Relative abundance, size and age structure, and stock status of blue cod in Dusky Sound, Fiordland, in 2008

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This report describes the results of the 2008 blue cod (*Parapercis colias*) potting survey of Dusky Sound in Fiordland. In addition, estimates are provided of relative population size and age structure, total mortality (Z), and spawner per recruit. This is the second survey in the Dusky Sound time series following a survey in 2002.

The survey used a two-phase stratified random station design with stations randomly selected for phase's 1 and 2 from 119 pre-selected reference stations. From 16 to 29 October 2008, 54 potting stations were surveyed (6 pots per station = 324 pot lifts) from six strata (inner, mid, outer, marine reserve, extreme outer, and open coast) that covered an area between the inner fiord and the open coast of Dusky Sound. During phase 1, 288 pot lifts were completed (89%) with 36 in phase 2.

The total blue cod catch in Dusky Sound was 1537 kg, consisting of 2207 blue cod. For all sized blue cod, station catch rates ranged from 15 to 48.81 kg per hour with an overall mean catch rate and coefficient of variance (c.v.) of 25.19 kg per hour and 5.8%. Catch rates of legal size blue cod ranged from 11.3 to 26.9 kg per hour, with an overall mean catch rate and c.v. of 18.9 kg per pot per hour and 5.8%. Highest catch rates were noted in the open coast, inner, and marine reserve. Fifty-five percent of blue cod caught exceeded the minimum legal size (33 cm and over).

Total length ranged from 16 to 56 cm. The raw length frequency distributions were generally unimodal and similar for all strata outside the marine reserve except the outer coast where the right hand tail had few large fish. Males were longer than females in all strata and overall mean length was 37.9 cm for males and 32.2 cm for females. Overall sex was skewed in favour of females (60% overall), but the mid, outer, and extreme outer strata had roughly balanced sex ratios, whereas the inner and open coast strata were strongly dominated by females (60% and 74% respectively).

Scaled length frequency distributions (scaled to strata fishable coastline length) were unimodal, but the male distribution is on average larger than that of females, and the mean size of males is larger that of females (37.8 cm for males and 32.2 cm for females). Otoliths were prepared and read for 174 males and 163 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 3 to 28 years, but most fish (over 90%) were between 4 and 18 years for males, and 3 and 14 years for females. Male age distribution is on average older than that of females with mean age of 10.1 years for males and 7.9 years for females.

Total mortality estimates (Z) for age at recruitment from 5 to 8 years ranged between 0.21 and 0.30 (both sexes combined) outside the marine reserve and 0.18 to 0.27 inside the marine reserve.

Most gonads were mature with 25% running ripe for both sexes, indicating that spawning had begun in October 2008.

The 2008 survey spawner (biomass) per recruit (SPR) adopting the default M value of 0.14 was $F_{52\%}$ (F = 0.11) (outside marine reserve) and $F_{62\%}$ (F = 0.07) (inside marine reserve) indicating that at the current level of fishing mortality in 2008, the expected contribution to the spawning biomass over the lifetime of an average recruit has been reduced to 52%, and 62% of the contribution in the absence of fishing. The level of exploitation (F) in 2008 is above the assumed target reference point of $F_{40\%}$

Time series comparison

The overall mean station catch rate (kg per hour) of all blue cod in 2008 increased by 60% since the 2002 survey and the overall mean catch rate of legal sized blue cod (33 cm and over) had increased by 76%. Catch rates in 2008 were similar in the post stratified marine reserve area and extreme outer strata, considerably increased in the inner half of the fiord (inner and mid strata), and had declined slightly in the open coast stratum outside Dusky Sound.

The scaled length frequency distributions for Dusky Sound in 2002 and 2008 are similar in shape, but there is a higher proportion of larger and older fish for both males and females in the 2008 population. Mean length and age increased between 2002 and 2008 (2002 males 34 cm and 7.5 years, 2008 males 38 cm and 10 years; 2002 females 29 cm and 7 years, 2008 females 32 cm and 8 years). The effect of this is that total mortality estimates (Z) for 2008 (outside marine reserve) are considerably lower than those from the 2002 survey (2002 $Z = 0.30$, 2008 $Z = 0.25$, at age of recruitment = 6 years).

Fifty-five percent of blue cod caught exceeded the minimum legal size (33 cm and over) in 2008; it was 44% in 2002.

In the 2008 Dusky Sound survey sex is skewed toward females with 60% of blue cod caught being female, similar to 2002 (56%).

Gonad stages also indicated that spawning was more advanced in October 2008 than it had been in October 2002 when spawning was only just beginning.

SPR estimates, adopting the default M of 0.14, were $F_{43\%}$ (F = 0.16) for 2002 and $F_{52\%}$ (F = 0.11) for 2008 (outside the marine reserve) indicating that the Dusky Sound blue cod stocks have been exploited at a level below the target reference point of $F_{40\%}$., i.e., applied fishing mortality was less than the MFish target. The 9% improvement in spawning biomass is due to a higher abundance of older fish in the 2008 survey. Sensitivity analyses using M of 0.17 resulted in increased spawning biomass contribution by 11% (2002), 13% (2008 outside MR), 16% (2008 MR). Conversely, lower mortality (0.11) decreased the spawning biomass contribution by similar proportions. The exploitation rate (F) is below the target reference point of $F_{40\%}$ for the 2002 and 2008 surveys for M value of 0.14 and 0,17, but slightly higher for M of 0.11.

1. INTRODUCTION

Blue cod (*Parapercis colias*) is heavily targeted and the species most frequently landed by recreational fishers in the South Island (Ministry of Fisheries 2008a). Blue cod is also an important species for Maori customary fishers, but the volume of catch is unknown. In the Southland Fisheries Management Area (FMA) BCO 5, recreational annual take was last estimated at 229 t during a 1999–2000 national diary survey (Ministry of Fisheries 2008a). Within Fiordland, recreational fishing is most intensely focused on Dusky and Doubtful Sounds, and off Preservation Inlet (Davey & Hartill 2008). Commercial landings in BCO 5 were 1386 t in the 2006–07 fishing season (Ministry of Fisheries 2008a), although only about 36 t of that is likely to come from north of Chalky Inlet in Fiordland (Starr & Kendrick 2008).

Blue cod have a restricted home range, generally less than 2 km (Rapson 1956, Mace & Johnston 1983, Mutch 1983, Carbines 2004a, Carbines & McKenzie 2001, 2004) and stocks of this species are likely to consist of many largely independent sub-populations within an FMA (Carbines 2004a). Due to this philopatric behaviour, blue cod are especially susceptible to localised depletion, and in response to regional differences in fishing pressure, recreational bag limits vary within and between South Island FMAs (BCO 3, BCO 5, and BCO 7). Key recreational blue cod fisheries within FMAs are currently monitored using relative abundance indices generated by standardised potting surveys, repeated about every four years. 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 (Beentjes & Carbines 2003, 2006, 2009), north Otago (Carbines & Beentjes 2006b), Paterson Inlet (Carbines 2007), and Dusky Sound (Carbines & Beentjes 2003). 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 over potting surveys have been used to estimate the age structure of blue cod caught in several potting survey areas throughout the South Island (Carbines et al. 2008). Estimates of total mortality for each survey were based on catch curve analysis (Ricker 1975) of these age distributions derived specifically for each survey, including Dusky Sound (Carbines et al. 2008).

A new objective for this project is to determine stock status of Dusky Sound 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 cannot be estimated reliably and are expected to represent a large proportion of the total catches. 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 (SPR) analyses ($F_{\%SPR}$). Hence, we are interested in the level of fishing mortality, derived from the catch curve analysis (Z) and estimates of M, relative to the recommended $F_{\%SPR}$ 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.

Fishing is one of the most popular and growing recreational activities in Fiordland. Mounting concerns about increased access and fishing pressure on Fiordland's fish stocks motivated a group of Fiordland fishers and local users to form the Guardians of Fiordland's Fisheries and Marine Environment Inc. in 1995 (Guardians of Fiordland's Fisheries 1999, Guardians of Fiordland's Fisheries & Marine Environment Inc. 2003). The Ministry of Fisheries agreed to work with the Guardians of Fiordland to monitor blue cod populations in Fiordland. Subsequently, a blue cod tagging programme in 2001 (Carbines & McKenzie 2004) and a standardised potting survey in 2002 (Carbines & Beentjes 2003, see Appendix 1) were carried out in Dusky Sound (Figure 1). At the time of the 2002 potting survey, Fiordland blue cod were managed as part of BCO 5 with open commercial access and a daily bag limit of 30 blue cod for recreational fishers. The Guardians of Fiordland have subsequently developed the Fiordland Marine Area which was established by the Fiordland Marine Management Act in 2005. This is an integrated management strategy for Fiordland and includes several marine reserves, a halt to daily bag limit accumulation, and a reduced daily bag limit of 20 blue cod for recreational fishes in the outer fiords. In the inner half of most fiords commercial fishing has also been prohibited, and the daily bag limit for recreational fishes further reduced to only three blue cod, with no daily accumulation. Milford and Doubtful Sounds have also been closed to blue cod fishing since 2005. In Dusky Sound all of these management strategies were applied and the Taumoana (Five Fingers Peninsula) Marine Reserve was also established in the outer part of the fiord in 2005 (Figure 2). It has been over three years since the integrated management strategy for the Fiordland Marine Area was put in place, and the Guardians of Fiordland requested a repeat of the initial 2002 Dusky Sound potting survey (Carbines & Beentjes 2003) to monitor the fisheries response to the new local scale management changes. The marine reserve survey was included at the request of the Guardians and permission to do so was granted by the Department of Conservation.

Overall objective

To estimate relative abundance, maturity state, sex ratio, and age structure and the relative abundance of blue cod (*Parapercis colias*) in Dusky Sound.

Specific objectives

To undertake a potting survey in Dusky Sound to estimate relative abundance, size- and age-at-maturity, sex ratio and collect otoliths from pre-recruited and recruited blue cod.

To analyses biological samples collected from the potting survey.

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

2. METHODS

2.1 Timing

A potting survey of Dusky Sound was carried out between 16 and 29 October 2008. October was chosen as the optimum time to conduct the survey as it remained consistent with the previous survey (15 to 26 October 2002, Carbines & Beentjes (2003)) and coincides with the anticipated spawning season (Carbines 2004a).

2.2 Survey areas

The five strata (*inner, mid, outer, extreme outer, and open coast*) used in the 2002 Dusky Sound survey were originally defined as part of a blue cod tag and release study in 2001 (Carbines & McKenzie 2004) (Figure 1). Stratum size was determined at a scale at which blue cod might be expected to form distinct stocks, separated by natural boundaries where possible (Carbines & McKenzie 2004). The 2008 survey area and strata are identical to 2002 except that stratum *outer* was subdivided into two strata; stratum *Marine Reserve* (Taumoana Marine Reserve) and stratum *outer* (remainder of the original *outer* stratum) (Figure 2).

Available blue cod habitat within Dusky Sound often constitutes a narrow band/ledge of light foul extending out from the shore or exposed headland reefs, usually shallower than 50 m (Carbines & Beentjes 2003, Carbines & McKenzie 2004). Very few blue cod are ever caught along cliff faces or in deep trenches. This habitat band was assumed to be reasonably constraining and the length of the coastline and equivalent submerged areas supporting such habitat (measured by the length of the 50 m contour line from Chart NZ7653) was assumed to be proportional to the amount of blue cod habitat in each stratum (Table 1).

2.3 Survey design

The survey used a two-phase stratified random station design (Francis 1984). The original 119 fisher selected stations used in the October 2001 tagging survey (Carbines & McKenzie 2004) covered most available blue cod habitat within Dusky Sound and were used as potential stations for both the previous potting survey in 2002 (see Figure 1) and the current potting survey in 2008 (Figure 2). From the index list of possible stations (see Table 1), eight stations per stratum were randomly selected for phase 1.

Over 85% of survey stations were allocated to phase 1 (n = 48) with the remainder available for phase 2 (n = 6) (the marine reserve stratum was excluded from phase two allocation). Allocation of phase 2 stations was based on the mean catch rate (kg per hour) of all blue cod per stratum (excluding the marine reserve stratum) and optimised using the "area mean squared" method of Francis (1984). In this way, stations were assigned iteratively to the stratum in which the expected gain is greatest, where expected gain is given by:

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

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

2.4 Vessels and gear

The 2008 Dusky Sound potting survey was conducted from F.V. *Golden Bay* (registration number 6097), a Bluff based commercial vessel equipped to set and lift rock lobster and blue cod pots, and skippered by the owner, Mr Gareth Hamilton. The vessel specifications are: 12 m length, 3 m breadth, 12 t, fibreglass monohull, powered by a 127 hp 6LXB Gardner diesel engine with propeller propulsion.

Six custom designed and built cod pots were used to conduct the survey. Pot specifications are: length 1200 mm, width 900 mm, depth 500 mm, 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 pot design and bait type were consistent with all previous South Island blue cod potting surveys undertaken by MFish.

A high-performance, 3-axis (3D) acoustic doppler current profiler (SonTek/YSI ADP; Acoustic Doppler Profiler, 500 kHz) ADCP) was deployed at each station.

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 first Dusky Sound survey in 2002 (Carbines & Beentjes 2003) and all previous South Island potting surveys. The six pots were set in clusters, separated by over 100 m to avoid pots competing for the same fish. Once on station the position of each of the six pots was determined by the skipper using local knowledge and the vessel sounder to locate a suitable area of foul or biogenic habitat. After each station was completed (six pot lifts) the next closest station in the stratum was fished. While it was not logistically possible to standardise for time of day or tides, each stratum was surveyed throughout the day, collectively giving stations roughly equal exposure to all daily tidal and time regimes. The order that strata were surveyed depended on the prevailing weather conditions, as exposed coastal 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 the acoustic doppler profiler was deployed at each station and recovered after the last pot of each set was lifted.

After 1 h pots were lifted aboard using the vessel's hydraulic pot lifter, emptied, and the contents sorted by species. Total weight per pot was recorded for each species (except for hagfish) to the nearest 10 g using 10 kg motion compensating Marel scales. The number of individuals of each species per pot was also recorded. For pots set outside the marine reserve, total length down to the nearest centimetre, sex, and gonad maturity were recorded for all blue cod, and the sagittal otoliths removed from a representative size range of males and females, from which the weight of each fish was also recorded to the nearest 10 g. Sex and maturity were determined by dissection and macroscopic examination of the gonads (Carbines 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. Sagittal otoliths were removed from a target of up to five fish of each sex per 1-cm size class over the available length range. Fish caught within the marine reserve were measured for total length and returned alive.

2.6 Data analysis

For each stratum and for all strata combined catch rates for all blue cod, legal sized blue cod (33 cm and over in Dusky Sound), and those 30 cm and over (MLS elsewhere) were estimated as both mean kilograms per pot per hour and 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 (mean kg per pot; mean kg per station).

The overall weighted mean catch rate for all strata (including and excluding the marine reserve) was determined by weighting each stratum mean by the stratum fishable coastline ($area_i$) divided by the sum of all strata fishable coastlines ($area_{total}$).

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

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.

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

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

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

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

Length frequency for blue cod for each sex is presented by individual stratum and for all strata combined (scaled to area). Mean length for each sex was calculated for individual stratum, and overall for all strata combined by treating all data as a single dataset. Overall weighted mean lengths were calculated by weighting each stratum mean by the stratum fishable coastline divided by the sum of all strata fishable coastlines.

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

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 fishable coastline divided by the sum of all strata fishable coastlines.

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

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 33 cm and over (local minimum legal size) and 30 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.

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 described 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 & D. Kater). Where counts differed, readers consulted to resolve the final age estimate and otoliths given a grade 5 (unreadable) were removed from the analysis.

2.8 Growth parameters

Von Bertalanffy growth models (von Bertalanffy 1938) were fitted to the length-age data by sex for the 2008 and the 2002 surveys separately, and for both surveys combined. The estimated growth parameters K, t_0 and L_{inf} were used in the spawner per recruit analyses.

2.9 Age composition

Age compositions of the 2008 Dusky Sound blue cod population outside the marine reserve 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 length of fishable coastline (i.e., the length of the 50 m contour line) of the individual strata (km) and not the catch weight, which would have resulted in a scaling factor of one because we measured every fish. This is consistent with the approach used for catch at age analyses of the first Dusky Sound survey in 2002 (Carbines et al. 2008). Length-weight coefficients (males and females separately) used in the catch at age analyses were estimated from the length-weight relationship of the blue cod that were individually weighed on these surveys (see Results). Scaled length frequency and age frequency proportions are presented together with coefficients of variation (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 was estimated for blue cod caught within the marine reserve in 2008 by using the age length key of both sexed and combined fish from all other strata applied to the marine reserve scaled length frequency data. Catch at age analyses were also carried out for the 2002 Dusky Sound survey because previous results shown in figure 20 of Carbines et al. (2008) were not scaled to strata area and hence are not directly comparable to 2008.

2.10 Total mortality (*Z*) estimates

Total mortality (*Z*) was estimated for the 2008 survey both outside and inside the marine reserve from catch-curve analysis using the Chapman Robson estimator (CR) (Chapman & Robson 1960). The catch curve was generated from the scaled 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 (excluding the marine reserve). The Z estimates for the 2002 survey Carbines et al. (2008) were re-estimated because the strata measurements by Carbines & Beentjes (2003) have been more accurately defined (see Table 1), and hence the Z estimates were modified accordingly.

2.11 Spawner per recruit analyses

Spawner per recruit calculations were carried out using CASAL (Bull et al. 2008) for the 2002 and 2008 (inside and outside the marine reserve) 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 both surveys combined, and are shown below:

	2002 survey		2008 survey		2002 and 2008 combined	
Parameter	Males	Females	Males	Females	Males	Females
K	0.16	0.13	0.10	0.12	0.13	0.13
t_0	0.16	-0.66	-1.06	-1.01	-0.46	-0.82
L_{inf}	53.12	48.96	57.35	50.20	54.21	49.38
A	7.825E-09	5.059E-09	9.290E-09	6.390E-09	8.030E-09	5.0772E-09
b	3.17	3.30	3.13	3.24	3.17	3.30

In the SPR analyses we used the von Bertalanffy growth parameters and length weight coefficients from then 2002 and 2008 combined surveys. Hence, the SPR curves for 2002 and 2008 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 (33 cm and 8 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 (assuming knife edged selectivity). (see Total mortality results in Section 3.6).

3. RESULTS

3.1 Stations surveyed

Fifty-four stations were surveyed (6 pots per station = 324 pot lifts) from six strata throughout and adjacent to Dusky Sound (Table 1, Figure 2, Appendix 3). Of the 54 stations, 48 were carried out in phase 1 (8 per stratum) with 5 allocated to the inner stratum and 1 to the mid stratum in phase 2. Depth ranged from 5 to 82 m. Environmental data recorded throughout the Dusky Sound survey are presented in Appendix 4.

3.2 Catch

A total of 1682 kg of catch was taken on the 2008 Dusky Sound survey, of which 1537 kg (91%) was blue cod, consisting of 2207 fish (Table 2). Bycatch included 9 fish, 1 octopus, and 1 rock lobster species. The five most common bycatch species by weight were scarlet wrasse (*Pseudolabrus miles*), octopus (*Octopus cordiformis*), girdled wrasse (*Notolabrus cinctus*), sea perch (*Helicolenus percoides*), and spotties (*Notolabrus celidotus*).

