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Relative abundance, size and age structure, and stock status of blue cod in Foveaux Strait in 2010

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This report describes the results of the 2010 Foveaux Strait blue cod (*Parapercis colias*) potting survey. This is the first fully random site allocation potting survey to be undertaken and begins a new time series for Foveaux Strait.

The survey used a two-phase stratified random site design with six sites per stratum randomly allocated for phase 1. Between 10^{th} of February and 16^{th} of June 2010, fifty-six potting sites were surveyed (6 pots per site = 336 pot lifts) from eight strata throughout Foveaux Strait. During phase 1, 288 pot lifts were completed (86%) with 48 in phase 2. The total blue cod catch was 1868 kg, consisting of 4340 blue cod. Overall catch rates ranged from 1.2 to 14.1 $kg.pot^{-1}$ with an overall mean rate of 4.8 $kg.pot^{-1}$ and coefficient of variation (c.v.) of 11.3%. Catch rates of legal size blue cod (33 cm and over) ranged from 0.46 to 5.1 kg per pot, with an overall mean of 2.1 $kg.pot^{-1}$ and a c.v. of 10.9%. Catch rates were highest in the western entrance of Foveaux Strait and off the northern coast of Stewart Island, and lowest in the large stratum around Ruapuke Island. Twenty-six percent of blue cod caught exceeded the minimum legal size (MLS).

Total length of the fish sampled ranged from 11 to 56 cm. Scaled length frequency distributions show that the strata had similar size structures, with few blue cod over 40 cm, apart from the stratum on the east coast of Stewart Island that had some large fish. The combined length distributions were unimodal with the male peak at about 34 cm and females at 30 cm. Males were larger than females in all strata and overall mean length was 30.5 cm for males and 27.8 cm for females. Overall sex ratio for all fish was 0.8:1, but skewed in favour of males (2.1:1) for fish above the MLS (33 cm and over).

A randomly stratified subset of otoliths were prepared and read for 151 males and 140 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 1 to 28 years, but most fish were between 4 and 9 years for males and 4 and 10 years for females. Mean age was 7.1 years for males and 6.9 years for females.

Total mortality estimates (Z) for age-at-recruitment from 5 to 8 years ranged between 0.34 and 0.46 (both sexes combined).

A macroscopic assessment of the gonads showed that most fish were in the early maturing stages with some running ripe or spent indicating that part of the survey occurred during the latter stages of the spawning season.

The spawner (biomass) per recruit (SPR) of the 2010 Foveaux Strait survey was $F_{35\%}$, indicating that at the current level of fishing mortality, the expected contribution to the spawning biomass over the lifetime of an average recruit has been reduced to 35% of the contribution in the absence of fishing. This level of exploitation (F) is above the Ministry of Fisheries target reference point of $F_{40\%}$ for this stock.

Catch versus video counts

To investigate the use of pots to estimate the actual abundance and size structure of blue cod populations, potting survey catch rates and size structure were compared to measures of blue cod populations from drift underwater video (DUV) transects done concurrently with potting at 12 random

sites. Five additional fixed sites (at hot spots) were also surveyed with the DUV to increase the range of fish densities for comparative purposes.

At least five replicate DUV transects were undertaken at each site directly prior to potting, and in total 85 video transects and 102 pots were deployed. The video surveyed 65 km of transects with an average transect width of 3.6 m (standard error plus or minus 0.07 m) covering a total area of 233 608 m^2. Within the area swept by the video, 288 general habitat breaks were identified and 1100 independent habitat sub-transects were recorded within them. The video counted 1525 blue cod, while the concurrent pots caught 2452 blue cod. Pots caught eight species of fish and one species of octopus and the DUV observed seventeen species of fish and one species of octopus.

The DUV had a higher proportion of small blue cod than pots. When no blue cod were seen, none or only a few were caught in pots; and where large densities were observed, catch rates were high. However, at several sites with low observed densities the concurrent pot sets recorded high catch rates. A correlation between the average density and catch rate was 0.50 for all and 0.54 for blue cod 20 cm or more, 0.67 for all blue cod and 0.70 for blue cod 20 cm or more (with a natural log transformation). Pots may therefore be attracting blue cod in from a distance greater than the area surveyed, or blue cod populations may be highly clumped within the survey area. The relationship between catch and count (i.e., catchability) may also be highly variable over time and/or location.

The primary substrata observed by the video at the random sites were mainly pea gravel and sand/gravel, while at fixed sites were mainly pea gravel, sand/gravel, and bedrock/sand. Blue cod were observed mainly on pea gravel, sand, sand gravel and bedrock at random sites, while at fixed sites they were observed mainly on pea gravel, bedrock/sand, sand gravel, sand/shell grit, and bedrock/sand. The ratio of fish-dependent and fish-independent proportional observations showed that at random sites all size classes of blue cod were highly associated with boulders. At fixed sites the ratio showed that large blue cod were more associated with sand/shell grit, and smaller blue cod with various forms of bedrock.

The main secondary habitat structures that the video recorded at random sites were “no structure”, or algal turf/sea tulips, shells, sea tulips or macroalgae. In contrast blue cod at random sites were observed most often with algal turf/sea tulips, sea tulips and sponge, and were seldom observed with “no structure”. Fixed sites had proportionately more sponge, macroalgae, and algal turf/sea tulips than random sites, with blue cod at fixed sites observed mainly with macroalgae and various forms of sponge. The ratio of fish-dependent and fish-independent proportional observations showed that at random sites blue cod were most associated with sponge on boulders, and at fixed sites blue cod were more associated with sponge on boulders, patch reef or macroalgae.

1 INTRODUCTION

In the South Island, blue cod (*Parapercis colias*) is a particularly desirable finfish that is mostly caught by pot or line from small vessels fishing over reef edges on shingle/gravel, biogenic or sandy bottoms close to rocky outcrops. The 2000 survey of marine recreational fishing found blue cod to be the third most frequently landed finfish species nationally, and the most frequently landed species in the South Island (Ministry of Fisheries 2010). Blue cod is also an important species for Maori customary fishers in all areas, but the catch is unknown.

Tagging experiments revealed that most 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 that stocks of this species are likely to consist of many largely independent sub–populations within each FMA (Carbines 2004a). Consequently blue cod are particularly susceptible to localised depletion within a FMA, and in response to local changes in fishing pressure, management actions such as daily bag limits (DBL) and minimum legal size (MLS) have varied among key fishing areas within all South Island FMAs (BCO 3, BCO 5 and BCO 7).

Southland is New Zealand's largest commercial blue cod fishery (BCO 5) with 1391 t landed in 2008–09 (Ministry of Fisheries Science Group 2010). A smaller amount of blue cod is landed annually by recreational fishers in BCO 5 (Ministry of Fisheries 2010). The commercial catch from the BCO 5 fishery is almost exclusively taken by a target cod pot fishery operating mainly within Foveaux Strait, around Stewart Island and southern Fiordland (Starr & Kendrick 2008). The Southland recreational blue cod catch is taken mainly by line fishing from northern Stewart Island (including Paterson Inlet, James et al. 2004), throughout Foveaux Strait (Warren et al. 1997) and in Fiordland (Davey & Hartill 2008).

Catch per unit effort (CPUE) analysis of the available commercial fisheries data showed that following four peak years (2001–02 to 2004–05) the accepted CPUE index for BCO 5 began to decline, with 2006–07 showing a drop of 16% from the average of those peak four years (Starr & Kendrick 2008). Consecutive years of decline in catch rates have also been concurrent with an increase in the number of pot sets per trip (Starr & Kendrick 2008). When the commercial fisheries data are explored by statistical area, a relatively small amount of effort outside statistical area 025 (Foveaux Strait) is apparent (Starr & Kendrick 2008). However, due to the way in which commercial fisheries data are recorded, the level of spatial detail is low in this analysis and no biological information were available to investigate population structure.

To monitor South Island blue cod populations, the Ministry of Fisheries (now the Ministry for Primary Industries) agreed to undertake a quadrennial series of potting surveys to generate relative biomass estimates in eight areas around the South Island. The surveys are located in key recreational fisheries within all three South Island FMA including the Marlborough Sounds (Blackwell 1997, 1998, 2002, 2005, 2008); Kaikoura and Motunau (Carbines & Beentjes 2006b, 2009); Banks Peninsula (Beentjes & Carbines 2003, 2006, 2009); North Otago (Carbines & Beentjes 2006a, 2011a); Dusky Sound (Carbines & Beentjes 2003, 2011b); and Paterson Inlet (Carbines 2007).

Catch rates and length frequencies of blue cod in the Foveaux Strait have been derived retrospectively from the potting phase of a tagging programme (Carbines & McKenzie 2001, strata 1–9 in Figure 1). In 2009 an industry funded potting survey then re-sampled 42 of the original survey sites and described changes in population structure and standardised catch rates (kg.pot.hour^{-1}) of blue cod in these areas of Foveaux Strait (Carbines 2009). The two surveys indicated that there were clear differences in the catch rates of blue cod between 1998 and 2009 in Foveaux Strait. Catch rates of pre-recruits appeared to have increased, and four strata in the central and eastern coastal areas of Foveaux Strait maintained consistent catch rates of legal sized blue cod between the two surveys, while the central Stewart Island stratum (4) showed an increase in catch rates of legal sized blue cod (33 cm TL and over). However, catch rates of legal sized fish in the four previously most productive strata at the western entrance of Foveaux Strait (strata 1–3) and around Ruapuke Island (stratum 8) had declined to around half the levels recorded in 1998. Comparisons of length frequency data also showed a dramatic decline in the proportion of legal sized blue cod since 1998. The decline in the proportion of legal sized blue cod was most apparent around Ruapuke Island and the western entrance to Foveaux Strait. In summary, comparisons between potting surveys using standardised methods suggests that major changes in blue cod population size and structure over the last decade have occurred.

In addition to assessing catch rates, monitoring maturity, length and age structure provide further means to evaluate the response of a population to changes in fishing pressure. These data will then be used to develop spawner per recruit ($F_{\%SPR}$) estimates.

While most of the potting surveys used a fixed site design, surveying known blue cod "hotspots" (Beentjes & Carbines 2003, 2006, 2009, Blackwell 1997, 1998, 2002, 2005, 2008, Carbines & Beentjes 2006a, 2006b, 2009, 2011a, 2011b), which has a number of potential biases (Stephenson et al. 2009), the 2010 Foveaux Strait survey used a random design.

1.1 Catch versus count

The use of a passive capture method such as pots to reliably estimate the actual abundance and size structure of blue cod populations requires further validation (Stephenson et al. 2009). Different methods have different selectivity biases and catch rates and size composition from potting can differ compared to other methods such as line fishing (Blackwell 2002, 2005, Carbines 1999). Pot catches can also have a highly variable and a largely unexplained relationship with counts from diver transects (Cole et al. 2001). To investigate the relationship between potting survey catch rates and size structure, with direct *in situ* observations of blue cod populations, the 2010 Foveaux Strait potting survey employed fish counts from remote flown video transects (see Morrison & Carbines 2006, Carbines & Cole 2009) undertaken at potting sites prior to the pots being set. This report therefore describes an initial 2010 random site potting survey of the greater Foveaux Strait area and provides a comparison with concurrently undertaken video transects.

Overall objective

1. To estimate relative abundance, maturity state, sex ratio, and age structure of blue cod (*Parapercis colias*) in Foveaux Strait.

Specific objectives

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

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

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

4. Undertake a Dropped Underwater Video (drift video) survey concurrently with the potting survey to provide comparative estimates for validating the video data.

2 METHODS

In this report we use only the terms and methods defined in the blue cod potting survey manual (Beentjes & Francis 2011), but note that other surveys carried out before this manual was written may have used different and inconsistent terminology. The main point of difference between the terms shown below and those used on other South Island surveys (except Marlborough Sounds) before 2010 is that the term station was used to refer to a site (see Appendix 1).

2.1 Timing

A random potting survey of the greater Foveaux Strait area was carried out between 10 February and 16 June 2010. February was chosen to begin the survey because weather conditions are generally more settled at this time and it is consistent with the previous 2009 fixed site survey of Foveaux Strait (Carbines 2009). However, the 2010 survey duration was a protracted four months due to extremely poor weather conditions.

2.2 Survey area

Foveaux Strait is a shallow body of water at the southern tip of New Zealand, separating the South Island and Stewart Island. It is about 80 km long and 23–53 km wide (Figure 1). The seafloor is principally alluvial gravel, locally overlaid with sand, sloping gently from 20 m deep in the east to 50 m deep in the west. Islands and reefs extend northwards across Foveaux Strait's shallow eastern entrance, northeast of Stewart Island. As Foveaux Strait separates the Tasman Sea from the South Pacific Ocean, it is subject to extremely strong tidal flows. It is also subject to the influence of the Tasman and Southland Currents from west to east (Houtman 1966, Heath 1972, 1981).

The Foveaux Strait survey area was defined after discussions with local fishers, Ministry of Fisheries (now Ministry for Primary Industries), and the South Marine Recreational Fisheries Forum. The survey area was stratified based on the 1998 (Carbines & McKenzie 2001) and 2009 surveys of Foveaux Strait (Carbines 2009). The survey area was divided arbitrarily into ten strata throughout the greater Foveaux Strait area (Figure 1). In the absence of specific habitat information or a clear understanding of the habitat requirements of blue cod, the area (km^2) within each stratum was taken as a proxy of available habitat for blue cod.

2.3 Survey design

The survey used a two-phase stratified random site design (Francis 1984), ensuring that sites were at least 2 km apart (Figure 1). The first six random sites generated for each of eight strata were allocated to phase 1 (n=48 sites, 288 pot lifts), with eight sites available for phase 2 (n=8 sites, 48 pot lifts).

Allocation of the phase 2 sites was based on the mean catch rate ($kg.hour^{-1}$) of all blue cod per stratum and optimised using the "area mean squared" method of Francis (1984). In this way, phase 2 sites were assigned iteratively to the stratum in which the expected gain is greatest, where expected gain is given by:

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

where for the ith stratum, $mean_i$ is the mean catch rate, $area_i$ is the area, and n_i is the number of sets in phase 1. In the iterative application of this equation, n_i is incremented by 1 each time a phase 2 set is allocated to stratum i. Pots were always allocated in groups of six which equates to one set.

An additional five fisher selected fixed sites were also sampled as part of the DUV survey, but these data were not included in the analysis data sets for catch rates, lengths or age, they were only used for comparison with the DUV data (See Section 2.16).

2.4 Vessels and gear

The Foveaux Strait survey was conducted from F.V. *Thetis*, a Bluff based commercial vessel equipped to set and lift rock lobster and blue cod pots and skippered by Mr Colin Topi. The vessel specifications are: 12.1 m length, 3.8 m breadth, 25 t, steel monohull, powered by a 160 hp GM diesel engine with propeller propulsion.

Six custom designed and built cod pots were used to conduct the survey. Pot specifications were: length 1200 mm, width 900 mm, depth 500 mm, 30 mm diameter synthetic inner mesh, 50 mm cyclone wire outer mesh, entrances 4 (Pot Plan 2 in Beentjes & Francis 2011). Pots were marked with a number from 1 to 6, and baited with paua guts in “snifter pottles”. Bait was topped up after every lift and replaced each day. The same pot design and bait type were used in all previous South Island blue cod potting survey time series except Marlborough Sounds where the pots used were of different dimensions and construction (Pot Plan 1 in Beentjes & Francis 2011).

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

2.5 Sampling methods

Sites were chosen randomly within each stratum. At each site an acoustic doppler current profiler (ADCP) was first deployed. Around this central point, six pots were set sequentially in a fixed hexagon pattern, starting from an initial starting point approximately 300 m due north of the ADCP location with each point (pot) approximately 300 m from the centre and 300 m from adjacent pots. Each pot was left to fish (soak) for approximately one hour during daylight hours, which is consistent with all previous blue cod potting surveys. After each site was completed (six pot lifts) the next closest site in the stratum was sampled. While it was not logistically possible to standardise for time of day or tides, each stratum was surveyed throughout the day, collectively giving strata roughly equal exposure to all daily tidal and time regimes. The order that strata were surveyed depended on the prevailing weather conditions, as exposed offshore strata could be surveyed only during calm conditions.

As each pot was set, a record was made on customised forms of pot number, latitude and longitude from GPS, depth, time of day, and standard trawl survey physical oceanographic data, 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 surface water visibility (secchi depth). The ADCP was deployed to record current speed and direction at the site and was recovered after the last pot of each set was lifted.

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

2.6 Data analysis

Analysis of catch rates and coefficients of variation (c.v.s), length weight parameters, scaled length and age frequencies and c.v.s, sex ratios, mean length and mean age use the equations documented in the blue cod potting manual (Beentjes & Francis 2011). For completeness these equations are reproduced in this report.

2.7 Relative abundance

Relative abundance indices were calculated as mean catch rates by set ($\bar{C}_{st}$), stratum ($\bar{C}_t$), and survey ($\bar{C}$) (all with units kg/pot) using the following equations.

$$\bar{C}_{st} = \sum\nolimits_p C_{pst} \Big/ m \qquad (2)$$

$$\bar{C}_t = \sum\nolimits_s \bar{C}_{st} \Big/ n_t \qquad (3)$$

$$\bar{C} = \sum\nolimits_t A_t \bar{C}_t \Big/ \sum\nolimits_t A_t \qquad (4)$$

where C_{pst} is the catch weight (kg) of all blue cod (or all recruited blue cod – that is, all those 33 cm and above) in the pth pot in the sth set in stratum t; m is the number of pots per set; n_t is the number of sets in stratum t; and A_t is the area of that stratum. Note that these indices include no adjustment for soak time.

The precision of the stratum and survey catch rates is set-based and should be described as a coefficient of variation (c.v.), calculated using

$$\text{c.v.}\left(\bar{C}_t\right) = \left[\frac{\sum_s \left(\bar{C}_{st} - \bar{C}_t\right)^2}{\left(n_t - 1\right) n_t}\right]^{0.5} \Bigg/ \bar{C}_t \qquad (5)$$

and

$$\text{c.v.}\left(\bar{C}\right) = \left[\sum\nolimits_t A_t^2 \,\text{s.e.}\left(\bar{C}_t\right)^2 \Big/ \left(\sum\nolimits_t A_t\right)^2\right]^{0.5} \Big/ \bar{C} \qquad (6)$$

2.8 Length-weight parameters

The length-weight parameters a_k, b_k from this survey are used in the equation

$$w_{lk} = a_k l^{b_k} \qquad (7)$$

which calculates the expected weight (kg) for a fish of sex k and length l (cm) in the survey catch. These parameters were calculated from the coefficients of sex-specific linear regressions of log(weight) on log(length) using all fish for which length, weight, and sex were recorded: b_k is the slope of the regression line, and $\log(a_k)$ is its *y*-intercept.

Weights of individual blue cod from the survey that were not weighed, are calculated from the length-weight relationship. Derived individual fish weights are then used to determine catch rates and c.v.s of blue cod for the minimum legal size (33 cm) and over.

2.9 Otolith preparation and reading

The most precise method for ageing blue cod otoliths 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 (50^{o} C for at least three hours), and sectioned transversely close to the nucleus with a diamond-tipped cut-off wheel. The sectioned surface of the otolith half was then glued to a glass slide and a second cut was made resulting in a section of about 2 mm thickness. The resultant thin section on the slide was then coated with a slide mountant and sanded with 600-grit sandpaper to about 1 mm thickness before viewing. Sections were observed at ×40 and ×100 magnification under transmitted light with a compound microscope.

Otolith sections exhibit alternating opaque and translucent zones and age estimates were made by counting the number of annuli (opaque zones) from the core to the distal edge of the section, a technique previously validated by, and for which a protocol is described by Carbines (2004b) for blue cod. Translucent zones are used to define each complete opaque zone, i.e., annuli are counted only if they have a translucent zone on both sides. The readability of each otolith was also graded from 1 (excellent) to 5 (unreadable). Otoliths were read independently by two experienced readers (G. Carbines and D. Kater). Where counts differed, readers consulted to resolve the final age estimate. Otoliths given a grade 5 (unreadable) or damaged were removed from the analysis.

2.10 Growth parameters

A von Bertalanffy growth model (von Bertalanffy 1938) was fitted to the length-age data by sex for the survey.

$$L_t = L_\infty \,(1 - \exp^{-K[t - t0]}) \qquad (8)$$

Where L_t is the length (cm) at age t, L_∞ the asymptotic mean maximum length, K is a constant (growth rate coefficient), t_0 hypothetical age (years) that fish has zero length.

The estimated growth parameters K, t_0 and L_∞ were used in the spawner per recruit analyses.

2.11 Scaled length and age frequencies

Length and age compositions of Foveaux Strait blue cod populations surveyed in 2010 were estimated using the NIWA program Catch-at-age (Bull & Dunn 2002). The program scales the length frequency data by area of the strata, number of sets in each stratum, and estimated catch weight determined from the length weight relationship of individual fish. The latter scaling should be negligible or very close to one if all fish on the survey are measured and the if actual weight of the catch is close to the estimated weight of the catch (which it should be).

The following equations (from Beentjes & Francis 2011) describe how length and age frequencies were calculated as numbers of fish. The length and age frequencies are expressed as proportions by dividing by total numbers.

For set s in stratum t, let W_{st} be the weight of blue cod caught, and let f_{lkst} be the number of blue cod of length l and sex k in the length sample from the catch. Then the sex-specific length frequency (LF) for stratum t, which represents the expected number at length and sex in a set from this stratum, is given by

$$f_{lkt} = 1/n_t \sum\nolimits_s^{\mathrm{LF}} \left[f_{lkst} \left(\frac{W_{st}}{\sum_{l',k'} w_{l'k'} f_{l'k'st}} \right) \left(\frac{\sum_{s'} W_{s't}}{\sum_{s'}^{\mathrm{LF}} W_{s't}} \right) \right] \tag{9}$$

where $\sum_s^{\mathrm{LF}}$ denotes a summation restricted to those sets for which there is a length sample.

Equation (9) allows for the possibility that not all blue cod caught in the survey were measured. In the 2010 Foveaux Strait case all fish were measured so the second and third terms have no effect on the length frequencies generated.

The sex-specific survey LF is given by

$$f_{lk} = \frac{\sum_t A_t f_{lkt}}{\sum_t A_t} \tag{10}$$

Sex-specific age frequencies (AFs) at the stratum and survey level were calculated by applying the age-length key, K_{lak} (where K_{lak} is the proportion of fish of length l and sex k that are of age a [so $\sum_a K_{lak} = 1$ for each value of k]) in the usual fashion:

$$f_{akt} = \sum\nolimits_l K_{lak} f_{lkt} \text{ and } f_{ak} = \sum\nolimits_l K_{lak} f_{lk} \tag{11}$$

LFs (or AFs) for sexes combined, at the stratum and survey level, were calculated by summing the sex-specific LFs (or AFs) across sex.

2.12 Sex ratios, and mean length and ages

Sex ratios (expressed as percentage male) and mean lengths, for either the stratum or survey level, were calculated from the stratum or survey LFs. Thus, for example, for stratum t the sex ratio was calculated as

$$100 \sum\nolimits_l f_{lmt} \Big/ \sum\nolimits_{l,k} f_{lkt} \tag{12}$$

(where the subscript m denotes males) and the mean length for sex k as

$$\sum\nolimits_l l f_{lkt} \Big/ \sum\nolimits_l f_{lkt} \tag{13}$$

Mean ages were calculated analogously from the AFs. For example, the equation for the mean age for sex k in stratum t is the same as Equation (13), with l replaced by a.

2.13 C.v.s for LFs and AFs

Bootstrap resampling was used to allow calculation of c.v.s for proportions and numbers at length and age (from Beentjes & Francis 2011). That is, simulated data sets were created by resampling (with replacement) sets from each stratum, and fish from each set (for length and sex information). Similarly, fish from the age-length-sex data were used to construct the age-length key.

LFs and AFs were calculated, as described above, for each simulated data set. For any number (or proportion) at age or length, f, a c.v. was calculated as

$$\text{c.v.}(f) = \sqrt{\frac{\sum_b (f_b - \bar{f})^2}{n_{\text{boot}} - 1}} \Big/ \bar{f} \qquad (14)$$

where f_b is the corresponding number (or proportion) calculated from the bth of n_{boot} simulated data sets, and $\bar{f}$ is the mean of the f_b. n_{boot} = 300 has been found to be an adequate number of simulated data sets for this calculation for most data sets.

