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Relative abundance, size and age structure, and stock status of blue cod off Banks Peninsula in 2012

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G. Carbines
V. Haist

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Ministry for Primary Industries
PO Box 2526
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TABLE OF CONTENTS

EXECUTIVE SUMMARY

Carbines, G.D.; Haist, V. (2017). Relative abundance, size and age structure, and stock status of blue cod off Banks Peninsula in 2012.

***New Zealand Fisheries Assessment Report 2017/37*. 126 p.**

This report describes the results of the 2012 Banks Peninsula blue cod (*Parapercis colias*) potting surveys. These were concurrent fixed and random site surveys, the fourth fixed site survey since 2002, and the first random site survey in Ministry for Primary Industries blue cod potting survey time series for Banks Peninsula. Both surveys used two-phase stratified designs, with five sites per stratum allocated for phase 1. Between 23 March and 6 May 2012, eighty sites were surveyed (6 pots per site, 480 pot lifts) from five inshore and two offshore strata around southern Banks Peninsula .The catch of each pot was weighed, and the length and sex of blue cod was recorded. Otoliths were read from 551 blue cod collected from both random and fixed sites representatively selected throughout Banks Peninsula. The resulting age-length keys were applied to the scaled length frequency distributions of both fixed and random site surveys to estimate the population age structures.

Fixed site survey

The fixed site survey used 35 phase 1 sites, with five additional sites allocated in phase 2. Total blue cod catch was 685 kg, consisting of 1096 fish. Blue cod catch rates by stratum ranged from 0.6 to 6.3 $kg.pot^{-1}$, with an overall mean catch rate of 4.3 $kg.pot^{-1}$ and coefficient of variation (CV) of 18.1%. Catch rates of legal size blue cod (at least 30 cm) ranged from 0.3 to 6.0 $kg.pot^{-1}$, with an overall mean catch rate of 4.1 $kg.pot^{-1}$ and CV of 19.5%. Catch rates were highest in the offshore strata, and lowest at the Akaroa Harbour entrance stratum. At offshore fixed sites 74% of blue cod caught were of legal size, compared to 40% of blue cod at inshore fixed sites.

Total lengths recorded at fixed sites ranged from 11 to 57 cm, however the average length was 8 cm larger in offshore strata than inshore strata. The length frequency distributions were mainly bimodal, with more small and fewer large fish caught at inshore sites than at offshore sites. Males were larger than females in all strata and overall mean length inshore was 28 cm for males and 25 cm for females, offshore it was 37 cm for males and 33 cm for females. Overall sex ratios for all and for legal sized fish were 1:0.5 (M:F) and 1:0.1 respectively inshore, and 0.8 and 0.6 respectively offshore. Age ranged from 2 to 35 years, with most blue cod between 4 and 8 years for males and 3 and 6 years for females inshore, and between 6 and 12 years for males and 6 and 15 years for females offshore. The mean weighted coefficients of variation (MWCVs) around the age distributions (about 30% inshore and 40% offshore) indicate that fish sampled in the 2012 surveys provided a reasonable representation of the overall inshore population, but less reasonable offshore. The total mortality estimate (Z) was 0.62 inshore and 0.15 offshore, assuming ages-at-recruitment to the fishery at 8 and 9 years, respectively. The spawning biomass per recruit ($F_{\%SPR}$) estimate indicates that the expected contribution to the spawning biomass over the lifetime of an average recruit has been reduced to 24% of the contribution in the absence of fishing inshore, and 92% of the contribution in the absence of fishing offshore. The level of exploitation (F) inshore is of concern as it is well below the Ministry for Primary Industries target reference point of $F_{40\%}$. Most gonads were in the early maturing stage with 1% of males and 7% of females running ripe.

Temporal comparisons between fixed site surveys

The overall catch rates from the 2012 fixed site survey were remarkably similar to those recorded in the 2008 fixed site survey for most inshore strata. However, among the two offshore strata there was an increase of 104% in the southern stratum, and a 40% decrease in the eastern stratum. The overall CVs from the 2012 survey catch rates (18%) was more than twice as big as previous surveys (6–7%). Gonad observations were also consistent with previous surveys.

Random site survey

The random site survey also used 35 phase 1 sites and five phase 2 sites. Total blue cod catch was 539 kg, consisting of 898 fish. For all sized blue cod, catch rates by stratum ranged from 0.3 to 4.0 $kg.pot^{-1}$ with an overall mean catch rate of 3.0 $kg.pot^{-1}$ and coefficient of variation (CV) of 31%. Catch rates of legal size blue cod by stratum ranged from 0.3 to 4.3 $kg.pot^{-1}$ with an overall mean catch rate of 2.8 $kg.pot^{-1}$ and CV of 36%. Catch rates were highest in the offshore strata, and lowest in the eastern inshore stratum. However, at random inshore sites 30% of blue cod caught were of legal size, compared to 79% at offshore sites. Within the Pohatu marine reserve (surveyed concurrently by the Department of Conservation) 58% of blue cod were of legal size compared to 36% of blue cod in the two adjacent inshore strata.

Total lengths recorded at random sites ranged from 12 to 55 cm. The length frequency distributions were mainly bimodal and similar to the fixed sites. Males were also larger than females in all strata, and overall mean length was 28 cm for males and 23 cm for females inshore was also much smaller than the average lengths of 39 cm for males and 34 cm for females offshore. Overall sex ratios for all and for legal sized blue cod were 1:0.5 (M:F) and 1:0.1 respectively inshore and 1:0.7 (M:F) and 1:0.3 respectively offshore. Age ranged from 2 to 38 years, with most blue cod inshore between 3 and 8 years for males and 3 and 6 years for females, and most offshore being between 6 and 15 years for males and 6 and 19 years for females.

The mean weighted coefficients of variation (MWCVs) around the age distributions (about 30% inshore and over 50% offshore) indicate that fish sampled in the 2012 surveys provided a reasonable representation of the overall inshore population, but only a poor representation offshore. The total mortality estimate (Z) was 0.61 inshore and 0.13 offshore, assuming ages-at-recruitment to the fishery of 8 and 9 years, respectively. The spawning biomass per recruit ($F_{\%SPR}$) estimate indicates that the expected contribution to the spawning biomass over the lifetime of an average recruit has been reduced to 25% of the contribution in the absence of fishing inshore, but the fishery has no detectable effect offshore. The level of exploitation (F) at inshore random sites is also of concern as it is well below the Ministry for Primary Industries target reference point of $F_{40\%}$.Most gonads were in the early maturing stage with 1% of males and 4% of females running ripe.

Comparison between survey designs

The rank order of catch rates among strata was not consistent between the 2012 fixed site and random site surveys. The catch rates at random sites were also about 30% less than the catch rates at fixed sites. However, random sites at one offshore and two inshore strata caught more blue cod than concurrently surveyed fixed sites. The overall CVs of the catch rates from the random site survey (over 30%) were about 50% larger than the size of the CVs from the fixed site survey (less than 20%). It appears that the random site survey may not have had sufficient effort to constrain the variance of the catch rates and that more effort (i.e., sites) may be required in future random surveys of Banks Peninsula.

The mean lengths of both male and female blue cod were a little smaller at fixed sites, resulting in Z estimates from the fixed site survey that were similar to those derived from the random site survey. It may therefore not be appropriate to compare mortality estimates between random site and fixed site surveys.

Drop underwater video (DUV)

DUV transects were conducted concurrently with pots at six sites directly prior to potting. The DUV system surveyed 26 km of transects covering a total area of 58 724 m^2, from which 663 independent benthic habitat observations were made, and 509 blue cod and their associated habitat features were recorded. Pots caught 227 blue cod, but with a higher proportion of legal size fish and proportionately fewer fish below 20 cm than the DUV observed. The estimated density of blue cod from video transects had very poor relationship with pot catches for blue cod less than 30 cm, but a good relationship for fish 30 cm and over. There remains considerably uncertainty in the ability of potting surveys to accurately describe the abundance and structure of blue cod populations. The relationship between blue cod and benthic habitat structure was also examined using the DUV.

1 INTRODUCTION

Blue cod (*Parapercis colias*) is the species most frequently landed by South Island recreational fishers, and an important species for Maori customary fishers (Ministry of Fisheries 2010). This report describes the 2012 potting survey of Banks Peninsula, the fourth in the time series following surveys in 2002, 2005, and 2008 (Beentjes & Carbines 2003, 2006, 2009). These surveys provide relative abundance indices as well as information on population size/age structure, mortality estimates, and sex ratio useful in monitoring the blue cod stocks in this area.

Blue cod is a particularly desirable finfish caught easily by line or pot from small vessels fishing over reef edges on shingle/gravel/sandy seabed. Tagging experiments show that most blue cod have a restricted home range (Rapson 1956, Mace & Johnston 1983, Mutch 1983, Carbines & McKenzie 2001, 2004, Carbines 2004a), and stocks of this species largely consist of many independent sub-stocks within each Fisheries Management Area (FMA) (Carbines 2004a). Due to this philopatric behaviour, blue cod can be susceptible to localised depletion within sub-areas of FMAs in response to local fishing pressure. Recreational fishing for blue cod is managed through bag limit strategies with a variety of minimum size limits being applied throughout the South Island FMAs (Ministry of Fisheries 2010).

In the 2000–01 Sustainability Round, the Ministry undertook to work with stakeholders in the Canterbury area to monitor blue cod populations. A relative biomass estimate based on potting surveys was initiated with a view to repeating surveys every three to four years. With the cooperation of the Department of Conservation, it was also possible to include the Flea Bay Marine Reserve as an unfished "control" area to monitor blue cod within the reserve (Carbines 2017), and over time assess and compare the impact of fishing on fish in the remainder of Banks Peninsula.

In addition to catch rate information, monitoring age structure provides a means of evaluating the response of a population to changes in fishing pressure. Otoliths collected during potting surveys are now used to calculate the age structure of blue cod throughout the South Island. Subsequent estimates of total mortality (Z) for each survey are based on catch curve analysis (Ricker 1975) of the age distributions derived specifically for each survey; thus it is possible to determine stock status using an MSY-related proxy. For blue cod in Banks Peninsula there is insufficient information to estimate B_{MSY}, in part because recreational catches have not been estimated reliably and are expected to represent a large proportion of the total catch. F_{MSY} is a more appropriate reference point for blue cod and the most widely used proxy for F_{MSY} currently is from spawner per recruit analyses ($F_{\%SPR}$). Hence, we are interested in where fishing mortality, derived from the catch curve analysis (Z) and estimates of M, lies in relation to the recommended $F_{45\%SPR}$ reference point for blue cod. This is documented in the Ministry of Fisheries 'Operational Guidelines for New Zealand's Harvest Strategy Standard' (Ministry of Fisheries 2011).

The three previous Banks Peninsula potting surveys used a selected fixed site design surveying known fishing spots (Beentjes & Carbines 2003, 2006, 2009), however, this type of survey has a number of potential biases and the catch indices cannot be extrapolated to the whole survey area as the samples are not taken randomly from the population. In a review of blue cod potting surveys, Stephenson et al. (2009) suggested using a more statistically robust random site survey, but acknowledged the need for some continuity with previous survey data. Consequently, for a comparison of these methods the 2012 Banks Peninsula potting survey began a new random site survey concurrently with a fourth fixed site survey.

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 and catch rates, and size composition from potting can differ compared to other methods such as line fishing (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 further investigate the relationship between potting survey catch rates (relative abundance – $kg.pot^{-1}$) and size structure with direct observations of blue cod, the 2012 Banks Peninsula potting survey also employed fish counts from remote video transects (see Morrison & Carbines 2006, Carbines & Cole 2009) done at potting sites immediately prior to potting. This report therefore describes both the concurrent fixed and random site potting surveys of the greater Southern Banks Peninsula area, and includes comparisons with concurrently undertaken flown video transects.

Overall objective

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

Specific objectives

1. To undertake a potting survey off Banks Peninsula (BCO 3) to estimate relative abundance, size- and age at-maturity, sex ratio. Collect otoliths from pre-recruited and recruited blue cod.

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

3. To determine stock status of blue cod populations in this area, and compare this with other previous surveys in this area and other survey areas.

4. To undertake a Dropped Underwater Video (DUV) survey concurrently with the potting survey to provide comparative estimates of biomass.

5. To determine F_{MSY} proxies for Banks Peninsula blue cod.

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 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 for surveys completed prior is that the term station is now used to refer to a pot rather than a site (see Appendix 1).

2.1 Timing

To continue the fixed site survey time series for Banks Peninsula with minimal temporal (seasonal) variability between surveys, the 2012 Banks Peninsula fixed and random site potting surveys were carried out concurrently between 26 March and 6 May2012. Previous surveys were done in January-April 2002 (Beentjes & Carbines 2003), April-May 2005 (Beentjes & Carbines 2006),and April-May 2008 (Beentjes & Carbines 2009).

2.2 Survey area

Located on the east coast of the South Island immediately south of Christchurch, Banks Peninsula is a large area (over 1100 km^2) of volcanic origin that provides the only significant rocky platforms in the mid Canterbury area. While Banks Peninsula encompasses two large harbours (i.e., Lyttleton and Akaroa) and many smaller bays, the blue cod potting survey area includes only the southern half of the Peninsula (where most blue cod fishing occurs) as water clarity outside of this area is often poor and appears to greatly reduce catchability.

The survey area covers the coastline from Snuffle Nose on the south western coast to Le Bons Bay on the eastern extreme of Banks Peninsula, with the marine reserve off Flea Bay (Figure 1) historically excluded from the survey area (Beentjes & Carbines 2003, 2006, 2009). The survey area was based on discussions with a long standing commercial blue cod fisher in Akaroa and several charter boat operators that regularly fish in this area. These fishers were given charts of the area and asked to mark discrete locations around Banks Peninsula where blue cod are most commonly caught (Beentjes & Carbines 2003). The coastline was then arbitrarily divided into five strata of similar size with boundaries often determined by headlands or bays (Figure 1). Discussions with fishers also indicated that much of the recreational catch of blue cod is taken offshore in two large but discrete sub tidal rocky platforms: Pompeys Rocks (20 km southeast of Pompeys Pillar), and Le Bons Rocks (36 km east of Le Bons Bay) (Figure 1). These offshore areas were also included as two offshore strata in the survey design (Beentjes & Carbines 2003, 2006, 2009).

The blue cod habitat adjacent to Banks Peninsula comprises a narrow band of foul extending only a short distance out from the cliff faces and exposed headland reefs. Previous surveys have assumed that this habitat band was reasonably constant in width and that the length of the coastline was proportional to the amount of blue cod habitat (see figure 2 in Carbines 2017). Thus the size of the inshore strata were recorded as length of coast rather than in square kilometres (Beentjes & Carbines 2003, 2006, 2009).

For the fourth fixed site survey in this time series, the same survey area and strata used in the 2002, 2005, and 2008 surveys were resurveyed in 2012. However, the actual "fixed" sites used in each survey were generated randomly from the 122 possible fixed sites originally identified in 2002 (Beentjes & Carbines 2003).

The same inshore survey strata were used for the 2012 random site survey of Banks Peninsula, with the coastline arbitrarily divided into one kilometre lengths and randomly selected, within each stratum. The area of each inshore stratum was taken as a proxy measure of available habitat for blue cod. However, the area of the two offshore strata (Le Bons Rocks and Pompeys Rocks) could not be quantified in the same manner because they are discrete areas or islands of rocky foul. To make inshore and offshore areas surveyed comparable for the random site survey, the offshore strata were re-defined by a basic single beam sonar survey to determine the location and effective size of each discrete area of rocky foul prior to the 2012 survey (Figure 1).

2.3 Survey design

Both the fixed and random site Banks Peninsula potting surveys used a two-phase stratified design, using six pots per site (Figures 2 and 3) and ensuring that sites were at least 100 m apart. Five sites per stratum (n=35 sites[1], 210 pot lifts) were allocated to phase one of both the fixed and random site surveys (Table 1 and 2). An additional five sites (30 pot lifts) were allocated to phase two for both the fixed and random site surveys (12.5%) (Figure 4). An additional seven random sites (42 pot lifts) were independently allocated to the marine reserve at the request of the Department of Conservation (Table 2, Figure 4) but were not used to determining the overall mean catch estimates of the fishable survey area. The full results of the marine reserve survey are presented separately in Carbines (2017).

[1] Fixed sites were randomly selected from a pool of 122 possible fixed fishing sites identified in 2002 (Figure 1).

Allocation of phase 2 sites was based on the mean catch rate ($kg.pot^{-1}$) of all blue cod per stratum (except the marine reserve) 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 *i*th 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.

2.4 Vessels and gear

The Banks Peninsula survey was conducted from F.V. *CherilynJ*, an Akaroa-based commercial vessel equipped to set and lift rock lobster and blue cod pots. The vessel was charted by Saltwater Science Ltd and skippered by Mr John Wright which ensured consistency (same vessel and skipper) with the 2002, 2005, and 2008 surveys (Beentjes & Carbines 2003, 2006, 2009). The vessel specifications are: 15.5 m length, 3.8 m breadth, 3.5 t, aluminium monohull, powered by a 230 hp Volvo Penta diesel engine with propeller propulsion. The trip code for the survey was CHJ1201.

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 are of different dimensions and construction (Pot Plan 1 in Beentjes & Francis 2011).

A high-performance, 3-axis (3D) acoustic doppler current profiler (RDI - 1200 kHz) was deployed at each site. The ADCP records current flow and direction in 5 m depth bins.

2.5 Sampling methods

In Banks Peninsula, inshore fixed sites were constrained by available rocky habitat and were adjacent to the coastline or submerged rocks, while offshore sites were relatively unconstrained by available rocky habitat within strata (See Figures 1 and 2). The ADCP was initially deployed roughly central to each fixed site (adjacent to the rocky habitat), and the six pots were set in clusters, separated by at least 100 m. Once on site, the position of each of the six pots was determined by the skipper using local knowledge and the vessel sounder to locate an area of foul ground (Figure 2).

Inshore random sites in Banks Peninsula were also constrained by available rocky habitat adjacent to the coastline, while offshore sites were only constrained by the stratum boundaries (Figure 3). The ADCP was initially deployed at the random point generated. Inshore, the six pots were set in a row adjacent to the coastline at the edge of the narrow band of rocky habitat, separated by approximately 100 m. Once on site, the position of each of the six pots was determined by the location of the random point and the edge of the available rocky habitat (Figure 3). At each random offshore site the ADCP was deployed, and around this central point, six pots were set sequentially in a fixed hexagon pattern with each point (pot) approximately 200 m from the centre and 200 m from adjacent pots. The six pots were set blind (i.e., not targeted by sonar) in the fixed grid pattern determined from an initial starting point approximately 200 m north of the random site location occupied by the ADCP (Figure 3).

At both random and fixed sites, pots were left to fish (soak) for approximately one hour during daylight hours. 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 each stratum roughly equal exposure to all daily tidal and time regimes. The order that strata were surveyed depended on the prevailing weather conditions, as exposed strata could only be surveyed during calm conditions.

As each pot was set, a record was made on customised forms (See Beentjes & Francis 2011) 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 water visibility (secchi depth). The ADCP was deployed at the centre of each site to record sea bottom temperature, and both current speed and direction throughout the pot sets and was recovered after the last pot of each set was lifted.

After one hour, pots were lifted aboard using the vessel's hydraulic pot lifter, emptied, and the contents sorted by species. Total weight per pot was recorded for each species to the nearest 10 g using 10 kg Merel motion compensating scales. The number of individuals of each species was also recorded per pot. 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. Otoliths were removed from a target of five fish of each sex per one centimetre size class over the available length range collected representatively throughout the survey area (excluding the marine reserve).

All blue cod (except for in the marine reserve) were sexed by dissection and direct examination of the gonads (Carbines 1998, 2004a). Gonads were also 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 (See Beentjes & Francis 2011).

2.6 Otolith preparation and reading

Due to the small size and cryptic banding pattern of blue cod otoliths, the best method for ageing them is to use a thin section mounted on a slide and viewed through a microscope (Carbines 2004b). Once removed by dissection, otoliths were rinsed with water, air-dried, and stored in paper envelopes. These were later embedded in a polymer resin, baked (50°C for at least three hours), and sectioned transversely about 1 mm either side of the nucleus with a diamond-tipped cut-off wheel. The thin section was then glued with resin onto a slide 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 for blue cod and a protocol described by Carbines (2004b). Translucent zones are used to define each complete opaque zone, i.e., annuli are counted only if they have a translucent zone on both sides. The readability of each otolith was also graded from 1 (excellent) to 5 (unreadable). Otoliths were read independently by two readers (Dr G. Carbines and Dr N. Usmar), and where counts differed the readers consulted to resolve the final age estimate. Otoliths given a grade 5 (unreadable) or damaged were removed from the analysis.

2.7 Data analysis

The data analyses follow the methods and equations described in the blue cod potting survey standards and specification document (Beentjes & Francis 2011), with exceptions noted here.

CPUE for fish of minimum legal size

The potting survey manual does not provide equations for calculating catch rates of fish greater than the minimum legal size (MLS), however the approach that has been used in recent years is an extension of the equations for calculating catch rates for the entire catch. For blue cod potting surveys, individual fish weights are measured for only a subset of the sampled fish, and catch rates for fish greater than or equal to the MLS are based on the predicted weight of individual fish based on their length. The set-specific CPUE (kg.pot^{-1}) for fish greater than the MLS is,

$$C_{st}^{legal} = \left(\sum_{p} \sum_{k=1,2} \sum_{l \geq MLS} f_{lkpst} \, a_k \, l^{b_k} \right) \Big/ m \qquad (1)$$

Where f_{lkpst} is the number of fish of length l and sex k (k=1 for males and k=2 for females) caught in pot p of set s of stratum t, m is the number of pot lifts in set s, and a_k and b_k are sex-specific length-weight parameters (described below). Note that the above equation assumes that all fish have been measured for length.

The sex-specific length-weight parameters a_k, b_k are calculated by fitting (maximum likelihood) the following equation to all samples where length, weight, and sex were recorded:

$$w_{ki} = a_k \left(l_{ki} \right)^{b_k} \varepsilon_{ki} \qquad (2)$$

where w_{ki} and l_{ki} are the weight and length of fish i of sex k and the ε_{ki} are normally distributed. To obtain length-weight parameters for unsexed fish (k=4) in the marine reserve, the above equation is fitted to the combined male and female length-weight data.

The equations for calculating the stratum and survey catch rates and CVs for fish greater than or equal to the MLS follow those in the potting survey manual (equations 2–5 of Beentjes & Francis 2011), replacing $\overline{C}_{st}$ with C_{st}^{legal}.

Length frequency, age frequency and total mortality estimates

Calculation of survey-level length frequency (LFs), age frequency (AFs), and total mortality (Z) follow the equations described in the potting survey manual (Beentjes & Francis 2011). Uncertainty in the LFs, AFs and Z estimates were calculated using the bootstrap procedures described in the survey manual. The LF and AF CVs were based on 300 bootstrap replicates and the Z confidence limits were based on 1000 replicates.

For the Banks Peninsula survey, fish sampled in the marine reserve were not included in calculating the survey level LFs, AFs and total mortality (Z) as the sex data may not be representative. Also, this area is closed to fishing and the objective of the survey Z estimates is to monitor the effects of fishing.

Growth parameters

Von Bertalanffy growth models were fitted (maximum likelihood) to the sex-specific length-age data:

$$l_{ki} = L_k^{\infty} \left(1 - \exp\left(K_k \left(t_{ki} - t_k^0 \right) \right) \right) + \varepsilon_{ki} \qquad (3)$$

where l_{ki} and t_{ki} are the length (cm) and age of fish i of sex k, respectively, $L_k^{\infty}, K_k,$ and t_k^0 are parameters of the growth model for sex k, and the ε_{ki} are normally distributed.

The estimated growth parameters, L_k^{∞}, K_k, and t_k^0, were used in the spawning biomass per recruit analyses.

Spawning biomass per recruit calculations

Spawning biomass per recruit (*SPR*, Ministry of Fisheries 2011) analysis estimates the impact of fishing on the reproductive capacity of the stock. *SPR* is a deterministic calculation, dependent on population growth, natural and fishing mortality, maturation, and fishing selectivity. For blue cod, the calculations are based on age- and sex-specific dynamics and spawning biomass is summed over male and female fish. The following equations give the number of fish at age *a* and sex *k* (N_{ka}) and the spawning biomass per recruit (S_F) for a given *F*:

$$N_{ka} = \begin{cases} 0.5 & a = 0 \\ N_{k,a-1} \exp\left(-s_{k,a-1}F - M\right) & 1 \geq a < mage \\ N_{k,a-1} \exp\left(-s_{k,a-1}F - M\right) \Big/ 1 - \exp\left(-s_{k,a-1}F - M\right) & a = mage \end{cases} \qquad (4)$$

$$S_F = \sum_k \sum_a \left(m_a \, a_k \left(l_{ka}\right)^{b_k} N_{ka} \right) \qquad (5)$$

where *M* is the natural mortality rate, s_{ka} is the selectivity for age *a* and sex *k*, m_a is the maturity for age *a*, l_{ka} is the mean length for age *a* and sex *k*, *mage* is the maximum age (50) and a_k and b_k are the length-weight parameters for sex *k* (see equation 2). $F_{\%SPR}$ is the fishing mortality (F) at a given spawning biomass per recruit (%SPR) relative to the spawning biomass per recruit in the absence of fishing (i.e. S_f/S_0).

Population parameters are either estimated based on survey data (s_{ka}, l_{ka}, a_k and b_k), or fixed at default values as specified in the potting survey manual: the instantaneous natural mortality rate is assumed to be 0.14, with sensitivity runs conducted for *M* values of 0.11 and 0.17; the maturation ogive assumes fish under age 3 are all immature, proportions mature of 0.1, 0.4, 0.7 for ages 4, 5, and 6, respectively, and 100% maturity for fish aged 7 and older; and fishery selectivity is assumed to be knife-edge at the age at MLS. The estimate of current fishing mortality (*F*) is equal to *Z-M,* and the SINS working group determined that the age of recruitment for the Z calculations would be the age where both male and female blue cod were at or above the MLS. Z and *SPR* results are also provided for ages at recruitment from 5 through to 10.

Note that the above equations assume that the surveys which generate the length-age data (and vB growth curves) occur at the time of spawning so that a fish aged 3 is exactly 3 years old. Also, knife-edged fishery selectivity is interpreted to mean that age-classes become fully selected when they reach the birthday where their mean length-at-age is greater than or equal to the MLS. Alternative interpretations of knife-edge selectivity are possible – for example, assuming full selectivity at the exact age where the mean length is equal to the MLS (i.e., full selectivity at some mid-point in the year).

2.8 Drop underwater video (DUV)

Catch rates (kg.pot^{-1}) from potting surveys are used as a proxy for actual abundance, but it is unknown how this measure of relative abundance is related to the actual abundance of blue cod (Stephenson et al. 2009). To address this we estimated blue cod populations using drop under water video (DUV) counts conducted concurrently at a sub-sample of four fixed and two random sites.

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 moving 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 Geographical Positioning System (GPS) and depth sounder.

The video camera was deployed at a height of at least 1.5 m off the seabed as the vessel steamed through the site area. Once the speed of the surface vessel exceeds that of the deployed video, the keel and tail fin orient the platform forward, and the video records a transect of approximately 600 m in length. Contact with the seabed is avoided by lifting and lowering the DUV 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 0700 and 1630 hours, when the swell was less than 2 m, and when speed exceeded 0.8 $m.s^{-1}$ (to prevent fish being able to follow the video and re-enter the video transect). At least three replicate video transects were done at each site directly prior to sampling with six replicate 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 partitioned into gross 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 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) substrata (categories based on 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 calculated between the number of blue cod counted at each DUV site and caught in pots at that site. Blue cod length frequencies were also compared between these methods to examine size selectivity (Cole et al. 2001). Data on fish abundance by size class from video and habitat data are presented separately for random and fixed sites, and a ratio of fish-dependent and fish-independent habitat observations was used to determine features of the benthic environment that were disproportionally utilised or absent of blue cod.

3 RESULTS

3.1 Sites surveyed

Forty fixed sites (6 pots per site, 240 pot lifts) and forty seven random sites (6 pots per site, 282 pot lifts) were surveyed over twenty-four fishable days from 26 March to 6 May 2012 (Tables 1 and 2, Figures 4 and 5, Appendix 2). However, the seven random sites surveyed in the marine reserve were excluded from the analysis for this report as at the time of reporting the Ministry for Primary Industries Inshore Working Group requested that only the fishable part of Banks Peninsula be reported. The results of the marine reserve sites are therefore analysed and discussed in a separate report for the Department of Conservation (Carbines 2017, also presented here as Appendix 18).

Of the 40 fixed sites, 35 were carried out in phase 1 (5 per stratum) with 5 allocated to offshore stratum 7 in phase 2 (Table 1).Of the 35 fishable random sites (i.e., excluding the marine reserve), 30 were carried out in phase 1 (5 per stratum) and 5 allocated to offshore stratum 7 in phase 2 (Table 2). Depth ranged from 3 to 91 m for fixed sites and 5 to 88 m for random sites. The mean soak time for fixed sites was 1 hour (range 58 to 64 min, s.e. = 4 sec) and 61 minutes (range 58 to 71 min, s.e. = 5 sec) for random sites. Environmental data recorded throughout the Banks Peninsula survey are presented in Appendix 3 and are stored on the Ministry for Primary Industries database *trawl*. The ADCP data is archived in a spreadsheet with the Research Data Manager, NIWA, Greta Point, Wellington.

3.2 Catch

A total of 1555 kg of catch was taken during the 2012 Banks Peninsula fixed and random site surveys, of which 1188 kg (76%) was blue cod, consisting of 1994 fish. However, the fixed site survey caught 58% of the total blue cod, with blue cod accounting for 78% of catch in the fixed site survey (Table 3) and 75% of the catch in the random site survey (Table 4).

Bycatch included 10 fish species and 1 octopus species in both the fixed site survey (Table 3) and the random site survey (Table 4). For both the fixed and random site surveys the five most common bycatch species by weight were banded wrasse (*Notolabrus fucicola*), octopus (*Octopus cordiformis*), scarlet wrasse (*Pseudolabrus miles*), sea perch (*Helicolenus percoides*), and spotty (*Notolabrus celidotus*) (Tables 3 and 4).

In the fixed site survey the mean catch rates of blue cod (all sizes) ranged from 0.60 kg.pot^{-1} for the inshore stratum at the head of Akaroa Harbour, to 6.28 kg.pot^{-1}in the southern offshore stratum 7 (Table 5, Figures 6 and 7). Overall mean catch rate and CV were 4.32 kg.pot^{-1} and 18.09%. For blue cod 30 cm and over (local minimum legal size) the highest catches also came from stratum 7 (6.02 kg.pot^{-1}) and the lowest catch rates were also from stratum 2 (0.32 kg.pot^{-1}). Overall mean catch rate and CV for fish of at least 30 cm from the fixed site survey were 4.08 kg.pot^{-1} and 19.543% (Table 6, Figures 6 and 7).

In the random site survey catch rates were lower, and the mean catch rates of blue cod (all sizes) ranged from 0.33 kg.pot^{-1} for the eastern inshore stratum 5, to 4.09 kg.pot^{-1} for the eastern offshore stratum 6 (Table 7, Figure 7). Overall mean catch rate and CV were 2.97 kg.pot^{-1} and 31.28%. For blue cod 30 cm and over the highest catches also came from stratum 6 (4.30 kg.pot^{-1}) and the lowest catch rates were again from stratum 5 (0.28 kg.pot^{-1}). Overall mean catch rate and CV for blue cod 30 cm and over from the random site survey were 2.79 kg.pot^{-1} and 33.59% (Table 8, Figure 7).

3.3 Biological and length frequency data

All of the 1994 blue cod caught during the 2012 Banks Peninsula fixed and random site surveys (excluding fish from the marine reserve) were measured and sexed (Figure 8).

Sex ratio
For all blue cod from the fixed site survey the sex ratio ranged from 1:0.3 (M:F) in the eastern inshore stratum 5 to 1:1.1 (M:F) in the eastern offshore stratum 6, and overall were 62% male at 1:0.6 (M:F)(Table 9). The sex ratio for blue cod 30 cm and over (local minimum legal size) ranged from 1:<0.1 (M:F) in stratum 5 to 1:0.8 (M:F)in stratum 6, and was overall 71% males (1:0.4) (Table 9). Overall the sex ratio of legal sized fish was more skewed towards males inshore (1:01) than offshore (1:0.6, Table 9).The size of blue cod at fixed sites ranged from 11 to 50 cm for females and 14 to 57 cm for males, although size varied greatly between inshore (mean = 28.8/24.7 cm M/F) and offshore (mean = 36.9/33 cm M/F) groupings of strata (Table 9).

The sex ratios of blue cod from the random site survey (excluding the marine reserve) ranged from 1:02 (M:F) in stratum 5 to 1:1.0 (M:F)in stratum 6, and overall were 64% male at 1:0.6 (M:F)(Table 10). The sex ratio for blue cod 30 cm and over ranged from 1: 0.1 (M:F) in all inshore strata to 1:0.7 (M:F)in offshore stratum 6 (Table 10). Overall the sex ratio of legal sized fish was more skewed towards males inshore (1:01) than offshore (1:0.5, Table 10). The size of blue cod at random sites ranged from 12 to

54 cm for females and 16 to 55 cm for males, but also varied greatly between inshore (mean = 27.6/23.0 cm M/F) and offshore (mean = 39.3/34.1 cm M/F) groupings of strata (Table 10).

Length frequency
In both the fixed and random site surveys, the length frequency distributions were bimodal in most strata, and the random site survey tended to have proportionately more small fish (Figure 8). The proportion of legal sized blue cod caught on the 2012 fixed site survey was 40% inshore and 74% offshore. The average length of blue cod from inshore strata (29 cm for males and 25 cm for females) was 8 cm smaller than blue cod from offshore strata (37cm for males and 33 cm for females, Table 9). For the concurrent random site survey, the proportion of legal sized blue cod caught was 30% inshore and 79% offshore. The average length of inshore blue cod (28 cm for males and 23 cm for females) was 11 cm smaller than those from offshore strata (39 cm for males and 34 cm for females, Table 10).The random site survey caught more small blue cod (less than 20 cm) than the fixed site survey, mainly in strata 1 and 2 (Harbour entrance and westwards) and 5 (eastern end of the Peninsula) inshore (Table 10, Figure 8).

Biological data
Of 1096 blue cod examined in the fixed site survey, 88% of the males and 78% of the females had gonads in the early maturing phase(Table 11). Of the 892 blue cod examined in the random site survey, 86% of the males and 82% of the females also had early maturing gonads (Table 12).

Otoliths were taken from 565 specimens taken throughout the fishable survey area (246 inshore, 319 offshore), of which 551 fish (240 inshore, 311 offshore) across the available size range were successfully read (Appendix 4 and 5). The combined survey length-weight relationship analysis included 216 females (range 11–54 cm) and 266 males (range 14–56 cm). Using the derived model $W = aL^b$, the length-weight parameters for Banks Peninsula were: males – a = 0.019138, b = 2.98181, females – a = 0.016939, b = 3.02644.

3.4 Ageing (between reader analyses)

From 565 otoliths collected during the 2012 Banks Peninsula surveys, 14 were rejected as unreadable or damaged, leaving 240 inshore otoliths (146 males 15–46 cm, 94 females 15–36 cm (Table 13)) and 311 offshore otoliths (166 males 14–56 cm, 145 females 11–54 cm (Table 14)). These otoliths were collected across all strata (Appendix 4 and 5).

Initial independently derived reader estimates of inshore otolith age class are compared in Figure 10 and show 70% agreement between the two readers, with reader 2 generally estimating slightly lower age classes than reader 1 (tabulated in Appendix 6). When the differences between age class estimates were resolved by agreement between the readers, reader 1 was 83% consistent with the agreed age class estimates compared to reader 2 who was 84% consistent with the agreed age classes (Figure 9, Appendix 7).

For offshore otoliths the initial independently derived reader estimates of age class are compared in Figure 11 and show 47% agreement between the two readers, with reader 2 generally estimating a higher age than reader 1 (tabulated in Appendix 8). When the differences between age class estimates were resolved by agreement between the readers, reader 1 was 58% consistent with the agreed age class estimates, compared to reader 2 who was 73% consistent with the agreed age classes (Figure 11, Appendix 9).

3.5 Growth

The fitted von Bertalanffy growth models for the 2012 inshore (strata 1–5) and offshore (strata 6–7) surveys are shown in Figure 12, and the growth parameters (K, t_0 *and* L_{inf}) shown below. Inshore male and female size-at-age is similar until about age 5, after which males grow a little faster and achieve a slightly larger L_{inf} than females. Offshore male and female size-at-age is similar until about age 7, after which males grow faster and achieve a much greater maximum length L_{inf} than offshore females, inshore males, and inshore females (Figure 12).

	Inshore (strata 1-5)			Offshore (strata 6–7)	
	Males	Females		Males	Females
Parameter			Parameter		
K	0.1527	0.1277	K	0.0855	0.0892
T_0	-0.1064	-0.6557	T_0	-1.5805	-1.8884
L_{inf}	46.99	45.82	L_{inf}	56.71	49.66

3.6 Length and age composition

Inshore

The scaled length and age distributions for inshore strata 1–5 combined (with the exception of the marine reserve) are shown for males and females fixed site (Figure 13) and random-site (Figure 14) potting surveys.

The inshore scaled length frequency distributions of blue cod from fixed and random site surveys were similar, although the mean size (27.5 cm) at fixed sites was six percent larger than the mean size (25.9 cm) at random sites (Figures 13 and 14). Length frequency distributions were multi-modal, males were larger than females and had peaks at about 17 cm, 24 cm, and 31 cm, while females had peaks at around 17 cm and 24 cm (Figures 13 and 14).

Age of inshore blue cod ranged from 2 to 20 years (Table 13), but there were few fish older than 10. For males, the dominant age-classes were 3, 4, 5, 6, 7 and 8 while for females the dominant age-classes were 3, 4, 5 and 6 (Figures 13 and 14). The mean age of males was higher in the fixed-site survey (6.6 compared to 6.1) as was the mean age of females (5.1 compared to 4.9). The mean weighted coefficients of variation (MWCVs) around the age distributions are moderate (less than 30%) indicating that fish sampled in the 2012 surveys provide a fair representation of the overall populations.

The inshore age-length-keys (ALKs) by sex are shown in Appendices 10 and 11 and mean-age-at-length is shown in Appendix 14. For both males and females, all lengths measured on the survey had at least one valid age reading in the age-length-keys.

Offshore

The scaled length and age distributions for offshore strata 6–7 combined are shown for males and females for the 2012 Banks Peninsula fixed site (Figure 15) and random-site (Figure 16) potting surveys. The length frequency distributions of blue cod from offshore fixed and random sites were similar, although the mean size (36.6 cm) at fixed sites was five percent larger than the mean size (34.9 cm) at random sites (Figures 15 and 16). Length frequency distributions were highly multi-modal with peaks at about 31 cm, 33 cm, 40 cm, 45 cm and 50 cm for males, while females had peaks at around 28 cm, 35 cm and 40 cm (Figures 15 and 16). A cumulative length frequency plot shows the similarities between random and fixed site surveys in both inshore and offshore areas (Figure 17).

The age of offshore blue cod ranged from 2 to 38 years (Table 14) and fish were common up until the age of 30. For males, the dominant age-classes were 6, 7, 8, 10, 11, 12 and 15 while for females the dominant age-classes were 6, 7, 8, 9, 10 and 13 (Figures 13 and 14). The mean age of males was higher in the fixed-site survey (13.4 compared to 12.4) as was the mean age of females (12.7 compared to 11.4). However, a cumulative age frequency plot shows the similarities between random and fixed site surveys in inshore and offshore areas (Figure 17).

The mean weighted coefficients of variation (MWCVs) around the age distributions are large (over 40% at fixed sites and over 50% at random sites) indicating that fish sampled in the 2012 offshore surveys provide a less than ideal representation of the overall populations.

The offshore age-length-keys (ALKs) by sex are shown in Appendices 12 and 13 and mean-age-at-length is shown in Appendix 15. For both males and females, all lengths measured on the survey had at least one valid age reading in the age-length-keys.

3.7 Total mortality (Z) estimates

Total mortality estimates (*Z*) and 95% confidence intervals for the 2012 Banks Peninsula fixed site survey are given for both the whole survey (Table 15) and separately for inshore (Table 16) and offshore (Table 17) strata groupings. Offshore *Z* estimates increase with the assumed age-at-recruitment to the fishery (between 5 and 10), but this was not the case for inshore *Z* estimates (Table 16). In the fixed site survey, inshore strata *Z* estimates (ranging from 0.39 to 0.62) were dramatically higher than those from offshore strata (ranging from 0.13 to 0.16).

For the 2012 Banks Peninsula random site survey, *Z* estimates and 95% confidence intervals are given for both the whole survey (Table 18) and separately for inshore (Table 19) and offshore (Table 20) strata groupings. Offshore *Z* estimates increase with the assumed age-at-recruitment (between 5 and 10) while inshore Z estimates increase to an assumed age of recruitment of 7 and then decline. Inshore strata *Z* estimates (ranging from 0.42 to 0.61) were also dramatically higher than those from offshore strata (ranging from 0.11 to 0.13).

Estimates of *Z* from the inshore strata were similar for the random site survey and the fixed site survey, but the offshore *Z* estimates were slightly higher for the fixed site survey than for the random site survey.

3.8 Spawner per recruit analyses

The age- and sex-specific values for fish size, maturity, and selectivity used in the SPR analysis are given in Appendix 16 for inshore strata and in Appendix 17 for offshore strata.

Spawning biomass per recruit analyses is plotted as $F_{\%\mathrm{SPR}}$ versus fishing mortality rate for inshore and offshore strata of the fixed site (Figures 18 and 19) and random site (Figures 20 and 21) surveys. Mortality parameters used in the analyses, and resulting $F_{\%\mathrm{SPR}}$ values are shown for inshore and offshore strata of the fixed site (Tables 21 and 22) and random site (Tables 23 and 24) surveys. Based on the default value of *M* of 0.14 and a fully-selected age of 8 years (both males and females fully selected in fisheries, based on growth curves and the MLS), the fishing mortality estimates were 0.62 and 0.61, corresponding to spawner biomass per recruit ratios of 24%and 25% for inshore strata of the fixed site and the random site surveys, respectively. This indicates that at recent levels of fishing mortality, the expected contribution to the spawning biomass over the lifetime of an average recruit has been reduced to about 25% of the contribution in the absence of fishing in the inshore area. $F_{\%SPR}$ estimates for *M* values of 0.11 and 0.17 ranged from19% to 31% (Tables 21 and 23).

Spawner biomass per recruit ratios were considerably higher among offshore strata, with minor variation between fixed site and random site surveys (Tables 22 and 24). Based on the default value of *M* of 0.14 and the estimated age when fully-selected in fisheries of 9 years, the fishing mortality at offshore fixed sites was estimated at 0.15 which corresponds to an spawner biomass per recruit ratio of 92%, but at offshore random sites *Z* was estimated at 0.13 corresponding to an spawner biomass per recruit ratio of 114%. The spawner biomass per recruit ratio estimates for *M* values of 0.11 and 0.17 ranged from 69% to 143% (Tables 22 and 24).

3.9 Drop underwater video

Video counts versus pot catch

Drop underwater video (DUV) transects were undertaken at three random and three fixed sites directly prior to sampling pots (see Table 25, Figure 22). A total of 33 DUV transects and 36 pots were deployed at the six sites surveyed with both methods. The DUV surveyed 26 km of transects with an average transect width of 2.4 m (s.e. ± 0.2 m) covering a total area of 58 624 m^2. Within the area swept by the DUV, 135 general habitat breaks were identified and 663 fish-independent habitat transects were recorded within them (Table 25). A total of 509 blue cod were observed using DUV, while the concurrent pots caught 227 blue cod (Table 25).

Species caught and observed

A total catch of 327 individuals was taken by pots at concurrent DUV surveyed sites, 78% of which were blue cod (Table 26). Fixed sites caught 79% blue cod and random sites caught 60% blue cod (Table 26). At the DUV surveyed sites, bycatch from potting included seven fish species. The five most common bycatch species from potting (by numbers) were banded wrasse *(Notolabrus fucicola*) girdled wrasse (*Notolabrus* cintus), spotty *(Notolabrus celidotus*), scarlet wrasse (*Pseudolabrus miles*), and sea perch (*Helicolenus* spp).

A total of 1757 individuals was observed in DUV transects (34 unidentified individuals), 29% of which were blue cod (Table 27). At both fixed and random sites 29% of the observed fish were blue cod (Table 27). Twenty four other fish species were observed in DUV transects, the five most common of which were sea perch, hapuka (*Polyprion oxyeneios*), spotty, scarlet wrasse, and butterfly perch (*Caesioperca lepidoptera*).

Length frequency comparisons

The length frequency distributions from the DUV surveyed sites are shown in Figure 23. Both the length frequency distributions for all blue cod observed, and only those observed without a camera head-on or off the bottom position (to improve precision) showed that the DUV sampled a considerably greater proportion of blue cod below 20 cm than did pots (Figure 23). However, more large blue cod were caught in pots than observed and it was less obvious that pots proportionally sample more blue cod over 30 cm (Figure 23). The cumulative distribution plots of length frequency confirm that the video has a higher proportion of smaller fish than pots do (Figure 23).

Comparison of catch rates and counts

Fish densities estimated by the area-swept DUV method were standardised in proportion to the mean pot catch rate for three size classes of blue cod (Figure 24). The variance was often high for both pots and the video (Figure 24). At site MR-3 few fish were either seen or caught; and high densities observed at site 7-E proceeded high catch rates. However, there were several sites with low observed densities and high catch rates (i.e., sites 3-F, 4-J, and MR-456), and high densities of under 20 cm fish observed but not caught (site 6-R1, 7E) (Figure 24). The correlation between the average density and catch rate of blue cod was -0.21 for fish less than 20 cm, 0.01 for fish between 20 cm an 29 cm, and 0.75 for fish 30 cm and over (Figure 25). For the natural logarithm of the data, the correlation was -0.21 for fish less than 20 cm, 0.12 for fish between 20 cm an 29 cm, and 0.71 for fish 30 cm and over (Figure 26).

Benthic habitat descriptions and utilisation

Benthic habitat data from the DUV method are presented, and a ratio of fish-dependent and fish-independent habitat observations was used to determine which primary substrata and secondary habitat structures (as defined in Section 2.9) blue cod are more commonly associated with, within the benthic environment.

Primary substrate

Using the DUV fish-independent habitat observations, the main primary substrates were sand/shell grit, muddy sand, sand/shell grit/gravel and boulder bedrock (Figure 27). Blue cod were observed mostly with sand/shell grit, sand/shell grit/gravel and boulders (Figure 27).

The main primary substrates observed in fish-dependent habitat observations were various forms of sand and grit and various forms of bedrock (Figure 27). However, using a ratio of the substrate category proportions observed between fish-dependent verses fish-independent habitat observations (i.e., substrate category occupancy in proportion to its availability), showed that blue cod were mainly associated with sand/shell grit, sand/shell grit/gravel, and jagged bedrock (Figure 27). Juvenile blue cod (under 20 cm) were most associated with forms of cobbles (Figure 27).

