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**Monitoring the recreational blue cod and sea perch fishery
in the Kaikoura – North Canterbury area**

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EXECUTIVE SUMMARY

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A four-month survey of boat ramps and charter vessel recreational fishing in the Kaikoura – North Canterbury area was undertaken during January to April 2003. The objective of the survey was to monitor changes in catch rates and sizes of blue cod (*Paraperchias colias*) and sea perch (*Helicolenus percooides*). Anglers from 751 fishing trips were interviewed at six boat ramps in Kaikoura (using the bus route survey design) and one ramp in Motunau over 45 randomly allocated sampling days. Blue cod and/or sea perch were the target species on 404 of the fishing trips, and length measurements of 1265 specimens (586 blue cod; 679 sea perch) were taken. Logbooks were distributed to 6 charter vessels, and data obtained for 497 fishing trips (including data from a previous project), from which 3217 length measurements (1598 blue cod; 1619 sea perch) were obtained. Simulation analyses determined the optimal design for monitoring future trends in abundance and size.

The total recreational fishing effort from Kaikoura and Motunau boat ramps during January–April 2003 was 5851 (\pm 164 SE) vessel hours, at an average of 3.12 hours and 2.7 persons per fishing trip. Males accounted for 82% and females 18% of fishers; the average experience was 31 days fished in the last year, and 58% of fishers were in the 31–50 age group. Anglers retained most legal sized blue cod (98%), but undersized blue cod (released) were a higher proportion of the catch in Motunau (57%) compared to Kaikoura (39%). Charter vessels (n = 6) made an average of 24 fishing trips (range, 3–54) for the 2003 summer, averaging 3.8 hours and 8.8 anglers per trip. For fishing trips where blue cod were caught (178 trips), the average catch rate was 2.3 blue cod per angler per trip. Similarly, the average catch rate for sea perch was 2.9 per angler per trip from 209 trips where it was caught. Most charter vessel clients (72%) were from New Zealand, with 28% from overseas.

The total recreational fishing catch (fish kept) of blue cod was estimated at 7380 (\pm 5866 SE) from private vessels. Average catch rates from private vessels varied from 0.26 per vessel hour (weekdays, Kaikoura) to 3.1 blue cod per vessel hour (weekends, Motunau). Similarly, catch of sea perch from private vessels was estimated at 22 212 (\pm 16 035 SE), with catch rates varying between 6.9 per vessel hour (weekdays, Kaikoura) and 0.6 per vessel hour (weekdays, Motunau). The estimated catch of blue cod and sea perch during January to April 2003 was about 18–19 t. A 73% reduction in catch of blue cod per trip (34.7 to 9.1) was observed between 1996 and 2003 at Motunau. This, combined with a significantly smaller mean length caught at Motunau, may indicate a general decline in blue cod populations at Motunau.

At current participation rates, monitoring the recreational blue cod and sea perch fishery in the Kaikoura – North Canterbury area with a bus route/access sampling design of 35 sample days (January – April) will yield 300+ harvest rate estimates capable of detecting a 20% decline in harvest rate (numbers), and more than the minimum 150 measured fish (per species) required to detect changes of 1 cm or more in mean size. Similar results can be expected for the charter vessel monitoring, with harvest rates being more precise due to the high experience level of charter operators. Improvements to the design used for this study are discussed, and it is recommended that any future monitoring of this fishery follows a standardised sampling design so accurate comparisons are possible.

1. INTRODUCTION

The national diary surveys of marine recreational fishing found blue cod (*ParaperCIAS colias*) to be the third most frequently landed species nationally (behind snapper and kahawai), and the most frequently landed species in the South Island (Annala et al. 2001). Surveys undertaken in 1992 and 1996 put the recreational harvest along the east coast of the South Island, in BCO 3, at between 175 and 245 t (Bradford et al. 1998). In addition, commercial fishers in this area land about 150 to 160 t of blue cod annually. Blue cod is also an important species for Maori customary fishers. About 80% of the recreational blue cod catch in BCO 3 is taken in Otago waters off Moeraki, Karitane, and Taieri Mouth; however, blue cod is still a very important species in the northern part of BCO 3. Although this species is distributed throughout New Zealand, tagging studies have shown it to be quite sedentary in nature and, in general, to exhibit little movement from its home area (Carbines 2001). Consequently, there are likely to be many, largely independent sub-stocks of blue cod, rendering this species susceptible to localised depletion.

Recreational fishers are concerned about the stocks of blue cod in the northern part of BCO 3. Many submissions to the Ministry of Fisheries Review of Sustainability Measures for 2000–01 provided anecdotal evidence of a decline in blue cod stocks in the northern part of BCO 3. The area of reef available is limited in the North Canterbury – Kaikoura area, with a narrow continental shelf and the Kermadec Trench coming close inshore at Kaikoura. Recent recreational catch rates are reported to be low. As a consequence, the recreational bag limit was lowered in December 2000 to 10 per day for the northern part of BCO 3 (from the Waimakariri River to Clarence Point).

Recreational fishers are also concerned about the stocks of sea perch (*Helicolenus percoides*) in the northern part of SPE 3. They have caught large numbers in the past, but most were probably discarded. Recreational anglers fishing near reefs often catch sea perch when targeting blue cod or tarakihi. The 1992 and 1996 recreational fishing surveys do not provide good estimates of the recreational sea perch catch due to problems with species identification and incomplete records.

Fishing pressure has increased in the Kaikoura area, including a marked increase in the number of charter boats. The recreational fishery off Motunau has dramatically declined over the past two years, resulting in many people transferring their fishing effort to Kaikoura. Recreational fishers report that low catch rates and the reduced bag limit for blue cod, combined with increasing numbers of recreational fishers, is resulting in an increasing trend towards fishing for sea perch in the northern part of SPE 3. Recreational fishers at both Kaikoura and Motunau report a reduction in the catch rate and size of sea perch.

There is no detailed information about blue cod and sea perch stocks in the North Canterbury – Kaikoura area. Information is required to monitor the blue cod and sea perch stocks in this area so that appropriate management actions can be taken if required. It is anticipated that further surveys will be undertaken at appropriate intervals in the future to provide a time series to monitor the status of blue cod and sea perch in this area and to gauge the effectiveness of the current management regime.

The overall objective of this project was to monitor the recreational blue cod and sea perch fishery in the North Canterbury – Kaikoura area. There were two specific objectives.

1. To monitor changes in recreational catch rates of blue cod and sea perch in the North Canterbury to Kaikoura area from a boat ramp survey.
2. To monitor changes in the size of blue cod and sea perch in recreational catches in the North Canterbury to Kaikoura area.

2. METHODS

2.1 Survey design and data collection

2.1.1 Boat ramp surveys

Boat ramps were surveyed on 45 randomly allocated sampling days at Kaikoura and Motunau between 28 December 2002 and 30 April 2003. Data on intercept rates (number of fishers per hour that caught blue cod or sea perch) during previous surveys at Kaikoura and Motunau were used to stratify sampling by weekends and weekdays for each location. Separate total catch and effort estimates were made for each of the four strata (2 locations \times 2 times [weekend/weekday]). These estimates were aggregated to obtain the total catch and effort for the region. Weekdays in the first week of January and Good Friday and Monday were included in weekend strata due to their holiday status.

A bus route survey design was used to sample the six Kaikoura boat ramps, and schedules were constructed according to Jones & Robson (1991). For each Kaikoura survey day, the starting location and direction of travel (North or South) was chosen randomly from a Mathcad worksheet routine (Appendix 1). At Motunau, a simple access point design was used for the one boat ramp, which launches onto a tidal bar.

When severe weather occurred on a sampling day and no vessels went out, a zero effort and zero catch were assumed. The survey interviewer made this decision on the day, after assessing the weather. It was assumed that the number of sampling days that fishing was not possible due to foul weather (5 of 45 sample days), was representative of the season.

Boat trailer counts were made at the beginning and end of each sampling session, and the time of launch and retrieval of each vessel within the session time was recorded. After launching, boat trailers at the main Kaikoura boat ramps (Boat Club and Public Ramp) were occasionally removed to and retrieved from nearby homes; counts were also made of these.

Anglers were asked to answer a 2 minute prepared questionnaire. Questions were asked about their age group, fishing experience (days fished in last year), fishing method, start and finish time, target species, and numbers and lengths of blue cod and sea perch caught.

Appendix 2 shows the session cover sheet and boat ramp questionnaire used for the boat ramp survey study.

2.1.2 Charter vessel logbook

A logbook was designed for charter vessels (Appendix 3) and distributed to six vessels in the Kaikoura – North Canterbury area. Data (catch, effort and length measurements) were obtained for 144 fishing trips between January and April 2003.

Permission was also given by the charter operators for data from a previous charter logbook project run by Trophia Ltd to be made available. That project ran from October 1999 to February 2001, and obtained data from 388 trips by 3 vessels. Comparisons are made between the two seasons.

