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EXECUTIVE SUMMARY

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This report describes the results of the 2007 Kaikoura and 2008 Motunau blue cod (*Parapercis colias*) potting surveys off north Canterbury. This is the second set of surveys in the north Canterbury time series following equivalent surveys conducted in 2004−05. There were major changes in the catch rates of blue cod between 2004 and 2007 in Kaikoura. The standardised mean catch rate (kg/pot/h) of all blue cod from all strata combined had almost doubled (91% increase) since the 2004 survey and the overall mean catch rate of legal sized blue cod (30 cm and over) has increased even more dramatically (96%). There were also major changes in the catch rates of blue cod in Motunau between 2005 and 2008 with a 46% decline in catch rates for all blue and a 44% decline for legal sized blue cod.

Kaikoura

In Kaikoura 20 stations were successfully surveyed (6 pots per station = 150 pot lifts) from two inshore strata (contiguous with the coastline) and two offshore strata (Conway Rocks/Bushett Shoal and 100 to 200 m range depth off the Kaikoura Peninsula) around Kaikoura between 3 and 12 December 2007. Of the total 1862 kg of catch, 1784 kg (96%) was blue cod, consisting of 1798 fish. Bycatch included 11 fish and 1 octopus species.

Kaikoura mean catch rates of blue cod (all sizes) ranged from 1.94 kg per pot per hour in stratum 2 (inshore, South Bay to south of Haumuri Bluffs) to 20.45 kg per pot per hour for offshore stratum 4 (100 to 200 m depth range off the Kaikoura Peninsula). Overall mean catch rate and c.v. were 5.00 kg per pot per hour and 8.2%. For blue cod 30 cm and over (minimum legal size), highest catch rates were also in stratum 4 (18.79 kg per pot per hour) and lowest catch rates in stratum 2 (1.16 kg per pot per hour). Overall mean catch rate and c.v. for blue cod 30 cm and over were 4.01 kg per pot per hour and 9.2%. The overall sex ratio was 0.7:1 (male:female), although the two strata with the lowest catches of blue cod were biased in favour of males (1.4:1).

Blue cod from Kaikoura ranged in length from 16 to 55 cm with a single modal peak apparent at about 33 cm when data for all strata are combined. The largest blue cod came from offshore stratum 4 and the smallest from inshore stratum 2. Mean lengths of males averaged about 3 cm more than females from all strata combined, and the largest fish were consistently male. Mean length of both males and females in the offshore stratum 4 was over 8 cm greater than the inshore stratum 2. Overall for all strata the proportion of blue cod of minimum legal size was 71%. Gonad stages indicate that blue cod were not spawning at the time of the survey (December).

The parameters of the length-weight relationship for blue cod from the Kaikoura survey were derived using the model $W = aL^b$, the length-weight parameters are as follows: males – a = 0.00826, b = 3.1875; females – a = 0.00651, b = 3.2632.

Otoliths were prepared and read for 155 males and 117 females from the 2007 Kaikoura survey and an age-length key was used to derive the age frequency distribution of the catch. Overall for all strata combined age ranged from 3 to 24 years with a strong mode from about 4 to 9 years, peaking at 6−7 years. The male age distribution is bimodal with peaks at 4 and 9 years, whereas the female age distribution has a single peak at 4 years. The mean ages were male 6.2 y and female 5.5 y. Total mortality (Z) for Kaikoura blue cod populations was estimated from catch-curve analysis using the Chapman Robson estimator (CR). The combined strata estimates were between 0.31 and 0.37 and these mortality estimates are consistent with those from the 2005 survey.

The substantial increase in catch rates in the offshore areas in 2007 compared to 2004 may be partially explained by a relatively strong cohort in 2004 which recruited to the fishery resulting in overall larger fish and greater catch rates in 2007. However, it is also possible that catchability may have altered between the 2004 and 2007 surveys in areas which are subject to periodic strong currents.

Motunau

In Motunau 15 stations were successfully surveyed (6 pots per station = 120 pot lifts) from three inshore strata contiguous with the coastline around Motunau between 7 and 15 January. Of the total 747 kg of catch, 725 kg (97%) was blue cod, consisting of 1824 fish. Bycatch included 7 fish and 1 octopus species.

Motunau mean catch rates of blue cod (all sizes) ranged from 4.11 kg per pot per hour in stratum 2 (north of Motunau to south of Sail Rock) to 8.86 kg per pot per hour for stratum 1 (south of Motunau to Double Corner). Overall mean catch rate and c.v. were 5.50 kg per pot per hour and 8.8%. For blue cod 30 cm and over (minimum legal size), highest catch rates were also in stratum 1 (4.93 kg per pot per hour) and lowest catch rates in stratum 2 (2.10 kg per pot per hour). Overall mean catch rate and c.v. for blue cod 30 cm and over were 3.33 kg per pot per hour and 15.7%. The overall sex ratio was 3.2:1 (male:female) and the bias toward males was consistent in all strata.

Blue cod from Motunau ranged in length from 16 to 43 cm with a slightly bimodal distribution consisting of a main modal peak apparent at about 27 cm and a smaller peak at about 32 cm when data for all strata are combined. The largest blue cod came from the southern stratum 3 and the smallest from the central stratum 2. Mean lengths of males averaged about 4 cm more than females from all strata combined, and the largest fish were consistently male. Overall for all strata the proportion of blue cod of minimum legal size was 35%. Gonad stages indicate that blue cod were not spawning at the time of the survey (January).

The parameters of the length-weight relationship for blue cod from the Motunau are as follows:
males – a = 0.00419, b = 3.3848; females – a = 0.00246, b = 3.5546.

Otoliths were prepared and read for 152 males and 135 females from the 2008 Motunau survey and an age-length key was used to derive the age frequency distribution of the catch. Overall for all strata combined age ranged from 3 to 12 years with a single mode peaking at 6−7 years. Both the male and female age distributions have a single peak at 6−7 years with the male age distribution tailing further to the right. The mean ages were male 6.1 y and female 5.1 y. Total mortality (Z) for Motunau blue cod populations was estimated for combined strata at between 0.53 and 0.84, which was marginally higher for all age classes in the 2008 survey than it was in the 2005 survey

The substantial decrease in catch rates in all Motunau strata in 2008 compared to 2005 could not be explained by a relatively weak cohort in 2005, and as environmental conditions at Motunau were similar for both surveys it seems unlikely that catchability would have altered dramatically between the two surveys. The relatively high estimates of mortality and the overall 44% decline in catch rates of legal sized blue cod in Motunau since the 2005 potting survey is of concern.

1. INTRODUCTION

In the South Island, blue cod (*Parapercis colias*) is a particularly desirable finfish that is mostly caught by pot or line from small vessels fishing over reef edges on shingle/gravel or sandy bottoms often close to rocky outcrops (Carbines 2003). The 2000 survey of marine recreational fishing found blue cod to be the third most frequently landed finfish species nationally, and the most frequently landed species in the South Island (Boyd & Reilly 2005). Blue cod caught in the South Island East Coast Fisheries Management Area (FMA) BCO 3 account for 46% of all recreational (BCO 3 estimated between 530 and 973 t in Boyd & Reilly (2005)), and 7% of all commercial blue cod landings nationally in 2006–07 (BCO 3: 177 t in Ministry of Fisheries (2008)). Blue cod is also an important species for Maori customary fishers in all areas, but the catch is unknown.

Tagging experiments reveal that most blue cod have a restricted home range (Rapson 1956, Mace & Johnston 1983, Mutch 1983, Carbines & McKenzie 2001, 2004, Carbines 2004a), and that stocks of this species are likely to consist of many largely independent sub populations within each FMA (Carbines 2004a). Due to this philopatric behaviour, blue cod are especially susceptible to localised depletion within an FMA, and managed recreational bag limit strategies differ among local areas within all South Island FMAs in response to local changes in localised fishing pressure (Ministry of Fisheries 2008).

A number of submissions concerning the Review of Sustainability Measures for 2000−01 provided anecdotal evidence of a decline in blue cod populations off north Canterbury leading to a lowering of the blue cod bag limit to 10 per day for the northern area of BCO 3 in November 2000 (from Waimakariri River to Clarence Point). Recreational fishers are also concerned about indications of increasing commercial catch around Kaikoura and the potential displacement of recreational fishing effort following the recent closure of the Marlborough Sounds blue cod fishery. Areas of suitable blue cod habitat off north Canterbury are relatively discrete and recreational catch is reported to be comparatively low (Bradford 1998, Carbines 2000, James & Unwin 2000, Hart & Walker 2004). The two main areas in north Canterbury where blue cod are most commonly targeted are Kaikoura (Figure 1) and Motunau (Figure 2) which are about 60 km apart. Hart & Walker (2004) estimated that the total number of blue cod taken by recreational fishes (from 1 January to 30 April 2003) was 2675 (standard error 4209) from Kaikoura and 4705 (standard error 4085) from Motunau, with corresponding weights of 3130 kg and 3152 kg respectively. Recreational line fishing catch rates of blue cod were 1.3 blue cod per hour in Kaikoura and 4.7 blue cod per hour in Motunau, with significantly smaller fish taken in Motunau (mean 38.0 cm) than in Kaikoura (mean 43.1 cm) (Hart & Walker 2004). Recreational catch rates (per trip) of blue cod decreased markedly from 1996 to 2003 for blue cod in both Kaikoura and Motunau (Hart & Walker 2004).

South Island recreational blue cod stocks are currently monitored using relative abundance indices and population structure generated by standardised fisheries independent potting surveys; this information is used to gauge the effectiveness of the current management regime (Ministry of Fisheries 2008). As well as north Canterbury, the Ministry of Fisheries has initiated a number of potting survey time series in key recreational fisheries locations including Marlborough Sounds (Blackwell 1997, 1998, 2002, 2005, 2008), Banks Peninsula (Beentjes & Carbines 2003, 2006, Beentjes & Carbines unpublished results), North Otago (Carbines & Beentjes 2006b), Paterson Inlet (Stewart Island) (Carbines 2007), and Dusky Sound (Carbines & Beentjes 2003). In the 2000–01 sustainability round the Ministry undertook to work with stakeholders in north Canterbury to monitor blue cod populations. The first north Canterbury potting surveys of blue cod relative abundance and population structure were undertaken off Kaikoura in December 2004 and Motunau in February 2005 (Carbines & Beentjes 2006a). This report describes the results of the second north Canterbury potting surveys in the time series carried out in December 2007 (Kaikoura) and January 2008 (Motunau). The objective was to conduct two separate potting surveys to estimate the age structure and relative abundance of blue cod off Kaikoura and Motunau.

1.1 2004 Kaikoura survey results

The initial standardised potting survey was carried out off Kaikoura between 4 and 16 December 2004 (Carbines & Beentjes 2006a). Twenty-five stations were surveyed (6 pots per station = 150 pot lifts) from two inshore and two offshore strata (see Figure 1). The total blue cod catch was 782 kg, consisting of 1296 fish. During phase 1, 120 pot lifts were completed (80%) with 30 in phase 2. The overall mean catch rate for the survey was 2.62 kg per pot per hour (c.v. 8.1%), but ranged from only 0.60 kg per pot per hour in the inshore stratum 2 south of Kaikoura to 7.97 kg per pot per hour in the offshore Kaikoura Peninsula stratum 4. Overall mean catch rate and c.v. for fish over 30 cm (minimum legal size) were 2.05 kg per pot per hour and 7.5%. Overall catch rate in Kaikoura was higher than the Marlborough Sounds, but lower than most other surveyed areas (Carbines et al. 2008).

In total, 68% of blue cod caught in Kaikoura were of legal size. The inshore stratum 2 south of Kaikoura had the smallest fish, followed by inshore stratum 3 off the Kaikoura Peninsula. Both strata had similar numbers of males and females. Fish from offshore stratum 1 south of Kaikoura were slightly larger, and the sex ratio was heavily biased toward males. This contrasted with the Kaikoura Peninsula offshore stratum 4 where fish were about 5 cm longer on average (especially females), and the sex ratio was biased towards females. The overall sex ratios were even (51% males); however stratum 1 was dominated by males (78%) and stratum 4 by females (78%). Compared to other surveyed areas, blue cod from Kaikoura were most similar in size and age to Dusky Sound and were on average both larger and older than most other surveyed areas except offshore Banks Peninsula (Carbines et al. 2008). Mortality estimates for Kaikoura were low compared to most other survey areas (0.29 to 0.41) (Carbines et al. 2008).

1.2 2005 Motunau survey results

The initial standardised potting survey was carried out off Motunau between 10 and 17 February 2005 (Carbines & Beentjes 2006a). Nineteen stations were surveyed (6 pots per station = 114 pot lifts) from three inshore strata (see Figure 2). The total blue cod catch was 1308 kg, consisting of 3223 fish. The overall mean catch rate for the survey was 10.19 kg per pot per hour, ranging from 8.74 kg per pot per hour in the central stratum 2, to 15.37 kg per pot per hour in the northern stratum 1. Overall mean catch rate and c.v. for fish over 30 cm were 5.97 kg per pot per hour and 9.80%. During phase 1, 90 pot lifts were completed (79%), an additional 24 stations completing phase 2. Although overall catch rates were higher, blue cod from all areas of Motunau were smaller than from Kaikoura and heavily biased towards males. Overall, 36% of blue cod caught in Motunau were of legal size.

The mean catch rates varied between strata, but were consistently higher off Motunau (although fish were smaller) than in the offshore stratum in Kaikoura. The overall catch rate in Motunau was higher than in any other surveyed areas (Carbines et al. in press). However, sex ratios were heavily biased toward males (73%) and average size and age was most similar to the Pelorus or Queen Charlotte Sounds (Carbines et al. in press). Motunau blue cod were smaller and younger than fish recorded in any other surveyed area outside of the Marlborough Sounds and mortality estimates (0.46 to 0.76) were considerably higher than most other areas surveyed (Carbines et al. in press).

2. METHODS

2.1 Timing

Two separate standardised potting surveys off north Canterbury were carried out between December 2007 and January 2008. December-January was chosen as the optimum time to conduct the survey because weather conditions are generally settled off the east coast of the South Island at this time and timing remained consistent with the previous surveys (Carbines & Beentjes 2006a). Kaikoura was surveyed between 3 and 12 December 2007, and Motunau between 7 and 15 January 2008.

2.2 Survey areas

Kaikoura and Motunau were surveyed separately as they are about 60 km apart. The survey areas remained consistent with the previous surveys. The southern and northern boundaries of the two survey areas were based on discussions with local fishers, the Dunedin office of the Ministry of Fisheries, and the Southern Recreational Advisory Committee (Carbines & Beentjes 2006a). Fishers were then given charts of the area and asked to mark discrete locations where blue cod are most commonly caught within the survey areas. From this information, the survey area off Kaikoura was subdivided into three contiguous strata from Kaikoura Peninsula to Haumuri Bluffs (two strata ranged from the coast to 100 m and one stratum from 100 to 200 m depth) and one discrete offshore stratum (Conway Rocks and Bushett Shoal) about 10 km south of Haumuri Bluffs (see Figure 1). Similarly, the survey area off Motunau was divided into three contiguous inshore strata from Double Corner to Sail Rock using the 30 m depth contour as the outer strata boundaries (Figure 2). Each stratum was assumed to contain roughly equal and random distributions of blue cod habitat and the total area (km^2) within each stratum was taken as a proxy measure of available habitat for blue cod.

2.3 Survey design

Both surveys used a two-phase stratified random station design (Francis 1984), adapted to allow for the use of pots (Beentjes & Carbines 2005). Before the survey, a minimum of 10 stations (sampling sites) per stratum was marked on charts as described above, ensuring that they were at least 300 m apart. An equal sampling allocation was used initially between strata and five stations per stratum were randomly selected for phase 1.

In phase 1 at least 75% of the stations were allocated with the remainder available for phase 2. Allocation of phase 2 stations was based on the mean catch rate (kg per pot per hour) of all blue cod per stratum and optimised using the "area mean squared" method of Francis (1984). In this way, stations were assigned iteratively to the stratum in which the expected gain is greatest, where expected gain is given by:

$$expected\ gain_i = area_i^{\,2}\ mean_i^{\,2} / (n_i(n_i+1))$$

where for the ith stratum $mean_i$ is the mean catch rate of blue cod per pot, $area_i$ is the area of the stratum, and n_i is the number of pots. Pots were always allocated in groups of six which equates to one set.

2.4 Vessels and gear

The Kaikoura survey was again conducted from F.V. *Mystique* (registration number 63405), a Kaikoura-based commercial vessel equipped to set and lift rock lobster and blue cod pots and, as in 2004, was skippered by the owner Mr Paul Reinke. The vessel specifications are: 12.5 m length, 4.1 m breadth, 8 t, aluminium monohull, powered by a 450 hp Volvo Penta diesel engine with propeller propulsion.

Due to vessel maintenance, the 2008 Motunau survey was not conducted from F.V. *Navigator* used in the previous survey. However, a similar Motunau-based commercial vessel (F.V. *Legacy,* registration number 64015) equipped to set and lift rock lobster and blue cod pots was used, but was skippered by, Mr Geoff Basher (owner of F.V. *Navigator*). The vessel specifications of F.V. *Legacy* are: 10 m length, 2.9 m breadth, 3 t, aluminium monohull, powered by a 350 hp Yanmar diesel engine with a 274 Hamilton jet unit.

Six custom designed and built cod pots were used to conduct the survey. Pot specifications are: length 1200 mm, width 900 mm, depth 500 mm, synthetic inner mesh, 30 mm diameter; 50 mm cyclone wire outer mesh, entrances 4. Pots were marked with a number from 1 to 6, and baited with paua guts. The same pots and bait were used in all previous South Island blue cod potting survey time series except Marlborough Sounds.

2.5 Sampling methods

At each station, six pots were set sequentially and each left to fish (soak) for 1 h during daylight hours (See Appendices 2 & 7). Soak time was standardised to be consistent with previous South Island potting surveys, including the first north Canterbury surveys. The six pots were set in clusters, separated by about 100 m to avoid pots competing for the same fish. Once on station the position of each of the six pots was determined by the skipper using local knowledge and the vessel sounder to locate a suitable area of foul or biogenic habitat. After each station was completed (six pot lifts) the next closest station in the stratum was fished. While it was not logistically possible to standardise for time of day or tides, each stratum was surveyed throughout the day, collectively giving stations roughly equal exposure to all daily tidal and time regimes. The order that strata were surveyed depended on the prevailing weather conditions, as exposed and periodically current effected offshore strata could be surveyed only during calm conditions.

As each pot was set, a record was made on customised forms of pot number, latitude and longitude from GPS, depth, time of day, and standard trawl survey physical oceanographic data[1], including wind direction, wind force, air temperature, air pressure, cloud cover, sea condition, sea colour, swell height, swell direction, bottom type, bottom contour, sea surface temperature, sea bottom temperature, wind speed, and water visibility (secchi depth).

After 1 h pots were lifted aboard using the vessel's hydraulic pot lifter, emptied, and the contents sorted by species. Total weight per pot was recorded for each species (except for hagfish) to the nearest 10 g using 5 kg Seaway scales. The number of individuals of each species per pot was also recorded. Total length down to the nearest centimetre, sex, and gonad maturity were recorded for all blue cod, and the sagittal otolith removed from a representative size range of males and females, from which weight of each fish was recorded to the nearest 10 g. Sex and maturity were determined by dissection and macroscopic examination of the gonads (Carbines 1998, 2004a). Gonads were recorded as one of five stages as follows: 1, immature or resting; 2, maturing (oocytes visible in females); 3, mature (hyaline oocytes in females, milt expressible in males); 4, running ripe (eggs and milt free flowing); 5,

[1] These are the first north Canterbury blue cod surveys to record physical oceanographic data.

spent. Sagittae otoliths, were removed from a target of up to five fish of each sex per 1-cm size class over the available length range.

2.6 Data analysis

For each stratum and for all strata combined catch rates for all blue cod and for legal sized blue cod (30 cm and over) were estimated as the mean kilograms per pot per hour. Coefficients of variation (c.v.) for each stratum were determined from:

$$cv_i = se_i / mean_i$$

where for the ith stratum se_i is the standard error, and $mean_i$ is the mean catch rate (kg per pot per hour).

The overall weighted mean catch rate for all strata was determined by weighting each stratum mean by the stratum area ($area_i$) divided by the sum of all strata areas ($area_{total}$).

$$mean_{overall} = \sum((mean_i * area_i)/area_{total})$$

The overall weighted mean standard error of the means was determined by squaring each standard error times its weighting, summing them, and then taking the square root.

$$se_{overall} = SQRT\ (\sum(se_i(area_i/area_{total}))^2)$$

The overall coefficient of variation for the survey was then determined from the overall mean and standard errors providing a weighted c.v.

$$cv_{overall} = se_{overall} / mean_{overall}$$

Length frequency for blue cod for each sex is presented by individual stratum and all strata combined. The raw length frequency data were not scaled because the area fished by a pot is unknown. Mean length for each sex was calculated for individual stratum and overall for all strata combined.