Secondary habitat structures
The main secondary habitat structures observed independently of fish was “no structure” (Figure 28). Blue cod of all size classes were also observed frequently with "no structure" and various forms of sponge (Figure 28). However, using the ratio of fish-dependent and fish-independent secondary habitat categories, shows that larger blue cod were most associated with bedrock and sponge, while smaller blue cod were most associated with algal turf, various forms of sponge and macro algae (Figure 28).

4 DISCUSSION

The 2012 blue cod potting survey was the first comparison of a full fixed and full random site survey design done at Banks Peninsula (Figure 7). This was the first random site survey and the fourth fixed site survey done in Banks Peninsula (Figure 6).

4.1 Fixed site survey design time series

For the fixed site survey, the overall catch rates of all blue cod (Table 5) and legal sized blue cod (at least 30 cm, Table 6) were similar to those recorded in the 2008 survey in the inshore strata 1, 3, 4, and 5 (See Figure 6). In 2012, there was an increase in catch rates over the entire survey area(up 67% for all blue cod and up 77% for legal sized blue cod) which was primarily driven by an unprecedented increase in the catch rates of blue cod in the southern offshore strata 7 (up 101% for all blue cod and up 114% for legal sized blue cod). However, there was a dramatic decline in catch rates in the smaller eastern offshore strata 6 (down 40% for all blue cod and down 38% for legal sized blue cod (Figure 6). Consequently, there is some concern about the variability since the catch rates of the offshore strata (6-7) and the high degree of weighting (by area) these strata have in determining the overall survey catch rates (See Table 1).

The overall CV for the 2012 fixed site survey catch rates was 18.1% for all blue cod and 19.5% for legal sized blue cod (Tables 5 and 6) which were notably higher than the overall CVs from previous Banks Peninsula fixed site surveys (5.7% to 7.7% for all blue cod, and 7.0% to 8.4% for legal sized blue cod (Beentjes and Carbines 2003, 2006, 2009).
Historical catch rates of blue cod in inshore strata have been relatively stable, and in the western inshore stratum (1) they have varied little since an initial decline from the 2002 survey (Figure 6). In contrast, the catch rates in stratum 2 (Akaroa Harbour entrance/headlands) have fluctuated considerably, with a general downward trend. Stratum 3 (west of the Pohatu marine reserve) catch rates are currently less than half of what was recorded in 2005 (down 56% for all blue cod and down 64% for legal sized blue cod). Further west in stratum 4 there have been similar declines in catch rates since 2005 (down 56% for all blue cod and down 58% for legal sized blue cod), while in stratum 5 (at the eastern end of Banks Peninsula) catch rates have remained relatively stable (Figure 6). The general conclusion is that apart from the relatively stable catch rates in the two strata at the ends of the inshore survey area (strata 1 and 5), the three inshore strata most utilised by recreational fishers have generally declining catch rates (Figure 6).

4.2 Comparisons of catch rates between survey designs

The rank order of catch rates of all blue cod among strata of the random site survey (i.e., strata 6, 7, 4, 3, 2, 1, 5) was not consistent with the rank order of strata in the fixed site survey (i.e., strata 7, 6, 4, 5, 3, 1, 2) (Tables 5 and 7). The rank order of strata catch rates of legal sized blue cod in the random site survey (i.e., strata7, 6, 5, 4, 3, 1, 2) was also not consistent with the strata rank order of the fixed site survey (i.e., strata 6, 7, 4, 3, 2, 1, 5) catch rates (Tables 6 and 8). Catch rates of all blue cod from the random site survey were 69% of the catch rates of the fixed site survey. For legal sized blue cod catch rates from the random site survey were 68% of the catch rates of the concurrent fixed site survey (Figure 7). However, the pattern of reduced catch in the random site survey was not consistent among strata for either all or legal sized blue cod, with random sites catching more than concurrent fixed sites in strata 2, 4, and 6 (Figure 7).

The overall CVs of the catch rates from the random site survey (over 30% - Tables 7 and 8) were almost twice the CVs from the fixed site survey (less than 20% - Tables 5 and 6). This suggests that the random site survey effort may not have been sufficient to constrain the variance of catch rates, particularly inshore (strata 1, 2 and 4). More specifically, catch rates varied more between random sites than between fixed sites and more random sites are required to achieve equivalent CVs in the Banks Peninsula survey. However, catch rates and CVs from a random site survey of five strata within Paterson Inlet on Stewart Island had about half the catch rate and twice the CVs of concurrently surveyed fixed sites (Carbines & Haist 2014). In another comparison of potting survey designs conducted in Pelorus Sound as part of the 2010 Marlborough Sounds survey, both catch rates and CVs were similar for fixed and random sites ((Beentjes & Carbines 2012). The 2010 Foveaux Strait random site blue cod survey also used a similar level of sampling effort to the 2012 Banks Peninsula random site survey, but the CVs of catch rates in Foveaux Strait were considerably lower (Carbines & Beentjes 2012). There is no simple relationship between random and fixed site survey catches as these appear to be quite area specific and are possibly related to the blue cod population size and the heterogeneity of benthic habitat in each survey area.

4.3 Reproductive condition

Observations of gonad stages were similar between fixed and random sites with most individuals in the early maturing stage, some running ripe and spent gonads found (Tables 11 and 12). This indicates that the timing of the survey (autumn) was at the conclusion of the spawning season and was consistent with the previous surveys done at a similar time of year (Beentjes & Carbines 2003, 2006, 2009). The proportion of running ripe phase individuals was similar at random sites (4%) and fixed sites (3%), suggesting that there is similar spawning periods at fixed and random sites (Tables 11 and 12). However, due to the timing of the survey only 19 fish were observed in the running ripe stage, it is not possible for this potting survey to contribute anything meaningful regarding the size at maturity.

4.4 Size and sex ratio

Length

Since the initial fixed site survey of Banks Peninsula in 2002 (Beentjes & Carbines 2003), blue cod from inshore strata have consistently been smaller than those from offshore strata (Beentjes and Carbines 2006, 2009). In the 2012 fixed site survey, the average length of blue cod from inshore strata was 8 cm smaller than those from offshore strata (Figure 9). The proportion of legal sized blue cod (30 cm and over) caught on the 2012 fixed site survey was 40% inshore and 74% offshore.

In the concurrent 2012 random site survey the average length blue cod from inshore strata was 11 cm smaller than those from offshore strata (Figure 9), and the proportion of legal sized blue cod caught was 30% inshore and 79% offshore. The random site survey caught proportionately more small blue cod (i.e., less than 20 cm) than the fixed site survey (Table 10, Figure 8), and this feature of random sites seems to be consistent between survey areas (fish taken from a random site survey in Paterson Inlet were also noticeably smaller than those from the concurrent fixed site survey (Carbines & Haist 2014)). The feature of having proportionally more larger fish at fisher selected fixed sites than at adjacent and concurrent random sites further highlights the potential bias in using fixed sites to describe the structure of blue cod in an area. As fishers select sites with the largest size and abundance of blue cod, these sites are likely to be in areas of high productivity that attract blue cod to them, potentially making them hyper-stable and less sensitive to fishing pressure than blue cod from the wider area.

While the results of the seven random sites done in the Pohatu marine reserve (nested between strata 2 and 3, See Figure 1) in 2012 have not been included in this report, it is interesting to note that the proportion of legal sized blue cod caught on the 2012 random site survey was 58% within the marine reserve and 36% in the pooled adjacent strata (Carbines 2017, see Appendix 18). This suggests that the low proportion of legal sized blue cod in open areas is a result of high fishing pressure, rather than the emigration of larger fish.

Sex

The overall sex ratio was 1:0.6 (M:F) at both fixed (62% males)and random (64% males) sites (Tables 9 and 10). Male bias was also more pronounced inshore among inshore strata for both fixed (68% male) and random (67% male) sites than at either offshore fixed (57% male) or random (58% males) sites (Tables 9 and 10).

For all blue cod inshore, the sex ratio was most skewed in the two eastern strata 4 and 5 for both fixed (1:0.3) and random (1:0.2–0.4) sites (Table 9 and 10). Sex ratios in offshore strata were more balanced in both fixed (1:0.8) and random (1:0.7) sites, notably more so at the eastern stratum 6 (1:1.1 at fixed sites, 1:1.0 at random sites) than at the southern stratum 7 (1:0.7 at fixed sites, 1:0.5 at random sites) (Tables 9 and 10).

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 (Tables 9 and 10) is consistent with the sex structure in a protogynous hermaphrodite. However, the male skewed sex ratios of legal sized blue cod in all inshore strata are contrary to an expected dominance of females resulting from higher selective fishing (MLS) removing the larger terminal sex males. Carbines (2004a), and subsequently Beentjes & Carbines (2005), hypothesize that the shift towards a higher proportion of males in heavily fished blue cod populations may be caused by removal of the inhibitory aggressive behavioural effects of large males resulting in a higher rate (and possibly earlier onset) of sex change by the remaining primary females (e.g., Kobayashi et al. 1993a, 1993b). This hypothesis is supported by the higher predominance of males at inshore sites, as this is where fishing pressure is likely to be highest and blue cod catch rates have not improved in any strata since the 2005 survey (Figure 6).

4.5 Population age structure

Scaled length frequency distributions were generally similar for fixed and random site surveys within inshore (Figures 13 and 14) and offshore areas (Figures 15 and 16). However, the average size of blue cod taken from inshore random sites was 1.6 cm smaller (0.5 years younger) than those taken from inshore fixed sites (Figures 11 and 12). At offshore random sites the average size of blue cod was 1.7 cm larger (1.4 years older) than those taken from offshore fixed sites, however, the mean weighted coefficient of variation was much higher offshore (Figures 15 and 16).

The proportion of blue cod that were legal sized (30 cm and over) among all inshore strata was 40% for fixed sites (up from 39% in 2008) and 30% for random sites. At offshore strata the proportion of legal sized blue cod was 74% at fixed sites (down from 84% in 2008) and 79% at random sites. Consequently, difference in the population structure of blue cod taken from concurrent fixed and random sites appears to be specific to the area surveyed. Making comparisons of the proportions of legal sized blue cod across years or areas is difficult because they are affected by both recruitment and fishing mortality.

The age distributions and total mortality estimates are based on scaled length data that were weighted (scaled) by stratum area (See Table 1). 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 are unevenly distributed in the DUV analysis (Section 3.9). 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 distributions show more clearly that at inshore random sites proportionately more small fish and fewer larger fish are caught than at inshore fixed sites (Figures 13 and 14). Inshore there are very few fish over 40 cm at either fixed or random sites, and the resulting population age structures show an abrupt decline on the right hand limb after eight years old and another after ten years old, with a low proportion of fish older than 11 years. At offshore random sites proportionately more large fish were caught than at offshore fixed sites (Figures 15 and 16). However, at both fixed and random sites there were many fish over 40 cm, and the resulting population age structures show a much more gradual decline on the right hand limb after eight years old, with a good proportion of fish older than 20 years.

4.6 Total mortality (*Z*)

In the 2012 Banks Peninsula potting survey, both fixed and random inshore sites yielded proportionately fewer older fish than both fixed and random offshore sites (Figure 17). The resulting mortality estimates (Z) from inshore sites (both fixed and random, Tables 16 and 19 respectively) were dramatically higher than those derived from offshore sites (both fixed and random, Tables 17 and 20 respectively). Because of the difference in population structure between survey areas, we suggest it may be appropriate to manage them separately.

Inshore fixed sites had a similar age composition to inshore random sites (Figure 17), and resulting mortality estimates (Z) were also similar (Tables 16 and 19). For the offshore sites, the random-site survey yielded slightly older fish than the fixed-site survey (Figure 17), resulting in slightly lower estimates of total mortality (Tables 17 and 20). Because of the difference in population structure between survey designs observed in this (and other surveys (e.g., Carbines & Haist 2014)), we suggest that it is also inappropriate to compare mortality estimates between random and fixed surveys.

Comparing temporally with the most recent 2008 Banks Peninsula fixed site potting survey estimates of Z for a fully-selected age of 8, the Z estimate of 0.74 for inshore strata (Beentjes & Carbines 2009) is higher than the equivalent inshore Z estimate of 0.62 from the 2012 survey (Table 16). The inference being that total mortality was reduced by 0.12 at inshore Banks Peninsula since 2008. However, it is worth noting that Z estimates for inshore Banks Peninsula were unusually high in 2008, and are currently more similar to Z estimates from 2002 (Z=0.53) and 2005 (Z=0.56). In contrast the 2012 offshore fixed site survey Z estimate (0.15) is identical to the equivalent 2008 estimate, and only 0.04 below a high of 0.19 estimated for the 2005 survey (Beentjes & Carbines 2009).

In spatial comparisons with the 2012 Banks Peninsula potting surveys Z estimates, all other potting survey Z estimates are considerably higher than the offshore Banks Peninsula area estimate (fixed sites Z=0.15, random sites Z=0.12), yet all other potting survey Z estimates are also well below the inshore Banks Peninsula area Z estimate (fixed sites Z=0.62, random sites Z=0.61 (with the exception of some areas in the Marlborough Sounds (Beentjes & Carbines 2012). Consequently, the inshore and offshore areas of Banks Peninsula represent the two extremes of mortality estimates from the MPI South Island potting survey network (i.e., the Marlborough Sounds (Beentjes & Carbines 2012), north Canterbury (Carbines & Beentjes 2009), north and south Otago (Beentjes & Carbines 2011, Carbines & Beentjes 2011a), Foveaux Strait (Carbines & Beentjes 2012), Paterson Inlet (Carbines & Haist 2014), Dusky Sound (Carbines & Beentjes 2011b).

Subsequent to these surveys, MPI developed a new age determination protocol (due to difficulties in ageing blue cod from the 2013 Marlborough Sounds potting survey) that is now used for potting surveys from all regions (Walsh 2017). Consequently, this may result in biased comparisons of both Z and $F_{\%SPR}$ with surveys that previously used a validated preceded (Carbines 2004b), and those using the new un-validated ageing protocol (Walsh 2017).

4.7 Stock status (spawning biomass per recruit ratio analyses)

The Ministry for Primary Industries *Harvest Strategy Standard* (Ministry of Fisheries 2011) 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 fishing mortality reference point for blue cod is F_{MSY}, which is the amount of fishing mortality that results in the maximum sustainable yield. A suggested proxy for F_{MSY} is in terms of spawning biomass per recruit, $F_{\%SPR}$. The Operational Guidelines for New Zealand's Harvest Strategy Standard' (Ministry of Fisheries 2011) includes the following table of recommended default values for $F_{\%SPR}$ and for B_{MSY} (expressed as $\%B_0$), based on stock productivity:

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 recommendation from the Southern Inshore Working Group, blue cod is categorised as a low productivity species, owing to complications related to sex change (particularly loss of females at high fishing pressure), which results in a spawning biomass per recruit target of 45%. In Banks Peninsula the spawning biomass per recruit estimates for the default M value of 0.14 were 24–25% for the inshore fixed site and random site surveys (Tables 21 and 23), indicating that the expected contribution to the spawning biomass over the lifetime of an average recruit has been reduced to about 25% of the contribution in the absence of fishing. The recent level of exploitation (F) for the inshore Banks Peninsula blue cod stock is above the F_{MSY} reference point. In contrast, for blue cod in the offshore Banks Peninsula the spawning biomass over the lifetime of an average recruit has been reduced to contribute 92% at fixed sites (Table 22) and 114% at random sites (Table 24) of the contribution in the absence of fishing. This recent level of exploitation (F) for the offshore Banks Peninsula blue cod stock is below the F_{MSY} reference point.

Spawner biomass per recruit values of over 100% were achieved because Z for offshore stocks was estimated to be lower than the assumed M of 0.14. Given that the offshore sites experience moderate fishing pressure, such low estimates of Z are surprising and may be the result of an incorrect assumption about M, or periodicity in recruitment, or inaccurate age determinations (i.e., over estimating age). As the otoliths for this study were prepared and read prior to the development of a new MPI Age Determination Protocol for blue cod (Walsh 2017), it is recommended that the estimates of Z and current Spawner Biomass Per Recruit ratios be accepted with caution.

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 spawning biomass per recruit values (Tables 21, 22, 23 and 24, Figures 18, 19, 20 and 21). A higher natural mortality (0.17) increased the spawning biomass at current *Z* relative to the unfished level. Conversely, a lower natural mortality (0.11) decreased the spawning biomass at current *Z* relative to the unfished level by a similar proportion.

4.8 Comparison of pot catch and video 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 that blue cod catch rates were 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).

For the 2012 Banks Peninsula potting survey we used concurrent observations of blue cod abundance and environmental descriptions from a flown dropped underwater video (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?

In Banks Peninsula, twenty five species were observed using DUV while only eight were caught by pots concurrently surveyed (Tables 26, 27). Compared to the DUV, pots caught very few blue cod less than 20 cm and proportionately fewer below the legal size (30 cm). In contrast pots caught a higher proportion of blue cod over the legal size compared to the DUV (Figure 23). For blue cod below 30 cm, the current study showed a very poor relationship between what the DUV observed and what pots (plan 2) caught (Figures 25 and 26). However, for blue cod over 30 cm there was a good relationship between DUV observations and what pots caught (Figures 25 and 26). However, due to weather and water visibility restrictions, only six sites could be concurrently DUV surveyed in the Banks Peninsula potting survey so this comparison is not strong and should be accepted with caution

Compared to other comparisons of DUV and potting (normally done across 20 sites), Banks Peninsula had a much better relationship between observed blue cod (30 cm and over) densities and catch rates (pot plan 1) than those observed by Cole et al. (2001) using SCUBA counts of blue cod in the Marlborough Sounds. The 2012 Bank Peninsula study also provided a better correlation coefficient between blue cod densities from DUV and pot catches in the Foveaux Strait (pot plan 2 - Carbines & Beentjes 2012), Paterson Inlet (pot plan 2 - Carbines & Haist 2014) and in the Marlborough Sounds (pot plan 1 - Beentjes & Carbines 2012).

In Banks Peninsula there was one instance of high densities observed with concurrent low catch rates, and several sites where fish were caught when few were observed (see Figure 24). It appears that either pots are attracting blue cod in from a distance greater than the area surveyed by the DUV (i.e., transects are too short), or that the pot capture distance is quite small and blue cod populations are highly clumped within the survey area. The relationship between catch and count (i.e., catchability) may however simply be highly variable over time and/or location. Given the high degree of unexplained variability among stratum catch rates in the current potting survey time series (See Figure 6), and the consistently poor relationship between observed densities of blue cod and subsequent pot catch rates (Cole et al. 2001, Beentjes & Carbines 2012, Carbines & Beentjes 2012, Carbines & Haist 2014) there is considerably uncertainty in the value of potting surveys generally (Stephenson et al. 2009). To help resolve this uncertainty we recommend that these catch-verses-count comparisons continue at several survey areas over several occasions, and that these comparisons use a wider DUV sample area or increase the number of DUV transects within the sample area closer to the pots.

Importance of recording habitat for blue cod potting surveys

The primary substrate most frequently observed with blue cod were sand with shell, grit or gravel (Figure 27). The secondary benthic habitat most frequently observed with blue cod was "no structure or various forms of sponge (Figure 28). However, by 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 were found in association with at a higher rate than in the benthic environment as a whole. Blue cod were most often found with sand/shell grit (Figure 27) with patches of bedrock and sponge (Figure 28).

Data on fish abundance and habitat from video provide information regarding environmental variables that appear to affect blue cod density and size structure. It identifies 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: Banks Peninsula 2012 survey stratum area, number of phase 1 and 2 sites, pot lifts, and depth of fisher selected fixed sites. All DUV sites are paired to a subsequent set of six survey pots deployed immediately after filming. *Note that previous fixed site surveys used only the basic coastline length to weight overall catch rates (Beentjes & Carbines 2003, 2006, & 2009).

	Size of strata*	Number of Selected sites (0)		Number of pot lifts (0)	Depth (m)		DUV
Stratum	Area (km^2)	Phase 1	Phase 2	Total	Mean	Range	Sites
1	3.98	5		30	21	13–30	
2	4.72	5		30	25	17–32	
3	3.98	5		30	23	12–40	1
4	3.89	5		30	17	5–33	1
5	4.08	5		30	15	7–26	
6	8.32	5		30	85	77–91	1
7	35.13	5	5	60	76	67–80	1
Total	64.1	35	5	240	42	5–91	4

Table 2: Banks Peninsula 2012 survey stratum area, number of phase 1 and 2 sites, pot lifts, and depth of random sites. All DUV sites are paired to a subsequent set of six survey pots deployed immediately after filming.

	Size of strata	Number of Random sites		Number of pot lifts	Depth (m)		DUV
Stratum	Area (km^2)	Phase 1	Phase 2	Total	Mean	Range	Sites
1	3.98	5		30	16	5–25	
2	4.72	5		30	25	19–36	
MR	2.15	7		42	19	5–35	2
3	3.98	5		30	18	9–31	
4	3.89	5		30	17	7–39	
5	4.08	5		30	11	6–16	
6	8.32	5		30	85	79–88	
7	35.13	5	5	60	76	70–81	
Total	66.25	42	5	282	37	5–88	2

Table 3: Catch weights, numbers of blue cod, bycatch species, and percentage of total weight from the 2012 fisher selected fixed sites (n=40).

Common name	Scientific name	Catch (kg)	Number	Percent of total catch
Blue cod	*Parapercis colias*	684.7	1096	81.8
Banded wrasse	*Notolabrus fucicola*	79.3	126	9.5
Octopus	*Octopus cordiformis*	22.5	4	2.7
Scarlet wrasse	*Pseudolabrus miles*	11.8	27	1.4
Sea perch	*Helicolenus percoides*	11.2	20	1.3
Spotty	*Notolabrus celidotus*	10.8	85	1.3
Girdled wrasse	*Notolabrus cinctus*	8.5	23	1.0
Leather Jackets	*Parika scaber*	2.9	11	0.3
Red cod	*Pseudophycis bachus*	2.1	7	0.3
Tarakihi	*Nemadactylus macropterus*	1.8	7	0.2
Hagfish	*Eptatertus cirrhatus*	0.8	1	0.1
Pigfish	*Congiopodus leucopaecilus*	0.3	1	<0.1
Total		836.9	1410	100.00

Table 4: Catch weights, numbers of blue cod, bycatch species, and percentage of total weight from the 2012 random sites (n=40). Marine reserve data not included (see Carbines 2017).

Common name	Scientific name	Catch (kg)	Number	Percent of total catch
Blue cod	*Parapercis colias*	539.4	898	75.1
Banded wrasse	*Notolabrus fucicola*	98.6	152	13.7
Octopus	*Octopus cordiformis*	29.8	4	4.1
Scarlet wrasse	*Pseudolabrus miles*	11.8	26	1.6
Sea perch	*Helicolenus percoides*	12.6	68	1.8
Spotty	*Notolabrus celidotus*	8.2	17	1.1
Girdled wrasse	*Notolabrus cinctus*	5.6	15	0.8
Leather Jackets	*Parika scaber*	4.2	26	0.6
Red cod	*Pseudophycis bachus*	2.9	8	0.4
Tarakihi	*Nemadactylus macropterus*	2.1	3	0.3
Hagfish	*Eptatertus cirrhatus*	1.4	4	0.2
Pigfish	*Congiopodus leucopaecilus*	1.1	1	0.2
Total		718.5	1224	100.00

Table 5: Mean catch rates for all blue cod caught in the 2012 Banks Peninsula fisher-defined fixed sites survey. Catch rates are expressed as $kg.pot^{-1}$ and s.e. and CV are set-based estimates. s.e., standard error, CV coefficient of variation.

Stratum	Sites	Pot lifts (N)	Mean (kg/pot)	s.e.	CV (%)
1	5	30	1.01	0.40	39.87
2	5	30	0.60	0.29	48.42
3	5	30	1.58	0.17	10.50
4	5	30	1.81	0.45	24.73
5	5	30	1.78	0.56	31.51
6	5	30	3.49	0.89	25.51
7	10	60	6.28	1.41	22.42
Overall	40	240	4.32	0.78	18.09

Table 6: Mean catch rates for blue cod 30 cm and over (MLS in BCO 3) caught in the 2012 Banks Peninsula fisher-defined fixed sites survey. Catch rates are expressed as $kg.pot^{-1}$ and s.e. and CV are set-based estimates. s.e., standard error, CV coefficient of variation.

Stratum	Sites	Pot lifts (N)	Mean (kg/pot)	s.e.	CV (%)
1	5	30	0.78	0.37	47.62
2	5	30	0.32	0.20	61.35
3	5	30	1.00	0.29	28.81
4	5	30	1.36	0.45	33.35
5	5	30	1.51	0.37	24.52
6	5	30	3.55	0.92	25.77
7	10	60	6.02	1.43	23.80
Overall	40	240	4.08	0.80	19.54

Table 7: Mean catch rates for all blue cod caught in the 2012 Banks Peninsula random site survey. Catch rates are expressed as kg.pot^{-1} and s.e. and CV are set-based estimates. s.e., standard error, CV coefficient of variation. Marine reserve data not included (see Carbines 2017).

Stratum	Sites	Pot lifts (N)	Mean (kg/pot)	s.e.	CV (%)
1	5	30	0.47	0.16	33.52
2	5	30	1.29	0.31	24.09
3	5	30	1.53	0.64	42.06
4	5	30	2.89	0.78	26.86
5	5	30	0.33	0.19	57.22
6	5	30	4.09	1.07	26.11
7	10	60	3.69	1.67	45.25
Overall	40	240	2.97	0.93	31.28

Table 8: Mean catch rates for blue cod 30 cm and over (MLS) caught in the 2012 Banks Peninsula random site survey. Catch rates are expressed as kg.pot^{-1} and s.e. and CV are set-based estimates. s.e., standard error, CV coefficient of variation. Marine reserve data not included (see Carbines 2017).

Stratum	Sites	Pot lifts (N)	Mean (kg/pot)	s.e.	CV (%)
1	5	30	0.29	0.12	41.36
2	5	30	0.45	0.24	54.84
3	5	30	0.89	0.47	52.62
4	5	30	2.12	0.59	27.97
5	5	30	0.28	0.15	52.45
6	5	30	4.30	1.14	26.42
7	10	60	3.61	1.69	46.67
Overall	40	240	2.79	0.94	33.59

Table 9: Mean lengths of blue cod in the 2012 Banks Peninsula fisher defined fixed site survey, by strata and sex: m, males; f, female. The sex ratio is shown as the number of females per male, and the percent of males (shown in brackets) is also given for all blue cod and those over the MLS (30 cm). The data is also summarised by groupings of inshore (1-5) and offshore (6-7) strata (See Figure 1).

			Length (cm)			Sex ratio M:F (% male)	
Strata	Sex	N	Mean	Minimum	Maximum	All blue cod	≥ 30 cm
1	M	52	28.2	18	40	1:0.7(58.4)	1:0.3(78.8)
	F	37	23.8	16	36		
2	M	26	27.6	19	40	1:0.9(53.1)	1:0.3(78.6)
	F	23	25.7	17	32		
3	M	98	27.3	15	41	1:0.5(64.9)	1:0.1(87.2)
	F	53	24.3	15	32		
4	M	96	28.8	17	46	1:0.3(74.4)	1:0.2(86.4)
	F	33	25.7	17	34		
5	M	92	31.2	18	42	1:0.3(76.7)	1:<0.1(96.7)
	F	28	24.5	17	31		
6	M	43	42.1	26	57	1:1.1(48.3)	1:0.9(52.6)
	F	96	36.8	22	50		
7	M	274	36.1	14	55	1:0.7(58.4)	1:0.6(64.3)
	F	195	32.2	11	47		
Inshore	M	364	28.8	15	46	1:0.5(67.7)	1:0.1(87.8)
1-5	F	174	24.7	15	36		
Offshore	M	317	36.9	14	57	1:0.8(56.8)	1:0.6(62.1)
6-7	F	241	33.0	11	50		
Overall (un-weighted)	M	681	32.6	14	57	1:0.6(62.1)	1:0.4(70.9)
	F	415	29.5	11	50		

Table 10: Mean lengths of blue cod in the 2012 Banks Peninsula random site survey(marine reserve catch not included, see Carbines 2017), by strata and sex: m, males; f, female. The sex ratio is shown as the number of females per male, and the percent of males (shown in brackets) is also given for all blue cod and those over the MLS (30 cm). The data is also summarised by groupings of inshore (1-5) and offshore (6-7) strata (See Figure 1).

			Length (cm)			Sex ratio M:F (% male)	
Strata	Sex	N	Mean	Minimum	Maximum	All blue cod	≥ 30 cm
1	M	28	26.1	17	40	1:0.7(59.6)	1:0.1(91.7)
	F	19	21.3	16	30		
2	M	85	24.7	17	43	1:0.7(57.8)	1:0.1(93.3)
	F	62	21.0	15	30		
3	M	101	26.9	17	41	1:0.5(69.2)	1:0.1(89.5)
	F	45	23.0	15	32		
4	M	134	30.2	18	42	1:0.4(71.3)	1:0.1(91.2)
	F	54	25.9	17	33		
5	M	26	27.5	18	38	1:0.2(86.7)	1:0.1(92.9)
	F	4	24.5	17	30		
6	M	51	43.2	27	55	1:1.0(50.5)	1:0.8(54.5)
	F	50	37.0	24	48		
7	M	147	38.0	16	53	1:0.6(61.5)	1:0.4(70.6)
	F	92	32.5	11	54		
Inshore	M	374	27.6	17	43	1:0.5(67.0)	1:0.1(88.2)
1-5	F	184	23.0	15	33		
Offshore	M	198	39.3	16	55	1:0.7(58.2)	1:0.3(78.1)
6-7	F	142	34.1	12	54		
Overall (un-weighted)	M	572	31.6	16	55	1:0.6(63.7)	1:0.3(75.3)
	F	326	27.9	12	54		

Table 11: Gonad stages of Banks Peninsula blue cod in 2012 fixed sites. 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	4.1	88.4	5.0	1.5	1.0	681
Females	4.6	78.1	10.6	0.0	6.7	415

Table 12: Gonad stages of Banks Peninsula blue cod in 2012 random sites. 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 (marine reserve catch not included).

	Gonad stage (%)					
	1	2	3	4	5	N
Males	6.3	86.2	5.2	1.2	1.0	572
Females	2.1	82.2	11.0	0.6	4.0	326

Table 13: Otolith raw data used in the catch at age, *Z* estimates, and SPR analyses for both the fixed and random 2012 Banks Peninsula inshore sites (strata 1-5, see Figure 1).

	No.	Length of aged fish (cm)			Age (years)		
Survey	otoliths	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Total	240	27.5	15	46	6.5	2	20
Male	146	29.8	15	46	7.3	2	20
Female	94	23.8	15	36	5.3	2	11

Table 14: Otolith raw data used in the catch at age, *Z* estimates, and SPR analyses for both the fixed and random 2012 Banks Peninsula offshore sites (strata 6-7, see Figure 1).

	No.	Length of aged fish (cm)			Age (years)		
Survey	otoliths	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Total	311	35.8	11	56	13.4	2	38
Male	166	37.7	14	56	13.4	2	35
Female	145	33.6	11	54	13.3	2	38

Table 15: Blue cod total mortality estimates (*Z*) with 95% confidence intervals and corresponding spawning biomass per recruit ratios (assuming M=0.14) for ages of recruitment (AgeR) from 5 to 10 for the 2012 Banks Peninsula fixed site survey. Analyses exclude the marine reserve data.

		Confidence intervals		
AgeR	*Z*	Lower	Upper	%SPR
5	0.15	0.12	0.20	90%
6	0.16	0.13	0.22	83%
7	0.17	0.13	0.23	78%
8	0.16	0.13	0.22	82%
9	0.15	0.11	0.20	92%
10	0.16	0.12	0.21	88%

Table 16: Blue cod total mortality estimates (*Z*) with 95% confidence intervals and corresponding spawning biomass per recruit ratios (assuming M=0.14) for ages of recruitment (AgeR) from 5 to 10 for the 2012 Banks Peninsula inshore fixed site survey (strata 1-5, see Figure 1).

		Confidence intervals		
AgeR	*Z*	Lower	Upper	%SPR
5	0.39	0.27	0.56	35%
6	0.47	0.33	0.70	30%
7	0.60	0.40	0.91	25%
8	0.62	0.42	0.93	24%
9	0.46	0.30	0.70	31%
10	0.47	0.30	0.74	30%

Table 17: Blue cod total mortality estimates (*Z*) with 95% confidence intervals and corresponding spawning biomass per recruit ratios (assuming M=0.14) for ages of recruitment (AgeR) from 5 to 10 for the 2012 Banks Peninsula offshore fixed site survey (strata 6-7, see Figure 1).

		Confidence intervals		
AgeR	*Z*	Lower	Upper	%SPR
5	0.13	0.10	0.17	107%
6	0.15	0.11	0.20	96%
7	0.15	0.12	0.21	89%
8	0.15	0.12	0.21	89%
9	0.15	0.12	0.20	92%
10	0.16	0.12	0.21	87%

Table 18: Blue cod total mortality estimates (*Z*) with 95% confidence intervals and corresponding spawning biomass per recruit ratios (assuming M=0.14) for ages of recruitment (AgeRec) from 5 to 10 for the 2012 Banks Peninsula random site survey. Analyses exclude the marine reserve stratum data.

		Confidence intervals		
AgeR	*Z*	Lower	Upper	%SPR
5	0.14	0.10	0.18	103%
6	0.14	0.11	0.19	97%
7	0.15	0.11	0.20	95%
8	0.14	0.11	0.19	102%
9	0.13	0.10	0.17	113%
10	0.13	0.10	0.18	107%

Table 19: Blue cod total mortality estimates (*Z*) with 95% confidence intervals and corresponding spawning biomass per recruit ratios (assuming M=0.14) for ages of recruitment (AgeR) from 5 to 10 for the 2012 Banks Peninsula inshore random site survey (strata 1-5, see Figure 1).

		Confidence intervals		
AgeR	*Z*	Lower	Upper	%SPR
5	0.42	0.29	0.63	32%
6	0.48	0.34	0.71	29%
7	0.61	0.41	0.91	25%
8	0.61	0.41	0.93	25%
9	0.44	0.29	0.69	31%
10	0.49	0.31	0.78	28%

Table 20: Blue cod total mortality estimates (*Z*) with 95% confidence intervals and corresponding spawning biomass per recruit ratios (assuming M=0.14) for ages of recruitment (AgeR) from 5 to 10 for the 2012 Banks Peninsula offshore random site survey (strata 6-7, see Figure 1).

		Confidence intervals		
AgeR	*Z*	Lower	Upper	%SPR
5	0.11	0.09	0.15	133%
6	0.12	0.09	0.16	120%
7	0.13	0.10	0.17	112%
8	0.13	0.10	0.16	114%
9	0.13	0.10	0.17	114%
10	0.13	0.10	0.17	108%

Table 21: Mortality rates and spawning biomass per recruit ratios, assuming an age of recruitment of 8, at three values of M (natural mortality) for the 2012 Banks Peninsula inshore fisher-selected fixed sites survey. Z=total mortality.

M	Z	%SPR
0.11	0.62	18%
0.14	0.62	24%
0.17	0.62	31%

Table 22: Mortality rates and spawning biomass per recruit ratios, assuming an age of recruitment of 9, at three values of M (natural mortality) for the 2012 Banks Peninsula offshore fisher-selected fixed sites survey. Z=total mortality.

M	Z	%SPR
0.11	0.15	69%
0.14	0.15	92%
0.17	0.15	116%

Table 23: Mortality rates and spawning biomass per recruit ratios, assuming an age of recruitment of 8, at three values of M (natural mortality) for the 2012 Banks Peninsula inshore random site survey. Z=total mortality.

M	Z	%SPR
0.11	0.61	19%
0.14	0.61	25%
0.17	0.61	31%

Table 24: Mortality rates and spawning biomass per recruit ratios, assuming an age of recruitment of 9, at three values of M (natural mortality) for the 2012 Banks Peninsula offshore random site survey. Z=total mortality.

M	Z	%SPR
0.11	0.13	85%
0.14	0.13	114%
0.17	0.13	143%

Table 25: Drop 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
Sites	6	6
Stations	33	36
Habitat sections	141	-
Habitat quadrats	689	-
Total transects length	25.7 km	-
Mean transect length	829 m (± 36.0)	-
Mean transect width	2.4 m (± 0.2)	-
Total area swept	58 624.3 m^2	
Blue cod	509 *	227

Table 26: Pot catch, numbers of blue cod, bycatch species, and percentage of total numbers from the 3 fixed and 3 random potted video sites. Bracketed numbers are the proportion of catch per site selection method (fixed or random).

Common name	Scientific name	Fixed Sites	Random Sites	Total Number	Percent catch
Blue cod	*Parapercis colias*	132	95	227	78.3
Banded wrasse	*Notolabrus fucicola*		25	25	8.6
Girdled wrasse	*Notolabrus cinctus*	8	4	12	4.1
Spotty	*Notolabrus celidotus*	7	2	9	3.1
Scarlet wrasse	*Pseudolabrus miles*	5	2	7	2.4
Sea perch	*Helicolenus* spp		5	5	1.7
Leather jacket	*Parika scaber*	4		4	1.4
Blue moki	*Latridopsis ciliaris*	1		1	0.3
Total		168	159	327	100.0

Table 27: Drop underwater video observed numbers of blue cod, bycatch species, and percentage of total numbers from the 3 fixed and 3 random potted video sites. The numbers in parenthesis are the proportion of observations per site selection method (random or fixed). *=total does not include unidentified species.

Common name	Scientific name	Fixed Sites	Random Sites	Total Number	Percent of total catch
Blue cod	*Parapercis colias*	201	308	509	29.0
Sea perch	*Helicolenus* spp.	191	133	324	18.4
Hapuku	*Polyprion oxygeneios*	0	209	209	11.9
Spotty	*Notolabrus celidotus*	54	146	200	11.4
Scarlet wrasse	*Pseudolabrus miles*	74	72	146	8.3
Butterfly perch	*Caesioperca lepidoptera*	50	36	86	4.9
Blue moki	*Latridopsis ciliaris*	32	47	79	4.5
Girdled wrasse	*Notolabrus cinctus*	19	48	67	3.8
Skate	*Raja* spp.	28	9	37	2.1
Banded wrasse	*Notolabrus fucicola*	7	18	25	1.4
Carpet shark	*Cephaloscyllium isabellum*	13	0	13	0.7
Tarakihi	*Nemadactylusma cropterus*	0	13	13	0.7
Butterfish	*Odax pullus*	0	9	9	0.5
Flat fish	*Rhombosolea* spp.	4	4	8	0.5
Slender roughy	*Optivis elongatus*	0	7	7	0.4
Sweep	*Scorpis lineolatus*	7	0	7	0.4
Opalfish	*Hemerocoetes* spp.	0	4	4	0.2
Red cod	*Pseudophycis bachus*	1	2	3	0.2
Rig	*Mustelus lenticulatus*	3	0	3	0.2
Southern pigfish	*Congiopodus leucopaecilus*	1	1	2	0.1
Gurnard	*Chelidonichthys kumu*	0	2	2	0.1
Leather jacket	*Parika scaber*	1	1	2	0.1
Rock lobster	*Jasus edwardsii*	1	0	1	0.1
Elephant fish	*Callorhinchus milii*	0	1	1	0.1
Trumpeter	*Latris lineata*	0	1	1	0.1
Unidentified		*3*	*31*	*34*	
Total*		687	1070	1757	100.0%

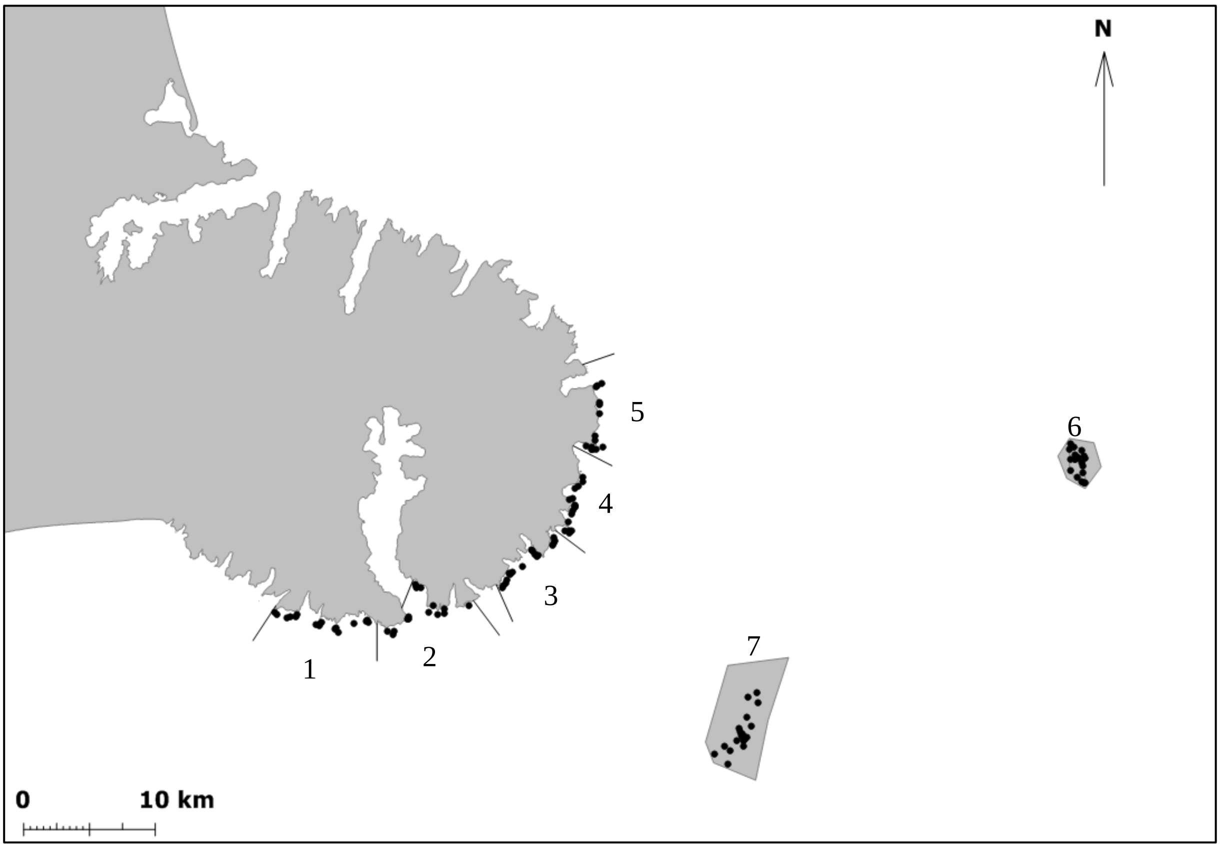


Figure 1: Banks Peninsula potting survey area consisting of five inshore (1-5) and two offshore strata (6-w7). The location of all 122 possible fixed sites (●) determined in 2002 (Beentjes & Carbines 2003) are shown. Note that the offshore strata shown here are based on a sonar survey of rocky seabed done in 2012 (see Section 2.2 Survey Area) and differ from the stylised offshore strata areas shown previously (Beentjes & Carbines 2003, 2006, 2009).

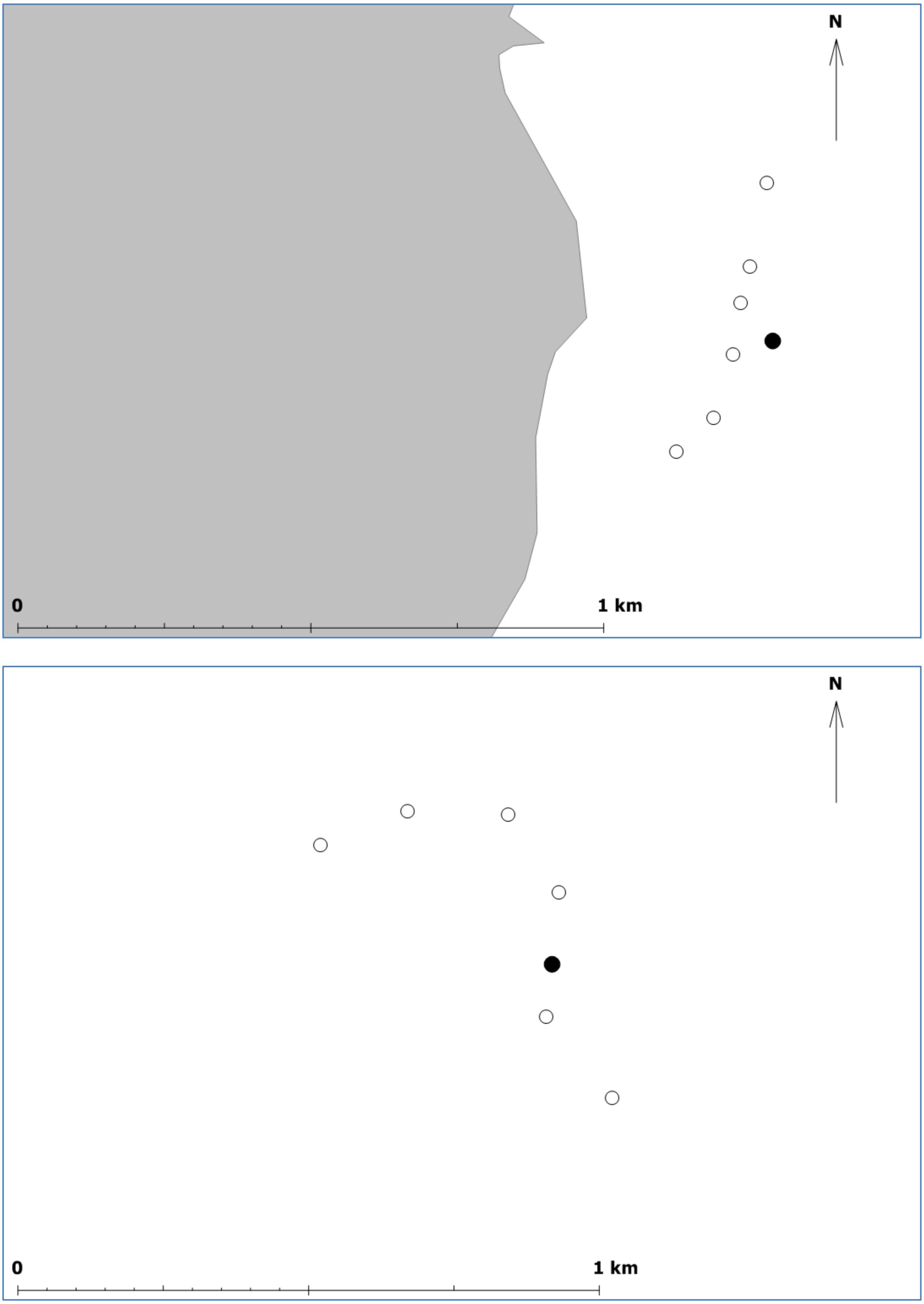


Figure 2: Placement of pots (○) and ADCP (●) at typical inshore(above) and offshore(below) fixed site.