Scaled length frequency and age frequency proportions are presented together with coefficients of variation (cv) for each length and age class, and the mean weighted coefficients of variation (MWCV).

2.14 Total mortality (Z) estimates

Total mortality (Z) was estimated from catch-curve analysis using the Chapman Robson estimator (CR) (Chapman & Robson 1960). 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.

For the 2010 Foveaux Strait survey, estimates of total mortality, Z, were calculated for four alternative values of the age at recruitment – a_{rec} = 5, 6, 7, and 8 y – using the maximum-likelihood estimator

$$\hat{Z} = \log_e\left(\frac{1 + \bar{a} - a_{\text{rec}}}{\bar{a} - a_{\text{rec}}}\right) \qquad (15)$$

where $\bar{a} = \sum_a^{\text{rec}} a f_a \Big/ \sum_a^{\text{rec}} f_a$ is the mean age of recruited fish in the sexes-combined age frequency for the survey, and $\sum_a^{\text{rec}}$ denotes summation across all recruited ages.

The estimation of c.v.s around the Z estimates is described in detail in Appendix 2.

2.15 Spawner per recruit analysis

A spawner per recruit analysis was used to estimate the %SPR corresponding to the *Z* estimate(s) calculated from catch curves. Spawner per recruit calculations were carried out using CASAL (Bull et al. 2005). The calculations involve simulating fishing with constant fishing mortality, *F*, in a population with deterministic recruitment, and determining the equilibrium spawning biomass per recruit (SPR) associated with that value of *F*. The %SPR for that *F* is then simply that SPR, expressed as a percentage of the equilibrium SPR when there is no fishing (i.e., when $F = 0$).

The von Bertalanffy growth curve and length-weight parameters (length in centimetres and weight in grams) were estimated from the age-length and length-weight data collected from the survey and are shown below:

Parameter	Males	Females
K	0.0874	0.1191
T_0	-1.5402	-1.2706
L_{inf}	58.9	45.5
A	9.15E-03	9.33E-03
B	3.1513	3.1458

The following input parameters were used in this analysis.

Growth parameters	von Bertalanffy growth parameters and length weight coefficients estimated from the current survey
Natural mortality	default assumed to be 0.14. Sensitivities were carried out for M values 20% above and below the default (0.11 and 0.17).
Maturity ogive	the default maturity ogive is 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-edged at age at MLS.
Fishing mortality (*F*)	fishing mortality is estimated from the catch curve analyses and assumed estimate of *M* ($F = Z - M$). The *Z* value is for age at recruitment = 6 years).

Because this is a ‘per-recruit’ analysis, it doesn’t matter what stock-recruit relationship is assumed. However, the calculations are simpler, and the simulated population reaches equilibrium faster, if recruitment is treated as independent of spawning biomass (i.e., a steepness of 1).

2.16 Video count

To assess whether catch rates from potting surveys are proportional to the actual abundance of blue cod, blue cod populations were assessed using drift underwater video (DUV) counts done concurrently at a sub-sample of 12 random survey sites and an additional 5 fixed sites (added to increase the range of densities over which count and catch comparisons could be made). Fixed sites were “hot spots” selected from the sites with the highest catch rates in a commercial BCO 5 fisherman's diary scheme operating from 2009 to 2010.

Sample collection

The DUV consists of a 35 kg bulb keel and tail fins which steady and orient a forward and downward facing mounting platform fitted with a low-light camera and scaling lasers (Morrison & Carbines 2006, Carbines & Cole 2009). It was suspended beneath a drifting vessel by a rope and a live-feed video cable so that location, time, depth, and date were all burned in real time onto the recorded digital video footage integrated with a surface Global Positioning System (GPS) and depth sounder.

The video camera was deployed at a height of at least 1.5 m off the seabed and the vessel drifted through the sample area recording. Once the drift speed of the surface vessel exceeded that of the deployed video, the keel and tail fin orients the platform forward, and the video records a transect of approximately 800 m length. Contact with the seabed is avoided by raising and lowering the video from the surface vessel throughout each transect and scaling lasers are used to back-calculate the size and variations of transect width. Transects were carried out between 07:00 and 16:30 hours, when the swell was less than 2 m, and when drift speed exceeded 0.8 $m.s^{-1}$ (to prevent fish being able to follow the video and re-enter the video transect). At least five replicate video transects were done at each site directly prior to setting the pots (as described in Section 2.5).

Video analysis

Each video transect was processed (viewed) twice. On the first viewing, transect dimensions were geo-referenced and transects were partitioned into general benthic habitat sections. All blue cod were geo-referenced and scaling lasers were used to estimate fish length (Morrison & Carbines 2006). At the location of each blue cod a benthic habitat sub-transect was sampled (approximately 5 m before and after the fish was observed). During the second viewing, each section of general habitat was sampled with at least five sequential sub-transects to record transect width from scaling-lasers and provide fish-independent descriptions of benthic habitat. Both fish-dependent and fish-independent habitat sub-transects recorded primary (geological) substrate (categories of grain size from sand to bedrock) and secondary habitat structure (categories of overlaying organic or geological benthic habitat), percentage cover (e.g., shells, sponges, macro-algae, etc.) topographic complexity and actual counts of benthic species where possible.

A correlation was determined between the number of blue cod counted and caught at each site, and a comparison of blue cod length frequencies made between methods to investigate size selectivity (Cole et al. 2001). Data on fish abundance by size class and habitat data are presented for random and fixed sites, and a ratio of fish-dependent and fish-independent habitat observations was used to identify which primary substrate and secondary habitat categories are utilised by blue cod at a greater rate than they are available in the general benthic environment.

3 RESULTS

3.1 Sites surveyed

Fifty-six sites were surveyed (6 pots per site making a total of 336 pot lifts) over twenty-one fishable days from eight strata throughout Foveaux Strait (Table 1, Figure 1, Appendix 3). Of the 56 sites, 48 were carried out in phase 1 (6 per stratum) and eight in phase 2 with 6 allocated to stratum 8, and 1 to each of stratum 1 and 4. Depth ranged from 2 to 93 m, and the mean soak time was 1 hour (range 53 to 66 min, s.e. = 0.00031). Environmental data recorded throughout the Foveaux Strait survey are presented in Appendix 4 and are stored on the Ministry for Primary Industries *trawl* database. The ADCP data is archived in a spreadsheet with the Research Database Manager, NIWA, Greta Point, Wellington.

3.2 Catch

A total of 2208 kg of catch was taken in the 2010 Foveaux Strait survey, of which 1868 kg (85%) was blue cod, consisting of 4340 fish (Table 2). Bycatch included nine fish species and one octopus species. The five most common bycatch species by weight were leatherjackets (*Parika scaber*), octopus (*Octopus cordiformis*), conger eels (*Conger verreauxi*), girdled wrasse (*Notolabrus cinctus*) and scarlet wrasse (*Pseudolabrus miles*).

Overall mean catch rate and c.v. for blue cod (all sizes) ranged from 1.17 kg per pot for stratum 7 to 14.14 kg per pot for stratum 2 (Table 3, Figure 2). Mean catch rates of blue cod 33 cm and over were 2.09 kg per pot and 10.87% (Table 4, Figure 2). Overall mean catch rate and c.v. were 4.80 kg per pot and 11.34% respectively. For blue cod 33 cm and over (local MLS) the highest catches came from stratum 1 (5.11 kg per pot). The lowest catch rates of blue cod 33 cm and over were from stratum 8 (0.46 kg per pot).

3.3 Biological and length frequency data

Of the 4340 blue cod caught, all were sexed and measured for length, and otoliths were taken and aged from a sub-sample of 314 fish, across the available size range and from all strata (Appendix 5). For all blue cod the sex ratio ranged from 0.6:1 (M:F) in stratum 2 to 2.3:1 (M:F) in stratum 7, and overall was roughly even at 0.8:1 (M:F) (Table 5). The sex ratio for blue cod 33 cm and over ranged from 1.3:1 (M:F) in stratum 2 to 3.9:1 (M:F) in stratum 7, and overall was skewed towards males (2.1:1) (Table 5). The size of blue cod ranged from 11 to 44 cm for females and 12 to 56 cm for males, although size varied among strata. The scaled length frequencies were normally distributed in most strata, but stratum 5 and 6 had bimodal distributions (Figure 3). Small blue cod (less than 15 cm) were most common in stratum 5, 6 and 8 and the largest blue cod came from stratum 10. The mean length of males was about 2.5 cm more than females in most strata and overall weighted mean male length was 30.5 cm and mean female length 27.8 cm (Table 5). Twenty six percent of the fish sampled were above the MLS.

Of 4340 blue cod examined, most had gonads in the early maturing phase. Fifteen-percent of males and 5% of females were in the running ripe stage, and 3% of males and 7% of females had spent gonads (Table 6).

The length-weight relationship analysis included 152 females (range 11–41 cm) and 162 males (range 12–56 cm). Using the derived model $W = aL^b$, the length-weight parameters for Foveaux Strait were: males – a = 0.00915, b = 3.1513, and R^2 = 0.98; females – a = 0.00933, b = 3.1458, and R^2 = 0.99.

3.4 Ageing (between reader analyses)

Of the 314 otoliths read, 23 were rejected as unreadable or damaged, leaving 291 otoliths (151 males 12–56 cm, 140 females 11–41 cm) for analysis (Table 7).

Initial independently derived reader estimates of age class are compared in Appendix 6 and show 51% agreement between the two readers, with reader 2 generally estimating lower age classes than reader 1 for fish over 35 cm. When the differences between age class estimates were resolved by agreement between the readers, reader 1 was 90% consistent with the agreed age class estimates compared to reader 2 who was only 56% consistent with the agreed age classes (Appendix 7). The tendency of reader 2 to underestimate the agreed age class worsened for fish beyond 10 years (Figure 4).

The length-age data are plotted and the von Bertalanffy model fits are shown for males and females separately (Figure 5). The growth parameters (K, t_0, and L_{inf}) are shown in the methods table of input data for the SPR analysis (see section 2.15). The growth parameters are similar for males and females except that males achieve a greater L_{inf} than females. (i.e., 58.9 cm for males and 45.5 cm for females) and male growth is initially faster, with more larger and older male fish.

3.5 Length and age composition

The scaled length/age frequency and cumulative frequencies are shown in Figure 6. The age-length-keys (ALKs) by sex are shown in Appendices 8 and 9 and mean age-at-length is shown in Appendix 10. All male fish lengths collected on the survey had at least one valid age reading in the age-length-key. For females there was one unmatched length at 44 cm; this fish was nominally assigned an age of 17 years based on the von Bertalanffy growth curve.

The scaled length frequency distribution for males is generally normally distributed with an overall mean length of 30.5 cm, although there are indications of minor peaks at 28 cm and 33 cm. Female length distribution is unimodal, but with a distinct left hand tail, and a mean overall length of 27.8 cm (Figure 6). The cumulative length distribution show clearly that males have a higher proportion of larger fish than females and also that the largest fish are males. The mean weighted coefficients of variation (MWCVs) around the length distributions are low (19% for both males and females) indicating that fish sampled in the survey provide a good representation of the overall population.

Age of blue cod ranged from 1 to 28 years (Table 7), but the bulk of males were between 4 and 9 years old and females between 4 and 10 years old (Figure 6). Only two male fish were older than 17 years and the oldest female fish was 16 years. The estimated population age distributions are unimodal for both sexes with the main peak at 6 years for both males and females. The cumulative age frequency plots indicate that the age distributions are similar for males and females, apart from a few older male fish. Further, mean age is similar (7.1 years for males and 6.9 years for females). Hence, although the mean size of females is smaller, the age distributions are much the same, a result of slower growth in females (Figure 5). The MWCVs around the age distributions are medium (29% for males and 32% for females) indicating that fish sampled in the survey for age provide a reasonable, but not ideal, representation of the overall population, assuming that acceptable MWCV values are less than 25%.

3.6 Total mortality (Z) estimates

Total mortality estimates (Z) and 95% confidence intervals for all strata combined and both sexes combined are given in Table 8. The combined strata mortality estimates for 2010 were between 0.34 and 0.46.

3.7 Spawner per recruit analyses

The spawner per recruit analyses are plotted as %SPR as a function of fishing mortality (Figure 7). Mortality parameters used in the analyses, and resulting $F_{\%SPR}$ values are shown in Table 9. Based on the default M of 0.14 and age-at-full recruitment of 6 years the fishing mortality estimated was 0.27, which corresponds to $F_{35.3\%}$. This indicates that at the 2010 levels of fishing mortality, the expected contribution to the spawning biomass over the lifetime of an average recruit has been reduced to 35% of the contribution in the absence of fishing. Other $F_{\%SPR}$ estimates for M values of 0.11 and 0.17 were $F_{26.2\%}$ and $F_{44.5\%}$ (Table 9).

3.8 Drift underwater video survey

Video counts versus pot catch

At least five drift underwater video (DUV) transects were undertaken at 12 random sites and five fixed sites directly prior to sampling pots (see Figure 8, Table 10). A total of 85 DUV transects and 102 pots were deployed at the 17 concurrently surveyed sites, five transects were not used due to technical issues and 4 pots were removed from the comparison due to the presence of predators (*Octopus cordiformis*). The DUV surveyed 65 km of transects with an average transect width of 3.6 m (with a standard error of plus or minus 0.07 m) covering a total area of 233 608 m^2. Within the area swept by the DUV, 288 general habitat breaks were identified and 1100 fish-independent habitat transects were recorded within them. A total of 1525 blue cod were observed using DUV, while the concurrent pots caught 2452 blue cod (Table 10).

Species caught and observed

A total catch of 2712 individuals was taken by pots at concurrently DUV surveyed sites, 90% of which were blue cod (Table 11). Fixed sites caught 96% blue cod and random sites caught 85% blue cod (Table 11). At the DUV surveyed sites bycatch from potting included seven fish and one octopus species. The five most common bycatch species from potting (by numbers) were leatherjackets (*Parika scaber*), scarlet wrasse (*Pseudolabrus miles*), girdled wrasse (*Notolabrus cinctus*), tarakihi (*Nemadactylus macropterus*), octopus (*Octopus cordiformis*) and trumpeter (*Latris lineata*).

A total of 3303 individual fish/octopus were observed in DUV transects, 46% of which were blue cod (Table 12). At fixed sites 53% of the observed fish were blue cod and at random sites 35% were blue cod (Table 12). Sixteen other fish species and one octopus species were observed in DUV transects, the five most common of which were leatherjackets (*Parika scaber*), banded wrasse (*Notolabrus fucicola*), scarlet wrasse (*Pseudolabrus miles*), spiny dogfish (*Squalus acanthias*) and kahawai (*Arripis trutta*).

Length frequency comparisons

The length frequency distributions from the DUV surveyed sites are shown in Figure 9. Both the length frequency distributions for all blue cod observed, and only those observed without a camera head-on position (to improve precision) showed that the DUV sampled considerably more blue cod below 23 cm than the pots did (Figure 9). Because there were few large blue cod caught or observed it is less obvious whether pots proportionally sample more blue cod over 33 cm (Figure 9). The cumulative distribution plots of length frequency confirm that the video has a higher proportion of smaller fish than the pots do (Figure 9).

Comparison of catch rates and counts

All fish densities estimated by the area-swept DUV method were standardised to the mean number per 1500 m2 and plotted against the mean pot catch per site for all blue cod and blue cod at least 20 cm (to reduce pot size selectivity) in Figure 10. However, there were few blue cod below 20 cm and there was little difference between the two figures, with the variance often high for both pots and the video (Figure 10). Generally where no fish were seen, no fish or only a few fish were caught; and where large densities were observed catch rates were high. While there were several sites with low observed densities and high catch rates (e.g., sites 2B, 5E, 2174 and 1145, respectively), there were no instances of high densities observed and low catch rates (Figures 10 and 11).

The correlation between the average density and catch rate was 0.50 for all blue cod and 0.54 for blue cod 20 cm or more (Figure 11). To provide better discrimination at the low end of the data, a natural log transformation is plotted in Figure 12, giving a subsequent correlation coefficient of 0.67 for all blue cod and 0.70 for blue cod 20 cm or more.

Benthic habitat descriptions and utilisation

Benthic habitat data from the DUV method are presented for random and fixed sites, and a ratio of fish-dependent and fish-independent habitat observations was used to determine which primary substrate and secondary habitat structures (as defined in Section 2.16) blue cod are more commonly associated with in the benthic environment.

Primary substrata

Using the DUV fish-independent habitat observations, the main primary substrate at random sites were pea gravel and sand/gravel (Figure 13), while pea gravel, sand/gravel, and bedrock/sand were more commonly observed at fixed sites (Figure 14). Blue cod were observed mostly with pea gravel at random sites (Figure 13), and among pea gravel, bedrock/sand, sand/gravel, and sand/shell grit at fixed sites (Figure 14).

The main primary substrate observed in both fish-dependent and fish-independent habitat observations for random sites was pea gravel, but using a ratio of the substrata category proportions observed in these two data sets showed that blue cod at random sites were most commonly observed with boulders (Figure 13). At fixed sites the main primary substrata observed in both fish-dependent and fish-independent habitat observations where pea gravel, bedrock/sand, sand/gravel and sand/shell grit, however, the above ratio showed that larger blue cod were more associated with sand/shell grit, and smaller blue cod with various forms of bedrock (Figure 14).

Secondary habitat structures

The main secondary habitat structures observed independently of fish at random sites were “no structure”, algal turf/sea tulips, macroalgae, sea tulips, and shell (Figure 15). However blue cod of all size classes were observed most frequently with algal turf/sea tulips and sea tulips, and were seldom observed in areas with no structure (Figure 15). Fish-independent observations at fixed sites showed more sponge, macroalgae, and algal turf/sea tulips than at random sites, while blue cod at fixed sites were observed with mainly macroalgae, sponge, and sponge on boulders and bedrock (Figure 16).

The main secondary habitat structure observed with blue cod at random sites was algal turf/sea tulips while fish-independent habitat observations were mainly devoid of secondary structure (Figure 15). Using the ratio of fish-dependent and fish-independent secondary habitat category proportions showed that blue cod (especially juveniles) at random sites were most associated with sponge on boulders (Figure 15). At fixed sites blue cod were observed mainly with macroalgae and various forms of sponge, while fish-independent habitat observations were mainly of “no structure” or macroalgae (Figure 16). Using the above ratio showed that blue cod at fixed sites were more often associated with sponge on boulders, boulders/macroalgae, and patch reef (Figure 16).

4 DISCUSSION

The 2010 Foveaux Strait potting survey was the first truly random blue cod survey. The overall c.v. for the catch rates of 11.3% for all blue cod and 10.9% for legal sized blue cod (Tables 2–4) suggesting that the survey effort was sufficient to provide an estimate of abundance. The mean catch rates varied among strata, but for both all blue cod and legal sized blue cod, relative abundance was notably higher in the western entrance to Foveaux Strait and off the adjacent northern coast of Stewart Island (strata 1–4, Figures 1–2) than in other areas.

Reproductive condition

Observations of gonad stages showed some spawning and spent gonads, with most blue cod in the early maturing or resting stage (Table 6). This indicates that the timing of the survey (autumn) was after the peak spawning, but suggests a more prolonged or later spawning period than previously thought (Carbines 1998, 2004a). As the 2010 potting survey was undertaken outside the main spawning period it was not possible to determine size or age-at-maturity.

Size and sex ratio

The overall sex ratio was relatively even for all blue cod in most strata except stratum 7 where it was 2.3:1 (M:F) (Table 5). For legal sized blue cod all strata were biased towards males with the bias most pronounced in stratum 4, 7, and 8 (Table 5). Blue cod are protogynous hermaphrodites with some (but not all) females changing into males as they grow (Carbines 2004a). The finding that males were larger on average than females and that the largest fish were males is consistent with sex structure in a protogynous hermaphrodite. However, the skewed sex ratios of legal sized blue cod in some strata are contrary to an expected dominance of females resulting from selective removal of the larger terminal sex fish (males). Beentjes & Carbines (2005) suggested that the shift towards a higher proportion of males in heavily fished blue cod populations may be caused by removal of the possible inhibitory effect of large males, and a consequent higher rate (and possibly earlier onset) of sex change by primary females. This hypothesis is supported by the predominance of males in most South Island blue cod fisheries that are known to be heavily fished (and with a 30 cm MLS in BCO 3), in particular, Motunau, inshore Banks Peninsula, and the Marlborough Sounds (Beentjes & Carbines 2003, 2006, 2009, Blackwell 1997, 1998, 2002, 2005, 2008, Carbines & Beentjes 2006a, 2009). However, in Foveaux Strait (where the MLS is 10% larger and the population has more large fish), the numbers of males and females were more balanced than in the above BCO 3 management areas.

Population length and age structure

Length frequency distributions are similar for most strata, with few fish over 40 cm present except for in stratum 10 (Figure 3). The proportion of legal sized (33 cm and over) blue cod was 26%, which is low compared with the adjacent potting surveys in Paterson Inlet (43%, Carbines 2007) and Dusky Sound (55%, Carbines & Beentjes 2011a).

The age distributions and total mortality estimates are based on scaled length data that were weighted (scaled) by stratum area. Scaling by area assumes that the size of each stratum is directly proportional to the amount of blue cod habitat, i.e., stratum area is assumed to be a proxy for habitat; however, this is probably not the case given that the habitat types where blue cod are most frequently found have been shown to be unevenly distributed in the DUV analysis. With improving seabed habitat mapping, in future it may be possible to scale catch data to more detailed estimates of the actual areas of suitable blue cod habitat within each stratum – as was recommended by the expert review panel following a workshop on blue cod potting surveys in April 2009 (Stephenson et al. 2009).

The scaled length frequency distribution shows few legal sized blue cod throughout Foveaux Strait (Figure 6). The resulting population age structure shows a steep decline on the right hand limb and a low proportion of fish older than 11 years.

Total mortality (Z)

Mortality estimates (Z) for 2010, with age-at-recruitment set at 6 years (Table 8), are considerably higher than equivalent estimates from adjacent survey areas in Dusky Sound (Carbines & Beentjes 2011a) and South Otago (Beentjes & Carbines 2011).

Stock status (spawner per recruit analyses)

The Ministry of Fisheries (now Ministry for Primary Industries) *Harvest Strategy Standard* (Ministry of Fisheries 2008) 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 target reference point for blue cod is F_{MSY}, which is the amount of fishing mortality that results in the maximum sustainable yield. The recommended proxy for F_{MSY} is the level of spawner per recruit $F_{\%SPR}$. The Operational Guidelines for New Zealand's Harvest Strategy Standard' (Ministry of Fisheries 2008) include 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 productivity	25%	$F_{30\%}$
Medium productivity	35%	$F_{40\%}$
Low productivity	40%	$F_{45\%}$
Very low productivity	$\geq$ 45%	$\leq F_{50\%}$

Based on the Ministry of Fisheries (2008) 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 $F_{40\%SPR}$. Our SPR estimates for the default M value of 0.14 were $F_{35\%}$ for Foveaux Strait, indicating that the expected contribution to the spawning biomass over the lifetime of an average recruit has been reduced to 35% of the contribution in the absence of fishing. Further, the level of exploitation (F) of Foveaux Strait blue cod stocks is greater than the F_{MSY} target reference point of $F_{40\%}$ (Table 9, see Figure 7), i.e., the fishing pressure in Foveaux Strait has resulted in an $F_{\%SPR}$ estimate that is 5% greater than the Ministry specified target.

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 9, see Figure 7). A higher natural mortality (0.17) increased spawning biomass contribution by 9%. Conversely, lower mortality (0.11) decreased the spawning biomass contribution by the same proportion. The exploitation rate (F) is below the target reference point of $F_{40\%}$ only for an M of 0.17 (Figure 7).

Comparisons between surveys

Prior to the 2010 random potting survey, a fixed site (hot spots selected by fishers) potting survey was undertaken in Foveaux Strait in 2009 using the same stratum boundaries and sampling methods, but with about half the sampling effort (Carbines 2009, See Figure 17). We do not expect major shifts in catchability to have occurred between the two surveys as weather conditions were similar because fishing was restricted to calm days in both surveys.

