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Relative abundance, size and age structure, and stock status of blue cod off Kaikoura and north Canterbury in 2011–12. Comparisons of potting survey designs and estimates of pot catchability and size selectivity.

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EXECUTIVE SUMMARY

Carbines, G.D.; Haist, V. (2018). Relative abundance, size and age structure, and stock status of blue cod off Kaikoura and north Canterbury in 2011–12. Comparisons of potting survey designs and estimates of pot catchability and size selectivity.
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This report describes the results of the 2011 Kaikoura and 2012 Motunau blue cod (*Parapercis colias*) potting surveys. These are the third fixed and first concurrent random site allocation potting surveys to be undertaken in the time series for Kaikoura and Motunau. A comparison of abundance and size distribution from flown video transects and subsequent pot catches was also done in the Motunau potting survey.

Kaikoura
Between 30 November and 21 December 2011, twenty-three fixed sites and twenty-six random sites were surveyed (6 pots per site, 294 pot lifts) from two coastal and two offshore strata off Kaikoura. The catch of each pot was weighed, and the length and sex of blue cod was recorded. Otoliths were read from 249 blue cod collected from both random and fixed sites representatively selected throughout the survey area. The resulting age-length keys (i.e. male and female) 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 20 phase 1 sites, with three additional sites allocated to the southern inshore stratum in phase 2. Total blue cod catch was 749 kg, consisting of 1610 fish. For all size blue cod catch rates by stratum ranged from 2.1 to 11.4 kg.pot^{-1}, with an overall mean catch rate of 4.0 kg.pot^{-1} and coefficient of variation (CV) of 15.0%. Catch rates of legal size blue cod (at least 30 cm) ranged from 1.5 to 10.0 kg.pot^{-1}, with an overall mean catch rate of 2.8 kg.pot^{-1} and CV of 13.3%. Catch rates of legal size fish were highest in the deep water (100–200 m) stratum offshore of the Kaikoura Peninsula, and lowest in the southern inshore stratum (south of Kaikoura). At fixed sites 50% of blue cod caught were of legal size.

Total lengths recorded at fixed sites ranged from 14 to 53 cm. The length frequency distributions were unimodal, with few fish below 20 cm or over 40 cm. Males were larger than females in all strata and overall mean length was 30 cm for males and 29 cm for females. Overall sex ratios for both all and legal sized fish were 1:1.0 (M:F). Age ranged from 2 to 31 years, with most blue cod between 5 and 8 years for both males and females. The total mortality estimate (Z) was 0.27, assuming age-at-recruitment to the fishery at 11 years. The spawning biomass per recruit ($F_{\%SPR}$) estimate indicates that the expected contribution to the spawning biomass over the lifetime of an average Kaikoura recruit has been reduced to 52% of the contribution in the absence of fishing, and this level of exploitation (F) is acceptable as it is within the Ministry of Primary Industries target reference point of $F_{45\%}$.

Temporal comparisons between fixed site surveys
For the fixed site survey, the overall catch rates of all blue cod and legal sized blue cod had declined by 20% and 30% respectively since the 2007 survey. Catch rates of all and legal size blue cod had declined in the two strata off the Kaikoura Peninsula, but increased in the southern inshore and offshore strata. The overall CVs for the 2011 survey catch rates were 15.0% for all and 13.3% for legal size blue cod, however, these could not be compared to previous surveys due to a change in the method of calculation from earlier surveys. Gonad observations in the 2011 survey had most fish in the maturing stages, with some running ripe, which was consistent with both the 2004 and 2007 fixed site surveys.

Random site survey
The random site survey used 23 phase 1 sites, and three phase 2 sites allocated to the inshore stratum south of Kaikoura. Total blue cod catch was 650 kg, consisting of 1372 fish. For all size blue cod, catch rates by stratum ranged from 0.6 to 8.2 kg.pot^{-1} with an overall mean catch rate of 2.6 kg.pot^{-1} and CV of 16.7%. Catch rates of legal size blue cod by stratum ranged from 0.3 to 7.15 kg.pot^{-1} with an overall

mean catch rate of 1.7 kg.pot^{-1} and CV of 16.4%. Catch rates of legal sized fish were highest in the deep water stratum off the Kaikoura Peninsula, and lowest in the inshore stratum south of Kaikoura. At random sites 54% of blue cod caught were of legal size.

Total lengths recorded at random sites ranged from 15 to 52 cm. The length frequency distributions were unimodal, with few fish below 20 cm or over 40 cm. Males were larger than females in all strata, although the overall mean length was 30 cm for both males and females. Overall sex ratios for all and for legal sized blue cod were 1:1.5 (M:F) and 1:1.7 respectively. Age ranged from 2 to 29 years, with most fish between 5 and 8 years for males and 5 and 10 years for females. The *Z* estimate for the random site survey was 0.26, assuming an age-at-recruitment of 11 years. The $F_{\%SPR}$ estimate indicates that the spawning biomass has been reduced to 52% which is within the Ministry of Primary Industries target reference point of $F_{45\%}$.

Comparison between survey designs
Overall catch rates of all and legal sized blue cod from the 2011 random site potting survey were 66% and 62%, respectively, of the catch rates from the concurrent fixed site survey, but was not consistent among strata for either all (29–165%) or legal (40–284%) sized blue cod. The strata rank order of random site catch rates of all blue cod and legal size blue cod was not consistent with the rank order of fixed sites. The overall CVs of the catch rates from the random site survey (over 16%) were only slightly higher than the CVs from the concurrent fixed site survey (over 15%).

Motunau
Between 23 January and 5 February 2012, eighteen fixed sites and twenty-one random sites were surveyed (6 pots per site, 234 pot lifts) from three coastal strata surrounding Motunau. The catch of each pot was weighed, and the length and sex of blue cod was recorded. Otoliths were read from 196 blue cod collected from both random and fixed sites representatively selected throughout the survey area. 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 15 phase 1 sites, with three additional sites allocated to the two most southern strata in phase 2. Total blue cod catch was 671 kg, consisting of 1871 fish. For all size blue cod catch rates by stratum ranged from 4.4 to 8.7 kg.pot^{-1}, with an overall mean catch rate of 5.5 kg.pot^{-1} and coefficient of variation (CV) of 12.0%. Catch rates of legal size blue cod (at least 30 cm) ranged from 2.6 to 4.4 kg.pot^{-1}, with an overall mean catch rate of 3.0 kg.pot^{-1} and CV of 16.6%. Catch rates of legal size fish were highest in the northern strata, and lowest in the southern stratum. At fixed sites 30% of blue cod caught were of legal size.

Total lengths recorded at fixed sites ranged from 14 to 45 cm. The length frequency distributions were unimodal, with few fish below 20 cm or over 35 cm. Males were larger than females in all strata and overall mean length was 29 cm for males and 25 cm for females. Overall sex ratios for both all and legal sized fish were 1:0.4 (M:F). Age ranged from 2 to 17 years, with most blue cod between 5 and 10 years for both males and females. The total mortality estimate (*Z*) was 0.39, assuming age-at-recruitment to the fishery at 11 years. The spawning biomass per recruit ($F_{\%SPR}$) estimate indicates that the expected contribution to the spawning biomass over the lifetime of an average Motunau recruit has been reduced to 45% of the contribution in the absence of fishing, and this level of exploitation (F) should be of some concern as it is beyond the Ministry of Primary Industries target reference point of $F_{45\%}$.

Temporal comparisons between fixed site surveys
For the fixed site survey, the overall catch rates of all blue cod have remained stable, but has declined by 10% for legal sized blue cod since the 2008 survey. Catch rates of all and legal size blue cod had declined in the southern stratum, but increased in the central strata off Motunau. The overall CVs for the 2012 fixed survey catch rates were 12.0% for all and 16.6% for legal size blue cod. However, these could not be compared to previous surveys due to a change in the method of calculation from earlier surveys. Gonad observations in the 2012 survey had almost all fish in the early maturing stage, with

very few individuals running ripe or spent, which was consistent with both the 2005 and 2008 fixed site surveys.

Random site survey
The random site survey used 18 phase 1 sites, and three phase 2 sites allocated to the central and southern strata. Total blue cod catch was 507 kg, consisting of 1537 fish. For all size blue cod, catch rates by stratum ranged from 1.8 to 7.0 kg.pot^{-1} with an overall mean catch rate of 3.0 kg.pot^{-1} and CV of 20.1%. Catch rates of legal size blue cod by stratum ranged from 1.0 to 3.8 kg.pot^{-1} with an overall mean catch rate of 1.6 kg.pot^{-1} and CV of 22.6%. Catch rates of legal sized fish were highest in the northern stratum, and lowest in the southern stratum. At random sites 27% of blue cod caught were of legal size.

Total lengths recorded at random sites ranged from 14 to 45 cm. The length frequency distributions were unimodal, with few fish below 20 cm or over 35 cm. Males were larger than females in all strata and the overall mean length was 28 cm for males and 23 cm females. Overall sex ratios for all and for legal sized blue cod were 1:0.8 (M:F) and 1:<0.1 respectively. Age ranged from 2 to 17 years, with most fish between 4 and 8 years for males and 3 and 7 years for females. The *Z* estimate for the random site survey was 0.42, assuming an age-at-recruitment of 11 years. The $F_{\%SPR}$ estimate indicates that the spawning biomass has been reduced to 44% which approximates the Ministry of Primary Industries target reference point of $F_{45\%}$.

Comparison between survey designs
Overall catch rates of all and legal sized blue cod from the 2012 random site potting survey were 54% and 52% respectively of the catch rates from the concurrent fixed site survey, and was consistent among strata for both all (41–80%) and legal (39–86%) sized blue cod. The stratum rank order of random site catch rates of all blue cod and legal size blue cod was consistent with the rank order of fixed sites. The overall CVs of the catch rates from the random site survey (over 23%) were higher than the CVs from the concurrent fixed site survey (over 16%).

Catchability and size selectivity of survey pots
Four to ten flown drop underwater video (DUV) transects were conducted at each of six sites, immediately prior to setting the type 2 survey pots (n=6), to compare size selectivity and catchability for the two methods. The DUV system surveyed a total area of 81 729 m^2 and 2622 blue cod (7–50 cm) were recorded. Pots subsequently caught 782 blue cod (15–45 cm). Compared to the DUV, the pots caught proportionately more blue cod over 25 cm. The estimated density of blue cod from video transects had a poor relationship with pot catches in Motunau.

Day versus night video comparisons
At one site, additional DUV transects were done in darkness prior to daybreak, and then repeated in daylight. Few blue cod below 30 cm and almost no legal size blue cod were observed at night compared to the subsequent daylight transects.

Habitat Preferences of blue cod
The ratio of fish-dependent and fish-independent video habitat observations revealed that blue cod were observed disproportionately more often on the primary substrates of bedrock/sand, sand/shell grit, pea gravel and sand, with the secondary habitats of boulders/cobbles/sponge/bryozoans and simply sponge/bryozoans. However, no structure was the largest category of secondary habitat observed in the benthic environment surveyed in Motunau.

1 INTRODUCTION

Blue cod (*Parapercis colias*) is a particularly desirable finfish easily caught and the most frequently landed recreational species in the South Island (Ministry for Primary Industries 2017). Blue cod is also an important species for Maori customary fishers in all areas, but the catch is unknown. Tagging shows that most blue cod have a restricted home range (Rapson 1956, Mace & Johnston 1983, Mutch 1983, Carbines & McKenzie 2001, 2004), 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 may be especially susceptible to localised depletion within subareas of FMAs, and in response to local fishing pressure, recreational daily bag limits vary within each and every South Island FMA (Ministry for Primary Industries 2017).

Commercial blue cod catch along the east coast of the South Island (BCO 3) has been constrained by a relatively small total allowable commercial catch (163 t), and accounts for only 7% of BCO quota nationally (Ministry for Primary Industries 2017). However, BCO 3 has been overcaught by up to 20 t in most years since 2003–04 (Ministry for Primary Industries 2017). Estimates of the recreational blue cod catch for BCO 3 have been highly variable (101–752 t), but the most recent estimate in 2012 (101 t) suggests that BCO 3 is a shared fishery with similar amounts of harvest from the commercial and recreation sectors.

Within BCO 3 there are currently three areas where recreational minimum legal size (MLS) and daily bag limits have varied in response to high fishing pressure (i.e., Otago, north Canterbury and Kaikoura; Ministry for Primary Industries 2017). The blue cod recreational bag limit in Otago remains at 30 fish per day, but has been reduced to 2 per day in the Marlborough Sounds (BCO 7), 10 per day in north Canterbury and 6 per day in Kaikoura. However, fishers in Kaikoura and north Canterbury remain concerned about declines in their catches and the sizes of blue cod, and about the increase in the number of Canterbury based private recreational fishers and charter boats operating in the area and the movement of commercial BCO 3 landings from Otago to Kaikoura (South Marine Recreational Fishers Advisory Group pers. comm.).

Ministry for Primary Industries potting surveys

To monitor South Island blue cod populations, the Ministry for Primary Industries undertakes a quadrennial series of potting surveys to generate relative biomass estimates in key recreational fisheries within all three South Island FMAs. Areas surveyed include: the Marlborough Sounds, Kaikoura, Motunau, Banks Peninsula, north and south Otago, Dusky Sound, Foveaux Strait, and Paterson Inlet (Ministry for Primary Industries 2017). These surveys provide relative abundance indices as well as information on population size/age structure, mortality estimates, and sex ratios used to monitor blue cod stocks. In addition to catch rate information, monitoring age structure provides a possible means of evaluating the response of a population to changes in fishing pressure. Otoliths collected during potting surveys are used to calculate the age structure of blue cod throughout areas of the South Island; as well as estimate total mortality (*Z*) for each survey based on catch curve analysis (Ricker 1975) Thus it is possible to determine stock status using an MSY-related proxy. For blue cod there is insufficient information to estimate B_{MSY} for each local population, in part because recreational catches have not been estimated reliably, and most likely represent a significant proportion of the total catch. F_{MSY} is a more appropriate reference point for blue cod populations supporting localised recreational fisheries, and the most widely used proxy for F_{MSY} is based on 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).

Kaikoura 2004 potting survey

An initial standardised potting survey was carried out off Kaikoura between 4 and 16 December 2004 (Carbines & Beentjes 2006). Twenty-five fixed sites were surveyed (6 pots per site = 150 pot lifts) from two inshore and two offshore strata (see Appendix 1). The total blue cod catch was 782 kg, consisting of 1296 fish. During phase 1, 120 pot lifts were completed (80%) with 30 in phase 2. The overall mean

catch rate for the survey was 2.62 kg.pot^{-1}, but ranged from only 0.60 kg.pot^{-1} in inshore stratum 2 to 7.97 kg.pot^{-1} in offshore stratum 4. Overall mean catch rate for fish over 30 cm (minimum legal size) was 2.05 kg.pot^{-1}.

In total, 68% of blue cod caught in Kaikoura were of legal size. The inshore strata 2 and 3 had the smallest fish. Fish from offshore stratum 1 were slightly larger, and the sex ratio was heavily biased toward males. This contrasted with the offshore stratum 4 where fish were about 5 cm longer on average, and the sex ratio was biased towards females. The overall sex ratios were even (51% males); however stratum 1 was dominated by males (78%) and stratum 4 by females (78%).

For all strata combined the overall age ranged from 3 to 8 years with a strong mode from about 4 to 8 years, peaking at 5−6 years (Carbines & Beentjes 2009). The mean ages were male 6.8 years and female 6.2 years. The combined strata *Z* estimates were between 0.31 and 0.37 (ages at recruitment of 5–8).

Motunau 2004 potting survey

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

For all strata combined overall age ranged from 3 to 12 years with a strong mode from about 5 to 7 years, peaking at 6 years (Carbines & Beentjes 2009). The mean ages were male 6.3 years and female 5.7 years. The combined strata *Z* estimates were between 0.53 and 0.84 (ages at recruitment between 5 and 8).

Kaikoura 2007 potting survey

In the second Kaikoura fixed site survey, 20 sites were successfully surveyed (6 pots per site = 150 pot lifts) from two inshore strata and two offshore strata around Kaikoura (See Appendix 1) between 3 and 12 December 2007 (Carbines & Beentjes 2009). Of the total 1862 kg of catch, 1784 kg (96%) was blue cod, consisting of 1798 fish. Kaikoura mean catch rates of blue cod (all sizes) ranged from 1.94 kg.pot^{-1} in stratum 2 to 20.45 kg.pot^{-1} for offshore stratum 4. Overall mean catch rate for all blue cod was 5.00 kg.pot^{-1}. For blue cod 30 cm and over, highest catch rates were also in stratum 4 (18.79 kg.pot^{-1}) and lowest catch rates in stratum 2 (1.16 kg.pot^{-1}). Overall mean catch rate for blue cod 30 cm and over was 4.01 kg.pot^{-1}. The overall sex ratio was 1:1.4 (male:female), although the two strata with the lowest catches of blue cod were biased in favour of males (1:0.7).

Blue cod from Kaikoura ranged in length from 16 to 55 cm with a single modal peak apparent at about 33 cm. The largest blue cod came from offshore stratum 4 and the smallest from inshore stratum 2. Mean lengths of males averaged about 3 cm longer than females from all strata combined. Mean length of both males and females in the offshore stratum 4 was over 8 cm greater than the inshore stratum 2. Overall for all strata the proportion of blue cod of minimum legal size was 71%.

Overall for all strata combined, age ranged from 3 to 24 years with a strong mode from about 4 to 9 years, peaking at 6−7 years (Carbines & Beentjes 2009). The mean ages were male 6.2 years and female 5.5 years. The combined strata *Z* estimates were between 0.32 and 0.37 (ages at recruitment of 5–8). The substantial increase in catch rates in the more tidal offshore areas in 2007 compared to 2004 could not be adequately explained and suggest that catchability may have altered between 2004 and 2007 in these areas (Carbines & Beentjes 2009).

Motunau 2008 potting survey

The second fixed site potting survey to be carried out off Motunau used 15 sites (6 pots per site = 120 pot lifts) from three inshore strata contiguous with the coastline around Motunau (See Appendix 2)

between 7 and 15 January (Carbines & Beentjes 2009). Of the total 747 kg of catch, 725 kg (97%) was blue cod, consisting of 1824 fish. Motunau mean catch rates of blue cod (all sizes) ranged from 4.11 kg.pot^{-1} in stratum 2 (north of Motunau to south of Sail Rock) to 8.86 kg.pot^{-1} for stratum 1. Overall mean catch rate for all blue cod was 5.50 kg.pot^{-1}. For blue cod 30 cm and over, highest catch rates were also in stratum 1 (4.93 kg.pot^{-1}) and the lowest catch rates were also in stratum 2 (2.10 kg.pot^{-1}). Overall mean catch rate for blue cod 30 cm and over was 3.33 kg.pot^{-1}. The overall sex ratio was 1:0.3 (male:female) and the bias toward males was consistent in all strata.

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

Overall for all strata combined age ranged from 3 to 12 years with a single mode peaking at 6−7 years (Carbines & Beentjes 2009). The mean ages were male 6.1 years and female 5.1 years. Total mortality for Motunau blue cod populations was estimated for combined strata at between 0.53 and 0.84 (ages at recruitment between 5 and 8 respectively).