2.2 Data analysis

Summary statistics

Summary statistics are presented of the principal variates of interest – catch, effort, catch rate, fisher demographics, species targeted. The appropriate catch rate for an access point survey, where the probability of sampling is independent of trip length, is the ratio-of-means harvest rate (Crone & Malvestuto 1991, Bradford 2000). Unless otherwise specified, catch (or harvest) in this report signifies what was caught by the anglers, and includes all fish caught, both those kept and those released. Fish that were retained or kept by anglers are referred to as ‘retained’ or ‘kept’.

Estimation of total catch and effort

In the boat ramp surveys, the total fishing effort for each sample day was estimated from counts of trailers at the boat ramps, retrievals and launches, and estimates of start and finish times obtained from angler interviews. Estimation of effort for Kaikoura followed the bus-route method of Jones and Robson (1991); at Motunau, effort was the total number of fishing trips for the day. Estimation of vessel harvest rates and variances followed the methods of Pollock et al., (1994, 1997), Jones et al. (1995), and Hoenig et al. (1997). These were scaled up to the estimates of total effort and total catch for January – April 2003. The total catch was estimated by multiplying the catch rate by the estimate of fishing effort in fisher hours. All equations, including those used for converting mean lengths to weights, are given in Appendix 4.

Optimal design for monitoring abundance and size of blue cod and sea perch

The power of various sampling strategies to detect changes in the mean harvest rate of the blue cod and sea perch was investigated by simulation, following the methods described by Manly (1991), Bradford & Francis (1999) and Bradford (2000). For private vessel angling, the harvest rate data used was catch (of blue cod and sea perch) per hour of fishing trip ($n = 399$ for blue cod and 342 for sea perch). The sea perch harvest rate data from the fishing competition strata (1 day only) was omitted, as it was significantly different from harvest rates in a normal weekend strata. No simulations were performed for the charter vessel data as there were only few fishing trips ($n = 144$) in the desirable sampling period targeting blue cod and sea perch (see Table 10). Ideally, charter vessel data from both summer seasons (2000 and 2003) would be combined to make up the simulation data set (catch per person per hour), but no data on number of fishers per trip were available from the 2000 season. The simulations addressed the question: What is the power ($1-\beta$; sensu Peterman 1990) of tests designed to detect a decline in mean catch rate (ratio-of-means) of 10%, 15%, 20%, 25%, 30%, and 35% at sample sizes of 100, 200, 300, 400, 500, and 1000 respectively? The simulations establish the required sample size necessary for an ongoing monitoring program for blue cod and sea perch at various levels of power. Note that tests are symmetrical, that is, detecting a drop of x % is logically equivalent to detecting an increase of $100x/(100-x)$ % (Bradford & Francis 1999). Hence, the results will apply equally to increases of 11%, 18%, 25%, 33%, 43%, and 54%. The procedure is as follows.

1. Create a modified version (e.g., reduce the mean by 10%) of the original data set.
2. Generate 1000 pairs of data of a sample size of 100 from original and modified sets using random sampling with replacement.
3. Analyse differences with a t -test (assuming equal variances) and estimate the proportion (P) of tests in which the differences are statistically significant ($p < 0.05$). P is a measure of the power of the test for that particular sample size.
4. Repeat steps 2 and 3 with sample sizes of 200 to 1000.
5. Repeat steps 1–4 with mean harvest rate differences of 15%, 20%, 25%, 30%, 35%.

6. Find the smallest sample size (if any) with $P > 0.8$. This will be the appropriate sample size for monitoring catch rates of the target species.

Sampling distributions of size (fork length in centimetres) approximated normal distributions, hence standard techniques for estimating the minimum sample size, based on variance and minimal detectable change (e.g., 1 cm, 2 cm etc), were utilised. Formulas used follow those of Snedecor & Cochran (1989).

Analyses and simulations were performed in Microsoft Excel and the R software package (R Development Core Team 2000).

3. RESULTS

3.1 Private vessel angling

Over the 45 sampling days, 750 interviews were carried out (Table 1). Of the fishing trips represented in those interviews, 374 were targeted at rock lobster and 408 at either blue cod or sea perch (only 399 trips that targeted either blue cod or sea perch supplied data suitable for catch rate analysis). A total of 257 blue cod and 618 sea perch were measured in Kaikoura and 329 blue cod and 61 sea perch were measured at Motunau (Table 1).

The average trip length was 3.11 hours at Kaikoura and 3.10 hours at Motunau. Start times of recreational fishing trips peaked between 8 a.m. and 9 a.m. at both Kaikoura and Motunau, despite the tidal nature of the fishing in Motunau (Figure 1).

Table 2 shows the distribution of interviews at Kaikoura by boat ramp and by day type strata. Most trips that targeted blue cod or sea perch were intercepted at either the boat club or the public ramp, (which are both in South Bay at Kaikoura), during the weekend or during a fishing competition.

Most (82.1%) of the people on these trips were male. The proportions did not differ much between Kaikoura and Motunau (Table 3).

Over 57% of the fishers interviewed were between the ages of 31 and 50. Slightly more of the fishers at Motunau were in the 41–50 year age group and slightly more of the fishers at Kaikoura were in the 31–40 year age group (Table 4). The average experience of fishers at Kaikoura was 33.1 days fishing in the last year, and 27.1 at Motunau.

Sea perch was the most abundant species caught at Kaikoura, followed by rock lobster and blue cod. At Motunau, blue cod was the most abundant, followed by rock lobster and sea perch. However, at Motunau only 43.5% of blue cod were retained, whereas at Kaikoura 61% were retained (Table 5).

Much higher numbers of non-legal blue cod were released at Motunau (1976) than at Kaikoura (355), and higher numbers of legal sea perch were caught at Kaikoura than at Motunau (Table 6).

3.2 Charter vessel angling

From October 1999 to February 2001, data from 388 trips on 3 vessels were recorded, and 995 blue cod and 980 sea perch were measured (Table 7). These three charter vessels recorded between 57 and 96 fishing trips, averaging 4.85 hours, 31.5 blue cod, and 31.8 sea perch per trip.

From August 2002 to May 2003, data from 214 trips on 6 vessels were recorded and 603 blue cod and 639 sea perch were measured (Table 7). These charter vessels averaged 3.78 hours, 8.96 anglers, 23.0 blue cod, and 30.5 sea perch per fishing trip. Of charter vessel clients, 28% were overseas visitors, and 72% were from New Zealand (Table 7).

Blue cod was the most abundant species caught by charter vessels during the first sampling period, followed by sea perch and then rock lobster. However, in the second sampling period, from August

2002 to May 2003, sea perch was the most abundant species followed by blue cod and rock lobster (Table 8).

Charter operators released relatively high numbers of both legal and nonlegal blue cod, and of sea perch, in both sampling periods (Table 9).

In order to compare the two sampling periods we looked at a subset of each, January to April inclusive, in 2000 and in 2003.

During the summer of 2000 (January – April), data from 132 trips on three vessels were recorded, and 307 blue cod and 260 sea perch were measured (Table 10). These three charter vessels recorded an average of 44 fishing trips (range = 15–96), averaging 5.38 hours, 36.8 blue cod, and 34.1 sea perch per trip.

During the summer of 2003, data from 100 trips on 6 vessels were recorded and 574 blue cod and 579 sea perch were measured (Table 10). These charter vessels recorded an average of 24 fishing trips (range = 3–48), averaging 4.24 hours, 9.06 anglers, 32.4 legal blue cod, and 35.4 sea perch per trip.

Blue cod was the most numerous species caught in both summers, followed by sea perch and rock lobster. The percentage of blue cod retained in 2000 was 71.7%, dropping slightly to 65.1% in 2003 (Table 11).

During the summer of 2000, there were more non-legal blue cod released than in the summer of 2003, when more legal blue cod were released. Similar numbers of sea perch were released in both summers (Table 12).

3.3 Size frequencies

Blue cod and sea perch sampled from private vessel catches at Motunau were significantly smaller than those from Kaikoura, and this difference was maintained over time (i.e., between the 1996 and 2003 surveys, Table 13; Size frequencies, Figure 2).

The mean size of blue cod caught by private vessels at Kaikoura increased from 37.8 cm FL in 1996 to 41.3 cm FL in 1999, and 40.8 cm FL in 2003. Sea perch from Kaikoura had a higher mean size in both 1996 (31.3 cm FL), and in 2003 (31.8 cm FL) than in 1999 (29.9 cm FL). The mean size of blue cod and sea perch caught at Motunau did not significantly change between 1996 and 2003 (Table 13).

Blue cod sampled from charter vessels during the comparable summer periods (January–April) in 2000 and 2003 generally peaked in abundance at 41–42 cm FL, but at Motunau, in 2003, the peak was lower, at 36 cm FL (Figure 3). Blue cod measured on Kaikoura charter vessels were larger on average in 2003 than in the previous survey in 2000, 43.1 cm FL compared with 40.7 cm FL, whereas those caught by charter vessels at Motunau were significantly smaller and did not change significantly between 2000 and 2003 (Table 14).