While the bycatch species were similar, by numbers the 2010 survey caught 77% blue cod and the 2009 survey caught 98% blue cod. The random site survey caught over nine times as many leatherjackets (*Parika scaber*) as the fixed site survey. Overall, for legal sized blue cod, catch rates in the 2010 survey were 33% of the equivalent 2009 survey (see Table 13, Figure 18). While the overall effort (i.e., number of pot lifts) in equivalent areas of the 2010 random site survey was about twice that of the fixed site survey, the coefficients of variation (c.v.) were similar (Table 10). In the 2010 random site survey individual stratum c.v. ranged from 16.2% to 65.1% with an overall c.v. of 11.7% for legal size blue cod. In the 2009 fixed site survey individual stratum c.v. ranged from 16.5% to 45.9% with an overall c.v. of 13.8% for legal size blue cod. Overall, for legal sized blue, the c.v. in the 2010 survey was 84% of the equivalent 2009 survey (Table 13).

The strata at the western entrance of Foveaux Strait (strata 1–2) and off the northern coast of Stewart Island (stratum 4) all had proportionately high catch rates in both surveys (Figure 18). However, the large strata around Ruapuke Island (stratum 8) and the North Islands (stratum 7) had proportionally very different catch rates (Figure 19) and c.v.s (Table 13). This may be due to the large amount of open sandy ground sampled in the random survey that was not sampled in the fixed site survey (See Figure 1 versus 17). Sub-dividing the two largest strata by consistent habitat types (i.e., coastal and adjacent foul versus open sand) may reduce variation and uncertainty in these strata for future random surveys.

The length frequency distributions for the two surveys were similar in shape, but in the 2010 survey there was a higher proportion of blue cod smaller than 15 cm and over minimum legal size (Figure 18). Twenty-six percent of blue cod caught exceeded the MLS in the 2010 survey, while only 19 percent of blue cod caught in the 2009 survey exceed the MLS. The consequence of a potential size selectivity bias from fixed sites having proportionally less fish over MLS than random sites is that estimates of M and consequently $F_{\%SPR}$ may be different using a random survey design than a fixed site design. While these differences in length frequency distributions between the two surveys designs may be due to higher levels of fishing at known fishing (fixed) sites, it is inappropriate to compare estimates of M and $F_{\%SPR}$ between random and fixed site surveys,

4.1 Comparisons between pot catch and DUV observations

Fishing gear, bait type and soak time are standardised in blue cod potting surveys (see Beentjes & Francis 2011), but other factors such as fish behaviour and environmental features can influence catchability and size selectivity in passive capture methods such as potting (Furevik 1994, Fogarty & Addison 1997, Robichaud et al. 2000). Cole et al. (2001) found blue cod catch rates to be unrelated to both time and tide in the Marlborough Sounds. However, when compared to diver transects, pots tended to under-sample small blue cod, being selective for fish over 15 cm (Cole et al. 2001). While there was a positive relationship between blue cod catch from pots (pot plan 1 from Beentjes & Francis 2011) and diver transects, it was weak and much of the variation remained unexplained (Cole et al. 2001).

In the 2010 Foveaux Strait potting survey we used concurrent observations of blue cod abundance and environmental descriptions from a DUV to investigate the relationship between actual counts of blue cod over a known area with catch rates and sizes of blue cod caught in survey pots (pot plan 2 in Beentjes & Francis 2011).

Does potting provide an index of relative abundance and size structure?

Twice as many species were observed using DUV than were caught by pots concurrently surveyed (Tables 11, 12). Pots caught similar proportions of blue cod over 20 cm, but under sampled smaller blue cod compared to the DUV (Figure 9).

The current study provided a better relationship between observed densities and catch rates than was observed by Cole et al. (2001) using SCUBA counts and pot catches of blue cod in the Marlborough Sounds. Furthermore, considerably larger correlation coefficients were observed between densities from DUV and pot catches of blue cod in Foveaux Strait (Figures 11, 12) than in the Marlborough Sounds (Carbines et al. 2011). In Foveaux Strait there were no instances of high densities observed with concurrent low catch rates, however, there were several sites where fish were caught when none (or few) were observed (see Figure 10). It is possible that pots are attracting blue cod in from a distance greater than the area surveyed, or that blue cod populations are highly clumped within the survey area, or that the relationship between catch and count (i.e., catchability) is highly variable over time and/or location. To help resolve this uncertainty we recommend that future concurrent pot and video comparisons should use a wider DUV sample area, increase the number of DUV transects within the sample area, and continue to do comparisons at several survey areas over several occasions.

Importance of recording habitat for blue cod potting surveys

Fixed sites (which are fishing hot spots) differed from random sites in both primary substrata and secondary habitat structures (as defined in Section 2.16). There were more categories of both primary substrata and secondary habitat structures observed at fixed sites than at random sites, with random sites generally characterized by softer primary substrata with some shell or sea tulips, as opposed to fixed sites with generally firmer primary substrata supporting more diverse biogenic habitats such as sponge and macro algae (Figures 14–16).

The primary substrate most frequently observed with blue cod at random sites were pea gravel, and sand and gravel (Figure 13), while at fixed sites they were pea gravel, bedrock/sand, and sand and gravel (Figure 14). Using the ratio of fish-dependent and fish-independent habitat observations it was possible to determine which primary substrate and secondary habitat categories blue cod are found in association with at a higher rate than those categories are found in the benthic environment. Blue cod at random sites were most associated with boulders (Figure 13), while larger blue cod at fixed sites were more commonly observed with sand/shell grit and smaller blue cod with various forms of bedrock (Figure 14).

The secondary habitat structure most frequently observed with blue cod at random sites was sponge on boulders (Figure 15), while at fixed sites it was a combination of sponge on boulders, patch reef and macroalgae on boulders or bedrock (Figure 16). However, in relation to the availability of each habitat category, blue cod were more commonly observed with sponge on boulders (Figure 15), while at fixed sites they were more associated with both macroalgae and various forms of sponge (Figure 16).

Data on fish abundance and habitat from video provide information regarding environmental variables affecting blue cod density and size structure. This can identify benthic habitats and structures of particular importance and allows for the construction of habitat maps, which will be particularly useful in terms of stratifying future potting surveys for more accurate scaling of relative abundance estimates (Stephenson et al. 2009). Video habitat data also provides a unique understanding of the ontogenetic needs of fish and can provide habitat information for other management purposes.

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Table 1: Foveaux Strait 2010 survey stratum area, number of phase 1 and 2 sites, pot lifts and depth.

Stratum	Stratum area (km)	Number of sets Phase 1	Number of sets Phase 2	Number of pot lifts	Depth (m) Mean	Depth (m) Range
1	221.8	6	1	42	46.3	17–59
2	245.0	6		36	34.4	30–48
4	160.0	6	1	42	29.0	2–38
5	248.6	6		36	34.4	30–38
6	261.8	6		36	25.6	12–33
7	412.5	6		36	45.6	24–64
8	545.8	6	6	72	45.1	20–79
10	238.8	6		36	55.1	16–93
Total	2 334.3	48	8	336	40.0	2–93

Table 2: Catch weight, numbers of blue cod, bycatch species, and percentage of total weight on the 2010 Foveaux Strait survey.

Common name	Scientific name	Catch (kg)	Number	Percent of total catch
Blue cod	*Parapercis colias*	1 867.69	4 340	84.58
Leatherjacket	*Parika scaber*	277.65	1 186	12.57
Octopus	*Octopus cordiformis*	15.72	9	0.71
Conger eel	*Conger verreauxi*	13.96	2	0.63
Girdled wrasse	*Notolabrus cinctus*	9.96	30	0.45
Scarlet wrasse	*Pseudolabrus miles*	8.74	33	0.40
Banded wrasse	*Notolabrus fucicola*	4.81	5	0.22
Tarakihi	*Nemadactylus macropterus*	3.93	18	0.18
Blue moki	*Latridopsis ciliaris*	2.25	3	0.10
Trumpeter	*Latris lineata*	2.21	4	0.10
Hag fish	*Eptatretus cirrhatus*	1.30	1	0.06
Total		2 208.22	5 631	100.00

Table 3: Mean catch rates for all blue cod caught in the 2010 Foveaux Strait survey. Catch rates are pot based and s.e. and c.v. are set-based. s.e., standard error, c.v. coefficient of variation.

Stratum	Pot lifts (N)	Mean (kg.pot^{-1})	s.e.	c.v. (%)
1	42	11.38	2.41	21.19
2	36	14.14	2.50	17.69
4	42	8.79	2.97	33.83
5	36	2.91	1.36	46.82
6	36	3.03	1.24	41.08
7	36	1.17	0.55	46.79
8	72	1.80	1.16	64.75
10	36	3.50	0.97	27.76
Overall	336	4.80	0.54	11.34

Table 4: Mean catch rates for blue cod 33 cm (MLS) and over caught in the 2010 Foveaux Strait survey. Catch rates are pot based and s.e. and c.v. are set-based. s.e., standard error, c.v. coefficient of variation.

Stratum	Pot lifts (N)	Mean (kg.pot^{-1})	s.e.	c.v. (%)
1	42	5.11	1.04	20.39
2	36	4.96	0.80	16.21
4	42	3.79	1.31	34.63
5	36	1.69	0.81	47.73
6	36	1.80	0.76	42.26
7	36	0.86	0.39	45.22
8	72	0.46	0.30	65.06
10	36	1.77	0.46	26.07
Overall	336	2.09	0.23	10.87

Table 5: Weighted mean lengths and weighted sex ratio (M:F) for all blue cod by stratum in the 2010 Foveaux Strait survey. Weighted sex ratio is also shown for blue cod 33 cm and over.

			Length (cm)			Sex ratio M:F (% male)	
Stratum	Sex	N	Mean	Minimum	Maximum	All blue cod	≥ 33 cm
1	M	456	31.3	18	49	0.8:1 (43.6)	2.2:1 (68.3)
	F	592	28.4	14	41		
2	M	413	30.7	20	43	0.6:1 (35.5)	1.3:1 (55.8)
	F	748	29.1	20	44		
4	M	527	29.7	17	43	1.2:1 (55.5)	3.7:1 (78.7)
	F	416	26.6	14	41		
5	M	122	31.1	20	44	1.1:1 (53.2)	2.3:1 (70.1)
	F	106	27.8	14	39		
6	M	144	30.3	16	43	1.3:1 (57.1)	2.6:1 (72.0)
	F	108	24.8	12	39		
7	M	46	33.6	18	42	2.3:1 (70.0)	3.9:1 (79.6)
	F	20	28.9	13	39		
8	M	187	27.9	12	44	0.9:1 (46.2)	3.4:1 (77.1)
	F	217	24.0	11	36		
10	M	113	32.2	20	56	0.9:1 (47.5)	1.5:1 (60.5)
	F	125	29.5	22	41		
Overall weighted	M	2008	30.5	12	56	0.8:1 (45.7)	2.1:1 (67.3)
	F	2332	27.8	11	44		

Table 6: Gonad stages of Foveaux Strait blue cod in 2010. 1, immature or resting; 2, maturing (oocytes visible in females); 3, mature (hyaline oocytes in females, milt expressible in males); 4, running ripe (eggs and milt free flowing); 5, spent.

	Gonad stage (%)					
	1	2	3	4	5	N
Males	1.6	78.9	1.1	15.0	3.4	2 008
Females	2.7	79.9	5.1	5.1	7.3	2 332

Table 7: Otolith raw data used in the catch-at-age, *Z* estimates, and SPR analyses for the 2010 Foveaux Strait survey.

	No.	Length of aged fish (cm)			Age (years)		
Survey	otoliths	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Total	291	29.2	11	56	7.5	1	28
Male	151	32.3	12	56	8.2	2	28
Female	140	25.8	11	41	6.6	1	16

Table 8: Total mortality estimates (*Z*) and 95% confidence intervals of blue cod from the 2010 Foveaux Strait potting survey using Chapman Robson method described in Appendix 2.

		Confidence intervals	
AgeR	*Z*	Lower	Upper
5	0.34	0.24	0.45
6	0.41	0.28	0.55
7	0.44	0.31	0.60
8	0.46	0.32	0.62

Table 9: Mortality parameters (Z, F, and M) and spawner per recruit (SPR) estimates at three values of M for the 2010 Foveaux Strait survey. F, fishing mortality; M, natural mortality; Z, total mortality. Age-at-recruitment was assumed to be 6 years old.

M	Z	F	SPR
0.11	0.41	0.30	$F_{26.2\%}$
0.14	0.41	0.27	$F_{35.3\%}$
0.17	0.41	0.24	$F_{44.5\%}$

Table 10: Drift Underwater Video (DUV) and pot sample details. Note that stations are individual transects and pots. *=includes equivalent number of fish-dependent habitat quadrats.

	DUV			Pots		
	Total	Random	Fixed	Pots	Random	Fixed
Sites	17	12	5	17	12	5
Stations	80	61	19	98	69	29
Habitat sections	228	133	95	-	-	-
Habitat quadrats	1100	657	443	-	-	-
Transect length	813 m (± 8.24)	792	884	-	-	-
Transect width	3.6 m (± 0.07)	2.9	4.5	-	-	-
Total area swept	233 608 m^2	137 220	86 388	Unknown		
Blue cod	1525 *	435 *	1090 *	2452	1128	1324

Table 11: Pot catch, numbers of blue cod, bycatch species, and percentage of total numbers from the 12 random and 5 fixed potted Drift Underwater Video (DUV) sites. Bracketed numbers are the percentage of catch per site selection method (random or fixed).

Common name	Scientific name	Random Sites	Fixed Sites	Total Number	Percent total catch
Blue cod	*Parapercis colias*	1 128 (85.1)	1 324 (95.5)	2 452	90.41
Leatherjacket	*Parika scaber*	161 (12.1)	11 (0.8)	172	6.34
Scarlet wrasse	*Pseudolabrus miles*	11 (0.8)	24 (1.7)	35	1.29
Girdled wrasse	*Notolabrus cinctus*	8 (0.6)	26 (1.9)	34	1.26
Tarakihi	*Nemadactylus macropterus*	5 (0.4)	0	5	0.18
Octopus	*Octopus cordiformis*	3 (0.2)	1 (0.1)	4	0.15
Trumpeter	*Latris lineata*	4 (0.3)	0	4	0.15
Banded wrasse	*Notolabrus fucicola*	3 (0.2)	0	3	0.11
Blue moki	*Latridopsis ciliaris*	3 (0.2)	0	3	0.11
Total		1 326	1 386	2 712	100.00

Table 12: Drift Underwater Video (DUV) observed numbers of blue cod, bycatch species, and percentage of total numbers from the 12 random and 5 fixed potted video sites. The numbers in parenthesis are the percentage of observations per site selection method (random or fixed). * total does not include unidentified species.

Common name	Scientific name	Random Sites	Fixed Sites	Total Number	Percent of total catch
Blue cod	*Parapercis colias*	435 (34.7)	1 090 (53.2)	1 525	46.17
Leatherjacket	*Parika scaber*	335 (26.7)	367 (17.9)	702	21.25
Banded wrasse	*Notolabrus fucicola*	0	337 (16.4)	337	10.20
Scarlet wrasse	*Pseudolabrus miles*	148 (11.8)	119 (5.8)	267	8.08
Spiny dogfish	*Squalus acanthias*	80 (6.4)	82 (4.0)	162	4.90
Kahawai	*Arripis trutta*	64 (5.1)	0	64	1.94
Tarakihi	*Nemadactylus macropterus*	25 (2.0)	25 (1.2)	50	1.51
Blue moki	*Latridopsis ciliaris*	45 (3.6)	1 (<0.1)	46	1.39
Jack mackerel	*Trachurus declivis*	40 (3.1)	0	40	1.21
Butterfly Perch	*Caesioperca lepidoptera*	11 (0.9)	23 (1.1)	34	1.03
Spotty	*Notolabrus celidotus*	23 (1.8)	2 (0.1)	25	0.76
Girdled wrasse	*Notolabrus cinctus*	20 (1.6)	0	20	0.61
Trumpeter	*Latris lineata*	16 (1.3)	3 (0.1)	19	0.57
Skate	*Raja* spp.	4 (0.3)	1 (<0.1)	5	0.15
Butterfish	*Odax pullus*	3 (0.2)	0	3	0.09
Octopus	*Octopus cordiformis*	2 (0.2)	0	2	0.06
Sea perch	*Helicolenus* spp.	1 (<0.1)	0	1	0.03
Southern pigfish	*Congiopodus leucopaecilus*	1 (<0.1)	0	1	0.03
Unidentified		*40*	*12*	*52*	-
Total*		1 253	2 050	3 303	100.00

Table 13: Mean catch rates for blue cod 33 cm (MLS) and over caught in the 2010 Foveaux Strait random survey and the equivalent 2009 Foveaux Strait fisher-selected fixed station survey. Catch rates are pot based and s.e. and c.v. are set-based. s.e., standard error, c.v. coefficient of variation.

	2010 random site survey				2009 fisher-selected fixed site survey			
Stratum	Pot lifts (N)	Mean (kg.pot^{-1})	s.e.	c.v. (%)	Pot lifts (N)	Mean (kg.pot^{-1})	s.e.	c.v. (%)
1	42	5.11	1.04	20.39	23	4.43	2.60	19.70
2	36	4.96	0.80	16.21	20	8.40	0.76	22.59
4	42	3.79	1.31	34.63	23	10.62	1.90	17.23
5	36	1.69	0.81	47.73	20	4.69	1.57	16.55
6	36	1.80	0.76	42.26	29	4.89	2.40	32.20
7	36	0.86	0.39	45.22	25	7.98	1.83	30.05
8	72	0.46	0.30	65.06	19	5.66	0.87	45.94
Overall	300	2.12	0.25	11.66	159	6.48	0.72	13.85

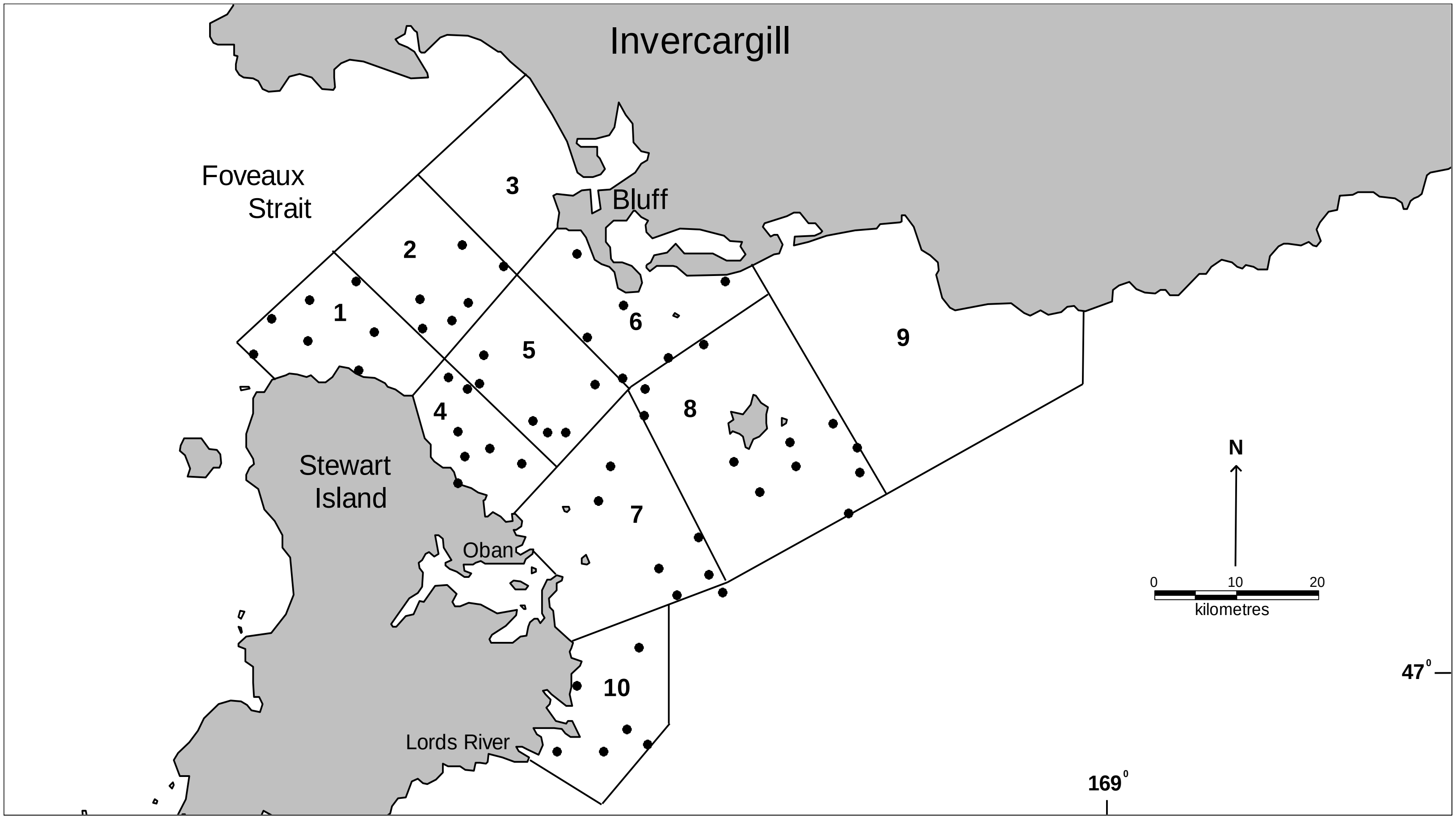


Figure 1: Sites surveyed in the 2010 Foveaux Strait survey. Strata 3 and 9 were not surveyed in 2010.

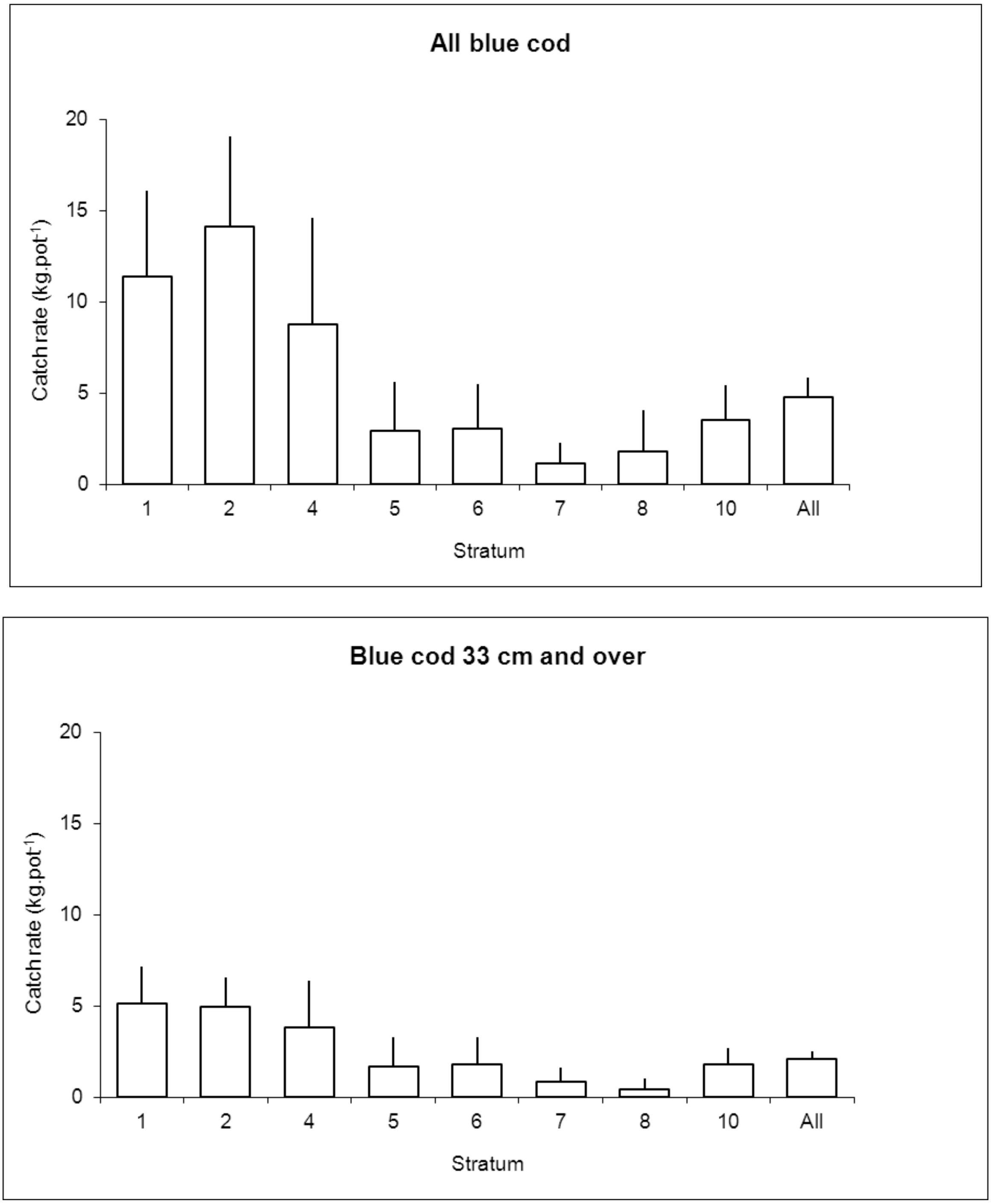


Figure 2: Catch rates and 95% confidence intervals for all blue cod and those 33 cm and over in the 2010 Foveaux Strait survey.

