Relative abundance, size and age structure, and stock status of blue cod off north Otago in 2009

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This report describes the results of the 2009 blue cod (*Parapercis colias*) potting survey off north Otago. This is the second in the north Otago time series following a survey in 2005.

The survey used a two-phase stratified random station design with five stations per stratum randomly selected for phase 1 from a list of at least 10 index stations per stratum. From 16 to 30 January 2009, 37 potting stations were surveyed (6 pots per station = 222 pot lifts) from six strata (four inshore and two offshore) that covered from Oamaru south to Cornish Head near Waikouaiti. During phase 1, 180 pot lifts were completed (81%) with 42 in phase 2. The total blue cod catch was 2554 kg, consisting of 4595 blue cod. For all sized blue cod, strata catch rates ranged from 37.2 to 119.3 kg per station per hour (six pots combined) with an overall mean catch rate of 68.1 kg per station per hour and coefficient of variation (c.v.) of 6.9%. Strata catch rates of legal size blue cod (30 cm and over) ranged from 22.6 to 100.9 kg per station per hour, with an overall mean catch rate of 53.4 kg per station per hour and a c.v. of 6.9%. Catch rates in 2009 were highest in the offshore stratum and lowest in the northern and southern inshore strata. Fifty-seven percent of blue cod caught exceeded the minimum legal size.

Total length ranged from 16 to 56 cm. Length frequency distributions using raw data show that the two offshore strata had similar size structures and no clear modes were present. Males were larger than females in all strata and overall mean length was 31.8 cm for males and 27.6 cm for females. Overall sex was heavily skewed in favour of males (73%), reaching up to 82% males in one offshore stratum.

Scaled length frequency distributions (scaled to stratum area) show the male distribution is on average larger than that of females, and that mean size of males is larger that of females (31 cm for males and 27 cm for females). Otoliths were prepared and read for 164 males and 129 females, and these were used to construct the age-length keys applied to the scaled length frequency distributions to estimate the population age structure for each sex. Age ranged from 2 to 27 years, but most fish (over 80%) were between 3 and 14 years for males and 2 and 13 years for females. Mean age was 7.9 years for males and 6.8 years for females.

Total mortality estimates (Z) for age at recruitment from 5 to 8 years ranged between 0.25 and 0.36 (both sexes combined).

Most gonads were early maturing stages with 25% running ripe for both sexes indicating that spawning was in its later stages in January 2009.

The 2009 survey spawner (biomass) per recruit (SPR) adopting the default M value of 0.14 was $F_{36\%}$, indicating that at the level of fishing mortality in 2009, the expected contribution to the spawning biomass over the lifetime of an average recruit has been reduced to 36% of the contribution in the absence of fishing. The level of exploitation (F) in 2009 was slightly above the Ministry of Fisheries target reference point of $F_{40\%}$

Time series comparison

Catch rates overall in 2009 were 14% higher than in 2005 for all blue cod and for blue cod 30 cm and over. Given the similarity in length distributions between surveys it appears that the higher catch rates

(kg per hour) in 2009 are more related to the numbers of fish caught than the size of fish. Further, the offshore strata in both surveys had higher catch rates than inshore strata primarily as a result of catching more, rather than larger, fish.

The scaled length frequency distributions for the 2005 and 2009 north Otago surveys are remarkably similar in shape, but in 2009 there was a slightly higher proportion of smaller and larger fish for both males and females in the population. The resulting population age structure indicates that there was a higher proportion of older fish in 2009 than 2005, partly attributable to faster growth in 2005. Total mortality estimates (Z) for 2009 are considerably lower than those from the 2005 survey (2005 Z = 0.39, 2009 Z = 0.29, at age of recruitment = 6 years).

Fifty-seven percent of blue cod caught exceeded the minimum legal size (30 cm and over) in 2009, similar to 2005 when it was 62%.

The sex proportion continued to be heavily skewed in favour of males (72% overall in 2005 and 73% in 2009). Gonad stages also indicated that spawning was more advanced in January 2009 than it had been in January 2005.

Spawner per recruit

SPR estimates for the default M value of 0.14 were $F_{24\%}$ for 2005 and $F_{36\%}$ for 2009, indicating that the expected contribution to the spawning biomass over the lifetime of an average recruit has been reduced to 24% and 36% respectively, of the contribution in the absence of fishing. Further, the level of exploitation (F) of north Otago blue cod stocks is greater than the Ministry of Fisheries F_{MSY} target reference point of $F_{40\%}$. Further, fishing mortality declined from 2005 to 2009 resulting in an increase in the spawning biomass contribution by 12%.

Sensitivity analyses using M of 0.17 increased spawning biomass contribution by 9% in 2002, and 11% in 2009. Conversely, M of 0.11 decreased the spawning biomass contribution by similar proportions. The exploitation rate (F) is below the target reference point of $F_{40\%}$ only for the 2009 survey for M of 0.17.

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, biogenic, or sandy bottoms close to rocky outcrops. 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 (Ministry of Fisheries Science Group 2008a). Blue cod catch in BCO 3 for the 2006–07 fishing year represented 46% of the total estimated recreational blue cod catch, but only 7% of commercial blue cod landings nationally (BCO 3 recreational estimate = 177 t, commercial estimate = 752 t) (Ministry of Fisheries Science Group 2008a). Blue cod is also an important species for Maori customary fishers in all areas, but the catch is unknown.

The "reef" area off north Otago supporting blue cod is not extensive, but consists of both inshore and offshore areas. Over recent years recreational fishers have become concerned about reported declines in catches and sizes of blue cod in north Otago and an apparent increase in the number of Canterbury based private recreational and charter boats operating in the area has been blamed (South Marine Recreational Fishers Advisory Group pers. comm.). Recreational fishers are concerned that the lowering of the blue cod bag limit to 10 per day for the northern area of BCO 3 in 2000 (from Waimakariri River to Clarence Point) and the closure of the Marlborough Sounds in 2008 may result in a shift of fishing effort south.

Tagging experiments reveal that most blue cod have a restricted home range of generally less than 2 km (Rapson 1956, Mace & Johnston 1983, Mutch 1983, Carbines 2004a, Carbines & McKenzie 2001, 2004), 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 in response to local changes in fishing pressure, managed bag limits and minimum legal size have been varied among key fishing areas within all South Island FMAs (BCO 3, BCO 5, and BCO 7).

Several South Island areas are monitored using relative abundance/biomass indices generated by standardised potting surveys repeated about every four years. Surveys are located in key recreational fisheries within all South Island FMA's. Time series of relative abundance indices are used to monitor the status of blue cod stocks in the Marlborough Sounds (Blackwell 1997, 1998, 2002, 2005, 2008), Kaikoura and Motunau (Carbines & Beentjes 2006a, 2009), Banks Peninsula (Carbines & Beentjes 2003, 2006a, 2009), north Otago (Carbines & Beentjes 2006b), Paterson Inlet (Carbines 2007), and Dusky Sound (Carbines & Beentjes 2003, in press). In addition to catch rates, monitoring age structure provides a further means to evaluate the response of a population to changes in fishing pressure. Otoliths collected during potting surveys have been used to calculate the age structure of blue cod throughout the South Island (Carbines et al. 2008). Estimates of total mortality (Z) for each survey are based on catch curve analysis (Ricker 1975) of the age distributions derived specifically for each survey (Carbines et al. 2008).

A new objective for this project is to determine stock status of north Otago blue cod stocks using an MSY-related proxy. B_{MSY} and F_{MSY} are both commonly used as analytical proxies to estimate MSY reference points. For blue cod there is insufficient information to estimate B_{MSY} since recreational catches have not been estimated reliably and are expected to represent a large proportion of the total catch. Hence F_{MSY} is a more appropriate reference point for blue cod and the most widely used proxy for F_{MSY} currently is spawner per recruit analyses ($F_{\%SPR}$). Hence, we are interested in where fishing mortality, derived from the catch curve analysis (Z) and estimates of M, is in relation to the recommended F_{40SPR} reference point for blue cod. This is documented in the Ministry of Fisheries' 'Operational Guidelines for New Zealand's Harvest Strategy Standard' (Ministry of Fisheries 2008b). $F_{\%SPR}$ reference point has not been estimated for any other previous blue cod survey.

In the 2000/01 Sustainability Round, the Ministry of Fisheries undertook to work with stakeholders to monitor north Otago blue cod populations. The first survey was conducted in January 2005 (Appendix 1) and blue cod in north Otago had some of the highest catch rates for legal sized blue cod (30 cm and over) from any area surveyed, and total mortality estimates were also relatively low (Carbines et al. 2008). This report describes the second survey in the north Otago time series, carried out in January 2009.

Overall objective

1. To estimate relative abundance, maturity state, sex ratio, and age structure of blue cod (*Parapercis colias*) around Oamaru to Cornish Head.

Specific objectives

1. To undertake a potting survey from Oamaru to Cornish Head to estimate relative abundance, size- and age-at-maturity, sex ratio and collect otoliths from pre-recruited and recruited blue cod.

2. To analyses biological samples collected from the potting survey.

3. To determine stock status of blue cod populations in this area.

2. METHODS

2.1 Timing

A potting survey off north Otago was carried out between 16 and 30 January 2009. 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 because the timing was consistent with that of the 2005 survey.

2.2 Survey areas

The original 2005 survey area was defined after discussions with local fishers, Ministry of Fisheries Dunedin, and the South Recreational Advisory Committee (Carbines & Beentjes 2006b). Fishers were given charts of the area and asked to mark discrete locations around north Otago where blue cod are commonly caught. The survey area was divided arbitrarily into three inshore and two offshore strata between Oamaru and Bobbys Head (Appendix 1). The outer boundaries of the inshore and offshore strata were defined by the 30 m and 50 m depth contours, respectively. The same five strata used in 2005 were surveyed as well as an additional inshore stratum to the south (Bobbys Head to Cornish Head) (Figure 1). The area (km^2) within each stratum was taken as a proxy of available habitat for blue cod.

2.3 Survey design

The survey used a two-phase stratified random station selection (Francis 1984). Before the survey, a minimum of 10 index stations (sampling sites) per stratum were marked on charts as described above, ensuring that they were at least 300 m apart (Figure 1). From the list of stations, five stations per stratum were randomly selected for phase 1.

Of 37 planned stations, 30 (80%) were allocated to phase 1 before the survey, with the remainder available for phase 2. Allocation of phase 2 stations was based on the mean catch rate (kg per hour) of all blue cod per stratum and optimised using the “area mean squared” method of Francis (1984). In this way, phase 2 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 or station, $area_i$ 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 north Otago survey was conducted from F.V. *Nimbus*, a Moeraki based commercial vessel equipped to set and lift rock lobster and blue cod pots and, as in 2005, was skippered by the owner Mr John Pile. The vessel specifications are: 10 m length, 3.5 m breadth, 8 t, wooden monohull, powered by a 320 hp 3208 Caterpillar diesel engine with propeller propulsion.

Six custom designed and built cod pots were used to conduct the survey. Pot specifications were: length 1200 mm, width 900 mm, depth 500 mm, 30 mm diameter synthetic inner mesh, 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 type were used in all previous South Island blue cod potting survey time series except Marlborough Sounds where the pots used are of slightly different dimensions (see Blackwell 2008).

A high-performance, 3-axis (3D) acoustic doppler current profiler (SonTek/YSI ADP; Acoustic Doppler Profiler, 500 kHz ADCP) was deployed at each station. The ADCP recorded current flow and direction in 5 m depth bins.

2.5 Sampling methods

At each station, six pots were set sequentially and each left to fish (soak) for 1 h during daylight hours. Soak time was standardised to be consistent with the 2005 survey and all previous South Island potting surveys. The six pots were set in clusters, separated by at least 100 m to avoid pots competing for fish. Once on station the position of each of the six pots was determined by the skipper using local knowledge and the vessel echo sounder to locate a suitable area of reef/cobble or biogenic habitat. After each station was completed (six pot lifts) the next closest station in the stratum was sampled. While it was not logistically possible to standardise for time of day or tides, each stratum was surveyed throughout the day, collectively giving strata roughly equal exposure to all daily tidal and time regimes. The order that strata were surveyed depended on the prevailing weather conditions, as exposed 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). Immediately before each set of the pots, an acoustic doppler current profiler (ADCP) was deployed at the centre of each station and recovered after the last pot of each set was lifted.

[1] This is the first north Otago blue cod survey to record physical oceanographic data.

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 to the nearest 10 g using 10 kg Merel motion-compensating 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, 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 1) mean kilograms per pot per hour, and 2) mean kilograms per station per hour. Coefficients of variation (c.v.) for each stratum were determined from:

$$cv_i = se_i / mean_i$$

where for the *i*th stratum se_i is the standard error, and $mean_i$ is the mean catch rate (kg per pot: kg per station).

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 ($area_{total}$).

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

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.

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

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 for all strata combined, scaled to strata area. Mean length for each sex was calculated for each individual stratum. Overall weighted mean lengths were calculated by weighting each stratum mean by the stratum area divided by the sum of all strata areas.

$$length\_mean_{overall} = \quad ((length\_mean_i * area_i)/area_{total})$$

Overall weighted sex ratio was calculated by standardising for the number of stations in each stratum and weighting the number of fish of each sex in each stratum by the stratum area divided by the sum of all strata areas.

$$relative\ fish\ number_{overall} = \quad (((fish\ number_i/number\ of\ stations_i)*area_i)/area_{total})$$

The *relative fish number*$_{overall}$ of each sex was then used to calculate weighted sex ratio or proportions.

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) and 33 cm and over (minimum legal size in other areas).

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.

Otolith 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 and a protocol described for blue cod by Carbines (2004b). 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 and D. Kater). Where counts differed, readers consulted to resolve the final age estimate. Otoliths given a grade 5 (unreadable) were removed from the analysis.

2.8 Growth parameters

A von Bertalanffy growth model (von Bertalanffy 1938) was fitted to the length-age data by sex for each survey, and also for both surveys combined. The estimated growth parameters K, t_0 and L_{inf} from the combined surveys were used in the spawner per recruit analyses.

2.9 Age composition

Age compositions of north Otago blue cod populations surveyed in January 2009 were estimated 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. 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 (c.v.) for each length and age class, and the mean weighted coefficients of variation (MWCV). The c.v. was calculated using 300 bootstraps. Catch at age analyses were also carried out for the 2005 north Otago survey because previous results shown in figure 19 of Carbines et al. (2008) were not scaled to the equivalent strata area and hence are not directly comparable to the current analysis for 2009.

2.10 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 2. 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 2). 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, including the new stratum 6.

Catch at age and Z estimates for the 2005 survey were re-estimated using the 2009 scaling. On re-examination of the 2005 length and age data, there were a number of large fish of both sexes that either did not have otoliths collected or ageing was not possible because of difficulty in reading. For example, the maximum length in 2005 was 54 and 43 cm for males and females respectively, but the maximum length of aged fish in the age length keys were 50 and 42 cm, respectively. Initial catch at age analyses using this age-length dataset resulted in a truncation of the right hand limb of the catch curve. To address this issue we selected the missing older ages from the 2009 age length key (6 females and 21 males) ensuring that all the largest lengths were represented by ages. Further, two of the 2005 otoliths were reread and provided two additional ages.

2.11 Spawner per recruit analyses

Spawner per recruit calculations were carried out using CASAL (Bull et al. 2008) for the 2005 and 2009 surveys separately. The input data to spawner per recruit analyses were as follows:

The von Bertalanffy growth curve and length-weight parameters were estimated from the age-length and length-weight data collected for each survey and for both surveys combined and are shown below.

	2005 survey		2009 survey		2005 and 2009	
Parameter	Males	Females	Males	Females	Males	Females
K	0.13	0.17	0.07	0.07	0.08	0.09
t_0	-0.22	-0.36	-1.96	-2.85	-1.59	-2.29
L_{inf}	52.43	42.17	65.51	55.36	60.80	51.17
a	6.4086E-06	4.2053E-06	8.4914E-06	5.3124E-06	8.199E-06	5.1374E-06
b	3.2743	3.4013	3.1782	3.3224	3.1965	3.3362

In the SPR analyses we used the von Bertalanffy growth parameters and length weight coefficients from then 2005 and 2009 combined surveys. Hence, the SPR curves for 2005 and 2009 were identical, when other parameters were held constant.

Natural mortality	default assumed to be 0.14 as documented in the 2008 plenary document (Ministry of Fisheries 2008a). Sensitivities were run for M values 20% above and below the default (0.11 and 0.17).
Maturity ogive	the maturity ogive was estimated from the results of Carbines (2004a) and was as follows: 0, 0, 0, 0.1, 0.4, 0.7, 1 where 10% of fish are mature at age 4, 40% at age 5 etc.
Selectivity	selectivity to the commercial fishery is described as knife-edge equal to age at MLS (30 cm and 7 years).
Fishing mortality (*F*)	fishing mortality was estimated from the catch curve analyses and assumed estimate of *M* ($F = Z - M$). The *Z* value is for age at recruitment = 6 years) (see Total mortality results Section 3.6).

3. RESULTS

3.1 Stations surveyed

Thirty-seven stations (= sets) were surveyed (6 pots per station = 222 pot lifts) over 11 fishable days from six strata throughout north Otago (Table 1, Figure 2, Appendix 3). Of the 37 stations, 30 were carried out in phase 1 (5 per stratum) with 3 allocated to stratum 5 and 2 to each of stratum 1 and 2 in phase 2. Depth ranged from 12 to 46 m. Environmental data recorded throughout the north Otago survey are presented in Appendix 4 and the ADCP data stored on the Ministry of Fisheries *trawl* database.

3.2 Catch

A total of 2620 kg of catch was taken on the north Otago survey, of which 2554 kg (97%) was blue cod, consisting of 4595 fish (Table 2). Bycatch included 9 fish and 1 octopus species. The five most common bycatch species by weight were octopus (*Octopus cordiformis*), scarlet wrasse (*Pseudolabrus miles*), leather jacket (*Parika scaber*), trumpeter (*Latris lineata*), and banded wrasse (*Notolabus fucicola*).

Mean catch rates of blue cod (all sizes) ranged from 37.23 kg per station per hour (six pots combined for each station) for the northern inshore stratum 2 to 119.30 kg per station per hour for the southern offshore stratum 5. Overall mean catch rate and c.v. were 68.12 kg per station per hour and 6.85% (Table 3). For blue cod 30 cm and over (local minimum legal size), highest and lowest catch rates were also in strata 5 and 2, respectively. Overall mean catch rate and c.v. for fish over 30 cm were 53.35 kg per station per hour and 6.90% (Table 4). For blue cod 33 cm and over (minimum legal size in other FMA's), highest and lowest catch rates were again in strata 5 and 2, respectively. Overall mean catch rate and c.v. for fish over 33 cm were 43.96 kg per station per hour and 7.51% (Table 5). For comparisons between the two north Otago surveys the mean catch rate for 2009 is also presented excluding the new stratum 6 (Tables 3, 4 and 5).