For blue cod the length-weight relationship was determined from the linear regression model ln W = b(ln L) + ln a, where W = weight (g), L = length (cm), and a and b are the regression coefficients. Weights of individual blue cod from both surveys that were not weighed were calculated from the length-weight relationship for each sex (see results) derived from individual weights recorded in each survey. Derived individual fish weights were used to determine catch rates of blue cod 30 cm and over (minimum legal size).

2.7 Otolith preparation and reading

Due to the small size of blue cod otoliths, the most precise method for ageing is the thin section technique (Carbines 2004b). Collected otoliths were rinsed with water, air-dried, and stored in paper envelopes. These were later embedded in Araldite polymer resin, baked, and sectioned along the transverse plane with a diamond-tipped cut-off wheel. Sections were then coated with a slide mountant and sanded with 600-grit sandpaper to about 1 mm thickness before viewing. Sections were observed at x40 and x100 magnification under transmitted light with a compound microscope.

Sections exhibit alternating opaque and translucent zones and age estimates are made by counting the number of annuli (opaque zones) from the core to the distal edge of the section, a technique previously validated by Carbines (2004a). Translucent zones are used to define each complete opaque zone, i.e., annuli are counted only if they have a translucent zone on both sides. The readability of each otolith

was also graded from 1 (excellent) to 5 (unreadable). Otoliths were read independently by two experienced readers (G. Carbines & D. Kater). Where counts differed, readers consulted to resolve the final age estimate and otoliths given a grade 5 (unreadable) were removed from the analysis.

2.8 Age composition

Age compositions of Kaikoura and Motunau blue cod populations were estimated separately using the NIWA program Catch-at-age (Bull & Dunn 2002). The program firstly scales the length frequency data to the catch or area of the strata. Secondly, the length-at-age data are converted into an age-length-key comprised of the proportion at age across each length, which is then applied to the scaled length frequency data to give an estimate of relative proportions or numbers at age. The length frequency data were scaled to the total area of the individual strata (km^2) and not the catch weight, which would have resulted in a scaling factor of 1, because we measured every fish. This is consistent with the approach used for catch at age analyses of the first north Canterbury surveys in 2004−05 (Carbines et al. 2008). Length weight coefficients (males and females separately) used in the catch at age analyses were estimated from the length-weight relationship of the blue cod that were individually weighed on these surveys (see Results). Scaled length frequency and age frequency proportions are presented together with coefficients of variation (cv) for each length and age class, and the mean weighted coefficients of variation (MWCV). The cv was calculated using 300 bootstraps.

2.9 Total mortality (*Z*) estimates

Total mortality (*Z*) was estimated from catch-curve analysis using the Chapman Robson estimator (CR) (Chapman & Robson 1960). The catch curve was generated from the scaled to area catch at age data. Details of the methodology are provided in Appendix 1. The CR method has been shown to be less biased than the simple regression catch curve analysis (Dunn et al. 2002). Catch curve analysis assumes that the right hand descending part of the curve declines exponentially and that the slope is equivalent to the total mortality Z ($M + F$). Implicit are the assumptions that recruitment and mortality are constant, that all recruited fish are equally vulnerable to capture, and that there are no age-estimation errors.

We used the method of Dunn et al. (2002) to estimate the variance (95% confidence intervals) associated with Z under three different parameters of recruitment, ageing error, and Z estimate error (Appendix 1). We estimated Z and 95% confidence intervals for each age at full recruitment from 5 to 8 years for both sexes combined for all strata combined.

3. RESULTS

3.1 Kaikoura survey

3.1.1 Stations surveyed

Twenty-five stations (= sets) were surveyed (6 pots per station = 150 pot lifts) from four strata around Kaikoura (Table 1, Figure 1, Appendix 2). Of the 25 stations, 20 were carried out in phase 1 (5 per stratum) with 4 allocated to stratum 2 and 1 to stratum 3 in phase 2. Depth ranged from 4 to 131 m. Environmental data recorded throughout the Kaikoura survey are presented in Appendix 3 and will be analysed as part of a separate study.

3.1.2 Catch

A total of 1186 kg of catch was taken on the Kaikoura survey, of which 1108 kg (93%) was blue cod, consisting of 1798 fish (Table 2). Bycatch included 11 fish and 1 octopus species. The five most common bycatch species by weight were banded wrasse (*Notolabus fucicola*), sea perch (*Helicolenus percoides*), octopus (*Octopus cordiformis*), ling (*Genypterus blacodes*), and scarlet wrasse (*Pseudolabrus miles*).

Mean catch rates of blue cod (all sizes) ranged from 1.94 kg per pot per hour for inshore stratum 2 (southwest of Kaikoura, coast to 100 m) to 20.45 kg per pot per hour for offshore stratum 4 (offshore of Kaikoura Peninsula, 100 to 200 m). Overall mean catch rate and c.v. were 5.00 kg per pot per hour and 8.19% (Table 3). For blue cod 30 cm and over (minimum legal size), highest and lowest catch rates were also in strata 4 and 2, respectively. Overall mean catch rate and c.v. for fish over 30 cm were 4.01 kg per pot per hour and 9.24% (Table 4). The overall mean catch rates are weighted by the strata areas and are considerably smaller than the average of the four strata catch rates due to the strong weighting effect of stratum 2, the largest stratum with relatively low catch rates.

3.1.3 Biological and length frequency data

Of the 1798 blue cod caught on the Kaikoura survey, all were sexed and measured for length, and otoliths were taken from 276 fish and stored. The sex ratio ranged from 0.4:1 (males:females) (stratum 4) to 2.1:1 (stratum 2), and was 0.7:1 overall skewed toward females (Table 5). The size of blue cod ranged from 16 to 34 cm for females and 19 to 43 cm for males, although size varied among strata. The length frequency distributions for strata 2 to 4 were unimodal with stratum 1 showing a bimodal distribution (Figure 3). On average, the largest blue cod were from stratum 4 and the smallest from stratum 2. Mean lengths of males were about 3 cm more than females in all strata and overall mean male length was 34.4 cm and mean female length 31.1 cm (Table 5). Mean length of both males and females in the offshore stratum 4 was over 8 cm greater than the inshore stratum 2. The proportion of legal sized (30 cm and over) blue cod caught on the survey was 71%.

Of 1798 blue cod examined, most were in the maturing and mature phase, but both sexes had gonad stages indicative of the early phase of spawning with 24% of females and 2% of males in the running ripe stage (Table 6). There were no fish with spent gonad stages.

Before calculating the length-weight relationship for Kaikoura blue cod, the data were examined for outliers, but none were found and the analysis included 115 females (range 16–45 cm) and 152 males (range 18–55 cm). Using the derived model $W = aL^b$, the length-weight parameters for Kaikoura are as follows: males – a = 0.00826, b = 3.1875, and $R^2 = 0.99$; females – a = 0.00651, b = 3.2632, and $R^2 = 0.99$.

3.1.4 Ageing (between reader analyses)

From 276 otoliths collected during the survey and sectioned, 4 were rejected as unreadable or damaged, leaving 272 readable otoliths (155 males 18–55 cm, 117 females 16–45 cm). Initial independently derived reader estimates of age class are compared in Appendix 4 and show 62% agreement between the two readers, with reader 2 consistently estimating lower age classes than reader 1. When the differences between age class estimates were resolved by agreement between the readers it was apparent that the more experienced reader 1 was 82% consistent with the agreed age class estimates compared to the less experienced reader 2 who was 65% consistent with the agreed age classes (Appendix 5). The tendency of reader 2 to underestimate the agreed age class worsens with increasing age class beyond 10 years (Figure 4).

3.1.5 Kaikoura age composition

The scaled length frequency and age distributions from the 2007 Kaikoura survey are shown as histograms and as cumulative frequency line plots for males, females, and both sexes combined (Figure 5). The age length key is shown in Appendix 6. Overall, for all four strata combined, age ranges from 3 to 24 years, but most fish (90%) are between 4 and 9 years old. The age distribution is bimodal with the main peak at about 4 years and a smaller peak at 8 years. There is little difference between the male and female age distributions except that the female distribution tends towards unimodal, and the mean age of females is slightly less than that of males (male = 6.2, females = 5.5 years).

3.1.6 Total mortality (*Z*) estimates

Total mortality estimates (*Z*) and 95% confidence intervals for the 2007 Kaikoura survey for all strata combined are given in Table 7, together with estimates from the 2004 survey (Carbines et al. 2008). The combined strata mortality estimates in 2007 were between 0.31 and 0.37. Mortality estimates are similar to those from the 2004 survey (0.29 to 0.43).

3.2 Motunau survey

3.2.1 Stations surveyed

Twenty stations (= sets) were surveyed (6 pots per station = 120 pot lifts) from three inshore strata around Motunau (Table 8, Figure 2, Appendix 7). Of the 20 stations, 15 were carried out in phase 1 (5 per stratum) and 1 allocated to stratum 1, and 4 to stratum 3 in phase 2. Depth ranged from 9 to 35 m, and environmental data recorded throughout the Motunau survey are presented in Appendix 8 and will be analysed as part of a separate study.

3.2.2 Catch

A total of 747 kg of catch was taken on the Motunau survey, of which 725 kg (97%) was blue cod, consisting of 1824 fish (Table 9). Bycatch included seven fish species and one octopus species. The three most common bycatch species by weight were conger eel (*Conger verreauxi*), octopus (*Octopus cordiformis*), and scarlet wrasse (*Pseudolabrus miles*).

Mean catch rates of blue cod (all sizes) ranged from 4.11 kg per pot per hour for stratum 2 (off and north of Motunau), to 8.86 kg per pot per hour for stratum 1 (north of Motunau off Sail Rock). Overall mean catch rate and c.v. were 5.50 kg per pot per hour and 8.79% (Table 10). For blue cod 30 cm and over (minimum legal size), highest and lowest catch rates were also in strata 1 and 2, respectively. Overall mean catch rate and c.v. for fish over 30 cm were 3.33 kg per pot per hour and 15.65% (Table 11).

3.2.3 Biological and length frequency data

Of the 1824 blue cod caught on the Motunau survey, all were sexed and measured for length, and otoliths were taken from 258 fish and stored. The sex ratio ranged from 2.5:1 (males:females) (stratum 1) to 4.1:1 (strata 2 & 3), and was 3.2:1 overall (Table 12). Length frequency distributions for all three strata were essentially unimodal, but with only slight size variations among the strata (Figure 6). Largest blue cod were from stratum 3 and smallest from stratum 2. Males were longer than females in all strata; overall mean male length was 29.4 cm and mean female length 25.3 cm (Table 12). The proportion of legal size (30 cm and over) blue cod caught on the survey was 35%.

Of 1824 blue cod examined, 99% of males and 98% of females had maturing stage gonads (Table 13). There were no fish with running ripe gonads and only 0.1% of males and no females had spent gonad stages.

Before calculating the length-weight relationship for Motunau blue cod, the data were examined for outliers, but none were found and the analysis included 76 females (range 16–32 cm) and 110 males (range 21–40 cm). Using the derived model $W = aL^b$, the length-weight parameters for Motunau are as follows: males – a = 0.00419, b = 3.3848, and $R^2 = 0.97$; females – a = 0.00246, b = 3.5546, and $R^2 = 0.93$.

3.2.4 Ageing (between reader analyses)

From 258 otolith collected during the survey and sectioned, 2 were rejected as unreadable or damaged, leaving 256 readable otoliths (163 males 19–42 cm, 93 females 16–32 cm). Initial independently derived reader estimates of age class are compared in Appendix 9 and show 73% agreement between the two readers. When the differences between age class estimates were resolved by agreement between the readers it was apparent that the more experienced reader 1 was 93% consistent with the agreed age class estimates compared to the less experienced reader 2 who was 80% consistent with the agreed age classes (Appendix 10). There is a slight tendency of reader 2 to under estimate the agreed age class for fish over 10 years (Figure 7).

3.2.5 Age composition

The scaled length frequency and age distributions from the 2008 Motunau survey are shown as histograms and as cumulative frequency line plots for males, females, and both sexes combined (Figure 8). The age length key is shown in Appendix 11. Overall, for all strata combined, age ranges from 3 to 12 years with a single modal peak at about 6 years. Most fish (99%) are between 3 and 11 years old. There is little difference between the male and female age distributions except that mean age of females is slightly less than that of males (male = 6.1, females = 5.1 years).

3.2.6 Total mortality (*Z*) estimates

Total mortality estimates (*Z*) and 95% confidence intervals for the 2008 Motunau survey for all strata combined are given in Table 14, together with estimates from the 2005 survey (Carbines et al. 2008). The combined strata estimates in 2008 were between 0.53 and 0.84. Mortality estimates are slightly higher than those from the 2005 survey (0.46 to 0.76).

4. DISCUSSION

The 2007–08 north Canterbury potting surveys provide the second indices in the time series of relative abundance and population structure of blue cod from Kaikoura and Motunau. Survey sampling methods and strata were identical to those in the 2004–05 surveys and results are directly comparable.

4.1 Kaikoura survey

There were major changes in the catch rates of blue cod between 2004 and 2007 in Kaikoura. The overall standardised mean catch rate (kg/pot/h) of all blue cod from all strata combined had almost doubled (91% increase) since the 2004 survey (Figure 9). However, this increase in catch rate was not consistent among all strata with increases of 223% in stratum 2, 157% in stratum 4, 31% in stratum 3, and a decrease of 23% in stratum 1 (Figure 9). The changes in standardised mean catch rate of legal sized blue cod (30 cm and over) have been even more dramatic, with increases of 96% overall (364% in stratum 2, 149% in stratum 4, 39% in stratum 3, and a decrease of 41% in the southern stratum 1) (Figure 9). However, the decrease in catch rates of blue cod in stratum 1 has not altered the rankings of mean catch rates by strata since the 2004 survey with strata 3 and 4 off the Kaikoura Peninsula still supporting the highest catch rates, followed by the southern stratum 1 and the inshore stratum 2 (Figure 9). The proportion of blue cod that were of legal size was also slightly higher in the 2007 survey (71%) than in the 2004 survey (68%).

The substantial increase in catch rates in the offshore areas in 2007 compared to 2004 may be partially explained by reference to the area scaled length and age distributions (see Figures 5 & 10). In 2004 both the length and age distributions were narrower with strong modes at about 27 cm total length and 5 to 6 years of age (Figure 10). By contrast, in 2007 the length frequency distribution is more skewed to the right and the age distribution shows a higher proportion of older fish (see Figure 5). These findings suggest that a relatively strong cohort in 2004 may have recruited to the fishery resulting in overall larger fish and greater catch rates in 2007. However, cumulative length and age frequency distributions comparing the size and ages for each survey indicate that there is very little difference in the shapes of the distributions between surveys (Figure 11). It is also possible that catchability may have altered between the 2004 and 2007 surveys in areas which are subject to periodic strong currents. While potting is not conducted during times of strong current flow, in the 2004 survey fishing was suspended for several days due to a strong current event following a southerly flow (Carbines & Beentjes 2006a). No strong current events suspended fishing during the 2007 survey and it is possible that during the 2004 survey catchability was reduced after the easing of the currents in off shore strata. Future surveys will record water current strength and direction during pot sets which may help to allow for possible changes in catchability.

Generally the raw unscaled length frequency distributions and average size of blue cod, both overall and by stratum, were remarkably consistent between the 2004 and 2007 surveys. However, the overall sex ratio in 2004 was 1:1 in contrast to the 2007 survey where the sex ratio was 0.7:1 overall skewed toward females, although the two strata with the lowest catches of blue cod were biased in favour of males (1.4:1).

The length frequency distributions and average size differ between scaled and unscaled data (see Figures 3 and 5). To a large extent this is because stratum 2 is 4 to 10 times larger than the other strata and stratum 2 also has the smallest blue cod; hence scaling by area results in a larger proportion of smaller fish and a smaller mean size. Furthermore, as in 2004 there were few fish caught in stratum 2 the c.v.s are also higher than desirable (see Figure 10). Scaling by area assumes that the size of each stratum is directly proportional to the amount of blue cod habitat; however, this is probably not the case given the discrete nature of areas of foul and biogenic habitat. We emphasise that the age distributions and total mortality estimates are based on scaled length data, and had we scaled to catch weight and not to stratum area we would have produced different results. With improving seabed

habitat mapping, in future it may be possible to scale catch data to more detailed estimates of the actual areas of suitable blue cod habitat within each stratum.

Total mortality is similar between the 2004 and 2007 surveys, although slightly less in 2008 (see Table 7) reflecting the greater number of large fish in the catches off the Kaikoura Peninsula in 2007. By comparison with adjacent survey areas, mortality in Kaikoura is considerably less than that in Motunau (see Tables 7 and 14), Marlborough Sounds, and inshore Banks Peninsula, but greater than that from offshore Banks Peninsula (Carbines et al. 2008).

Blue cod generally spawn from spring to mid summer (Carbines 1998, 2004a). Observations of gonad stages in 2007 were relatively similar to the 2004 survey in Kaikoura, but with a higher proportion of more developed stages with most blue cod in the maturing and mature phase. In 2007 many females had gonad stages indicative of spawning with 24% of females and 2% of males in the running ripe stage. There were no fish with spent gonad stages indicating that the timing of the survey (December) was before the peak spawning period which appeared to be later in 2007 than it had been in 2004.

4.2 Motunau survey

There were major changes in the catch rates of blue cod between 2005 and 2008 with a decline in catch rates of similar magnitude for all three strata (Figure 12). However, the rankings of mean strata catch rates for both all and legal sized blue cod were unchanged. The standardised mean catch rate of all blue cod declined 42% in stratum 1, 53% in stratum 2, 45% in stratum 3, and 46% overall since the 2005 Motunau survey (Figure 12). The decline in the standardised mean catch rate of legal sized blue cod has been slightly less dramatic overall (44%) and in the two northern strata (34% in stratum 1, 35% in stratum 2), but there has been a more dramatic decline in legal sized blue cod in the southern stratum 3 (49%) (Figure 12). Environmental conditions at Motunau were similar for both surveys, although water visibility was slightly improved in the 2008 survey.

Overall the strata raw length frequency distributions and average size of blue cod in 2008 were remarkably consistent with the results from the 2005 survey as was the proportion of legal size (30 cm and over) blue cod caught (36% in 2005 and 35% in 2008). Similarly, there were no major differences in area scaled length and age frequency distributions or average size between 2008 and 2005 (see Figures 8 and 13) to indicate that recruitment had been poor in recent years. Cumulative length and age frequency distributions, comparing the size and ages for each survey, confirm that there is very little difference in the shapes of the distributions between surveys (Figure 14). There does not appear to be same difference between scaled and unscaled length data as for Kaikoura because of the more uniform size of fish among the three Motunau strata (see comment in Section 4.1 on scaling to strata area).

Total mortality was marginally higher for all age classes in the 2008 survey than it was in the 2005 survey (see Table 14). By comparison with adjacent survey areas, mortality is considerably greater than that for Kaikoura (see Tables 7 and 14), and offshore Banks Peninsula; but similar to that in Marlborough Sounds and inshore Banks Peninsula (Carbines et al. 2008).

Observations of gonad stages were similar to the 2005 survey in Motunau; 99% of males and 98% of females had early maturing stage gonads, indicating that these blue cod were not spawning at the time of the survey (January). Virtually all fish had only the earliest stages of gonad development and there were almost no mature, running ripe, or spent gonads suggesting that spawning had concluded at the time of the survey.

4.3 Comparison of blue cod from Motunau and Kaikoura

Although Motunau and Kaikoura are only about 60 km apart there are distinct and consistent differences between the blue cod populations from these areas. As observed in recreational fishing surveys (Hart & Walker 2004) and in the previous 2004−05 north Canterbury potting surveys (Carbines & Beentjes 2006a), blue cod from Motunau were considerably smaller than those caught in Kaikoura (by about 5 cm on average overall), but have much higher catch rates than Kaikoura. Blue cod from Motunau were also heavily biased towards males by about 3 to 1 in both surveys (see Table 12) compared to Kaikoura where it was closer to 1 to 1 (see Table 5). Mortality is also greater in Motunau reflecting the more restricted size and age range.