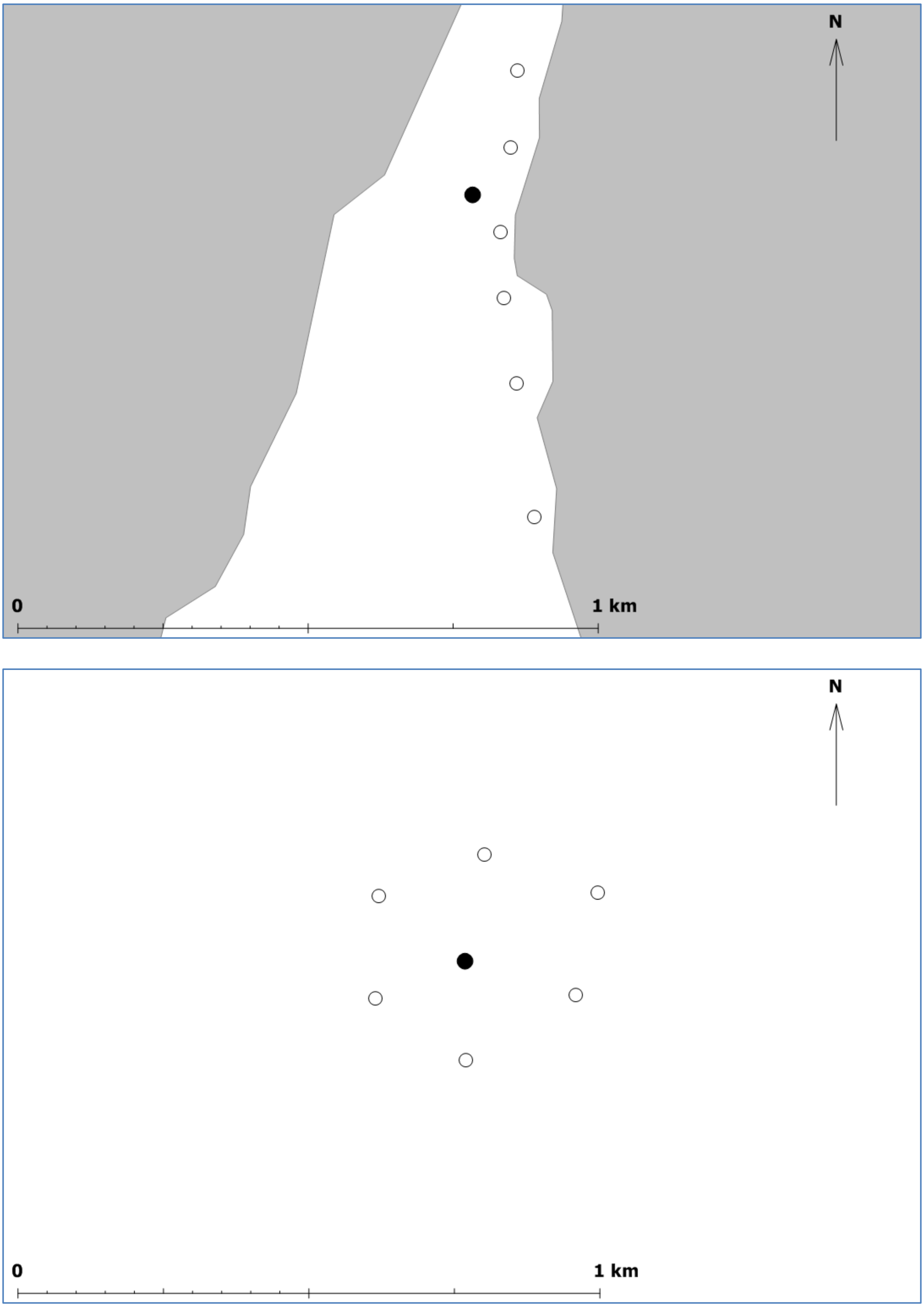


Figure 3: Placement of pots (○) and ADCP (●) at typical inshore(above) and offshore (below) random site.

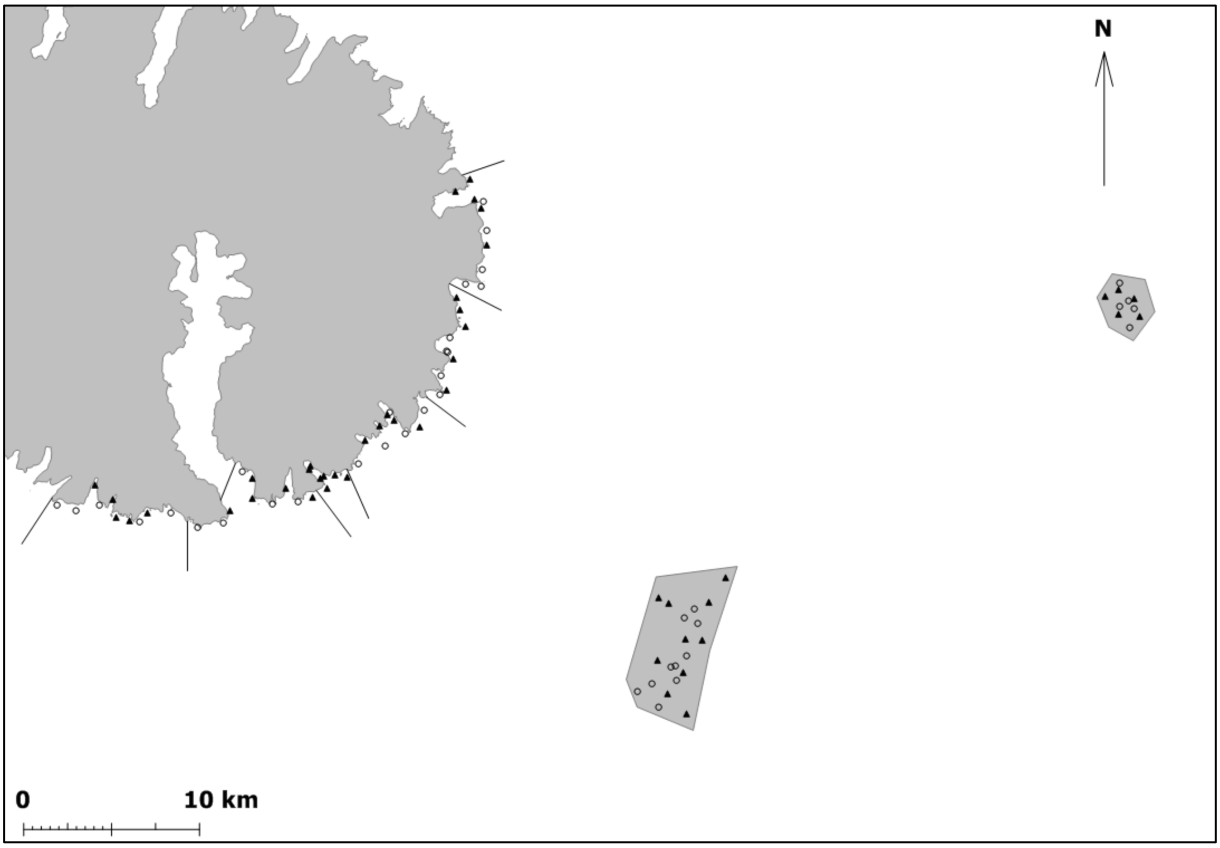
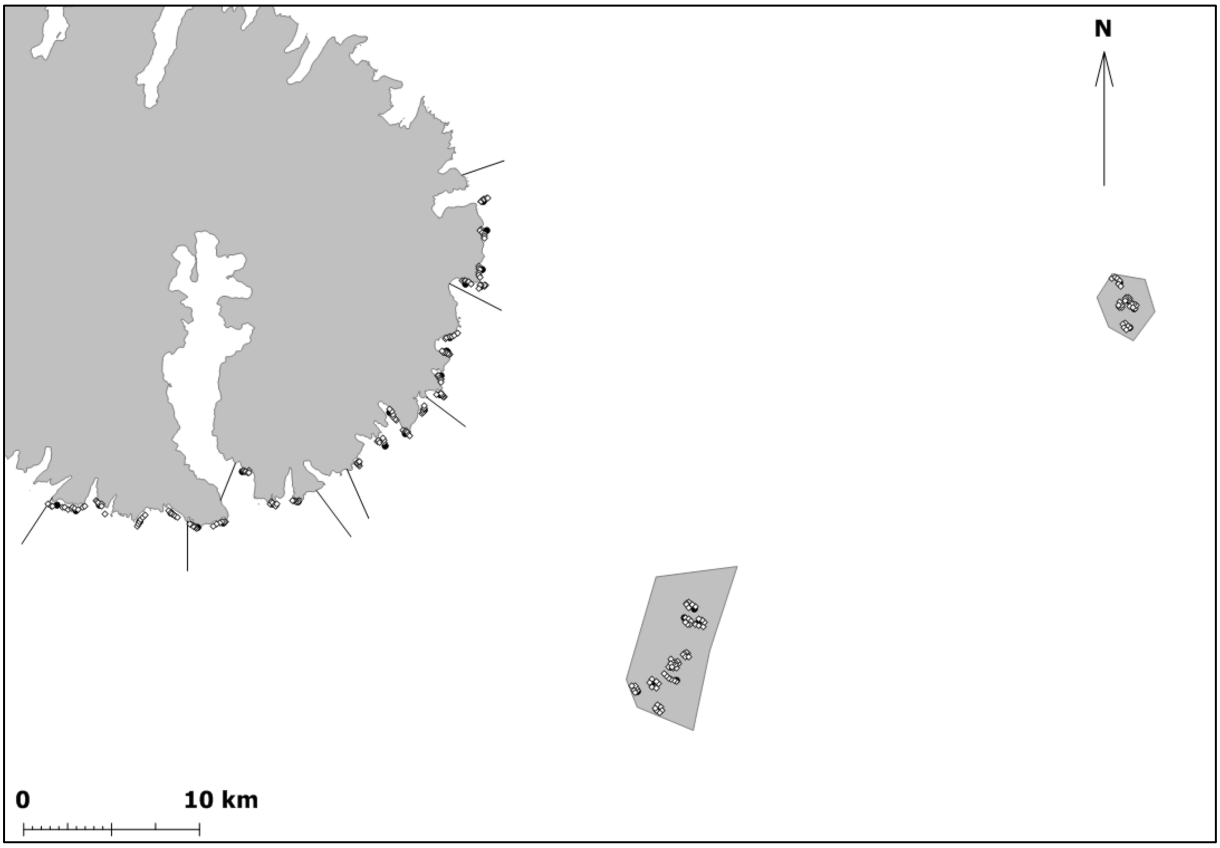


Figure 4: Fixed (○) and random (▲) site locations surveyed in the 2012 Banks Peninsula survey.



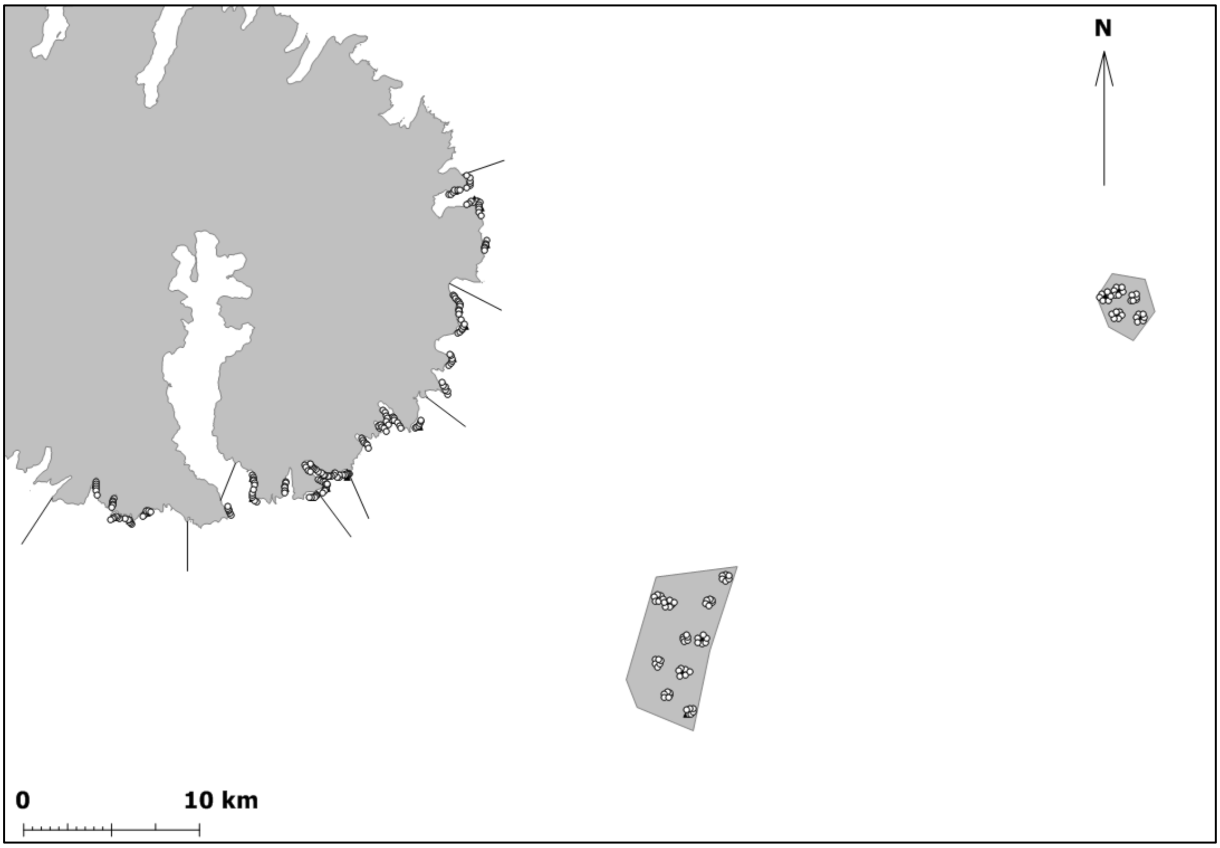


Figure 5: Fixed (above) and random (below) stations (6 pots ○ and an ADCP ●) surveyed in the 2012 Banks Peninsula survey.

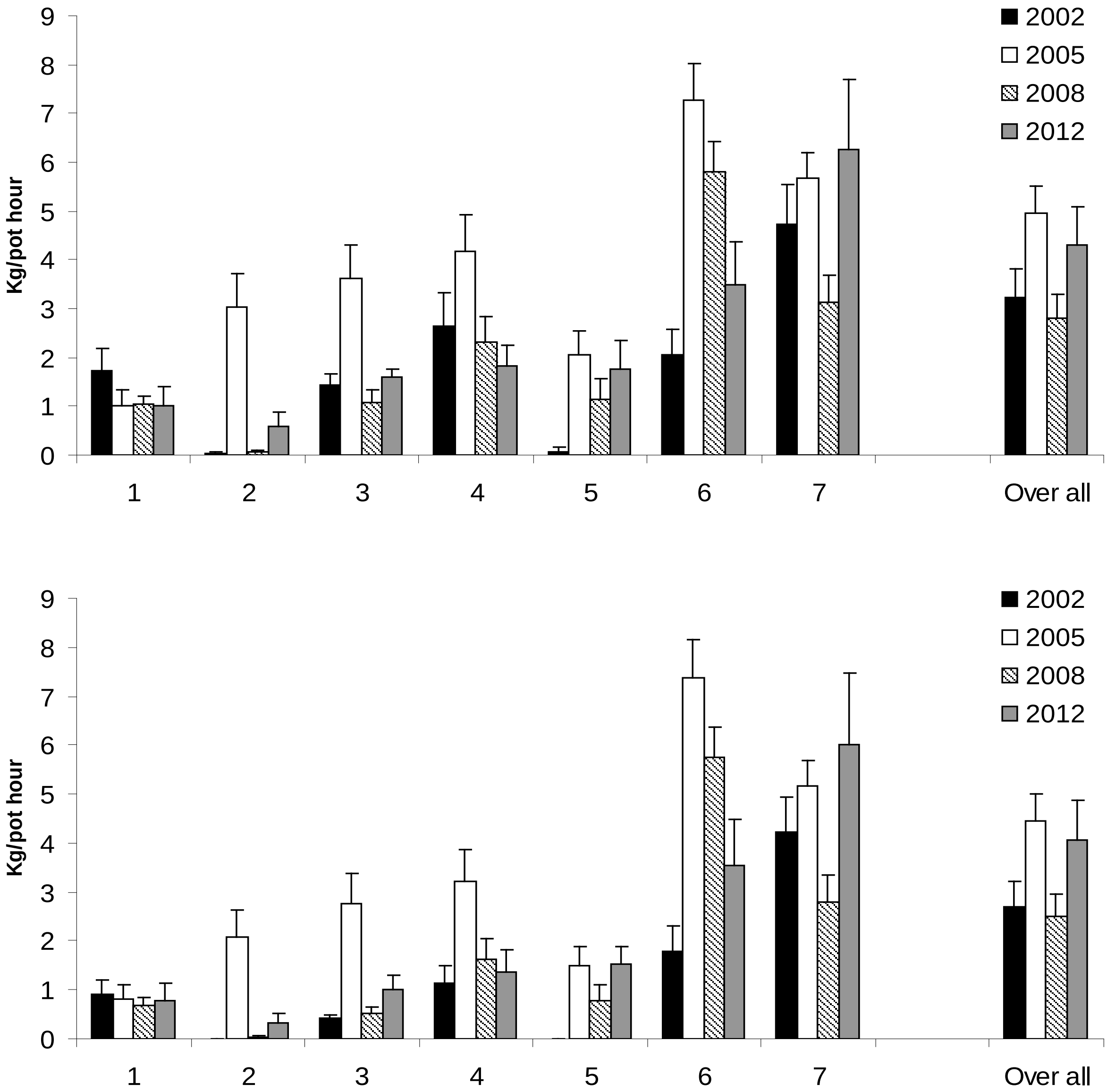
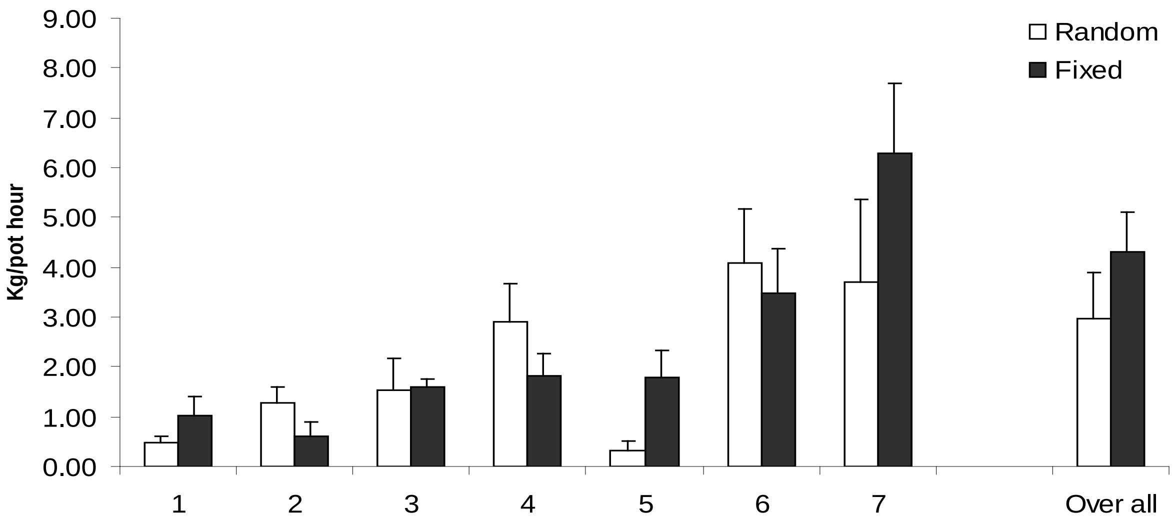


Figure 6: Catch rates (kg.pot^{-1}) and 95% confidence intervals for all blue cod (above) and those 30 cm and over (below)from the 2002, 2005, 2008 and 2012 Banks Peninsula fisher selected fixed site surveys.



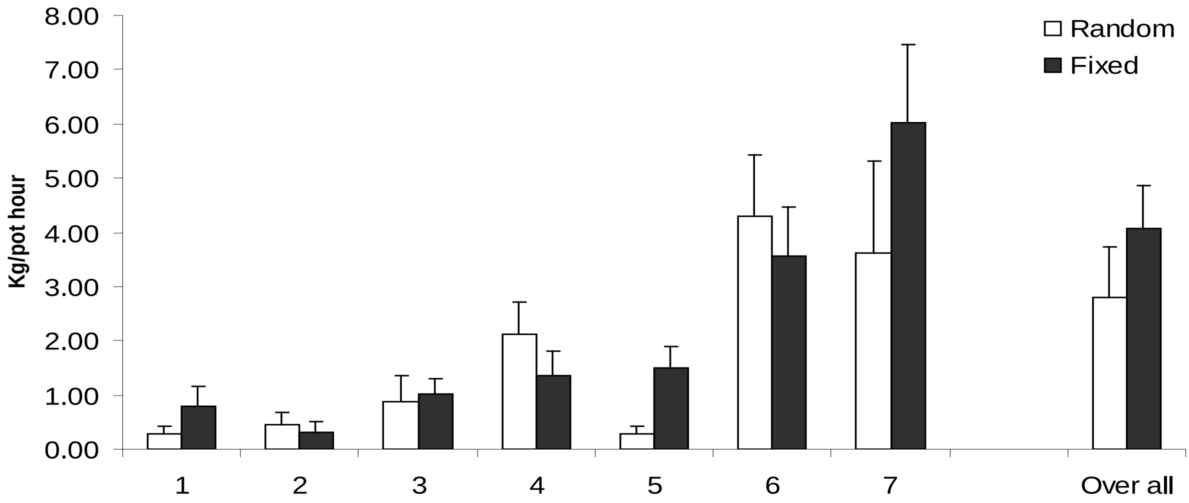


Figure 7: Catch rates (kg.pot^{-1}) and 95% confidence intervals for all blue cod (above) and those 30 cm and over (below) from the 2012 Banks Peninsula random site and fisher selected fixed site surveys.

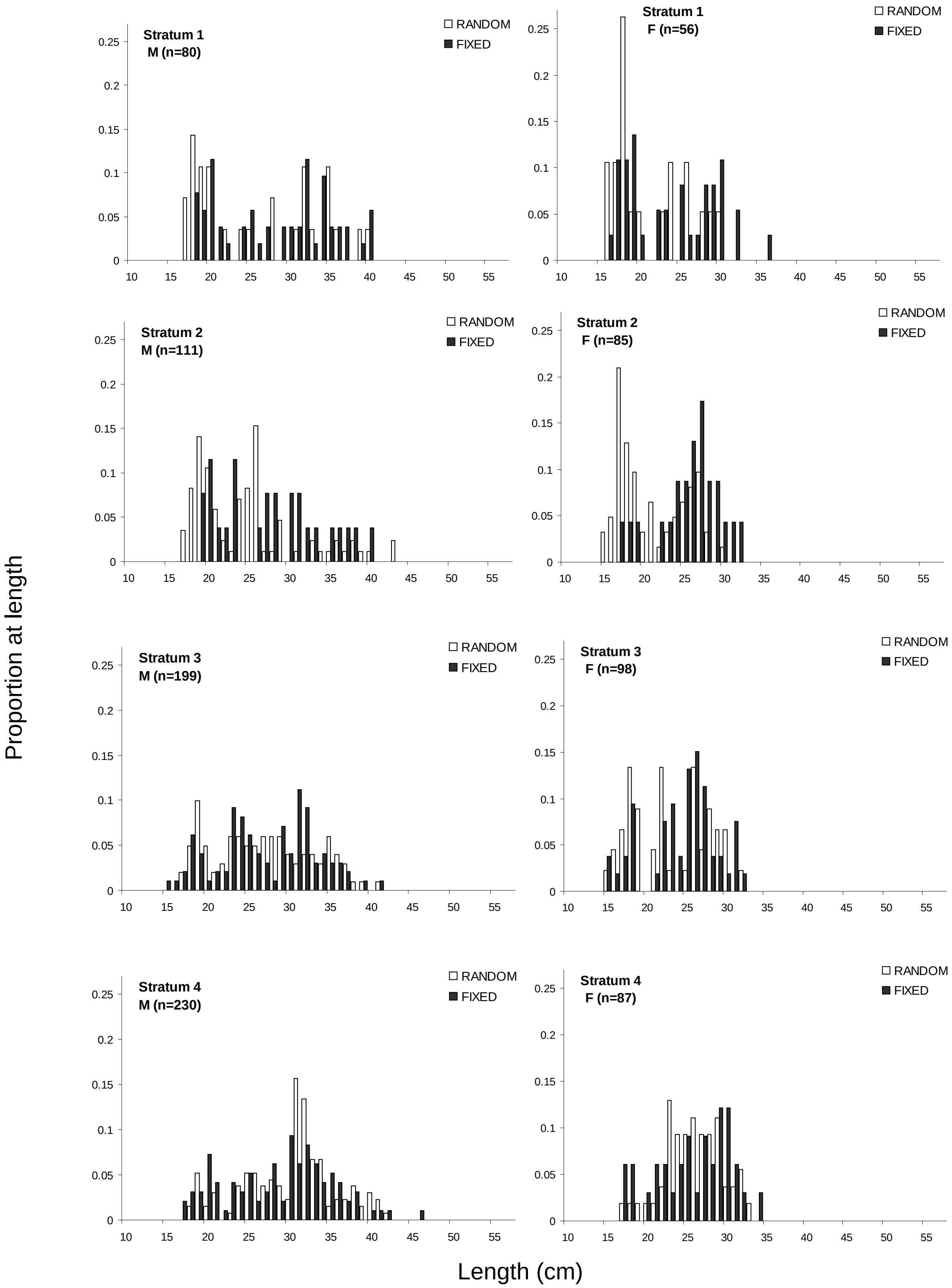


Figure 8: Unscaled proportion length frequency distributions by sex within stratum for fixed and random sites. Proportions for each sex within each stratum sum to 1.

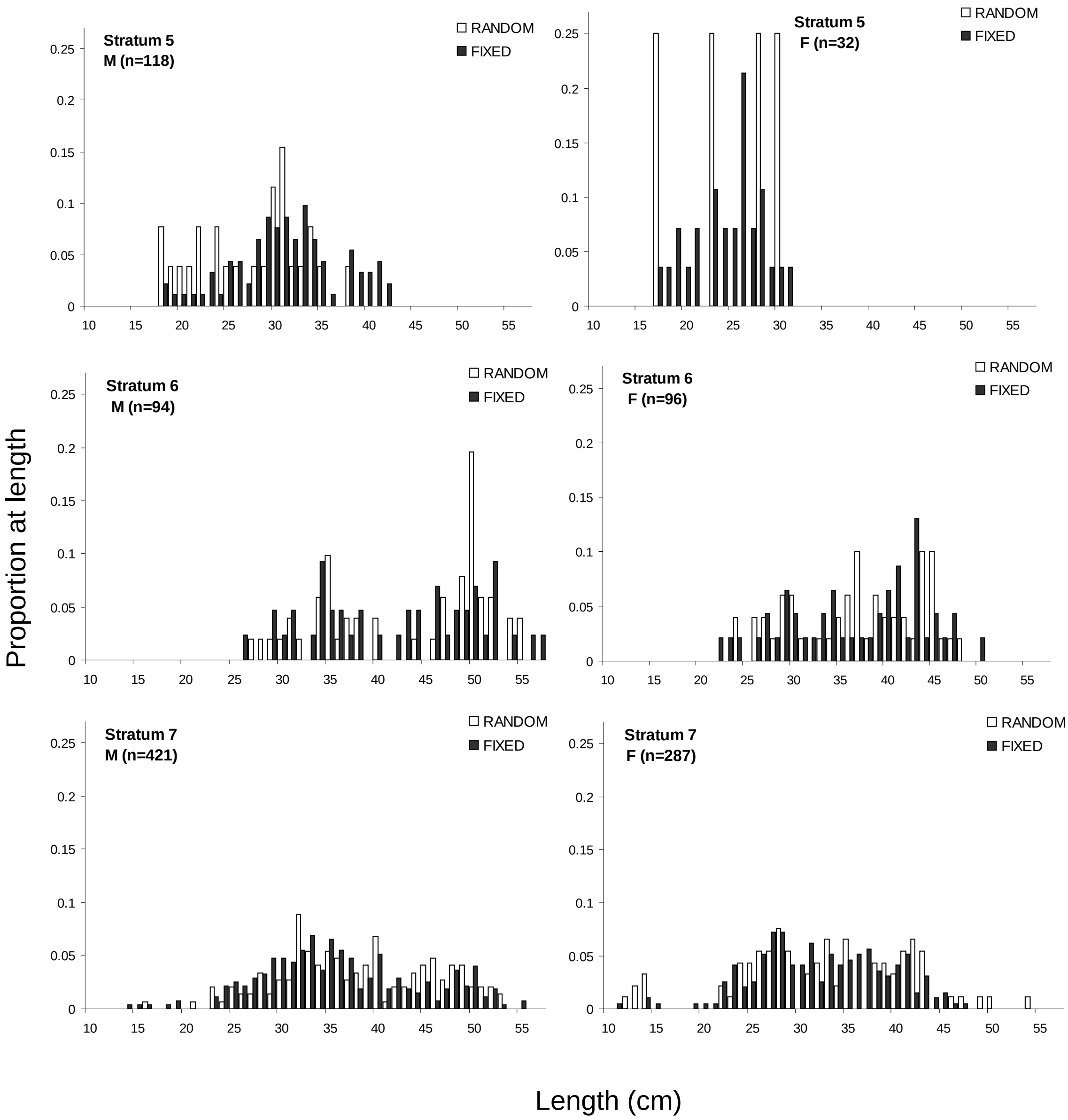


Figure 8 – ***continued***

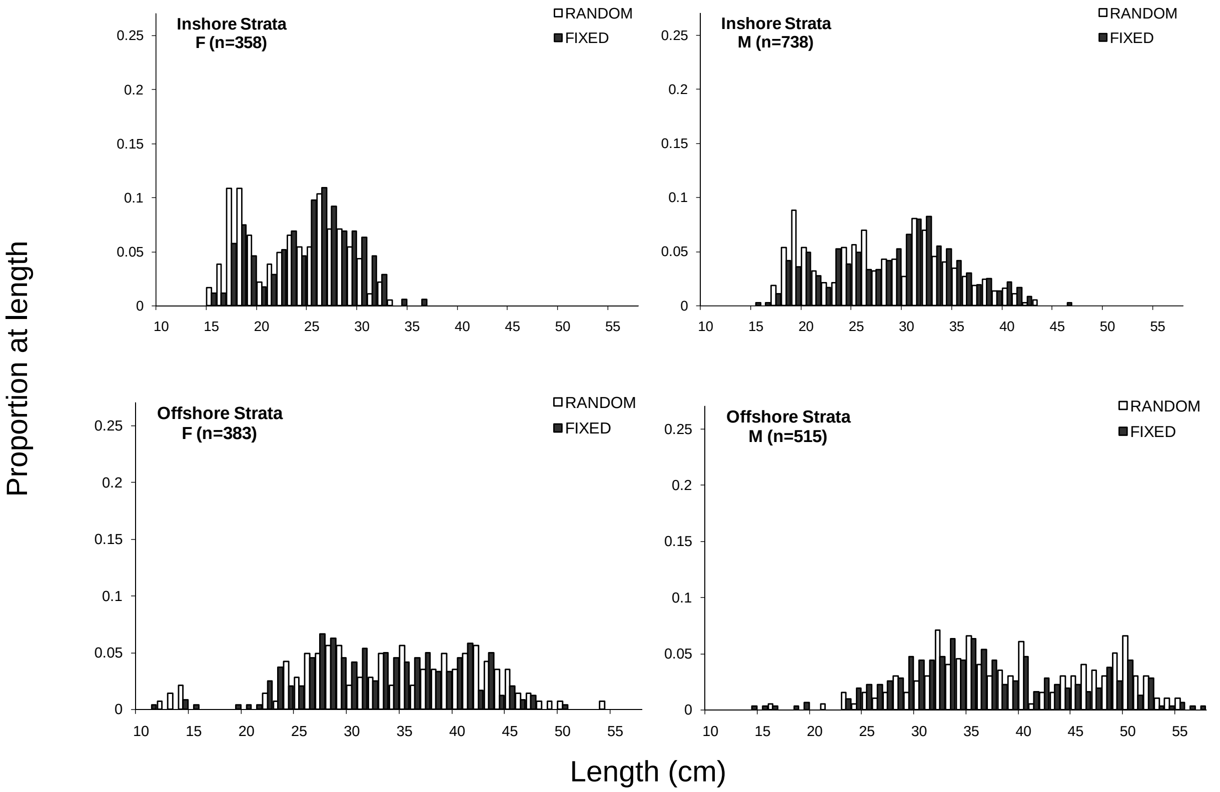


Figure 9: Unscaled proportion length frequency distributions by sex within inshore (strata 1-5) and offshore (strata 6-7) areas for fixed and random sites. Proportions for each sex within each stratum sum to 1.

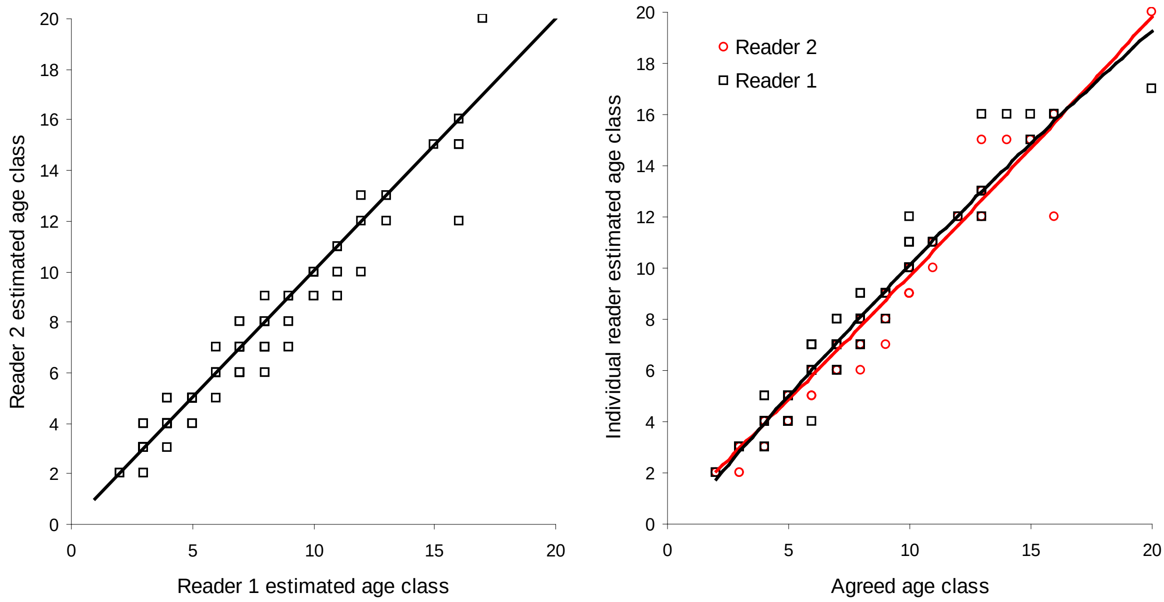


Figure10: Banks Peninsula 2012 survey comparison of individual reader age class estimates from inshore otoliths(n = 240), on the right plotted against each other and on the left with the 1:1 line plotted (solid) fitted, as well as the mean for each age recorded by reader 2 for each age recorded by reader 1 (red dashed polynomial trend line fitted). In the right panel the agreed age class estimates is plotted against the individual age class estimates with a polynomial trend line fitted for each reader.

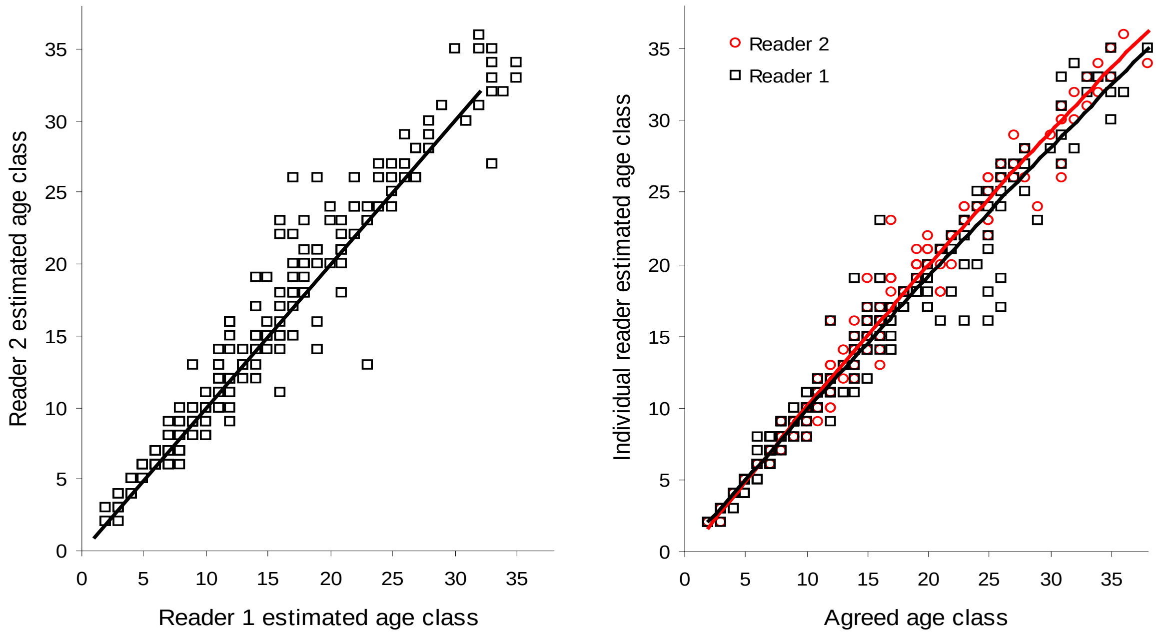


Figure 11: Banks Peninsula 2012 survey comparison of individual reader age class estimates from offshore otoliths(n = 311), on the right plotted against each other and on the left with the 1:1 line plotted (solid) fitted, as well as the mean for each age recorded by reader 2 for each age recorded by reader 1 (red dashed polynomial trend line fitted). In the right panel the agreed age class estimates is plotted against the individual age class estimates with a polynomial trend line fitted for each reader.

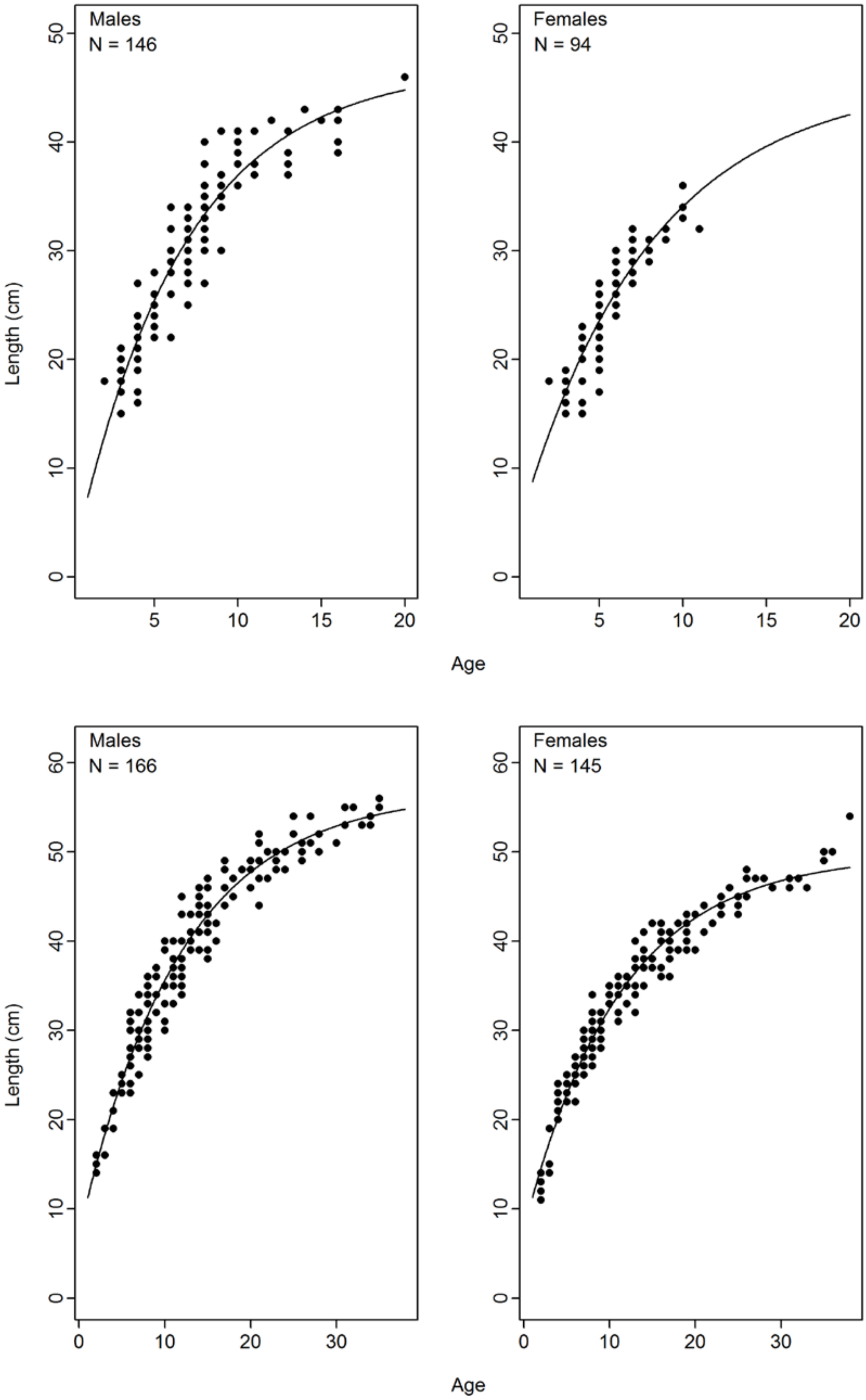


Figure 12: Observed age and length data by sex for the 2012 Banks Peninsula survey inshore strata 1-5 (upper panel) and offshore strata 6 and 7 (lower panel) comparison of male (left) and female (right) von Bertalanffy growth models fitted to the data. See Tables 13 and 14 for description of inshore and offshore biological samples respectively.

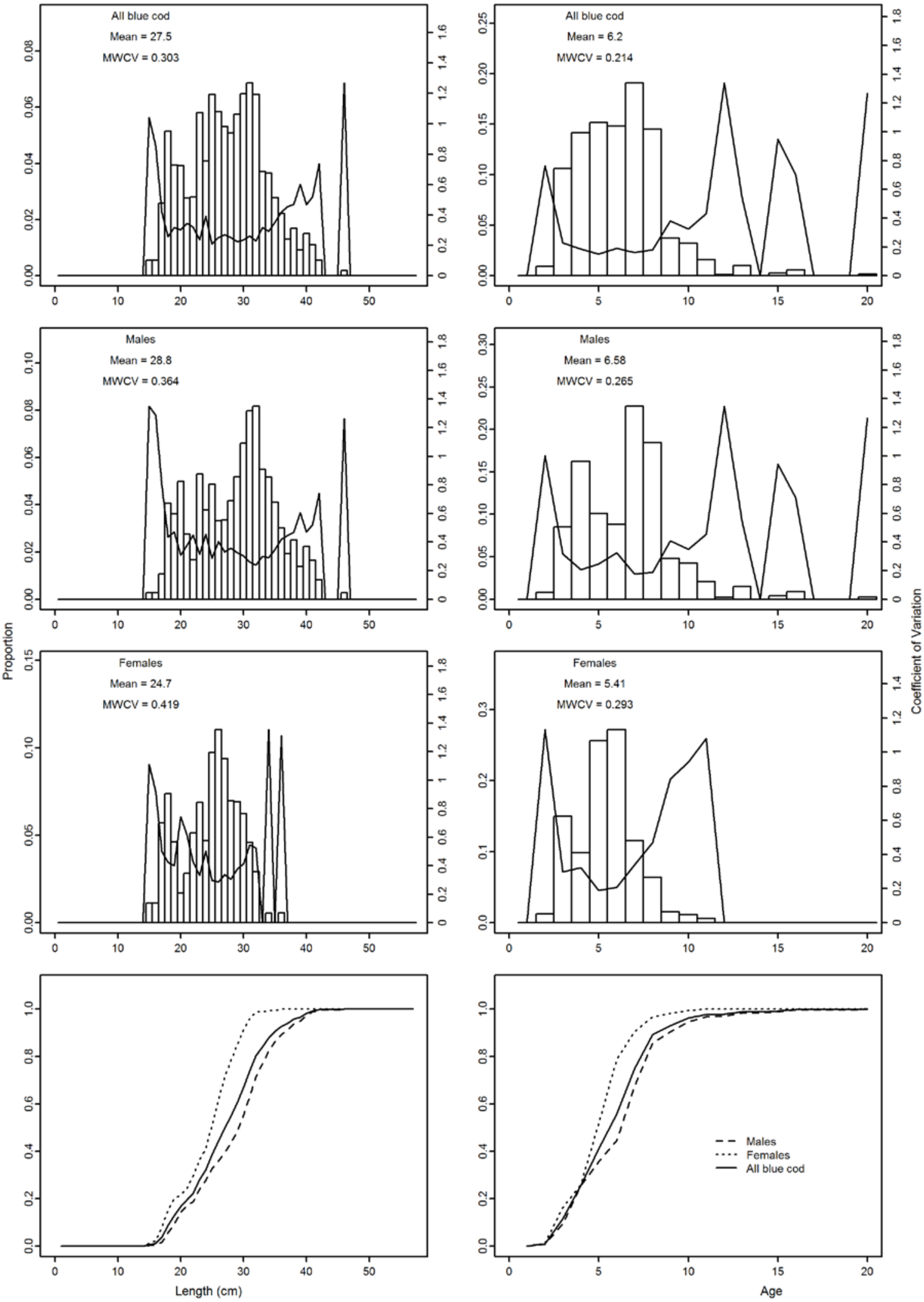


Figure 13: Scaled length frequency, age frequency, and cumulative distributions for total, male, and female blue cod for the 2012 Banks Peninsula inshore (strata 1-5) fixed site survey. N, sample size; MWCV, mean weighted coefficient of variation.