Mean station catch rates of blue cod (all sizes) ranged from 48.75 kg per hour for the open coast stratum (outside the mouth) to 14.97 kg per hour for the outer stratum. Overall mean catch rate was 25.45 kg per hour and c.v. 5.52% and 25.19 kg per hour and c.v. 5.81% with the marine reserve stratum excluded (Table 3). For blue cod 33 cm and over (minimum legal size), highest and lowest catch rates were also from the open coast (26.93 kg/h) and outer strata (11.25 kg/h) respectively. Overall mean catch rate for fish 33 cm and over was 19.34 kg per hour and c.v 5.58% and 18.94 kg per hour and c.v. 5.84% with the marine reserve stratum excluded (Table 4). The overall mean catch rate for fish 30 cm and over was 23.08 kg per hour and c.v 5.86% with the marine reserve stratum excluded (Table 4).

3.3 Biological and length frequency data

Of the 2207 blue cod caught on the 2008 survey, all were measured for length, and apart from the 285 fish caught in the marine reserve, all were sexed. A representative sub-set of otoliths were also taken from 337 fish and stored. The proportion by sex ranged from 0.35:1 (male:female) in the open coast stratum to 1.27:1 in the mid stratum, and overall was 0.67:1 in favour of females (Table 5). Weighting the sex ratio by stratum size notably increased the proportion of males (0.80:1) due to the small weighting of the open coast stratum (8%) which accounted for almost half of all females caught in the 2008 survey (Table 5). The size of blue cod varied among strata outside the marine reserve and ranged from 19 to 56 cm over all (19 to 49 cm for females, 21 to 56 cm for males); inside the reserve size ranged from 16 to 54 cm (both sexes). The length frequency distributions were generally unimodal and similar for all strata outside the marine reserve except the outer coast where the right hand tail had fewer large fish (Figure 3). The length frequency distribution for the marine reserve differed, in that the right hand tail had more large fish. Weighted mean length of males was over 5 cm greater than females overall (males = 38.2 cm, female = 32.6 cm) (Table 5) and generally increased with increasing penetration into the fiord for both males and females. The proportion of legal sized (33 cm and over) blue cod caught on the 2008 survey was 55% and the proportion above 30 cm (MLS for BCO 3) was 82%.

Of 1922 blue cod examined for reproductive status, most were in the mature phase, with 25% of both females and males in the running ripe stage, indicative of the early phase of spawning (Table 6). Only one fish (female) was observed with a spent gonad.

Before calculating the length-weight relationship for Dusky Sound blue cod, two outliers were removed and the analysis included 165 females (range (19–49 cm) and 175 males (range 21–56 cm). Using the derived model $W = aL^b$, where W= weight in g and L= length in cm, the length-weight parameters for Dusky Sound are as follows: males – a = 0.009292, b = 3.1309, and R^2 = 0.99; females – a = 0.008327, b = 3.2427, and R^2 = 0.99.

3.4 Ageing (between reader analyses)

From 345 otoliths collected during the survey and sectioned, 8 were rejected as unreadable or damaged, leaving 337 readable otoliths (174 males 21–56 cm, 163 females 19–49 cm) (Table 7 &

Appendix 5). Initial independently derived reader estimates of age class are compared in Appendix 6 and show 50% agreement between the two readers, with reader 2 generally estimating lower age classes than reader 1 for fish over 48 cm. When the differences between age class estimates were resolved by agreement between the readers, the more experienced reader 1 was 88% consistent with the agreed age class estimates, while the less experienced reader 2 was only 53% consistent with the agreed age classes (Appendix 7). The tendency of reader 2 to underestimate the agreed age class was mainly restricted to fish beyond 15 years (Figure 4).

The length-age data are plotted and the von Bertalanffy model fits are shown in 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 males grow faster than females and that growth was slightly faster in 2002 for both males and females than in 2008. The combined model used in the SPR analyses is also shown.

3.5 Length and age composition

3.5.1 Outside marine reserve

The scaled length frequency and age distributions from the 2008 Dusky Sound survey, for all combined strata outside the marine reserve, 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 2008 survey are shown in Appendices 8 and 9. The length distribution for females is strongly unimodal with a clear peak at 32 cm, whereas the male distribution, although unimodal, is wider with higher proportions of larger fish and has no clear peak (Figure 6). Mean length was 37.8 cm for males and 32.2 cm for females. The cumulative distributions plots of length frequency show clearly that male size distribution is on average larger than that of females. The mean weighted coefficients of variation (MWCVs) around the length distributions are medium (30% for males and 25% for females) indicating that fish sampled in the survey provide a reasonable representation of the overall population.

Age of blue cod in the 2008 survey ranged from 3 to 28 years, but most fish (over 90%) were between 4 and 18 years old for males and 3 and 14 years old for females (Figure 6, Appendices 8 and 9). The estimated population age distributions are unimodal with the peaks at about 10 years for males and about 8 years for females (Figure 6). The cumulative distributions plots of age frequency show clearly that male age distribution is on average older than that of females and hence mean age of males is greater than that of females (10.1 years for males and 7.9 years for females). The MWCVs around the age distributions are medium (34% for males and 31% 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%.

3.5.2 Within the marine reserve

The scaled length frequency and age distributions from the 2008 Dusky Sound survey within the marine reserve are shown as a histogram and a cumulative frequency line plot for both sexes combined (Figure 7). The length distribution is strongly unimodal with a peak at about 38 cm and mean length of 35.9 cm. The mean weighted coefficient of variation (MWCV) around the length distributions is 42% indicating that fish sampled provide a less than desirable representation of the overall population within the reserve.

The estimated population age distribution of both sexes combined within the marine reserve was based on the age length key constructed from fish caught outside the marine reserve (see Methods). The age distribution is unimodal with a peak at about 10 years and mean age of 9.6 years. The

MWCV around the age distribution is 29%, providing a less than desirable representation of the marine reserve population age structure, assuming that acceptable MWCV values are less than 25%.

For comparison, the scaled length frequency and age distributions from the 2002 Dusky Sound survey with all strata are shown as a histogram and a cumulative frequency line plot for both sexes combined (Figure 8), and the scaled length and age cumulative frequency for the 2005 and 2008 surveys are shown in Figure 9.

3.6 Total mortality (*Z*) estimates

Total mortality estimates (*Z*) and 95% confidence intervals for the 2008 Dusky Sound survey for both sexes combined, outside and inside the marine reserve, are given in Table 8. The combined strata mortality estimates in 2008 outside the marine reserve were between 0.21 and 0.30, and inside the marine reserve were 0.18 to 0.27.

Revised total mortality estimates from the 2002 survey are also provided in Table 8. In 2002 the marine reserve did not exist and this stratum was included in the outer stratum. Estimates were between 0.30 and 0.31.

3.7 Spawner per recruit analyses

The spawner per recruit analyses for the 2002 and 2008 Dusky Sound surveys are plotted as %SPR as a function of fishing mortality (F) (Figure 10). Mortality parameters used in the analyses are shown in Table 9 and resulting $F_{\%SPR}$ values in Table 10. Based on the default M of 0.14 the fishing mortality estimated from the 2002 survey was 0.16 which corresponds to $F_{42.6\%}$. Similarly for 2008 fishing mortality outside the marine reserve was estimated at 0.11 and inside at 0.07 which corresponds to $F_{51.5\%}$ and $F_{63.3\%}$, respectively. This indicates that at the 2002 and 2008 levels of fishing mortality, the expected contribution to the spawning biomass over the lifetime of an average recruit has been reduced to 52% and 63% respectively, of the contribution in the absence of fishing. Within the marine reserve the reduction is 62%. 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 10.

4. DISCUSSION

The 2008 Dusky Sound potting survey provides the second index in the time series of relative abundance and population structure of blue cod from this area. Survey sampling methods and strata were identical to those used in the 2002 survey, except that stratum outer was smaller in 2008 because of the introduction of the marine reserve in 2005. However, catch rates in 2002 were re-estimated from the smaller stratum outer, and hence the results of the 2002 and 2008 surveys outside the marine reserve are directly comparable. Overall coefficient of variation was higher in 2002 (less than 7% for pot and 10% for station catch rates) than in 2008 (less than 5% for pot and 6% for station catch rates) and these are low compared to most other time series maybe in part to having at least eight stations per strata instead of the normal five used in most other potting surveys (Carbines et al. 2008).

4.1 Comparison between 2002 and 2008 Dusky Sound surveys

Catch rates

In previous surveys the standardised catch rate index used has been the mean kilogram per pot per hour which has used pots as the base unit of catch. However, pots are not set truly independently in the current time series methodology, but rather in clumps of six pots at each station. Consequently, we have presented the current survey catch rate index as mean kilogram per station per hour and used the combined total catch of the six pots at each station as the base unit of catch. For consistency we have also concurrently presented catch rates using pots as the basic unit of catch for the 2002 (Appendix 1) and 2008 (tables 3 & 4) in the Dusky Sound potting survey time series.

There were major changes in the catch rates of blue cod between 2002 and 2008 in Dusky Sound. The overall mean catch rate (kilograms per station per hour) of all blue cod and of legal sized blue cod (33 cm and over) from all strata combined (outside the marine reserve) had increased 60% and 76% respectively, since the 2002 survey (Figures 11 and 12). Furthermore this increase in catch rate was consistent among all strata; with the exception of the open coast stratum all blue cod and legal sized blue cod catch rates had declined by 4% and 18% respectively. These changes have dramatically altered the spatial dynamics of blue cod relative abundance in Dusky Sound, with much higher catch rates in 2008 coming from strata inner, mid and outer than in 2002 (Figures 11 and 12). The proportion of blue cod that were of legal size was also notably higher in the 2008 survey (55%) than in the 2002 survey (44%). In contrast, catch rates in the marine reserve in 2008 (compared to the same post stratified area open to fishing in 2002) were remarkably similar.

We use changes in standardised catch rates as a proxy for changes in relative abundance of blue cod in these survey areas. However, in the absence of direct observations of blue cod abundance and environmental variables during both potting surveys (Appendix 4), we cannot rule out or allow for variations in catchability as a determinant in changes in relative abundance. Generally though we do not expect major shifts in catchability to have occurred between these surveys as weather conditions were similar, both surveys having fine periods interspersed with periods of heavy rain. There were also no areas of significant currents, and fishing in exposed areas was restricted to calm days in both surveys.

Population length and age structure

The age distributions, and total mortality estimates are based on scaled length data that were weighted (scaled) by strata fishable coastline length. Scaling by area assumes that the size of each stratum is directly proportional to the amount of blue cod habitat (i.e., it is assumed to be a proxy for habitat) however, this is probably not always the case given the discrete nature of areas of foul and biogenic habitat. There are some substantial differences among the Dusky Sound strata fishable coastline lengths (see Table 1) and if the assumption that fishable coastline and habitat are proportional does not hold, there is the possibility of bias in the population length and age structure. 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 – this was recommended by the expert review panel following a workshop on blue cod potting surveys in April 2009 (Stephenson et al. 2009).

The scaled length frequency distributions for Dusky Sound blue cod in 2002 and 2008 are similar in shape, but there is a higher proportion of larger fish for both males and females in the 2008 population (see Figures 6, 8, and 9). Similarly, the resulting population age structure indicates that there was a higher proportion of older fish in 2008 than 2002 and hence this is why total mortality (Z) declined between 2002 and 2008 (see Table 8). Indeed the mean length and age increased between 2002 and 2008 (2002 males 34 cm and 7.5 years, 2008 males 38 cm and 10 years; 2002 females 29 cm and 7 years, 2008 females 32 cm and 8 years).

Explanations invoking recruitment to explain the differences in the population length and age structure are at best speculative given that there has been 6 years between surveys. However, the management measures[2] put in place in 2005 by the Guardians of Fiordland may well have contributed to the overall increase in size and age, and also catch rates in the inner fiord. While we have not produced the post-stratified length frequency distribution for the 2002 equivalent marine reserve area, it is notable that in 2008 the marine reserve had a higher proportion of large and older fish than elsewhere (Figure 7).

Total mortality (Z)

Mortality estimate (Z) for 2008 at age at recruitment of 6 years is considerably lower than the 2002 survey (2002 = 0.30, 2008 = 0.25, see Table 8).). The decrease in Z is a result of the estimated population age structure, with a higher proportion of older fish present in 2008 (see Figures 6, 8, and 9). The lowest Z was estimated for the marine reserve (0.21) using the age length key from fish caught outside the marine reserve — for this Z to be valid we assume that growth is the same inside and outside the marine reserve.

Sex ratio

The un-weighted proportion by sex in Dusky Sound is skewed toward females with 60% of blue cod caught in 2008 being female, which is similar to 56% in 2002. Blue cod are protogynous hermaphrodites with some (but not all) females changing into males as they grow (Carbines 2004a). The Dusky Sound survey findings that males were larger on average than females and that the largest fish were males is consistent with sex structure in protogynous hermaphrodites.

In areas where fishing pressure is known to be high, such as Motunau, inshore Banks Peninsula, and the Marlborough Sounds, the sex ratios are skewed towards males which is contrary to an expected dominance of females resulting from selective removal of the larger final phase male fish (Beentjes & Carbines 2003, 2006, 2008, Blackwell 1997, 1998, 2002, 2005, 2008, Carbines & Beentjes 2006a, 2009). 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 as a consequence results in a higher rate (and possibly earlier onset) of sex change by primary females. In the 2008 Dusky Sound survey the three strata with the lowest catches of blue cod (mid, outer and extreme outer) were 54% males, supporting the theory that more heavily fished areas can become dominated by males.

Reproductive condition

Gonad stages observed in 2008 were more developed than those observed in the 2002 survey. During the 2002 survey most blue cod had resting and maturing gonads (some mature and only a few running ripe) indicating that spawning had only just begun (Carbines & Beentjes 2003). The higher proportion of blue cod with gonads in the mature and running ripe phase in 2008 (see Table 6) suggest that spawning had begun earlier in 2008 than in 2002.

4.2 Stock status (spawner per recruit analyses)

The Ministry of Fisheries *Harvest Strategy Standard* 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

[2] No accumulation, reduced recreational bag limit of 20 blue cod for the outer fiord, no commercial fishing, and the bag limit further reduced to three blue cod in the inner fiord.

spawner per recruit $F_{\%SPR}$. The draft Operational Guidelines for New Zealand's Harvest Strategy Standards 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	≤ $F_{50\%}$

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 $F_{43\%}$ for 2002 and $F_{51\%}$ for 2008, indicating that the expected contribution to the spawning biomass over the lifetime of an average recruit has been reduced to 43% and 51% in 2002 and 2008 respectively, of the contribution in the absence of fishing. Further, the level of exploitation (F) of Dusky Sound blue cod stocks is below the F_{MSY} target reference point of $F_{40\%}$ (Table 10, see Figure 10), i.e., fishing pressure applied in 2002 and 2008 was less than the target fishing pressure. Inside the marine reserve in 2008 the $F_{\%SPR}$ estimate was 62% which is well below the target reference point (Table 10, see Figure 10).

Based on the estimated population age structures and an assumed default M of 0.14, fishing mortality declined between 2002 and 2008 (see Table 9) resulting in an increase in the spawning biomass contribution by 8%. Further, within the marine reserve in 2008 spawning biomass contribution is 12% greater than outside which indicates that the absence of fishing in this area since 2005 may have contributed to a partial rebuilding of the size and age structure. Management measures outside the marine reserve restricting bag limits, halting accumulation, and limiting commercial access to the outer fiords appear to have contributed to the improvement in the spawning biomass contribution between 2002 and 2005.

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 10, see Figure 10). A higher natural mortality (0.17) increased spawning biomass contribution by 11% (2002), 13% (2008 outside MR) and, 16% (2008 MR). Conversely, lower mortality (0.11) decreased the spawning biomass contribution by similar proportions. The exploitation rate (F) is below the target reference point of $F_{40\%}$ for the 2002 and 2008 surveys for M value of 0.14 and 0,17, but slightly higher for M of 0.11.

4.3 Fishing effort

Commercial fishers take an annual average of 32.5 t of blue cod (1994-95 to 2006-07) from the Fiordland area between Chalky Inlet and Charles Sound (statistical area 031) (Starr & Kendrick 2008) and since 2005 commercial fishing has been restricted to the outer half of the fiords. Recreational fishing is permitted throughout Dusky Sound (excluding the marine reserve), although 90% of effort occurs in the outer and coastal areas where commercial fishing takes place (Davey & Hartill 2008). The 18% decline in the relative abundance of legal size blue cod (Figure 12) and the relatively smaller mean size of blue cod from the open coast stratum (See Table 5) appear to reflect the more intense fishing pressure in this area. In contrast, the inner half of Dusky Sound has seen more than a doubling in the relative abundance of legal size blue cod and dramatic increases in mean size that appear to be consistent with the low levels of fishing pressure in this area.

However, in the area of the Taumoana (Five Fingers Peninsula) Marine Reserve (see Figure 2), where there has theoretically been no fishing pressure since 2005, the relative abundance (catch rates) of legal sized blue cod has remained much the same as it was in 2002 (Figure 12). Furthermore, the relative abundance of pre-recruited blue cod has declined in the reserve since the 2002 survey (see Figure 11). There was, however, an increase in the proportion of large fish, and this has resulted in an improved contribution to the spawning biomass from the marine reserve fish (see above). The relatively recent management regimes established by the Fiordland Marine Management Act in 2005 will therefore need to be evaluated through ongoing long-term monitoring of both fishing pressure and fisheries independent blue cod population data in Dusky Sound.

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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. (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.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.
Davey, N.K; Hartill, B. (2008). A characterisation of recreational fisheries in the Fiordland Marine Area monitoring between 2006 and 2008. Final Research Report for Ministry of Fisheries Project SAP2006-01, Objectives 1 and 2. 42 p. (Unpublished report held by Ministry of Fisheries, Wellington.)
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.
Guardians of Fiordland's Fisheries. (1999). Beneath the Reflections. A Characterisation of Fiordland's Fisheries. 120 p. (Report held by Ministry of Fisheries, Dunedin, New Zealand).
Guardians of Fiordland's Fisheries & Marine Environment Inc. (2003). Fiordland Marine Conservation Strategy. 138 p. (Report held by Ministry of Fisheries, Dunedin, New Zealand).
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. 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.
Starr, P.J.; Kendrick, T.H. (2008). Review of the BCO 5 Fishery. New Zealand Seafood Industry Council Ltd (SEAFIC) Report to South East Finfish Management Ltd. 51 p.

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: Dusky Sound 2008 stratum references stations, coastline area, number of phase 1 and 2 stations, pot lifts, and depth (the 2002 stratum outer, included the marine reserve).

Stratum	Number of reference stations	Area of strata (km)	Number of sets Phase 1	Phase 2	Number of pot lifts	Depth (m) Mean	Range
inner	23	74.56	8	5	78	36	5–49
mid	31	61.61	8	1	54	26	5–64
marine reserve	8	19.90	8		48	28	5–48
outer	17	74.82	8		48	28	13–75
extreme outer	25	44.22	8		48	50	18–68
open coast	15	23.3	8		48	34	18–82
Total	119	298.41	48	6	324	33	5–82

Table 2: Catch weights, numbers of blue cod, bycatch species, and percentage of total weight on the 2008 Dusky Sound survey. *Estimated weight using average weight of 0.4 kg for hagfish (the mean of 12 weighed hag fish from Dusky Sound survey (Carbines & Beentjes 2003)).