Some of the smaller fish measured, such as blue cod below the minimum legal size, were presumably not retained, and as such, should not have been measured. The drop off below 40 cm FL is likely to be evidence that fish below this level are often released, as was indicated by several charter operators (Figure 3).

Blue cod sizes were compared between locations and between charter and private vessels. The mean size of blue cod was larger at Kaikoura than at Motunau, from both private and charter vessels, and charter vessels measured larger blue cod than private vessels at both Kaikoura and Motunau, though this may be related to the release of blue cod up to 40 cm FL (anecdotal comments from charter operators) (Table 15).

The size of sea perch measured on charter vessels varied significantly between location and year, with the largest fish (on average) being from Kaikoura in 2003, and the smallest being from Kaikoura in 2000 (Table 14). As with blue cod, the sea perch showed wider distributions in 2003, due possibly to the larger sample sizes (Figure 4).

The size of sea perch varied significantly, and differently, between charter and private vessels in each location. Sea perch measured on charter vessels were larger on average than those measured at boat ramps at Kaikoura, but smaller on average than private vessel samples at Motunau (Table 15).

3.4 Effort, catch, and harvest rates

The total recreational fishing effort (targeting blue cod and sea perch) from Kaikoura and Motunau boat ramps during January–April 2003 was 5851 (± 164 SE) vessel hours, at an average of 3.12 hours and 2.7 persons per fishing trip (Table 16).

Total catch of blue cod and sea perch by the North Canterbury – Kaikoura angling community during January – April 2003 was estimated at 18.5 tonnes (Table 17). Of this, 6.3 tonnes was blue cod, and 12.3 tonnes was sea perch. Most of the catch (15 t) came from Kaikoura (Table 17).

The catch of blue cod from private vessels was estimated at 7380 (± 5866 SE), with catch rates varying from 0.26 blue cod per vessel hour (weekdays, Kaikoura) to 3.1 blue cod per vessel hour (weekends, Motunau). Similarly, catch for sea perch from private vessels was estimated at 22 212 ($\pm 16 035$ SE), with catch rates varying between 6.9 per vessel hour (weekdays, Kaikoura) and 0.6 per vessel hour (weekdays, Motunau). The catch rate of blue cod was significantly higher at Motunau than at Kaikoura, but the total weight of blue cod caught was similar due to the smaller fish caught at Motunau (Table 17).

Catch rates of blue cod at Kaikoura have decreased marginally since 1996, while sea perch catch rates have increased (Table 16). At Motunau, the catch rate of blue cod per trip has decreased markedly since 1996 and increased slightly for sea perch between 1996 and 2003 (Table 18).

Charter logbook data show increases from 2000 to 2003 in catch rates of blue cod per trip and per hour fishing and for sea perch per trip. However the catch rate of sea perch per hour fishing decreased slightly (Table 18).

3.5 Optimal monitoring design

A sample size (number of target blue cod/sea perch trip interviews) of 1000 could detect a 10% decline in harvest rates of sea perch, but not of blue cod (Table 19). Declines of 20% in harvest rates of both species were detectable with a sample size of 300 to 350 (Table 19). To achieve this under the sampling protocol used in this study would require 35 sampling days. Sampling efficiency could be increased at Kaikoura by sampling only at the two main Kaikoura boat ramps (Boat Club and Public Ramp, both in South Bay), which received greater than 90% of the effort, but estimates of total effort and catch would not be attainable with that design.

A sample size of 130 measured lengths each of blue cod and sea perch is capable of detecting a 1 cm difference in mean length (Table 20). If the desired precision were the ability to detect a difference of 2 cm in mean size, only 33 samples would be required. Alternatively, detecting a difference in mean size of 0.5 cm would require 520 samples of each species (Table 20).

4. DISCUSSION

This study is the first comprehensive assessment of the recreational fishery for blue cod and sea perch in the Kaikoura – North Canterbury region, and establishes a solid baseline with which future work can be compared. Carbines (2000) characterised the general recreational fishery in Kaikoura, but sampling in that study was limited to a 2-week, high usage period, during Christmas/New Year of 1998–99 and employed a roving access design to cover all types of recreational fishing. Other surveys of the region have been part of large national recreational fishing surveys such as those by Bradford et al. (1998) for private anglers and James & Unwin (2000) for charter vessels.

Monitoring fishing effort of blue cod and sea perch yielded precise estimates of total effort (5851 ± 164 SE vessel hours). This is probably due to the relatively high sampling effort, as the 45 sample days represented 20% of total possible fishing days. As a result of this, an estimate of total catch was also obtained for January–April 2003. However, the variation in catch rates and skewed distribution resulted in imprecise estimates of total catch of blue cod and sea perch ($15\,543 \pm 11\,780$ and $29\,319 \pm 19\,528$ respectively), almost half of which were subsequently released, resulting in an estimated 18 t retained overall.

The main result of note was the significant difference in mean size of blue cod between private vessels from Kaikoura and Motunau. On average, blue cod caught from Kaikoura weighed 1.2 kg, compared with 0.7 kg from Motunau. The size frequency distribution for Motunau private vessels is knife-edge above the legal minimum size, which is generally a sign of a heavily exploited stock. The net result of this is that even though almost twice as many blue cod were estimated to be caught from Motunau (4705 ± 4085) compared with Kaikoura (2675 ± 4209), the estimated catch in tonnes was very similar (both 3.1 t). This size difference was also present in the 1996 surveys (Table 13), suggesting that exploitation has been quite high for some time in Motunau, but the alternative hypothesis of differences in growth between these populations cannot be discounted at this which has implications for appropriate legal minimum length. If exploitation at Kaikoura continues to increase, as is quite likely, a similar response in Kaikoura blue cod populations may be detected in the future.

Between 2000 and 2003, the overall mean catch rate of blue cod on charter vessels increased from 14.2 per hour of fishing, to 17 per hour of fishing. However data on average number of anglers per vessel are unavailable from 2000, hence it is difficult to interpret the increasing catch rates. Catch rates of sea perch dropped slightly over the same period, but in the absence of angler data it is difficult to interpret this. It is not unreasonable to assume, however, that average numbers of anglers per charter vessel fishing trip would have remained fairly constant over this time, and that harvest rate trends are a combination of changes in fishing efficiency and abundance of target species.

The large decrease in catch rates of blue cod from private vessels in Motunau between 1996 and 2003 indicates a possible decline in abundance of blue cod. A 73% reduction in catch of blue cod per trip (34.7 to 9.1) was observed between 1996 and 2003 at Motunau, with no significant change in mean size caught (see Table 16). No data on trip length for Motunau in 1996 were available to affect a standardized comparison, but fishing at Motunau is primarily controlled by a tidal bar, hence it is not unreasonable to assume trip length has remained relatively constant. This trend will need to be watched closely in the future and taken into consideration by managers.

Private vessel catch rates of blue cod at Kaikoura decreased by 24% between the 1996 and 2003 surveys, from 3.3 to 2.5 per trip, though the catch per vessel hour contradicted that trend, increasing from 0.6 to 1.3 between 1999 and 2003. The mean size of blue cod caught on private vessels increased from 37.8 to 40.8 cm FL between 1996 and 2003. These trends do not give a clear indication of what is happening in the fishery, and may reflect a change in the behaviour of anglers, or be a function of the different natures of these surveys.

In the absence of quantitative data on the distribution of blue cod and sea perch fishers landed to the various boat ramps in Kaikoura, 80% of sampling effort was allocated to the two main boat ramps in South Bay (boat club and public ramp), and 20% to the four lesser-used ramps. After 45 sampling days and 176 BCO/SPE target interviews in Kaikoura (excluding the competition day), only 7 (or 4%) of these had been obtained from the lesser-used boat ramps and no BCO/SPE target interviews had been obtained from the Pier slipway. Furthermore, 80% of all fishing trips were completed before 2:00 p.m. in Kaikoura. Hence, there is potential to increase sampling efficiency of the bus-route survey design by allocating sampling effort to these important strata in proportion to the effort they receive, without compromising the ability to estimate total effort. The Pier slipway could be dropped from the bus-route survey. A possible bias towards the two main boat ramps is that the large blocks of time assigned to them tended to include the middle of the day, which was when most trips that had targeted blue cod or sea perch were intercepted. However, the randomised counts of boat trailers should have ensured that total effort estimates were unbiased.

Simulation analysis found that our survey design was capable of detecting 20% decreases in the average harvest rates of blue cod and sea perch with a sample size of 300 to 350 individual fishing trips. A minimum of 35 sampling days is probably required to obtain this sample. Relatively small changes (1 cm and upward) in mean size of blue cod and sea perch can be detected with a random sample of 150 measurements from each of the target populations (blue cod – private and charter vessels; sea perch – private and charter vessels). Thus, the main emphasis on future surveys needs to be on optimising the sampling of harvest rate estimates, as it will be relatively easy to obtain the desired sample numbers for monitoring sizes.