The substantial decrease in catch rates in all Motunau strata in 2008 compared to 2005 could not be explained by a relatively weak cohort in 2005, and catchability may have also altered between these two Motunau potting surveys. The relatively high estimates of mortality and the overall 44% decline in catch rates of legal sized blue cod in Motunau since the 2005 potting survey was of concern (Carbines & Beentjes 2009).

Pot catches verses underwater observations

The basic premise of potting surveys as long term monitoring programmes is that this passive capture method provides estimates of the relative abundance and size structure of blue cod populations within the survey areas.

However, a review of the blue cod potting programme recommended that this premise requires further validation (Stephenson et al. 2009). Different methods have different size selectivity and catch rates, and size composition from potting can differ both between pot types (Beentjes & Carbines 2012, Carbines & Beentjes 2012, Carbines & Haist 2017b) and with other methods such as line fishing (Carbines 1999, 2008).

Pot catches have a weak, highly variable and largely unexplained relationship with counts from diver transects (Cole et al. 2001), and continuous video recordings of blue cod entries and exits from pots show that less than 8% of approaches lead to entries, and that local topography can constrain pot entries in some situations (Cole et al. 2004). Comparisons of remote flown video transects done immediately prior to potting also show a higher proportion of small blue cod observed than were caught, and the relationship between pot catch and video counts (i.e., catchability) has often been poor and highly variable over time and/or location (Beentjes & Carbines 2012, Carbines & Beentjes 2012, Carbines & Haist 2014, 2017a, 2017b). To further investigate the relationship between potting survey catch rates and size structure with direct *in situ* video observations of blue cod, the 2012 Motunau potting survey employed fish counts from five replicate drop underwater video (DUV) flown transects immediately prior to setting six pots at six survey sites.

For snapper (*Pagrus auratus*) it has been observed that night time observations of sleeping fish are more effective for DUV surveys (e.g., Compton et al. 2012) than daylight observations (Morrison & Carbines 2006). To investigate the value of night time DUV observation of blue cod, one site in Motunau ran night transects prior to dawn, then repeated them after sunrise prior to setting survey pots.

Overall objective

1. To estimate relative abundance, maturity state, sex ratio, and age structure of blue cod (*Parapercis colias*) off north Canterbury.

Specific objectives

1. To undertake a potting survey off Kaikoura and Motunau 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 these areas 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 Kaikoura and Motunau 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 3).

2.1 Timing

To continue the fixed site survey time series for north Canterbury with minimal temporal (seasonal) variability between surveys, the 2011 Kaikoura fixed and random site potting surveys were carried out concurrently between 30 November and 31 December 2011. Previous fixed site surveys were done in December 2004 (Carbines & Beentjes 2006) and December 2007 (Carbines & Beentjes 2009).

The 2012 Motunau fixed and random site potting surveys were carried out concurrently between 23 January and 5 February 2012. Previous fixed site surveys were done in February 2005 (Carbines & Beentjes 2006) and January 2008 (Carbines & Beentjes 2009).

2.2 Survey areas

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

outer strata boundaries (Figure 2). In the absence of any detailed local benthic habitat information, each stratum was assumed to contain roughly equal and random distributions of blue cod habitat and the total area (km^2) within each stratum was taken as a proxy measure of available habitat for blue cod.

For the third fixed site survey in this time series, the same survey area and strata used in the 2004/05 and 2009/10 surveys were resurveyed in 2011/12. However, the actual "fixed" sites used in each survey were generated randomly from the 41 possible fixed sites in Kaikoura (Figure 1) and 65 possible fixed sites in Motunau (Figure 2), originally identified in 2004 (Carbines & Beentjes 2006).

2.3 Survey designs

Both the fixed and random site potting surveys in Kaikoura and Motunau used a two-phase stratified design, using six pots per site (Figure 3), ensuring that sites were at least 300 m apart. Five sites per stratum (n=20 sites, 120 pot lifts) were allocated to phase one of the Kaikoura fixed site survey, while six sites for most strata (n=23 sites, 138 pot lifts) were allocated to phase one of the Kaikoura random site survey (Tables 1 and 2). An additional three sites (18 pot lifts) were allocated to phase two for both the Kaikoura fixed and random site surveys (13.0% and 11.5% respectively) (Figure 4). In Motunau, five sites per stratum (n=15 sites, 90 pot lifts) were allocated to phase one of the fixed site survey, while six sites per stratum (n=18 sites, 108 pot lifts) were allocated to phase one of the random site survey (Tables 3 and 4). An additional three sites (18 pot lifts) were allocated to phase two for both the Motunau fixed and random site surveys (16.7% and 14.3% respectively) (Figure 5).

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

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

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

2.4 Vessels and gear

The Kaikoura survey was conducted from F.V. *Mystique* II (registration number 63405), a Kaikoura-based commercial vessel equipped to set and lift rock lobster and blue cod pots. The vessel specifications are: 12.5 m length, 4.1 m breadth, 8 t, aluminium monohull, powered by a 450 hp diesel engine. The Motunau survey was again conducted from the F.V. *Navigator* (registration number 64015), a Motunau-based commercial vessel equipped to set and lift rock lobster and blue cod pots. The vessel specifications are: 12 m length, 2.9 m breadth, 3 t, aluminium monohull, powered by a 350 hp diesel engine.

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 (ADCP) was deployed at each site. The ADCP records current flow and direction in 5 m depth bins.

2.5 Sampling methods

The ADCP was initially deployed at each fixed site location, and the six pots were then set at least 100 m apart. The position of each of the six pots was determined by the skipper using local knowledge and the vessel sounder on site to direct the location of pots (Figure 3).

At each random site location the ADCP was first deployed. 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 hexagon 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, 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 each site to record 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.

All blue cod were sexed through dissection and direct macroscopic observations, 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 below 1 mm thickness before viewing. Sections were observed at ×40 and ×100 magnification under transmitted light with a compound microscope (Carbines 2004b).

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 (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 (G. Carbines and 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).

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 sexed and 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. 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 $\bar{C}_{st}$ 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.

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, $L_k^{\infty}, K_k,$ 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*:

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

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

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 $\left(\text{i.e. } S_f / S_0\right)$.

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 analyses conducted for *M* values of 0.11 and 0.17; the maturation ogive assumes that 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 10.

Note that the above equations assume that the surveys which generate the length-age data (and von Bertalanffy 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 Pot catches as a proxy for abundance and size structure

To determine the degree to which potting surveys provide indices of relative abundance and size structure, we attempted to estimate blue cod abundance and population structure using remotely flown video transects immediately prior to potting at a sub-sample of the Motunau potting survey sites. At one site DUV transects were also done at night and repeated after dawn prior to potting.

Sample collection
The drop under water video (DUV) system used 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, Beentjes & Carbines 2012, Carbines & Beentjes 2012, Carbines & Haist 2014, 2017a, 2017b, Compton et al. 2012). It was suspended beneath the 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 and the vessel steamed through the sample area. Once the speed of the surface vessel exceeded that of the deployed video, the keel and tail fin orients the platform forward, and the video records a transect of approximately 600 m length. Contact with the seabed is avoided by raising and lowering the video from the surface vessel throughout each transect and scaling lasers are used to back-calculate the size and variations of transect width. Daylight transects were carried out between 0600 and 1330 hours (night transects were done between 0249 and 0524), when the swell was no more than a metre, and when drift speed exceeded 0.8 $m.s^{-1}$ (to prevent fish being able to follow the video and re-enter the video transect). At least five replicate video transects were done at each site directly prior to 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 general benthic habitat sections. All blue cod were geo-referenced and scaling lasers were used to estimate fish length (Morrison & Carbines 2006, Carbines & Usmar 2013). 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 of grain size from sand to bedrock) and secondary habitat structure (categories of overlaying organic and/or geological benthic habitat), percentage cover (e.g., shells, sponges, macro-algae, etc.) topographic complexity and actual counts of benthic species where possible.

3 RESULTS

3.1 Sites surveyed

Kaikoura
Twenty-three fixed sites (6 pots per site, 138 pot lifts) and twenty-six random sites (6 pots per site, 156 pot lifts) were surveyed between 30 November and 21 December 2011 (Tables 1 and 2, Figure 4, Appendix 4). Twenty of the fixed sites were carried out in phase 1 (5 per stratum) with three sites allocated to stratum 2 in phase 2 (Table 1). Of the 26 random sites, 23 were carried out in phase 1 (5–6 per stratum), with three phase 2 sites also allocated to stratum 2 (Table 2). Depth ranged from 4 to 152 m for fixed sites and 9 to 130 m for random sites. Environmental data recorded throughout the 2011 Kaikoura potting surveys are presented in Appendix 5 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.

Motunau
Seventeen fixed sites (6 pots per site, 108 pot lifts) and twenty-one random sites (6 pots per site, 126 pot lifts) were surveyed between 23 January and 5 February 2012 (Tables 3 and 4, Figure 5, Appendix 6). Fifteen of the fixed sites were carried out in phase 1 (5 per stratum) with two sites allocated to stratum 2 and one site to stratum 3 in phase 2 (Table 3). Of the 21 random sites, 18 were carried out in phase 1 (6 per stratum), with two sites allocated to stratum 2 and one site to stratum 3 in phase 2 (Table 4). Depth ranged from 12 to 34 m for fixed sites and 7 to 34 m for random sites. Environmental data recorded throughout the 2012 Motunau potting surveys are presented in Appendix 7 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 composition

Kaikoura
A total of 1537 kg of catch was taken on the 2011 Kaikoura fixed and random site potting surveys, of which 1399 kg (91%) was blue cod, consisting of 2982 fish. Blue cod accounted for 91% of catch by weight in both the fixed site survey (Table 5) and the random site survey (Table 6).

In the fixed site survey, bycatch included ten fish and one octopus species (Table 5), and in the random site survey, bycatch included nine fish and one octopus species (Table 6). For the fixed site survey, the five most common bycatch species by weight were octopus (*Octopus cordiformis*), banded wrasse (*Notolabrus fucicola*), sea perch (*Helicolenus percides*), scarlet wrasse (*Pseudolabrus miles*), and girdled wrasse (*Notolabrus cinctus*) (Table 5). For the random site survey the five most common bycatch species by weight were octopus, sea perch, scarlet wrasse, banded wrasse and girdled wrasse (Table 6).

Motunau
A total of 1341 kg of catch was taken on the 2012 Motunau fixed and random site potting surveys, of which 1178 kg (88%) was blue cod, consisting of 3408 fish. Blue cod accounted for 94% of catch by weight in the fixed site survey (Table 7) and 81% of the catch in the random site survey (Table 8).

In the fixed site survey, bycatch included eleven fish and one octopus species (Table 7), in the random site survey, bycatch also included eleven fish and one octopus species (Table 8). For both the fixed site survey and the random site survey, the five most common bycatch species by weight were leatherjackets (*Parika scaber*), octopus, scarlet wrasse, girdled wrasse, and spotty (*Notolabrus celidotus*) (Tables 7 and 8).

3.3 Catch rates

Kaikoura
In the Kaikoura fixed site survey the mean catch rates of blue cod (all sizes) ranged from 2.14 kg.pot^{-1} for the coastal southern stratum 2, to 11.44 kg.pot^{-1} for the deep water (i.e., 100–200 m) stratum 4 off the Kaikoura Peninsula (Table 9, Figure 4). Overall mean catch rate and CV were 3.96 kg.pot^{-1} and 14.99%. For blue cod 30 cm and over (local minimum legal size) the lowest catch rates were also from stratum 2 (1.51 kg.pot^{-1}) and the highest were also from stratum 4 (10.00 kg.pot^{-1}) (Table 10, Figure 4). The fixed site time series for the 2004, 2007 and 2011 Kaikoura potting surveys is shown in Figure 6.

In the random site survey, mean catch rates of blue cod (all sizes) ranged from 0.61 kg.pot^{-1} for the coastal stratum 2 to 8.22 kg.pot^{-1} for the deep water stratum 4 (Table 11, Figure 4). Overall mean catch rate and CV were 2.62 kg.pot^{-1} and 16.71%. For blue cod 30 cm and over the lowest catch rates were also from stratum 2 (0.25 kg.pot^{-1}) and the highest were also from stratum 4 (7.15 kg.pot^{-1}). Overall mean catch rate and CV for blue cod 30 cm and over from the random site survey were 1.72 kg.pot^{-1} and

16.39% (Table 12, Figure 4). The random and fixed site catch rates for the 2011 Kaikoura potting surveys are shown in Figure 7.

Motunau
In the Motunau fixed site survey the mean catch rates of blue cod (all sizes) ranged from 4.43 kg.pot^{-1} for the southern stratum 3, to 8.70 kg.pot^{-1} for the northern stratum 1 (Table 13, Figure 5). Overall mean catch rate and CV were 5.53 kg.pot^{-1} and 11.95%. For blue cod 30 cm and over (local minimum legal size) the lowest catch rates were also from stratum 3 (2.57 kg.pot^{-1}) and the highest were also from stratum 1 (4.38 kg.pot^{-1}). Overall mean catch rate and CV for fish of at least 30 cm from the fixed site survey were 3.01 kg.pot^{-1} and 16.62% (Table 14, Figure 5). The fixed site time series for the 2005, 2008 and 2012 Motunau potting surveys is shown in Figure 8.

In the random site survey, mean catch rates of blue cod (all sizes) ranged from 1.81 kg.pot^{-1} for the southern stratum 3 to 6.95 kg.pot^{-1} for the northern stratum 1 (Table 15, Figure 5). Overall mean catch rate and CV were 2.97 kg.pot^{-1} and 20.13%. For blue cod 30 cm and over the lowest catch rates were also from stratum 3 (0.99 kg.pot^{-1}) and the highest were also from stratum 1 (3.77 kg.pot^{-1}). Overall mean catch rate and CV for blue cod 30 cm and over from the random site survey were 1.56 kg.pot^{-1} and 22.60% (Table 16, Figure 5). The random and fixed site catch rates for the 2012 Motunau potting surveys are shown in Figure 9.

3.4 Length frequency and sex ratio

Kaikoura
Of the 2982 blue cod caught on the 2011 Kaikoura fixed and random site potting surveys, all were measured for length and all were sexed, otoliths were taken throughout the survey area and ages read from 249 fish across the available size range (Appendix 8).

For the fixed site survey, the sex ratio of all blue cod ranged from 1:4.0 (M:F) in stratum 4 to 1:0.4 (M:F) in stratum 1, and overall were 49% male at 1:1.0 (M:F) (Table 17). The sex ratio for blue cod 30 cm and over ranged from 1:3.4 (M:F) in stratum 4 to 1:<0.1 (M:F) in stratum 2, but overall was balanced at 50% males (1:1.0) (Table 17). The size of blue cod at fixed sites ranged from 14 to 43 cm for females and 16 to 53 cm for males, although average size varied by up to 9 cm among strata (Figure 10).

For the random site survey, the sex ratio of all blue cod ranged from 1:4.7 (M:F) in stratum 4 to 1:0.6 (M:F) in stratum 1, and overall were 41% male at 1:1.5 (M:F) (Table 18). The sex ratio for blue cod 30 cm and over ranged from 1:4.3 (M:F) in stratum 4 to 1:0.1 (M:F) in stratum 2, but overall were skewed towards females (1:1.7) (Table 18). The size of blue cod at random sites ranged from 15 to 46 cm for females and 16 to 52 cm for males, but average size varied by up to 8.5 cm among strata (Figure 10).

The length frequency distributions were unimodal for strata 1 and 3, but multimodal for strata 2 and 4 of both the fixed and random site potting surveys (Figure 10). Fish taken in the random site potting survey were similar in size to those from the fixed site survey in all strata (Tables 17 and 18). For both survey types, small blue cod (less than 20 cm) were reasonably uncommon except in stratum 2, and large blue cod (over 40 cm) were reasonably uncommon except in stratum 4 (Figure 7). The deep water stratum 4 had the largest blue cod in both the fixed and random site surveys (Figure 7). In the fixed site survey the mean lengths of males were 2–6 cm more than females in all strata (Table 17), while in the random site survey the mean lengths of males were 1–5 cm more than females in all strata (Table 18). For the fixed site survey the overall mean length was 30.1 cm for males and 29.0 cm for females (Table 7), and for the random site survey the overall mean length was 30.3 cm for males and 29.6 cm for females (Table 18). The proportion of legal sized blue cod caught on the 2011 Kaikoura fixed site survey was 50% compared to 54% for the random site survey (Figure 10).

Motunau
Of the 3408 blue cod caught on the 2012 Motunau fixed and random site potting surveys, all were measured for length and all were sexed, otoliths were taken throughout the survey area and ages read from 196 fish across the available size range (Appendix 9).

For the fixed site survey, the sex ratio of all blue cod ranged from 1:0.4 (M:F) in stratum 3 to 1:0.3 (M:F) in stratum 2, and overall were 73% male at 1:0.4 (M:F) (Table 19). The sex ratio for blue cod 30 cm and over ranged from 1:0.1 (M:F) in stratum 1 to 1:<0.1 (M:F) in stratum 3, and overall was 94% males (1:1.0) (Table 19). The size of blue cod at fixed sites ranged from 14 to 34 cm for females and 15 to 45 cm for males, and the average size varied by no more than 1 cm among strata (Figure 11).

For the random site survey, the sex ratio of all blue cod ranged from 1:0.9 (M:F) in stratum 3 to 1:0.8 (M:F) in stratum 2, and overall were 55% male at 1:0.8 (M:F) (Table 20). The sex ratio for blue cod 30 cm and over all ranged from 1:0.9 (M:F) in stratum 3 to 1:0.8 (M:F) in stratum 2, and overall were 55% males (1:1.7) (Table 20). The size of blue cod at random sites ranged from 14 to 34 cm for females and 16 to 45 cm for males, and average size varied by less than 1.0 cm among strata (Figure 11).

The length frequency distributions were bimodal for both the fixed and random site potting surveys (Figure 11). Fish taken in the random site potting survey were similar in size to those from the fixed site survey in all strata, with a very large proportion of 25–26 cm fish in stratum 3 (Figure 11). For both survey types, small blue cod (less than 20 cm) were more common in the two southern strata, and large blue cod (over 35 cm) were uncommon in all strata (Figure 11). In the fixed site survey the mean lengths of males were 3–5 cm more than females in all strata (Table 19), while in the random site survey the mean lengths of males were 4–6 cm more than females in all strata (Table 20). For the fixed site survey the overall mean length was 28.8 cm for males and 24.5 cm for females (Table 19), and for the random site survey the overall mean length was 28.3 cm for males and 23.4 cm for females (Table 20). The proportion of legal sized blue cod caught on the 2012 Motunau fixed site survey was 30% compared to 27% for the random site survey (Figure 11).

3.5 Reproductive phase

Kaikoura
Blue cod from both the Kaikoura fixed and random site potting surveys had both maturing phase and running ripe gonads (Tables 21 and 22). The smallest fish with running ripe gonads were 27 cm for females and 29 cm for females.

Motunau
Blue cod from both the Motunau fixed and random site potting surveys had almost exclusively early maturing phase gonads (Tables 23 and 24). As very few fish were observed in the running ripe or spent stages it was not possible to determine the size at which running ripe fish become common at random sites.