Common name	Scientific name	Catch (kg)	Number	Percent of total catch
Blue cod	*Parapercis colias*	1536.5	2207	91.3
Scarlet wrasse	*Pseudolabrus miles*	81.5	357	4.8
Octopus	*Octopus cordiformis*	27.6	6	1.6
Girdled wrasse	*Notolabrus cinctus*	17.2	53	1.0
Sea perch	*Helicolenus percoides*	8.4	26	0.5
Spotty	*Notolabrus celidotus*	5.9	54	0.4
Tarakihi	*Nemadactylus macropterus*	1.4	4	0.1
Leatherjacket	*Parika scaber*	1.2	4	0.1
Maori chief	*Notothenia angustata*	0.8	1	<0.1
Trumpeter	*Latris lineata*	0.6	2	<0.1
Rock lobster	*Jasus edwardsii*	0.5	1	<0.1
Hagfish	*Eptatretus cirrhatus**	0.4	1	<0.1
Total		1682	2716	

Table 3: Dusky Sound 2008 mean blue cod catch rate (by pot and station landings), standard error, and c.v. per stratum and overall for all blue cod both with the marine reserve included and separated out.

Stratum	Pot lifts (N)	Mean (kg/pot)	s.e.	*c.v.* %	Mean (kg/stn)	s.e.	*c.v.* %
inner	78	5.36	0.45	8.43	32.05	2.66	8.31
mid	54	3.95	0.45	11.30	23.70	3.32	14.01
outer	48	2.49	0.29	11.61	14.97	1.59	10.61
MR	48	4.84	0.56	11.65	29.03	4.93	16.98
extreme outer	48	3.43	0.40	11.74	20.55	3.35	16.32
open coast	48	8.13	0.86	10.62	48.75	9.45	19.39
Overall							
MR included	324	4.24	0.19	4.47	25.45	1.40	5.52
MR excluded	276	4.20	0.20	4.74	25.19	1.46	5.81

Table 4: Dusky Sound 2008 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) both with the marine reserve included and separated out. In the last row the overall catch rates for blue cod 30 cm and over are given as a comparison to areas with that MLS.

Stratum	Pot lifts (N)	Mean (kg/pot)	s.e.	*c.v.* %	Mean (kg/stn)	s.e.	*c.v.* %
inner	78	4.29	0.38	8.83	25.73	2.34	9.11
mid	54	3.35	0.38	11.34	20.12	2.93	14.59
outer	48	1.87	0.25	13.38	11.25	1.50	13.37
MR	48	4.16	0.55	13.20	24.96	4.71	18.89
extreme outer	48	2.44	0.30	12.15	14.65	2.22	15.16
open coast	48	4.49	0.48	10.72	26.93	4.16	15.43
Overall ≥33 cm							
MR excluded	276	3.16	0.16	5.08	18.94	1.11	5.84
MR included	324	3.22	0.15	4.78	19.34	1.08	5.58
Overall ≥30 cm							
MR excluded	276	3.85	0.18	4.91	23.08	1.31	5.86

Table 5: Dusky Sound 2008 lengths of blue cod by strata and sex. Overall weighted and unweighted mean length, and weighted sex ratios are also given.

			Length (cm)			Sex ratio M:F (% male)		
Strata	Sex	N	Mean	Minimum	Maximum	All blue cod	≤ 33 cm	≤ 30 cm
inner	m	214	40.1	24	55	0.7:1 (40%)	0.2:1 (20%)	0.3:1 (22%)
	f	320	33.5	22	49			
mid	m	142	39.1	24	56	1.3:1 (56%)	0.6:1 (36%)	0.6:1 (38%)
	f	111	34.1	25	46			
marine reserve	u	285	36.2	16	54	-	-	-
outer	m	91	37.4	21	52	1.2:1 (55%)	0.7:1 (40%)	0.5:1 (35%)
	f	74	32.1	19	47			
extreme outer	m	136	36.4	23	53	1.2:1 (53%)	0.4:1 (30%)	0.3:1 (23%)
	f	117	30.4	19	48			
open coast	m	190	35.8	25	55	0.4:1 (26%)	0.2:1 (16%)	0.2:1 (19%)
	f	527	31.3	22	45			
Overall unweighted	m	773	37.9	21	56	0.7:1 (40%)	0.3:1 (22%)	0.3:1 (23%)
(outside reserve)	f	1149	32.2	19	49			
Overall weighted	m	773	38.2	21	56	0.8:1 (44%)	0.3:1 (25%)	0.3:1 (25%)
(outside reserve)	f	1149	32.6	19	49			

Table 6: Dusky Sound 2008 gonad stages of blue cod. 1, immature or resting; 2, maturing (oocytes visible in females); 3, mature (hyaline oocytes in females, milt expressible in males); 4, running ripe (eggs and milt free flowing); 5, spent.

	Gonad stage (%)					
	1	2	3	4	5	N
Males	0.6	28.1	46.7	24.6	0.0	773
Females	1.0	20.6	53.4	24.8	0.1	1149

Table 7: Otolith raw data used in the catch at age, Z estimates and SPR analyses for the Dusky Sound surveys.

Survey	No. otos	Length of aged fish (cm)			Age (years)		
		Mean	Minimum	Maximum	Mean	Minimum	Maximum
2002 (total)	629	33.2	14	55	8.0	2	27
2002 (male)	318	35.9	18	55	8.3	3	27
2002 (female)	311	30.5	14	48	7.6	2	23
2008 (total)	337	37.0	19	56	10.4	3	28
2008 (male)	174	39.8	21	56	11.6	4	28
2008 (female)	163	33.9	19	49	9.1	3	23

Table 8: Total mortality estimates (*Z*) and 95% confidence intervals of blue cod from the 2002 and 2008, Dusky Sound potting surveys using Chapman Robson method described in Appendix 2.

Area (year)	AgeR	*Z*	cv	Low		Medium		High	
				Lower	Upper	Lower	Upper	Lower	Upper
Dusky 2002	5	0.31	0.18	0.24	0.39	0.23	0.41	0.20	0.45
	6	0.30	0.18	0.24	0.37	0.22	0.40	0.20	0.43
	7	0.30	0.18	0.24	0.37	0.22	0.39	0.20	0.42
	8	0.27	0.18	0.21	0.33	0.21	0.36	0.19	0.38
Dusky 2008 excl. marine reserve	5	0.21	0.23	0.17	0.26	0.15	0.27	0.15	0.27
	6	0.25	0.23	0.20	0.31	0.19	0.33	0.19	0.33
	7	0.27	0.23	0.21	0.34	0.20	0.35	0.20	0.35
	8	0.30	0.23	0.23	0.37	0.22	0.39	0.22	0.39
Dusky 2008 marine reserve	5	0.18	0.30	0.14	0.23	0.14	0.23	0.12	0.26
	6	0.21	0.30	0.16	0.27	0.15	0.28	0.14	0.29
	7	0.23	0.30	0.18	0.29	0.17	0.30	0.15	0.33
	8	0.27	0.30	0.21	0.34	0.19	0.35	0.18	0.36

Table 9: Mortality parameters (Z, F, and M) used in the spawner per recruit (SPR) analyses for the 2002 and 2008 Dusky Sound surveys. MR, marine reserve; F, fishing mortality; M, natural mortality; Z, total mortality.

	2002		2008 (outside MR)		2008 (MR)	
M	Z	F	Z	F	Z	F
0.11	0.3	0.19	0.25	0.14	0.21	0.1
0.14	0.3	0.16	0.25	0.11	0.21	0.07
0.17	0.3	0.13	0.25	0.08	0.21	0.04

Table 10: Spawner per recruit estimates at three values of M for the 2002 and 2008 Dusky Sound surveys. Corresponding F values are shown above in Table 9. MR, marine reserve. M, natural mortality.

M	2002	2008 (outside MR)	2008 (MR)
0.11	$F_{31.7\%}$	$F_{38.3\%}$	$F_{46.5\%}$
0.14	$F_{42.6\%}$	$F_{51.5\%}$	$F_{62.3\%}$
0.17	$F_{53.8\%}$	$F_{65.0\%}$	$F_{78.6\%}$

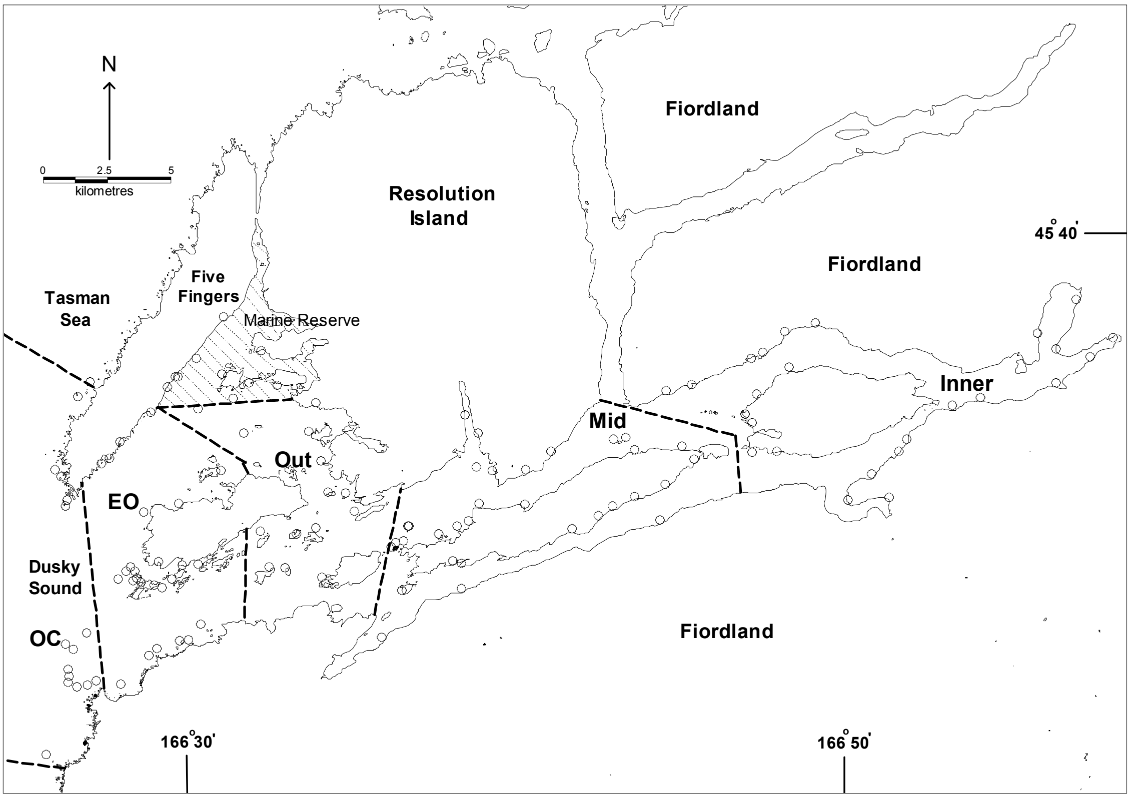


Figure 1: Map of the Dusky Sound area showing the five strata and possible stations. Strata are OC (open coast), EO (extreme outer), Out (outer), Mid and Inner. Detailed results of this survey were given by Carbines & Beentjes (2003).

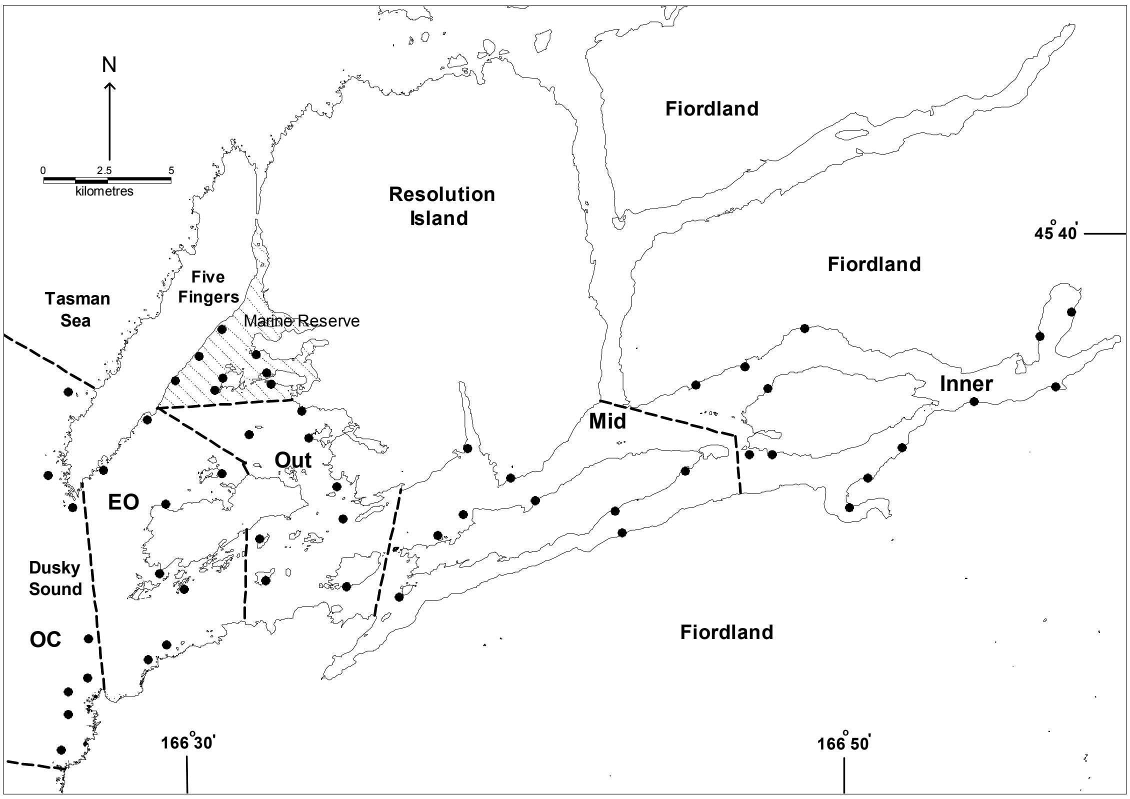


Figure 2: Map of the Dusky Sound area showing the six strata and 54 stations of the 2008 blue cod potting survey including 8 stations in the Taumoana (Five Fingers Peninsula) marine reserve.

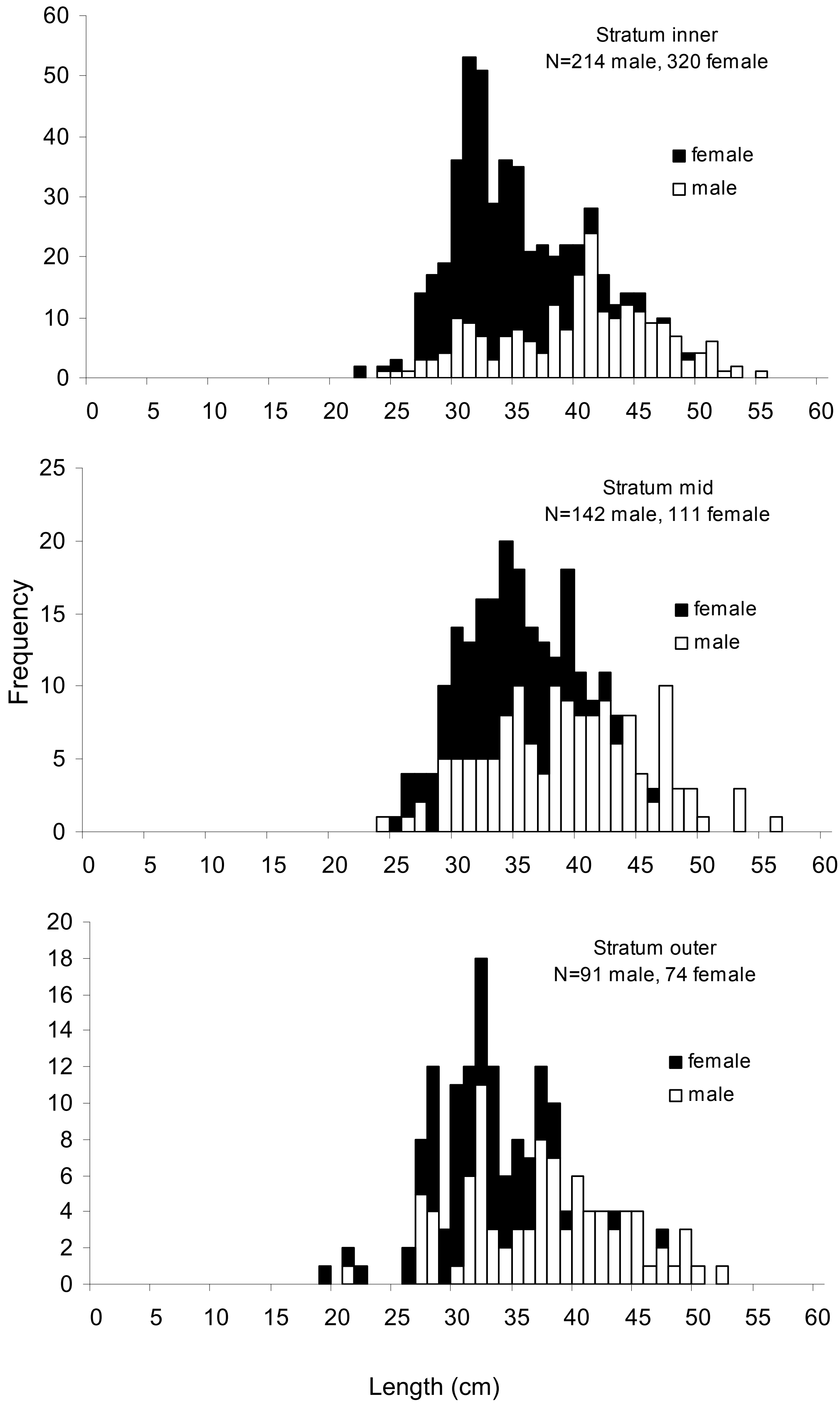


Figure 3: Unscaled length frequency distributions of blue cod for each stratum including the marine reserve for the Dusky Sound 2008 survey.