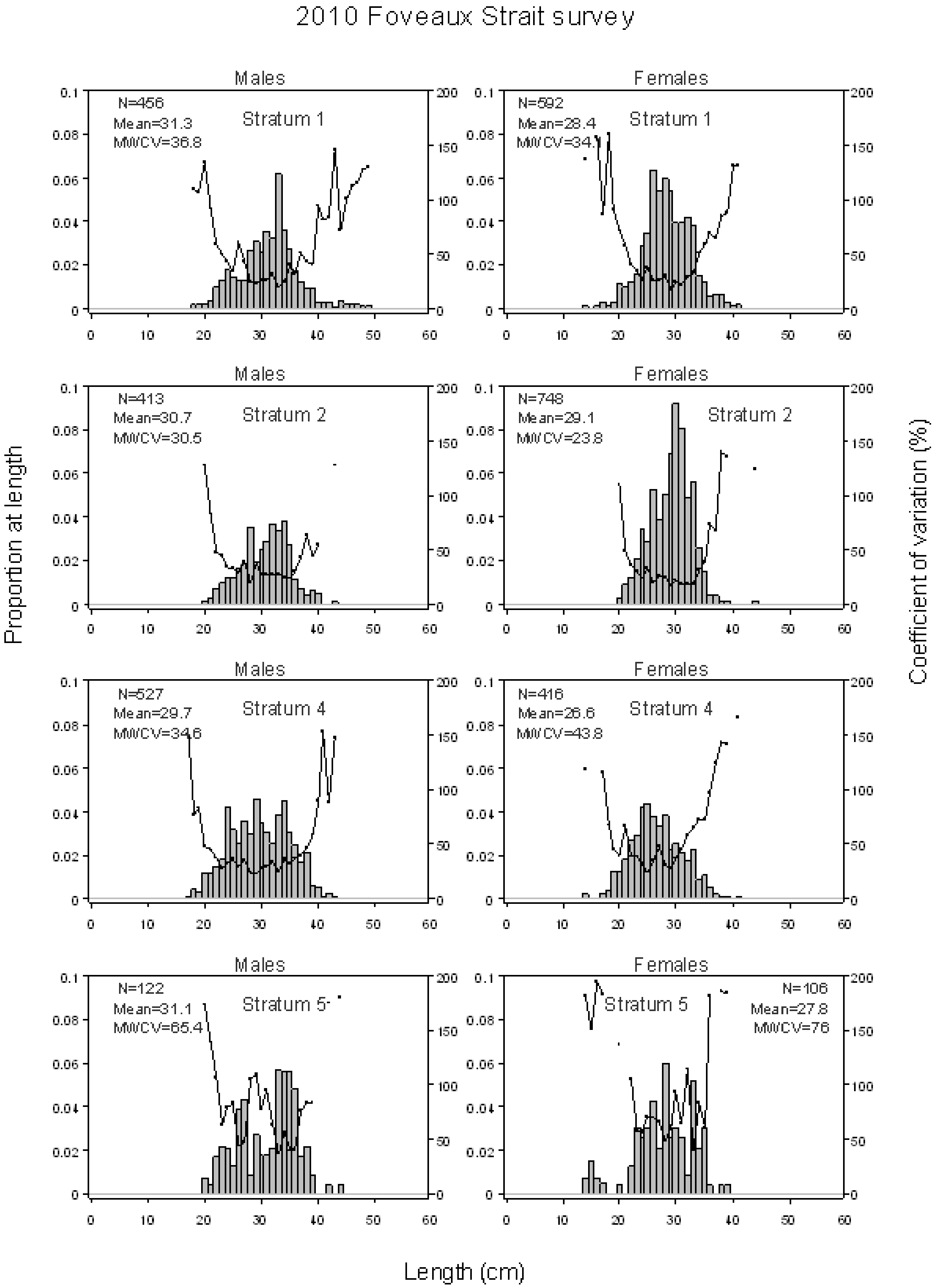


Figure 3: Scaled proportion length frequency distributions of blue cod for each stratum (1, 2, 4, 5, 6, 7, 8, and 10). Proportions for each stratum sum to 1.

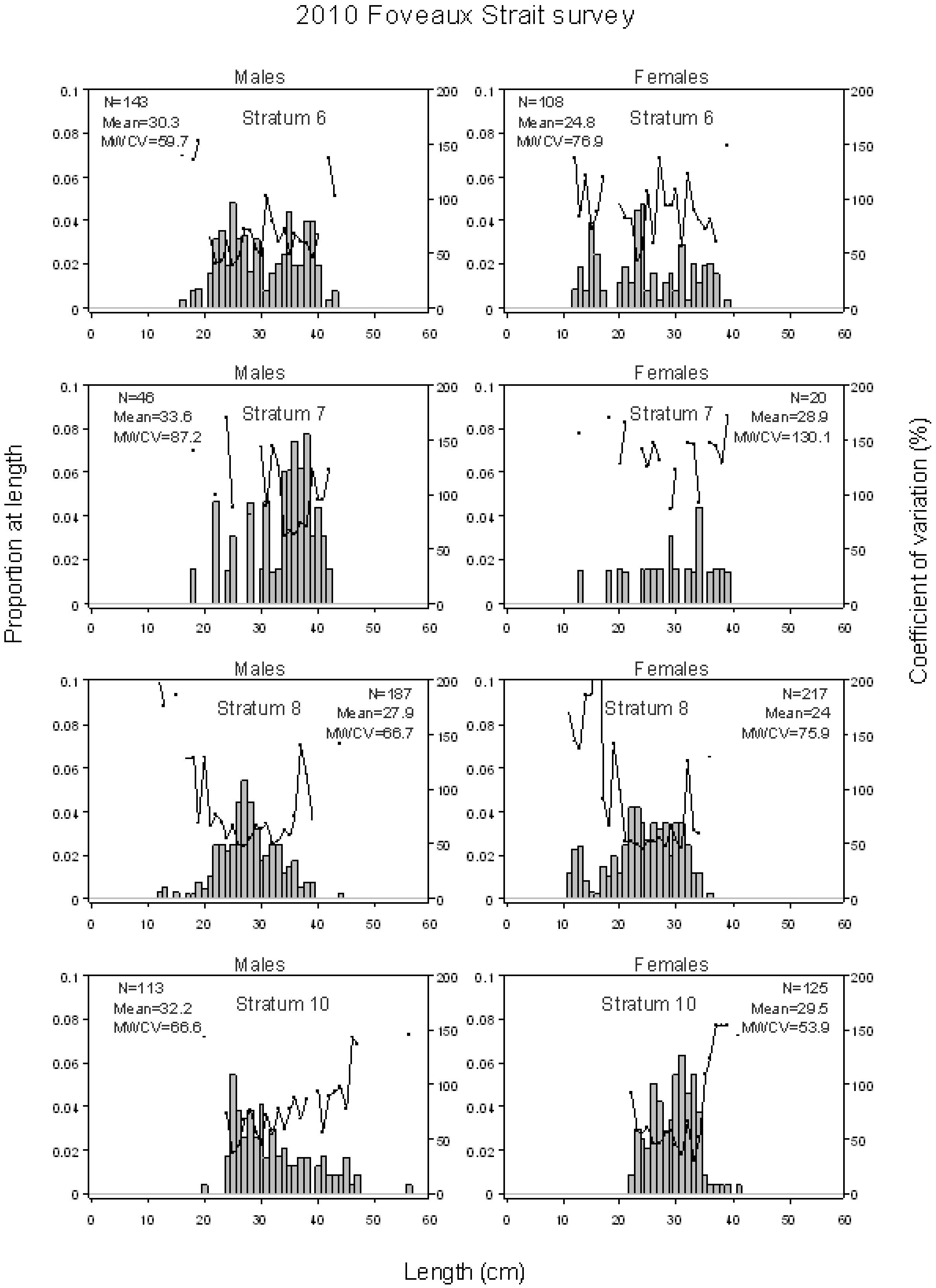


Figure 3 – ***continued***

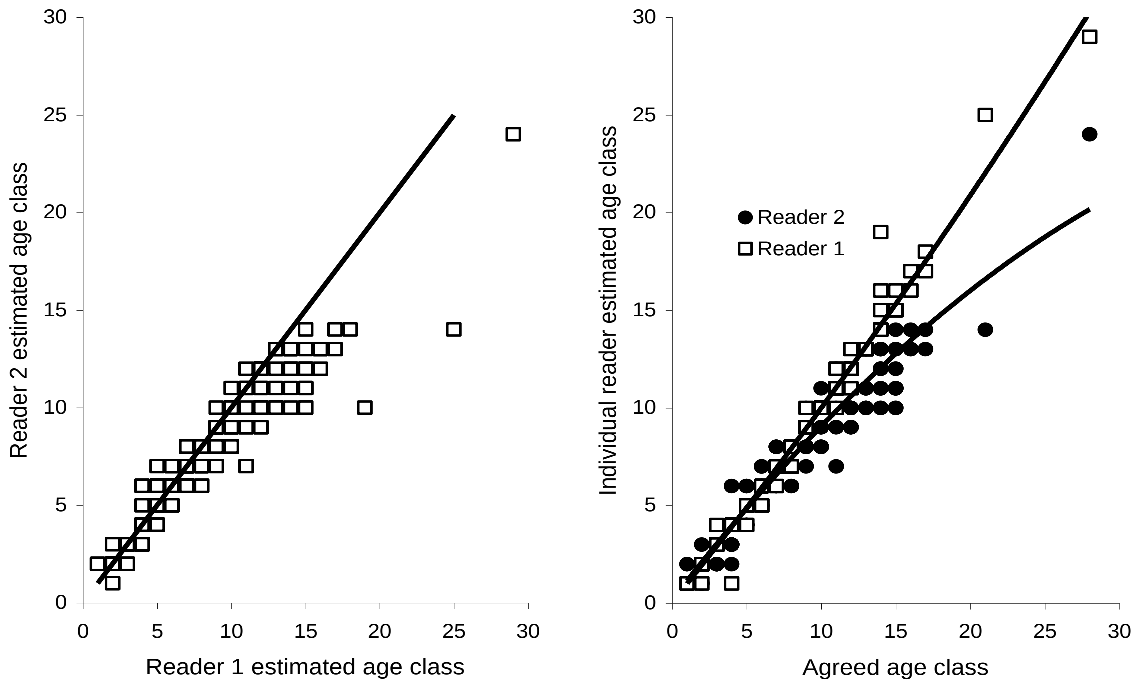


Figure 4: Foveaux Strait 2010 survey comparison of individual reader age class estimates from otoliths plotted against each other on the left with the 1:1 line plotted and in the right panel the agreed age class estimates on the right (n = 291), with polynomial trend line fitted.

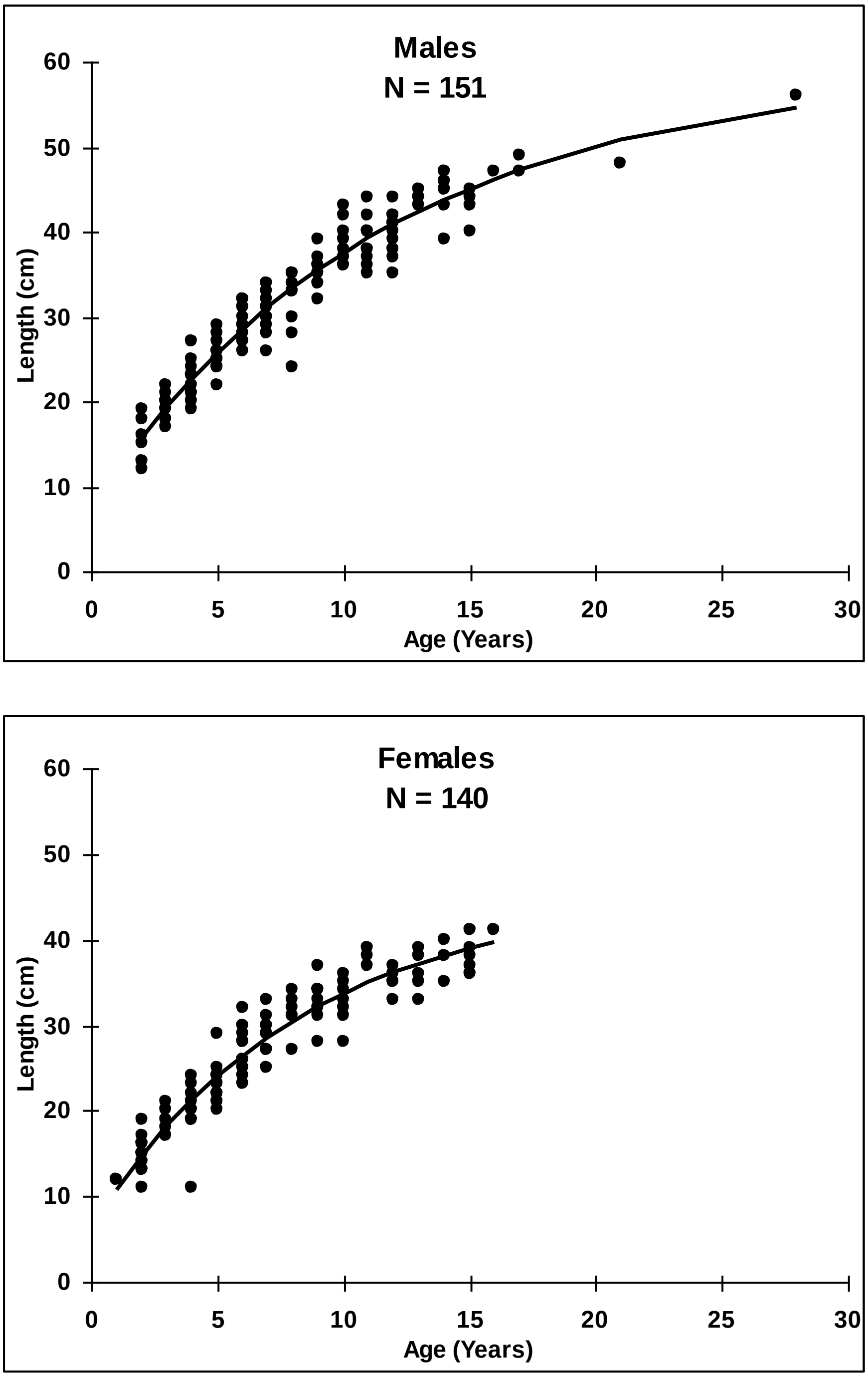


Figure 5: Observed age and length data by sex for the 2010 Foveaux Strait survey. von Bertalanffy growth models are fitted to the data. See Table 8 for description of samples.

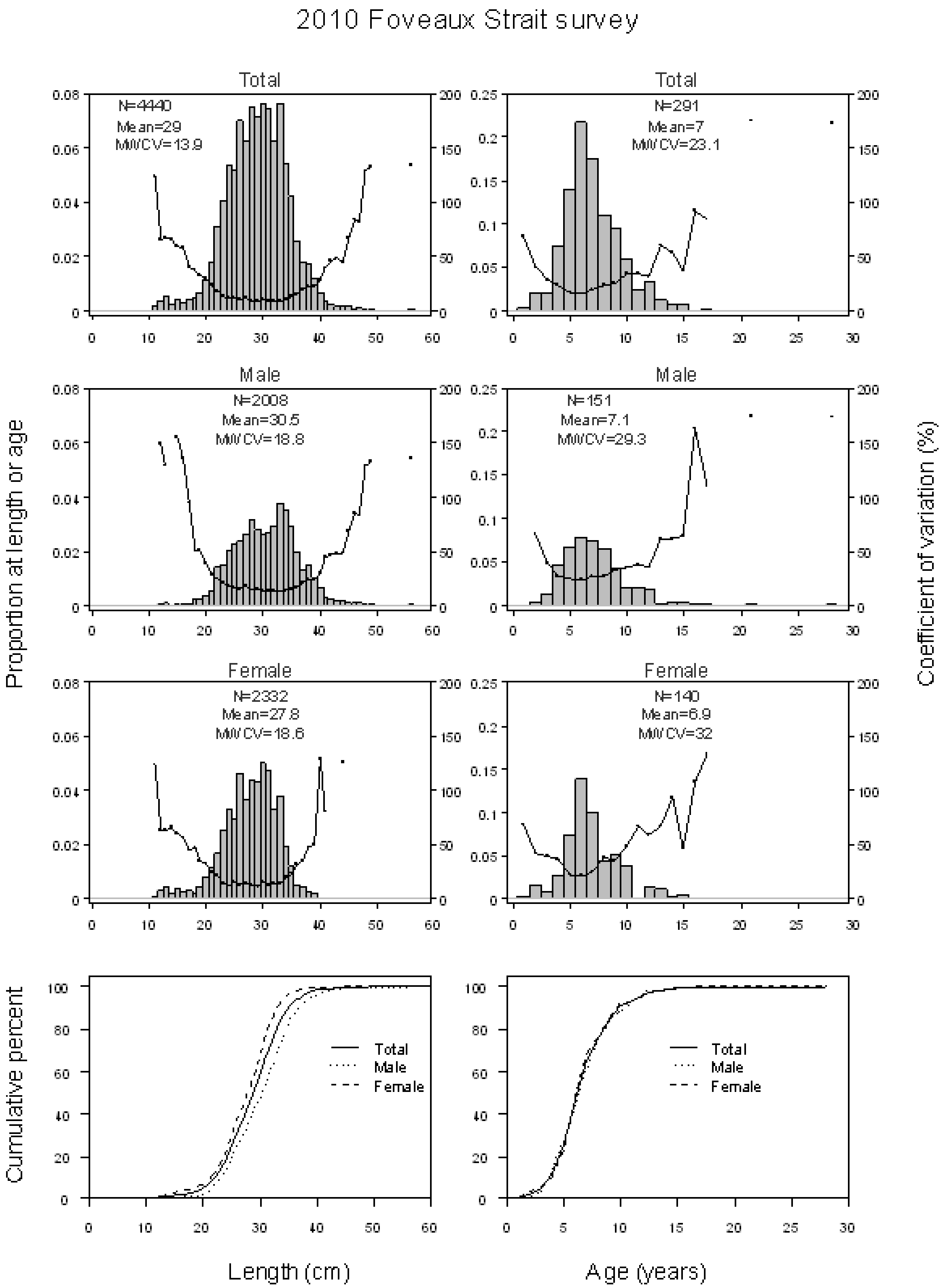


Figure 6: Scaled length frequency, age frequency, and cumulative distributions for total, male, and female blue cod for all strata (1, 2, 4, 5, 6, 7, 8 and 10) combined, for the 2010 Foveaux Strait survey. N, sample size; MWCV, mean weighted coefficient of variation.

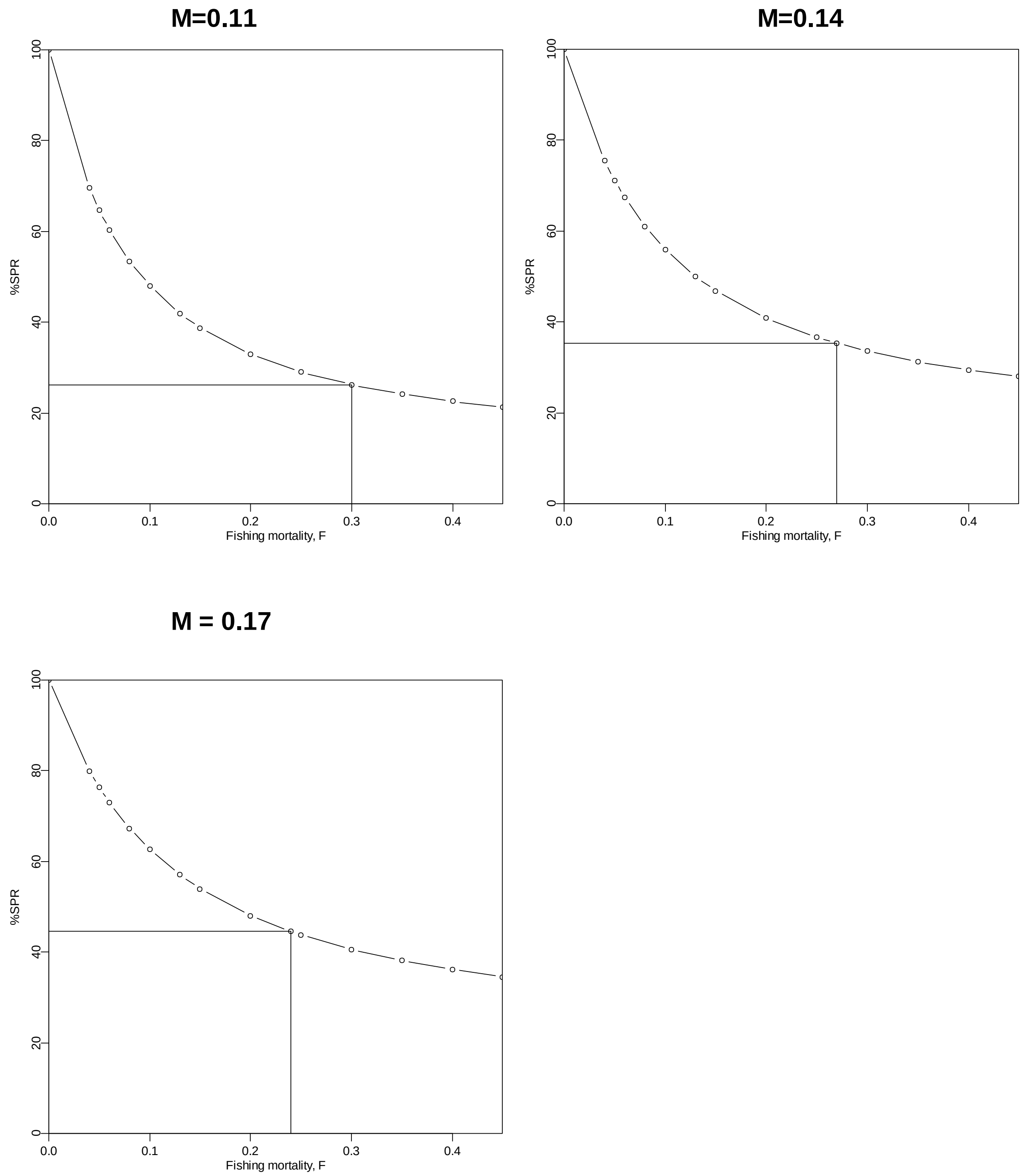


Figure 7: Plot of spawner per recruit (SPR) as a function of fishing mortality for the 2010 Foveaux Strait survey at three values of M (0.11, 0.14, 0.17). See Table 10 for fishing mortalities and $F_{SPR\%}$. The y-axis has been inverted because a low fishing mortality corresponds to a high %SPR.

