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Bocaccio Update

Mise à jour sur le bocaccio

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Abstract

The present paper updates the available information on the stock status of bocaccio (*Sebastes paucispinis*) in BC waters. It updates information on catch, CPUE, and survey indices where appropriate, from the previous PSARC document (Stanley et al. 2001). In addition, given the importance of the results from the NMFS triennial and West Coast Vancouver Island (WCVI) shrimp surveys with respect to stock status, it provides more comprehensive analyses of these data to communicate more accurately the degree of certainty around the point estimates and the inference of declines in abundance. The document notes the strong evidence of a significant decline in relative abundance from the early 1980's off the southwest coast of BC but also recent stability in the same indices and provides two management directions for consideration. Considering that the only remedial action available for managers is to control catches, Option #1 endorses capping catches at current levels provided existing indices do not decline. Option #1 might also be adopted as an interim measure until a more complex catch reduction strategy can be implemented. Option #2 endorses reducing catch to an arbitrary target level. A significant reduction in catch may be possible through implementation of a voluntary avoidance program, possibly in conjunction with regulatory disincentives to catch bocaccio. However, the document emphasizes that the available assessment information is not adequate to predict how much a given reduction in catch will affect the population nor able to provide specific advice on the amount of reduction required. The choice between options is dependent on the degree to which the southern BC area reflects all BC waters, and whether the higher relative abundance recorded in the early 1980's is indicative of the long term average abundance or reflects peak levels resulting from periods of good recruitment. This uncertainty in the interpretation of the available abundance indices, along with their low precision, means that it is presently not feasible to reliably estimate stock status for British Columbia bocaccio.

Résumé

Le présent document met à jour les données disponibles sur l'état du stock de bocaccio (*Sebastes paucispinis*) en Colombie-Britannique ainsi que les données sur les prises, les CPUE et les indices de relevés présentées dans le précédent document du CEESP (Stanley *et al*., 2001). De plus, compte tenu de l'importance des résultats du relevé de la crevette au large de la côte ouest de l'île de Vancouver et du relevé triennal du *National Marine Fisheries Service (NMFS)* en ce qui a trait à l'état du stock, ce document fournit des analyses plus complètes de ces données afin de communiquer avec plus d'exactitude le degré de certitude lié aux estimations ponctuelles des baisses d'abondance et aux conclusions relatives à celles-ci. Le document relève les données solides montrant une forte baisse de l'abondance relative au large de la côte sud-ouest de la C.-B. à partir du début des années 1980 et la stabilité récente de ces mêmes indices. Deux directives de gestion à considérer sont également présentées. Étant donné que la seule mesure corrective possible pour les gestionnaires est de limiter les prises, la première option consiste à limiter les prises aux niveaux actuels dans la mesure où les indices actuels ne baissent pas. Cette option pourrait également être adoptée à titre de mesure provisoire en attendant la mise en œuvre d'une stratégie de réduction des prises plus complexe. La deuxième option consiste à réduire le nombre de prises en établissant une limite de prises arbitraire. Une réduction importante des prises pourrait être possible par le biais de la mise en œuvre d'un programme d'évitement volontaire, possiblement de concert avec des mesures réglementaires visant à dissuader les pêcheurs de capturer le bocaccio. Il est cependant souligné, dans le document, que les données d'évaluation disponibles ne permettent pas de prévoir les effets d'une réduction des prises donnée sur la population et, de ce fait, de formuler des conseils précis relatifs à la réduction nécessaire. Le choix d'une option est dicté par la mesure dans laquelle la zone du sud-ouest de la C.-B. est jugée représentative de toutes les eaux de la province. Ce choix varie également selon que l'abondance relative plus élevée observée au début des années 1980 est représentative de l'abondance moyenne à long terme ou qu'elle ne constitue qu'un sommet à la suite d'une période de bon recrutement. Cette incertitude liée à l'interprétation des indices d'abondance disponibles, jumelée à la faible précision de ces indices, fait en sorte qu'il est actuellement impossible d'estimer de façon fiable l'état du stock de bocaccio en C.-B.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

The present paper has three objectives with respect to the current stock status of bocaccio (*Sebastes paucispinis*) in British Columbia (BC) waters. Firstly, we have updated information on catch, commercial catch per unit effort (CPUE), and survey data where appropriate from the previous PSARC document (Stanley et al. 2001). Secondly, given the importance of results of the National Marine Fisheries Service (NMFS) triennial and Department of Fisheries and Oceans, Canada (DFO) West Coast Vancouver Island (WCVI) shrimp surveys in considering stock status, we have provided more comprehensive analyses of these data to communicate more accurately the degree of certainty around the point estimates and the inference of a decline in abundance. Finally, we elaborate what we suggest are appropriate scientific and management directions for bocaccio.

2.0 BASIS OF COSEWIC CLASSIFICATION

A recent review of the status of bocaccio in Canadian waters was conducted by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). This review was based on the first PSARC review document (Stanley et al. 2001) but also included subsequent discussions with, and requests for additional analyses from, the senior author. The final summary report is in the process of being released (COSEWIC in press). If released in its present form, it recommends a "Threatened" designation noting that "a combination of low recruitment and impact by harvest has resulted in severe declines and low spawning abundance of this Canadian species".

3.0 POSSIBLE THREATS TO BOCACCIO IN CANADIAN WATERS

3.1 HABITAT CONSTRAINTS OR LOW NUMBERS

The most likely threats to bocaccio include: 1) population reduction to such an extent that random events may lead to extirpation, for example genetic drift; 2) significant reduction or degradation of habitat; 3) sustained recruitment failure, and 4) unsustainable fishing mortality. The previous document (Stanley et al. 2001) indicated that the first two risks do not seem plausible at present time for bocaccio. Firstly, current harvest implies a standing adult population of at least many 10's of thousands and probably 100's of thousands in BC waters. Secondly, we do not know of any evidence to indicate at present that the available habitat has been reduced. The distribution is coast wide along the continental shelf edge and has been confirmed for some inland waters and inlets, the Strait of Georgia, Hecate Strait and Queen Charlotte Sound. Furthermore, there is no evidence that the quality of habitat is being degraded with respect to coastwide productivity of bocaccio. However, the lack of knowledge on the distribution and ecology of larval and juvenile stages in BC waters precludes any definitive statement regarding the trends in the amount of available habitat.

3.2 Poor recruitment

It is likely that the bocaccio population in BC has been adversely affected by poor recruitment from the mid-1970's to late 1990's in parallel with the U.S. population. As summarized in MacCall (2002):

> " Environmental conditions providing for successful reproduction (i.e., producing more offspring than are needed to replace the current year's natural losses) are not understood, but such events are infrequent, and have occurred in 13 of the last 50 years (26%), and only 4 of those were large enough to replace more than the average 3.8 years (1/0.26) between successful reproductions. Importantly, none of those unusually large events have happened since 1978, contributing to the decline in abundance. The U.S. west coast experiences a 60-year cycle of conditions that alternate between favourable (ca. 1941-1975) and unfavourable (1976-1998) for many coastal species of fish (MacCall 1996). It is likely that the higher frequency of poor bocaccio reproductive successes since 1978 (and especially during the 1980's) has been associated with the unfavourable phase of the long-term ocean climate cycle. Evidence is accumulating that a new favourable period began in 1999, and bocaccio have recently achieved two successful reproductions in 1999 and 2002. This also demonstrates that the stock has not been reduced to a "depensatory" level…."

There now appears to be definitive evidence that the ocean regime changed again in 1999 and there is also increasing evidence for a corresponding improvement in recruitment for other groundfish populations (McFarlane 2003, G. A. McFarlane, DFO, pers. comm.). The evidence for a strong 1999 year class of bocaccio in California has also strengthened with additional data (MacCall 2003a,b). Nevertheless, while poor recruitment may have been the major source of the decline in BC waters, there are no direct means available for enhancing recruitment. Managers can only attempt to maintain a sufficient spawning biomass to take advantage of improved environmental conditions. We have no means for determining whether the 1999 cohort in BC is larger than the previous cohorts from the same decade. We note MacCall's statement above that a strong year class has been observed in California from a spawning biomass estimated to be less than 10% of the unfished biomass and probably less than 20% of B_{MSY}.

3.3 Fishing mortality

There are no means for estimating the extent to which fishing mortality has contributed to the decline in bocaccio abundance in BC. The previous document suggested that reported trawl landings in the 1985-1995 period were inflated owing to misreporting (Table 1). This assumption is supported by a sudden drop in trawl landings concurrent with introduction of 100% monitoring in 1996, prior to the introduction of the "other" rockfish trip limit of 15,000 lbs in 1997/98. A plausible view is that bocaccio trawl landings for 1985-1995 were similar to the average of the 1980-1984 period and 1996 of 100-300 t.

Even if the reported landings for 1985-1995 were accurate, they do not coincide well with the period of the steepest decline in the bocaccio population. The available abundance indices for the WCVI show the decline occurred primarily between 1980 or 1982 and 1989, with the greatest rate of decline occurring during the first half of the 1980s. However, reputed catches of bocaccio only started to increase around 1985 and it would have taken several years for their effect to accumulate. This lends some support to the hypothesis that the decline was mainly due to recruitment failure than to overexploitation, although it is possible that removals exacerbated the decline by the late 1980s and early 1990s. Therefore, it seems unlikely that landings in the 1980s caused the observed decline in the indices, especially when similar levels of landings at present are associated with stable survey and commercial CPUE indices.

The most recent assessment for the California stock of bocaccio (MacCall 2003a,b) concludes that overfishing ended in 1998, and current harvests currently are about ½ F_{MSY} even though current spawning abundance is estimated to be currently 5.6-8.5% of the "unfished" level. The increasing evidence for a strong 1999 year class has led to more optimistic predictions for rebuilding (MacCall, 2003b). This work has also updated the value used for *M*, the instantaneous rate of natural mortality, using a bias-corrected version of Hoenig's method (1983). The previous estimate was 0.20 and this has been reduced to 0.15 or possibly as low as 0.10. These new estimates imply generation times of 14 and 11 years respectively. We also note that the maximum weight for bocaccio has been updated to 9.1 kg, from 7 kg (FishBase 2000).

4.0 UPDATE OF COMMERCIAL FISHERY INFORMATION

Note that **catch** represents all harvest, including those fish that are retaining as **landings** as well as those that are **discards**. We also assume that are discarded fish are killed thus the estimates of total catch represents total mortality. Table 1 shows reported **catch** from all bottom trawl fishing, and **landings** from midwater trawling and hook-and-line (HL) fisheries. A small amount of discarding may go unreported while midwater trawling for hake. Combined catch from these sources totalled about 300 t in 2002. Catch per unit effort in the bottom trawl fishery continues to appear stable, indicating neither a further decline nor increase (Figure 1). There are insufficient biological samples to characterize the length or age composition of the commercial catches over time. Our historical catch estimates do not include possible catches by non-US foreign trawlers prior to 1980. We suspect that the tendency for Japanese and Soviet Union vessels to target on deeper Pacific ocean perch outside the 12 mile limit would have led to limited bocaccio catches, but this remains unknown owing to the lack of observer data.

Bocaccio is a minor element of the bottom trawl fishery contributing less than 1% of the bottom trawl landings. Trawl fishers report a small amount of targeting. Even though caught often as a bycatch, their occurrence is reported to be reasonably predictable in time and space, especially in recent years. The introduction of IVQ's has led to more communication among fishers on the fishing grounds thus fishers are receiving constant updates on the species mix in different locations.

Annual coastwide HL landings are about 10-30 t (1995-2002) (Appendix 1) as in the previous document. Omitted from these tables are estimates of the discards in the commercial HL fisheries (halibut, ZN and Schedule II) as well as catches in the recreational and First Nations' fisheries. Observer data from the halibut component of the HL fishery (Figure 2) indicate an average catch rate of 0.32 bocaccio/1000 hooks for all sets observed from 1999-2002. The range among years was 0.11-0.73. Given that the average number of hooks/year in this fishery was about 7,400,000 (International Pacific Halibut Commission: IPHC), this implies a total catch of about 2,400 pieces/y. Using the estimate of a 4 kg mean weight from the previous report indicates a total catch of about 10 t. However, it should be noted that a more comprehensive spatial expansion algorithm could lead to different estimates given the variance in catch rate over space implicit in Figure 2. Mindful of the same caveat, the data from the HL observer program can also provide estimates of bycatch in the ZN and Schedule II HL fisheries by expanding the average number of observed bocaccio in observed sets by the average number of sets/y (Figure 2). The ZN fishery (1999-2002) averaged 6,540 sets annually with an overall catch rate of 0.15 bocaccio/set. The Schedule II fishery, from 2001-2002 averaged 6,072 sets annually with an average of 0.67 bocaccio per set. These statistics equate to annual total catches of 981 and 4,068 pieces respectively, or about 4 t and 16 t/y. These observer-based estimates of commercial HL catches include specimens both landed and discarded. The combined estimates reflect a total catch of about 30 t from all groundfish HL fisheries, slightly higher than the reported landings provided in Appendix 1 and the previous document. Since bocaccio is an incidental species in all HL fisheries, we assume that catches is these fisheries have not varied widely over time and probably fluctuate with bocaccio abundance.

The level of observer coverage was too limited in 1999 and 2000 to estimate HL catches and catch rates for those two years, but the level of coverage in 2001 and 2002 indicates that these data might provide additional, albeit imprecise, relative abundance indices which will assist in tracking large-scale trends in bocaccio abundance. This assumes, however, that the fishery and the proportion observed remains comparable among years. Any action by the fleet to reduce the incidental catch will preclude comparing current with future CPUE. Of interest in these data is the significant presence of bocaccio in the north coast halibut HL fishery, which was previously undocumented. There also have been observations of bocaccio in the sablefish HL and shrimp trawl fisheries but using simple extrapolations indicate total catches of less than 0.5 t in each of these fisheries.

There are anecdotal reports that bocaccio, among other rockfish, has been a nuisance in the commercial troll fishery for salmon, particularly off the west coasts of Vancouver Island (WCVI) and the Queen Charlotte Islands (WCQCI). However, Wrohan et al. 2002 indicated that of 934 rockfish identified to species between 1998-2001 by troll fishery observers off the WCVI, only one was bocaccio. The same report estimated that the annual rockfish bycatch ranged from 225-29,000 rockfish pieces between 1998-2001 off the WCVI (Troll Area G). Given an overall ratio of 0.001 bocaccio/rockfish in identified rockfish, the estimated annual bycatch in this fishery equates to fewer than 30 pieces. While this estimate may be too low, given the anecdotal reports, it is likely that bocaccio catches are negligible at present in the WCVI salmon troll fishery. It should also be noted that the annual fishing effort in this fishery has shrunk steadily from over 89,000 d/y in 1982 to less than 4,400 d/y from 1999-2002.

No troll observer data are available for the salmon troll fishery operating off the west coast of the Queen Charlotte Islands (WCQCI). We examined the 2002–2003 fisher "mail-in" logbook data, which imply fewer than 400 pieces or 2 t/y. However, we suspect that there may be confusion in distinguishing between widow rockfish and bocaccio. We also note a similar decline in effort in this fishery from 24,000 d/y in the early 1980's to 900-3,550 d/y from 1999-2002.

The impact of the recreational fishery appears negligible. While the previous document confirmed bocaccio catches in at least the Strait of Georgia, the overall coastwide catch must be very small. The creel survey is now attempting to identify rockfish catches to species but no bocaccio were reported in 2001 or 2002. We have no reason to assume First Nations catches of bocaccio are large enough to affect coastwide productivity or abundance.

Total trawl catches of bocaccio have been about 260 t since 1996. Of this, over 85% is caught during bottom trawling and the rest while mid-water trawling. In 2002, over 50% of the bottom trawl catch came from Queen Charlotte Sound, which covers the central portion of the BC coast. About 37-82 t/y (1996-2002) was caught from Area 3C plus minor area 25 of Area 3D, the region examined in the NMFS triennial and DFO shrimp surveys.

To summarize, total reported catch from groundfish trawl (all catch) and landings from HL was 303 t in 2002. This total should be increased to 330 t, given the assumption that total catch (landings and discards) in the groundfish HL fisheries is about 30 t. Added to this total would be another few tonnes per year for all other fisheries combined, giving a collective estimate of the total catch of bocaccio of about 335 t/y based on the data for 2002. Of this total, 87% comes from the groundfish trawl fishery, 9% from the groundfish HL fishery and the remaining 4% from numerous other fisheries. We assume that very few bocaccio survive capture, even when discarded, therefore 335 t/y is an estimate of total fishery mortality for this species.

During the December 2003 PSARC review it was suggested that a 5-year average would be more appropriate than just using the 2002 estimate. While we have credible estimates for trawl catches over a longer period, we lack these for the other fisheries. Thus the only option for extending the averaging period would be to combine a 5-year average for "reported" trawl catches (Table 1) and to assume that the additional 32 t of catches from other sources has been relatively constant over the same period. This would result in a total 5-year average of approximately 311 t which is probably not different from the slightly higher total estimated in the previous paragraph, given the uncertainties in the annual catch totals. We suggest that a realistic estimate of current total catch (mortality) is 300-350 t, regardless of which recent period is used to estimate this total.

5.0 REVIEW AND UPDATE OF EXISTING TRAWL SURVEY INDICES

5.1 NMFS TRIENNIAL SURVEY

The data for bocaccio from the U.S. National Marine Fisheries Service (NMFS) triennial survey were completely reanalysed for the entire Vancouver INPFC region (Appendix 2). This survey has operated in Canadian waters seven times between 1980 and 2001. This reanalysis was done to estimate bootstrap confidence bounds for the biomass estimates and to investigate the properties of these biomass estimates for the entire Vancouver INPFC region, including the estimates from US waters immediately south of the U.S.-Canada border. This border closely corresponds to the Canadian definition of the Canadian Economic Fishing Zone.

The estimated biomass trend for the Canadian waters is the same as that reported by Stanley et al. (2001) with bootstrap confidence bounds that are very close to the previously reported analytical confidence bounds (Figure 3). The trends for the U.S. Vancouver INPFC and total Vancouver INPFC areas (Appendix 2:Figure 5) are somewhat different to the trend in the Canadian waters due to the leverage of a single very large tow (9,000 kg) observed in U.S. waters in 1989. This tow greatly inflates the biomass estimates for that year for these two time series, with a correspondingly low precision for the biomass estimates (Figure 3). The overall conclusion of a reduction in the bocaccio biomass in the total Vancouver INPFC region is unchanged from the inclusion of this single large tow. However, the leverage of this tow, in combination with low incidence of bocaccio, demonstrates the difficulty and imprecision associated with monitoring this species and in using these biomass indices for determining trends in abundance.

Scaled length frequency distributions for bocaccio were provided by the NMFS for each year and for each of the major INPFC regions that are surveyed by the triennial survey (Appendix 2). There are few length frequency data available for bocaccio from the Vancouver INPFC region, particularly from Canadian waters, so the entire set of available length frequency data were examined. There is no evidence, based on these data, that there has been a shift in the population mean length, an observation that might be expected for a population that had declined to the extent indicated by the available indices. However, any underlying trends that might be present are obscured by the large variation in length distribution within each region, across years. This instability in the length distributions between surveys and across regions indicates that the surveyed fraction of the population has not been consistent. This result is not surprising, given the low density of this species and the likely patchy distribution of the population. Lack of consistency in the estimated population length frequencies is a further indication that these survey results need to be interpreted with caution, particularly when estimating levels of population decline.

5.2 WCVI SHRIMP TRAWL SURVEY

The data for bocaccio from the DFO west coast Vancouver Island (WCVI) shrimp trawl survey were also completely reanalysed (Appendix 3). The shrimp trawl survey has operated off the WCVI in nearly every year since 1973 and has recorded rockfish catch to species since 1975. It represents the longest series of biomass estimates available for bocaccio in Canadian waters. This reanalysis was done to estimate swept area biomass estimates for this species as suggested by Starr et al. (2002) and to estimate bootstrap confidence bounds with the biomass estimates. A mean density estimator was used, as opposed to the original inverse distance weighted spatial expansion (Figure 4). When we observed a significant difference between the mean density trend and the previous spatial expansion, we then reanalysed the data using the original spatial analysis approach (Figure 4).

With respect to recreating the original spatial analysis, we did not document the original distance weighting parameters so we had to recreate the trend using a “best guess” of these values. We were able to recreate the same overall trend with the one exception of the much lower estimate for 1979 and slightly higher estimates for 1982-1984. The higher estimates are easily explained as the result of the different parameter choices, which presumably altered the leverage of a few large tows. We cannot account for the significant change of the 1979 point. An examination of the data indicated there were only four small catches of bocaccio during this year, thus it would appear to be a data input error and not a result of the spatial expansion. We view this current result as the correct version of the spatial expansion method.

The new time series of mean density estimates for bocaccio from the shrimp trawl survey differs from the series that reported in Stanley et al. (2001; Figure 5). If differs modestly from the corrected spatial version of the present report, but of significance to interpreting the abundance trends is the much lower estimate for 1976 and slightly lower estimate for 1978.

We prefer the shrimp trawl survey series based on a mean density estimator rather than a spatial expansion estimator for several reasons. One is that estimates based on spatial expansion using an inverse distance weighted algorithm are probably more appropriate for species which are broadly and evenly distributed over the survey area, like shrimp. Given the patchy distribution of bocaccio, and the fact that the bocaccio catchability in a shrimp trawl is low, large tows which already have undue leverage, become even more influential if they represent a larger than average area in the context of a spatial expansion algorithm. We also note that the mean density estimator is not greatly affected by the assumptions used in converting the data into swept area biomass indices.

The time trend for bocaccio shown in Figure 5 shows relatively low biomass estimates in the 1970s followed by an increase in the biomass estimates in the mid-1980s which then drops to low levels again in the late 1980s and has continued to the present. These biomass estimates have very low precision, as do the triennial survey biomass estimates (Appendix 3).