3.3 Biological and length frequency data

Of the 4595 blue cod caught on the north Otago survey, all were sexed and measured for length, and otoliths were taken from 306 fish across the available size range (Appendix 5). The sex ratio ranged from 1.7:1 (male:females) in stratum 2 to 4.4:1 in stratum 5, and overall was skewed toward males 2.7:1 (Table 6). The size of blue cod ranged from 16 to 50 cm for females and 16 to 56 cm for males, although size varied among strata. The unscaled length frequency distributions for strata 1 to 3 were unimodal with stratum 4 to 6 showing more bimodal distributions (Figure 3). Mean lengths of males were about 5 cm more than females in all strata and overall weighted mean male length was 31.8 cm and mean female length 27.6 cm (Table 6). Mean length of males and females in the offshore stratum 5 was 3─5 cm greater than the inshore strata 2, 4, and 6. The proportion of legal sized (30 cm and over) blue cod caught on the 2009 survey was 57%, and of these 86% were male.

Of 4595 blue cod examined, most had gonads in the early maturing phase. With 25% of both females and males in the running ripe stage and 5% of males and 8% of females having spent gonads, which is indicative of the late phase of spawning (Table 7).

Before calculating the length-weight relationship for north Otago blue cod, the data were examined for outliers and four were removed. The analysis included 135 females (range 16–50 cm) and 166 males (range 16–56 cm). Using the derived model $W = aL^b$, the length-weight parameters for north Otago are as follows: males – a = 0.00849, b = 3.1782, and R^2 = 0.98; females – a = 0.00531, b = 3.3224, and R^2 = 0.99.

3.4 Ageing (between reader analyses)

From 306 otoliths collected during the 2009 survey and sectioned, 13 were rejected as unreadable or damaged, leaving 293 readable otoliths (164 males 16–56 cm, 129 females 16–50 cm, see Table 8 and Appendix 5). Initial independently derived reader estimates of age class are compared in Appendix 6 and show 67% agreement between the two readers, with reader 2 generally estimating lower age classes than reader 1 for fish over 40 cm. When the differences between age class estimates were resolved by agreement between the readers the more experienced reader 1 was 85% consistent with the agreed age class estimates compared to less experienced reader 2 who was 73% consistent with the agreed age classes (Appendix 7). However, the tendency of reader 2 to underestimate the agreed age class was restricted mainly to fish beyond 15 years (Figure 4).

The length-age data are plotted and the von Bertalanffy model fits are shown for the 2005 and 2009 surveys separately and combined (Figure 5). The growth parameters (K, t_0 and L_{inf}) are shown in the methods table of input data for the SPR analysis (Section 2.11). The models indicate that growth is slower for both males and females in 2009 compared to 2005; however, the 2009 data have more larger and older fish which can have a major affect on the shape of the fitted model. In addition, the 2005 curve is lacking ages for some of the largest fish collected on the survey.

3.5 Length and age composition

The scaled length frequency and age distributions from the 2009 north Otago survey are shown as histograms, and as cumulative frequency line plots for males, females, and both sexes combined (Figure 6). The age length keys (ALKs) by sex for the 2009 survey, and also the 2005 survey, are shown in Appendices 8–11. The 2005 ALK (augmented with older ages from 2009) is included for completeness and to allow the reader to make comparisons. Mean-age-at-length for the 2005 survey (augmented with older ages from 2009) and 2009 survey and they are shown in Appendices 12 and 13.

The 2009 survey scaled length frequency distribution for males is unimodal with a mean length of 31 cm, whereas females show indications of a bimodal distribution with modes at about 22 cm and 27 cm and an overall mean length 27 cm. Female length frequency distributions are also skewed to the right with fewer larger fish (Figure 6). The cumulative distribution plots of length frequency show clearly that male size distribution is on average greater than that of females. Further, mean size of males is larger that of females (31 cm for males and 27 cm for females). The mean weighted coefficients of variation (MWCVs) around the length distributions are low (15% for males and 24% for females), indicating that fish sampled in the survey provide a reasonable representation of the overall population.

Age of blue cod in the 2009 survey ranged from 2 to 27 years, but most fish (over 80%) were between 3 and 14 years old for males and 2 and 13 years old for females (Figure 6, Appendices 10 and 11) . The estimated population age distribution is generally unimodal for males with the main peak at about 9 years and bimodal for females with peaks at about 4 and 6 years. The cumulative distribution plots of age frequency show clearly that male age distribution is on average greater than that of females. Further, mean age of males is greater than that of females (7.9 years for males and 6.8 years for females). The MWCVs around the age distributions are medium (29% for males and 30% for females), indicating that fish sampled in the survey for age provide a less than desirable representation of the overall population, assuming that acceptable MWCV values are less than 25%. For comparison the scaled length and age frequencies for the 2005 survey is given in Figure 7 and the scaled length and age cumulative frequency for the 2005 and 2009 surveys are shown in Figure 8.

3.6 Total mortality (*Z*) estimates

Total mortality estimates (*Z*) and 95% confidence intervals for the 2009 north Otago survey for all strata combined and both sexes combined are given in Table 9, together with revised estimates from the 2005 survey. The combined strata mortality estimates for 2009 were between 0.25 and 0.36, and for 2005 between 0.33–0.43.

3.7 Spawner per recruit analyses

The spawner per recruit analyses for the 2005 and 2009 surveys are plotted as %SPR as a function of fishing mortality (Figure 9). Mortality parameters used in the analyses are shown in Table 10 and resulting $F_{\%SPR}$ values in Table 11. Based on the default M of 0.14, the fishing mortality estimated from the 2005 survey was 0.25 which corresponds to $F_{24.5\%}$. Similarly, for 2009 fishing mortality was estimated at 0.15 which corresponds to $F_{36\%}$.This indicates that at the 2005 and 2009 levels of fishing mortality, the expected contribution to the spawning biomass over the lifetime of an average recruit has been reduced to 24% and 36% respectively, of the contribution in the absence of fishing. Other $F_{\%SPR}$ estimates are given for M values of 0.11 and 0.17 (20% below and above the default value of 0.14) in Table 11.

4. DISCUSSION

The 2009 potting survey provides the second observation in the time series of relative abundance and population structure of blue cod from north Otago. Sampling methods and strata were identical to those in the 2005 survey and results are directly comparable (with the exception of the new stratum 6).

4.1 Comparisons between surveys

Catch rates

In previous surveys the standardised catch rate has been presented as the mean kilogram per pot per hour, using pots as the base unit of catch. However, pots are not set independently using the current methodology, but are set in clumps of six at each station. Consequently, we have presented the current survey catch rate as mean kilogram per station per hour and used the combined total catch and effort of the six pots at each station as the base unit for CPUE. For consistency we have also presented catch rates using pots as the basic unit of catch in the 2005 (Appendix 1) and 2009 surveys (see Tables 3, 4, and 5). Overall coefficients of variation were similar in the 2005 and 2009 catch data (about 6% for pots and less than 7% for station catch rates) and these are low compared to most other potting surveys in New Zealand (Carbines et al. 2008).

For both all sized blue cod (Figure 10) and legal sized blue cod (30 cm and over, Figure 11) the overall station catch rate in 2009 was 14% greater than that recorded in the 2005 survey. For blue cod 33 cm and over (legal size in other areas) the catch rate had increase by 19% since the 2005 survey (See Table 5 and Appendix 1, Table C). However, the increase in catch rates were not consistent across all strata. There has been little change in the catch rate of all sized blue cod in the northern offshore stratum 3 and the southern inshore stratum 4, while in the northern inshore stratum 2 there has been a 17% decrease. Similarly, there has been little change in the catch rates of legal sized blue cod in stratum 4, while there has been a 30% reduction in legal size blue cod in stratum two and a 9% decline in stratum 3 (Figure 11). While it is not statistically appropriate to compare among strata because stations are not selected truly at random, the changes in catch rates of blue cod in 2009 have not altered the general theme of offshore strata 3 and 5 continuing to support the highest catch rates of north Otago blue cod, although they are now more closely followed by the catch rates in the central inshore stratum 1 (Figures 10 and 11).

The length frequency distributions scaled by stratum size are remarkably similar between surveys, although there was a higher proportion of the smallest and largest fish present in 2009 which may partly explain the catch rate differences (see Figures 6, 7, and 8). While there were higher catch rates of larger fish in 2009 than in 2005 (Figure 11), the similarity in the overall scaled length distributions between surveys indicates that the higher catch rates in 2009 were more related to the numbers of fish caught than fish size. These surveys were not designed to detect recruitment events and given that four years elapsed between the surveys, attempts to explain the increased catch rates through recruitment pulses or modal progression are difficult.

In this survey, changes in catch rates are assumed to be a proxy for changes in relative abundance of blue cod. We do not expect major shifts in catchability to have occurred between the two north Otago surveys as weather conditions were similar, there were no areas of significant currents, and fishing in exposed areas was restricted to calm days in both surveys.

Reproductive condition

Blue cod generally spawn from spring to mid-summer (Carbines 1998, 2004a). Observations of gonad stages in 2009 were similar to those from the 2005 survey in north Otago, with most fish in the maturing phase and a higher proportion of running ripe and spent stages in 2009 (Table 7). This indicates that the timing of the survey (January) was after the peak spawning period and that spawning appeared to be earlier in 2009 than it had been in 2005.

Size and sex ratio

The overall proportion of males has not changed between 2005 and 2009 (72% and 73%). In both surveys all strata were biased towards males (Table 6). Blue cod are protogynous hermaphrodites with some (but not all) females changing into males as they grow (Carbines 2004a). The finding that males were larger on average than females and that the largest fish were males is consistent with sex structure in protogynous hermaphrodites. However, the skewed sex ratios are contrary to an expected dominance of females resulting from selective removal of the larger terminal sex fish (males). Beentjes & Carbines (2005) suggested that the shift towards a higher proportion of males in heavily fished blue cod populations may be caused by removal of the possible inhibitory effect of large males, and a consequent higher rate (and possibly earlier onset) of sex change by primary females. This hypothesis is supported by the predominance of males in most South Island blue cod fisheries that are known to be heavily fished, in particular, Motunau, inshore Banks Peninsula, and the Marlborough Sounds (Blackwell 1997, 1998, 2002, 2005, 2008, Beentjes & Carbines 2003, 2006, 2009, Carbines & Beentjes 2006a, 2009).

Population length and age structure

The age distributions and total mortality estimates are based on scaled length data that were weighted (scaled) by strata area. Scaling by area assumes that the size of each stratum is directly proportional to the amount of blue cod habitat, i.e., area is assumed to be a proxy for habitat; however, this is probably not the case given the discrete nature of areas of foul and possible biogenic habitat. 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 – as was recommended by the expert review panel following a workshop on blue cod potting surveys in April 2009 (Stephenson et al. 2009). However, as area is currently the only available proxy for blue cod habitat it was used for scaling.

The scaled length frequency distributions for the 2005 and 2009 north Otago surveys are remarkably similar in shape, but in 2009 there was a slightly higher proportion of smaller and larger fish for both males and females in the population (Figure 9). The resulting population age structure indicates that there was a higher proportion of older fish in 2009 than in 2005 and hence why total mortality (Z) was so much less in 2009 (Figure 8). This was despite supplementing the missing older ages in 2005 with those from 2009. There appear to be more older fish in 2009 than the scaled length frequency distribution would suggest, given their similar shapes. The different age structure is partly attributable to faster growth in 2005 (see Figure 5).

Total mortality (Z)

Mortality estimates (Z) for 2009, with age at recruitment set at 6 years, are considerably lower than those from the 2005 survey (2005 = 0.39, 2009 = 0.29, see Table 9). The difference is a result of the small peak in ages between 7 and 10 years in the 2009 population age structure which was absent in 2005; the 2005 survey showed a steeper decline after 6 years and had fewer older fish (see Figures 6, 7, and 8). Assuming a Z somewhere between the 2005 and 2009 survey estimates for recruitment at 6 years (Z = 0.29–0.39), total mortality in north Otago is considerably less (also for recruitment set at 6 years) than in adjacent survey areas Motunau, Kaikoura, inshore Banks Peninsula, and the Marlborough Sounds (Carbines et al. 2008).

4.2 Stock status (spawner per recruit analyses)

The Ministry of Fisheries Harvest Strategy Standard (Ministry of Fisheries 2008b) specifies that a Fishery Plan should include a fishery target reference point, and this may be expressed in terms of biomass or fishing mortality. The more appropriate target reference point for blue cod is F_{MSY}, which is the amount of fishing mortality that results in the maximum sustainable yield. The recommended proxy for F_{MSY} is the level of spawner per recruit $F_{\%SPR}$. The draft Operational Guidelines for New Zealand's Harvest Strategy Standard' (Ministry of Fisheries 2008b) includes the following table of recommended default values for F_{MSY} (expressed as $F_{\%SPR}$ levels from spawning biomass per recruit analysis), and also for B_{MSY} (expressed as $\%B_0$).

Productivity level	**$\%B_0$**	**$F_{\%SPR}$**
High	25	$F_{30\%}$
Medium	35	$F_{40\%}$
Low	40	$F_{45\%}$
Very low	≥ 45	$\leq F_{50\%}$

Based on the draft 'Operational Guidelines for New Zealand's Harvest Strategy Standard' (Ministry of Fisheries 2008b) and recommendations from the Southern Inshore Working Group, blue cod is categorised as an exploited species with medium productivity and hence the recommended default proxy for F_{MSY} is $F_{40\%}$. Our SPR estimates for the default M value of 0.14 were $F_{24\%}$ for 2005 and $F_{36\%}$ for 2009, indicating that the expected contribution to the spawning biomass over the lifetime of an average recruit has been reduced to 24% and 36% respectively, of the contribution in the absence of fishing. Further, the level of exploitation (F) of north Otago blue cod stocks is greater than the F_{MSY} target reference point of $F_{40\%}$ (Table 11, see Figure 9), i.e., fishing pressure applied in 2005 and 2009 was greater than the target fishing pressure, albeit only by 4% for 2009.

Based on the estimated population age structures and an assumed default M of 0.14, fishing mortality declined from 2005 to 2009 (see Table 10) resulting in an increase in the spawning biomass contribution by 12%.

Sensitivity analyses using M values of 0.11 and 0.17 (20% below and above the default of 0.14) resulted in substantial differences in the $F_{\%SPR}$ from the default M value (Table 11, see Figure 9). A higher natural mortality (0.17) increased spawning biomass contribution by 9% in 2002, and 11% in 2009. Conversely, lower mortality (0.11) decreased the spawning biomass contribution by similar proportions. The exploitation rate (F) is below the target reference point of $F_{40\%}$ only for the 2009 survey for M of 0.17 (Figure 9).

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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.)

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.)

Bull, B.; Francis, R.I.C.C.; Dunn, A.; McKenzie, A.; Gilbert, D.J.; Smith, M.H.; Bian, R. (2008). CASAL (C++ algorithmic stock assessment laboratory): CASAL User Manual v2.20-2008/02/14. *NIWA Technical Report 130*. 275 p.

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. (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.; Beentjes, M.P. (2009). Relative abundance, size and age structure, and mortality of blue cod off north Canterbury in 2007−08. *New Zealand Fisheries Assessment Report 2009/37*. 56 p.

Carbines, G.; Beentjes, M.P. (in press). Relative abundance, size and age structure, and mortality of blue cod in Dusky Sound 2008. Draft *New Zealand Fisheries Assessment Report*. 53 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.

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.

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.

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. (2008a). 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).

Ministry of Fisheries. (2008b). Operational Guidelines for New Zealand's Harvest Strategy Standard. (Draft). 66 p. (unpublished document held by Ministry of Fisheries, 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.

Stephenson, P.; Sedberry, G.; Haist, V. (2009). Review of blue cod potting surveys in New Zealand. Draft May 14, 2009. BCOREV-2009-22, 14 pp. (Unpublished report held by Ministry of Fisheries, Wellington.)

von Bertalanffy, L. (1938). A quantitative theory of organic growth. *Human Biology 10*: 181–213.

Table 1: North Otago 2009 survey stratum area, number of phase 1 and 2 stations (sets), pot lifts, and depth.

Stratum	Number of reference stations	Area of strata (km)	Number of sets Phase 1	Number of sets Phase 2	Number of pot lifts	Depth (m) Mean	Depth (m) Range
1	10	153.1	5	2	42	26.5	19–34
2	12	243.5	5	2	42	22.0	18–29
3	10	149.9	5		30	40.2	35–46
4	10	115.9	5		30	21.0	12–30
5	10	200.1	5	3	48	39.0	30–46
6	10	54.3	5		30	21.1	13–29
Total	62	916.8	30	7	222	28.7	12–46

Table 2: Catch weights, numbers of blue cod, bycatch species, and percentage of total weight on the 2009 north Otago survey.

Common name	Scientific name	Catch (kg)	Number	Percent of total catch
Blue cod	*Parapercis colias*	2553.96	4595	97.49
Octopus	*Octopus cordiformis*	36.00	6	1.37
Scarlet wrasse	*Pseudolabrus miles*	11.23	34	0.43
Leatherjacket	*Parika scaber*	8.39	24	0.32
Trumpeter	*Latris lineata*	2.95	3	0.11
Banded wrasse	*Notolabrus fucicola*	2.06	6	0.08
Girdled wrasse	*Notolabrus cinctus*	1.60	4	0.06
Tarakihi	*Nemadactylus macropterus*	1.60	2	0.06
Sea perch	*Helicolenus percoides*	1.09	2	0.04
Southern bastard cod	*Pseudophycis barbata*	0.40	1	0.02
Spotty	*Notolabrus celidotus*	0.35	1	0.01
Total		2619.63	4678	100

Table 3: Mean blue cod catch rate (by pot and station (stn) landings), standard error, and c.v. per stratum and overall for all blue cod in 2009 (both including and excluding stratum 6).

Stratum	Pot lifts (N)	Mean (kg/pot)	s.e.	c.v. (%)	Mean (kg/stn)	s.e.	c.v. (%)
1	42	12.02	1.81	15.04	72.14	12.11	16.78
2	42	6.21	1.10	17.78	37.23	6.72	18.04
3	30	12.66	1.65	13.05	75.98	11.72	15.42
4	30	8.18	1.68	20.57	41.53	17.35	41.79
5	48	19.88	1.96	9.83	119.30	10.93	9.16
6	30	6.96	1.11	16.03	41.75	9.55	22.88
Overall	222	11.51	0.69	6.03	68.12	4.67	6.85
(excluding 6)	192	11.80	0.73	6.23	69.78	4.92	7.05

Table 4: Mean blue cod catch rate (by pot and station landings), standard error, and c.v. per stratum and overall for blue cod 30 cm and over (BCO 3 legal sized) in 2009 (both including and excluding stratum 6).