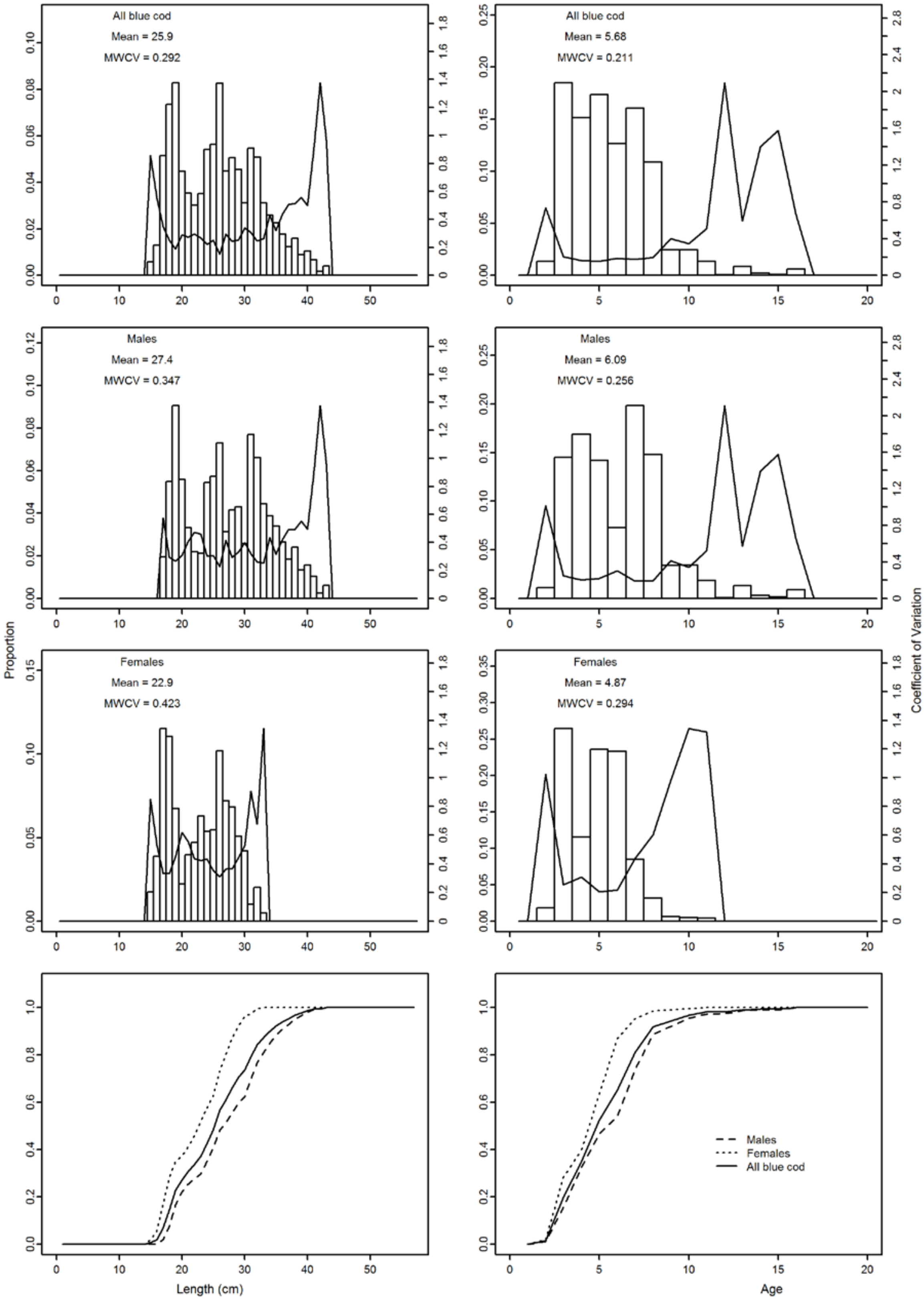


Figure 14: Scaled length frequency, age frequency, and cumulative distributions for total, male, and female blue cod for the 2012 Banks Peninsula inshore (strata 1-5) random site survey (not including the marine reserve stratum). N, sample size; MWCV, mean weighted coefficient of variation.

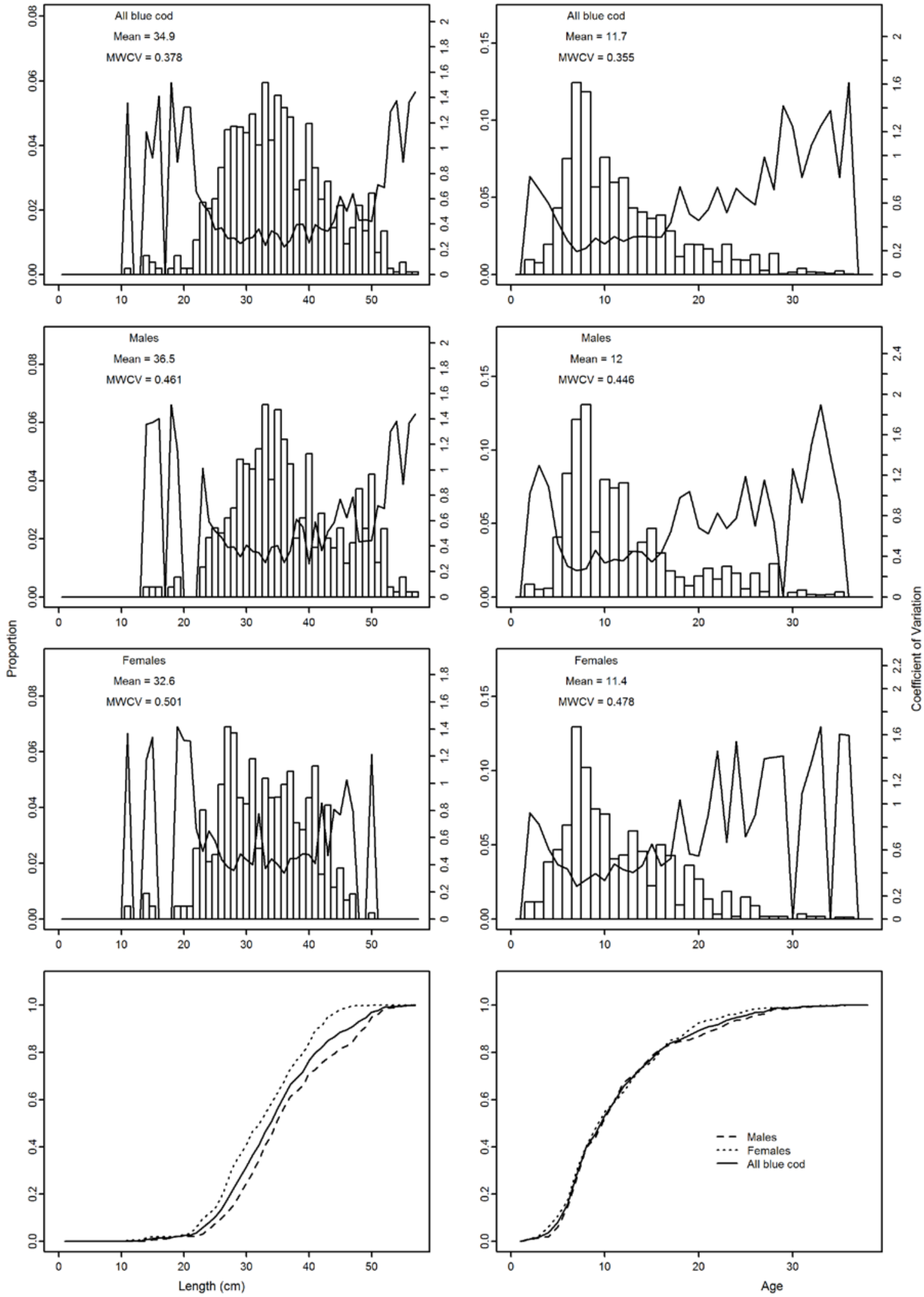


Figure 15: Scaled length frequency, age frequency, and cumulative distributions for total, male, and female blue cod for the 2012 Banks Peninsula offshore (strata 6-7) fixed site survey. N, sample size; MWCV, mean weighted coefficient of variation.

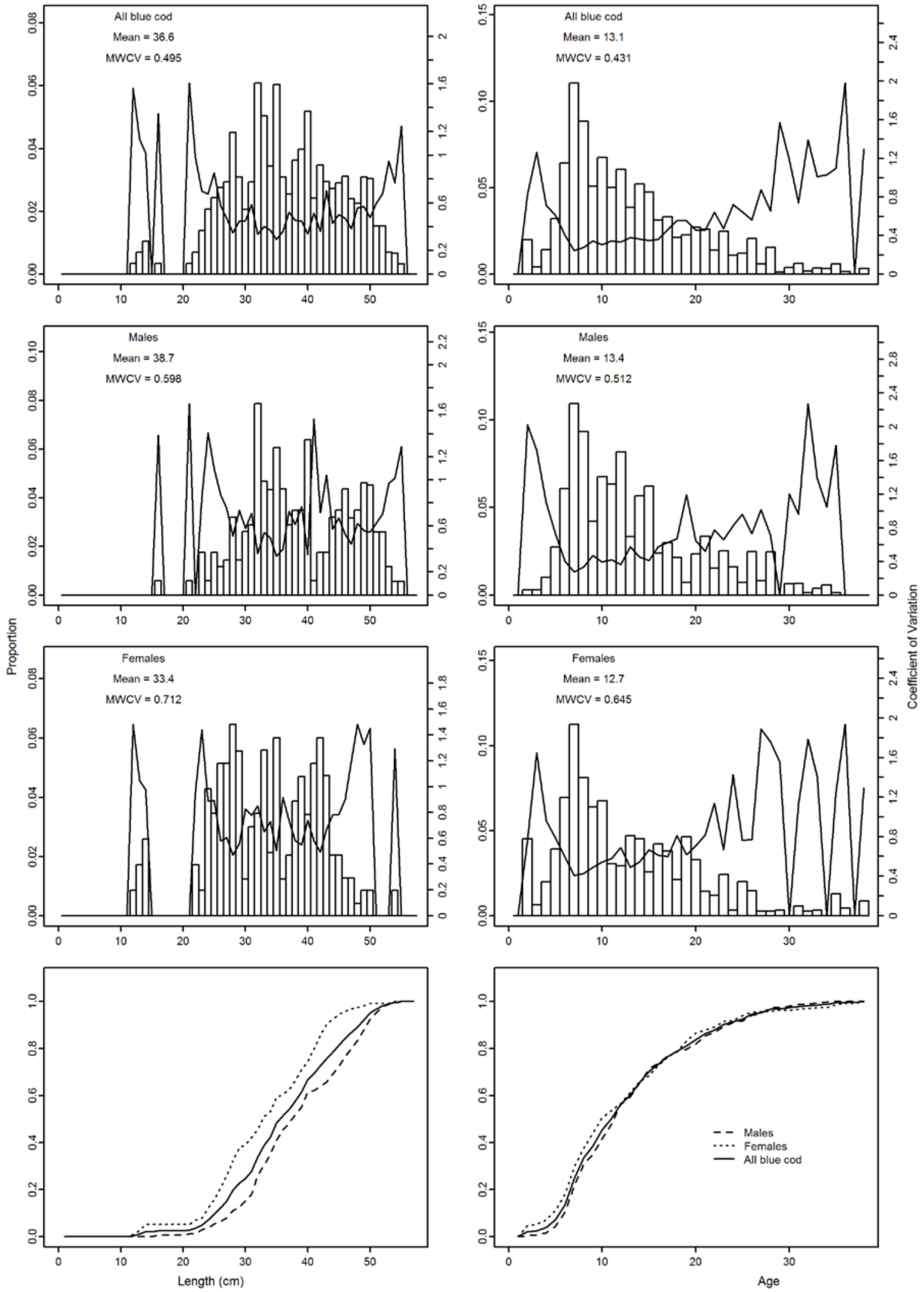


Figure 16: Scaled length frequency, age frequency, and cumulative distributions for total, male, and female blue cod for the 2012 Banks Peninsula offshore (strata 6-7) random site survey (not including the marine reserve stratum). N, sample size; MWCV, mean weighted coefficient of variation.

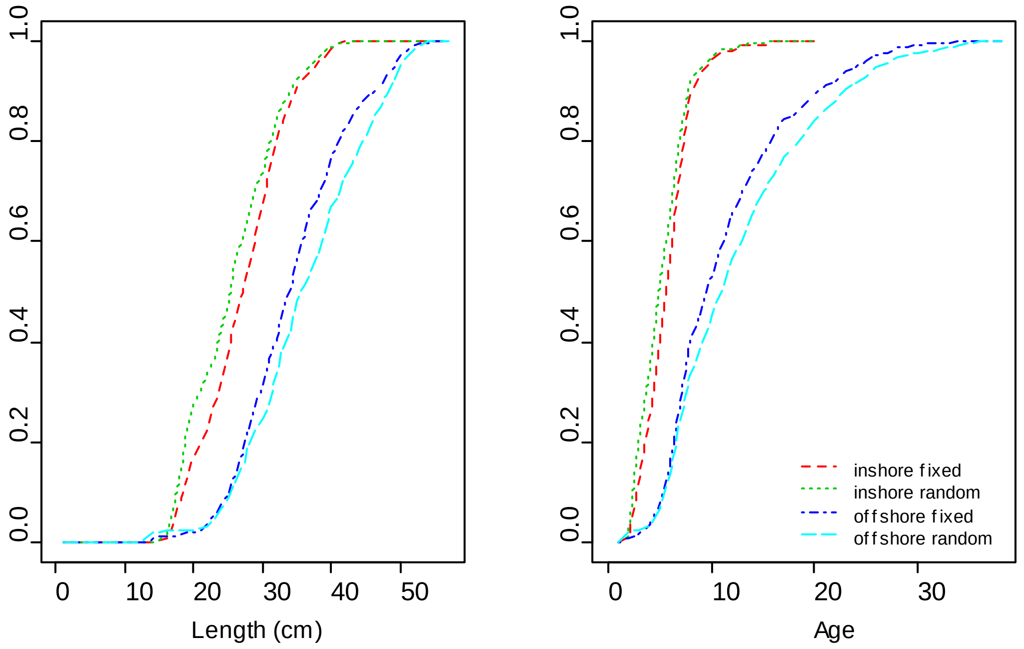


Figure 17: Banks Peninsula 2012 survey scaled cumulative length frequency distributions (by inshore (strata 1-5) and offshore (strata 6-7)) from the random and fixed site surveys (marine reserve fish are not included).

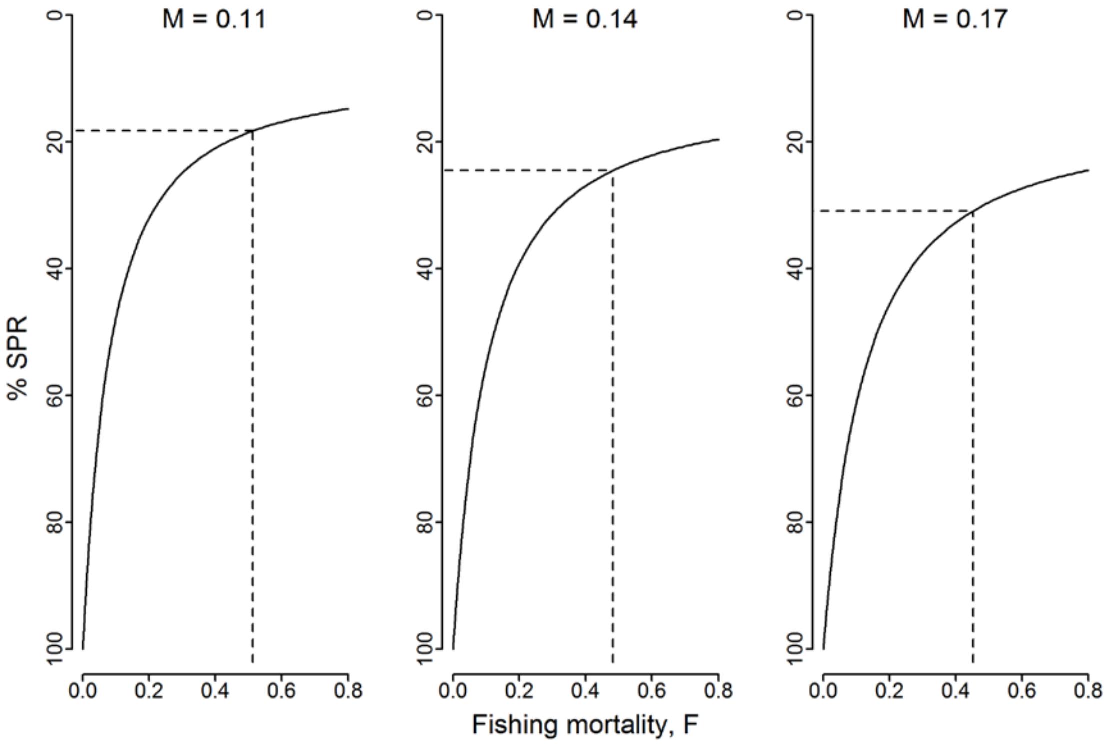


Figure 18:Plot of spawner per recruit (SPR) relative to unfished SPR as a function of fishing mortality for the 2012 Banks Peninsula inshore fixed-site design survey at three values of M (0.11, 0.14, 0.17). The dashed line shows the survey estimate of F and resulting % SPR, assuming an age of recruitment of 8. The y-axis has been inverted because a low fishing mortality corresponds to a high %SPR.

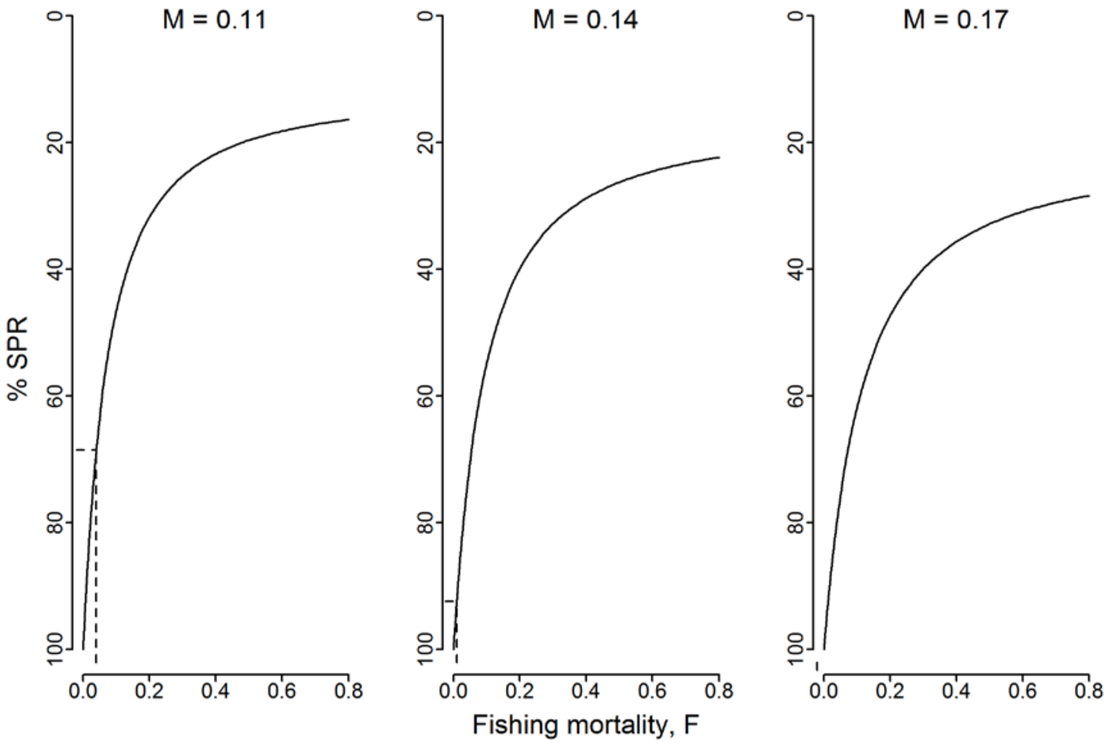


Figure 19: Plot of spawner per recruit (SPR) relative to unfished SPR as a function of fishing mortality for the 2012 Banks Peninsula offshore fixed-site design survey at three values of M (0.11, 0.14, 0.17). The dashed line shows the survey estimate of F and resulting % SPR, assuming an age of recruitment of 9. The y-axis has been inverted because a low fishing mortality corresponds to a high %SPR.

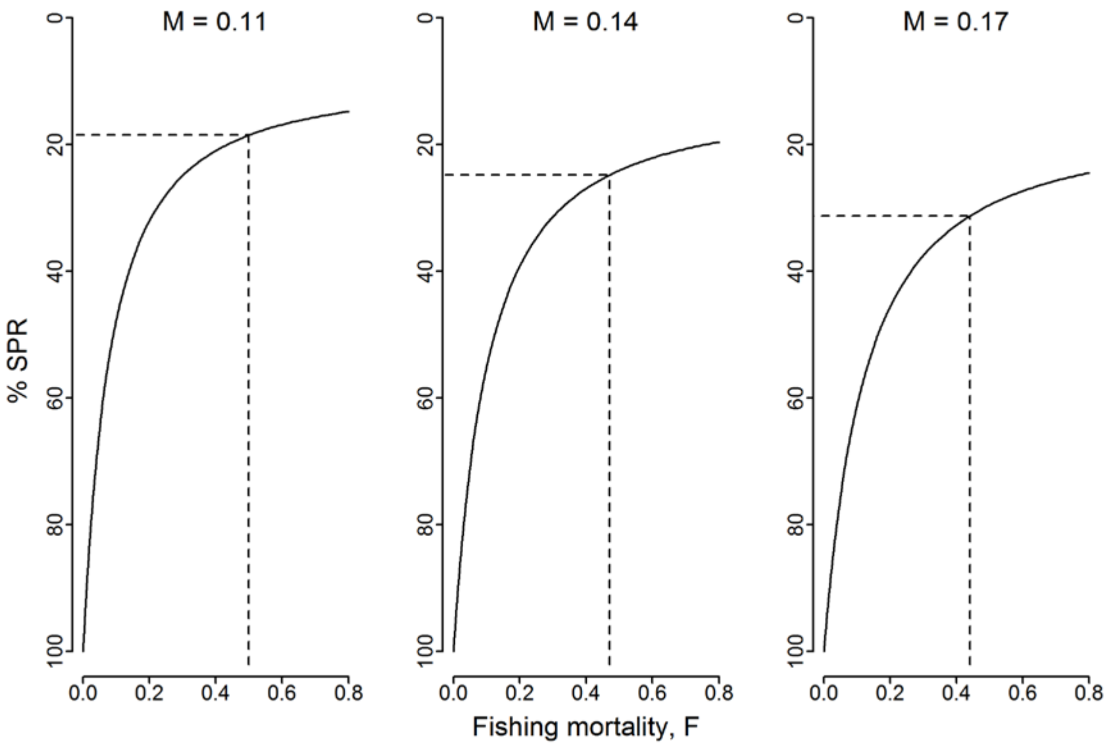


Figure 20: Plot of spawner per recruit (SPR) relative to unfished SPR as a function of fishing mortality for the 2012 Banks Peninsula inshore random-site design survey at three values of M (0.11, 0.14, 0.17). The dashed line shows the survey estimate of F and resulting % SPR, assuming an age of recruitment of 8. The y-axis has been inverted because a low fishing mortality corresponds to a high %SPR.

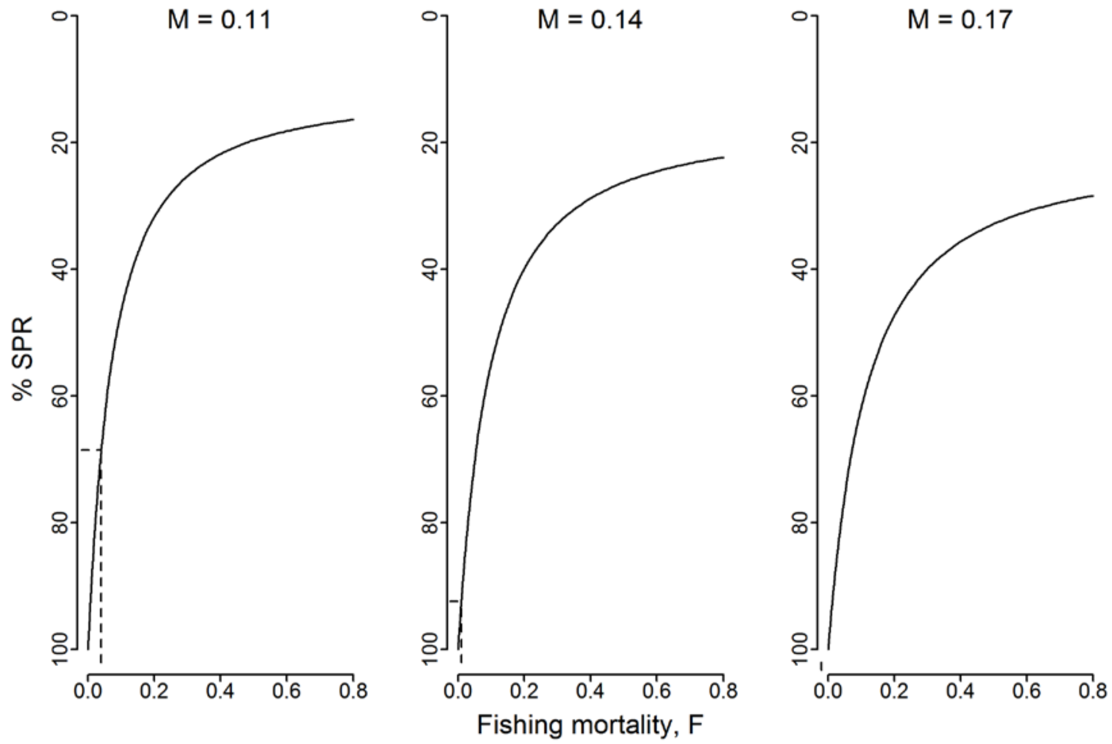
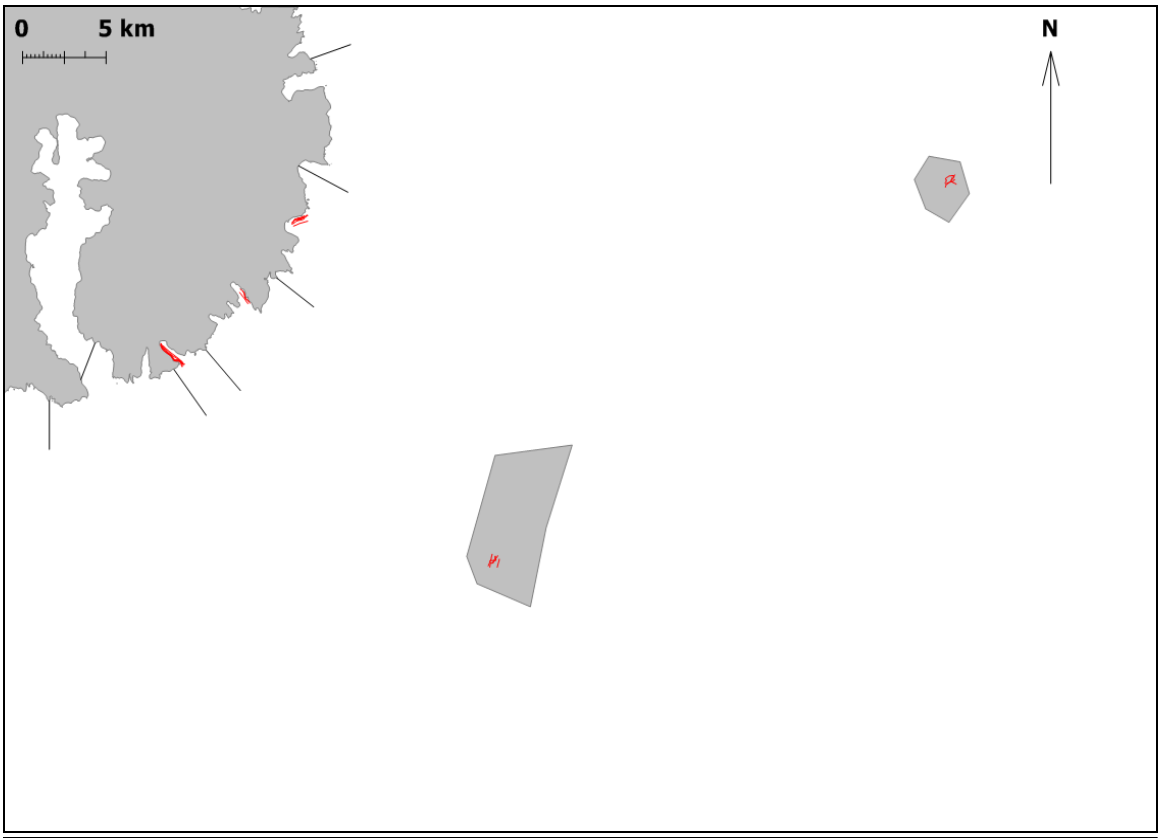


Figure 21: Plot of spawner per recruit (SPR) relative to unfished SPR as a function of fishing mortality for the 2012 Banks Peninsula offshore random-site design survey at three values of M (0.11, 0.14, 0.17). The dashed line shows the survey estimate of F and resulting % SPR, assuming an age of recruitment of 9. The y-axis has been inverted because a low fishing mortality corresponds to a high %SPR.



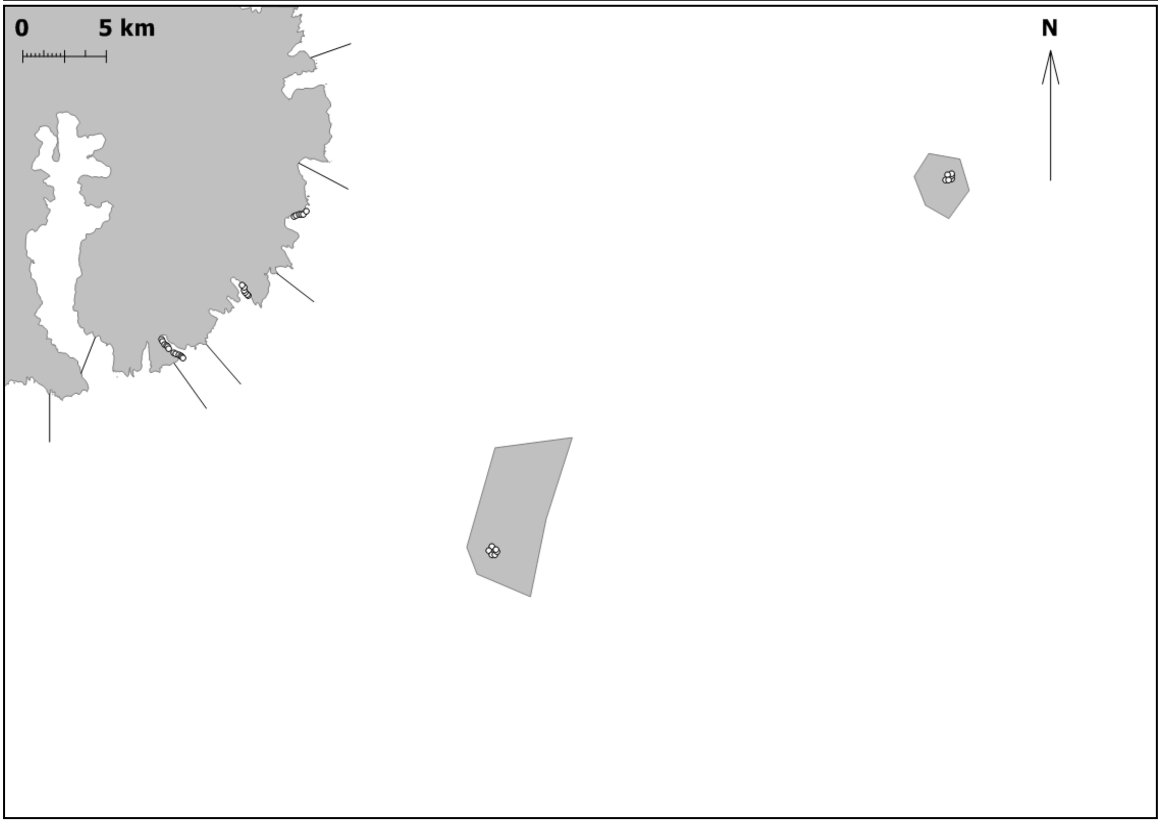


Figure 22: Six sites with DUV transects stations (above, n=3-8 per site) surveyed prior to pots (below, n=6 pots ○ per site) in the 2012 Banks Peninsula survey.

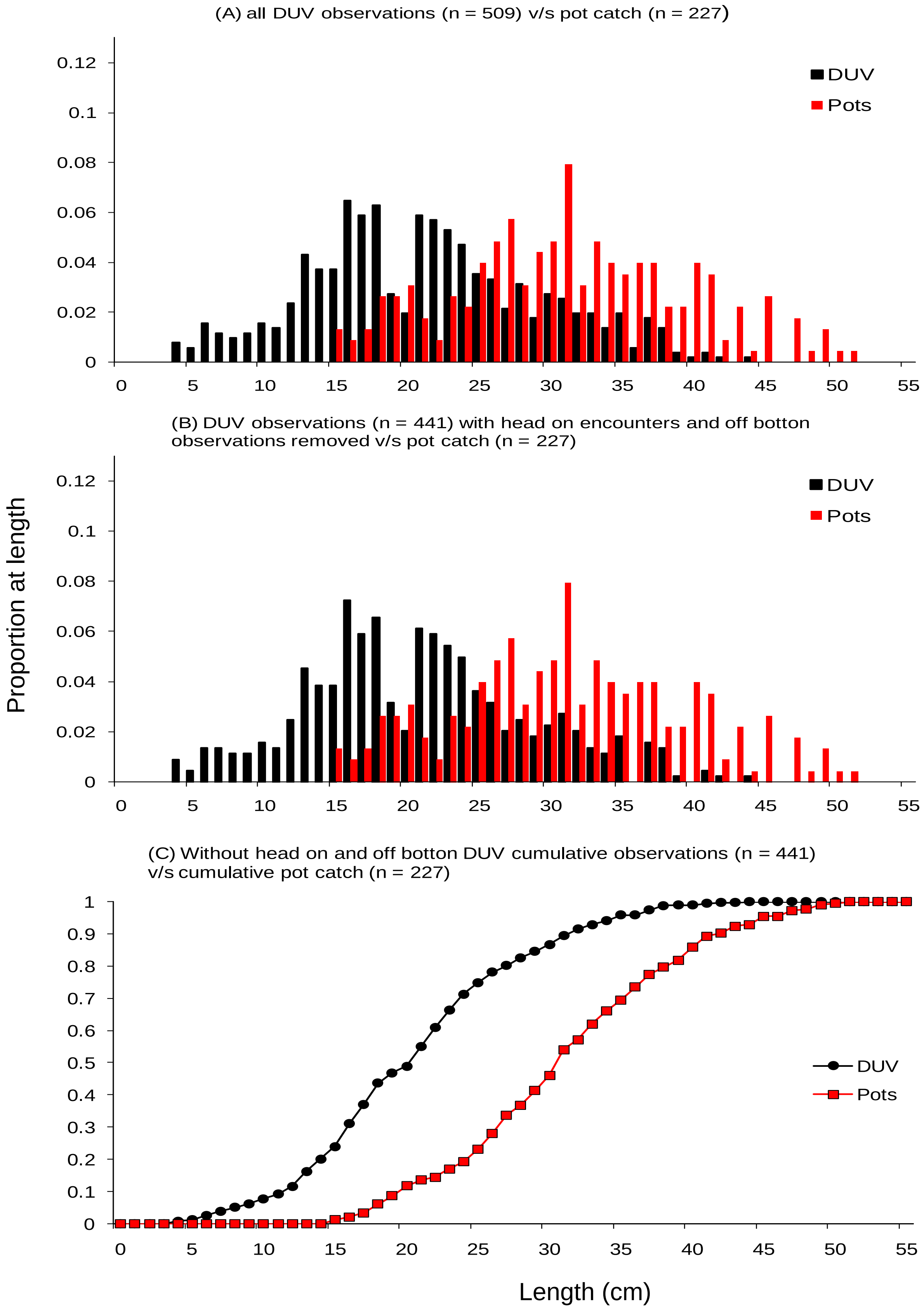


Figure 23: (A) –All measured video observations of blue cod sizes plotted against sizes from concurrent pot catch. (B) – Blue cod sizes from video observations without head-on body orientation to camera or off bottom observations plotted against sizes from pot catch. (C)– Cumulative frequency distribution without video head-on body orientation or off bottom observations.

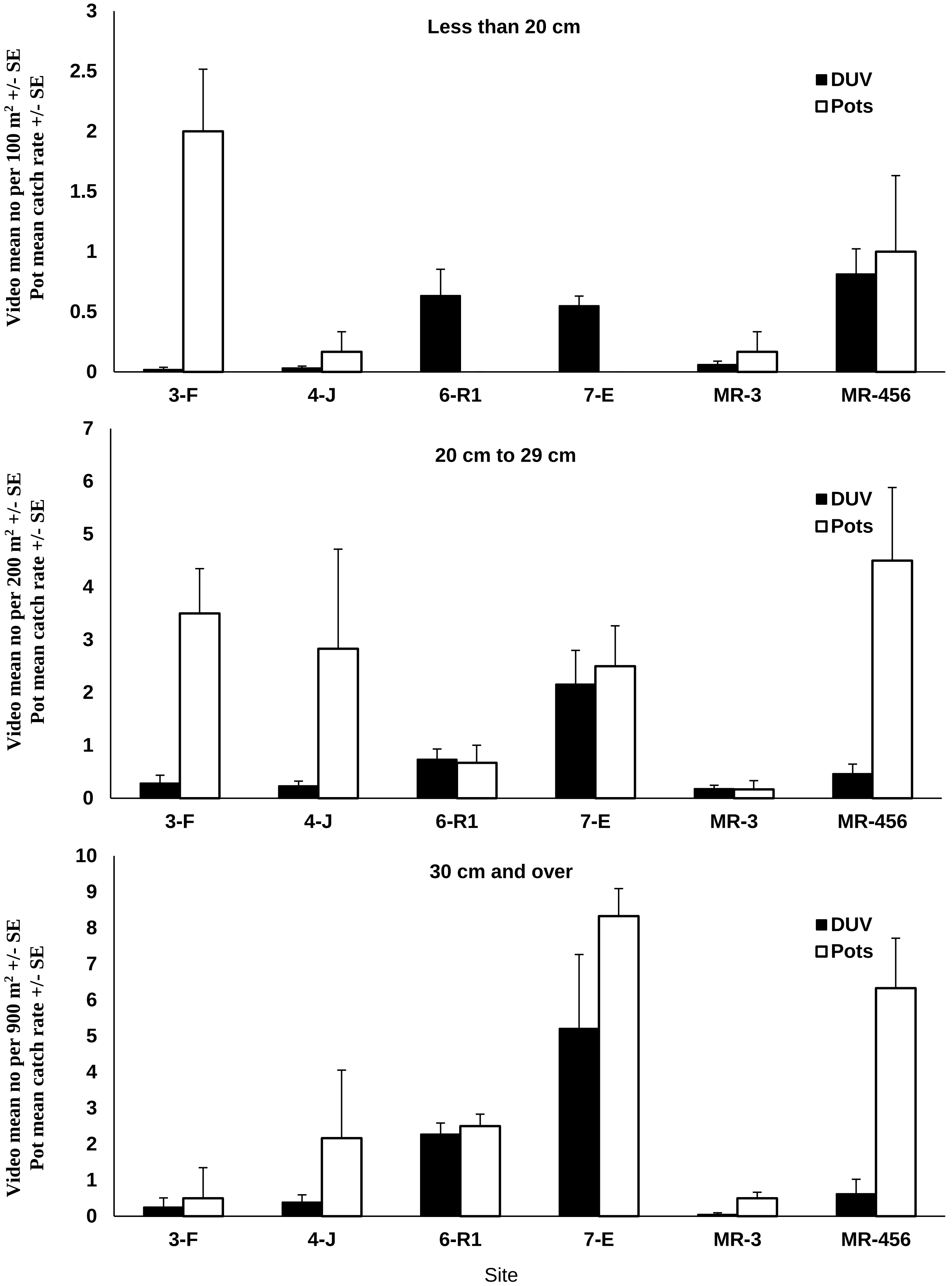


Figure 24: Mean site relative abundance (Number.pot^{-1}) from pots versus the equivalent mean site density estimates from the area swept video method for three size classes of blue cod, less than 20 cm (top), 20-29 cm (centre), 30 cm and over (bottom). Error bars are ± one standard error.

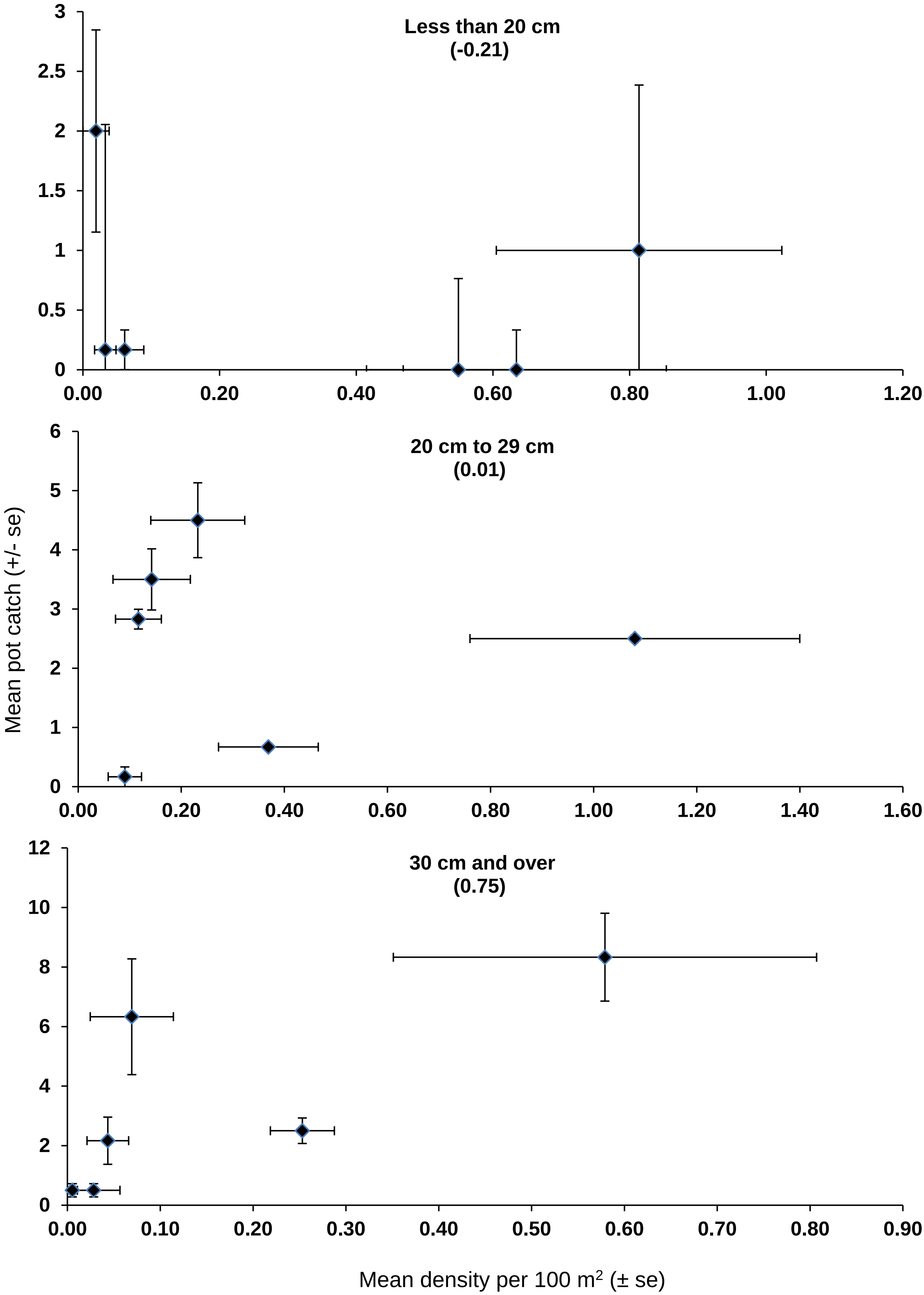


Figure 25: Mean density versus catch rate (kg.pot^{-1}) for three size classes of blue cod dual surveyed with DUV and pots, error bars are ± one standard error. The correlation coefficient is shown in brackets below the size class title.

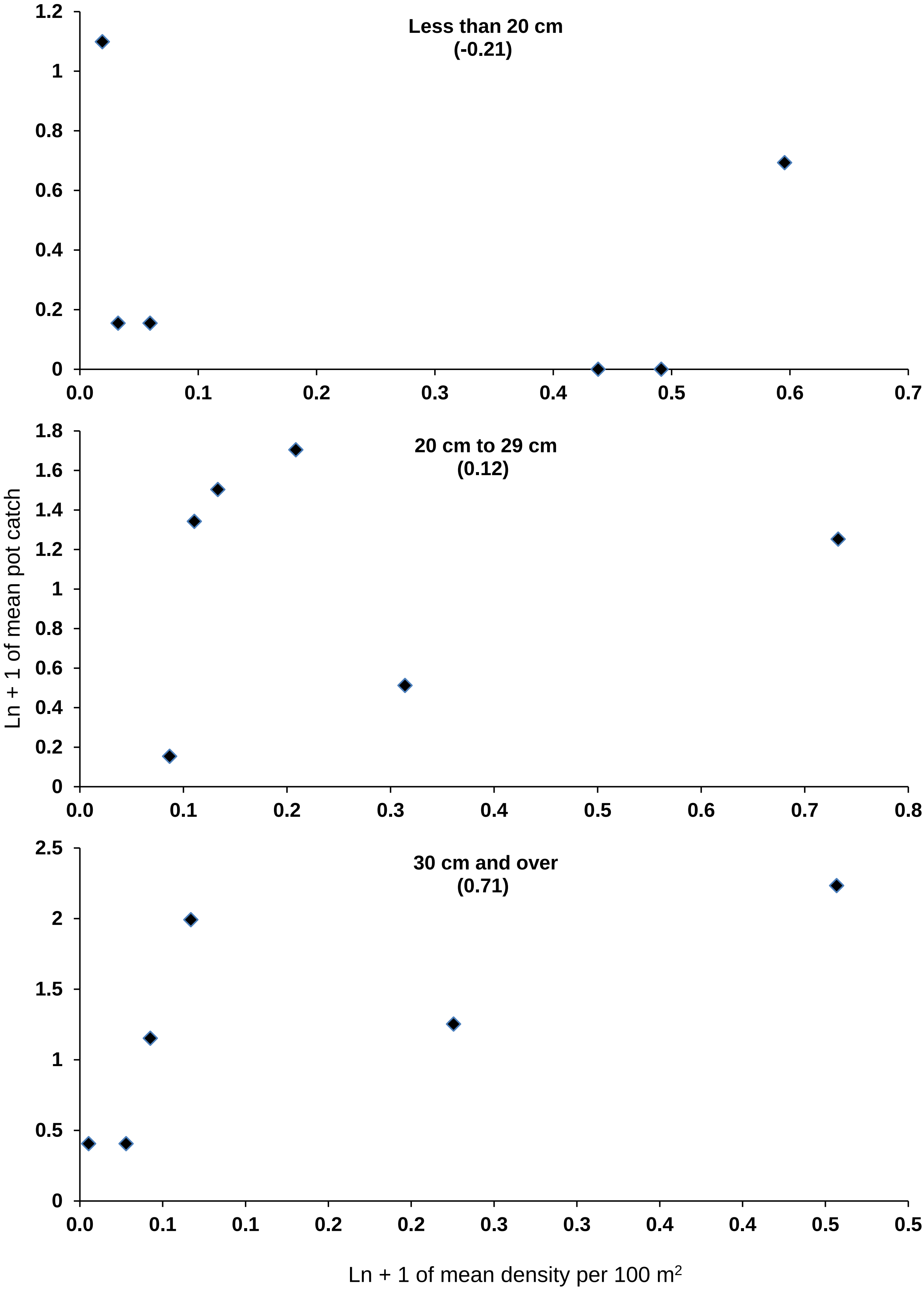


Figure 26: Ln + 1 of mean density versus catch rate (kg.pot^{-1}) for three size classes of blue cod dual surveyed with DUV and pots, error bars are ± one standard error. The correlation coefficient is shown in brackets below the size class title.