A direct comparison of the shrimp survey biomass estimates with the triennial survey biomass estimates shows reasonably good correspondence (Appendix 3), although the overall level of biomass in the shrimp survey did not increase until 1982 while the triennial survey started high in 1980. However, the overall magnitude of the increase and decline is similar in the two surveys from 1982 to the present. The critical difference between these two sets of indices is the existence of low biomass estimates from the shrimp survey preceding the increase in biomass observed in the 1980s. While this observation information was apparent in the first submission, the updates to the estimates in the late 1970s, in particular the lower relative points for 1976, 1978 indicated by the mean density series and the corrected point for 1979, indicate that the biomass levels for bocaccio in the 1970s more closely resembled the biomass levels currently estimated than those estimated during the peak period in the mid-1980s. This observation can be interpreted either that there was a general increase in bocaccio biomass in the early 1980s compared to the 1970s or that the biomass estimates observed in the 1970s and early 1980s were low due to operational differences in the shrimp survey or simply to chance. It is recommended that any models which attempt to analyse the extent of population change for WCVI bocaccio should include the indices from both of these surveys.

5.3 HECATE ST. ASSEMBLAGE SURVEY

The data for bocaccio from the DFO Hecate Strait assemblage trawl survey were completely reanalysed (Appendix 4). This survey has operated in Hecate Strait since 1984, with 11 surveys having been completed, but only three of which occurred in the 1980s. This reanalysis was done to estimate swept area biomass estimates for this species as suggested by Sinclair (1999) and to estimate bootstrap confidence bounds with the biomass estimates.

The estimated biomass trend for this survey is very similar to the CPUE series reported by Stanley et al. (2001) with wide bootstrap confidence bounds that are similar to those observed for bocaccio in the triennial and the WCVI shrimp trawl surveys (Figure 6). This survey estimated relatively large biomass levels in the 1984 and 1987 surveys, but the estimate then fell in 1989 and has remained consistently low since then. The depth range and the location of this survey do not make it an ideal monitoring tool for bocaccio and we do not consider the indices from this survey as reliable as those available from the NMFS triennial survey or the DFO shrimp trawl survey. However, the time trend exhibited by this survey is reasonably consistent with the trends for bocaccio observed by both the NMFS triennial survey and the WCVI shrimp trawl survey (Figure 7), perhaps indicating that the processes which are affecting the abundance of this species are operating over the entire coast.

6.0 NEW SURVEYS

6.1 IPHC HL SURVEY

Starting in 2003, the Department of Fisheries and Oceans (DFO) has begun collaborating with the IPHC in their annual coastwide HL survey. Non-halibut catches are now recorded to species. In 2003, 19 bocaccio were observed in 170 fishing sets **(**Figure 2**).** While catch frequency and catch rates are too low for to provide a stand-alone index, in combination with the HL observer programs, this survey has the potential to assist in monitoring large scale changes in bocaccio abundance.

6.2 QUEEN CHARLOTTE SOUND BOTTOM TRAWL SURVEY

The Queen Charlotte Sound Pacific ocean perch survey was not updated for this report; this survey has not been repeated since 1995. However, the first in what is proposed to be a long-term relative abundance survey of Queen Charlotte Sound and southern Hecate Strait was conducted in 2003. Bocaccio catches were observed in the 23 of the 239 20-minute bottom tows (Figure 8). The primary purpose of this survey is to provide relative abundance indices for most fish species affected by bottom trawling. While results presented in Stanley et al. (2003) indicate it will provide reasonably precise tracking of many of these populations, it will be less precise for bocaccio. The estimated relative error for the catch density of bocaccio in this first year was 0.66. Thus the survey will be similar to the NMFS survey or the DFO shrimp trawl survey in that it will only be able to indicate large-scale changes over a long period.

7.0 POTENTIAL MANAGEMENT DIRECTIONS WITH RESPECT TO BOCACCIO

As noted in the previous report (Stanley et al. 2001), the available evidence points strongly to a decline in bocaccio abundance over the last two decades in southern offshore waters. This decline parallels even stronger evidence of a decline in U.S. stocks to the south. Furthermore, the magnitude of the decline is probably large, possibly as large as that reported in the U.S. and implied by the NMFS triennial survey off the southwest coast of BC. The shrimp trawl survey points to a similar decline over the same time period but also indicates that bocaccio biomass levels may have been lower in the mid-1970s, and perhaps were at similar levels to those observed at present. There is little information for determining long term trends in central and northern BC waters except for the Hecate Strait assemblage survey which is not considered a good indicator of bocaccio abundance.

While the evidence points to the likelihood of a large decline since the early 1980s, it is impossible to estimate the size of the decline with any certainty. The shrimp survey also raises the possibility that abundance in the late 1970's and early 1980s, when the NMFS triennial survey began, may have been much larger than the long term average abundance prior to that period. The U.S. assessments note the presence of a large 1978 year class that may have contributed to the estimated peak in biomass in the mid 1980's (MacCall 2003a,b).

Over the shorter term, since about 1995, all the available indices, including the NMFS triennial, DFO shrimp and Hecate Strait indices, and the commercial fishery CPUE's, indicate stable abundance. Nevertheless, while the recent stability may reduce concern, the reasonable likelihood that a large population decline has occurred over the last 20 years, with no evidence of recent rebuilding, indicates this population should be closely monitored and that there is a likely need to intervene with species-specific management actions.

While there are numerous management options and tactics available, we advise that choosing the appropriate strategy will be hampered by the lack of quantitative stock status information which precludes providing model-based estimates of safe harvest levels. It should also be noted that, while our ability to monitor catches and relative abundance trends is improving, we will not benefit from any new monitoring programs for a number of years, and monitoring species with distributional characteristics like those for bocaccio will always be imprecise. We discuss below possible directions for management of bocaccio. Given that the only "threat" over which there is apparently management control is fishing mortality, we have limited this discussion to options for controlling harvest.

7.1 DIRECTION 1: STOP THE DECLINE IN SPAWNING BIOMASS

The simplest response is to rely 1) on the recent stability in relative abundance and 2) the possibility that the decline manifest in the NMFS triennial survey and the DFO shrimp survey was from possible historic highs in abundance, to cap catches at current levels. This approach would take into account that the large harvests in U.S. waters associated with their long-term decline have stopped and BC catches are probably similar to, or lower than, they have been in the past. It would also rely on the indications that there has been a strong 1999 year class in the U.S. which may indicate that low spawning biomasses are capable of generating strong cohorts. This approach would be conditional on a continuation of stable survey and commercial indices and that abundance monitoring continues to be maintained and/or improved as required.

We note that management directions that act to control harvests presume the ability not only to invoke controls over the pertinent fisheries but to assess the success of the controls. In this regard, we can have confidence in the trawl catch estimates owing to the nearly 100% observer coverage and while other fisheries are not monitored to the same extent, the monitoring has improved dramatically in recent years.

7.2 DIRECTION 2. START REBUILDING TO HIGHER LEVELS

The discussion above suggests that the recent levels of Canadian catch for bocaccio are not associated with declining biomass indices. One possible interpretation of this observation is that the current catches of approximately 300-350 t/year since the mid-1990s have been sustainable, even given the relatively low precision of the available indicators of abundance. However, it is not possible to quantify this conclusion nor is it possible to predict what the future biomass trend will be if catches are allowed to continue at this level.

A strategy that might increase bocaccio abundance is to reduce future removals. However, this strategy cannot be evaluated quantitatively and it is presently not possible to predict by how much the stock would increase, if at all. Nevertheless, it is reasonable to predict that the probability of an increase would be higher for a strategy of reduced catches compared to a strategy of maintaining the existing level of catches, with other factors (recruitment, stock and fishery distribution, etc.) held constant.

Initially, managers, scientists and fishers could jointly develop a bocaccio avoidance strategy that would eliminate targeting on bocaccio and reduce targeting on other species at times and in locations where the bocaccio incidence tends to be higher. The success of this strategy is easily determined and if target reductions are not met, then stronger dis-incentives can be added to the strategy in succeeding years.

At this time, we recommend against immediate adoption of more aggressive catch reduction strategies, such as, for example, attempting to reduce catches to near zero. Firstly, we suggest that there is good scope for reducing catches through voluntary agreements. These should be tried before implementing more severe measures. The other is that the uncertainty in the interpretation of the abundance indices justifies adopting a less aggressive approach in the initial phases of any rebuilding plan.

7.3 LIMITATIONS IN CURRENT METHODOLOGY AVAILABLE FOR MONITORING BOCACCIO

It will always be difficult to gauge whether bocaccio stock abundance is increasing in response to management activities because the available indicators for monitoring abundance are extremely imprecise. The CVs range from just over 30% to 100% or larger (Appendix 2, 3 & 4). These high CVs are the consequence of the "patchy" distribution that characterises this species and suggest that a lack of precision will always accompany estimates of bocaccio abundance.

The current evaluation of the decline of this species is based primarily on the observation that a range of indicators have all shown similar imprecise trajectories. Therefore, it is likely that any rebuilding of this species will be gauged on an equivalent evaluation of a range of indicators. This is the reason that the research programme for this species proposes to establish and use a number of indicators to monitor this stock, including the WCVI shrimp trawl survey, the Hecate Strait Assemblage Survey and the development of a new series of synoptic surveys that will cover most areas of the west coast of Canada.

There is some scope to build production population models to evaluate this species. However, the low precision of the biomass surveys will translate into highly imprecise model estimates of key management parameters and equally imprecise model projections. This situation will probably not improve within the next 10 years, or at least until better methods are developed to monitor fish populations that are characterised by "patchy" distributions.

It is sometimes possible to convert a set of relative biomass indices into absolute biomass estimates, which can then be treated as if a specific amount of biomass is available. This approach is often adopted when there are relatively few abundance indices available and can help when abundance estimates are imprecise (an imprecise absolute estimate is always more informative than a relative abundance estimate). However, such an approach is not considered good practice for trawl survey abundance indices because converting to an absolute estimate requires making assumptions about fish behaviour and trawl selectivity that are difficult to gauge and could potentially lead to serious errors in the assessment and management of this species.

8.0 FUTURE RESEARCH AND MANAGEMENT ACTIVITIES

We have noted above the ongoing development or improvement in the department's ability to monitor harvests and track relative abundance of all groundfish species. The ability to assess bocaccio would also be assisted by specific research activities. These could include:

1. Increasing the focus on biological sampling and ageing of bocaccio to estimate age of recruitment and age of maturity for bocaccio in BC waters;
2. Conducting preliminary genetics analysis to look for significant stock structure [Note: one sample has recently been submitted to genetics researchers with the NMFS]
3. Develop assessment models which incorporate multiple indices of abundance and which include realistic levels of uncertainty. The utility of such models will not be high, given the low precision of the biomass indices, but it is possible that such analyses may provide insight into the dynamics of alternative rebuilding programs.
4. Examine the spatial/temporal distribution of catches through interviewing fishers and examining catch data to identify means for reducing incidental capture of bocaccio;
5. Improve the statistical basis for estimating HL catches;
6. Continue to work on strategic approaches for Groundfish fisheries management and research.

9.0 SUMMARY COMMENTS REGARDING STOCK STATUS

1. There is evidence of a large decline since 1980 off the southwest coast of Vancouver Island;
2. A parallel decline in U.S. states to the south is well documented;
3. It is not clear whether the abundance in 1980 was a historical high or represents a long term average abundance;
4. The indices are too imprecise to attach any quantitative estimates to the degree of decline;
5. We do not know whether the observed decline on the WCVI is an index for the total BC population, although a similar trend has been observed in the Hecate Strait groundfish survey;
6. Population size in terms of numbers of individuals is still reasonably large with respect to issues such as genetic drift;
7. Because the distribution of the species is widespread in BC waters, habitat limitation or habitat degradation is not a threat to the population;
8. Abundance appears to have been stable in the most recent 6 years;
9. The primary threat to this species is most likely a sustained period of poor recruitment, but this could be exacerbated by fishing when the population is at low levels of spawning biomass;
10. Current fishery mortality is about 335 t. Of this, the groundfish trawl fishery contributes about 87%, the commercial HL fisheries contribute about 9% and a variety of other fisheries contribute the remaining 4%. These latter fisheries include recreational, First Nations, and commercial salmon troll among others;
11. Controlling fishing mortality is the only current means of remedial action;

12. There are tools available to reduce catches from present levels. The success of such management actions can be monitored because of the present high levels of observer coverage;
13. The available stock status information is too limited and imprecise to provide specific harvest targets for the present or near future.

10.0 RECOMMENDATIONS FOR MANAGEMENT DIRECTIONS

1. Current levels of monitoring of bocaccio catches in fisheries where this species is taken should be maintained and, in some cases, increased. While a very minor contributor to total catch, one example of where direct monitoring could be improved is the North Coast troll fishery. It should be noted, however, that catch estimation for fisheries with less than 100% coverage programs (i.e. HL fisheries) can be biased by an "observer" effect. We also emphasize that any change in management regulations, especially if intended to reduce bocaccio catch, will discredit the assumption that commercial CPUE can track relative abundance.
2. The fishery management plan should specify allowable bocaccio catches;
3. Managers should consider two harvest options.
    a. Option #1 recommends capping harvests levels at current levels which are approximately 300-350 t coastwide across all fisheries. We suggest that managers consider implementation of this option at the earliest opportunity while more complex management strategies are elaborated;
    b. Option #2 recommends reducing catches to an arbitrarily lower target level in the groundfish trawl and HL fisheries. Initially this target could be met through a voluntary avoidance plan developed in discussion with harvesters. If, subsequently, it is observed that catch reduction targets are not being met, managers should consider the progressive implementation of dis-incentives to ensure that the targets are met.
4. The selection of a target harvest level must be arbitrary because there is currently no model-based method available for determining an appropriate harvest target. However, provided that abundance indices remain stable, at this time this document recommends against adopting aggressive catch reduction strategies which are intended to reduce catches to near zero;
5. Research scientists, managers and fishers should cooperatively develop voluntary avoidance strategies which can be implemented quickly to 1) insure catches do not increase, or 2) achieve a target reduction in catch.
6. Management should request an update on stock status within three years.

11.0 ACKNOWLEDGMENTS

The authors wish to acknowledge the help of Lisa Lacko and Kate Rutherford in summarizing B.C. catch and research data. The reassessment of U.S. data would not have been possible without the extensive assistance of Mark Wilkins of the National Marine Fisheries Service. Finally, we appreciate the assistance of Vivian Haist in interpreting the triennial survey data.

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13.0 REQUEST FOR WORKING PAPER

PSARC GROUNDFISH SUBCOMMITTEE

Date Submitted: 31 October 2003

Individual or group requesting advice: Groundfish Management Unit

Proposed PSARC Presentation Date: December 2003

Subject of Paper (title to be developed): An update on bocaccio

Lead Author: TBA **–** but to include R. Stanley and P. Starr

Fisheries Management Author(s)/Reviewer: TBA (**Rationale for request:**

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated bocaccio in its status classification of "threatened" in November 2002. COSEWIC's criterion for "threatened" is: a species likely to become endangered (facing imminent danger of extirpation or extinction) if limiting factors are not reversed. The committee's reason for this status is "A combination of low recruitment and impact by harvest has resulted in severe declines and low spawning abundance of this Canadian species".

The committee's quantitative criteria are stated as: "Meets criteria for Endangered A2b, but sampling is limited to the southern part of the range; therefore listed as Threatened".
The "A2b" criteria is: A) Declining total population, 2) Population size reduction that is observed, estimated, inferred or suspected over the last 10 year or 3 generations, whichever is longer, (to be greater than or equal to 50%) where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on b) An index of abundance appropriate for the taxon.

The Species at Risk Act (SARA) entered into force on June 5, 2003. SARA, under Section 27, specifies a process to act on the COSEWIC designation. The process requires a decision by the Governor in Council (GIC) to: a) refer the matter back to COSEWIC for further information or consideration, b) accept the COSEWIC assessment and add the species to the legal list (Schedule 1 of SARA), or c) decide to not add the species to the legal list. A decision with respect to bocaccio at this stage in the process is pending; the Minister of Fisheries and Oceans provides a recommendation on this decision, flowing through to the GIC through the Minister of the Environment.

Adding bocaccio to the “legal list” invokes further consultative, analytic, and decision-making processes that have potentially significant implications for fisheries in the Pacific Region. Implications include potential restrictions on fisheries (target and/or bycatch species), impacts on coastal communities, increased costs to stakeholders to meet SARA requirements, and inclusion of provisions in fisheries management plans to protect and recover listed species.

A working paper on bocaccio that addresses the science objectives and questions provided below is requested to assist stakeholders and the Department in preparing for the possible listing of bocaccio. Furthermore, given possible delays in the decision process and, if necessary, formulation of a recovery strategy, it seems prudent to provide managers with harvest advice for bocaccio in the interim as well as a summary of current science and management initiatives that relate to research and management of bocaccio.

Objectives of Working Paper:

This document will:

1. Update catch and survey information on bocaccio;
2. Review and discuss the “limiting factors” that the population is facing in Canadian waters;
3. In view of these “limiting factors”, assess effects of potential management directions for bocaccio;
4. Identify existing research initiatives that can help support management of bocaccio;
5. Suggest additional activities that could help to address bocaccio issues.

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

A. Does an update of information provide any significant change in results presented in the earlier document?

B. What have been and will be the limiting factors/threats for bocaccio in BC waters?

C. What is the nature of the harvest advice that can be provided to managers about bocaccio?

D. Identify activities that are in place, or could be put in place to improve the basis for advice on bocaccio;

Stakeholders Affected:

As the bocaccio range is coast-wide and the depth distribution varies from 0-600 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, particularly if the species is legally listed.

Timing Issues Related to When Advice is Necessary:

The advice needs to be sensitive to the timing constraints imposed by the process specified by SARA. It is anticipated that presentation of the paper at the December 8-10, 2003 Groundfish PSARC Subcommittee meeting will permit the Department to meet its obligations in providing advice flowing to managers:

Table 1. Total combined reported catches (t) of bocaccio by DFO Major Area for trawl and HL methods.

	Major area									
Year	**4B**	**3C**	**3D**	**5A**	**5B**	**5C**	**5D**	**5E**	**Unk.**	**Total**
1966	0.0	0.0	0.0	0.0	0.0	0.0	4.5	0.0	0.0	4.5
1967	0.0	0.0	52.0	89.1	19.8	0.0	0.0	0.0	0.0	160.9
1968	0.0	0.1	34.2	19.0	48.6	0.0	0.0	0.0	0.0	101.9
1969	0.0	2.3	87.3	247.8	477.3	0.0	0.0	0.0	0.0	814.6
1970	0.0	78.7	129.4	55.3	42.0	0.0	0.6	0.0	0.0	306.0
1971	0.0	12.1	19.9	36.5	103.6	0.0	0.0	0.0	0.0	172.1
1972	0.0	9.3	63.0	11.2	130.3	0.0	9.0	0.0	0.0	222.8
1973	0.0	24.2	74.1	170.5	475.2	0.0	2.4	0.0	0.0	746.3
1974	0.0	8.5	30.0	205.1	464.1	0.0	0.0	0.0	0.0	707.7
1975	0.0	17.2	20.1	253.4	211.5	0.0	2.0	0.0	0.0	504.2
1976	0.0	48.2	162.0	187.0	82.8	0.1	14.8	0.0	0.0	494.8
1977	0.0	29.4	20.9	47.7	217.0	0.2	59.5	1.4	0.0	376.0
1978	0.1	8.4	19.7	89.3	61.8	7.9	47.8	14.4	0.0	249.3
1979	0.3	17.0	67.1	86.5	179.6	67.7	56.7	3.7	0.0	478.5
1980	0.1	3.0	11.6	27.0	93.4	23.6	18.3	0.5	0.0	177.5
1981	0.1	3.6	7.5	13.9	44.9	3.4	15.7	0.6	0.0	89.7
1982	0.0	1.6	9.8	26.8	52.3	1.9	7.8	0.5	0.0	100.6
1983	1.5	9.3	36.7	28.8	65.0	4.6	3.1	0.1	0.0	149.1
1984	0.0	14.9	50.1	42.5	35.9	16.3	9.6	0.0	0.0	169.3
1985	0.0	35.5	128.2	85.3	74.5	75.4	7.4	0.3	0.0	406.6
1986	0.4	81.5	222.9	157.0	194.8	26.0	10.8	7.3	0.0	700.7
1987	0.0	33.2	172.7	171.2	246.4	57.8	23.0	5.4	0.0	709.6
1988	0.0	293.3	301.2	233.8	392.3	35.9	18.3	48.2	0.0	1322.9
1989	0.0	103.6	232.1	162.5	176.5	43.3	22.6	44.0	0.0	784.6
1990	0.0	83.4	186.2	257.0	378.5	95.6	30.3	1.5	0.0	1032.5
1991	0.1	78.6	242.9	304.2	367.8	45.8	15.9	8.2	0.0	1063.5
1992	0.3	152.3	208.9	258.5	194.0	51.0	73.0	11.8	0.0	949.6
1993	0.8	134.0	323.9	250.1	239.5	49.3	89.7	42.4	0.0	1129.5
1994	0.3	103.6	177.0	118.8	111.3	46.7	41.2	8.8	0.0	607.7
1995	0.2	57.4	112.8	147.2	93.1	63.9	28.0	7.7	30.7	541.0
1996	0.1	42.8	58.1	51.6	62.9	18.8	17.5	8.5	38.0	298.2
1997	0.0	21.2	42.5	72.3	54.0	11.6	17.5	5.5	15.5	240.1
1998	0.0	32.1	57.9	74.1	55.4	10.5	15.7	5.7	14.5	265.9
1999	0.0	30.8	66.8	53.7	46.2	11.6	6.7	3.7	17.6	237.1
2000	0.0	25.2	65.6	48.3	109.6	6.7	7.3	6.1	25.7	294.5
2001	0.0	33.9	68.4	54.1	74.2	9.7	14.7	11.3	25.9	292.1
2002	0.0	25.9	49.7	71.4	93.9	18.7	16.2	8.2	19.5	303.5

Table 2. Annual landings (t) of bocaccio in U.S. waters by INPFC area. (n.a. = not available)

Year	Alaska	Vancouver-US (N. Wash.)	Columbia (S. Wash.- N. Ore.)	Eureka (S. Ore.- N. Cal.)	Monterey (Cen. Cal.)	Conception (S. Cal.)	Unkn.	Total
				INPFC Area				
1967		4.1						4.1
1968		19.1						19.1
1969		6.2						6.2
1970		1.2						1.2
1971		11.5						11.5
1972		3.8						3.8
1973								0.0
1974		0.5						0.5
1975								0.0
1976		2.8						2.8
1977		14.9						14.9
1978		1.7	9.5					11.3
1979		27.5	27.1					54.6
1980								n.a.
1981		39.0	644.1	846.3	2689.2	936.4	5.9	5160.9
1982		31.8	634.8	655.9	3286.0	1426.2	1.2	6035.9
1983		157.5	763.5	492.0	3466.5	990.3	1.6	5871.4
1984		147.1	251.8	243.9	2819.0	576.6	2.0	4040.4
1985		128.7	478.6	260.2	1245.3	407.3	0.3	2520.4
1986		81.9	273.1	85.1	1090.2	570.6	1.2	2102.1
1987		116.5	242.6	119.7	1631.1	447.9	7.7	2565.5
1988		99.5	189.4	92.2	1210.1	343.4	3.1	1937.7
1989		283.9	217.3	99.3	1537.1	396.2	2.2	2536.0
1990		304.7	143.7	139.5	1215.5	418.8	1.6	2223.8
1991	1.3	393.7	184.6	56.8	885.7	300.9	2.1	1825.1
1992	1.4	215.9	143.2	62.8	798.7	608.6	3.5	1834.1
1993	1.0	139.8	144.9	121.8	666.4	590.1	0.8	1664.8
1994	3.0	52.7	105.1	55.7	436.6	504.1		1157.2
1995	3.0	51.4	95.7	61.1	421.1	261.0		893.3
1996	5.9	35.8	83.5	38.7	281.6	156.5		602.0
1997	3.8	57.8	75.8	11.1	245.2	59.8		453.5
1998	6.2	47.9	48.1	15.6	99.2	39.0		256.0
1999	n.a	10.6	24.5	17.3	50.9	8.9		112.2
2000	n.a	2.0	0.3	2.5	22.9	2.3		30.0
2001	n.a	7.9	1.5	0.3	18.4	3.8		31.9

Table 3 Recorded landings and discards (t) by fishery and major area (Offshore hake refers to catches in the joint-venture and foreign nation supplemental fisheries).