4.4 Catchability

With any fishing method there is potential selectivity bias so that size and species composition from potting may differ from that of other methods such as trawling (Furevik 1994) or line fishing (Blackwell 2002, 2005, Carbines 1999). While bait type and soak time are standardised in all blue cod potting surveys, other factors such as inter- and intra-species interactions, fish behaviour, pot interference, and features of the environment can also be important in passive capture methods such as potting (Whitelaw et al. 1991, Furevik 1994, Fogarty & Addison 1997, Robichaud et al. 2000). Cole et al. (2001) found blue cod catch rates unrelated to both time and tide in the Marlborough Sounds, but there may be potential for tide to affect the selectivity of potting in some areas (Warren et al. 1997). Future surveys will measure actual current flow and may potentially be used together with other environmental variables to standardise catch rates. Pots appear to be selective for blue cod over 15 cm (see Figures 3 and 6) (Cole et al. 2001, 2003, Carbines 2004a) and under-sample small blue cod compared to diver transects (Cole et al. 2001, 2003). At a localised scale, Cole et al. (2001) found a positive but weak relationship between blue cod catch from pots and diver transects. However, Beentjes & Carbines (2005) considered potting to be a suitable method at the larger spatial scale of a potting survey. Large variations in standardised catch rates were recorded in both the Kaikoura and Motunau potting survey time series. We use changes in catch rates as a proxy for changes in relative abundance of blue cod in these survey areas. However, in the absence of direct observations of blue cod abundance and environmental variables during concurrent potting surveys, we can not rule out or allow for variations in catchability as a determinant in changes in relative abundance.

4.5 Recreational fishing effort

Estimates of recreational catch per unit effort off Kaikoura in 1996 and 2003 indicated a trend of declining numbers of legal sized blue cod caught per trip from 1996 to 2003 (Bradford 1998, Hart & Walker 2004). However, substantial increases in standardised catch rates from potting surveys have occurred in most areas of the Kaikoura survey between 2004 and 2007, with the notable exception of the least accessible southern off shore stratum 1 (over 30 km south of Kaikoura) where standardised catch rates have declined markedly (41% decline in legal size blue cod) since 2004. The 1996 and 2003 recreational fishing surveys lack sufficient spatial detail to allow comparison of fishing effort among the Kaikoura or Motunau potting survey strata (Hart & Walker 2004). However, an earlier and more spatially detailed recreational survey off Kaikoura (Carbines 2000) showed that most of recreational fishing effort in the Kaikoura area occurred in the most accessible inshore stratum 2 which has recorded a 364% increase in standardised catch rates of legal sized blue cod since 2004. However, the mean length of both males and females in the less accessible offshore stratum 4 was over 8 cm more than in the more heavily fished inshore stratum 2.

The 1996 and 2003 recreational fishing surveys (Bradford 1998, Hart & Walker 2004) showed a 73% reduction in the catch numbers of blue cod per trip (34.7 to 9.1 fish) and a significant decline in mean length of blue cod indicating a general decline in blue cod populations at Motunau over this time. While no reduction in the size of blue cod was recorded in the 2008 Motunau potting survey, the overall 44% decline in catch rates of legal sized blue cod since the 2005 potting survey is of concern.

The substantial decline in catch rates in the Motunau survey was in contrast to the observations of the survey vessel skipper who is of the view that blue cod catch rates have improved since the 2005 Motunau survey.

The smaller mean size overall of Motunau fish and the skewed sex ratio in favour of males compared to Kaikoura is not proportional to fishing pressure since 71% (4049 hours) of the estimated recreational fishing effort for north Canterbury is in Kaikoura compared to 29% (1576 hours) in Motunau (Hart & Walker 2004), However, these areas may have different productivities which have contributed to the differences in relative abundance between these areas. The recent closure of the Marlborough Sounds to blue cod fishing may result in displacement of fishing effort to nearby areas such as north Canterbury and hence ongoing monitoring is recommended, including recreational fishing catch effort surveys.

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6. REFERENCES

Beentjes, M.P.; Carbines, G.D. (2003). Abundance of blue cod off Banks Peninsula in 2002. *New Zealand Fisheries Assessment Report 2003/16*. 25 p.

Beentjes, M.P.; Carbines, G. (2005). Population structure and relative abundance of blue cod (*Parapercis colias*) off Banks Peninsula and in Dusky Sound, New Zealand. *New Zealand Journal of Marine and Freshwater Research 39*: 77 − 90.

Beentjes, M.P.; Carbines, G. (2006). Abundance of blue cod off Banks Peninsula in 2005. *New Zealand Fisheries Assessment Report 2006/01*. 24 p.

Beentjes, M.P.; Carbines, G.D. (2009). Abundance, size and age composition, and mortality of blue cod off Banks Peninsula in 2008. *New Zealand Fisheries Assessment Report 2009/25*. 46 p.

Blackwell, R.G. (1997). Abundance, size composition, and sex ratio of blue cod in the Marlborough Sounds, September 1995. *NIWA Technical Report 88*. 52 p.

Blackwell, R.G. (1998). Abundance, size and age composition, and yield-per-recruit of blue cod in the Marlborough Sounds, September 1996. *NIWA Technical Report 30*. 47 p.

Blackwell, R.G. (2002). Abundance, size and age composition of recruited blue cod in the Marlborough Sounds, September 2001. Final Research Report for Ministry of Fisheries Project BCO2001/01. (Unpublished report held by Ministry of Fisheries, Wellington.)

Blackwell, R.G. (2005). Abundance and size composition of recruited blue cod in the Marlborough Sounds, September 2004. Final Research Report for Ministry of Fisheries Research Project BCO2004/01. 18 p. (Unpublished report held by Ministry of Fisheries, Wellington.)

Blackwell, R.G. (2008). Abundance and size composition of recruited blue cod in the Marlborough Sounds, September 2007. Final Research Report for Ministry of Fisheries Research Project BCO2006/01 24 p. (Unpublished report held by Ministry of Fisheries, Wellington.)

Boyd, R.O.; Reilly, J.L. (2005). 1999/2000 National marine recreational fishing survey: harvest estimates. Final Research Report for Ministry of Fisheries Research Project REC9803. (Unpublished report held by Ministry of Fisheries, Wellington.)

Bradford, E. (1998). Harvest estimates from the 1996 national marine recreational fishing surveys. New Zealand Fisheries Assessment Research Document 98/16. 27 p. (Unpublished report held in NIWA library, Wellington.)

Bull, B.; Dunn, A. (2002). Catch-at-age: User Manual v1.06.2002/09/12. NIWA Internal Report 114. 23 p. (Unpublished report held in NIWA Library, Wellington.)

Carbines, G. (1998). Blue cod age validation, tagging feasibility and sex inversion. Final Research Report for Ministry of Fisheries Project SOBCO4. 74 p. (Unpublished report held by Ministry of Fisheries, Wellington.)

Carbines, G.D. (1999). Large hooks reduce catch-and-release mortality of blue cod *Parapercis colias* in the Marlborough Sounds of New Zealand. *North American Journal of Fisheries Management 19*: 992–998.

Carbines, G.D. (2000). Kaikoura recreational fishing survey (1989/99). Final Research Report for Ministry of Fisheries Project REC9808. (Unpublished report held by Ministry of Fisheries, Wellington.)

Carbines, G**.** (2003). Blue cod. Chapter 23 (pp 182−185). In: Andrew, N.; Francis, M. (eds) 2003. The living reef. The ecology of New Zealand's rocky reefs. Craig Potton Publishing, Nelson. 283 p.

Carbines, G. (2004a). Age, growth, movement and reproductive biology of blue cod (*Parapercis colias*–Pinguipedidae): Implications for fisheries management in the South Island of New Zealand. Unpublished Ph.D. thesis, University of Otago, Dunedin, New Zealand. 224 p.

Carbines, G. (2004b). Age determination, validation, and growth of blue cod, *Parapercis colias*, in Foveaux Strait, New Zealand. *New Zealand Journal of Marine and Freshwater Research 38*: 201−214.

Carbines, G.D. (2007). Relative abundance, size, and age structure of blue cod in Paterson Inlet (BCO 5), November 2006. *New Zealand Fisheries Assessment Report 2007/37. 31* p.

Carbines, G.; Beentjes, M.P. (2003). Relative abundance of blue cod in Dusky Sound in 2002. *New Zealand Fisheries Assessment Report 2003/37*. 25 p.

Carbines, G.; Beentjes, M.P. (2006a). Abundance of blue cod in north Canterbury in 2004 and 2005. *New Zealand Fisheries Assessment Report 2006/30*. 26 p.

Carbines, G.; Beentjes, M.P. (2006b). Abundance of blue cod in north Otago in 2005. *New Zealand Fisheries Assessment Report 2006/29.* 20 p.

Carbines, G.D.; Dunn, A.; Walsh, C. (2008). Age composition and derived estimates of total mortality for blue cod taken in South Island potting surveys, 2002–2005. *New Zealand Fisheries Assessment Report 2008/68.*. 74 p.

Carbines, G.; McKenzie, J. (2001). Movement patterns and stock mixing of blue cod in Southland (BCO 5). Final Research Report for Ministry of Fisheries Project BCO9702. 16 p. (Unpublished report held by Ministry of Fisheries, Wellington.)

Carbines, G.; McKenzie, J. (2004). Movement patterns of blue cod in Dusky Sound in 2002. *New Zealand Fisheries Assessment Report 2004/36*. 13 p.

Chapman, D.G.; Robson, D.S. (1960). The analysis of a catch curve. *Biometrics 16*: 354–368.

Cole, R.G.; Alcock, N.K. Hadley, S.L; Grange, K.R.; Black, S.; Cairney, D.; Day, J: Ford, S.; Jerret, A.R. (2003). Selective capture of blue cod *Parapercis colias* by potting: behavioral observations and effects of capture method on peri-mortem fatigue. *Fisheries Research 60*: 381–392.

Cole, R.G.: Tindale, D.S.; Blackwell, R.G. (2001). A comparison of diver and pot sampling for blue cod (*Parapercis colias*: Pinguipedidae). *Fisheries Research 52*: 191–201.

Dunn, A.; Francis, R.I.C.C.; Doonan, I.J. (2002). Comparison of the Chapman-Robson and regression estimators of Z from catch-curve data when non-sampling stochastic error is present. *Fisheries Research 59*: 149–159.

Fogarty, M.J.; Addison, J.T. (1997). Modelling capture processes in individual traps: entry, escapement and soak time. *ICES Journal of Marine Science 54*: 193–205.

Francis, R.I.C.C. (1984). An adaptive strategy for stratified random trawl surveys. *New Zealand Journal of Marine and Freshwater Research 18*: 59–71.

Furevik, D. (1994). Behaviour of fish in relation to pots. In: Ferno, A.; Olsen, S. (eds) Marine fish behaviour in capture and abundance estimation. Fishing News Books, United States. pp 28−44.

Hart, A.M; Walker, N.A. (2004). Monitoring the recreational blue cod and sea perch fishery in the Kaikoura - North Canterbury area. *New Zealand Fisheries Assessment Report 2004/45*. 30 p.

James, G.D.; Unwin, M.J. (2000). National marine diary survey of recreational fishing from charter vessels, 1997–98. *NIWA Technical Report 70*. 51 p.

Mace, J.T.; Johnston, A.D. (1983). Tagging experiments on blue cod (*Parapercis colias*) in the Marlborough Sounds, New Zealand. *New Zealand Journal of Marine and Freshwater Research 17*: 207–211.

Ministry of Fisheries. (2008). Report from the Fishery Assessment Plenary, May 2008: stock assessments and yield estimates. Ministry of Fisheries. 990 p. (Unpublished report held in NIWA library, Wellington).

Mutch, P.G. (1983). Factors influencing the density and distribution of the blue cod (*Parapercis colias*) (Pisces: Mugilodae). Unpublished MSc thesis, University of Auckland, New Zealand. 76 p.

Myers, R.A.; Bridson, J.; Barrowman, N.J. (1995). Summary of worldwide spawner and recruitment data. *Canadian Technical Report of Fisheries and Aquatic Sciences 2024*. 327 p.

Rapson, A.M. (1956). Biology of the blue cod (*Parapercis colias* Forster) of New Zealand. Unpublished PhD thesis, Victoria University, Wellington, New Zealand. 103 p.

Ricker, W.E. (1975). Computation and interpretation of biological statistics of fish populations. *Canadian Bulletin of Fisheries Research 191*: 29–73.

Robichaud, D; Hunte, W.; Chapman, M.R. (2000). Factors affecting the catchability of reef fishes in antillean fish traps. *Bulletin of Marine Science 67(2)*: 831–844.

Warren, E.; Grindley, R.; Carbines, G.; Teirney, L. (1997). Characterisation of the Southland blue cod fishery (1991–1996). 38 p. (Unpublished report held by Ministry of Fisheries, Dunedin.)

Whitelaw, A.W; Sainsbury, K.J; Dews, G.J; Campbell, R.A. (1991). Catching characteristics of four fish-trap types on the North West Shelf of Australia. *Australian Journal of Marine and Freshwater Research 42*: 369–382.

Table 1: Kaikoura 2007 stratum coastline area, number of phase 1 and 2 stations, pot lifts, and depth.

Stratum	Area of strata (km^2)	Number of sets		Number of pot lifts	Depth (m)	
		Phase 1	Phase 2		Mean	Range
1	9.6	5		30	35	23–55
2	96.0	5	4	54	18	4–38
3	24.8	5	1	36	72	20–98
4	15.7	5		30	114	59–131
Total	139.43	20	5	150	54	4–131

Table 2: Catch weights, numbers of blue cod, bycatch species, and percentage of total weight on the 2007 Kaikoura survey. *Estimated weight using average weight of 0.4 kg for hagfish (the mean of 12 weighed hag fish from Dusky Sound survey (Carbines & Beentjes 2003)).

Common name	Scientific name	Catch (kg)	Number	Percent of total catch
Blue cod	*Parapercis colias*	1108.1	1798	93.4
Banded wrasse	*Notolabrus fucicola*	25.4	64	2.1
Sea perch	*Helicolenus percoides*	18.5	35	1.6
Octopus	*Octopus cordiformis*	8.1	3	0.7
Ling	*Genypterus blacodes*	6.9	1	0.6
Scarlet wrasse	*Pseudolabrus miles*	6.1	21	0.5
Spotty	*Notolabrus celidotus*	4.4	27	0.4
Girdled wrasse	*Notolabrus cinctus*	3.5	21	0.3
Maori chief	*Notothenia angustata*	1.9	1	0.2
Hagfish	*Eptatretus cirrhatus**	1.6	4	0.1
Southern bastard cod	*Pseudophysis barbata*	1.0	1	0.1
Southern pigfish	*Congiopodus leucopaecilus*	0.3	1	<0.1
Blue moki	*Latridopsis ciliars*	0.2	1	<0.1
Total		1186	1978	

Table 3: Kaikoura 2007 mean blue cod catch rate, standard error, and c.v. per stratum and overall for all blue cod.

Stratum	Pot lifts (N)	Mean (kg/lift)	s.e.	c.v. (%)
1	30	4.07	0.83	20.30
2	54	1.94	0.42	21.79
3	36	7.44	1.05	14.12
4	30	20.45	2.20	10.74
Overall	150	5.00	0.41	8.19

Table 4: Kaikoura 2007 mean blue cod catch rate, standard error, and c.v. per stratum and overall for blue cod 30 cm and over (legal sized).

Stratum	Pot lifts (N)	Mean (kg/lift)	s.e.	c.v. (%)
1	30	3.00	0.67	22.46
2	54	1.16	0.34	29.48
3	36	6.06	0.99	16.26
4	30	18.79	2.22	11.81
Overall	150	4.01	0.37	9.24

Table 5: Kaikoura 2007 mean lengths of blue cod by strata and sex

Strata	Sex	N	Mean length (cm)
1	m	138	33.0
	f	74	27.5
2	m	173	29.8
	f	81	24.2
3	m	201	34.7
	f	228	30.5
4	m	235	38.2
	f	668	32.5
Overall	m	747	34.4
	f	1051	31.1

Table 6: Kaikoura 2007 gonad stages of blue cod. 1, immature or resting; 2, maturing (oocytes visible in females); 3, mature (hyaline oocytes in females, milt expressible in males); 4, running ripe (eggs and milt free flowing); 5, spent.

	Gonad stage (%)					
	1	2	3	4	5	N
Males	7.9	64.5	26.0	1.6	0.0	747
Females	2.8	44.7	28.4	24.1	0.0	1051

Table 7: Total mortality estimates (*Z*) and 95% confidence intervals of blue cod from the 2004 and 2007, Kaikoura potting surveys using Chapman Robson method described in Appendix 1.

				Low		Medium		High	
Area (year)	AgeR	*Z*	cv	Lower	Upper	Lower	Upper	Lower	Upper
Kaikoura 2004	5	0.41	0.34	0.28	0.56	0.27	0.59	0.25	0.63
	6	0.43	0.34	0.31	0.57	0.30	0.59	0.27	0.64
	7	0.37	0.34	0.26	0.50	0.26	0.51	0.24	0.54
	8	0.29	0.34	0.22	0.38	0.21	0.39	0.19	0.42
Kaikoura 2007	5	0.32	0.27	0.24	0.42	0.23	0.43	0.20	0.48
	6	0.31	0.27	0.24	0.40	0.23	0.41	0.20	0.45
	7	0.36	0.27	0.27	0.47	0.26	0.48	0.24	0.53
	8	0.37	0.27	0.27	0.47	0.26	0.48	0.25	0.51

Table 8: Motunau 2008 stratum coastline length, number of phase 1 and 2 stations, pot lifts, and depth.

	Area of strata	Number of sets		Number of	Depth (m)	
Stratum	(km^2)	Phase 1	Phase 2	pot lifts	Mean	Range
1	41.3	5	1	36	26	19–35
2	66.9	5		30	21	13–30
3	176.1	5	4	54	19	9–29
Total	284.3	15	5	120	22	9–35

Table 9: Catch weights, numbers of blue cod, bycatch species, and percentage of total weight on the 2008 Motunau survey.

Common name	Scientific name	Catch (kg)	Number	Percent of total catch
Blue cod	*Parapercis colias*	724.9	1824	97.0
Conger eel	*Conger verreauxi*	8.0	2	1.1
Octopus	*Octopus cordiformis*	4.0	1	0.5
Scarlet wrasse	*Pseudolabrus miles*	3.0	12	0.4
Red cod	*Pseudophycis bachus*	2.8	1	0.4
Girdled wrasse	*Notolabrus cinctus*	2.2	11	0.3
Spotty	*Notolabrus celidotus*	1.1	11	0.1
Leatherjacket	*Parika scaber*	0.5	2	0.1
Tarakihi	*Nemadactylus macropterus*	0.5	3	0.1
Total		747	1867	

Table 10: Motunau 2008 mean blue cod catch rate, standard error, and c.v. per strata and overall for all blue cod.

Stratum	Pot lifts (N)	Mean (kg/lift)	s.e.	c.v. (%)
1	36	8.86	0.96	10.83
2	30	4.11	0.61	14.84
3	54	5.24	0.71	13.56
Overall	114	5.50	0.48	8.79

Table 11: Motunau 2008 mean blue cod catch rate, standard error, and c.v. per strata and overall for blue cod 30 cm and over (legal sized).

Stratum	Pot lifts (N)	Mean (kg/lift)	s.e.	c.v. (%)
1	42	4.93	0.96	19.47
2	30	2.10	0.61	29.03
3	42	3.42	0.78	22.69
Overall	114	3.33	0.52	15.65

Table 12: Motunau 2008 mean lengths of blue cod by strata and sex.

Strata	Sex	N	Mean length (cm)
1	m	592	29.1
	f	241	25.1
2	m	265	28.9
	f	65	26.1
3	m	532	30.0
	f	129	25.3
Overall	m	1389	29.4
	f	435	25.3

Table 13: Motunau 2008 gonad stages of blue cod. 1, immature or resting; 2, maturing (oocytes visible in females); 3, mature (hyaline oocytes in females, milt expressible in males); 4, running ripe (eggs and milt free flowing); 5, spent.

	Gonad stage (%)					
	1	2	3	4	5	N
Males	0.6	99.2	0.1	0.0	0.1	1389

Females	1.1	98.4	0.5	0.0	0.0	435			

Table 14: Total mortality estimates (*Z*) and 95% confidence intervals of blue cod from the 2005 and 2008 Motunau potting surveys using Chapman Robson method described in Appendix 1.

