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Summary of Results of the 2003 Queen Charlotte Sound Bottom Trawl Survey

Sommaire des résultats du relevé au chalut de fond effectué en 2003 dans le bassin de la Reine-Charlotte

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Abstract

This document summarizes the general methods and results from the 2003 groundfish bottom trawl survey in Queen Charlotte Sound and southern Hecate Strait. The survey conducted 239 useable tows in depths of 50-500 m from July 3-August 9 on board the F/V Viking Storm. The survey was jointly conducted and funded by the Canadian Research and Conservation Society, and Fisheries and Oceans Canada. The objective of this year's survey was to examine its capability to provide long-term indices of relative abundance for fish species affected by bottom trawling, primarily in the survey area.

Results indicate that if the survey were repeated in its current design it could meet its primary objective and would cost approximately $312,000/y. It will also provide a research platform that will contribute essential biological samples, and oceanographic information. The document recommends that the survey be continued for the planned three years with minor modifications that will be identified with additional analyses of the 2003 results. The additional years will provide insight into the magnitude of the interannual process error and thus be used to determine the optimal frequency of the survey.

Résumé

Ce document résume les méthodes et les résultats du relevé au chalut du poisson de fond réalisé en 2003 dans le bassin de la Reine-Charlotte et le sud du détroit d'Hécate. Dans le cadre du relevé, le navire de pêche F/V*Viking Storm a* effectué 239 traits de chalut utilisables, à des profondeurs de 50 à 500 m, du 3 juillet au 9 août. La Canadian Research and Conservation Society et Pêches et Océans Canada ont réalisé et financé conjointement le relevé. Cette année, le relevé avait pour objectif d'examiner sa capacité de fournir des indices à long terme de l'abondance relative d'espèces de poissons touchées par le chalutage de fond, principalement dans la région du relevé.

Les résultats indiquent que si l'on répétait le relevé selon son plan actuel, il permettrait d'atteindre son objectif principal et coûterait environ 312 000 dollars par année. Le relevé constituera une plate-forme de recherche qui fournira des échantillons biologiques essentiels et des données océanographiques. Le document recommande de poursuivre le relevé durant les trois années prévues en y apportant de légères modifications qui seront précisées à la suite d'analyses supplémentaires des résultats de 2003. Les années de relevé supplémentaires permettront d'estimer l'erreur de méthode d'une année à l'autre et d'ainsi déterminer la fréquence optimale du relevé**.**

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Introduction

A previous working paper (Sinclair et al. 2003) recommended further development of fisheries independent, relative abundance indices using bottom trawl surveys in British Columbia (B.C.) waters. It presented an analysis predicting that a coastwide sampling density of 1,000 bottom tows would provide adequate estimates of relative abundance over time to support stock assessment for a majority of the groundfish species affected by trawling. However, the report emphasized that these benefits would only accrue over the longer term (10-20 y). The precision would be too low to accurately characterize modest changes in abundance over short periods for most species.

The document concluded that this approach should be initiated for most of the B.C. coast not currently covered by other surveys. As an interim step, it recommended that a pilot survey be conducted in a reduced area, at the same spatial sampling intensity, to verify the predicted precision. Furthermore it recommended that this survey should be conducted in PMFC major areas 5A and 5B (Queen Charlotte Sound: QCSd). This area was recommended for a number of reasons. Firstly, it was not covered by an existing bottom trawl survey. Secondly, this area represents a significant portion of the bottom trawl fishery. Thirdly, the large proportion of trawlable bottom in this area would allow the survey to cover the full spectrum of commercial species in the 50-500 m depth range. Finally, as the central region of the coast, it would be a useful starting point for building relative indices for tracking abundance and collecting samples of relatively minor species that might be affected by trawling but without commercial value.

The Pacific Scientific Advice Review Committee (PSARC) and the Regional Management Executive Committee (RMEC) accepted these recommendations. In February 2003, the Canadian Groundfish Research and Conservation Society (CGRCS) committed to funding the vessel and net costs, and a significant portion of the staffing costs needed to conduct the survey and analyze the results. The Science Branch of Fisheries and Oceans Canada (DFO) committed to funding additional scientific staff, and to provide the scientific sampling equipment.

Final design details were approved in May and the survey was conducted from July to August of 2003. This document summarizes the general methodology, results and costs of the 2003 survey, and comments that it appears to be a cost-effective means to provide adequate relative abundance indices of groundfish stocks in the survey area. Full results and methodology will be published under separate cover. If the survey is to be continued, a more detailed analysis will be conducted in early 2004 to fine-tune the design and the on-board activities.

Methods

General survey outline

The survey was conducted aboard the commercial stern trawler, F/V *Viking Storm*, from July 3 to August 9. Mid to late summer was chosen to ensure that the winter to summer movements of the fish had stabilized and to take advantage of better weather. The personnel consisted of the fishing captain, four deckhands and five scientific staff. The survey was conducted in four legs of eight, 11, 11 and eight days.

Fishing Design

The study area extended from 50-500 m in bottom depth. It did not include inlets and enclosed waters on the eastern borders of QCSd (Figure 2). The southern boundary extends from Hope Island in the southeast corner at the entrance of Queen Charlotte Strait to Cape Scott, and then follows Cape Scott Islands to 50° 52′ N, then west to 500 m. The western boundary continues to the northwest from 50° 52′ N following the 500 m contour off the west coast of Queen Charlotte Islands to include 52° 20′ N (the new Moresby Gully Pacific ocean perch boundary part way up the west coast of the Queen Charlotte Islands). The northern Boundary cuts across Hecate Strait at 52°40′ N.

We moved north from the 5B-5C boundary to be approximately contiguous with the southern extent of Hecate Strait Assemblage survey. It thus includes the South Moresby grounds (Oil Drum, Hippa Spot), Ramsey Island, and NW Middle Bank. We have excluded the protected sponge reefs and the hook-and-line rockfish closed areas near Cape Scott and Cape St. James (Figure 2). The overall survey surface area (50-500 m) is about 28,308 km^2 (Table 1).

Most of the survey, excluding the southern Hecate Strait portion area falls within Major Areas 5A and 5B. In 2003, total groundfish catches (excluding Halibut) were about 18,000 t with Pacific ocean perch the dominant species.

Pacific ocean perch	4,382.3
Arrowtooth flounder	1,942.8
Yellowmouth rockfish	1,485.7
Yellowtail rockfish	1,329.0
Widow rockfish	1,178.6
Lingcod	1,071.9
Big skate	1,049.9
Rock sole	770.0
Redbanded rockfish	660.7
Silvergray rockfish	546.7
Other species	3,883.9
Total	1,8301.4

We used a sampling target of 240 tows for the proposed area under allocation scheme five from Sinclair et al. (2003). This target is less than the 400 tows recommended. Noting that DFO-Groundfish staff conducted 11 other surveys in 2003, we concluded that the 400 tows was not a sampling effort we could hope to sustain nor a sampling density we could hope to extend to other areas. We also concluded that the marginal improvement in precision of adding 160 more tows would not justify the expense. Since sample precision increases with $\sqrt{n}$, increasing from 240 tows to 400 tows would improve sampling precision by only 30%. Furthermore, assuming an additional process error CV of 0.2 (Francis et al. 2003), the marginal gain would be less than 30%. We used the depth strata recommended in Sinclair et al. 2003, namely:

$50 \text{ m} < D \leq 125 \text{ m}$ (27 fm– 68 fm)
$125 \text{ m} < D \leq 200 \text{ m}$ (68 fm –109 fm)
$200 \text{ m} < D \leq 330 \text{ m}$ (109 fm–180 fm)
$330 \text{ m} < D \leq 500 \text{ m}$ (180 fm–273 fm)

We used two spatial strata (one interior boundary) separated by Mitchell's and Reed Troughs (Figure 2). This separates a core Queen Charlotte Sound area, including Cape Scott Bank and Goose Bank from a southern Hecate Strait/Cape St. James/Middle Bank area. The size and importance of these two regions appear congruent with the northern Hecate Strait region covered by the Hecate Strait Assemblage study. Species are more mixed in the southern portion; the northern portion tends to be dominated by rockfish (Figure 2). We therefore have eight strata within the QCSd Survey. Using the gullies to bound zones is a poor decision for deeper, gully-dwelling creatures like Pacific ocean perch, but more appropriate for the shallower species. For example, rock sole populations are more likely to conform to the banks than the gullies.

We used Option Five allocation strategy by depth (Sinclair et al. 2003). This allocation scheme is influenced by the variance in total catch in the commercial tows as follows:

> "The fifth allocation scheme requires an additional analysis from historical data, in which all biomass is treated as if it were one species. This gives estimates of the parameters θ_{hs} for a hypothetical species s composed of all fish biomass captured by the tows under consideration" (Sinclair et al. 2003: p7).

This choice contradicted the recommendation in the earlier document to weigh by area of the strata (Option Two). We chose Option Five to shift the focus to areas that are fished more intensively, and to provide more observations on rockfish species, which tend to exhibit more variable catch rates. From Fig. 9 of Sinclair et al. 2003, it was apparent that Option Five is superior for the deeper rockfish species at the expense of shallower non-rockfish species. The main effect was to allocate a few tows away from the shallow stratum to the two intermediate depth strata (Figure 3).

Selection of blocks, tow definition and tow location

The sampling element was defined as a 4 km^2 block. Figure 4 shows the initial random selection of 240 blocks following the weighted selection strategy outlined above. We anticipated having to reject blocks owing to untrawlable bottom, therefore we selected an additional 80 secondary blocks, in advance, to be used to replace rejected original blocks. The protocol was to choose the nearest secondary block to the rejected primary block in the same stratum. Near the end of the survey through a combination of using up all secondary tows in some strata, and having to make pragmatic choices in order avoid excessive travelling time, we adopted an ad hoc-random approach. In this case, as we rejected a block, we identified from the same stratum the nearest polygon (10-20 blocks) of trawlable blocks as identified by the fishing skipper. We then chose, at random, a replacement from within that polygon.

Fishing commenced at sunrise and finished before sunset (approximately 0600-2130). For each tow, sensors in the net recorded depth, temperature, door spread, headrope height, and degree of bottom contact, at 1-second time intervals. Redundant records of location and net mensuration were manually recorded at approximately 5-minute time intervals in the wheelhouse, as was the time of winch release and lockup. We also collected temperature at depth using a SEABIRD 39 temperature/depth probe attached near the headrope.

Target tow length was 20 minutes on bottom with minimum on-bottom duration of 15 minutes. At least half of the bottom-time of the tow had to be within the block, and the tow was to follow the depth contours and pass through the centre of the block, if possible. The fishing scope (amount of trawl warp deployed) was at the discretion of the captain. If the net hung up after 15 minutes, the tow was still considered useable, as long as the net was retrieved quickly and without significant damage. If a hang-up occurred earlier than this, the tow was rejected and the survey block was either re-attempted or rejected. Some blocks were rejected prior to fishing, when the fishing captain deemed the block to be untrawlable based on sounder information and prior knowledge. All rejected blocks were replaced by alternates. In total, 253 survey tows were attempted. Fourteen tows had to be aborted. Second attempts to fish the same block, and in one case three attempts, succeeded in providing useable tows for four of the 11 blocks.

The catches from 233 of the 239 useable tows were completely sorted and weighed to species. The total catch in six large tows (> 1,500 kg) was estimated by the skipper. We then sorted and weighed the total catch of all species except the dominant species, which was estimated by subtraction. Between tows, we sampled as many species as possible, some for length/sex/maturity and some for length/sex/maturity/age. No other specialty sampling or activities were conducted during the survey.

Choice of species to sample was ad hoc. We attempted to sample all the dominant species in the tows plus additional species that were considered higher priority (i.e., lingcod, bocaccio, Pacific cod). If the survey is continued, we plan to use the results of 2003 to provide a more rigorous basis for selecting samples. This will include a review of the objectives of the sampling with respect to the purpose of this survey as well as the overall needs for groundfish research.

Estimation of survey relative errors in estimating catch density

We estimated survey precision by calculating the coefficient of variation (CV) around the estimates of biomass. The swept area biomass estimates were determined as the catch rate per swept area expanded by the total area in each stratum. The area covered by each tow (swept area) was calculated as the mean doorspread (the distance between the trawl doors) multiplied by the distance that the vessel travelled during the tow. Doorspread measures were obtained electronically from sensors and were recorded throughout each tow at one-second time intervals. The distance travelled during each tow was determined using the Great Circle Distance (GSD) formula with latitude and longitude obtained from GPS and recorded at one second time intervals. Details of the GCD calculation can be found at http://mathworld.wolfram.com/GreatCircle.html.

The observations were analysed using the following equations. The biomass in any year *y* was obtained by summing the product of the CPUE and the area surveyed across the surveyed strata *i* for each species *s*:

$$B_s = \sum_i C_{s_i} A_i = \sum_i B_{s_i} \qquad \textbf{Eq. 1}$$

where C_{s_i} = mean CPUE density (kg/km^2) for species *s* in stratum *i*

A_i = area of stratum *i* (km^2), and

B_{s_i} = estimated biomass of species *s* in stratum *i*.

The variance of the survey biomass estimate V_{B_s} for species *s* is calculated in kg^2 as follows:

$$V_{B_s} = \sum_i \sigma_{s_i}^2 A_i^2 / n_i \qquad \textbf{Eq. 2}$$

where $\sigma_{s_i}^2$ = variance of CPUE (kg^2/km^4) for species *s* in stratum *i*

n_i = number of tows in stratum *i*

CPUE $\left(C_{s_i}\right)$ was calculated as a density in kg/km^2 by

$$C_{s_i} = \frac{\sum_{j=1}^{n_i} \left(W_{s_i j} \middle/ D_{ij} w_{ij} \right)}{n_i} \qquad \textbf{Eq. 3}$$

where $W_{s_i j}$ = catch weight (kg) for species *s* in stratum *i* and tow *j*
D_{ij} = distance travelled (km) by tow *j* in stratum *i*
w_{ij} = wingspread width (km) for tow *j* in stratum *i*
n_i = number of tows for stratum *i*

The CV for each species s was calculated as follows:

$$CV_s = \frac{\sqrt{V_{B_s}}}{B_s} \qquad \textbf{Eq. 4}$$

Five thousand bootstrap replicates with replacement were made on the survey data to estimate bias corrected 95% confidence regions for each survey species (Efron 1982).

Estimation of relative errors in commercial catch rates

For a comparison of survey CVs with the CVs one could predict from commercial catch information, we used the method described by Schnute and Haigh (2003) as was used to design this survey (Sinclair et al. 2003). This model is derived from a compound binomial/gamma distribution. The binomial component is used to accommodate the large proportion of zero catches that are typical of research trawl surveys. This distribution is defined in terms of three parameters: p_{s_i}, the proportion of zero tows in stratum *i* for species *s*; μ_{s_i}, the mean density (kg/km^2) of the non-zero tows in stratum *i* for species *s*; and ρ_{s_i}, the coefficient of variation of the non-zero tows in stratum *i* for species *s*.

The Schnute and Haigh (2003) model then uses these three input parameter values to calculate biomass and variance predictions for each stratum and for the entire survey, given a specified allocation of tows n_i and an area A_i for each stratum and an underlying compound binomial/gamma distribution. First, the quantities δ_{s_i} and ν_{s_i} are calculated for each species *s* in stratum *i*:

$$\delta_{s_i} = (1 - p_{s_i})\mu_{s_i}$$
$$\nu_{s_i} = 1 \big/ \rho^2 \qquad \textbf{Eq. 5}$$

The biomass for species *s* in stratum *i* is then:

$$B_{s_i} = \delta_{s_i} A_i \qquad \textbf{Eq. 6}$$

and $\sigma_{s_i}^2$, the variance associated with the CPUE for species *s* in stratum *i* is:

$$\sigma_{s_i}^2 = \left(1 - p_{s_i}\right)\left(1 + \nu_{s_i} p_{s_i}\right) {\mu_{s_i}^2}\big/{\nu_{s_i}}, \qquad \textbf{Eq. 7}$$

The total biomass, variance and CV for species *s* using the tow allocation scheme $n_1 \ldots n_j$ and the areas $A_1 \ldots A_j$ for *j* strata can then be calculated using equations 1, 2 and 3.