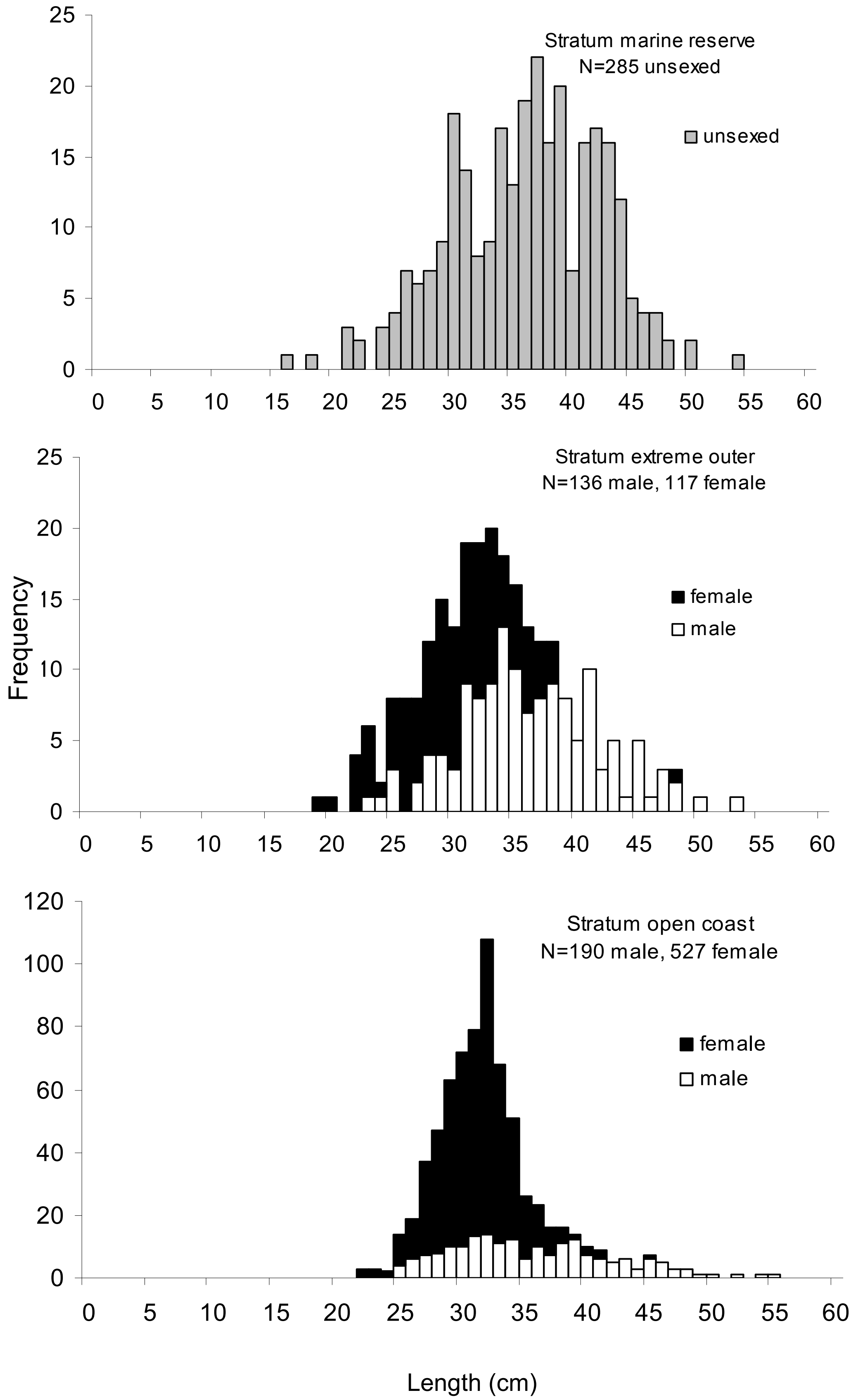


Figure 3 – ***continued***

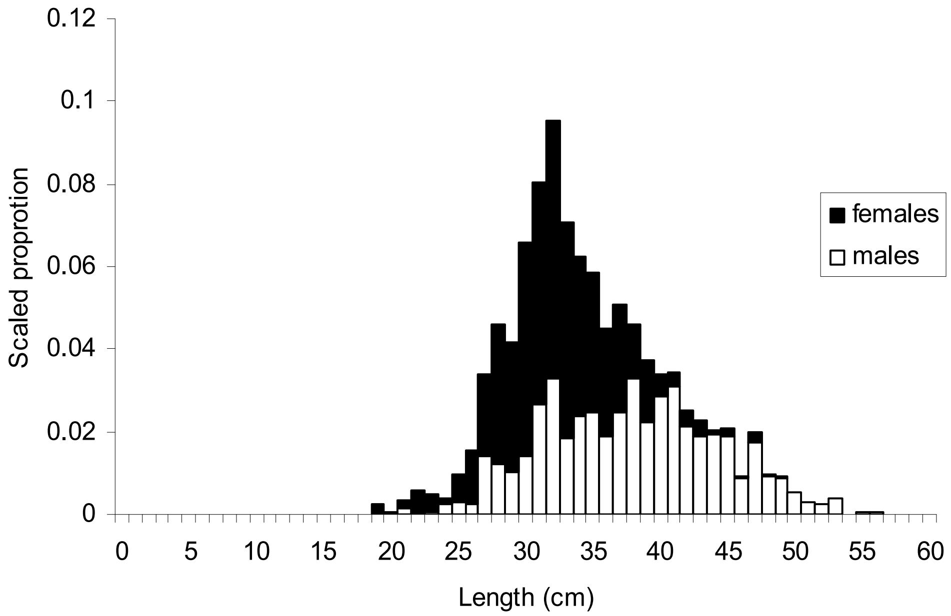


Figure 3 – *continued* (above is the scaled length frequency distribution for all strata except marine reserve)

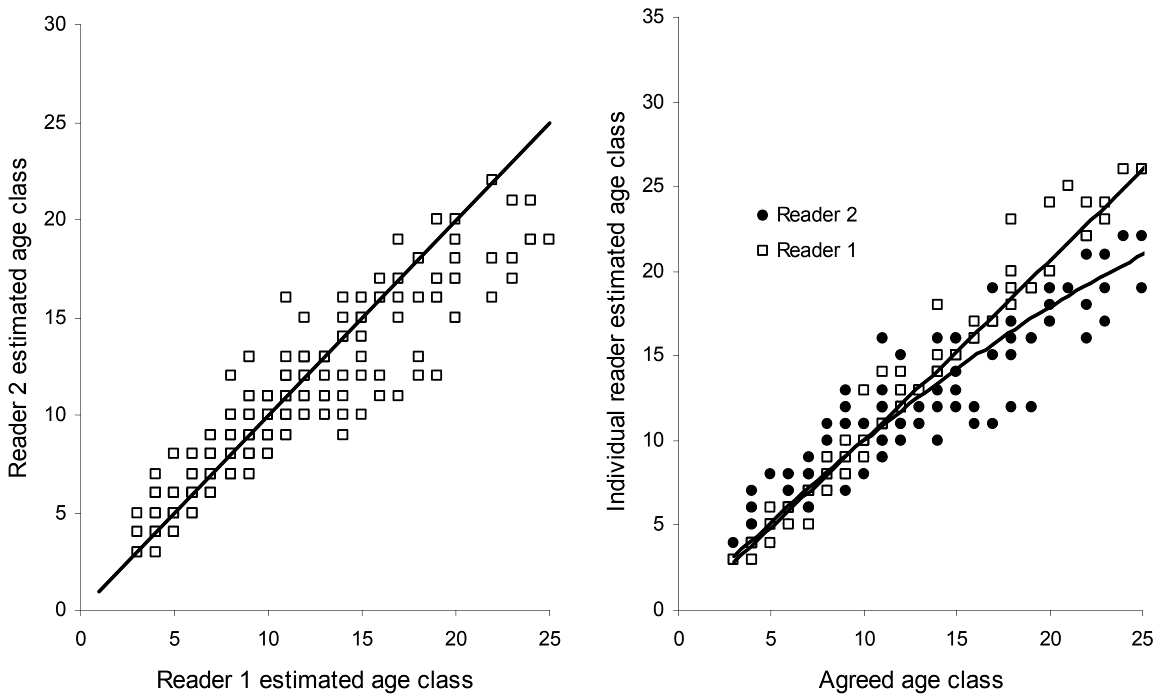


Figure 4: Dusky 2008 survey comparison of individual reader age class estimates from otoliths plotted against each other on the left with the 1:1 line plotted and in the right panel the agreed age class estimates on the right (n = 337), with polynomial trend line fitted.

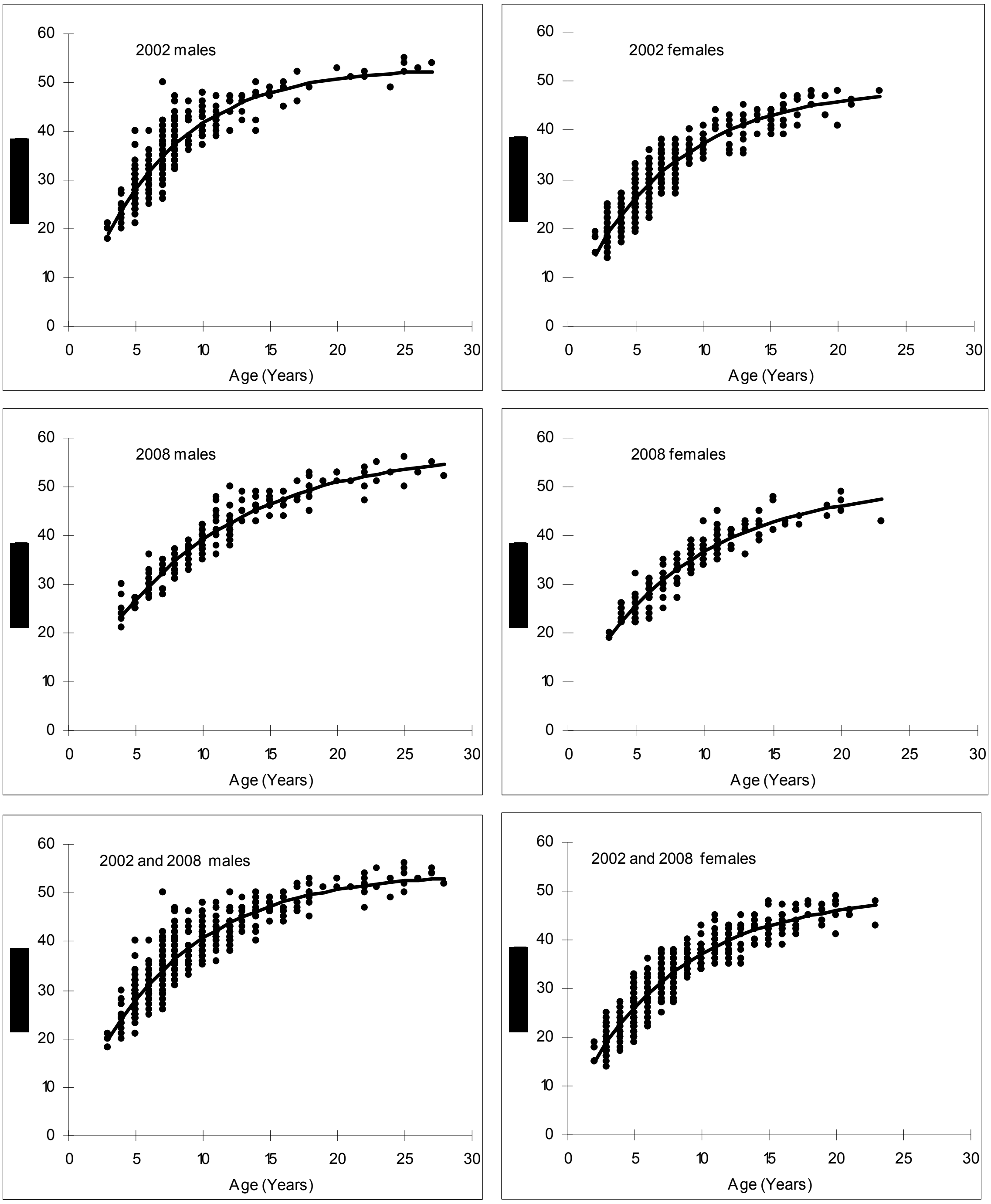


Figure 5: Age and length plots by sex for the 2002 and 2008 Dusky Sound surveys, separately and combined. von Bertalanffy growth models are fitted to the data. See Table 7 for description of samples.

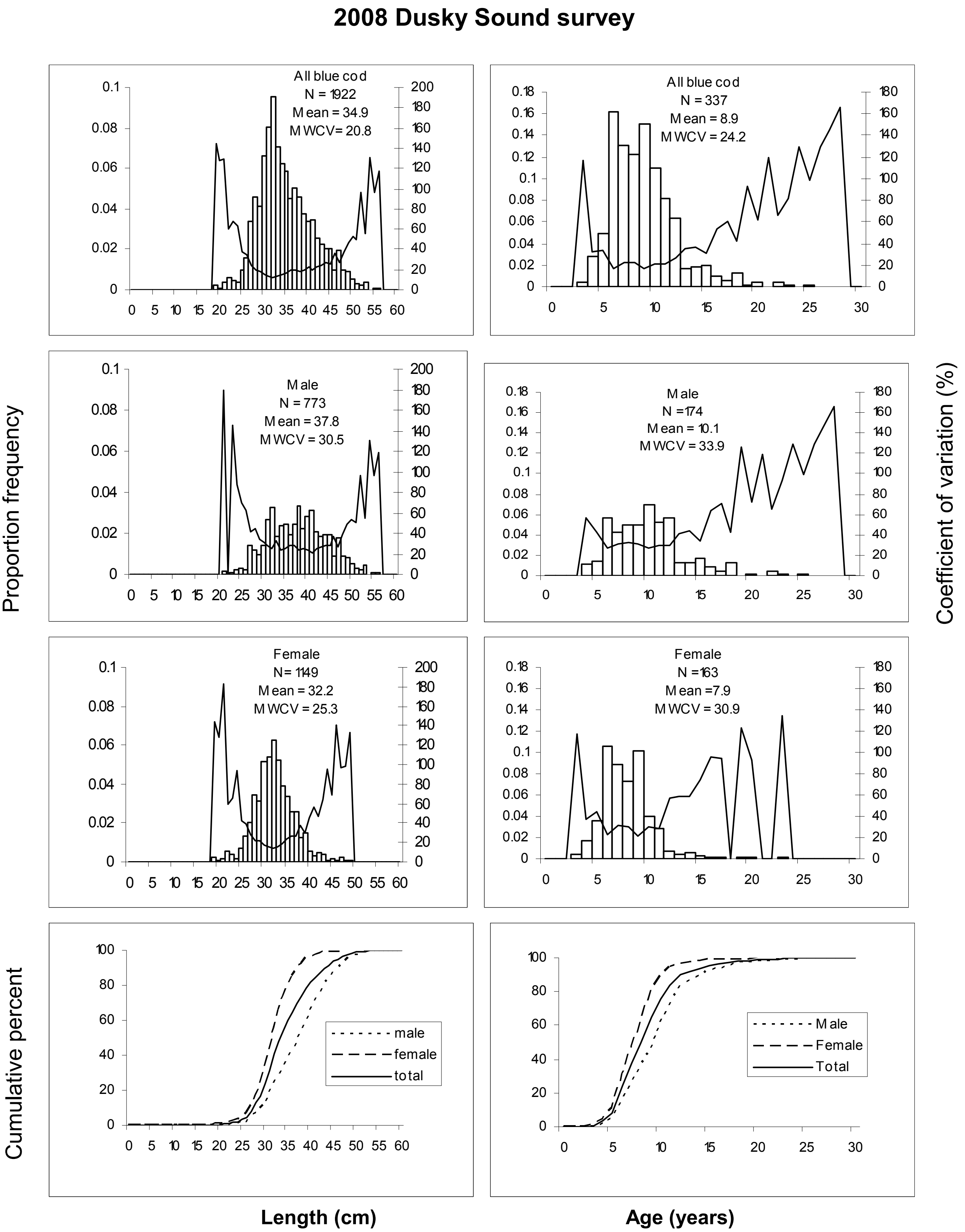


Figure 6: Scaled length frequency, age frequency, and cumulative distributions for total, male, and female blue cod for all strata combined, outside the marine reserve, for the 2008 Dusky Sound survey. N, sample size; MWCV, mean weighted coefficient of variation.

2008 Dusky Sound survey (marine reserve)

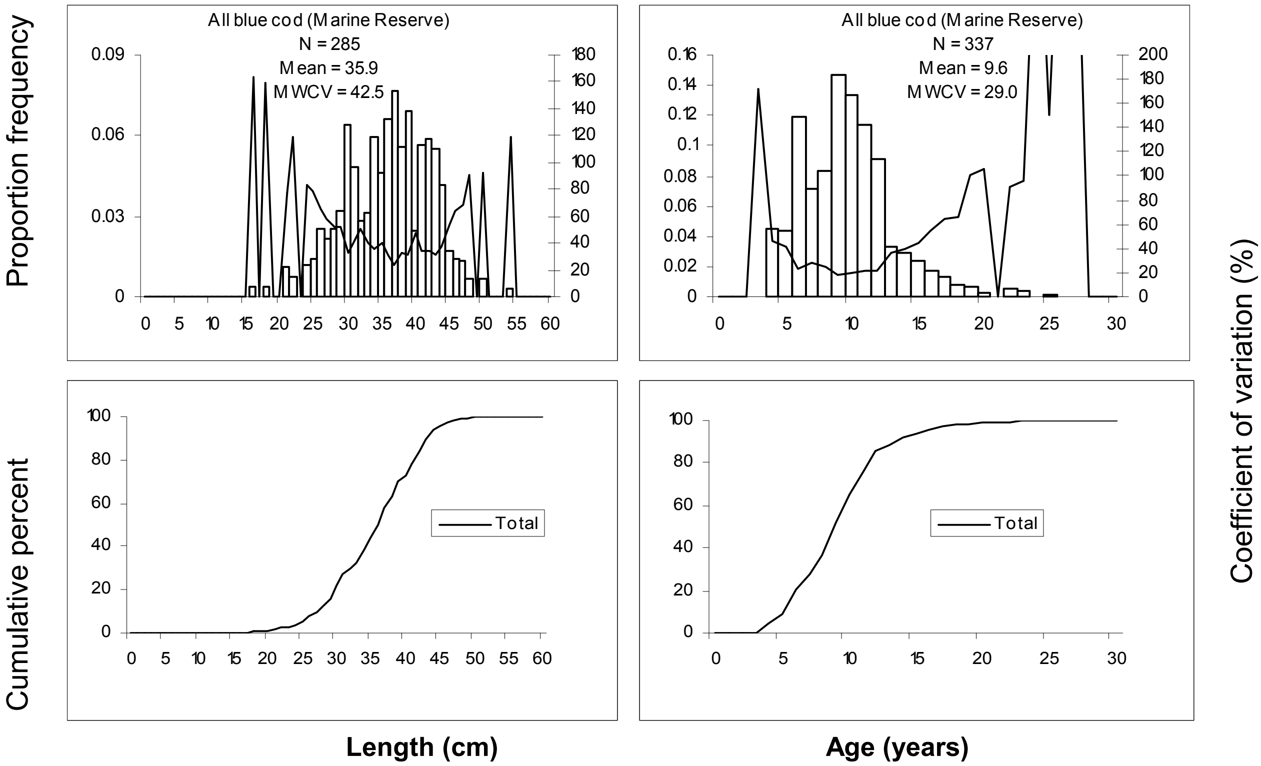


Figure 7: Scaled length frequency, age frequency, and cumulative distributions for unsexed blue cod for the 2008 Dusky Sound within the marine reserve. N, sample size; MWCV, mean weighted coefficient of variation.