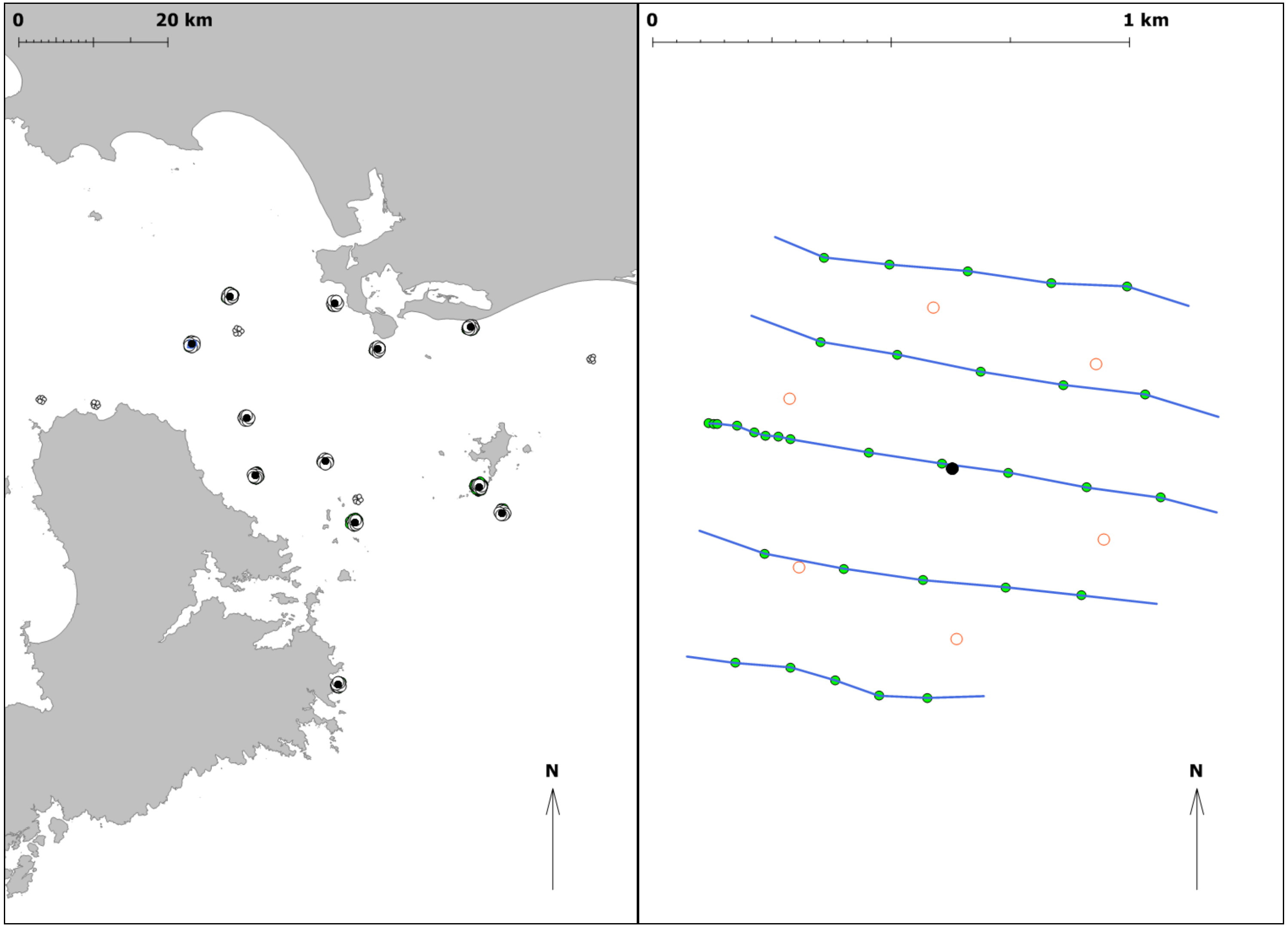


Figure 8: Drift underwater video versus potting sites. Left - the study area showing the 17 sites surveyed with 6 pots (open dots) and 5 video transects. The 12 random sites have a solid dot in the center of the pot cluster and the 5 fixed sites do not. Right – an example site showing pots (open dots), video transects (lines) and habitat sub-transects (solid dots).

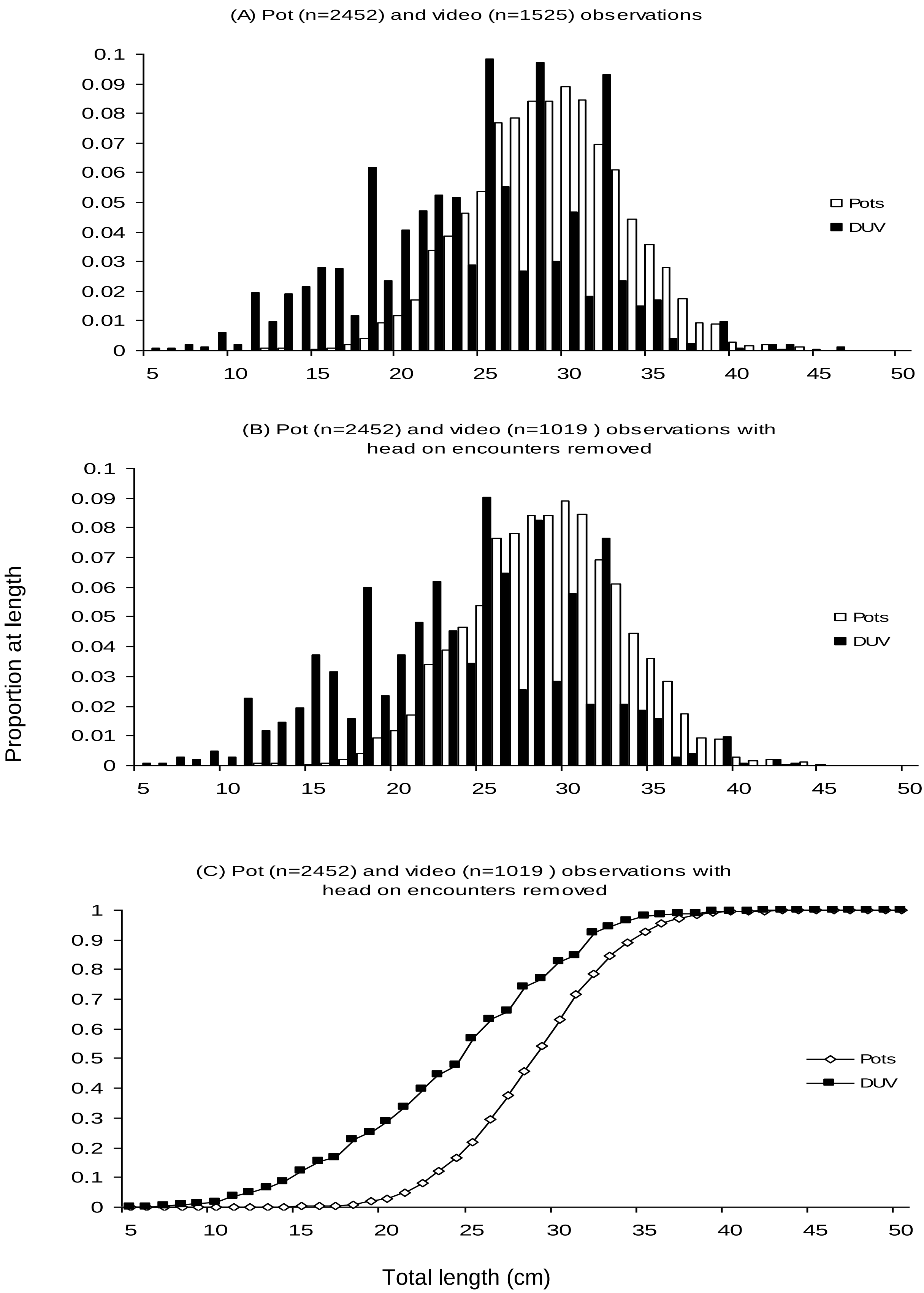


Figure 9: (A) all measured video observations of blue cod sizes plotted against sizes from concurrent pot catch. (B) blue cod sizes from video observations without head-on body orientation to camera plotted against sizes from pot catch. (C) cumulative frequency distribution without video head-on body orientation.

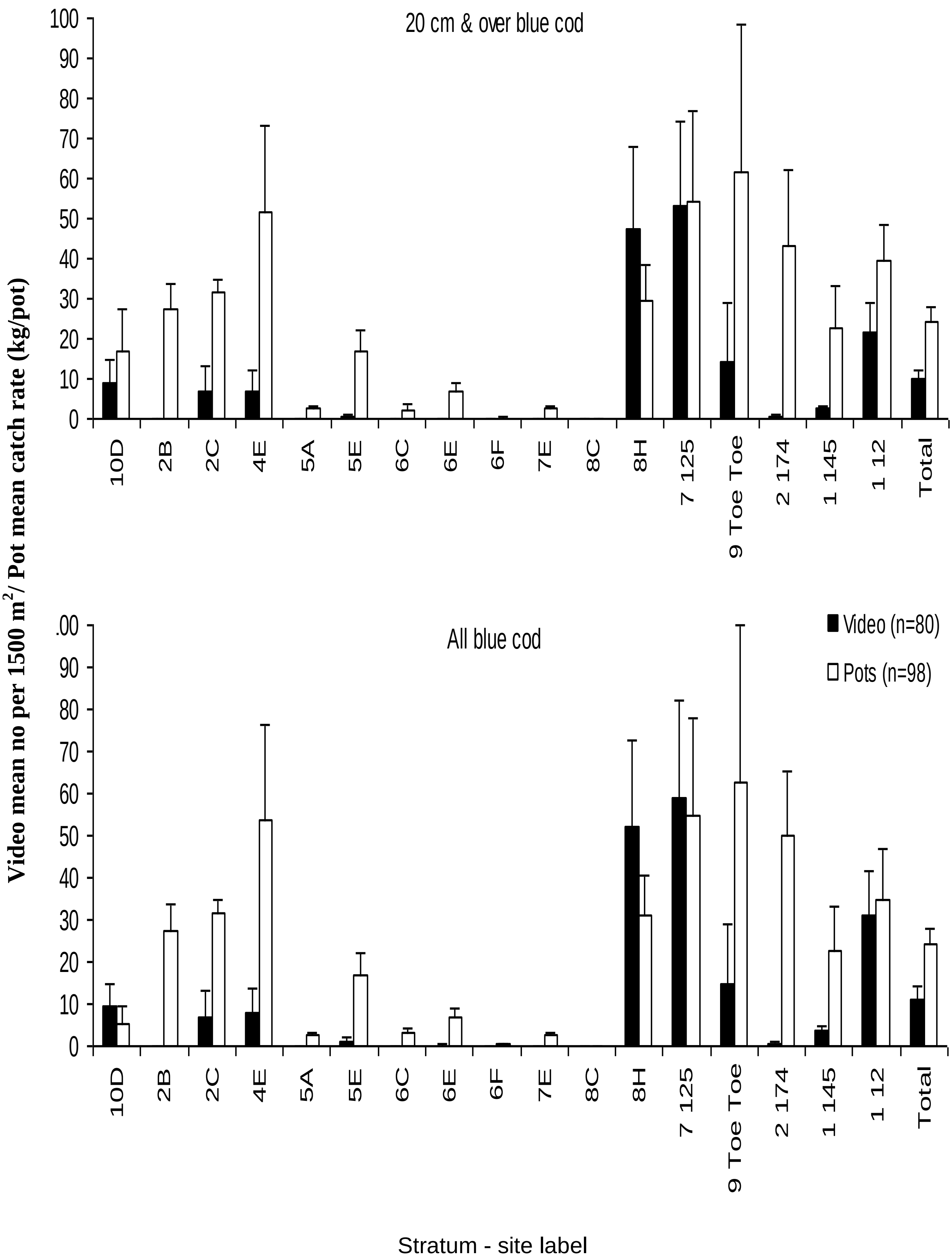
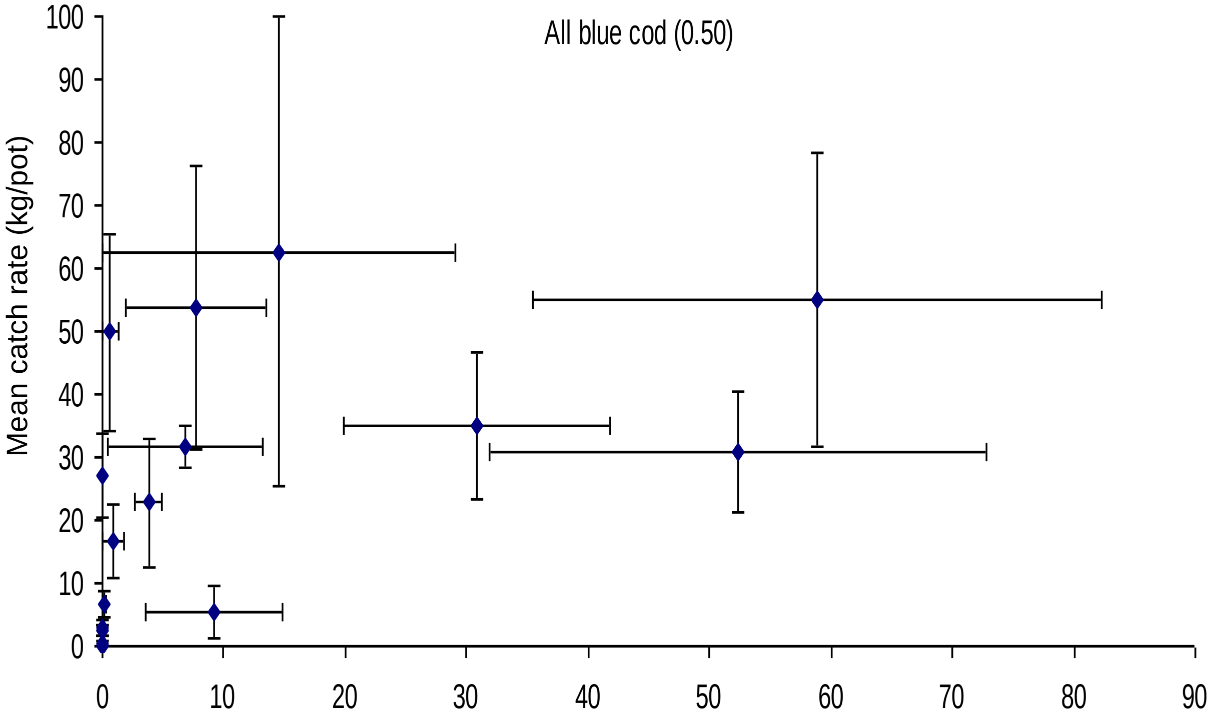


Figure 10: Mean site relative abundance (catch rates) from pots versus the equivalent mean site density estimates from the area swept video method for all blue cod (top) and blue cod 20 cm and over (bottom). Error bars are +/- one standard error.



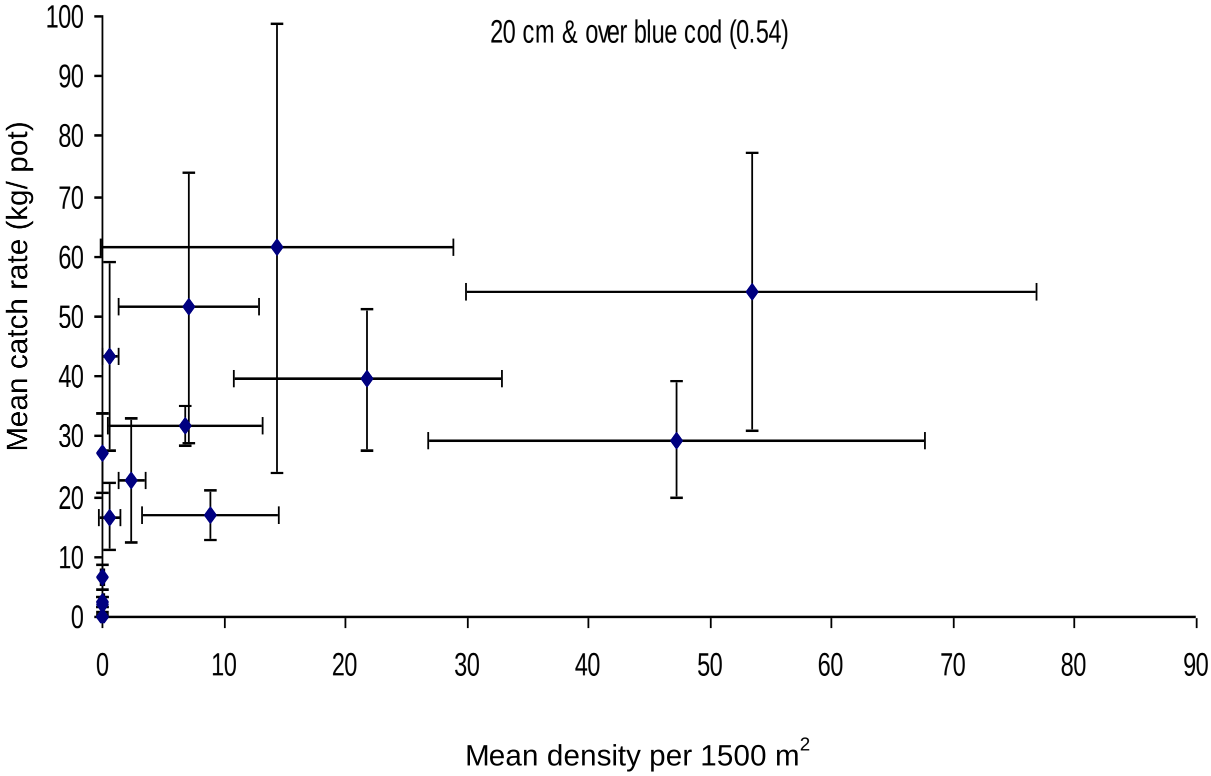


Figure 11: Mean density versus catch rate of all (top) and ≥20 cm (bottom) blue cod dual surveyed with video and pots. The number in brackets is the correlation coefficient, error bars are +/- one standard error.

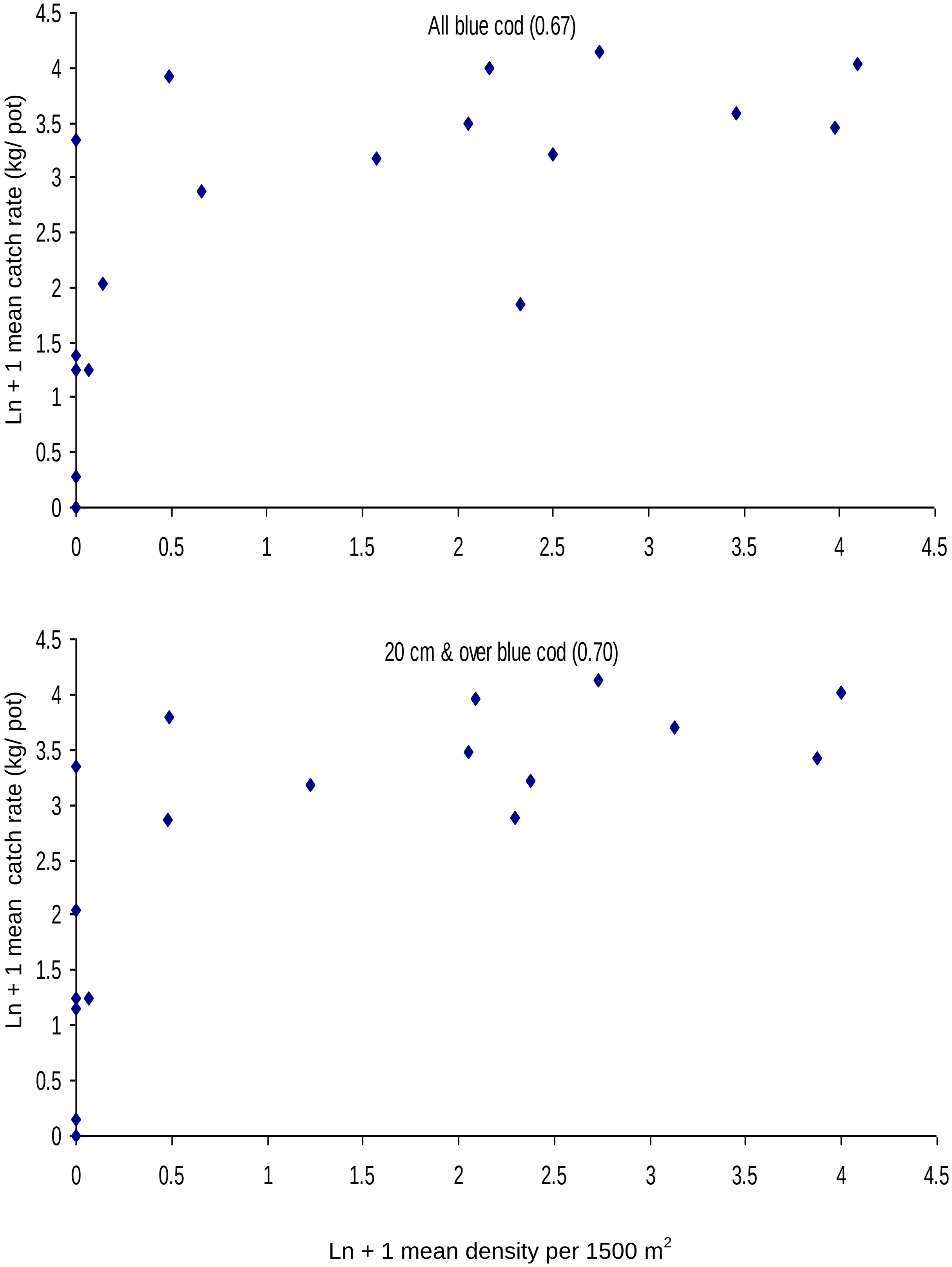


Figure 12: Mean natural log (+1) density versus the natural log (+1) catch rate of all (top) and ≥20 cm (bottom) blue cod dual surveys with video and pots. The number in brackets is the correlation coefficient. The standard errors (see Figure 11) are not plotted for clarity of these graphs.

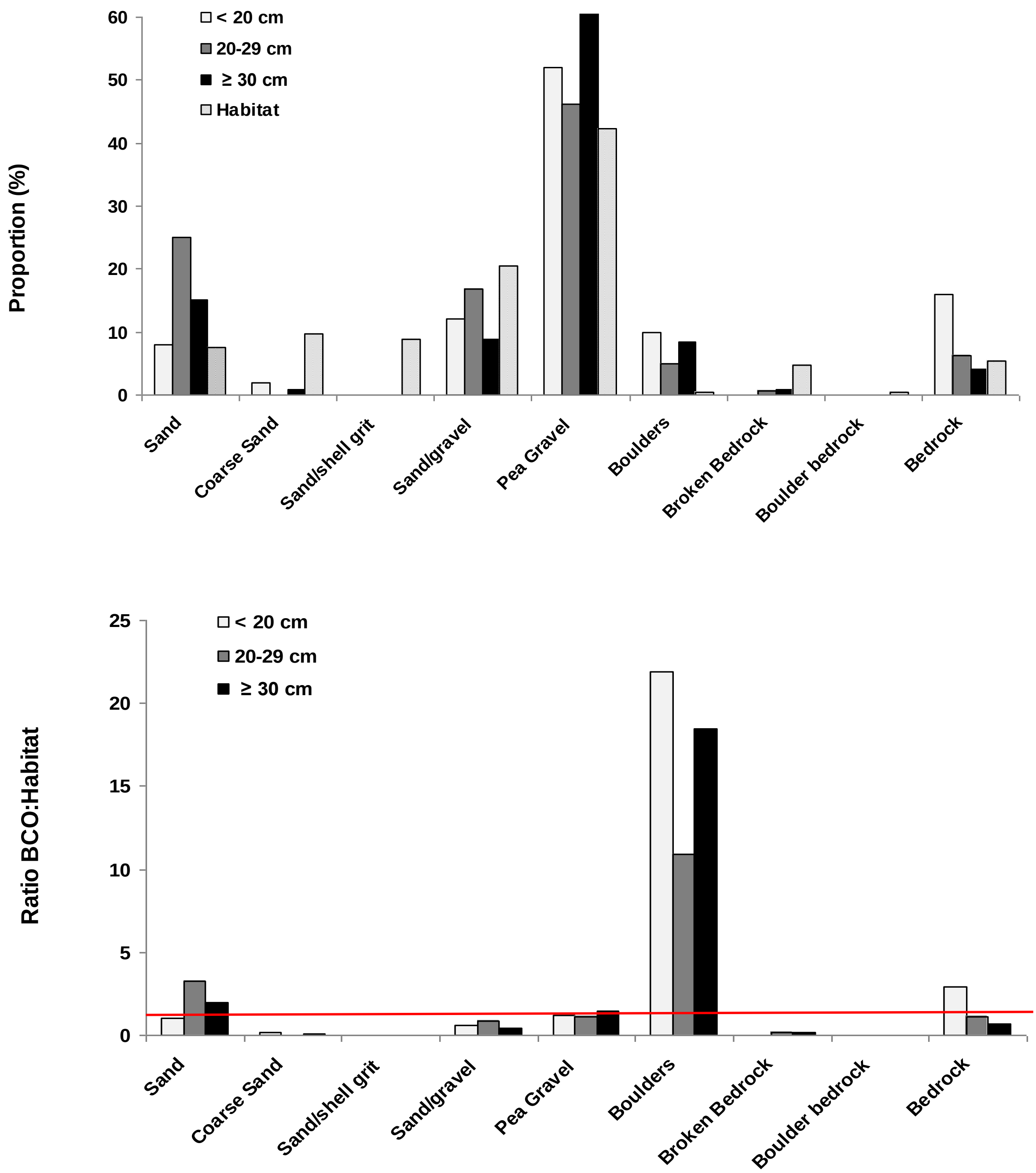


Figure 13: Proportion of primary substrata observations in association with blue cod and fish-independent video observations from random sites (top). The ratio of the proportion of blue cod-associated primary substrata and the fish-independent substrata recorded by the video at random sites is shown in the bottom figure. A horizontal line is drawn at a ratio of 1:1.