Values for p_{s_i}, μ_{s_i}, and ρ_{s_i} were calculated for each of the 24 species examined in Sinclair et al. 2003 and based on commercial catch information for tows conducted in each aerial stratum between 1997 and 2002 at each of the four depth ranges used in this survey. Because the survey aerial strata do not conform to standard DFO management units, only tows with valid latitude and longitude positions could be included. These parameter values were then combined with information on the survey area and the number of tows achieved during the 2003 QCSd survey to obtain predicted CVs. This set of parameters constitutes the data that would have been used if the method used in Sinclair et al. (2003) had been applied to the specific area surveyed in 2003.

Results

General results

From the total of 38 days, 3.25 days were required for travel at the start and end, three days were required for unloading and personnel change during the survey, 0.75¾ day was lost to equipment breakdown on the vessel, and three days were lost to weather. Our original estimate was six to seven weeks. We completed 239 successful survey tows plus three successful camera tows for a gross average of 6.4 tows/y. We averaged over nine useable survey tows/y on full fishing days.

From the total of 239 useable tows, 202 were chosen from the original set, 22 from the secondary set and 15 were chosen using the ad hoc approach. Blocks were initially assigned to depth strata based on nautical chart depths. Owing to actual placement of the tow and errors in the interpolated depths in the charts, some completed tows had to be re-assigned to different depth strata (Table 2). Each tow's depth stratum was determined as the modal stratum indicated in the SEABIRD 1-second fixes. Fishing skippers generally attempted to fish the centre of the block parallel to the depth contours (Figure 6).

Estimation of trawlable area or blocks

Since the primary blocks were chosen randomly from within each stratum, we can use the proportion deemed untrawlable to calculate the proportion of the survey area that is untrawlable. From Table 3, over 83% was shown to be trawlable. While we have few observations in some strata, these same strata represent a small proportion of the survey area, thus we can be confident that this is a reasonable estimate. Given there are 7,552 4-km^2 blocks in the survey area; we can assume that about 1,280 blocks are untrawlable. It is tempting to suggest that conducting the survey will be come more efficient, as we eliminate untrawlable blocks, however, since we only removed 40 blocks in 2003, this will take a long time.

During the planning phase, fishing skippers noted that while they could predict blocks that were likely untrawlable, they should all be examined as a few should prove fishable for 20-minute tows. This assumption was borne out during the survey.

The variability in survey estimates

The 239 useable tows captured 88 t of fish, 37% of this was Pacific ocean perch (Table 4, Appendix Table 10 and Appendix Table 11). The average fish catch in the useable tows was 377 kg (Figure 7). We recorded 105 fish species or species groups. Of these, 92 were identified to species and 13 were grouped (e.g., pricklebacks). We typically observed 10-20 species per tow (Figure 8).

We examined the precision for the original 23 species considered during the design phase (Sinclair et al. 2003) and an additional 21 species, which had at least ten observations among the 239 useable survey tows (about 4% of the total tows). Three of the species in the original list of 24 species did not meet this 10-tow criterion (shortraker rockfish: eight tows; wolf eel: three tows; and sand sole: 0 tows) but were kept, as they were part of the first list.

The estimates of survey precision and area swept biomass are summarized for the 44 species, ranked in order of precision (Table 5). For those species, which we can assume might be assessed separately by region, we have reported the results for the two spatial strata separately. Results for the same species for the entire survey area combined are provided in Table 7 and Figure 9 (see Table 6 for definition of acronyms and Appendix Table 12and Appendix Table 13 for results by area). Of the 52 population or stocks indicated in the Table 5, 14 indicate a CV less than 0.20. These populations account for about 60% of both retained and total trawl catch produced by commercial bottom trawling in the region covered by the survey. An additional 20 of these populations are associated with CV's of 0.20-0.40. Combined with the previous category, the 34 stocks account for about 80% of all retained and total commercial bottom trawl catch from the survey area.

Comparison with predictions from Sinclair et al. 2003

This comparison of sampling error predictions between those provided by Sinclair et al. 2003 and the 2003 survey results is confined to the list of 24 species developed by Sinclair et al. (2003). One species (sand sole) in the original list of 24 species was not taken at all in the survey, but this outcome was predicted in Sinclair et al (2003). Eight survey CVs were below a 20% threshold, with the CVs for 23 species ranging from 11% for arrowtooth flounder to 69% for wolf eel (Figure 9).

Only 3 of the 23 species had predicted survey CVs based on the Schnute and Haigh (2003) model within 10% of the observed CV and 13 of 23 were within 50% of the observed CV (Figure 10 and Figure 11). Eight of the observed CVs were larger than the predicted CVs while 15 were smaller. This result probably indicates that the method does not seem to consistently over- or under-predict the survey CVs.

There are eleven species for which the predicted CVs are higher than the bootstrap confidence bounds for the analytic CVs and only one where the predicted CV is below the lower limit of the bootstrap confidence bounds (Table 7) indicating that this method fails for some species. These species, for which the CVs are higher than the survey bootstrap confidence bounds tend to be species, which are either discarded or actively avoided (Pacific cod, sablefish, dogfish, arrowtooth flounder). This indicates that the CVs for these species may be inflated in the commercial data owing to the behaviour of the commercial fleet rather than to the underlying population variability and which leads to bias in the CV prediction.

Nevertheless, the results indicate that the design number of tows was probably not excessive, given that only eight of the 23 survey CVs were below the 20% threshold and only a further two more were between 20 and 30% (Table 5).This indicates that basing the design of a multispecies survey on a suite of species taken in the commercial fishery is a reasonable tool to use in situations where there are few alternative data sources.

In addition to using commercial catch rates to predict precision, one can use other surveys. For the overlapping species, results from the QCSd survey appear similar to those for the NMFS 2001 survey for the Vancouver Area (Weinberg 2001) (Figure 12). The NMFS survey CV's have been prorated from 79 tows to 239, assuming that precision is proportional to $\sqrt{n}$.

Graphical simulation

To illustrate how well the proposed survey would track a known population, we developed a simulator that uses sample size (number of tows), sampling error for each stock in the proposed survey area from the 2003 results, an estimate of process error of 0.2 (Francis et al. 2003), and a specified biomass trend (Figure 13 and Figure 14). As noted in Sinclair et al. 2003, the effective precision of a survey is actually determined by the combined effects of the sampling error, discussed at length above, and process error.

$$CV_{TOTAL} = \sqrt{(CV_{SAMPLING})^2 + (CV_{PROCESS})^2}$$

The sample error is proportional to variability among observations within one year and sample size. The process error is the additional variability added by those influences that can vary among years, excluding changes in actual abundance. This could be caused by changes in fishing power brought about by different nets, vessels or captains. It can also be caused by variation in the availability or vulnerability of the fish owing to variation in their environment from one year to the next. We have no means of estimating this component at present so have assumed a general value of 0.20 from Francis et al. 2003. It is somewhat simplistic to assume a constant $CV_{PROCESS}$; it is more likely to be proportional to $CV_{SAMPLING}$, however we cannot assess this at this time. The effect on CV_{TOTAL} for various levels of $CV_{SAMPLING}$ is shown below:

$CV_{SAMPLING}$	$CV_{PROCESS}$	CV_{TOTAL}
0.1	0.2	0.22
0.2	0.2	0.28
0.3	0.2	0.36
0.4	0.2	0.45
0.5	0.2	0.54
0.6	0.2	0.63

Each display is tailored to the presumptive stock assessment needs for a given species. Pacific ocean perch is modelled over 20 years, for the southern survey section only (Sea Otter and Reed Troughs) (n=121) with abundance increasing 5%/y. Rock sole abundance for the whole survey area (n=239), and presumably more dynamic over time, is simulated over 10 years, and we assume abundance is decreasing 15%/y. The LOWESS fit indicates how an assessment might “perceive” the biomass trajectory as opposed to the true trajectory.

The impressions these graphics provide are obviously influenced by choice of scaling, magnitude and shape of the trends, and the duration. Nevertheless they are presented to provide insight as to how survey results might “appear” as each is added to a stock assessment model. We can easily generate alternative scenarios or more examples on request. The random examples shown were the first three and were not selected.

The simulations indicate that for those species with higher precision ($CV_{SAMPLING} < 0.3$), as for Pacific ocean perch and rock sole, the survey will successfully capture general trends through time, but individual survey points will often appear anomalous. For a $CV_{SAMPLING}$ of 0.369 for canary rockfish, the general trend can still be captured, but for these species short term trends of 2-3 years can appear to be moving in opposite direction of the overall trend. For species with even lower precision, the survey may incorrectly indicate trends for up to seven years. It is clear that for the species associated with low precision, the survey will be useful only in identifying large population shifts over the long term.

Additional survey results

The survey provided 1,372 samples of over 30,000 specimens (Table 8), averaging about six species/tow. About 55% of the samples included ageing parts in addition to length, sex and maturity. The average number of pieces per sample was 20 and 25 specimens for ageing and length/sex samples respectively. This is smaller than the targeted 50 pieces per sample because many samples represented all the specimens captured in the tow.

Bottom contact reading and temperature at depth were recorded during the survey on virtually every tow. One example of how survey data could be integrated to study the sources of inter-annual variance (‘process error’) in abundance is provided in Figure 15.

Summary of costs

We estimate that the ongoing costs of the charter vessel will be about $7,250/y for an annual cost for a 6-week charter of about $304,500. The annualized costs of purchasing and maintaining two fishing trawls would be about $5,000. This estimate is based on a purchase price for two complete nets and footropes of $50,000, a depreciation of 10%/y, and net maintenance costs of $5,000/y. It also assumes that the nets will be used 50% of the time by other surveys, thus, use by the QCSd survey will account for 50% of the annualized costs. We have ignored the purchase and maintenance price of net sensors as the charter vessels will continue to use these during commercial fishing.

We estimate that the annualized cost for purchasing and maintaining scientific field equipment would be approximately $5,500. This estimate is derived by taking 6.7% of the replacement price of $83,000 for a full set (including backups) of all survey equipment (i.e., contact sensors, temperature/depth probes, motion compensating balances, automatic fish measuring boards, laptops). The 6.7% factor is derived from an estimated depreciation rate of 20%, divided by three, based on the assumption that the QCSd survey will represent 33% of the usage.

If we assume a cost of $500/y to put a scientific staff member on the survey then staffing the survey with five scientific staff for a six week cruise equals an annual cost of $21,000. Cruise preparation will require about 15 working days at $400/y equalling $6,000. Data processing after the cruise will require 40 working days at $400/y or approximately $16,000. The total costs of scientific staff will be approximately $43,000/y. We have not included the cost of analyses.

The cost estimates summarized above indicate a total annual expenditure by all participants combined of about $358,000. Funds returned by the sale of fish in 2003 equalled $45,707, therefore we can expect the annual costs of this charter in 2003 to be about $312,000.

Discussion

Was the survey an operational success?

There were no problems in conducting the survey. The proposed design of 240 tows, allocated among eight strata was completed in 38 days, less time than predicted. There were no surprise costs and little time was lost to equipment breakdown or weather. The lengths of trip legs (9-11 days) helped significantly to reduce discarding of commercially valuable catches. The majority of the grounds, over 80%, appear to be trawlable given the choice of trawl net and footrope.

The net was not only able to negotiate most of the bottom but appeared to provide an acceptable “catchability” of the main species. The net in combination with the choice of 20-minute tows provided an acceptable catch rate for most species of interest and yielded an adequate number of biological sampling opportunities. Shorter tow lengths (20 vs. 30 minutes) successfully reduced the likelihood of very large tows, produced a workable average catch, probably increased the proportion of trawlable ground, and allowed the survey to complete an extra 0.25-0.50 tows/y.

Was it a success from indexing point of view?

We do not know of an accepted standard for whether a survey provides adequate precision. Sinclair et al. (2003) proposed a target CV of 0.20. While this is a reasonable standard for considering one species at a time, the total benefit accruing from a survey must also address the number of different indices being generated. Secondly, as commented by a reviewer of Sinclair et al. (2003), a 0.20 standard might be overly rigorous for long-lived and less variable species which might only need assessment on five, ten or 15-y intervals. Assessment of these species, which vary in abundance more slowly over time, benefit from the "pooling" effect of repeated annual estimates. This in turn indicates that a CV standard is dependent on the frequency of the survey. Finally, the adequacy of a standard must also address what alternatives are available. Recent discussion involving species-at-risk issues (Stanley et al. 2003) would indicate that pertinent insight has been derived from surveys with very poor precision.

Notwithstanding the comments above, if we assume that the survey frequency will be every year or at least every two years, we suggest for discussion purposes that we assign the following descriptors for the range of observed stock CVs ($CV_{SAMPLING}$):

- "excellent" = < 0.20;
- "good" = 0.20-30;
- "adequate" = 0.30-0.40;
- "poor" = 0.40-0.60;
- "very poor" = > 0.60.

Using the above descriptors, Table 5 indicates that 240 tows in the QCSd survey can provide at least adequate precision for 34 stocks, which represent 80% of the biomass landed or captured in the study area.

We note that the above group includes numerous species/stocks associated with contentious TACs. It also includes species, such as some skates, of relevance to SARA issues. The general impression is that the survey is worth the cost, provided the added imprecision owing to $CV_{PROCESS}$ does not overwhelm the ability of the survey to track trends. We should derive insight into the $CV_{PROCESS}$ by comparing 2003 results with those to be gathered in 2004 and 2005.

The survey might be improved by re-allocating 240 tows among the existing strata, but the gain will likely be modest and only improve precision for some species at the expense of others. These issues will be examined if the survey is continued. The overall target sampling density of 240 appears appropriate. We recommend against a reduction. Furthermore, a modest increase in sampling effort will have negligible impact and not cause the survey to cross some critical precision threshold.

What additional benefits will be derived from the survey?

The large number of biological samples collected will clearly benefit groundfish research, especially in conjunction with the ongoing collection of samples from the commercial fishery. Since the survey samples would be collected from a nearly constant sampling design they are more comparable over time and possibly more representative of the actual population. The commercial samples, which are more representative of the harvested portion of the population, are influenced by spatial and temporal trends in the fishery.

As trends emerge in the relative index, the biological sampling will provide a better understanding of why the trends occur. In particular they will help distinguish between the impacts of fishing and “natural” variation in recruitment.

We demonstrated in Figure 15 the potential for collecting additional information during the survey. The accuracy of these oceanographic data is acceptable for physical oceanographic research, and these data will be appended to large-scale global oceanographic databases. They may also be useful for explaining short term anomalies in the relative abundance trends (i.e., explaining some of the process error) in future stock assessments as well as detecting ocean climate changes on the actual fishing grounds.

While we were close to working capacity in the 2003 survey, we expect to modestly expand survey activities and take better advantage of the research platform provide by this survey. This could include specialty sampling such as obtaining genetics samples or tagging. We note however, that the ability to multi-task depends on the vessel chosen for the survey.

Predictions based on commercial data and other surveys

In the process of examining the feasibility and designing a coastwide synoptic survey approach, Sinclair et al. (2003) used commercial catch and effort data to predict survey precision as well as explore alternative stratification and tow allocation models. The data collected by the 2003 QCSd survey was used to test the predictions made by Sinclair et al. (2003) and to refine the use of commercial catch and effort data in designing future bottom trawl surveys on the British Columbia coast. It is clear that commercial fishery data can be useful for drawing inference about the feasibility of survey designs especially when there are no alternative data sources.

Precision of the NMFS triennial survey in INPFC Vancouver region also appeared congruent with results of the 2003 QCSd survey. This is not surprising since the US survey targets the same depth range and has similar objectives. We can assume that the NMFS survey will be especially useful for designing a Canadian survey of the Vancouver area, off the west coast of Vancouver Island. While not presented in this document, we also briefly looked at Hecate Strait results in comparison with 2003 QCSd results. As might be expected, the shallower Hecate Strait survey provided more precise estimates for shallow-water species than did the QCSd survey, but proved less precise for the deeper species.