2002 Dusky Sound survey

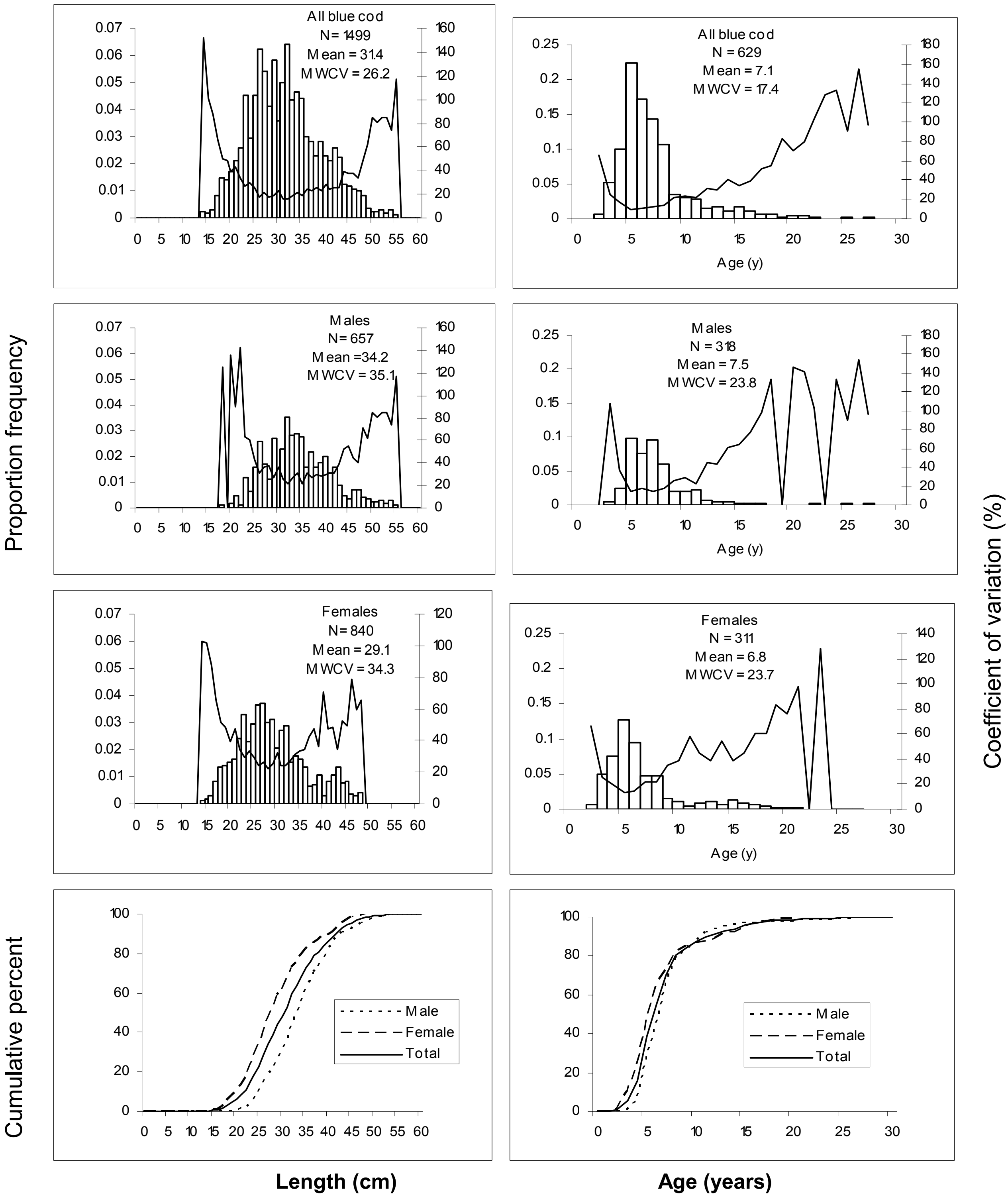


Figure 8: Scaled length frequency, age frequency, and cumulative distributions for total, male, and female blue cod for all strata combined for the 2002 Dusky Sound survey. N, sample size; MWCV, mean weighted coefficient of variation.

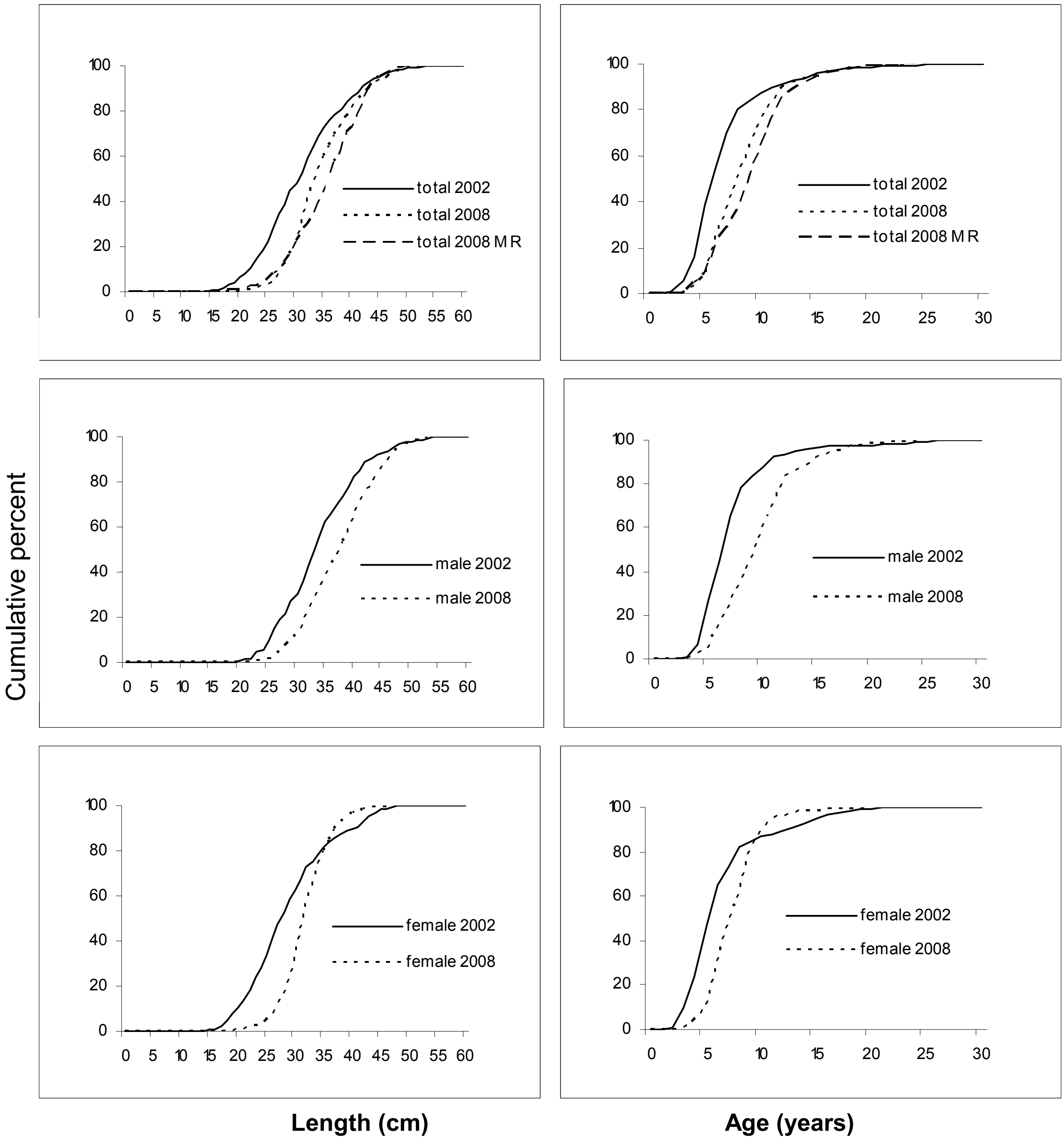


Figure 9: Scaled length and age cumulative frequency distributions for total, male, and female blue cod for the 2002 and 2008 Dusky Sound surveys.

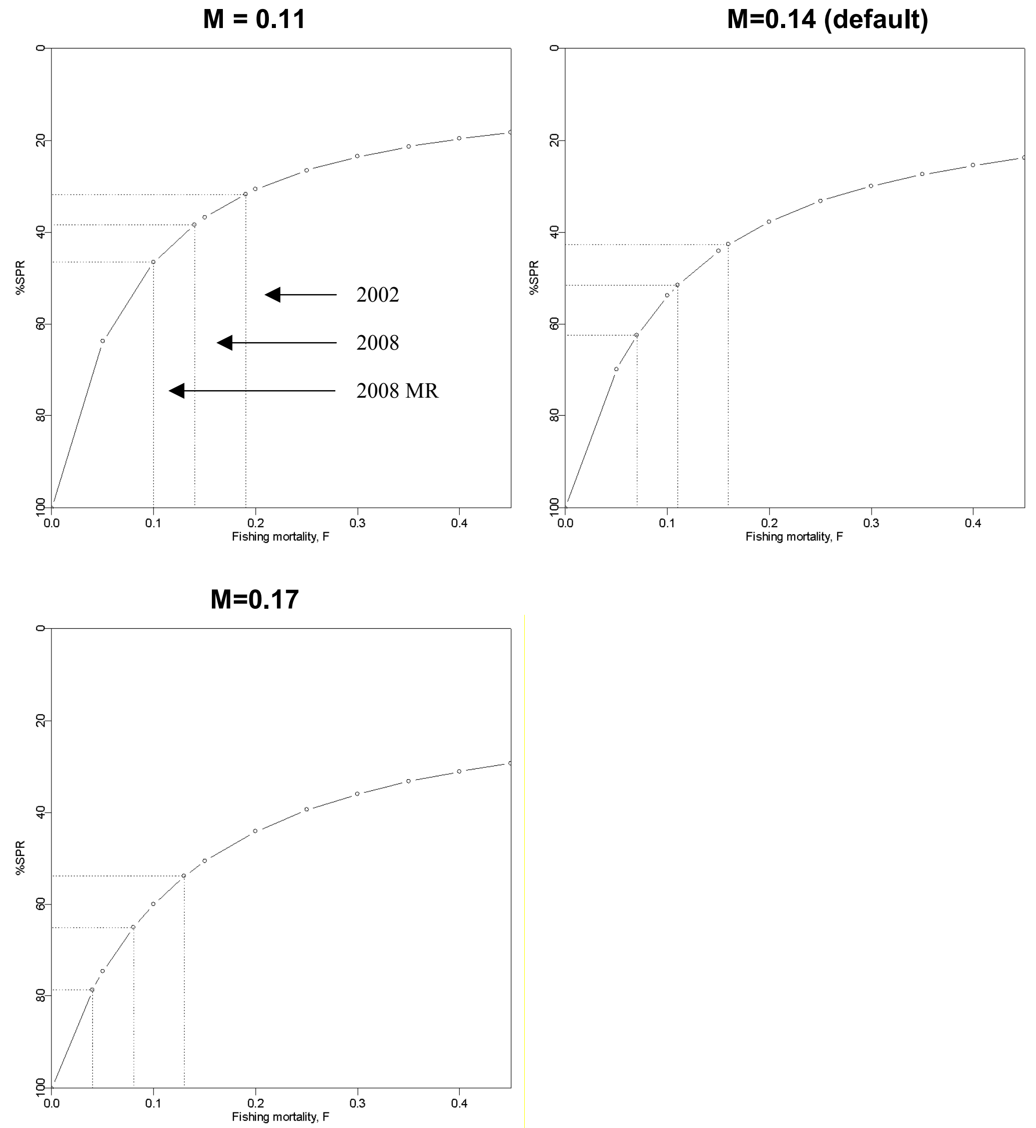


Figure 10: Plot of spawner per recruit (SPR) as a function of fishing mortality for the 2002 and 2008 surveys at three values of M (0.11, 0.14, 0.17). The 2008 SPR plots are for the entire survey excluding the marine reserve, and for the marine reserve exclusively. See Tables 9 and 10 for fishing mortalities and $F_{SPR\%}$. The y-axis has been inverted because a low fishing mortality corresponds to a high %SPR.

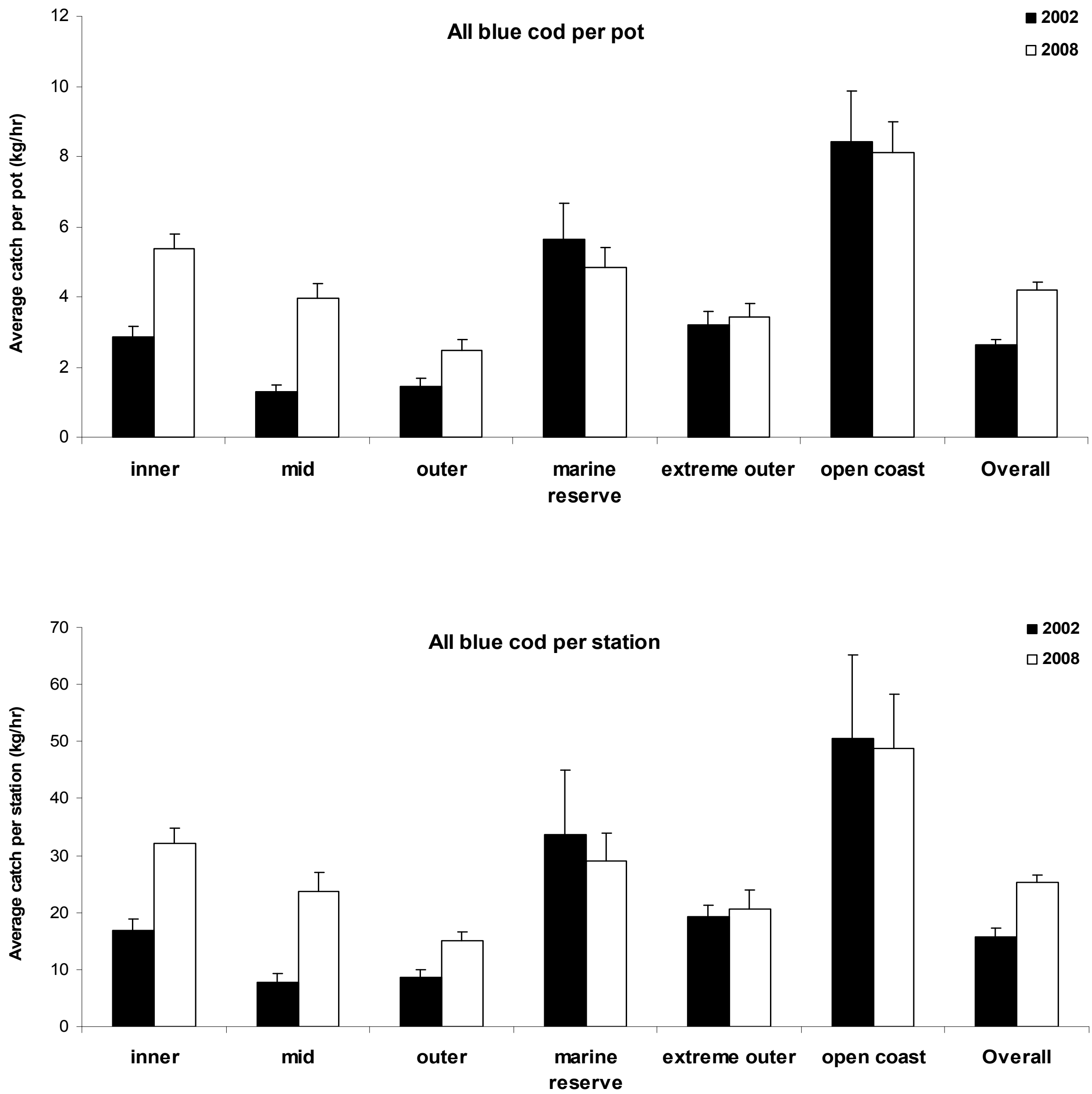
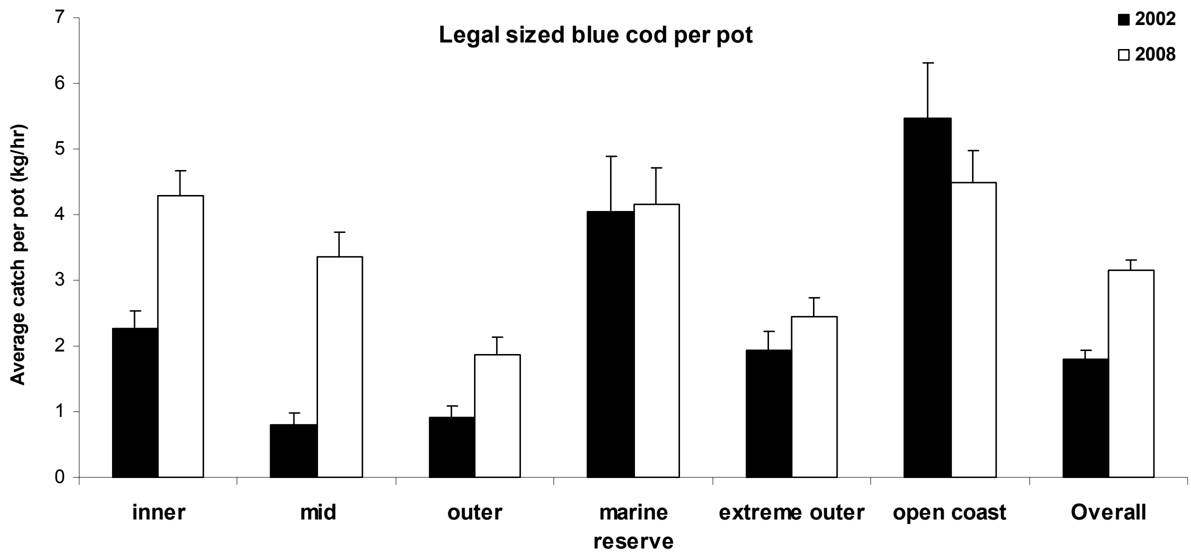


Figure 11: Between survey comparisons of mean standardised catch rates (kilogram/hour) by stratum and overall weighted mean (excluding marine reserve) for all blue cod caught in the 2002 and 2008 Dusky Sound potting surveys. Catch rates are presented both by pot landings and total station landings (i.e., the combined landings of the six pots at each station) blue cod. Error bars are the standard error of the mean.



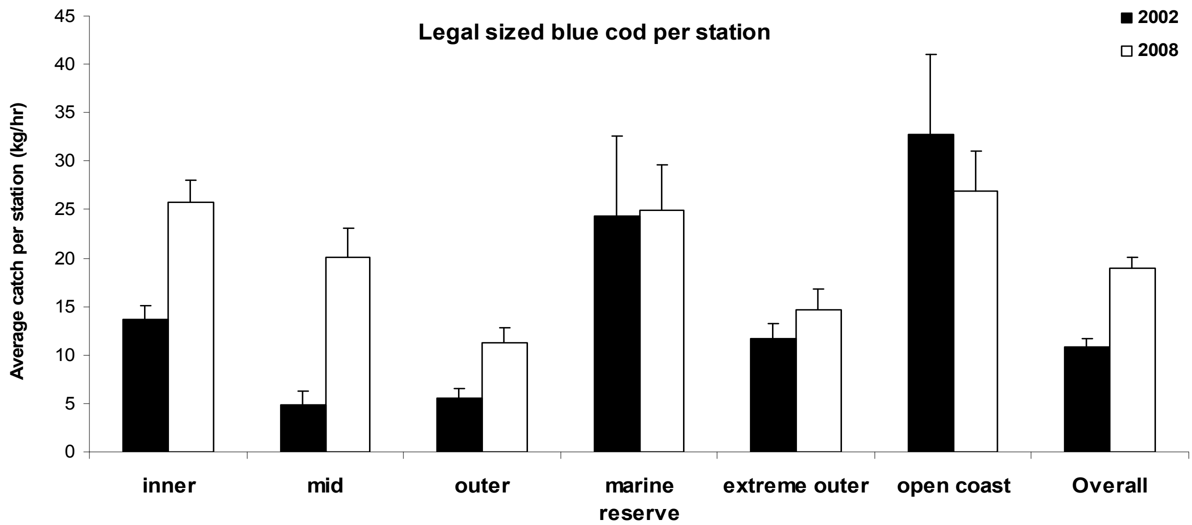


Figure 12: Between survey comparisons of mean standardised catch rates (kilogram/hour) by stratum and overall weighted mean (excluding the marine reserve) for legal sized (33 cm and over) blue cod caught in the 2002 and 2008 Dusky Sound potting surveys. Catch rates are presented both by pot landings 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 2002 Dusky Sound potting survey

From 15 to 26 October 2002, 44 potting stations were surveyed (6 pots per station = 264 pot lifts) from five strata (inner, mid, outer, extreme outer, and open coast) that covered an area between the inner fiord and the open coast of Dusky Sound (figure A, Carbines & Beentjes 2003). During phase 1, 228 pot lifts were completed (86%) with 36 in phase 2. The survey took 12 fishing days to complete.