Using the derived model $W = aL^b$, the length-weight parameters for both random and fixed sites of Kaikoura in 2011 were: males – a = 0.0117934, b = 3.09246, females – a = 0.0070425, b = 3.23949.

3.6 Ageing (between reader analyses)

Kaikoura
From 267 otoliths collected during the 2011 Kaikoura surveys, 18 were rejected as unreadable or damaged, leaving 249 otoliths (139 males 16–53 cm, 110 females 14–46 cm) (Table 25). These otoliths were collected across all strata (See Appendix 8).

Initial independently derived reader estimates of otolith age class are compared in Figure 12 and show 26% initial agreement between the two readers, with reader 2 estimating slightly lower age classes than reader 1 (tabulated in Appendix 9). When the differences between age class estimates were resolved by agreement between the readers, reader 1 was 63% consistent with the agreed age class and reader 2 was 40% consistent with the agreed age classes (Figure 12, Appendix 10).

Motunau
Of the 226 otoliths collected during the 2012 Motunau potting surveys, 30 were rejected as unreadable or damaged, leaving 196 otoliths (111 males 15–45 cm, 85 females 15–34 cm) (Table 26). These otoliths were collected across all strata (See Appendix 11).

Initial independently derived reader estimates of otolith age class are compared in Figure 13 and show 80% initial agreement between the two readers, with reader 2 again estimating slightly lower age classes than reader 1 (tabulated in Appendix 12). When the differences between age class estimates were resolved by agreement between the readers, both reader 1 and reader 2 were 80% consistent with the agreed age class (Figure 13, Appendix 13).

3.7 Growth

Kaikoura
The age/length data and fitted von Bertalanffy growth models for the 2011 Kaikoura potting surveys are shown in Figure 14, and the growth parameters (K, t_0 *and* L_{inf}) are shown below.

Parameter	Males	Females
K	0.089529	0.081738
T_0	-1.4781	-2.85847
L_{inf}	53.5	45.2

Motunau
The age/length data and fitted von Bertalanffy growth models for the 2012 Motunau potting surveys are also shown in Figure 14, and the growth parameters (K, t_0 *and* L_{inf}) are shown below.

Parameter	Males	Females
K	0.088205	0.113784
T_0	-1.90412	-2.00294
L_{inf}	50.7	40.0

3.8 Length and age composition

Kaikoura
The scaled length and age frequency distributions for all strata combined are shown for males, females, and both sexes combined for the 2011 Kaikoura fixed site (Figure 15) and random site potting surveys (Figure 16). Other than a very small peak in the frequency of 17–18 cm fish, the scaled length frequency distributions are unimodal for blue cod from both fixed and random sites, with males generally larger than females in both survey designs (Figures 15 and 16).

Age of blue cod ranged from 2–31 years (Table 25), but there were very few fish older than 15 years (Figures 15 and 16). For both males and females at fixed sites, the dominant age-classes were 5–8 years (Figure 15). At random sites the dominant age-classes were also 5–8 years for both males and females (Figure 16). The scaled mean age was similar in the fixed site and random site surveys for both males (8.1 compared to 8.2 years) and females (9.1 compared to 9.9 years). The mean weighted coefficients of variation (MWCVs) around the age distributions are moderate for males (32% and 32%) indicating a fair representation of the overall male population. However the MWCVs around the female age

distributions (39% and 40%) are a less convincing representation of the overall female population (Figures 15 and 16).

The Kaikoura survey age-length-keys (ALKs) are shown in Appendix 14 for males and Appendix 15 for females, and mean-age-at-length is shown in Appendix 16. For both males and females, all lengths measured on the survey had at least one valid age reading in the age-length-keys.

Motunau
The scaled length and age frequency distributions for all strata combined are shown for males, females, and both sexes combined for the 2012 Motunau fixed site (Figure 17) and random site (Figure 18) potting surveys. A small peak in the frequency of 18–19 cm fish was more pronounced among random sites, but the scaled length frequency distributions were effectively unimodal for blue cod from both fixed and random sites, with males generally larger than females in both survey designs (Figures 17 and 18).

Age of blue cod ranged from 2–17 years (Table 26), but there were very few fish older than 10 years (Figures 17 and 18). The dominant age-classes at fixed sites were 6 and 8 years for males, and 5–7 years for females (Figure 17). At random sites the dominant age-classes were 5, 6 and 8 years for males, and 5–7 years for females (Figure 18). The scaled mean age was similar in the fixed site and random site surveys for both males (8.0 compared to 7.6 years) and females (6.4 compared to 5.9 years). The mean weighted coefficients of variation (MWCVs) around the age distributions are moderate for males (32% and 32%) and females (35% and 34%) indicating a fair representation of the overall population. The scaled cumulative length and age frequency distributions of the Motunau and Kaikoura potting surveys are compared in Figure 19.

The Motunau age-length-keys (ALKs) are shown in Appendix 17 for males and Appendix 18 for females, and mean-age-at-length is shown in Appendix 19. For both males and females, all lengths measured on the survey had at least one valid age reading in the age-length-keys.

3.9 Total mortality (*Z*) estimates

Kaikoura
Total mortality estimates (*Z*) and 95% confidence intervals for the 2011 Kaikoura fixed and random site potting surveys are given in Tables 27 and 28 respectively, and are very similar for the fixed and random site surveys. For the fixed site survey, *Z* estimates range from 0.23 to 0.30, and for the random site survey *Z* estimates range from 0.21 to 0.30 (ages at recruitment of 5–12 years).

Motunau
Total mortality estimates and 95% confidence intervals for the 2012 Motunau fixed and random site potting surveys are given in Tables 29 and 30 respectively, and are similar for the fixed and random site surveys. For both the fixed and random site surveys, *Z* estimates ranged from 0.29 to 0.48 (ages at recruitment of 5–12 years).

3.10 Spawner per recruit analyses

Kaikoura
The age- and sex-specific values for fish size, maturity, and selectivity used in the 2011 Kaikoura survey SPR analysis are given in Appendix 20.

Spawning biomass per recruit analyses is plotted against fishing mortality rate for the Kaikoura fixed site survey in Figure 20, and the random site survey in Figure 21. Mortality parameters used in the analyses, and resulting $F_{\%SPR}$ values are shown in Tables 31 and 32. Based on the default value of *M* of 0.14 and age at recruitment of 11 years, the fishing mortality estimates for the Kaikoura fixed and random site surveys was 0.39 and 0.42 respectively, corresponding to %SPRs of 52% in both cases. For both the fixed and random site surveys the %SPR estimates for *M* values of 0.11 and 0.17 were 39% and 65% respectively (Tables 31 and 32).

Motunau
The age- and sex-specific values for fish size, maturity, and selectivity used in the 2012 Motunau survey SPR analysis are given in Appendix 21.

Spawning biomass per recruit analyses is plotted against fishing mortality rate for the Motunau fixed site survey in Figure 22, and the random site survey in Figure 23. Mortality parameters used in the analyses, and resulting $F_{\%SPR}$ values are shown in Tables 33 and 34. Based on the default value of *M* of 0.14 and age at recruitment of 11 years, the fishing mortality estimates for the Motunau fixed and random site surveys was 0.39 and 0.42 respectively, corresponding to %SPRs of 45% and 44% respectively. For the fixed site survey %SPR estimates for *M* values of 0.11 and 0.17 were 35% and 55% respectively (Table 33), and for the random site survey were 33% and 53% respectively (Table 34).

3.11 Pot catches as a proxy for abundance and size structure

Video counts versus pot catches
Due to sea conditions (i.e., swells over 1.0 m and/or poor bottom water visibility) no sites were surveyed in Kaikoura, and only six sites in Motunau were surveyed with flown video transects (Table 35, Figure 24). A total of 41 drop underwater video (DUV) transects were undertaken at the six potting survey sites (36 pot lifts) directly prior to sampling with type 2 survey pots (Table 35). The DUV surveyed over 42 km of transects with an average transect length of 889 m (s.e. ± 35.4 m) and width of 2.3 m (s.e. ± 0.1 m) covering a total area of 81 729 m^2. A total of 2622 blue cod were observed using DUV, while the survey pots caught 782 blue cod (Table 35).

Species caught and observed
A total catch of 813 individual fish was taken by pots at concurrent DUV surveyed sites, 96% of which were blue cod (Table 36). At the DUV surveyed sites, bycatch from potting included five fish species, listed in order of the most common these were spotty (*Notolabrus celidotus*), sea perch (*Helicolenus* spp), leatherjacket (*Parika scaber*), scarlet wrasse (*Pseudolabrus miles*), and girdled wrasse (*Notolabrus cinctus*).

A total of 3819 individuals were observed in DUV transects, 69% of which were blue cod (Table 37). Eighteen fish species and one octopus species were observed in DUV transects, the five most common of which were leatherjacket, scarlet wrasse, tarakihi (*Nemadactylus mactopterus*), spotty, and butterfly perch (*Caesioperca lepidoptera*).

Length frequency comparisons
Fish observed either off the bottom or at a camera angle over 45 degrees were removed (n=558) to improve precision (See Carbines & Usmar 2013), and the resulting proportional length frequency distribution showed the DUV sampled a considerably greater proportion of blue cod below 24 cm than was caught by pots (Figure 25).

Comparison of catch rates and counts
Fish densities estimated by the area-swept DUV method for three size classes of blue cod are shown in Figure 26. Most blue cod (of all size classes) were observed at site 1-R3, but pot catches of blue cod over 20 cm were higher in most other strata. Relatively low densities of fish observed at site 3-3G also preceded relatively high catches (Figure 26).

Pots caught few fish below 20 cm (Figure 25), although the correlation between the average site density and catch rate was 0.53 (Figure 27). However, for fish 20–29 cm and of legal size, the correlations between average site density and catch rate were 0.39 and -0.69 respectively (Figure 27).

Comparison of night and day counts
At site 2-2D, six DUV transects were done at night (2-2D-N) and then eight transects were done again after daybreak (2-2D) prior to potting (Figure 26). However, relatively few blue cod below 30 cm and almost no legal size blue cod were observed at night compared to the subsequent daylight transects (Figure 26).

Benthic habitat descriptions and utilisation
Within the area swept by the DUV, 215 general habitat breaks were identified and 999 fish-independent habitat transects were recorded within them (Table 35). A total of 2622 blue cod were observed with associated habitat using the DUV (Table 35). Benthic habitat data from the DUV method are presented in Figures 28 and 29, and a ratio of fish-dependent and fish-independent habitat observations was used to determine which primary substrata and secondary habitat structures have disproportionately higher association with blue cod.

A total of seventeen categories of primary substrate were observed, and the fish-independent habitat observations show the main primary substrates were sand/shell/gravel and sand/shell grit, while fish-dependent observations show that all size classes of blue cod were observed mostly with these primary substrates (Figure 28). However, using the ratio of substrate category proportions observed between fish-dependent verses fish-independent habitat observations (i.e., substrate category occupancy in proportion to its availability), showed that less than 20 cm blue cod were disproportionately associated with cobbles, pea gravel and sand/gravel, while larger blue cod were disproportionately associated with broken bedrock/cobble/gravel, cobbles/gravel, and cobbles (Figure 28).

In total thirty-one categories of secondary habitat structures were observed, and the fish-independent habitat observations show that the main secondary habitat structures observed was "no structure" (Figure 29). Blue cod of all size classes were observed most frequently with boulders/cobbles/sponge/bryozoan and sponge/macro algae (Figure 29). However, the ratio of fish-dependent and fish-independent secondary habitat categories shows that larger blue cod were disproportionately associated with broken bedrock/cobbles/sponge/bryozoan and bedrock/sponge, while smaller blue cod were disproportionately associated with macro-algae, sponge/red bryozoans and horse mussel/sponge (Figure 29).

4 DISCUSSION

The 2011/12 blue cod potting surveys were the first comparison of fixed and random site survey designs done in Kaikoura (Figure 4) and Motunau (Figure 5). These were the first random site surveys and the third fixed site survey done in Kaikoura and Motunau (Carbines & Beentjes 2006, 2009).

4.1 Fixed site survey design time series

Kaikoura
For the Kaikoura fixed site survey, the overall catch rates of all blue cod (Table 9) and legal sized blue cod (at least 30 cm, Table 10) declined by 20% and 30% respectively since the 2007 survey (Figure 6). Catch rates of all and legal size blue cod declined most within strata 3 (53% and 66%) and 4 (44% and 47%), but also increased in both strata 1 (38% and 21%) and 2 (9% and 23%) (Figure 6).

The historical declines in catch rates of blue cod within stratum 1 have been reversed since the 2004 survey, however, the historical increases in all other strata were also reversed between the 2007 and 2011 surveys (Figure 6). Since 2004, the rank order of catch rates for both all and legal size blue cod among strata (i.e., 4, 1, 3, 2) changed in the 2007 survey (i.e., 4, 3, 1, 2), but altered back to the 2004 rank order in the 2011 survey (i.e., 4, 1, 3, 2, Figure 6).

Motunau
For the Motunau fixed site survey, the overall catch rates of all blue cod (Table 13) has remained stable, but legal sized blue cod (Table 14) declined by 10% since the 2007 survey (Figure 8). Catch rates of all and legal size blue cod remained stable within stratum 1 (0% and 10% decline), increased within stratum 2 (61% and 60%) and declined within stratum 3 (15% and 25%) (Figure 8).

The historical declines in catch rates of blue cod within all strata have been halted since the 2005 survey, and reversed in stratum 2 between the 2008 and 2012 surveys (Figure 8). Between 2005 and 2008 the rank order of catch rates for both all and legal size blue cod among strata (i.e., 1, 3, 2) remained consistent, but changed in the 2012 survey (i.e., 1, 2, 3, Figure 8).

4.2 Comparisons of catch rates between survey designs

Kaikoura
Overall catch rates of all and legal sized blue cod from the 2011 Kaikoura random site potting survey (Tables 11 and 12) were only 66% and 61% respectively of the catch rates from the concurrent fixed site survey (Tables 9 and 10). However this level of reduced catch in the random site survey was not consistent among all strata as more blue cod (all and legal size) were caught in stratum 3 of the random site survey than the fixed site survey (Figure 7).

In the 2011 Kaikoura potting surveys, the strata rank order of random site catch rates of all and legal size blue cod (i.e., strata 4, 3, 1, 2) was not consistent with the rank order of fixed sites (i.e., strata 4, 1, 3, 2) (Figure 7). In 2011 the CV of the overall catch rate from the random site (n=26) survey (over 16%, Tables 11 and 12) was only slightly higher than the CV from the concurrent fixed site (n=23) survey (over 13%, Tables 9 and 10), and the 2011 Kaikoura random site survey has lower variance of catch rates than random site surveys in other potting survey areas (Carbines & Haist 2012, 2017a, 2017b).

Motunau
Overall catch rates of all and legal sized blue cod from the 2012 Motunau random site potting survey (Tables 15 and 16) were only 54% and 52% respectively of the catch rates from the concurrent fixed site survey (Tables 13 and 14). This level of reduced catch in the random site survey was also consistent among all strata for both all and legal blue cod (Figure 8).

In the 2012 Motunau potting surveys, the stratum rank order of random site catch rates of all and legal size blue cod was consistent with the rank order of fixed sites (i.e., strata 1, 2, 3, Figure 9). However, the CV of the overall catch rate from the random site (n=21) survey (over 20%, Tables 15 and 16) was higher than the CV from the concurrent fixed site (n=18) survey (over 12%, Tables 13 and 14). CVs for the 2012 Motunau random site survey were higher than for the random site survey off Kaikoura, but were consistent with CVs for random site surveys from other areas (Carbines & Haist 2012, 2017a, 2017b).

4.3 Reproductive condition

Kaikoura
Observations of gonad stages in the Kaikoura 2011 potting surveys were very similar between fixed and random sites, with 97% and 98% of fixed and random site individuals in the maturing stages and only 3% of both fixed and random site individuals running ripe (Tables 21 and 22). This indicates that the timing of the survey (early summer) was at the start of the spawning season, and is consistent with the previous surveys in 2004 (Carbines & Beentjes 2006) and 2007 (Carbines & Beentjes 2011). The smallest fish with running ripe gonads were 27 cm for females and 29 cm for females indicating that blue cod in Kaikoura are sexually mature at this size.

Motunau
Observations of gonad stages in the Motunau 2012 potting surveys were very similar between fixed and random sites, with 98% and 96% of individuals in the early maturing stage and virtually no running ripe or spent individuals (Tables 23 and 24). This indicates that the timing of the Motunau surveys (mid-summer) was conducted just prior to the spawning season and is consistent with the previous surveys in 2005 (Carbines & Beentjes 2006) and 2008 (Carbines & Beentjes 2009). However, with almost no running ripe fish, it was not possible to determine the size/age-at-sexual maturity for the Motunau survey area.

In more enclosed potting survey areas, fixed sites are often constrained to the coastline (Carbines & Haist 2014), however the similarity in reproductive condition between blue cod from the two survey designs suggest no such fine scale variability in the onset of spawning at either Kaikoura or Motunau, probably because fixed sites are not as constrained along the coast (Figures 4 and 5) as in other survey areas (Carbines & Haist 2014).

4.4 Size and sex ratio

Kaikoura
In the Kaikoura fixed site surveys, the percentage of males declined from 51% in 2004 (Carbines & Beentjes 2006) to 42% in 2009 (Carbines & Beentjes 2009), but subsequently increased to 49% in 2011 (Table 17). The percentage of males over the time series has remained consistently balanced within stratum 3 (2004=53%, 2007=47%, 2011=55%), consistently low in stratum 4 (22%, 26%, 20%), and variable in stratum 1 (78%, 65%, 71%) and stratum 2 (50%, 68%, 63%) (Carbines & Beentjes 2006, 2009, Table 17). Fifty percent of legal sized blue cod from fixed sites in Kaikoura were male in 2011, although strata 1–3 were heavily biased towards males (over 70%), only 23% of legal size blue cod were males in the numerically dominant stratum 4 (Table 17). The most pronounced male bias for all size blue cod for both fixed and random sites was in stratum 1, while the most pronounced male bias for legal size sized blue cod for both fixed and random sites was in stratum 2 (Tables 17 and 18). Sex ratios were consistent between survey types, although the male bias was higher in all strata for the fixed site survey, with overall 49% of all blue cod and 50% of legal sized blue cod in the fixed site survey being male (Table 17), compared to the random site survey where 41% of all blue cod and 37% of legal sized blue cod were male (Table 18).

Motunau
In the Motunau fixed site surveys, the percentage of males remained stable between 74% in 2005 (Carbines & Beentjes 2006) to 76% in 2009 (Carbines & Beentjes 2009), but has subsequently declined to 55% in 2011 (Table 19). The percentage of males over the time series has also remained consistent within all strata from 2005 to 2008 (Carbines & Beentjes 2006, 2009), with all strata experiencing a similarly large decline in the proportion of males in 2012 (Table 19). Ninety-four percent of legal sized blue cod from fixed sites in Motunau were male in 2012, and all strata were heavily biased towards males (over 91%, Table 19). The most pronounced male bias for all size blue cod for both fixed and

random sites was in stratum 2, while the most pronounced male bias for legal size sized blue cod for both fixed and random sites was in stratum 1 (Tables 19 and 20). Sex ratios of all blue cod were consistent between survey types, although the male bias was higher in all strata for the fixed site survey, with overall 73% of all blue cod being male. However, 94% of legal sized blue cod in the fixed site survey were male (Table 19), compared to 96% in the random site survey (Table 20).