	4B			3C					3D							5A		
Nation	Canada	Canada		Canada	Canada	USA	Offshore hake		Canada	Canada	USA	Canada	Offshore hake		Nation	Canada	Canada	USA
Gear	Midwater	Bottom		Midwater	Bottom	Trawl	Trawl		Midwater	Bottom	Trawl	Troll	Trawl		Gear	Midwater	Bottom	Trawl
Year	Trawl	Trawl	Total	Trawl	Trawl	landed	catch	Total	Trawl	Trawl	landed	landed	catch	Total	Year	Trawl	Trawl	USA
1966			0					0						0	1966			
1967			0					0			51.96			51.96	1967		0.22	88.91
1968			0			0.08		0.08		1.43	32.73			34.16	1968		5.66	13.37
1969			0			2.27		2.27		1.03	86.22			87.25	1969		1.11	246.68
1970			0			78.69		78.69		3.04	126.39			129.43	1970		0.39	54.88
1971			0			12.11		12.11			19.89			19.89	1971			36.45
1972			0			9.26		9.26			63			63	1972			11.21
1973			0			24.18		24.18			74.07			74.07	1973			170.47
1974			0		0.37	8.16		8.53		3.01	27.01			30.02	1974		1.48	203.58
1975			0		0.54	16.66		17.2			20.07			20.07	1975		3.41	249.98
1976			0		2.59	45.58		48.17		6.24	155.74			161.98	1976	0.82	7.42	178.74
1977			0		28.97	0.46		29.43		10.14	10.74			20.88	1977	0.65	16.76	30.28
1978		0.06	0.06		6.87	1.49		8.36	0.03	19.11	0.52			19.66	1978		76.04	13.26
1979		0.29	0.29		15.01	2.02		17.03		31.79	35.27			67.06	1979		44.33	42.16
1980		0.06	0.06		3.03			3.03		11.63				11.63	1980		27.03	
1981		0.08	0.08		3.56			3.56		7.47				7.47	1981		13.94	
1982			0		1.56			1.56		9.78				9.78	1982		26.8	
1983		1.52	1.52		9.3			9.3		36.73				36.73	1983		28.76	
1984			0		14.9			14.9		50.08				50.08	1984		42.52	
1985			0		35.46			35.46		128.18				128.18	1985		85.25	
1986		0.43	0.43	0.18	81.3			81.48	25.1	197.8				222.9	1986		157	
1987			0	1.49	31.7			33.19	23.16	149.57				172.73	1987	1.39	169.81	
1988			0		288.95		4.34	293.29	44.24	256.34			0.6	301.18	1988	2.25	231.57	
1989		0.01	0.01		101.23		2.38	103.61	5.64	223.79			2.7	232.13	1989	0.39	162.1	
1990			0		81.08		2.31	83.39	18.54	167.25			0.4	186.19	1990	5.1	251.85	
1991		0.11	0.11	0.3	76.4		1.92	78.62	5.92	236.46			0.48	242.86	1991		304.24	
1992	0.04	0.21	0.25	1.04	148.78		2.46	152.28	4.02	204.88			0.02	208.92	1992	15.19	243.26	
1993	0.21	0.54	0.75	0.27	130.68		3.04	133.99	32.51	290.06			1.28	323.85	1993	3.87	246.2	
1994	0.24	0.05	0.29	0.67	96.4		6.57	103.64	17.26	155.64			4.09	176.99	1994	5.4	113.38	
1995	0.2		0.2	2.67	53.16		1.6	57.43	9.78	103.05				112.83	1995	7.99	139.18	
1996	0.06	0.02	0.08	1.3	38.56		2.93	42.79	28.82	29.28				58.1	1996	4.26	47.33	
1997		0.01	0.01	0.08	19.9		1.26	21.24	17.1	25.39				42.49	1997	3.29	69.02	
1998			0	1.03	29.61		1.41	32.05	11.59	46.29				57.88	1998	7.91	66.18	
1999			0	3.55	25.67		1.62	30.84	28.94	37.85				66.79	1999	9.24	44.5	
2000			0	1.29	23.71		0.22	25.22	10.82	54.78		0.01		65.61	2000	11.93	33.78	
2001			0	1.03	32.2		0.66	33.89	12.52	55.83				68.35	2001	10.95	43.13	
2002			0	0.23	25.67			25.9	12.67	37.02				49.69	2002	20.8	50.63	

Table 3 cont'd

Nation Gear Year	5D Canada Midwater Trawl	5D Canada Bottom Trawl	5D Offshore hake Trawl catch	5D Canada Troll landed	5D Total	5E Canada Midwater Trawl	5E Canada Bottom trawl	5E Offshore hake Trawl catch	5E Canada Troll landed	5E Total	Unknown Canada Trawl	Unknown Canada H & L landed	Unknown Total	Nation Gear Year	Grand total
1966		4.51			4.51					0.00			0.00	1966	4.51
1967					0.00					0.00			0.00	1967	160.93
1968					0.00					0.00			0.00	1968	101.88
1969					0.00					0.00			0.00	1969	814.59
1970		0.63			0.63					0.00			0.00	1970	306.00
1971					0.00					0.00			0.00	1971	172.08
1972		9.02			9.02					0.00			0.00	1972	222.80
1973		2.37			2.37					0.00			0.00	1973	746.29
1974					0.00					0.00			0.00	1974	707.70
1975		2.03			2.03					0.00			0.00	1975	504.20
1976		14.84			14.84					0.00			0.00	1976	494.80
1977		59.46			59.46		1.37			1.37			0.00	1977	376.03
1978	4.28	43.54			47.82	0.08	14.30			14.38			0.00	1978	249.30
1979	2.17	54.48			56.65	0.05	3.69			3.74			0.00	1979	478.49
1980	0.34	17.97			18.31		0.46			0.46			0.00	1980	177.46
1981		15.72			15.72		0.59			0.59			0.00	1981	89.71
1982		7.79			7.79		0.52			0.52			0.00	1982	100.64
1983	0.04	3.06			3.10	0.09				0.09			0.00	1983	149.11
1984	0.40	9.16			9.56					0.00			0.00	1984	169.25
1985	2.49	4.95			7.44		0.33			0.33			0.00	1985	406.60
1986		10.84			10.84		7.25			7.25			0.00	1986	700.67
1987		22.95			22.95		5.39			5.39			0.00	1987	709.61
1988		18.29			18.29		48.15			48.15			0.00	1988	1322.91
1989		22.57			22.57		44.03			44.03			0.00	1989	784.62
1990	0.23	30.11			30.34		1.48			1.48			0.00	1990	1032.46
1991	0.01	15.86			15.87		8.17			8.17			0.00	1991	1063.46
1992	9.05	63.93			72.98		11.81			11.81			0.00	1992	949.61
1993	13.91	75.80			89.71	0.22	42.13			42.35			0.00	1993	1129.48
1994	2.92	38.27			41.19	0.04	8.73			8.77			0.00	1994	607.71
1995	5.48	22.49			27.97		7.71			7.71		30.66	30.66	1995	540.99
1996	2.59	14.91			17.50	0.22	8.30			8.52	13.45	24.50	37.95	1996	298.16
1997	3.26	14.21			17.47		5.53			5.53	3.52	11.95	15.47	1997	240.07
1998	1.53	14.14			15.67		5.74			5.74	4.17	10.30	14.47	1998	265.86
1999	3.03	3.66			6.69	0.71	3.02			3.73	4.21	13.34	17.55	1999	237.11
2000	1.20	5.84	0.18	0.10	7.32	0.06	5.39	0.49	0.20	6.14	6.20	19.45	25.65	2000	294.52
2001	0.60	14.12			14.72	5.30	5.97			11.27	3.80	22.06	25.86	2001	292.08
2002	0.87	15.31			16.18	2.41	5.83			8.24	4.70	14.75	19.45	2002	303.52

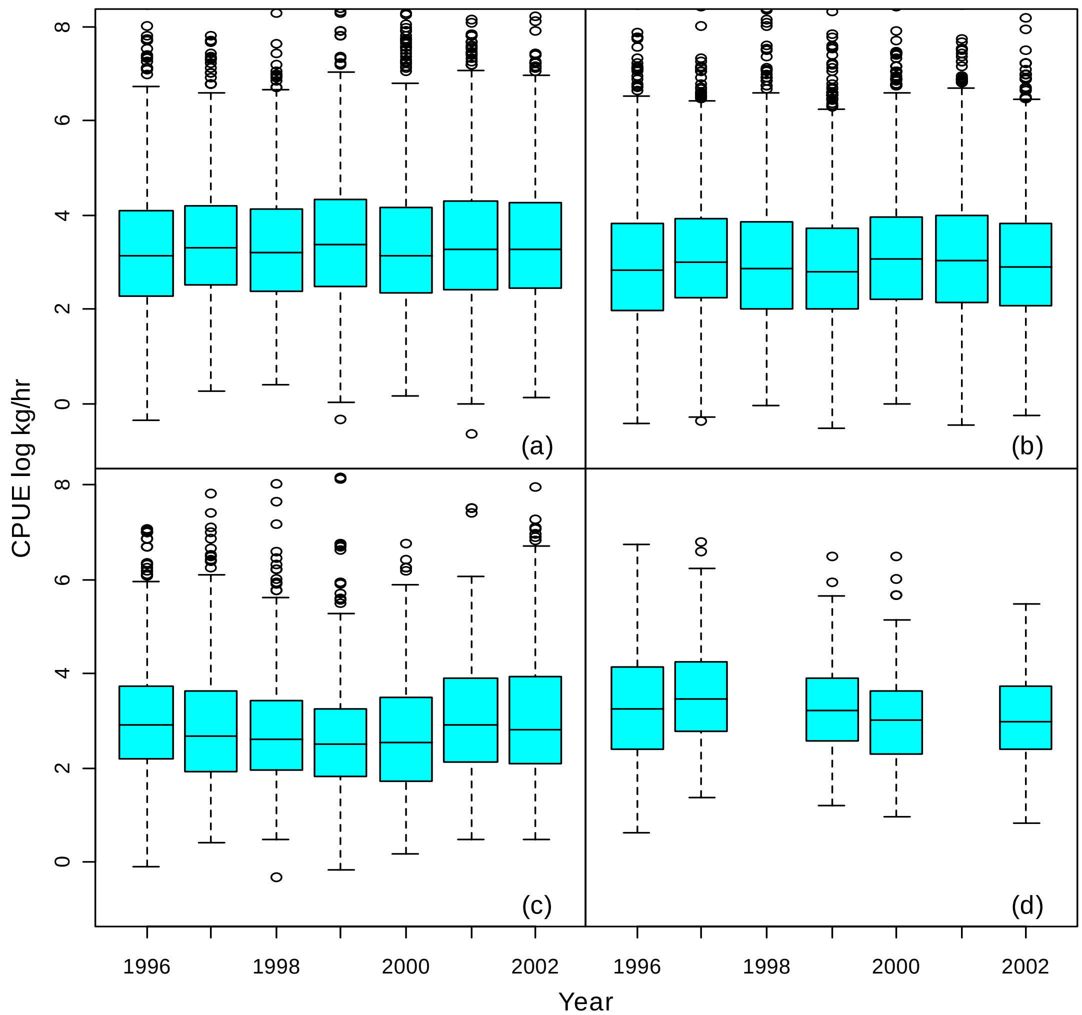

Figure 1. Box and whiskers plot of bocaccio CPUE (log kg/hr) in the commercial trawl fishery in each coastal region: (a) 3CD; (b) 5AB; (c) 5CD; (d) 5E. For each box, the upper and lower bounds indicate the 75th and 25th percentiles, respectively; the central horizontal line indicates the median; the upper and lower whiskers are positioned at 1.5 times the inter-quartile range; and the open circles indicate values that fall outside the whiskers.

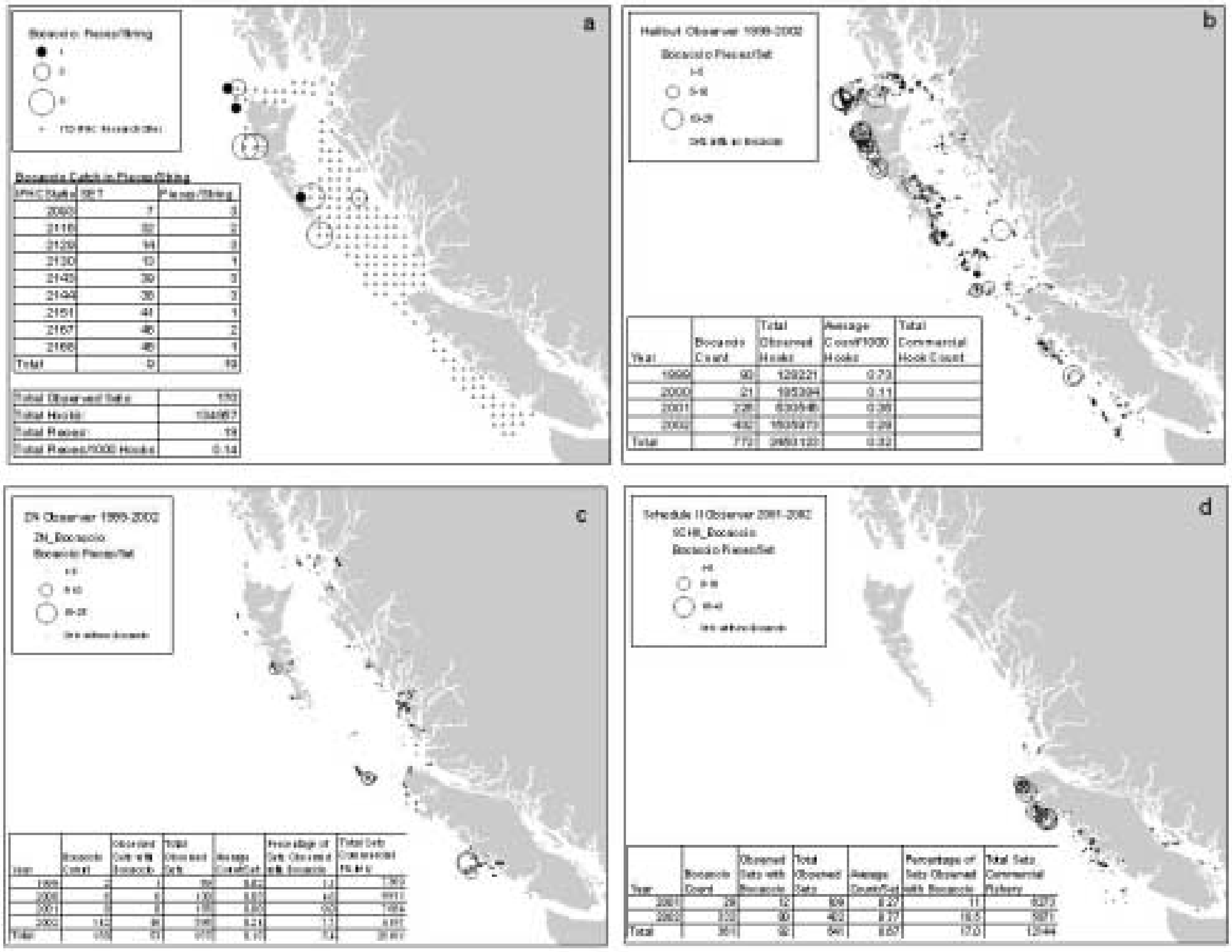

Figure 2. Summary of HL catches of bocaccio in the a) IPHC set line survey (2003), b) observers in the halibut fishery, c) observers in the ZN fishery, and d) observes in the Schedule II fishery.

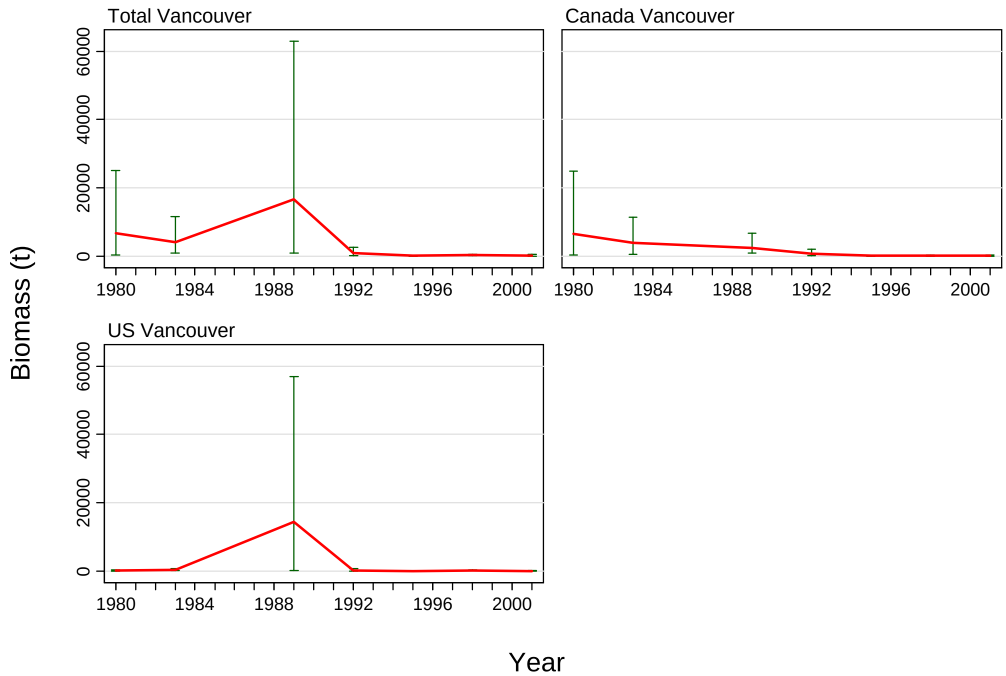

Figure 3. Three biomass estimates for the INPFC Vancouver region (total region, Canadian waters only and U.S. waters only) with 95% bias corrected error bars estimated from 5000 bootstraps.