The total blue cod catch in Dusky Sound was 873 kg, consisting of 1515 blue cod. The overall mean catch rate and c.v. for the survey was 2.8 kg per pot lift and 6.3% respectively (Table A). For fish of all sizes, catch rates ranged from 1.3 kg per pot per hour in the mid stratum to 8.4 kg per pot per hour for the open cost stratum. When analysed by station (i.e., the sum of the six pots catch) the c.v. increases by 4.1% to 10.4% overall for all sized blue cod (Table A).

For blue cod 33 cm total length and over (minimum legal size), catch rates by strata mirrored those of all fish, ranging from 0.8 to 5.5 kg per pot per hour with an overall mean catch rate and c.v. of 2.0 kg per pot per hour and 6.6% (Table B). When analysed by station the c.v. increases 2.2% to 8.8% overall for legal sized fish.

Forty-four percent of blue cod caught exceeded the minimum legal size (33 cm and over) and 61% were over 30 cm (MLS BCO 3). Dusky Sound had large blue cod and modest catch rates in relation to most other areas surveyed in the Ministry of Fisheries South Island potting survey network (Carbines et al. 2008).

Blue cod from strata within Dusky Sound had similar size structures with some modes discernible at about 27 cm. This contrasted with blue cod from the open coast stratum which were about 3 cm longer on average, with fewer small fish present and a clear mode at about 33 cm (Carbines & Beentjes 2003). Males were longer than females in all strata and overall mean length was 34.7 cm for males and 30.1 cm for females. The average age was 7.6 years for males and 6.9 years for females with the total mortality estimate shown in Table 8. Overall sex was skewed in favour of females (78% overall) with only the outer stratum dominated by males (60%). Most gonads were resting or maturing with about 20% mature or running ripe for both sexes indicating that spawning was only beginning in October 2002 (Carbines & Beentjes 2003).

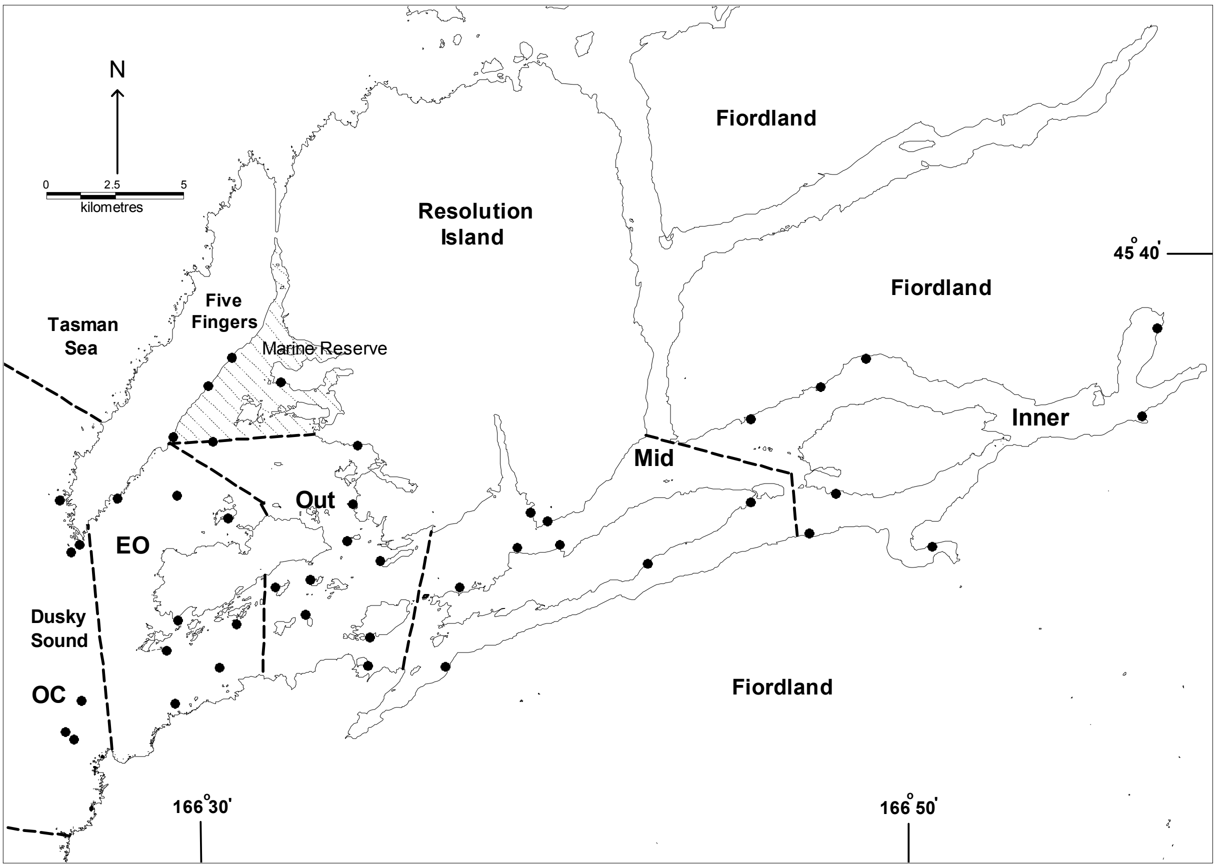
Table A: 2002 mean catch rate, standard error, and c.v. per stratum and overall for all blue cod retrospectively calculated with the marine reserve separated out. These are presented both by pot and by station (grouping of the 6 pots used at each station). In the last row the overall catch rates for blue cod 30 cm and over are given as a comparison to areas with that MLS. Note the overall values differ from Carbines & Beentjes (2002) as revised estimates of stratum size are used (see Table 1).

Stratum	Pot lifts (N)	Mean (kg/pot)	s.e.	c.v. %	Mean (kg/station)	s.e.	c.v. %
inner	48	2.79	0.31	11.11	16.74	2.01	12.03
mid	48	1.28	0.19	14.84	7.69	1.69	21.95
outer	60	1.43	0.23	16.08	8.55	1.31	15.30
MR	24	5.62	1.03	18.33	33.76	11.15	33.01
extreme outer	48	3.21	0.36	11.21	19.26	2.04	10.59
open coast	36	8.42	1.46	17.34	50.55	14.64	28.97
Overall (MR excluded)	240	2.63	0.16	6.22	15.77	1.55	9.84
Overall (MR included)	264	2.83	0.18	6.27	16.97	1.77	10.40

Table B: 2002 mean catch rate, standard error, and c.v. per stratum and overall for ≥ 33 cm blue cod retrospectively calculated with the marine reserve separated out. These are presented both by pot and by station (grouping of the 6 pots used at each station). Note the overall values differ from Carbines & Beentjes (2002) as revised estimates of stratum size are used (see Table 1).

Stratum	Pot lifts (N)	Mean (kg/pot)	s.e.	c.v. %	Mean (kg/station)	s.e.	c.v. %
inner	48	2.27	0.27	11.96	13.62	1.44	10.60
mid	48	0.81	0.17	20.58	4.86	1.33	27.36
outer	60	0.92	0.17	18.65	5.52	1.06	19.12
MR	24	4.05	0.83	20.46	24.32	8.27	33.98
extreme outer	48	1.94	0.28	14.38	11.62	1.65	14.15
open coast	36	5.46	0.84	15.45	32.76	8.32	25.39
Overall ≥33 cm							
MR included	264	1.95	0.13	6.64	11.70	1.03	8.81
MR excluded	240	1.80	0.13	6.97	10.79	0.93	8.64
Overall ≥30 cm							
MR excluded	240	2.19	0.16	7.11	13.11	1.26	9.57

Figure A: Map of the Dusky Sound area showing the five strata and stations (dots) of the 2002 blue cod potting survey (MFish Project BCO2000/01). Strata are OC (open coast), EO (extreme outer), Out (outer), Mid and Inner. Detailed results of this survey were given by Carbines & Beentjes (2003).



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, $S\ (=e^{-Z})$, 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

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

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

We used the simulation model developed by Dunn et al. (2002) to estimate the variance of Z, and hence attempt to evaluate the variance of these estimates when the steady state assumptions are relaxed. An approximate simulated 95% confidence interval for the estimates of $\hat{Z}$ was calculated from the 2002 and 2008 Dusky Sound 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, Dusky Sound 2008.

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-Oct-08	1	OC	OCA	46	9:52	3	20.6	35
1	16-Oct-08	1	OC	OCA	50	10:06	5	18.6	42
1	16-Oct-08	1	OC	OCA	45	10:15	4	17.4	43
1	16-Oct-08	1	OC	OCA	37	10:24	6	16.0	38
1	16-Oct-08	1	OC	OCA	37	10:35	2	17.1	38
1	16-Oct-08	1	OC	OCA	27	10:47	1	6.9	18
2	16-Oct-08	1	OC	OC3	44	13:20	1	9.3	16
2	16-Oct-08	1	OC	OC3	42	13:25	2	13.4	26
2	16-Oct-08	1	OC	OC3	37	13:32	6	10.6	24
2	16-Oct-08	1	OC	OC3	35	13:37	4	8.5	16
2	16-Oct-08	1	OC	OC3	31	13:45	5	3.4	7
2	16-Oct-08	1	OC	OC3	29	13:52	3	6.5	12
3	16-Oct-08	1	OC	OC15	46	15:40	3	12.9	22
3	16-Oct-08	1	OC	OC15	35	15:45	5	9.6	18
3	16-Oct-08	1	OC	OC15	44	15:50	4	5.2	6
3	16-Oct-08	1	OC	OC15	37	15:55	6	2.7	6
3	16-Oct-08	1	OC	OC15	51	16:00	2	10.4	15
3	16-Oct-08	1	OC	OC15	48	16:05	1	13.3	27
4	17-Oct-08	1	EO	EO29	29	8:45	1	6.6	10
4	17-Oct-08	1	EO	EO29	33	8:50	2	3.2	8
4	17-Oct-08	1	EO	EO29	27	8:56	6	2.3	7
4	17-Oct-08	1	EO	EO29	27	9:01	4	0.9	2
4	17-Oct-08	1	EO	EO29	33	9:07	3	3.2	5
4	17-Oct-08	1	EO	EO29	24	9:13	5	9.6	16
5	17-Oct-08	1	EO	EO10	48	12:03	5	2.8	3
5	17-Oct-08	1	EO	EO10	46	12:08	3	4.3	6
5	17-Oct-08	1	EO	EO10	37	12:13	4	2.2	3
5	17-Oct-08	1	EO	EO10	38	12:18	6	4.5	8
5	17-Oct-08	1	EO	EO10	26	12:24	2	2.0	1
5	17-Oct-08	1	EO	EO10	26	12:28	1	3.0	6
6	17-Oct-08	1	OUT	OUT21	27	14:55	1	1.6	3
6	17-Oct-08	1	OUT	OUT21	35	15:00	2	2.1	4
6	17-Oct-08	1	OUT	OUT21	31	15:05	6	1.8	3
6	17-Oct-08	1	OUT	OUT21	37	15:10	4	3.5	7
6	17-Oct-08	1	OUT	OUT21	18	15:15	3	1.8	2
6	17-Oct-08	1	OUT	OUT21	22	15:20	5	5.1	6
7	17-Oct-08	1	OUT	OUT4	37	16:55	5	3.1	5
7	17-Oct-08	1	OUT	OUT4	37	17:00	3	0.0	0
7	17-Oct-08	1	OUT	OUT4	37	17:05	4	0.0	0
7	17-Oct-08	1	OUT	OUT4	18	17:07	6	2.7	4
7	17-Oct-08	1	OUT	OUT4	27	17:13	2	6.7	10
7	17-Oct-08	1	OUT	OUT4	13	17:17	1	0.0	0
8	18-Oct-08	1	EO	EO19	40	9:05	1	6.7	7
8	18-Oct-08	1	EO	EO19	40	9:10	2	2.0	5
8	18-Oct-08	1	EO	EO19	18	9:15	6	5.9	8
8	18-Oct-08	1	EO	EO19	24	9:20	4	4.2	13
8	18-Oct-08	1	EO	EO19	37	9:25	3	0.9	1

Set	Date	Phase	Stratum	Pot lift station	Depth (m)	Time set	Pot number	Catch of blue cod (kg)	Number of fish
8	18-Oct-08	1	EO	EO19	27	9:30	5	0.8	2
9	18-Oct-08	1	EO	EO15	33	11:35	5	6.3	11
9	18-Oct-08	1	EO	EO15	18	11:40	3	3.5	6
9	18-Oct-08	1	EO	EO15	31	11:45	4	1.5	1
9	18-Oct-08	1	EO	EO15	18	11:50	6	4.6	6
9	18-Oct-08	1	EO	EO15	18	11:55	2	1.2	5
9	18-Oct-08	1	EO	EO15	37	12:00	1	4.5	7
10	18-Oct-08	1	OUT	OUT15	37	14:10	1	1.5	2
10	18-Oct-08	1	OUT	OUT15	18	14:15	2	3.7	4
10	18-Oct-08	1	OUT	OUT15	37	14:20	6	2.0	3
10	18-Oct-08	1	OUT	OUT15	46	14:25	4	2.9	4
10	18-Oct-08	1	OUT	OUT15	40	14:30	3	9.0	10
10	18-Oct-08	1	OUT	OUT15	73	14:40	5	2.9	2
11	18-Oct-08	1	OUT	OUT14	37	16:42	5	3.6	5
11	18-Oct-08	1	OUT	OUT14	33	16:48	3	2.9	4
11	18-Oct-08	1	OUT	OUT14	37	16:53	4	0.0	0
11	18-Oct-08	1	OUT	OUT14	37	17:00	6	4.8	3
11	18-Oct-08	1	OUT	OUT14	75	17:05	2	0.0	0
11	18-Oct-08	1	OUT	OUT14	33	17:10	1	0.5	1
12	19-Oct-08	1	MID	MID22	48	8:50	1	2.6	2
12	19-Oct-08	1	MID	MID22	64	8:55	2	0.5	1
12	19-Oct-08	1	MID	MID22	18	9:00	6	6.3	8
12	19-Oct-08	1	MID	MID22	22	9:05	4	1.7	3
12	19-Oct-08	1	MID	MID22	24	9:10	3	3.1	3
12	19-Oct-08	1	MID	MID22	18	9:15	5	5.5	5
13	19-Oct-08	1	MID	MID19	31	11:05	5	4.0	3
13	19-Oct-08	1	MID	MID19	26	11:10	3	0.0	0
13	19-Oct-08	1	MID	MID19	18	11:15	4	0.6	1
13	19-Oct-08	1	MID	MID19	38	11:20	6	14.9	16
13	19-Oct-08	1	MID	MID19	64	11:25	2	6.2	7
13	19-Oct-08	1	MID	MID19	18	11:30	1	9.7	9
14	19-Oct-08	1	MID	MID31	18	13:35	1	1.6	2
14	19-Oct-08	1	MID	MID31	62	13:40	2	2.3	3
14	19-Oct-08	1	MID	MID31	27	13:45	6	0.4	1
14	19-Oct-08	1	MID	MID31	27	13:50	4	4.6	4
14	19-Oct-08	1	MID	MID31	18	13:55	3	2.4	3
14	19-Oct-08	1	MID	MID31	24	14:00	5	0.7	1
15	19-Oct-08	1	INN	INN21	9	15:55	5	7.1	5
15	19-Oct-08	1	INN	INN21	7	16:00	3	13.1	15
15	19-Oct-08	1	INN	INN21	16	16:05	4	19.3	22
15	19-Oct-08	1	INN	INN21	16	16:10	6	4.6	7
15	19-Oct-08	1	INN	INN21	11	16:15	2	1.7	3
15	19-Oct-08	1	INN	INN21	16	16:20	1	1.5	1
16	20-Oct-08	1	INN	INN8	22	7:50	1	5.2	6
16	20-Oct-08	1	INN	INN8	22	7:55	2	0.0	0
16	20-Oct-08	1	INN	INN8	44	8:00	6	5.0	4
16	20-Oct-08	1	INN	INN8	18	8:05	3	2.7	4
16	20-Oct-08	1	INN	INN8	18	8:55	1b	0.0	0
16	20-Oct-08	1	INN	INN8	18	8:30	5	0.0	0