4.5 Population length and age structure

Kaikoura
Other than a very small peak in the frequency of 17–18 cm fish, the scaled length frequency distributions are unimodal for blue cod from both fixed and random sites, with males generally larger than females in both survey designs (Figures 15 and 16). The proportion of legal sized blue cod caught on the three Kaikoura fixed site potting surveys initially increased from 68% in 2004 to 71% in 2007, but has since declined to 50% in the 2011 survey. The proportion of legal sized blue cod caught in the first Kaikoura random site survey was 54%, reflecting a slightly higher mean (both sexes combined) size in the random site survey (29 cm, Figure 16) than in the fixed site survey (28 cm, Figure 15). However, comparing proportions of legal sized blue cod across years or areas is difficult because they are affected by both recruitment and fishing mortality.

Because there were relatively few fish over 40 cm from either the fixed or random site potting surveys in Kaikoura, the resulting population age structures both show a rapid decline on the right hand limb after nine years and a low proportion of fish older than 16 years.

Motunau
A small peak in the frequency of 18–19 cm fish was also recorded in Motunau, but the scaled length frequency distributions were essentially unimodal for blue cod from both fixed and random sites, with males generally larger than females in both survey designs (Figures 17 and 18). The proportion of legal sized blue cod caught on the three Motunau fixed site potting surveys initially remained stable from 36% in 2005 to 35% in 2008, but has since declined to 30% in the 2011 survey. The proportion of legal sized blue cod caught in the first Motunau random site survey was 27%, reflecting a slightly higher mean (both sexes combined) size in the fixed site survey (28 cm, Figure 17) than in the random site survey (27 cm, Figure 18). However, we again caution that comparing proportions of legal sized blue cod across years or areas is difficult because they are affected by both recruitment and fishing mortality.

Because there were only relatively moderate numbers of fish 30–40 cm and very few over 40 cm from either fixed or random site potting surveys in Motunau, the resulting population age structures both show a rapid decline on the right hand limb after six years and a low proportion of fish older than 10 years.

4.6 Total mortality (*Z*)

Kaikoura
Because the two Kaikoura potting survey designs had similar age distributions (Figure 15 and 16), the resulting mortality estimates (*Z*) from the fixed site survey (Table 27) were similar to those from the random site survey (Table 28). Assuming a consistent age at recruitment of six years, mortality estimates from the Kaikoura fixed site potting survey time series have steadily decreased from the 2004 (Z=0.43, Carbines & Beentjes 2006), 2009 (Z=0.31, Carbines & Beentjes 2009) and 2011 survey (Z=0.24, Table 27).

Motunau
The two potting survey designs in Motunau also had similar age distributions (Figure 17 and 18) and resulting *Z* estimates (Tables 29 and 30). Assuming a consistent age at recruitment of six years, mortality estimates from the Motunau fixed site potting survey time series were consistently high in the 2005

(Z=0.60, Carbines & Beentjes 2006) and 2009 (Z=0.63, Carbines & Beentjes 2009) surveys, but had halved in the 2011 survey (Z=0.34, Table 29).

Because differences in population structure have been observed between fixed and random site designs run concurrently in other area (Carbines & Haist 2012, 2017a, 2017b), we have suggested that it is not appropriate to compare mortality estimates between random and fixed site surveys, however this does not appear to be the case in the Kaikoura and Motunau potting surveys where the more consistent spatial distribution of random and fixed sites (Figures 4 and 5) is not as impacted by coastal clustering of fixed sites as in more sheltered survey areas (Carbines & Haist 2012, 2017a, 2017b).

4.7 Stock status (spawning biomass per recruit ratio analyses)

The Ministry of Fisheries *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 more appropriate target reference point for blue cod is F_{MSY}, which is the amount of fishing mortality that results in the maximum sustainable yield. The recommended proxy for F_{MSY} is the level of spawner per recruit $F_{\%SPR}$. The 'Operational Guidelines for New Zealand's Harvest Strategy Standard' (Ministry of Fisheries 2011) includes the following table of recommended default values for F_{MSY} (expressed as $F_{\%SPR}$ levels from spawning biomass per recruit analysis), and also for B_{MSY} (expressed as $\%B_0$). Based on the recommendation from the Southern Inshore Working Group, blue cod is categorised as a low productivity species, as a result of influence of fishing on sex change, which results in a fishing mortality reference point for $F_{\%SPR}$ of 45%.

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%	$\leq F_{50\%}$

Kaikoura
In the most recent Kaikoura potting surveys the SPR estimates for an age of recruitment of 11 and the default *M* value of 0.14 were 52% for both the fixed and random site surveys (Table 31 and 32), indicating that the expected contribution to the spawning biomass over the lifetime of an average recruit has been reduced to 52% of the contribution in the absence of fishing. These results suggest that recent levels of exploitation (*F*) for the Kaikoura blue cod stock are safely below the F_{MSY} reference point.

Sensitivity analyses using *M* values of 0.11 and 0.17 (20% below and above the default of 0.14) resulted in substantial differences in the $F_{\%SPR}$ values (Tables 31 and 32, Figures 20 and 21). A higher natural mortality (0.17) increased the spawning biomass at current *F* relative to the unfished level by 13 percent, conversely a lower natural mortality (0.11) decreased the spawning biomass at current *F* relative to the unfished level by an equivalent amount.

Motunau
In the most recent Motunau potting surveys the SPR estimates for an age of recruitment of 11 and the default *M* value of 0.14 were 44%–45% for the fixed site survey (Table 33) and the random site survey (Table 34), indicating that the expected contribution to the spawning biomass over the lifetime of an average recruit has been reduced to 44%–45% of the contribution in the absence of fishing at both fixed and random sites. These results suggest that recent levels of exploitation (*F*) for the Motunau blue cod stock are at the F_{MSY} reference point and this stock is fully exploited.

Sensitivity analyses using *M* values of 0.11 and 0.17 resulted in substantial differences in the $F_{\%SPR}$ values (Tables 33 and 34, Figures 22 and 23). A higher natural mortality (0.17) increased the spawning biomass at current *F* relative to the unfished level by about 10 percentage points and conversely a lower

natural mortality (0.11) decreased the spawning biomass at current *F* relative to the unfished level by an equivalent amount.

4.8 Does potting provide a robust index of abundance and size structure?

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 at 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).

During the 2010 Marlborough Sounds potting survey concurrent observations of blue cod abundance from a flown dropped underwater video (DUV) was also used at 20 survey sites to investigate the relationship between observed density and sizes of blue cod and subsequent catch in type 1 pots (pot plan 1 in Beentjes & Francis 2011). Like diver transects, the DUV also had a much higher proportion of small blue cod than the type 1 pots, and a correlation between average density and catch was only 0.27 for all and -0.19 for blue cod 30 cm or more (Beentjes & Carbines 2012). During the 2010 Foveaux Strait potting survey concurrent observations of blue cod abundance from a DUV were also used at 17 sites with type 2 pots (pot plan 2 in Beentjes & Francis 2011). The DUV again had a higher proportion of small blue cod than the type 2 pots, and a correlation between average density and catch was only 0.50 for all and 0.54 for blue cod 20 cm or more (Carbines & Beentjes 2012). In the current Motunau study, the DUV again sampled a much greater proportion of small blue cod (Figure 25). The correlations between the blue cod density observed by the DUV and the subsequent catch rates in type 2 survey pots were very weak (Figure 27) and consistent with most DUV comparisons with type 2 pots (Carbines and Beentjes 2012, Carbines & Haist 2014, 2017a, 2017b).

Continuous video recordings of blue cod entries and exits from pots also show that less than 8% of approaches lead to entries, and that local topography can constrain pot entries in some situations (Cole et al. 2004). Environmental conditions that maximise catchability will strengthen the relationship between what is observed in situ and what is subsequently caught, and DUV/pot comparisons from areas with more homogenous habitat structure have tended to have better catchability than those with more heterogeneous benthic habitat structure (Carbines & Beentjes 2012, Carbines & Haist 2014, 2017a, 2017b). Like most other potting survey areas surveyed with the DUV (i.e., Carbines & Beentjes 2012, Carbines & Haist 2014, 2017a, 2017b), there were many fish independent observations devoid of secondary structure in Motunau, and the "preferred" secondary habitats of large and small blue cod accounted for only 20% and 15% of the benthic environment respectively (See Section 4.9, Figure 29).

Because pots have both size selectivity and variable catchability problems (Cole et al 2001, Beentjes & Carbines 2012, Carbines & Beentjes 2012, Carbines & Haist 2014, 2017a, 2017b) they are far from an ideal method for assessing blue cod populations, and the limitations of this method needs to be more explicitly stated as a limitation of future potting surveys. Due to the inconsistency of pots, catch rates and mortality estimates should also not be compared between survey areas.

4.9 The importance of recording benthic habitat

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 associated with at a higher rate, than observed randomly in the benthic environment. Blue cod were most often found on the primary structure of sand/shell grit/gravel, sand/shell grit, pea gravel and sand (Figure 28) with the secondary structures of boulders/cobbles/sponge/bryozoans and sponge/bryozoan (Figure 29). However, the ratio of fish-dependent and fish-independent habitat observations identifies the primary substrates broken bedrock/sand and cobbles/gravel, and the secondary habitat categories of broken bedrock/cobbles/sponge/bryozoans and bedrock/sponge to have disproportionate association with larger blue cod. Smaller blue cod were found to be most associated with the primary substrates cobbles and various forms of gravel, and the secondary habitat categories of macro-algae and various forms of cobbles/sponge/bryozoan.

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: Kaikoura 2011 survey stratum area, number of phase 1 and 2 sites, pot lifts, and depth of fisher selected fixed sites. *Note that previous fixed site surveys used only basic strata size to weight overall catch rates (Carbines & Beentjes 2006, 2009), and these have been retained for consistency of the fixed site survey time series.

	Size of strata *	Number of Fixed sites		Number of pot lifts	Depth (m)	
Stratum	Area (km^2)	Phase 1	Phase 2	Total	Mean	Range
1	9.6	5		30	37	27–51
2	96.0	5	3	48	18	4–35
3	24.8	5		30	62	42–91
4	15.7	5		30	115	103–152
Total	139.4	20	3	138	53	4–152

Table 2: Kaikoura 2011 survey stratum area, number of phase 1 and 2 sites, pot lifts, and depth of random sites. *Note that strata were more accurately mapped for the random site survey as they were used to generate random sites and weight overall catch rates.

	Size of strata *	Number of Random sites		Number of pot lifts	Depth (m)	
Stratum	Area (km^2)	Phase 1	Phase 2	Total	Mean	Range
1	26.7	5		30	32	21–44
2	97.2	6	3	54	22	9–48
3	24.2	6		36	76	15–108
4	15.8	6		36	114	93–130
Total	163.9	23	3	156	57	9–130

Table 3: Motunau 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 basic strata size to weight overall catch rates (Carbines & Beentjes 2006, 2009), and these have been retained for consistency of the fixed site survey time series.

	Size of strata *	Number of Fixed sites		Number of pot lifts	Depth (m)		DUV
Stratum	Area (km^2)	Phase 1	Phase 2	Total	Mean	Range	Sites
1	41.3	5		30	25	15–34	
2	66.9	5	2	42	23	18–29	2
3	176.1	5	1	36	19	12–27	2
Total	284.3	15	3	108	22	12–34	4

Table 4: Motunau 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. *Note that strata were more accurately mapped for the random site survey as they were used to generate random sites and weight overall catch rates.

	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	37.7	6		36	26	14–33	2
2	74.5	6	2	48	23	16–34	
3	179.4	6	1	42	18	17–25	
Total	291.5	18	3	126	22	7–34	2

Table 5: Kaikoura survey catch weights, numbers of blue cod, bycatch species, and percentage of total weight from the 2011 fisher selected fixed sites (n=23).

Common name	Scientific name	Catch (kg)	Number	Percent of total catch
Blue cod	*Parapercis colias*	749.1	1610	91.4
Octopus	*Octopus cordiformis*	23.3	7	2.8
Banded wrasse	*Notolabrus fucicola*	14.7	29	1.8
Sea perch	*Helicolenus percoides*	13.8	30	1.7
Scarlet wrasse	*Pseudolabrus miles*	6.9	20	0.8
Girdled wrasse	*Notolabrus cinctus*	6.7	29	0.8
Spotty	*Notolabrus celidotus*	1.7	15	0.2
Hagfish	*Eptatretus cirrhatus*	1.1	1	0.1
Dwarf scorpionfish	*Scorpaena papillosus*	1.0	5	0.1
Tarakihi	*Nemadactylus macropterus*	0.9	2	0.1
Southern bastard cod	*Pseudophysis barbata*	0.3	1	<0.1
Butterfly perch	*Caesioperca lepidoptera*			<0.1
Total		819.6	1750	100.0

Table 6: Kaikoura survey catch weights, numbers of blue cod, bycatch species, and percentage of total weight from the 2011 random sites (n=26).

Common name	Scientific name	Catch (kg)	Number	Percent of total catch
Blue cod	*Parapercis colias*	650.0	1372	90.7
Octopus	*Octopus cordiformis*	20.1	9	2.8
Sea perch	*Helicolenus percoides*	15.9	38	2.2
Scarlet wrasse	*Pseudolabrus miles*	13.3	30	1.9
Banded wrasse	*Notolabrus fucicola*	7.4	21	1.0
Girdled wrasse	*Notolabrus cinctus*	3.7	18	0.5
Hagfish	*Eptatretus cirrhatus*	3.4	3	0.5
Tarakihi	*Nemadactylus macropterus*	1.6	2	0.2
Red cod	*Pseudophycis bachus*	1.2	2	0.2
Spotty	*Notolabrus celidotus*	0.2	1	<0.1
Blue moki	*Latridopsis ciliars*	0.2	1	<0.1
Total		717	1497	100.0

Table 7: Motunau survey catch weights, numbers of blue cod, bycatch species, and percentage of total weight from the 2012 fisher selected fixed sites (n=18).

Common name	Scientific name	Catch (kg)	Number	Percent of total catch
Blue cod	*Parapercis colias*	670.7	1871	94.4
Leatherjackets	*Parika scaber*	16.5	53	2.3
Octopus	*Octopus cordiformis*	6.5	2	0.9
Scarlet wrasse	*Pseudolabrus miles*	5.9	18	0.8
Girdled wrasse	*Notolabrus cinctus*	4.7	15	0.7
Spotty	*Notolabrus celidotus*	1.9	17	0.3
Banded wrasse	*Notolabrus fucicola*	1.4	3	0.2
Blue moki	*Latridopsis ciliars*	1	1	0.1
Conger eel	*Conger verreauxi*	0.9	1	0.1
Sea perch	*Helicolenus percoides*	0.6	2	0.1
Red cod	*Pseudophycis bachus*	0.4	1	0.1
Dwarf scorpionfish	*Scorpaena papillosus*	0.2	1	0.0
Tarakihi	*Nemadactylus macropterus*	0.1	1	0.0
Total		710.8	1986	100.0

Table 8: Motunau survey catch weights, numbers of blue cod, bycatch species, and percentage of total weight from the 2012 random sites (n=21).

Common name	Scientific name	Catch (kg)	Number	Percent of total catch
Blue cod	*Parapercis colias*	507.1	1537	80.5
Leatherjackets	*Parika scaber*	52.1	176	8.3
Octopus	*Octopus cordiformis*	23.8	8	3.8
Scarlet wrasse	*Pseudolabrus miles*	15	49	2.4
Girdled wrasse	*Notolabrus cinctus*	11.2	37	1.8
Spotty	*Notolabrus celidotus*	8.1	71	1.3
Banded wrasse	*Notolabrus fucicola*	4.9	12	0.8
Sea perch	*Helicolenus percoides*	2.4	6	0.4
Blue moki	*Latridopsis ciliars*	2	2	0.3
Conger eel	*Conger verreauxi*	1.8	2	0.3
Red cod	*Pseudophycis bachus*	0.8	2	0.1
Scorpion fish	*Scorpaena papillosus*	0.5	3	0.1
Tarakihi	*Nemadactylus macropterus*	0.4	5	0.1
Total		630.1	1910	100.0

Table 9: Mean catch rates for all blue cod caught in the 2011 Kaikoura 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	6.58	2.65	40.21
2	8	48	2.14	0.60	28.10
3	5	30	3.52	0.64	18.22
4	5	30	11.44	1.82	15.92
Overall	23	138	3.96	0.59	14.99

Table 10: Mean catch rates for blue cod 30 cm and over (MLS in BCO 3) caught in the 2011 Kaikoura 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	3.83	1.49	39.02
2	8	48	1.51	0.34	22.73
3	5	30	2.05	0.67	32.75
4	5	30	10.00	1.72	17.18
Overall	23	138	2.79	0.37	13.33

Table 11: Mean catch rates for all blue cod caught in the 2011 Kaikoura 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.

Stratum	Sites	Pot lifts (N)	Mean (kg/pot)	s.e.	CV (%)
1	5	30	3.71	1.26	33.96
2	9	54	0.61	0.37	60.66
3	6	36	5.83	1.98	33.97
4	6	36	8.22	1.30	15.78
Overall	26	156	2.62	0.44	16.71

Table 12: Mean catch rates for blue cod 30 cm and over (MLS) caught in the 2011 Kaikoura 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.

Stratum	Sites	Pot lifts (N)	Mean (kg/pot)	s.e.	CV (%)
1	5	30	1.69	0.64	37.63
2	9	54	0.25	0.19	75.48
3	6	36	4.07	1.39	34.23
4	6	36	7.15	1.19	16.65
Overall	26	156	1.72	0.28	16.39

Table 13: Mean catch rates for all blue cod caught in the 2012 Motunau 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	8.70	1.27	14.64
2	5	30	6.58	1.23	18.72
3	8	48	4.43	0.90	20.47
Overall	18	108	5.53	0.66	11.95

Table 14: Mean catch rates for blue cod 30 cm and over (MLS in BCO 3) caught in the 2012 Motunau 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	4.38	1.00	22.80
2	5	30	3.36	0.96	28.64
3	8	48	2.57	0.67	26.26
Overall	18	108	3.01	0.50	16.62

Table 15: Mean catch rates for all blue cod caught in the 2012 Motunau 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.

Stratum	Sites	Pot lifts (N)	Mean (kg/pot)	s.e.	CV (%)
1	6	36	6.95	1.70	24.497
2	8	48	3.77	1.62	42.88
3	7	42	1.81	0.61	33.57
Overall	21	126	2.97	0.60	20.13

Table 16: Mean catch rates for blue cod 30 cm and over (MLS) caught in the 2012 Motunau 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.

Stratum	Sites	Pot lifts (N)	Mean (kg/pot)	s.e.	CV (%)
1	6	36	3.77	1.47	39.02
2	8	48	1.82	0.88	47.99
3	7	42	0.99	0.32	32.19
Overall	21	126	1.56	0.35	22.60

Table 17: Mean lengths of blue cod in the 2011 Kaikoura 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).