Absolute biomass estimates

Only 5 species registered mean bootstrap biomass estimates greater than 2,000 t, with the largest biomass levels associated with Pacific ocean perch and arrowtooth flounder (Table 5). A plot of the biomass estimates with associated bias corrected 95% confidence intervals shows proportionately wide bounds for all 44 species (Figure 16).

Not only is there considerable uncertainty around the estimates of biomass, we emphasize strongly that, at best**,** they represent minimum estimates of actual biomass. There are many assumptions involved with inferring absolute abundance from these data. Among them is the assumption that the net captures 100% (catchability=1.0) of all specimens in the total area between the doors over the length of the tow, and from the entire water column. It also assumes that the trawlable fraction of the survey area (80%) is representative of the untrawlable fraction. These assumptions are certainly untrue for most species. For many species, catchability may be less than 25% or even 1% for those species not observed in the survey catches (e.g., prowfish) or some of those represented by fewer than 10 tows (Table 11) less than 1%. Catchability will also be proportional to size within a species. For example, it can be assumed that catchability will differ between large and small halibut. By using distance between the doors and not the wingtips, it is probably reasonable to assume for most species that these biomass estimates are "minimum" estimates of biomass but it is to be remembered that actual biomass values may be orders of magnitude greater. These estimates should not be used directly and in isolation of other data to infer status of stocks relative to current harvests.

While we discourage placing confidence in the present estimates of absolute biomass, this conceptual approach could prove beneficial in a limited number of cases and will become increasingly important over time. For those species which are highly vulnerable to trawl gear and might be assumed to have catchabilities that approach 1.0, the "minimum" biomass estimates may provide some guidance during assessment. Over time, it also may be possible to estimate the catchability of some species by comparing stock assessment estimates of biomass with the swept-area estimates from this survey (Millar and Methot, 2002).

Recommendations

1. The QCSd survey should be continued as proposed for 2004 and 2005 and use the same target of 240 tows. At the end of the three years, with the added insight about interannual variance, we will be better able to assess the precision of the survey and recommend the optimal frequency within the context of an overall groundfish survey strategy (see Recommendation #4). We suggest that the provision of relative indices of these populations will greatly improve the stock assessment advice that will be provided to managers for all these populations, but caution that it will require many years for that impact to be manifest.

2. The 2003 results should be examined to determine whether a reallocation of the tows among strata will improve precision prior to conducting the 2004 survey.

3. Based on the better knowledge of the expected number of sampling opportunities and on-board sampling capability during the charter, the current ad hoc method of choosing samples should be made more rigorous to ensure comparability over time.

4. DFO in collaboration with its research partners should develop a PSARC document outlining a comprehensive, coastwide groundfish survey strategy for submission to 2004 PSARC meeting.

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Request for Working Paper

Date Submitted: October 28, 2003

Individual or group requesting advice: Science, Management and Fishing Industry

Proposed PSARC Presentation Date: December 2003

Subject of Paper:

Summary of results of the 2003 Queen Charlotte Sound Bottom trawl survey

Science Lead Author: Rick Stanley

Rationale for request:

A 5-week bottom trawl survey of Queen Charlotte Sound and Southern Hecate Strait was conducted in 2003 by Fisheries and Oceans Canada and the Canadian Groundfish Research and Conservation Society. The primary objective of the 2003 survey was to examine the feasibility of using this survey to provide long-term relative abundance indices for groundfish populations in this area. It was also expected that such a survey would provide a standardized vehicle for collecting groundfish biological samples as well as having other collateral benefits.

While there is little doubt that such a survey would assist groundfish research and management, repeating this survey at regular intervals represents a major long term commitment of groundfish research resources. Therefore there is an immediate need to examine the 2003 results and determine whether the survey should be continued and, if so, identify how the design could be improved.

Objective of Working Paper:

The primary purpose of this document is to examine whether the survey will meet its objective of providing a relative index of abundance for a suite of groundfish species/populations at acceptable levels of precision while keeping costs to a reasonable level. The second purpose of this study is to examine whether the design is optimized and what changes could be made to improve the precision. The report will conclude with recommendations for whether the survey should be continued, what the long-term costs will be, and, if it is to be continued, what major changes should be made.

Question(s) to be addressed in the Working Paper:

1. What will be the expected precision in the relative abundance indices for each groundfish species/population monitored by this survey?
2. With respect to precision, does the survey appear to be capable of meeting the intended stock assessment and groundfish management objectives?
3. Can the survey be modified to improve precision without increasing costs?
4. Was the survey design followed during the execution of the survey?
5. What were the costs of the survey and what are the implications of these costs to meet the survey objectives?
6. What additional benefits will the survey provide?
7. Should additional activities be added to the survey?
8. Should the survey be continued and at what frequency?

Stakeholders Affected:

This survey is intended to provide trends in abundance and biological composition for all groundfish species vulnerable to bottom trawl, which inhabit depths of 50-500 m, in the central region of the coast. It therefore will provide critical assessment information for virtually all exploited groundfish stocks in this area. Additionally, since the survey covers a large portion of the central B.C. coast, it will be used to index coastwide abundance for those species that lack spatial structure or those for which the stock structure is unknown. The latter group of species has particular relevance with respect to SARA-related issues.

Therefore, the survey should benefit all groundfish harvesters (commercial, First Nations and recreational) directly and will address a significant element of the SARA information needs as they pertain to groundfish.

How Advice May Impact the Development of a Fishing Plan:

Results of the survey will have little immediate impact on Fishing Plans. It is expected that commercial catches in the survey are too small to affect TAC or IVQ management.

Over the longer term, results of the survey will have major impact on the stock assessment advice provided prior to development of fishing plans.

Timing Issues Related to When Advice is Necessary:

The decisions on whether to proceed with this survey must be available quickly so that preparations can begin for the 2004 groundfish field season.

Table 1. Stratum designations, number of useable tows, and total area for each stratum in the 2003 Queen Charlotte Sound survey.

Stratum number	Area designation	Depth zone	Number tows	Area (km^2)
18	5AB-1	50-125 m	29	5428
19		125-200 m	56	5700
20		200-330 m	30	3136
21		330-500 m	6	556
22	5AB-2	50-125 m	6	2308
23		125-200 m	39	5120
24		200-330 m	54	4760
25		330-500 m	19	1300

Table 2. Target number of tows per stratum and actual number of tows per stratum.

Area Stratum	**Depth Stratum**	**Target Number of Sets**	**Delivered Number of Sets**	**Difference**
5AB North	1	8	5	-3
	2	42	39	-3
	3	53	54	1
	4	19	19	0
Subtotal:		**122**	**117**	**-5**
5AB South	1	26	29	3
	2	62	57	-5
	3	28	30	2
	4	2	6	4
Subtotal:		**118**	**122**	**4**
Total:		**240**	**239**	**-1**

Table 3. Number of blocks trawlable by stratum and estimates of untrawlable area by stratum.

Area Stratum	Depth Stratum (m)	Number of Blocks	Num Blocks Trawlable	Num Blocks Untrawlable	Percent Trawlable	Trawlable Area (km2)	Untrawlable Area (km2)
5AB South	50-125	26	20	6	76.9%	80	24
	125-200	60	49	11	81.7%	196	44
	200-330	28	22	6	78.6%	88	24
	330-500	3	3		100.0%	12	0
Subtotal:		*117*	*94*	*23*	*80.3%*	*376*	*92*
5AB North	50-125	8	6	2	75.0%	24	8
	125-200	42	33	9	78.6%	132	36
	200-330	53	49	4	92.5%	196	16
	330-500	20	18	2	90.0%	72	8
Subtotal:		*123*	*106*	*17*	*86.2%*	*424*	*68*
Total:		240	200	40	83.3%	800	160

Table 4. Retained, discarded, total catch (kg) and frequency of occurrence (tows) by fish species.

Species	**Retained Weight (kg)**	**Discarded Weight (kg)**	**Total Weight (kg)**	**Frequency**
Arrowtooth Flounder	167.3	7,945.7	8,113.0	212
Rex Sole	143.2	3,142.0	3,285.2	200
Pacific Ocean Perch	18,608.2	17,385.7	35,993.9	180
Dover Sole	338.5	2,426.9	2,765.4	172
Spotted Ratfish		1,637.2	1,637.2	151
Sablefish		1,975.0	1,975.0	135
Redbanded Rockfish	396.8	1,283.6	1,680.4	129
Silvergray Rockfish	487.7	2,584.2	3,071.9	127
Spiny Dogfish		2,170.0	2,170.0	126
Shortspine Thornyhead	312.3	1,400.4	1,712.7	106
Pacific Cod	77.2	797.7	874.9	104
Walleye Pollock	5.9	319.2	325.1	92
Pacific Hake		1,772.9	1,772.9	87
Flathead Sole	0.5	718.0	718.5	82
Longnose Skate		594.9	594.9	81
Rougheye Rockfish	227.3	1,323.1	1,550.4	78
English Sole	14.6	925.6	940.2	75
Petrale Sole	1.8	274.7	276.5	67
Lingcod	94.5	486.1	580.6	56
Greenstriped Rockfish	1.0	150.3	151.3	51
Redstripe Rockfish	2,919.5	483.8	3,403.3	48
Pacific Halibut		729.2	729.2	47
Sharpchin Rockfish	210.5	931.8	1,142.3	43
Yellowmouth Rockfish	169.6	2,321.1	2,490.7	40
Canary Rockfish	61.3	1,355.7	1,417.0	37
Rosethorn Rockfish	21.4	113.3	134.7	36
Rock Sole	39.1	468.2	507.3	35
Pacific Sanddab		839.7	839.7	33
Yellowtail Rockfish	689.2	565.5	1,254.7	31
Splitnose Rockfish	344.1	4,374.0	4,718.1	28
Darkblotched Rockfish	46.8	167.6	214.4	25
Yelloweye Rockfish	4.1	258.0	262.1	21
Widow Rockfish	14.6	169.9	184.5	13
Bocaccio	13.6	143.1	156.7	12
Big Skate		369.6	369.6	12
Total:	**25,410.6**	**62,603.5**	**88,014.1**	**2,772**

Table 5. Estimated survey CVs for all stocks represented in the survey observations.

Species	Stock	Minimum biomass	CVs
Rex Sole	Combined	2438.2	0.100
Shortspine Thornyhead	Combined	1034.8	0.108
Arrowtooth Flounder	Combined	6058.0	0.108
Sablefish	Combined	1149.3	0.131
Dover Sole	South	1531.1	0.136
Dover Sole	North	308.9	0.143
Pacific Hake	Combined	1193.4	0.145
Redbanded Rockfish	Combined	1094.2	0.163
Pacific Ocean Perch	South	17409.4	0.167
Walleye Pollock	Combined	268.6	0.183
Flathead Sole	Combined	564.1	0.187
Pacific Ocean Perch	North	6765.7	0.193
Silvergray Rockfish	North	1964.7	0.194
Petrale Sole	Combined	315.4	0.196
Longnose Skate	Combined	504.6	0.208
Pacific Cod	North	526.0	0.213
English Sole	South	773.3	0.229
Pacific Halibut	Combined	853.2	0.237
Lingcod	South	381.9	0.250
Rosethorn Rockfish	Combined	88.8	0.253
Silvergray Rockfish	South	639.2	0.262
Slender Sole	Combined	86.9	0.267
Rock Sole	South	676.9	0.268
Pacific Cod	South	353.3	0.278
Greenstripe Rockfish	Combined	122.9	0.278
Blackfin Sculpin	Combined	9.8	0.288
Pacific Sanddab	Combined	1185.8	0.288
Sandpaper Skate	Combined	24.4	0.312
Curlfin Sole	Combined	14.4	0.313
Blackbelly Eelpout	Combined	51.8	0.334
Eulachon	Combined	34.7	0.342
Yellowmouth Rockfish	Combined	1714.5	0.346
Canary Rockfish	Combined	1331.3	0.358
Threadfin Sculpin	Combined	9.3	0.384
Yelloweye Rockfish	Combined	256.4	0.408
Spiny Dogfish	Combined	2799.9	0.408
Rougheye Rockfish	Combined	982.9	0.436
Yellowtail Rockfish	Combined	989.3	0.442
Shortraker Rockfish	Combined	71.0	0.455
Sharpchin Rockfish	Combined	751.0	0.479
Darkblotched Rockfish	Combined	138.2	0.500
English Sole	North	377.1	0.536
Redstripe Rockfish	Combined	2828.0	0.550
Widow Rockfish	Combined	182.2	0.584
Bocaccio	Combined	137.3	0.661
Lingcod	North	543.7	0.685
Big Skate	Combined	643.5	0.690
Wolf Eel	Combined	10.0	0.704
Rock Sole	North	57.1	0.761
Splitnose Rockfish	Combined	2934.2	0.793
Spotted Ratfish	Combined	3605.1	0.815

Table 6. Acronyms for species examined for estimation of survey relative error.

Arrowtooth Flounder	ARF	Rex Sole	RXL
Big Skate	BIS	Rock Sole	ROL
Blackbelly Eelpout	BEP	Rosethorn Rockfish	RTR
Blackfin Sculpin	BSN	Rougheye Rockfish	RER
Bocaccio	BOR	Sablefish	SBF
Canary Rockfish	CAR	Sand Sole	SAL
Curlfin Sole	CUL	Sandpaper Skate	SPS
Darkblotched Rockfish	DBR	Sharpchin Rockfish	SCR
Dover Sole	DOL	Shortraker Rockfish	SRR
English Sole	ENL	Shortspine Thornyhead	SSY
Eulachon	EUN	Silvergray Rockfish	SGR
Flathead Sole	FHL	Slender Sole	SLL
Greenstripe Rockfish	GSR	Spiny Dogfish	DOG
Lingcod	LIN	Splitnose Rockfish	SNR
Longnose Skate	LNS	Spotted Ratfish	RAT
Pacific Cod	PAC	Threadfin Sculpin	TSN
Pacific Hake	PAK	Walleye Pollock	WAP
Pacific Halibut	PAH	Widow Rockfish	WWR
Pacific Ocean Perch	POP	Wolf Eel	WOE
Pacific Sanddab	PAD	Yelloweye Rockfish	YYR
Petrale Sole	PEL	Yellowmouth Rockfish	YMR
Redbanded Rockfish	RBR	Yellowtail Rockfish	YTR
Redstripe Rockfish	RSR		

Table 7. Analytic and bootstrap results for 44 species from the total 2003 Queen Charlotte Sound survey. Analytic results are presented for the biomass (Eq. 1) and the CV (Eq. 4). Bootstrap results are for 5,000 replicate samples taken with replacement. Bias corrected 95% confidence intervals are presented and the bootstrap CV is calculated relative to the bootstrap mean biomass.