Set	Date	Phase	Stratum	Pot lift station	Depth (m)	Time set	Pot number	Catch of blue cod (kg)	Number of fish
17	20-Oct-08	1	INN	INN7	49	10:35	1	4.1	6
17	20-Oct-08	1	INN	INN7	31	10:40	5	4.4	4
17	20-Oct-08	1	INN	INN7	37	10:45	3	4.8	6
17	20-Oct-08	1	INN	INN7	35	10:50	6	11.8	17
17	20-Oct-08	1	INN	INN7	35	10:55	2	6.0	10
17	20-Oct-08	1	INN	INN7	26	11:43	1b	7.7	9
18	20-Oct-08	1	INN	INN18	18	13:15	1	13.3	20
18	20-Oct-08	1	INN	INN18	29	13:20	2	4.2	6
18	20-Oct-08	1	INN	INN18	29	13:25	6	3.7	7
18	20-Oct-08	1	INN	INN18	22	13:30	3	5.3	9
18	20-Oct-08	1	INN	INN18	44	14:35	5	2.6	3
18	20-Oct-08	1	INN	INN18	37	14:20	1b	0.0	0
19	20-Oct-08	1	INN	INN10	44	15:55	1	2.6	3
19	20-Oct-08	1	INN	INN10	18	16:00	4	4.4	7
19	20-Oct-08	1	INN	INN10	5	16:05	3	3.9	4
19	20-Oct-08	1	INN	INN10	29	14:10	6	4.9	6
19	20-Oct-08	1	INN	INN10	22	16:15	2	4.0	5
19	20-Oct-08	1	INN	INN10	27	17:00	1b	5.8	9
20	21-Oct-08	1	INN	INN15	37	20:20	1	1.6	2
20	21-Oct-08	1	INN	INN15	18	20:25	2	2.1	4
20	21-Oct-08	1	INN	INN15	18	20:30	6	7.0	11
20	21-Oct-08	1	INN	INN15	26	8:35	5	4.2	6
20	21-Oct-08	1	INN	INN15	26	8:40	4	8.0	13
20	21-Oct-08	1	INN	INN15	18	9:25	1b	1.2	2
21	21-Oct-08	1	MID	MID28	18	11:15	1	4.6	7
21	21-Oct-08	1	MID	MID28	11	11:25	4	7.9	6
21	21-Oct-08	1	MID	MID28	16	11:30	6	1.5	3
21	21-Oct-08	1	MID	MID28	16	11:35	5	3.6	4
21	21-Oct-08	1	MID	MID28	22	11:40	2	4.3	5
21	21-Oct-08	1	MID	MID28	22	12:20	1b	3.0	4
22	21-Oct-08	1	MID	MID25	26	13:45	1	4.3	5
22	21-Oct-08	1	MID	MID25	13	13:55	2	2.7	4
22	21-Oct-08	1	MID	MID25	27	14:00	5	0.0	0
22	21-Oct-08	1	MID	MID25	18	14:05	6	8.9	7
22	21-Oct-08	1	MID	MID25	18	14:10	4	5.5	6
22	21-Oct-08	1	MID	MID25	5	14:50	1b	0.6	2
23	21-Oct-08	1	MID	MID5	13	16:45	1	1.0	1
23	21-Oct-08	1	MID	MID5	37	16:50	4	1.3	2
23	21-Oct-08	1	MID	MID5	29	16:55	6	1.5	1
23	21-Oct-08	1	MID	MID5	18	17:00	5	6.7	11
23	21-Oct-08	1	MID	MID5	37	17:05	2	1.7	2
23	21-Oct-08	1	MID	MID5	27	17:10	3	1.5	2
24	22-Oct-08	1	EO	EO21	64	9:05	4	0.8	1
24	22-Oct-08	1	EO	EO21	37	9:10	1	0.0	0
24	22-Oct-08	1	EO	EO21	37	9:15	2	1.8	3
24	22-Oct-08	1	EO	EO21	27	9:20	6	0.7	1
24	22-Oct-08	1	EO	EO21	46	9:25	3	1.9	3
24	22-Oct-08	1	EO	EO21	37	9:30	5	1.7	2
25	22-Oct-08	1	EO	EO24	27	10:55	5	1.6	2

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
25	22-Oct-08	1	EO	EO24	37	11:00	3	5.0	6
25	22-Oct-08	1	EO	EO24	18	11:05	6	1.3	2
25	22-Oct-08	1	EO	EO24	26	11:10	2	5.6	7
25	22-Oct-08	1	EO	EO24	31	11:15	1	1.7	3
25	22-Oct-08	1	EO	EO24	64	11:20	4	1.0	1
26	22-Oct-08	1	OC	OC26	64	13:55	4	2.8	5
26	22-Oct-08	1	OC	OC26	37	14:00	1	0.8	2
26	22-Oct-08	1	OC	OC26	71	14:10	2	2.3	4
26	22-Oct-08	1	OC	OC26	62	14:15	6	3.7	7
26	22-Oct-08	1	OC	OC26	62	14:25	3	0.0	0
26	22-Oct-08	1	OC	OC26	73	14:40	5	0.0	0
27	22-Oct-08	1	OUT	OUT22	37	16:25	5	4.8	6
27	22-Oct-08	1	OUT	OUT22	68	16:30	3	0.0	0
27	22-Oct-08	1	OUT	OUT22	68	16:35	6	1.2	1
27	22-Oct-08	1	OUT	OUT22	18	16:40	2	3.2	3
27	22-Oct-08	1	OUT	OUT22	27	16:45	1	2.1	3
27	22-Oct-08	1	OUT	OUT22	37	16:50	4	1.7	3
28	23-Oct-08	1	OC	OC8	69	9:35	5	5.5	5
28	23-Oct-08	1	OC	OC8	37	9:40	3	2.2	3
28	23-Oct-08	1	OC	OC8	62	9:45	6	2.2	4
28	23-Oct-08	1	OC	OC8	73	9:50	2	3.0	5
28	23-Oct-08	1	OC	OC8	66	9:55	1	3.6	3
28	23-Oct-08	1	OC	OC8	62	10:00	4	5.3	5
29	23-Oct-08	1	OC	OC10	73	11:35	4	11.5	11
29	23-Oct-08	1	OC	OC10	66	11:40	1	11.0	12
29	23-Oct-08	1	OC	OC10	64	11:45	2	12.2	19
29	23-Oct-08	1	OC	OC10	59	11:50	6	3.7	6
29	23-Oct-08	1	OC	OC10	48	11:55	3	5.2	7
29	23-Oct-08	1	OC	OC10	57	12:00	5	0.5	1
30	23-Oct-08	1	OC	OC5	82	14:05	4	2.4	4
30	23-Oct-08	1	OC	OC5	73	14:20	1	7.6	15
30	23-Oct-08	1	OC	OC5	71	14:25	2	9.3	15
30	23-Oct-08	1	OC	OC5	55	14:30	6	1.5	3
30	23-Oct-08	1	OC	OC5	48	14:35	3	9.4	16
30	23-Oct-08	1	OC	OC5	42	14:40	5	14.2	25
31	23-Oct-08	1	EO	EO3	60	16:25	5	12.6	15
31	23-Oct-08	1	EO	EO3	55	16:30	3	3.6	4
31	23-Oct-08	1	EO	EO3	49	16:35	6	10.3	17
31	23-Oct-08	1	EO	EO3	42	16:40	2	1.6	2
31	23-Oct-08	1	EO	EO3	68	16:45	1	4.8	7
31	23-Oct-08	1	EO	EO3	57	16:50	4	6.7	8
32	24-Oct-08	1	OC	OC1	26	8:55	4	0.0	0
32	24-Oct-08	1	OC	OC1	27	9:00	1	19.6	38
32	24-Oct-08	1	OC	OC1	18	9:08	6	5.0	10
32	24-Oct-08	1	OC	OC1	37	9:20	2	20.9	42
32	24-Oct-08	1	OC	OC1	38	9:30	3	11.2	22
32	24-Oct-08	1	OC	OC1	42	9:35	5	11.4	19
33	24-Oct-08	1	EO	EO5	40	11:55	5	7.5	9
33	24-Oct-08	1	EO	EO5	44	12:05	2	1.1	2

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
33	24-Oct-08	1	EO	EO5	31	12:00	3	1.0	2
33	24-Oct-08	1	EO	EO5	37	12:10	6	4.4	7
33	24-Oct-08	1	EO	EO5	26	12:15	1	0.3	1
33	24-Oct-08	1	EO	EO5	49	12:20	4	0.8	1
34	24-Oct-08	1	OUT	OUT1	31	14:00	4	5.7	10
34	24-Oct-08	1	OUT	OUT1	27	14:05	1	4.7	5
34	24-Oct-08	1	OUT	OUT1	22	14:10	6	1.5	3
34	24-Oct-08	1	OUT	OUT1	55	14:15	2	0.9	2
34	24-Oct-08	1	OUT	OUT1	42	14:20	3	1.2	2
34	24-Oct-08	1	OUT	OUT1	44	14:25	5	6.1	9
35	24-Oct-08	1	OUT	OUT17	18	16:08	5	3.6	4
35	24-Oct-08	1	OUT	OUT17	18	16:10	3	1.2	1
35	24-Oct-08	1	OUT	OUT17	38	16:15	2	1.8	3
35	24-Oct-08	1	OUT	OUT17	27	16:20	6	0.5	1
35	24-Oct-08	1	OUT	OUT17	22	16:25	1	0.0	0
35	24-Oct-08	1	OUT	OUT17	20	16:30	4	1.4	2
36	25-Oct-08	1	INN	INN2	40	10:45	3	4.0	4
36	25-Oct-08	1	INN	INN2	33	10:50	5	5.0	6
36	25-Oct-08	1	INN	INN2	18	10:55	6	8.5	8
36	25-Oct-08	1	INN	INN2	29	11:00	2	4.4	7
36	25-Oct-08	1	INN	INN2	18	11:05	4	11.9	11
36	25-Oct-08	1	INN	INN2	18	11:10	1	6.5	7
37	25-Oct-08	1	INN	INN6	18	12:30	4	8.5	8
37	25-Oct-08	1	INN	INN6	18	12:35	1	3.1	4
37	25-Oct-08	1	INN	INN6	22	12:40	2	1.7	2
37	25-Oct-08	1	INN	INN6	22	12:45	6	4.2	4
37	25-Oct-08	1	INN	INN6	20	12:50	5	11.7	13
37	25-Oct-08	1	INN	INN6	20	12:55	3	1.9	3
38	25-Oct-08	1	MID	MID15	48	15:25	3	3.8	5
38	25-Oct-08	1	MID	MID15	37	15:30	5	6.0	9
38	25-Oct-08	1	MID	MID15	48	15:35	6	5.1	6
38	25-Oct-08	1	MID	MID15	40	15:40	2	2.0	2
38	25-Oct-08	1	MID	MID15	33	15:45	4	3.6	5
38	25-Oct-08	1	MID	MID15	22	15:50	1	0.0	0
39	25-Oct-08	1	MID	MID10	18	17:30	2	3.9	4
39	25-Oct-08	1	MID	MID10	44	17:35	6	12.0	19
39	25-Oct-08	1	MID	MID10	24	17:40	4	10.1	11
39	25-Oct-08	1	MID	MID10	18	17:45	1	5.6	9
39	25-Oct-08	1	MID	MID10	27	17:50	5	3.4	4
39	25-Oct-08	1	MID	MID10	31	17:55	3	8.4	10
40	26-Oct-08	1	OUT	OUT19	29	8:25	3	3.1	5
40	26-Oct-08	1	OUT	OUT19	37	8:30	5	4.4	5
40	26-Oct-08	1	OUT	OUT19	27	8:35	1	1.0	1
40	26-Oct-08	1	OUT	OUT19	37	8:40	4	1.0	1
40	26-Oct-08	1	OUT	OUT19	18	8:45	6	4.3	9
40	26-Oct-08	1	OUT	OUT19	22	8:50	2	2.4	4
41	26-Oct-08	1	MR	MR2	18	11:10	2	0.9	1
41	26-Oct-08	1	MR	MR2	29	11:20	6	0.6	1
41	26-Oct-08	1	MR	MR2	18	11:30	4	0.7	1

Set	Date	Phase	Stratum	Pot lift station	Depth (m)	Time set	Pot number	Catch of blue cod (kg)	Number of fish
41	26-Oct-08	1	MR	MR2	13	11:40	1	4.8	4
41	26-Oct-08	1	MR	MR2	33	11:50	5	3.1	6
41	26-Oct-08	1	MR	MR2	37	12:00	3	14.9	14
42	26-Oct-08	1	MR	MR1	48	13:25	3	0.8	2
42	26-Oct-08	1	MR	MR1	31	13:35	5	9.1	10
42	26-Oct-08	1	MR	MR1	48	13:45	1	1.0	1
42	26-Oct-08	1	MR	MR1	40	13:55	4	2.0	2
42	26-Oct-08	1	MR	MR1	38	14:05	6	0.6	1
42	26-Oct-08	1	MR	MR1	48	14:15	2	0.9	2
43	26-Oct-08	1	MR	MR3	37	15:35	3	0.9	1
43	26-Oct-08	1	MR	MR3	44	15:45	5	7.0	8
43	26-Oct-08	1	MR	MR3	29	15:55	2	3.6	5
43	26-Oct-08	1	MR	MR3	40	16:05	1	4.5	4
43	26-Oct-08	1	MR	MR3	15	16:15	4	1.9	2
43	26-Oct-08	1	MR	MR3	40	16:25	6	3.5	5
44	27-Oct-08	1	MR	MR4	29	9:10	6	2.9	2
44	27-Oct-08	1	MR	MR4	42	9:20	4	0.4	2
44	27-Oct-08	1	MR	MR4	42	9:30	1	0.0	0
44	27-Oct-08	1	MR	MR4	40	9:40	2	4.3	10
44	27-Oct-08	1	MR	MR4	42	9:50	5	0.0	0
44	27-Oct-08	1	MR	MR4	33	10:00	3	3.7	5
45	27-Oct-08	1	MR	MR5	40	11:30	3	6.4	8
45	27-Oct-08	1	MR	MR5	13	11:35	5	6.6	6
45	27-Oct-08	1	MR	MR5	37	11:40	2	4.3	8
45	27-Oct-08	1	MR	MR5	5	11:45	1	0.6	1
45	27-Oct-08	1	MR	MR5	9	11:50	4	1.7	2
45	27-Oct-08	1	MR	MR5	44	11:55	6	8.7	8
46	27-Oct-08	1	MR	MR6	18	13:30	6	12.5	13
46	27-Oct-08	1	MR	MR6	18	13:40	4	5.9	6
46	27-Oct-08	1	MR	MR6	22	13:50	1	11.0	13
46	27-Oct-08	1	MR	MR6	22	14:00	2	9.2	11
46	27-Oct-08	1	MR	MR6	24	14:10	5	12.1	13
46	27-Oct-08	1	MR	MR6	15	14:20	3	0.0	0
47	27-Oct-08	1	MR	MR7	22	15:35	3	8.3	11
47	27-Oct-08	1	MR	MR7	18	15:45	5	6.2	7
47	27-Oct-08	1	MR	MR7	20	15:55	2	6.0	12
47	27-Oct-08	1	MR	MR7	18	16:05	1	2.2	3
47	27-Oct-08	1	MR	MR7	18	16:15	4	5.3	6
47	27-Oct-08	1	MR	MR7	24	16:25	6	9.9	13
48	27-Oct-08	1	MR	MR8	22	17:35	6	11.2	16
48	27-Oct-08	1	MR	MR8	18	17:45	4	9.8	11
48	27-Oct-08	1	MR	MR8	18	17:55	1	5.9	7
48	27-Oct-08	1	MR	MR8	18	18:05	2	7.4	11
48	27-Oct-08	1	MR	MR8	26	18:15	5	6.3	6
48	27-Oct-08	1	MR	MR8	22	18:25	3	3.0	4
49	28-Oct-08	2	MID	MID17	48	9:15	3	3.3	6
49	28-Oct-08	2	MID	MID17	48	9:20	5	10.2	9
49	28-Oct-08	2	MID	MID17	26	9:25	2	1.9	3
49	28-Oct-08	2	MID	MID17	27	9:30	1	0.9	1

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
49	28-Oct-08	2	MID	MID17	27	9:35	4	3.3	3
49	28-Oct-08	2	MID	MID17	29	9:40	6	2.5	3
50	28-Oct-08	2	INN	INN4	27	11:50	6	5.0	4
50	28-Oct-08	2	INN	INN4	18	11:55	4	0.5	1
50	28-Oct-08	2	INN	INN4	18	12:00	1	4.5	3
50	28-Oct-08	2	INN	INN4	18	12:05	2	5.4	7
50	28-Oct-08	2	INN	INN4	11	12:10	5	9.0	13
50	28-Oct-08	2	INN	INN4	24	12:15	3	15.3	12
51	28-Oct-08	2	INN	INN13	18	14:05	3	8.0	12
51	28-Oct-08	2	INN	INN13	42	14:10	5	3.8	7
51	28-Oct-08	2	INN	INN13	48	14:15	2	3.0	6
51	28-Oct-08	2	INN	INN13	37	14:20	1	2.3	3
51	28-Oct-08	2	INN	INN13	37	14:25	4	7.1	9
51	28-Oct-08	2	INN	INN13	38	14:30	6	8.6	12
52	28-Oct-08	2	INN	INN12	18	16:00	6	12.8	21
52	28-Oct-08	2	INN	INN12	18	16:05	4	0.2	1
52	28-Oct-08	2	INN	INN12	18	16:10	1	17.1	31
52	28-Oct-08	2	INN	INN12	31	16:15	2	4.5	6
52	28-Oct-08	2	INN	INN12	27	16:20	5	3.7	4
52	28-Oct-08	2	INN	INN12	42	16:20	3	5.6	9
53	29-Oct-08	2	INN	INN24	22	10:45	3	5.1	7
53	29-Oct-08	2	INN	INN24	48	10:50	5	1.2	1
53	29-Oct-08	2	INN	INN24	20	10:55	2	5.6	8
53	29-Oct-08	2	INN	INN24	29	11:00	1	7.1	9
53	29-Oct-08	2	INN	INN24	33	11:05	4	1.4	2
53	29-Oct-08	2	INN	INN24	27	11:10	6	6.3	7
54	29-Oct-08	2	INN	INN20	18	12:55	6	3.7	4
54	29-Oct-08	2	INN	INN20	35	13:00	4	9.0	8
54	29-Oct-08	2	INN	INN20	46	13:05	1	2.6	3
54	29-Oct-08	2	INN	INN20	31	13:10	2	1.0	1
54	29-Oct-08	2	INN	INN20	33	13:15	5	4.2	5
54	29-Oct-08	2	INN	INN20	18	13:20	3	4.4	5

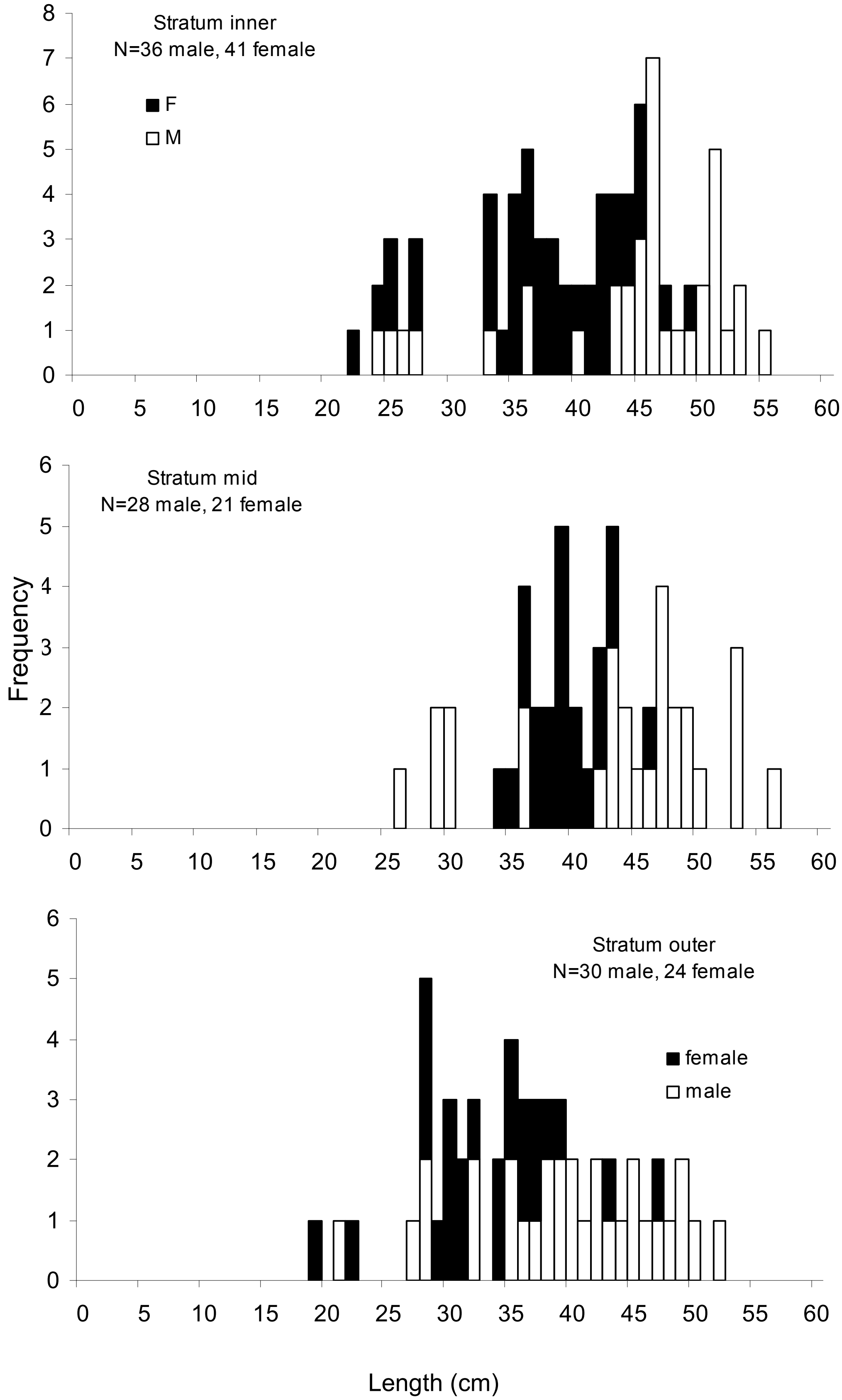
Appendix 4: Summary of Dusky Sound 2008 oceanographic environmental station data recorded in the format of MFish trawl data base. Depths are measured in meters, directions in compass degrees (999 = nil), wind force in the Beaufort scale, temperatures in degrees centigrade, air pressure in millibars, cloud cover in oktas, sea condition in the Douglas scale, sea colour in a categorical scale from 1 (deep blue) to 8 (yellow green), swell height in the Douglas classification 1 (low) to 3 (heavy), bottom type in a categorical scale from 1 (mud or ooze) to 9 (stone), bottom contour in a categorical scale from 1 (smooth/flat) to 5 (very rugged), and wind speed in kilometres per hour.