				Low		Medium		High	
Area (year)	AgeR	*Z*	cv	Lower	Upper	Lower	Upper	Lower	Upper
Motunau 2005	5	0.46	0.27	0.32	0.62	0.31	0.64	0.28	0.71
	6	0.60	0.27	0.42	0.80	0.40	0.84	0.38	0.91
	7	0.67	0.27	0.46	0.92	0.45	0.93	0.42	0.95
	8	0.76	0.27	0.52	1.05	0.51	1.06	0.50	1.11
Motunau 2008	5	0.53	0.18	0.39	0.70	0.37	0.73	0.34	0.78
	6	0.63	0.18	0.46	0.82	0.44	0.85	0.41	0.89
	7	0.71	0.18	0.52	0.93	0.51	0.94	0.48	0.99
	8	0.84	0.18	0.62	1.07	0.61	1.09	0.58	1.10

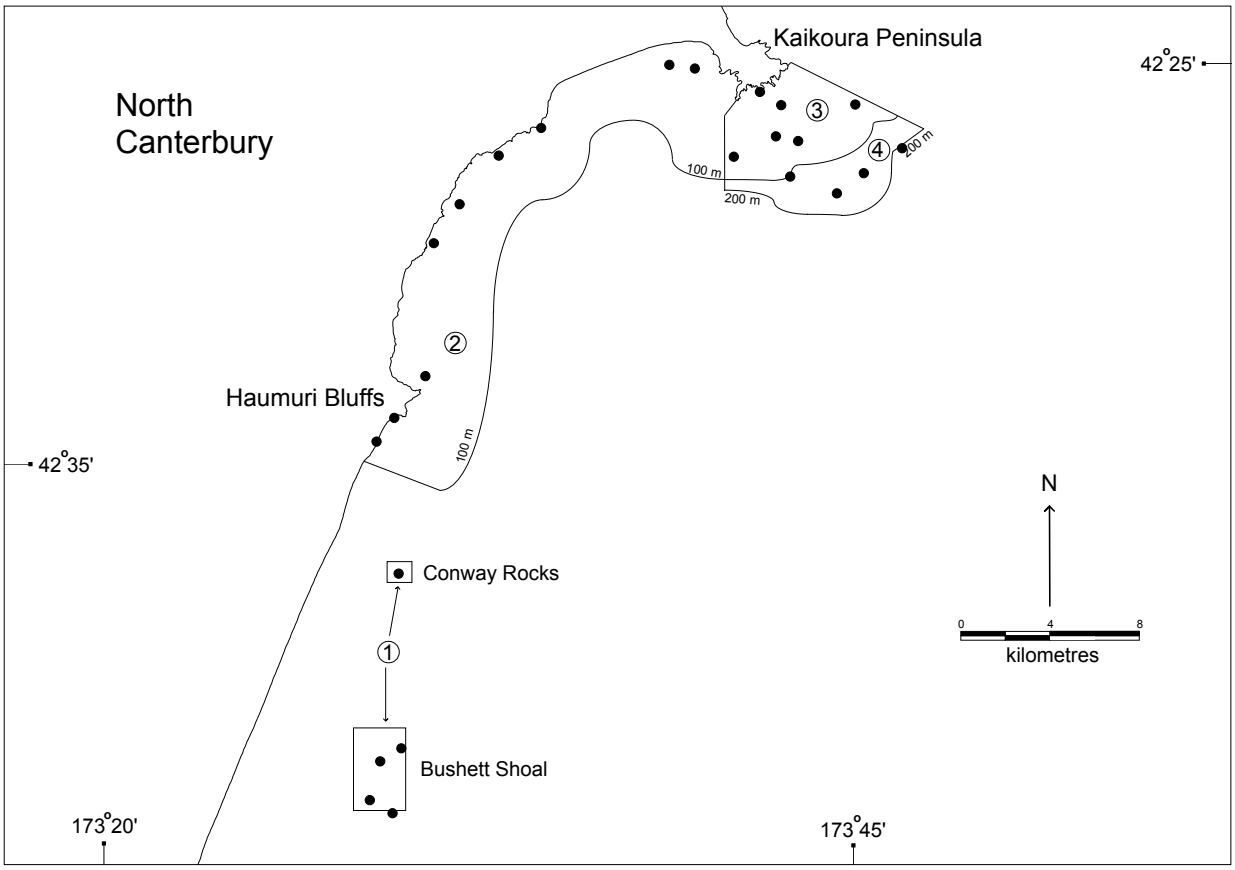

Figure 1: Map of north Canterbury coast and Kaikoura Peninsula showing strata (1–4) and stations for the 2007 Kaikoura survey.

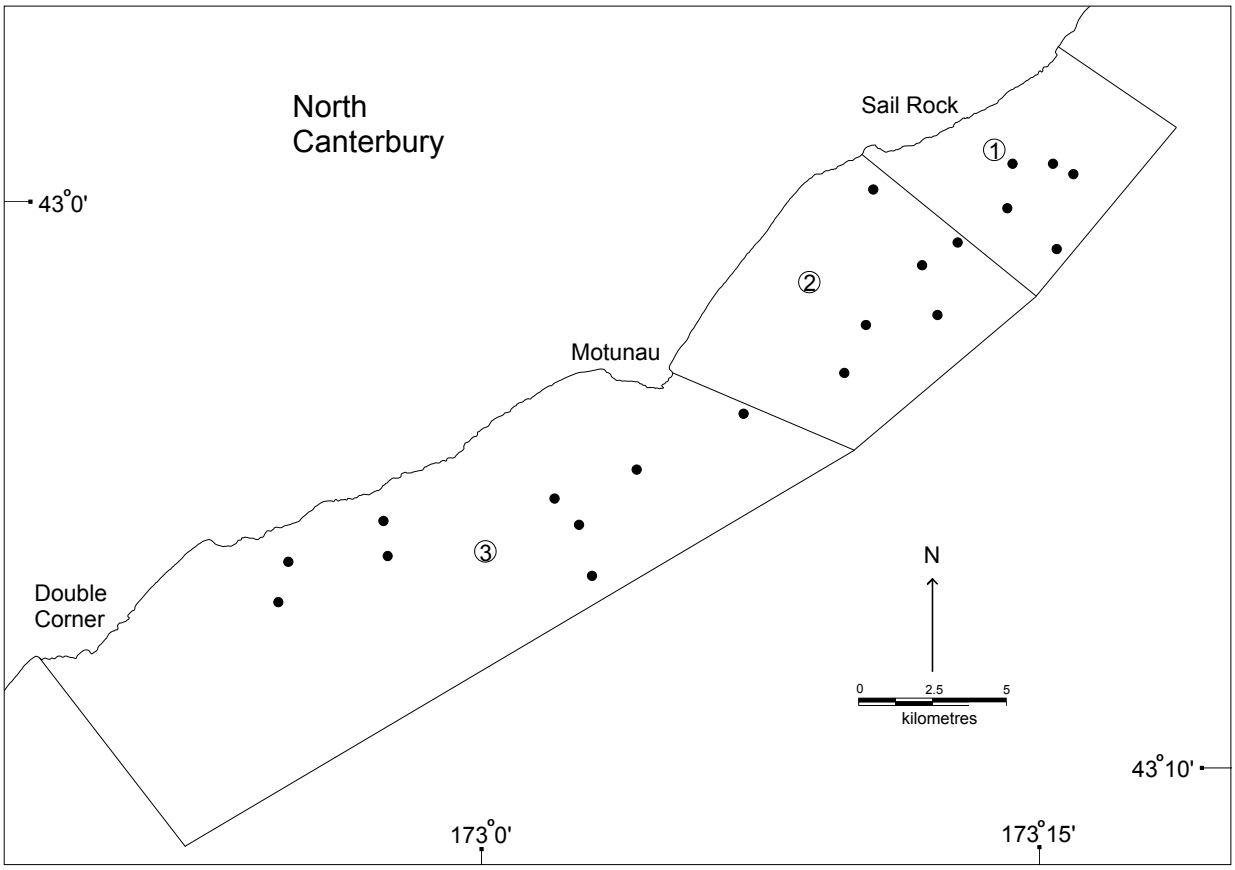

Figure 2: Map of north Canterbury coast around Motunau showing strata (1–3) and stations for the 2008 Motunau survey.

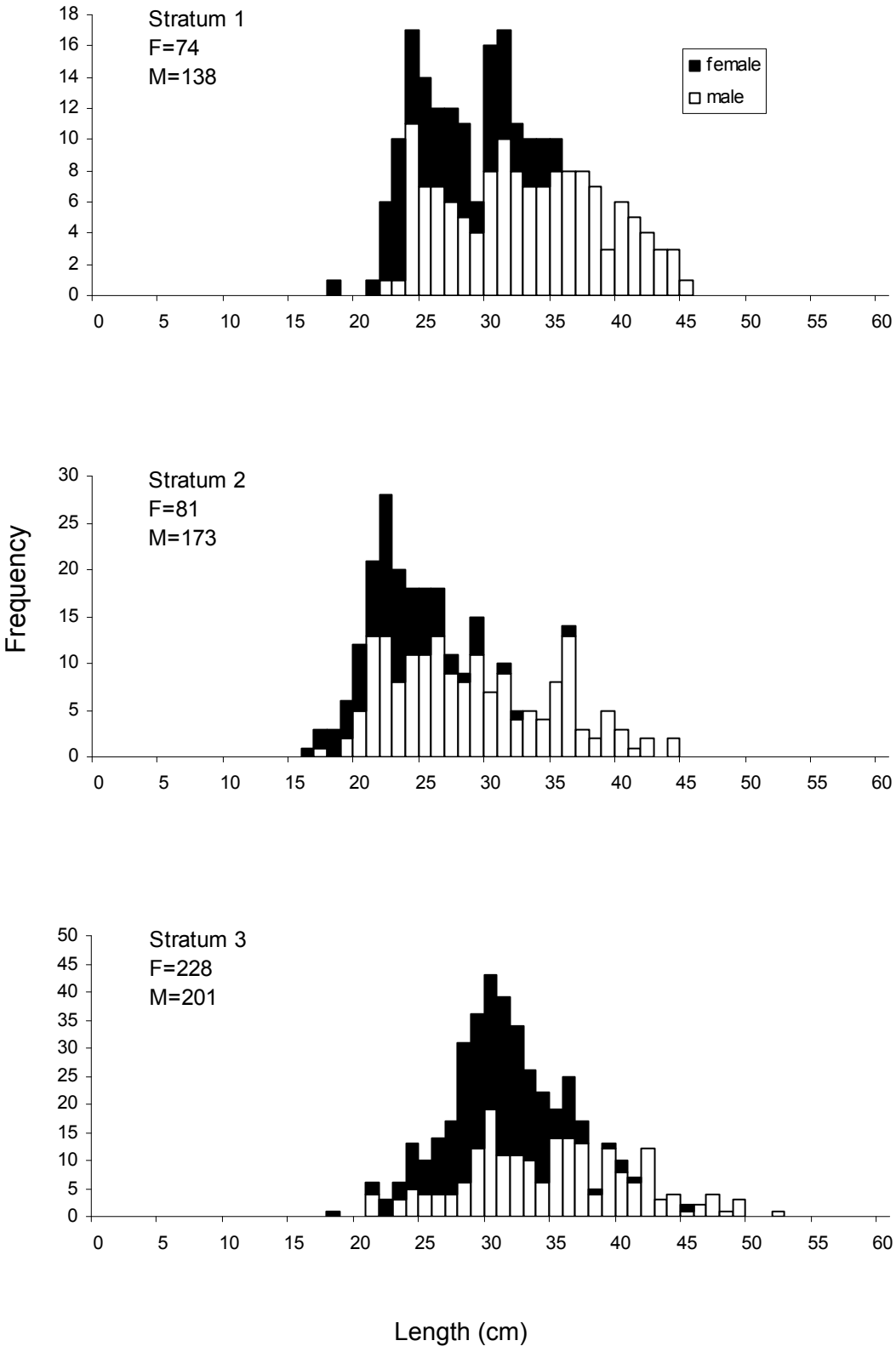

Figure 3: Unscaled length frequency distributions of blue cod for each stratum (1–4) and all strata combined for the Kaikoura 2007 survey.

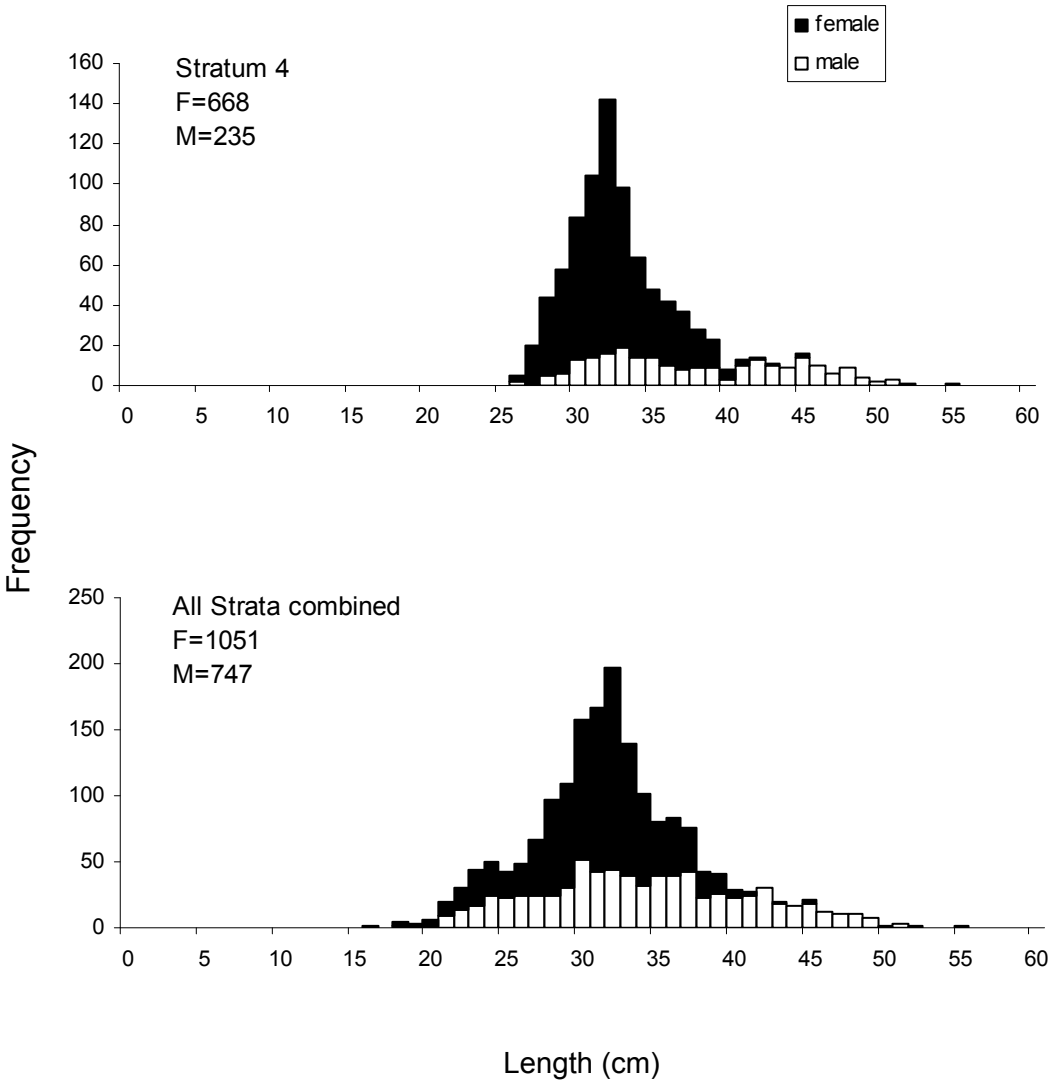

Figure 3 – ***continued***

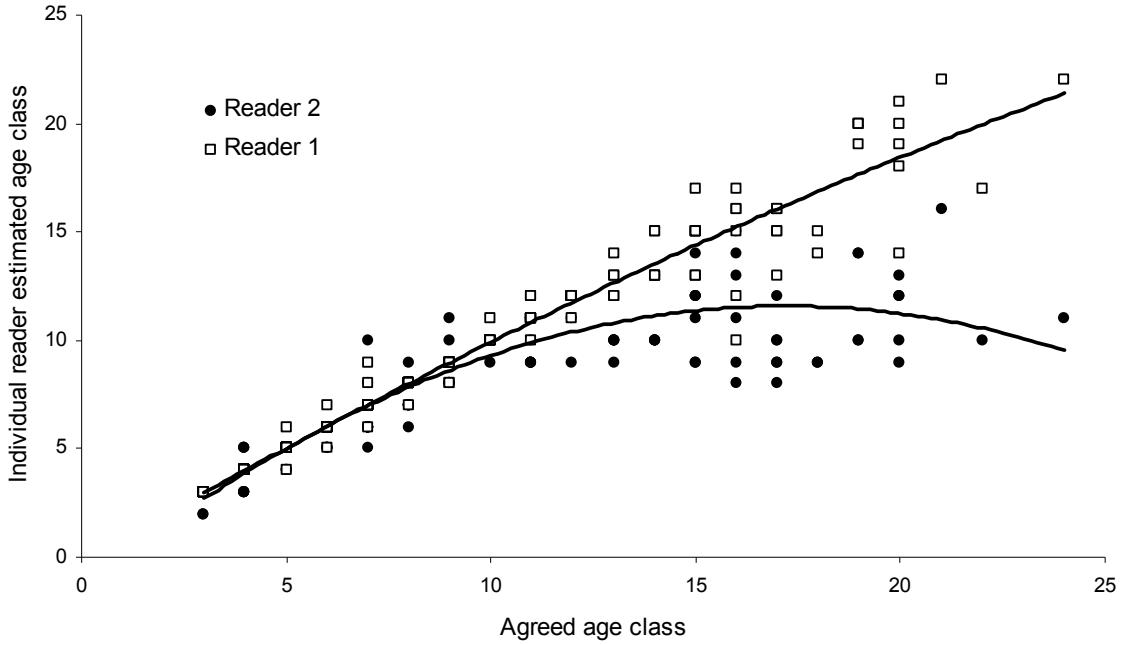

Figure 4: Kaikoura survey comparison of individual reader age class estimates from otoliths plotted against the agreed age class estimates (n = 272). Polynomial trend lines are fitted to the individual age class estimates of each reader.

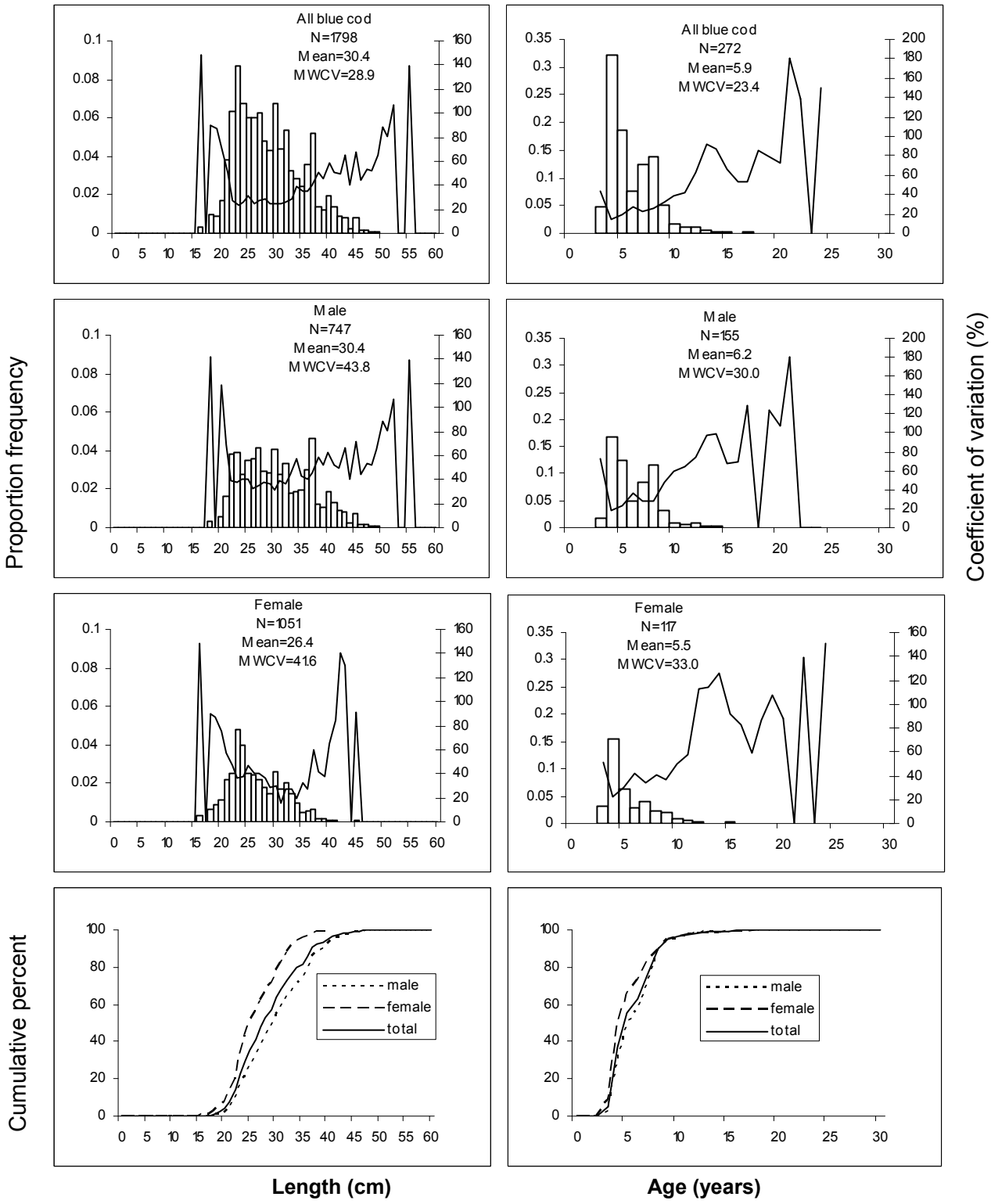

Figure 5: Scaled length frequency, age frequency, and cumulative distributions for total, male, and female blue cod for all strata (1–4) combined for the 2007 Kaikoura survey. N, sample size; MWCV, mean weighted coefficient of variation.