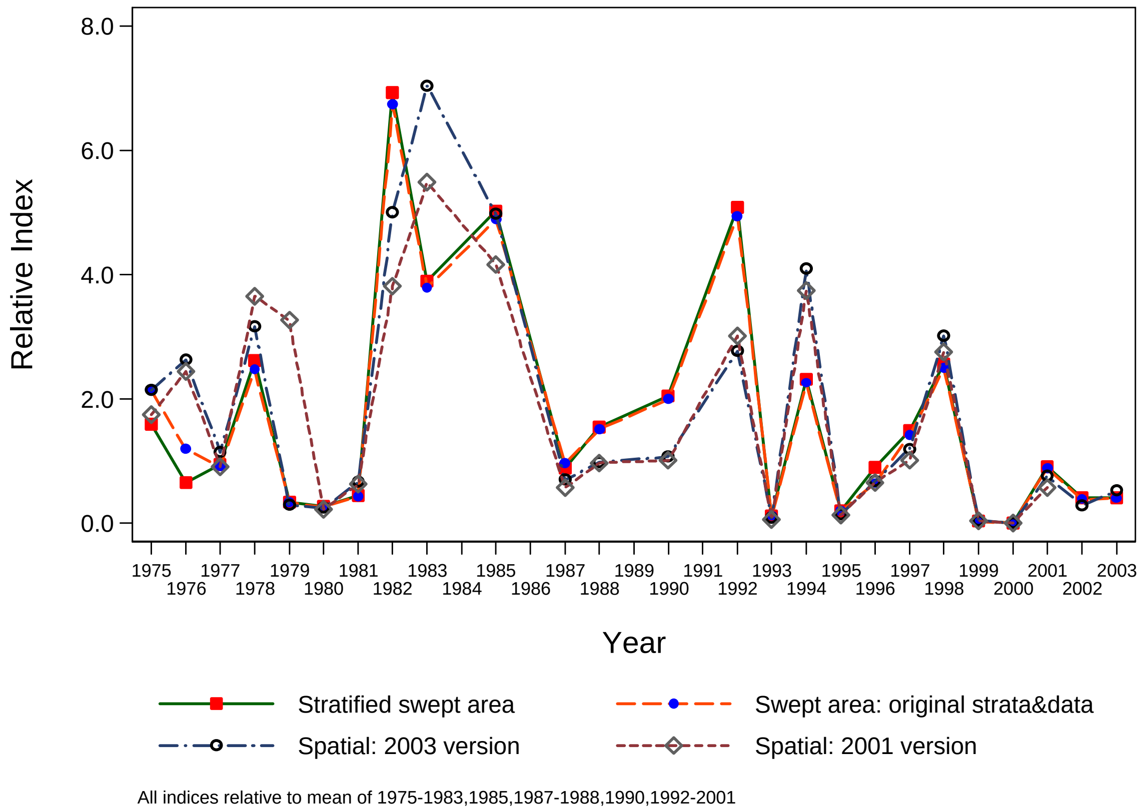

Figure 4. Comparison of a range of biomass indices using the WCVI shrimp trawl survey data: a) swept area using the stratification that was adopted by Starr et al. 2002, Figure 22; b) swept area using the original survey stratification and without dropping any tows; c) a recalculated spatial shrimp index and d) the original spatial index used in 2001

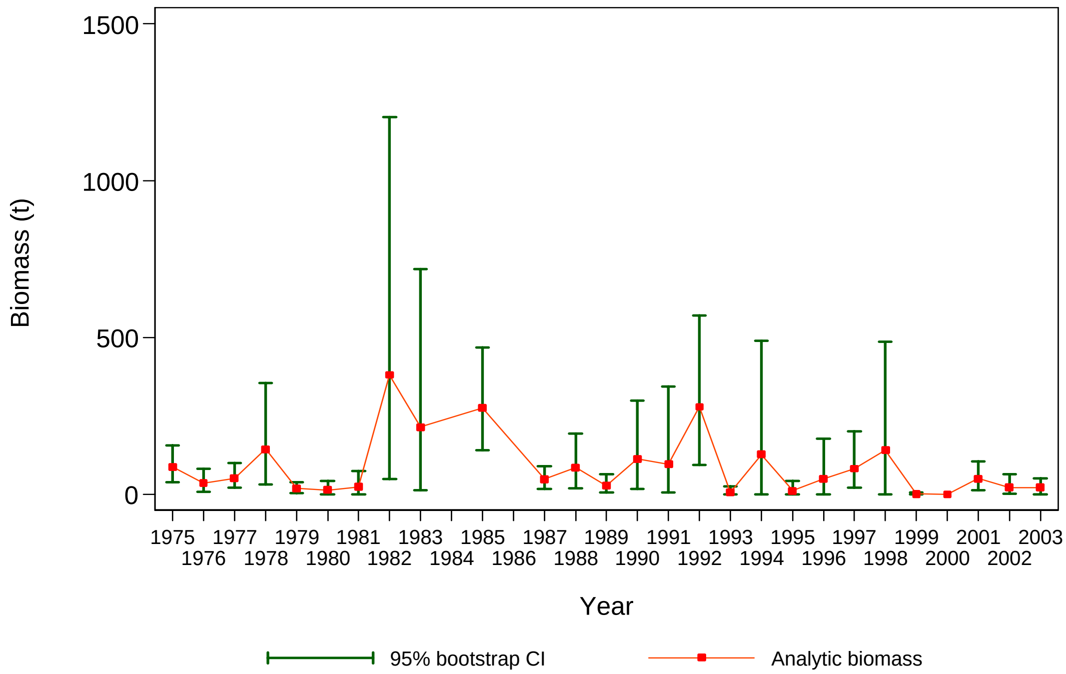

Figure 5. Plot of biomass estimates for bocaccio from the WCVI shrimp trawl survey for the period 1975 to 2003. Bias corrected 95% confidence intervals from 1000 bootstrap replicates are plotted.

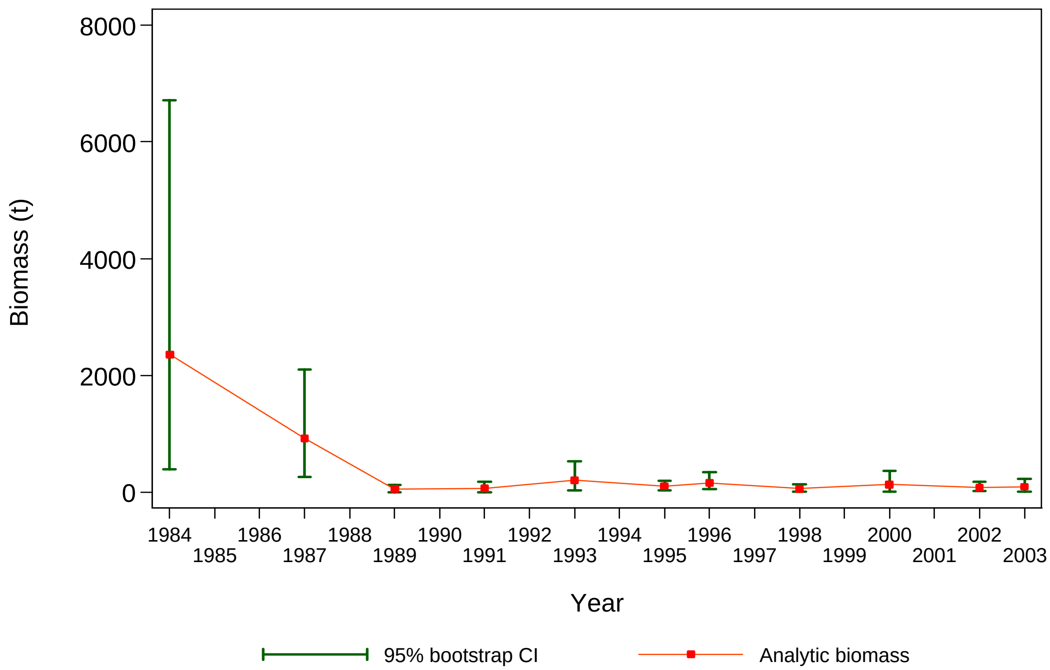

Figure 6. Plot of biomass estimates for bocaccio from the Hecate Strait assemblage trawl survey for the period 1984 to 2003. Bias corrected 95% confidence intervals from 5000 bootstrap replicates are plotted.

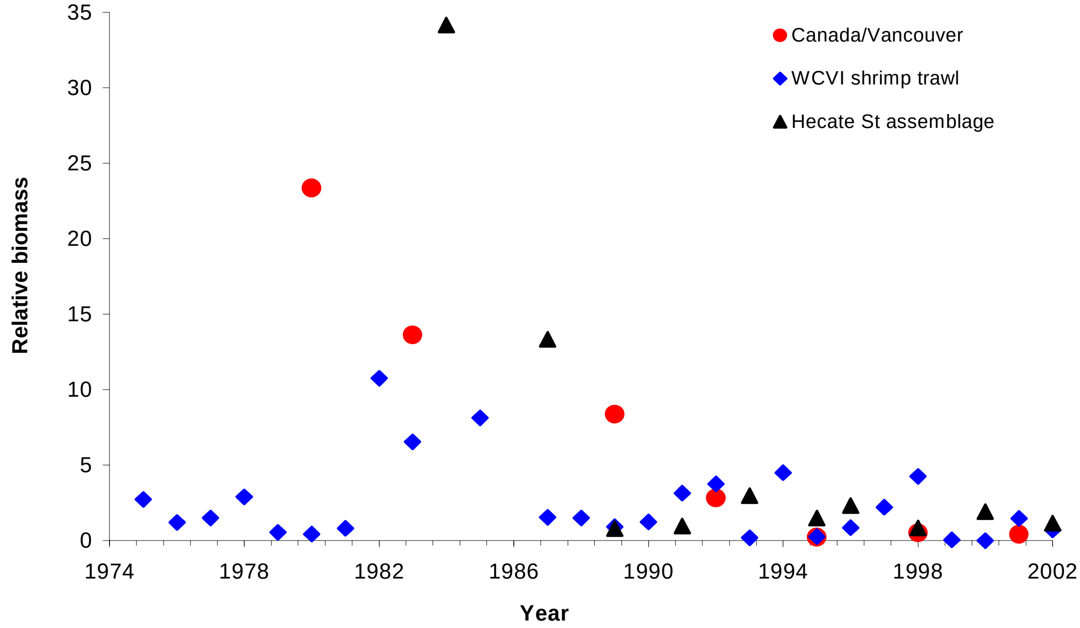

Figure 7. Comparison of the three available sets of trawl survey data for bocaccio in Canadian waters: a) NMFS triennial survey for the Canada/Vancouver region; b) WCVI shrimp trawl survey; c) Hecate St. assemblage survey. All survey indices have been standardized relative to the geometric mean of the 1989, 1995 and 1998 indices, the only years of overlap in these surveys.

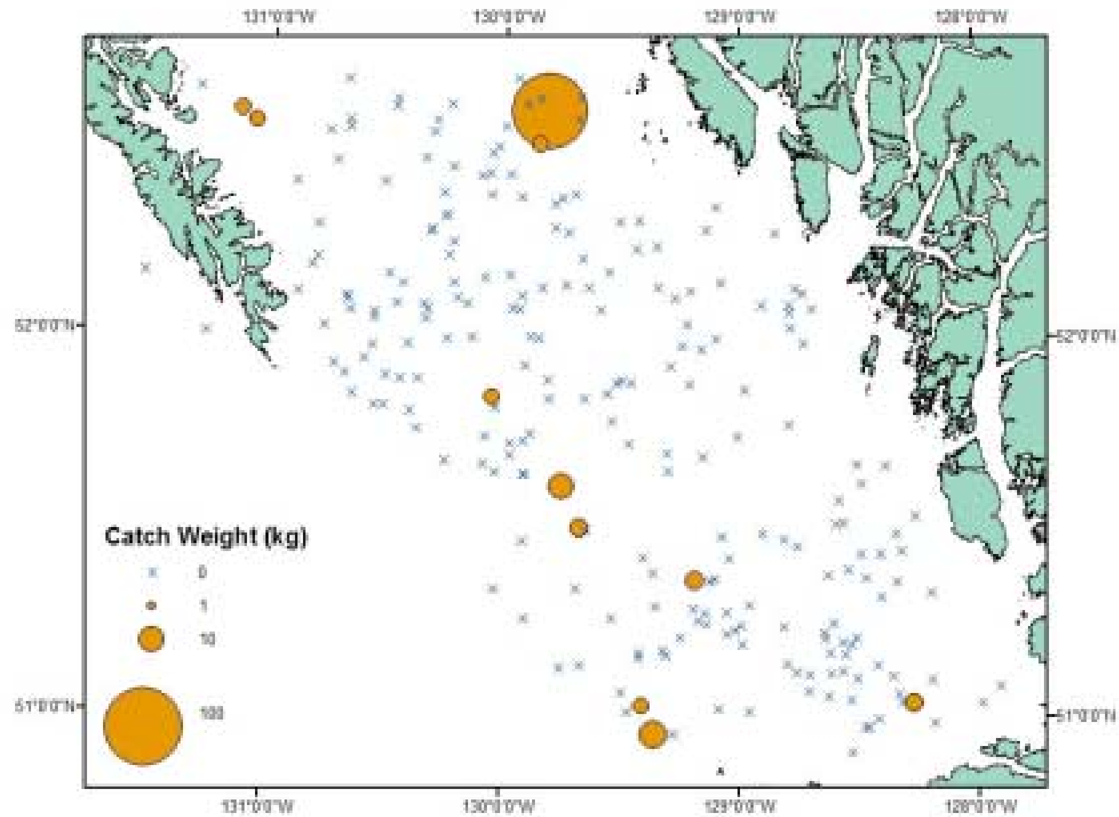

Figure 8. Plot of successful bottom trawl tows during the 2003 Queen Charlotte Sound survey. Orange circles refer to catches of bocaccio.

14.0 APPENDIX 1. NMFS TRIENNIAL SURVEY

14.1 METHODS

1. This analysis is based on tow-by-tow data from the U.S. National Marine Service (NMFS) triennial survey covering the entire Vancouver INPFC region (Mark Wilkins NMFS *pers. comm.*) for the seven survey years that ventured into Canadian waters (Table 4). All usable tows have an associated net width and distance travelled, allowing for the calculation of the area swept by the tow. Biomass indices and the associated analytical CVs for bocaccio were calculated for the total Vancouver INPFC region and for each of the Canadian and Vancouver sub-regions, using appropriate area estimates for each stratum.

Table 4. Number of usable tows performed and area surveyed in the INPFC Vancouver region separated by the international border between Canada and the United States. Strata 37, 38 and 39 (Table 5) were dropped from this analysis, as they were not consistently conducted over the survey period.

	Number tows			**Area surveyed (km^2)**		
Survey year	**Canadian waters**	**U.S. waters**	**Total**	**Canadian waters**	**U.S. waters**	**Total**
1980	59	26	85	7,399	4,738	12,137
1983	47	70	117	7,399	4,738	12,137
1989	67	87	154	9,413	4,699	14,112
1992	61	79	140	9,413	4,699	14,112
1995	64	63	127	9,762	4,976	14,738
1998	55	72	127	9,696	4,801	14,497
2001	36	67	103	9,608	4,976	14,584
Total	389	464	853	–	–	–

Table 5. Amount of relevant area (km^2) by survey year and by stratum in the INPFC Vancouver region shown divided into the amount of area available in the waters of each country. Cells highlighted in grey are strata which are located in the 366–500 m depth range which were not consistently surveyed throughout the period.

Stratum	**Canadian waters & year**				**U.S. waters & year**			
Number	**1980**	**1983**	**1989 & 1992**	**1995 & >**	**1980**	**1983**	**1989 & 1992**	**1995 & >**
10					3,537	1,307		
11	6,572					2,230		
12		6,572						
17							1,033	1,033
18			159				2,123	2,123
19			8,224	8,224			363	363
27							125	125
28			88	88			787	787
29			942	942			270	270
30					443	66		
31	325					377		
32		325						
37								102
38				66				175
39				442				
50					758	127		
51	503					631		
52		503						
Total	7,400	7,400	9,413	9,762	4,738	4,738	4,701	4,978

2. Tow data were provided by stratum and location of the tow, including by country fished based on tow start position (Table 4). The definition of the strata varied between years (Table 5) in terms of the stratum numbering and the amount of area fished in each year (Table 4). In general, the size of the total area fished was about twice as large in Canadian waters than in U.S. waters (Table 5), although more tows tended to be performed in U.S. waters (Table 4). The analysis was confined to strata which covered depth ranges (between 55 and 366 m) that had been consistently surveyed throughout the seven surveys (Table 5). Note that no bocaccio have ever been caught in the deepest strata.

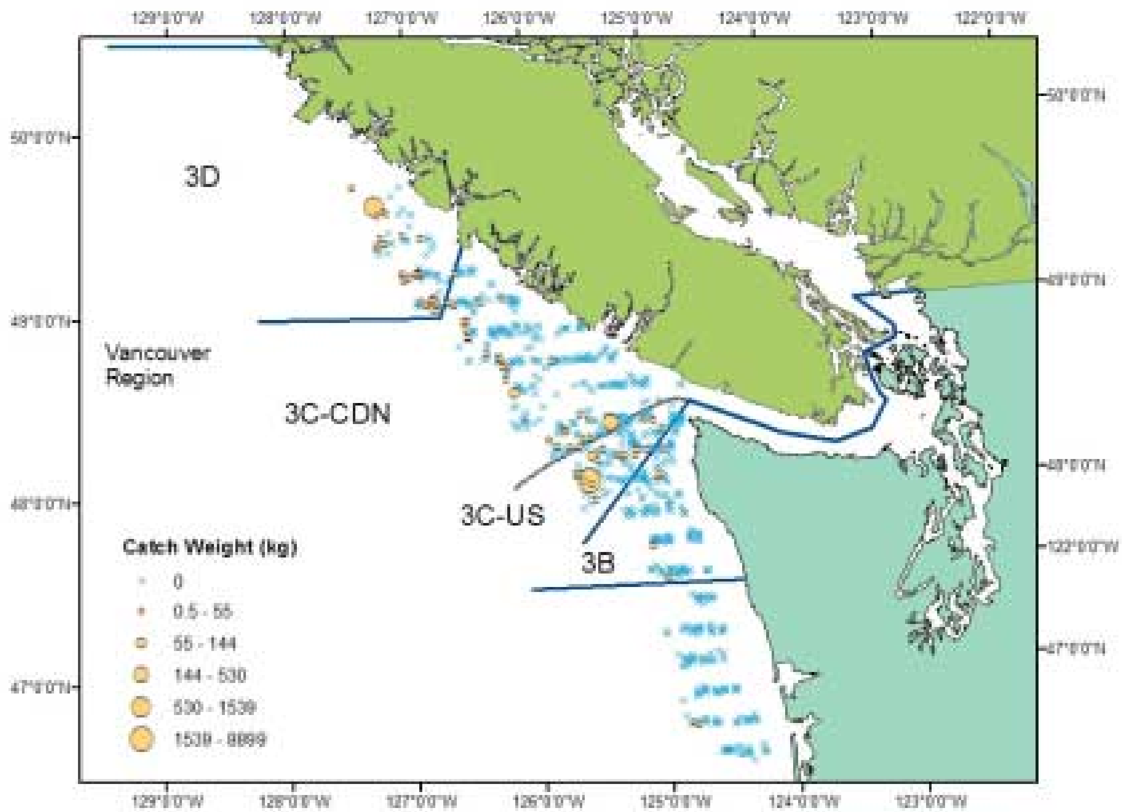

Figure 9. Map of the location of all tows from the triennial survey in the Vancouver INPFC region for the seven surveys listed in Table 4. Relative catch totals for bocaccio are shown for those tows which caught bocaccio.

3. The data were analysed using the following equations. The biomass in any year y was obtained by summing the product of the bocaccio CPUE and the area surveyed across the surveyed strata i:

$$B_y = \sum_{i=1}^{k_y} C_{y_i} A_{y_i} = \sum_{i=1}^{k_y} B_{y_i} \qquad \textbf{Eq. 1}$$

where C_{y_i} = mean CPUE density (kg/km^2) for bocaccio in year y in stratum i

A_{y_i} = area of stratum i (km^2) in year y

k_y = number of strata in year y

B_{y_i} = biomass of bocaccio in stratum i for year y

CPUE $\left(C_{y_i}\right)$ in stratum i for year y was calculated as a density in kg/km^2 by

$$C_{y_i} = \frac{\sum_{j=1}^{n_{y_i}} \left(W_{y_i j} \big/ D_{y_i j} w_{y_i j} \right)}{n_{y_i}} \qquad \textbf{Eq. 2}$$

where $W_{y_i j}$ = catch weight (kg) in year y in stratum i and tow j

$D_{y_i j}$ = distance travelled (km) in year y by tow j in stratum i

$w_{y_i j}$ = wingspread width (km) in year y for tow j in stratum i

n_{y_i} = number of tows in year y for stratum i

The variance of the survey biomass estimate V_{B_y} in year y is calculated in kg^2 as follows:

$$V_{B_y} = \sum_{i=1}^{k_y} \sigma_{y_i}^2 A_{y_i}^2 \big/ n_{y_i} = \sum_{i=1}^{k_y} V_{y_i} \qquad \textbf{Eq. 3}$$

where $\sigma_{y_i}^2$ = variance of CPUE (kg^2/km^4) for year y in stratum i

V_{y_i} = variance of bocaccio in stratum i for year y

It was assumed that the variance and CPUE within any stratum was equal, even for strata that were split by the presence of the U.S./Canada border. The total biomass $\left(B_{y_i}\right)$ within a stratum which straddled the border was split between the two countries $\left(B_{y_{i_c}}\right)$ by the ratio of the relative area within each country:

$$B_{y_{i_c}} = B_{y_i} \frac{A_{y_{i_c}}}{A_{y_i}}$$ **Eq. 4**

where $A_{y_{i_c}}$ = area (km^2) within country c in year y and stratum i

The variance $V_{y_{i_c}}$ for that part of stratum i within country c was calculated as being in proportion to the ratio of the square of the area within each country c relative to the total area of stratum i. This assumption resulted in the CVs within each country stratum being the same as the CV in the entire stratum:

$$V_{y_{i_c}} = V_{y_i} \frac{A^2_{y_{i_c}}}{A^2_{y_i}}$$ **Eq. 5**

The partial variance $V_{y_{i_c}}$ for country c was used in Eq. 3 instead of the total variance in the stratum V_{y_i} when calculating the variance for the total biomass in U.S. or Canadian waters.

The CV for each year y was calculated as follows:

$$CV_s = \frac{\sqrt{V_{B_s}}}{B_s}$$ **Eq. 6**

4. Biomass estimates were bootstrapped for 5000 random draws with replacement to obtain bias corrected (Efron 1982) 95% confidence regions for each year and for three area categories (total Vancouver region, Canadian Vancouver only and U.S. Vancouver only) based on the distribution of biomass estimates and using the above equations.

14.2 RESULTS

5. The biomass estimates and the associated annual CVs obtained from the above methods were very similar to the equivalent estimates of biomass and CV provided by NMFS for the same strata (Table 6), with the exception of some small differences in the 2001 estimate. The time series trend of biomass estimates for the Canadian-Vancouver sub-region (Figure 10) is the same as that plotted in Stanley et al. (2001). The trends for the U.S.-Vancouver sub-region and the total Vancouver region each show a large peak in the biomass in 1989 (Figure 10) which is associated with a single tow begun just south of the U.S.-Canada border and continuing into Canada for the tow. This tow is assigned to the U.S. waters because the protocol established by NMFS uses the tow starting position to define the country of origin. All the bocaccio biomass estimates, particularly the early ones which estimated the higher biomass levels, have large CVs and are highly uncertain (Table 6).