			Length (cm)			Sex ratio M:F (% male)	
Strata	Sex	N	Mean	Minimum	Maximum	All blue cod	≥ 30 cm
1	M	343	29.6	21	51	1:0.4 (70.7)	1:0.2 (85.5)
	F	143	26.6	17	36		
2	M	195	27.9	16	42	1:0.6 (62.9)	1:<0.1 (95.8)
	F	115	23.7	14	31		
3	M	147	29.0	16	45	1:0.8 (55.3)	1:0.4 (70.0)
	F	119	26.8	19	38		
4	M	110	37.2	23	53	1:4.0 (20.0)	1:3.4 (22.8)
	F	439	31.7	23	43		
Overall (un-weighted)	M	795	30.1	16	53	1:1.0 (49.4)	1:1.0 (49.6)
	F	816	29.0	14	43		

Table 18: Mean lengths of blue cod in the 2011 Kaikoura random 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).

			Length (cm)			Sex ratio M:F (% male)	
Strata	Sex	N	Mean	Minimum	Maximum	All blue cod	≥ 30 cm
1	M	188	28.6	21	44	1:0.6 (62.0)	1:0.2 (82.6)
	F	115	25.9	20	46		
2	M	60	27.4	17	38	1:0.9 (54.1)	1:0.1 (94.7)
	F	51	23.5	15	32		
3	M	222	30.2	16	51	1:1.0 (49.2)	1:1.0 (49.2)
	F	229	29.6	18	40		
4	M	89	35.9	23	52	1:4.7 (17.6)	1:4.3 (19.0)
	F	418	31.4	22	44		
Overall (un-weighted)	M	559	30.3	16	52	1:1.5 (40.7)	1:1.7 (37.3)
	F	813	29.6	15	46		

Table 19: Mean lengths of blue cod in the 2012 Motunau 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).

			Length (cm)			Sex ratio M:F (% male)	
Strata	Sex	N	Mean	Minimum	Maximum	All blue cod	≥ 30 cm
1	M	587	28.2	16	41	1:0.3 (77.5)	1:0.1 (91.2)
	F	170	25.1	17	32		
2	M	409	28.6	15	45	1:0.3 (78.1)	1:<0.1 (95.5)
	F	115	23.7	14	31		
3	M	370	30.0	19	42	1:0.4 (75.5)	1: <0.1 (96.4)
	F	155	25.3	17	34		
Overall (un-weighted)	M	1366	28.8	15	45	1:0.4 (73.0)	1:0.1 (94.1)
	F	505	24.5	14	34		

Table 20: Mean lengths of blue cod in the 2012 Motunau random 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).

			Length (cm)			Sex ratio M:F (% male)	
Strata	Sex	N	Mean	Minimum	Maximum	All blue cod	≥ 30 cm
1	M	518	28.4	17	40	1:0.8 (54.5)	1:<0.1 (95.5)
	F	248	23.7	14	31		
2	M	375	28.3	16	43	1:0.8 (55.4)	1: <0.1 (94.7)
	F	182	22.8	15	32		
3	M	172	27.8	18	47	1:0.9 (53.4)	1:<0.1 (98.4)
	F	42	24.3	16	34		
Overall (un-weighted)	M	1065	28.3	16	45	1:0.8 (54.7)	1: <0.1 (96.1)
	F	472	23.4	14	34		

Table 21: Gonad stages of Kaikoura blue cod in 2011 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	1.8	74.0	23.0	1.3	0.0	795
Females	1.8	48.7	47.6	1.8	0.0	815

Table 22: Gonad stages of Kaikoura blue cod in 2011 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.

	Gonad stage (%)					
	1	2	3	4	5	N
Males	0.7	75.7	22.0	1.6	0.0	559
Females	0.4	49.4	49.0	1.2	0.0	813

Table 23: Gonad stages of Motunau 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	0.7	99.0	0.1	0.2	0.0	1366
Females	3.2	95.6	0.8	0.0	0.4	505

Table 24: Gonad stages of Motunau 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.

	Gonad stage (%)					
	1	2	3	4	5	N
Males	2.0	97.3	0.2	0.3	0.3	1065
Females	5.7	94.3	0.0	0.0	0.0	472

Table 25: Otolith raw data used in the catch at age, *Z* estimates, and SPR analyses for both the fixed and random 2011 Kaikoura sites.

	No.	Length of aged fish (cm)			Age (years)		
Survey	otoliths	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Total	249	31.7	14	53	11.4	2	31
Male	139	34.3	16	53	12.0	3	31
Female	110	28.4	14	46	10.6	2	27

Table 26: Otolith raw data used in the catch at age, *Z* estimates, and SPR analyses for both the fixed and random 2012 Motunau sites.

	No.	Length of aged fish (cm)			Age (years)		
Survey	otoliths	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Total	196	27.0	15	45	7.8	2	17
Male	111	30.0	15	45	9.1	3	17
Female	85	23.2	15	34	6.1	2	14

Table 27: 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 12 for the 2011 Kaikoura fixed site survey.

		Confidence intervals		
AgeR	*Z*	Lower	Upper	%SPR
5	0.23	0.17	0.33	59%
6	0.24	0.17	0.34	57%
7	0.27	0.20	0.37	51%
8	0.27	0.19	0.38	52%
9	0.24	0.18	0.33	57%
10	0.25	0.18	0.35	54%
11	0.27	0.19	0.39	52%
12	0.30	0.21	0.43	48%

Table 28: 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 12 for the 2011 Kaikoura random site survey.

		Confidence intervals		
AgeR	*Z*	Lower	Upper	%SPR
5	0.21	0.15	0.29	66%
6	0.22	0.16	0.30	63%
7	0.24	0.18	0.33	57%
8	0.25	0.18	0.33	56%
9	0.23	0.17	0.32	59%
10	0.25	0.18	0.35	55%
11	0.26	0.19	0.37	52%
12	0.30	0.22	0.42	47%

Table 29: 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 12 for the 2012 Motunau fixed site survey.

		Confidence intervals		
AgeR	*Z*	Lower	Upper	%SPR
5	0.29	0.21	0.41	54%
6	0.34	0.23	0.48	49%
7	0.33	0.23	0.48	50%
8	0.36	0.27	0.54	46%
9	0.37	0.26	0.54	46%
10	0.45	0.31	0.64	42%
11	0.39	0.28	0.55	45%
12	0.48	0.34	0.68	41%

Table 30: 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 12 for the 2012 Motunau random site survey.

		Confidence intervals		
AgeR	*Z*	Lower	Upper	%SPR
5	0.31	0.22	0.44	52%
6	0.33	0.23	0.49	49%
7	0.32	0.22	0.46	51%
8	0.35	0.24	0.52	48%
9	0.36	0.25	0.53	47%
10	0.43	0.30	0.62	43%
11	0.42	0.28	060.	44%
12	0.50	0.34	0.74	40%

Table 31: Mortality rates and spawning biomass per recruit ratios, assuming an age of recruitment of 11, at three values of M (natural mortality) for the 2011 Kaikoura fisher-selected fixed sites survey. Z=total mortality.

M	Z	%SPR
0.11	0.27	39%
0.14	0.27	52%
0.17	0.27	65%

Table 32: Mortality rates and spawning biomass per recruit ratios, assuming an age of recruitment of 11, at three values of M (natural mortality) for the 2011 Kaikoura random sites survey. Z=total mortality.

M	Z	%SPR
0.11	0.26	39%
0.14	0.26	52%
0.17	0.26	65%

Table 33: Mortality rates and spawning biomass per recruit ratios, assuming an age of recruitment of 11, at three values of M (natural mortality) for the 2012 Motunau fisher-selected fixed sites survey. Z=total mortality.

M	Z	%SPR
0.11	0.39	35%
0.14	0.39	45%
0.17	0.39	55%

Table 34: Mortality rates and spawning biomass per recruit ratios, assuming an age of recruitment of 11, at three values of M (natural mortality) for the 2012 Motunau random site survey. Z=total mortality.

M	Z	%SPR
0.11	0.42	33%
0.14	0.42	44%
0.17	0.42	53%

Table 35: Drop underwater video (DUV) and pot sample details. Note that stations are individual transects and pots. The number of stations in brackets were additional ones done at night. *=includes equivalent number of fish-dependent habitat quadrats.

	DUV	Pots
Sites	6	6
Stations	41 (6)	36
Stations per site	4–10	6
Habitat sections	215	-
Habitat quadrats	999	-
Total transects length	41.8 km	-
Mean transect length	889 m (± 35.4)	-
Mean transect width	2.3 m (± 0.1)	-
Total area swept	81 729 m^2	
Blue cod	2622 *	782
Mean size	24.1 cm (± 0.1)	27.1 cm (±0.2)
Length range	7–50 cm	15–45 cm

Table 36: Pot catch, numbers of blue cod, bycatch species, and percentage of total numbers from the 4 fixed (including one night and day) and 2 random potted video sites in the Motunau 2012 potting survey.

Common name	Scientific name	Fixed Sites	Random Sites	Total Number	Percent of Total catch
Blue cod	*Parapercis colias*	494	288	782	96.2
Spotty	*Notolabrus celidotus*	2		2	0.2
Sea perch	*Helicolenus* spp	1		1	0.1
Leatherjacket	*Parika scaber*	23		23	2.8
Scarlet wrasse	*Pseudolabrus miles*	2	1	3	0.4
Girdled wrasse	*Notolabrus cinctus*		2	2	0.2
Total		522	291	813	100.0

Table 37: Drop underwater video observed numbers of blue cod, bycatch species, and percentage of total numbers from the 4 fixed (including one night and day) and 2 random potted video sites in the Motunau 2012 potting survey. *=total does not include unidentified species.

Common name	Scientific name	Fixed Sites	Random Sites	Total Number	Percent of total catch
Blue cod	*Parapercis colias*	1519	1103	2622	68.7
Leatherjacket	*Parika scaber*	313	24	337	8.8
Scarlet wrasse	*Pseudolabrus miles*	134	130	264	6.9
Tarakihi	*Nemadactylus macropterus*	132	39	171	4.5
Spotty	*Notolabrus celidotus*	156	2	158	4.1
Butterfly perch	*Caesioperca lepidoptera*		84	84	2.2
Sea perch	*Helicolenus* spp.	10	70	80	2.1
Blue moki	*Latridopsis ciliaris*	15	28	43	1.1
Rock lobster	*Jasus edwardsii*	10	13	23	0.6
Banded wrasse	*Notolabrus fucicola*	8	3	11	0.3
Gurnard	*Chelidonichthyskumu*	10		10	0.3
Red cod	*Pseudophycis bachus*	1	2	3	0.1
Skate	*Raja* spp.	2	1	3	0.1
Octopus	*Octopus cordiformis*	2		2	0.1
Rig	*Mustelus lenticulatus*	2		2	0.1
Southern pigfish	*Congiopodus leucopaecilus*	2		2	0.1
Carpet shark	*Cephaloscyllium isabellum*	1		1	<0.1
Conger eel	*Conger* spp.	1		1	<0.1
Flat fish	*Rhombosolea* spp.	1		1	<0.1
Red scorpion fish	*Scorpaena* spp.	1		1	<0.1
Unidentified		*3*	*4*	*7*	
Total*		2320	1499	3819	100.0

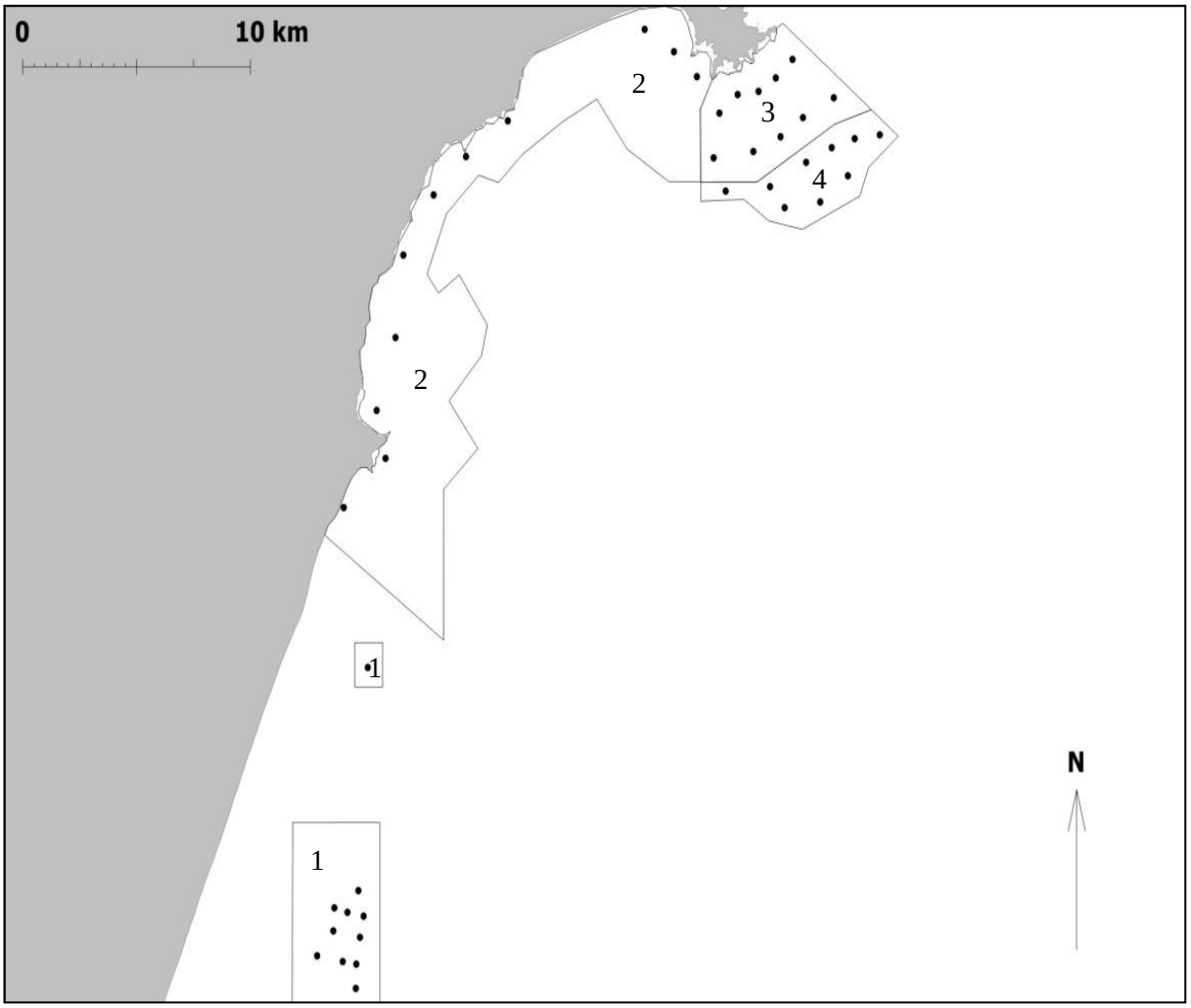


Figure 1: Kaikoura potting survey area consisting of four strata. The location of all 41 possible fixed sites (●) determined in 2004 (Carbines & Beentjes 2006) are shown.

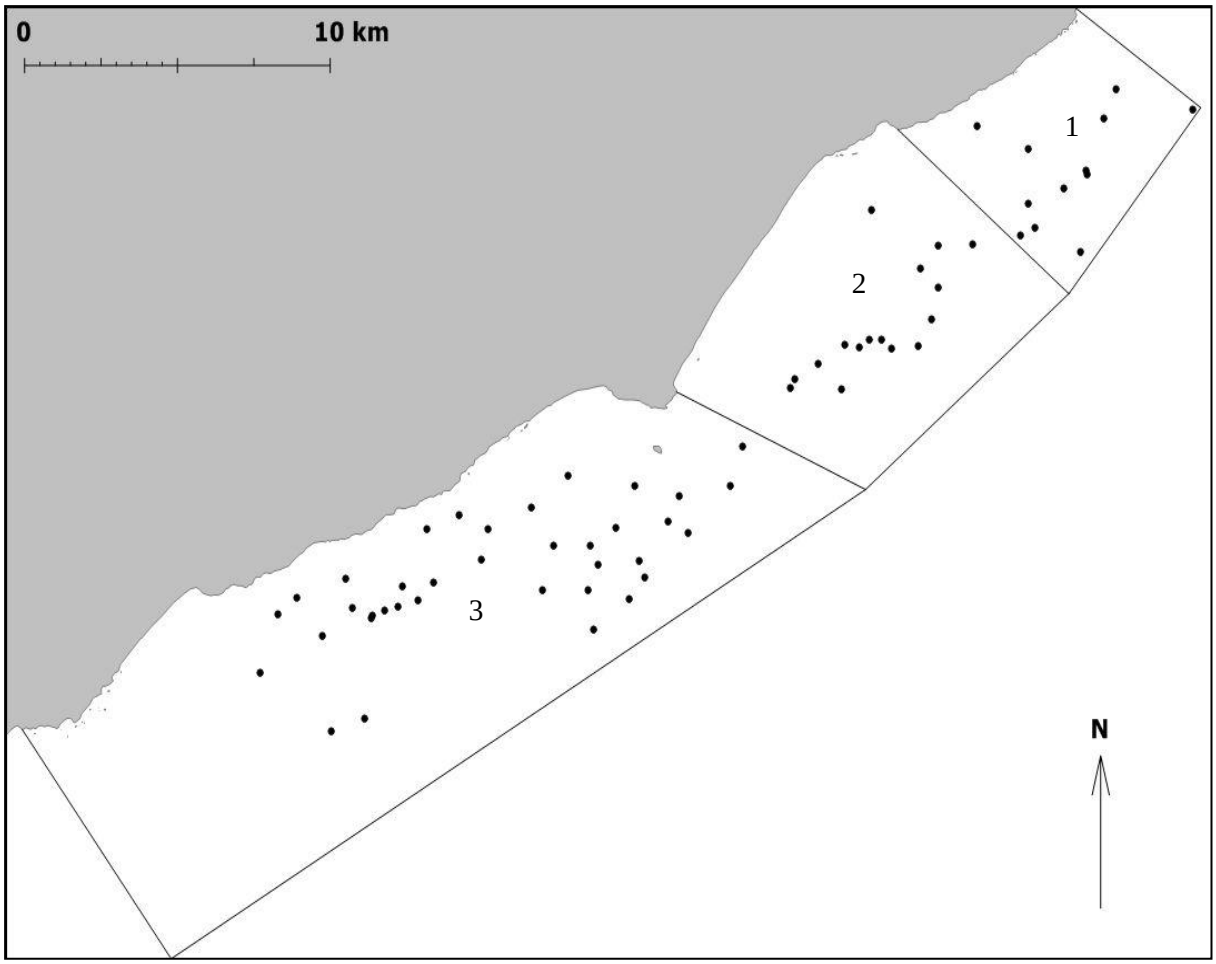


Figure 2: Motunau potting survey area consisting of three strata. The location of all 65 possible fixed sites (●) determined in 2004 (Carbines & Beentjes 2006) are shown.