Species	**Biomass (t)**	**Bootstrap mean biomass (t)**	**Bootstrap lower bound**	**Bootstrap upper bound**	**Bootstrap CV**	**Analytic CV**
Pacific Ocean Perch	24159.0	24190.8	18489.9	31086.5	0.1312	0.1302
Yellowtail Rockfish	984.7	989.3	334.6	2120.4	0.4422	0.4390
Yellowmouth Rockfish	1721.3	1714.5	764.7	3162.7	0.3460	0.3421
Arrowtooth Flounder	6069.1	6058.0	4949.4	7568.5	0.1082	0.1109
Silvergray Rockfish	2606.5	2598.7	1882.0	3550.1	0.1608	0.1607
Dover Sole	1842.5	1838.4	1470.8	2303.5	0.1152	0.1145
Lingcod	935.5	937.3	427.2	1962.5	0.4111	0.4096
Redstripe Rockfish	2833.8	2828.0	825.5	7236.2	0.5500	0.5451
Canary Rockfish	1336.2	1331.3	593.3	2504.0	0.3579	0.3620
Rock Sole	739.0	742.3	403.6	1133.8	0.2488	0.2546
Pacific Cod	878.6	879.6	619.0	1203.2	0.1688	0.1692
Petrale Sole	315.3	315.4	202.3	450.4	0.1962	0.1929
Redbanded Rockfish	1095.6	1094.2	794.3	1513.8	0.1625	0.1638
Yelloweye Rockfish	259.7	256.4	104.5	528.1	0.4078	0.4018
Bocaccio	135.7	137.3	28.8	376.2	0.6613	0.6558
Sandpaper Skate	24.2	24.4	12.7	43.0	0.3118	0.3153
Big Skate	644.6	643.5	111.3	1860.7	0.6902	0.6872
Wolf Eel	10.0	10.0	0.0	27.7	0.7041	0.6949
Spiny Dogfish	2806.1	2799.9	1153.8	5875.4	0.4080	0.4100
Sablefish	1149.0	1149.3	889.3	1485.2	0.1311	0.1274
Greenstripe Rockfish	123.2	122.9	70.9	209.8	0.2777	0.2786
Rougheye Rockfish	979.0	982.9	285.2	1929.7	0.4362	0.4298
Shortraker Rockfish	71.2	71.0	22.1	149.9	0.4547	0.4450
Rex Sole	2436.3	2438.2	1987.4	2947.9	0.0997	0.0998
Spotted Ratfish	3623.9	3605.1	580.5	12188.6	0.8149	0.7982
Shortspine Thornyhead	1034.1	1034.8	839.2	1275.2	0.1077	0.1083
Pacific Hake	1187.7	1193.4	868.9	1547.6	0.1454	0.1450
Walleye Pollock	268.5	268.6	187.0	383.6	0.1829	0.1813
Longnose Skate	505.3	504.6	358.4	781.4	0.2078	0.2031
Flathead Sole	564.3	564.1	387.7	811.5	0.1865	0.1862
Slender Sole	86.8	86.9	53.6	149.4	0.2669	0.2629
English Sole	1152.5	1148.6	724.5	1801.5	0.2341	0.2315
Pacific Halibut	852.8	853.2	524.6	1329.0	0.2365	0.2394
Blackbelly Eelpout	51.5	51.8	25.2	95.0	0.3339	0.3398
Sharpchin Rockfish	753.9	751.0	267.2	1738.6	0.4788	0.4860
Rosethorn Rockfish	88.8	88.8	50.9	139.5	0.2533	0.2548
Eulachon	35.0	34.7	15.6	63.4	0.3415	0.3409
Pacific Sanddab	1185.6	1185.8	597.9	1964.2	0.2882	0.2957
Splitnose Rockfish	2953.0	2934.2	306.4	9269.3	0.7927	0.7850
Darkblotched Rockfish	138.1	138.2	46.4	318.1	0.5000	0.4987
Blackfin Sculpin	9.7	9.8	5.3	16.4	0.2882	0.2911
Threadfin Sculpin	9.4	9.3	3.8	18.1	0.3837	0.3783
Widow Rockfish	182.2	182.2	25.8	455.8	0.5835	0.5828
Curlfin Sole	14.4	14.4	6.5	24.4	0.3129	0.3166

Table 8. Summary of biological samples collected during the 2003 QCSd survey.

		L/S/M/Age		L/S				
Species name	Total Samples	Number of samples	Number of specimens	Number of samples	Number of specimens	Number of tows species caught	% of tows sampled	% of total catch wt.
Arrowtooth flounder	94	29	1077	65	2367	213	44.1	16.6
Aurora rockfish	1	1	1			1	100.0	100.0
Big skate	12			12	49	12	100.0	62.2
Bocaccio	10	10	38			12	83.3	89.1
Canary rockfish	11	10	323	1	1	37	29.7	47.0
Chub mackerel	1	1	25			1	100.0	62.8
Chum salmon	1			1	7	3	33.3	63.7
Curlfin sole	3	2	4	1	2	11	27.3	26.0
Darkblotched rockfish	13	13	88			25	52.0	48.7
Dover sole	55	18	684	37	1009	172	32.0	34.4
Dusky rockfish	1	1	1			1	100.0	100.0
English sole	29	13	597	16	582	75	38.7	34.9
Eulachon	3			3	329	40	7.5	6.4
Flathead sole	30	10	385	20	712	82	36.6	28.9
Greenstriped rockfish	41	39	318	2	20	51	80.4	83.3
Lingcod	55	54	189	1	1	56	98.2	97.6
Longnose skate	72			72	112	81	88.9	86.5
Pacific cod	100	2	77	98	1307	105	95.2	81.3
Pacific hake	7	6	178	1	13	87	8.0	10.2
Pacific halibut	44			44	108	47	93.6	80.5
Pacific ocean perch	101	74	3067	27	846	181	55.8	9.2
Pacific sand lance	1			1	50	6	16.7	85.7
Pacific sanddab	13	5	229	8	395	33	39.4	10.0
Pacific tomcod	1			1	6	3	33.3	72.7
Petrale sole	64	62	381	2	5	67	95.5	96.7
Pink salmon	1			1	1	5	20.0	23.9
Pygmy rockfish	1	1	100			5	20.0	21.0
Quillback rockfish	5	4	30	1	30	6	83.3	57.6
Redbanded rockfish	121	121	942			129	93.8	81.1
Redstripe rockfish	17	11	485	6	330	47	36.2	7.7
Rex sole	87	23	934	64	2788	201	43.3	20.8
Rock sole	16	11	319	5	135	35	45.7	44.4
Rosethorn rockfish	28	27	329	1	18	36	77.8	75.3
Rougheye rockfish	51	51	383			78	65.4	36.1
Roughtail skate	4			4	4	4	100.0	100.0
Sablefish	24	17	435	7	134	135	17.8	44.2
Sandpaper skate	23			23	28	26	88.5	77.5
Sharpchin rockfish	16	8	279	8	348	43	37.2	20.7
Shortraker rockfish	7	7	25			8	87.5	93.7
Shortspine thornyhead	52	23	833	29	1129	106	49.1	35.5
Silvergrey rockfish	25	22	456	3	90	127	19.7	34.0
Slender sole	9	3	114	6	303	95	9.5	34.4
Spiny dogfish	11			11	430	126	8.7	24.6
Splitnose rockfish	11	9	319	2	83	28	39.3	2.9
Spotted ratfish	20			20	1044	151	13.2	19.0
Threadfin sculpin	1			1	6	21	4.8	9.4
Walleye pollock	19	7	155	12	500	92	20.7	43.4
Widow rockfish	5	5	75			13	38.5	52.7
Yelloweye rockfish	21	21	79			21	100.0	100.0
Yellowmouth rockfish	24	24	543			40	60.0	30.9
Yellowtail rockfish	10	8	231	2	45	32	31.3	27.7
Total	1372	753	14728	619	15367			

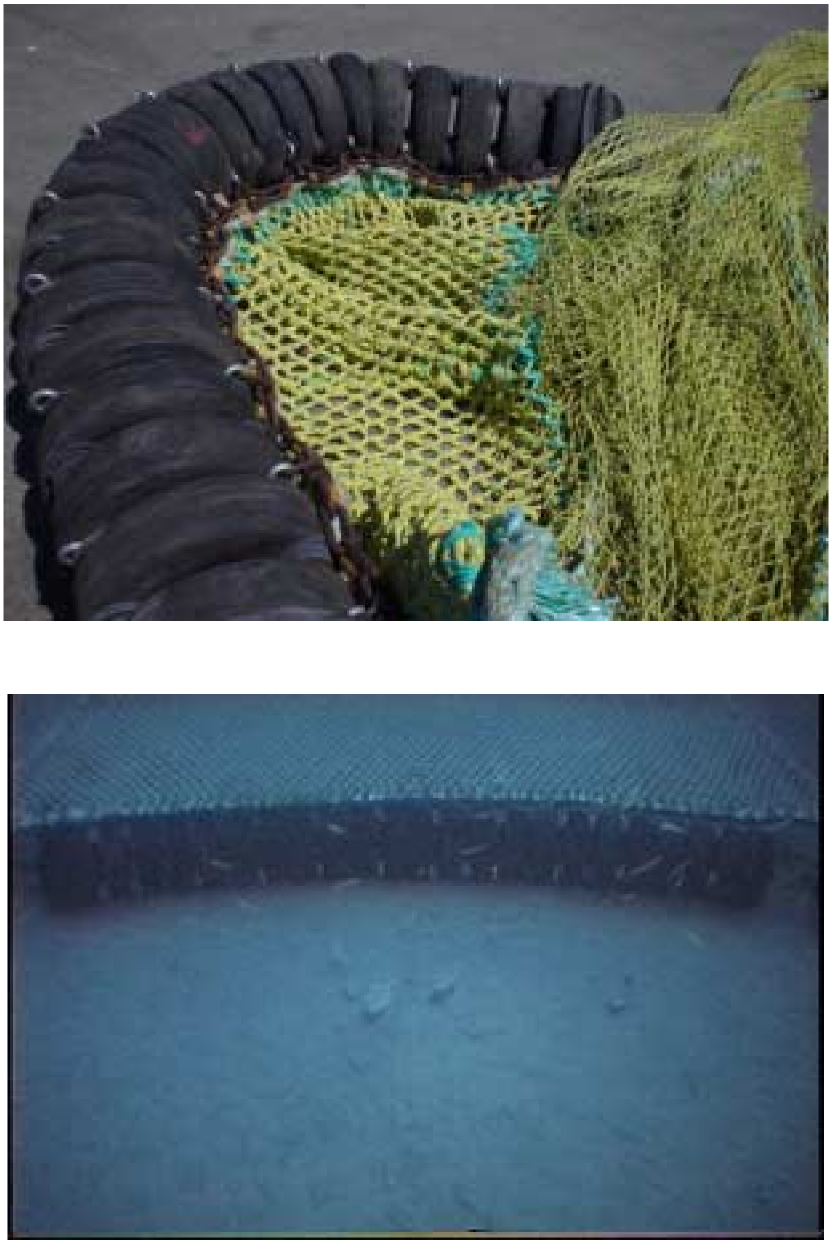


Figure 1. Pictures of tire gear in the bosom of the footrope.

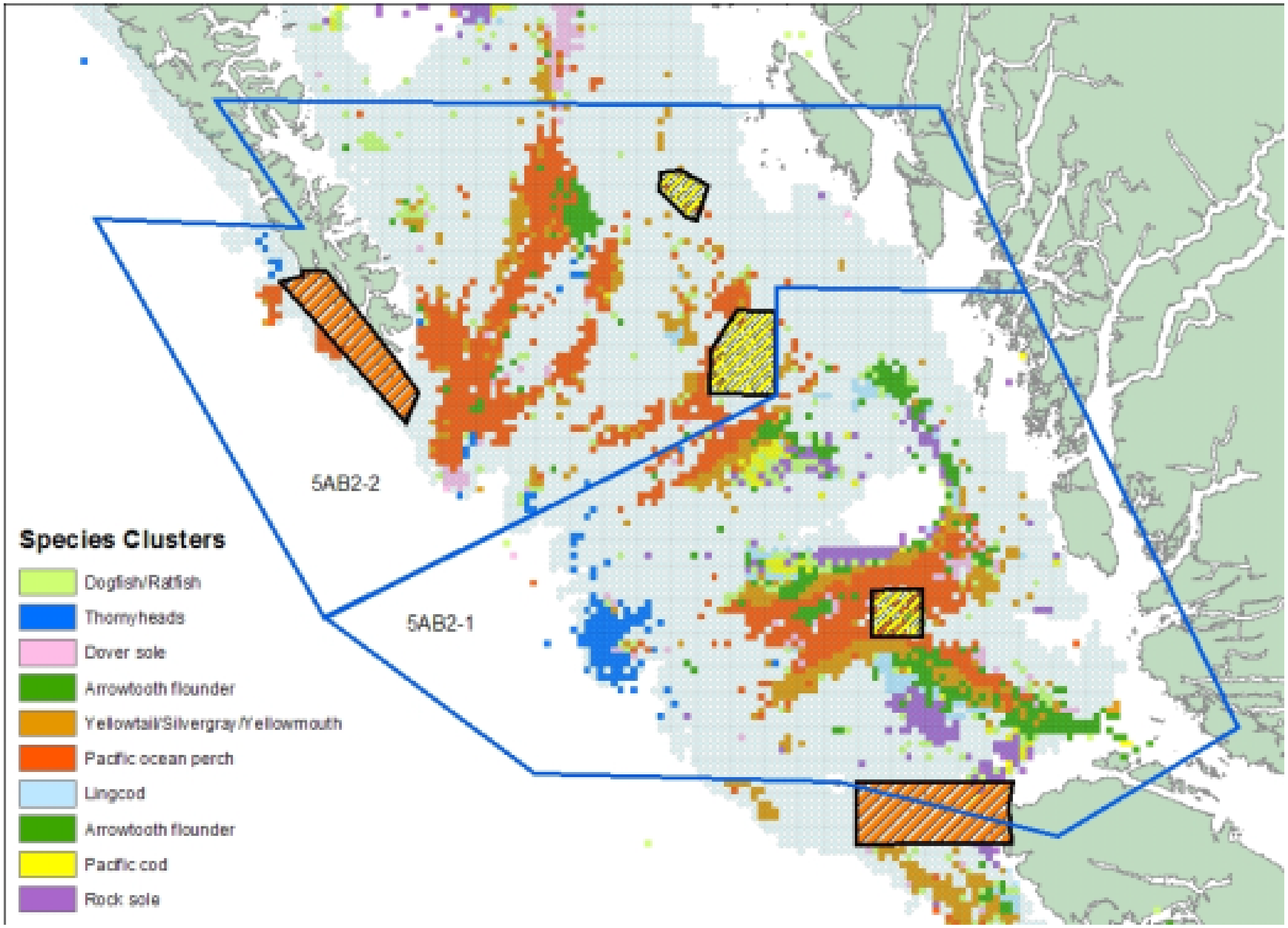
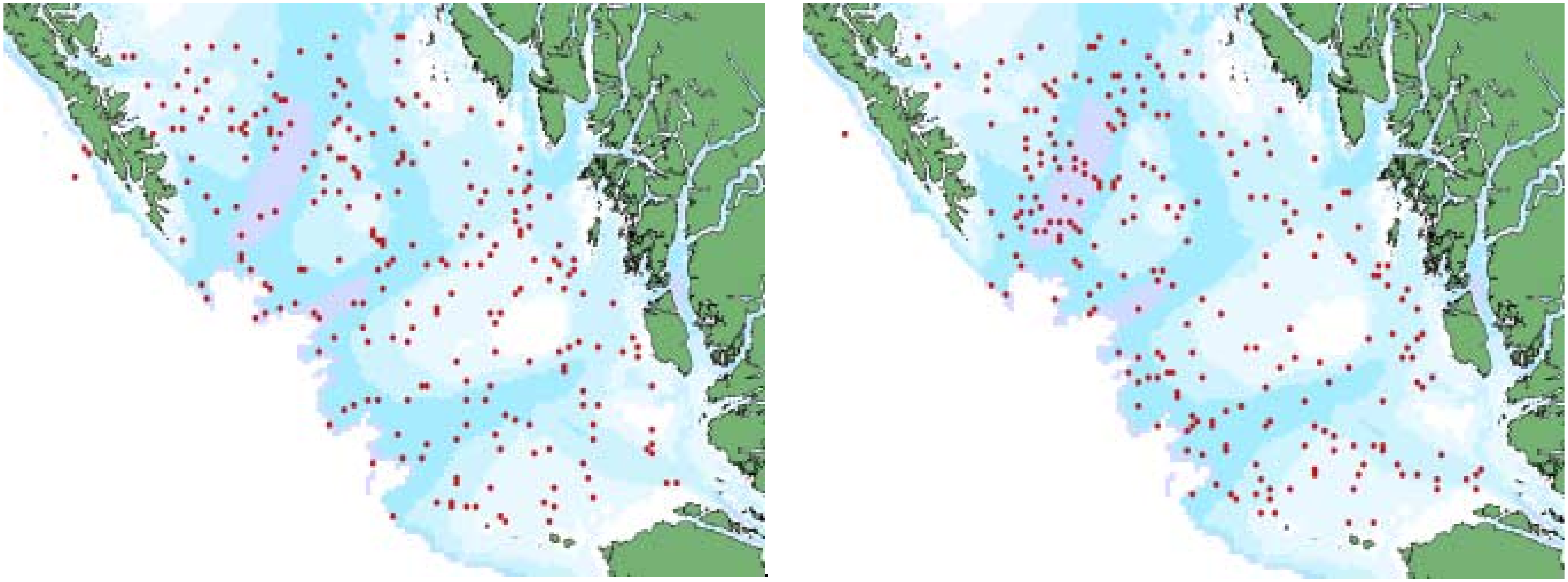


Figure 2. Proposed QCSd survey area. Yellow striped polygons represent sponge reef areas. Orange striped zones represent Hook-and-line rockfish closed areas. Catch weights for 38 commercially important species were obtained from the PacHarvTrawl database. These weights were apportioned based on trawl locations, onto a grid consisting of 4-km2 blocks. The total weight in each block was summed and individual species weights were then converted to proportions. Cluster analysis was performed on the resulting dataset using the "clara" (clustering large applications) method (Kaufman and Rousseeuw, 1990).