At current participation rates, monitoring the recreational blue cod and sea perch fishery in the Kaikoura–North Canterbury area with a sampling design of 35 sample days (January–April) will yield 300 to 350 harvest rate estimates, capable of detecting a 20% decline in harvest rate, and more than the minimum 150 measured fish (per species) required to detect changes of 1 cm or more in mean size. Similar results can be expected for the charter vessel monitoring, with harvest rates being more precise due to the greater experience of the charter operators. It is recommended that any future monitoring of this fishery follow a standardised sampling design so accurate comparisons are possible.

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Table 1: Location, strata, number of days, number of interviews, number of complete interviews of trips that targeted BCO or SPE, and the number of interviews that included targeting of CRA.

Location	Strata	Days sampled	No. of interviews	BCO/SPE			CRA trip interviews
				trip interviews	BCO measured	SPE measured	
Kaikoura	Weekend	20	411	164	232	542	217
	Weekday	7	50	12	7	51	38
	Competition	1	76	57	18	25	6
	Total	28	537	233	257	618	261
Motunau	Weekend	12	194	154	264	49	101
	Weekday	5	19	12	65	12	12
	Total	17	213	166	329	61	113
Grand Total		45	750	399	586	679	374

Table 2: Distribution of interviews by ramps at Kaikoura.

Boat ramp	Stratum	Hours sampled	Total no. of interviews	BCO/SPE target interviews	CRA target interviews
Armors Beach	Weekend	6.92	7	1	3
	Weekday	2.85	1	0	1
	Competition	0.08	0	0	0
Boat Club	Weekend	79.48	316	113	190
	Weekday	20.63	41	9	31
	Competition	5.28	37	26	4
Boat Harbour	Weekend	8.08	7	2	5
	Weekday	3.53	3	1	3
	Competition	0.50	1	0	0
Barney's Rock	Weekend	3.73	5	1	4
	Weekday	1.73	2	2	0
	Competition	0.10	0	0	0
Public Ramp	Weekend	27.88	74	47	13
	Weekday	8.45	2	0	2
	Competition	3.73	38	31	2
Pier Slipway	Weekend	2.75	2	0	2
	Weekday	1.15	1	0	1
	Competition	0.12	0	0	0
Total		177.02	537	233	261

Table 3: Percentage of fishers by sex and location interviewed.

Location	Male	Female
Kaikoura	81.2	18.8
Motunau	83.1	16.9
Overall	82.1	17.9

Table 4: Percentage of fishers interviewed by age group and location interviewed.

Location	Age groups						
	<15	15-20	21-30	31-40	41-50	51-60	61+
Kaikoura	7.0	3.4	9.0	25.9	29.6	15.1	10.0
Motunau	10.9	4.6	7.5	32.5	27.5	10.9	6.1
Overall	8.8	4.0	8.3	28.8	28.7	13.2	8.2

Table 5: Total number caught and percentage of catch retained of the top ten species at Kaikoura and Motunau from 750 (sampled) recreational fishing trips from private vessels from 28 December 2002 to 30 April 2003.

Location	Species	Total caught	% of catch retained
Kaikoura	Sea perch	4273	69.6
	Rock lobster	748	96.3
	Blue cod	941	61.0
	Butterfish	140	100.0
	Spiny dogfish	118	50.0
	Red cod	85	62.4
	Moki	40	100.0
	Barracouta	45	88.9
	Hapuku	16	100.0
	Tarakihi	14	100.0
Motunau	Blue cod	3548	43.5
	Rock lobster	1234	99.2
	Sea perch	854	48.9
	Kina	227	100.0
	Wrasse spp.	78	38.5
	School shark	27	96.3
	Red cod	14	78.6
	Barracouta	30	33.3
	Kahawai	12	83.3
	Leatherjacket	14	64.3

Table 6: Numbers of blue cod and sea perch, legal retained catch, legal released and not legal released, from 750 recreational fishing trips on private fishing vessels from 2 January to 27 April 2003.

Location	Species	No. legal kept	No. legal released	No. non legal released
Kaikoura	Blue cod	574	12	355
	Sea perch	2972	1301	n/a
Motunau	Blue cod	1544	28	1976
	Sea perch	418	436	n/a

Table 7: Numbers of trips, vessels, blue cod and sea perch measurements recorded on charter logbook by sampling period charter vessels;--, not recorded.

Survey period	No. of trips	No. of vessels	No. of BCO measured	No. of SPE measured	% NZ fishers	% overseas
Oct 1999 – Feb 2001	388	3	995	980	--	--
Aug 2002 – May 2003	214	6	603	639	71.8	28.2

Table 8: Total number caught and percentage of catch retained of the top ten species at Kaikoura and Motunau from recreational fishing on charter vessels by survey period.

Survey period	Species	Total caught	% of catch retained
Oct 1999 –	Blue cod	15 155	72.4
Feb 2001	Sea perch	12 347	79.2
	Rock lobster	11 720	36.1
	Hapuku	503	99.8
	Barracouta	333	97.9
	Spiny dogfish	263	2.3
	Trumpeter	233	99.1
	Tarakihi	113	99.1
	Paua	98	95.9
	Red cod	86	94.2
Aug 2002 –	Sea perch	6 518	82.4
May 2003	Blue cod	5 601	66.4
	Rock lobster	2 138	46.1
	Red cod	139	79.1
	School shark	100	99.0
	Spiny dogfish	88	44.3
	Barracouta	61	100.0
	Hapuku	55	100.0
	Tarakihi	21	100.0
	Trumpeter	15	100.0

Table 9: Numbers of blue cod and sea perch, legal retained catch, legal released and not legal released, from recreational fishing trips on charter vessels, by survey period.

Survey period	Species	No. retained	No. legal released	No. not legal released
Oct 1999 – Feb 2001	BCO	10 978	1 246	2 931
	SPE	9 781	2 566	n/a
Aug 2002 – May 2003	BCO	3 721	1 209	671
	SPE	5 374	1 144	

Table 10: Numbers of trips, vessels, blue cod and sea perch measurements recorded in charter logbooks, by summer period.

Sampling period	No. of trips	No. of vessels	No. of BCO measured	No. of SPE measured
Jan – Apr 2000	132	3	307	260
Jan – Apr 2003	144	6	574	579

Table 11: Numbers of the top ten species caught at Kaikoura and Motunau from recreational fishing on charter vessels, by summer period, within the sampling periods.

Summer	Species	% kept	Total
January – April 2000	Blue cod	71.7	6 109
	Sea perch	81.0	4 496
	Rock lobster	44.3	3 324
	Hapuku	99.6	256
	Barracouta	98.2	169
	Tarakihi	98.5	65
	Spiny dogfish	11.3	53
	Red cod	95.1	41
	School shark	94.9	39
	Trumpeter	100.0	36
January – April 2003	Blue cod	65.1	5 115
	Sea perch	79.4	4 213
	Rock lobster	47.9	1 833
	Red cod	80.9	131
	School shark	99.0	100
	Barracouta	100.0	60
	Spiny dogfish	41.7	60
	Hapuku	100.0	55
	Tarakihi	100.0	21
	Trumpeter	100.0	15

Table 12: Numbers of blue cod and sea perch, legal retained catch, legal released and not legal released, from recreational fishing trips on charter vessels by summer period; n/a, not applicable.

Summer	Species	No. retained	No. legal released	No. non legal released
January – April 2000	BCO	4380	478	1251
	SPE	3642	854	
January – April 2003	BCO	3477	1189	623
	SPE	4166	927	

Table 13: ANOVA results and *post-hoc* tests for analysis of mean length of blue cod and sea perch from recreational fishing surveys in 1996, 1999, and 2003. Subscripts a, b and c indicate groupings in *post-hoc* tests.

Source of variability	Blue cod				Sea perch			
	D.F	MS	F	P	D.F	MS	F	P
Location/Survey	9643	4533	435.6	< 0.001	3099	613	36.0	< 0.001
Mean lengths of target species (cm)				Mean lengths of target species (cm)				
	Location	Year	Length		Location	Year	Length	
	Kaikoura	1996	37.8b		Kaikoura	1996	31.3a	
		1999	41.4a			1999	29.9b	
		2003	40.8a			2003	31.8a	
	Motunau	1996	34.9c		Motunau	1996	29.6b	
		2003	34.5c			2003	29.9b	

Table 14: ANOVA results for analysis of mean length of blue cod and sea perch from charter vessels from Kaikoura and Motunau, January–April 2000 and 2003. Subscripts a, b, c and d indicate groupings in post-hoc tests.