6. The large biomass estimated in 1989 in the U.S. Vancouver stratum is the result of a single tow which caught about 9000 kg of bocaccio. This is by far the largest bocaccio tow ever recorded in the Vancouver region in all seven surveys. It is possible that the most appropriate time series to use for depicting the Canadian bocaccio stock is the total Vancouver INPFC region series, given the survey design and the exclusion of a single tow which turns out to have so much leverage on the biomass estimate for that year. Using the

total Vancouver INPFC region bocaccio series does not change the overall conclusions about the bocaccio population trend but is a statistically more robust interpretation of the data. A reanalysis of the data using a stratification that estimated independent CPUE densities on each side of the border did not appreciably change the pattern presented in Figure 10.

7. Frequency distributions by survey year of the bocaccio catch weight across all tows shows that only a few tows catch bocaccio (Figure 11). Only 91 tows from a total 853 tows in this data set caught bocaccio over the entire history of the survey. An important observation from these data is that the proportion of tows which contain bocaccio has declined since the beginning of the triennial survey series (Figure 12). This result indicates that it is highly likely that there has been a decline in the density of bocaccio over the twenty-one year period covered by this survey, in spite of the large uncertainty associated with each biomass estimate. However, it is not possible to accurately estimate the amount of the decline, given the large degree of variability shown by the data and the very high proportion (greater than 80%) of zero tows that occurred even in the early years of the survey. This is well illustrated by the wide confidence interval resulting from bootstrap distribution of survey biomasses presented in Figure 10, making it difficult to estimate the true level of the observed decline.

8. Bocaccio biomass has been declining in all five INPFC regions covered by the triennial survey (Figure 13). This consistency of trend among these regions indicates that there has likely been an overall decline in the abundance of this species in the area covered by this survey over the 24 years of coverage. However, the large error bars associated with the biomass indices for each region indicate that, as shown for the Vancouver INPFC region, there is considerable uncertainty in the quantum of the decline that has taken place over this period.

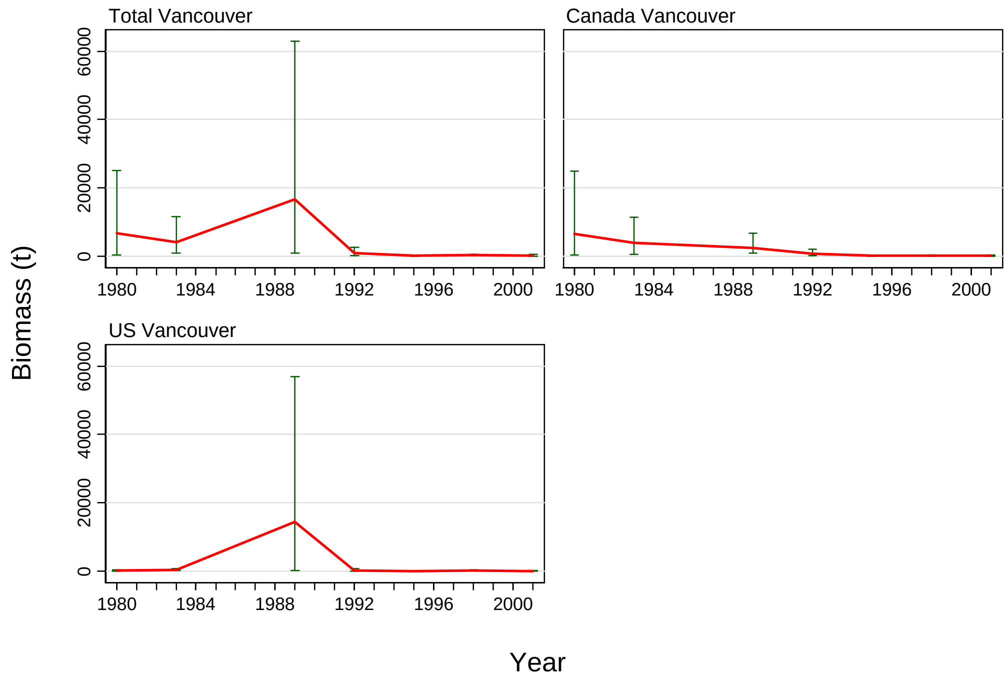

Figure 10. Three biomass estimates for the INPFC Vancouver region (total region, Canadian waters only and U.S. waters only) with 95% bias corrected error bars estimated from 5000 bootstraps.

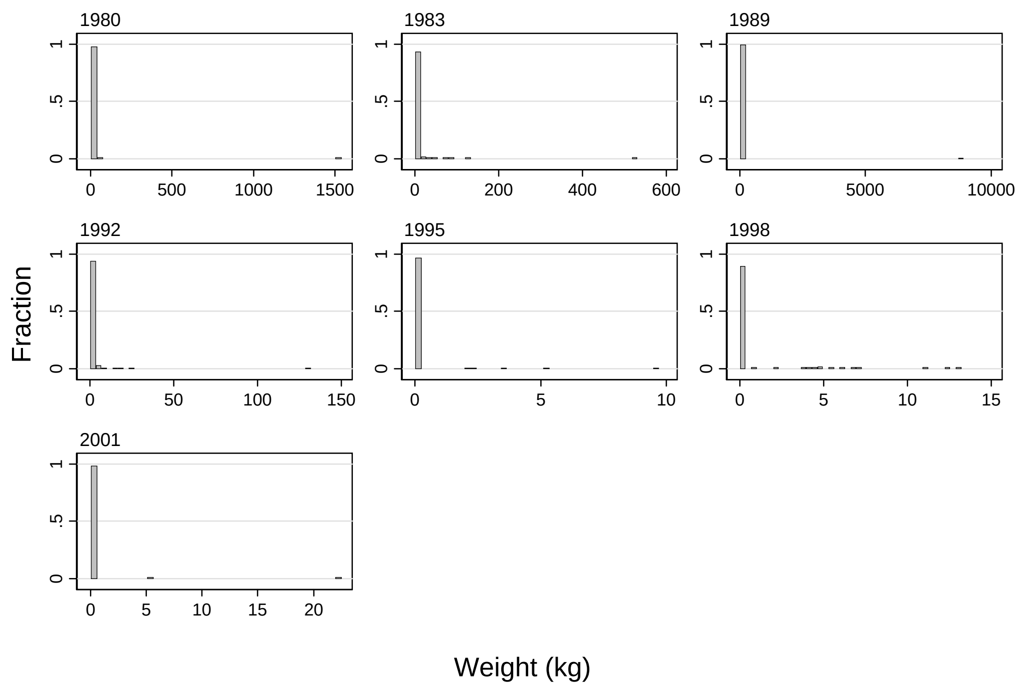

Figure 11. Frequency distribution of tow catch weights (kg) by year for the Vancouver INPFC region.

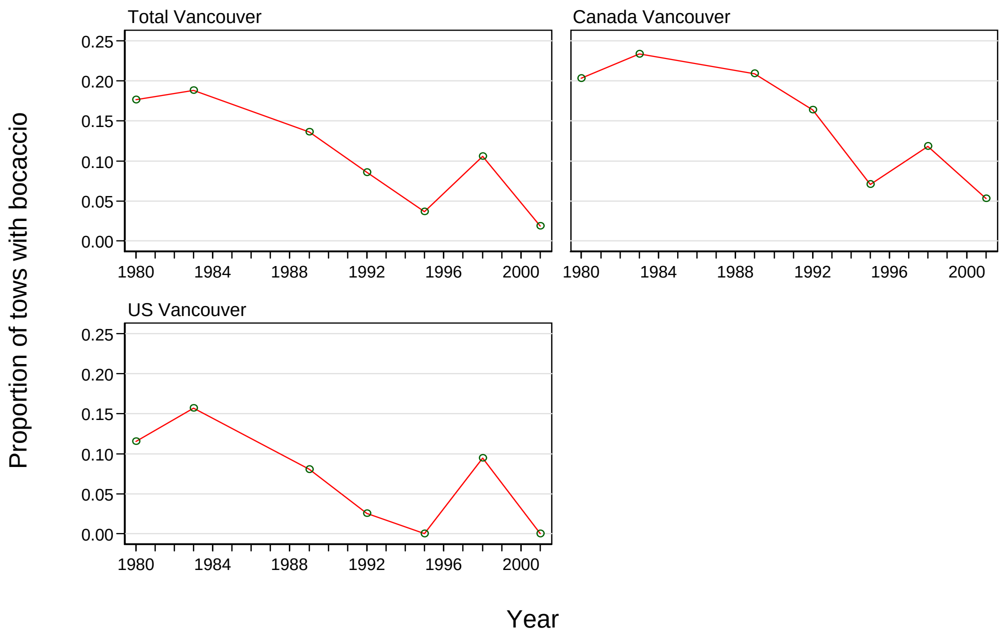

Figure 12. Proportion of tows with bocaccio by year for the Vancouver INPFC region (total region, Canadian waters only and U.S. waters only).

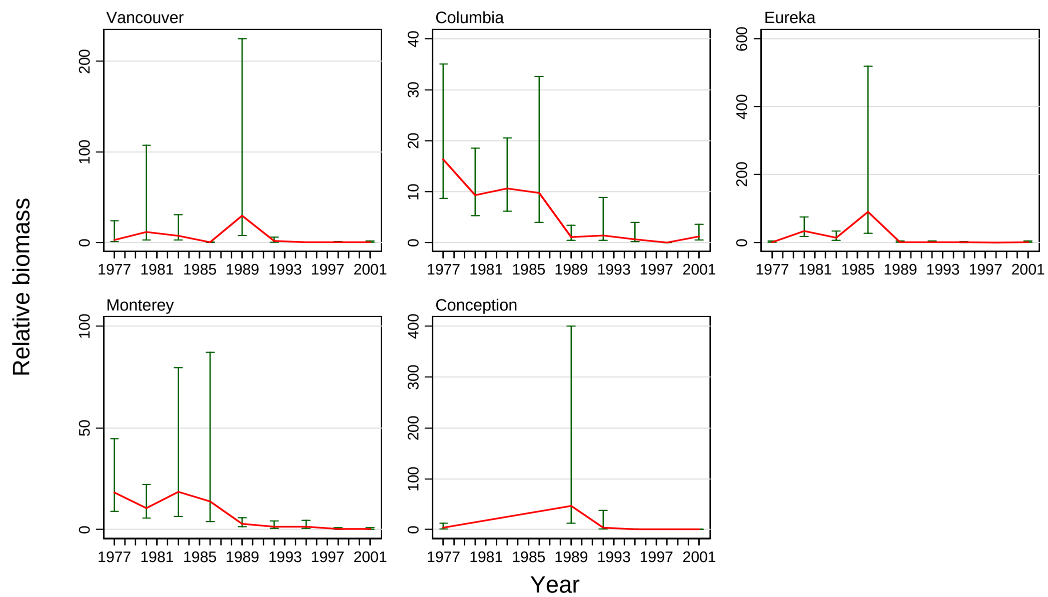

Figure 13. Biomass trends for bocaccio for the five INPFC regions covered by the triennial survey in each survey year since 1977. The biomass indices are expressed as relative to the average biomass for the 1989 to 2001. Error bars are approximated by ±1.96*SE, assuming that the indices are lognormally distributed. The 1977 and 1986 indices for the Vancouver INPFC region are for the U.S. waters only.

Table 6. Biomass estimates for the Vancouver INPFC region (total region, Canadian waters only and U.S. waters only). Biomass estimates are calculated as in Eq. 1. The bootstrap estimates are based on 5000 random draws with replacement

Estimate type	Year	Biomass	Mean bootstrap	NMFS biomass	Lower bound	Upper bound	CV bootstrap	CV Analytic	NMFS CV
Total Vancouver	1980	6,699	6,592	6,699	390	25,030	0.908	0.915	0.915
	1983	4,150	4,159	4,150	830	11,669	0.633	0.634	0.634
	1989	16,666	16,131	16,666	941	62,908	0.909	0.917	0.917
	1992	991	971	991	193	2,578	0.640	0.665	0.665
	1995	76	74	76	21	162	0.478	0.482	0.482
	1998	288	287	295	146	468	0.280	0.286	0.286
	2001	147	141	164	0	470	0.808	0.823	0.837
Canada Vancouver	1980	6,541	6,434	6,541	260	24,877	0.931	0.937	0.937
	1983	3,819	3,829	3,819	505	11,325	0.685	0.688	0.688
	1989	2,348	1,959	2,348	941	6,745	0.576	0.518	0.518
	1992	794	798	794	138	2,070	0.639	0.652	0.652
	1995	65	64	65	17	134	0.466	0.467	0.467
	1998	145	144	152	49	273	0.400	0.397	0.379
	2001	120	117	157	0	386	0.798	0.798	0.837
U.S. Vancouver	1980	159	159	159	0	378	0.585	0.605	0.605
	1983	332	330	332	110	716	0.452	0.456	0.456
	1989	14,318	14,172	14,318	79	56,911	0.987	0.992	0.992
	1992	197	173	197	31	619	0.794	0.736	0.736
	1995	11	11	11	1	30	0.662	0.629	0.629
	1998	143	143	143	62	258	0.344	0.359	0.359
	2001	27	25	7	0	98	0.976	0.955	0.837

14.3 COMPARISON OF LENGTH FREQUENCIES FOR BOCACCIO FOR DIFFERENT REGIONS COVERED BY THE TRIENNIAL SURVEY

9. Scaled numbers of bocaccio by 1 cm length bins were supplied on request by Mark Wilkins (NMFS) for all the INPFC regions covered by the triennial survey (Table 7). The actual number of fish measured was not supplied, but it is likely that in most years relatively few were measured, given the low observed catches of bocaccio in the survey (see Figure 12 as an example).

10. Mean lengths weighted by the estimated number of fish represented in each sample were calculated for each survey year, sex and INPFC region (Table 8). Available mean lengths are variable between survey years and between INPFC regions, making it difficult to make comparisons across survey years or regions. However, it does not seem likely that there has been a systematic shift in mean length over the period of the survey, whether we look at the trend by sex and INPFC region (Figure 14) or at simple averages across regions (Table 8). There is a suggestion that mean length decreases with decreasing latitude (Table 8; Figure 15), with the average across all surveys showing a possible drop for the more southerly INPFC regions. But this observation should be considered weak given the large between-year variability. The average length for females appears to be larger than for males and this is consistent across the six major survey areas (Table 8; Figure 15). However, this conclusion is also weak due to the large amount of between-year variability.

11. Plots of the cumulative length frequency distributions by year, area and sex are generally extremely variable, indicating that the sampled fraction of the bocaccio population has varied considerably over the history of the survey. This is not surprising, given the high proportion of zero tows and the likely patchy and clumped distribution for this species.

    a. The Vancouver INPFC region shows reasonable consistency in the male distribution between surveys except for the 1983 survey, where both the male and female samples are considerably smaller than in the other years (Figure 16). The female cumulative distributions are very variable, with the 1989 female distribution shifted to the left of the other surveys and the 2001 female distribution appears to be the largest.

    b. The Columbia INPFC region shows an extraordinary amount of variation between survey years, making it likely that the population was not sampled consistently across the surveys (Figure 17). Population numbers for this region appear to be relatively low compared to Vancouver or Monterey and may reflect that there is less suitable habitat for this species in this region.

    c. Like the Columbia region, the Eureka INPFC region shows a large amount of between year variation in the available length frequencies for both sexes (Figure 18). Again, it is likely that the population was not sampled consistently across the surveys.

    d. The Monterey INPFC region has the most consistent series of length frequency samples in terms of coverage over the years (Table 7; Figure 19). However, the between year variation is clearly very high in this region as well, indicating that different fractions of the population must have been sampled in each survey.

    e. The Conception INPFC region was not sampled in the 1980, 1983 and 1986 surveys (Table 7). Like the Vancouver region, the Conception region had an extremely large estimated population in the 1989 survey, except that the disparity is even greater. Again the between year variation is very high (Figure 20), indicating that different parts of the population must have been sampled in each survey.

12. This analysis of the available bocaccio length frequency data does not contradict or directly support the observations of declining bocaccio biomass levels. This is partly because there is considerable between year variability in the estimated frequency distributions, even when the length frequency distributions are summed across all areas for the years with a reasonable amount of data (Figure 21). This amount of between year variability indicates that the survey has inconsistently sampled the bocaccio population and consequently the survey trends in biomass for this species must be interpreted with caution, particularly when estimating an absolute level of decline. This level of uncertainty is to be expected, given the large proportion of zero tows, the clumped distribution of the species and a likely declining population size.

13.

Table 7. Estimated numbers of bocaccio and the number of bocaccio represented in the length frequencies by survey year and major INPFC region. The greyed boxes are those year and region combinations that had reasonably large estimated numbers but which do not have a representative length frequency. N/A: not surveyed

Year	Vancouver	Columbia	Eureka	Monterey	Conception
Population estimate in numbers					
1977	762,971	203,147	14,992	3,321,696	748,611
1980	1,918,749	347,818	688,734	3,813,018	N/A
1983	1,118,877	247,612	194,367	3,014,315	N/A
1986	31,651	199,419	978,406	2,190,037	N/A
1989	3,445,651	16,090	18,838	2,045,630	34,438,989
1992	223,198	19,702	11,224	691,096	838,838
1995	18,203	15,422	7,398	342,413	189,049
1998	70,197	0	0	128,753	23,749
2001	29,163	15,313	6,040	139,722	86,624
Number fish in scaled length frequencies					
1977		147,483		3,237,177	747,536
1980	39,186	237,056	636,839	3,813,012	N/A
1983	1,054,609	187,127	158,963	3,014,310	N/A
1986	30,508	119,494	939,621	2,130,922	N/A
1989	3,425,969	14,759	10,010	2,045,630	34,438,992
1992	223,190	10,524	11,224	691,097	838,837
1995	18,203	15,423	7,398	342,420	189,049
1998	70,714	0	0	127,997	23,450
2001	29,160	15,313	6,039	139,722	86,623

Table 8. Weighted (by numbers of fish) mean lengths (cm) by survey year and major INPFC region.

Year	Vancouver	Columbia	Eureka	Monterey	Conception	Mean[1]
						Males
1977		64.6		51.5	43.8	50.8
1980		44.8	39.9	42.4		42.1
1983	46.2	51.3	49.0	51.8		51.2
1986		56.0	47.6	47.4		47.8
1989	65.4	66.7	62.0	31.3	28.0	32.4
1992	62.8		55.2	37.0	42.2	42.4
1995	60.9	54.0	45.4	43.1	25.7	39.5
1998	64.1			42.3	38.1	51.4
2001	49.0	68.2	65.0	42.7	37.1	43.6
Mean[1]	58.1	57.9	52.0	43.3	35.8	49.4
Females						
1977		76.9		52.2	46.6	52.0
1980		44.8	42.0	42.2		42.3
1983	47.8	52.1	53.5	54.5		53.7
1986		60.5	59.1	59.1		59.1
1989	69.6		70.0	32.1	28.4	31.0
1992	71.4	75.0	47.0	36.9	44.5	46.1
1995	70.6	55.0		51.6	28.6	42.7
1998	72.5			39.9	32.6	45.5
2001	80.2	71.1	70.3	34.0	36.5	45.6
Mean[1]	68.7	62.2	57.0	44.7	36.2	53.8

[1] The means on this row or column are unweighted averages of the available survey data.

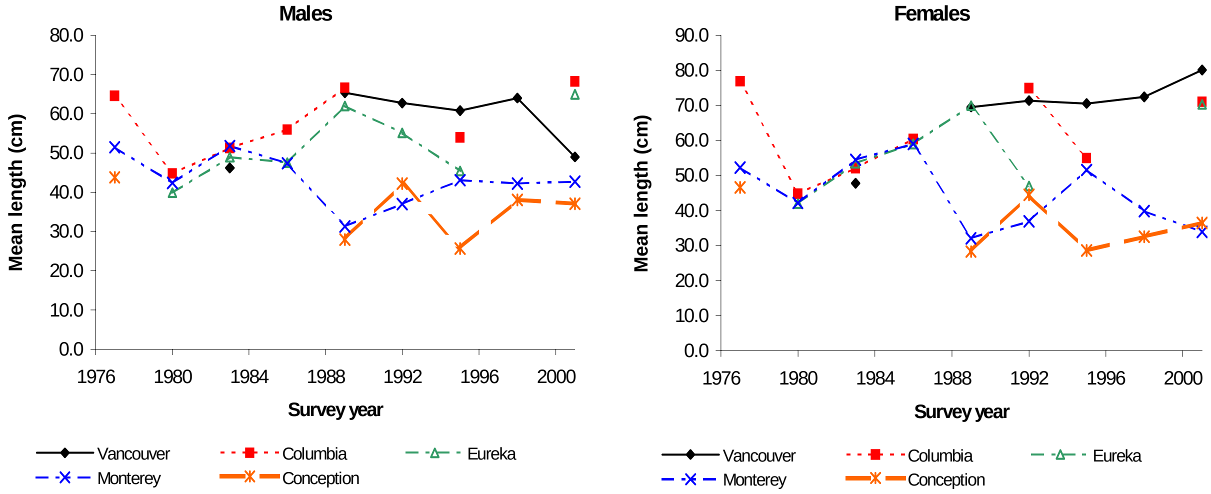

Figure 14. Mean length (cm) by major INPFC region and survey year. [left panel] males; [right panel] females.