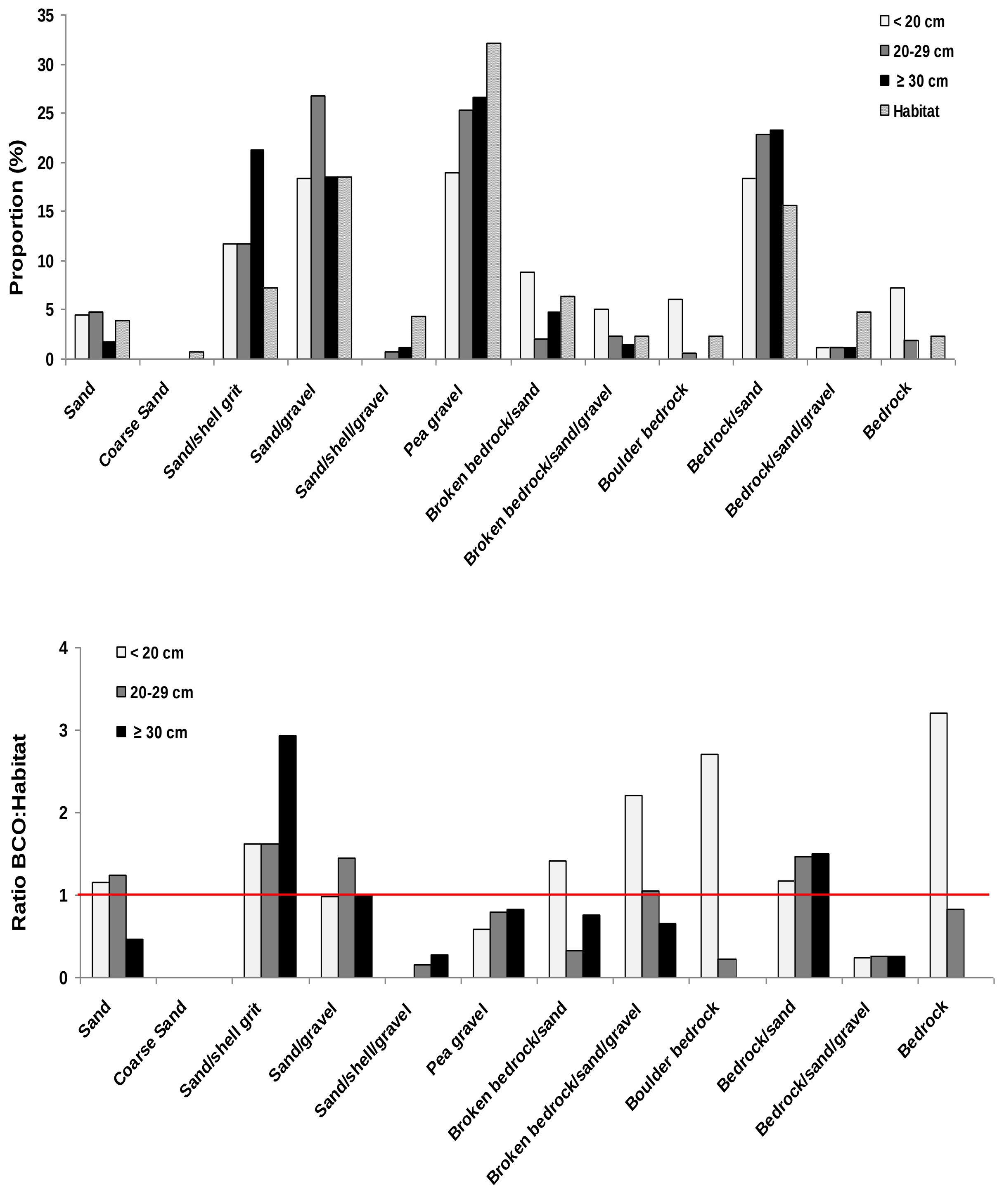


Figure 14: Proportion of primary substrata observations in association with blue cod and fish independent video observations from fixed fisher-selected sites (top). The ratio of the proportion of blue cod associated primary substrata and the fish independent substrata recorded by the video at fixed sites is shown in the bottom figure. A horizontal line is drawn at a ratio of 1:1.

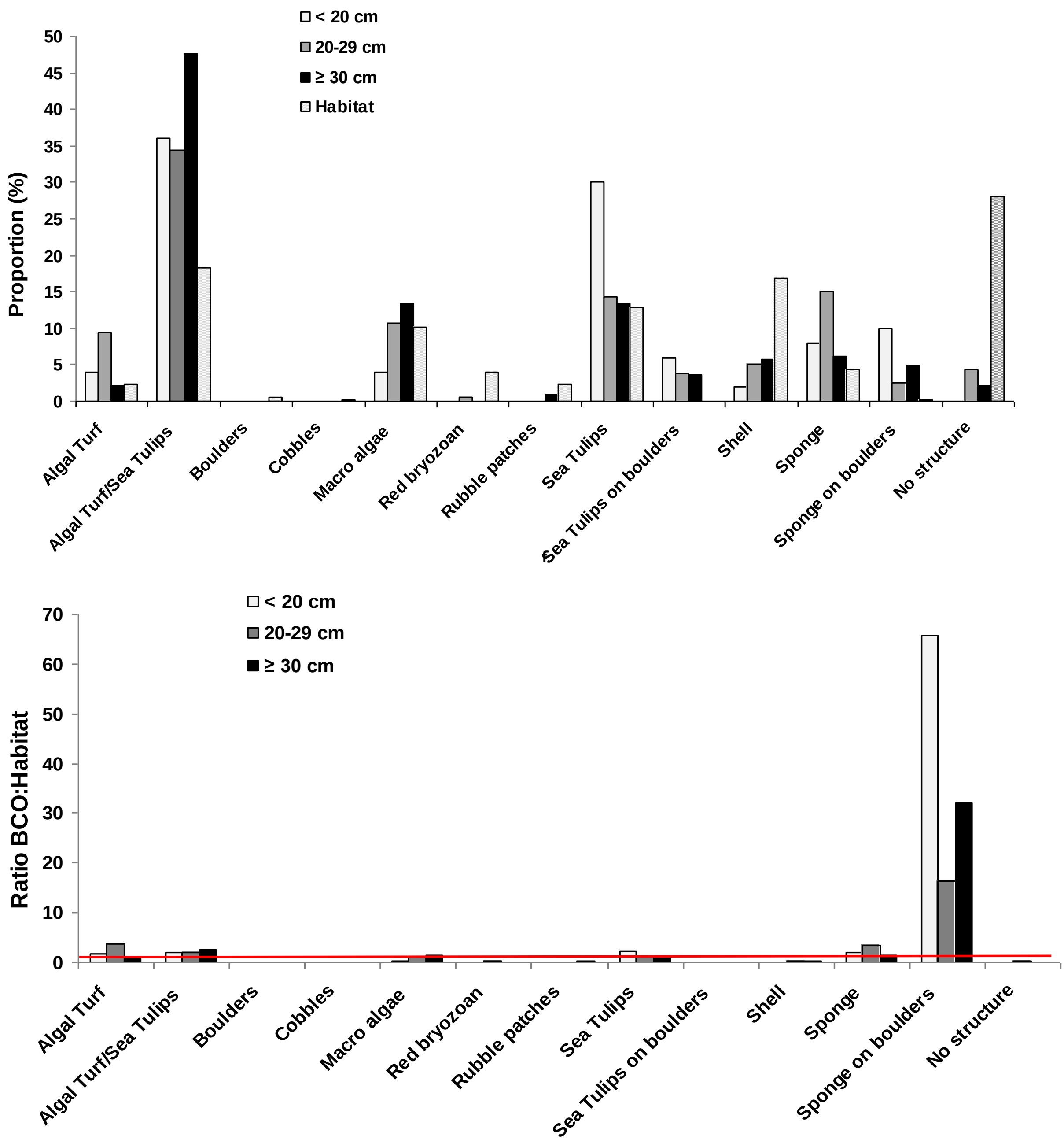


Figure 15: Proportion of secondary structure observations in association with blue cod and fish independent video observations from random sites. The ratio of the proportion of blue cod associated secondary habitat and the fish independent secondary habitat recorded by the video at random sites is shown in the bottom figure. A horizontal line is drawn at a ratio of 1:1.

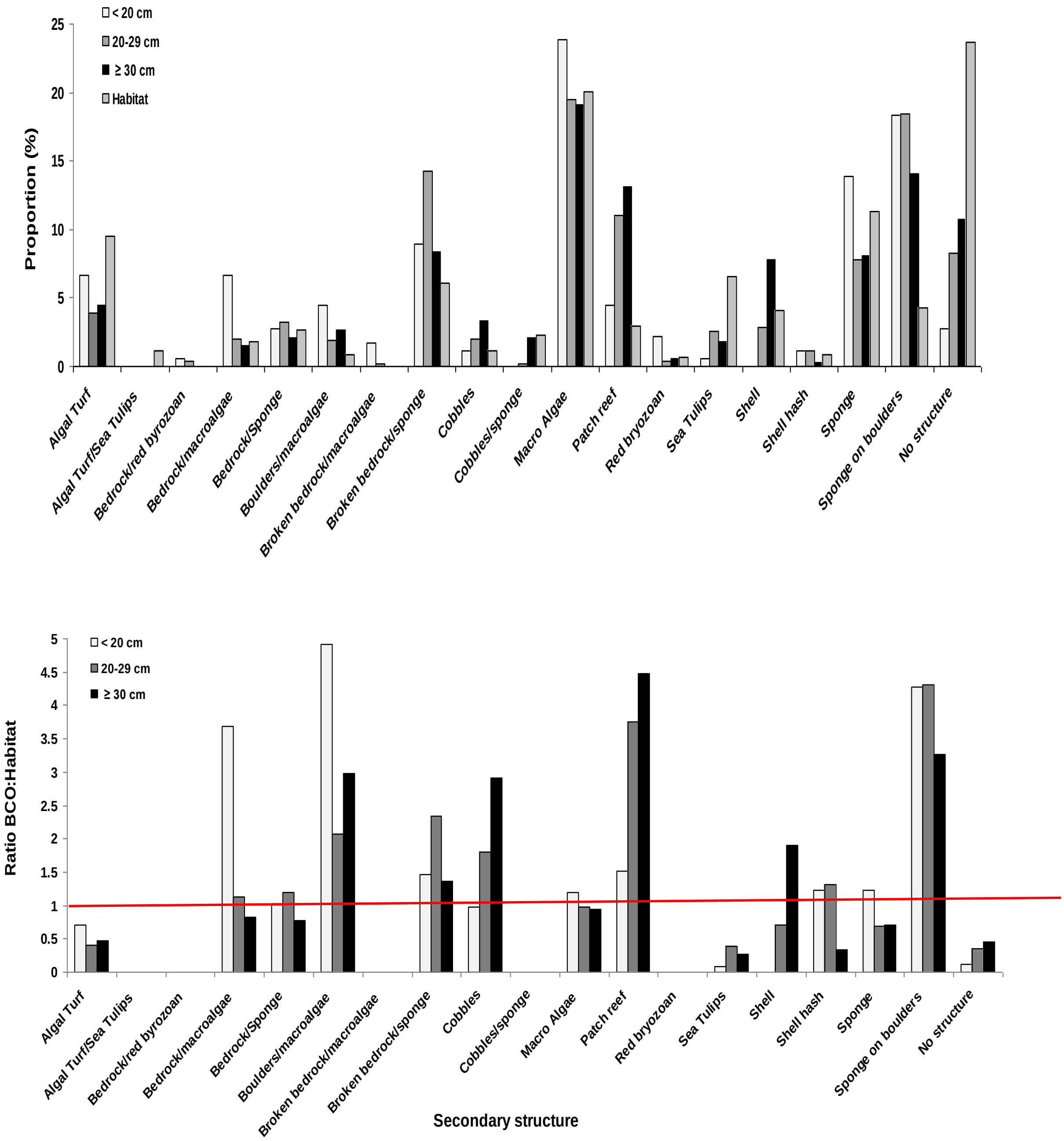


Figure 16: Proportion of secondary structure blue cod were observations in association with and fish independent video observations from fixed fisher-selected sites. The ratio of the proportion of blue cod associated secondary habitat and the fish independent secondary habitat recorded by the video at fixed sites is shown in the bottom figure. A horizontal line is drawn at a ratio of 1:1.

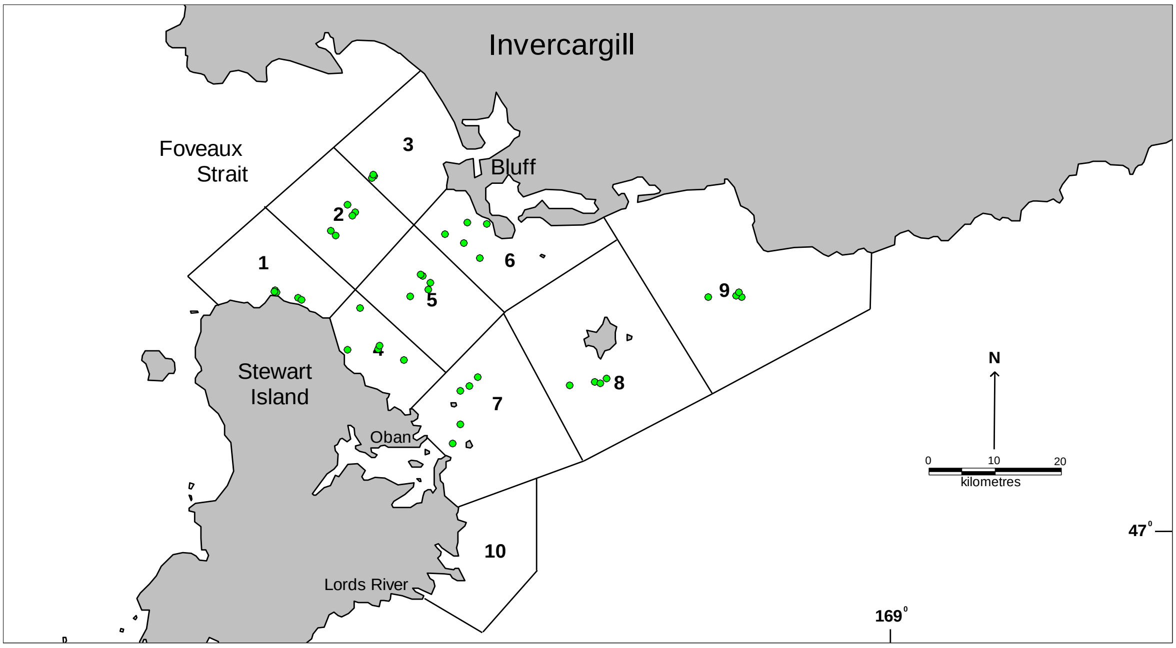


Figure 17: Potting site locations in the 2009 Foveaux Strait fisher-selected fixed site survey (data from Carbines 2009).

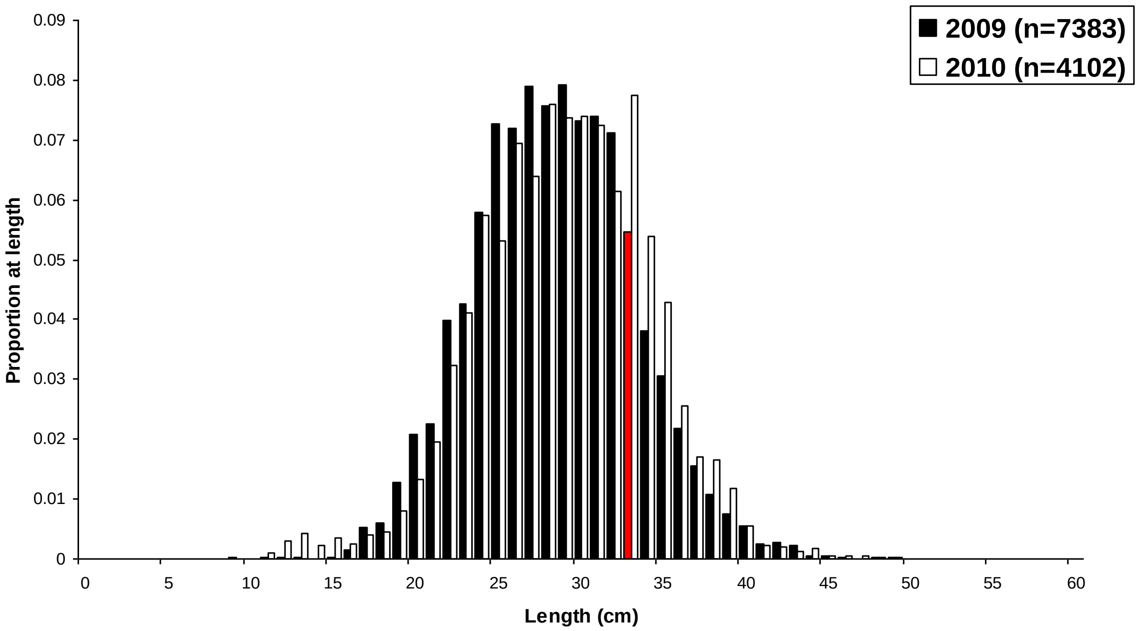


Figure 18: Proportion length frequency distributions of blue cod from common strata (i.e., 1, 2, 4, 5, 6, 7 and 8) of the 2010 Foveaux Strait random site survey and the 2009 Foveaux Strait fisher fixed site survey (data from Carbines 2009). Proportions for each survey sum to 1. Coloured bar is MLS (33 cm).

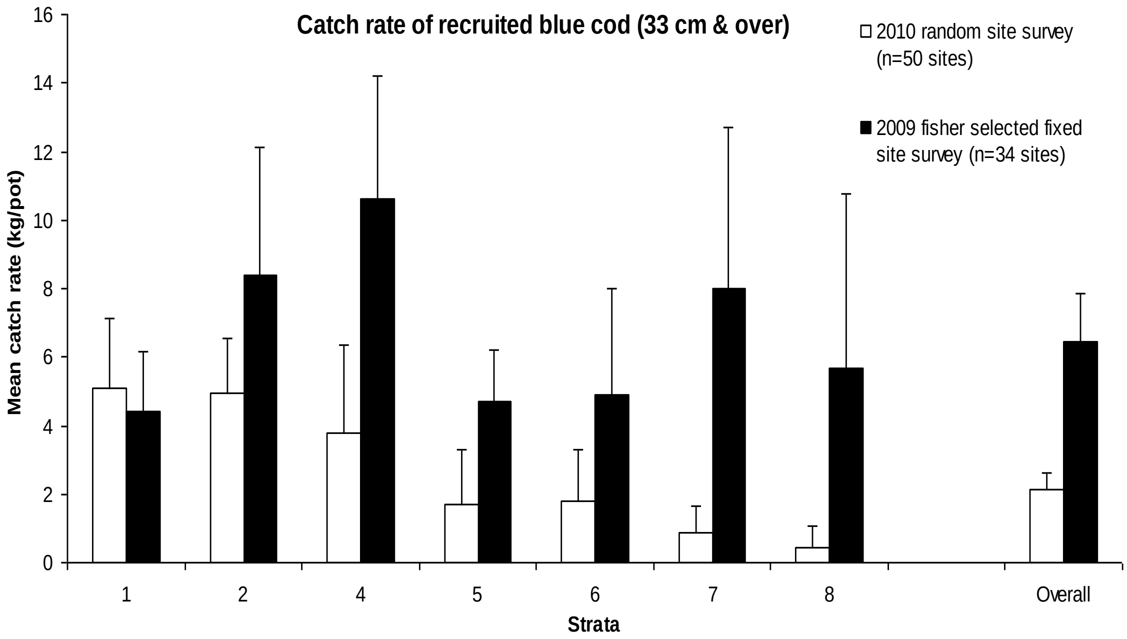


Figure 19: Catch rates and 95% confidence intervals for blue cod 33 cm and over from the 2010 Foveaux Strait random site survey and the 2009 Foveaux Strait fisher-selected site survey (data from Carbines 2009).

Appendix 1: Terminology used in potting surveys.

In this report we use the terms defined in the blue cod potting survey manual (Beentjes & Francis 2011)

Site A geographical location near to which sampling may take place during a survey. A site may be either fixed or random (see below). A site may be specified as a latitude and longitude or a section of coastline (for the latter, use the latitude and longitude at the centre of the section).

Fixed site A predetermined site within a given stratum, that has a fixed location (single latitude and longitude or the centre point location of a section of coastline) and is available to be used repeatedly on subsequent surveys in that area. Which fixed sites are used in a particular survey is determined by random selection from all available fixed sites in each stratum. Fixed sites are sometimes referred to as an index site or fisher-defined site (note these are the sites used in the 2009 Foveaux Strait survey)**.**

Random site A site that can have any location (single latitude and longitude) generated randomly from within a stratum, given the constraints of proximity to other selected sites for a specific survey (note these are the sites used in the 2010 Foveaux Strait survey).

Site label An alphanumeric label of no more than 4 characters unique within a survey time series. A site label identifies each fixed site and also specifies which stratum it lies in. Site labels are constructed by concatenating the stratum code with an alpha label (A–Z) that is unique within that stratum. Thus, sites within stratum 2 could be labelled 2A, 2B, and sites in stratum 3 could be labelled 3A, 3B etc. Note that random sites do not have site labels.

Set A group of pots deployed in the vicinity of a selected site in a specific survey. The pots are set in a cluster or linear configuration.

Set number A number assigned to the each set within a survey. Set numbers are defined sequentially in the order fished. Thus, any set within a survey is uniquely defined by a trip code and set number. Note that the set number is not recorded in the *trawl* database in isolation, but is entered as part of attribute *station_no* in table *t_station*.

Station The position (latitude and longitude) at which a single pot (or other fishing gear) is deployed at a site during a survey, i.e. it is unique for the trip.

Pot number Pots are numbered sequentially (1 to 6 or 1 to 9) in the order they are placed during a set.

Station number A number which uniquely identifies each station within a survey. The station number is formed by concatenating the set number with the pot number. Thus, pot 4 in set 23 would be station number 234. This convention is important in enabling users of the *trawl* database to determine whether two pots are from the same set. Note that the set numbers for potting surveys are not recorded anywhere else in the *trawl* database.

Pot placement There are two types of pot placement 1) Directed, where the position of each pot is directed by the skipper using local knowledge and the vessel SONAR to locate a suitable area of reef/cobble or biogenic habitat (note this is how pots were set in the fixed site 2009 Foveaux Strait survey). 2) Systematic, where the position of each pot is determined from a fixed pattern set systematically around a site centre point. The pots are set blind with no knowledge of the bottom type (note this is how pots were set in the fixed site 2010 Foveaux Strait survey).

Appendix 2: Methodology for estimating c.v.s for total mortality (*Z*) (from Beentjes & Francis 2011).