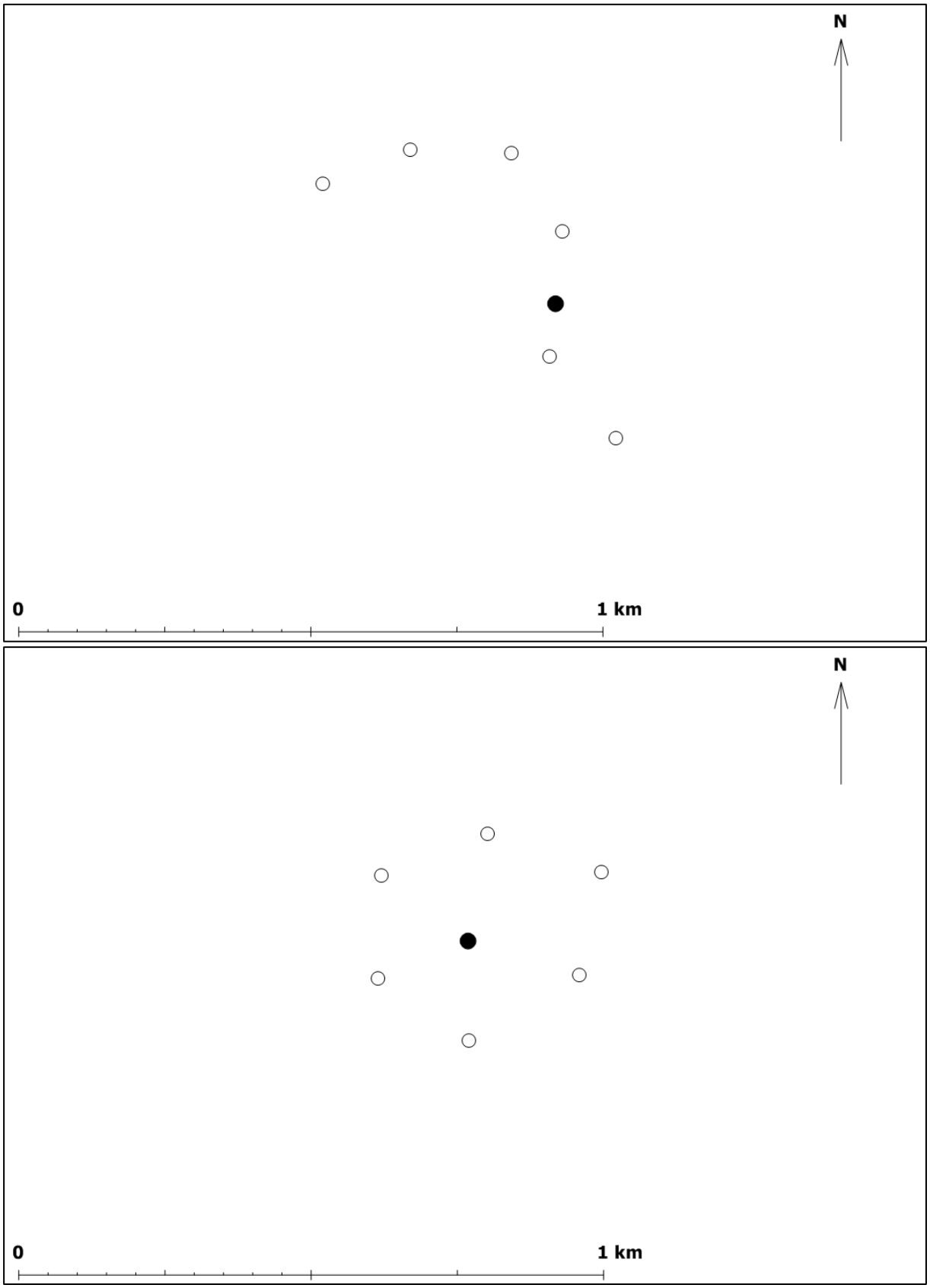


Figure 3: Placement of six pots (○) and ADCP (●) at typical fixed site (above) and random site (below).

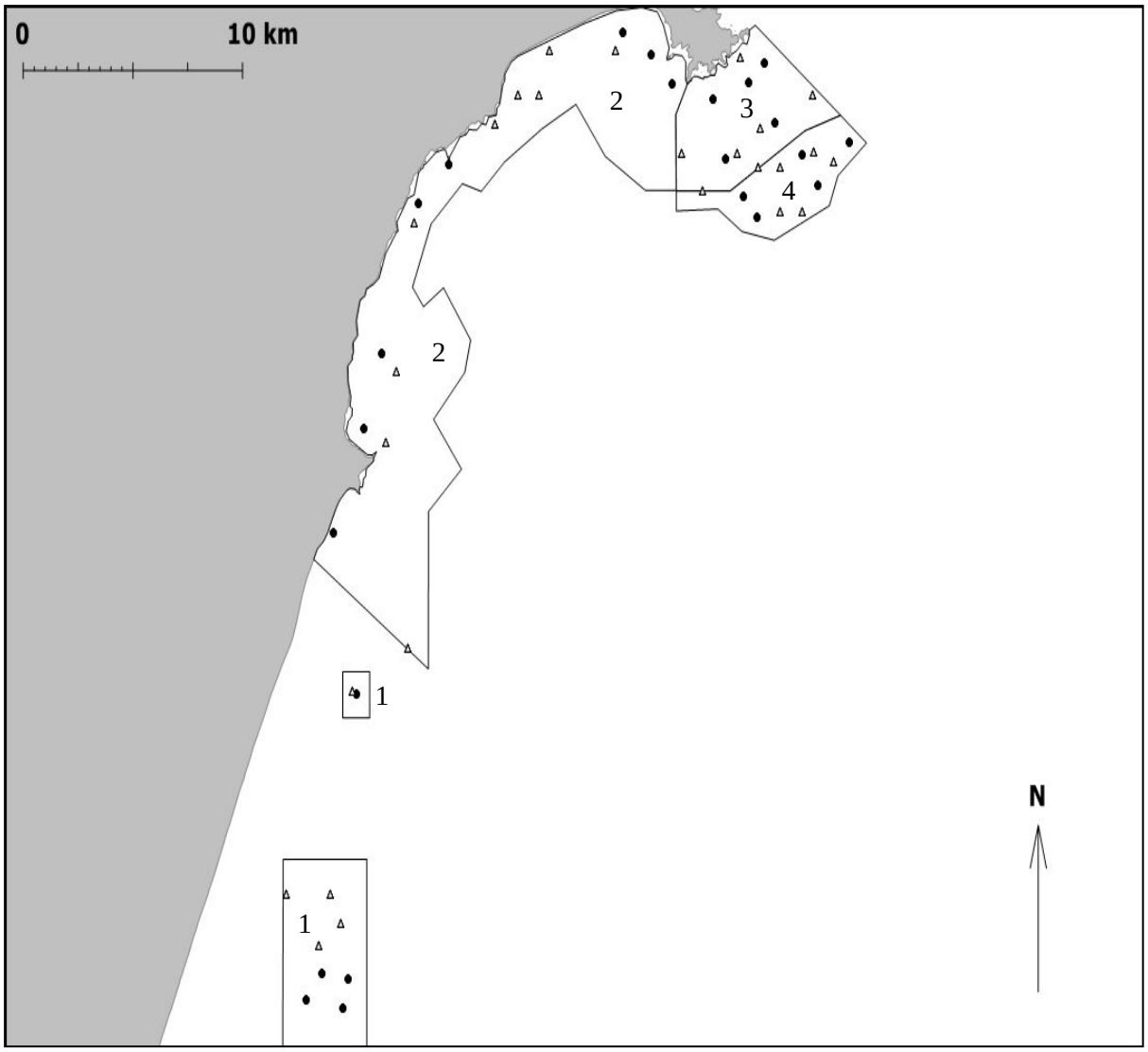


Figure 4: Fixed (○) and random (▲) site locations surveyed in the 2011 Kaikoura surveys.

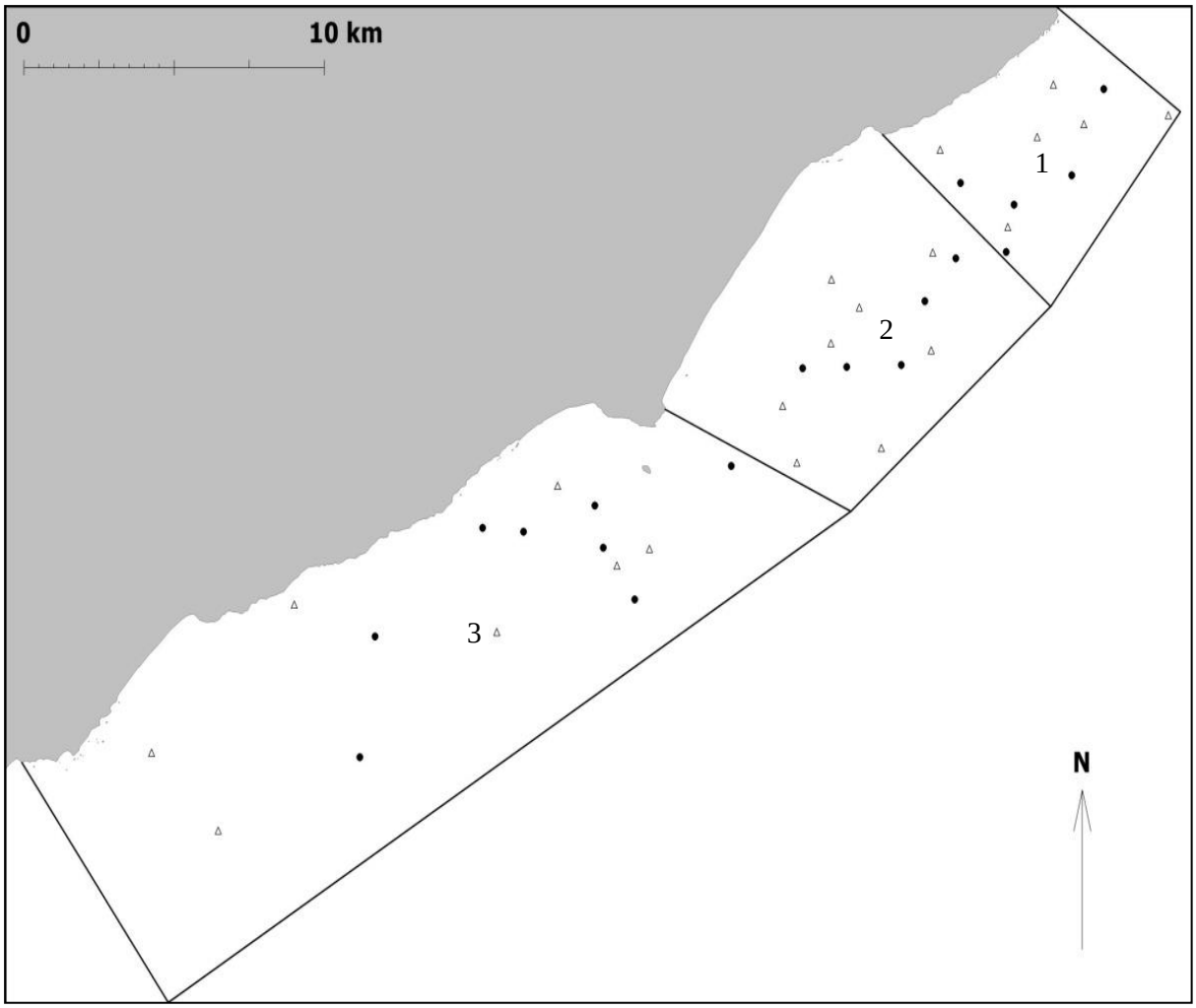


Figure 5: Fixed (●) and random (∆) site locations surveyed in the 2012 Motunau surveys.

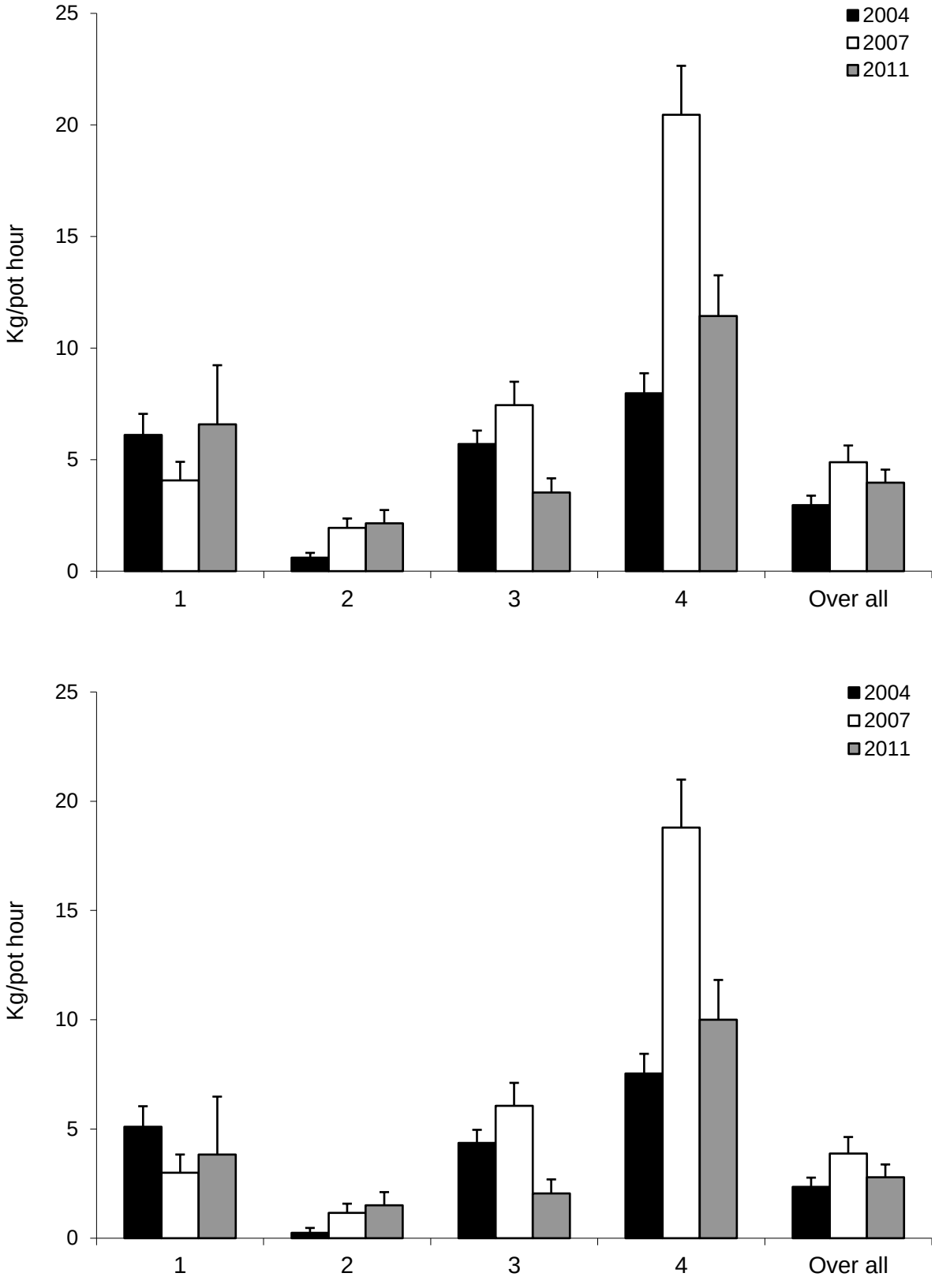


Figure 6: Strata catch rates (kg.pot^{-1}) and 95% confidence intervals for all blue cod (above) and those 30 cm and over (below) from the 2004, 2007, and 2011 Kaikoura selected fixed site surveys.

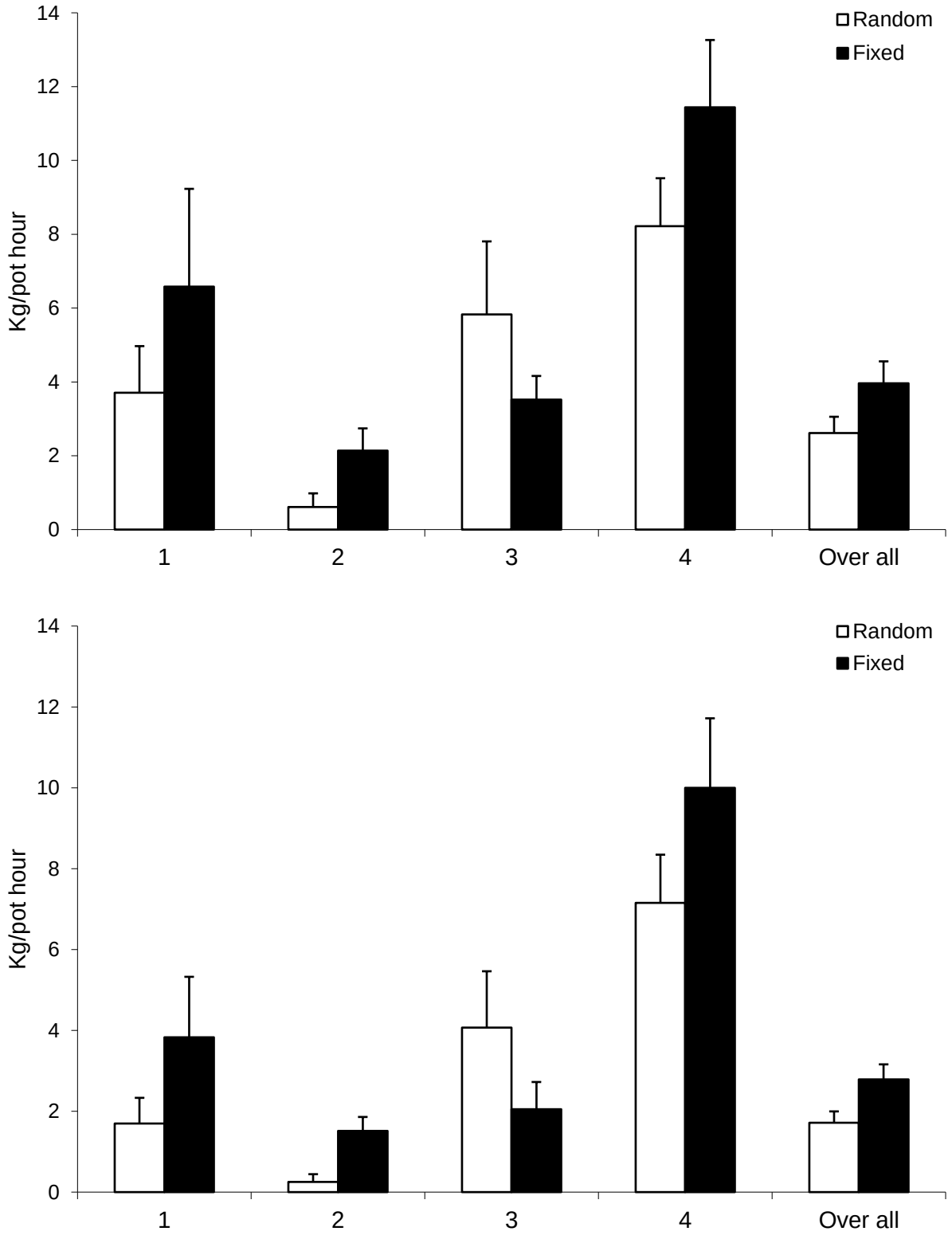


Figure 7: Strata catch rates (kg.pot^{-1}) and 95% confidence intervals for all blue cod (above) and those 30 cm and over (below) from the 2011 Kaikoura fixed and random site surveys.