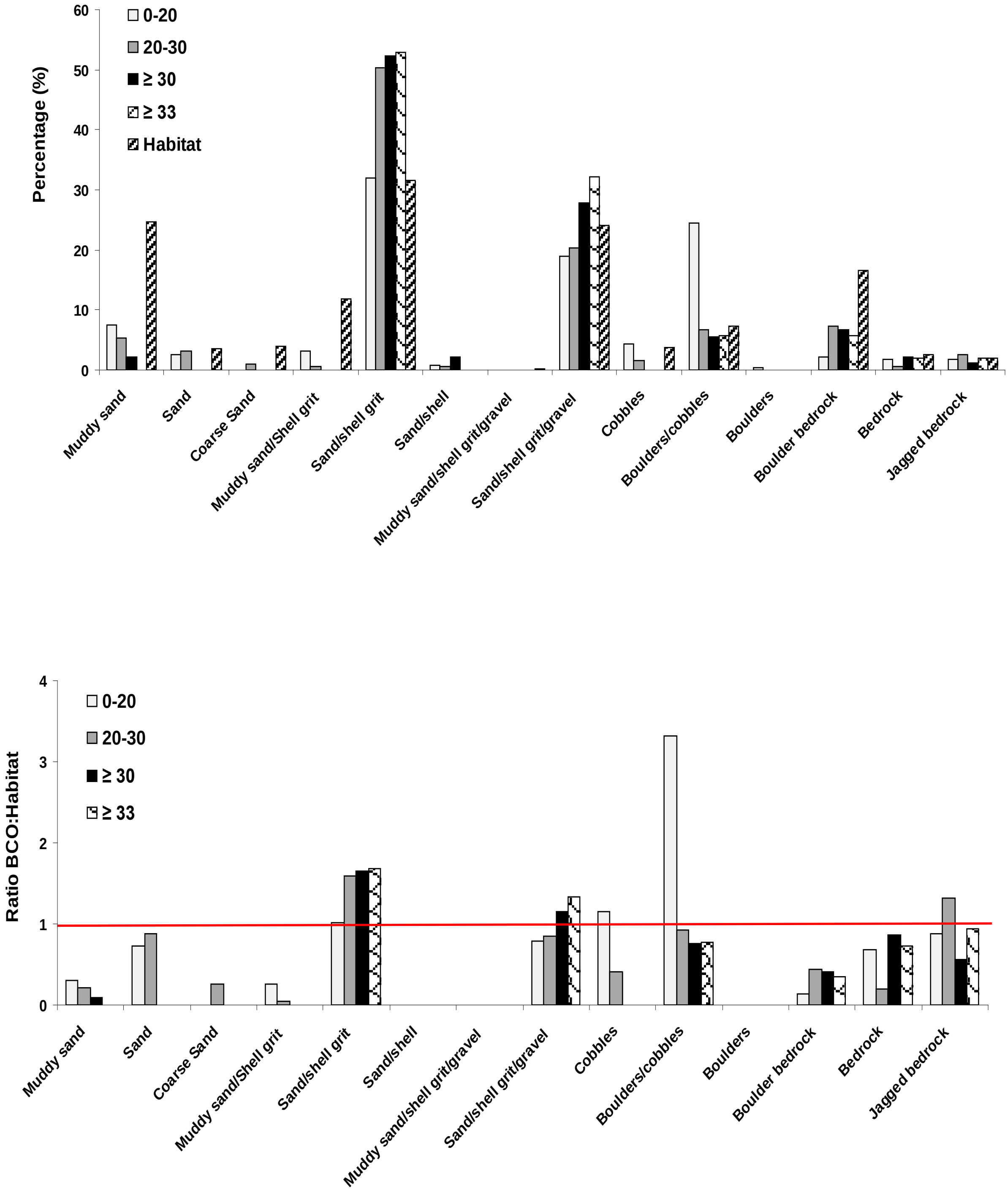
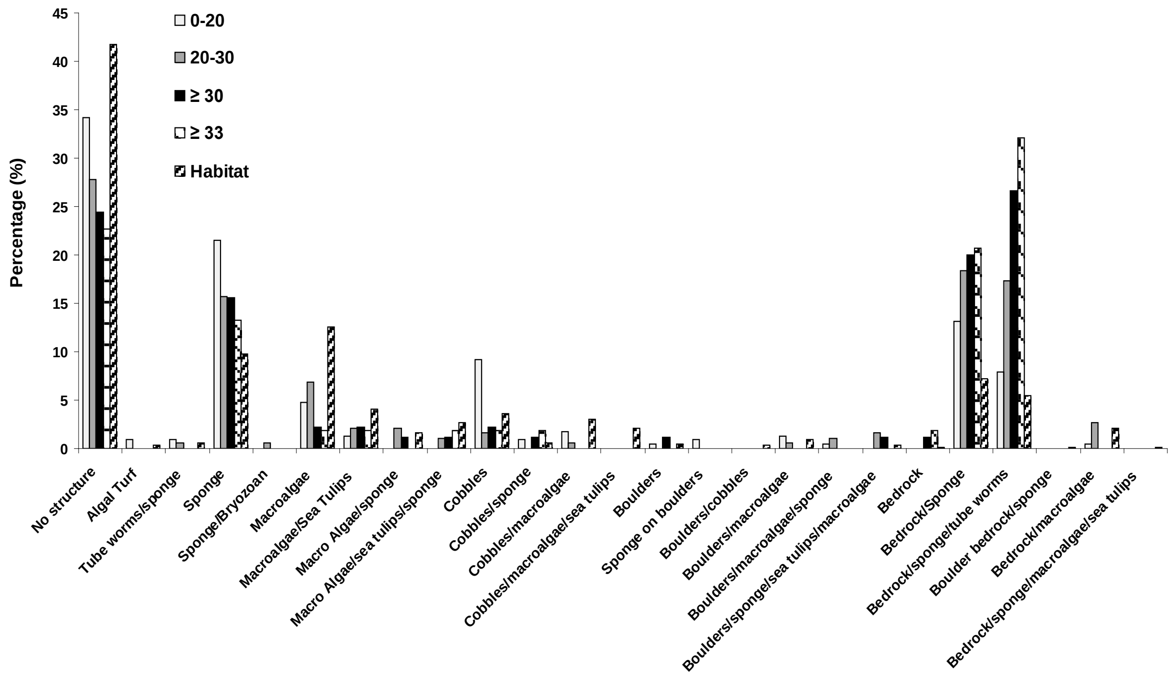


Figure 27: Proportion of blue cod (three size classes) and fish-independent DUV observations of primary substrate from all sites (top). The ratio of the proportion of blue cod-associated primary substrate and the fish-independent substrate recorded by the video at fixed sites is shown in the bottom figure with a line drawn at a 1:1 ratio.



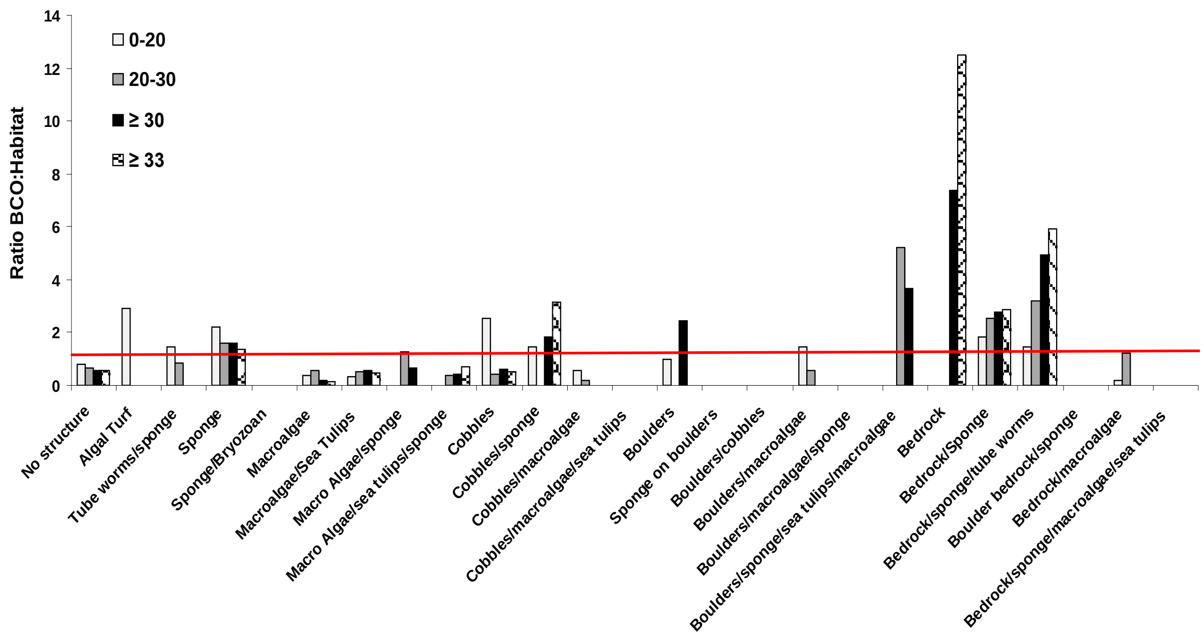


Figure 28: Proportion of blue cod (three size classes) and fish-independent DUV observations of secondary structure from all sites (top). The ratio of the proportion of blue cod-associated primary substrate and the fish-independent substrate recorded by the video at random sites is shown in the bottom figure with a line drawn at a 1:1 ratio.

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. Fixed sites are known fishing spots identified by local fishers. 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 a fisher-selected site**.**
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.
Site label	An alphanumeric label of no more than 4 characters unique within a survey time series. A site label identifies each site and also specifies which stratum it lies in. Fixed 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 fixed site label remain constantly fixed to that location for all surveys. In contrast, random sites are regenerated for each survey and use a numeric label based on the order in which they were randomly generated, followed by the letter R and then concatenated with the stratum code. Thus, sites within stratum 2 could be labelled 2R1, 2R3, and sites in stratum 3 could be labelled 3R1, 3R2 etc.
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) 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.
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 (this is how pots are set at fixed sites). 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 (this is how pots are set at random sites).

Appendix 2: Summary of survey pot lift station data, Banks Peninsula 2012. For sites R=random.

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot	Catch of blue cod (kg)	Catch of blue cod Number
1	26-Mar-12	1	1	A	30	08:30	2	0.4	2
1	26-Mar-12	1	1	A	30	08:35	3	1.3	2
1	26-Mar-12	1	1	A	29	08:40	1	2.6	4
1	26-Mar-12	1	1	A	23	08:45	4	0.0	0
1	26-Mar-12	1	1	A	21	08:53	5	0.1	1
1	26-Mar-12	1	1	A	23	09:00	6	0.6	2
2	26-Mar-12	1	1	C	19	10:07	6	0.7	2
2	26-Mar-12	1	1	C	18	10:12	5	0.1	1
2	26-Mar-12	1	1	C	20	10:17	4	2.2	3
2	26-Mar-12	1	1	C	18	10:21	1	0.0	0
2	26-Mar-12	1	1	C	17	10:26	3	0.1	1
2	26-Mar-12	1	1	C	18	10:30	2	0.0	0
3	26-Mar-12	1	1	E	15	11:47	2	0.6	1
3	26-Mar-12	1	1	E	16	11:51	3	0.2	1
3	26-Mar-12	1	1	E	17	11:54	1	0.6	2
3	26-Mar-12	1	1	E	17	11:57	4	0.3	3
3	26-Mar-12	1	1	E	16	12:02	5	0.0	0
3	26-Mar-12	1	1	E	21	12:06	6	0.4	3
4	26-Mar-12	1	1	H	28	13:25	6	2.0	7
4	26-Mar-12	1	1	H	25	13:30	5	2.7	6
4	26-Mar-12	1	1	H	24	13:35	4	0.0	0
4	26-Mar-12	1	1	H	22	13:40	1	5.4	9
4	26-Mar-12	1	1	H	21	13:45	3	2.2	7
4	26-Mar-12	1	1	H	20	13:50	2	3.2	10
5	27-Mar-12	1	3	B	31	06:46	2	0.1	1
5	27-Mar-12	1	3	B	23	06:50	3	2.2	4
5	27-Mar-12	1	3	B	26	06:54	1	2.2	4
5	27-Mar-12	1	3	B	22	06:59	4	0.8	1
5	27-Mar-12	1	3	B	25	07:05	5	1.4	4
5	27-Mar-12	1	3	B	25	07:10	6	0.0	0
6	27-Mar-12	1	3	E	23	08:26	6	3.5	10
6	27-Mar-12	1	3	E	21	08:29	5	1.6	3
6	27-Mar-12	1	3	E	21	08:34	4	1.4	4
6	27-Mar-12	1	3	E	27	08:40	1	0.9	3
6	27-Mar-12	1	3	E	27	08:44	3	2.3	6
6	27-Mar-12	1	3	E	25	08:50	2	1.9	5
7	27-Mar-12	1	3	H	26	10:10	2	1.5	7
7	27-Mar-12	1	3	H	30	10:15	3	1.5	5
7	27-Mar-12	1	3	H	31	10:19	1	1.6	8
7	27-Mar-12	1	3	H	32	10:24	4	0.6	3
7	27-Mar-12	1	3	H	37	10:29	5	1.6	7
7	27-Mar-12	1	3	H	40	10:35	6	1.7	13
8	27-Mar-12	1	3	K	21	11:57	6	2.4	5
8	27-Mar-12	1	3	K	22	12:03	5	6.3	14
8	27-Mar-12	1	3	K	18	12:07	4	0.2	1

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot	Catch of blue cod (kg)	Number
8	27-Mar-12	1	3	K	19	12:13	1	1.0	2
8	27-Mar-12	1	3	K	19	12:18	3	0.0	0
8	27-Mar-12	1	3	K	21	12:23	2	2.2	5
9	27-Mar-12	1	2	J	30	14:04	2	0.0	0
9	27-Mar-12	1	2	J	31	14:07	3	0.0	0
9	27-Mar-12	1	2	J	28	14:11	1	0.0	0
9	27-Mar-12	1	2	J	32	14:14	4	0.0	0
9	27-Mar-12	1	2	J	29	14:19	5	0.0	0
9	27-Mar-12	1	2	J	25	14:25	6	0.0	0
10	29-Mar-12	1	5	H	16	07:58	6	0.0	0
10	29-Mar-12	1	5	H	15	08:02	5	1.9	8
10	29-Mar-12	1	5	H	16	08:10	4	0.0	0
10	29-Mar-12	1	5	H	17	08:15	1	0.0	0
10	29-Mar-12	1	5	H	16	08:22	3	0.0	0
10	29-Mar-12	1	5	H	17	08:28	2	0.0	0
11	29-Mar-12	1	5	G	7	09:45	2	0.0	0
11	29-Mar-12	1	5	G	7	09:50	3	0.0	0
11	29-Mar-12	1	5	G	10	09:55	1	0.0	0
11	29-Mar-12	1	5	G	13	10:00	4	2.1	3
11	29-Mar-12	1	5	G	13	10:04	5	2.2	4
11	29-Mar-12	1	5	G	14	10:08	6	1.7	4
12	29-Mar-12	1	5	B	12	11:30	6	2.6	6
12	29-Mar-12	1	5	B	15	11:34	5	1.6	5
12	29-Mar-12	1	5	B	16	11:37	4	3.8	7
12	29-Mar-12	1	5	B	16	11:41	1	0.0	0
12	29-Mar-12	1	5	B	15	11:45	3	10.7	23
12	29-Mar-12	1	5	B	17	11:48	2	0.5	3
13	29-Mar-12	1	5	C	24	13:06	2	0.0	0
13	29-Mar-12	1	5	C	26	13:09	3	2.0	5
13	29-Mar-12	1	5	C	22	13:14	1	1.9	3
13	29-Mar-12	1	5	C	20	13:18	4	3.3	5
13	29-Mar-12	1	5	C	15	13:22	5	0.7	3
13	29-Mar-12	1	5	C	15	13:26	6	0.6	2
14	30-Mar-12	1	5	R1	14	07:48	6	0.0	0
14	30-Mar-12	1	5	R1	14	07:52	1	0.0	0
14	30-Mar-12	1	5	R1	14	07:55	4	0.0	0
14	30-Mar-12	1	5	R1	15	08:00	3	0.0	0
14	30-Mar-12	1	5	R1	15	08:06	5	0.0	0
14	30-Mar-12	1	5	R1	12	08:19	2	0.4	3
15	30-Mar-12	1	5	R2	12	09:34	2	0.2	1
15	30-Mar-12	1	5	R2	10	09:37	5	0.4	2
15	30-Mar-12	1	5	R2	7	09:41	3	0.0	0
15	30-Mar-12	1	5	R2	7	09:44	4	0.0	0
15	30-Mar-12	1	5	R2	7	09:47	1	0.0	0
15	30-Mar-12	1	5	R2	6	09:51	6	0.0	0
16	30-Mar-12	1	5	R3	16	11:04	6	1.3	4
16	30-Mar-12	1	5	R3	12	11:08	1	0.6	3
16	30-Mar-12	1	5	R3	12	11:12	4	0.8	2

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot	Catch of blue cod (kg)	Number
16	30-Mar-12	1	5	R3	7	11:16	3	0.1	1
16	30-Mar-12	1	5	R3	10	11:19	5	0.0	0
16	30-Mar-12	1	5	R3	9	11:22	2	0.0	0
17	30-Mar-12	1	5	R5	13	12:42	2	3.3	7
17	30-Mar-12	1	5	R5	11	12:45	5	0.0	0
17	30-Mar-12	1	5	R5	13	12:49	3	1.7	3
17	30-Mar-12	1	5	R5	14	12:54	4	0.5	2
17	30-Mar-12	1	5	R5	13	13:00	1	0.0	0
17	30-Mar-12	1	5	R5	14	13:04	6	0.5	2
18	31-Mar-12	1	7	R1	76	08:26	1	0.0	0
18	31-Mar-12	1	7	R1	77	08:34	2	0.0	0
18	31-Mar-12	1	7	R1	78	08:41	3	0.0	0
18	31-Mar-12	1	7	R1	78	08:50	4	0.0	0
18	31-Mar-12	1	7	R1	78	08:56	5	0.0	0
18	31-Mar-12	1	7	R1	77	09:04	6	0.0	0
19	31-Mar-12	1	7	R2	77	10:47	6	21.0	17
19	31-Mar-12	1	7	R2	76	10:52	5	20.9	22
19	31-Mar-12	1	7	R2	77	10:58	4	14.4	13
19	31-Mar-12	1	7	R2	78	11:03	3	4.7	5
19	31-Mar-12	1	7	R2	75	11:09	2	17.7	12
19	31-Mar-12	1	7	R2	78	11:14	1	12.9	12
20	31-Mar-12	1	7	R3	73	12:52	1	0.0	0
20	31-Mar-12	1	7	R3	73	12:56	2	0.0	0
20	31-Mar-12	1	7	R3	74	13:03	3	0.0	0
20	31-Mar-12	1	7	R3	73	13:12	4	0.0	0
20	31-Mar-12	1	7	R3	73	13:18	5	0.0	0
20	31-Mar-12	1	7	R3	73	13:26	6	0.0	0
21	1-Apr-12	1	6	B	81	08:45	6	2.1	4
21	1-Apr-12	1	6	B	82	08:50	5	4.9	3
21	1-Apr-12	1	6	B	84	08:58	4	3.0	2
21	1-Apr-12	1	6	B	85	09:03	3	0.0	0
21	1-Apr-12	1	6	B	85	09:10	2	4.1	3
21	1-Apr-12	1	6	B	82	09:17	1	10.2	9
22	1-Apr-12	1	6	E	86	10:43	1	7.5	8
22	1-Apr-12	1	6	E	87	10:48	2	0.5	1
22	1-Apr-12	1	6	E	88	10:52	3	3.2	2
22	1-Apr-12	1	6	E	86	10:57	4	7.1	6
22	1-Apr-12	1	6	E	83	11:01	5	2.3	4
22	1-Apr-12	1	6	E	82	11:07	6	8.4	6
23	1-Apr-12	1	6	F	79	12:51	6	9.5	7
23	1-Apr-12	1	6	F	89	12:56	5	5.3	6
23	1-Apr-12	1	6	F	91	13:01	4	0.0	0
23	1-Apr-12	1	6	F	85	13:05	3	2.4	2
23	1-Apr-12	1	6	F	86	13:10	2	2.5	2
23	1-Apr-12	1	6	F	83	13:16	1	0.0	0
24	2-Apr-12	1	6	R1	85	14:14	1	1.9	3
24	2-Apr-12	1	6	R1	83	14:19	2	2.6	5
24	2-Apr-12	1	6	R1	84	14:23	3	2.6	3

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot	Catch of blue cod (kg)	Number
24	2-Apr-12	1	6	R1	84	14:29	4	4.7	3
24	2-Apr-12	1	6	R1	88	14:35	5	2.3	2
24	2-Apr-12	1	6	R1	88	14:40	6	1.8	3
25	3-Apr-12	1	4	R1	7	07:38	1	4.9	8
25	3-Apr-12	1	4	R1	10	07:43	2	2.7	4
25	3-Apr-12	1	4	R1	10	07:48	3	3.1	6
25	3-Apr-12	1	4	R1	12	07:54	4	2.0	5
25	3-Apr-12	1	4	R1	13	08:00	6	8.5	17
25	3-Apr-12	1	4	R1	15	08:05	5	2.2	6
26	3-Apr-12	1	4	J	14	13:01	5	3.4	8
26	3-Apr-12	1	4	J	16	13:04	6	5.2	16
26	3-Apr-12	1	4	J	13	13:08	4	2.9	4
26	3-Apr-12	1	4	J	12	13:12	3	1.5	2
26	3-Apr-12	1	4	J	15	13:16	2	0.1	1
26	3-Apr-12	1	4	J	15	13:23	1	0.0	0
27	4-Apr-12	1	4	R3	15	07:47	1	1.7	3
27	4-Apr-12	1	4	R3	13	07:51	2	0.3	1
27	4-Apr-12	1	4	R3	12	07:56	3	0.8	2
27	4-Apr-12	1	4	R3	12	08:01	4	5.1	8
27	4-Apr-12	1	4	R3	12	08:07	6	2.4	7
27	4-Apr-12	1	4	R3	16	08:13	5	0.0	0
28	4-Apr-12	1	4	R10	18	10:31	5	3.1	6
28	4-Apr-12	1	4	R10	18	10:36	6	8.1	16
28	4-Apr-12	1	4	R10	20	10:39	4	7.2	12
28	4-Apr-12	1	4	R10	18	10:43	3	4.6	8
28	4-Apr-12	1	4	R10	17	10:48	2	1.6	2
28	4-Apr-12	1	4	R10	14	10:52	1	0.0	0
29	4-Apr-12	1	4	H	17	12:10	1	0.8	1
29	4-Apr-12	1	4	H	15	12:12	2	0.0	0
29	4-Apr-12	1	4	H	15	12:16	3	0.0	0
29	4-Apr-12	1	4	H	14	12:20	4	2.8	4
29	4-Apr-12	1	4	H	13	12:24	6	0.0	0
29	4-Apr-12	1	4	H	12	12:28	5	0.0	0
30	5-Apr-12	1	3	R5	29	07:35	5	0.0	0
30	5-Apr-12	1	3	R5	27	07:39	6	0.0	0
30	5-Apr-12	1	3	R5	31	07:45	4	0.0	0
30	5-Apr-12	1	3	R5	30	07:49	3	0.0	0
30	5-Apr-12	1	3	R5	26	07:55	2	0.0	0
30	5-Apr-12	1	3	R5	29	07:59	1	0.0	0
31	5-Apr-12	1	3	F	13	11:30	1	2.2	8
31	5-Apr-12	1	3	F	12	11:34	2	1.7	6
31	5-Apr-12	1	3	F	14	11:38	3	0.3	1
31	5-Apr-12	1	3	F	14	11:42	4	2.1	7
31	5-Apr-12	1	3	F	12	11:46	6	1.2	6
31	5-Apr-12	1	3	F	12	11:51	5	1.2	8
32	5-Apr-12	1	2	H	28	13:38	5	0.0	0
32	5-Apr-12	1	2	H	28	13:42	6	0.0	0
32	5-Apr-12	1	2	H	27	13:45	4	0.0	0

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot	Catch of blue cod (kg)	Number
32	5-Apr-12	1	2	H	29	13:49	3	0.0	0
32	5-Apr-12	1	2	H	31	13:54	2	0.0	0
32	5-Apr-12	1	2	H	28	13:58	1	0.0	0
33	5-Apr-12	1	2	E	20	15:21	1	0.6	1
33	5-Apr-12	1	2	E	19	15:24	2	2.9	6
33	5-Apr-12	1	2	E	18	15:28	3	0.5	1
33	5-Apr-12	1	2	E	20	15:32	4	3.0	9
33	5-Apr-12	1	2	E	17	15:36	6	1.8	4
33	5-Apr-12	1	2	E	18	15:39	5	0.5	2
34	6-Apr-12	1	1	J	13	07:13	5	0.3	1
34	6-Apr-12	1	1	J	19	07:16	6	2.7	14
34	6-Apr-12	1	1	J	20	07:20	4	1.0	4
34	6-Apr-12	1	1	J	19	07:23	3	0.0	0
34	6-Apr-12	1	1	J	22	07:26	2	0.7	3
34	6-Apr-12	1	1	J	22	07:30	1	0.0	0
35	6-Apr-12	1	1	R5	14	09:02	1	0.4	1
35	6-Apr-12	1	1	R5	19	09:07	2	0.4	4
35	6-Apr-12	1	1	R5	17	09:10	3	0.0	0
35	6-Apr-12	1	1	R5	9	09:13	4	1.2	4
35	6-Apr-12	1	1	R5	11	09:17	6	0.6	1
35	6-Apr-12	1	1	R5	13	09:20	5	0.4	1
36	6-Apr-12	1	1	R4	24	10:42	5	1.6	3
36	6-Apr-12	1	1	R4	23	10:45	6	1.2	4
36	6-Apr-12	1	1	R4	24	10:48	4	0.0	0
36	6-Apr-12	1	1	R4	23	10:51	3	0.4	2
36	6-Apr-12	1	1	R4	24	10:54	2	1.0	3
36	6-Apr-12	1	1	R4	16	10:58	1	2.1	6
37	6-Apr-12	1	1	R1	5	12:32	1	0.0	0
37	6-Apr-12	1	1	R1	8	12:35	2	0.0	0
37	6-Apr-12	1	1	R1	9	12:39	3	0.8	3
37	6-Apr-12	1	1	R1	11	12:42	4	0.0	0
37	6-Apr-12	1	1	R1	12	12:46	6	0.0	0
37	6-Apr-12	1	1	R1	11	12:50	5	0.3	4
38	6-Apr-12	1	2	A	22	14:27	5	0.0	0
38	6-Apr-12	1	2	A	23	14:30	6	1.2	4
38	6-Apr-12	1	2	A	24	14:33	4	0.4	2
38	6-Apr-12	1	2	A	19	14:36	3	0.8	3
38	6-Apr-12	1	2	A	18	14:40	2	0.1	1
38	6-Apr-12	1	2	A	24	14:44	1	0.9	4
39	7-Apr-12	1	1	R3	25	07:22	1	0.5	1
39	7-Apr-12	1	1	R3	21	07:26	2	0.0	0
39	7-Apr-12	1	1	R3	23	07:29	3	0.0	0
39	7-Apr-12	1	1	R3	25	07:33	4	0.9	1
39	7-Apr-12	1	1	R3	23	07:37	6	0.0	0
39	7-Apr-12	1	1	R3	21	07:41	5	0.0	0
40	7-Apr-12	1	1	R2	8	08:59	5	1.7	5
40	7-Apr-12	1	1	R2	10	09:03	6	0.0	0
40	7-Apr-12	1	1	R2	11	09:07	4	0.2	2

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot	Catch of blue cod (kg)	Number
40	7-Apr-12	1	1	R2	11	09:10	3	0.0	0
40	7-Apr-12	1	1	R2	13	09:13	2	0.3	2
40	7-Apr-12	1	1	R2	13	09:17	1	0.0	0
41	7-Apr-12	1	2	R2	19	11:04	1	0.0	0
41	7-Apr-12	1	2	R2	20	11:08	2	0.0	0
41	7-Apr-12	1	2	R2	19	11:12	3	1.4	7
41	7-Apr-12	1	2	R2	20	11:17	4	2.7	14
41	7-Apr-12	1	2	R2	21	11:20	6	2.2	23
41	7-Apr-12	1	2	R2	19	11:24	5	1.6	8
42	9-Apr-12	1	5	R4	8	08:12	5	0.0	0
42	9-Apr-12	1	5	R4	7	08:15	6	0.0	0
42	9-Apr-12	1	5	R4	10	08:19	4	0.0	0
42	9-Apr-12	1	5	R4	9	08:22	3	0.0	0
42	9-Apr-12	1	5	R4	10	08:27	2	0.0	0
42	9-Apr-12	1	5	R4	11	08:31	1	0.0	0
43	9-Apr-12	1	4	R2	17	10:17	1	1.4	3
43	9-Apr-12	1	4	R2	18	10:20	2	0.0	0
43	9-Apr-12	1	4	R2	15	10:27	3	1.2	1
43	9-Apr-12	1	4	R2	20	10:30	4	0.0	0
43	9-Apr-12	1	4	R2	20	10:33	6	0.0	0
43	9-Apr-12	1	4	R2	21	10:36	5	0.0	0
44	9-Apr-12	1	4	G	18	11:51	5	4.0	8
44	9-Apr-12	1	4	G	16	11:54	6	0.2	1
44	9-Apr-12	1	4	G	15	11:57	4	3.2	5
44	9-Apr-12	1	4	G	14	12:00	3	0.4	1
44	9-Apr-12	1	4	G	12	12:04	2	0.9	2
44	9-Apr-12	1	4	G	10	12:07	1	0.0	0
45	9-Apr-12	1	2	R5	34	13:57	1	1.9	5
45	9-Apr-12	1	2	R5	33	14:02	2	3.6	6
45	9-Apr-12	1	2	R5	36	14:07	3	0.7	1
45	9-Apr-12	1	2	R5	35	14:12	4	0.0	0
45	9-Apr-12	1	2	R5	33	14:18	6	1.7	2
45	9-Apr-12	1	2	R5	33	14:23	5	0.0	0
46	12-Apr-12	1	2	C	26	07:10	5	0.0	0
46	12-Apr-12	1	2	C	29	07:14	6	0.2	1
46	12-Apr-12	1	2	C	29	07:18	4	0.0	0
46	12-Apr-12	1	2	C	30	07:23	3	2.9	6
46	12-Apr-12	1	2	C	27	07:27	2	0.2	1
46	12-Apr-12	1	2	C	31	07:31	1	2.2	4
47	12-Apr-12	1	2	R1	24	09:05	1	5.1	8
47	12-Apr-12	1	2	R1	26	09:08	2	1.4	5
47	12-Apr-12	1	2	R1	22	09:12	3	2.7	5
47	12-Apr-12	1	2	R1	24	09:16	4	1.1	5
47	12-Apr-12	1	2	R1	23	09:20	6	2.3	10
47	12-Apr-12	1	2	R1	21	09:24	5	1.7	5
48	12-Apr-12	1	2	R4	21	10:55	5	3.7	25
48	12-Apr-12	1	2	R4	24	10:58	6	0.9	5
48	12-Apr-12	1	2	R4	24	11:01	4	0.0	0

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot	Catch of blue cod (kg)	Number
48	12-Apr-12	1	2	R4	25	11:05	3	0.0	0
48	12-Apr-12	1	2	R4	23	11:08	2	0.2	1
48	12-Apr-12	1	2	R4	24	11:12	1	0.7	2
49	12-Apr-12	1	2	R3	25	12:34	1	0.0	0
49	12-Apr-12	1	2	R3	22	12:37	2	0.6	1
49	12-Apr-12	1	2	R3	22	12:40	3	1.1	3
49	12-Apr-12	1	2	R3	24	12:43	4	1.0	5
49	12-Apr-12	1	2	R3	21	12:46	6	0.4	1
49	12-Apr-12	1	2	R3	19	12:49	5	0.0	0
50	13-Apr-12	1	7	C	77	08:07	1	3.0	4
50	13-Apr-12	1	7	C	77	08:13	2	10.3	21
50	13-Apr-12	1	7	C	77	08:19	3	7.8	11
50	13-Apr-12	1	7	C	80	08:25	4	11.8	20
50	13-Apr-12	1	7	C	78	08:33	5	5.8	20
50	13-Apr-12	1	7	C	78	08:39	6	4.7	10
51	13-Apr-12	1	7	F	75	10:11	6	7.2	16
51	13-Apr-12	1	7	F	76	10:16	5	1.5	1
51	13-Apr-12	1	7	F	77	10:22	4	0.0	0
51	13-Apr-12	1	7	F	77	10:29	3	0.0	0
51	13-Apr-12	1	7	F	76	10:35	2	1.2	1
51	13-Apr-12	1	7	F	76	10:42	1	2.7	6
52	13-Apr-12	1	7	R4	81	12:06	1	0.0	0
52	13-Apr-12	1	7	R4	78	12:12	2	0.0	0
52	13-Apr-12	1	7	R4	77	12:19	3	0.0	0
52	13-Apr-12	1	7	R4	78	12:25	4	0.3	2
52	13-Apr-12	1	7	R4	77	12:31	5	0.0	0
52	13-Apr-12	1	7	R4	79	12:37	6	0.0	0
53	16-Apr-12	1	7	K	78	07:51	6	0.0	0
53	16-Apr-12	1	7	K	79	07:58	5	0.0	0
53	16-Apr-12	1	7	K	80	08:03	4	0.0	0
53	16-Apr-12	1	7	K	80	08:09	3	0.0	0
53	16-Apr-12	1	7	K	80	08:14	2	0.0	0
53	16-Apr-12	1	7	K	78	08:20	1	0.0	0
54	16-Apr-12	1	7	G	77	09:40	1	0.0	0
54	16-Apr-12	1	7	G	76	09:45	2	0.1	1
54	16-Apr-12	1	7	G	75	09:50	3	36.0	50
54	16-Apr-12	1	7	G	76	09:55	4	9.3	14
54	16-Apr-12	1	7	G	77	10:00	5	0.0	0
54	16-Apr-12	1	7	G	77	10:05	6	0.1	1
55	16-Apr-12	1	7	R5	78	11:35	6	5.2	12
55	16-Apr-12	1	7	R5	78	11:41	5	1.2	3
55	16-Apr-12	1	7	R5	75	11:46	4	8.4	11
55	16-Apr-12	1	7	R5	75	11:52	3	7.1	9
55	16-Apr-12	1	7	R5	77	11:58	2	17.5	21
55	16-Apr-12	1	7	R5	78	12:04	1	9.4	15
56	16-Apr-12	1	7	B	74	13:32	1	0.5	1
56	16-Apr-12	1	7	B	74	13:37	2	0.3	4
56	16-Apr-12	1	7	B	75	13:42	3	0.0	0

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot	Catch of blue cod (kg)	Number
56	16-Apr-12	1	7	B	76	13:47	4	0.0	0
56	16-Apr-12	1	7	B	76	13:52	5	14.4	12
56	16-Apr-12	1	7	B	75	13:57	6	11.1	14
57	20-Apr-12	1	6	R2	83	09:44	4	12.7	8
57	20-Apr-12	1	6	R2	84	09:49	5	11.6	8
57	20-Apr-12	1	6	R2	88	09:56	6	6.0	9
57	20-Apr-12	1	6	R2	86	10:02	1	2.6	2
57	20-Apr-12	1	6	R2	83	10:09	2	11.1	9
57	20-Apr-12	1	6	R2	80	10:18	3	4.5	2
58	20-Apr-12	1	6	R3	85	11:38	3	10.2	6
58	20-Apr-12	1	6	R3	87	11:42	2	0.0	0
58	20-Apr-12	1	6	R3	87	11:48	1	0.0	0
58	20-Apr-12	1	6	R3	87	11:53	6	0.0	0
58	20-Apr-12	1	6	R3	88	11:58	5	0.0	0
58	20-Apr-12	1	6	R3	86	12:05	4	1.4	1
59	20-Apr-12	1	6	6D	85	13:30	4	15.4	9
59	20-Apr-12	1	6	6D	87	13:36	5	0.0	0
59	20-Apr-12	1	6	6D	88	13:40	6	6.9	5
59	20-Apr-12	1	6	6D	89	13:44	1	4.6	5
59	20-Apr-12	1	6	6D	85	13:48	2	0.0	0
59	20-Apr-12	1	6	6D	77	13:53	3	3.8	4
60	21-Apr-12	1	6	R5	81	09:00	3	5.6	3
60	21-Apr-12	1	6	R5	85	09:06	1	6.2	4
60	21-Apr-12	1	6	R5	84	09:12	6	7.9	9
60	21-Apr-12	1	6	R5	81	09:18	2	2.9	5
60	21-Apr-12	1	6	R5	85	09:24	5	0.5	1
60	21-Apr-12	1	6	R5	79	09:30	4	1.2	1
61	21-Apr-12	1	6	6K	87	10:48	4	0.0	0
61	21-Apr-12	1	6	6K	87	10:52	5	0.0	0
61	21-Apr-12	1	6	6K	86	10:56	2	0.0	0
61	21-Apr-12	1	6	6K	87	11:00	6	1.0	1
61	21-Apr-12	1	6	6K	88	11:05	1	0.0	0
61	21-Apr-12	1	6	6K	89	11:10	3	0.0	0
62	21-Apr-12	1	6	R4	85	12:31	3	0.0	0
62	21-Apr-12	1	6	R4	84	12:36	1	0.0	0
62	21-Apr-12	1	6	R4	88	12:40	6	11.8	7
62	21-Apr-12	1	6	R4	84	12:46	2	0.0	0
62	21-Apr-12	1	6	R4	86	12:51	5	10.6	7
62	21-Apr-12	1	6	R4	87	12:57	4	0.0	0
63	22-Apr-12	1	5	E	8	07:48	1	0.5	1
63	22-Apr-12	1	5	E	9	07:53	2	2.4	5
63	22-Apr-12	1	5	E	10	07:57	3	5.6	9
63	22-Apr-12	1	5	E	12	08:01	4	2.7	5
63	22-Apr-12	1	5	E	12	08:05	5	1.5	4
63	22-Apr-12	1	5	E	15	08:10	6	5.0	15
64	22-Apr-12	1	4	D	15	09:40	6	2.3	7
64	22-Apr-12	1	4	D	13	09:43	5	1.5	5
64	22-Apr-12	1	4	D	15	09:46	4	6.4	10

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot	Catch of blue cod (kg)	Number
64	22-Apr-12	1	4	D	16	09:50	3	0.0	0
64	22-Apr-12	1	4	D	16	09:55	2	6.6	17
64	22-Apr-12	1	4	D	15	09:59	1	2.9	7
65	22-Apr-12	1	4	B	33	11:16	1	1.2	4
65	22-Apr-12	1	4	B	31	11:20	2	1.3	6
65	22-Apr-12	1	4	B	29	11:24	3	2.3	10
65	22-Apr-12	1	4	B	24	11:29	4	0.0	0
65	22-Apr-12	1	4	B	25	11:33	5	4.5	10
65	22-Apr-12	1	4	B	24	11:37	6	0.0	0
66	22-Apr-12	1	4	R5	39	12:52	6	8.9	31
66	22-Apr-12	1	4	R5	30	12:56	5	0.0	0
66	22-Apr-12	1	4	R5	25	12:59	4	0.0	0
66	22-Apr-12	1	4	R5	22	13:04	3	0.0	0
66	22-Apr-12	1	4	R5	19	13:09	2	10.9	25
66	22-Apr-12	1	4	R5	17	13:14	1	6.2	17
67	23-Apr-12	1	3	R3	9	07:23	1	2.1	5
67	23-Apr-12	1	3	R3	13	07:28	2	2.2	10
67	23-Apr-12	1	3	R3	13	07:33	3	0.8	5
67	23-Apr-12	1	3	R3	16	07:38	4	0.5	2
67	23-Apr-12	1	3	R3	16	07:43	5	0.8	6
67	23-Apr-12	1	3	R3	20	07:49	6	0.0	0
68	23-Apr-12	1	3	R4	16	08:59	6	3.4	9
68	23-Apr-12	1	3	R4	15	09:02	5	3.2	17
68	23-Apr-12	1	3	R4	18	09:05	4	4.1	9
68	23-Apr-12	1	3	R4	14	09:10	3	0.4	1
68	23-Apr-12	1	3	R4	19	09:17	2	1.9	10
68	23-Apr-12	1	3	R4	25	09:21	1	0.8	2
69	23-Apr-12	1	3	R2	12	10:33	1	1.0	2
69	23-Apr-12	1	3	R2	11	10:37	2	0.8	4
69	23-Apr-12	1	3	R2	10	10:41	3	0.2	2
69	23-Apr-12	1	3	R2	11	10:44	4	0.7	1
69	23-Apr-12	1	3	R2	18	10:48	5	1.2	4
69	23-Apr-12	1	3	R2	22	10:52	6	0.1	1
70	23-Apr-12	1	3	R1	11	12:28	6	2.5	4
70	23-Apr-12	1	3	R1	12	12:31	5	3.7	12
70	23-Apr-12	1	3	R1	12	12:34	4	1.4	5
70	23-Apr-12	1	3	R1	15	12:38	3	2.1	8
70	23-Apr-12	1	3	R1	19	12:42	2	6.3	19
70	23-Apr-12	1	3	R1	21	12:47	1	5.8	8
78	26-Apr-12	2	7	L	77	07:52	6	11.2	13
78	26-Apr-12	2	7	L	78	07:57	5	15.8	21
78	26-Apr-12	2	7	L	80	08:03	4	8.8	7
78	26-Apr-12	2	7	L	78	08:11	3	0.0	0
78	26-Apr-12	2	7	L	79	08:18	2	5.9	4
78	26-Apr-12	2	7	L	76	08:24	1	5.7	9
79	26-Apr-12	2	7	D	75	09:40	1	7.9	8
79	26-Apr-12	2	7	D	75	09:45	2	9.1	13
79	26-Apr-12	2	7	D	75	09:50	3	24.6	13

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot	Catch of blue cod (kg)	Number
79	26-Apr-12	2	7	D	75	10:00	5	2.6	4
79	26-Apr-12	2	7	D	75	10:05	6	20.9	13
80	26-Apr-12	2	7	R6	76	11:24	6	0.2	1
80	26-Apr-12	2	7	R6	76	11:28	5	0.0	0
80	26-Apr-12	2	7	R6	74	11:33	4	0.0	0
80	26-Apr-12	2	7	R6	74	11:38	3	0.0	0
80	26-Apr-12	2	7	R6	75	11:43	2	0.0	0
80	26-Apr-12	2	7	R6	76	11:48	1	4.8	7
81	4-May-12	2	7	R7	77	08:47	1	11.2	12
81	4-May-12	2	7	R7	74	08:52	2	5.8	3
81	4-May-12	2	7	R7	70	08:57	3	9.7	10
81	4-May-12	2	7	R7	71	09:05	4	0.9	2
81	4-May-12	2	7	R7	76	09:10	5	10.6	13
81	4-May-12	2	7	R7	74	09:16	6	13.9	10
82	4-May-12	2	7	I	78	10:33	6	0.0	0
82	4-May-12	2	7	I	67	10:37	5	0.0	0
82	4-May-12	2	7	I	77	10:42	4	0.0	0
82	4-May-12	2	7	I	77	10:48	3	0.0	0
82	4-May-12	2	7	I	78	10:53	2	0.0	0
82	4-May-12	2	7	I	80	10:58	1	1.5	5
83	4-May-12	2	7	R8	76	12:12	1	4.3	3
83	4-May-12	2	7	R8	76	12:18	2	1.9	1
83	4-May-12	2	7	R8	77	12:23	3	0.0	0
83	4-May-12	2	7	R8	78	12:28	4	0.3	2
83	4-May-12	2	7	R8	77	12:33	5	1.2	2
83	4-May-12	2	7	R8	76	12:38	6	13.9	13
84	5-May-12	2	7	R9	75	08:42	6	0.0	0
84	5-May-12	2	7	R9	74	08:47	5	0.0	0
84	5-May-12	2	7	R9	73	08:51	4	0.1	1
84	5-May-12	2	7	R9	73	08:56	3	0.0	0
84	5-May-12	2	7	R9	73	09:00	2	0.0	0
84	5-May-12	2	7	R9	74	09:05	1	0.0	0
85	5-May-12	2	7	A	74	10:33	1	14.4	21
85	5-May-12	2	7	A	72	10:37	2	18.6	19
85	5-May-12	2	7	A	73	10:42	3	6.7	8
85	5-May-12	2	7	A	73	10:47	4	8.3	10
85	5-May-12	2	7	A	74	10:52	5	7.0	7
85	5-May-12	2	7	A	72	10:58	6	5.8	10
86	5-May-12	2	7	R10	79	12:15	6	0.5	1
86	5-May-12	2	7	R10	77	12:20	5	1.5	1
86	5-May-12	2	7	R10	78	12:25	4	0.1	1
86	5-May-12	2	7	R10	77	12:30	3	0.0	0
86	5-May-12	2	7	R10	79	12:35	2	0.1	1
86	5-May-12	2	7	R10	80	12:40	1	0.1	1
87	6-May-12	2	7	E	72	12:25	1	8.8	11
87	6-May-12	2	7	E	75	12:30	2	12.7	16
87	6-May-12	2	7	E	78	12:35	3	7.2	7
87	6-May-12	2	7	E	76	12:40	4	8.1	9

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot	Catch of blue cod (kg)	Number
87	6-May-12	2	7	E	75	12:45	5	6.0	8
87	6-May-12	2	7	E	74	12:50	6	17.0	14