Stratum	Pot lifts (N)	Mean (kg/pot)	s.e.	c.v. (%)	Mean (kg/stn)	s.e.	c.v. (%)
1	42	9.58	1.56	16.28	57.50	9.65	16.79
2	42	3.77	0.62	16.45	22.62	3.47	15.36
3	30	10.42	1.54	14.78	62.54	11.42	18.26
4	30	5.19	1.30	25.05	31.14	10.28	33.03
5	48	16.80	1.88	11.19	100.85	10.00	9.92
6	30	4.42	0.89	20.14	26.52	6.62	24.95
≥ 30 cm							
Overall	222	8.89	0.60	6.70	53.35	3.68	6.90
(excluding 6)	192	9.17	0.63	7.35	55.04	3.89	7.07

Table 5: Mean blue cod catch rate (by pot and station landings), standard error, and c.v. per stratum and overall for blue cod 33 cm and over (legal sized in other FMAs) in 2009 (both including and excluding stratum 6).

Stratum	Pot lifts (N)	Mean (kg/pot)	s.e.	c.v. (%)	Mean (kg/stn)	s.e.	c.v. (%)
1	42	7.86	1.22	15.56	47.17	7.74	16.40
2	42	2.74	0.51	18.48	16.45	2.72	16.52
3	30	8.85	1.37	15.53	53.11	10.56	19.88
4	30	3.70	0.87	23.56	22.17	7.15	32.24
5	48	14.58	1.79	12.30	87.48	10.04	11.48
6	30	3.19	0.72	22.64	19.13	5.52	28.85
≥ 33 cm							
Overall	222	7.33	0.52	7.10	43.96	3.30	7.51
(excluding 6)	192	7.59	0.59	7.79	45.52	3.49	7.67

Table 6: Mean lengths of blue cod by strata and sex in 2009. Overall weighted mean length and sex ratios are given for all strata both including and excluding stratum 6 separately.

			Length	(cm)		Sex ratio M:F (% male)		
Strata	Sex	N	Mean	Min	Max	All blue cod	< 30 cm	≥ 30 cm
1	m	600	32.9	19	48	2.5:1 (71%)	1.2:1 (56%)	4.0:1 (80%)
	f	243	29.1	16	39			
2	m	434	28.5	16	48	1.7:1 (63%)	1.5: 1 (61%)	2.2: 1 (68%)
	f	252	27.2	16	42			
3	m	432	34.6	20	50	2.9:1 (74%)	0.8: 1 (44%)	8.5: 1 (90%)
	f	148	27.5	16	49			
4	m	430	29.7	18	44	2.6:1 (72%)	1.4:1 (59%)	12.8:1 (93%)
	f	166	25.2	17	35			
5	m	1040	34.7	20	56	4.4:1 (81%)	1.3:1 (56%)	9.9:1 (91%)
	f	239	29.1	18	50			
6	m	435	30.3	16	47	2.5:1 (71%)	1.3:1 (56%)	9.5:1 (91%)
	f	176	25.4	17	39			
Overall weighted	m	3371	31.8	16	56	2.7:1 (73%)	1.3:1 (57%)	6.1:1 (86%)
	f	1224	27.6	16	50			
Overall weighted	m	2936	31.9	16	56	2.7:1 (73%)	1.3:1 (57%)	5.9:1 (86%)
(excl. 6)	f	1040	27.8	16	50			

Table 7: Gonad stages of blue cod in 2009. 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	1.1	62.5	6.4	25.2	4.7	3371
Females	3.9	51.5	11.7	24.8	8.1	1224

Table 8: Otolith raw data used in the catch at age, *Z* estimates and SPR analyses for the north Otago surveys in 2005 and 2009. The 2005 data with the subscript $_{mix}$ were augmented with ages from the 2009 survey and this dataset was used to generate *Z* from catch at age (see methods section 2.10).

		Length of aged fish (cm)			Age (years)		
Survey	No. otos	Mean	Min	Max	Mean	Min	Max
2005 (total)	219	29.7	17	50	6.8	3	19
2005 (male)	125	31.2	18	50	7.1	3	19
2005 (female)	94	27.6	17	42	6.3	3	15
2005 (total)$_{\_mix}$	248	31.5	17	54	7.8	3	22
2005 (male) $_{\_mix}$	148	33.5	18	54	8.4	3	22
2005 (female) $_{mix}$	100	28.5	17	43	6.9	3	17
2009 (total)	293	31.8	16	56	9.0	2	27
2009 (male)	164	33.8	16	56	9.4	2	26
2009 (female)	129	29.4	16	50	8.5	2	27

Table 9: Total mortality estimates (*Z*) and 95% confidence intervals of blue cod from the 2005 and 2009, north Otago potting surveys using Chapman Robson method described in Appendix 2. The 2005 survey estimates were generated from catch at age supplemented with ages from 2009 (see Table 8).

				Low		Medium		High	
Area (year)	AgeR	*Z*	Cv	Lower	Upper	Lower	Upper	Lower	Upper
2005 $_{mix}$	5	0.33	20.9	0.25	0.42	0.23	0.45	0.21	0.48
	6	0.39	20.9	0.29	0.50	0.28	0.54	0.25	0.57
	7	0.40	20.9	0.30	0.51	0.29	0.53	0.27	0.59
	8	0.43	20.9	0.32	0.55	0.32	0.56	0.29	0.60
2009	5	0.25	22.1	0.19	0.31	0.18	0.33	0.16	0.35
	6	0.29	22.1	0.23	0.37	0.22	0.38	0.19	0.43
	7	0.32	22.1	0.25	0.40	0.24	0.42	0.21	0.45
	8	0.36	22.1	0.27	0.46	0.26	0.47	0.24	0.49

Table 10: Mortality parameters (Z, F, and M) used in the spawner per recruit (SPR) analyses for the 2005 and 2009 north Otago surveys. F, fishing mortality; M, natural mortality; Z, total mortality.

	2005		2009	
M	Z	F	Z	F
0.11	0.39	0.28	0.29	0.18
0.14	0.39	0.25	0.29	0.15
0.17	0.39	0.22	0.29	0.12

Table 11: Spawner per recruit estimates at three values of M for the 2005 and 2009 north Otago surveys. Corresponding F values are shown above in Table 10. M, natural mortality.

M	2005	2009
0.11	$F_{17.1\%}$	$F_{24.9\%}$
0.14	$F_{24.5\%}$	$F_{35.6\%}$
0.17	$F_{32.7\%}$	$F_{47.3\%}$

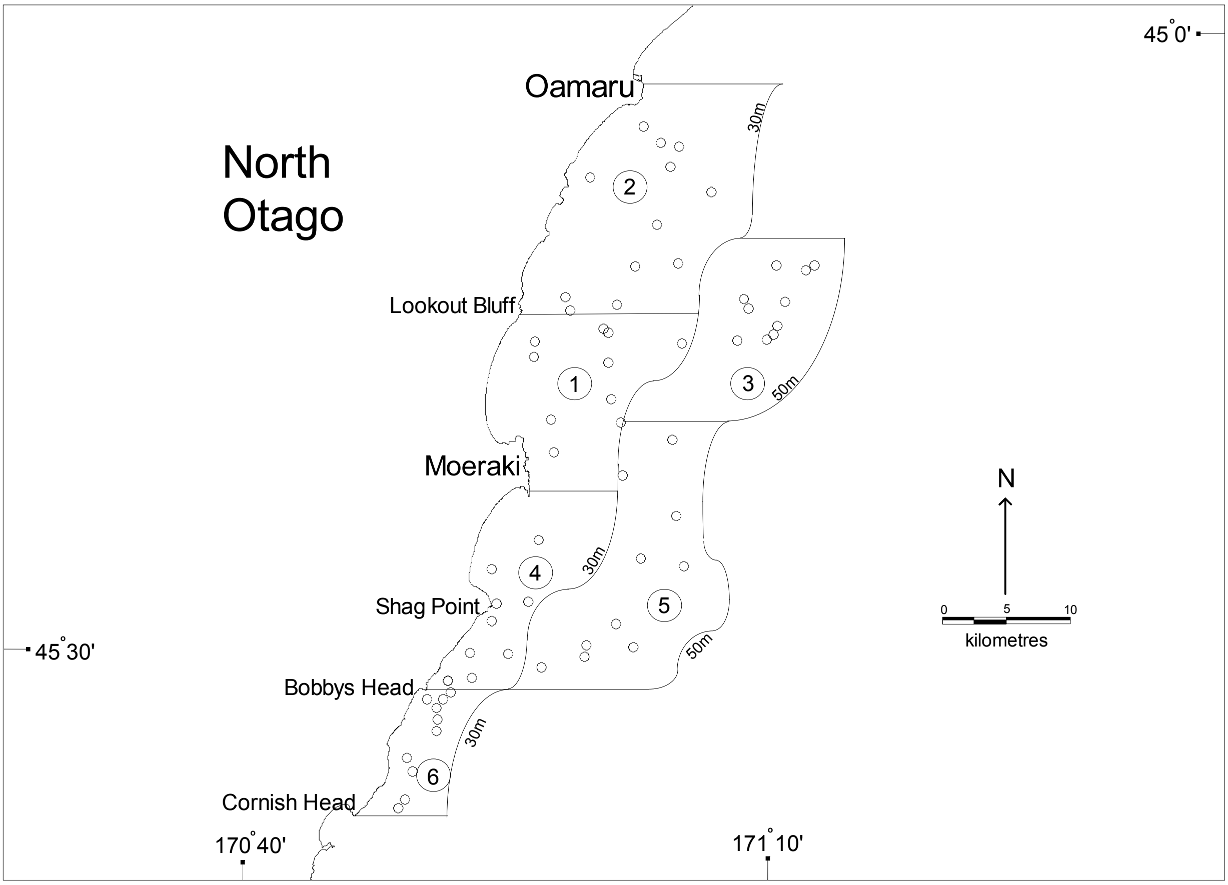


Figure 1: Map of north Otago coast showing strata (1–6) and all possible stations.

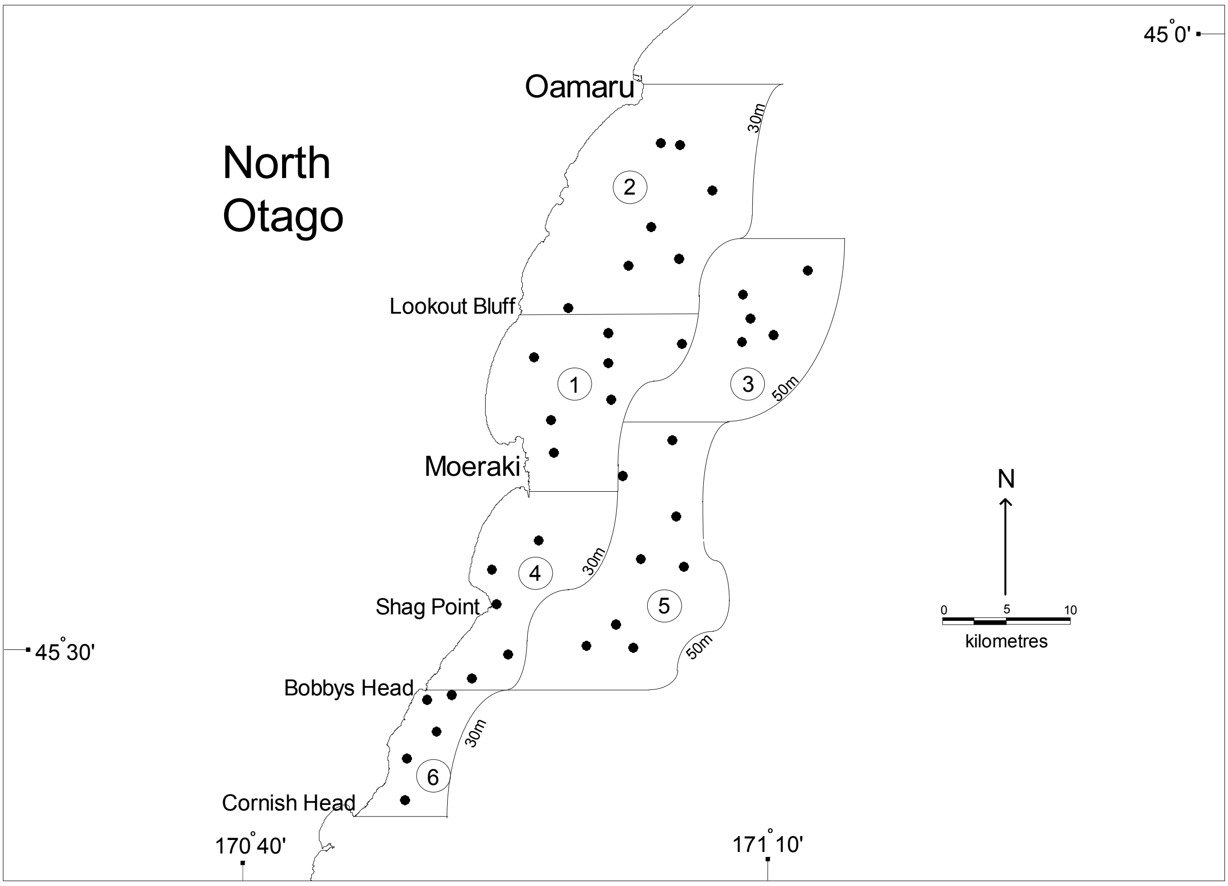


Figure 2: Map of north Otago coast showing strata (1–6) and stations sampled for the 2009 survey.

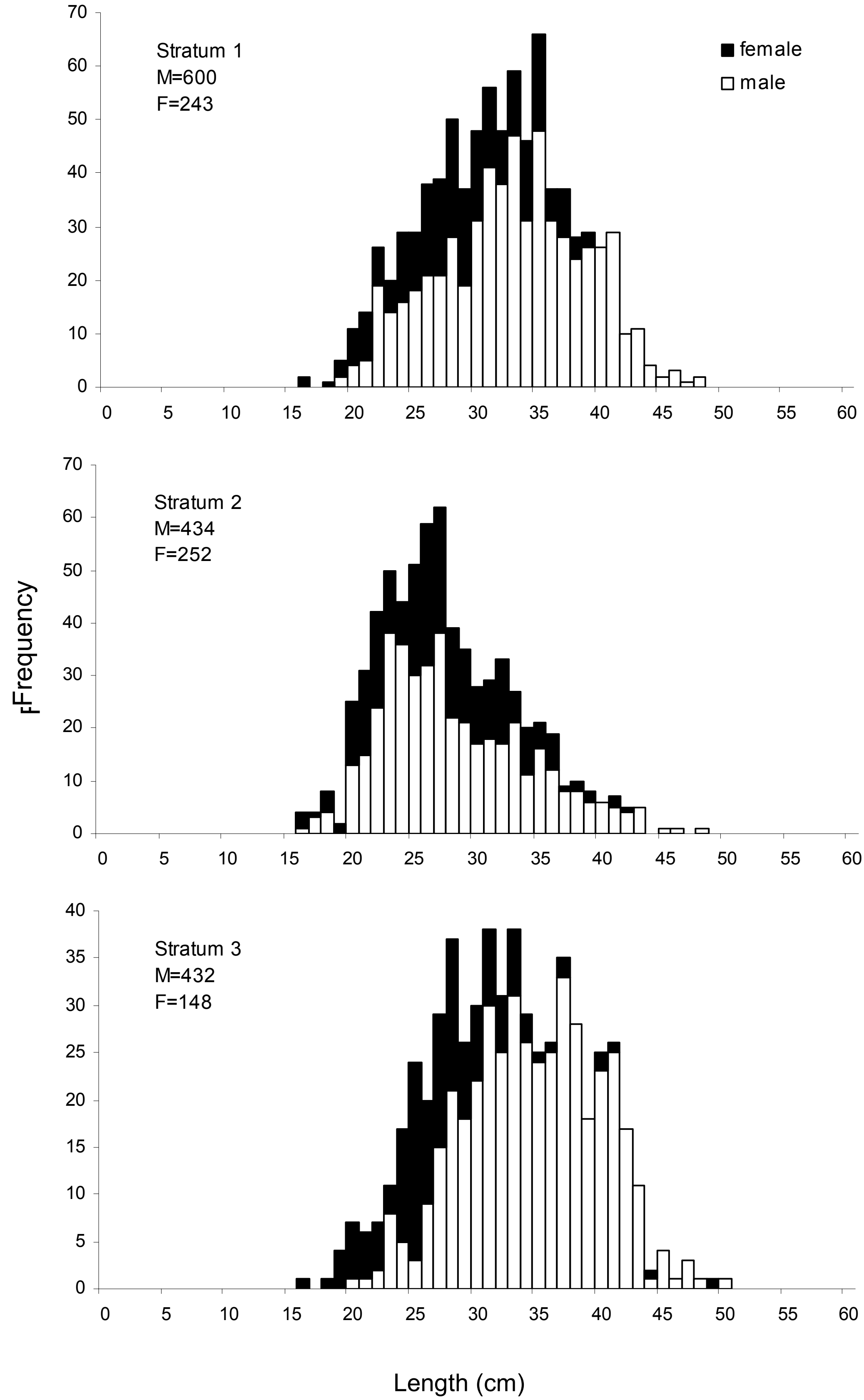


Figure 3: Unscaled length frequency distributions of blue cod for each stratum (1–6) and all strata combined for the 2009 survey.