Source of variability	Blue cod				Sea perch			
	D.F	MS	F	P	D.F	MS	F	P
Location	877	2356.1	71.7	<0.001	835	1133.3	64.4	<0.001
Summer	877	144.7	4.4	0.036	835	9898.3	562.4	<0.001
Interaction	877	402.4	12.2	<0.001	835	13522.3	768.3	<0.001

Mean length of blue cod (cm)			Mean length of sea perch (cm)		
Location	Summer	Length	Location	Summer	Length
Kaikoura	2000	40.7b	Kaikoura	2000	17.1a
	2003	43.1c		2003	34.1d
Motunau	2000	38.6a	Motunau	2000	29.0c
	2003	38.0a		2003	27.6b

Table 15: ANOVA results for analysis of mean length of blue cod and sea perch from boat ramp surveys and charter vessel logbooks from Kaikoura and Motunau, January–April 2003. Subscripts a, b and c indicate groupings in post-hoc tests.

Source of variability	Blue cod				Sea perch			
	D.F	MS	F	P	D.F	MS	F	P
Boat ramp/Charter	1156	2325.3	82.1	<0.001	1254	0.1	0.0	0.931
Location	1156	9269.8	327.3	<0.001	1254	2805.1	173.5	<0.001
Interaction	1156	121.2	4.3	0.039	1254	849.1	52.5	<0.001

Mean length of blue cod (cm)			Mean length of sea perch (cm)		
	Location	Length		Location	Length
Charter	Kaikoura	43.0d	Charter	Kaikoura	34.1d
	Motunau	38.0b		Motunau	27.6a
Boat ramp	Kaikoura	40.8c	Boat ramp	Kaikoura	31.8c
	Motunau	34.5a		Motunau	29.9b

Table 16: Estimated total recreational effort by recreational angling vessels targeting blue cod and sea perch from Kaikoura – North Canterbury from 1 January to 30 April 2003.

Location	Weekends	Weekdays
	Effort (hours ± SE)	Effort (hours ± SE)
Kaikoura	2 478 (57)	1 571 (132)
Motunau	1 351 (55)	225 (55)
Total: 5 851 ± 164 vessel hours		

Table 17: Estimated total recreational catch of blue cod and sea perch by recreational angling vessels from Kaikoura – North Canterbury from 1 January to 30 April 2003.

Common name	Scientific name	Location	No. caught (\pm SE)	No. kept (\pm SE)	Estimated kg kept
Blue cod	<i>ParaperCIAS colias</i>	Kaikoura	4 541 (7 314)	2 675 (4 209)	3 130
		Motunau	11 002 (9 234)	4 705 (4 085)	3 152
Sea Perch	<i>Helicolenus percoides</i>	Kaikoura	26 819 (19 102)	21 047 (15 840)	11 786
		Motunau	2 499 (4 055)	1 165 (2 480)	536
TOTAL	<i>ParaperCIAS colias</i>		15 543 (11 780)	7 380 (5 866)	6 282
	<i>Helicolenus percoides</i>		29 319 (19 528)	22 212 (16 035)	12 322

Table 18: Catch rates (numbers per trip and per fishing time) of legal blue cod and all sea perch from boat ramp surveys (letters represent the year, KAI = Kaikoura, MOT=Motunau; number represent the year e.g. 96 = 1996) and charter logbooks (from the summer period, January to April). NB: Data collected during January to April were used from the 1996 survey.

	Location/ Project	No. of BCO		No. of SPE	
		per trip	per hour fishing	per trip	per hour fishing
Boat ramp survey	KAI03	2.5	1.3	18.0	9.2
	KAI99	3.2	0.6	17.9	3.5
	KAI96	3.3	-	7.8	-
	MOT03	9.1	4.7	5.0	2.6
	MOT96	34.7	-	1.9	-
Charter logbook	2003	45.2	17.0	42.1	13.2
	2000	36.8	14.2	15.7	15.2

Table 19: Power (1-β) of simulated tests to detect specified reductions (10–35%) in mean angling catch rates of blue cod and sea perch at various sample sizes. Tests where power is greater than 0.8 are considered sufficient.

Harvest rate reduction (%)	Sample size (n)						Sample size (n)					
	100	200	300	400	500	1000	100	200	300	400	500	1000
	Blue cod (retained)						All blue cod caught					
10%	0	0	0	0	0	0	0	0	0	0	0	0
15%	0	0	0	0	0.10	1	0	0	0	0	0.35	1
20%	0	0	0.57	0.99	1	1	0	0	0.79	1	1	1
25%	0	0.80	1	1	1	1	0.01	0.91	1	1	1	1
30%	0.16	1	1	1	1	1	0.24	1	1	1	1	1
35%	0.85	1	1	1	1	1	0.91	1	1	1	1	1
	Sea perch (retained)						All sea perch caught					
10%	0	0	0	0	0	0	0	0	0	0	0	0.97
15%	0	0	0	0	0.1	1	0	0	0	0.69	1	1
20%	0	0	0.56	1	1	1	0	0.39	1	1	1	1
25%	0	0.83	1	1	1	1	0.07	1	1	1	1	1
30%	0.14	1	1	1	1	1	0.87	1	1	1	1	1
35%	0.84	1	1	1	1	1	1	1	1	1	1	1

Table 20: Sample size (number of specimens measured) required to detect specified differences (0.5 – 3 cm) in mean size of blue cod (*Paraperchias colias*) and sea perch (*Helicolenus percoides*) caught by private and charter vessels in the Kaikoura-Motunau angling community.

Minimal detectable size difference (cm)	Sample sizes			
	Blue cod		Sea perch	
	Private vessels	Charter vessels	Private vessels	Charter vessels
0.5	492	228	471	519
1	123	57	118	130
1.5	55	26	53	58
2	31	15	30	33
2.5	20	10	19	21
3	14	7	14	15

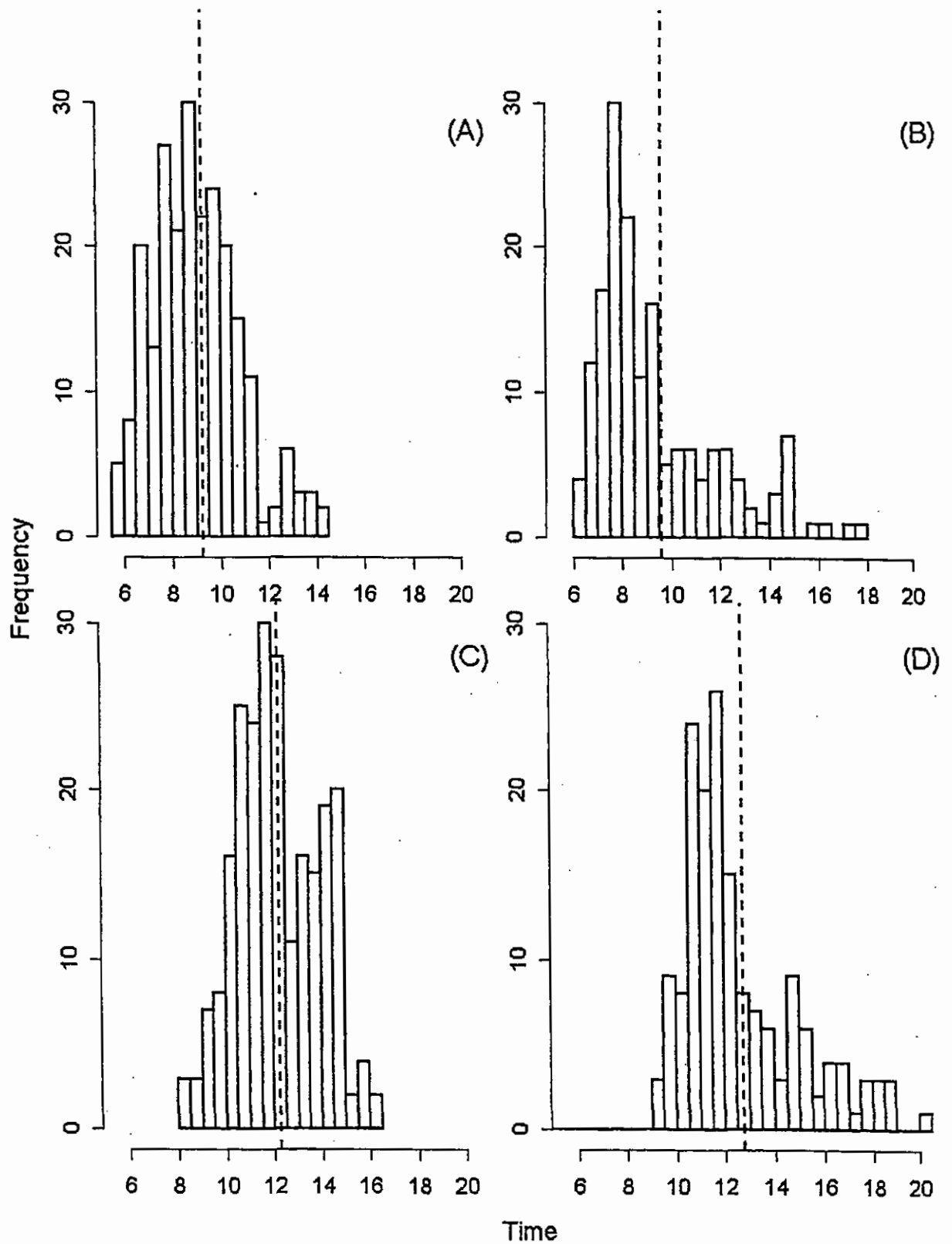


Figure 1: Distribution of angling start (Kaikoura, A; Motunau, B) and finish (Kaikoura, C; Motunau, D) times for those trips targeting blue cod and sea perch. Vertical lines indicate the mean start and finish times.