Appendix 3: Summary of the Banks Peninsula 2012 survey oceanographic environmental station data recorded in the format of the trawl data base.
Depths are measured in metres, directions in compass degrees (999 = nil), wind force in the Beaufort scale, temperatures in degrees Celcius, 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 metres, 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	26.0	310	1	18.5	1024	0	2	7	2.0	180	7	2	11.5	*	5.2	2.6
2	18.3	200	1	18.5	1024	2	2	7	1.5	180	7	2	11.5	*	5.0	3.0
3	17.0	150	2	18.1	1025	0	2	7	1.0	180	7	3	11.5	*	12.0	2.9
4	23.3	060	2	21.3	1025	0	1	7	1.0	080	7	3	11.5	*	11.8	3.7
5	25.3	999	0	12.9	1029	5	2	7	0.5	180	7	3	11.5	*	0.0	4.0
6	24.0	150	1	19.4	1029	3	2	7	0.5	180	7	3	11.5	*	2.5	4.0
7	32.7	050	3	20.1	1029	4	2	7	0.8	080	7	3	11.5	*	13.0	5.1
8	20.0	000	2	21.1	1029	2	2	7	0.5	180	7	3	11.5	*	11.7	5.0
9	29.2	005	3	22.1	1020	1	2	8	0.5	180	7	4	11.5	*	10.5	2.9
10	16.2	060	4	14.5	1035	4	3	7	0.5	135	7	4	11.5	*	20.5	3.1
11	10.7	030	4	16.4	1035	5	2	7	0.5	030	7	2	11.5	*	20.1	4.1
12	15.2	010	3	17.1	1035	3	3	7	1.0	210	7	3	11.5	*	15.2	4.3
13	20.3	030	3	17.6	1035	3	3	7	1.0	060	7	2	11.5	*	16.1	4.7
14	14.0	000	2	14.2	1034	2	2	7	1.0	030	7	2	11.5	*	8.5	2.0
15	8.2	025	2	19.7	1034	2	2	7	1.0	030	9	2	12.0	*	9.4	1.8
16	11.0	000	1	19.6	1034	2	2	7	1.0	030	7	3	12.0	*	4.8	3.3
17	13.0	010	2	20.6	1032	1	2	7	1.0	030	7	2	12.0	*	7.7	4.0
18	77.3	060	3	14.3	1031	4	2	6	1.0	060	8	1	12.0	*	14.5	8.1
19	76.8	080	1	16.5	1031	3	2	6	1.5	060	7	3	12.0	*	5.2	8.4
20	73.2	030	2	19.6	1030	2	2	6	1.5	060	7	2	12.1	*	8.2	8.5
21	83.2	030	2	14.1	1029	5	2	4	1.5	060	7	2	11.5	*	7.4	6.1
22	85.3	030	1	16.2	1029	3	2	4	1.0	060	7	2	11.4	*	4.2	6.0
23	85.5	999	0	20.8	1028	3	1	4	1.0	060	7	3	11.4	*	0.0	6.4
24	85.3	060	1	22.1	1027	6	1	4	0.5	090	7	2	11.8	*	6.3	7.8
25	11.2	999	0	13.7	1025	7	1	7	0.5	060	7	2	11.3	*	0.0	4.7
26	14.2	999	0	17.0	1025	7	3	7	0.5	060	7	4	11.2	*	0.0	6.5
27	13.3	270	1	13.1	1027	8	3	7	1.0	060	7	4	10.8	*	1.9	3.0
28	17.5	060	2	16.1	1027	8	4	7	1.5	060	7	4	11.8	*	7.3	3.1
29	14.3	060	1	17.2	1027	8	4	8	2.0	060	7	2	11.8	*	5.7	2.3

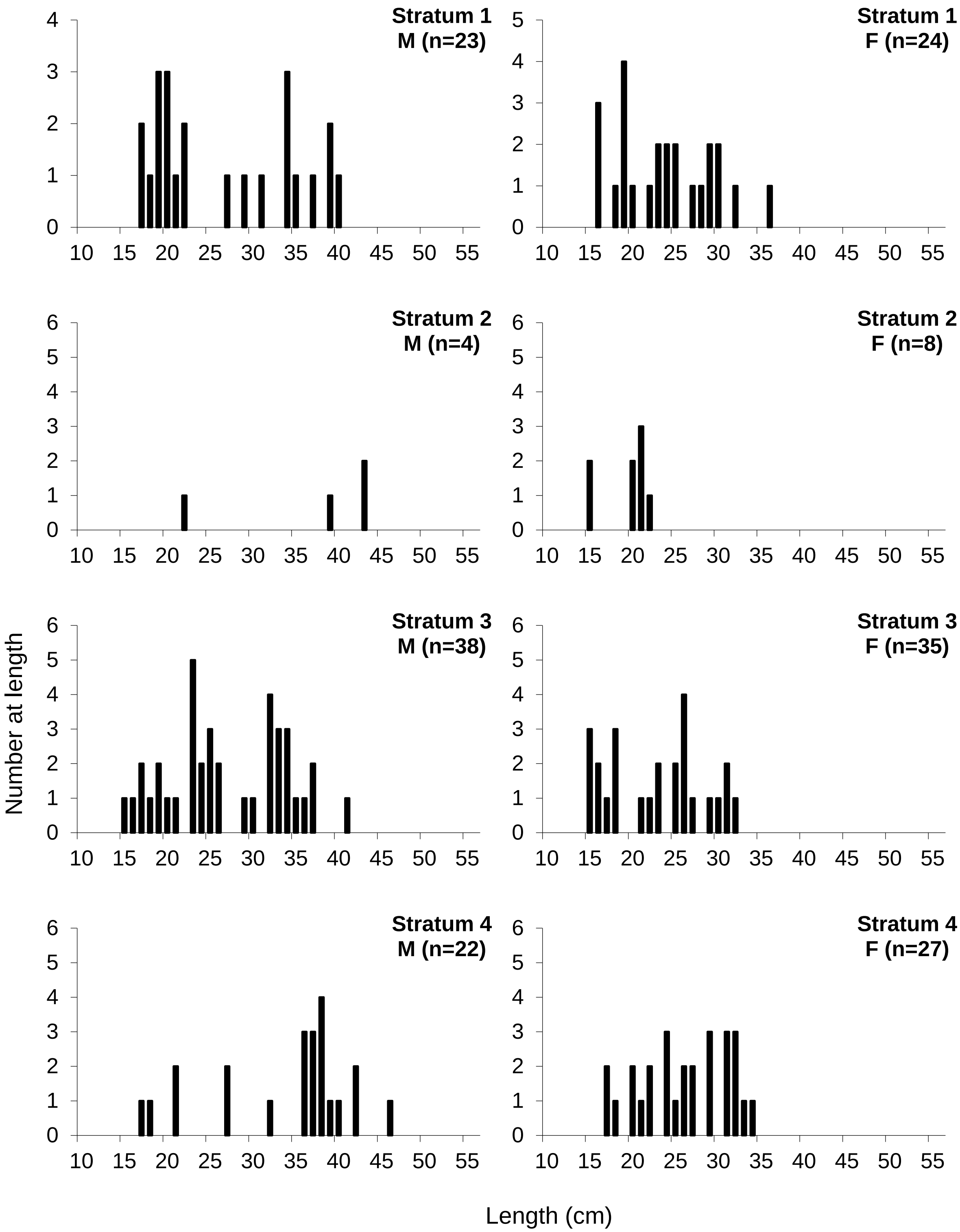
Appendix 3– *continued*

Set	Average Depth	Wind Direction	Wind Force	Air Temp	Air Pressure	Cloud Cover	Sea Condition	Sea Colour	Swell Height	Swell Direction	Bottom Type	Bottom Contour	Surface Temp	Bottom Temp	Wind Speed	Secchi Depth
30	28.7	050	2	14.3	1029	2	3	8	1.5	050	7	3	10.2	*	12.6	1.7
31	12.8	999	0	15.7	1029	1	1	5	<0.5	150	7	2	11.0	*	0.0	6.8
32	28.5	090	2	18.2	1027	0	4	8	2.0	090	7	2	11.0	*	9.2	2.0
33	18.7	270	3	15.7	1026	0	2	7	0.0	000	7	2	11.5	*	16.9	4.0
34	19.2	350	4	14.8	1028	0	3	7	0.3	090	7	1	11.5	*	30.1	2.4
35	13.8	999	0	18.5	1029	0	0	7	0.0	000	7	2	11.5	*	0.0	4.4
36	22.3	300	1	20.8	1029	0	1	7	0.3	120	7	3	11.5	*	3.4	3.7
37	9.3	999	0	21.7	1028	0	0	7	0.0	000	4	1	11.5	*	0.0	3.2
38	21.7	090	2	20.5	1028	0	3	8	1.0	120	7	4	11.5	*	9.4	2.9
39	23.0	040	2	12.3	1024	1	2	8	0.5	120	7	2	11.0	*	10.3	2.3
40	11.0	000	4	18.4	1032	0	2	8	0.3	210	7	1	11.8	*	26.5	2.5
41	19.7	270	2	15.7	1031	0	3	8	0.5	270	7	2	11.5	*	11.1	2.4
42	9.2	240	1	15.8	1027	0	2	8	0.5	060	3	1	11.2	*	4.1	0.4
43	18.5	060	1	19.1	1027	6	3	7	1.5	060	7	3	12.0	*	5.2	1.8
44	14.2	060	1	17.8	1027	7	3	7	1.0	060	7	2	12.0	*	3.8	1.8
45	34.0	090	3	19.8	1023	2	4	7	1.5	060	7	3	13.0	*	17.0	4.7
46	28.7	060	2	9.8	1025	2	3	7	1.5	090	7	3	11.5	*	9.2	3.0
47	23.3	000	2	11.4	1025	2	3	6	1.0	060	7	2	11.5	*	11.1	8.3
48	23.5	999	0	13.1	1024	7	2	7	0.5	150	7	2	11.5	*	0.0	4.3
49	22.2	180	2	14.2	1024	6	3	7	1.0	150	7	3	11.0	*	8.2	2.4
50	77.8	050	4	14.2	1019	3	4	5	2.0	320	7	1	12.0	*	29.9	5.2
51	76.2	330	4	14.4	1018	2	4	5	2.0	320	7	2	12.0	*	22.3	6.2
52	78.3	320	4	15.1	1017	6	4	5	2.0	320	7	2	12.0	*	25.5	6.0
53	79.2	230	3	14.3	1038	7	3	5	1.0	210	7	2	12.0	*	13.4	8.0
54	76.3	220	3	14.7	1038	6	3	5	1.0	240	7	2	12.0	*	20.0	7.0
55	76.8	210	2	15.7	1039	3	3	5	1.0	210	7	3	12.0	*	11.6	7.3
56	75.0	210	3	15.7	1038	4	3	6	1.0	210	7	2	12.0	*	13.6	7.6
57	84.0	030	2	13.5	1029	2	3	5	2.0	150	7	3	11.5	*	12.0	8.2
58	86.7	030	4	15.4	1029	3	3	5	2.0	150	6	1	11.5	*	23.5	8.0
59	85.2	030	4	15.2	1029	3	4	5	2.0	150	7	2	11.5	*	21.0	8.1
60	82.5	210	2	13.2	1029	1	2	5	1.5	010	7	2	11.5	*	7.6	8.1

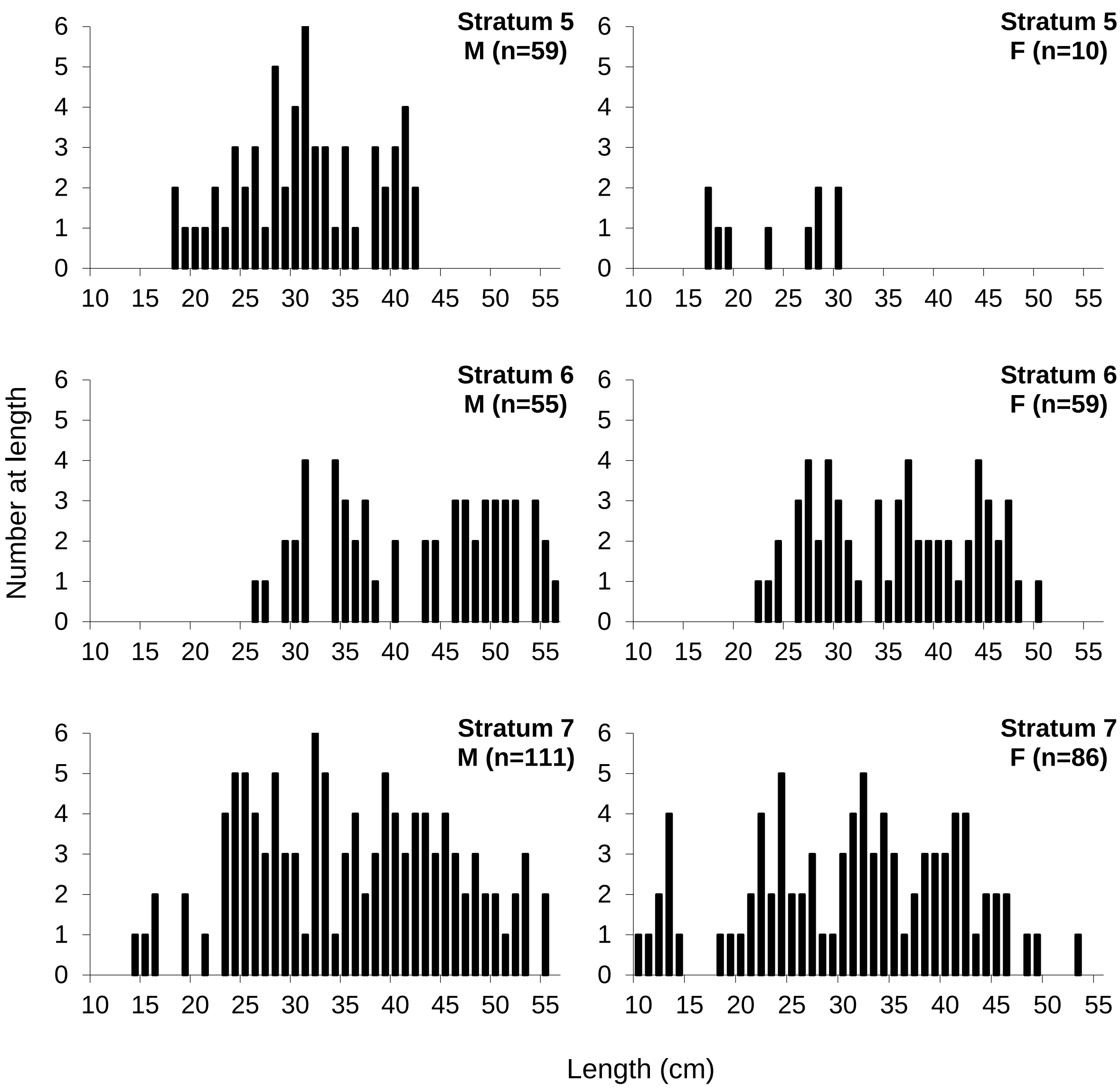
Appendix 3– *continued*

Set	Average Depth	Wind Direction	Wind Force	Air Temp	Air Pressure	Cloud Cover	Sea Condition	Sea Colour	Swell Height	Swell Direction	Bottom Type	Bottom Contour	Surface Temp	Bottom Temp	Wind Speed	Secchi Depth
61	87.3	210	2	16.1	1029	1	3	5	1.5	010	7	2	11.5	*	11.9	8.1
62	85.7	210	2	16.5	1029	2	2	5	1.0	190	7	3	11.5	*	10.2	8.0
63	11.0	240	1	11.5	1029	3	2	7	1.5	190	7	4	11.5	*	5.0	4.3
64	15.0	350	3	14.1	1029	4	2	7	0.5	065	7	3	11.5	*	18.7	3.1
65	27.7	210	3	14.8	1027	4	3	7	0.5	070	7	4	11.5	*	20.1	3.1
66	25.3	040	4	14.9	1027	3	3	7	0.5	040	7	4	11.5	*	22.8	3.0
67	14.5	330	1	10.4	1028	6	2	7	0.3	130	7	3	11.7	*	6.0	2.4
68	17.8	999	0	12.6	1028	6	2	7	0.3	130	7	4	11.7	*	0.0	3.4
69	14.0	999	0	15.3	1028	4	1	7	0.3	060	7	2	11.6	*	0.0	4.4
70	15.0	240	1	20.2	1028	5	1	7	0.3	060	7	2	11.6	*	2.8	4.1
78	26.7	340	2	14.3	1016	2			1.0	000	7	2	11.6	*	8.2	8.7
79	24.3	000	2	17.1	1015	2			1.0	000	7	1	11.8	*	9.6	8.9
80	17.7	000	2	17.1	1015	2			1.0	000	7	1	11.8	*	9.6	8.9
81	7.7	220	3	12.2	1027	7	3	5	2.0	200	7	2	11.7	*	14.1	7.5
82	30.8	240	1	15.0	1027	8	3	5	2.0	200	7	2	11.7	*	7.2	7.5
83	8.3	240	1	16.8	1027	8	3	5	2.0	200	7	1	11.7	*	6.2	7.6
84	17.5	100	1	11.6	1036	8	4	3	2.5	150	7	1	11.6	*	5.9	6.8
85	78.0	060	2	11.7	1038	8	4	3	2.5	150	7	3	11.8	*	8.6	7.0
86	75.0	050	2	11.5	1038	8	4	3	2.5	150	7	2	11.8	*	11.5	6.9
87	75.2	340	2	14.3	1016	2			1.0	000	7	2	11.6	*	8.2	8.7

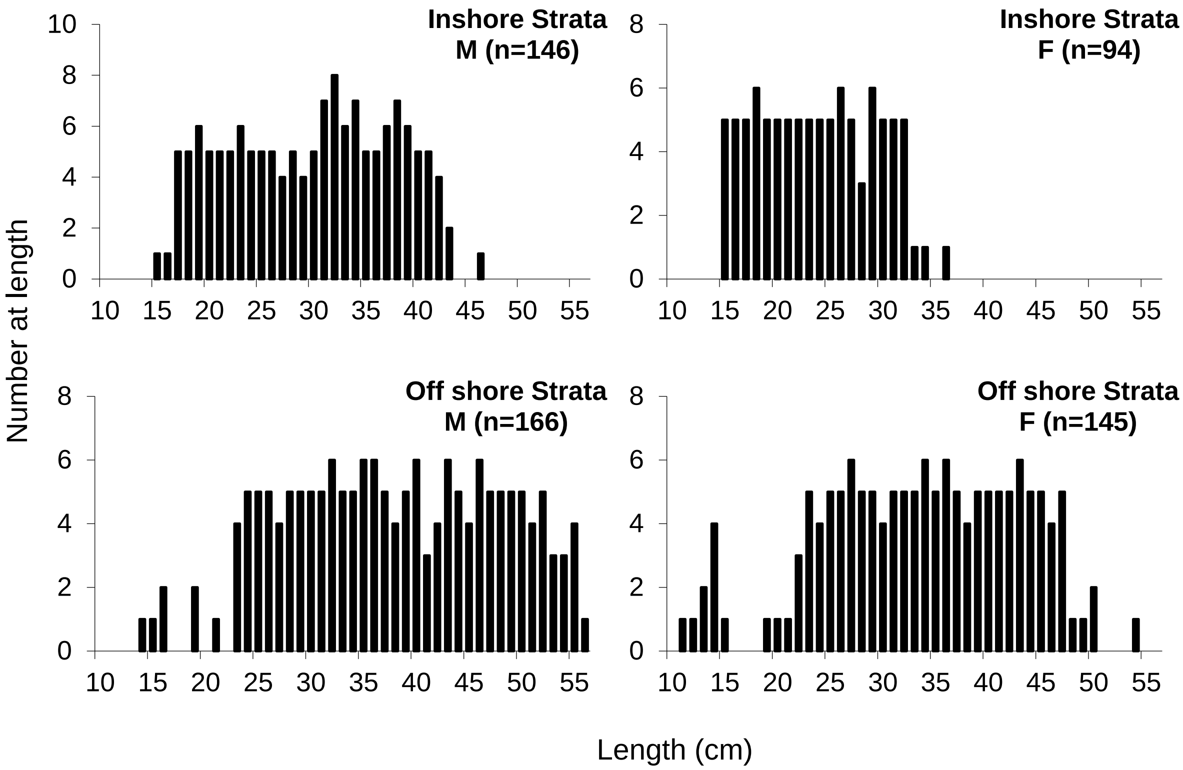
Appendix 4: Unscaled length frequency distributions of blue cod for each stratum from which otoliths were used in the Banks Peninsula 2012 age length keys.



Appendix 4– *continued*



Appendix 5: Unscaled length frequency distributions of blue cod for inshore (1-5) and offshore (6-7) strata (See Figure 1) from which otoliths were used in the Banks Peninsula 2012 age length keys.



Appendix 6: Between-reader comparisons (using first independent readings only) for otolith data collected in Banks Peninsula 2012 inshore strata (1-5).

Reader two															Age class (reader one)					
difference	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	Total
-4															1					1
-3																				0
-2							2	3		2	1									8
-1		2	1	4	2	12	9	4	3	2		1			3					43
0	2	32	30	28	18	18	14	6	7	6	1	2		1	3					168
1		5	5		3	4	1				1									19
2																				0
3																1				1
Total	2	39	36	32	23	34	26	13	10	10	3	3	0	1	7	1	0	0	0	240
% agreement	100	82	83	88	78	53	54	46	70	60	33	67		100	43	0				70

Appendix 7:Independent reader comparisons with agreed age from otolith data collected in Banks Peninsula 2012 inshore strata (1-5).

Reader one															Agreed age class					
difference	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	Total
-3																			1	1
-2					1															1
-1			5	4		3	4	1				1								18
0	2	34	31	30	20	25	21	9	10	7	1	3		1	4					198
1			2		5	4	4		3					1						19
2									1				1							2
3												1								1
Total	2	34	38	34	26	32	29	10	14	7	1	5	1	2	4	0	0	0	1	240
% agreement	100	100	82	88	77	78	72	90	71	100	100	60	0	50	100				0	83

Reader two															Agreed age class					
difference	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	Total
-4															1					1
-3																				0
-2							1	1												2
-1		2	1	2	3	8	8	2	5	1		1								33
0	2	32	37	32	23	24	20	7	9	6	1	3		2	3				1	202
1													1							1
2												1								1
Total	2	34	38	34	26	32	29	10	14	7	1	5	1	2	4	0	0	0	1	240
% agreement	100	94	97	94	88	75	69	70	64	86	100	60	0	100	75				100	84

Appendix 8: Between-reader comparisons (using first independent readings only) for otolith data collected in Banks Peninsula 2012 offshore strata (6-7).

Reader two	Age class (reader one)																			
difference	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	Total
-10																			1	1
-9																				
-8																				
-7																				
-6																			1	1
-5															1			2		3
-4																				
-3											1							1	1	3
-2							1		4		1		1		1	2			2	12
-1		1				3	6	5	2	4	2	1	1	2	4				10	41
0	10	3	7	12	16	17	15	8	7	6	6	9	4	5	1	2	3		16	147
1	1	2	5	4	5	2	2	2	3	5		1	3	1	2	3	1	2	9	53
2						1	1			2	1				1	1	5	2	8	22
3										1	1		3			1	1		4	11
4								1			3			1					3	8
5													1			1	1		1	4
6															1					1
7															2			1		3
8																				
9																1				1
Total	11	6	12	16	21	23	25	16	16	18	15	11	13	9	13	11	11	8	55	311
% agreement	91	50	58	75	76	74	60	50	44	33	40	82	31	56	8	18	27	0	29	47

Appendix 9: Independent reader comparisons with agreed age from otolith data collected in Banks Peninsula 2012 offshore strata (6-7).

Reader one																Agreed age class				
difference	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	Total
-9																			2	2
-8																				
-7																			3	3
-6																			1	1
-5																			2	2
-4																			6	6
-3											1		1	2		2			7	13
-2									1			2	2		1	1			5	12
-1		1	2	5	4	5	3	2	2	3	5		1	3	1	2	2	5	15	61
0	10	4	7	12	16	19	17	9	11	8	9	10	7	5	4	4	3	1	23	179
1					1	4	4	2	2	2			2	3	1				2	23
2					1									1					2	4
3															2					2
4											1									1
5													1							1
6															1					1
7																				
Total	10	5	9	17	22	28	24	13	16	13	16	12	14	14	10	9	5	6	68	311
% agreement	100	80	78	71	73	68	71	69	69	62	56	83	50	36	40	44	60	17	34	58

Reader two																Agreed age class				
difference	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	Total
-5																			2	2
-4																			2	2
-3															1				3	4
-2									2	1	2		2		1				8	16
-1		1				2	2	3	2	1	3	1	1	1	4				5	26
0	10	4	9	17	22	26	21	10	12	9	8	10	9	10	3	5	5	1	37	228
1							1			2	2	1	1	1	1	1		4	9	23
2													1	1		2		1	2	7
3																				0
4											1			1						2
5																				0
6																1				1
Total	10	5	9	17	22	28	24	13	16	13	16	12	14	14	10	9	5	6	68	311
% agreement	100	80	100	100	100	93	88	77	75	69	50	83	64	71	30	56	100	17	54	73

Appendix 10: The proportion of fish at age and length and the total number at length and at age for male blue cod sampled from the 2012 inshore (strata 1-5, see Figure 1) Banks Peninsula survey (age -length-key, ALK).

	Age (years)																				
Len (cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
15	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
16	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
17	0	0	0.4	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
18	0	0.2	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
19	0	0	0.83	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
20	0	0	0.2	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
21	0	0	0.2	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
22	0	0	0	0.6	0.2	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
23	0	0	0	0.83	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
24	0	0	0	0.6	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
25	0	0	0	0	0.8	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	5
26	0	0	0	0	0.8	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
27	0	0	0	0.25	0	0	0.25	0.5	0	0	0	0	0	0	0	0	0	0	0	0	4
28	0	0	0	0	0.2	0.2	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	5
29	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	4
30	0	0	0	0	0	0.4	0.2	0.2	0.2	0	0	0	0	0	0	0	0	0	0	0	5
31	0	0	0	0	0	0	0.86	0.14	0	0	0	0	0	0	0	0	0	0	0	0	7
32	0	0	0	0	0	0.13	0.63	0.25	0	0	0	0	0	0	0	0	0	0	0	0	8
33	0	0	0	0	0	0	0.33	0.67	0	0	0	0	0	0	0	0	0	0	0	0	6
34	0	0	0	0	0	0.14	0.14	0.57	0.14	0	0	0	0	0	0	0	0	0	0	0	7
35	0	0	0	0	0	0	0	0.8	0.2	0	0	0	0	0	0	0	0	0	0	0	5
36	0	0	0	0	0	0	0	0.4	0.2	0.4	0	0	0	0	0	0	0	0	0	0	5
37	0	0	0	0	0	0	0	0	0.5	0	0.33	0	0.17	0	0	0	0	0	0	0	6
38	0	0	0	0	0	0	0	0.29	0	0.14	0.43	0	0.14	0	0	0	0	0	0	0	7
39	0	0	0	0	0	0	0	0	0	0.5	0	0	0.33	0	0	0.17	0	0	0	0	6
40	0	0	0	0	0	0	0	0.2	0	0.6	0	0	0	0	0	0.2	0	0	0	0	5
41	0	0	0	0	0	0	0	0	0.2	0.4	0.2	0	0.2	0	0	0	0	0	0	0	5
42	0	0	0	0	0	0	0	0	0	0	0	0.25	0	0	0.5	0.25	0	0	0	0	4
43	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0.5	0	0	0	0	2
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Total	0	1	14	25	13	9	22	23	8	11	6	1	5	1	2	4	0	0	0	1	146

Appendix 11: The proportion of fish at age and length and the total number at length and at age for female blue cod sampled from the 2012 inshore (strata 1-5, see Figure 1) Banks Peninsula survey (age -length-key, ALK).

	Age (years)																				
Len (cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
15	0	0	0.8	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
16	0	0	0.8	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
17	0	0	0.8	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
18	0	0.17	0.67	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
19	0	0	0.8	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
20	0	0	0	0.4	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
21	0	0	0	0.6	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
22	0	0	0	0.6	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
23	0	0	0	0.4	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
24	0	0	0	0	0.4	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
25	0	0	0	0	0.8	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
26	0	0	0	0	0.33	0.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
27	0	0	0	0	0.2	0.6	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	5
28	0	0	0	0	0	0.67	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	3
29	0	0	0	0	0	0.33	0.5	0.17	0	0	0	0	0	0	0	0	0	0	0	0	6
30	0	0	0	0	0	0.4	0.2	0.4	0	0	0	0	0	0	0	0	0	0	0	0	5
31	0	0	0	0	0	0	0.2	0.6	0.2	0	0	0	0	0	0	0	0	0	0	0	5
32	0	0	0	0	0	0	0.6	0	0.2	0	0.2	0	0	0	0	0	0	0	0	0	5
33	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
34	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
36	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Total	0	1	20	13	21	17	10	6	2	3	1	0	0	0	0	0	0	0	0	0	94

Appendix 12: The proportion of fish at age and length and the total number at length and at age for male blue cod sampled from the 2012 offshore (strata 6-7, see Figure 1) Banks Peninsula survey (age -length-key, ALK).

	Age (years)																										
Len (cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	>25	Total
14	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
15	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
16	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
19	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
21	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
23	0	0	0	0.25	0.5	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
24	0	0	0	0	0.8	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
25	0	0	0	0	0.8	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
26	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
27	0	0	0	0	0	0.5	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
28	0	0	0	0	0	0.2	0.6	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
29	0	0	0	0	0	0	0.8	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
30	0	0	0	0	0	0.2	0.2	0.4	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
31	0	0	0	0	0	0.4	0	0.4	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
32	0	0	0	0	0	0.17	0.67	0	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
33	0	0	0	0	0	0	0	0.4	0	0.4	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
34	0	0	0	0	0	0	0.4	0.2	0.2	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
35	0	0	0	0	0	0	0	0.33	0	0.33	0.17	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
36	0	0	0	0	0	0	0	0.17	0.33	0	0.17	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
37	0	0	0	0	0	0	0	0	0.2	0	0.6	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
38	0	0	0	0	0	0	0	0	0	0	0.25	0.5	0	0	0.25	0	0	0	0	0	0	0	0	0	0	0	4
39	0	0	0	0	0	0	0	0	0	0.2	0	0	0.2	0.2	0.4	0	0	0	0	0	0	0	0	0	0	0	5
40	0	0	0	0	0	0	0	0	0	0.17	0.17	0.17	0.33	0	0	0.17	0	0	0	0	0	0	0	0	0	0	6
41	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0.33	0.33	0	0	0	0	0	0	0	0	0	0	0	3
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0.75	0	0	0	0	0	0	0	0	0	0	4
43	0	0	0	0	0	0	0	0	0	0	0	0.33	0.17	0.17	0.33	0	0	0	0	0	0	0	0	0	0	0	6
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0.2	0	0.2	0	0	0	0.2	0	0	0	0	0	5
45	0	0	0	0	0	0	0	0	0	0	0	0.25	0	0.5	0	0	0	0.25	0	0	0	0	0	0	0	0	4
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0.33	0	0.17	0	0	0.17	0	0	0	0	0	0	6
47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0.4	0	0	0.2	0.2	0	0	0	0	5
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0.2	0.2	0	0	0.2	0.2	0	0	5
49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0.2	0.2	0	0.2	0	0	0.2	5
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0.2	0.2	0	0.4	5
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0	0	0	0	0.75	4
52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0.2	0.6	5
≥53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0.66	3
Total	0	3	2	3	10	14	15	14	5	8	8	11	5	9	11	4	4	3	1	3	5	2	3	2	2	19	166

Appendix 13: The proportion of fish at age and length and the total number at length and at age for female blue cod sampled from the 2012 (strata 6-7, see Figure 1) Banks Peninsula survey (age -length-key, ALK).

	Age (years)																										
Len (cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	>25	Total
11	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
12	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
13	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
14	0	0.75	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
15	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
19	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
20	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
21	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
22	0	0	0	0.33	0.33	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
23	0	0	0	0.4	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
24	0	0	0	0.25	0.5	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
25	0	0	0	0	0.2	0.4	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
26	0	0	0	0	0	0.6	0.2	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
27	0	0	0	0	0	0.17	0.67	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
28	0	0	0	0	0	0	0.4	0.4	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
29	0	0	0	0	0	0	0.4	0.2	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
30	0	0	0	0	0	0	0.5	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
31	0	0	0	0	0	0	0	0.4	0.4	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
32	0	0	0	0	0	0	0	0.2	0.4	0	0.2	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	5
33	0	0	0	0	0	0	0	0	0	0.8	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
34	0	0	0	0	0	0	0	0.17	0	0.5	0.17	0	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	6
35	0	0	0	0	0	0	0	0	0	0.2	0.2	0.2	0.2	0.2	0	0	0	0	0	0	0	0	0	0	0	0	5
36	0	0	0	0	0	0	0	0	0	0	0.17	0.5	0	0	0	0.17	0.17	0	0	0	0	0	0	0	0	0	6
37	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0.2	0.2	0.2	0	0	0	0	0	0	0	0	0	0	5
38	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0.25	0.25	0	0.25	0	0	0	0	0	0	0	0	0	4
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0.2	0.2	0.2	0.2	0	0	0	0	0	0	5
40	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0.4	0.2	0	0.2	0	0	0	0	0	0	0	5
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0.2	0.2	0	0.2	0	0.2	0	0	0	0	0	5
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0.2	0	0.2	0.2	0	0	0.2	0	0	0	0	5
43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.17	0.5	0	0	0.17	0	0.17	0	6
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0.4	0	0.4	0	5
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0.2	0.4	5
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0	0.75	4
47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	5
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
≥49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4
Total	0	7	3	6	7	8	13	10	8	8	5	5	7	5	3	6	5	2	5	4	2	1	5	1	4	15	145

Appendix 14: Mean age-at-length for the 2012 inshore Banks Peninsula survey.

	Males		Females		All fish	
Length (cm)	N	Mean age	N	Mean age	N	Mean age
15	1	3.0	5	3.2	6	3.2
16	1	4.0	5	3.2	6	3.3
17	5	3.6	5	3.4	10	3.5
18	5	2.8	6	3.0	11	2.9
19	6	3.2	5	3.4	11	3.3
20	5	3.8	5	4.6	10	4.2
21	5	3.8	5	4.4	10	4.1
22	5	4.6	5	4.4	10	4.5
23	6	4.2	5	4.6	11	4.4
24	5	4.4	5	5.6	10	5.0
25	5	5.4	5	5.2	10	5.3
26	5	5.2	6	5.7	11	5.5
27	4	6.8	5	6.0	9	6.3
28	5	6.4	3	6.3	8	6.4
29	4	6.5	6	6.8	10	6.7
30	5	7.2	5	7.0	10	7.1
31	7	7.1	5	8.0	12	7.5
32	8	7.1	5	8.2	13	7.5
33	6	7.7	1	10.0	7	8.0
34	7	7.7	1	10.0	8	8.0
35	5	8.2	0	0.0	5	8.2
36	5	9.0	1	10.0	6	9.2
37	6	10.3	0	0.0	6	10.3
38	7	10.3	0	0.0	7	10.3
39	6	12.0	0	0.0	6	12.0
40	5	10.8	0	0.0	5	10.8
41	5	10.6	0	0.0	5	10.6
42	4	14.5	0	0.0	4	14.5
43	2	15.0	0	0.0	2	15.0
46	1	20.0	0	0.0	1	20.0
Total	146	7.2	94	5.3	240	6.5

Appendix 15: Mean age-at-length for the 2012 offshore Banks Peninsula survey.

	Males		Females		All fish	
Length (cm)	N	Mean age	N	Mean age	N	Mean age
11	0	0.0	1	2.0	1	2.0
12	0	0.0	1	2.0	1	2.0
13	0	0.0	2	2.0	2	2.0
14	1	2.0	4	2.3	5	2.2
15	1	2.0	1	3.0	2	2.5
16	2	2.5	0	0.0	2	2.5
19	2	3.5	1	3.0	3	3.3
20	0	0.0	1	4.0	1	4.0
21	1	4.0	1	4.0	2	4.0
22	0	0.0	3	5.0	3	5.0
23	4	5.0	5	4.6	9	4.8
24	5	5.2	4	5.0	9	5.1
25	5	5.4	5	6.2	10	5.8
26	5	6.0	5	6.6	10	6.3
27	4	7.0	6	7.0	10	7.0
28	5	7.0	5	7.8	10	7.4
29	5	7.2	5	8.0	10	7.6
30	5	7.8	4	7.8	9	7.8
31	5	7.6	5	9.0	10	8.3
32	6	7.2	5	10.0	11	8.5
33	5	9.4	5	10.4	10	9.9
34	5	8.6	6	10.3	11	9.6
35	6	9.8	5	12.0	11	10.8
36	6	10.2	6	13.3	12	11.8
37	5	10.8	5	14.2	10	12.5
38	4	12.5	4	14.8	8	13.6
39	5	13.4	5	17.6	10	15.5
40	6	12.5	5	16.2	11	14.2
41	3	14.0	5	17.4	8	16.1
42	4	15.8	5	18.0	9	17.0
43	6	13.5	6	21.2	12	17.3
44	5	16.2	5	23.4	10	19.8
45	4	14.5	5	24.6	9	20.1
46	6	15.8	4	29.3	10	21.2
47	5	18.8	5	28.8	10	23.8
48	5	20.6	1	26.0	6	21.5
49	5	21.4	1	35.0	6	23.7
50	5	24.6	2	35.5	7	27.7
51	4	26.0	0	0.0	4	26.0
52	5	26.0	0	0.0	5	26.0
53	3	32.7	0	0.0	3	32.7
54	3	28.7	1	38.0	4	31.0
55	4	32.3	0	0.0	4	32.3
56	1	35.0	0	0.0	1	35.0
Total	166	13.4	145	13.3	311	13.4

Appendix 16: Parameter values used in the 2012 inshore Banks Peninsula SPR analyses.

	Males				Females			
Age	Length (cm)	Weight (kg)	Selectivity	Maturity	Length (cm)	Weight (kg)	Selectivity	Maturity
1	7.3	0.0	0	0	7.3	0.0	0	0
2	12.9	0.0	0	0	12.9	0.0	0	0
3	17.8	0.1	0	0	17.8	0.1	0	0
4	21.9	0.2	0	0.1	21.9	0.2	0	0.1
5	25.4	0.3	0	0.4	25.4	0.3	0	0.4
6	28.5	0.4	0	0.7	28.5	0.4	0	0.7
7	31.1	0.5	1	1	31.1	0.5	0	1
8	33.4	0.7	1	1	33.4	0.7	1	1
9	35.3	0.8	1	1	35.3	0.8	1	1
10	37.0	0.9	1	1	37.0	0.9	1	1
11	38.4	1.0	1	1	38.4	1.0	1	1
12	39.6	1.1	1	1	39.6	1.1	1	1
13	40.6	1.2	1	1	40.6	1.2	1	1
14	41.5	1.3	1	1	41.5	1.3	1	1
15	42.3	1.4	1	1	42.3	1.4	1	1
16	43.0	1.4	1	1	43.0	1.4	1	1
17	43.5	1.5	1	1	43.5	1.5	1	1
18	44.0	1.5	1	1	44.0	1.5	1	1
19	44.5	1.6	1	1	44.5	1.6	1	1
20	44.8	1.6	1	1	44.8	1.6	1	1
21	45.1	1.6	1	1	45.1	1.6	1	1
22	45.4	1.7	1	1	45.4	1.7	1	1
23	45.6	1.7	1	1	45.6	1.7	1	1
24	45.8	1.7	1	1	45.8	1.7	1	1
25	46.0	1.7	1	1	46.0	1.7	1	1
26	46.1	1.8	1	1	46.1	1.8	1	1
27	46.2	1.8	1	1	46.2	1.8	1	1
28	46.4	1.8	1	1	46.4	1.8	1	1
29	46.4	1.8	1	1	46.4	1.8	1	1
30	46.5	1.8	1	1	46.5	1.8	1	1
31	46.6	1.8	1	1	46.6	1.8	1	1
32	46.6	1.8	1	1	46.6	1.8	1	1
33	46.7	1.8	1	1	46.7	1.8	1	1
34	46.7	1.8	1	1	46.7	1.8	1	1
35	46.8	1.8	1	1	46.8	1.8	1	1
36	46.8	1.8	1	1	46.8	1.8	1	1
37	46.8	1.8	1	1	46.8	1.8	1	1
38	46.9	1.8	1	1	46.9	1.8	1	1
39	46.9	1.8	1	1	46.9	1.8	1	1
40–50	from growth curve	from growth curve	1	1	from growth curve	from growth curve	1	1

Appendix 17: Parameter values used in the 2012 offshore Banks Peninsula SPR analyses.

	Males				Females			
Age	Length (cm)	Weight (kg)	Selectivity	Maturity	Length (cm)	Weight (kg)	Selectivity	Maturity
1	11.2	0.026	0	0	11.3	0.026	0	0
2	15.0	0.061	0	0	14.6	0.056	0	0
3	18.4	0.113	0	0	17.6	0.099	0	0
4	21.5	0.180	0	0.1	20.3	0.153	0	0.1
5	24.4	0.262	0	0.4	22.8	0.218	0	0.4
6	27.0	0.356	0	0.7	25.1	0.291	0	0.7
7	29.5	0.461	0	1	27.2	0.371	0	1
8	31.7	0.573	1	1	29.1	0.457	0	1
9	33.8	0.690	1	1	30.9	0.545	1	1
10	35.6	0.811	1	1	32.5	0.635	1	1
11	37.4	0.934	1	1	33.9	0.726	1	1
12	38.9	1.057	1	1	35.3	0.817	1	1
13	40.4	1.180	1	1	36.5	0.906	1	1
14	41.7	1.300	1	1	37.6	0.993	1	1
15	43.0	1.417	1	1	38.7	1.077	1	1
16	44.1	1.531	1	1	39.6	1.159	1	1
17	45.1	1.640	1	1	40.5	1.236	1	1
18	46.1	1.745	1	1	41.2	1.311	1	1
19	46.9	1.846	1	1	42.0	1.381	1	1
20	47.7	1.941	1	1	42.6	1.447	1	1
21	48.5	2.032	1	1	43.2	1.510	1	1
22	49.2	2.117	1	1	43.8	1.569	1	1
23	49.8	2.198	1	1	44.3	1.624	1	1
24	50.3	2.273	1	1	44.7	1.676	1	1
25	50.9	2.344	1	1	45.1	1.724	1	1
26	51.3	2.411	1	1	45.5	1.769	1	1
27	51.8	2.473	1	1	45.9	1.811	1	1
28	52.2	2.531	1	1	46.2	1.850	1	1
29	52.6	2.585	1	1	46.5	1.886	1	1
30	52.9	2.635	1	1	46.8	1.919	1	1
31	53.2	2.682	1	1	47.0	1.950	1	1
32	53.5	2.725	1	1	47.2	1.978	1	1
33	53.8	2.765	1	1	47.5	2.004	1	1
34	54.0	2.802	1	1	47.6	2.028	1	1
35	54.2	2.837	1	1	47.8	2.051	1	1
36	54.4	2.869	1	1	48.0	2.071	1	1
37	54.6	2.898	1	1	48.1	2.090	1	1
38	54.8	2.926	1	1	48.2	2.108	1	1
39	54.9	2.951	1	1	48.4	2.124	1	1
40–50	from growth curve	from growth curve	1	1	from growth curve	from growth curve	1	1

Appendix 18: Carbines, G. (2017). Establishing a standardised fine mesh potting survey time series to monitor the relative abundance and length frequency of blue cod in the Pohatu Marine Reserve. Saltwater Science Research. Survey and Monitoring Report 2017/1. 34 p. (Unpublished report held by the Department of Conservation Christchurch). Presented here with the permission of the Department of Conservation Christchurch for ease of access.

Establishing a standardised fine mesh potting survey time series to monitor the relative abundance and length frequency of blue cod in the Pohatu Marine Reserve, Banks Peninsula

Saltwater Science Research, Survey and Monitoring Report Number 1

A report prepared for:
Department of Conservation
Canterbury Conservancy
Private Bag 4715
Christchurch, 8011

Prepared by:

Dr G. Carbines

Saltwater Science Ltd

Torbay
North Shore 0630

E-mail: glen@saltwaterscience.co.nz

1. Keywords

Blue cod, *Parapercis colias*, relative abundance, cod pots, tagging, population length structure, Pohatu Marine Reserve, Banks Peninsula, 2008, 2012.

2. Abstract

This report describes the results of the first two blue cod (*Parapercis colias*) potting surveys of the Pohatu marine reserve (Banks Peninsula) established in 1999. The surveys objectives were to estimate blue cod relative abundance and length age structure, and to tag and return all blue cod caught.

2008
Nine sites were surveyed (6 pots per site = 54 pot lifts) from the Pohatu marine reserve and two adjacent control (fished) strata between 24-25 September 2008 on behalf of the Department of Conservation (DoC). Of the total 99.7 kg of catch, 93.7 kg (94%) was blue cod, consisting of 195 fish. Bycatch included five fish species. All blue cod were tagged, and all fish caught were returned alive.

The potting survey revealed differences in blue cod length structure between the unfished Pohatu marine reserve and adjacent fished areas directly East and West of the marine reserve (though not statistically significant). Mean catch rates (inferring relative abundance) of blue cod (all sizes) ranged from 1.14 kg per pot per hour in the stratum directly west of the marine reserve, to 1.86 kg per pot per hour for the stratum directly east of the marine reserve. Overall mean catch rate and coefficient of variation (c.v.) were 1.64 kg per pot per hour and 14%. For blue cod 30 cm and over (minimum legal size - MLS), highest catch rates were in the marine reserve (1.43 kg per pot per hour) and lowest catch rates were in the stratum directly west (0.92 kg per pot per hour). Overall mean catch rate and c.v. for blue cod 30 cm and over were 1.23 kg per pot per hour and 17%.

Blue cod from fished strata ranged in length from 18 to 45 cm with a single modal peak apparent at about 29 cm in the west stratum, and at 26 cm in the east stratum. Blue cod in the marine reserve stratum ranged in length from 18 to 48 cm with a main peak at about 27 cm and a second at 43 cm. The marine reserve contained comparatively more fish over the 30 cm MLS than either fished strata. The average size of blue cod in the marine reserve was 31.1 cm compared to 28.9 cm from the pooled fished strata and the proportion of blue cod of legal size in the pooled fished sites was 36% compared to 52% in the marine reserve.

2012
Seven sites were surveyed (6 pots per site = 42 pot lifts) from the Pohatu marine reserve between 24-25 April 2012 on behalf of the DoC. Of the total 194.2 kg of catch, 155.2 kg (80%) was blue cod, consisting of 261 fish. Bycatch included four fish species and one octopus. Most blue cod were tagged (n=239), and all fish caught were returned alive.

Concurrently, forty sites were equivalently surveyed (6 pots per site = 240 pot lifts) from seven strata throughout Banks Peninsula (March-May 2012) on behalf of the Ministry for Primary Industries (MPI). Data from these surveys allowed a more robust repeat comparisons of blue cod populations in the unfished marine reserve (7 sites) and its two adjacent fished strata (10 sites), to reveal statistically significant differences in both length structure and relative abundance.