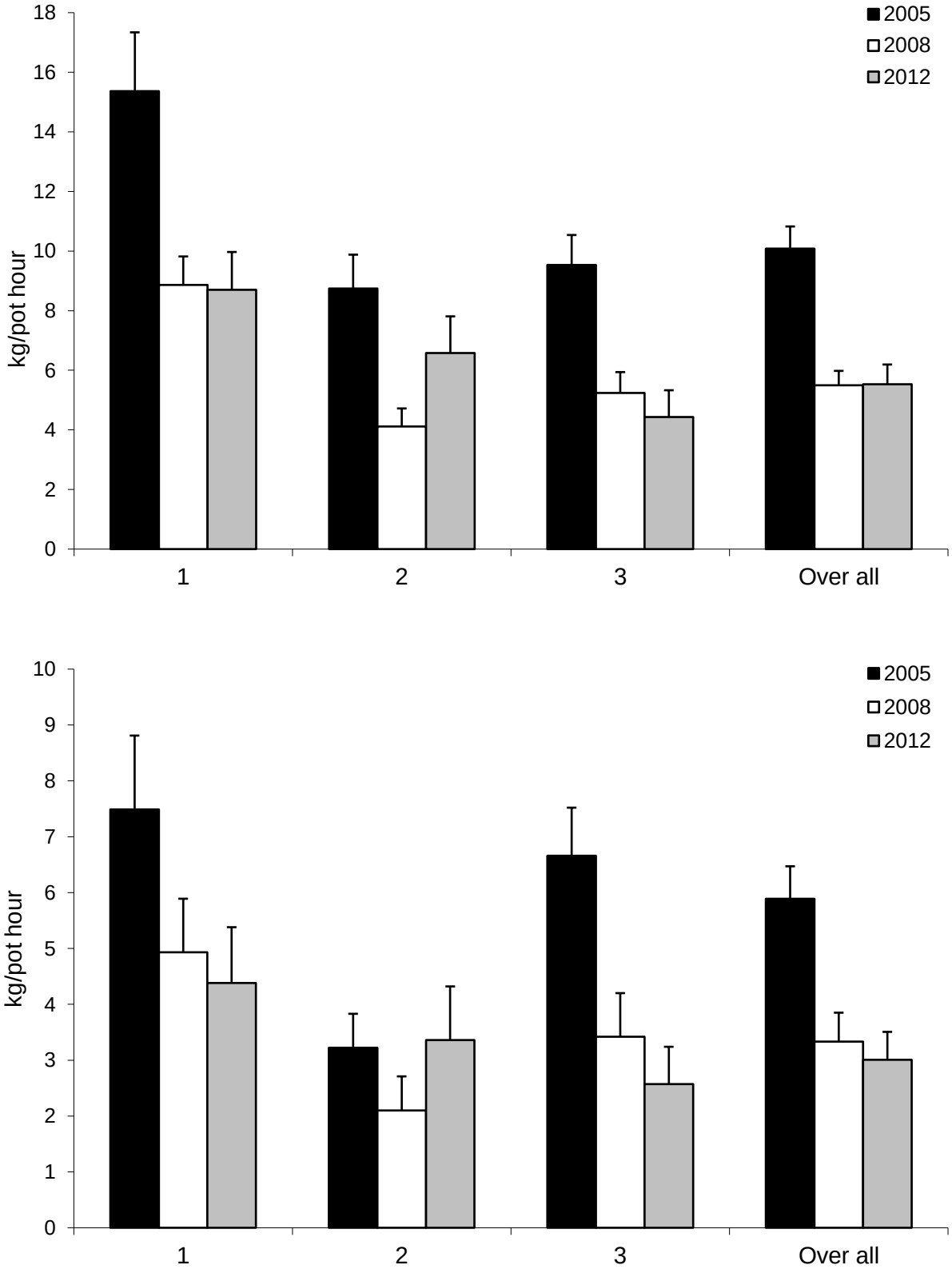


Figure 8: Strata catch rates (kg.pot^{-1}) and 95% confidence intervals for all blue cod (above) and those 30 cm and over (below) from the 2005, 2008, and 2012 Motunau selected fixed site surveys.

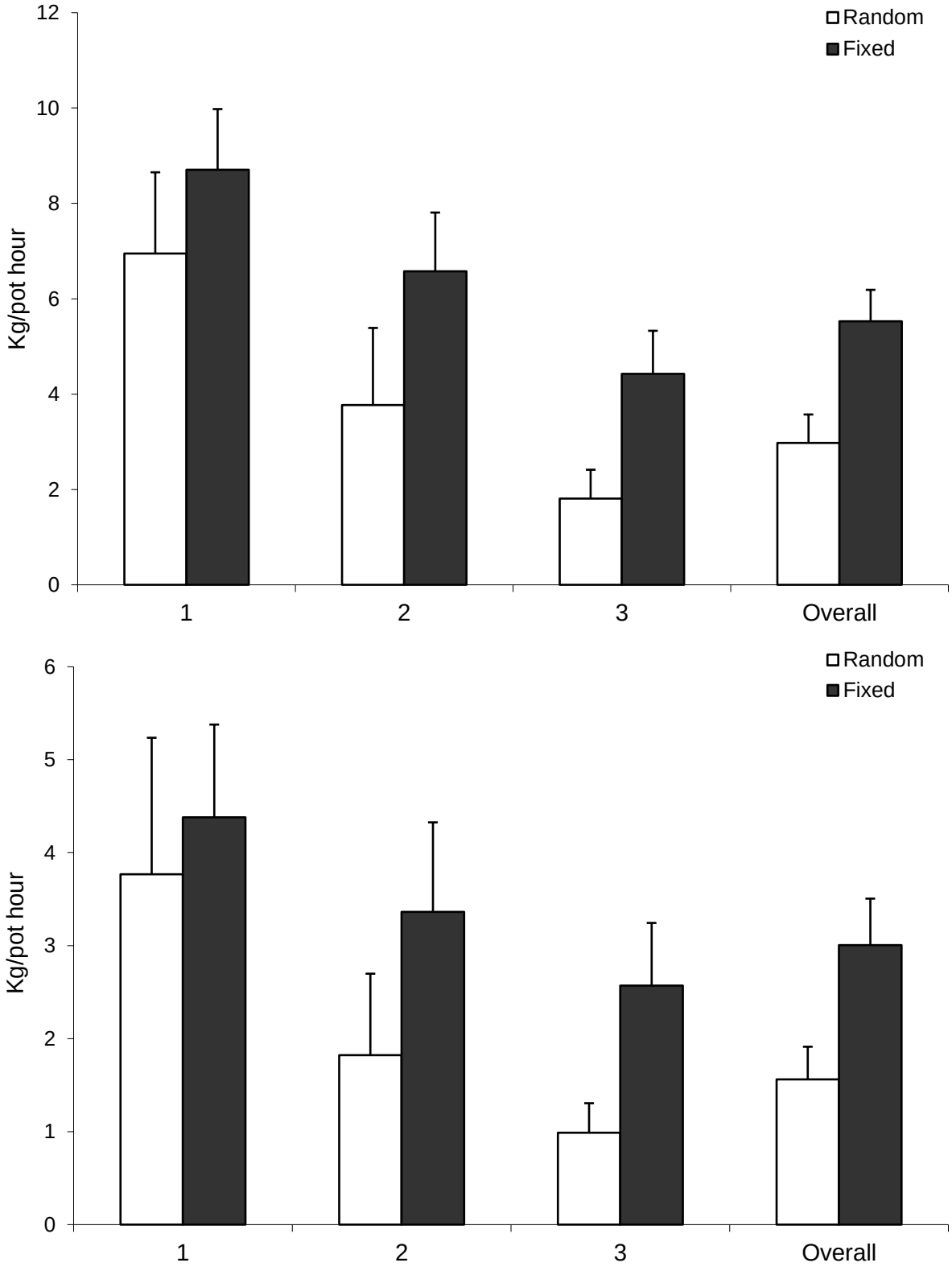


Figure 9: Strata catch rates (kg.pot^{-1}) and 95% confidence intervals for all blue cod (above) and those 30 cm and over (below) from the 2012 Motunau fixed and random site surveys.

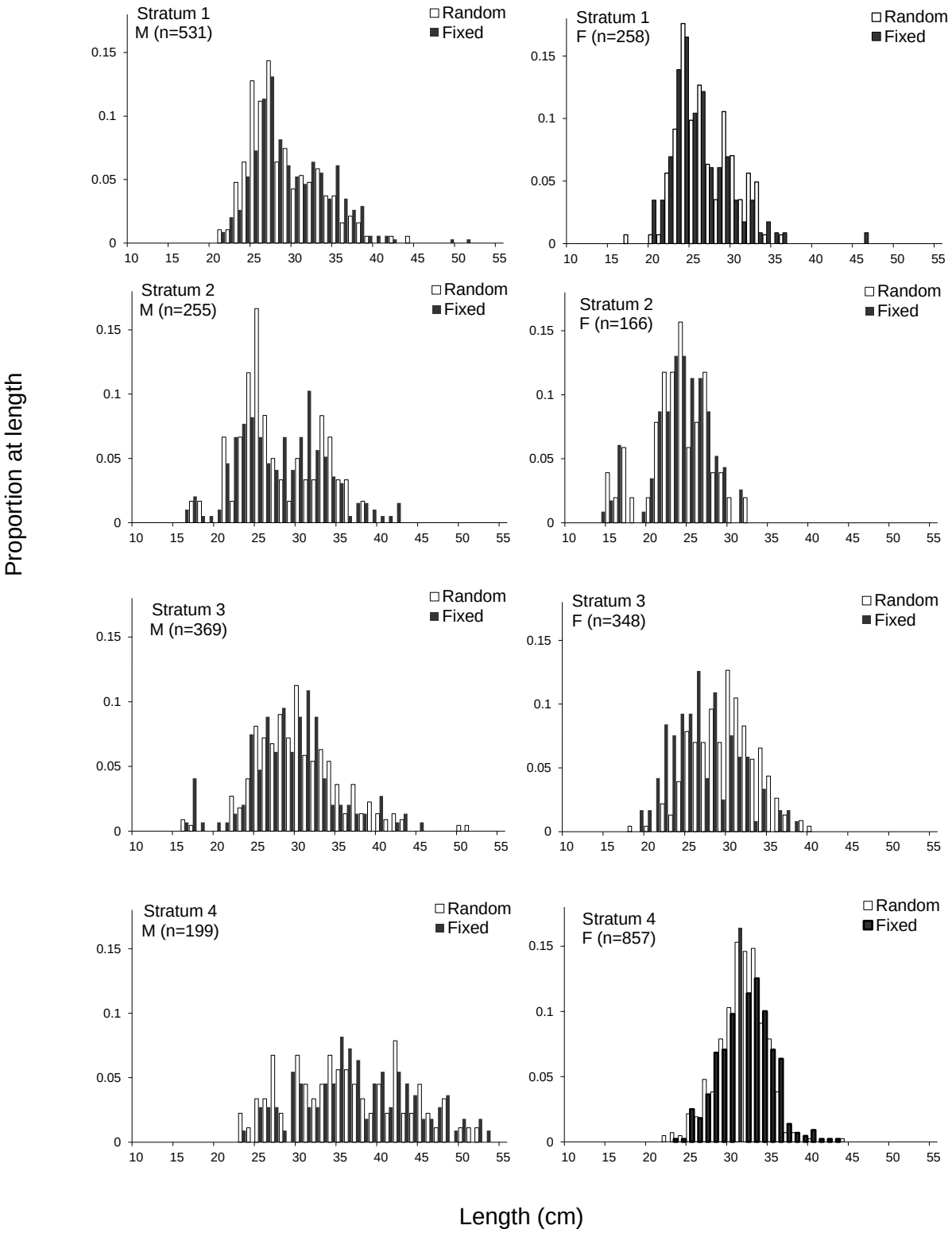


Figure 10: Unscaled proportion length frequency distributions by sex within stratum for fixed and random sites of the Kaikoura 2011 surveys. For each of the fixed and random surveys the proportions for each sex within each stratum sum to 1.

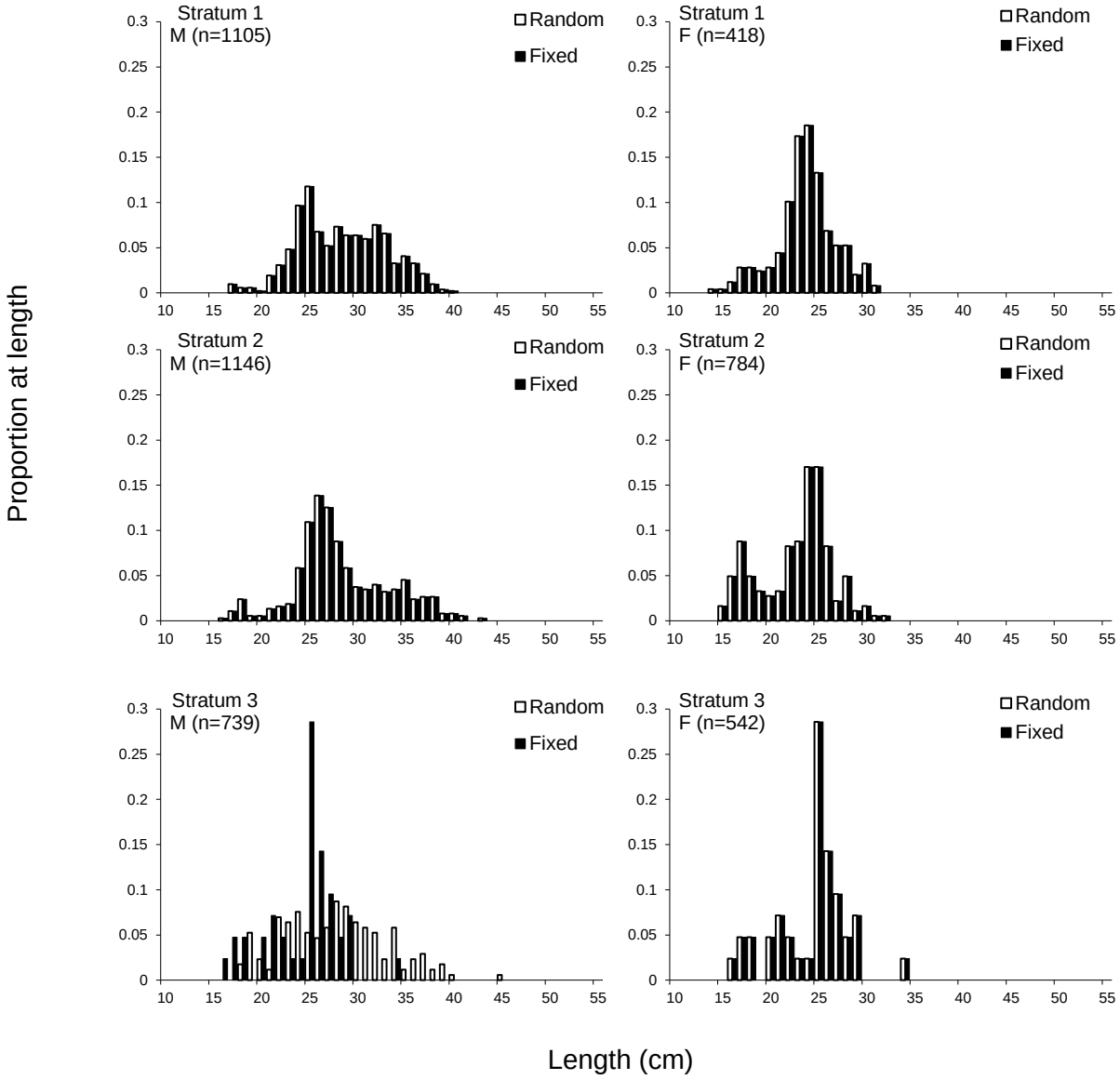


Figure 11: Unscaled proportion length frequency distributions by sex within stratum for fixed and random sites of the Motunau 2012 surveys. For each of the fixed and random surveys the proportions for each sex within each stratum sum to 1.

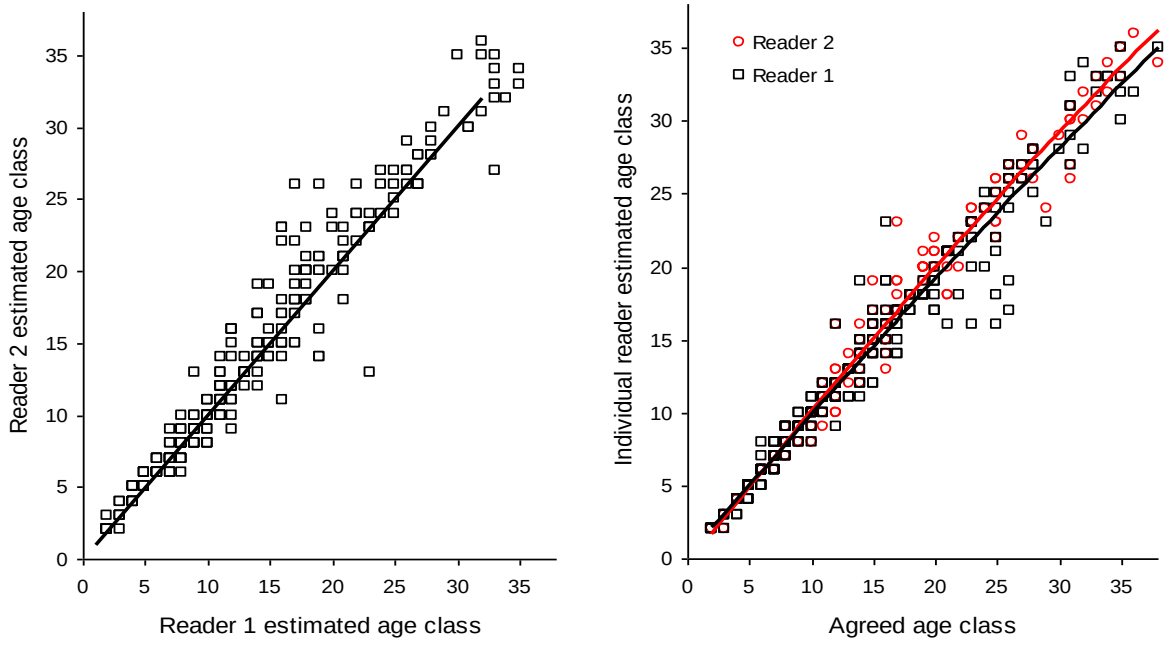


Figure 12: Kaikoura 2011 survey comparison of individual reader age class estimates from otoliths (n=249), on the left plotted against each other with a 1:1 line plotted. In the right panel the agreed age class estimates is plotted against the readers' age class estimates with a polynomial trend line fitted for each reader.