Scheme 2: Allocation by bottom area.

Scheme 5: Allocation by catch weight of commercial fish.

Figure 3. One simulation of tow placement using allocation Options two and five.

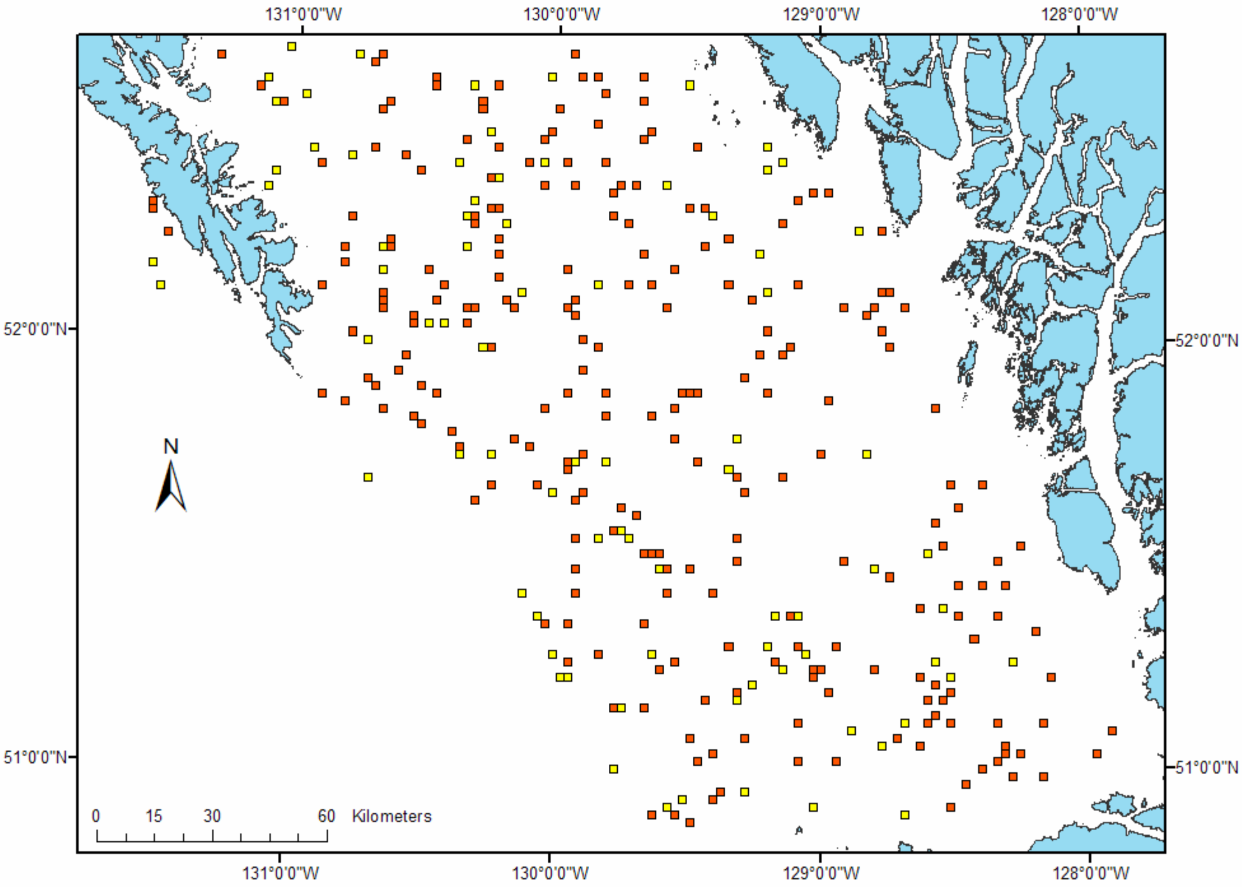


Figure 4. Initial random selection of 240 primary (red blocks) and 60 secondary (yellow) blocks.

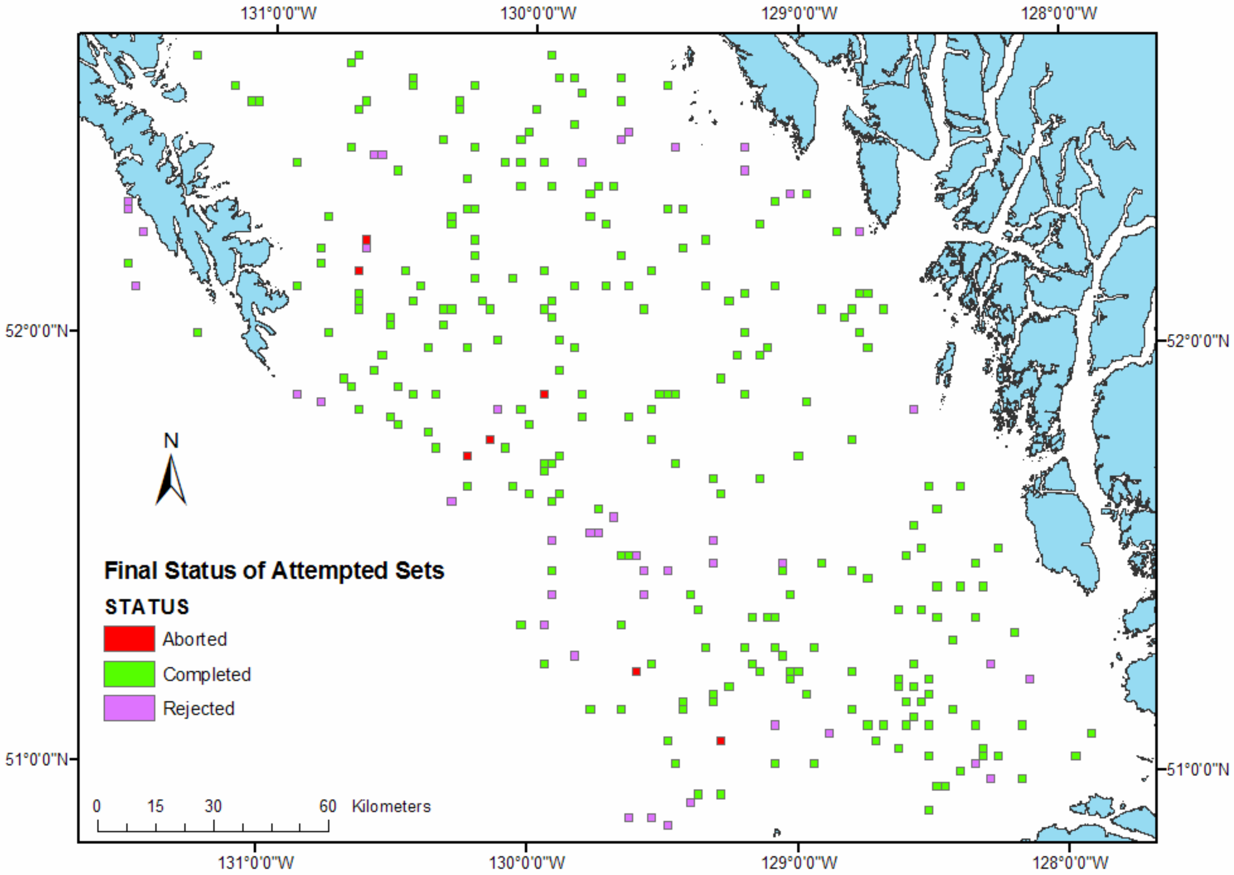


Figure 5. Actual surveyed blocks with rejected and aborted blocks.

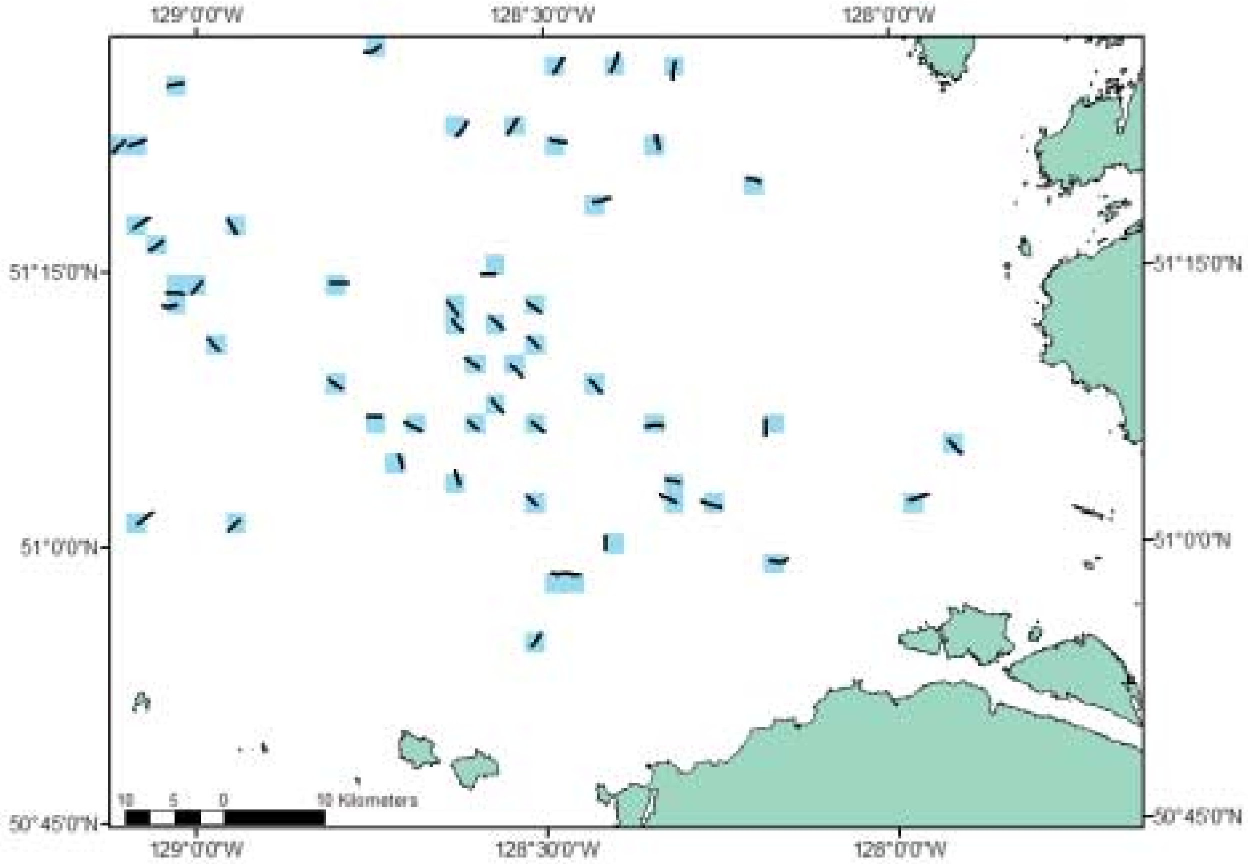


Figure 6. Location of tows within blocks from a southeast section of the survey area.

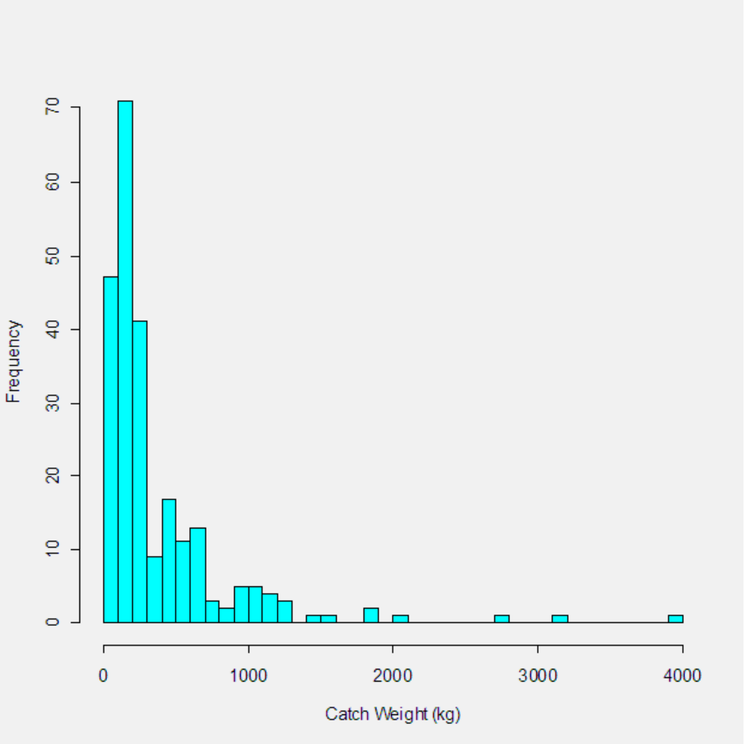


Figure 7. Frequency distribution of observed catches by tow.

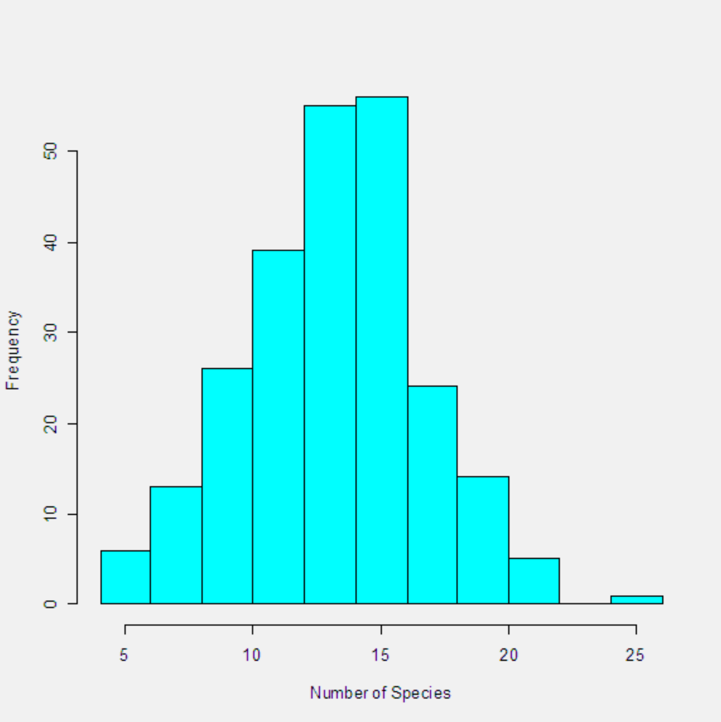


Figure 8. frequency distribution of number of species per tow

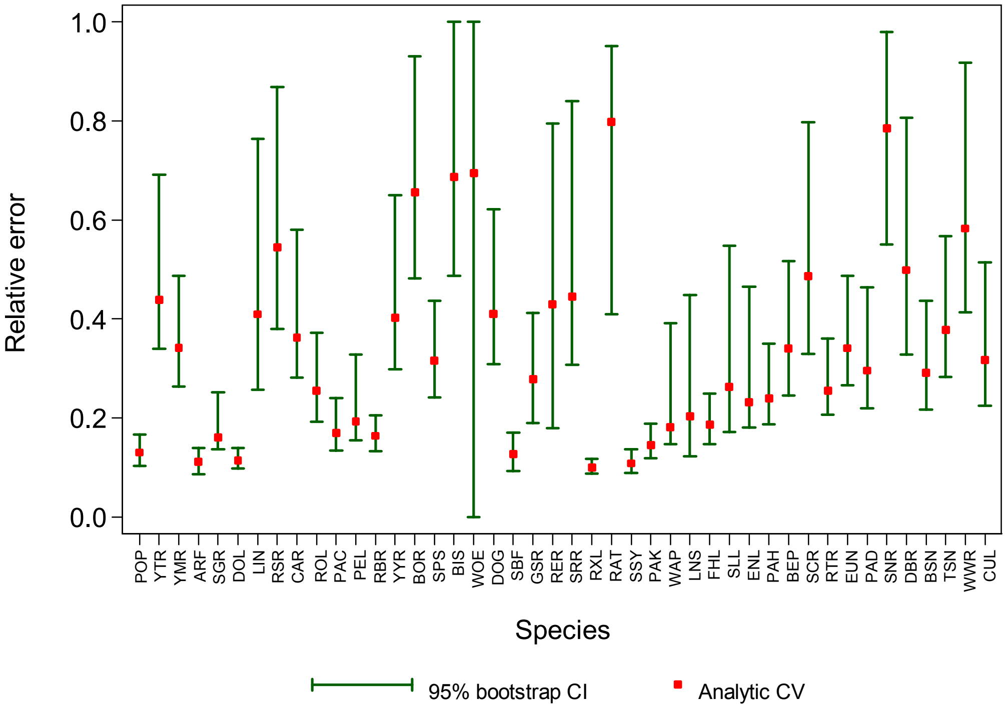


Figure 9. Plot of CV estimates for the combined aerial strata of the 2003 Queen Charlotte Sound trawl survey (with bias corrected 95% confidence intervals from 5,000 bootstrap replicates for 44 species (see Table 6 for definition of the acronyms).