In 2012, the mean catch rates of blue cod (all sizes) ranged from 1.29 kg per pot per hour in the stratum directly west of the marine reserve (8% decrease), to 3.70 kg per pot per hour within the reserve area (99% increase). Overall mean catch rate and coefficient of variation (c.v) were 1.86 kg per pot per hour (13% increase) and 16%. For blue cod 30 cm and over, the highest catch rates were again in the marine reserve (2.97 kg per pot per hour, 108% increase) and again lowest in the stratum directly west of the marine reserve (0.45 kg per pot per hour, 51% decline). Overall mean catch rate and c.v. for blue cod 30 cm and over were 1.11 kg per pot per hour (10% decline) and 22%.

Blue cod from the two pooled adjacent fished strata ranged in length from 15 to 43 cm, but consisted of fish mainly below 30 cm (MLS) with a bimodal distribution peaking at 19 cm and 26 cm. In contrast, blue cod in the marine reserve stratum ranged in length from 17 to 47 cm and consisted of fish mainly over MLS (with a peak at about 33 cm). In 2012, the average size of blue cod in the marine reserve (31.3 cm) had changed little since 2008. However, in the pooled fished strata the average size of blue cod had declined by 2.4 cm since 2008 to only 26.5 cm. The proportion of blue cod of legal size in the pooled control sites had consequently declined to 22% in the pooled fished strata while increasing to 58% in the marine reserve.

Conclusions and Recommendations

Comparisons of blue cod relative abundance and population length structure from the 2008 and 2012 potting surveys of the Pohatu marine reserve and adjacent fished areas suggest that fishing mortality has had a profound effect on blue cod populations of inshore Banks Peninsula. Furthermore, it appears that the protection offered by the small Pohatu marine reserve had become more important in shaping the structure and relative size of blue cod populations in 2012 than latitudinal differences observed in 2008. Consequently, there is considerable value to both the DoC and recreational fishers in continuing to monitor blue cod within the Pohatu marine reserve as an unfished "control" stratum within the wider MPI Banks Peninsula random site potting survey time series. It is important that the marine reserve survey time and methods are standardised with the wider MPI potting survey.

It is critical that timing and methods continue to be consistent between DoC and MPI surveys. It is also important that sampling is restricted to water visibility greater than 2 m, as less visibility appears to have a dramatic impact on blue cod catchability (as demonstrated by repeat sampling of sites in 2008).

From both the 2008 and 2012 potting surveys, 434 blue cod were also tagged and released in and around the Pohatu marine reserve. As this is the first blue cod tagging program carried out on the east coast of the South Island, it is important that a formal analysis of the distances moved by recovered fish is completed. All data has therefore been provided to the Department of Conservation.

3. Introduction

In the South Island, blue cod (*Parapercis colias*) is a particularly desirable finfish that is caught by pot or line over reef edges on shingle/gravel or sandy bottoms often close to rocky or biogenic outcrops (Carbines 2003). A 2000 survey of marine recreational fishing found blue cod to be the third most frequently landed finfish species nationally, and the most frequently landed species in the South Island (Boyd & Reilly 2002). An earlier survey of recreational fishing from Akaroa in 1996 found that blue cod was the most common catch outside Akaroa Heads (Bell 1997). Blue cod is also an important species for Maori customary fishers in all areas, but the catch is unknown.

Tagging programmes reveal that most blue cod have a restricted home range of less than a kilometre (Rapson 1956, Mace & Johnston 1983, Carbines & McKenzie 2000, 2004), and direct observations further suggest that blue cod may form haremic groupings (Mutch 1983). It is this philopatric behaviour which makes blue cod susceptible to localised depletion and in response to changes in local fishing pressure, managed bag limit strategies have been varied both among and within regional areas. Marine reserves have also been used as an effective blue cod management strategy providing localised relief from fishing pressure (Cole et al. 2000, Davidson 2001).

The marine reserve at Flea Bay (Pohatu) is located along the southern coastline of Banks Peninsula approximately 4 km east of the entrance to Akaroa Harbour (Figure 1). The 215 hectare marine reserve was established on the 4th July 1999 and is one of New Zealand’s smallest marine reserves (Figure 2). In order to measure and compare the blue cod population inside the Pohatu marine reserve with the wider Banks Peninsula population, Saltwater Science Ltd undertook two standardised fine mesh potting surveys of the marine reserve in September 2008 and April 2012. These results will allow the Department of Conservation to gauge the effectiveness of the small Pohatu marine reserve at protecting blue cod populations along the southern Banks Peninsula coastline.

4. Background

4.1 Underwater visual transects in and around Pohatu reserve

In 2000 the Department of Conservation established a biological data set for Pohatu marine reserve to compare densities and sizes of particular species between reserve and control sites (Davidson *et al.* 2001). Reef fish presence/absence and densities were collected at eight reserve and six control sites. At each site, the size class of blue cod were recorded from six to ten underwater diver visual fish transects 30 meters in length and two meters wide (52 reserve: 39 control). A total of 10 species of reef fish were recorded with blue cod observed at 50 % of both reserve and control sites.

Blue cod were assigned to three size classes: juvenile (< 10 cm), sub-legal (10 - 30 cm) and adult (>30 cm). No juvenile blue cod (< 10 cm total length) or individuals over the minimum legal size (MLS) 30 cm in length were recorded either in reserve or control sites. While the mean density of sub-legal blue cod was generally low (see Appendix 1), it was higher at pooled control sites (3.75 per 60 m^2) than marine reserve sites (1.25 per 60 m^2). However, variation among transects was high and the difference in blue cod density was not statistically significant (Davidson *et al.* 2001). No actual length data for blue cod was reported by Davidson *et al.* (2001).

In 2002, Davidson & Abel (2003) resampled the same 14 sites surveyed in 2000 by Davidson *et al.* (2001). Again no juveniles (< 10 cm) were observed and only 24 blue cod were recorded in total (reserve n = 13/control n = 11). While the mean density of sub-legal blue cod (10 - 30 cm) in the control sites had remained much the same, there had been a slight increase in the density of sub-legal blue cod in the marine reserve (see Appendix 1). However in 2002, legal sized blue cod > 30 cm were recorded from four of the five reserve sites, but were absent from control sites (Appendix 1). This difference in abundance of legal sized blue cod was statistically significant but it is only based on six fish (see Davidson & Abel 2003, Appendix 2).

In the 2002 re-survey, the mean size of blue cod from the reserve sites was 27.3 cm compared to 21.4 cm from control sites and this difference was statistically significant (Davidson & Abel 2003). However, the difference in the mean size of blue cod between the reserve and control sites was due to more small fish (< 20 cm) outside the reserve and more large fish (> 30 cm) inside the reserve (Davidson & Abel 2003).

4.2 Potting surveys off Banks Peninsula

A standardised fine mesh potting survey time series off Banks Peninsula was initiated by the Ministry for Primary Industries (formerly MFish & MAF) in January to April in 2002 (Beentjes & Carbines 2003). The survey area covered five inshore strata along the southern and eastern coastline of Banks Peninsula, as well as two off shore strata (Figure 1). Potting surveys were repeated again in April-May 2005 (Beentjes & Carbines 2006), April-May 2008 (Beentjes & Carbines 2009), and March-May 2012 (Carbines & Haist 2012). These surveys provide relative abundance indices (catch rates - kg per pot per hour) as well as information on population structure and mortality estimates of blue cod stocks off Banks Peninsula. Unfortunately, the Pohatu marine reserve (Figures 1 & 2) has never been included as a stratum in the potting survey time series.

2008 Potting Survey
For the 2008 MPI potting survey off Banks Peninsula, forty "fixed" sites were randomly picked (within strata) from 122 possible fisher selected sites identified in 2002 (see Beentjes & Carbines 2003) and surveyed (6 pots per site = 240 pot lifts) in April-May (Beentjes & Carbines 2009). The results summarised below do not include the marine reserve (Beentjes & Carbines 2009), as it was surveyed separately in September 2008 (see Results section).

Of the total 689 kg of catch, 579 kg (84%) was blue cod, consisting of 726 fish. Mean catch rates of blue cod (all sizes) ranged from 0.07 kg per pot per hour in stratum 2 (Akaroa Harbour entrance adjacent to the marine reserve), to 5.8 kg per pot per hour for offshore stratum 6 located over Le Bons Rocks (Figure 1). Overall mean catch rate and coefficient of variation (c.v. – see Section 6.5) were 2.6 kg per pot per hour and 8%. For blue cod 30 cm and over (MLS), the highest catch rates were also in stratum 6 (5.74 kg per pot per hour) and the lowest catch rates were also in stratum 2 (0.04 kg per pot per hour). Overall mean catch rate and c.v. for blue cod 30 cm and over were 2.3 kg per pot per hour and 8%. The mean catch rate of the two offshore strata was also three time higher than mean catch rate of the five inshore strata (Beentjes & Carbines 2009).

Blue cod from combined inshore strata around Banks Peninsula ranged in length from 16 to 46 cm with a single modal peak apparent at about 29 cm (Beentjes & Carbines 2009). In contrast blue cod in the two offshore strata were considerably larger, ranging in length from 10 to 56 cm. The mean length of males in the offshore strata was nearly 13 cm greater than the inshore strata and for females the difference was 10 cm. Overall for all strata the proportion of blue cod of MLS was 61%, however inshore only 39% of blue cod were of legal size compared to 84% offshore.
2012 Potting Survey
For the 2012 MPI potting survey of Banks Peninsula, forty fixed sites were again randomly selected from the pool of 122 possible fisher selected sites and surveyed (6 pots per station = 240 pot lifts) in April-May 2012 (Carbines & Haist 2012). However, due to an international review of MPI potting

surveys identifying problems with fisher selected fixed sites (Stephenson et al. 2009), an additional forty "random" sites were randomly selected within the seven Banks Peninsula strata and surveyed (6 pots per site = 240 pot lifts) concurrently with the fixed sites as a comparison (Carbines & Haist 2012).

Of the 837 kg (13 species) caught at the forty fixed sites, 685 kg (82%) was blue cod, consisting of 1096 fish. Mean catch rates of blue cod (all sizes) ranged from 0.60 kg per pot per hour in stratum 2 (Akaroa Harbour entrance), to 6.3 kg per pot per hour for offshore stratum 7 located over Pompeys Rocks. Overall mean catch rate and coefficient of variation (c.v.) were 4.3 kg per pot per hour and 18%. For blue cod 30 cm and over (MLS), the highest catch rates were also in stratum 7 (6.0 kg per pot per hour) and the lowest catch rates were also in stratum 2 (0.32 kg per pot per hour). Overall mean catch rate and c.v. for blue cod 30 cm and over were 4.1 kg per pot per hour and 20%.

The forty random sites caught 719 kg (13 species), 540 kg (75%) was blue cod, consisting of 898 fish. Mean catch rates of blue cod (all sizes) ranged from 0.29 kg per pot per hour in stratum 1 (west of the Akaroa Harbour entrance), to 4.3 kg per pot per hour for offshore stratum 6 over Le Bons Rock. Overall mean catch rate and coefficient of variation (c.v.) were 2.8 kg per pot per hour and 34%. For blue cod 30 cm and over (MLS), the highest catch rates were also in stratum 6 (4.3 kg per pot per hour) and the lowest catch rates were also in stratum 1 (0.29 kg per pot per hour). Overall mean catch rate and c.v. for blue cod 30 cm and over were 2.8 kg per pot per hour and 34%.

In the 2008 survey, blue cod from inshore Banks Peninsula ranged in total length from 16 to 46 cm with a single modal peak apparent at about 29 cm (Beentjes & Carbines 2009). In contrast, blue cod from the two offshore strata were considerably larger (10 to 56 cm), on average over 12 cm larger for males and over 10 cm larger for females. The proportion of blue cod of MLS (30 cm and over) was 84% offshore, but only 39% inshore.

Four years later in 2012, blue cod from inshore Banks Peninsula had a similar length range (15 to 46 cm TL), but with three clear modal peaks at about 18 cm, 25 cm, and 32 cm (Carbines & Haist 2012). Blue cod from the offshore strata were still considerably larger (11 to 57 cm), but the average size was now only 9 cm larger (males and females) offshore. The proportion of legal sized blue cod had also declined to 76% offshore and 35% inshore.

5. Objectives

1. To estimate relative abundance and length frequency of blue cod in the Pohatu marine reserve using at least five standardised potting sites (30 pot lifts) in 2008 and 2012.

2. To tag and return alive all blue cod caught in the Pohatu marine reserve.

6. Methods

All methods used were consistent with previous standardised fine mesh potting surveys (see Carbines et al 2008). MPI have subsequently summarised those methods verbatim in a blue cod potting survey standards and specifications manual (Beentjes & Francis 2011) following the recommendations of an international review panel (Stephenson et al 2011).

6.1 Timing

An initial potting survey of the Pohatu marine reserve was carried out between 24 and 25 September 2008. It was not possible to undertake the survey of the marine reserve concurrently with the wider MPI potting survey (April/May, Beentjes & Carbines 2009) as there was no engagement between MPI/NIWA and DoC prior to the survey commencing. Unfortunately, the 2008 MPI potting survey was immediately followed by a consistent southerly swell that reduced water visibility to less than one meter in the marine reserve from May through to September 2008.

A second potting survey of the Pohatu marine reserve was done (24-25 April 2012) concurrently with the wider MPI potting survey of Banks Peninsula (March-May 2012). For a full description of the 2012 MPI potting survey timing see Carbines and Haist (2012).

6.2 Survey area

The Pohatu marine reserve extends about 600 m offshore and has only about 6 km of coastline (including islands & rocks), and an area of only just over 2 km^2. Yet the reserve has several types of benthic habitat including *Carpophylium* forests, encrusting rock communities, rock barrens, red algae beds, mobile and stable sand habitats, and deeper areas of mud and shell (Figure 2). Substrata are divided in two major types; soft substrate (i.e. sands, silt, shell) representing 74% of the reserve, and hard substrate (i.e. rock, boulder, cobble, pebble) comprising 26% of the reserve (Davidson 2008). Figure 2 shows that sand is widespread in the centre of the reserve with encrusting rock communities dominating the outer coastline and *carpophyllum* forest in more sheltered inshore areas. While some parts of the reserve are up to 40 m deep, most areas between 10 m to 20 m depth (Figure 2).

The standardised potting method operates six pots separated by about 100 m, and when used along the coastline (as in Banks Peninsula, see Beentjes & Carbines 2003, 2005, 2009, Carbines & Haist 2012) a site requires at least 600 m. The coastline of the marine reserve was therefore divided into eight areas (possible sites) of similar size (Figure 3). These boundaries were used to define survey sites in the Pohatu reserve stratum in both 2008 (Figure 3) and 2012 (Figure 4).

6.3 Survey design

In 2008 it was not possible to survey the marine reserve concurrently with the wider MPI "fixed" site potting survey (April-May), consequently two “fixed” sites in each of the adjacent strata (see strata 2 & 3 in Figure 1) were re-surveyed concurrently with the marine reserve in September 2008 as a standalone comparison (Figure 3). The September DoC potting survey used a single-phase stratified fixed site design, using the four closest sites in adjacent MPI strata (2 & 3 in Figure 1) from the April/May 2008 MPI potting survey (Beentjes & Carbines 2009), and five sites in the marine reserve chosen at random from eight possible sites (as defined in section 6.2 & Figure 3). In the 2008 DoC survey, the design consisted of 3 strata, 9 sites, and 54 pot sets (Table 1).

In 2012, it was possible to survey the marine reserve concurrently with the wider Banks Peninsula strata of the MPI potting survey (Carbines & Haist 2012). As all areas of the reserve were included as possible sample sites, and because the placement of the pots within them was constrained by site boundaries (see Figure 4), the reserve was included in the more statistically robust random site survey design (Stephenson et al 2011). By including the marine reserve stratum, the 2012 MPI random site survey design consisted of 8 strata, 42 sites, and 282 pot sets (Table 2). For a full description of the 2012 MPI potting survey design see Carbines and Haist (2012).

6.4 Vessel and gear

As in all previous MPI potting surveys of Banks Peninsula (Beentjes & Carbines 2003, 2006, 2009), the Pohatu marine reserve potting survey was conducted from FV *CherilynJ* and skippered by the owner Mr John Wright. FV *CherilynJ* is an Akaroa-based commercial vessel (registration number 63139) equipped to set and lift rock lobster and blue cod pots. The vessel specifications are: 10.5 m length, 3.8 m breadth, 3.5 t, aluminium monohull, powered by a 230 hp Volvo Penta diesel engine with propeller propulsion.

Six custom designed and built cod pots were used to conduct the survey (pot type 2 as defined by Beentjes & Francis 2011). Pot specifications were as follows: length 1200 mm, width 900 mm, depth 500 mm, synthetic inner mesh, 30 mm diameter; 50 mm cyclone wire outer mesh, four entrances. Pots were marked with a number from 1 to 6, and baited with a standardised bait (paua guts).

6.5 Sampling methods

As in previous potting surveys of Banks Peninsula (Beentjes & Carbines 2003, 2006, 2009), six pots were set at each site and left to fish (soak) for a standardised 1 hour during daylight hours. The six pots were set in a line (separated by about 100 m) along the edge of the foul, with the position of each of the six pots determined by site boundaries and separation distance (Figures 3 & 4).

As each pot was set, a record was made on customised forms of pot number, latitude and longitude from GPS, depth, and time of day. Standard trawl survey physical oceanographic data was recorded for each site, including wind direction, wind force, air temperature, air pressure, cloud cover, sea condition, sea colour, swell height, swell direction, bottom type, bottom contour, sea surface temperature, sea bottom temperature, wind speed, and water visibility (secchi depth). After 1 h pots were lifted aboard using the vessel’s hydraulic pot

After each pot was lifted, fish were quickly removed from pots with wet cotton gloves and placed in onboard holding tanks fed with constant running seawater. All fish were then measured to the nearest centimeter below total length. All blue cod were tagged with a yellow 15 mm (tail size) Hallprint type TBA-2 t-bar anchor fish tag inserted ventrally through the postcleithrum (at the base of the pelvic fin, see Figure 5), using a Dennison tag-fast III tag gun with No. 08941 needles. Fish were then placed in a recovery tank. Mortality using this method is estimated to be less than one in a thousand blue cod (Carbines 2004a), which is considerably less than the mortality of hooked blue cod returned with no tagging (Carbines 1999). All tags were printed with an individual identification number (001-750), the words “DoC - GPS & date”, and a contact phone number (03-304-5123).

At the conclusion of each site (6 pots) all fish in the recovery tank were released at the center of the potting site. A single central release per site ensured that blue cod were released no further than approximately 300 m from their point of capture, that all blue cod have sufficient time to recover from tagging, and that losses from predators were avoided.

6.6 Data analysis

The data analyses follow the methods and equations described in the blue cod potting survey standards and specification document (Beentjes & Francis 2011) and were consistent with the 2009 and 2012 Banks Peninsula potting surveys (Beentjes & Carbines 2009, Carbines & Haist 2012). Catch rates were analysed for all blue cod and separately for both legal sized fish (≥30 cm) and undersized blue cod (<30 cm). Catch rates are presented as mean kilograms per pot per hour with the overall mean catch rate weighted by strata size for comparability with MPI surveys (Beentjes & Carbines 2009, Carbines & Haist 2012). Coefficients of variation (c.v.) for each stratum were determined from:

$$cv_i = se_i / mean_i$$

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

Length frequencies for blue cod are presented by individual stratum. Length frequency data were not scaled as the area fished by a pot is unknown and the area of each site is not a homogeneous representation of available blue cod habitat. Mean length was calculated for individual strata and overall for all strata combined. The unscaled length frequency distributions of blue cod from marine reserve and pooled adjacent control strata were also compared.

The length-weight relationship used the linear regression model ln W = b(ln L) + ln a, where W = weight (g), L = length (cm), a and b are the regression coefficients which for unsexed fish were derived using the length-weight relationship of both males and females recorded in Beentjes & Carbines (2009) and Carbines and Haist (2012).

Statistical comparisons of blue cod lengths and site catch (as pots are not true replicates) were made using a single factor ANOVA. Comparisons were made spatially between fished (strata 2 & 3) and un-fished (reserve) areas for each survey.

7. Results

7.1 Sites surveyed

2008 Potting Survey

Nine sites were surveyed (6 pots per site = 54 pot lifts) from three strata in the September 2008 potting survey of the Pohatu marine reserve and two adjacent control areas (Table 1 & Figure 3). Five sites were surveyed in the marine reserve and two control sites were surveyed in each of the adjacent MPI strata (see strata 2 & 3 in Figure 3). Depth ranged from 11 to 38 m with only the marine reserve having sites shallower than 20 m (Table 1). Environmental data recorded throughout the survey are presented in Appendix 2 and shows that the survey was conducted entirely on rocky bottom in relatively calm conditions with good water visibility (3.6 – 7.9 m).

2012 Potting Survey

Seven sites were surveyed (6 pots per site = 42 pot lifts) in the April 2012 DoC potting survey of the Pohatu marine reserve (Table 2 & Figure 4). Within the reserve the depth ranged from 5 to 35 m, and within the two adjacent MPI strata the depth ranged from 9 to 36 m (Table 2 & Figure 7). Environmental data recorded throughout the survey of the reserve are presented in Appendix 3 and shows that the survey was again conducted entirely on rocky bottom in relatively calm conditions with variable water visibility (1.7 – 9.1 m). Note that only site 3R5 in the marine reserve had water visibility that was below 2 m (Appendix 3).

7.2 Catch

2008 Potting Survey

An estimated total of 99.8 kg of catch was taken on the September 2008 DoC potting survey of the Pohatu marine reserve and adjacent areas, of which 93.7 kg (94%) was blue cod, consisting of 195 fish (Table 3). Bycatch included 5 fish species, the most common by number were spotty (*Notolabrus celidontus*), banded wrasse (*Notolabrus fucicola*)/Maori chief (*Notothenia angustata*), girdled wrasse (*Notolabrus cinctus), and* scarlet wrasse (*Pseudolabrus miles*). All fish were released alive at the capture site.

Mean catch rates of blue cod (all sizes) ranged from 1.40 kg per pot per hour in control stratum 2 (closest to the Akaroa Harbour entrance), to 1.86 kg per pot per hour in the Pohatu marine reserve (Figures 1 & 3, Table 4). Overall mean catch rate and coefficient of variation (c.v.) were 1.64 kg per pot per hour and 14.6% respectively.

For blue cod not yet recruited into the fishery (pre-recruits) below 30 cm (minimum legal size), mean catch rates ranged from 0.43 kg per pot per hour in the marine reserve to 0.70 kg per pot per hour in control stratum 3 directly east of the marine reserve (Figure 3, Table 5). Overall mean catch rate and c.v. for pre-recruited blue cod were 0.50 kg per pot per hour and 15.4% respectively. A comparison between the site catches of pre-recruited blue cod in fished strata verses the reserve was not statistically significant (F=$0.88_{(1,7)}$ p=0.3802).

For blue cod 30 cm and over (legal size) the highest catch rates were in the marine reserve (1.43 kg per pot per hour) and lowest catch rates in stratum 2 (0.92 kg per pot per hour) (Table 6). Overall mean catch rate and c.v. for blue cod 30 cm and over were 1.23 kg per pot per hour and 16.8% respectively. A comparison between the site catches of legal sized blue cod in fished strata verses the reserve was also not statistically significant (F=$2.54_{(1,7)}$ p=0.1548).

Standardised catch rates of blue cod by strata and size class for the September 2008 DoC potting survey are summarised in Figure 6. This shows similar total catches overall, but proportionately more pre recruited blue cod in the control strata and more legal sized blue cod in the marine reserve stratum.

2012 Potting Survey

An estimated total of 194.2 kg of catch was taken on the DoC April 2012 potting survey of the Pohatu marine reserve, of which 155.2 kg (80%) was blue cod, consisting of 261 fish (Table 7). Bycatch included 4 fish species, the most common by number were banded wrasse, spotty and girdled/scarlet wrasse. One large (12.2 kg) octopus (*Octopus cordiformis*) was also caught in the reserve. Blue cod were tagged and all animals were released alive at the capture site.

From the wider 2012 MPI random site survey of seven fishable Banks Peninsula strata (Figure 8), an estimated total of 718.5 kg of catch was taken, of which 539.4 kg (75%) was blue cod, consisting of 898 fish (Table 8). Bycatch included 10 fish and one octopus species, the most common by number were banded wrasse, spotty, leather jacket (*Parika scaber*)/girdled wrasse, scarlet wrasse, and one octopus. All fish were killed for dissection to determine sex and reproductive states.

Mean catch rates of blue cod (all sizes) ranged from 0.33 kg per pot per hour in stratum 5 (eastern coastline to Le Bons Bay), to 4.3 kg per pot per hour in the offshore stratum 6 at Le Bons Rocks (Figures 1 & 8, Table 7). Overall mean catch rate and coefficient of variation (c.v.) were 2.97 kg per pot per hour and 31.3% respectively. For only the marine reserve and its two adjacent strata (same comparison as in 2008), mean catch rates of blue cod (all sizes) ranged from 1.29 kg per pot per hour in stratum 2 (Akaroa Harbour entrance), to 3.7 kg per pot per hour in the marine reserve (Figure 7, Table 8). Overall mean catch rate and coefficient of variation (c.v.) for these three strata was 1.86 kg per pot per hour and 15.5% respectively.

For blue cod not yet recruited into the fishery (≥30 cm), mean catch rates ranged from 0.73 kg per pot per hour (in the marine reserve and stratum 2) to 0.88 kg per pot per hour in stratum 3 (Figure 7, Table 9). Overall mean catch rate and c.v. for pre-recruited blue cod in and around the marine reserve was 0.79 kg per pot per hour and 10.25% respectively. A comparison between the site catches of pre-recruited blue cod in fished strata verses the reserve was not statistically significant (F=0.21$_{(1,15)}$ p=0.6523).

For blue cod 30 cm and over (legal size) in and around the marine reserve, the highest catch rates were in the marine reserve (1.43 kg per pot per hour) and lowest catch rates in stratum 2 (0.92 kg per pot per hour) (Table 10). A comparison between the site catches of legal sized blue cod in fished strata verses the reserve was statistically significant (F=9.80$_{(1,15)}$ p=0.0069).

From the wider MPI survey, the highest catch rates of legal sized blue cod were from the two offshore strata (4.30 & 3.61 kg per pot per hour), and the marine reserve having the highest catch rates among the inshore strata (2.97 kg per pot per hour). Overall mean catch rate and c.v. for recruited blue cod throughout the fishable part of Banks Peninsula was 2.97 kg per pot per hour and 31.28% respectively.

Standardised catch rates of blue cod by strata and size class in 2008 and 2012 are summarised in Figures 6 and 9 respectively. Figure 6 shows similar total catches overall, but proportionately more pre recruited blue cod in the control strata and more legal sized blue cod in the marine reserve stratum. Figure 9 shows that in 2012 there had been a decline catch rate of recruited blue cod in the two control strata, and a dramatic increase in the catch rate of legal sized blue cod in the marine reserve since 2008 (Figure 6).

7.3 Size compositions

2008 Potting Survey

During the September 2008 DoC potting survey of the Pohatu marine reserve and adjacent strata, 195 blue cod were caught, measured for total length and tagged. None were sexed as this requires dissection (Carbines 2004a, Beentjes & Carbines 2009, Carbines & Haist 2012). Length frequency distributions of unsexed blue cod from adjacent control strata 2 and 3 were similar, however the small sample sizes precludes drawing any conclusion on the shape of the distributions from these strata (Figure 10). Blue cod from the two control strata ranged in length from 18 to 45 cm with a single modal peak apparent at about 29 cm in stratum 3 and 25/26 cm in stratum 2 (Figure 10). Blue cod in the marine reserve stratum ranged in length from 18 to 48 cm and contained comparatively more fish over the minimum legal size (30 cm and over) than either strata 2 or 3 (Figure 10). However, due to the low sample size it is difficult to assign modes to the marine reserve stratum as the length frequency distribution was almost bimodal with a main peak at about 27 cm and a smaller cluster around 43 cm (Figure 10).

The higher proportion of larger fish is evident from the long and thick right hand tail of the length frequency distribution from the reserve stratum compared to the length frequency distribution from control strata (Figure 11). The average size of blue cod in the marine reserve was 31.1 cm compared to 28.9 cm from the control strata and this difference was statistically significant (F=12.16$_{(1,194)}$ p=0.0006). The proportion of blue cod of legal size (≥30 cm) within the marine reserve was 52% compared to 36% in the fished control strata.

2012 Potting Survey

During the April 2012 DoC potting survey of the Pohatu marine reserve, 261 blue cod were caught and measured for total length, 239 were tagged, and all fish were returned alive (unsexed). Unscaled length frequency distributions of unsexed blue cod form the marine reserve stratum ranged in length from 17 to 47 cm and contained predominantly fish over the minimum legal size (30 cm and over) (Figure 11). The marine reserve length frequency distributions of had clear modes at 19 cm, 28 cm, 33 cm, and 39 cm (Figure 11). From the wider concurrent MPI Banks Peninsula potting survey, 127 and 146 blue cod were caught and measured in stratum 2 and stratum 3 respectively (Figure 7, Carbines & Haist 2012). The length frequency distributions of blue cod form strata 2 and 3 ranged in length from 15 to 43 cm and contained mainly fish below the legal size (Figure 11). Stratum 2 (Akaroa Harbour entrance) had clear length modes at 19 cm and 26 cm, but very few fish over 27 cm (Figure 11). Blue cod from stratum 3 (east of the reserve) also had clear length modes at 19 cm and 26 cm, but also had proportionately more legal sized blue cod than stratum 2 (Figure 11).

The proportion of larger fish in the marine reserve had increased in 2012, with an even thicker right hand tail to the length frequency distribution from the reserve stratum compared to the control strata (Figure 11). The average size of blue cod had remained consistent in the marine (31.3 cm), but had declined by 2.4 cm in the control strata (26.5 cm) and this difference was also statistically significant ($F=150.92_{(1,552)}$ $p<0.0001$). The proportion of blue cod of legal size (≥30 cm) had increased slightly to 58% within the marine reserve, but had declined by more than a third in the fished strata where only 22% of blue cod were now of legal size.

7.4 Tagging

In the September 2008 DoC potting survey all 195 blue cod caught in and adjacent to the Pohatu marine reserve were tagged and released on site (Table 11). However, in 2012 only 239 of 261 blue cod caught within the Pohatu marine reserve were tagged and released on site (Table 12). Twenty two blue cod were either too small to tag, or escaped during the tagging process (post measuring). Tagging data has been provided to the Department of Conservation as the return phase and analysis of the tag return data is not included within the scope of this study.

8. Discussion

2008 Potting Survey

The results of the September 2008 DoC potting survey provided the first standardised fine mesh pot relative abundance index (standardised catch rates) of blue cod in the Pohatu marine reserve. Given the small number of sites (n=9) sampled in the September 2008 potting survey, the overall coefficient of variation (c.v.) of 15% for all blue cod indicates a surprisingly precise estimate of relative abundance and is similar to the precision of the total survey estimates in the more intensive (40 sites) MPI April/May 2008 potting survey (8%) (Beentjes & Carbines 2009).

The overall mean catch rates varied among strata, but generally increased with easterly distance from the Akaroa Heads. Catches of pre-recruited blue cod (<30 cm) were also highest in the eastern stratum (3), but the mean catch rate of legal size blue cod (≥30 cm) was 36% higher in the marine reserve stratum than in the control strata (Figure 6). The average size of blue cod in the marine reserve (31.1 cm) was also 2.2 cm larger than blue cod from the pooled control strata (28.9 cm). These results reveal differences in the population size and length structure of the marine reserve stratum compared to its adjacent control strata.

Given the theoretical absence of potential fishing discard mortality in the marine reserve, it seems most likely that differences in the relative abundance of pre-recruited (<30 cm) blue cod among strata (Figure 6) are the result of an environmental gradient(s) in benthic habitat quality (e.g., Carbines & Cole 2009), water clarity, and/or catchability improving with longitude. However, the proportion of legal sized blue cod in the marine reserve (52%) compared to the adjacent fished strata (36%) suggests that despite of its small size, the Pohatu marine reserve is effective at reducing fishing mortality of resident blue cod .

2012 Potting Survey
The April 2012 DoC potting survey provided the second standardised potting survey of relative abundance for blue cod in the Pohatu marine reserve. While the concurrent MPI (March-May 2012) potting survey provided the opportunity for a more robust repeat of the 2008 comparison between the un-fished Pohatu marine reserve and adjacent fished strata (n=17 sites, Figure 7).

The overall coefficient of variation (c.v.) of 16% for all blue cod again indicates another very precise estimate of relative abundance within the marine reserve. The overall mean catch rates again varied among strata, and generally increased with longitude, except in the marine reserve which had almost doubled in mean relative abundance of all blue cod in the four years since 2008 (Figures 6 & 9). Interestingly, the relative abundance of pre-recruited blue cod (<30 cm) had also almost double in strata 2 and the marine reserve, but had remained unchanged in stratum 3 (Figures 6 & 9). The mean relative abundance of legal size blue cod (≥30 cm) had also more than doubled since 2008, and was now well over four times higher in the marine reserve stratum than in the control strata (Figure 9).

The average size of blue cod had remained unchanged in the marine reserve (31.3 cm), but this was now 6.9 cm larger than the declining average size of blue cod from the fished control strata (24.4 cm). These results reveal rapidly growing differences in the population size and structure of the marine reserve stratum compared to its adjacent control strata.

The proportion of legal sized blue cod in the marine reserve (58%) compared to the adjacent fished strata (22%) had further increased and confirms that the Pohatu marine reserve has had a significant effect at constraining fishing mortality. In contrast, adjacent blue cod populations outside the marine reserve appear to have undergone profound changes with fishing mortality significantly reducing both size and relative abundance.

Potting Survey Time Series
The 2008 DoC potting survey of the Pohatu marine reserve and adjacent strata was considered a standalone "fixed" site survey because it was not seasonally aligned with the 2008 MPI "fixed" site survey. But because all of the marine reserve coastline was divided into possible sample sites (see Section 6.2 & Figure 3), all areas of that stratum have essentially the same chance of being selected. This is exactly the process latter used by Carbines & Haist (2012) to determine random sites along all of the inshore Bank Peninsula strata for the 2012 and subsequent surveys. Because the 2008 DoC potting survey of the marine reserve stratum retrospectively became a "random" site survey it should be included as the first "random" site survey in Banks Peninsula, making the marine reserve "random" site time series four years longer than the MPI time series given the likely intention of MPI to move entirely to random site survey designs in the future (Stephenson et al. 2009).

Comparisons of sampling methods
With any fishing method there is potential selectivity bias so that size and species composition may differ between capture methods (Furevik 1994). While bait type and soak time can be standardised, other factors such as inter- and intra-species interactions, fish behaviour, pot/line interference, and

features of the environment (e.g., water visibility) can also be important in passive capture methods (Whitelaw et al. 1991, Furevik 1994, Fogarty & Addison 1997, Robichaud et al. 2000).

Pots appear to be selective for blue cod over 18 cm (See Figures 11 & 12) and under-sample small blue cod compared to diver (Cole et al. 2001) and flown video transects (Carbines & Usmar 2013, Carbines & Haist 2014). At a localised scale, Cole et al. (2001) found a positive but weak relationship between blue cod catch from pots and diver transects. However, the results of the September 2008 potting survey of the Pohatu marine reserve were consistent with the latest under water visual survey of the reserve conducted in 2002 (Davidson & Able 2003). While there is clearly a size selectivity bias (pots sampling on average larger blue cod), both surveys found the mean size of blue cod in the reserve was higher than in the control areas and that the abundance of legal size blue cod was also highest in the reserve (Davidson & Abel 2003). Both studies also identified that the difference in the mean size of blue cod between the reserve and control areas was due to both small fish (< 20 cm) outside the reserve as well as large fish (> 30 cm) inside the reserve (see Davidson & Abel 2003, Appendix 2). In addition to costs and logistics, the fundamental difference between these studies was the number of fish sampled (under water visual survey n = 24 verses potting n = 195/554), which suggests that under water visual surveys may not be the best method for sampling blue cod in the exposed and turbid waters off Banks Peninsula.

A comparison of concurrent potting and line fishing survey methods made in Paterson Inlet (Stewart Island) showed that both lines and pots caught similar amounts of target species over a similar size range (Carbines 2009). However, potting captures proportionally more larger sized blue cod than line fishing (Carbines 1999, 2009) and the methods can show proportional differences in their respective catch per unit effort indices with potting having more precision in relative abundance indices. Potting is also easier to standardise without the issue of fisher variation associated with line fishing.
A further comparison of concurrent potting and flown video transects at 22 potting sites in Paterson Inlet also found that pots catch a higher proportion of larger blue cod and proportionately fewer fish below 20 cm than the video observed (Carbines & Haist 2014). Like Cole et al. (2001), Carbines and Haist (2014) also found only a weak relationship between pot catch and blue cod density, warning that changes in catchability may at times undermine pot catch as a reliable proxy for blue cod abundance. While a low cv of the mean catch rates infers precision (i.e., pots consistently measuring the same thing), they may not necessarily always be accurate (i.e., measuring the right thing) due to unexplained changes in catchability.

Catchability of pots
Reduced water visibility is often a feature of the inshore waters off Banks Peninsula (Beentjes & Carbines 2003, 2006, 2009, Davidson & Able 2003) and the current study allowed a comparison of sites sampled during poor water visibility (<1.3 m) in April 2008 (i.e., sites 2K & 2L in stratum 2, see Appendix 2 & 3 in Beentjes & Carbines 2009) and resample in September 2008 with vastly improved water visibility (>4.4 m).

During the April/May 2008 MPI survey the overall catch rate in stratum 2 was extremely low (0.07 kg per pot hour) and no fish were caught in sites 2K or 2L, however in the September 2008 DoC survey the catch rate in stratum 2 (1.40 kg per pot hour) was 20 times higher and more consistent with previous estimates (Beentjes & Carbines 2003, 2006). It is also interesting to note that in the April/May 2008 survey MPI that strata 2 and 5 (see Figure 1) contained sites sampled in water visibility below 1.5 m, both having disproportionately high stratum coefficients of variation compared to other strata sample with better water visibility (see Table 2 & Appendix 3 in Beentjes & Carbines 2009). These results strongly indicate that blue cod have reduced catchability in low water visibility conditions and sampling should only take place when water visibility is above a threshold of about two metres.

10. Recommendations

The first two standardised fine mesh potting surveys of the Pohatu marine reserve provide the foundation for a robust method of cost effectively estimating blue cod population relative abundance and length structure. Potting surveys have already demonstrated dramatic differences in blue cod population size and structure both spatially between the reserve and adjacent fished areas, and temporally between surveys in 2008 and 2012. As an ongoing time series to monitor the relative abundance and population structure of blue cod there is obvious value to both the Department of Conservation and the Ministry for Primary Industries to continue to include the Pohatu marine reserve as an un-fished stratum in the wider Banks Peninsula random site potting survey every three or four years.

It is prudent to keep the survey time and survey methods standardised (Beentjes & Francis 2011) and restricting surveys to water visibility greater than 2 m is strongly advised as poor visibility has an obvious impact on catchability. Where possible future potting surveys should also make some attempt to temporally stratify for time of day or tides, so that sites in each stratum are given equal exposure to daily tidal and time regimes. Environmental data (see Appendix 2 & 3) should also be collected and an acoustic doppler current profiler deployed at each site so that catch rates can potentially be standardised in the future.

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Table 1: Stratum coastline length, number of sites, pot lifts, and depths from the September 2008 Pohatu Marine Reserve and adjacent strata potting survey. Note that there were no phase two sites in these strata.

Stratum	Size of strata (coastline km)	Number of sites	Number of pot lifts	Depth (m) Mean	Range
2	9.44	2	12	34.1	29–38
Reserve	*5.80*	*5*	*30*	*24.5*	*11–37*
3	7.96	2	12	24.8	20–29
Total	23.2	9	54	26.7	11–38

Table 2: Banks Peninsula 2012 survey stratum area, number of phase 1 and 2 sites, pot lifts, and depth of random sites. Flown video sites are paired to a subsequent set of six survey pots deployed immediately after filming. For the full 2012 Banks Peninsula potting survey results see Carbines & Haist (2012).

	Size of strata	Number of sites		Number of pot lifts	Depth (m)		DUV
Stratum	Area (km^2)	Phase 1	Phase 2	Total	Mean	Range	Sites
1	3.98	5		30	16	5–25	
2	4.72	5		30	25	19–36	
Reserve	*2.15*	*7*		*42*	*19*	*5–35*	*2*
3	3.98	5		30	18	9–31	
4	3.89	5		30	17	7–39	
5	4.08	5		30	11	6–16	
6	8.32	5		30	85	79–88	
7	35.13	5	5	60	76	70–81	
Total	66.25	42	5	282	37	5–88	2

Table 3: Catch weights and numbers of species and percentage of total catch on the September 2008 DoC potting survey of the Pohatu Marine Reserve and adjacent strata (n=9 sites).

Common name	Scientific name	Catch (kg)	Number	Percent of total catch
Blue cod	*Parapercis colias*	93.7	195	94.0
Spotty	*Notolabrus celidotus*	1.1	7	1.1
Banded wrasse	*Notolabrus fucicola*	2.0	5	2.0
Maori chief	*Notothenia angustata*	2.1	3	2.1
Girdled wrasse	*Notolabrus cinctus*	0.9	3	0.9
Scarlet wrasse	*Pseudolabrus miles*	0.1	1	0.1
Total		99.9	214	100.0

Table 4: Mean catch rate, standard error (s.e.) and coefficient of variation (c.v.) per stratum and overall for all blue cod (n=195) caught on the September 2008 Pohatu Marine Reserve and adjacent strata potting survey.

Stratum	Pot lifts (N)	Mean (kg/lift)	s.e.	c.v. (%)
2	12	1.40	0.43	30.57
Reserve	*30*	*1.86*	*0.36*	*19.52*
3	12	1.75	0.42	24.00
Overall	54	1.64	0.24	14.62

Table 5: Mean catch rate, standard error (s.e.) and coefficient of variation (c.v.) per stratum and overall for pre-recruited blue cod under 30 cm (minimum legal size BCO 3) (n=109) caught on the September 2008 Pohatu Marine Reserve and adjacent strata potting survey.

Stratum	Pot lifts (N)	Mean (kg/lift)	s.e.	c.v. (%)
2	12	0.48	0.22	45.97
Reserve	*30*	*0.43*	*0.09*	*19.65*
3	12	0.70	0.17	24.54
Overall	54	0.50	0.08	15.44

Table 6: Mean catch rate, standard error (s.e.) and coefficient of variation (c.v.) per stratum and overall for legal sized blue cod 30 cm and over (minimum legal size BCO 3) (n=86) caught on the September 2008 Pohatu Marine Reserve and adjacent strata potting survey.

Stratum	Pot lifts (N)	Mean (kg/lift)	s.e.	c.v. (%)
2	12	0.92	0.35	37.80
Reserve	*30*	*1.43*	*0.32*	*22.62*
3	12	1.05	0.31	29.17
Overall	54	1.23	0.21	16.75

Table 7: Catch weights and numbers of species and percentage of total catch from the April 2012 DoC random site (n=7) potting survey of the Pohatu Marine Reserve (top table) and the March-May MPI random site (n=35) potting survey of the wider Banks Peninsula area (bottom table). For a full description of the wider 2012 Banks Peninsula potting survey methods and results see Carbines & Haist (2012).

Common name	Scientific name	Catch (kg)	Number	Percent of total catch
Blue cod	*Parapercis colias*	155.2	261	79.9
Banded wrasse	*Notolabrus fucicola*	23.7	27	12.2
Octopus	*Octopus cordiformis*	10.2	1	5.3
Girdled wrasse	*Notolabrus cinctus*	2.7	3	1.4
Spotty	*Notolabrus celidotus*	1.2	6	0.6
Scarlet wrasse	*Pseudolabrus miles*	1.2	3	0.6
Total		194.2	301	100.0

Common name	Scientific name	Catch (kg)	Number	Percent of total catch
Blue cod	*Parapercis colias*	539.4	898	75.1
Banded wrasse	*Notolabrus fucicola*	98.6	152	13.7
Octopus	*Octopus cordiformis*	29.8	4	4.1
Scarlet wrasse	*Pseudolabrus miles*	11.8	26	1.6
Sea perch	*Helicolenus percoides*	12.6	68	1.8
Spotty	*Notolabrus celidotus*	8.2	17	1.1
Girdled wrasse	*Notolabrus cinctus*	5.6	15	0.8
Leather Jackets	*Parika scaber*	4.2	26	0.6
Red cod	*Pseudophycis bachus*	2.9	8	0.4
Tarakihi	*Nemadactylus macropterus*	2.1	3	0.3
Hagfish	*Eptatertus cirrhatus*	1.4	4	0.2
Pigfish	*Congiopodus leucopaecilus*	1.1	1	0.2
Total		718.5	1224	100.00

Table 8: The top table shows the mean catch rate, standard error (s.e.) and coefficient of variation (c.v.) per stratum and overall for all blue cod (n=554) caught on the April 2012 Pohatu Marine Reserve and adjacent strata potting survey. The bottom table shows the same results, but puts the Marine Reserve in context with the wider 2012 Banks Peninsula potting survey (from Carbines & Haist 2012). Strata are shown in Figure 1.

Stratum	Pot lifts (N)	Mean (kg/lift)	s.e.	c.v. (%)
2	30	1.29	0.31	24.09
Reserve	*42*	*3.70*	*0.59*	*16.02*
3	30	1.53	0.64	42.06
Overall (incl MR)	102	1.86	0.29	15.51

Stratum	Sites	Pot lifts (N)	Mean (kg/pot)	s.e.	c.v. (%)
1	5	30	0.47	0.16	33.52
2	5	30	1.29	0.31	24.09
Reserve	*7*	*42*	*3.70*	*0.59*	*16.02*
3	5	30	1.53	0.64	42.06
4	5	30	2.89	0.78	26.86
5	5	30	0.33	0.19	57.22
6	5	30	4.09	1.07	26.11
7	10	60	3.69	1.67	45.25
Overall (*excl Reserve*)	40	240	2.97	0.93	31.28

Table 9: Mean catch rate, standard error (s.e.) and coefficient of variation (c.v.) per stratum and overall for pre-recruited blue cod under 30 cm (minimum legal size BCO 3) (n=349) caught on the April 2012 Pohatu Marine Reserve and adjacent strata potting survey.

Stratum	Pot lifts (N)	Mean (kg/lift)	s.e.	c.v. (%)
2	30	0.88	0.17	18.94
Reserve	*42*	*0.73*	*0.11*	*15.21*
3	30	0.73	0.16	21.95
Overall	102	0.79	0.08	10.52

Table 10: The top table shows the mean catch rate, standard error (s.e.) and coefficient of variation (c.v.) per stratum and overall for legal sized blue cod 30 cm and over (minimum legal size BCO 3) (n=205) caught on the April 2012 Pohatu Marine Reserve and adjacent strata potting survey. The bottom table shows the same results, but puts the Marine Reserve (MR) in context with the wider 2012 Banks Peninsula potting survey (from Carbines & Haist 2012). Strata are shown in figure 1.