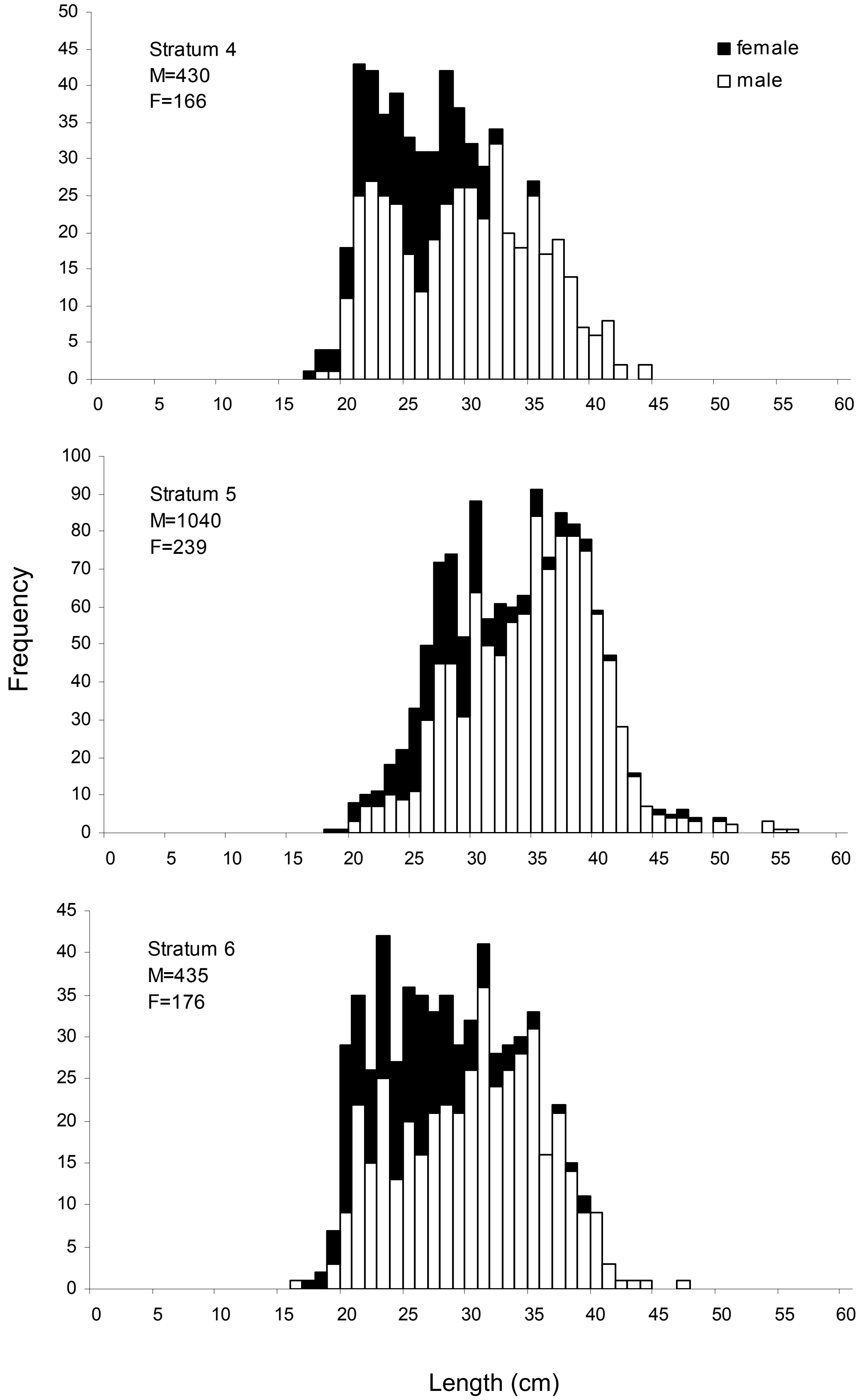


Figure 3 – ***continued***

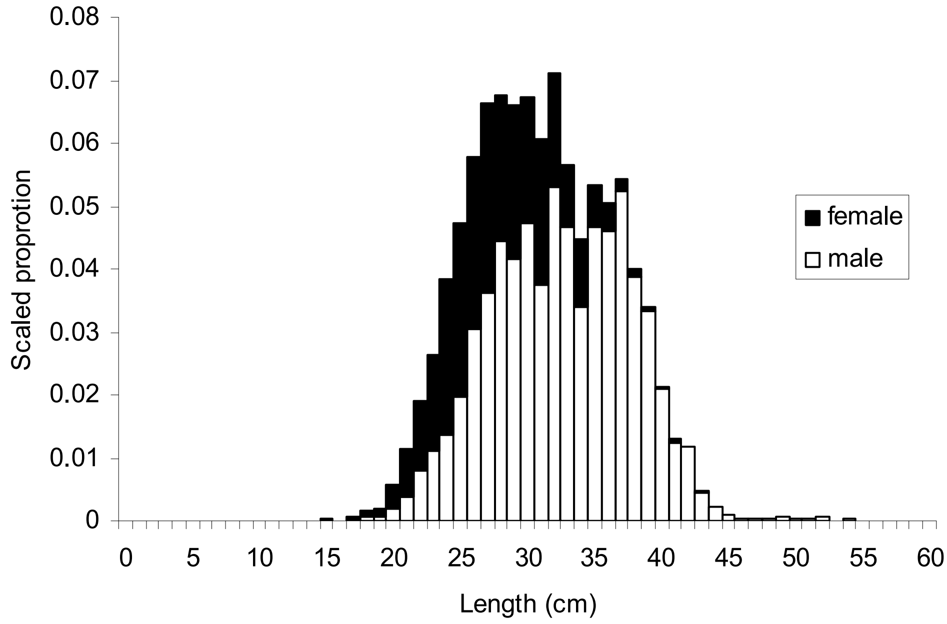


Figure 3 – ***continued. Scaled length frequency for all strata combined.***

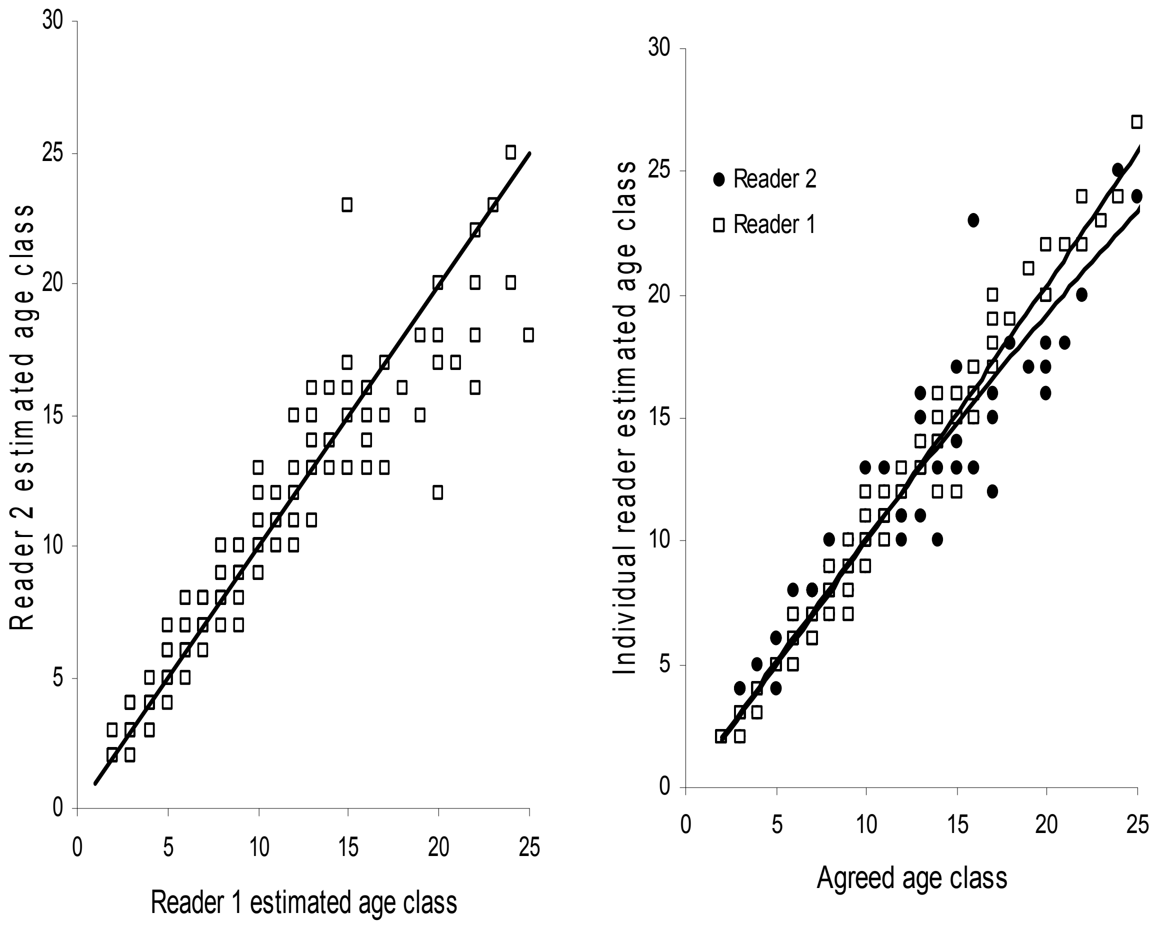


Figure 4: 2009 survey comparison of individual reader age class estimates from otoliths plotted against each other on the left and against the agreed age class estimates on the right (n = 293). Polynomial trend lines are fitted to the individual reader age class estimates on the right and to the fitted line in the left hand panel represents a 1:1 line.

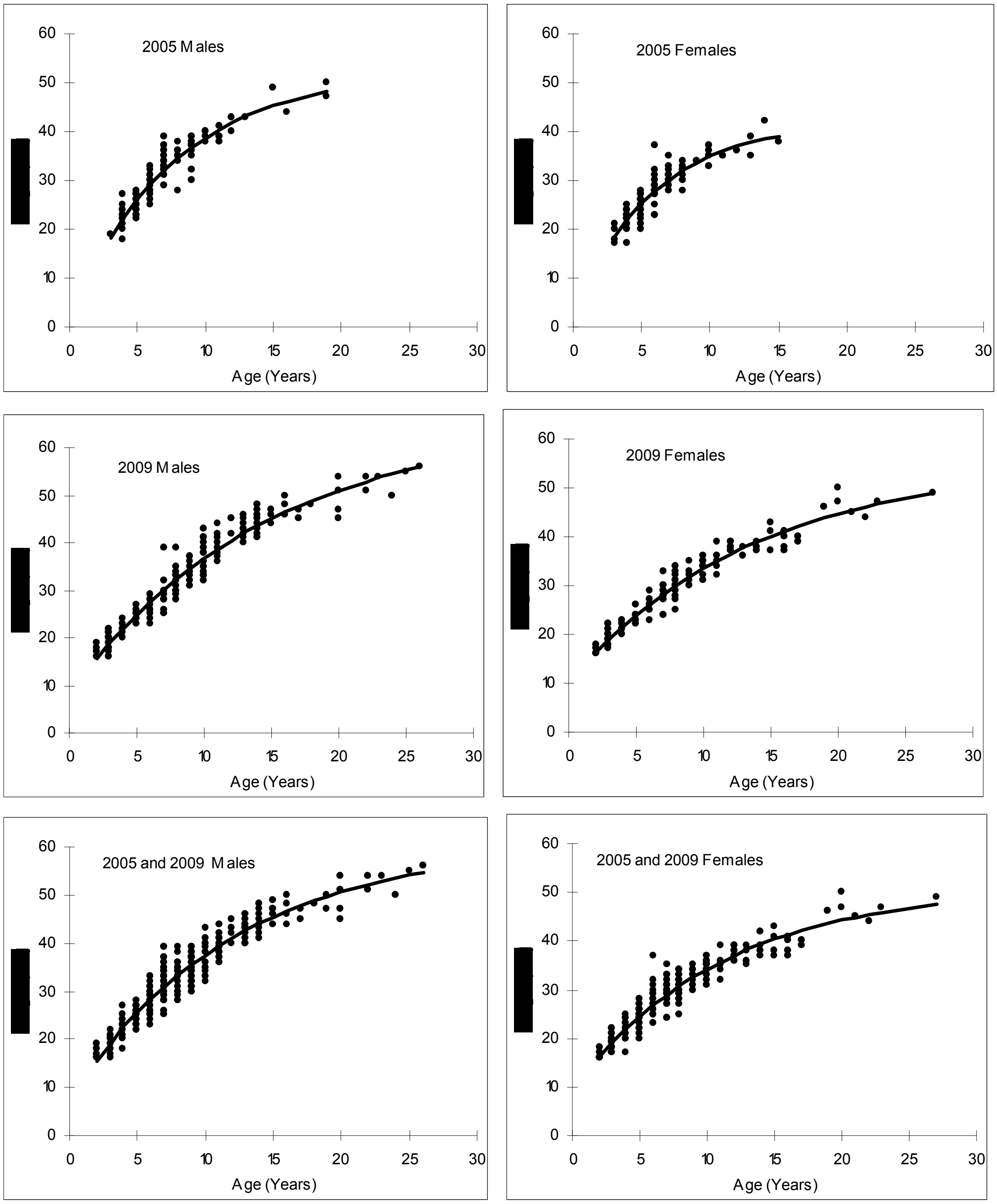


Figure 5: Observed age and length data by sex for the 2005 and 2009 north Otago surveys; von Bertalanffy growth models are fitted to the data separately by sex and for both surveys combined. See Table 8 for description of samples. The 2005 plots are for the original age length data, i.e., not supplemented with ages from 2009.

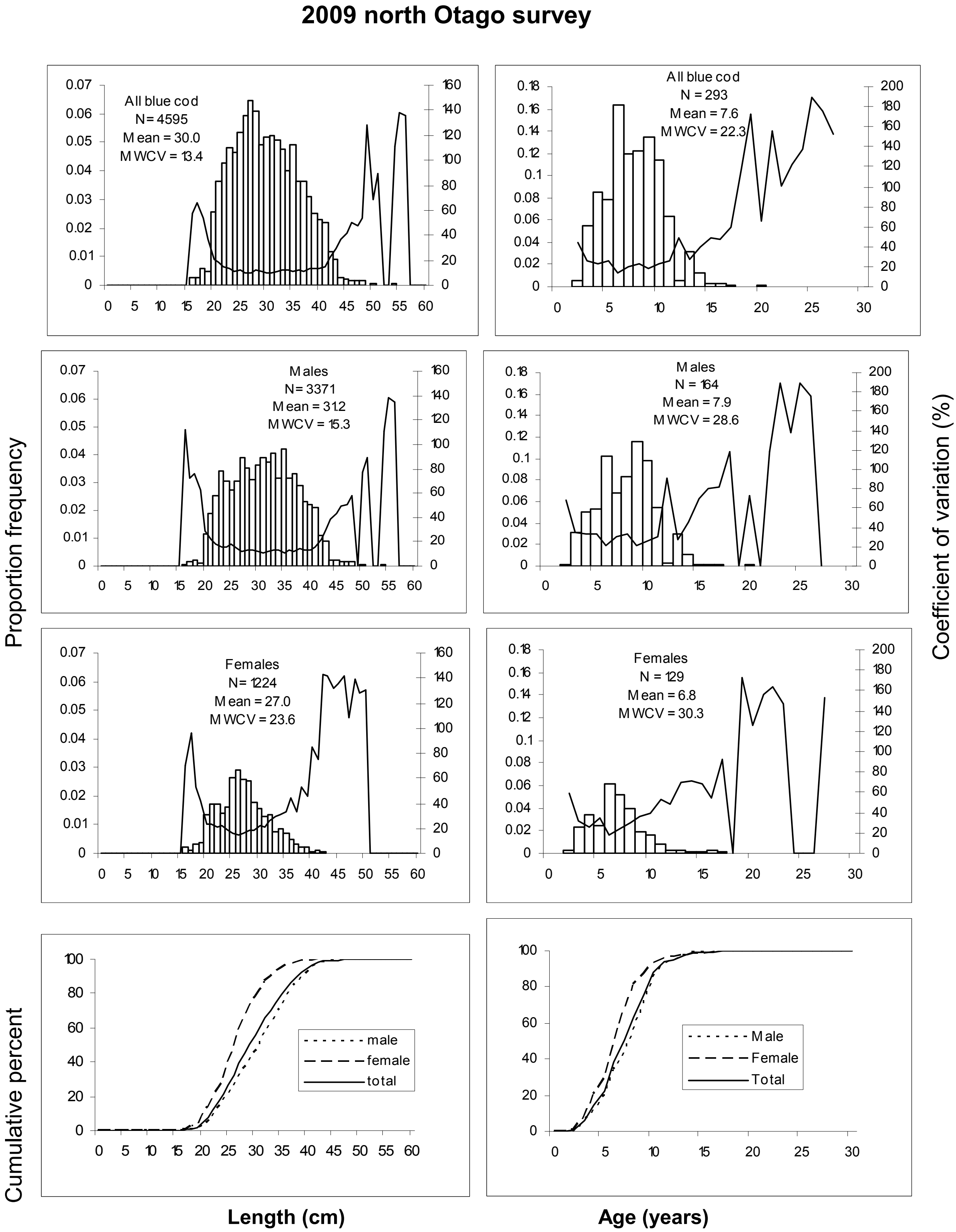


Figure 6: Scaled length frequency, age frequency, and cumulative distributions for total, male, and female blue cod for all strata (1–6) combined for the 2009 north Otago survey. N, sample size; MWCV, mean weighted coefficient of variation.