For each age at recruitment, a_{rec}, a 95% confidence interval for the associated total mortality estimate, $\hat{Z}$, was calculated using the following simulation procedure, adapted from that of Dunn et al. (2002). This involves drawing a simple random sample of ages from the recruited part of each of 1000 simulated population in which there is annual variation in *Z* (described by a lognormal distribution with mean $\hat{Z}$ and c.v. c_Z = 0.10) and in recruitment (where log recruitment is normally distributed with standard deviation σ_{R} = 0.7). In such a population, the relative frequency of fish at age a = 1,…, 50 is given by

$$f_a = e^{-Z_a + R_a} \tag{16}$$

where Z_a is the cumulative mortality defined by

$$Z_1 = 0, \quad Z_a = \sum_{a'=2}^{a} \hat{Z} d_{a'} \tag{17}$$

the d_a are lognormally distributed with mean 1 and c.v. c_Z, and the R_a are normally distributed with mean 0 and s.d. σ_{R}.

With ageing errors assumed to be normally distributed with c.v. c_{age} = 0.15, the relative frequency of fish at *apparent* age *a* is given by

$$f'_a = \sum_{a'=1}^{50} f_{a'} E_{a'a} \tag{18}$$

where *E* is an ageing-error matrix, calculated by setting $E_{a'a} = \text{F}(a + 0.5, a', c_{\text{age}}) - \text{F}(a - 0.5, a', c_{\text{age}})$ [and F(x,μ,c) is the cumulative probability function for the normal distribution with mean μ and c.v. c] and then normalizing the rows of this matrix to sum to 1.

The size, *n*, of the sample of ages from the recruited population was calculated, as follows, to mimic the sampling error in the real data. The mean-weighted c.v. for the recruited part of the real data is calculated as

$$c_{\text{samp}} = \frac{\sum_{a \ge a_{rec}} f_{a,\text{obs}} c_{a,\text{obs}}}{\sum_{a \ge a_{rec}} f_{a,\text{obs}}} \tag{19}$$

where $f_{a,\text{obs}}$ is the age frequency from the real (unsimulated) data, and $c_{a,\text{obs}}$ is its c.v. The mean-weighted c.v. is used to calculate *n* as

$$n = \left(\frac{\sum_{a \ge a_{rec}} \sqrt{f''_a (1 - f''_a)}}{c_{\text{samp}}} \right)^2 \tag{20}$$

where, to maintain consistency in sample sizes across simulated populations, the proportions at age f''_a were calculated as for the f_a above, except that c_Z and σ_{R} were set to zero; then f''_a was set to 0 for $a < a_{\text{rec}}$, and the f''_a are normalised to sum to 1.

Finally, a random sample of size *n* is selected from the AF f''_a; a maximum-likelihood estimate of *Z* and is calculated from this sample; the set of 1000 *Z* estimates is scaled to have mean $\hat{Z}$; and the bounds of the 95% confidence interval for $\hat{Z}$ are set to the 0.025 and 0.975 quantiles of the scaled *Z* estimates (the scaling is necessary because the maximum-likelihood estimate can be biased, particularly when there is ageing error).

Appendix 3: Summary of survey pot lift station data, Foveaux Strait 2010.

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot number	Catch of blue cod (kg)	Catch of blue cod Number of fish
1	10-Feb-10	1	4	A	33	8:10	1	23.2	77
1	10-Feb-10	1	4	A	33	8:16	2	19.0	46
1	10-Feb-10	1	4	A	33	8:23	3	10.9	29
1	10-Feb-10	1	4	A	33	8:29	4	21.3	53
1	10-Feb-10	1	4	A	34	8:35	6	21.5	63
1	10-Feb-10	1	4	A	34	8:41	5	8.8	24
2	10-Feb-10	1	4	C	18	10:53	5	0.0	0
2	10-Feb-10	1	4	C	23	10:58	6	0.0	0
2	10-Feb-10	1	4	C	23	11:03	4	0.8	1
2	10-Feb-10	1	4	C	26	11:08	3	0.0	0
2	10-Feb-10	1	4	C	22	11:13	2	0.0	0
2	10-Feb-10	1	4	C	24	11:18	1	0.0	0
3	10-Feb-10	1	4	D	2	12:45	1	2.7	5
3	10-Feb-10	1	4	D	4	12:50	2	0.0	0
3	10-Feb-10	1	4	D	11	12:55	3	0.0	0
3	10-Feb-10	1	4	D	10	13:00	4	0.0	0
3	10-Feb-10	1	4	D	9	13:05	6	0.0	0
3	10-Feb-10	1	4	D	7	13:10	5	0.0	0
4	10-Feb-10	1	5	F	36	15:17	5	5.3	12
4	10-Feb-10	1	5	F	37	15:22	6	7.7	17
4	10-Feb-10	1	5	F	37	15:27	4	10.6	25
4	10-Feb-10	1	5	F	38	15:32	3	7.2	16
4	10-Feb-10	1	5	F	37	15:37	2	4.6	11
4	10-Feb-10	1	5	F	37	15:42	1	3.8	9
5	11-Feb-10	1	6	D	31	6:51	1	8.0	13
5	11-Feb-10	1	6	D	30	6:57	2	3.2	11
5	11-Feb-10	1	6	D	31	7:03	3	7.9	16
5	11-Feb-10	1	6	D	31	7:08	4	13.6	33
5	11-Feb-10	1	6	D	30	7:15	6	8.0	12
5	11-Feb-10	1	6	D	31	7:21	5	10.9	19
6	11-Feb-10	1	6	A	28	9:01	5	8.4	22
6	11-Feb-10	1	6	A	29	9:07	6	2.7	3
6	11-Feb-10	1	6	A	29	9:12	4	2.5	2
6	11-Feb-10	1	6	A	29	9:17	3	7.1	15
6	11-Feb-10	1	6	A	29	9:23	2	1.4	24
6	11-Feb-10	1	6	A	28	9:28	1	1.7	6
7	11-Feb-10	1	8	D	28	11:00	1	0.0	0
7	11-Feb-10	1	8	D	28	11:06	2	0.0	0
7	11-Feb-10	1	8	D	28	11:12	3	0.1	1
7	11-Feb-10	1	8	D	28	11:17	4	0.5	1
7	11-Feb-10	1	8	D	28	11:23	6	0.0	0
7	11-Feb-10	1	8	D	28	11:29	5	0.0	1
8	11-Feb-10	1	8	B	28	13:00	5	0.0	0
8	11-Feb-10	1	8	B	27	13:06	6	0.0	0
8	11-Feb-10	1	8	B	27	13:12	4	0.0	0
8	11-Feb-10	1	8	B	27	13:19	3	0.0	0
8	11-Feb-10	1	8	B	28	13:25	2	0.0	0

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot number	Catch of blue cod (kg)	Catch of blue cod Number of fish
8	11-Feb-10	1	8	B	28	13:32	1	0.0	0
9	11-Feb-10	1	6	B	27	15:10	1	0.0	0
9	11-Feb-10	1	6	B	26	15:16	2	0.0	0
9	11-Feb-10	1	6	B	26	15:22	3	4.2	10
9	11-Feb-10	1	6	B	25	15:29	4	1.7	4
9	11-Feb-10	1	6	B	27	15:36	6	0.8	1
9	11-Feb-10	1	6	B	27	15:41	5	0.6	1
10	12-Feb-10	1	4	B	34	7:35	5	16.8	36
10	12-Feb-10	1	4	B	35	7:40	6	13.4	27
10	12-Feb-10	1	4	B	34	7:46	4	12.4	26
10	12-Feb-10	1	4	B	33	7:52	3	14.4	28
10	12-Feb-10	1	4	B	34	7:56	2	2.6	8
10	12-Feb-10	1	4	B	36	8:02	1	8.9	24
11	12-Feb-10	1	5	C	34	10:15	1	0.0	0
11	12-Feb-10	1	5	C	34	10:21	2	1.5	2
11	12-Feb-10	1	5	C	34	10:27	3	0.0	0
11	12-Feb-10	1	5	C	35	10:36	4	3.3	6
11	12-Feb-10	1	5	C	35	10:42	6	2.9	8
11	12-Feb-10	1	5	C	34	10:48	5	1.3	2
12	12-Feb-10	1	5	B	34	12:09	5	0.0	0
12	12-Feb-10	1	5	B	34	12:15	6	0.0	0
12	12-Feb-10	1	5	B	34	12:21	4	0.0	0
12	12-Feb-10	1	5	B	34	12:28	3	0.0	0
12	12-Feb-10	1	5	B	34	12:35	2	0.0	0
12	12-Feb-10	1	5	B	34	12:41	1	0.0	0
13	12-Feb-10	1	5	D	31	14:26	1	0.4	3
13	12-Feb-10	1	5	D	30	14:31	2	0.0	0
13	12-Feb-10	1	5	D	30	14:37	3	0.0	0
13	12-Feb-10	1	5	D	30	14:44	4	0.0	0
13	12-Feb-10	1	5	D	31	14:50	6	0.1	2
13	12-Feb-10	1	5	D	30	14:56	5	0.0	0
14	16-Feb-10	1	7	D	32	8:03	5	3.2	4
14	16-Feb-10	1	7	D	33	8:10	6	3.4	6
14	16-Feb-10	1	7	D	33	8:17	4	3.3	9
14	16-Feb-10	1	7	D	34	8:25	3	4.5	8
14	16-Feb-10	1	7	D	35	8:35	2	4.1	4
14	16-Feb-10	1	7	D	34	8:42	1	2.2	2
15	16-Feb-10	1	7	C	61	11:24	1	0.7	1
15	16-Feb-10	1	7	C	62	11:34	2	0.0	1
15	16-Feb-10	1	7	C	59	11:45	3	0.6	3
15	16-Feb-10	1	7	C	58	11:54	4	0.0	0
15	16-Feb-10	1	7	C	58	12:05	6	0.0	0
15	16-Feb-10	1	7	C	61	12:15	5	0.9	1
16	16-Feb-10	1	7	B	51	13:55	5	0.0	0
16	16-Feb-10	1	7	B	52	14:02	6	0.0	0
16	16-Feb-10	1	7	B	51	14:07	4	0.0	0
16	16-Feb-10	1	7	B	50	14:16	3	0.0	0
16	16-Feb-10	1	7	B	52	14:24	2	0.0	0
16	16-Feb-10	1	7	B	52	14:32	1	0.0	0

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot number	Catch of blue cod (kg)	Catch of blue cod Number of fish
17	16-Feb-10	1	7	F	58	16:09	1	1.1	1
17	16-Feb-10	1	7	F	58	16:15	2	1.5	2
17	16-Feb-10	1	7	F	62	16:25	3	0.0	0
17	16-Feb-10	1	7	F	64	16:33	4	0.7	1
17	16-Feb-10	1	7	F	64	16:40	6	4.1	7
17	16-Feb-10	1	7	F	61	16:45	5	1.0	1
18	17-Feb-10	1	5	E	37	10:33	5	11.4	31
18	17-Feb-10	1	5	E	37	10:41	6	11.0	24
18	17-Feb-10	1	5	E	37	10:47	4	16.0	32
18	17-Feb-10	1	5	E	37	10:54	3	2.1	3
18	17-Feb-10	1	5	E	37	11:00	2	0.6	2
18	17-Feb-10	1	5	E	37	11:05	1	5.0	8
19	17-Feb-10	1	5	A	34	15:44	1	1.5	3
19	17-Feb-10	1	5	A	33	15:50	2	3.6	5
19	17-Feb-10	1	5	A	33	15:57	3	0.0	0
19	17-Feb-10	1	5	A	33	16:03	4	0.0	0
19	17-Feb-10	1	5	A	33	16:08	6	3.7	4
19	17-Feb-10	1	5	A	34	16:15	5	1.3	3
20	18-Feb-10	1	6	E	25	11:57	5	6.4	16
20	18-Feb-10	1	6	E	23	11:05	6	2.0	5
20	18-Feb-10	1	6	E	23	11:11	4	2.3	6
20	18-Feb-10	1	6	E	29	11:18	3	0.3	1
20	18-Feb-10	1	6	E	30	11:26	2	1.4	4
20	18-Feb-10	1	6	E	29	11:32	1	4.3	8
21	22-Feb-10	1	6	F	12	8:30	1	0.0	0
21	22-Feb-10	1	6	F	13	8:35	2	0.0	0
21	22-Feb-10	1	6	F	14	8:40	3	0.0	0
21	22-Feb-10	1	6	F	14	8:46	4	0.0	0
21	22-Feb-10	1	6	F	13	8:52	6	0.0	0
21	22-Feb-10	1	6	F	12	8:57	5	0.3	2
22	22-Feb-10	1	6	C	13	12:55	5	4.5	6
22	22-Feb-10	1	6	C	31	13:00	6	0.0	0
22	22-Feb-10	1	6	C	31	13:06	4	0.1	2
22	22-Feb-10	1	6	C	31	13:12	3	0.1	3
22	22-Feb-10	1	6	C	33	13:19	2	0.0	0
22	22-Feb-10	1	6	C	31	13:26	1	4.6	7
23	23-Feb-10	1	4	E	33	10:54	1	0.0	0
23	23-Feb-10	1	4	E	34	10:59	2	0.6	2
23	23-Feb-10	1	4	E	36	11:05	3	6.2	28
23	23-Feb-10	1	4	E	37	11:12	4	19.0	51
23	23-Feb-10	1	4	E	38	11:18	6	37.4	124
23	23-Feb-10	1	4	E	35	10:23	5	39.5	117
24	23-Feb-10	1	4	F	38	16:29	5	8.9	24
24	23-Feb-10	1	4	F	38	16:35	6	4.3	7
24	23-Feb-10	1	4	F	36	16:40	4	54.0	95
24	23-Feb-10	1	4	F	37	16:46	3	2.5	8
24	23-Feb-10	1	4	F	38	16:53	2	5.7	14
24	23-Feb-10	1	4	F	38	17:00	1	5.4	15
25	24-Feb-10	1	2	C	33	10:57	1	8.5	19

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot number	Catch of blue cod (kg)	Number of fish
25	24-Feb-10	1	2	C	32	11:02	2	13.4	26
25	24-Feb-10	1	2	C	30	11:08	3	19.7	39
25	24-Feb-10	1	2	C	30	10:14	4	14.1	31
25	24-Feb-10	1	2	C	31	11:21	6	15.7	39
25	24-Feb-10	1	2	C	32	10:26	5	13.3	36
26	24-Feb-10	1	2	B	32	16:20	5	10.3	27
26	24-Feb-10	1	2	B	32	16:25	6	10.9	21
26	24-Feb-10	1	2	B	32	16:30	4	22.5	48
26	24-Feb-10	1	2	B	34	16:36	3	16.2	35
26	24-Feb-10	1	2	B	34	16:42	2	7.2	13
26	24-Feb-10	1	2	B	33	16:48	1	6.5	13
27	01-Mar-10	1	8	A	43	8:04	1	0.0	0
27	01-Mar-10	1	8	A	45	8:09	2	0.0	0
27	01-Mar-10	1	8	A	44	8:16	3	0.0	0
27	01-Mar-10	1	8	A	41	8:24	4	0.0	0
27	01-Mar-10	1	8	A	40	8:30	6	0.0	0
27	01-Mar-10	1	8	A	40	8:38	5	0.0	0
28	01-Mar-10	1	8	E	72	10:27	5	0.0	0
28	01-Mar-10	1	8	E	71	10:34	6	0.0	0
28	01-Mar-10	1	8	E	74	10:40	4	0.1	1
28	01-Mar-10	1	8	E	74	10:46	3	0.0	1
28	01-Mar-10	1	8	E	73	8:54	2	0.0	0
28	01-Mar-10	1	8	E	72	11:00	1	0.0	0
29	01-Mar-10	1	8	C	53	15:54	1	0.0	0
29	01-Mar-10	1	8	C	51	16:01	2	0.0	0
29	01-Mar-10	1	8	C	51	16:08	3	0.0	0
29	01-Mar-10	1	8	C	52	16:14	4	0.0	0
29	01-Mar-10	1	8	C	51	16:20	6	0.0	0
29	01-Mar-10	1	8	C	48	16:26	5	0.0	0
30	05-Mar-10	1	2	E	37	12:24	5	22.8	32
30	05-Mar-10	1	2	E	37	12:30	6	19.1	47
30	05-Mar-10	1	2	E	35	12:36	4	19.1	55
30	05-Mar-10	1	2	E	38	12:45	3	28.2	74
30	05-Mar-10	1	2	E	38	12:53	2	19.6	39
30	05-Mar-10	1	2	E	37	13:00	1	17.9	33
31	05-Mar-10	1	2	D	31	15:20	1	9.8	18
31	05-Mar-10	1	2	D	35	15:28	2	4.5	12
31	05-Mar-10	1	2	D	33	15:37	3	5.8	23
31	05-Mar-10	1	2	D	35	15:42	4	11.6	30
31	05-Mar-10	1	2	D	36	15:49	5	11.2	23
31	05-Mar-10	1	2	D	33	15:55	6	13.1	33
32	08-Mar-10	1	1	B	58	7:51	5	4.7	5
32	08-Mar-10	1	1	B	58	7:57	6	3.6	7
32	08-Mar-10	1	1	B	58	8:04	4	3.7	5
32	08-Mar-10	1	1	B	58	8:10	3	7.4	9
32	08-Mar-10	1	1	B	58	8:16	2	12.9	24
32	08-Mar-10	1	1	B	57	8:22	1	5.0	8
33	08-Mar-10	1	1	A	51	9:59	1	3.8	12
33	08-Mar-10	1	1	A	54	10:04	2	3.2	8

Set		Phase	Stratum	Site	Depth (m)	Time set	Pot number	Catch of blue cod (kg)	Number of fish
33	08-Mar-10	1	1	A	59	10:10	3	5.4	7
33	08-Mar-10	1	1	A	55	10:15	4	0.6	1
33	08-Mar-10	1	1	A	51	10:21	6	3.1	9
33	08-Mar-10	1	1	A	51	10:26	5	4.0	9
34	08-Mar-10	1	1	E	29	12:55	5	8.5	14
34	08-Mar-10	1	1	E	32	13:00	6	1.5	3
34	08-Mar-10	1	1	E	31	13:06	4	12.2	30
34	08-Mar-10	1	1	E	25	13:11	3	7.4	25
34	08-Mar-10	1	1	E	17	13:16	2	14.6	42
34	08-Mar-10	1	1	E	26	13:20	1	7.8	24
35	08-Mar-10	1	1	D	48	14:53	1	11.0	24
35	08-Mar-10	1	1	D	48	14:59	2	10.4	25
35	08-Mar-10	1	1	D	46	15:05	3	46.6	113
35	08-Mar-10	1	1	D	48	15:10	4	16.7	37
35	08-Mar-10	1	1	D	48	15:15	6	20.9	54
35	08-Mar-10	1	1	D	47	15:20	5	9.8	26
36	09-Mar-10	1	1	C	50	7:52	5	24.2	58
36	09-Mar-10	1	1	C	50	7:58	6	25.5	66
36	09-Mar-10	1	1	C	51	8:03	4	13.0	36
36	09-Mar-10	1	1	C	52	8:09	3	8.0	23
36	09-Mar-10	1	1	C	53	8:15	2	12.9	34
36	09-Mar-10	1	1	C	52	8:20	1	23.1	49
37	09-Mar-10	1	2	A	45	10:29	1	8.9	26
37	09-Mar-10	1	2	A	37	10:35	2	37.1	76
37	09-Mar-10	1	2	A	32	10:40	3	29.6	69
37	09-Mar-10	1	2	A	37	10:45	4	19.9	49
37	09-Mar-10	1	2	A	48	10:50	6	8.3	21
37	09-Mar-10	1	2	A	44	10:55	5	25.3	62
38	09-Mar-10	1	2	F	31	12:56	5	4.2	7
38	09-Mar-10	1	2	F	31	13:03	6	7.0	16
38	09-Mar-10	1	2	F	32	13:08	4	10.5	30
38	09-Mar-10	1	2	F	32	13:14	3	13.6	31
38	09-Mar-10	1	2	F	32	13:19	2	2.3	6
38	09-Mar-10	1	2	F	31	13:25	1	1.5	2
39	10-Mar-10	1	10	B	56	8:23	1	0.0	0
39	10-Mar-10	1	10	B	56	8:28	2	0.0	0
39	10-Mar-10	1	10	B	55	8:34	3	0.0	0
39	10-Mar-10	1	10	B	56	8:39	4	0.9	2
39	10-Mar-10	1	10	B	56	8:45	6	6.9	10
39	10-Mar-10	1	10	B	56	8:50	5	0.0	0
40	10-Mar-10	1	10	F	80	11:02	5	1.8	2
40	10-Mar-10	1	10	F	83	11:10	6	2.5	2
40	10-Mar-10	1	10	F	90	11:20	4	7.1	9
40	10-Mar-10	1	10	F	93	11:30	3	4.6	9
40	10-Mar-10	1	10	F	87	11:40	2	3.2	4
40	10-Mar-10	1	10	F	82	11:50	1	2.9	6
41	10-Mar-10	1	10	C	57	13:34	1	0.0	0
41	10-Mar-10	1	10	C	64	13:39	2	0.0	0
41	10-Mar-10	1	10	C	67	13:45	3	9.4	16

Set		Phase	Stratum	Site	Depth (m)	Time set	Pot number	Catch of blue cod (kg)	Number of fish
41	10-Mar-10	1	10	C	64	13:50	4	9.3	13
41	10-Mar-10	1	10	C	54	13:55	6	8.3	19
41	10-Mar-10	1	10	C	60	14:00	5	6.8	17
42	10-Mar-10	1	10	A	73	15:30	5	5.5	10
42	10-Mar-10	1	10	A	65	15:35	6	2.2	4
42	10-Mar-10	1	10	A	70	15:40	4	2.6	6
42	10-Mar-10	1	10	A	76	15:45	3	8.3	13
42	10-Mar-10	1	10	A	76	15:50	2	4.4	8
42	10-Mar-10	1	10	A	72	15:55	1	3.1	3
43	10-Mar-10	1	10	E	33	17:37	1	0.0	0
43	10-Mar-10	1	10	E	34	17:42	2	0.0	0
43	10-Mar-10	1	10	E	37	17:48	3	0.0	0
43	10-Mar-10	1	10	E	40	17:54	4	0.0	0
43	10-Mar-10	1	10	E	36	18:00	6	0.0	0
43	10-Mar-10	1	10	E	33	18:07	5	0.3	1
44	11-Mar-10	1	10	D	17	13:20	5	1.8	3
44	11-Mar-10	1	10	D	16	13:25	6	0.7	1
44	11-Mar-10	1	10	D	25	13:30	4	22.2	57
44	11-Mar-10	1	10	D	28	13:36	3	0.0	0
44	11-Mar-10	1	10	D	17	13:41	2	1.8	1
44	11-Mar-10	1	10	D	19	13:46	1	9.6	22
45	28-Mar-10	1	8	F	33	10:11	1	6.1	17
45	28-Mar-10	1	8	F	35	10:18	2	8.8	24
45	28-Mar-10	1	8	F	35	10:25	3	28.8	97
45	28-Mar-10	1	8	F	37	10:32	4	6.0	21
45	28-Mar-10	1	8	F	35	10:38	6	5.4	14
45	28-Mar-10	1	8	F	26	10:44	5	2.1	5
46	28-Mar-10	1	7	E	25	17:21	5	3.4	5
46	28-Mar-10	1	7	E	25	17:26	6	2.3	3
46	28-Mar-10	1	7	E	26	17:31	4	0.0	0
46	28-Mar-10	1	7	E	25	17:36	3	2.5	4
46	28-Mar-10	1	7	E	24	17:41	2	1.5	2
46	28-Mar-10	1	7	E	24	17:46	1	1.3	1
47	29-Mar-10	1	7	A	41	7:20	1	0.0	0
47	29-Mar-10	1	7	A	45	7:27	2	0.0	0
47	29-Mar-10	1	7	A	46	7:32	3	0.0	0
47	29-Mar-10	1	7	A	44	7:38	4	0.0	0
47	29-Mar-10	1	7	A	42	7:44	6	0.0	0
47	29-Mar-10	1	7	A	40	7:50	5	0.0	0
48	29-Mar-10	1	1	F	44	13:55	5	16.6	35
48	29-Mar-10	1	1	F	43	14:00	6	14.4	28
48	29-Mar-10	1	1	F	50	14:05	4	25.9	44
48	29-Mar-10	1	1	F	37	14:10	3	18.4	40
48	29-Mar-10	1	1	F	35	14:15	2	18.8	36
48	29-Mar-10	1	1	F	33	14:20	1	6.5	9
49	31-Mar-10	2	8	L	61	9:25	1	0.0	0
49	31-Mar-10	2	8	L	63	9:35	2	0.0	0
49	31-Mar-10	2	8	L	64	9:45	3	0.0	0
49	31-Mar-10	2	8	L	65	9:55	4	0.0	0