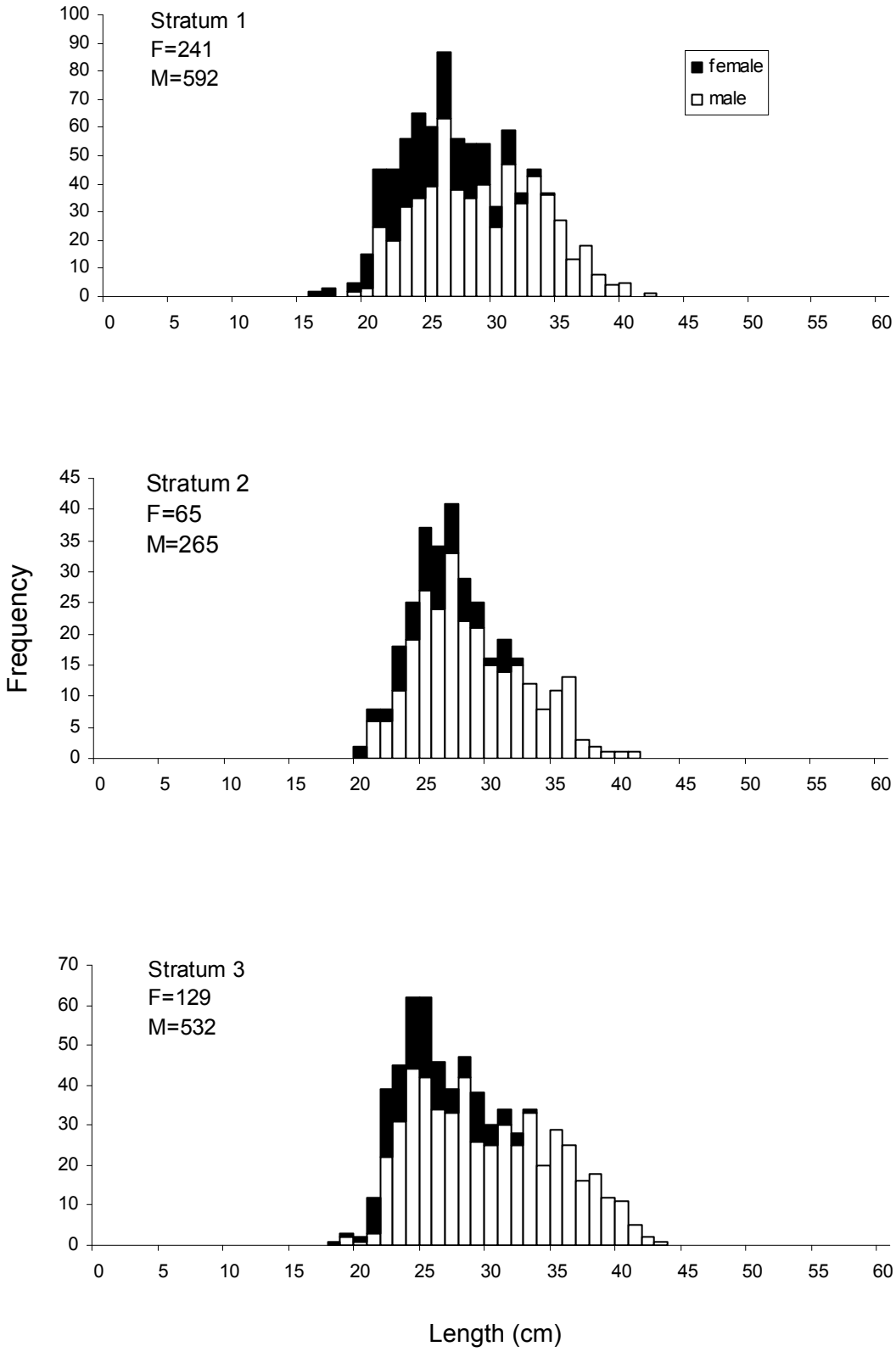

Figure 6: Unscaled length frequency distributions of blue cod for each stratum (1–3) and all strata combined for the Motunau 2008 survey.

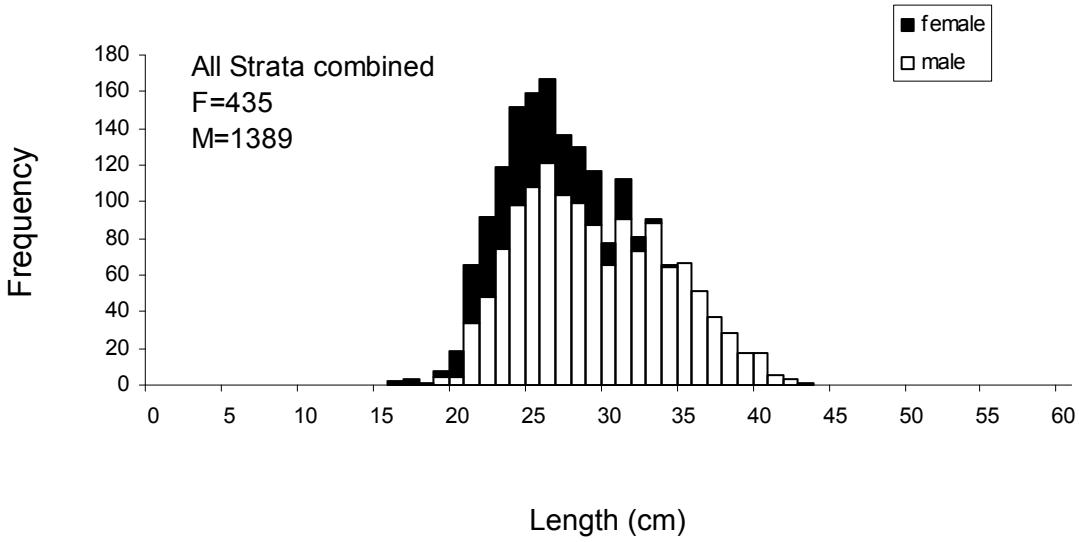

Figure 6 – ***continued***

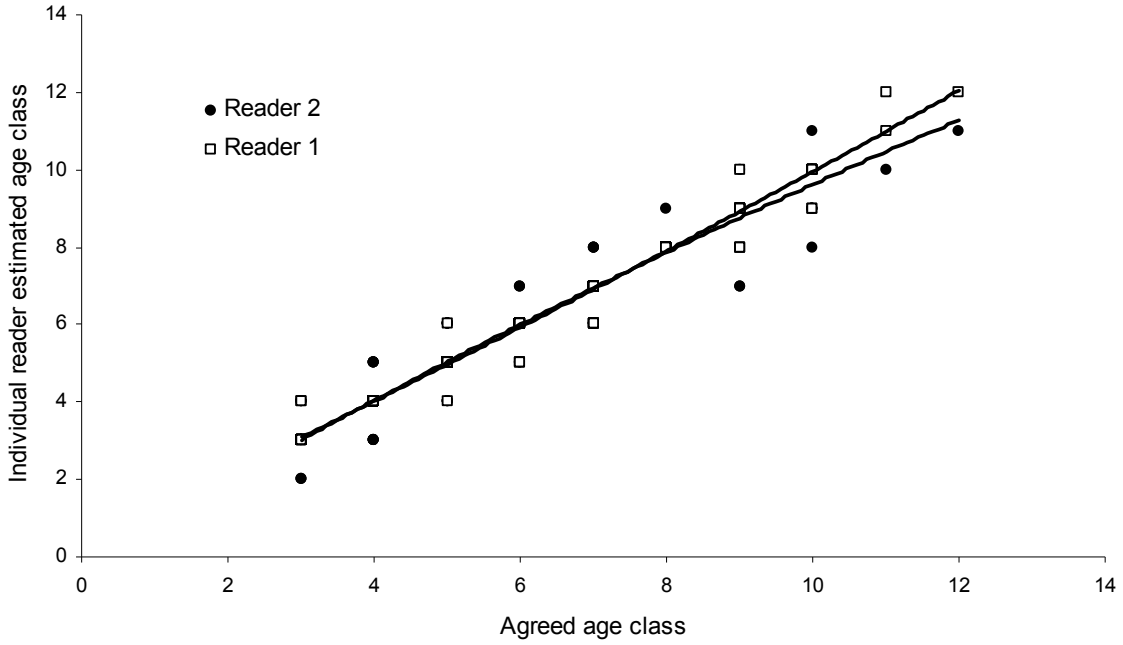

Figure 7: Motunau survey comparison of individual reader age class estimates from otoliths plotted against the agreed age class estimates (N = 256). Polynomial trend lines are fitted to the individual age class estimates of each reader.

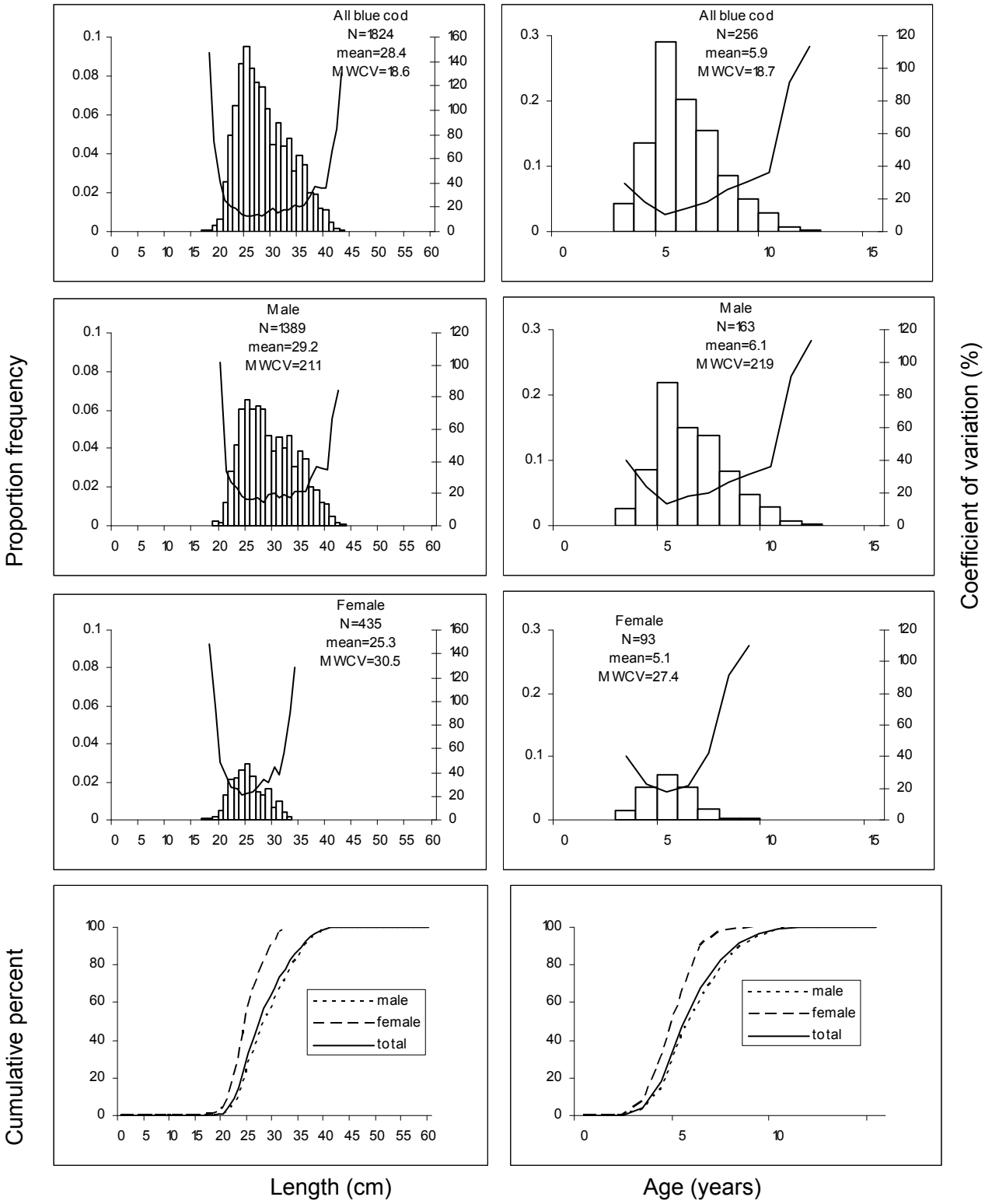

Figure 8: Scaled length frequency, age frequency, and cumulative distributions for total, male, and female blue cod for all strata (1–3) combined for the 2008 Motunau survey. N, sample size; MWCV, mean weighted coefficient of variation.

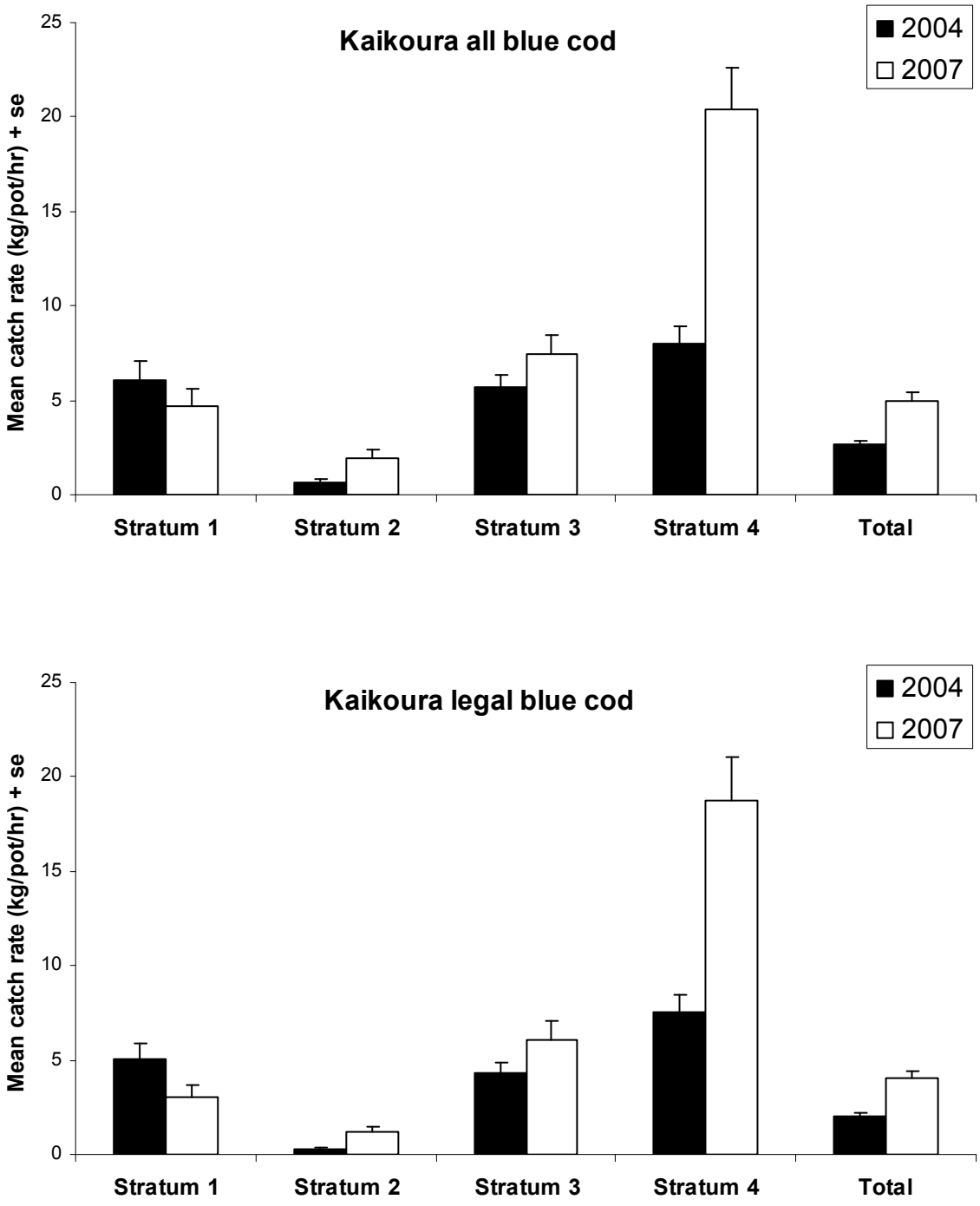

Figure 9: Between survey comparisons of mean standardised catch rates (kg/pot/hour) by stratum (1–4) and overall for all and legal sized (30 cm and over) blue cod caught in the 2004 and 2007 Kaikoura potting surveys. Error bars are the standard error of the mean and the total is the overall weighted (by strata area) mean.

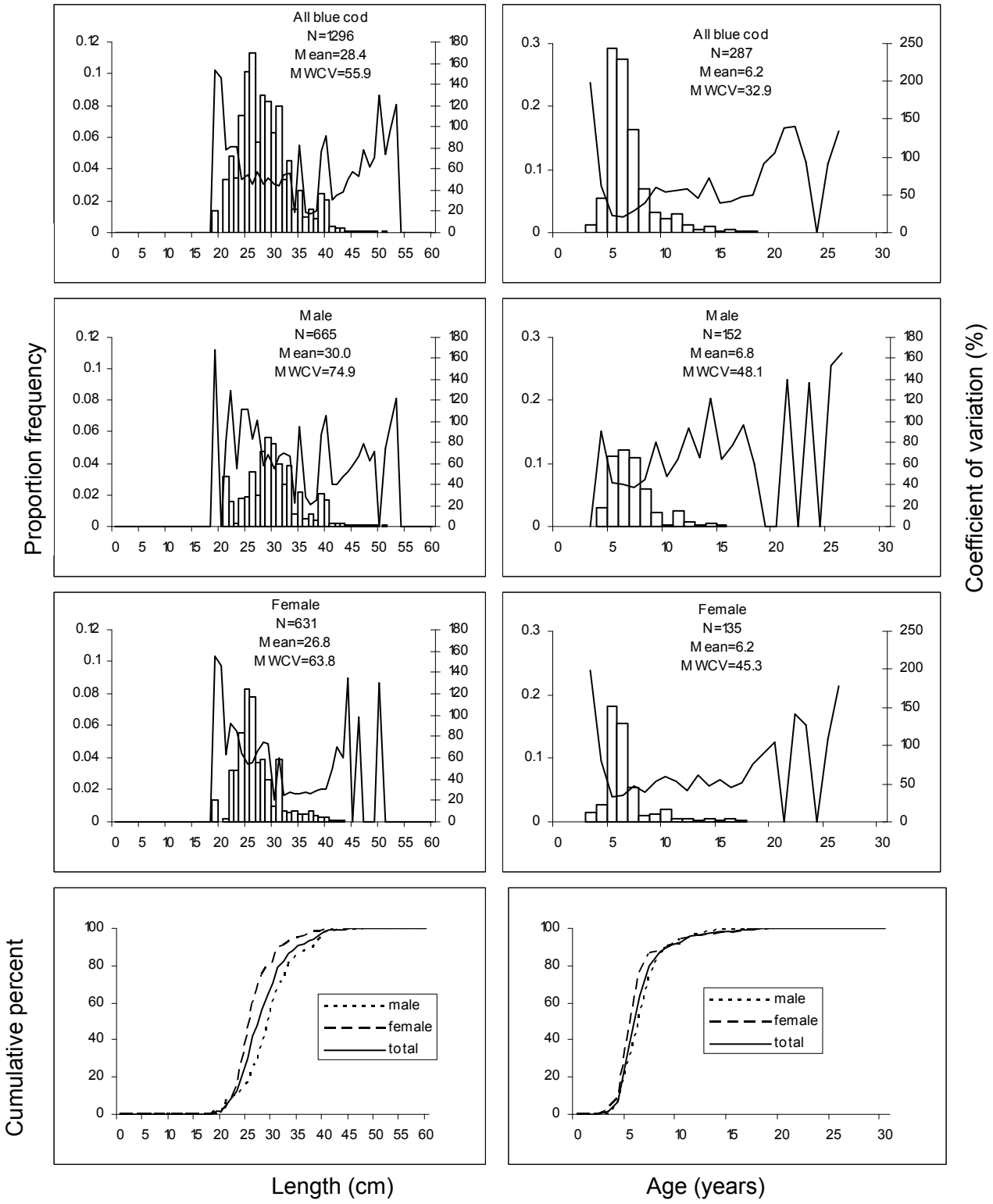

Figure 10: Scaled length frequency, age frequency, and cumulative distributions for total, male, and female blue cod for all strata (1–4) combined for the 2004 Kaikoura survey. N, sample size; MWCV, mean weighted coefficient of variation. See Carbines et al. (2008) for details.