2005 north Otago survey

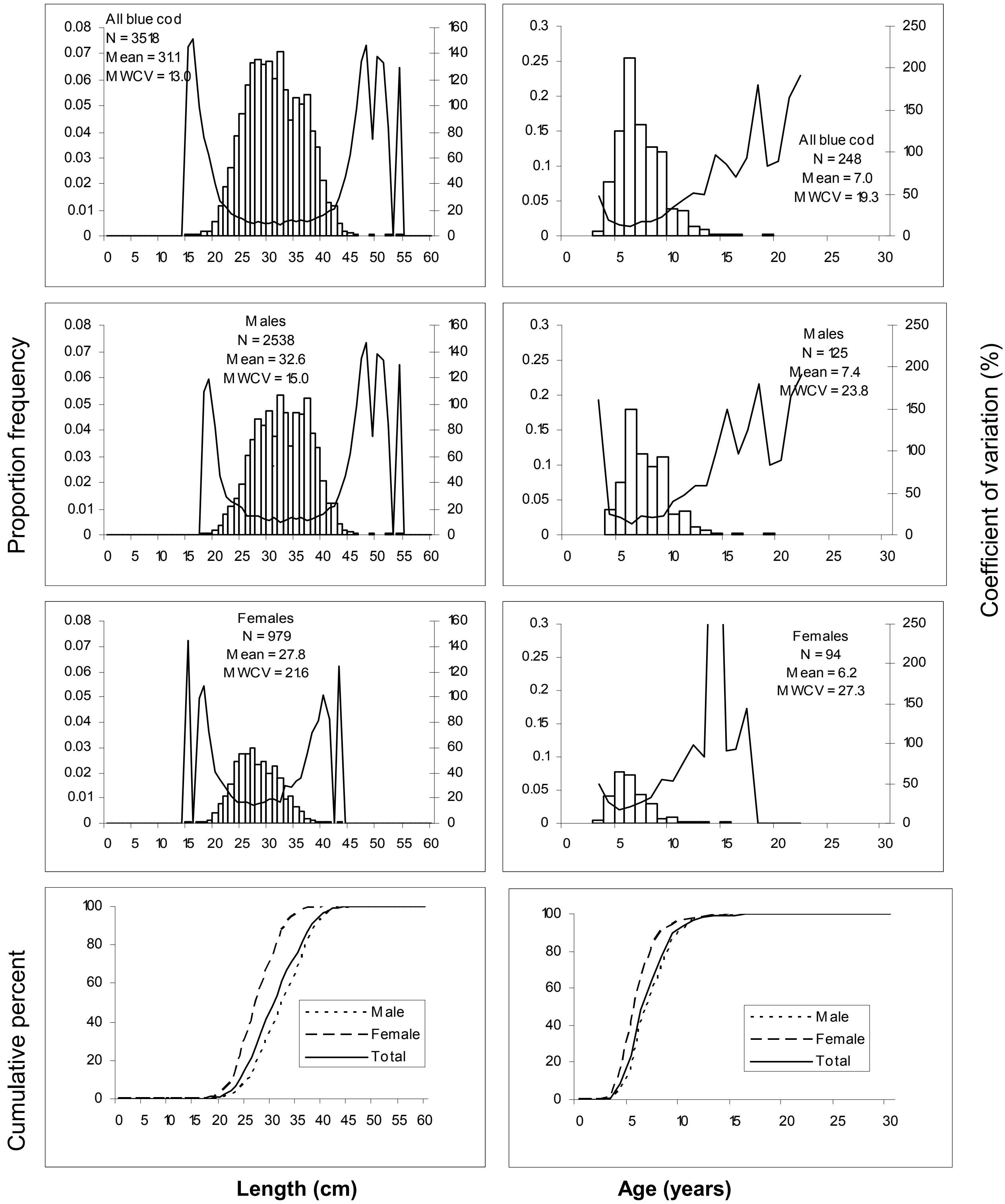


Figure 7: Scaled length frequency, age frequency, and cumulative distributions for total, male, and female blue cod for all strata (1–5) combined for the 2005 north Otago survey. N, sample size; MWCV, mean weighted coefficient of variation. See Carbines et al. (2008) for details. The 2005 age plots are supplemented with ages from 2009.

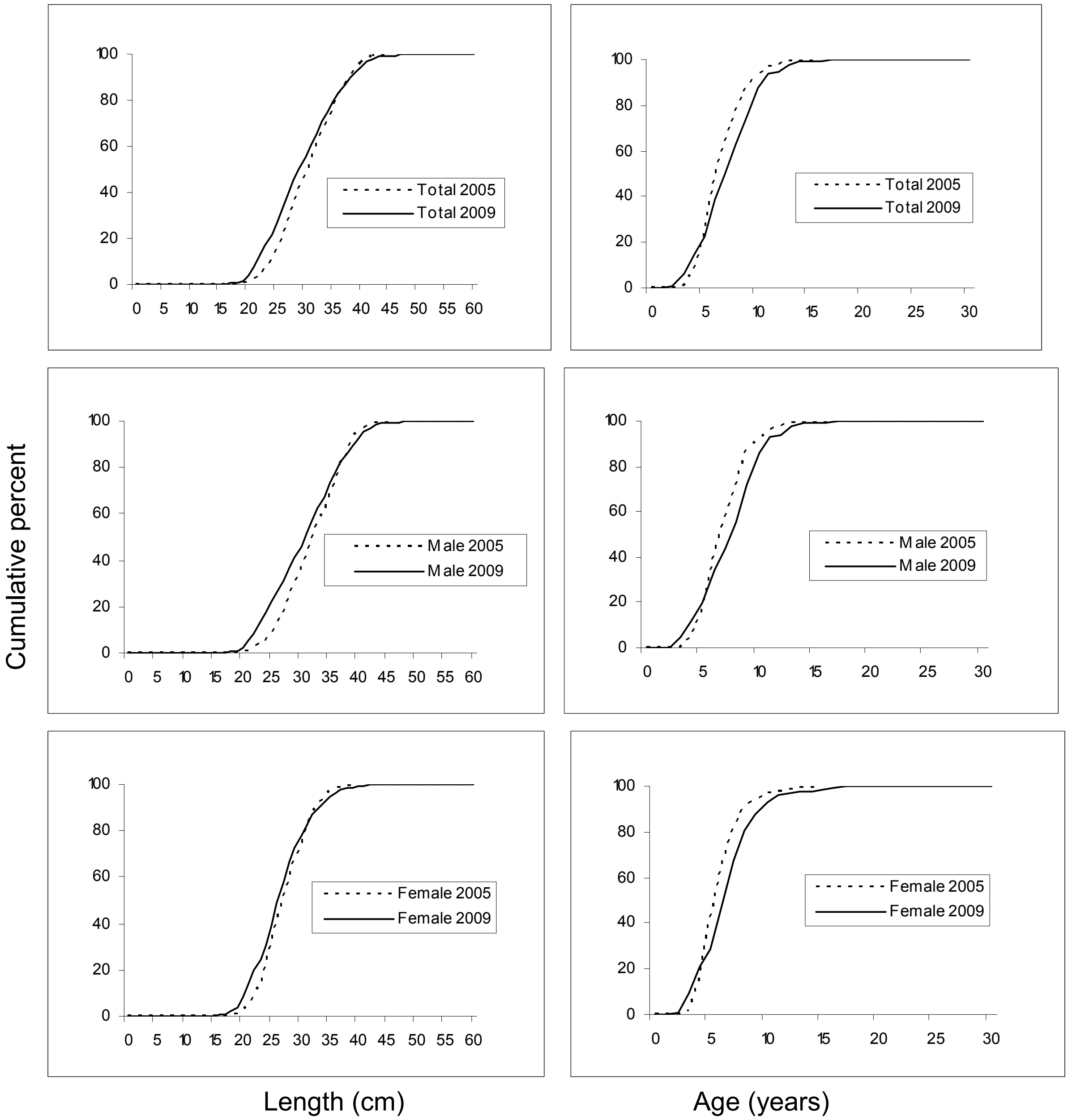


Figure 8: Scaled length and age cumulative frequency distributions for total, male, and female blue cod for the 2005 and 2009 north Otago surveys. The 2005 age plots are supplemented with ages from 2009.

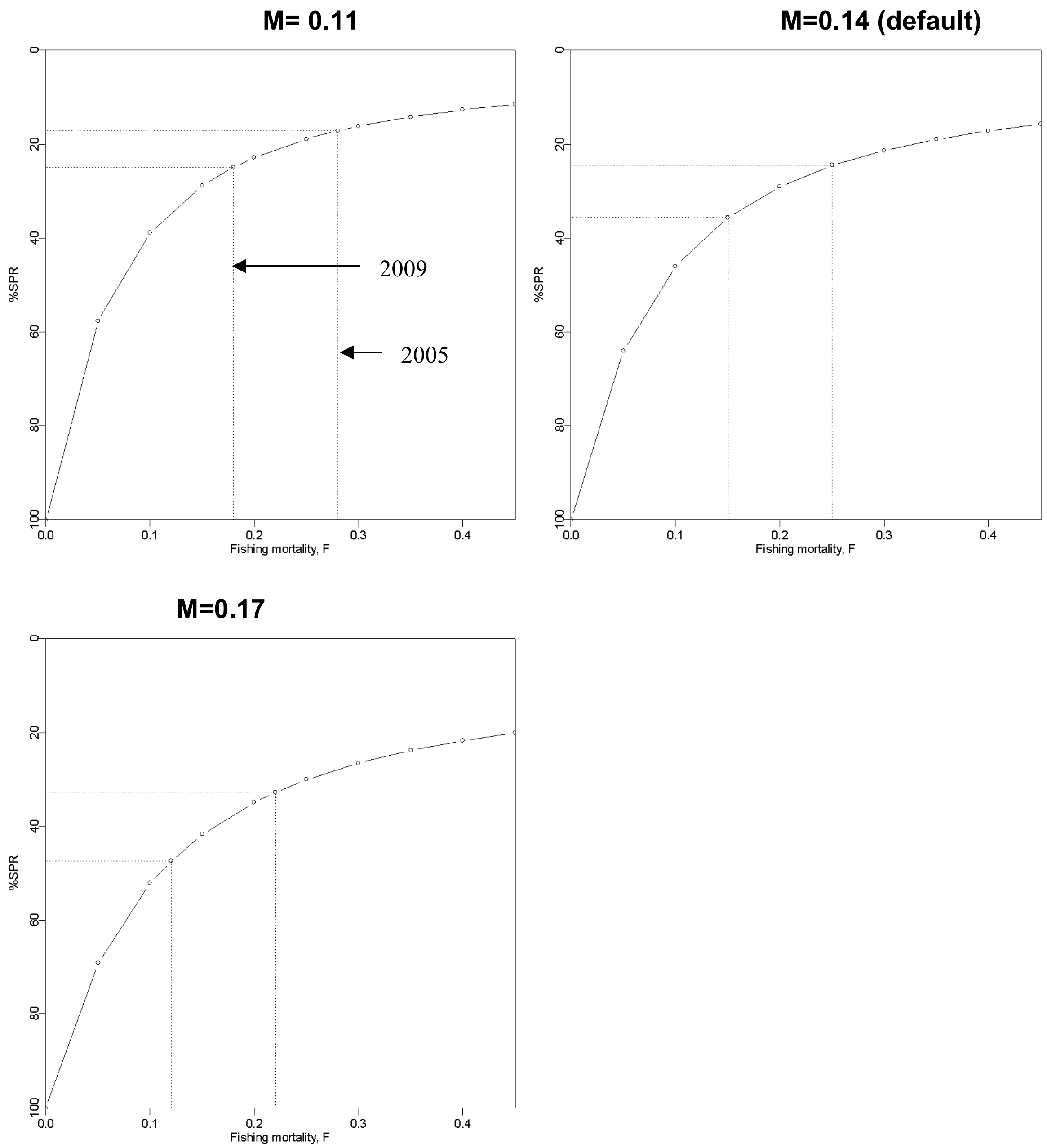
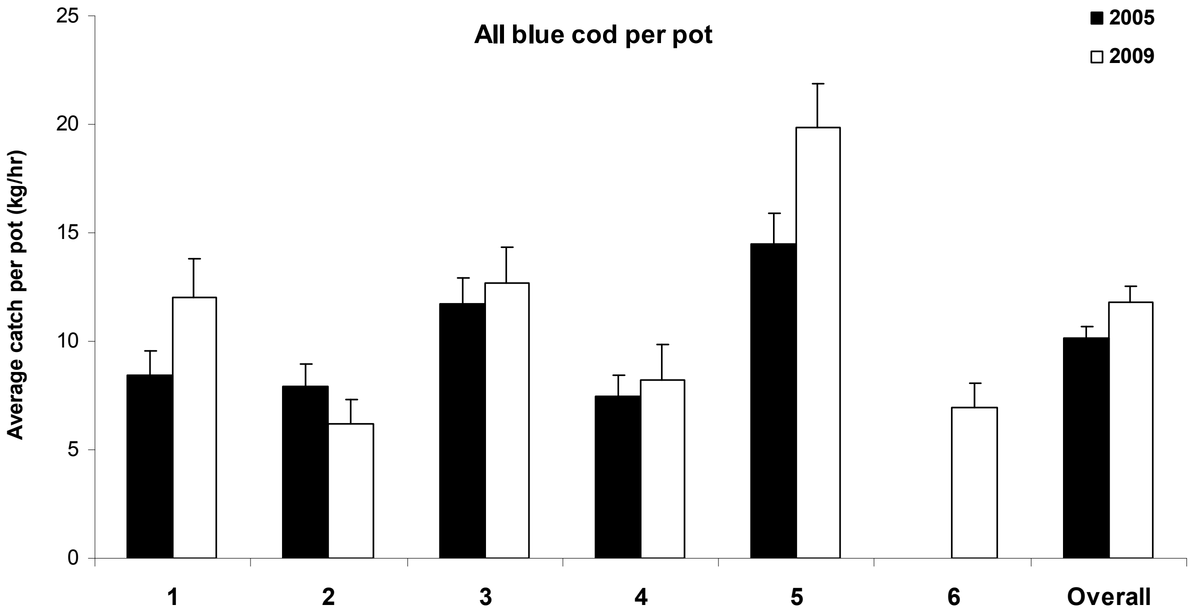


Figure 9: Plot of spawner per recruit (SPR) as a function of fishing mortality for the 2005 and 2009 north Otago surveys at three values of M (0.11, 0.14, 0.17). See Tables 10 and 11 for fishing mortalities and $F_{SPR\%}$. The y-axis has been inverted because a low fishing mortality corresponds to a high %SPR. The 2005 plots are based on Z estimates supplemented with ages from 2009.



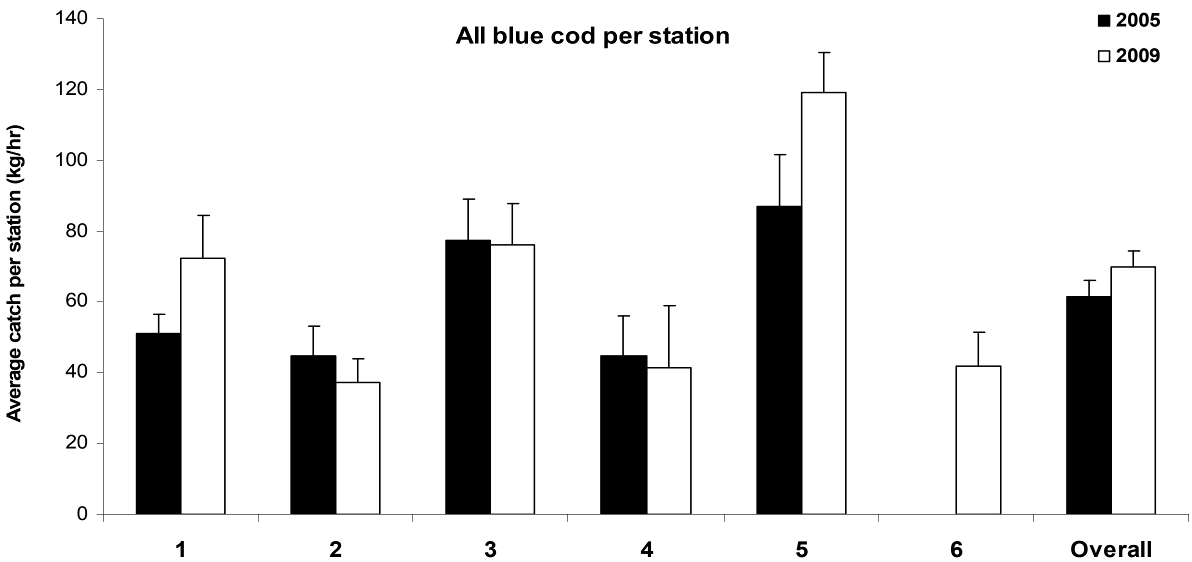


Figure 10: Between survey comparisons of mean standardised catch rates (kg/hour) by stratum (1–6) and overall weighted mean (excluding stratum 6) for all blue cod caught in the 2005 and 2009 north Otago potting surveys. Catch rates are presented both by pot landings and total station landings (i.e., the combined landings of the six pots at each station) blue cod. Error bars are the standard error of the mean.

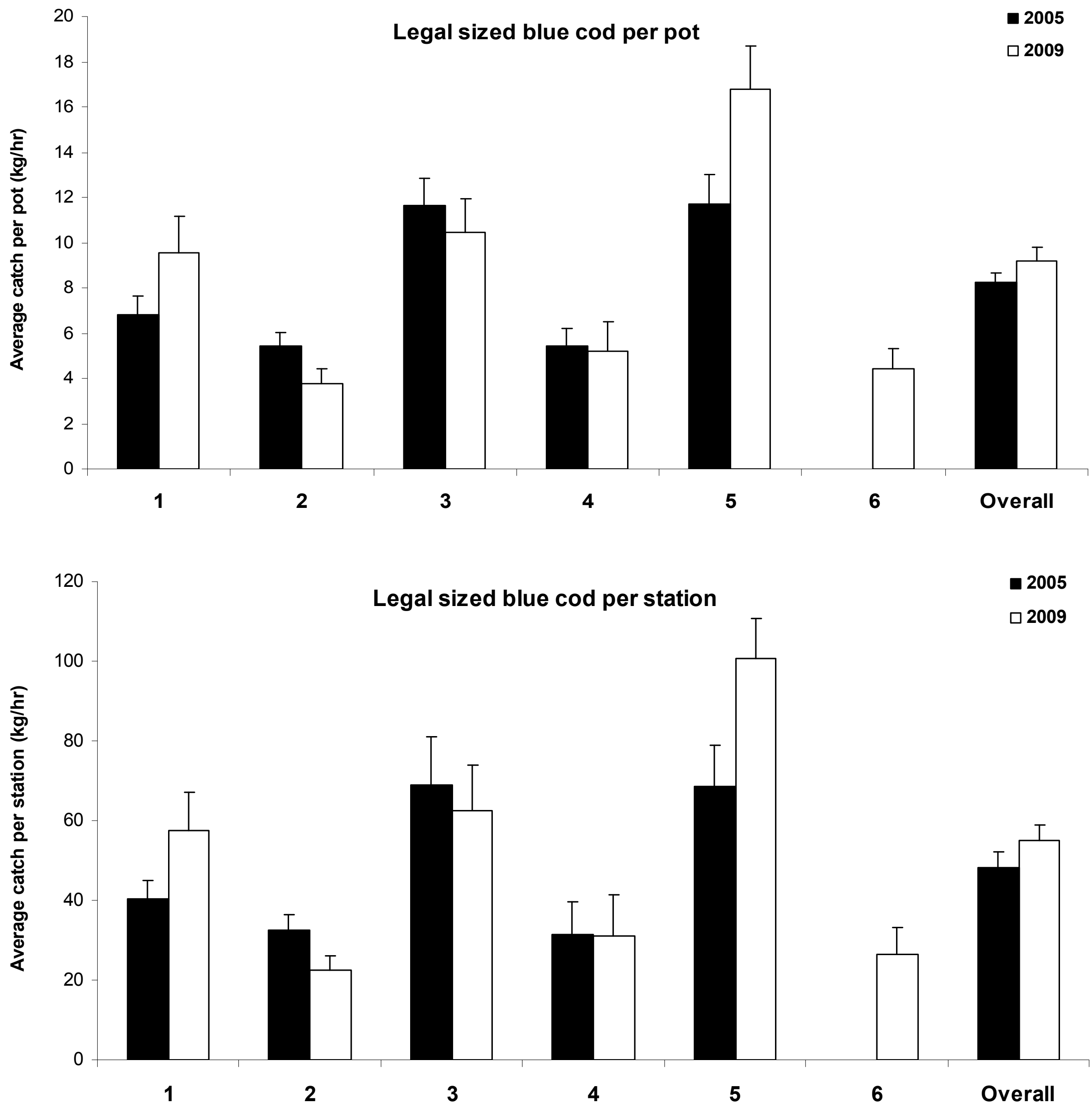


Figure 11: Between survey comparisons of mean standardised catch rates (kg/hour) by stratum (1–6) and overall weighted mean (excluding stratum 6) for legal sized (30 cm and over) blue cod caught in the 2005 and 2009 north Otago potting surveys. Catch rates are presented both by pot landings and total station landings (i.e., the combined landings of the six pots at each station) blue cod. Error bars are the standard error of the mean.