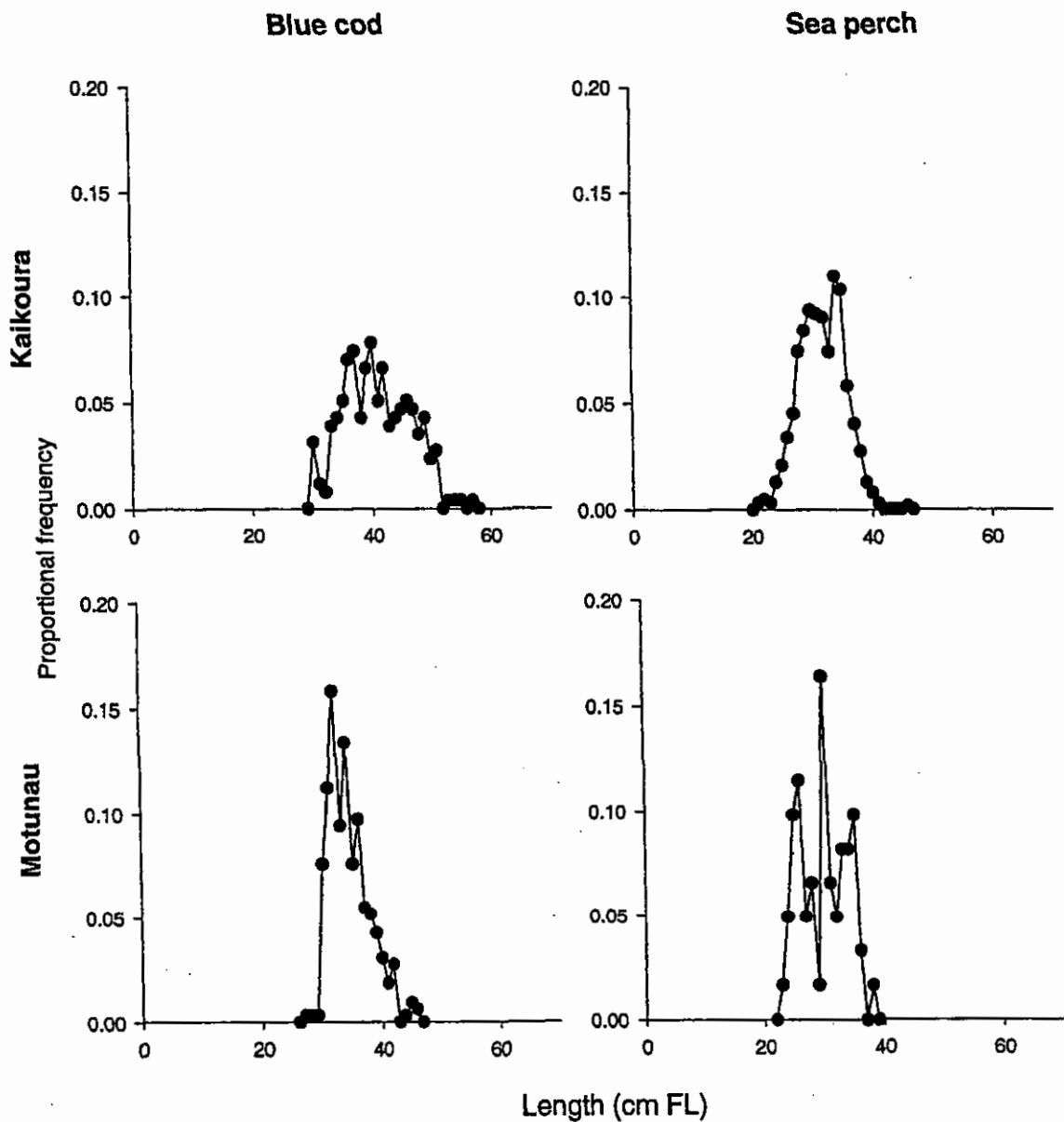


Figure 2: Proportional size frequencies of blue cod and sea perch from boat ramp surveys at Kaikoura and Motunau sampled from 2 January to 27 April, 2003.

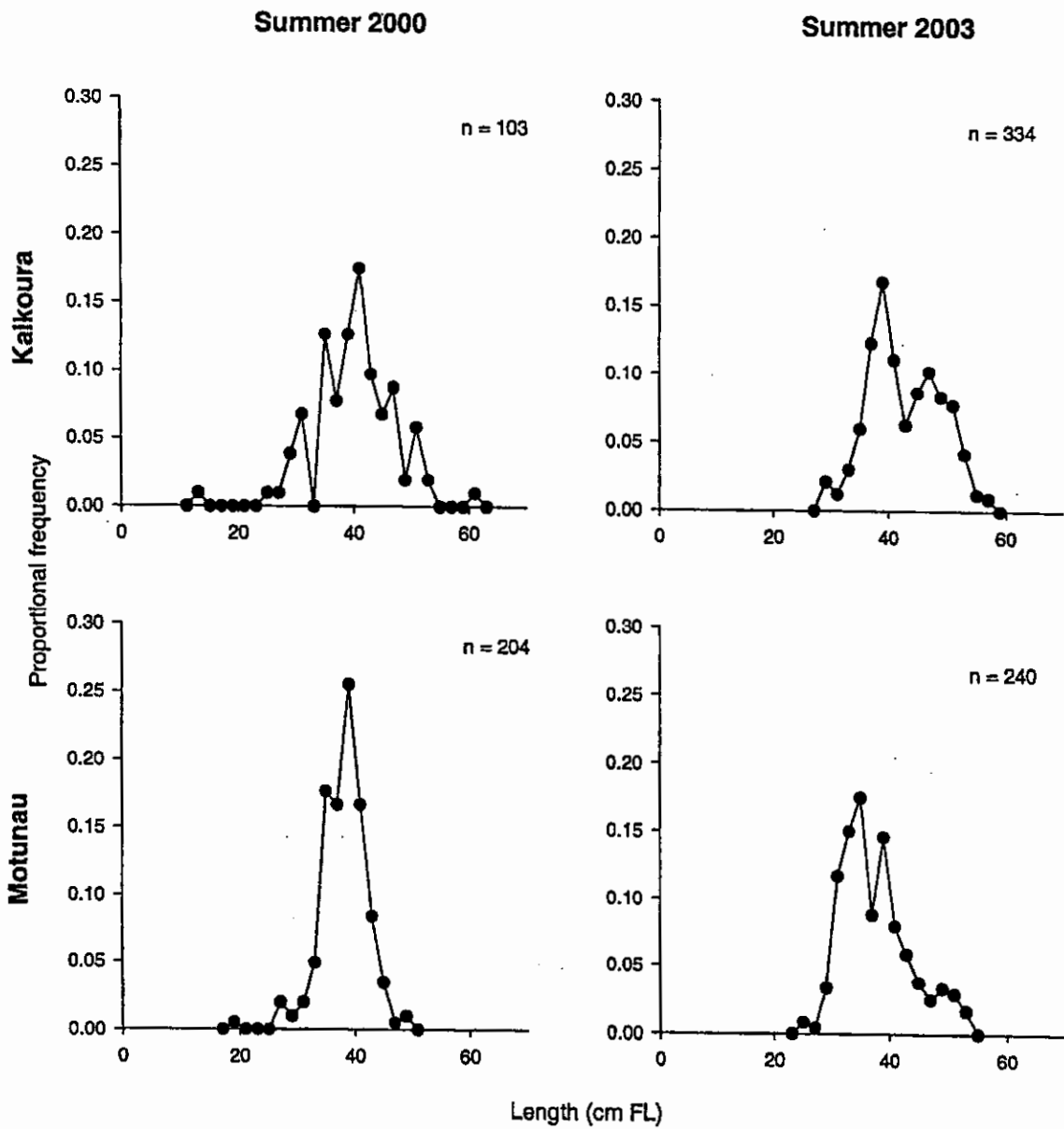


Figure 3: Proportional size frequencies of blue cod from charter logbooks in Kaikoura and Motunau from Summer 2000, January to April 2000; Summer 2003, January to April 2003.