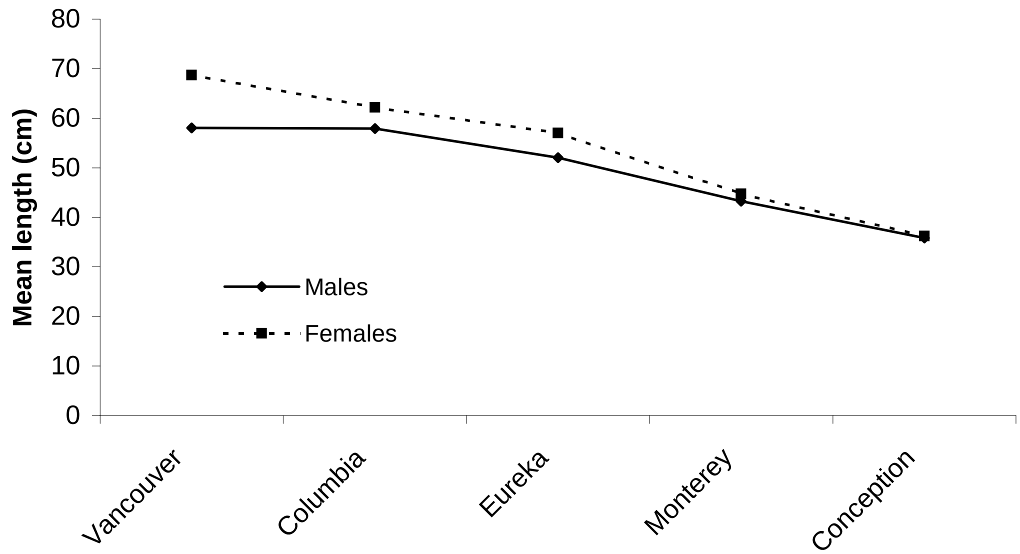

Figure 15. Plot of mean lengths (in cm) by major survey area and sex averaged over all available years for each area. The mean length by sex and survey year are weighted by the number of fish in each 1 cm length category but the mean across surveys weights each year and sex equally.

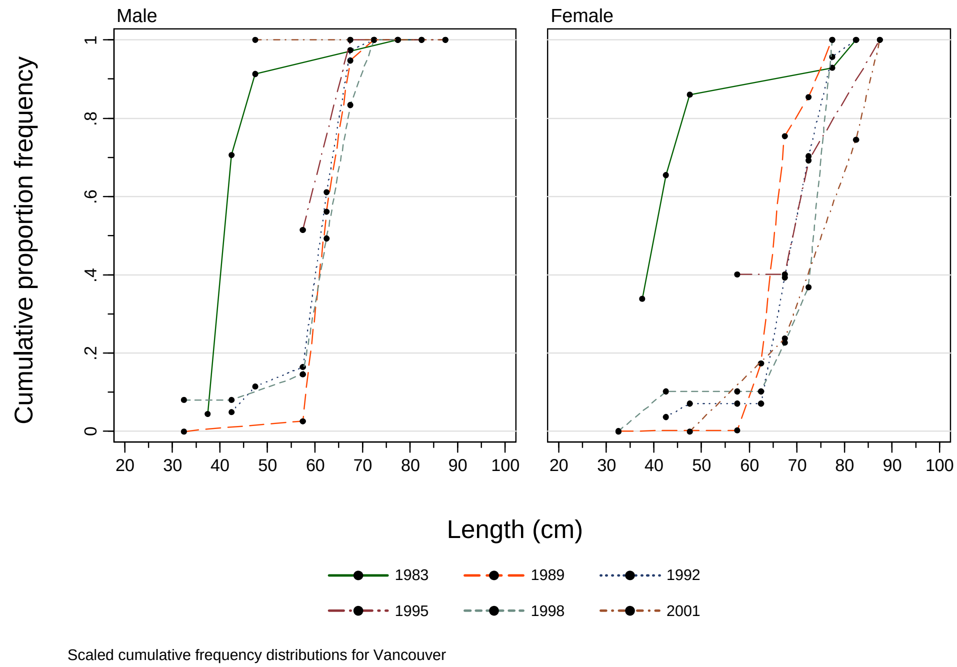

Figure 16. Cumulative frequency distributions by sex for the Vancouver INPFC region by survey year for years with available survey data.

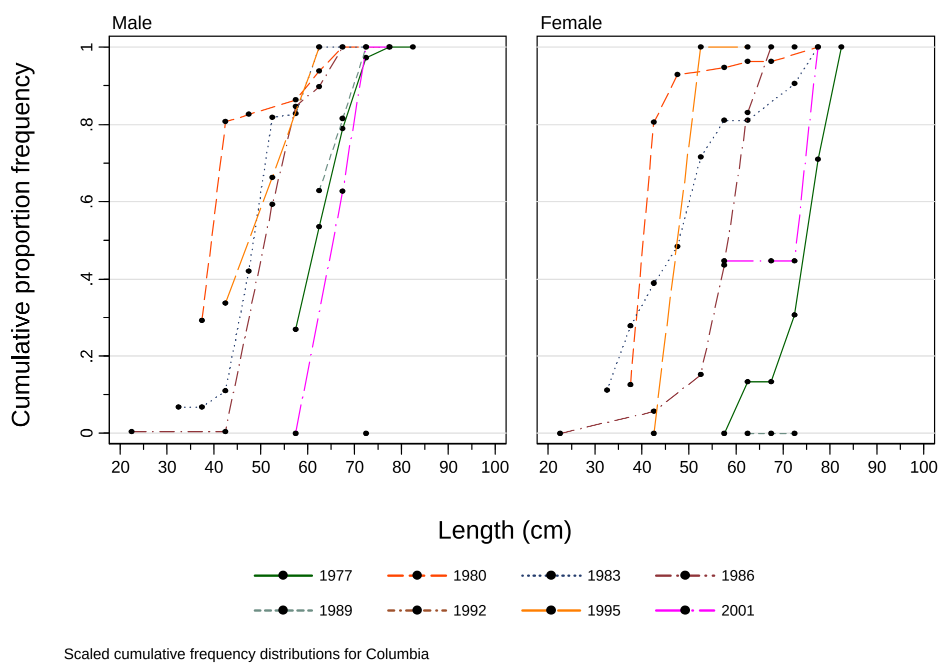

Figure 17. Cumulative frequency distributions by sex for the Columbia INPFC region by survey year for years with available survey data.

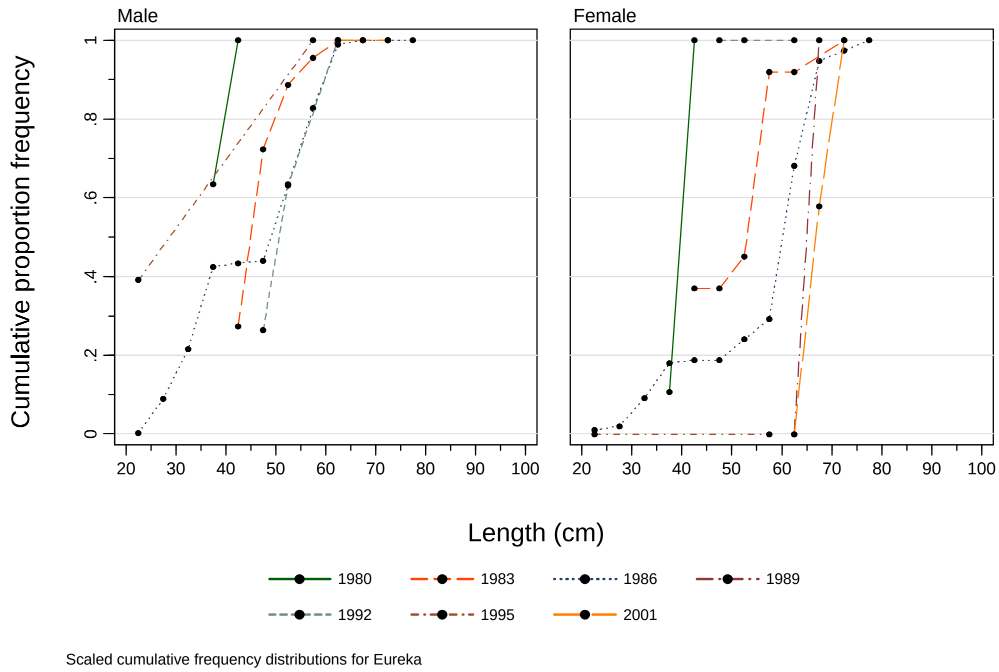

Figure 18. Cumulative frequency distributions by sex for the Eureka INPFC region by survey year for years with available survey data.

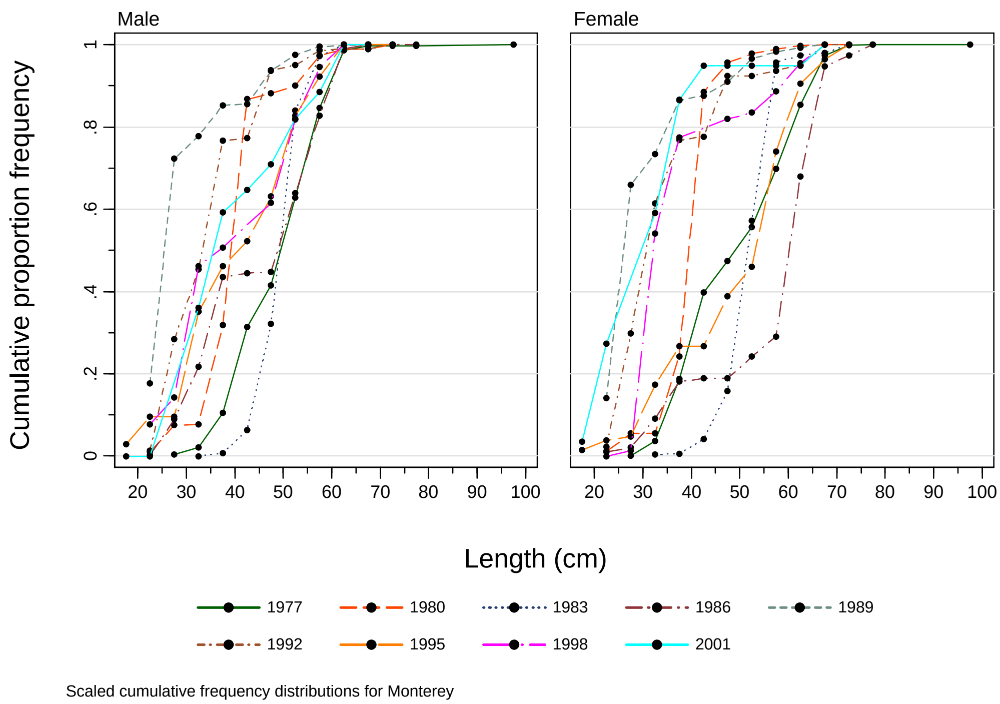

Figure 19. Cumulative frequency distributions by sex for the Monterey INPFC region by survey year for years with available survey data.

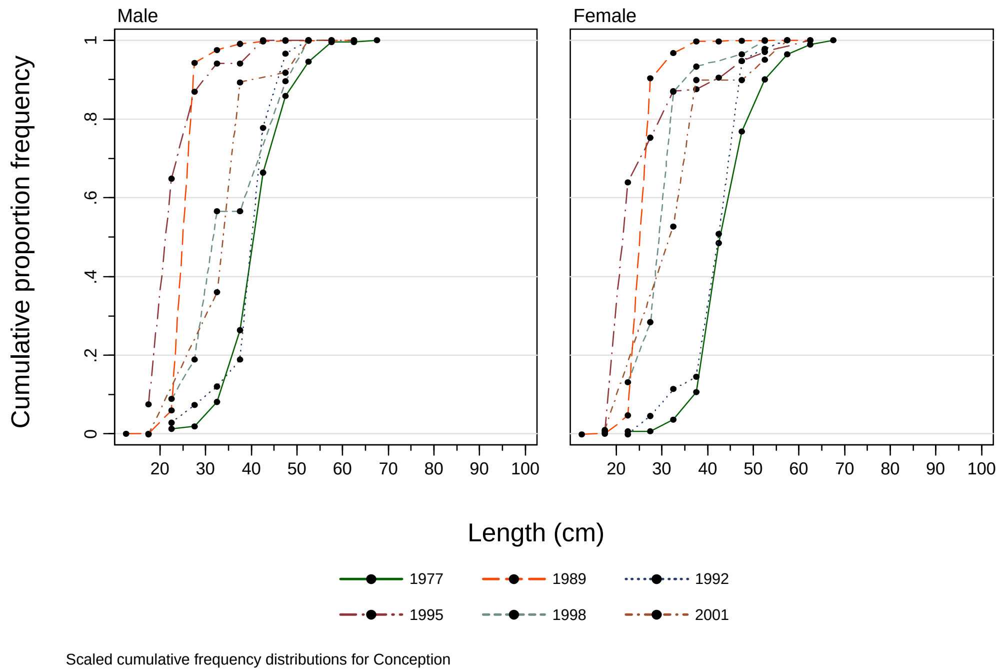

Figure 20. Cumulative frequency distributions by sex for the Conception INPFC region by survey year for years with available survey data.

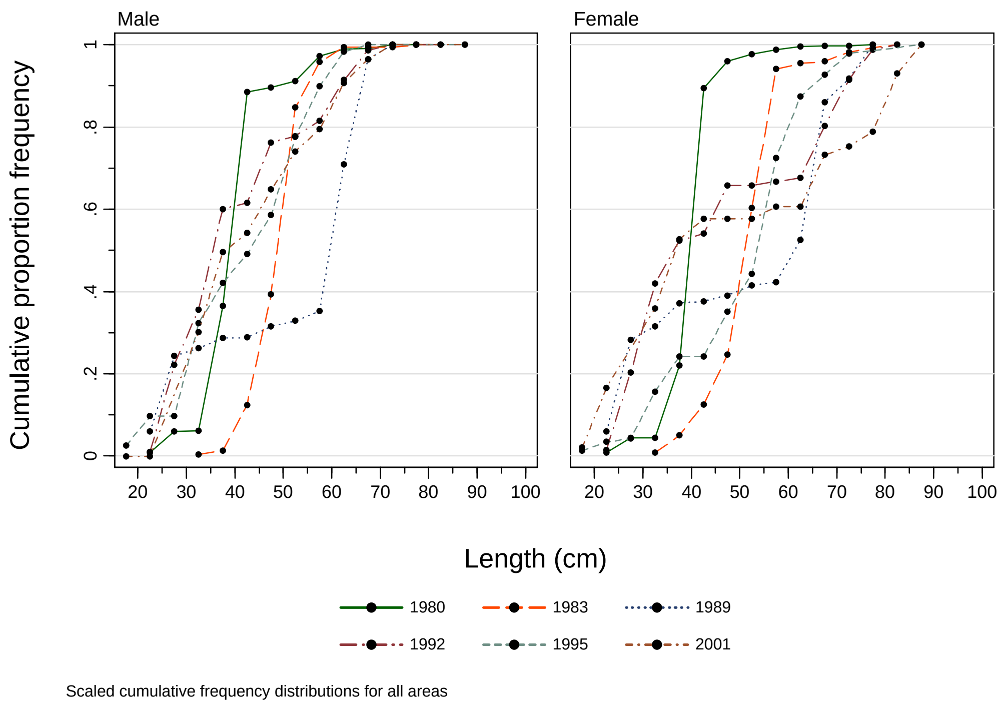

Figure 21. Cumulative frequency distributions by sex for all areas combined by survey year for years with the best available survey data.

15.0 APPENDIX 2. DFO WCVI SHRIMP SURVEY

15.1 METHODS

1. This analysis is based on tow-by-tow data from the west coast Vancouver Island shrimp trawl survey that has operated in most years off the west coast from 1973 to 2003, and identified rockfish to species since 1975 (survey results for 1973 are omitted for this reason). This survey is therefore the longest series that is available to monitor bocaccio. We have adopted the recommendations for this survey that were documented by Starr et al. (2002) in their reanalysis of the data from the same survey for west coast Vancouver Island pacific cod. These recommendations include:

    a. stratifying the data into two areas, Areas 124 and 125 (Table 9) with some minor modifications, because these are the areas that have been monitored the most consistently over the history of the survey. The modifications included dropping some tows which occurred in the most northerly part of Area 125 in the early to mid-1970s because these tows were not repeated in later surveys (Table 9). There are also a number of outlier tows which appear to be data errors which were also dropped (Figure 22).

    b. a small number of tows were moved from Area 124 to 123 as these tows were made in inshore waters and were clearly spatially more closely associated with Area 123.

    c. Starr et al. (2002) provided area weights in square kilometres for each of these redefined strata (Table 9).

Table 9. List of tows available from the WCVI shrimp trawl survey by survey year and stratum. Only tows from strata 124 and 125 were used in the analysis.

	Area stratum			Dropped tows		Total
Year	**123**	**124**	**125**	**Number**	**Bocaccio (kg)**	**tows**
1975	0	62	17	6	24	85
1976	0	69	18	2	32	89
1977	0	130	26	0	–	156
1978	6	134	36	5	0	181
1979	0	52	24	0	–	76
1980	0	59	26	0	–	85
1981	0	58	30	0	–	88
1982	0	56	25	0	–	81
1983	0	51	26	0	–	77
1985	1	59	22	0	–	82
1987	0	50	18	0	–	68
1988	0	69	10	0	–	79
1989	0	67	0	0	–	67
1990	0	72	10	0	–	82
1991	0	86	0	0	–	86
1992	0	77	6	0	–	83
1993	0	70	33	0	–	103
1994	3	67	30	0	–	100
1995	0	63	23	0	–	86
1996	28	60	12	0	–	100
1997	30	61	21	3	0	115
1998	28	44	22	1	0	95
1999	28	51	31	2	0	112
2000	31	43	30	1	0	105
2001	35	48	22	1	0	106
2002	33	50	26	1	0	110
2003	32	46	19	0	–	97
Total	**255**	**1754**	**563**	**22**	**56**	**2594**
Area (km^2)	447.7	1714.3	969.5			3131.5

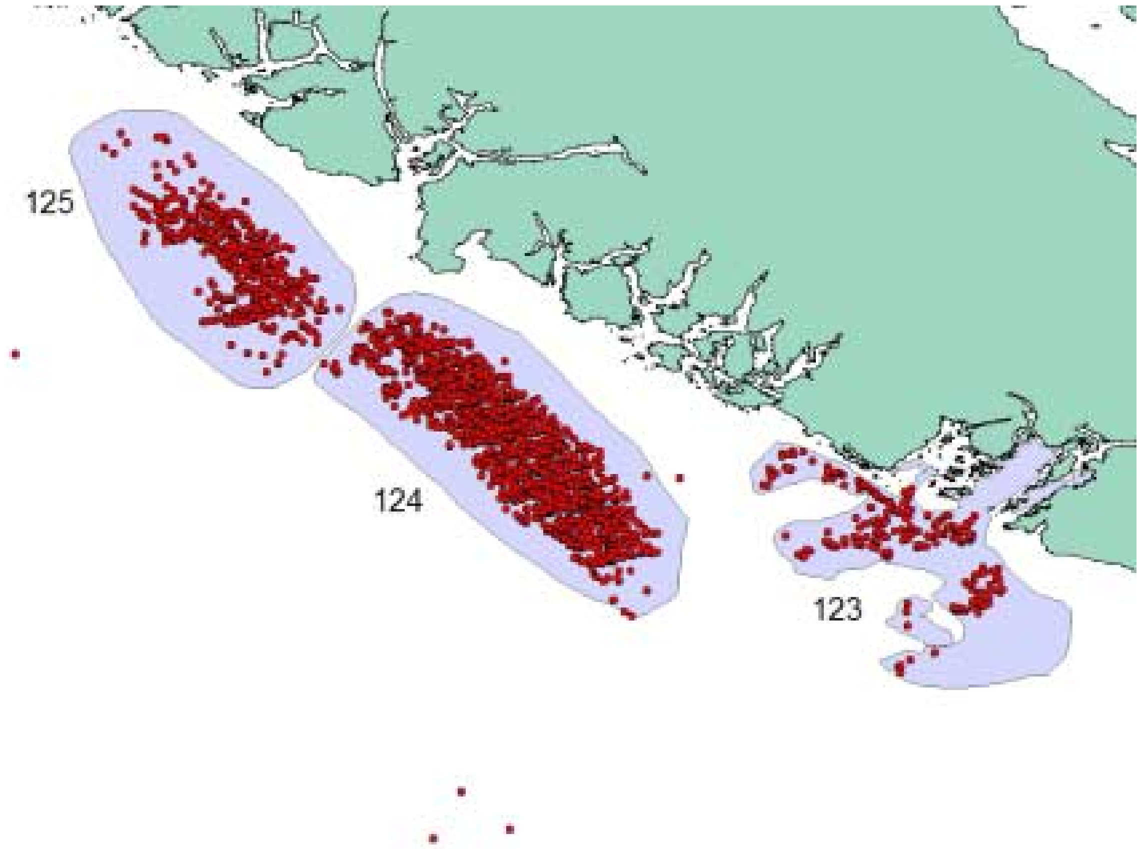

Figure 22. Map of the locations of all trawls in areas 123, 124 and 125 that were associated with the west coast Vancouver Island shrimp trawl survey. Areas 124 and 125 are the strata that have been surveyed the most consistently over the history of the survey and which are in locations most likely to catch bocaccio.