Set		Phase	Stratum	Site	Depth (m)	Time set	Pot number	Catch of blue cod (kg)	Number of fish
49	31-Mar-10	2	8	L	64	10:05	6	0.0	0
49	31-Mar-10	2	8	L	62	10:15	5	0.0	0
50	31-Mar-10	2	8	G	57	12:03	5	0.0	0
50	31-Mar-10	2	8	G	58	12:08	6	1.2	2
50	31-Mar-10	2	8	G	56	12:13	4	0.5	1
50	31-Mar-10	2	8	G	56	12:18	3	0.0	0
50	31-Mar-10	2	8	G	58	12:23	2	0.0	0
50	31-Mar-10	2	8	G	58	12:28	1	0.0	0
51	31-Mar-10	2	8	J	37	14:10	1	0.0	0
51	31-Mar-10	2	8	J	38	14:20	2	0.0	0
51	31-Mar-10	2	8	J	40	14:30	3	0.0	0
51	31-Mar-10	2	8	J	41	14:40	4	0.0	0
51	31-Mar-10	2	8	J	39	14:50	6	0.0	0
51	31-Mar-10	2	8	J	38	15:00	5	0.0	0
52	03-Apr-10	2	1	G	49	8:07	5	0.0	0
52	03-Apr-10	2	1	G	45	8:12	6	0.0	0
52	03-Apr-10	2	1	G	45	8:17	4	12.2	17
52	03-Apr-10	2	1	G	50	8:22	3	6.0	8
52	03-Apr-10	2	1	G	48	8:27	2	25.4	40
52	03-Apr-10	2	1	G	48	8:32	1	2.3	4
53	03-Apr-10	2	4	G	34	16:30	1	1.0	1
53	03-Apr-10	2	4	G	31	16:35	2	1.0	1
53	03-Apr-10	2	4	G	32	16:40	3	1.8	2
53	03-Apr-10	2	4	G	29	16:45	4	2.0	2
53	03-Apr-10	2	4	G	34	16:50	6	2.0	4
53	03-Apr-10	2	4	G	31	16:55	5	1.1	1
54	05-Apr-10	2	8	H	30	13:07	5	16.3	41
54	05-Apr-10	2	8	H	25	13:12	6	2.0	3
54	05-Apr-10	2	8	H	20	13:17	4	0.6	1
54	05-Apr-10	2	8	H	32	13:22	3	16.8	60
54	05-Apr-10	2	8	H	26	13:27	2	16.0	35
54	05-Apr-10	2	8	H	22	13:32	1	15.6	45
55	05-Apr-10	2	8	K	23	15:47	1	0.2	2
55	05-Apr-10	2	8	K	23	15:52	2	0.1	1
55	05-Apr-10	2	8	K	23	15:57	3	0.4	18
55	05-Apr-10	2	8	K	23	16:02	4	0.9	1
55	05-Apr-10	2	8	K	24	16:07	6	0.3	2
55	05-Apr-10	2	8	K	25	16:12	5	0.0	0
56	16-Jun-10	2	8	I	77	14:47	4	0.0	0
56	16-Jun-10	2	8	I	79	14:58	1	0.0	0
56	16-Jun-10	2	8	I	79	15:08	2	0.1	2
56	16-Jun-10	2	8	I	77	15:18	5	0.0	1
56	16-Jun-10	2	8	I	77	15:28	3	0.2	5
56	16-Jun-10	2	8	I	77	15:38	6	0.1	1

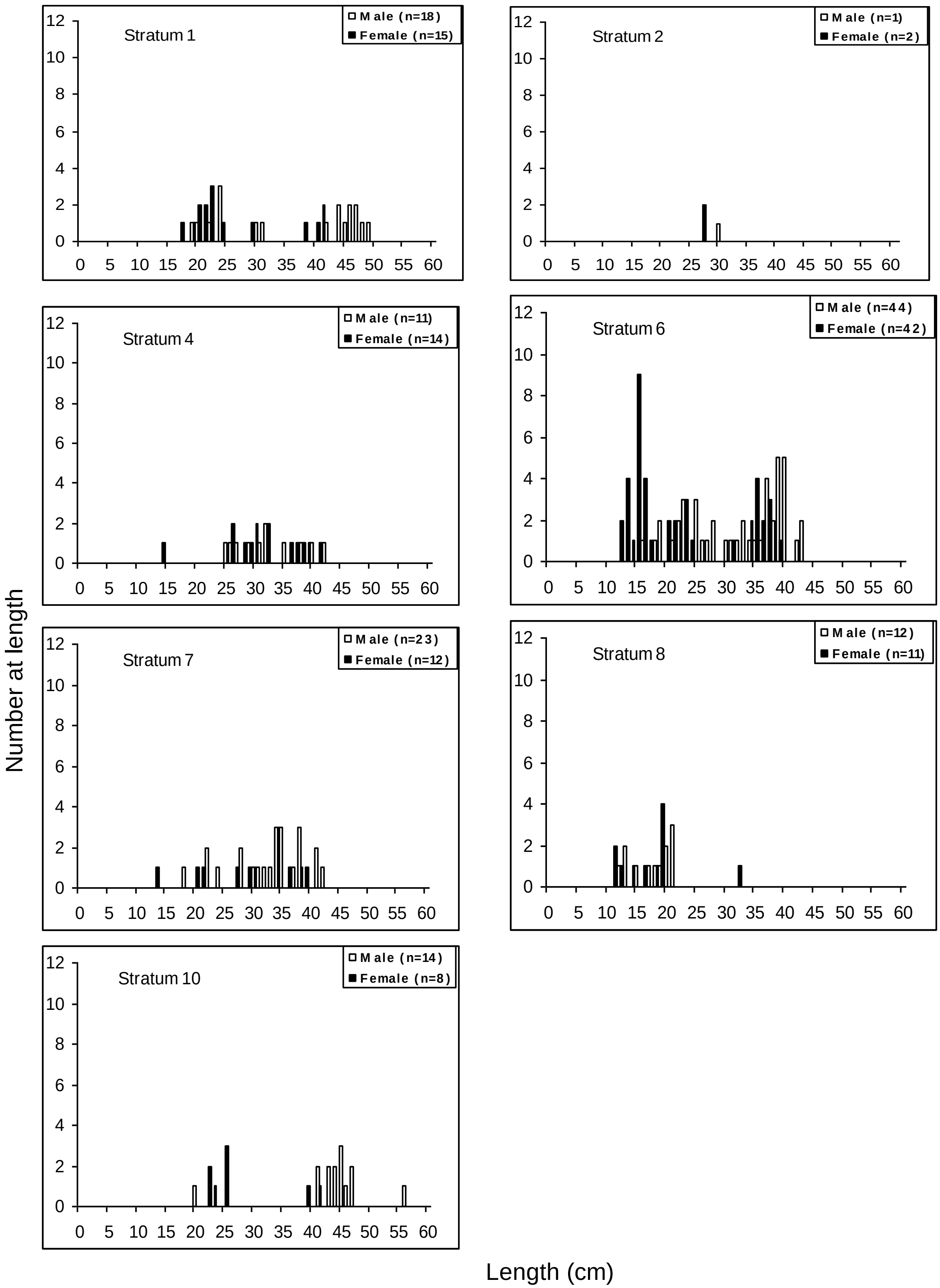
Appendix 4: Summary of the Foveaux Strait 2010 survey oceanographic environmental station data recorded in the format of MPI trawl data base. Depths are measured in metres, directions in compass degrees (999 = nil), wind force in the Beaufort scale, temperatures in degrees centigrade, air pressure in 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 13 (sponge beds), bottom contour in a categorical scale from 1 (smooth/flat) to 5 (very rugged), and wind speed in metres per second.

Set	Average Depth	Wind Direction	Wind Force	Air Temp	Air Pressure	Cloud Cover	Sea Condition	Sea Colour	Swell Height	Swell Direction	Bottom Type	Bottom Contour	Surface Temp	Bottom Temp	Wind Speed	Secchi Depth
1	34	135	2	11.6	1023	6	1	2	0.3	090	6	2	15.8	15.0	11.5	8.5
2	23	135	3	14.1	1024	6	1	2	0.4	090	4	2	14.0	13.5	19.4	7.5
3	7	135	2	15.7	1024	6	1	7	0.3	090	3	1	14.1	14.0	10.5	8.7
4	37	135	3	16.8	1023	6	1	6	0.3	090	6	1	15.0	14.2	17.1	9.1
5	31	135	3	12.0	1020	6	1	2	1.0	135	4	1	14.5	14.1	17.2	9.4
6	29	135	2	13.2	1021	5	1	2	1.0	135	4	1	14.5	14.3	9.5	8.6
7	28	000	0	18.7	1021	2	1	6	1.0	090	4	1	15.0	14.3	1.0	15.2
8	27	135	1	20.4	1020	5	1	4	1.5	135	4	1	14.9	14.4	5.4	11.2
9	26	315	3	17.9	1019	3	1	4	0.8	135	4	1	14.8	14.5	18.5	8.7
10	34	270	4	13.7	1016	4	1	2	0.5	270	4	1	14.6	14.3	21.0	7.4
11	34	270	2	16.5	1014	3	1	5	0.5	270	4	2	14.6	14.3	10.6	8.5
12	34	225	3	22.1	1013	1	1	5	0.3	270	4	1	14.6	14.3	17.0	8.6
13	30	270	3	17.9	1012	1	3	6	1.0	270	4	1	14.6	14.3	18.0	8.8
14	34	225	3	13.9	1023	5	1	4	1.0	135	4	1	13.4	13.3	14.4	11.6
15	60	225	4	14.4	1023	3	4	5	3.0	135	4	2	13.3	13.2	20.4	11.3
16	51	225	4	15.5	1022	5	4	1	2.8	135	4	1	13.4	13.2	30.1	11.4
17	61	225	3	16.6	1022	6	4	6	3.0	135	4	1	13.4	13.2	18.0	11.5
18	37	270	3	15.2	1021	4	1	6	0.5	090	4	1	13.5	13.6	13.1	9.1
19	33	090	3	21.9	1018	3	1	6	1.5	135	4	1	14.3	14.0	11.2	10.3
20	26	270	4	15.2	1010	5	3	6	0.5	135	4	1	15.2	15.1	27.9	6.5
21	13	045	4	20.5	1023	4	1	7	0.5	225	4	1	15.5	15.5	27.8	4.6
22	28	000	2	21.5	1024	4	3	7	1.5	270	4	1	15.1	15.0	7.5	7.0
23	35	315	3	17.9	1019	3	4	7	1.0	315	4	1	14.2	14.1	19.3	10.3
24	38	293	1	22.4	1017	0	3	7	1.0	315	4	2	14.6	14.4	5.2	9.5
25	31	090	3	17.9	1013	3	1	7	0.8	270	6	1	14.5	14.5	13.4	12.0

Appendix 4– ***continued*****.**

Set	Average Depth	Wind Directio n	Wind Force	Air Temp	Air Pressure	Cloud Cover	Sea Conditio n	Sea Colour	Swell Height	Swell Directio n	Bottom Type	Bottom Contour	Surface Temp	Bottom Temp	Wind Speed	Secchi Depth
26	*18*	33	33	045	2	17.7	1009	3	1	6	0.8	135	6	1	14.6	14.5
27	*24*	43	42	045	2	14.2	1010	8	3	2	1.3	135	4	1	14.0	14.0
28	*39*	72	73	000	3	16.1	1008	8	3	2	1.8	135	4	1	14.0	14.0
29	*29*	53	51	225	3	13.0	1005	8	4	7	1.0	135	4	1	14.0	14.0
30	*20*	37	37	270	3	16.1	1022	6	4	7	1.3	270	4	1	14.3	14.3
31	*17*	31	34	270	2	15.4	1024	7	4	7	1.0	270	4	1	14.3	14.3
32	*31*	57	58	225	4	15.1	1025	8	4	7	1.8	270	4	1	14.4	14.4
33	*28*	51	53	225	4	15.4	1025	5	4	6	1.0	225	4	1	14.4	14.4
34	*14*	26	27	270	0	19.5	1026	3	1	7	0.3	270	4	1	14.5	14.5
35	*26*	48	47	225	3	19.2	1026	2	3	5	0.8	270	4	1	14.5	14.5
36	*29*	52	51	090	5	12.3	1025	8	4	7	0.5	270	4	1	14.4	14.4
37	*25*	45	41	090	4	12.5	1025	8	4	7	0.5	270	4	2	14.5	14.4
38	*17*	31	31	090	3	14.9	1024	8	4	7	0.3	270	4	1	14.5	14.5
39	*31*	56	56	315	3	13.6	1017	8	1	7	2.0	045	3	1	13.9	14.0
40	*45*	82	86	315	4	14.8	1016	8	3	7	2.0	045	7	3	13.9	13.8
41	*31*	57	61	315	3	14.4	1014	8	3	7	2.0	045	4	2	13.9	13.9
42	*39*	72	72	315	3	15.1	1013	8	3	7	2.0	045	7	1	13.9	13.8
43	*18*	33	35	225	3	17.1	1012	8	3	2	0.3	045	3	1	14.6	14.6
44	*10*	19	20	225	3	13.7	1023	5	4	7	1.0	135	7	3	13.5	13.5
45	*18*	33	33	135	1	20.3	1040	1	3	7	3.0	135	7	3	13.7	13.5
46	*13*	24	25	045	4	12.0	1038	0	1	5	0.5	135	4	1	13.0	13.0
47	*23*	41	43	000	4	11.5	1036	5	3	2	1.0	045	3	1	13.0	12.9
48	*18*	33	40	045	3	21.9	1036	1	3	1	1.5	225	7	4	13.5	13.5
49	*34*	61	63	045	3	18.9	1029	8	3	7	2.0	135	3	1	13.1	13.0
50	*32*	58	57	090	2	15.1	1029	8	3	7	2.0	090	3	1	13.1	13.0
51	*20*	37	39	090	2	20.8	1028	8	3	7	1.0	090	3	1	13.0	13.1
52	*27*	48	48	225	3	12.9	1015	8	3	2	2.0	270	6	2	14.4	13.5
53	*19*	34	32	180	3	11.0	1015	8	1	7	0.3	090	4	2	13.5	13.3
54	*12*	22	26	315	3	11.7	1017	4	3	7	1.3	135	7	4	14.5	14.1
55	*13*	23	24	270	4	11.9	1015	5	3	5	2.0	270	4	1	14.4	14.2
56	*43*	79	77	000	4	12.4	1024	6	3	1	1.5	180	4	1	12.2	12.2

Appendix 5: Unscaled length frequency distributions of blue cod for each stratum from which otoliths were used in the Foveaux Strait 2010 age length key.



Appendix 6: Between-reader comparisons (using first independent readings only) for otolith data collected in Foveaux Strait 2010.

Reader two																	Age class (reader one)				
difference	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	Total
-11																				1	1
-10																					0
-9																			1		1
-8																					0
-7																					0
-6																					0
-5															2					1	3
-4											1			1	5	1	1	1			10
-3												3	3	2	2	3	1				14
-2								2	1	4	3	6	3	2	1						22
-1		2	5	8	7	3	5	6	8	5	1	6	1	4	1						62
0		31	11	19	18	21	13	4	9	8	7	4	3								148
1	5	1		1	6	3	7		1	2	1										27
2				2	1																3
Total	5	34	16	30	32	27	25	12	19	19	13	19	10	9	11	4	2	1	1	1	291
% agreement	0	91	69	63	56	78	52	33	47	42	54	21	30	0	0	0	0	0	0	0	51

Appendix 7: Independent reader comparisons with agreed age from otolith data collected in Foveaux Strait 2010.

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																					0
-5															2						2
-4											1			2	4		1			1	9
-3												4	3	3	2	2	1				15
-2				1				2	1	4	2	6	3	3	2	1					25
-1		2	5	7	7	3	5	7	8	4	1	4		4	1						58
0		32	12	19	19	24	14	7	10	8	10	5	3								163
1	3	1			4	2	4		1	1	1										17
2				1																	1
Total	3	35	17	28	30	29	23	16	20	17	15	19	9	12	11	3	2	0	0	1	291
% agreement	0	91	71	68	63	83	61	44	50	47	67	26	33	0	0	0	0			0	56

Reader one																Agreed age class					
difference	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	Total
-3				1																	1
-2																					0
-1		1			2	4	2	4			1	1									15
0	3	34	16	27	28	25	21	12	19	17	12	17	9	9	10	2	1				262
1			1						1		2	1		1	1	1	1			1	10
2														1							1
3																					0
4																				1	1
5														1							1
Total	3	35	17	27	30	29	23	16	20	17	15	19	9	12	11	3	2	0	0	2	291
% agreement	100	97	94	100	93	86	91	75	95	100	80	89	100	75	91	67	50			0	90

Appendix 8: Estimates of proportion of length-at-age for male blue cod sampled from the 2010 Foveaux Strait survey (age -length-key, ALK).

	Age (years)																		
	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**23**	**24**	Total
Lgth (cm)																			
12	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
13	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
16	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
17	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
18	0.33	0.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
19	0.25	0.5	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
20	0	0.6	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
21	0	0.25	0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
22	0	0.4	0.4	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
23	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
24	0	0	0.2	0.6	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0	5
25	0	0	0.25	0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
26	0	0	0	0.67	0.17	0.17	0	0	0	0	0	0	0	0	0	0	0	0	6
27	0	0	0.4	0.2	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	5
28	0	0	0	0.25	0.25	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	4
29	0	0	0	0.2	0.6	0.2	0	0	0	0	0	0	0	0	0	0	0	0	5
30	0	0	0	0	0.2	0.6	0.2	0	0	0	0	0	0	0	0	0	0	0	5
31	0	0	0	0	0.6	0.4	0	0	0	0	0	0	0	0	0	0	0	0	5
32	0	0	0	0	0.6	0.2	0	0.2	0	0	0	0	0	0	0	0	0	0	5
33	0	0	0	0	0	0.25	0.75	0	0	0	0	0	0	0	0	0	0	0	4
34	0	0	0	0	0	0.4	0.2	0.4	0	0	0	0	0	0	0	0	0	0	5
35	0	0	0	0	0	0	0.43	0.29	0	0.14	0.14	0	0	0	0	0	0	0	7
36	0	0	0	0	0	0	0	0.5	0.33	0.17	0	0	0	0	0	0	0	0	6
37	0	0	0	0	0	0	0	0.2	0.4	0.2	0.2	0	0	0	0	0	0	0	5
38	0	0	0	0	0	0	0	0	0.17	0.5	0.33	0	0	0	0	0	0	0	6
39	0	0	0	0	0	0	0	0.2	0.4	0	0.2	0	0.2	0	0	0	0	0	5
40	0	0	0	0	0	0	0	0	0.17	0.5	0.17	0	0	0.17	0	0	0	0	6
41	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	4
42	0	0	0	0	0	0	0	0	0.2	0.2	0.6	0	0	0	0	0	0	0	5
43	0	0	0	0	0	0	0	0	0.25	0	0	0.25	0.25	0.25	0	0	0	0	4
44	0	0	0	0	0	0	0	0	0	0.2	0.2	0.4	0	0.2	0	0	0	0	5
45	0	0	0	0	0	0	0	0	0	0	0	0.25	0.5	0.25	0	0	0	0	4
46	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	3
47	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0.25	0.25	0	0	4
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Total	7	11	16	14	14	12	10	10	10	11	14	4	9	4	1	2	1	1	151

Appendix 8: Estimates of proportion of length-at-age for female blue cod sampled from the 2010 Foveaux Strait survey (age -length-key, ALK).

	Age (years)																
Lgth (cm)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	Total
11	0	0.5	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	2
12	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
13	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
14	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
15	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
16	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
17	0	0.33	0.67	0	0	0	0	0	0	0	0	0	0	0	0	0	3
18	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
19	0	0.2	0.2	0.6	0	0	0	0	0	0	0	0	0	0	0	0	5
20	0	0	0.2	0.6	0.2	0	0	0	0	0	0	0	0	0	0	0	5
21	0	0	0.2	0.4	0.4	0	0	0	0	0	0	0	0	0	0	0	5
22	0	0	0	0.2	0.8	0	0	0	0	0	0	0	0	0	0	0	5
23	0	0	0	0.2	0.6	0.2	0	0	0	0	0	0	0	0	0	0	5
24	0	0	0	0.17	0.67	0.17	0	0	0	0	0	0	0	0	0	0	6
25	0	0	0	0	0.25	0.5	0.25	0	0	0	0	0	0	0	0	0	4
26	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	4
27	0	0	0	0	0	0	0.75	0.25	0	0	0	0	0	0	0	0	4
28	0	0	0	0	0	0.6	0	0	0.2	0.2	0	0	0	0	0	0	5
29	0	0	0	0	0.2	0.2	0.6	0	0	0	0	0	0	0	0	0	5
30	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0	4
31	0	0	0	0	0	0	0.2	0.4	0.2	0.2	0	0	0	0	0	0	5
32	0	0	0	0	0	0.2	0	0.2	0.4	0.2	0	0	0	0	0	0	5
33	0	0	0	0	0	0	0.17	0.17	0.17	0.17	0	0.17	0.17	0	0	0	6
34	0	0	0	0	0	0	0	0.17	0.67	0.17	0	0	0	0	0	0	6
35	0	0	0	0	0	0	0	0	0	0.2	0	0.4	0.2	0.2	0	0	5
36	0	0	0	0	0	0	0	0	0	0.2	0	0.2	0.2	0	0.4	0	5
37	0	0	0	0	0	0	0	0	0.25	0	0.25	0.25	0	0	0.25	0	4
38	0	0	0	0	0	0	0	0	0	0	0.25	0	0.25	0.25	0.25	0	4
39	0	0	0	0	0	0	0	0	0	0	0.5	0	0.25	0	0.25	0	4
40	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5	4
Total	3	28	6	12	16	15	11	6	10	7	4	5	5	3	7	2	140

Appendix 9: Mean age-at-length for the 2010 Foveaux Strait survey.

	All fish		Males		Females	
Length (cm)	N	Mean age (y)	N	Mean age (y)	N	Mean age (y)
11	2	3.0			2	3.0
12	4	1.3	1	2.0	3	1.0
13	7	2.0	2	2.0	5	2.0
14	4	2.0	0		4	2.0
15	11	2.0	1	2.0	10	2.0
16	7	2.0	1	2.0	6	2.0
17	4	2.8	1	3.0	3	2.7
18	4	2.8	3	2.7	1	3.0
19	9	3.2	4	3.0	5	3.4
20	10	3.7	5	3.4	5	4.0
21	9	4.0	4	3.8	5	4.2
22	10	4.3	5	3.8	5	4.8
23	9	4.6	4	4.0	5	5.0
24	11	5.2	5	5.4	6	5.0
25	8	5.4	4	4.8	4	6.0
26	10	5.7	6	5.5	4	6.0
27	9	6.0	5	5.0	4	7.3
28	9	7.0	4	6.5	5	7.4
29	10	6.2	5	6.0	5	6.4
30	9	6.8	5	7.0	4	6.5
31	10	7.4	5	6.4	5	8.4
32	10	7.6	5	6.8	5	8.4
33	10	9.0	4	7.8	6	9.8
34	11	8.5	5	8.0	6	9.0
35	12	10.5	7	9.3	5	12.2
36	11	11.2	6	9.7	5	13.0
37	9	11.0	5	10.4	4	11.8
38	10	12.0	6	11.2	4	13.3

Appendix 9 – *continued*.

	All fish		Males		Females	
Length (cm)	N	Mean age (y)	N	Mean age (y)	N	Mean age (y)
39	9	11.7	5	11.0	4	12.5
40	7	12.0	6	11.7	1	14.0
41	8	13.8	4	12.0	4	15.5
42	5	11.4	5	11.4	0	
43	4	13.0	4	13.0	0	
44	5	12.8	5	12.8	0	
45	4	14.0	4	14.0	0	
46	3	14.0	3	14.0	0	
47	4	15.3	4	15.3	0	
48	1	21.0	1	21.0	0	
49	1	17.0	1	17.0	0	
56	1	28.0	1	28.0	0	
Totals	291	7.5	151	8.2	140	6.6