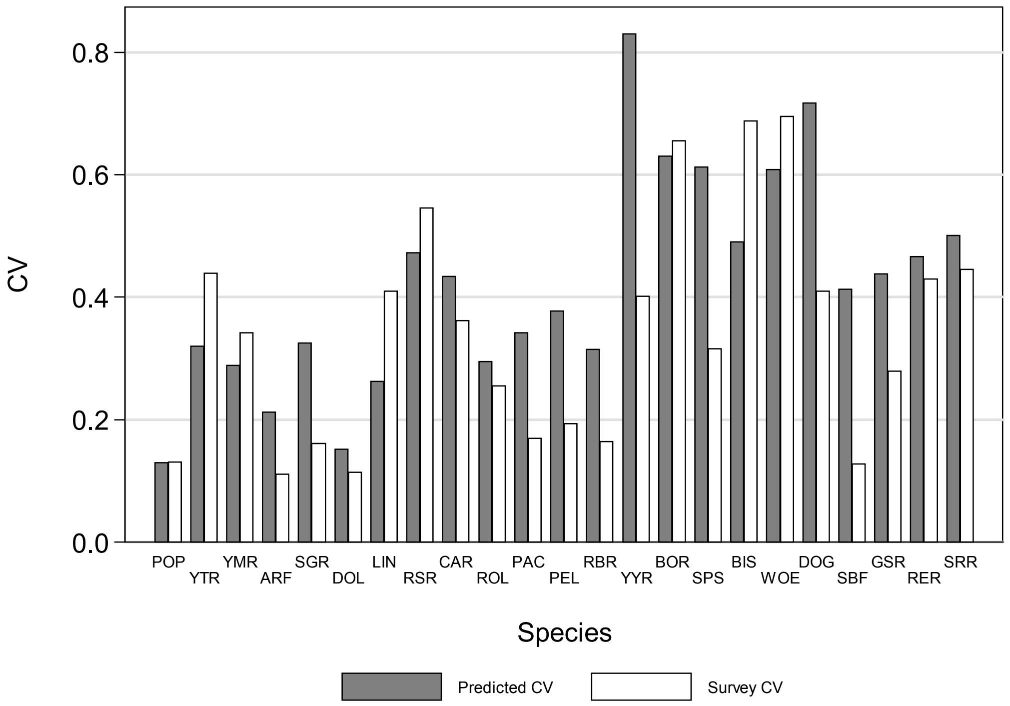


Figure 10. Direct comparison of the analytical survey CVs (Eq. 4) with the CVs predicted based on commercial catch and effort using the method described by Schnute & Haigh (2003). The species acronyms are provided in Table 6.

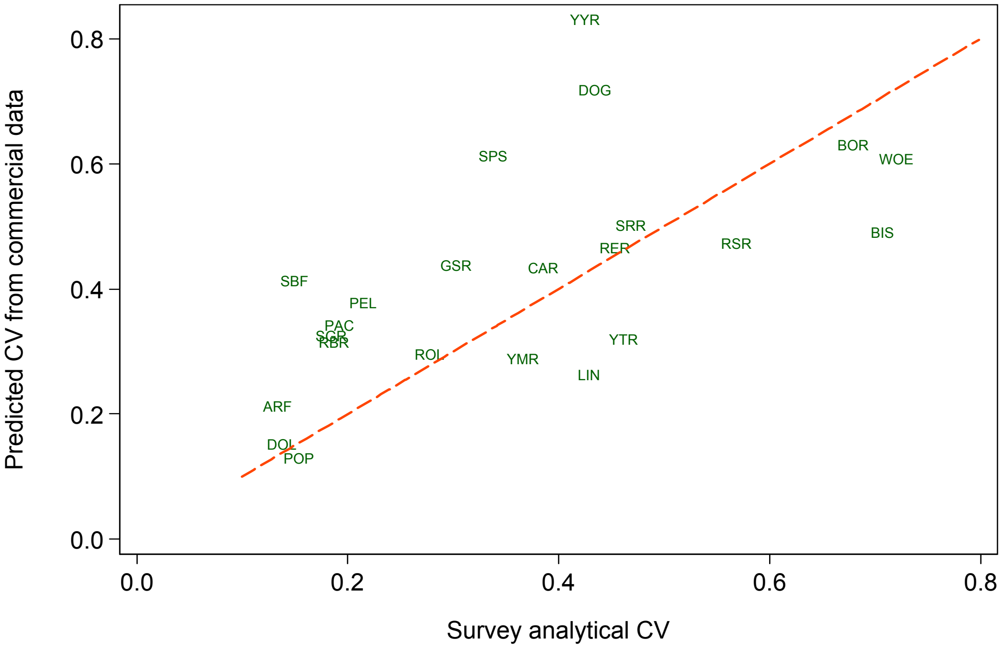


Figure 11. Comparison of the analytical survey CVs (Eq. 4) with the CVs predicted based on commercial catch and effort using the method described by Schnute & Haigh (2003). Dashed line is the one-to-one line and the species plotting symbols are provided in Table 6.

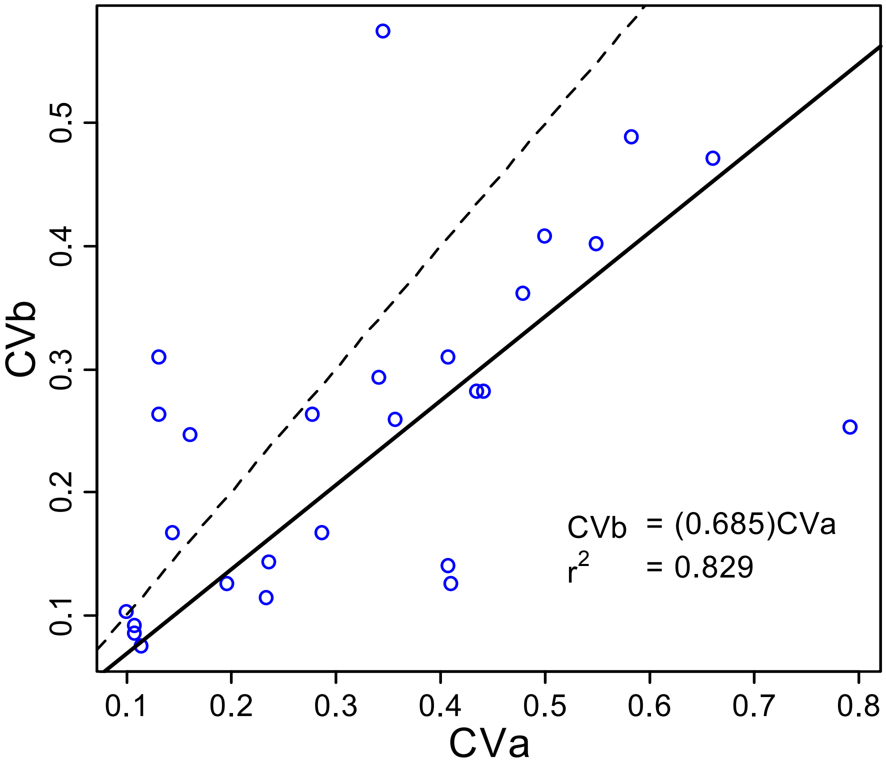


Figure 12. Plot of CV's 27 species of fish captured in both the 2003 QCSd survey (CVa) and the 2001 NMFS survey of f the Vancouver Region (CVb) for prorated to 239 tows. The solid line indicates the fitted regression while the dotted line indicates the 1:1 line.

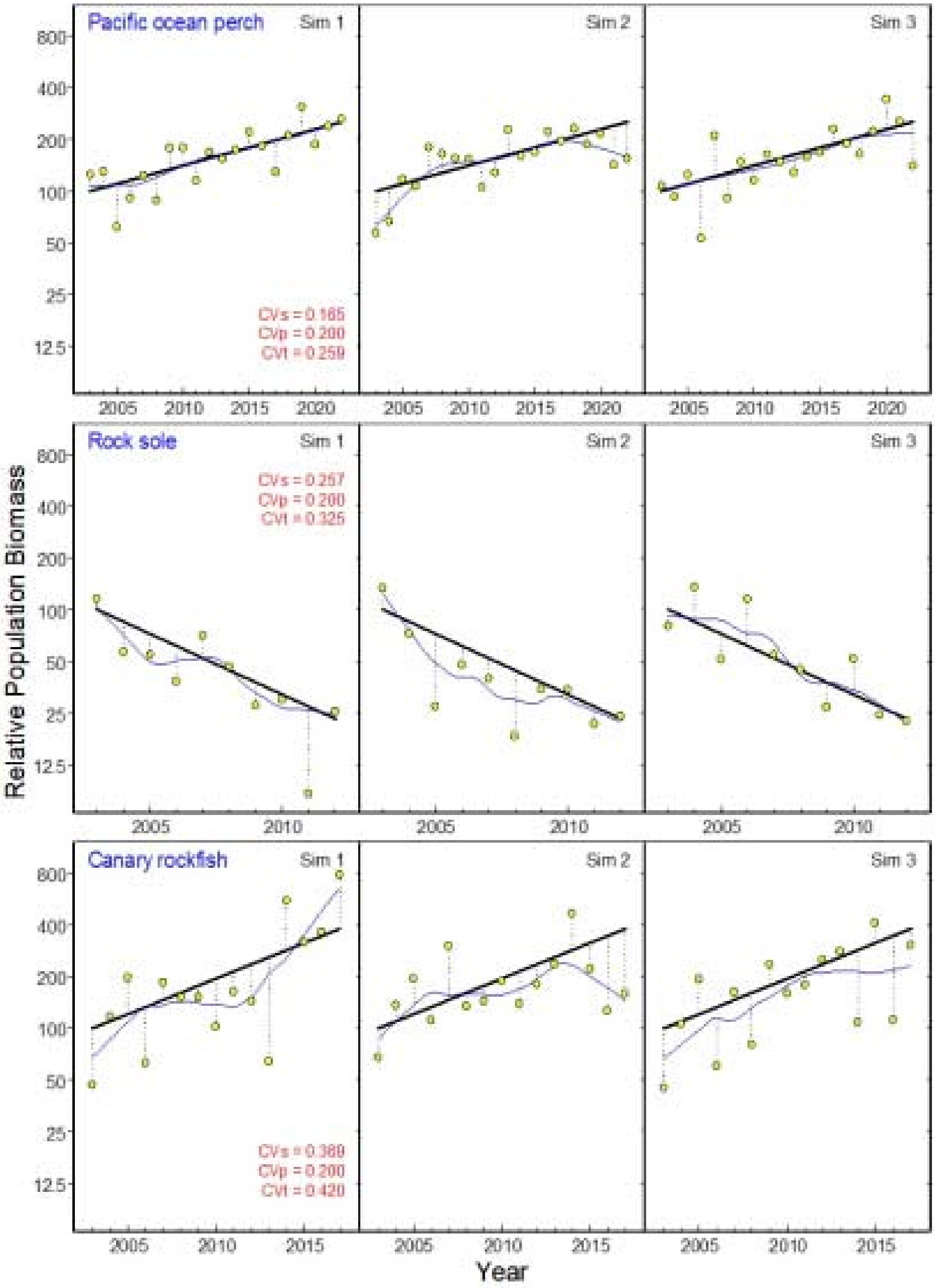


Figure 13. Three simulated time series of surveys based on sampling CV from the QCSd survey and Process CV of 0.20. Black line is the actual trend. Blue line is LOWESS fit. Top: Pacific ocean perch (QCSd–South), K=121, CVs=0.167; actual abundance increasing 5%/y for 20y; Mid: Rock sole (QCSd), K=239, CVs=0.257; actual abundance decreasing 15%/y for 10y; Top: Canary rockfish (QCSd), K=249, CVs=0.369; actual abundance increasing 10%/y for 15y.

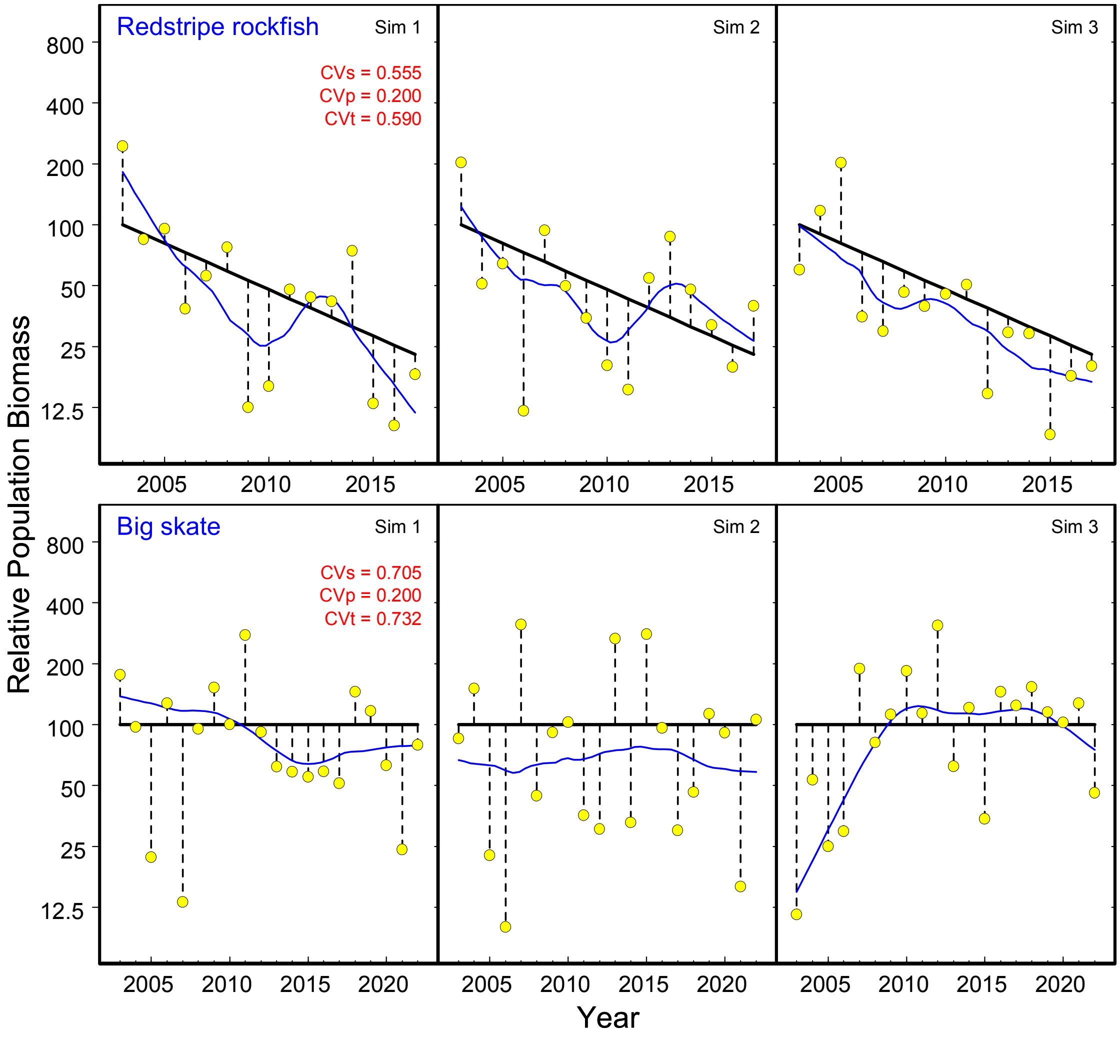


Figure 14. Two simulated time series of surveys based on sampling CV from the QCSd survey and Process CV of 0.20. Black line is the actual trend. Blue line is LOWESS fit. Top: Redstripe rockfish, K=239, CVs=0.550; actual abundance declining 10%/y for 15y; Bottom Mid: Big Skate (QCSd), K=239, CVs=0.690; actual abundance stable for 20y .

