas in shades of yellow.

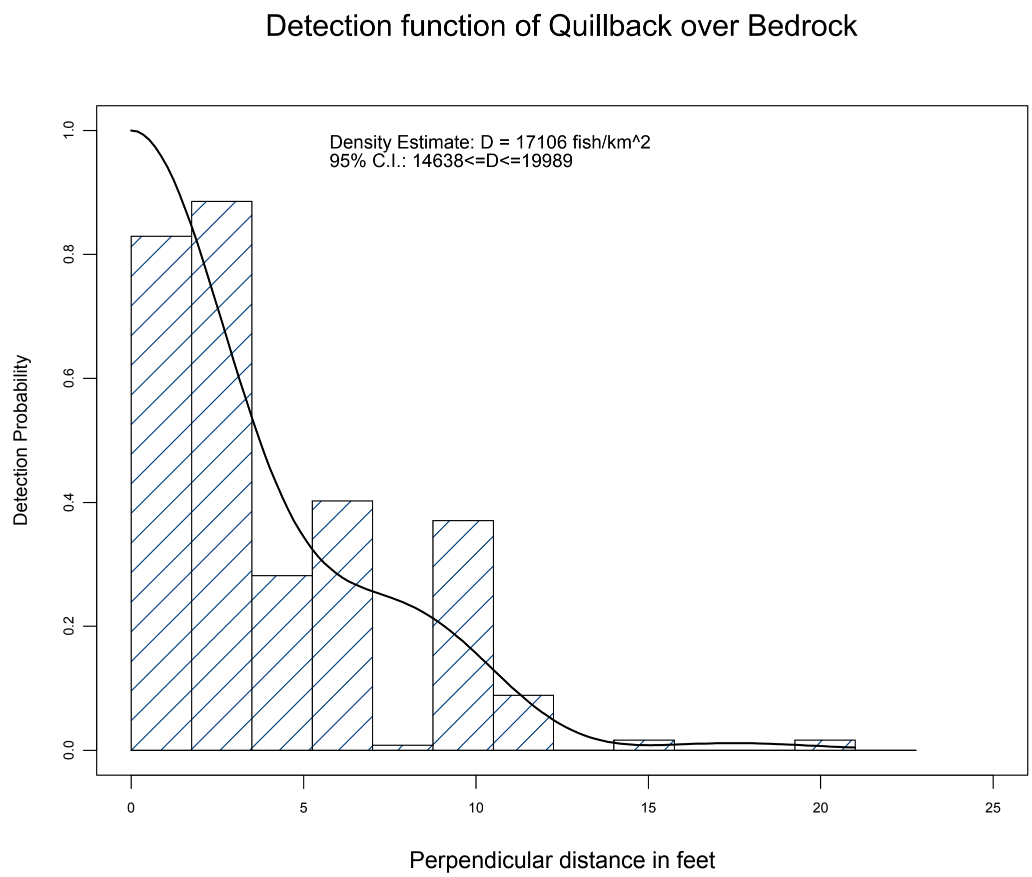


Figure 27. Detection function for quillback rockfish over bedrock habitat from preliminary data collected on *Aquarius* transects conducted in the Strait of Georgia 2003.

Appendix A.

DHALIWAL ANNOUNCES STRONG COMMITMENT TO REBUILD AND PROTECT ROCKFISH STOCKS

NR-PR-01-118E December 14, 2001

Vancouver – The Honourable Herb Dhaliwal, Minister of Fisheries and Oceans and MP for Vancouver-South Burnaby, today announced that strong measures for rebuilding rockfish stocks will be put in place by April 2002 to protect these populations for future generations, particularly for the Strait of Georgia and Johnstone Strait.

Scientific data reveal that rockfish populations are declining. In addition, a recent Pacific Scientific Advice Review Committee (PSARC) report confirmed that, despite the introduction of some conservation measures, improvements are not evident and more restrictive measures are needed. Given that rockfish live more than a 100 years, have a low productivity and mature slowly, rebuilding these stocks takes a long time and must be carefully managed.

"Significant declines in these populations, coupled with the low productivity rate for these stocks, requires urgent attention and the introduction of conservation restrictions that will reverse declines and ensure stock rebuilding is secured. Achievement of this objective requires a harvest rate of less than two per cent," Mr. Dhaliwal said.

"Over the coming weeks, my officials will be consulting with commercial and recreational fishers, First Nations and other interested stakeholders to develop a plan that will achieve this target. We need to work together to protect these stocks and the measures we introduce must be able to achieve this target."

Specific measures that will be considered include the closure of directed rockfish fisheries, reduction of rockfish by-catch, establishment of closed areas for fishing, improvements to catch monitoring and increased stock assessment. Extensive rockfish habitat areas will be closed to all fishing to provide a buffer against scientific uncertainty and existing catch data gaps, and for the essential protection and rebuilding of rockfish stocks. These measures are also expected to provide needed protection for lingcod stocks.

The life history and biological characteristics of rockfish and lingcod also make stock assessment difficult. Many stock assessment tools used in other fisheries cannot be applied to rockfish and lingcod. To better understand these fish and their distribution, Fisheries and Oceans Canada will increase its current information base on this species. A stock assessment framework for inshore rockfish is expected to be developed by December 2002. Increased catch monitoring programs will be necessary to assist in providing stock assessment data and enable assessment of harvest rates.

In November 2001, a multi-disciplinary workshop on inshore rockfish was held in Nanaimo. There was wide consensus on the importance of developing and implementing conservation measures to protect these groundfish species. The details of these measures, including specific locations, size, and timing of potential closed areas, will be determined through a consultative process throughout the Winter/Spring, 2002.