Appendix 1: Summary of the results from the 2005 north Otago survey

The initial potting survey was carried out off north Otago between 12 and 27 January 2005. Thirty-four stations were successfully surveyed (6 pots per station = 204 pot lifts) from three inshore and two offshore strata (Figure A). During phase 1, 150 pot lifts were completed (74%) with 54 in phase 2.

The total blue cod catch was 2079 kg, consisting of 3519 fish. The mean catch rates varied among all strata but were highest in both offshore strata (Figures 10 and 11). North Otago had some of the highest catch rates recorded from any area surveyed in the Ministry of Fisheries South Island potting survey network (Carbines et al. 2008). The overall mean catch rate and c.v. for the survey was 10.1 kg per pot lift and 5.4% respectively (Table A). For fish of all sizes, catch rates ranged from 7.5 kg per pot per hour in the southern inshore stratum off Shag Point to 14.5 kg per pot per hour for the southern offshore stratum, also off Shag Point. When analysed by station (i.e., the sum of the six pots catch) the c.v. increases by 2.6% to 8.0% overall for all blue cod (Table A). For blue cod 30 cm total length and over (local minimum legal size), catch rates by strata mirrored those of all fish, ranging from 5.4 to 11.7 kg per pot per hour with an overall mean catch rate and c.v. of 8.2 kg per pot per hour and 5.3% (Table B). When analysed by station the c.v. increases 2.4% to 7.7% overall for legal sized fish. For blue cod 33 cm and over (minimum legal size in other FMA's), highest and lowest catch rates again mirrored those of all fish and overall mean catch rate and c.v. for fish 33 cm and over were 6.38 kg per pot hour and 5.58% (Table C). When analysed by station the c.v. increases 2.8% to 8.4% overall for fish 33 cm and over.

Blue cod from the three inshore strata had similar size structures. This contrasted with fish from the two offshore strata, which were about 3–4 cm longer on average with fewer small fish. Males were longer than females in all strata and overall mean male length was 33.2 cm and female length 28.2 cm. Sixty-two percent of the 3518 blue cod caught exceeded the minimum legal size (30 cm and over). The occurrence of spent gonad stages also indicated that spawning had begun before the survey started in mid January 2005. Estimates of total mortality (*z*) for the 2005 survey are re-estimated and presented concurrently with 2009 survey estimates in the current report (See Table 9).

Table A: Mean blue cod catch rate (by pot and station landings), standard error, and c.v. per stratum and overall for all blue cod in 2005 (stratum 6 not surveyed).

Stratum	Pot lifts (N)	Mean (kg/pot)	s.e.	c.v. (%)	Mean (kg/stn)	s.e.	c.v. (%)
1	30	8.46	1.06	12.58	50.79	5.48	10.80
2	60	7.89	1.08	13.74	44.91	7.96	17.73
3	42	11.74	1.14	9.72	77.24	11.63	15.06
4	30	7.45	1.00	13.40	44.68	11.15	24.95
5	42	14.50	1.43	9.88	86.97	14.60	16.78
Overall	204	10.14	0.54	5.40	61.30	4.88	7.96

Appendix 1– ***continued***

Table B: Mean blue cod catch rate (by pot and station landings), standard error, and c.v. per stratum and overall for blue cod 30 cm and over (BCO 3 legal sized) in 2005.

Stratum	Pot lifts (N)	Mean (kg/pot)	s.e.	c.v. (%)	Mean (kg/stn)	s.e.	c.v. (%)
1	30	6.78	0.89	13.13	40.27	4.81	11.95
2	60	5.46	0.58	10.56	32.32	4.21	13.03
3	42	11.66	1.17	10.06	68.76	12.40	18.04
4	30	5.41	0.77	14.18	31.60	8.08	25.56
5	42	11.73	1.27	10.85	68.48	10.51	15.34
≥ 30 cm							
Overall	204	8.22	0.44	5.30	48.36	3.73	7.71

Table C: Mean blue cod catch rate (by pot and station landings), standard error, and c.v. per stratum and overall for blue cod 33 cm and over (legal sized in other FMAs) in 2005.

Stratum	Pot lifts (N)	Mean (kg/pot)	s.e.	c.v. (%)	Mean (kg/stn)	s.e.	c.v. (%)
1	30	5.20	0.70	13.41	31.20	5.24	16.78
2	60	3.83	0.38	9.83	23.00	2.77	12.05
3	42	9.62	1.04	10.81	57.74	11.33	19.62
4	30	4.15	0.59	14.16	24.05	5.61	23.32
5	42	9.25	1.07	11.52	55.50	8.86	15.97
≥ 33 cm							
Overall	204	6.38	0.36	5.58	38.18	3.19	8.35

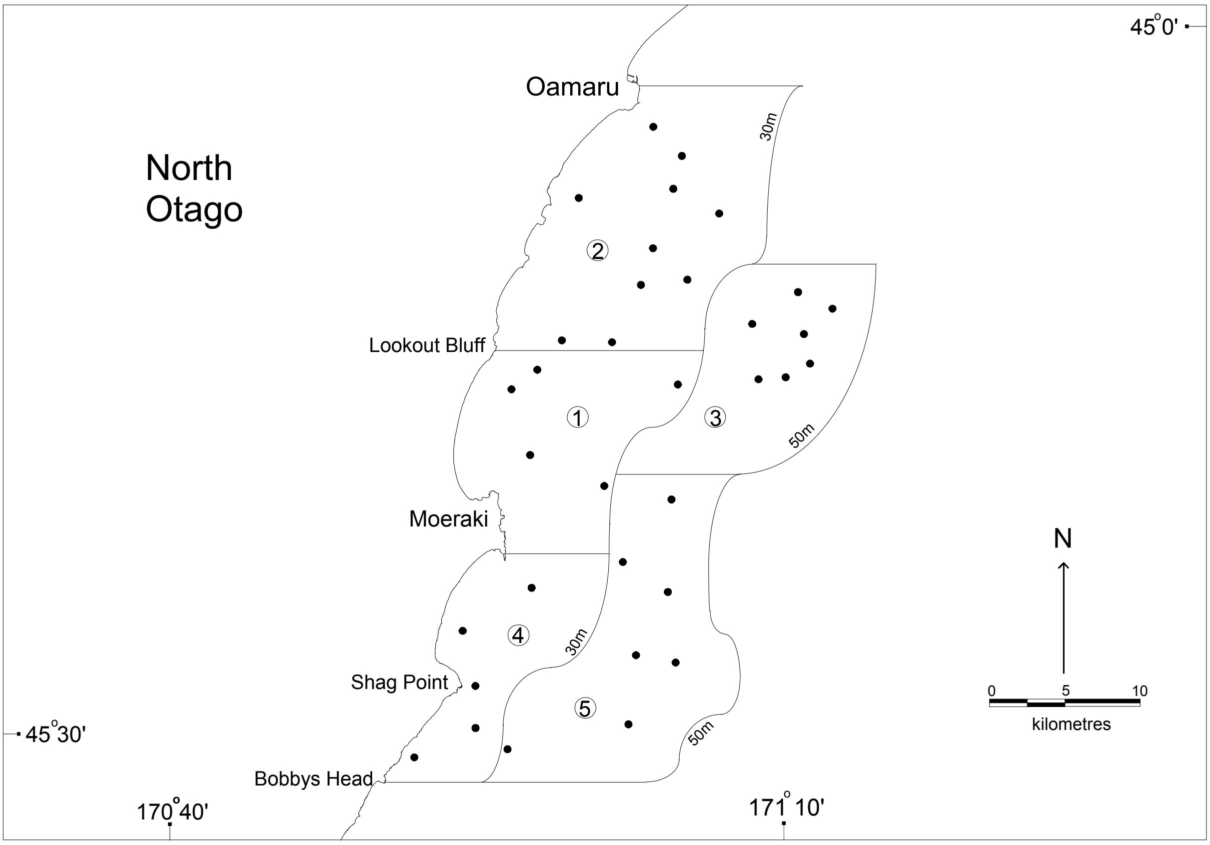


Figure A: Map of north Otago coast showing strata (1–5) and stations sampled for the 2005 survey.

Appendix 2: 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

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

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 2005 and 2009 North Otago 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 $\hat{Z}$.

Appendix 2– *continued*

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 (σ_R = 0.7), and also consider low (σ_R = 0.5) and high levels (σ_R = 1.0) based on the lower and upper quartiles.

Appendix 3: Summary of survey pot lift station data, north Otago 2009.

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	16-Jan-09	1	1	B	33	7:05	1	3.8	10
1	16-Jan-09	1	1	B	33	7:10	2	15.1	25
1	16-Jan-09	1	1	B	33	7:15	3	18.7	33
1	16-Jan-09	1	1	B	33	7:25	4	9.7	18
1	16-Jan-09	1	1	B	33	7:30	5	10.7	22
1	16-Jan-09	1	1	B	34	7:35	6	18.4	30
2	16-Jan-09	1	3	E	38	9:20	6	1.8	4
2	16-Jan-09	1	3	E	37	9:25	5	18.6	24
2	16-Jan-09	1	3	E	38	9:30	4	10.6	16
2	16-Jan-09	1	3	E	39	9:35	3	12.9	24
2	16-Jan-09	1	3	E	38	9:40	2	17.8	20
2	16-Jan-09	1	3	E	39	9:44	1	9.2	22
3	16-Jan-09	1	3	C	36	11:12	1	10.8	19
3	16-Jan-09	1	3	C	38	11:17	2	4.4	8
3	16-Jan-09	1	3	C	38	11:20	3	6.3	16
3	16-Jan-09	1	3	C	40	11:24	4	5.7	11
3	16-Jan-09	1	3	C	39	11:27	5	4.5	11
3	16-Jan-09	1	3	C	40	11:33	6	5.4	16
4	19-Jan-09	1	3	D	42	7:03	6	5.6	16
4	19-Jan-09	1	3	D	42	7:07	5	39.2	52
4	19-Jan-09	1	3	D	44	7:10	4	35.4	48
4	19-Jan-09	1	3	D	44	7:14	3	4.2	8
4	19-Jan-09	1	3	D	43	7:18	2	15.7	21
4	19-Jan-09	1	3	D	41	7:23	1	9.3	13
5	19-Jan-09	1	3	F	44	11:00	1	13.3	17
5	19-Jan-09	1	3	F	44	11:05	2	18.8	25
5	19-Jan-09	1	3	F	44	11:09	3	24.1	28
5	19-Jan-09	1	3	F	43	11:14	4	5.7	12
5	19-Jan-09	1	3	F	44	11:16	5	8.1	14
5	19-Jan-09	1	3	F	46	11:21	6	14.9	23
6	19-Jan-09	1	3	A	35	13:30	6	8.1	12
6	19-Jan-09	1	3	A	38	13:33	5	12.7	23
6	19-Jan-09	1	3	A	37	13:38	4	16.6	19
6	19-Jan-09	1	3	A	38	13:42	3	16.5	23
6	19-Jan-09	1	3	A	38	13:45	2	23.0	33
6	19-Jan-09	1	3	A	38	13:50	1	0.9	2
7	20-Jan-09	1	5	E	40	7:45	1	52.3	61
7	20-Jan-09	1	5	E	41	7:49	2	12.3	15
7	20-Jan-09	1	5	E	40	7:53	3	23.4	41
7	20-Jan-09	1	5	E	39	7:57	4	27.2	32
7	20-Jan-09	1	5	E	41	8:00	5	12.4	22
7	20-Jan-09	1	5	E	39	8:04	6	26.8	38
8	20-Jan-09	1	5	B	44	10:45	6	4.7	7
8	20-Jan-09	1	5	B	45	10:49	5	12.0	22
8	20-Jan-09	1	5	B	44	10:50	4	14.3	27
8	20-Jan-09	1	5	B	44	10:57	3	22.9	34
8	20-Jan-09	1	5	B	45	11:00	2	0.3	2

Set	Date	Phase	Stratum	Pot lift station	Depth (m)	Time set	Pot number	Catch of blue cod (kg)	Number of fish
8	20-Jan-09	1	5	B	46	11:05	1	1.2	2
9	20-Jan-09	1	5	C	38	12:37	1	16.4	22
9	20-Jan-09	1	5	C	39	12:42	2	23.3	38
9	20-Jan-09	1	5	C	39	12:46	3	11.5	20
9	20-Jan-09	1	5	C	40	12:50	4	17.1	25
9	20-Jan-09	1	5	C	39	12:54	5	30.3	43
9	20-Jan-09	1	5	C	40	12:59	6	10.1	16
10	21-Jan-09	1	5	F	36	7:20	6	20.6	30
10	21-Jan-09	1	5	F	35	7:24	5	45.9	63
10	21-Jan-09	1	5	F	34	7:28	4	14.0	21
10	21-Jan-09	1	5	F	34	7:32	3	18.7	32
10	21-Jan-09	1	5	F	30	7:36	2	15.3	36
10	21-Jan-09	1	5	F	34	7:40	1	14.0	29
11	21-Jan-09	1	5	G	36	9:55	1	43.7	65
11	21-Jan-09	1	5	G	35	9:59	2	11.6	24
11	21-Jan-09	1	5	G	35	10:03	3	18.0	26
11	21-Jan-09	1	5	G	34	10:07	4	19.2	27
11	21-Jan-09	1	5	G	34	10:11	5	21.1	35
11	21-Jan-09	1	5	G	34	10:15	6	23.0	45
12	21-Jan-09	1	1	A	30	12:00	6	16.8	26
12	21-Jan-09	1	1	A	30	12:04	5	13.8	23
12	21-Jan-09	1	1	A	30	12:08	4	0.0	0
12	21-Jan-09	1	1	A	31	12:12	3	4.8	5
12	21-Jan-09	1	1	A	30	12:16	2	6.7	6
12	21-Jan-09	1	1	A	30	12:20	1	18.7	29
13	21-Jan-09	1	1	G	25	13:55	1	46.5	97
13	21-Jan-09	1	1	G	26	13:59	2	40.8	70
13	21-Jan-09	1	1	G	27	14:03	3	1.6	2
13	21-Jan-09	1	1	G	27	14:07	4	5.6	8
13	21-Jan-09	1	1	G	28	14:11	5	7.6	11
13	21-Jan-09	1	1	G	29	14:15	6	4.6	5
14	22-Jan-09	1	2	E	25	7:45	6	4.9	10
14	22-Jan-09	1	2	E	24	7:49	5	4.2	8
14	22-Jan-09	1	2	E	23	7:53	4	6.2	14
14	22-Jan-09	1	2	E	24	7:57	3	23.4	73
14	22-Jan-09	1	2	E	23	7:59	2	6.2	14
14	22-Jan-09	1	2	E	23	8:03	1	14.0	47
15	22-Jan-09	1	1	C	25	9:38	1	9.8	26
15	22-Jan-09	1	1	C	24	9:42	2	7.4	18
15	22-Jan-09	1	1	C	24	9:46	3	34.2	50
15	22-Jan-09	1	1	C	23	9:50	4	2.7	3
15	22-Jan-09	1	1	C	22	9:54	5	13.4	16
15	22-Jan-09	1	1	C	21	9:58	6	4.1	15
16	22-Jan-09	1	1	D	30	11:36	1	5.2	6
16	22-Jan-09	1	1	D	29	11:40	2	10.5	16
16	22-Jan-09	1	1	D	29	11:44	3	1.1	1
16	22-Jan-09	1	1	D	30	11:48	4	1.4	2
16	22-Jan-09	1	1	D	32	11:52	5	2.1	2
16	22-Jan-09	1	1	D	33	11:56	6	1.6	2

Set	Date	Phase	Stratum	Pot lift station	Depth (m)	Time set	Pot number	Catch of blue cod (kg)	Number of fish
17	22-Jan-09	2	1	E	21	13:25	6	48.0	83
17	22-Jan-09	2	1	E	19	13:29	5	8.8	22
17	22-Jan-09	2	1	E	21	13:33	4	2.7	3
17	22-Jan-09	2	1	E	21	13:37	3	14.1	17
17	22-Jan-09	2	1	E	21	13:40	2	24.6	19
17	22-Jan-09	2	1	E	22	13:44	1	17.4	21
18	23-Jan-09	1	6	A	23	7:38	1	24.2	52
18	23-Jan-09	1	6	A	22	7:42	2	5.2	27
18	23-Jan-09	1	6	A	24	7:46	3	1.5	3
18	23-Jan-09	1	6	A	25	7:50	4	0.8	2
18	23-Jan-09	1	6	A	23	7:54	5	2.9	9
18	23-Jan-09	1	6	A	27	7:58	6	1.8	10
19	23-Jan-09	1	6	B	19	9:15	6	1.5	9
19	23-Jan-09	1	6	B	16	9:18	5	3.9	10
19	23-Jan-09	1	6	B	17	9:21	4	2.0	4
19	23-Jan-09	1	6	B	16	9:24	3	8.6	13
19	23-Jan-09	1	6	B	16	9:26	2	5.5	10
19	23-Jan-09	1	6	B	15	9:30	1	19.1	33
20	23-Jan-09	1	6	C	27	10:56	1	6.8	24
20	23-Jan-09	1	6	C	27	11:00	2	6.5	20
20	23-Jan-09	1	6	C	24	11:03	3	5.1	13
20	23-Jan-09	1	6	C	22	11:06	4	17.0	32
20	23-Jan-09	1	6	C	21	11:09	5	10.9	28
20	23-Jan-09	1	6	C	21	11:12	6	5.4	17
21	23-Jan-09	1	6	D	16	12:30	6	3.1	13
21	23-Jan-09	1	6	D	14	12:33	5	0.2	1
21	23-Jan-09	1	6	D	13	12:36	4	0.0	0
21	23-Jan-09	1	6	D	13	12:39	3	3.6	7
21	23-Jan-09	1	6	D	14	12:42	2	3.8	14
21	23-Jan-09	1	6	D	14	12:45	1	0.2	1
22	23-Jan-09	1	6	E	25	14:05	1	8.2	35
22	23-Jan-09	1	6	E	28	14:08	2	15.0	28
22	23-Jan-09	1	6	E	28	14:11	3	9.4	21
22	23-Jan-09	1	6	E	29	14:14	4	10.7	18
22	23-Jan-09	1	6	E	27	14:17	5	13.0	31
22	23-Jan-09	1	6	E	27	14:20	6	12.8	32
23	24-Jan-09	1	4	I	17	7:40	6	17.3	35
23	24-Jan-09	1	4	I	17	7:43	5	8.7	22
23	24-Jan-09	1	4	I	19	7:46	4	0.8	4
23	24-Jan-09	1	4	I	22	7:49	3	2.9	12
23	24-Jan-09	1	4	I	24	7:52	2	7.9	24
23	24-Jan-09	1	4	I	25	7:55	1	3.9	23
24	24-Jan-09	1	4	E	29	9:25	1	16.3	32
24	24-Jan-09	1	4	E	30	9:28	2	14.0	28
24	24-Jan-09	1	4	E	29	9:32	3	4.8	12
24	24-Jan-09	1	4	E	30	9:35	4	23.0	34
24	24-Jan-09	1	4	E	29	9:38	5	23.3	48
24	24-Jan-09	1	4	E	24	9:41	6	4.9	24
25	24-Jan-09	1	4	C	21	11:00	6	0.3	2