2. These data were analysed using the following equations which assume that tow locations were selected randomly within a stratum relative to the biomass of bocaccio. This was not an assumption made by the original survey design and the area stratification definition in Figure 22 was not used when conducting the survey. The original survey design used latitudinal transects and selected the stations randomly along the transect. The biomass in any year y was obtained by summing the product of the CPUE and the area surveyed across the surveyed strata i:

$$B_y = \sum_{i=1}^{k} C_{y_i} A_i = \sum_{i=1}^{k} B_{y_i} \qquad \textbf{Eq. 7}$$

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

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

B_{y_i} = biomass of bocaccio in stratum *i* for year *y*.

k = number of strata

CPUE $\left(C_{y_i}\right)$ for bocaccio in stratum *i* for year *y* was calculated as a density in kg/km^2 by

$$C_{y_i} = \frac{\sum_{j=1}^{n_{y_i}} \left(W_{y_i j} \Big/ D_{y_i j} w_{y_i j} \right)}{n_{y_i}} \qquad \textbf{Eq. 8}$$

where $W_{y_i j}$ = catch weight (kg) for bocaccio in stratum *i* for year *y* and tow *j*

$D_{y_i j}$ = distance travelled (km) by tow *j* in stratum *i* for year *y*

$w_{y_i j}$ = net opening (km) by tow *j* in stratum *i* for year *y*

n_{y_i} = number of tows in stratum *i*

The variance of the survey biomass estimate V_y for bocaccio in year *y* is calculated in kg^2 as follows:

$$V_y = \sum_{i=1}^{k} \sigma_{y_i}^2 A_i^2 \Big/ n_{y_i} = \sum_{i=1}^{k} V_{y_i} \qquad \textbf{Eq. 9}$$

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

V_{y_i} = variance of bocaccio in stratum *i* for year *y*

The CV for bocaccio for each year *y* was calculated as follows:

$$CV_y = \frac{\sqrt{V_y}}{B_y} \qquad \textbf{Eq. 0}$$

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

15.2 RESULTS

4. Estimated biomass levels for bocaccio from the WCVI shrimp trawl survey appear to have been relatively low in the 1970s, risen to higher levels in the 1980s and then dropped to levels in the 1990s that were equivalent to the levels observed in the 1970s (Figure 23; Table 10). Confidence bounds are wide and the estimated CVs for bocaccio from this survey range from around 0.3 to 1.0, depending on the year (Table 10). The proportion of tows which contain bocaccio shows a trend which is similar to the overall abundance trend, with a lower incidence of bocaccio in the 1970s and 1990s and a higher incidence in the 1980s (Figure 24). As for other surveys taking bocaccio, the estimated biomass levels seem to be related to the proportion of tows containing bocaccio, with the high biomasses having the highest incidence of bocaccio. Conversely, lower estimates for bocaccio recorded in the 1970 and 1990 surveys are associated with relatively lower incidences of this species (Figure 24). An exception to this trend is the relatively high incidence of bocaccio in 1975 even though the estimated biomass was not particularly high (Table 10).

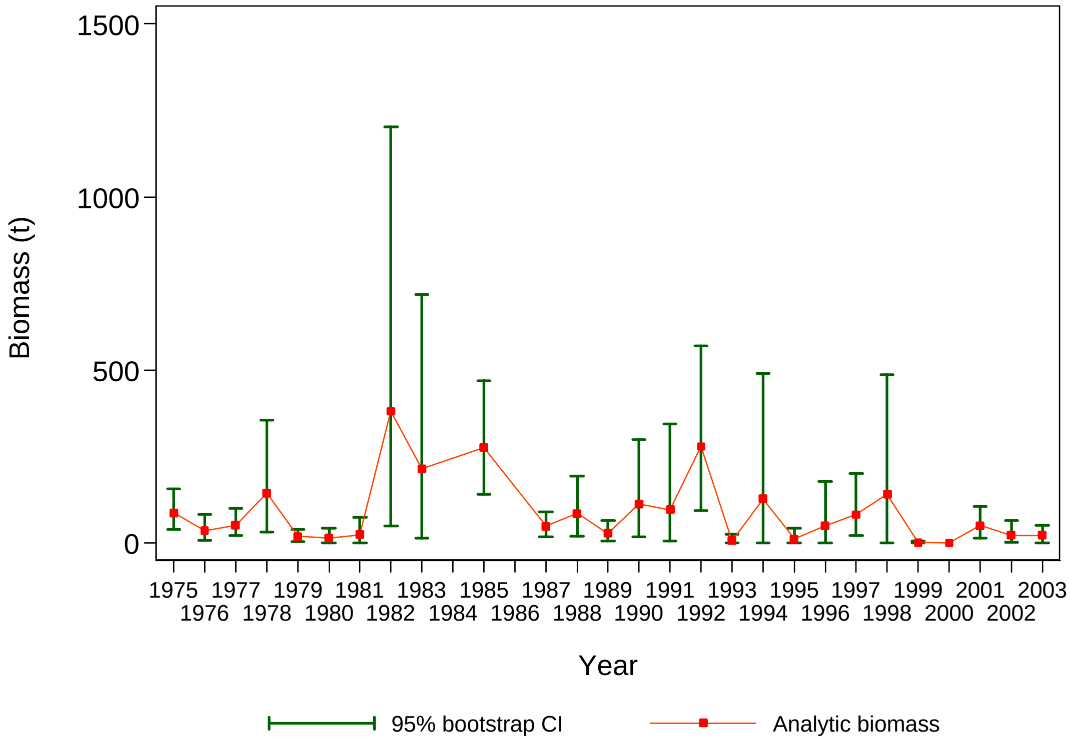

Figure 23. Plot of biomass estimates for bocaccio from the WCVI shrimp trawl survey for the period 1975 to 2003. Bias corrected 95% confidence intervals from 1000 bootstrap replicates are plotted.

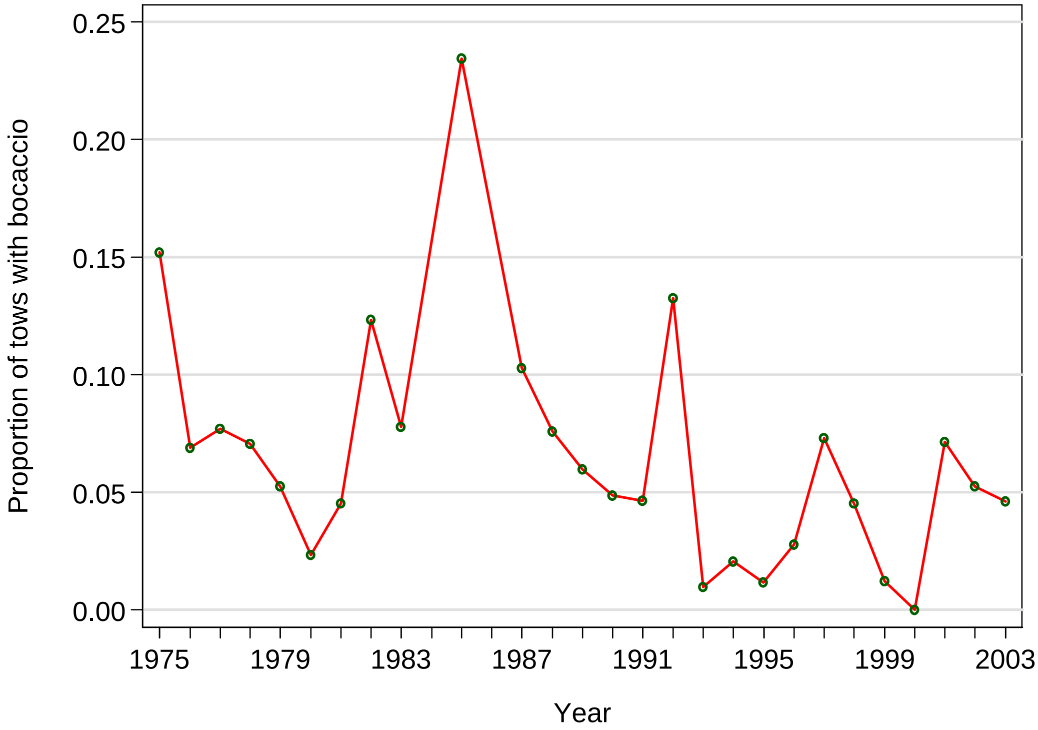

Figure 24. Proportion of tows by year which contain bocaccio for the WCVI shrimp trawl survey.

Table 10. Biomass estimates for bocaccio from the WCVI shrimp trawl survey for the survey years 1973 to 2003. Biomass estimates are based on a post-stratification of this survey into two strata (Figure 22) and by assuming that the survey tows were randomly selected within these areas. Bootstrap bias corrected confidence intervals and CVs are based on 1000 random draws with replacement. The analytic CV (Eq. 4) is based on the assumption of random tow selection within a stratum.

Survey Year	Biomass (t)	Mean bootstrap biomass (t)	Lower bound biomass (t)	Upper bound biomass (t)	Bootstrap CV	Analytic CV (Eq.10)
1975	87.6	86.4	38.7	158.5	0.3464	0.3417
1976	35.6	36.8	7.9	84.4	0.5211	0.5015
1977	51.4	52.4	22.2	98.7	0.3785	0.3860
1978	143.4	147.1	30.8	340.3	0.5349	0.5620
1979	18.7	18.9	4.1	39.2	0.4597	0.4894
1980	14.5	14.3	0.0	42.3	0.7098	0.7237
1981	24.1	26.0	0.3	72.5	0.7331	0.7852
1982	380.6	395.0	47.6	1222.7	0.7805	0.7948
1983	213.9	215.2	13.4	702.4	0.8574	0.8604
1985	275.8	276.2	143.5	486.2	0.2992	0.3034
1987	48.6	48.9	15.9	86.9	0.3761	0.3786
1988	85.1	86.4	19.0	190.0	0.4970	0.5083
1989	27.7	27.5	5.8	71.5	0.5327	0.4898
1990	112.6	112.8	15.4	300.3	0.6029	0.5908
1991	96.3	94.7	4.5	345.3	0.8767	0.8133
1992	279.0	280.4	87.4	583.3	0.4328	0.4123
1993	6.5	6.4	0.0	26.1	0.9881	1.0000
1994	127.5	125.2	0.0	496.0	0.9791	0.9452
1995	10.7	10.5	0.0	44.7	1.0392	1.0000
1996	48.9	49.7	0.0	164.7	0.8944	0.9133
1997	81.9	81.9	20.7	202.3	0.5551	0.5489
1998	140.9	144.2	0.0	511.0	0.8947	0.8996
1999	1.7	1.8	0.0	6.8	0.9731	1.0000
2000	0.0	0.0	–	–	–	0.0000
2001	50.1	49.6	12.7	105.8	0.4778	0.4554
2002	22.1	22.4	1.3	61.5	0.7029	0.7187
2003	22.3	22.8	0.0	49.2	0.5402	0.5513

5. The effect of stratification is not large, with the biomass estimates being very comparable when using the stratification proposed by Starr et al. or completely ignoring the areas and treating the survey as a single random stratum (). Exceptions to this are the estimates for 1990 and 1992, which are higher for the stratified estimate. The CVs for both stratification options are very comparable, with the differences being very small in all years.

6. A comparison with biomass estimates based on the original area designations and retaining all tows shows very little difference with the stratified estimates presented in Table 10, except for slightly higher estimates in 1975, 1976, 1978 and 1987 and slightly lower estimates in 1996). This indicates that the biomass trends for bocaccio shown in Figure 23 and Figure 4 are inherent in the data rather than imposed by the assumptions.

7. The spatial analysis uses the Inverse distance weighted (IDW) spatial interpolation algorithm to estimate the biomass of bocaccio within the shrimp survey boundaries for Areas 124 and 125. Inverse distance weighted interpolation determines cell values using a linearly weighted combination of a set of sample points. The weight is a function of inverse distance. The surface being interpolated should be that of a locationally dependent

variable. The IDW method provides options for controlling the significance of known points upon the interpolated values, based upon their distance from the output point. In particular, by defining a higher power option, more emphasis can be placed on the nearest points. Thus, nearby data will have the most influence, and the surface will have more detail (be less smooth). Specifying a lower value for power will provide a bit more influence to those of the surrounding points which are a little farther. The power is a positive, real number. In the present report, we used a power of 2, which is the most commonly used value.

In addition to the power value, characteristics of the interpolated surface can also be controlled by applying a variable or fixed search radius, which limits the number of points that can be used for calculating each interpolated cell. A fixed radius ensures that, for each interpolated cell, the radius of the circle used to find input points remains the same. We used a fixed search radius of 5 km, which is approximately the distance between survey points. We also specified that the minimum number of points to include in the interpolation of each cell be 0 so that the search radius would not increase for those cells which were more than 5 km from a measured value. We felt that this might be realistic for an aggregating species like bocaccio since it's reasonable to assume that this species probably exists in a clumped distribution over the survey area.

8. A comparison of the biomass indices from the WCVI shrimp survey with U.S. National Marine Fisheries Service (NMFS) triennial survey shows good correspondence for the years of overlap (Figure 25). The triennial survey series only begins in 1980 and starts at a high level while the shrimp trawl survey series starts at a low level, rises to similar higher levels in the mid-1980s and then drops again (Figure 25). When these two surveys are compared directly, it can be seen that there is reasonably good correspondence between the two surveys in the years of overlap, with the exception of the early 1980s, when the triennial survey recorded much higher relative biomass levels than did the WCVI shrimp trawl survey. It is not clear how best to interpret these results, but it may be that the high levels of bocaccio biomass observed in the 1980s may have been the result of a period of good recruitment and that the levels currently being observed may be more reflective of the biomass levels that result from average to poor recruitments. It is also possible that, for whatever reason, bocaccio were more vulnerable to trawl gear in the early 1980's.

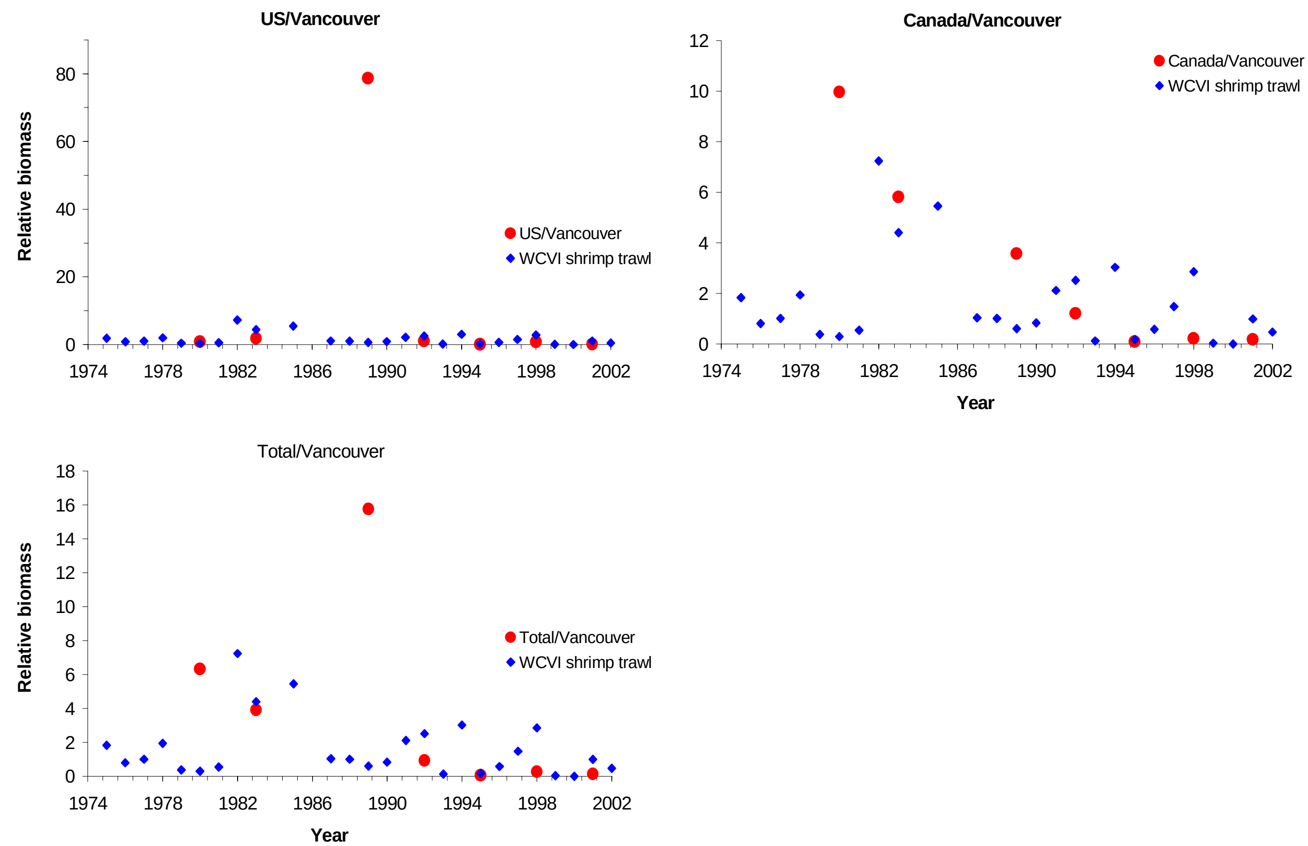

Figure 25. Comparison of the WCVI shrimp trawl survey with three sets of biomass indices from the NMFS triennial survey. Each series has been normalised against the geometric mean of the indices for 1980, 1983, 1989, 1992, 1995, 1998 and 2001, which are the seven years that the triennial survey has ventured into Canadian waters.

16.0 APPENDIX 3. DFO WCVI SHRIMP SURVEY DEPTH ANALYSIS

Background

The November 2003 PSARC review noted that the WCVI shrimp survey was inconsistent among surveys with respect to the maximum depth surveyed. This was because the design of the survey specified that the seaward extension of the transects would terminate when shrimp CPUE declined to zero. To examine how this aspect of the survey design might affect the conclusions with respect to bocaccio, the Subcommittee requested additional analysis to determine whether the variable depth coverage among years would affect the comparability of the survey indices.

Methods

1. We first re-calculated the size of each area stratum above and below a demarcation depth of 160 m (Table 11). This cutoff depth was chosen because the survey covered up to this depth consistently across all years (see Paragraph 3 below). The estimated areas per stratum (Table 11) differed from the previous analysis (Starr & Sinclair 2002) which used a GIS program then bounded the set locations with hand-drawn polygons. The present analysis employed the method typically used by the shrimp biologists wherein the GIS "masks" are characterized by a larger buffer region around the outer most set locations.
2. The shrimp trawl survey catches for bocaccio were reanalysed using this revised stratification using the methods described in Appendix 3. Confidence regions were estimated from 5000 bootstrap resamples. Survey indices using the revised areas for all of Areas 124 and 125 were compared with the indices presented in Appendix 3 to ensure that the changes in the estimated area did not affect the trend in the original series of indices.

Table 11. Area (km^2) of each stratum above and below the 160 m depth demarcation. Areas in "Total_2" column were used by Starr & Sinclair (2002) to weight the same two strata and were also used in the analysis provided in the draft PSARC document.

Stratum	<=160 m	>160 m	Total	Total_2
124	2166	425	2591	1714
125	1493	572	2065	969

Results

3. There has been consistent sampling in the west coast Vancouver Island trawl survey in each survey year up to the 160 m depth interval (Table 12; Figure 22). Therefore the selection of this demarcation depth seems appropriate. Deeper tows were interspersed throughout the survey period, but at least nine years lacked tows deeper than 160 m, implying a lack of comparability over the time series if deeper tows are included. There were a reasonable number of tows in the 140-160 m depth interval in every survey year, so we concluded that comparable yearly estimates could be obtained by confining the analysis to all tows shallow of 160 m.

4. We have plotted four sets of survey estimates (Figure 27). The first set is the series from Appendix 3. Because that series was calculated using the areas contained in column "Total_2" (Table 11), we recalculated the same series using the areas contained in the column "Total" (Table 11) to see if there was any substantive effect from using the recalculated areas. Because there was little effect, we then calculated two further series for comparison: a series where each of the two area strata (124 and 125) were divided into two depth strata: one above and one below 160 m and a further analysis where only the depth strata below 160 m were used. Note that none of these assumptions changed the general trend of the results.

Table 12. Number of tows from the WCVI shrimp trawl survey by survey year separated into 20 m depth intervals from valid tows performed in strata 124 and 125. Depth zones are indicated by the endpoint of the depth interval.

	Depth Interval (20 m)											Deepest
Year	**60**	**80**	**100**	**120**	**140**	**160**	**180**	**200**	**220**	**240**	**Total**	**tow (m)**
1975			9	35	29	12					85	154
1976			13	41	28	7					89	146
1977			15	41	60	37	3				156	174
1978	2	4	7	51	67	48	2				181	176
1979			6	23	30	16	1				76	172
1980			8	23	34	16	3	1			85	187
1981			5	24	32	21	4	2			88	192
1982			7	20	31	18	4	1			81	192
1983			4	16	31	20	3	1	2		77	219
1985			7	24	26	22	3				82	168
1987			2	19	29	15	3				68	172
1988			6	26	30	15	2				79	176
1989			8	23	23	13					67	159
1990			6	25	33	16	2				82	175
1991			8	33	30	15					86	159
1992			9	28	25	20	1				83	162
1993			7	30	41	22	3				103	165
1994				31	43	24	2				100	166
1995			7	26	36	17					86	159
1996			17	33	29	20	1				100	164
1997		1	25	38	34	16				1	115	251
1998		1	17	29	30	16	1		1		95	217
1999	1	1	13	30	40	27					112	159
2000		2	16	20	37	29	1				105	170
2001		2	17	30	37	20					106	159
2002		1	22	28	38	20	1				110	161
2003		2	20	30	29	16					97	160

5. We suggest that the most robust of the four series plotted in Figure 27 is the final one which only uses the data collected from tows set at 160 m or less (Figure 28). These strata were sampled consistently in each survey. Figure 28 plots that series with the confidence regions calculated from the 5000 bootstrap samples.