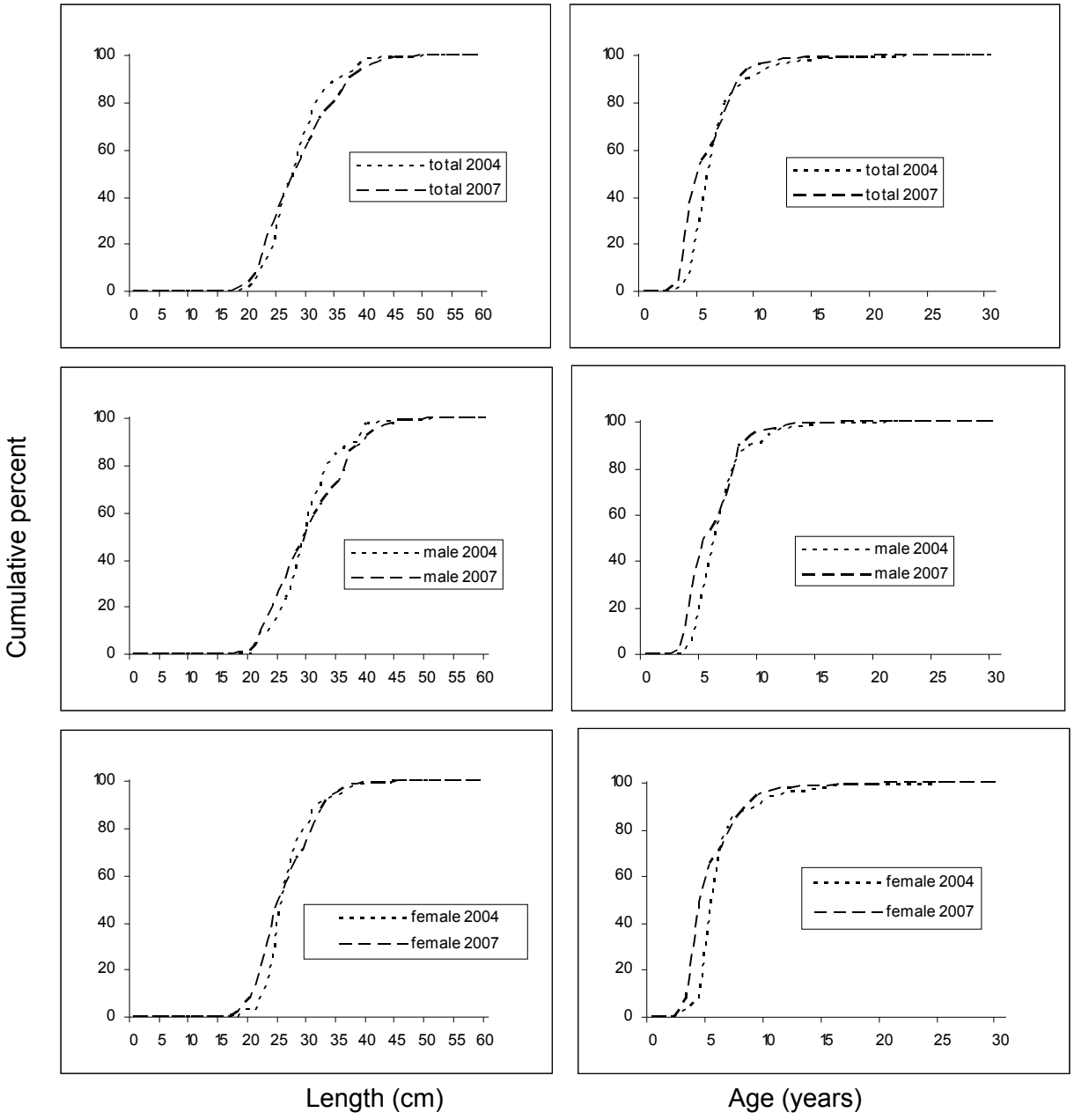

Figure 11: Scaled length and age cumulative frequency distributions for total, male, and female blue cod for the 2004 and 2007 Kaikoura surveys.

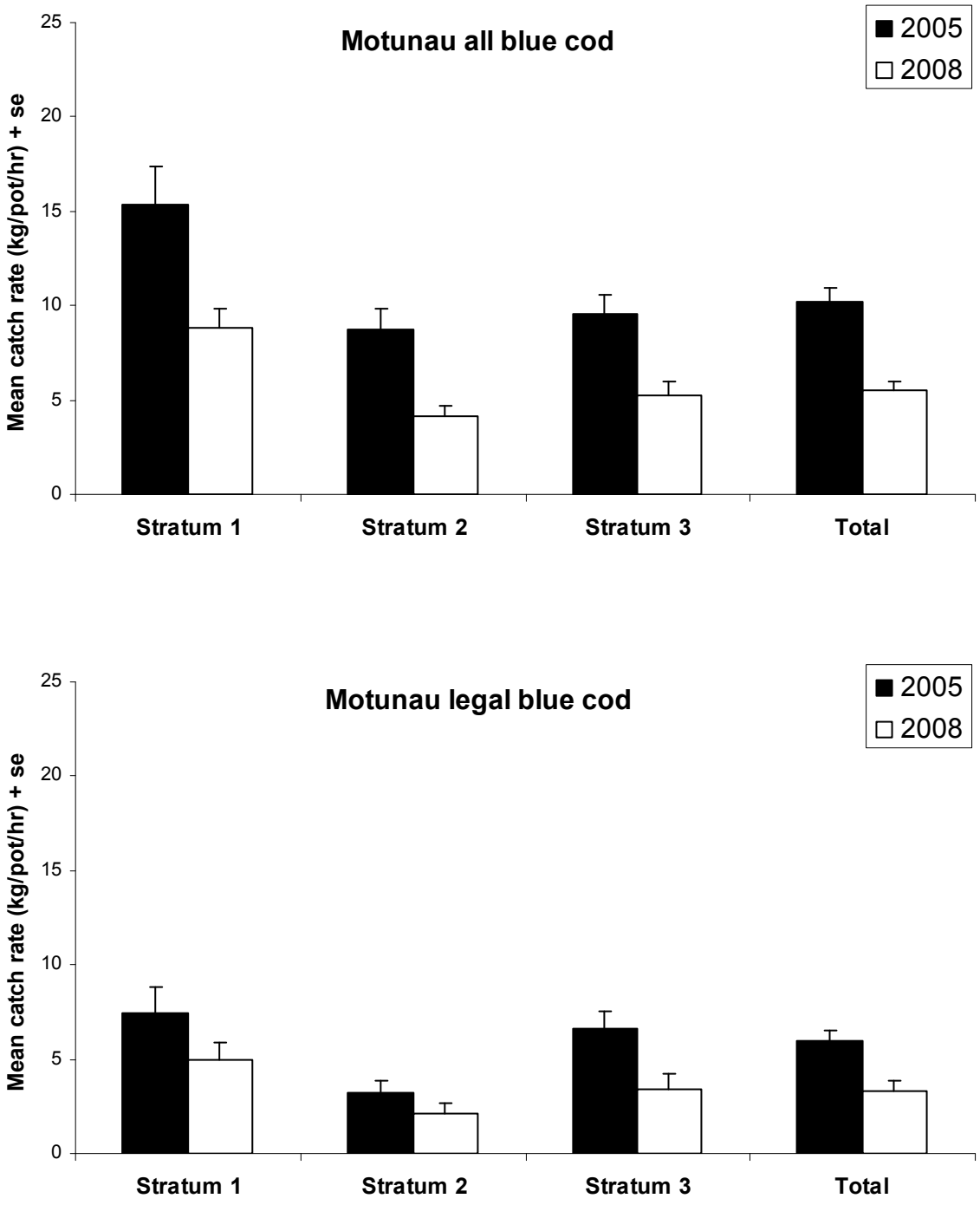

Figure 12: Between survey comparisons of mean standardised catch rates (kg/pot/hour) by stratum (1–3) and overall for all and legal sized (30 cm and over) blue cod caught in the 2005 and 2008 Motunau potting surveys. Error bars are the standard error of the mean and the total is the overall weighted (by strata area) mean.

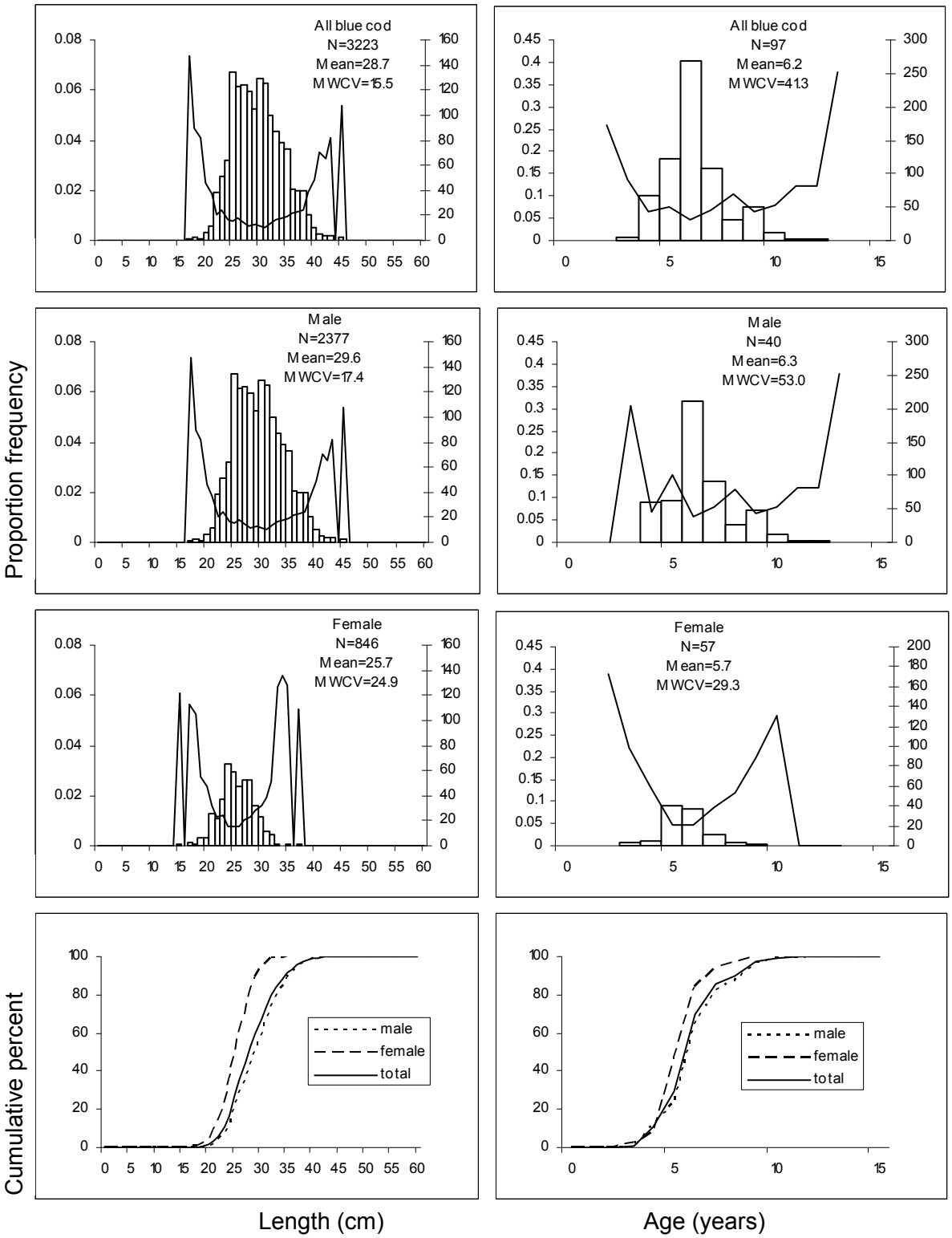

Figure 13: Scaled length frequency, age frequency, and cumulative distributions for total, male, and female blue cod for all strata (1–3) combined for the 2005 Motunau survey. N, sample size; MWCV, mean weighted coefficient of variation. See Carbines et al. (2008) for details.

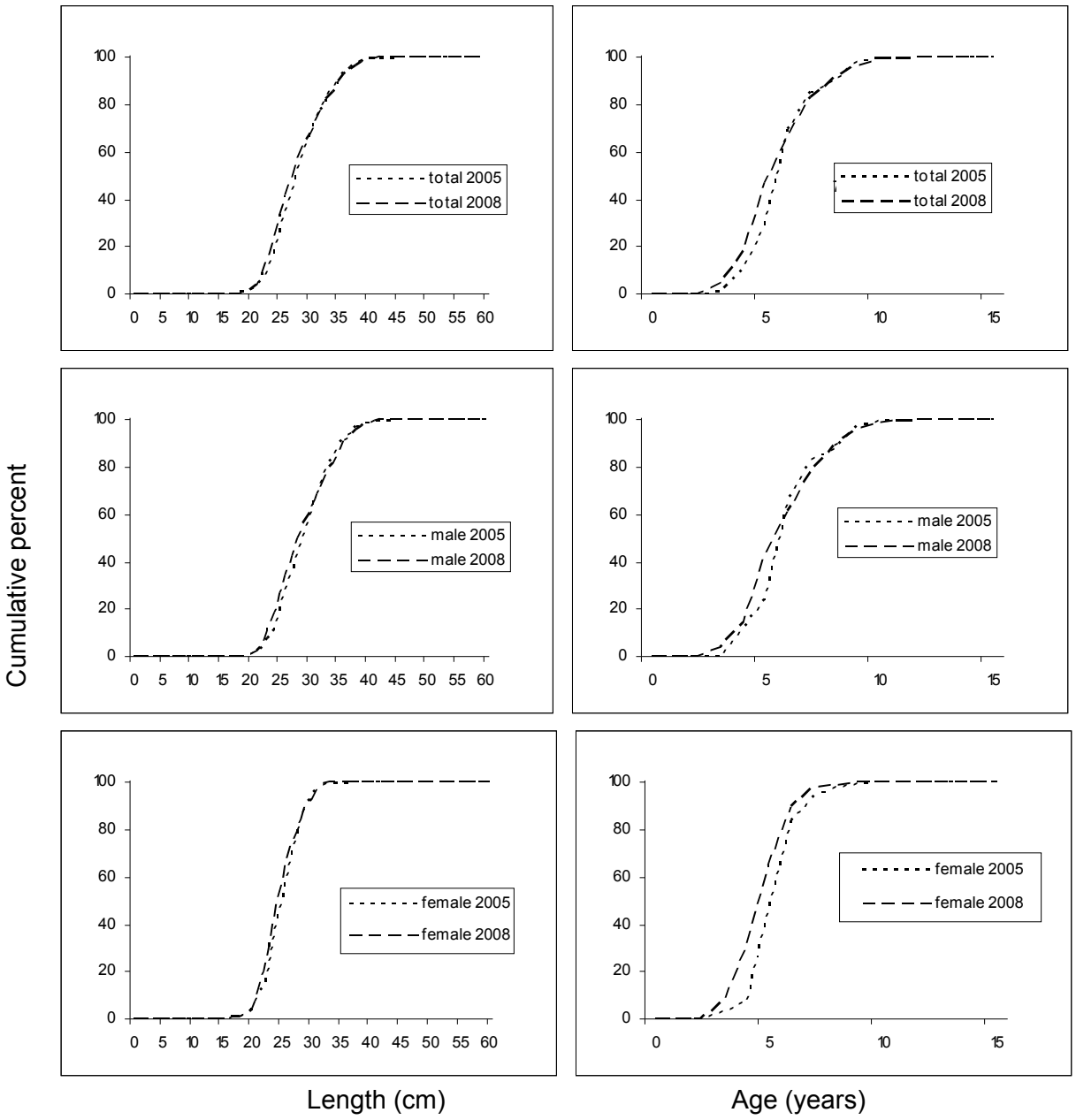

Figure 14: Scaled length and age cumulative frequency distributions for total, male, and female blue cod for the 2005 and 2008 Motunau surveys.

Appendix 1: Methodology for estimating total mortality (*Z*).
(Modified from Carbines et al. 2008)

ESTIMATES OF TOTAL MORTALITY (*Z*)

The term "catch curve" has commonly been used to describe an age frequency distribution from a catch (or sample) of a population, and has been widely used in fisheries research in the estimation of total mortality (*Z*) (i.e., the sum of natural mortality, *M,* and fishing mortality, *F*). The assumption is that this curve declines exponentially on its right hand limb and the rate of exponential decline is *Z*.

A common method for estimating *Z* from catch curve data is the Chapman Robson (1960) estimator (CR). Their estimator is based on a minimum variance unbiased estimator for the related survival parameter, $S\ \left(=e^{-Z}\right)$, and is defined as

$$\mathrm{CR} = \log_e\left(\frac{1+\bar{a}-1/n}{\bar{a}}\right) \qquad [1]$$

where $\bar{a}$ is the mean age (above the recruitment age) and n is the sample size.

Chapman & Robson (1960) also showed that

$$\mathrm{Bias(CR)} \approx \frac{\left(1-e^{-Z}\right)^2}{ne^{-Z}} \approx \mathrm{Variance(CR)} \qquad [2]$$

However, both the estimates and variance of *Z* assume that the population sampled has a stable age structure, "steady state" (i.e., that recruitment and mortality are constant), that fish of age greater than some known age (the recruitment age) are equally vulnerable to sampling, and that there are no age estimation errors (Ricker 1975).

We used the simulation model developed by Dunn et al. (2002) to estimate the variance of *Z*, and hence attempt to evaluate the variance of these estimates when the steady state assumptions are relaxed. An approximate simulated 95% confidence interval for the estimates of $\hat{Z}$ was calculated from the 2007 Kaikoura and 2008 Motunau blue cod potting survey samples (males and females combined) using the simulation models of Dunn et al. (2002). Here, we simulated 1000 age distributions with a known value of $\hat{Z}$ (the 'true' estimate), that included annual variation in *Z* (described by a normal distribution with c.v. σ_Z), error in sampling (described as a lognormally distributed error with a constant c.v., cv_{sampling}), ageing error (normally distributed errors described by a constant c.v., cv_{ageing}), and variability in recruitment (described by lognormally distributed recruitment deviations with standard deviation σ_R, and autocorrelation φ). Then, for each simulated age distribution, we estimated the CR estimate of *Z*, and hence evaluated the 95% empirical confidence intervals for the estimate of $\hat{Z}$.

However, as the CR estimator is biased, we adjusted the empirical 95% intervals by (i) estimating a scaling factor to adjust the mean empirical estimate to the 'true' estimate, and (ii) applied this scaling factor to the 95% intervals to estimate bias corrected intervals for $\hat{Z}$.

THE NATURE AND MAGNITUDE OF THE INTRODUCED STOCHASTIC ERROR

In simulating age distributions for catch curve derived estimates of mortality (Z), we attempted to approximate the values of parameters that could be found in typical blue cod populations. The parameters (and symbols used to describe each) and values that have been used in the simulation model are shown below:

Parameter		Low	Medium	High
Ageing error (coefficient of variation)	cv_a	0.10	0.15	0.20
Error in Z (coefficient of variation)	cv_Z	0.00	0.10	0.20
Error in recruitment	σ_R	0.50	0.70	1.00

Ageing error is a likely source of bias, but its scale can be difficult to estimate (Dunn et al. 2002). We assumed that ageing error is normally distributed with a c.v. of $cv_a = 0.15$, but also considered $cv_a = 0.10$ (low) and $cv_a = 0.20$ (high).