Stratum	Pot lifts (N)	Mean (kg/lift)	s.e.	c.v. (%)
2	30	0.45	0.24	54.84
Reserve	*42*	*2.97*	*0.54*	*18.18*
3	30	0.89	0.47	52.62
Overall	102	1.11	0.27	21.60

Stratum	Sites	Pot lifts (N)	Mean (kg/pot)	s.e.	c.v. (%)
1	5	30	0.29	0.12	41.36
2	5	30	0.45	0.24	54.84
Reserve	*7*	*42*	*2.97*	*0.54*	*18.18*
3	5	30	0.89	0.47	52.62
4	5	30	2.12	0.59	27.97
5	5	30	0.28	0.15	52.45
6	5	30	4.30	1.14	26.42
7	10	60	3.61	1.69	46.67
Overall (*excl Reserve*)	40	240	2.97	0.93	31.28

Table 11: Summary information of tagged blue cod releases Pohatu Marine Reserve and adjacent strata in 2008.

			Tag Numbers		Total Length (cm)			Release Location	
Date	Site	No. Tagged	Min	Max	Min	Max	Depth	Latitude	Longitude
24/9/2008	2L	9	54	62	23	45	35	43 ^{o} 53.181 S	173 ^{o} 00.705 E
25/9/2008	2K	36	164	200	18	43	33	43 ^{o} 53.252 S	173 ^{o} 00.289 E
25/9/2008	3B	22	114	135	20	42	24	43 ^{o} 51.920 S	173 ^{o} 02.788 E
25/9/2008	3A	29	136	165	19	37	27	43 ^{o} 52.125 S	173 ^{o} 02.617 E
24/8/2008	MR7	18	1	18	18	40	22	43 ^{o} 52.596 S	173 ^{o} 01.249 E
24/8/2008	MR8	21	19	39	20	43	28	43 ^{o} 52.533 S	173 ^{o} 01.903 E
24/8/2008	MR6	12	40	53	21	48	35	43 ^{o} 53.003 S	173 ^{o} 01.085 E
25/9/2008	MR5	29	63	94	20	45	27	43 ^{o} 52.817 S	173 ^{o} 01.180 E
25/9/2008	MR4	19	95	113	18	45	13	43 ^{o} 52.512 S	173 ^{o} 00.603 E
Total	N=9	195	1	200	18	48	27	N=9	N=9

Table 12: Summary information of tag returns in the Pohatu Marine Reserve in 2012.

			Tag Numbers		Total Length (cm)			Release Location	
Date	Site	No. Tagged	Min	Max	Min	Max	Depth	Latitude	Longitude
24/4/2012	MR7	61	501	600	19	47	21	43 52.510 S	173 01.967 E
24/4/2012	MR7a	26	513	538	18	42	24	43 52.500 S	173 01.551 E
24/4/2012	MR2	29	539	619	17	42	18	43 52.528 S	173 01.045 E
24/4/2012	MR1	4	620	623	18	44	8	43 52.299 S	173 00.601 E
24/4/2012	MR6	50	624	673	21	43	18	43 52.902 S	173 01.165 E
25/4/2012	MR3	4	674	677	19	43	10	43 52.393 S	173 00.394 E
25/4/2012	MR5	65	678	742	17	43	12	43 52.731 S	173 00.963 E
Total	N=7	239	501	742	17	47	16	N=7	N=7

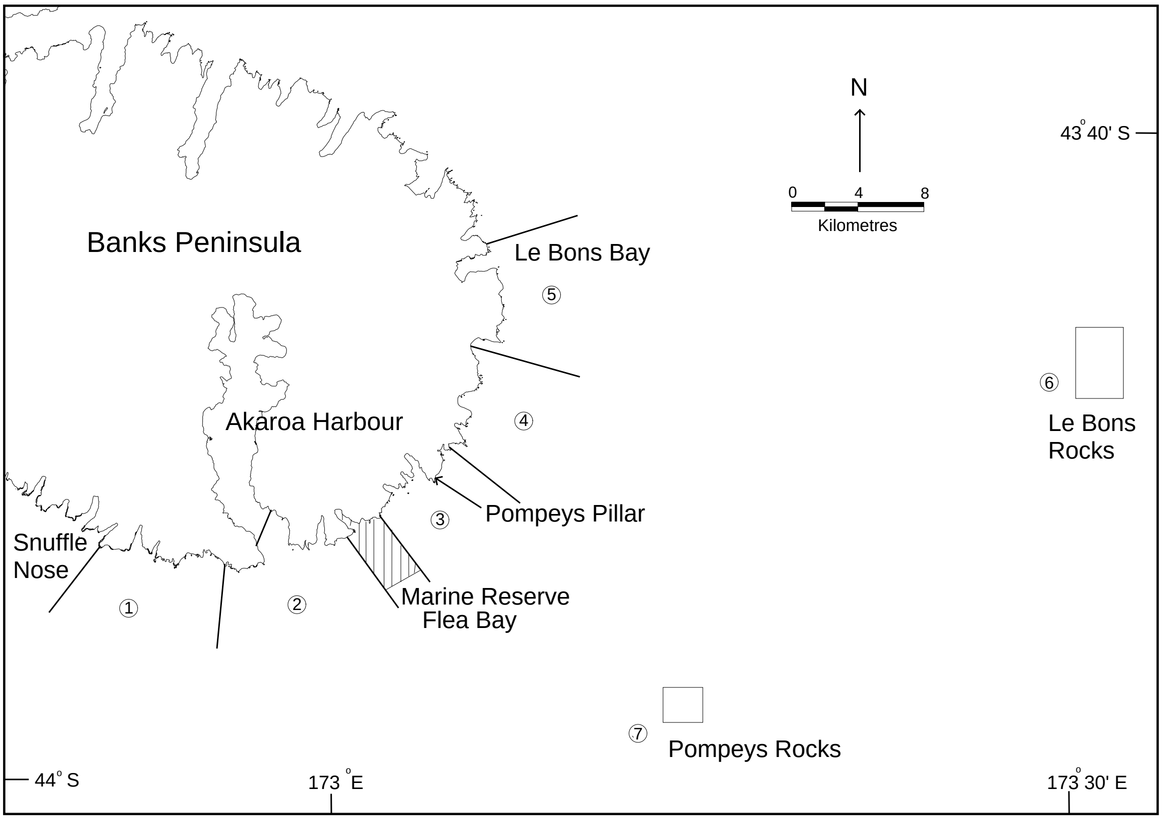


Figure 1: Banks Peninsula area showing the Pohatu (Flea Bay) marine reserve and strata of MPI potting surveys. Detailed results of these surveys are in Beentjes & Carbines (2003, 2006 & 2009) and Carbines & Haist (2012). Figure from Carbines *et al.* 2008. Note that the marine reserve does not extend 5 km out to sea as depicted (see Figure 2 for close up of reserve and actual boundaries).

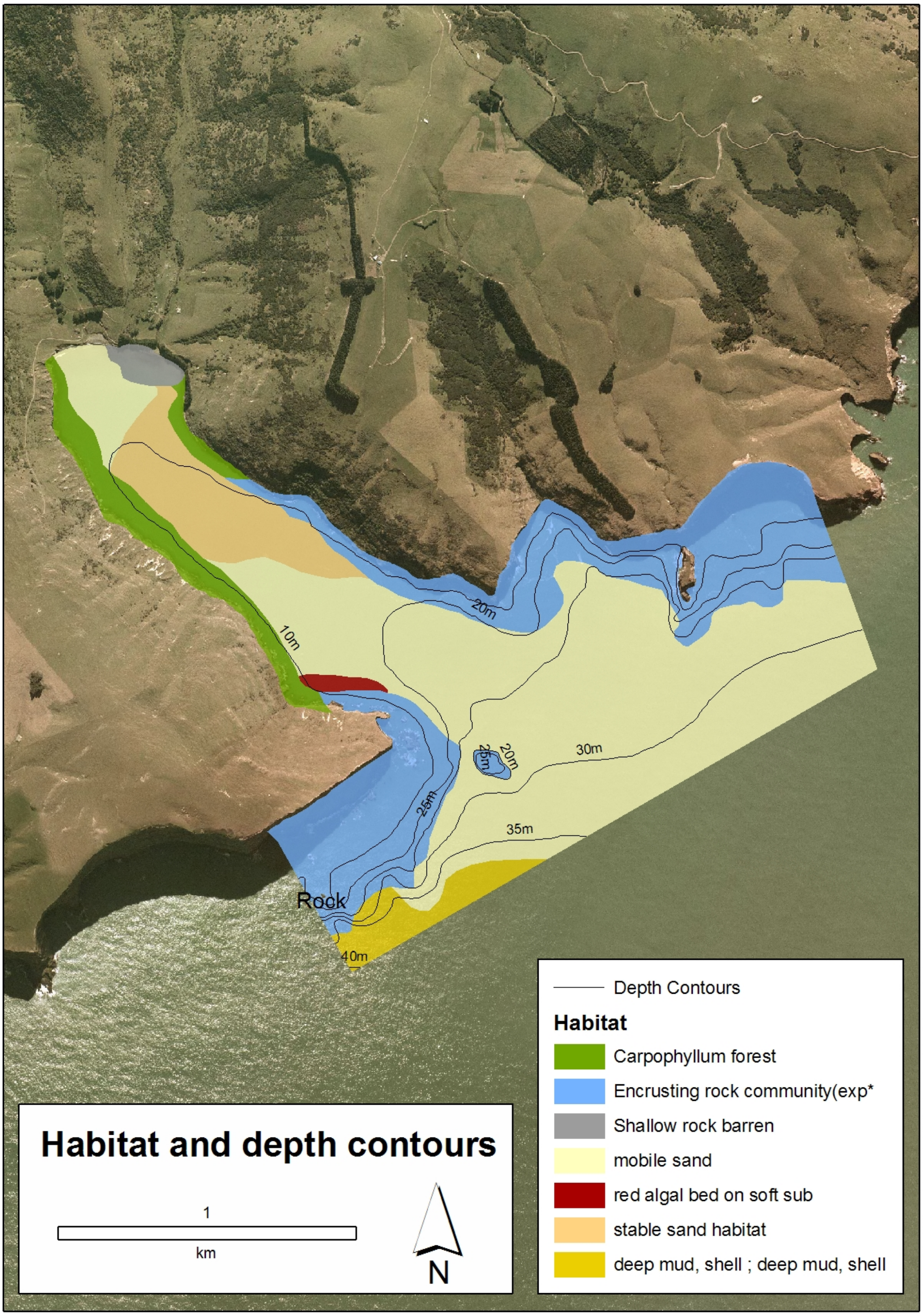


Figure 2: Pohatu marine reserve area shown as a habitat map with depth contours. Figure provided by the Department of Conservation, data from Davidson (2008).

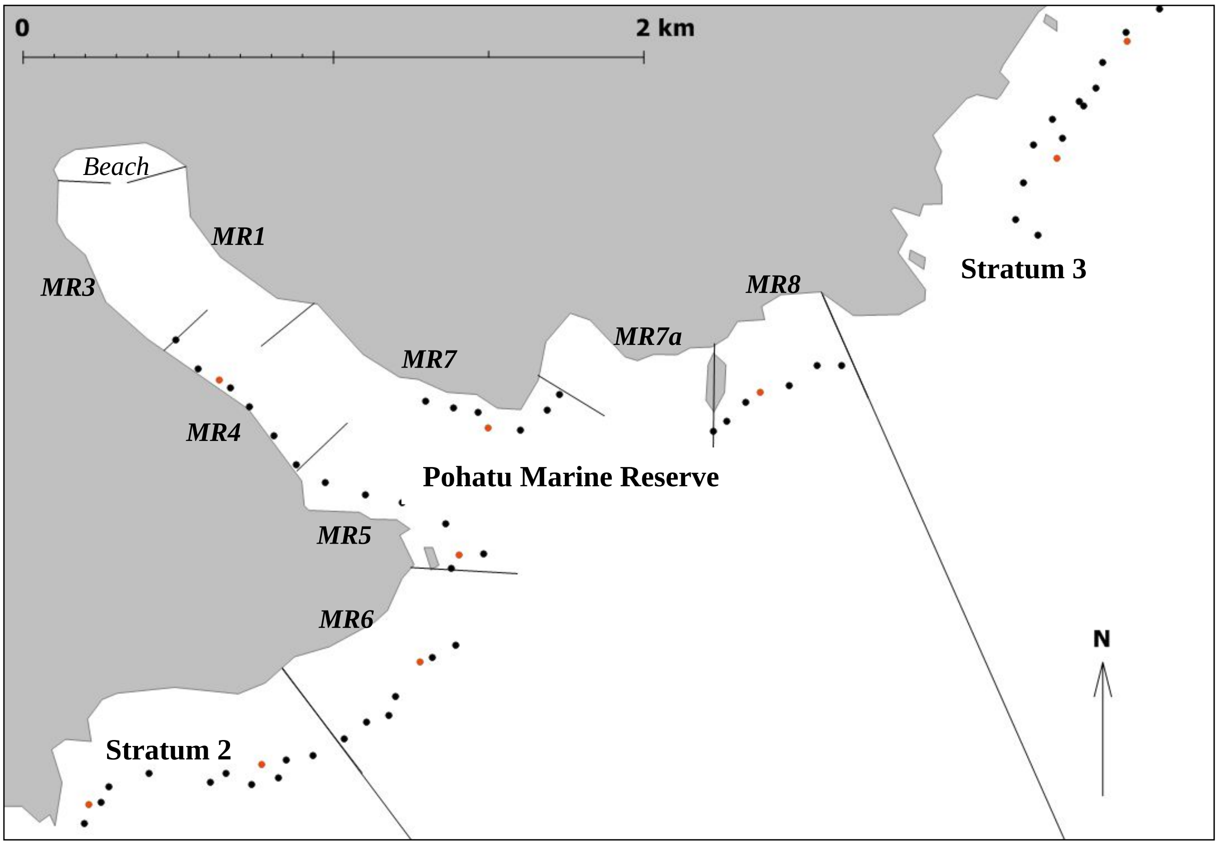


Figure 3: The Pohatu marine reserve was divided into eight along shore sites (approximately 1 km) and sampled with six fine mesh cod pots (●) at five sites (n=30 pot lifts) in September 2008. Two sites in each of the adjacent established MPI survey area strata (see Beentjes & Carbines 2003, 2006, 2009, Carbines & Haist 2012) were sampled concurrently with fine mesh cod pots (n=20 pot lifts). Blue cod were measured (TL), tagged and released at one location per site (●).

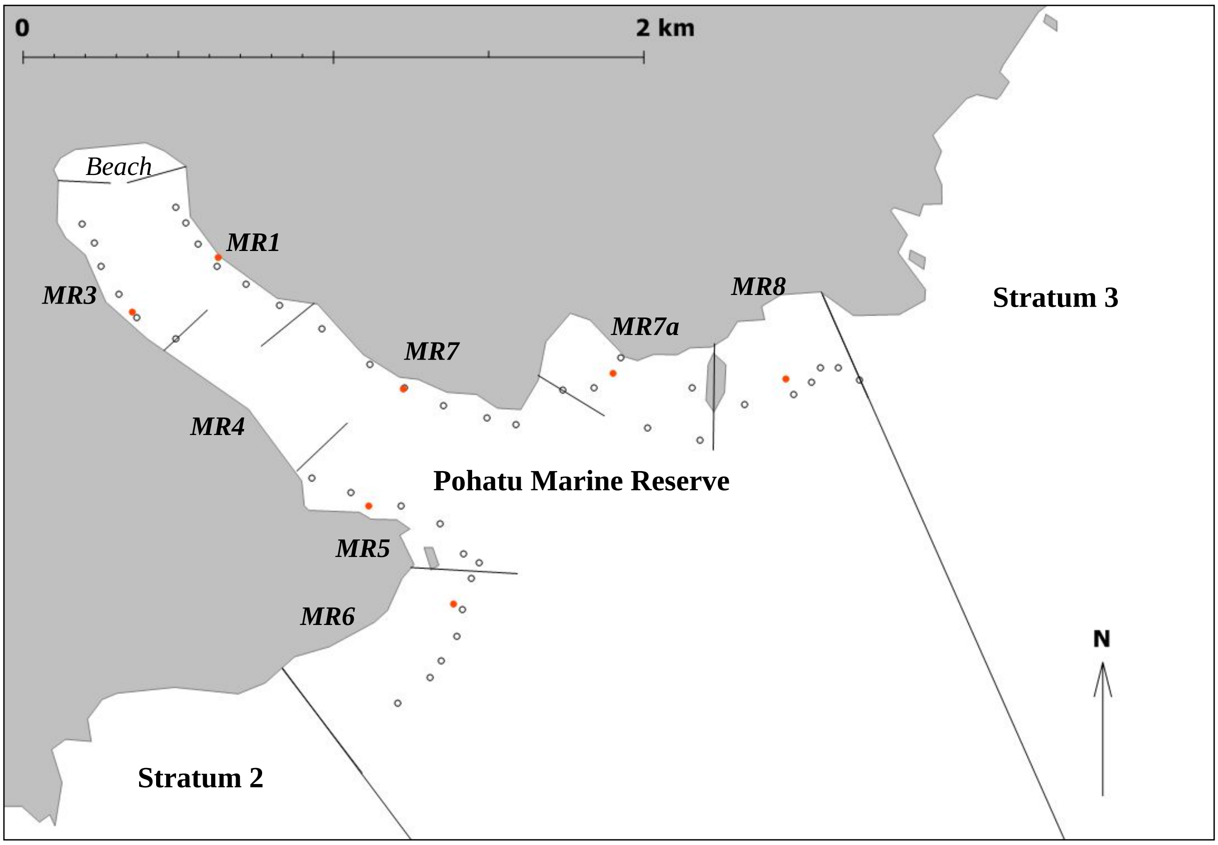


Figure 4: The Pohatu marine reserve was divided into eight along shore sites (approximately 1 km) and sampled with six fine mesh cod pots (○) at seven sites (n=42 pot lifts) in April 2012. Five sites in each of the two adjacent fished MPI survey area strata were sampled concurrently with six fine mesh cod pots (n=60 pot lifts, (see Carbines & Haist 2012). Blue cod were measured (TL), tagged and released at one location per site (●) within the marine reserve.

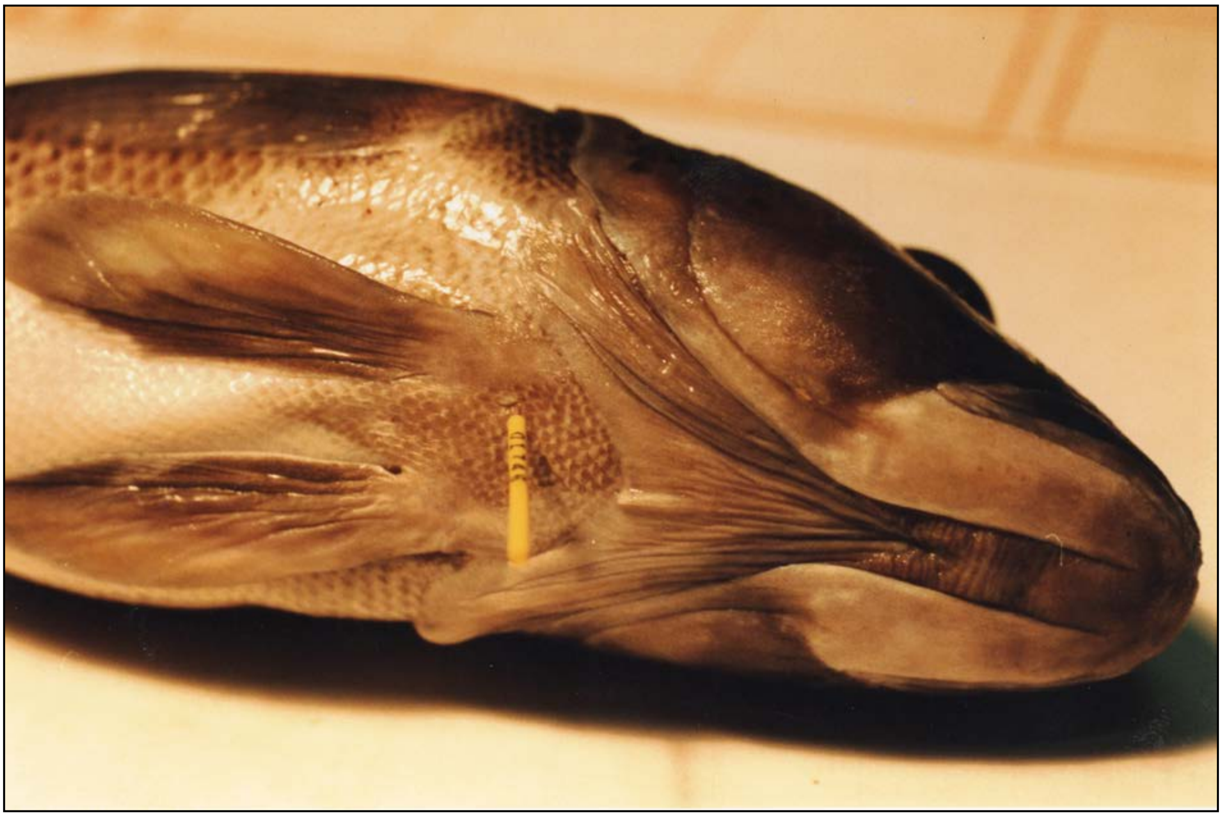


Figure 5: Blue cod were tagged with a yellow Hallprint type TBA-2 t-bar anchor fish tag (inserted ventrally through the postcleithrum at the base of the pelvic fin) and released in the Pohatu Marine Reserve and adjacent strata in 2008 (n=195, see figure 3) and again in the marine reserve in 2012 (n=238, see figure 4).

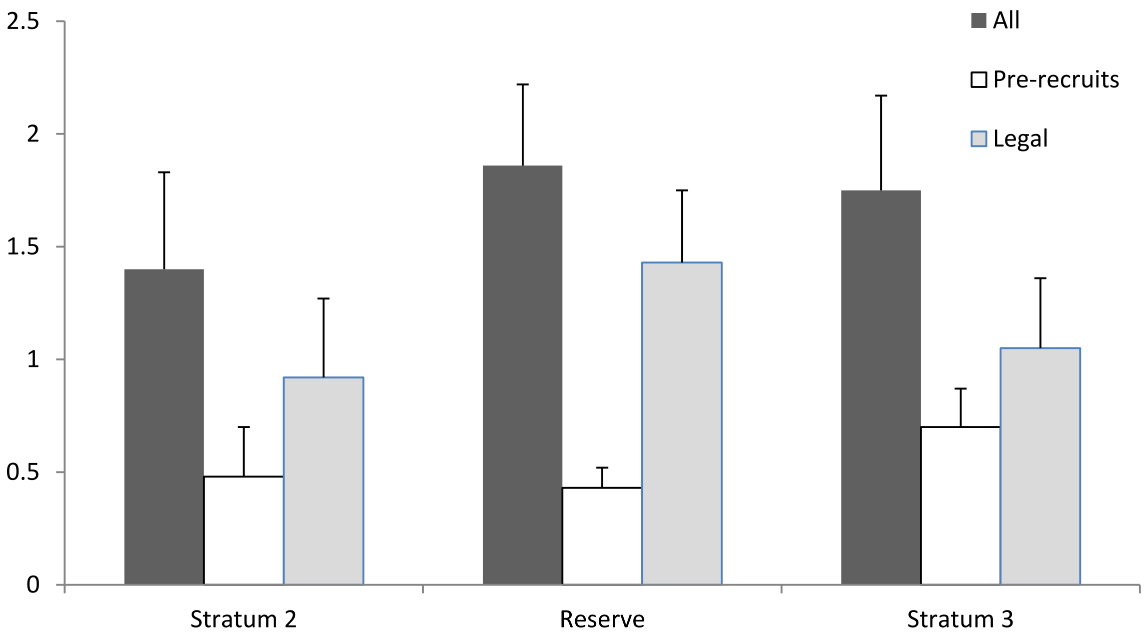


Figure 6: Mean catch rates (kg per pot hour) and standard error by size class from the Pohatu marine reserve stratum and two adjacent strata in the September 2008 potting survey (Figure 2) .

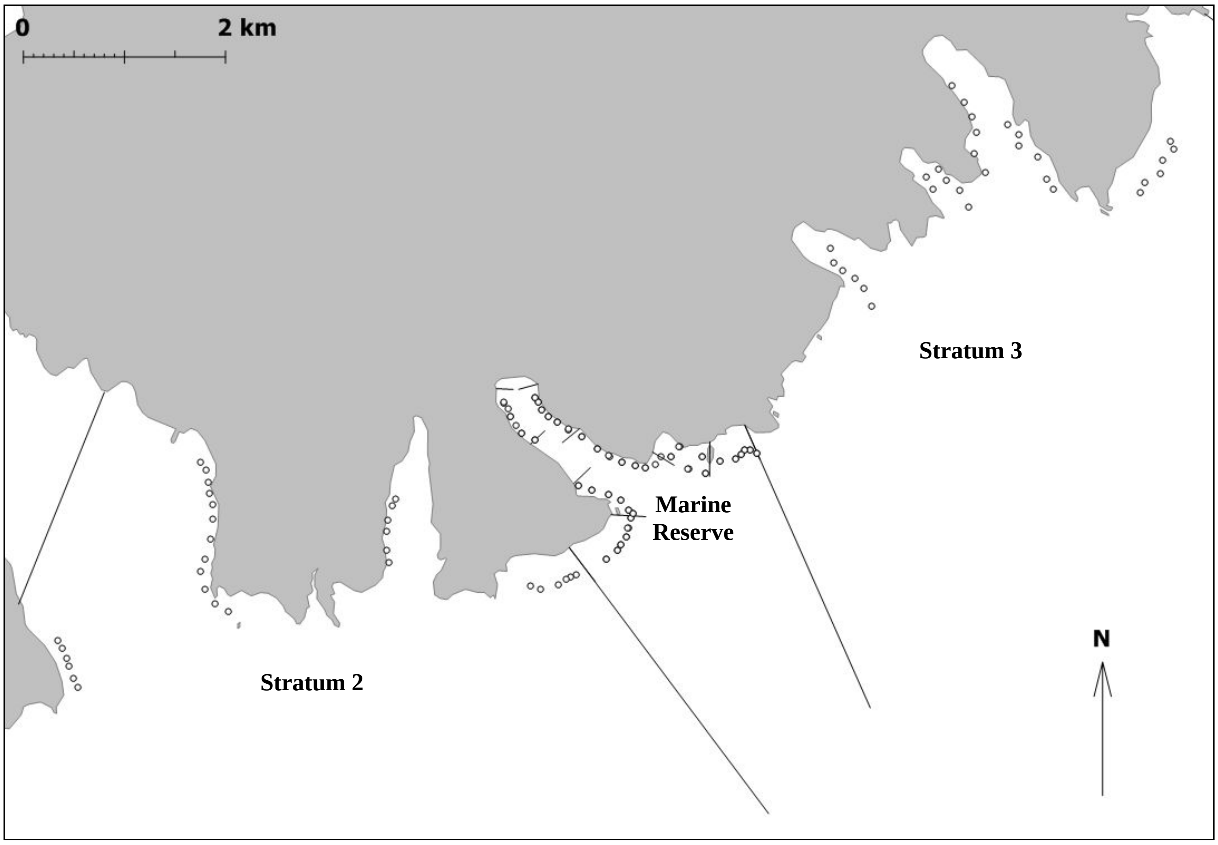


Figure 7: Random site fine mesh potting survey stations/pots (○) at seven sites in the Pohatu marine reserve (n=42 pot lifts) and five sites in each of the two adjacent strata (n=60 pot lifts) taken from the concurrent Ministry for Primary Industries Banks Peninsula potting survey (Carbines & Haist 2012).

Figure 8: 2012 Banks Peninsula random potting survey sites (▲), sampled with six fine mesh pots at each site selected randomly throughout seven strata of the Ministry for Primary Industries blue cod potting survey (Carbines & Haist 2012). The Pohatu marine reserve was surveyed concurrently in 2012 by the Department of Conservation.

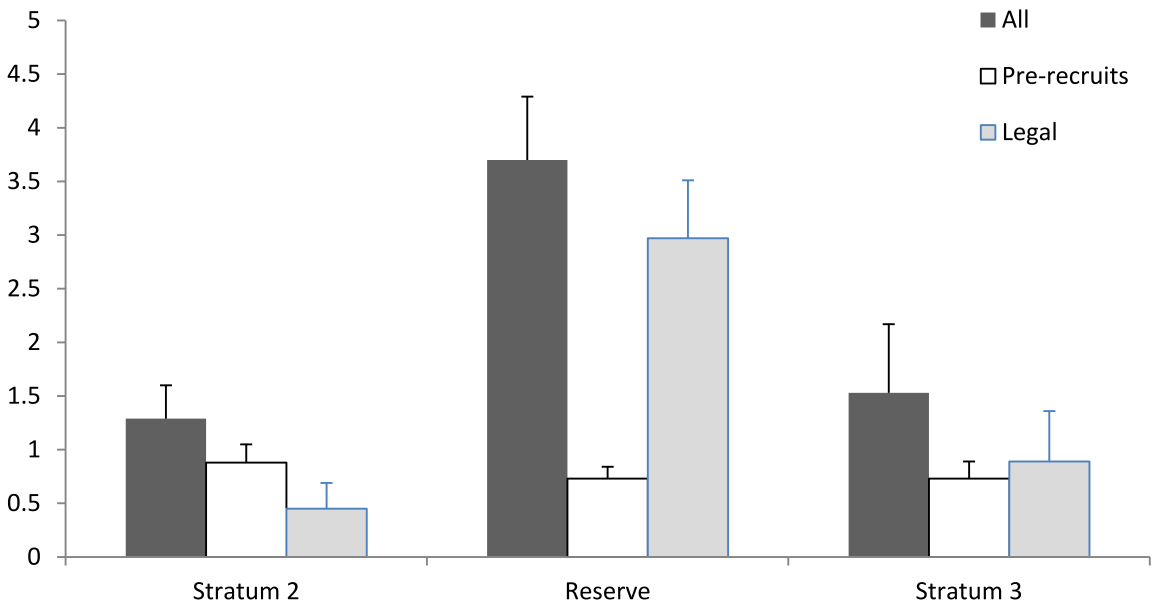


Figure 9: Mean catch rates (kg per pot hour) and standard error by size class for blue cod from the Pohatu marine reserve stratum and adjacent two strata in the April 2012 potting survey (Figure 3).

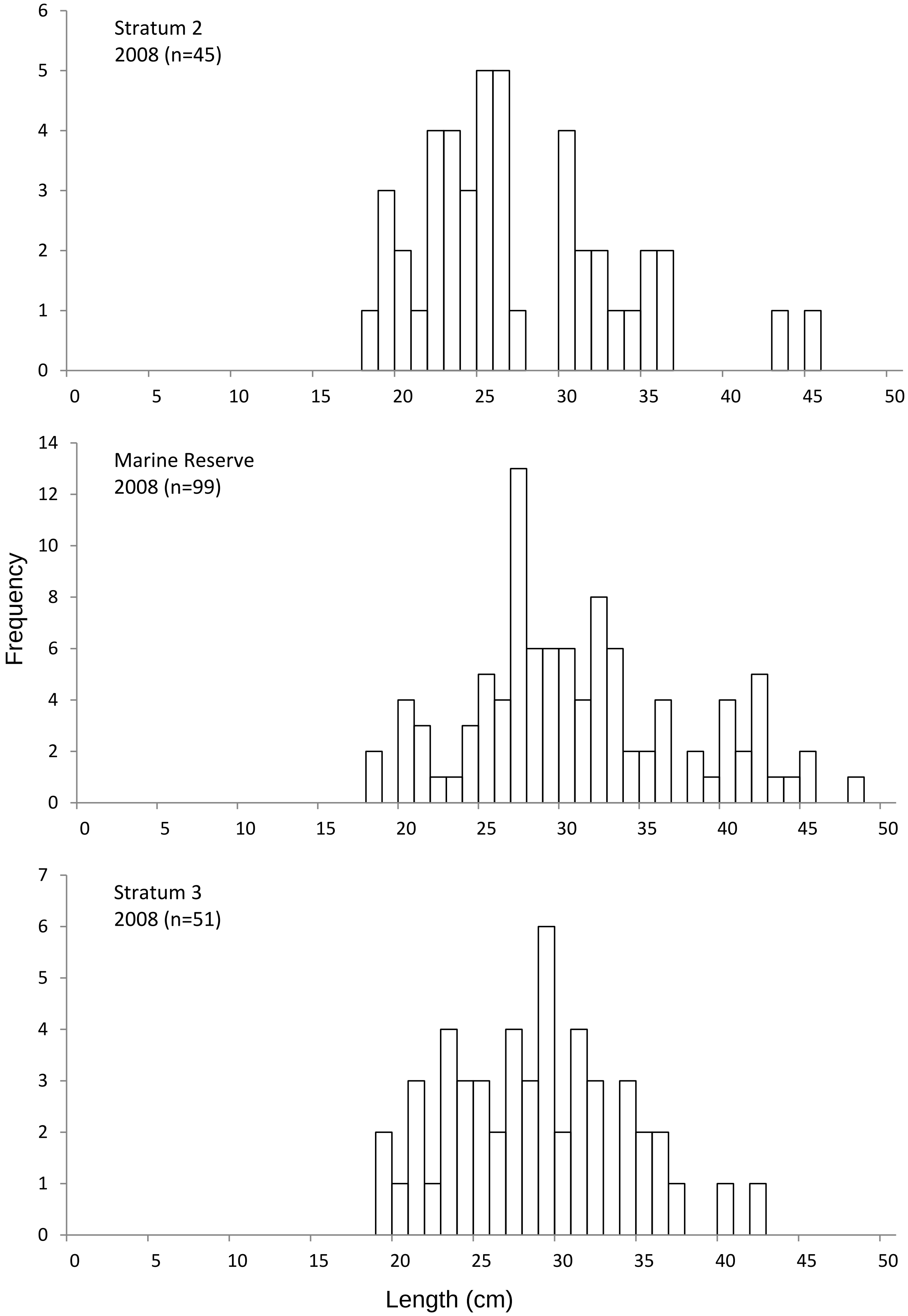


Figure 10: Length frequency distributions (not scaled) of unsexed blue cod for the Pohatu marine reserve stratum and two adjacent strata in the September 2008 potting survey (Figure 3).

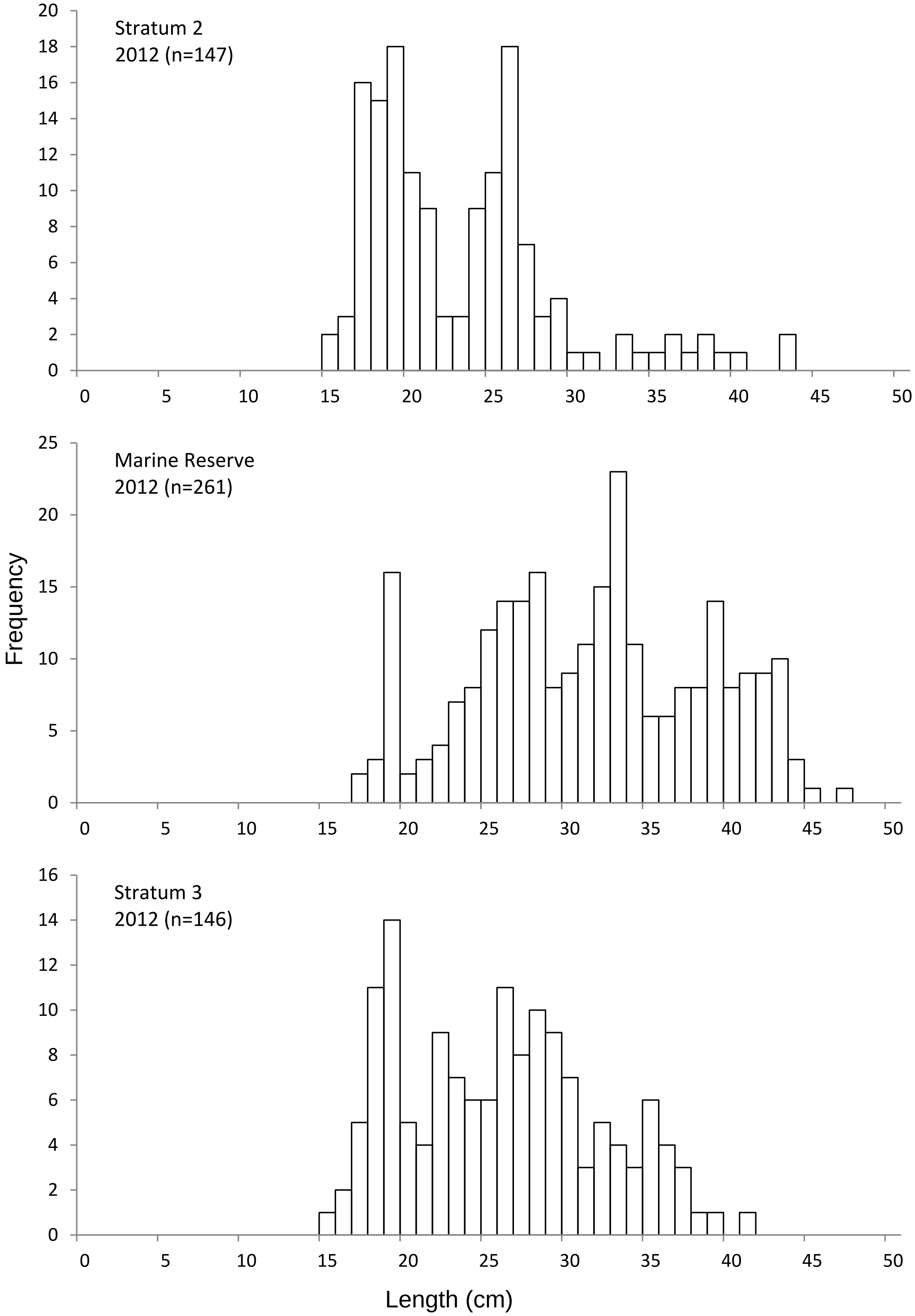
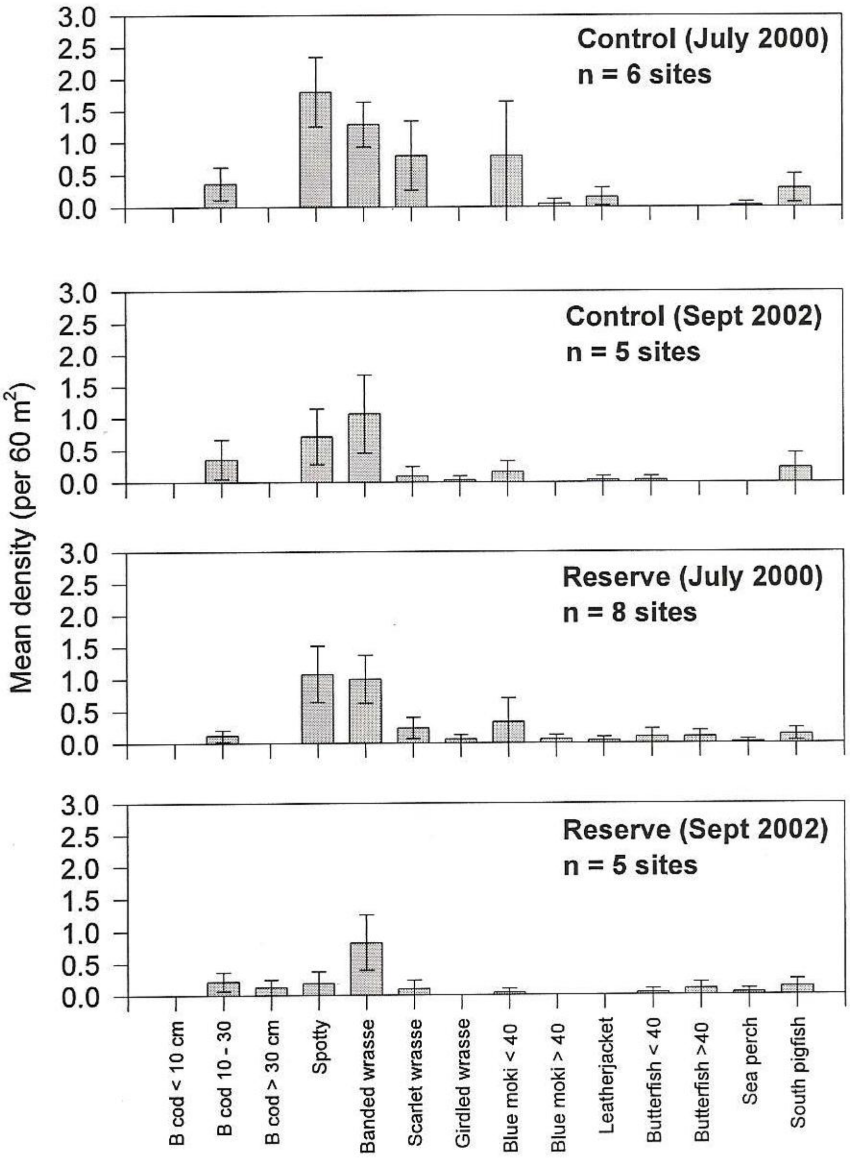


Figure 11: Length frequency distributions (not scaled) of unsexed blue cod for the Pohatu marine reserve stratum and two adjacent strata in the April 2012 potting survey (Figure 4).

Appendix 1: Mean fish density for pooled control and reserve sites from underwater visual transects done in July 2000 and September 2002 (see Section 4.1). Figure from Davidson & Able 2003.



Appendix 2: Summary of the September 2008 Banks Peninsula oceanographic environmental site data recorded in the format of MPI trawl data base. Depths are measured in meters, directions in compass degrees (999 = nil), wind force in the Beaufort scale, temperatures in degrees centigrade, air pressure in millibars, cloud cover in oktas, sea condition in the Douglas scale, sea colour in a categorical scale from 1 (deep blue) to 8 (yellow green), swell height in the Douglas classification 1 (low) to 3 (heavy), bottom type in a categorical scale (7 = rock), bottom contour in a categorical scale from 1 (smooth/flat) to 5 (very rugged), and wind speed in metres per second.

Site	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
MR7	*22.5*	*045*	*0*	*12.7*	*1011*	*8*	*3*	*07*	*0.75*	*135*	*7*	*3*	*10.0*	*10.0*	*1.4*	*3.7*
MR8	*27.3*	*045*	*4*	*14.7*	*1012*	*7*	*3*	*07*	*1.00*	*135*	*7*	*3*	*10.0*	*9.9*	*22.9*	*3.6*
MR6	*34.2*	*045*	*4*	*11.9*	*1012*	*1*	*3*	*05*	*1.00*	*135*	*7*	*4*	*10.0*	*9.9*	*20.5*	*4.2*
2L	35.7	090	2	16.2	1013	4	3	07	0.75	135	7	3	10.0	9.9	9.3	6.8
MR5	*25.5*	*270*	*1*	*12.5*	*1024*	*1*	*1*	*06*	*0.50*	*090*	*7*	*3*	*10.0*	*10.0*	*5.8*	*5.7*
MR4	*13.0*	*180*	*2*	*17.9*	*1024*	*0*	*1*	*06*	*0.00*	*999*	*7*	*2*	*10.0*	*10.0*	*9.8*	*7.8*
3A	25.5	225	1	23.5	1023	4	1	06	0.50	180	7	3	9.9	10.5	2.9	7.9
3B	24.0	225	1	22.1	1024	0	1	06	0.50	180	7	3	10.1	10.1	4.1	6.8
2K	32.5	090	2	21.1	1023	3	1	06	0.50	180	7	3	9.9	10.5	11.2	4.4

Appendix 3: Summary of the September 2012 Banks Peninsula oceanographic environmental site data recorded in the format of MPI trawl data base. Depths are measured in meters, directions in compass degrees (999 = nil), wind force in the Beaufort scale, temperatures in degrees centigrade, air pressure in millibars, cloud cover in oktas, sea condition in the Douglas scale, sea colour in a categorical scale from 1 (deep blue) to 8 (yellow green), swell height in the Douglas classification 1 (low) to 3 (heavy), bottom type in a categorical scale (7=rock), bottom contour in a categorical scale from 1 (smooth/flat) to 5 (very rugged), and wind speed in metres per second.

Site	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
2R2	19.7	270	2	15.7	1031	0	3	8	0.5	270	7	2	11.5	11.4	11.1	2.4
2R5	34.0	90	3	19.8	1023	2	4	7	1.5	060	7	3	13.0	11.5	17.0	4.7
2R1	23.3	000	2	11.4	1025	2	3	6	1	060	7	2	11.5	11.4	11.1	8.3
2R4	23.5	999	0	13.1	1024	7	2	7	0.5	150	7	2	11.5	11.4	0.0	4.3
2R3	22.2	180	2	14.2	1024	6	3	7	1	150	7	3	11.0	11.4	8.2	2.4
3R5	28.7	050	2	14.3	1029	2	3	8	1.5	050	7	3	10.2	11.3	12.6	1.7
3R3	14.5	330	1	10.4	1028	6	2	7	0.25	130	7	3	11.7	11.5	6.0	2.4
3R4	17.8	999	0	12.6	1028	6	2	7	0.25	130	7	4	11.7	11.5	0.0	3.4
3R2	14.0	999	0	15.3	1028	4	1	7	0.25	060	7	2	11.6	11.5	0.0	4.4
3R1	15.0	240	1	20.2	1028	5	1	7	0.25	060	7	2	11.6	11.5	2.8	4.1
MR8	*26.7*	*270*	*1*	*11.0*	*1028*	*2*	*1*	*7*	*0.25*	*030*	*7*	*3*	*11.8*	11.5	*6.1*	*5.4*
MR7a	*24.3*	*150*	*1*	*16.9*	*1028*	*0*	*1*	*7*	*0.25*	*030*	*7*	*2*	*11.7*	11.5	*1.5*	*6.3*
MR7	*17.7*	*130*	*1*	*19.7*	*1028*	*0*	*1*	*7*	*0.25*	*060*	*7*	*2*	*11.6*	11.5	*7.3*	*8.7*
MR1	*7.7*	*120*	*1*	*20.4*	*1028*	*0*	*1*	*7*	*0*	*999*	*7*	*1*	*11.8*	11.5	*3.7*	*8.0*
MR6	*30.8*	*090*	*2*	*22.0*	*1027*	*2*	*2*	*7*	*0.5*	*040*	*7*	*3*	*11.7*	11.5	*11.4*	*7.7*
MR3	*8.3*	*100*	*3*	*18.1*	*1027*	*0*	*1*	*7*	*0*	*999*	*7*	*2*	*11.8*	11.5	*14.9*	*7.1*
MR5	*17.5*	*090*	*2*	*20.8*	*1027*	*0*	*2*	*7*	*0.25*	*060*	*7*	*7*	*11.8*	11.5	*9.4*	*9.1*