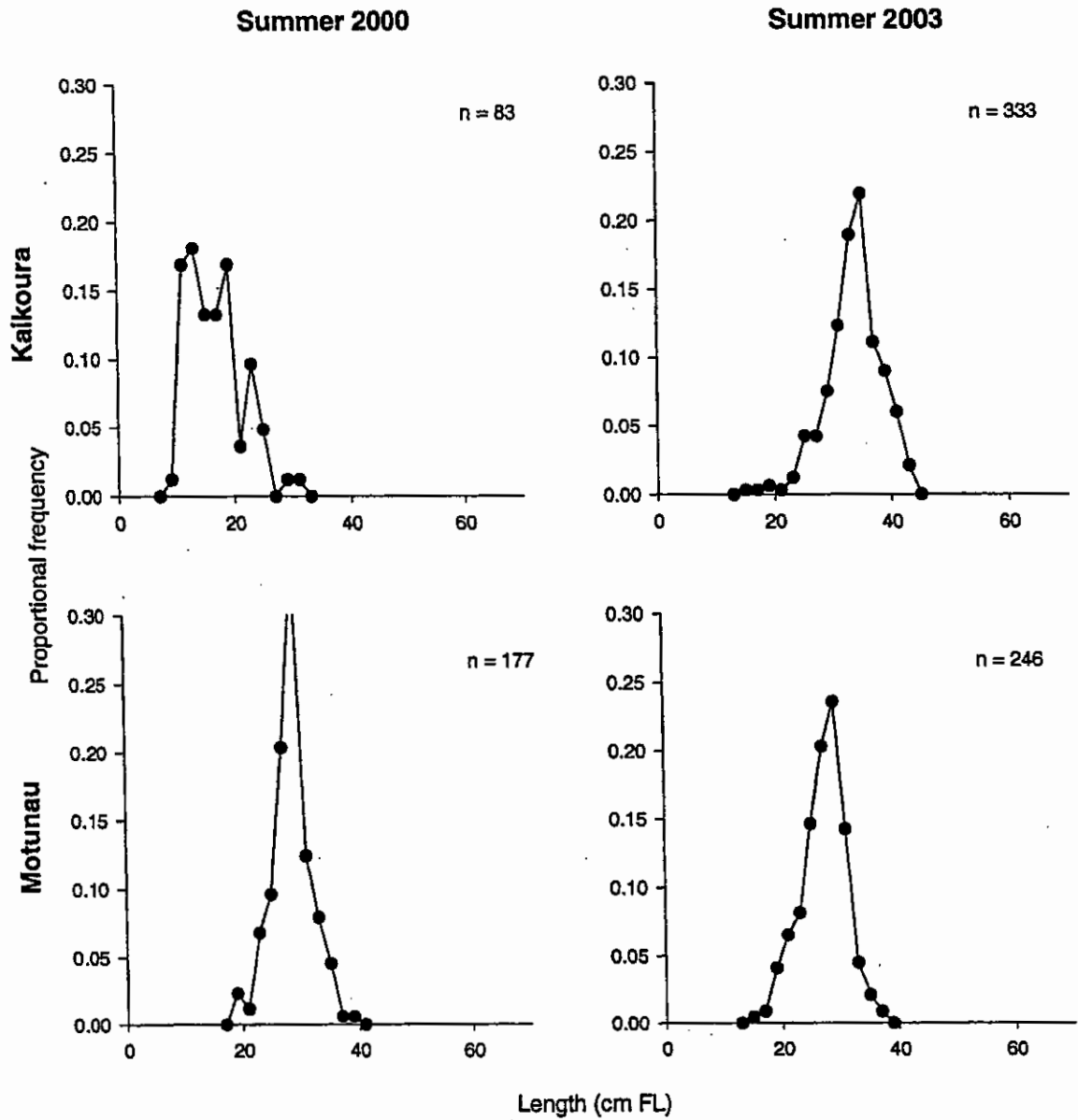


Figure 4: Proportional size frequencies of sea perch from charter logbooks in Kaikoura and Motunau from: Summer 2000, January to April 2000; Summer 2003, January to April 2003.

Appendix 1: An example of a bus route schedule for Kaikoura boat ramp sampling generated from a MathCad® worksheet.

Saturday, 11 January (Kaikoura)

Schedule for Bus Route

direction = 0
start_site = 3

Direction (0:down 1:up)

Arrival Times

arrive2 = $\begin{pmatrix} 7 & 0 \\ 9 & 3 \\ 15 & 15 \\ 15 & 44 \\ 17 & 13 \\ 17 & 49 \end{pmatrix}$

First Ramp
Second Ramp
Third Ramp

Departure Times

depart2 = $\begin{pmatrix} 8 & 58 \\ 14 & 56 \\ 15 & 33 \\ 16 & 43 \\ 17 & 42 \\ 18 & 0 \end{pmatrix}$

First Ramp
Second Ramp
Third Ramp

Ramp 1: Armers Beach
Ramp 2: Pier Ramp
Ramp 3: Public Ramp
Ramp 4: Boat Club
Ramp 5: Barneys Rock
Ramp 6: Boat Harbour

This schedule for Saturday, 11 January begins at the "start_site = 3", which is Public Ramp, at 0700h. The interviewer stays till 0858, then proceeds in the "direction = 0", which is down (i.e. from Ramp 3 to Ramp 4, rather than "up", which is Ramp 3 to Ramp 2), beginning at Ramp 4 (Boat Club) at 0903 am. The completion of the day's schedule is at Ramp 2 (Pier Ramp), at 1800 hours.

Appendix 2. Session and interview questionnaires used in the boat ramp surveys

Session sheet

BCO/SPE Boat ramp survey				Survey Code <input style="width: 100%;" type="text"/>							
Session cover sheet				Interviewer <input style="width: 100%;" type="text"/>							
Date: <input style="width: 80%;" type="text"/>				Ramp:	<input type="checkbox"/> WB	<input type="checkbox"/> R	<input type="checkbox"/> AB	<input type="checkbox"/> PB	<input type="checkbox"/> BC	<input type="checkbox"/> GB	<input type="checkbox"/>
Start time: <input style="width: 80%;" type="text"/>				Vantage Point:		<input type="checkbox"/> KP	<input type="checkbox"/> RL	<input type="checkbox"/> HB	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Finish time: <input style="width: 80%;" type="text"/>				Vantage	1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				Point Counts	2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
# boat trailers at:											
Session Start				Middle of Session				Session Finish			
<input style="width: 100%;" type="text"/>				<input style="width: 100%;" type="text"/>				<input style="width: 100%;" type="text"/>			
Tides and Moon											
		Time						Level			
Low tide		<input style="width: 20%;" type="text"/>		:		<input style="width: 20%;" type="text"/>		am/pm		<input style="width: 20%;" type="text"/>	
High tide		<input style="width: 20%;" type="text"/>		:		<input style="width: 20%;" type="text"/>		am/pm		<input style="width: 20%;" type="text"/>	
Moon phase		<input style="width: 100%;" type="text"/>									
Weather conditions											
Sea state:		1 <input type="checkbox"/> 0.1-0.5		2 <input type="checkbox"/> 0.5-1.0		3 <input type="checkbox"/> 1.0-2.5		4 <input type="checkbox"/> 2.5-4.0			
Rain:		1 <input type="checkbox"/> Nil		2 <input type="checkbox"/> Light, continuous		3 <input type="checkbox"/> Light, scattered		4 <input type="checkbox"/> Medium, scattered			
Overhead:		1 <input type="checkbox"/> Sunny, continuous		2 <input type="checkbox"/> Mainly sunny		3 <input type="checkbox"/> Mainly cloudy		4 <input type="checkbox"/> Cloudy, continuous			
Wind speed		1 <input type="checkbox"/> Nil		2 <input type="checkbox"/> Light (1-10 knots)		3 <input type="checkbox"/> Medium (11-20 knots)		4 <input type="checkbox"/> Strong (21+ knots)			
Wind direction		<input type="checkbox"/> N	<input type="checkbox"/> NE	<input type="checkbox"/> E	<input type="checkbox"/> SE	<input type="checkbox"/> S	<input type="checkbox"/> SW	<input type="checkbox"/> W	<input type="checkbox"/> NW	<input type="checkbox"/> Variable	
		<input type="checkbox"/> Nil									
Boat Launches						Boat Retrievals					
Time	Time	Time	Time	Time	Time	Time	Time	Time	Time	Time	Time
Boat Trailers Removed off site (Y/N)						Boat Trailers Retrieved off site (Y/N)					

Interview sheet

BCO/SPE Boat ramp survey

Section

[]

INTERVIEW ONE

Intercept time [] : [] : [] am/pm
 Outcome [] I [] R [] N [] O [] Z [] X
 # Fishers [] # males []
 # females []
 Age group 1 [] 15-20 4 [] 41-50
 2 [] 21-30 5 [] 51-60
 3 [] 31-40 6 [] 61+
 Days fished in last year [] [] []

Fishing zone [] [] []
 Target species [] [] []
 Method []
 # rods [] [] []
 #hooks per rod [] [] []
 Burley Yes No
 Fishfinder Yes No
 Fish start time [] : [] : [] am/pm
 Fish finish time [] : [] : [] am/pm
 Time not fishing (hrs) [] [] []

Catch

Species Code	# Retained	# Legal Released	# Not Legal Released
B C O			
S P E			

B	C	O	S	P	E
Length (cm)			Length (cm)		

INTERVIEW TWO

Intercept time [] : [] : [] am/pm
 Outcome [] I [] R [] N [] O [] Z [] X
 # Fishers [] # males []
 # females []
 Age group 1 [] 15-20 4 [] 41-50
 2 [] 21-30 5 [] 51-60
 3 [] 31-40 6 [] 61+
 Days fished in last year [] [] []

Fishing zone [] [] []
 Target species [] [] []
 Method []
 # rods [] [] []
 #hooks per rod [] [] []
 Burley Yes No
 Fishfinder Yes No
 Fish start time [] : [] : [] am/pm
 Fish finish time [] : [] : [] am/pm
 Time not fishing (hrs) [] [] []

Catch

Species Code	# Retained	# Legal Released	# Not Legal Released
B C O			
S P E			

B	C	O	S	P	E
Length (cm)			Length (cm)		

Appendix 3: Charter operator logbook

Charter Operator Logbook

Operator Number

Fill in a new column for each new trip, each new zone fished within a trip, and each method used (catch from each trip, zone, and method to be separated). Always enter the Date, Zone, Trip time, Methods used and Catch. Enter the sizes of retained catch where time permits.