Stochastic variation in Z has considerable impact on the shape of an empirical catch-curve, but no data are available to describe the type or magnitude of stochastic variation. We assume either that there was no variation in Z (low) and variation defined as lognormally distributed, uncorrelated, and without trend, with error described by a cumulative variance of $cv_Z = 0.1$ (medium) and $cv_Z = 0.2$ (high).

We assume errors in log recruitment to be normally distributed with standard deviation σ_R,. We based the values chosen for the simulations on data given by Myers et al. (1995). This details the standard deviation and first order autocorrelation of estimated recruitment for a wide variety of international fisheries. Lower, mid, and upper quartiles were derived from this table (using those series with more than 10 years data) selected from the orders Aulopiformes, Clupeiformes, Gadiformes, Lophiiformes, Ophidiiformes, Perciformes (except Percidae), Pleuronectiformes, and Scorpaeniformes. The lower, mid, and upper quartiles from these data were σ_R, = 0.48, σ_R, = 0.67, and σ_R, = 1.00. We assume variation in recruitment based on the median values ($\sigma_R = 0.7$), and also consider low ($\sigma_R = 0.5$) and high levels ($\sigma_R = 1.0$) based on the lower and upper quartiles.

Appendix 2: Summary of survey pot lift station data, Kaikoura 2007.

Set	Date	Phase	Stratum	Pot lift station	Depth (m)	Time set	Pot number	Catch of blue cod (kg)	Catch of blue cod Number of fish
1	3-Dec-07	1	2	2C	10.8	07:05	4	0.0	0
1	3-Dec-07	1	2	2C	18.3	07:10	5	0.0	0
1	3-Dec-07	1	2	2C	14.4	07:15	1	1.8	6
1	3-Dec-07	1	2	2C	14.8	07:20	2	0.0	0
1	3-Dec-07	1	2	2C	13.5	07:25	6	0.0	0
1	3-Dec-07	1	2	2C	7.3	07:30	3	0.5	1
2	3-Dec-07	1	2	2E	8.4	08:50	3	0.0	0
2	3-Dec-07	1	2	2E	10.4	08:55	6	5.3	12
2	3-Dec-07	1	2	2E	14.4	09:00	2	4.5	12
2	3-Dec-07	1	2	2E	16.6	09:10	1	3.4	7
2	3-Dec-07	1	2	2E	19.8	09:15	5	3.7	6
2	3-Dec-07	1	2	2E	16.3	09:20	4	4.0	13
3	3-Dec-07	1	2	2G	30.2	12:28	4	0.4	1
3	3-Dec-07	1	2	2G	23.4	12:34	5	0.7	2
3	3-Dec-07	1	2	2G	22.7	12:39	1	6.6	22
3	3-Dec-07	1	2	2G	17.9	12:50	2	2.4	8
3	3-Dec-07	1	2	2G	28.9	12:56	6	0.7	2
3	3-Dec-07	1	2	2G	31.1	13:01	3	1.5	5
4	4-Dec-07	1	2	2H	21.9	06:22	3	1.2	4
4	4-Dec-07	1	2	2H	24.1	06:29	6	1.4	6
4	4-Dec-07	1	2	2H	25.6	06:35	2	0.0	0
4	4-Dec-07	1	2	2H	22.7	06:41	5	6.8	23
4	4-Dec-07	1	2	2H	22.7	06:47	1	1.2	2
4	4-Dec-07	1	2	2H	22.1	06:54	4	7.6	12
5	4-Dec-07	1	2	2J	18.3	09:40	4	9.2	16
5	4-Dec-07	1	2	2J	15.7	09:45	1	4.1	18
5	4-Dec-07	1	2	2J	16.8	09:50	5	2.9	4
5	4-Dec-07	1	2	2J	19.4	09:56	2	0.0	0
5	4-Dec-07	1	2	2J	23.2	10:08	6	0.0	0
5	4-Dec-07	1	2	2J	25.2	10:14	3	0.0	0
6	4-Dec-07	1	3	3B	19.8	12:29	3	3.3	8
6	4-Dec-07	1	3	3B	25.6	12:33	6	0.2	2
6	4-Dec-07	1	3	3B	37.5	12:40	2	2.1	6
6	4-Dec-07	1	3	3B	32.0	12:45	5	1.0	2
6	4-Dec-07	1	3	3B	23.8	12:50	1	1.9	9
6	4-Dec-07	1	3	3B	25.2	12:55	4	2.9	7
7	5-Dec-07	1	1	1G	22.9	06:47	4	2.8	8
7	5-Dec-07	1	1	1G	23.4	06:53	1	3.8	10
7	5-Dec-07	1	1	1G	32.2	06:58	5	2.6	7
7	5-Dec-07	1	1	1G	26.0	07:04	2	1.5	3
7	5-Dec-07	1	1	1G	24.1	07:11	6	8.3	22
7	5-Dec-07	1	1	1G	26.5	07:16	3	2.2	7
8	5-Dec-07	1	1	1E	32.4	08:42	3	13.0	15
8	5-Dec-07	1	1	1E	30.0	08:48	6	3.3	6
8	5-Dec-07	1	1	1E	28.3	08:53	2	0.0	0
8	5-Dec-07	1	1	1E	27.1	08:58	5	2.5	4

8	5-Dec-07	1	1	1E	31.3	09:03	1	2.5	6

				Pot lift			Pot	Catch of blue cod	
Set	Date	Phase	Stratum	station	Depth (m)	Time set	number	(kg)	Number of fish
8	5-Dec-07	1	1	1E	36.0	09:09	4	2.8	6
9	5-Dec-07	1	1	1C	54.3	10:31	4	0.0	0
9	5-Dec-07	1	1	1C	54.5	10:36	1	11.3	17
9	5-Dec-07	1	1	1C	45.2	10:41	5	0.0	0
9	5-Dec-07	1	1	1C	40.4	10:46	2	0.0	0
9	5-Dec-07	1	1	1C	47.5	10:51	6	0.0	0
9	5-Dec-07	1	1	1C	54.9	10:56	3	5.0	6
10	5-Dec-07	1	1	1A	40.2	12:05	3	2.4	5
10	5-Dec-07	1	1	1A	26.2	12:10	6	19.4	36
10	5-Dec-07	1	1	1A	36.4	12:15	2	2.7	6
10	5-Dec-07	1	1	1A	41.1	12:20	5	0.0	0
10	5-Dec-07	1	1	1A	45.2	12:25	1	2.6	4
10	5-Dec-07	1	1	1A	43.5	12:30	4	4.4	9
11	5-Dec-07	1	1	1K	33.5	14:14	4	5.3	7
11	5-Dec-07	1	1	1K	31.3	14:23	1	0.0	0
11	5-Dec-07	1	1	1K	30.4	14:28	5	7.2	8
11	5-Dec-07	1	1	1K	28.9	14:34	2	10.6	13
11	5-Dec-07	1	1	1K	31.6	14:39	6	1.6	2
11	5-Dec-07	1	1	1K	36.0	14:45	3	4.2	5
12	8-Dec-07	1	3	3G	84.7	08:42	1	3.3	6
12	8-Dec-07	1	3	3G	85.8	08:48	4	6.8	10
12	8-Dec-07	1	3	3G	90.7	08:53	3	5.7	11
12	8-Dec-07	1	3	3G	95.6	08:58	5	26.9	34
12	8-Dec-07	1	3	3G	88.1	09:05	2	6.5	9
12	8-Dec-07	1	3	3G	88.5	09:10	6	14.4	21
13	8-Dec-07	1	3	3F	77.4	12:02	6	8.1	19
13	8-Dec-07	1	3	3F	77.9	12:09	2	8.8	19
13	8-Dec-07	1	3	3F	79.0	12:18	5	11.1	17
13	8-Dec-07	1	3	3F	78.8	12:25	3	17.3	24
13	8-Dec-07	1	3	3F	78.6	12:33	4	16.9	32
13	8-Dec-07	1	3	3F	79.6	12:43	1	10.6	22
14	9-Dec-07	1	3	3J	79.2	07:15	1	1.3	2
14	9-Dec-07	1	3	3J	87.8	08:25	4	1.8	2
14	9-Dec-07	1	3	3J	92.2	07:34	3	3.3	5
14	9-Dec-07	1	3	3J	92.5	08:45	5	3.8	7
14	9-Dec-07	1	3	3J	85.8	07:54	2	1.4	3
14	9-Dec-07	1	3	3J	79.0	08:05	6	1.1	2
15	9-Dec-07	1	3	3H	87.2	09:35	6	8.5	14
15	9-Dec-07	1	3	3H	89.6	09:42	2	12.6	14
15	9-Dec-07	1	3	3H	95.8	09:52	5	11.9	19
15	9-Dec-07	1	3	3H	97.7	10:01	3	23.5	24
15	9-Dec-07	1	3	3H	94.9	10:08	4	11.6	16
15	9-Dec-07	1	3	3H	88.1	10:15	1	6.5	8
16	9-Dec-07	1	4	4B	105.5	13:24	1	6.8	13
16	9-Dec-07	1	4	4B	107.7	12:32	4	7.9	14
16	9-Dec-07	1	4	4B	113.2	12:41	3	13.0	17

16	9-Dec-07	1	4	4B	114.5	12:49	5	15.6	19
16	9-Dec-07	1	4	4B	107.7	12:57	2	14.9	24

				Pot lift			Pot	Catch of blue cod	
Set	Date	Phase	Stratum	station	Depth (m)	Time set	number	(kg)	Number of fish
16	9-Dec-07	1	4	4B	104.2	13:06	6	4.4	7
17	10-Dec-07	1	4	4F	112.8	05:57	6	14.8	22
17	10-Dec-07	1	4	4F	58.5	06:06	2	31.9	56
17	10-Dec-07	1	4	4F	115.6	06:15	5	31.6	54
17	10-Dec-07	1	4	4F	120.5	06:24	3	26.6	37
17	10-Dec-07	1	4	4F	126.6	06:33	4	24.9	36
17	10-Dec-07	1	4	4F	126.7	06:42	1	25.2	28
18	10-Dec-07	1	4	4E	106.4	09:41	1	28.1	34
18	10-Dec-07	1	4	4E	106.3	09:49	4	6.6	7
18	10-Dec-07	1	4	4E	108.3	09:58	3	12.7	13
18	10-Dec-07	1	4	4E	105.0	10:07	5	7.6	12
18	10-Dec-07	1	4	4E	106.4	10:15	2	5.9	7
18	10-Dec-07	1	4	4E	109.9	10:23	6	12.0	19
19	10-Dec-07	1	4	4I	118.7	12:16	6	31.5	47
19	10-Dec-07	1	4	4I	120.5	12:23	2	9.3	15
19	10-Dec-07	1	4	4I	123.8	12:30	5	40.1	60
19	10-Dec-07	1	4	4I	121.2	12:38	3	18.2	30
19	10-Dec-07	1	4	4I	122.0	12:45	4	21.0	28
19	10-Dec-07	1	4	4I	119.1	12:53	1	6.6	11
20	11-Dec-07	1	4	4H	121.8	06:03	1	16.3	25
20	11-Dec-07	1	4	4H	121.8	06:10	4	39.4	52
20	11-Dec-07	1	4	4H	122.9	06:18	3	44.0	51
20	11-Dec-07	1	4	4H	130.9	06:27	5	31.4	55
20	11-Dec-07	1	4	4H	126.7	06:36	2	42.3	71
20	11-Dec-07	1	4	4H	123.3	06:47	6	23.2	39
21	11-Dec-07	2	3	3C	52.5	10:37	6	6.1	14
21	11-Dec-07	2	3	3C	59.8	10:45	2	5.6	9
21	11-Dec-07	2	3	3C	63.1	10:50	5	8.0	10
21	11-Dec-07	2	3	3C	64.2	10:56	3	6.0	9
21	11-Dec-07	2	3	3C	60.5	11:03	4	3.3	5
21	11-Dec-07	2	3	3C	53.6	11:08	1	3.7	8
22	11-Dec-07	2	2	2I	15.4	12:36	1	0.0	0
22	11-Dec-07	2	2	2I	14.1	12:42	4	0.0	0
22	11-Dec-07	2	2	2I	12.6	12:47	3	0.0	0
22	11-Dec-07	2	2	2I	12.3	12:54	5	1.6	8
22	11-Dec-07	2	2	2I	9.0	13:00	2	2.3	8
22	11-Dec-07	2	2	2I	15.2	13:06	6	3.5	7
23	12-Dec-07	2	2	2A	11.2	06:44	6	0.0	0
23	12-Dec-07	2	2	2A	4.2	06:50	2	0.0	0
23	12-Dec-07	2	2	2A	9.0	06:56	5	0.0	0
23	12-Dec-07	2	2	2A	10.1	07:03	3	0.0	0
23	12-Dec-07	2	2	2A	9.0	07:08	4	0.0	0
23	12-Dec-07	2	2	2A	5.7	07:14	1	0.0	0
24	12-Dec-07	2	2	2B	6.2	08:26	1	0.0	0

24	12-Dec-07	2	2	2B	9.9	08:32	4	0.0	0
24	12-Dec-07	2	2	2B	14.6	08:38	3	17.6	22
24	12-Dec-07	2	2	2B	13.9	08:45	5	1.6	2
24	12-Dec-07	2	2	2B	15.7	08:52	2	0.6	1

				Pot lift			Pot	Catch of blue cod	
Set	Date	Phase	Stratum	station	Depth (m)	Time set	number	(kg)	Number of fish
24	12-Dec-07	2	2	2B	18.1	08:59	6	0.0	0
25	12-Dec-07	2	2	2F	20.3	10:28	6	0.2	1
25	12-Dec-07	2	2	2F	32.2	10:34	2	0.6	2
25	12-Dec-07	2	2	2F	37.7	10:41	5	3.1	12
25	12-Dec-07	2	2	2F	26.7	10:48	3	2.9	6
25	12-Dec-07	2	2	2F	20.3	10:55	4	0.0	0
25	12-Dec-07	2	2	2F	34.9	11:03	1	1.1	3

Appendix 3: Summary of Kaikoura oceanographic environmental station data recorded in the format of MFish trawl data base. Depths are measured in meters, directions in compass degrees (999 = nil), wind force in the Beaufort scale, temperatures in degrees centigrade, air pressure in millibars, cloud cover in oktas, sea condition in the Douglas scale, sea colour in a categorical scale from 1 (deep blue) to 8 (yellow green), swell height in the Douglas classification 1 (low) to 3 (heavy), bottom type in a categorical scale from 1 (mud or ooze) to 9 (stone), bottom contour in a categorical scale from 1 (smooth/flat) to 5 (very rugged), and wind speed in metres per second.

Set	Average Depth	Wind Direction	Wind Force	Air Temp	Air Pressure	Cloud Cover	Sea Condition	Sea Colour	Swell Height	Swell Direction	Bottom Type	Bottom Contour	Surface Temp	Bottom Temp	Wind Speed	Secchi Depth
1	13.2	999	0	20.6	1024	1	1	07	0.75	070	2	4	14.7	14.1	0.0	3.6
2	14.3	045	1	20.3	1022	1	1	07	0.75	070	7	3	14.7	14.1	2.0	5.4
3	25.7	180	1	20	1022	0	1	07	0.75	070	2	3	14.7	14.1	2.0	4.4
4	23.2	270	2	16.7	1033	8	3	04	0.50	180	2	4	15.5	15.0	2.0	3.8
5	19.8	090	2	18.4	1034	7	2	05	0.50	090	3	3	16.0	15.0	9.4	1.8
6	27.3	045	4	19.8	1033	3	3	05	0.75	090	7	5	15.3	15.0	19.5	4.5
7	25.8	270	0	16.7	1028	3	2	04	1.00	090	7	5	15.0	14.7	1.5	4.0
8	30.8	000	0	20.6	1028	2	2	04	1.50	040	7	4	15.0	13.8	0.5	5.3
9	49.5	300	1	21.8	1027	2	2	04	1.00	030	7	2	15.7	14.0	3.0	8.0
10	38.8	000	1	20.9	1026	2	2	04	0.75	030	7	3	15.7	14.0	8.6	7.7
11	31.9	000	1	22.6	1024	1	2	04	1.00	030	7	3	16.0	15.0	2.0	5.7
12	88.9	050	4	19.9	1035	2	4	04	1.50	050	6	2	14.0	13.5	22.0	5.1
13	78.5	050	4	19.1	1033	2	4	04	1.50	050	6	2	14.0	13.2	29.0	5.0
14	86.1	030	1	16.5	1032	8	3	04	2.25	050	6	2	14.5	14.0	4.3	6.4
15	92.2	000	0	22.4	1032	8	3	04	2.00	050	6	2	15.5	14.0	0.5	8.9
16	108.8	160	2	20.8	1032	8	3	04	1.50	050	6	2	15.0	14.0	7.8	6.8
17	110.1	180	1	16.1	1033	8	3	04	1.00	040	6	2	15.0	14.0	5.0	8.8
18	107.0	999	0	19.9	1032	7	3	04	1.15	040	6	3	16.0	14.0	0.0	8.9
19	120.9	180	0	21.6	1033	7	3	04	1.00	040	6	2	15.0	14.0	1.1	11.6
20	124.6	035	1	19.8	1029	6	3	04	1.25	035	6	2	15.3	14.1	3.0	10.2
21	58.9	040	1	23.7	1029	6	3	05	1.00	040	6	2	15.5	14.2	2.5	10.5
22	13.1	999	0	21.7	1029	7	2	06	0.25	150	4	3	17.0	14.5	0.0	6.4
23	8.2	999	0	24.5	1029	5	2	07	1.25	060	4	3	15.7	14.9	0.0	3.0
24	13.1	999	0	26.2	1030	4	2	07	1.00	060	4	4	17.0	15.0	0.0	5.0
25	28.7	999	0	27	1029	4	2	07	0.25	060	4	2	18.5	15.0	0.0	4.1

Appendix 4: Between-reader comparisons (using first independent readings only) for otolith data collected in Kaikoura 2007.

Reader two																Age class (reader one)					
difference	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	Total
-11																				1	1
-10																					0
-9																			1		1
-8																					0
-7															1		1			2	4
-6															3	2				2	7
-5														2	1		1	1	1		6
-4													3	1	1	1	1				7
-3												3	4		2					2	11
-2								2		1	2	2	1		1	1					10
-1			2	5	2	6	11	6	4	2	2	2			1	1					44
0			10	47	27	11	13	22	14	10	8	6									168
1				4	1		2	2	2		1										12
3								1													1
Total			12	56	30	17	26	33	20	13	13	13	8	3	10	5	3	1	2	7	272
% agreement			83	84	90	65	50	67	70	77	62	46	0	0	0	0	0	0	0	0	62

Appendix 5: Independent reader comparisons with agreed age from otolith data collected in Kaikoura 2007.

Reader one																	Agreed age class					
difference	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	Total
-6																1				1	2
-5																				1	1
-4																1	1	1			3
-3																		1			1
-2															2		2			2	6
-1					1	1	1	1	2		1	1	2	3		1	3			1	18
0			12	55	29	15	24	30	19	11	11	8	2		4	2			1	1	224
1					1	1	1			1	2		1	2		1			3	2	15
2							1								1						2
Total			12	55	31	17	27	31	21	12	14	9	5	5	7	6	6	2	4	8	272
% agreement			100	100	94	88	89	97	90	92	79	89	40	0	57	33	0	0	25	13	82

Reader two																	Agreed age class					
difference	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	Total
-12																				1	1
-13																				1	1
-11																				1	1
-10																				1	1
-9																	1	2	2		5
-8																1	2			2	5
-7																1	2			1	4
-6															2						2
-5																1	1		2	1	5
-4													1	4	1						6
-3												1	4		3	1					9
-2							1	1			4					1					7
-1			2	5	2	4	11	6	4	1	1	1		1	1	1					40
0			10	47	29	13	13	23	15	11	9	7									177
1				3			1	1	1												6
2									1												1
3							1														1
Total			12	55	31	17	26	31	21	12	14	9	5	5	7	6	6	2	4	8	272
% agreement			83	85	94	76	50	74	71	92	64	78	0	0	0	0	0	0	0	0	65

Appendix 6. Age length key for Kaikoura 2007 survey for both sexes combined.