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	27	000	2	18.5	1014	2	4	06	3.0	180	7	4	12.0	11.5	10.7	6.7
2	44	000	2	18.5	1014	8	4	06	3.0	225	7	2	12.5	12.0	6.2	6.5
3	48	180	4	17.4	1015	8	4	04	4.0	270	7	3	12.0	11.5	20.6	7.0
4	29	000	2	11.5	1017	8	4	04	3.0	270	7	2	12.0	11.5	11.5	7.6
5	26	000	3	12.2	1016	8	2	04	2.0	270	7	4	12.0	12.0	14.9	6.4
6	27	000	2	13.5	1014	8	2	04	2.0	270	7	5	11.5	11.0	4.5	5.7
7	13	270	1	13.9	1014	8	2	04	0.0	999	7	3	11.5	12.0	7.0	5.0
8	40	180	2	11.4	1020	8	2	04	1.0	270	7	3	12.5	12.0	8.3	8.0
9	37	180	3	12.7	1021	8	2	04	0.5	270	7	4	12.0	11.5	15.5	7.8
10	37	270	3	12.1	1022	8	2	04	0.5	270	7	3	12.0	11.5	15.0	7.0
11	33	270	3	10.8	1023	8	2	04	0.5	270	7	3	12.0	11.5	17.0	7.2
12	48	090	3	8.8	1025	8	1	04	0.0	999	7	4	11.0	10.0	13.0	6.6
13	18	999	0	14.5	1025	5	1	04	0.0	999	7	3	10.0	11.0	0.0	4.1
14	18	270	4	14.8	1023	3	1	04	0.0	999	7	3	12.0	11.5	23.5	3.0
15	16	270	4	12.8	1021	3	2	08	0.0	999	7	2	12.0	11.5	29.0	3.0
16	22	000	1	10.8	1018	2	1	08	0.0	999	7	5	10.3	11.0	5.0	1.6
17	49	999	0	16.5	1018	6	1	08	0.0	999	7	1	8.5	10.0	0.0	2.1
18	18	270	1	12.3	1017	6	1	08	0.0	999	7	3	11.5	11.5	11.0	1.0
19	44	270	1	11.5	1017	8	1	08	0.0	999	7	3	12.0	12.5	12.0	1.5
20	37	225	1	10.8	1019	8	1	08	0.0	999	7	4	9.0	10.5	4.0	2.7
21	18	225	3	12.7	1019	8	1	08	0.0	999	7	3	11.0	11.5	18.3	2.8
22	26	022	2	13.4	1019	8	1	06	0.0	999	7	2	11.5	11.0	9.0	4.1
23	13	270	1	12.1	1017	8	1	06	0.5	270	7	4	11.5	11.5	4.3	4.5
24	37	270	1	14.9	1016	7	3	06	3.0	135	7	2	11.5	12.0	7.3	7.0
25	31	999	0	11.7	1017	7	3	06	2.5	270	7	3	12.0	12.0	0.0	8.7
26	37	180	4	7.5	1018	8	4	04	2.0	270	7	4	12.0	12.0	25.0	9.0
27	27	180	4	19.0	1018	4	3	01	1.0	180	7	5	12.5	12.0	20.0	6.5

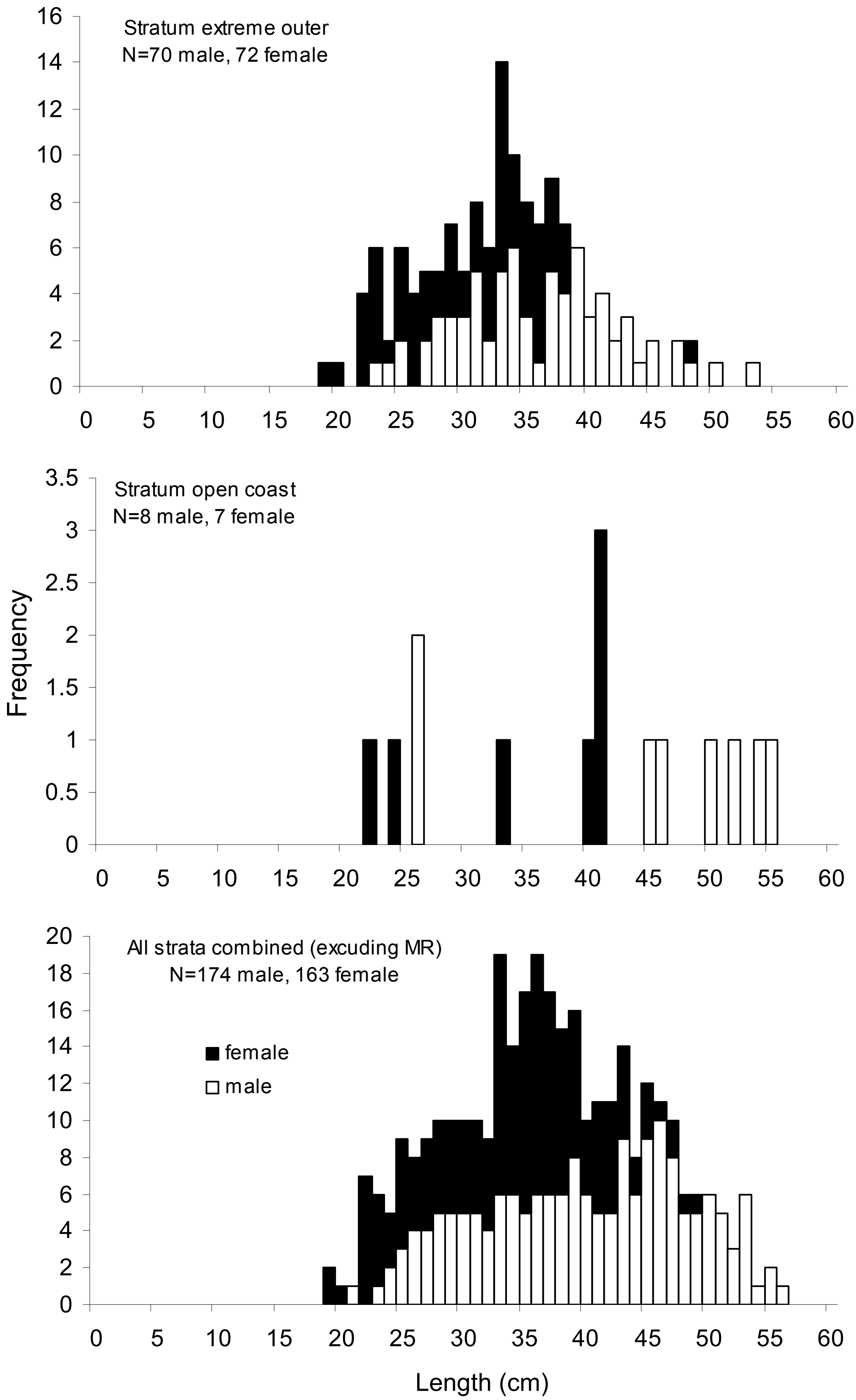
Appendix 4 – *continued*

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
28	66	135	4	13.1	1022	4	3	07	4.0	225	7	3	12.0	11.3	23.4	10.7
29	66	135	3	12.4	1023	7	4	07	4.0	225	7	3	11.8	11.5	20.0	8.5
30	73	180	3	13.1	1021	4	4	01	4.0	225	7	3	12.0	12.0	16.0	8.0
31	68	180	3	13.1	1021	4	4	01	4.0	225	7	3	12.0	12.0	17.0	8.0
32	27	000	2	10.2	1016	8	4	05	3.0	225	7	2	11.8	11.5	10.0	8.6
33	26	180	1	11.6	1015	8	3	05	0.5	225	7	3	11.8	11.8	5.5	5.2
34	27	000	1	12.6	1012	8	1	05	0.0	999	7	4	12.0	12.0	4.5	9.2
35	22	345	1	12.2	1011	8	1	05	0.0	999	7	4	12.0	12.0	4.6	7.2
36	18	180	5	10.7	1005	8	3	05	0.0	999	7	3	12.5	11.5	36.2	3.9
37	18	180	2	9.6	1004	4	1	05	0.0	999	7	2	12.5	12.5	12.7	2.8
38	22	180	1	10.4	1005	8	3	05	0.0	999	7	2	12.0	12.0	6.2	4.9
39	18	180	2	10.2	1006	7	1	05	0.0	999	7	4	12.0	12.0	11.4	5.3
40	27	90	2	8.7	1017	0	1	05	0.3	270	7	3	11.5	11.5	7.2	11.0
41	13	000	2	13.3	1017	5	2	05	0.0	999	7	2	12.0	11.5	10.5	8.2
42	48	325	3	12.8	1017	7	3	05	2.0	225	7	2	12.0	11.5	17.7	8.7
43	40	325	4	11.8	1015	8	3	05	1.5	225	7	2	12.0	11.8	30.8	7.3
44	42	325	4	12.2	1015	8	4	05	1.0	225	7	4	12.0	11.8	27.6	9.5
45	5	325	1	12.9	1018	8	3	05	0.0	999	7	1	12.0	11.8	6.0	8.5
46	22	325	5	12.5	1018	7	4	03	0.0	999	7	1	11.0	11.0	34.9	9.8
47	18	325	7	13.7	1017	5	4	03	0.5	225	7	1	11.0	11.0	42.7	11.5
48	18	325	4	13.1	1017	3	4	03	0.5	225	7	2	11.0	11.0	30.0	14.0
49	27	180	1	13.5	1009	8	1	07	0.0	999	7	4	12.5	12.5	2.3	3.8
50	18	130	3	16.5	1005	8	1	08	0.0	999	7	3	13.0	12.5	19.9	3.2
51	37	270	5	14.8	1003	8	3	08	0.0	999	7	2	13.0	12.5	34.0	2.6
52	18	195	3	14.1	1003	8	3	08	0.0	999	7	2	13.0	12.8	15.8	2.5
53	29	270	5	10.3	1011	8	3	08	0.0	999	7	2	10.5	11.0	32.0	2.8
54	46	180	0	10.4	1014	8	1	08	0.0	999	7	3	11.5	12.0	0.0	2.0

Appendix 5: Unscaled length frequency distributions or blue cod from which otoliths were collected and used in the 2008 age length key. Data are presented for each stratum and all strata combined (excluding the marine reserve).



Appendix 5 – ***continued***



Appendix 6: Between-reader comparisons (using first independent readings only) for otolith data collected in Dusky Sound 2008.

Reader two															Age class (reader one)					
difference	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	Total
-7																			1	1	2
-6																	1	1		4	6
-5														1	1	1		1		7	11
-4														1		1				3	5
-3													2	1	1				2	3	9
-2									2	2	2	2	3	1	1		1	1	2	2	19
-1				1	3	4	4	7	9	9	4	3	1		2		1			1	49
0			2	10	14	24	12	8	25	15	19	8	8	7	8	2	2	2		2	168
1			2	2	4	3	5	3	5	6	4	6		1	2	1			1		45
2				1	1							1									3
3			1	3		2	2	2	3		1			1			1				16
4								1	2												3
5											1										1
Total			8	21	27	39	30	29	55	42	42	32	27	27	30	21	23	23	25	23	337
% agreement			25	48	52	62	40	28	45	36	45	25	30	26	27	9.5	8.7	8.7	0	9	50

Appendix 7: Independent reader comparisons with agreed age from otolith data collected in Dusky Sound in 2008.

Reader one																					
	Agreed age class																				
difference	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	Total
-2							1														1
-1				2	1	1		2	2	2											10
0			3	16	20	32	21	19	40	31	31	20	11	11	14	5	5	4	3	12	298
1					1			4	1			2		1		1		3		3	16
2												1						2		3	6
3										1	1										2
4														1						2	3
5																		1			1
Total			3	18	22	33	22	25	43	34	32	23	11	13	14	6	5	10	3	20	337
% agreement			100	89	91	97	95	76	93	91	97	87	100	85	100	83	100	40	100	60	88

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
-7																			1		1
-6																	1	1		3	5
-5																1				2	3
-4														2		1				3	6
-3															1			2	2	3	8
-2									1	2	3	3	2	1	1		1	1		4	19
-1				1	3	3	5	8	7	8	4	5	1	1	2			2		3	53
0			2	11	15	25	12	11	27	17	19	8	8	7	8	3	2	3		2	180
1			1	3	3	3	4	3	4	6	4	6		1	2	1					41
2				2		2	1	2	2		1			1			1	1			13
3				1	1			1	1	1		1									6
4									1												1
5											1										1
Total			0	17	21	33	22	24	41	33	31	22	11	13	14	6	5	10	3	20	337
% agreement			0	65	71	76	55	46	66	52	61	36	73	54	57	50	40	30	0	10	53

Appendix 8: Estimates of proportion of length at age for male blue cod sampled from the Dusky Sound 2008 survey (age -length-key, ALK).

Length	Age (years)																								
(cm)	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	Total
21	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
24	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
25	0.33	0.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
26	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
27	0	0.75	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
28	0.2	0	0.6	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
29	0	0	0.4	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
30	0.2	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
31	0	0	0.6	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
32	0	0	0.25	0.5	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
33	0	0	0.17	0.5	0.17	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
34	0	0	0	0.17	0.67	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
35	0	0	0	0.2	0.2	0.4	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
36	0	0	0.17	0	0.17	0.17	0.33	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
37	0	0	0	0	0.17	0.5	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
38	0	0	0	0	0	0.33	0.33	0.17	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
39	0	0	0	0	0	0.25	0.5	0	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
40	0	0	0	0	0	0	0.33	0.33	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
41	0	0	0	0	0	0	0.2	0.4	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
42	0	0	0	0	0	0	0.6	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
43	0	0	0	0	0	0	0	0.22	0.56	0.11	0.11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
44	0	0	0	0	0	0	0	0.5	0.17	0	0	0.17	0.17	0	0	0	0	0	0	0	0	0	0	0	0	6
45	0	0	0	0	0	0	0	0.22	0	0.33	0.22	0	0	0	0.22	0	0	0	0	0	0	0	0	0	0	9
46	0	0	0	0	0	0	0	0	0.1	0	0.3	0.5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	10
47	0	0	0	0	0	0	0	0.12	0	0.12	0	0.38	0.12	0.12	0	0	0	0	0.12	0	0	0	0	0	0	8
48	0	0	0	0	0	0	0	0.2	0	0	0.2	0.2	0	0.2	0.2	0	0	0	0	0	0	0	0	0	0	5
49	0	0	0	0	0	0	0	0	0	0.2	0.2	0.2	0.2	0	0.2	0	0	0	0	0	0	0	0	0	0	5
50	0	0	0	0	0	0	0	0	0.17	0	0	0	0	0	0.5	0	0	0	0.17	0	0	0.17	0	0	0	6
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0.2	0.2	0.2	0	0.2	0	0	0	0	0	5
52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.67	0	0	0	0	0	0	0	0	0	0.33	3
53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.17	0	0.33	0	0.17	0	0.17	0	0.17	0	0	6
54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0.5	0	2
56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Total	7	9	16	11	11	12	17	15	17	6	8	11	4	3	10	1	3	1	4	2	1	2	1	1	1	174

Appendix 9: Estimates of proportion of length at age for female blue cod sampled from the Dusky Sound 2008 survey (age -length-key, ALK).

Length	Age (years)																					
(cm)	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total
19	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0.43	0.57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
23	0	0.4	0.4	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
24	0	0.33	0.33	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
25	0	0.33	0.33	0.17	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
26	0	0.75	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
27	0	0	0.2	0.4	0.2	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
28	0	0	0.2	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
29	0	0	0	0.8	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
30	0	0	0	0.4	0.4	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
31	0	0	0	0.4	0.2	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
32	0	0	0.2	0	0.6	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
33	0	0	0	0	0	0.46	0.54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13
34	0	0	0	0	0.12	0.12	0.5	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	8
35	0	0	0	0	0.08	0.17	0.33	0.25	0.17	0	0	0	0	0	0	0	0	0	0	0	0	12
36	0	0	0	0	0	0.08	0.46	0.15	0.23	0	0.08	0	0	0	0	0	0	0	0	0	0	13
37	0	0	0	0	0	0	0.45	0.27	0.18	0.09	0	0	0	0	0	0	0	0	0	0	0	11
38	0	0	0	0	0	0	0.22	0.44	0.22	0.11	0	0	0	0	0	0	0	0	0	0	0	9
39	0	0	0	0	0	0	0.25	0.25	0.38	0	0	0.12	0	0	0	0	0	0	0	0	0	8
40	0	0	0	0	0	0	0	0	0.5	0.25	0	0.25	0	0	0	0	0	0	0	0	0	4
41	0	0	0	0	0	0	0	0	0.17	0.5	0.17	0	0.17	0	0	0	0	0	0	0	0	6
42	0	0	0	0	0	0	0	0	0.17	0	0.33	0.17	0	0.17	0.17	0	0	0	0	0	0	6
43	0	0	0	0	0	0	0	0.2	0	0	0.2	0.2	0	0.2	0	0	0	0	0	0	0.2	5
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0.5	0	0	0	0	2
45	0	0	0	0	0	0	0	0	0.33	0	0	0.33	0	0	0	0	0	0.33	0	0	0	3
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
47	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0.5	0	0	0	2
48	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Total	3	11	13	17	11	14	31	17	17	6	5	5	3	2	2	0	2	3	0	0	1	163