TRIP	ZONE	METHOD			
Date		L	LL	N	
		N	P	D	
day month year					
Trip time	Start			am/pm	
	End			am/pm	
Total # of fishers		NZ	Overseas		
Effort	# Rods				
Line (L)	# Hooks per rod				
	Fishing time (hrs)				
Longline (LL)	# Hooks				
	Fishing time (hrs)				
Net (N)	Length (m)				
	Fishing time (hrs)				
Pots (P)	# pots				
	Pot time (hrs per pot)				
Diving (D)	# divers				
	Time (hrs per diver)				
Other (describe)					
		(hrs)			

TRIP	ZONE	METHOD			
Date		L	LL	N	
		N	P	D	
day month year					
Trip time	Start			am/pm	
	End			am/pm	
Total # of fishers		NZ	Overseas		
Effort	# Rods				
Line (L)	# Hooks per rod				
	Fishing time (hrs)				
Longline (LL)	# Hooks				
	Fishing time (hrs)				
Net (N)	Length (m)				
	Fishing time (hrs)				
Pots (P)	# pots				
	Pot time (hrs per pot)				
Diving (D)	# divers				
	Time (hrs per diver)				
Other (describe)					
		(hrs)			

Catch	# Retained	# Legal Released	# Not Legal Released
Species Code			

Catch	# Retained	# Legal Released	# Not Legal Released
Species Code			

Measure as many retained Blue Cod (BCO) and Sea Perch (SPE) as possible. Measure fish in cm or mm from the tip of the nose to the tail fork (or tail tip if no fork).

TRIP ONE SIZES				TRIP TWO SIZES							
B	C	O	S	P	E	B	C	O	S	P	E
Length (cm)			Length (cm)			Length (cm)			Length (cm)		

Appendix 4. Effort, catch, and catch rate equations

Estimation of total effort

The fishing effort (vessel hours) for sample day m in Kaikoura was estimated by the method of Jones and Robson (1991) as follows:

$$e_m = fT \sum_i^n \left[\left(\frac{1}{w_i} \right) \sum_j X_{ij} \right] \quad (1)$$

where T is the time taken to complete the bus route (varied depending on weather, but generally between 9 and 11 hours), n is the number of boat ramps (6), w_i is the interviewer wait time at boat ramp i , X_{ij} is the time trailer j spends at boat ramp i during the sample session.

A correction factor (Sumner et al. 2002) was used to adjust the effort for fishing that occurred before the morning shift commenced at time t .

$$f = \frac{\sum_j (r_j - L_j)}{\sum_j b_j} \quad (2)$$

where

$$b_j = \begin{cases} r_j - t, & L_j < t \\ r_j - L_j, & L_j \geq t \end{cases}$$

r_j is the retrieval time for boat j and L_j is the launch time for boat j .

The fishing effort (vessel hours) for sample day m in Motunau was estimated as follows:

$$e_m = \sum_i^n L_i \quad (3)$$

where L_i is the effort (in hours) of fishing trip i , and n is the total number of fishing trips.

The estimated variance $V(\bar{e}_k)$ within stratum k ($k = 4$; 2 locations x weekend/weekday) is calculated as follows (Pollock et al. 1994).

$$s_k^2 = \frac{1}{n_k - 1} \sum_{m=1}^{n_k} (e_{km} - \bar{e})^2 \quad (4)$$

where n_k is the sample size (days) for stratum k , e_{km} is the effort for stratum k on day m and \bar{e}_k is the mean daily fishing effort (in hours and fishing trips) for stratum k . The variance associated with the estimate of the mean, with finite population correction (Neter et al. 1988) is

$$V(\bar{e}_k) = \frac{s_k^2}{n_k} \left(\frac{N_k - n_k}{N_k} \right) \quad (5)$$

where N_k is the total number of days in stratum k . The total effort for stratum k is estimated as

$$\hat{E}_k = \frac{N_k}{n_k} \sum_{m=1}^{n_k} e_{km} \quad (6)$$

The variance associated with \hat{E}_k is estimated by

$$V(\hat{E}_k) = N_k^2 V(\bar{e}_k) \quad (7)$$

The standard error is calculated by the usual method

$$SE(\hat{E}_k) = \sqrt{V(\hat{E}_k)} \quad (8)$$

The total effort is estimated by summing the effort for each stratum as follows

$$\hat{E} = \sum_{k=1}^n \hat{E}_k \quad (9)$$

where n is the number of strata. Similarly, the variance of \hat{E} is estimated as

$$V(\hat{E}) = \sum_{k=1}^n V(\hat{E}_k) \quad (10)$$

The standard error of \hat{E} is calculated by the usual method.

$$SE(\hat{E}) = \sqrt{V(\hat{E})} \quad (11)$$

Estimation of catch rate and total catch

The ratio-of-means catch rate for each stratum (\hat{H}_k) is estimated as:

$$\hat{H}_k = \frac{\bar{c}_k}{\bar{L}_k} = \frac{\sum_{j=1}^{n_k} c_{kj} / n_k}{\sum_{j=1}^{n_k} L_{kj} / n_k} \quad (12)$$

where n_k is the number of vessels in stratum k where the catch was recorded, c_{jk} is the catch for boat j in stratum k , and L_{jk} the effort, in hours, for boat j in stratum k . The variances for \bar{c}_k and \bar{L}_k can be calculated by the usual method described in (2) without the finite population correction factor.

Variance of \hat{H}_k is estimated using the formulae of Kendall & Stuart (1969)

$$\hat{V}(\hat{H}_k) = \hat{H}_k^2 \left(\frac{s_y^2}{\bar{y}^2} + \frac{s_x^2}{\bar{x}^2} - \frac{2Cov(\bar{y}, \bar{x})}{\bar{y}\bar{x}} \right) \quad (13)$$

The covariance term was assumed to be zero. The total catch for stratum k is estimated as

$$\hat{C}_k = \hat{E}_k \hat{H}_k \quad (14)$$

The variance was estimated using the formula described in Kendall & Stuart (1969).

$$V(\hat{C}_k) = \hat{C}_k^2 \left(\frac{V(\hat{E}_k)}{\hat{E}_k^2} + \frac{V(\hat{H}_k)}{\hat{H}_k^2} + \frac{2Cov(\hat{E}_k, \hat{H}_k)}{\hat{E}_k \hat{H}_k} \right) \quad (15)$$

where the covariance term is assumed to be 0. The total catch was estimated by summing the catch for each strata as follows

$$\hat{C} = \sum_{k=1}^n \hat{C}_k \quad (16)$$

The variance of \hat{C} is estimated as

$$V(\hat{C}) = \sum_{k=1}^n V(\hat{C}_k) \quad (17)$$

The standard error of \hat{C} is estimated by the usual method

$$SE(\hat{C}) = \sqrt{V(\hat{C})} \quad (18)$$

Estimation of the weight of the catch retained by anglers

Total weight (in kg) was estimated by:

1. Calculating the proportion of catch in 2 cm size classes (blue cod: 28 to 48 cm; sea perch: 28 to 46 cm).
2. Allocating the total estimated catch (in numbers) into the relevant size class
3. Converting the length to weight estimates in kg using the length-weight relationships from Table A1).
4. Multiplying the weight by the total estimated catch for that size class.

Table A1. Length (cm) –weight (g) relationships for blue cod and sea perch.

Common name	Scientific name	Equation	Source for equation
Blue cod	<i>ParaperCIAS colias</i>	$W=1.02 \times 10^{-2} L^{3.123}$	Blackwell (1997)
Sea perch	<i>Helicolenus percoides</i>	$W=7.767 \times 10^{-3} L^{3.219}$	Schofield & Livingston (1996)