The department is committed to ensuring the sustainability of British Columbia's groundfish fisheries. With input from harvesters and other interests, appropriate management measures will be put in place to protect and rebuild these species of concern in order to provide sustainable benefits for Canadians in the future.

"I wish to emphasize the importance I attach to rockfish conservation. I am hopeful that the department's consultation process will result in agreement on a suite of measures, by this April, which will meet the target of less than two per cent harvest rate. If this is not the case, I am prepared to unilaterally impose the necessary management measures by April 2002," Mr. Dhaliwal added.

Appendix B.
INSHORE ROCKFISH MANAGEMENT GOALS

BG-PR-02-005E May 27, 2002

Outlined below are the components of the inshore rockfish conservation strategy that are being implemented in 2002.

1. Rockfish conservation areas will be expanded to protect rockfish habitat. They will provide a buffer against scientific uncertainty, and for the essential protection and rebuilding of rockfish stocks. Rockfish conservation areas will be most extensive in the inside waters (Strait of Georgia and Johnstone Strait) where science indicates that stock declines have been most precipitous. A first set of expanded conservation areas will take effect in mid to late June, and following consultations, a full slate of rockfish conservation areas will be established for the 2003 fishing season. Details about these conservation areas will be released shortly.

2. Fishing mortality will be substantially reduced. Current estimates of harvest rates are six per cent for the inside waters and four per cent for the outside waters. To reduce harvest rates to the precautionary sustainable harvest rate of less than 1.5 per cent requires drastic reduction of directed rockfish harvest and of rockfish by-catch levels in the inside waters and significant reductions in the outside waters.

   On December 14, 2001, Fisheries and Oceans Canada stated that a harvest rate of less than two per cent was necessary to reverse declines and ensure stock rebuilding of inshore rockfish stocks. A recent Pacific Scientific Advice Review Committee report recommends that a sustainable fishing mortality rate for inshore rockfish species must be less than 0.75 of the natural mortality rate. Natural mortality rate has been conservatively estimated to be two per cent. A sustainable fishing rate for inshore rockfish must therefore be 1.5 per cent or less.

3. Comprehensive catch monitoring programs will be established that will allow for an accounting of all significant inshore rockfish catch (retained and released). In 2002, significant increases in catch monitoring levels are being implemented in many fisheries.

   Commercial fishery monitoring tools will include increased number of fishery observers, use of experimental camera technology, dockside monitoring, logbook data and biological sampling at landing sites. Improvements to the coverage of recreational creel surveys are being developed, and consultations are currently on-going with First Nations to develop or improve catch monitoring programs. Catch monitoring standards as outlined in Fisheries and Oceans Canada's framework entitled *Pacific Region Fishery Monitoring and Reporting Framework* will be developed for the 2003 fishing season and may be fully implemented by the following year.

4. A stock assessment framework for inshore rockfish will be developed by December 2002. Complementary stock monitoring programs, which will include the collection of abundance and biological data, will be developed in consultation with and participation of commercial and recreational harvesters and First Nations. This framework will enable the Department to more accurately assess rockfish abundance and evaluate the progress toward rebuilding objectives.

Appendix C.
Request for Working Paper

Date Submitted: 17 March 2004

Individual or group requesting advice: Groundfish Management Unit

Proposed PSARC Presentation Date: May 2004

Subject of Paper: Stock assessment framework for Inshore rockfish

Lead Author: Lynn Yamanaka

Fisheries Management Author(s): Kim West

Rationale for request:

In 2002, a comprehensive plan to address a conservation concern for inshore rockfish was implemented in B.C. The plan covers four areas under the fisheries management and stock assessment regime: a) protect a part of inshore rockfish populations from harvest through the use of rockfish conservation areas, b) collect information on total fishery mortalities through improved catch monitoring programs, c) reduce harvests to levels that are less than the estimates of natural mortality (ie. less than 2%), and d) improve the ability to assess the status of inshore rockfish populations and monitor changes in abundance.

Information on inshore rockfish populations is required to address the following objectives: monitor changes in relative abundance, and provide support for development of fisheries conservation-based management strategies.

Preparation of a stock assessment framework is requested to provide a detailed outline of scientific monitoring and assessment plans for inshore rockfish necessary to address the objectives and elements of the conservation strategy cited above. Detailed survey designs for monitoring and assessment will be based on the framework.

Questions to be addressed in the Working Paper:

1. What is known about the biology and abundance of inshore rockfish in B.C.
2. What methods of monitoring are required to measure changes in relative abundance over time of inshore rockfish populations in B.C.
3. What research activities are required to support assessment and monitoring of inshore rockfish in B.C.

Objectives of Working Paper:

1. Outline historical fishery and abundance trends of inshore rockfish.
2. Outline current biological information on inshore rockfish.
3. Provide survey methods and considerations for survey design for monitoring and assessing the relative abundance and biological parameters of inshore rockfish.
4. Provide recommendation for survey and research requirements on a priority basis.

Stakeholders Affected:

As the inshore rockfish range is coast-wide and the depth distribution varies from 0-300 meters, multiple stakeholder groups are affected.

How Advice May Impact the Development of a Fishing Plan:

The advice is critical for development of fishing plans.

Timing Issues Related to When Advice is Necessary:

The advice is required to provide on-going assessments of performance measures of the fishing plan (ie. quotas, fishery mortality rates, rockfish protection areas, catch monitoring standards) and support development of a fisheries management framework (ie. biological reference points, rebuilding targets, and timeframes)

Approved:

Science Manager: ________________________________;

Date:_______________________

Fisheries Manager: ______________________________;

Date:_______________________