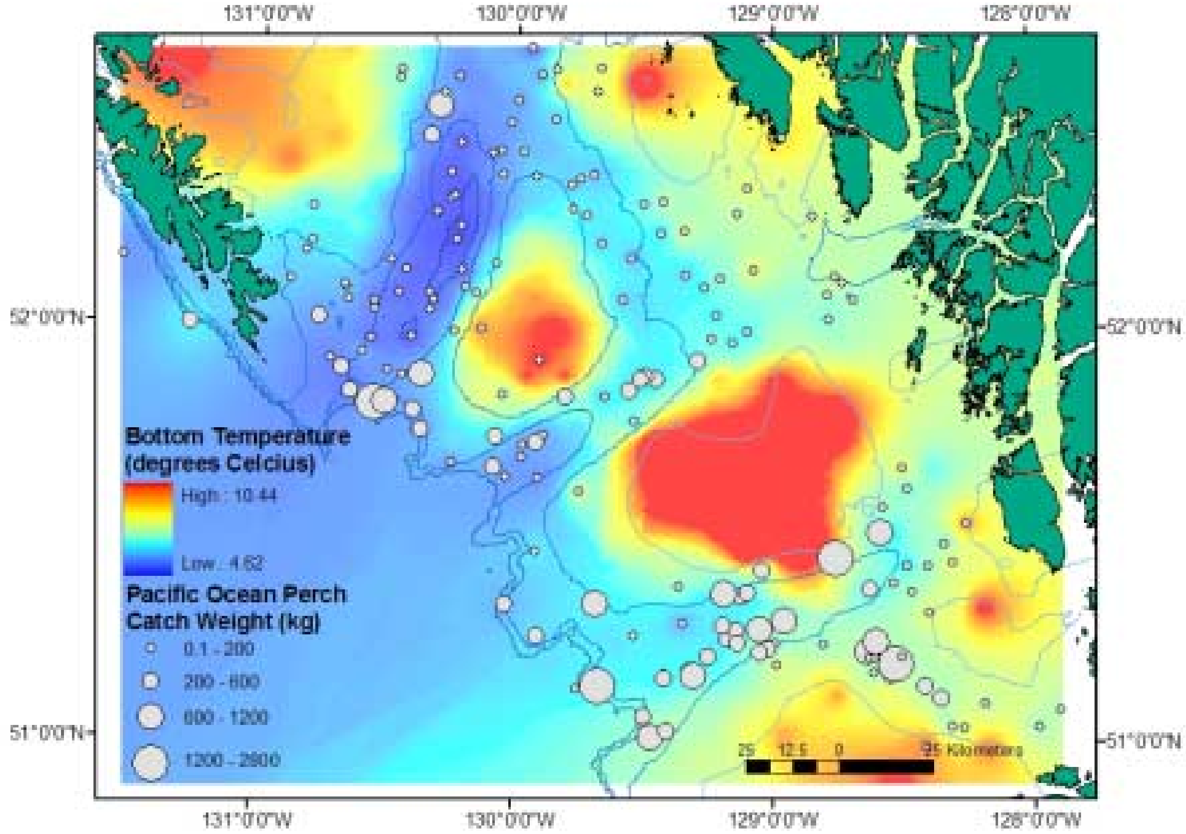


Figure 15. Catch per tow of Pacific ocean perch displayed over bottom bathymetry and interpolated bottom temperature.

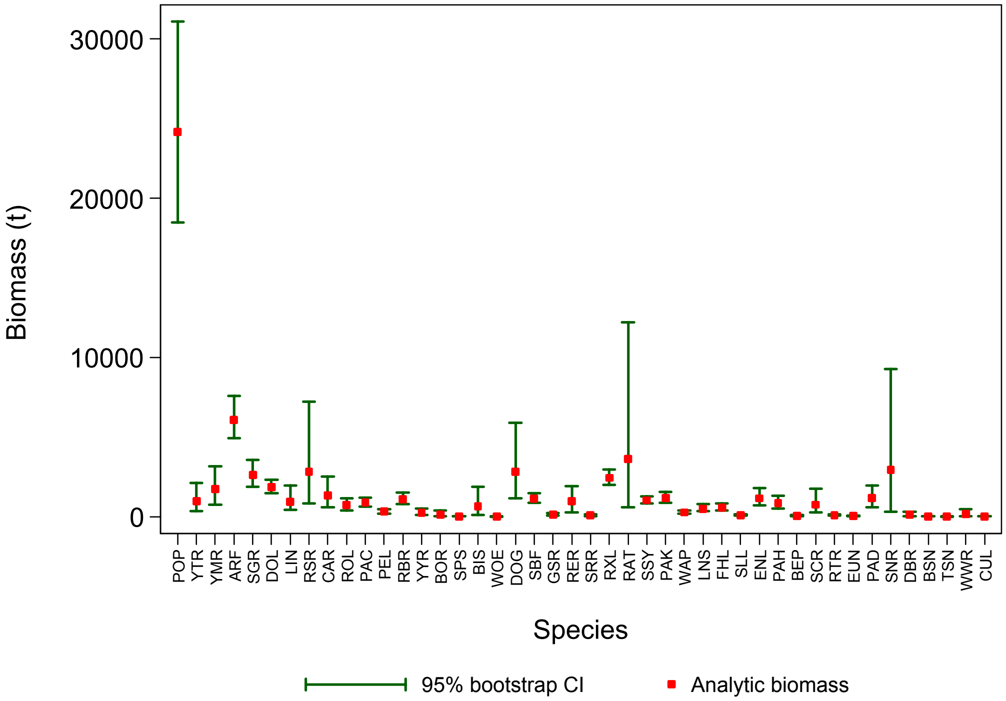


Figure 16. Plot of biomass estimates for the combined aerial strata of the 2003 Queen Charlotte Sound trawl survey with bias corrected 95% confidence intervals from 5,000 bootstrap replicates for 44 species.

Appendices

Table 9. Net specifications

Part	Standard Length	Material	Metric Length	Units	Material
Rigging					
Sweep Line	90	7/8 cable	27.4	m	22 mm cable
Upper bridle	90	3/4 cable	27.4	m	19 mm cable
Lower bridle	90	7/8 cable	27.4	m	22 mm cable
Door Legs	36	7/8 cable	11.0	m	22 mm cable
Pickups	42	7/8 cable	12.8	m	22 mm cable
Hook ups	8.8 t	BMMDV80	8 mt	mt	BMMDV80
Net frame					
Headline	74.5	5/8 cable	22.7	m	16 mm cable
Headline floats	90	8" plastic Spheres			200 mm plastic spheres
Riblines		1" Polysteel rope			25 mm polysteel rope
Bolsch Line	68.33	9/8" poly steel rope	20.8	m	29 mm polysteel rope
Fishing Line	107.33	14 mm long link chain	32.7	m	14 mm long link chain
Foot Rope					
Foot Rope	107.33	5/8 Chain	32.7	m	16 mm chain
Foot rope bosom	14	16 in Tire gear with 2 in Spacing	4.3	m	400 mm tire gear with 50 mm spacing
Root rope wing1	18.33	18" rock hopper, 18 " disks spaced 18 " apart	5.6	m	450 mm rock hopper 450 mm spacing
Root rope wing2	8.83	18" rock hopper, 18 " disks spaced 18 " apart	2.7	m	450 mm rock hopper 450 mm spacing
Web					
Belly	5”	3.5 mm Euroline	127	mm	3.5 mm Euroline
Square	5”	3.5 mm Euroline	127	mm	3.5 mm Euroline
Side Panel	5”	3.5 mm Euroline	127	mm	3.5 mm Euroline
Taper	4.5”	3.5 mm Euroline	114	mm	3.5 mm Euroline
Intermediate	4.5”	3.5 mm Euroline	114	mm	3.5 mm Euroline
Codend	4.5”	3.5 mm Euroline	114	mm	3.5 mm Euroline
Guard Mesh	4.5 or 5 “	Double 4.5 mm Euroline	114 or 127	mm	Double 4.5 mm Euroline
Liner	3/4”	Notless Nylon	19	mm	Notless Nylon

Table 10. Retained, discarded, and total catch by fish species from 239 useable tows.

Species	Retained Weight (kg)	Discarded Weight (kg)	Total Weight (kg)
Arrowtooth Flounder	167.3	7,945.7	8,113.0
Aurora Rockfish		0.7	0.7
Barracudinas		0.0	0.0
Big Skate		369.6	369.6
Bigfin Eelpout		5.2	5.2
Bigmouth Sculpin		10.3	10.3
Black Eelpout		1.0	1.0
Black Rockfish		0.8	0.8
Blackbelly Eelpout		78.0	78.0
Blackfin Poacher		0.3	0.3
Blackfin Sculpin		15.5	15.5
Blackgill Rockfish		1.8	1.8
Blacktail Snailfish		0.1	0.1
Blacktip Poacher		0.0	0.0
Blue Lanternfish		0.0	0.0
Bluespotted Poacher		0.0	0.0
Bocaccio	13.6	143.1	156.7
Brown Irish Lord		3.7	3.7
Brown Rockfish		7.0	7.0
Butter Sole		2.2	2.2
Canary Rockfish	61.3	1,355.7	1,417.0
Chilipepper		3.2	3.2
Chub Mackerel		74.7	74.7
Chum Salmon		47.0	47.0
Curlfin Sole		8.9	8.9
Darkblotched Rockfish	46.8	167.6	214.4
Daubed Shanny		0.0	0.0
Dover Sole	338.5	2,426.9	2,765.4
Dusky Rockfish		2.0	2.0
Eelpouts		2.4	2.4
English Sole	14.6	925.6	940.2
Eulachon		46.8	46.8
Fish Eggs		0.0	0.0
Flathead Sole	0.5	718.0	718.5
Goldfish		2.3	2.3
Greenstriped Rockfish	1.0	150.3	151.3
Hagfishes		0.1	0.1
Harlequin Rockfish		2.4	2.4
Inanimate Object(s)		0.6	0.6
Jacks		1.7	1.7
Kelp Greenling		4.6	4.6
Lampreys		0.0	0.0
Lanternfishes		0.2	0.2
Lingcod	94.5	480.3	574.8
Longnose Skate		594.9	594.9
Northern Lampfish		1.2	1.2
Northern Ronquil		0.0	0.0
Northern Spearnose Poacher		0.0	0.0
Pacific Cod	77.2	797.7	874.9
Pacific Hake		1,772.9	1,772.9
Pacific Halibut		729.2	729.2
Pacific Herring		9.8	9.8
Pacific Ocean Perch	18,608.2	17,385.7	35,993.9
Pacific Sand Lance		0.7	0.7
Pacific Sanddab		839.7	839.7
Pacific Staghorn Sculpin		0.0	0.0
Pacific Tomcod		1.1	1.1
Pacific Viperfish		0.0	0.0
Pearly Prickleback		0.1	0.1
Perches		0.3	0.3
Petrale Sole	1.8	274.7	276.5
Pink Salmon		7.1	7.1

Species	Retained Weight (kg)	Discarded Weight (kg)	Total Weight (kg)
Poachers		0.1	0.1
Pricklebacks		0.0	0.0
Pygmy Poacher		0.4	0.4
Pygmy Rockfish		16.2	16.2
Quillback Rockfish		63.1	63.1
Ragfish		0.0	0.0
Redbanded Rockfish	396.8	1,283.6	1,680.4
Redstripe Rockfish	2,919.5	481.5	3,401.0
Rex Sole	143.2	3,142.0	3,285.2
Ribbed Sculpin		0.0	0.0
Ribbon Barracudina		0.1	0.1
Ridgeheads		0.0	0.0
Rock Sole	39.1	468.2	507.3
Rosethorn Rockfish	21.4	113.3	134.7
Roughback Sculpin		0.0	0.0
Rougheye Rockfish	227.3	1,323.1	1,550.4
Roughtail Skate		25.0	25.0
Sablefish		1,975.0	1,975.0
Sandpaper Skate		39.8	39.8
Sculpins		0.6	0.6
Sharpchin Rockfish	210.5	931.8	1,142.3
Shining Tubeshoulder		0.0	0.0
Shortbelly Rockfish		13.3	13.3
Shortfin Eelpout		0.3	0.3
Shortraker Rockfish	42.3	81.6	123.9
Shortspine Thornyhead	312.3	1,400.4	1,712.7
Silvergray Rockfish	487.7	2,584.2	3,071.9
Slender Sole		100.6	100.6
Slim Sculpin		0.2	0.2
Smalldisk Snailfish		0.0	0.0
Spiny Dogfish		2,170.0	2,170.0
Spinyhead Sculpin		0.0	0.0
Splitnose Rockfish	344.1	4,374.0	4,718.1
Spotfin Sculpin		0.8	0.8
Spotted Ratfish		1,637.2	1,637.2
Sturgeon Poacher		0.3	0.3
Threadfin Sculpin		8.9	8.9
Tubeshoulders		0.0	0.0
Viperfishes		0.0	0.0
Walleye Pollock	5.9	319.2	325.1
Wattled Eelpout		0.4	0.4
Widow Rockfish	14.6	169.9	184.5
Wolf Eel		7.2	7.2
Yelloweye Rockfish	4.1	266.6	270.7
Yellowmouth Rockfish	169.6	2,321.1	2,490.7
Yellowtail Rockfish	689.2	565.5	1,254.7
Subtotal:	***25,453***	***63,307***	***88,760***
Non-Finfish		1,361.7	1,361.7
Total:	**25,453**	**64,669**	**90,122**

*Note: 0.0 indicate amounts of less than 0.05 kg

Table 11. Frequency of occurrence in useable tows for all species/groups by area and depth stratum.