Set	Date	Phase	Stratum	Pot lift station	Depth (m)	Time set	Pot number	Catch of blue cod (kg)	Number of fish
25	24-Jan-09	1	4	C	19	11:03	5	0.0	0
25	24-Jan-09	1	4	C	17	11:06	4	0.0	0
25	24-Jan-09	1	4	C	12	11:09	3	0.0	0
25	24-Jan-09	1	4	C	14	11:12	2	0.0	0
25	24-Jan-09	1	4	C	13	11:15	1	1.4	8
26	24-Jan-09	1	4	B	15	12:36	1	9.4	13
26	24-Jan-09	1	4	B	15	12:39	2	6.5	20
26	24-Jan-09	1	4	B	13	12:41	3	3.9	8
26	24-Jan-09	1	4	B	14	12:44	4	4.4	13
26	24-Jan-09	1	4	B	14	12:47	5	7.5	24
26	24-Jan-09	1	4	B	14	12:50	6	5.0	11
27	26-Jan-09	1	2	F	18	7:15	6	2.9	2
27	26-Jan-09	1	2	F	18	7:18	5	4.7	13
27	26-Jan-09	1	2	F	18	7:21	4	2.2	3
27	26-Jan-09	1	2	F	19	7:24	3	2.7	2
27	26-Jan-09	1	2	F	19	7:28	2	0.0	0
27	26-Jan-09	1	2	F	19	7:31	1	1.4	3
28	26-Jan-09	1	2	D	19	8:55	1	1.7	4
28	26-Jan-09	1	2	D	18	8:58	2	9.2	22
28	26-Jan-09	1	2	D	19	9:02	3	0.9	1
28	26-Jan-09	1	2	D	19	9:05	4	1.3	6
28	26-Jan-09	1	2	D	19	9:07	5	1.0	3
28	26-Jan-09	1	2	D	18	9:10	6	5.6	23
29	26-Jan-09	1	2	A	22	10:46	6	8.1	29
29	26-Jan-09	1	2	A	22	10:49	5	0.0	0
29	26-Jan-09	1	2	A	23	10:53	4	0.0	0
29	26-Jan-09	1	2	A	22	10:56	3	0.0	0
29	26-Jan-09	1	2	A	22	10:59	2	33.3	82
29	26-Jan-09	1	2	A	22	11:02	1	2.2	4
30	26-Jan-09	1	2	H	27	12:26	1	0.0	0
30	26-Jan-09	1	2	H	26	12:30	2	0.0	0
30	26-Jan-09	1	2	H	27	12:33	3	2.2	2
30	26-Jan-09	1	2	H	28	12:36	4	1.1	1
30	26-Jan-09	1	2	H	29	12:39	5	0.1	1
30	26-Jan-09	1	2	H	29	12:42	6	20.9	60
31	28-Jan-09	2	5	D	30	7:45	1	37.3	41
31	28-Jan-09	2	5	D	36	7:50	2	5.6	12
31	28-Jan-09	2	5	D	46	7:54	3	23.7	44
31	28-Jan-09	2	5	D	43	7:58	4	15.6	20
31	28-Jan-09	2	5	D	46	8:03	5	11.8	24
31	28-Jan-09	2	5	D	45	8:08	6	21.1	38
32	28-Jan-09	2	5	I	40	9:55	6	0.0	0
32	28-Jan-09	2	5	I	39	10:00	5	55.4	71
32	28-Jan-09	2	5	I	39	10:03	4	1.5	8
32	28-Jan-09	2	5	I	39	10:06	3	4.6	4
32	28-Jan-09	2	5	I	40	10:09	2	38.7	29
32	28-Jan-09	2	5	I	40	10:11	1	46.6	45
33	28-Jan-09	2	5	H	39	12:00	1	19.4	28
33	28-Jan-09	2	5	H	40	12:04	2	20.1	36

Set	Date	Phase	Stratum	Pot lift station	Depth (m)	Time set	Pot number	Catch of blue cod (kg)	Number of fish
33	28-Jan-09	2	5	H	39	12:06	3	15.0	21
33	28-Jan-09	2	5	H	39	12:09	4	14.7	19
33	28-Jan-09	2	5	H	39	12:12	5	37.3	29
33	28-Jan-09	2	5	H	39	12:15	6	2.5	4
34	28-Jan-09	1	4	J	26	14:00	6	8.1	17
34	28-Jan-09	1	4	J	25	14:03	5	8.2	19
34	28-Jan-09	1	4	J	25	14:06	4	2.8	8
34	28-Jan-09	1	4	J	25	14:09	3	10.1	29
34	28-Jan-09	1	4	J	26	14:12	2	43.5	99
34	28-Jan-09	1	4	J	27	14:15	1	6.5	27
35	29-Jan-09	2	2	B	24	8:30	1	17.4	52
35	29-Jan-09	2	2	B	23	8:35	2	11.0	21
35	29-Jan-09	2	2	B	23	8:38	3	6.7	18
35	29-Jan-09	2	2	B	24	8:41	4	7.5	13
35	29-Jan-09	2	2	B	24	8:44	5	6.2	22
35	29-Jan-09	2	2	B	24	8:48	6	5.2	30
36	29-Jan-09	2	2	J	19	10:45	6	15.0	43
36	29-Jan-09	2	2	J	19	10:48	5	9.7	15
36	29-Jan-09	2	2	J	19	10:51	4	2.5	3
36	29-Jan-09	2	2	J	19	10:54	3	10.4	14
36	29-Jan-09	2	2	J	21	10:57	2	5.3	19
36	29-Jan-09	2	2	J	20	10:59	1	3.5	9
37	30-Jan-09	2	1	I	21	12:50	1	16.4	33
37	30-Jan-09	2	1	I	20	12:53	2	4.1	9
37	30-Jan-09	2	1	I	19	12:56	3	12.4	19
37	30-Jan-09	2	1	I	20	12:59	4	5.9	8
37	30-Jan-09	2	1	I	21	13:02	5	4.6	17
37	30-Jan-09	2	1	I	21	13:05	6	8.7	15

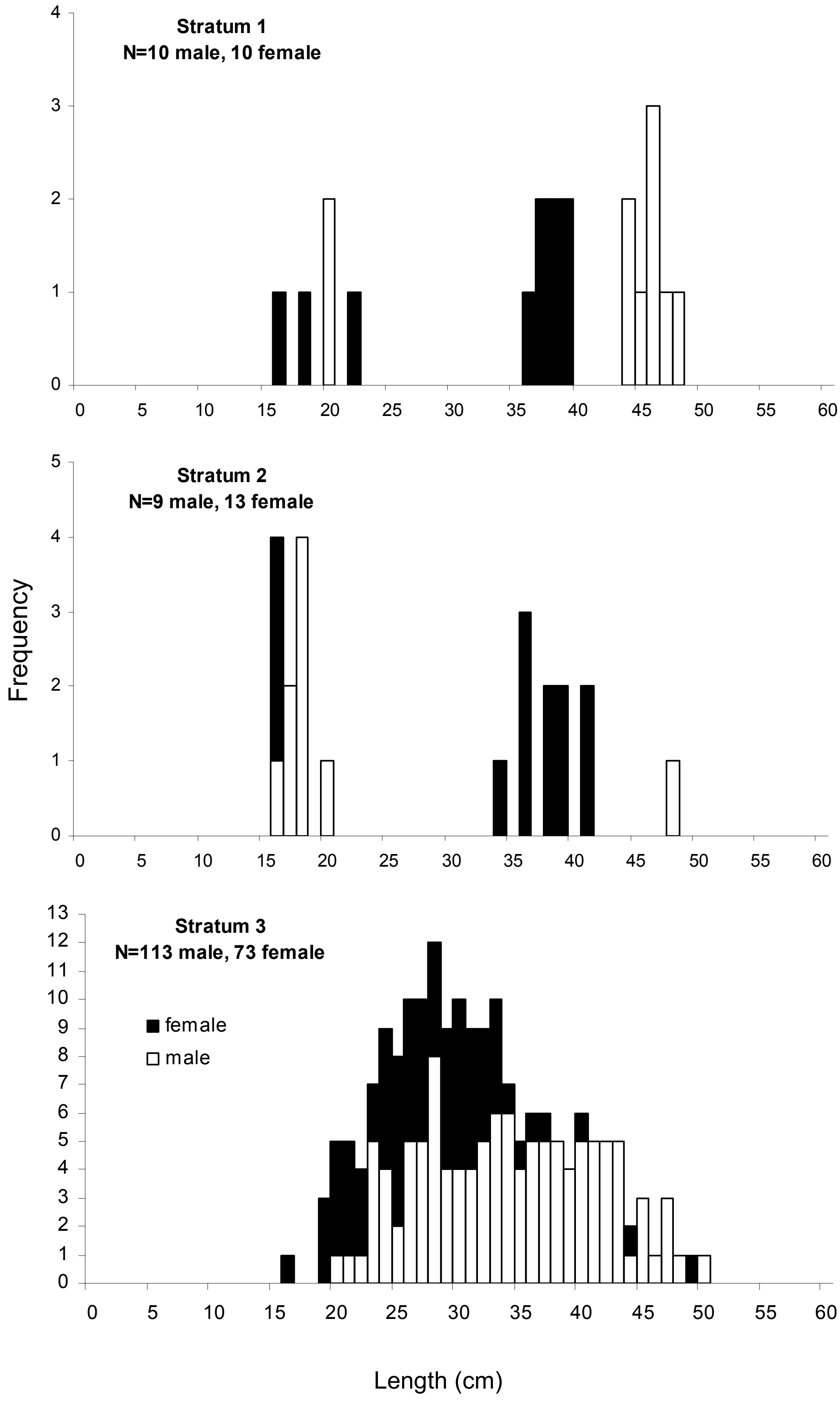
Appendix 4: Summary of north Otago oceanographic environmental station data recorded in the format of Ministry of Fisheries trawl data base. Depths are measured in metres, directions in compass degrees (999 = nil), wind force in the Beaufort scale, temperatures in degrees Celsius, air pressure in millibars, 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	33	000	3	19.1	1005	7	4	1	4.0	068	7	3	16.5	16.0	16.5	6.9
2	39	000	4	19.2	1005	7	4	1	3.5	068	7	3	16.0	16.3	21.5	6.8
3	36	000	3	22.5	1004	5	4	1	3.0	068	7	2	16.3	16.0	17.1	6.8
4	41	225	4	13.1	1004	2	3	1	1.0	180	7	2	14.5	14.5	16.3	7.6
5	44	315	2	22.8	1003	3	1	1	1.5	135	7	2	14.6	14.5	5.2	6.5
6	38	000	3	17.8	1000	7	3	1	1.0	135	7	4	15.5	15.5	9.5	6.0
7	40	270	3	17.1	1010	6	3	4	1.5	135	7	2	14.3	14.0	13.3	6.1
8	46	225	1	16.5	1012	7	3	4	1.0	135	7	3	14.3	14.0	2.3	8.0
9	38	045	2	17.2	1013	8	1	4	1.0	135	7	2	14.4	14.0	10.3	6.8
10	14	000	3	14.7	1017	3	3	1	1.0	135	7	1	14.4	14.2	19.1	7.3
11	36	000	4	20.1	1017	4	3	1	1.0	135	7	2	14.3	14.2	26.2	7.9
12	30	000	4	19.9	1016	7	4	1	1.0	135	7	2	14.4	14.3	23.5	7.4
13	25	022	4	18.7	1015	7	4	3	1.0	135	7	1	16.0	16.0	22.7	4.9
14	23	270	3	20.1	1017	7	1	5	0.0	999	7	1	16.1	16.0	16.0	6.1
15	25	270	0	29.7	1018	4	1	8	0.0	999	7	1	16.3	16.1	0.0	2.6
16	30	270	1	28.5	1017	3	1	8	0.0	999	7	1	16.3	16.1	6.1	2.8
17	22	270	1	28.5	1017	3	1	8	0.0	999	7	1	16.4	16.2	15.6	4.2
18	23	000	1	17.8	1015	8	1	6	0.5	135	7	3	15.5	15.5	4.1	6.0
19	15	000	2	20.2	1015	7	1	6	0.5	135	7	2	15.5	15.5	12.7	5.6
20	27	000	4	23.4	1013	4	4	6	0.5	135	7	1	15.5	15.5	23.0	6.6
21	14	000	3	24.1	1013	2	4	4	0.5	135	7	3	15.5	15.5	13.1	5.6
22	25	000	1	23.2	1013	3	4	4	0.5	135	7	1	15.5	15.4	7.0	5.7
23	25	999	0	19.2	1017	2	2	5	0.3	315	7	2	15.6	15.5	0.0	7.8
24	29	999	0	26.4	1017	3	2	4	0.3	315	7	1	15.6	15.5	0.0	8.5
25	13	999	0	25.1	1017	1	2	4	0.0	999	7	3	15.5	15.5	0.0	9.2

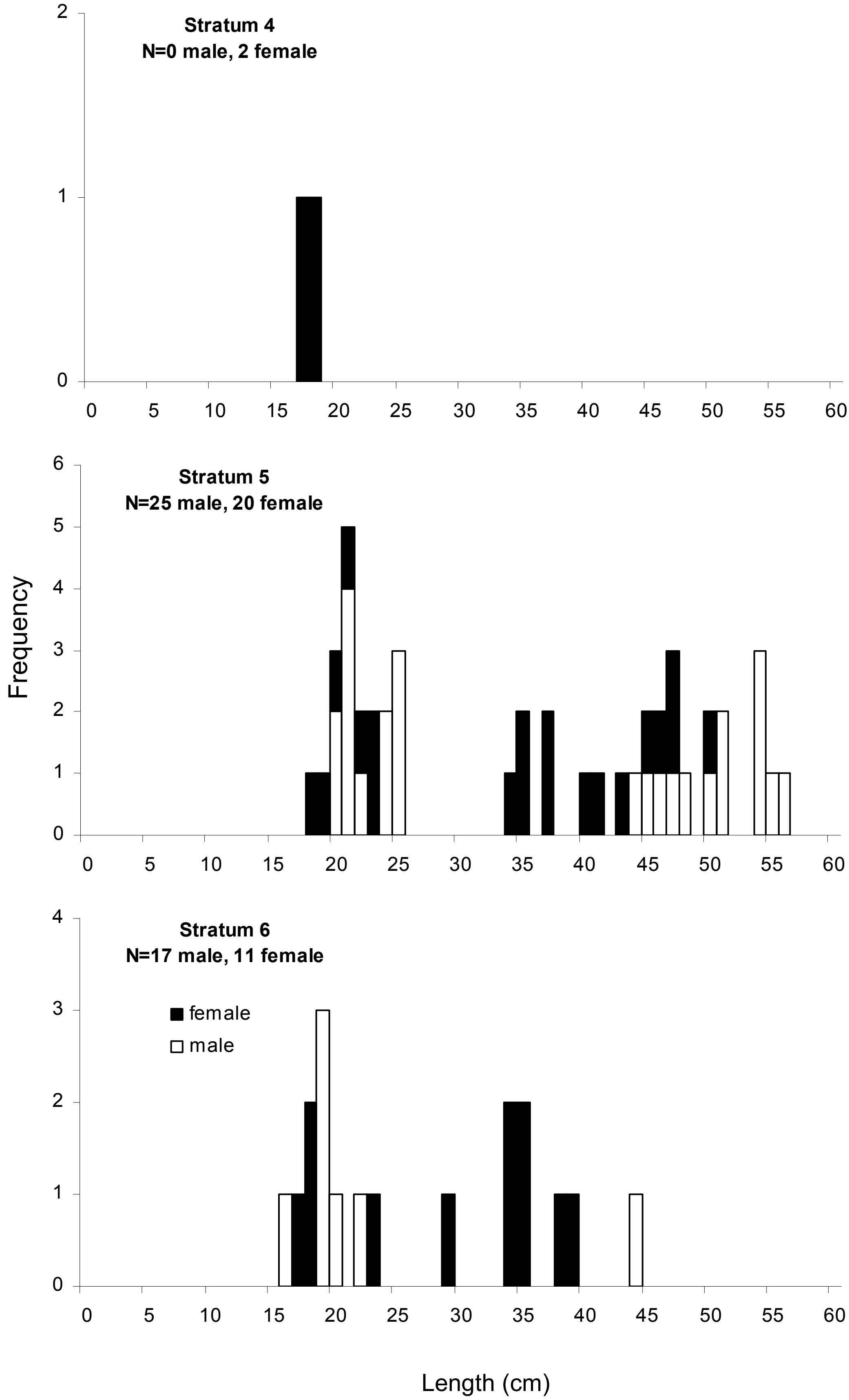
Appendix 4– *continued*.