Length (cm)	Age (years)																			No.aged
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	
16	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
19	0	0	0.67	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
20	0	0	0.17	0.83	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
21	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
22	0	0	0.2	0.6	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
23	0	0	0.09	0.82	0.09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
24	0	0	0.1	0.8	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
25	0	0	0	0.89	0.11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
26	0	0	0	0.6	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
27	0	0	0	0.1	0.8	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
28	0	0	0	0	0.56	0.11	0.22	0.11	0	0	0	0	0	0	0	0	0	0	0	0	9
29	0	0	0	0	0.36	0.45	0.09	0.09	0	0	0	0	0	0	0	0	0	0	0	0	11
30	0	0	0	0	0.27	0.36	0.36	0	0	0	0	0	0	0	0	0	0	0	0	0	11
31	0	0	0	0.11	0.22	0.11	0.44	0.11	0	0	0	0	0	0	0	0	0	0	0	0	9
32	0	0	0	0	0	0.1	0.3	0.5	0.1	0	0	0	0	0	0	0	0	0	0	0	10
33	0	0	0	0	0	0.2	0.2	0.2	0.3	0.1	0	0	0	0	0	0	0	0	0	0	10
34	0	0	0	0	0	0.22	0.22	0.11	0.33	0	0	0.11	0	0	0	0	0	0	0	0	9
35	0	0	0	0	0	0	0.33	0.22	0.22	0.11	0.11	0	0	0	0	0	0	0	0	0	9
36	0	0	0	0	0	0	0.2	0.2	0.4	0.1	0.1	0	0	0	0	0	0	0	0	0	10
37	0	0	0	0	0	0	0.1	0.4	0	0.2	0.2	0	0	0	0.1	0	0	0	0	0	10
38	0	0	0	0	0	0	0.1	0.3	0.1	0	0.1	0	0	0.1	0	0	0.2	0.1	0	0	10
39	0	0	0	0	0	0	0.1	0.3	0	0.1	0	0	0	0	0.1	0.1	0.1	0.1	0	0.1	10
40	0	0	0	0	0	0	0	0.3	0.1	0	0	0.2	0	0	0.1	0.1	0.1	0	0	0.1	10
41	0	0	0	0	0	0	0	0.25	0.25	0.12	0	0	0.12	0	0	0	0	0	0.12	0.12	8
42	0	0	0	0	0	0	0.2	0.2	0.2	0.2	0	0	0.2	0	0	0	0	0	0	0	5
43	0	0	0	0	0	0	0	0	0.33	0.17	0.33	0	0	0	0	0	0.17	0	0	0	6
44	0	0	0	0	0	0	0	0	0	0.6	0.2	0.2	0	0	0	0	0	0	0	0	5
45	0	0	0	0	0	0	0	0	0	0	0.14	0	0.29	0.14	0	0	0	0	0.14	0.28	7
46	0	0	0	0	0	0	0	0	0.17	0	0.5	0.17	0	0	0.17	0	0	0	0	0	6
47	0	0	0	0	0	0	0	0	0	0	0.2	0.4	0	0.2	0	0	0.2	0	0	0	5
48	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0.2	0.4	0.2	0	0	0	0	5
49	0	0	0	0	0	0	0	0	0	0	0.2	0.2	0.2	0.2	0	0.2	0	0	0	0	5
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0.5	2
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0	0	0	0.33	0.33	3
52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0.5	0	2
53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Total																					272

Appendix 7: Summary of survey pot lift station data, Motunau 2008. Italicises are estimated from lengths.

Set	Date	Phase	Stratum	Pot lift station	Depth (m)	Time set	Pot number	Catch of blue cod (kg)	Catch of blue cod Number of fish
1	07-Jan-08	1	1	1P	26.0	05:55	1	11.0	20
1	07-Jan-08	1	1	1P	26.0	05:57	4	5.5	16
1	07-Jan-08	1	1	1P	28.0	06:02	6	6.7	19
1	07-Jan-08	1	1	1P	24.8	06:05	3	6.7	24
1	07-Jan-08	1	1	1P	24.7	06:08	2	8.9	33
1	07-Jan-08	1	1	1P	26.0	06:13	5	18.7	34
2	07-Jan-08	1	1	1G	22.5	10:11	5	15.8	36
2	07-Jan-08	1	1	1G	26.3	10:13	2	5.7	19
2	07-Jan-08	1	1	1G	24.1	10:16	3	6.5	20
2	07-Jan-08	1	1	1G	21.6	10:20	6	23.3	51
2	07-Jan-08	1	1	1G	19.9	10:23	4	21.6	37
2	07-Jan-08	1	1	1G	22.9	10:26	1	17.2	40
3	07-Jan-08	1	1	1K	35.2	14:17	1	10.9	48
3	07-Jan-08	1	1	1K	35.2	14:19	6	4.4	22
3	07-Jan-08	1	1	1K	33.3	14:23	4	2.4	16
3	07-Jan-08	1	1	1K	33.5	14:27	3	0.6	3
3	07-Jan-08	1	1	1K	33.4	14:31	2	12.9	25
3	07-Jan-08	1	1	1K	32.3	14:35	5	4.5	26
4	08-Jan-08	1	1	1L	23.5	06:27	1	*4.6*	10
4	08-Jan-08	1	1	1L	23.1	06:35	4	*12.9*	24
4	08-Jan-08	1	1	1L	23.9	06:36	6	*5.0*	14
4	08-Jan-08	1	1	1L	21.0	06:41	3	*9.0*	22
4	08-Jan-08	1	1	1L	19.0	06:45	2	*6.1*	16
4	08-Jan-08	1	1	1L	21.0	06:48	5	*10.0*	27
5	08-Jan-08	1	1	1M	27.0	09:26	5	*7.8*	24
5	08-Jan-08	1	1	1M	28.0	09:29	2	*20.0*	43
5	08-Jan-08	1	1	1M	28.0	09:33	3	*13.0*	27
5	08-Jan-08	1	1	1M	30.5	09:36	4	*3.7*	19
5	08-Jan-08	1	1	1M	33.9	09:41	6	*2.5*	16
5	08-Jan-08	1	1	1M	33.7	09:44	1	*3.3*	12
6	08-Jan-08	1	2	2C	17.9	11:57	1	*5.7*	12
6	08-Jan-08	1	2	2C	17.8	12:00	6	*6.6*	16
6	08-Jan-08	1	2	2C	24.1	12:03	4	*9.5*	21
6	08-Jan-08	1	2	2C	20.9	12:05	3	*7.1*	14
6	08-Jan-08	1	2	2C	18.0	12:08	2	*11.0*	27
6	08-Jan-08	1	2	2C	13.2	12:11	5	*4.1*	12
7	08-Jan-08	1	2	2D	14.2	13:49	5	*0.0*	0
7	08-Jan-08	1	2	2D	13.8	13:57	2	*0.0*	0
7	08-Jan-08	1	2	2D	13.8	14:02	3	*0.0*	0
7	08-Jan-08	1	2	2D	14.2	14:06	4	*0.0*	0
7	08-Jan-08	1	2	2D	14.5	14:09	6	*0.0*	0
7	08-Jan-08	1	2	2D	14.5	14:14	1	*0.0*	0
8	09-Jan-08	1	2	2F	29.1	06:44	5	*2.0*	7
8	09-Jan-08	1	2	2F	29.1	06:48	2	*3.5*	9
8	09-Jan-08	1	2	2F	28.3	06:52	3	*1.8*	6
8	09-Jan-08	1	2	2F	29.5	06:57	4	*4.2*	11

Set	Date	Phase	Stratum	Pot lift station	Depth (m)	Time set	Pot number	Catch of blue cod (kg)	Catch of blue cod Number of fish
8	09-Jan-08	1	2	2F	28.8	07:02	6	*2.5*	6
8	09-Jan-08	1	2	2F	28.1	07:05	1	*11.6*	28
9	09-Jan-08	1	2	2I	19.3	08:42	1	*9.2*	28
9	09-Jan-08	1	2	2I	22.2	08:45	6	*5.1*	16
9	09-Jan-08	1	2	2I	18.9	08:49	4	*5.9*	17
9	09-Jan-08	1	2	2I	19.6	08:53	3	*4.8*	14
9	09-Jan-08	1	2	2I	20.4	08:59	5	*4.9*	12
9	09-Jan-08	1	2	2I	18.5	13:26	2	*4.4*	11
10	09-Jan-08	1	2	2L	23.3	10:31	5	*2.5*	12
10	09-Jan-08	1	2	2L	23.6	10:35	2	*4.6*	15
10	09-Jan-08	1	2	2L	21.8	10:38	3	*1.5*	4
10	09-Jan-08	1	2	2L	22.9	10:42	4	*4.8*	11
10	09-Jan-08	1	2	2L	24.2	10:46	6	*0.3*	1
10	09-Jan-08	1	2	2L	24.7	11:45	1	*5.9*	20
11	10-Jan-08	1	3	3A	16.9	08:20	1	*5.0*	7
11	10-Jan-08	1	3	3A	17.0	08:23	6	*5.9*	22
11	10-Jan-08	1	3	3A	14.0	08:27	4	*20.5*	30
11	10-Jan-08	1	3	3A	14.1	08:31	3	*12.3*	34
11	10-Jan-08	1	3	3A	15.6	08:35	2	*12.4*	34
11	10-Jan-08	1	3	3A	13.2	08:38	5	*28.5*	49
12	10-Jan-08	1	3	3F	21.5	09:49	1	*5.6*	14
12	10-Jan-08	1	3	3F	21.2	09:52	6	*7.9*	18
12	10-Jan-08	1	3	3F	19.4	09:56	4	*5.4*	14
12	10-Jan-08	1	3	3F	19.6	09:59	3	*6.5*	16
12	10-Jan-08	1	3	3F	20.0	10:02	2	*7.9*	22
12	10-Jan-08	1	3	3F	20.6	10:05	5	*5.5*	15
13	11-Jan-08	1	3	3M	28.1	08:44	5	*6.2*	24
13	11-Jan-08	1	3	3M	28.8	08:48	2	*10.1*	36
13	11-Jan-08	1	3	3M	27.3	08:52	3	*4.6*	13
13	11-Jan-08	1	3	3M	25.8	08:56	4	*0.5*	2
13	11-Jan-08	1	3	3M	28.0	08:59	6	*2.0*	11
13	11-Jan-08	1	3	3M	28.6	09:03	1	*2.7*	17
14	11-Jan-08	1	3	3AA	10.5	10:50	1	*2.6*	5
14	11-Jan-08	1	3	3AA	13.4	10:53	6	*3.4*	8
14	11-Jan-08	1	3	3AA	10.8	10:57	4	*8.7*	13
14	11-Jan-08	1	3	3AA	11.3	11:01	3	*4.4*	8
14	11-Jan-08	1	3	3AA	13.8	11:05	2	*6.9*	11
14	11-Jan-08	1	3	3AA	13.1	11:08	5	*0.0*	0
15	11-Jan-08	1	3	3AH	9.2	12:35	5	*4.4*	4
15	11-Jan-08	1	3	3AH	10.9	12:39	2	*1.2*	2
15	11-Jan-08	1	3	3AH	11.1	12:43	3	*0.0*	0
15	11-Jan-08	1	3	3AH	13.3	12:46	4	*0.0*	0
15	11-Jan-08	1	3	3AH	13.7	12:50	6	*0.0*	0
15	11-Jan-08	1	3	3AH	13.9	12:53	1	*0.0*	0
16	14-Jan-08	2	3	3K	23.0	06:07	5	*3.8*	12
16	14-Jan-08	2	3	3K	23.8	06:10	2	*12.1*	21
16	14-Jan-08	2	3	3K	23.4	06:13	3	*3.2*	14

16	14-Jan-08	2	3	3K	24.6	06:18	4	*10.1*	21

Set	Date	Phase	Stratum	Pot lift station	Depth (m)	Time set	Pot number	Catch of blue cod (kg)	Number of fish
16	14-Jan-08	2	3	3K	24.1	06:22	6	*9.0*	17
16	14-Jan-08	2	3	3K	22.5	06:25	1	*10.6*	21
17	14-Jan-08	2	3	3AG	18.3	09:50	5	*2.9*	5
17	14-Jan-08	2	3	3AG	17.9	09:53	2	*0.7*	3
17	14-Jan-08	2	3	3AG	17.5	09:56	4	*2.9*	5
17	14-Jan-08	2	3	3AG	17.7	10:00	6	*7.4*	12
17	14-Jan-08	2	3	3AG	18.7	10:03	1	*3.4*	5
17	14-Jan-08	2	3	3AG	18.8	10:06	3	*2.4*	3
18	14-Jan-08	2	3	3AK	22.3	11:24	3	*2.7*	5
18	14-Jan-08	2	3	3AK	19.8	11:27	1	*1.2*	2
18	14-Jan-08	2	3	3AK	20.7	11:31	6	*2.4*	10
18	14-Jan-08	2	3	3AK	21.5	11:34	4	*5.4*	12
18	14-Jan-08	2	3	3AK	22.0	11:38	2	*0.0*	0
18	14-Jan-08	2	3	3AK	17.6	11:42	5	*3.3*	16
19	15-Jan-08	2	1	1R	25.4	05:53	5	*6.9*	21
19	15-Jan-08	2	1	1R	20.8	05:56	2	*6.2*	17
19	15-Jan-08	2	1	1R	20.3	05:59	4	*8.4*	15
19	15-Jan-08	2	1	1R	22.8	06:03	6	*8.0*	18
19	15-Jan-08	2	1	1R	27.7	06:06	1	*1.7*	5
19	15-Jan-08	2	1	1R	28.0	06:09	3	*6.6*	14
20	15-Jan-08	2	3	3Z	19.6	08:26	3	*0.8*	1
20	15-Jan-08	2	3	3Z	18.8	08:29	1	*9.5*	19
20	15-Jan-08	2	3	3Z	19.9	08:33	6	*1.9*	5
20	15-Jan-08	2	3	3Z	18.6	08:36	4	*2.3*	8
20	15-Jan-08	2	3	3Z	20.4	08:39	2	*2.6*	10
20	15-Jan-08	2	3	3Z	20.2	08:42	5	*1.4*	5

Appendix 8: Summary of Motunau oceanographic environmental station data recorded in the format of MFish trawl data base. Depths are measured in meters, directions in compass degrees (999 = nil), wind force in the Beaufort scale, temperatures in degrees centigrade, air pressure in millibars, cloud cover in oktas, sea condition in the Douglas scale, sea colour in a categorical scale from 1 (deep blue) to 8 (yellow green), swell height in the Douglas classification 1 (low) to 3 (heavy), bottom type in a categorical scale from 1 (mud or ooze) to 9 (stone), bottom contour in a categorical scale from 1 (smooth/flat) to 5 (very rugged), and wind speed in metres per second.

Set	Average Depth	Wind Direction	Wind Force	Air Temp	Air Pressure	Cloud Cover	Sea Condition	Sea Colour	Swell Height	Swell Direction	Bottom Type	Bottom Contour	Surface Temp	Bottom Temp	Wind Speed	Secchi Depth
1	25.9	000	2	20.0	1016	7	3	04	0.25	090	7	2	16.0	16.0	7.5	9.8
2	22.9	000	3	20.5	1016	8	3	04	0.50	000	7	5	16.0	16.0	13.0	9.0
3	33.8	000	3	23.9	1014	7	3	04	0.75	045	7	2	16.3	16.3	15.8	10.6
4	21.9	210	1	16.8	1021	7	2	05	0.50	045	7	2	15.5	16.5	1.9	10.5
5	30.2	000	2	19.2	1021	8	3	04	0.50	090	7	2	16.0	15.5	12.6	11.2
6	18.7	045	1	22.1	1020	7	3	04	0.50	090	7	2	16.0	16.0	6.1	13.0
7	14.2	045	2	19.8	1019	6	3	04	0.50	090	7	1	16.5	16.3	7.5	9.7
8	28.8	090	3	16.7	1023	8	3	06	0.50	090	7	2	16.3	16.5	14.8	11.4
9	19.8	090	2	16.4	1024	8	3	06	0.50	090	7	4	16.3	16.0	10.3	10.2
10	23.4	090	3	18.1	1023	8	3	05	0.50	090	7	3	16.5	16.0	16.2	9.8
11	15.1	045	4	13.7	1031	1	3	04	0.50	090	7	3	16.3	16.0	23.4	8.9
12	20.4	045	3	13.1	1032	0	3	04	0.50	090	7	2	16.5	16.3	19.0	4.4
13	27.8	045	3	15.0	1036	0	3	01	0.75	090	7	3	16.3	16.3	16.9	10.5
14	12.2	045	4	16.4	1035	2	3	07	1.00	090	7	4	17.3	16.3	23.0	3.7
15	12.0	045	5	16.7	1034	0	4	08	1.00	090	7	2	17.5	16.5	32.0	3.8
16	23.6	315	4	21.4	1000	5	4	03	0.50	090	7	2	17.0	17.0	24.0	6.6
17	18.2	315	4	22.0	1000	6	3	06	0.50	090	7	1	16.8	16.5	16.5	6.0
18	20.7	315	3	21.7	1000	7	3	07	0.25	090	7	2	16.3	16.5	18.7	5.1
19	24.2	090	2	16.4	1017	2	3	06	0.50	135	7	4	17.0	16.5	6.3	11.5
20	19.6	090	2	16.4	1017	2	3	07	0.50	135	7	2	17.0	16.5	11.1	7.1

Appendix 9: Between-reader comparisons (using first independent readings only) for otolith data collected in Motunau 2008.

Reader two											Age class (reader one)									
difference	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	Total
-2									1												1
-1			2	6	4	4	7	1	1	6	1	2									34
0			16	28	51	41	16	18	15	3											188
1			4	5	9	7	3	2	1	1											32
2								1													1
Total			22	39	64	52	26	22	18	10	1	2									256
% agreement			73	72	80	79	62	82	83	30	0	0									73

Appendix 10: Independent reader comparisons with agreed age from otolith data collected in Motunau 2008.

Reader one											Agreed age class									
difference	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	Total
-1					1	3	5		3	2											14
0			22	36	61	46	26	19	16	9	1	1									237
1			2		1				1		1										5
Total			24	36	63	49	31	19	20	11	2	1									256
% agreement			92	100	97	94	84	100	80	82	50	100									93

Reader two											Agreed age class									
difference	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	Total
-2									2	1											3
-1			2	4	4	3	7			5	1	1									27
0			18	28	53	44	21	18	17	4	1										204
1			4	4	6	2	3	1	1	1											22
Total			24	36	63	49	31	19	20	11	2	1									256
% agreement			75	78	84	90	68	95	85	36	50	0									80

Appendix 11: Age length key Motunau 2008 for both sexes combined.

Length (cm)	Age (years)												No. aged
	1	2	3	4	5	6	7	8	9	10	11	12	
16	0	0	1	0	0	0	0	0	0	0	0	0	2
17	0	0	1	0	0	0	0	0	0	0	0	0	1
18	0	0	0	0	0	0	0	0	0	0	0	0	
19	0	0	1	0	0	0	0	0	0	0	0	0	3
20	0	0	1	0	0	0	0	0	0	0	0	0	7
21	0	0	0.38	0.62	0	0	0	0	0	0	0	0	13
22	0	0	0.25	0.58	0.17	0	0	0	0	0	0	0	12
23	0	0	0.07	0.57	0.36	0	0	0	0	0	0	0	14
24	0	0	0.05	0.27	0.68	0	0	0	0	0	0	0	22
25	0	0	0	0.15	0.75	0.1	0	0	0	0	0	0	20
26	0	0	0	0.18	0.59	0.23	0	0	0	0	0	0	22
27	0	0	0	0	0.44	0.5	0.06	0	0	0	0	0	16
28	0	0	0	0	0.27	0.53	0.2	0	0	0	0	0	15
29	0	0	0	0	0	0.71	0.29	0	0	0	0	0	14
30	0	0	0	0	0.1	0.3	0.4	0.2	0	0	0	0	10
31	0	0	0	0	0.08	0.54	0.31	0	0.08	0	0	0	13
32	0	0	0	0	0	0.27	0.64	0.09	0	0	0	0	11
33	0	0	0	0	0	0.43	0.14	0.43	0	0	0	0	7
34	0	0	0	0	0	0	0.6	0.2	0.2	0	0	0	5
35	0	0	0	0	0	0	0.22	0.56	0.22	0	0	0	9
36	0	0	0	0	0	0	0.14	0.43	0.14	0.29	0	0	7
37	0	0	0	0	0	0	0.12	0.38	0.5	0	0	0	8
38	0	0	0	0	0	0	0	0.25	0.25	0.25	0.25	0	4
39	0	0	0	0	0	0	0	0	0.71	0.29	0	0	7
40	0	0	0	0	0	0	0	0	0.17	0.5	0.17	0.17	6
41	0	0	0	0	0	0	0	0	0.67	0.33	0	0	6
42	0	0	0	0	0	0	0	0	0	1	0	0	1
Total													255