Species	**Area Stratum 1: 5AB South**				**Area Stratum 2: 5AB North**				Total
	Depth Strata				**Depth Strata**				
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**	
Anemone	3		2	2		1			8
Anthozoa	1						2	1	4
Arminidae	1								1
Arrowtooth Flounder	13	56	30	4	5	39	48	17	212
Arthropoda	1								1
Ascidians And Tunicates	3	8	2			3	7	1	24
Aurora Rockfish							1		1
Barracudinas								1	1
Basket Stars	5	7	1			3	3	1	20
Big Skate	11				1				12
Bigfin Eelpout		1	2		2	2	1	1	9
Bigmouth Sculpin			1			2			3
Black Eelpout								5	5
Black Rockfish						1			1
Blackbelly Eelpout	7	36	9	4	1	2	4	3	66
Blackfin Poacher		1	4	1					6
Blackfin Sculpin		1	5			4	15	1	26
Blackgill Rockfish							1		1
Blacktail Snailfish			1				1	1	3
Blacktip Poacher			1				1		2
Blood Star			1						1
Blue Lanternfish			2				1		3
Bluespotted Poacher						2			2
Bocaccio		4	2			5	1		12
Box Crabs		3							3
Bristly Crab			1						1
Brittle Stars			2			5	2	3	12
Brown Irish Lord						1			1
Brown Rockfish						1	2		3
Butter Sole	2								2
Canary Rockfish	6	12	4		1	13	1		37
Cancer Branneri	2								2
Chilipepper		1				1			2
Chitons		1							1
Chub Mackerel	1								1
Chum Salmon		1				1	1		3
Cookie Star			1		1				2
Coonstripe Shrimp						2			2
Curlfin Sole	9					2			11
Cushion Star		2	2			3	2	1	10
Darkblotched Rockfish		3	9	3			8	2	25
Daubed Shanny	1								1
Decorator Crab	1	2	1			2	1		7
Dover Sole	9	48	28	4	3	18	44	18	172
Dusky Rockfish						1			1
Eelpouts		4		1		1	1	1	8
English Sole	15	34	8		4	12	2		75
Eulachon	2	16	1		1	2	13	5	40
Fish Eggs	1				1		1		3
Fish-eating Star						2			2
Flathead Sole	5	46	9		3	6	13		82
Fragile Urchin		31	8	4		11	23	10	87
Gastropods		2				2		1	5
Giant Pacific Octopus			2	1			1		4
Giant Red Sea Cucumber			1						1
Glass Shrimp								1	1
Glass Sponges	1								1
Goldfish							1		1
Gorgonian Corals						1	4	2	7
Green Urchin						1			1

Species	**Area Stratum 1: 5AB South**				**Area Stratum 2: 5AB North**				Total
	Depth Strata				**Depth Strata**				
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**	
Greenstriped Rockfish	4	23	4		3	15	2		51
Hagfishes								1	1
Harlequin Rockfish		1				1			2
Heart Urchins							3	1	4
Hermit Crabs	1								1
Inanimate Object(s)							2		2
Isopods	1					1			2
Jacks	1								1
Jellyfish	10	12	2	1	4	11	9	8	57
Kelp Greenling	2								2
Lampreys							1		1
Lanternfishes								3	3
Lingcod	17	12			4	18	5		56
Lithodes			1				1	1	3
Long-armed Sea Star	2	1				1	2		6
Longnose Skate	6	30	4	3	1	14	11	12	81
Mud Star		1					4	1	6
Neon Flying Squid			1				1	1	3
Northern Lampfish							5	2	7
Northern Ronquil	1				1				2
Northern Spearnose Poacher					1				1
Octopus		1						1	2
Opalescent Inshore Squid	1								1
Oregontriton		1	2	1			2		6
Pacific Bobtail Squid	3	15	1		2	3	3		27
Pacific Cod	14	26	4		4	35	21		104
Pacific Hake	1	12	27	6	2		22	17	87
Pacific Halibut	14	13	3		3	11	3		47
Pacific Herring	5	14	1		2	9	1		32
Pacific Ocean Perch	4	44	30	6	1	24	52	19	180
Pacific Red Octopus			1				1	1	3
Pacific Sand Lance	5		1						6
Pacific Sanddab	19	6	3		2	3			33
Pacific Staghorn Sculpin						1			1
Pacific Tomcod	2	1							3
Pacific Viperfish							1	2	3
Peanutworms						1			1
Pearly Prickleback							1		1
Perches		1							1
Petrale Sole	14	19	1		5	23	5		67
Pink Salmon							4	1	5
Pink Scallop, (aka Reddish Scallop)	1				1				2
Pink Shrimp	3	15	7			7	16		48
Pink Shrimp (smooth)		11	1		1	1	5		19
Poachers	1			1			1		3
Prawn	2	10	5			13	15		45
Pricklebacks								1	1
Proboscisworm			1						1
Purple Sea Urchins						1			1
Pygmy Poacher			1				2		3
Pygmy Rockfish	1	2				2			5
Quillback Rockfish	6								6
Ragfish							1		1
Redbanded Rockfish		28	27	5		9	52	8	129
Redstripe Rockfish	6	19	4		2	11	5		47
Rex Sole	16	55	26	5	4	34	46	14	200
Ribbed Sculpin						1			1
Ribbon Barracudina								3	3
Ridgeheads							1		1
Rock Sole	21	6			4	4			35
Rose Starfish	1					1	1		3
Rosethorn Rockfish		5	9	1		3	17	1	36
Roughback Sculpin	1								1
Rougheye Rockfish	1	10	16	5		2	27	17	78
Roughtail Skate						1	1	2	4

Species	Area Stratum 1: 5AB South				Area Stratum 2: 5AB North				Total
	Depth Strata				Depth Strata				
	1	2	3	4	1	2	3	4	
Sablefish	1	37	27	6	1	10	34	19	135
Sand Star		1							1
Sandpaper Skate		5	1	1		1	7	11	26
Scallop	1					2			3
Sculpins		1					1		2
Sea Cucumber	4	8	9	2		1	5	2	31
Sea Lilies And Feather Stars								1	1
Sea Pen		2							2
Sea Pens	1								1
Sea Urchins	1	6	1		1	6	1		16
Sea Whip	2	3		1	1	3	5		15
Seaslugs						1		1	2
Sharpchin Rockfish	1	7	6			12	14	3	43
Shining Tubeshoulder							1		1
Shortbelly Rockfish		1				1			2
Shortfin Eelpout		2					1	2	5
Shortraker Rockfish			1	2			2	3	8
Shortspine Thornyhead		6	28	6			47	19	106
Shrimp							1	1	2
Sidestripe Shrimp		13	7		1	4	33	2	60
Silvergray Rockfish	5	35	11	1	3	33	38	1	127
Slender Sole	4	35	17		1	10	27	1	95
Slim Sculpin	1				1				2
Smalldisk Snailfish								1	1
Solasteridae	1								1
Spike Shrimp (horned Shrimp)					1				1
Spiny Dogfish	12	37	9		5	34	22	7	126
Spiny Red Sea Star			2			2	1		5
Spinyhead Sculpin		1							1
Splitnose Rockfish			7				18	3	28
Sponges	3	9	7	4	2	14	16	5	60
Spotfin Sculpin	2								2
Spotted Ratfish	19	51	14	2	6	37	18	4	151
Squat Lobster	1	1	1						3
Squids	1	7	16	5		3	24	18	74
Starfish	2	5	1	1	1	6	4	3	23
Sturgeon Poacher					1	1	3		5
Threadfin Sculpin	7	5	1		1	6		1	21
Tubeshoulders			1						1
Vermillion Starfish		1	1				1		3
Viperfishes							1	1	2
Walleye Pollock	4	18	6	2	4	26	28	4	92
Wattled Eelpout		3				2			5
Widow Rockfish	1	4	2	1		1	4		13
Wolf Eel	2		1						3
Yelloweye Rockfish	1	7			1	12			21
Yellowmouth Rockfish		9	14	1		1	14	1	40
Yellowtail Rockfish	1	17	1			8	4		31
Yelloweye Rockfish	1	9			1	14	1		26
Yellowmouth Rockfish		12	14	1		1	17	1	46
Yellowtail Rockfish	1	21	1			8	4		35
Total:	**370**	**1093**	**531**	**94**	**102**	**673**	**955**	**308**	**4126**

Table 12. Analytic and bootstrap results for 44 species from the southern aerial stratum of the 2003 QCSd survey.

Analytic results are presented for the biomass (Eq. 1) and the CV (Eq. 4). Bootstrap results are for 5,000 replicate samples taken with replacement. Bias corrected 95% confidence intervals are presented and the bootstrap CV is calculated relative to the bootstrap mean biomass south

Species	Biomass (t)	Bootstrap mean biomass (t)	Bootstrap lower bound	Bootstrap upper bound	Bootstrap CV	Analytic CV
Pacific Ocean Perch	17407.8	17409.4	12528.9	23822.3	0.1665	0.1649
Yellowtail Rockfish	355.9	355.0	87.3	914.3	0.5692	0.5718
Yellowmouth Rockfish	1194.3	1188.4	362.2	2347.1	0.4230	0.4305
Arrowtooth Flounder	4253.2	4260.2	3254.6	5480.1	0.1323	0.1343
Silvergray Rockfish	640.4	639.2	371.3	1040.9	0.2619	0.2672
Dover Sole	1533.5	1531.1	1162.3	1975.6	0.1359	0.1346
Lingcod	384.6	381.9	236.7	621.6	0.2499	0.2534
Redstripe Rockfish	1893.5	1909.3	212.2	5942.9	0.7743	0.7788
Canary Rockfish	337.8	336.6	121.6	714.0	0.4462	0.4414
Rock Sole	681.1	676.9	366.2	1089.4	0.2679	0.2685
Pacific Cod	352.8	353.3	195.2	582.6	0.2775	0.2769
Petrale Sole	105.6	105.4	63.0	165.8	0.2446	0.2445
Redbanded Rockfish	552.2	553.2	365.0	825.5	0.2080	0.2099
Yelloweye Rockfish	42.8	43.1	13.7	86.8	0.4322	0.4330
Bocaccio	30.6	30.7	9.4	60.6	0.4251	0.4356
Sandpaper Skate	11.6	11.5	1.4	29.6	0.6016	0.5994
Big Skate	618.2	621.9	91.7	1868.3	0.7123	0.7153
Wolf Eel	10.0	10.1	0.0	28.2	0.6890	0.6949
Spiny Dogfish	2012.2	2023.1	384.8	5012.1	0.5675	0.5669
Sablefish	662.9	663.9	442.7	969.8	0.2024	0.2059
Greenstripe Rockfish	93.1	93.4	43.3	180.0	0.3593	0.3584
Rougheye Rockfish	814.0	819.7	122.6	1760.8	0.5192	0.5155
Shortraker Rockfish	35.8	35.7	0.0	103.6	0.7159	0.7161
Rex Sole	1813.3	1811.2	1437.1	2264.2	0.1174	0.1200
Spotted Ratfish	419.0	419.9	263.4	685.7	0.2505	0.2499
Shortspine Thornyhead	512.5	513.3	378.4	686.3	0.1523	0.1510
Pacific Hake	1000.4	1001.2	706.7	1352.0	0.1623	0.1645
Walleye Pollock	58.4	59.0	29.3	97.3	0.2937	0.2990
Longnose Skate	237.0	237.5	166.5	316.3	0.1609	0.1614
Flathead Sole	438.4	437.5	291.3	658.3	0.2108	0.2084
Slender Sole	57.5	57.6	38.5	83.3	0.1944	0.1924
English Sole	774.9	773.3	469.5	1173.3	0.2290	0.2290
Pacific Halibut	594.7	599.4	297.2	1028.2	0.3113	0.3166
Blackbelly Eelpout	49.7	49.8	23.7	94.7	0.3520	0.3519
Sharpchin Rockfish	50.6	50.4	14.1	110.1	0.4753	0.4810
Rosethorn Rockfish	38.8	38.9	13.9	79.6	0.4236	0.4319
Eulachon	22.9	22.8	7.0	49.7	0.4624	0.4647
Pacific Sanddab	1155.4	1150.2	562.8	1946.0	0.3049	0.3030
Splitnose Rockfish	470.9	472.1	6.5	1257.9	0.6217	0.6115
Darkblotched Rockfish	96.4	96.4	19.7	270.7	0.6720	0.6851
Blackfin Sculpin	2.7	2.6	0.1	9.2	0.8565	0.8379
Threadfin Sculpin	7.0	7.0	2.4	14.9	0.4449	0.4470
Widow Rockfish	109.2	110.7	5.5	353.6	0.7945	0.8016
Curlfin Sole	13.7	13.7	5.8	23.9	0.3328	0.3299

Table 13. Analytic and bootstrap results for 44 species from the northern aerial stratum of the 2003 QCSd survey.

Analytic results are presented for the biomass (Eq. 1) and the CV (Eq. 4). Bootstrap results are for 5,000 replicate samples taken with replacement. Bias corrected 95% confidence intervals are presented and the bootstrap CV is calculated relative to the bootstrap mean biomass.

Species	**Biomass (t)**	**Bootstrap mean biomass (t)**	**Bootstrap lower bound**	**Bootstrap upper bound**	**Bootstrap CV**	**Analytic CV**
Pacific Ocean Perch	6751.1	6765.7	4544.9	9754.5	0.1934	0.1906
Yellowtail Rockfish	628.8	636.0	93.9	1657.8	0.6049	0.6066
Yellowmouth Rockfish	527.0	520.6	140.4	1313.0	0.5403	0.5448
Arrowtooth Flounder	1815.9	1819.2	1277.4	2771.2	0.1996	0.1964
Silvergray Rockfish	1966.1	1964.7	1325.4	2843.4	0.1937	0.1944
Dover Sole	309.0	308.9	235.3	407.8	0.1427	0.1409
Lingcod	550.9	543.7	104.2	1592.6	0.6847	0.6726
Redstripe Rockfish	940.3	943.1	274.6	2138.9	0.4914	0.4887
Canary Rockfish	998.4	994.1	300.9	2108.1	0.4556	0.4608
Rock Sole	57.8	57.1	3.3	169.6	0.7605	0.7644
Pacific Cod	525.8	526.0	334.5	781.4	0.2127	0.2132
Petrale Sole	209.6	209.8	110.4	338.4	0.2635	0.2626
Redbanded Rockfish	543.3	542.4	329.4	882.8	0.2527	0.2522
Yelloweye Rockfish	217.0	215.9	64.6	487.3	0.4808	0.4734
Bocaccio	105.1	105.5	7.7	339.9	0.8335	0.8372
Sandpaper Skate	12.6	12.6	7.4	19.2	0.2392	0.2461
Big Skate	26.4	26.0	0.0	105.7	1.0006	1.0000
Wolf Eel	0.0	0.0	–	–	–	0.0000
Spiny Dogfish	793.9	794.6	538.5	1139.0	0.1910	0.1900
Sablefish	486.1	485.8	380.4	598.7	0.1117	0.1090
Greenstripe Rockfish	30.1	30.2	16.8	48.6	0.2669	0.2675
Rougheye Rockfish	165.0	164.3	111.0	236.0	0.1923	0.1919
Shortraker Rockfish	35.4	35.1	7.4	82.4	0.5283	0.5259
Rex Sole	623.0	621.3	444.7	866.1	0.1737	0.1741
Spotted Ratfish	3204.9	3220.6	220.0	11817.8	0.9140	0.9020
Shortspine Thornyhead	521.6	521.6	378.0	700.3	0.1578	0.1551
Pacific Hake	187.3	187.5	110.7	311.3	0.2684	0.2715
Walleye Pollock	210.1	209.3	137.1	318.1	0.2159	0.2163
Longnose Skate	268.4	268.5	139.9	510.6	0.3555	0.3549
Flathead Sole	125.9	127.2	40.2	244.7	0.4123	0.4126
Slender Sole	29.4	29.0	6.8	82.5	0.6872	0.6801
English Sole	377.6	377.1	89.9	883.1	0.5357	0.5278
Pacific Halibut	258.1	257.1	119.1	436.0	0.3084	0.3059
Blackbelly Eelpout	1.8	1.8	0.6	3.9	0.4570	0.4475
Sharpchin Rockfish	703.3	701.4	230.4	1755.5	0.5224	0.5198
Rosethorn Rockfish	50.1	50.0	25.3	86.0	0.2982	0.3041
Eulachon	12.1	12.0	3.9	25.7	0.4438	0.4453
Pacific Sanddab	30.2	30.0	4.1	85.0	0.6712	0.6520
Splitnose Rockfish	2482.1	2500.3	84.3	8719.3	0.9152	0.9267
Darkblotched Rockfish	41.8	42.2	9.8	88.7	0.4721	0.4712
Blackfin Sculpin	7.1	7.1	4.0	10.9	0.2479	0.2474
Threadfin Sculpin	2.4	2.4	0.2	6.7	0.7068	0.7030
Widow Rockfish	73.0	74.6	2.8	232.0	0.8226	0.8236
Curlfin Sole	0.7	0.7	0.0	1.8	0.6948	0.7063