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
26	15	045	1	28.1	1017	0	1	7	0.0	999	7	2	15.5	15.5	4.6	7.4
27	19	135	2	17.9	1017	4	1	4	0.5	135	7	1	16.3	16.3	12.0	6.9
28	19	135	1	23.4	1017	5	1	6	0.5	135	7	2	16.3	16.2	4.7	8.5
29	22	135	3	23.8	1016	2	1	4	0.8	135	7	1	16.5	16.6	17.0	7.8
30	27	135	3	21.5	1014	2	3	1	0.8	135	7	1	17.0	16.5	17.5	7.5
31	30	225	4	12.8	1017	2	4	6	1.0	180	7	3	14.5	14.0	21.2	8.1
32	40	180	1	18.1	1018	4	3	6	0.8	180	7	1	14.5	14.0	5.0	7.1
33	39	180	0	21.3	1017	6	3	6	0.5	180	7	2	14.5	14.1	1.0	7.0
34	27	045	3	23.1	1016	7	1	6	0.5	180	7	1	16.2	16.0	16.2	8.2
35	24	315	2	16.2	1014	8	1	6	0.5	135	7	2	15.5	15.5	10.0	7.5
36	20	315	3	18.0	1013	8	1	8	0.5	135	7	1	16.2	16.1	14.0	6.4
37	21	315	2	19.1	1012	8	3	6	0.5	135	7	1	16.1	15.9	7.5	6.2

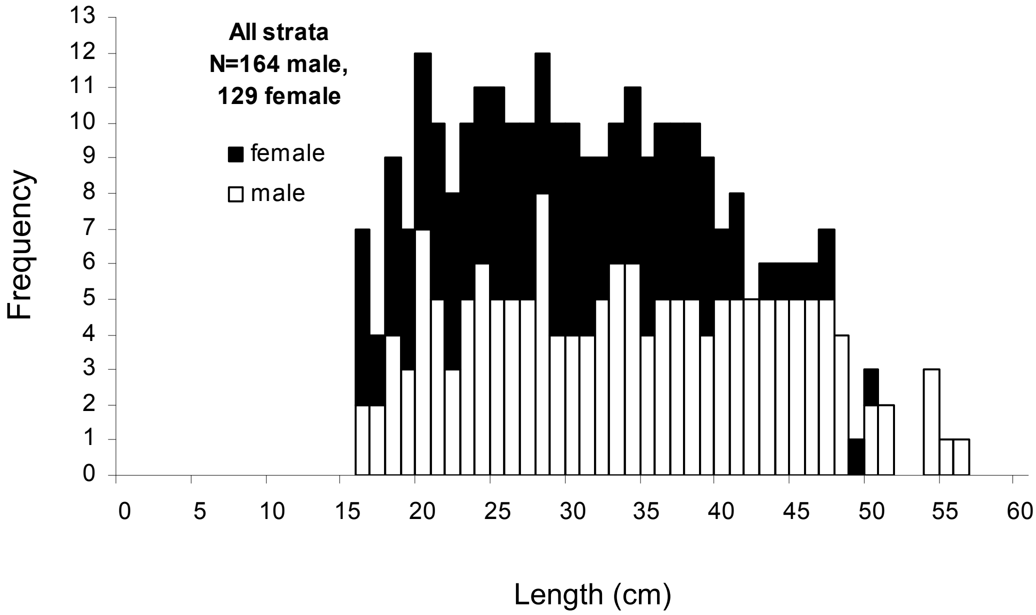
Appendix 5: Unscaled length frequency distributions of blue cod for each stratum and all strata combined from which otolith were used in the 2009 age length key.



Appendix 5 – *continued*



Appendix 5 – ***continued***



Appendix 6: Between-reader comparisons (using first independent readings only) for otolith data collected in north Otago 2009.

Reader two difference	Age class (reader one)																				Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	
-8																				1	1
-7																					0
-6																				1	1
-5																					0
-4																	1		1	3	5
-3																1				3	4
-2									1			3	2		2	2	1	1		2	14
-1			2	2	1	1	1	1	1	2	2	3		1		1			1	1	20
0		11	24	16	13	22	16	15	16	17	12	4	10	8	1	4	1			6	196
1		1	4	1	4	3	7	3	5	3	1	1	2		1					1	37
2					1	2		3		1			2	1	1						11
3										1		1	1								3
4																					0
5																					0
6																					0
7																					0
8															1						1
Total		12	30	19	19	28	24	22	23	24	15	12	17	10	6	8	3	1	2	18	293
% agreement		92	80	84	68	79	67	68	70	71	80	33	59	80	17	50	33	0	0	33	67

Appendix 7: Independent reader comparisons with agreed age from otolith data collected in north Otago 2009.

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
-3															1						1
-2									1					1							2
-1			1	1		3	4	1	1	1	2					1					15
0		11	29	19	16	24	20	21	21	21	14	7	16	9	4	5	1			11	249
1						2		1	1	1	1	1	1	1	2	2	1	1		2	17
2										2				1			1		1	3	8
3																	1				1
Total		11	30	20	16	29	24	23	24	25	17	8	17	12	7	8	4	1	1	16	293
% agreement		100	97	95	100	83	83	91	88	84	82	88	94	75	57	63	25	0	0	69	85

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
-5																	1				1
-4														1						1	2
-3																1				2	3
-2												1	1		2		1		1	4	10
-1			2	2	1	1		2	2	1	1	3		1	1	2	1			2	22
0		11	25	17	13	25	18	16	17	20	13	4	11	9	2	4	1	1		6	213
1			3	1	2	2	6	3	5	3	2		2		1					1	31
2						1		2			1		2	1	1						8
3										1			1								2
4																					0
5																					0
6																					0
7																1					1
Total		11	30	20	16	29	24	23	24	25	17	8	17	12	7	8	4	1	1	16	293
% agreement		100	83	85	81	86	75	70	71	80	76	50	65	75	29	50	25	100	0	38	73

Appendix 8: Estimates of proportion of length at age for male blue cod sampled from the north Otago 2005 survey (age -length-key, ALK). Supplemented with ages from 2009.

Length (cm)	Age (years)																		No. aged
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	
18	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
19	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
20	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
21	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
22	0	0.83	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
23	0	0.67	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
24	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
25	0	0.14	0.71	0.14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
26	0	0	0.67	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
27	0	0.14	0.57	0.29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
28	0	0	0.17	0.67	0	0.17	0	0	0	0	0	0	0	0	0	0	0	0	6
29	0	0	0	0.83	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	6
30	0	0	0	0.83	0	0	0.17	0	0	0	0	0	0	0	0	0	0	0	6
31	0	0	0	0.67	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	6
32	0	0	0	0.17	0.5	0	0.33	0	0	0	0	0	0	0	0	0	0	0	6
33	0	0	0	0.4	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	5
34	0	0	0	0	0.4	0.6	0	0	0	0	0	0	0	0	0	0	0	0	5
35	0	0	0	0	0.17	0.67	0.17	0	0	0	0	0	0	0	0	0	0	0	6
36	0	0	0	0	0.17	0.67	0.17	0	0	0	0	0	0	0	0	0	0	0	6
37	0	0	0	0	0.14	0	0.86	0	0	0	0	0	0	0	0	0	0	0	7
38	0	0	0	0	0	0.2	0.4	0.2	0.2	0	0	0	0	0	0	0	0	0	5
39	0	0	0	0	0.17	0	0.33	0.17	0.33	0	0	0	0	0	0	0	0	0	6
40	0	0	0	0	0	0	0	0.75	0	0.25	0	0	0	0	0	0	0	0	4
41	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
42	0	0	0	0	0	0	0	0	0.2	0.2	0.4	0.2	0	0	0	0	0	0	5
43	0	0	0	0	0	0	0	0	0	0.67	0.33	0	0	0	0	0	0	0	3
44	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
45	0	0	0	0	0	0	0	0	0	0.2	0.2	0.2	0	0	0.2	0	0	0.2	5
46	0	0	0	0	0	0	0	0	0	0	0.4	0.2	0.2	0.2	0	0	0	0	5
47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
48	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0.25	0	0.25	0	0	4
49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
53	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	1	1
No. aged	1	18	20	26	15	13	15	5	5	5	6	5	1	3	1	1	3	5	148

Appendix 9: Estimates of proportion of length at age for female blue cod sampled from the north Otago 2005 survey (age -length-key, ALK). Supplemented with ages from 2009.

																		Age (years)	
Length (cm)	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	No. aged
17	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
18	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
20	0.4	0.4	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
21	0.2	0.6	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
22	0	0.8	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
23	0	0.5	0.17	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
24	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
25	0	0.2	0.6	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
26	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
27	0	0	0.33	0.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
28	0	0	0.14	0.57	0.14	0.14	0	0	0	0	0	0	0	0	0	0	0	0	7
29	0	0	0	0.75	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	4
30	0	0	0	0.2	0.6	0.2	0	0	0	0	0	0	0	0	0	0	0	0	5
31	0	0	0	0.17	0.67	0.17	0	0	0	0	0	0	0	0	0	0	0	0	6
32	0	0	0	0.17	0.17	0.67	0	0	0	0	0	0	0	0	0	0	0	0	6
33	0	0	0	0	0.33	0.33	0	0.33	0	0	0	0	0	0	0	0	0	0	3
34	0	0	0	0	0	0.33	0.67	0	0	0	0	0	0	0	0	0	0	0	3
35	0	0	0	0	0.17	0	0	0.33	0.33	0	0.17	0	0	0	0	0	0	0	6
36	0	0	0	0	0	0	0	0.5	0	0.5	0	0	0	0	0	0	0	0	2
37	0	0	0	0.5	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	2
38	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
39	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5	0	0	0	2
41	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0.67	0	0	0	0	3
42	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
43	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
No. aged	6	17	18	18	12	9	2	5	2	1	2	1	3	3	1	0	0	0	100

Appendix 10: Estimates of proportion of length at age for male blue cod sampled from the north Otago 2009 survey (age -length-key, ALK).

	Age (years)																			
Length (cm)	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	No. aged
16	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
17	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
18	0.25	0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
19	0.33	0.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
20	0	0.71	0.29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
21	0	0.6	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
22	0	0.33	0.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
23	0	0	0.5	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
24	0	0	0.17	0.67	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
25	0	0	0	0.4	0.4	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	5
26	0	0	0	0.2	0.6	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	5
27	0	0	0	0.2	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
28	0	0	0	0	0.38	0.5	0.12	0	0	0	0	0	0	0	0	0	0	0	0	8
29	0	0	0	0	0.5	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	0	4
30	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	4
31	0	0	0	0	0	0	0.25	0.75	0	0	0	0	0	0	0	0	0	0	0	4
32	0	0	0	0	0	0.2	0.2	0.4	0.2	0	0	0	0	0	0	0	0	0	0	5
33	0	0	0	0	0	0	0.33	0.33	0.33	0	0	0	0	0	0	0	0	0	0	6
34	0	0	0	0	0	0	0.17	0.67	0.17	0	0	0	0	0	0	0	0	0	0	6
35	0	0	0	0	0	0	0.25	0.25	0.5	0	0	0	0	0	0	0	0	0	0	4
36	0	0	0	0	0	0	0	0.2	0.6	0.2	0	0	0	0	0	0	0	0	0	5
37	0	0	0	0	0	0	0	0.6	0	0.4	0	0	0	0	0	0	0	0	0	5
38	0	0	0	0	0	0	0	0	0.4	0.6	0	0	0	0	0	0	0	0	0	5
39	0	0	0	0	0	0.25	0.25	0	0.25	0.25	0	0	0	0	0	0	0	0	0	4
40	0	0	0	0	0	0	0	0	0.2	0.2	0	0.6	0	0	0	0	0	0	0	5
41	0	0	0	0	0	0	0	0	0.4	0.2	0	0.2	0.2	0	0	0	0	0	0	5
42	0	0	0	0	0	0	0	0	0	0.2	0.2	0.4	0.2	0	0	0	0	0	0	5
43	0	0	0	0	0	0	0	0	0.2	0	0	0.6	0.2	0	0	0	0	0	0	5
44	0	0	0	0	0	0	0	0	0	0.2	0	0.4	0.2	0.2	0	0	0	0	0	5
45	0	0	0	0	0	0	0	0	0	0	0.2	0.2	0.2	0	0	0.2	0	0	0.2	5
46	0	0	0	0	0	0	0	0	0	0	0	0.4	0.2	0.2	0.2	0	0	0	0	5
47	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0.4	0	0.2	0	0	0.2	5
48	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0.25	0	0.25	0	0	4
49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50	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	0	0	0	1	2
52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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	0.99	3
55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
No. aged	4	16	9	9	16	11	11	16	16	11	2	14	9	4	3	2	1	0	10	164

Appendix 11: Estimates of proportion of length at age for female blue cod sampled from the north Otago 2009 survey (age -length-key, ALK).

Length (cm)	Age (years) 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	No. aged
16	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
17	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
18	0.2	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
19	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
20	0	0.4	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
21	0	0.2	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
22	0	0.4	0.4	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
23	0	0	0.4	0.4	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
24	0	0	0	0.6	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	5
25	0	0	0	0	0.83	0	0.17	0	0	0	0	0	0	0	0	0	0	0	0	6
26	0	0	0	0.2	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
27	0	0	0	0	0.4	0.4	0.2	0	0	0	0	0	0	0	0	0	0	0	0	5
28	0	0	0	0	0	0.75	0.25	0	0	0	0	0	0	0	0	0	0	0	0	4
29	0	0	0	0	0.17	0.5	0.33	0	0	0	0	0	0	0	0	0	0	0	0	6
30	0	0	0	0	0	0.33	0.33	0.33	0	0	0	0	0	0	0	0	0	0	0	6
31	0	0	0	0	0	0	0.4	0.4	0.2	0	0	0	0	0	0	0	0	0	0	5
32	0	0	0	0	0	0	0.25	0.25	0.25	0.25	0	0	0	0	0	0	0	0	0	4
33	0	0	0	0	0	0.25	0.25	0.5	0	0	0	0	0	0	0	0	0	0	0	4
34	0	0	0	0	0	0	0.2	0	0.6	0.2	0	0	0	0	0	0	0	0	0	5
35	0	0	0	0	0	0	0	0.2	0.6	0.2	0	0	0	0	0	0	0	0	0	5
36	0	0	0	0	0	0	0	0	0.2	0.4	0	0.4	0	0	0	0	0	0	0	5
37	0	0	0	0	0	0	0	0	0	0	0.4	0	0.2	0.2	0.2	0	0	0	0	5
38	0	0	0	0	0	0	0	0	0	0	0.4	0.2	0.2	0	0.2	0	0	0	0	5
39	0	0	0	0	0	0	0	0	0	0.2	0.4	0	0.2	0	0	0.2	0	0	0	5
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5	0	0	0	2
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0.67	0	0	0	0	3
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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	0
56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
No. aged	7	14	11	7	13	13	12	8	9	6	6	3	3	3	5	2	0	1	6	129

Appendix 12: Mean-age-at-length for the 2005 north Otago survey. (Supplemented with ages from 2009).

Length (cm)	All fish		Males		Females	
	N	Mean age (y)	N	Mean age (y)	N	Mean age (y)
17	2	3.5	0	–	2	3.5
18	3	3.3	1	4.0	2	3.0
19	1	3.0	1	3.0	0	–
20	6	3.8	1	4.0	5	3.8
21	7	4.0	2	4.0	5	4.0
22	11	4.2	6	4.2	5	4.2
23	12	4.6	6	4.3	6	4.8
24	12	4.5	6	4.5	6	4.5
25	12	5.0	7	5.0	5	5.0
26	11	5.2	6	5.3	5	5.0
27	13	5.4	7	5.1	6	5.7
28	13	6.2	6	6.2	7	6.3
29	10	6.2	6	6.2	4	6.3
30	11	6.7	6	6.5	5	7.0
31	12	6.7	6	6.3	6	7.0
32	12	7.5	6	7.5	6	7.5
33	8	7.3	5	6.6	3	8.3
34	8	8.0	5	7.6	3	8.7
35	12	9.2	6	8.0	6	10.3
36	8	8.8	6	8.0	2	11.0
37	9	8.6	7	8.7	2	8.0
38	6	10.3	5	9.4	1	15.0
39	7	10.0	6	9.5	1	13.0
40	6	12.5	4	10.5	2	16.5
41	4	14.5	1	11.0	3	15.7
42	6	12.8	5	12.6	1	14.0
43	4	13.0	3	12.3	1	15.0
44	1	16.0	1	16.0	0	–
45	5	15.2	5	15.2	0	–
46	5	14.2	5	14.2	0	–
47	1	19.0	1	19.0	0	–
48	4	15.5	4	15.5	0	–
49	1	20.0	1	20.0	0	–
50	1	19.0	1	19.0	0	–
51	2	21.0	2	21.0	0	–
52	1	19.0	1	19.0	0	–
53	0	–	0	–	0	–
54	1	21.0	1	21.0	0	–
Total	248		148		100	

Appendix 13: Mean-age-at-length for the 2009 north Otago survey.

Length (cm)	All fish		Males		Females	
	N	Mean age (y)	N	Mean age (y)	N	Mean age (y)
16	7	2.1	2	2.5	5	2.0
17	4	2.5	2	2.5	2	2.5
18	9	2.8	4	2.8	5	2.8
19	7	2.9	3	2.7	4	3.0
20	12	3.4	7	3.3	5	3.6
21	10	3.6	5	3.4	5	3.8
22	8	3.8	3	3.7	5	3.8
23	9	4.8	4	4.8	5	4.8
24	11	5.4	6	5.0	5	5.8
25	11	6.1	5	5.8	6	6.3
26	10	5.9	5	6.0	5	5.8
27	10	6.3	5	5.8	5	6.8
28	12	6.9	8	6.8	4	7.3
29	10	7.0	4	6.8	6	7.2
30	10	7.8	4	7.5	6	8.0
31	9	8.8	4	8.8	5	8.8
32	9	9.0	5	8.6	4	9.5
33	10	8.7	6	9.0	4	8.3
34	11	9.4	6	9.0	5	9.8
35	9	9.7	4	9.3	5	10.0
36	10	10.8	5	10.0	5	11.6
37	10	11.8	5	9.8	5	13.8
38	10	12.0	5	10.6	5	13.4
39	9	11.3	4	9.0	5	13.2
40	7	13.3	5	12.0	2	16.5
41	8	13.1	5	11.6	3	15.7
42	5	12.6	5	12.6	0	–
43	6	13.0	5	12.6	1	15.0
44	6	14.7	5	13.2	1	22.0
45	6	16.2	5	15.2	1	21.0
46	6	15.0	5	14.2	1	19.0
47	7	17.7	5	16.2	2	21.5
48	4	15.5	4	15.5	0	–
49	1	27.0	0	–	1	27.0
50	3	20.0	2	20.0	1	20.0
51	2	21.0	2	21.0	0	–
52	0	–	0	–	0	–
53	0	–	0	–	0	–
54	3	21.7	3	21.7	0	–
55	1	25.0	1	25.0	0	–
56	1	26.0	1	26.0	0	–
Totals	293		164		129	