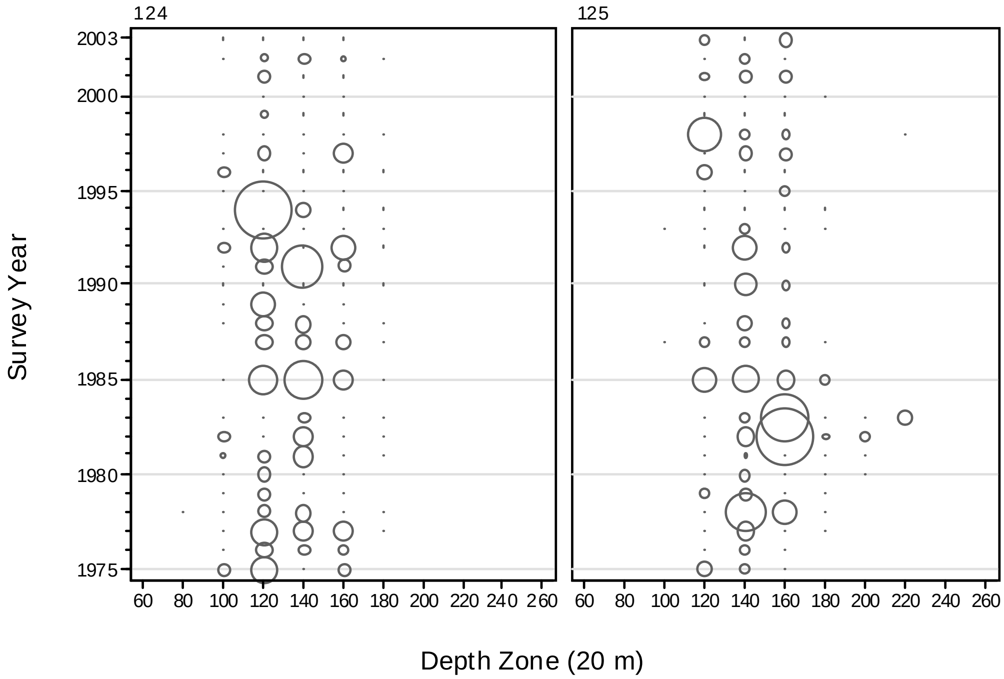

Figure 26. Distribution of catch weight of bocaccio by stratum, survey year and 20 m depth zone. Depth zones are indicated by the endpoint of the depth interval.

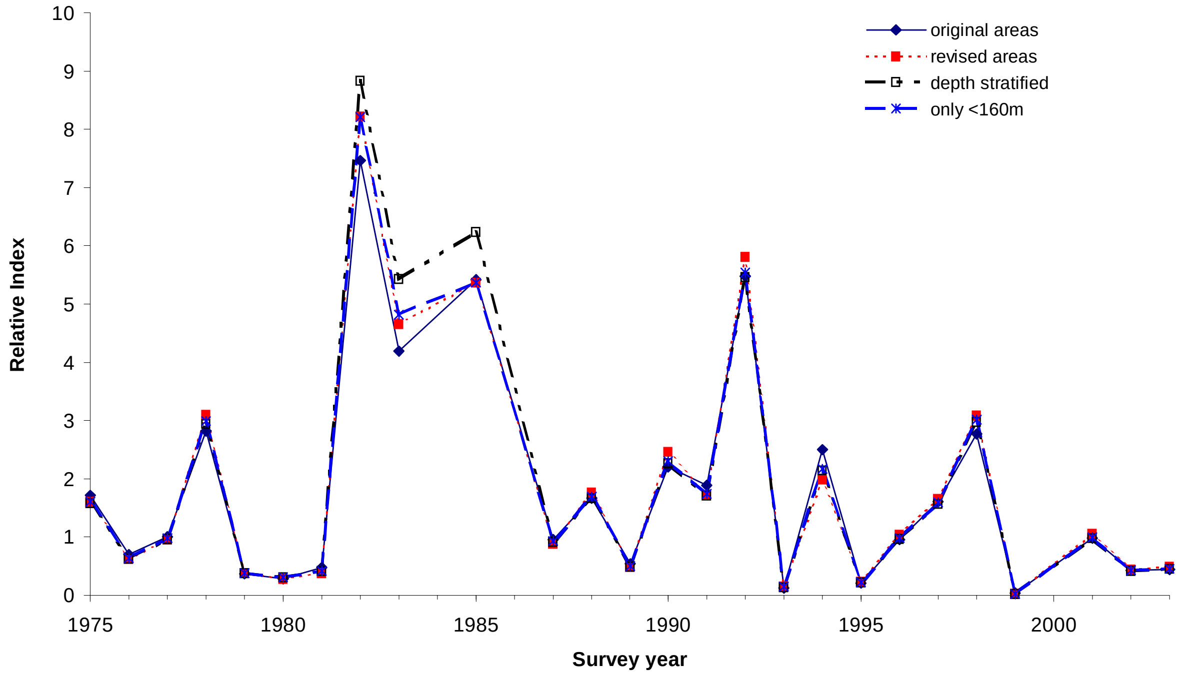

Figure 27. Comparison of four sets of relative biomass estimates for bocaccio: a) original analysis presented in draft PSARC document; b) same analysis using revised areas for this assessment; c) a depth stratified analysis divided at 160 m; d) an analysis constrained to the depth strata at 160 m or lower. Each survey series has been standardised relative to its geometric mean.

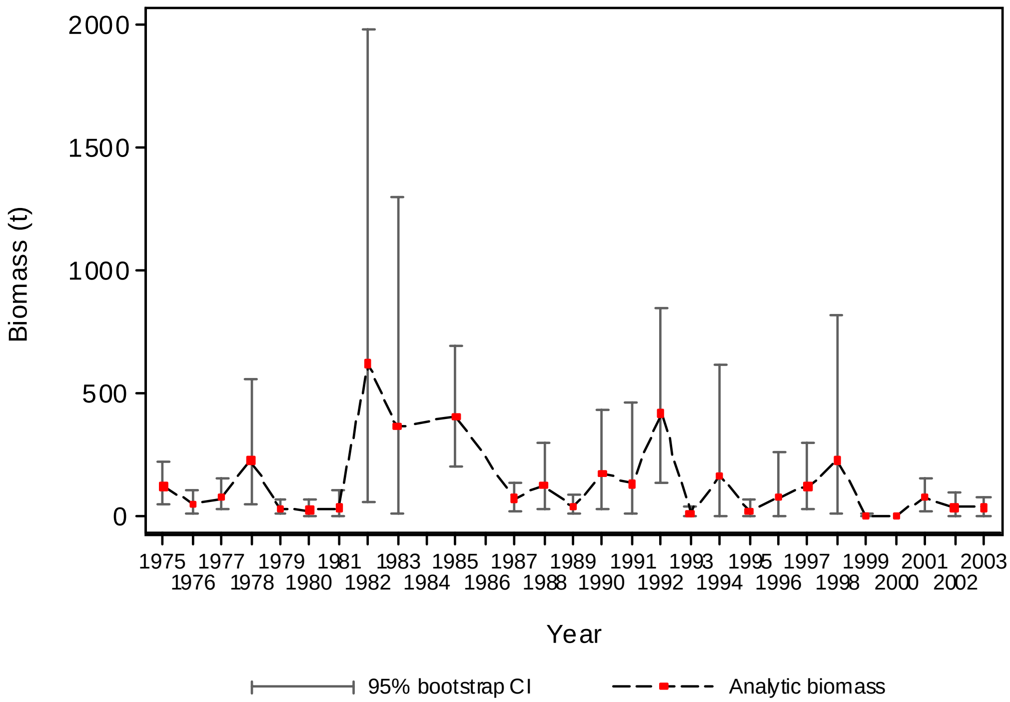

Figure 28. Plot of biomass estimates for bocaccio from the WCVI shrimp trawl survey for the period 1975 to 2003 using shrimp using only tows from 160 m or less. Bias corrected 95% confidence intervals from 5000 bootstrap replicates are plotted.

17.0 APPENDIX 4. HECATE STRAIT SURVEY

17.1 METHODS

1. This analysis is based on tow-by-tow data from the Hecate Strait assemblage survey for all years from 1984 to 2003 (Figure 29). We have adopted the recommendations for this survey contained in the PSARC document by Sinclair (1999). These recommendations include:

   a. distributing the tows into strata represented by 10 fathom depth intervals;

   b. only analysing the data in the range of 10 to 80 fathoms (to ensure comparability between surveys); and

   c. applying a constant factor of 0.0486 km^2/h to convert the estimates of CPUE in kg/h to swept area estimates (see Eq. 3 below).

Table 13. Number of tows by depth zone and year of the Hecate Strait assemblage survey. Also shown are the estimated sizes of each stratum for the survey in square kilometres.

Year	**10-19 fm**	**20-29 fm**	**30-39 fm**	**40-49 fm**	**50-59 fm**	**60-69 fm**	**70-79 fm**	**Total**
1984	19	19	23	25	23	23	14	146
1987	15	12	12	11	16	10	9	85
1989	17	12	12	15	12	9	13	90
1991	18	12	15	10	21	15	6	97
1993	16	20	11	15	10	15	7	94
1995	16	19	15	16	14	14	7	101
1996	25	24	21	10	11	10	4	105
1998	14	11	17	13	13	14	4	86
2000	19	22	19	14	15	11	6	106
2002	15	17	15	16	11	9	5	88
2003	15	16	17	18	16	10	5	97
Area (km^2)	2,657	1,651	908	828	912	792	612	8,360

2. We were not able to reconstruct exactly the distribution of tows by depth zone and survey year as presented by Sinclair (1999) in his Table 4, but the differences were relatively small (compare Table 13 with Table 4 in Sinclair 1999). I suspect these differences may be due to different conversion assumptions as the depth data are provided in metres and the depth intervals are defined in fathoms. Alternatively, the original data may have been recorded in fathoms and there may be a loss in precision when converting from fathoms to metres and back to fathoms. Three definitions of depth based on the two depth fields provided (depth at the beginning of each set, depth at the end of each set, and mean depth for the set) were tested to see if the Sinclair Table 4 distribution could be duplicated. All three definitions performed similarly, but depth at the beginning of the set was adopted, as this distribution seemed to be the closest to that provided in the Sinclair Table 4.

3. The data were analysed using the following equations, which assume that tow locations were selected randomly within a stratum relative to the biomass of bocaccio. This was not an assumption made by the original survey design and the depth zone stratum definitions presented in Table 13 were not used when conducting the survey. The biomass in any year *y* was obtained by summing the product of the CPUE and the area surveyed across the surveyed strata *i*:

$$B_y = \sum_{i=1}^{k} C_{y_i} A_i = \sum_{i=1}^{k} B_{y_i} \qquad \textbf{Eq. 11}$$

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

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

B_{y_i} = biomass of bocaccio in stratum *i* for year *y*.

k = number of strata

CPUE $\left(C_{y_i}\right)$ for bocaccio in stratum *i* for year *y* was calculated as a density in kg/km^2 by

$$C_{y_i} = \frac{\sum_{j=1}^{n_{y_i}} \left(W_{y_i j} \big/ E_{y_i j} 0.0486 \right)}{n_{y_i}} \qquad \textbf{Eq. 12}$$

where $W_{y_i j}$ = catch weight (kg) for bocaccio in stratum *i* for year *y* and tow *j*

$E_{y_i j}$ = effort (h) by tow *j* in stratum *i* for year *y*

0.0486 = constant factor (km^2/h) applied to convert CPUE in kg/h to swept area (kg/km^2)

n_{y_i} = number of tows in stratum *i*

The variance of the survey biomass estimate V_y for bocaccio in year *y* is calculated in kg^2 as follows:

$$V_y = \sum_{i=1}^{k} \sigma_{y_i}^2 A_i^2 \big/ n_{y_i} = \sum_{i=1}^{k} V_{y_i} \qquad \textbf{Eq. 13}$$

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

V_{y_i} = variance of bocaccio in stratum *i* for year *y*

The CV for bocaccio for each year *y* was calculated as follows:

$$CV_y = \frac{\sqrt{V_y}}{B_y} \quad \textbf{Eq. 14}$$

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).

17.2 RESULTS

5. Estimated biomass levels for bocaccio from the Hecate Strait assemblage trawl survey have dropped from a point estimate of over 2000 t in the first year of the survey to a relatively constant level between about 50 and 200 t, beginning with the 1989 survey (Figure 30; Table 14). Confidence bounds are wide and the estimated CVs for bocaccio from this survey range from around 0.40 to 0.68, depending on the year (Table 14). The proportion of tows which contain bocaccio has dropped from near 0.10 in the first two surveys to a relatively constant level of between 0.04 and 0.07 (Figure 31). The survey estimated biomass seems to be closely related to the proportion of tows containing bocaccio, with the high biomasses recorded in the 1984 and 1987 surveys having the highest incidence of bocaccio. Conversely, the low estimates for bocaccio recorded in the 1989 and 1998 surveys are associated with low incidences of this species (Figure 31).

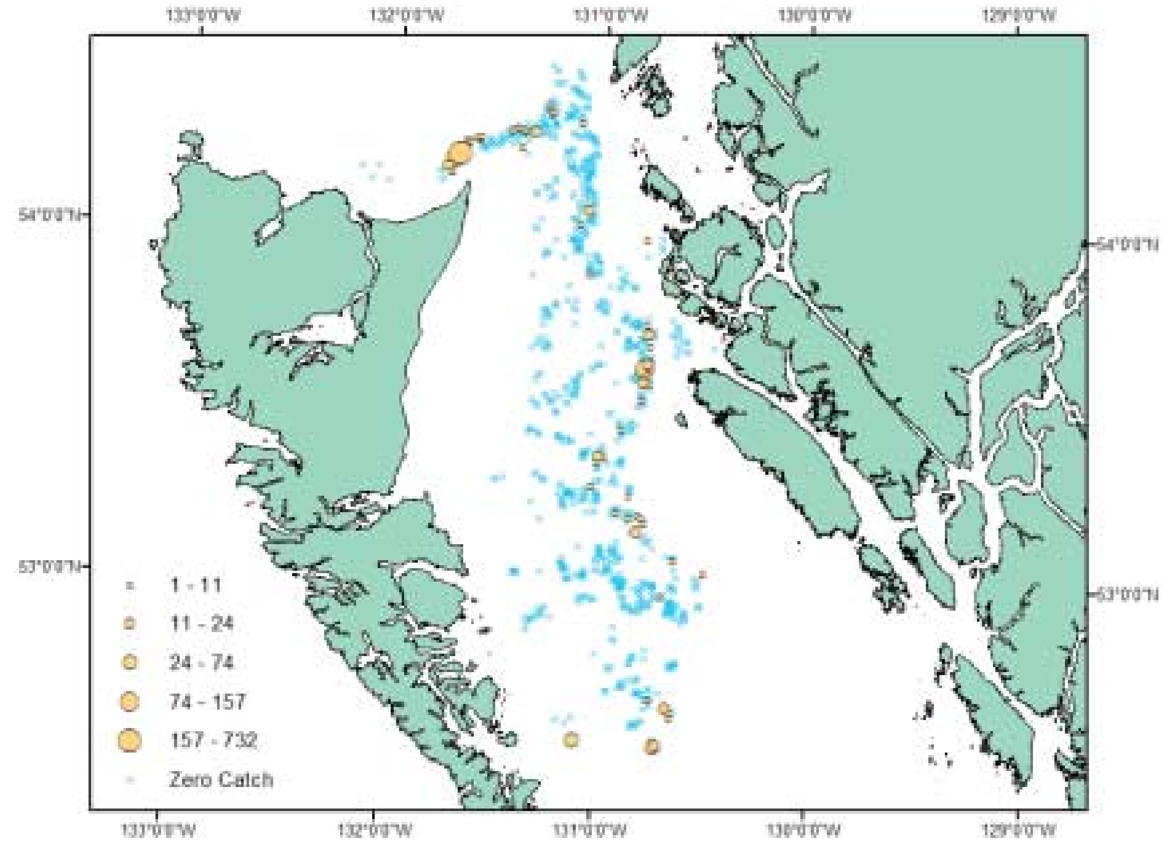

Figure 29. Plot of starting tow locations for all survey tows in the Hecate Strait assemblage trawl survey. Tows which took bocaccio are indicated by a variable circle which is proportional to the catch weight taken (in kg).

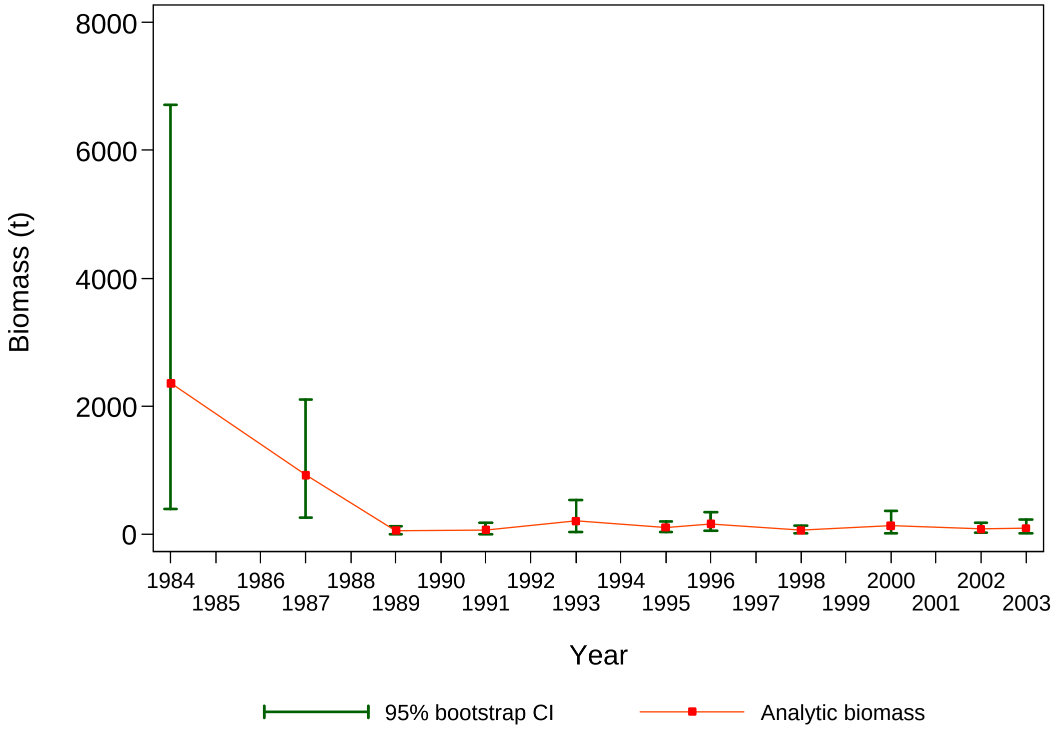

Figure 30. Plot of biomass estimates for bocaccio from the Hecate Strait assemblage trawl survey for the period 1984 to 2003. Bias corrected 95% confidence intervals from 5000 bootstrap replicates are plotted.

Table 14. Biomass estimates for bocaccio from the Hecate Strait assemblage trawl survey for the survey years 1984 to 2003. Biomass estimates are based on a post-stratification of this survey into 10-fathom depth zones (Table 13) and by assuming that the survey tows were randomly selected within these depth zones. Bootstrap bias corrected confidence intervals and CVs are based on 5000 random draws with replacement. The analytic CV (Eq. 4) is based on the assumption of random tow selection within a stratum.

Survey year	**Biomass (t)**	**Mean bootstrap biomass (t)**	**Lower bound biomass (t)**	**Upper bound biomass (t)**	**Bootstrap CV**	**Analytic CV (Eq 14)**
1984	2359.2	2332.6	394.5	6708.2	0.6756	0.6771
1987	921.6	922.0	256.6	2103.3	0.4937	0.5012
1989	55.2	55.1	0.0	125.9	0.5405	0.5402
1991	66.8	66.7	0.0	176.2	0.6516	0.6427
1993	206.2	206.2	31.4	532.2	0.6356	0.6361
1995	103.0	103.0	35.9	197.9	0.3960	0.3928
1996	160.3	160.6	52.1	344.6	0.4587	0.4568
1998	57.9	58.2	10.9	130.1	0.5180	0.5133
2000	133.3	134.0	12.5	360.1	0.6628	0.6758
2002	80.5	81.2	20.4	171.8	0.4655	0.4607
2003	93.6	93.1	10.7	227.1	0.5653	0.5671

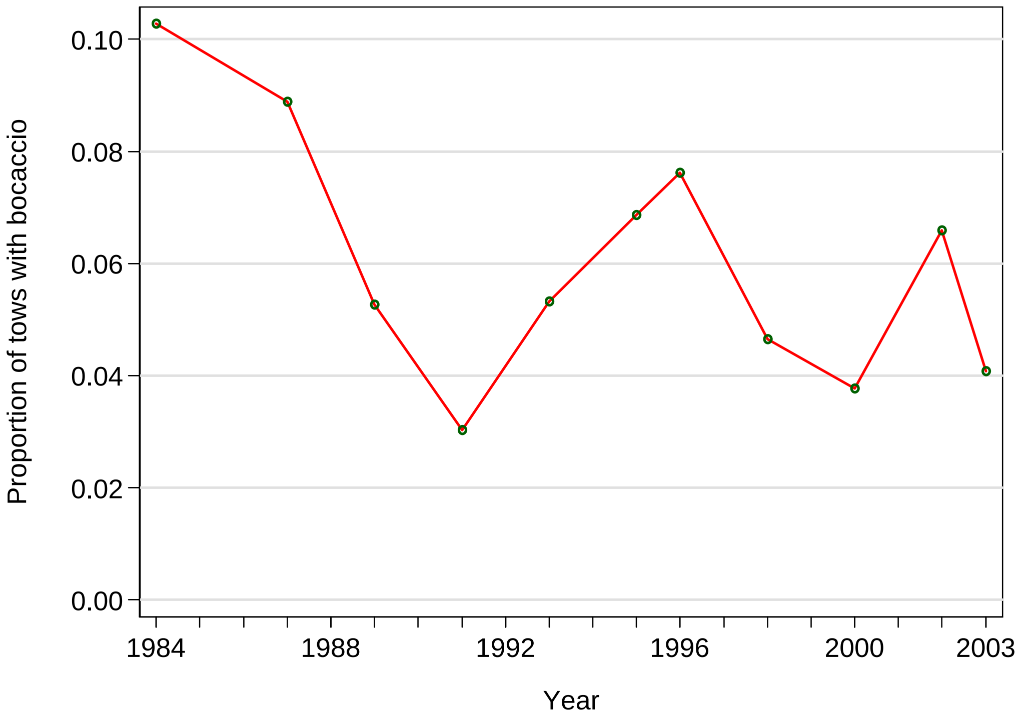

Figure 31. Proportion of tows by year which contain bocaccio for the Hecate Strait assemblage trawl survey.