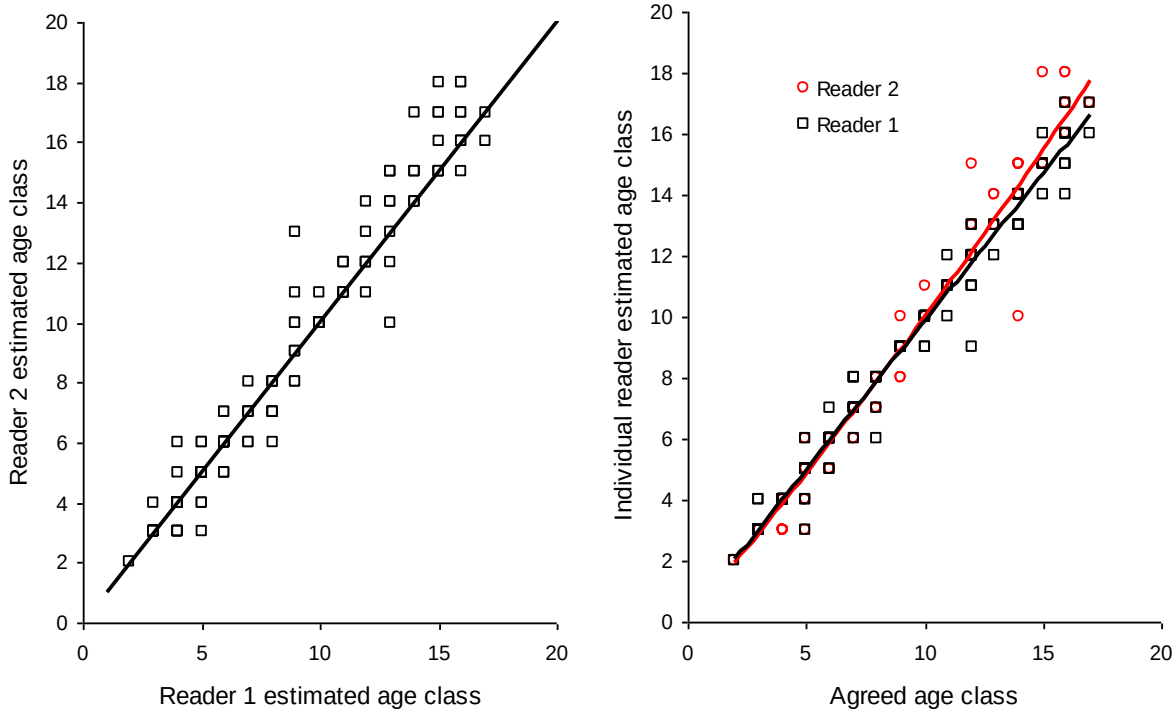


Figure 13: Motunau 2012 survey comparison of individual reader age class estimates from otoliths (n=196), on the left plotted against each other with a 1:1 line plotted fitted. In the right panel the agreed age class estimates is plotted against the readers' age class estimates with a polynomial trend line fitted for each reader.

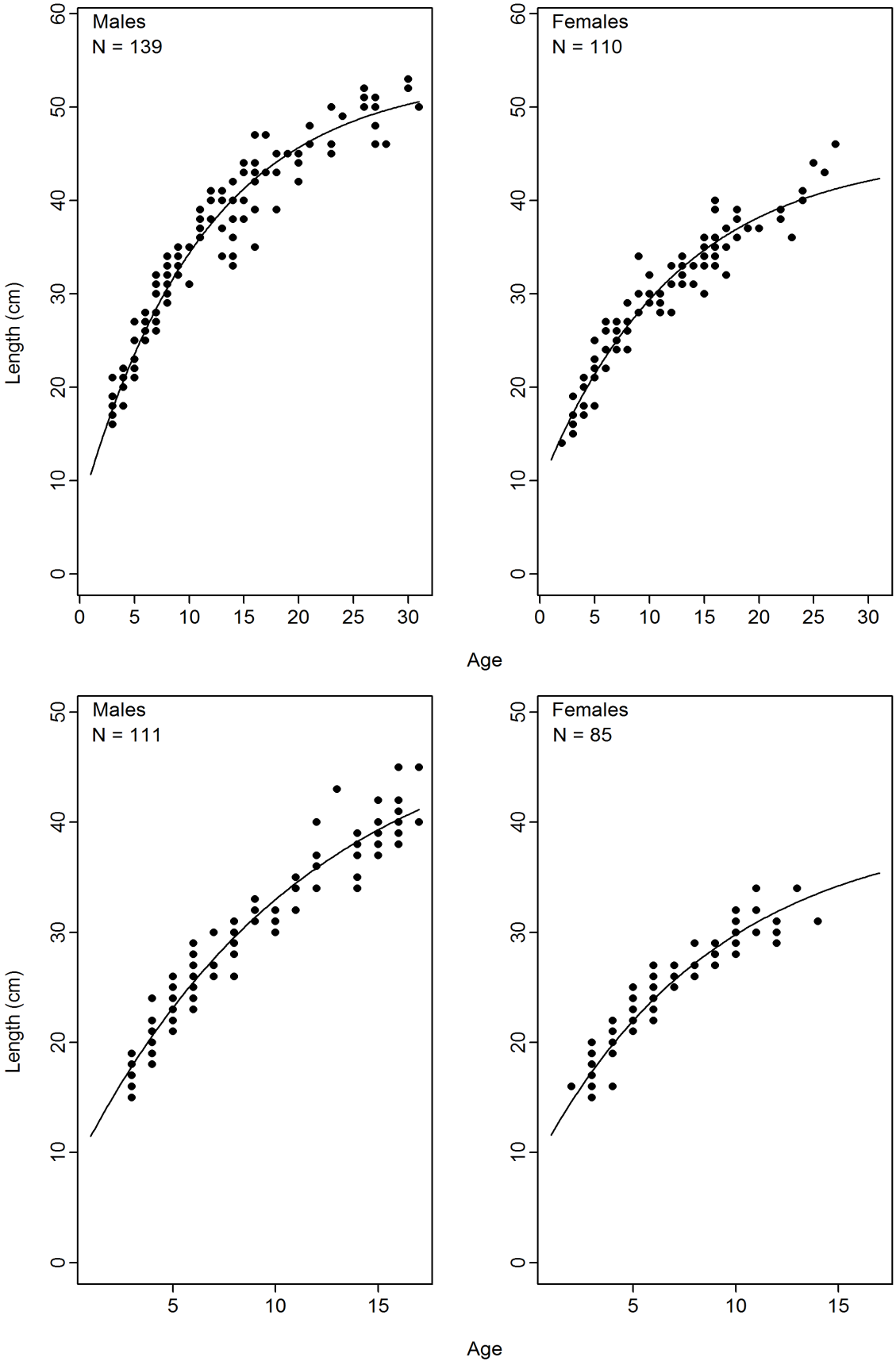


Figure 14: Observed age and length data by sex for the 2011 Kaikoura survey (upper panel) and 2012 Motunau survey (lower panel) comparison of male (left) and female (right) von Bertalanffy growth models fitted to the data. See Tables 25 and 26 for description of Kaikoura and Motunau biological samples respectively.

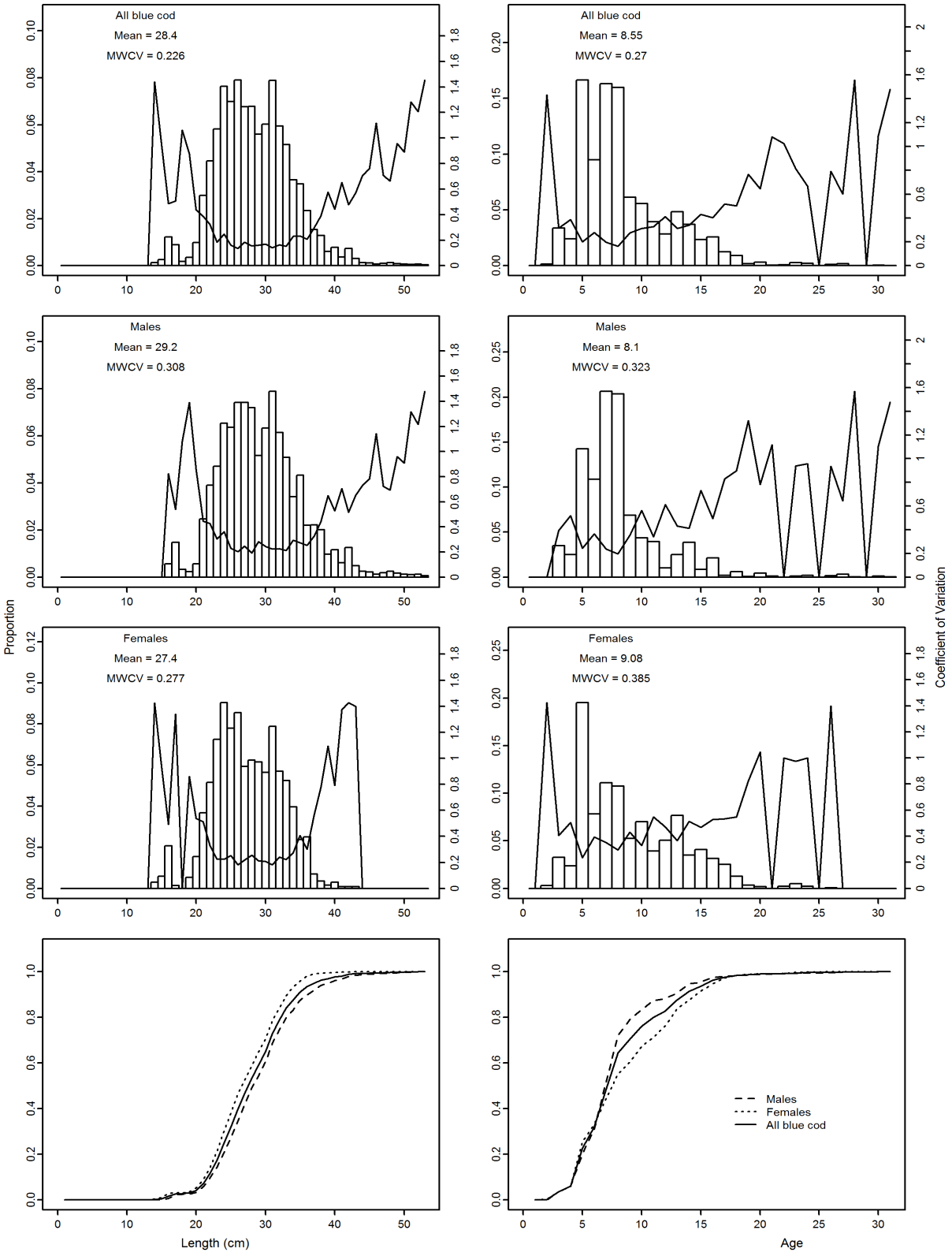


Figure 15: Scaled length frequency, age frequency, and cumulative distributions for total, male, and female blue cod for the 2011 Kaikoura fixed site survey. N, sample size; MWCV, mean weighted coefficient of variation.

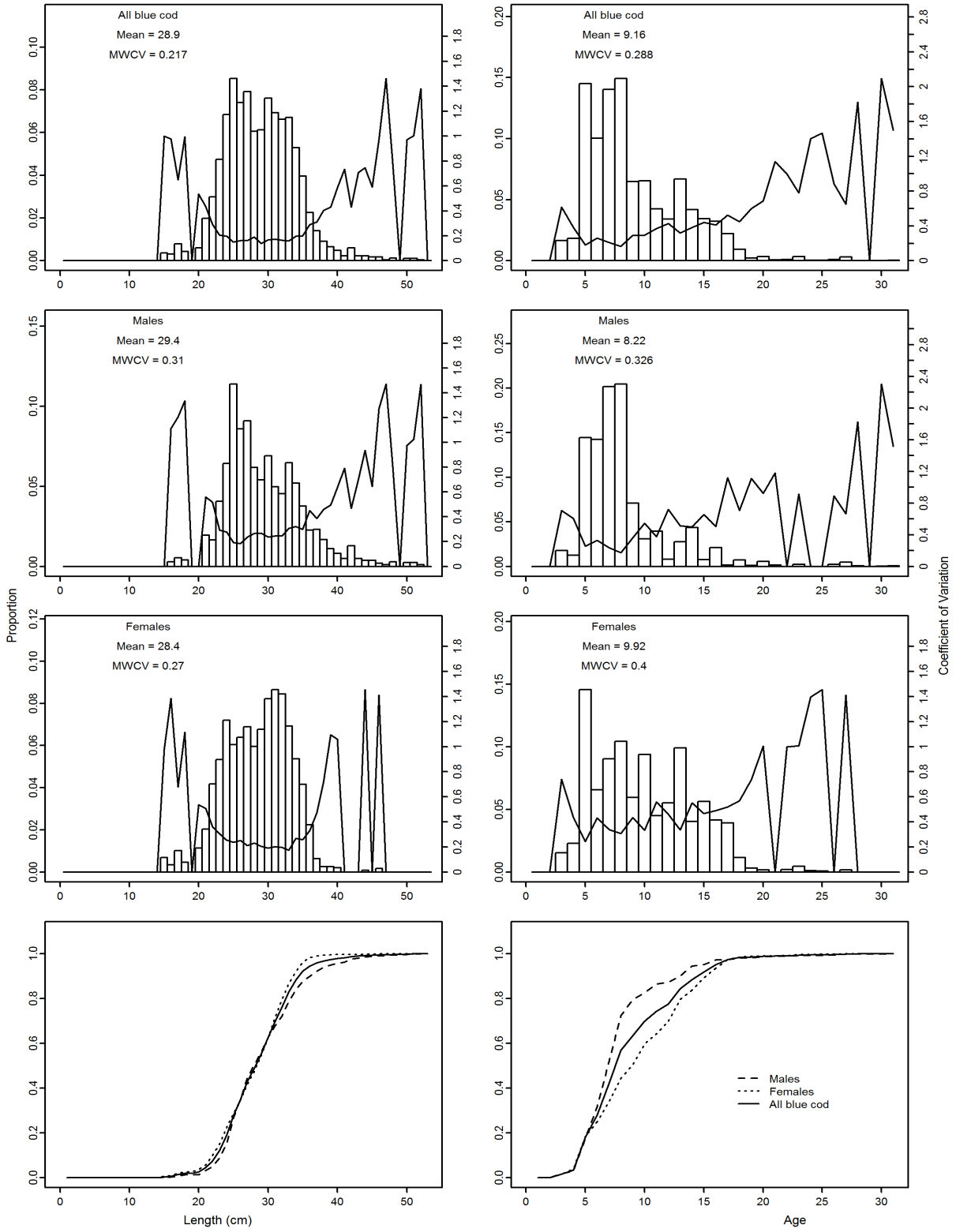


Figure 16: Scaled length frequency, age frequency, and cumulative distributions for total, male, and female blue cod for the 2011 Kaikoura random site survey. N, sample size; MWCV, mean weighted coefficient of variation.

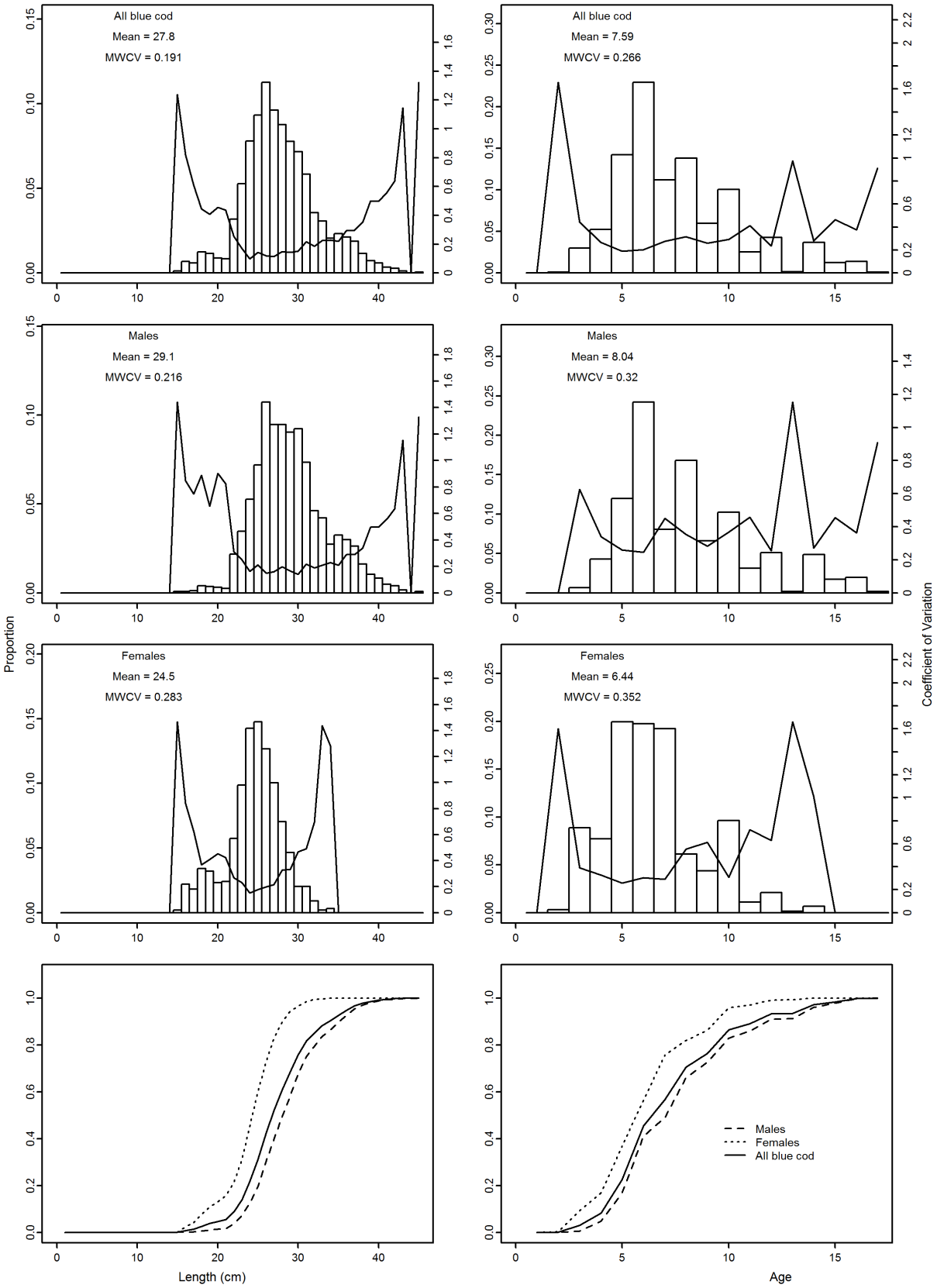


Figure 17: Scaled length frequency, age frequency, and cumulative distributions for total, male, and female blue cod for the 2012 Motunau fixed site survey. N, sample size; MWCV, mean weighted coefficient of variation.

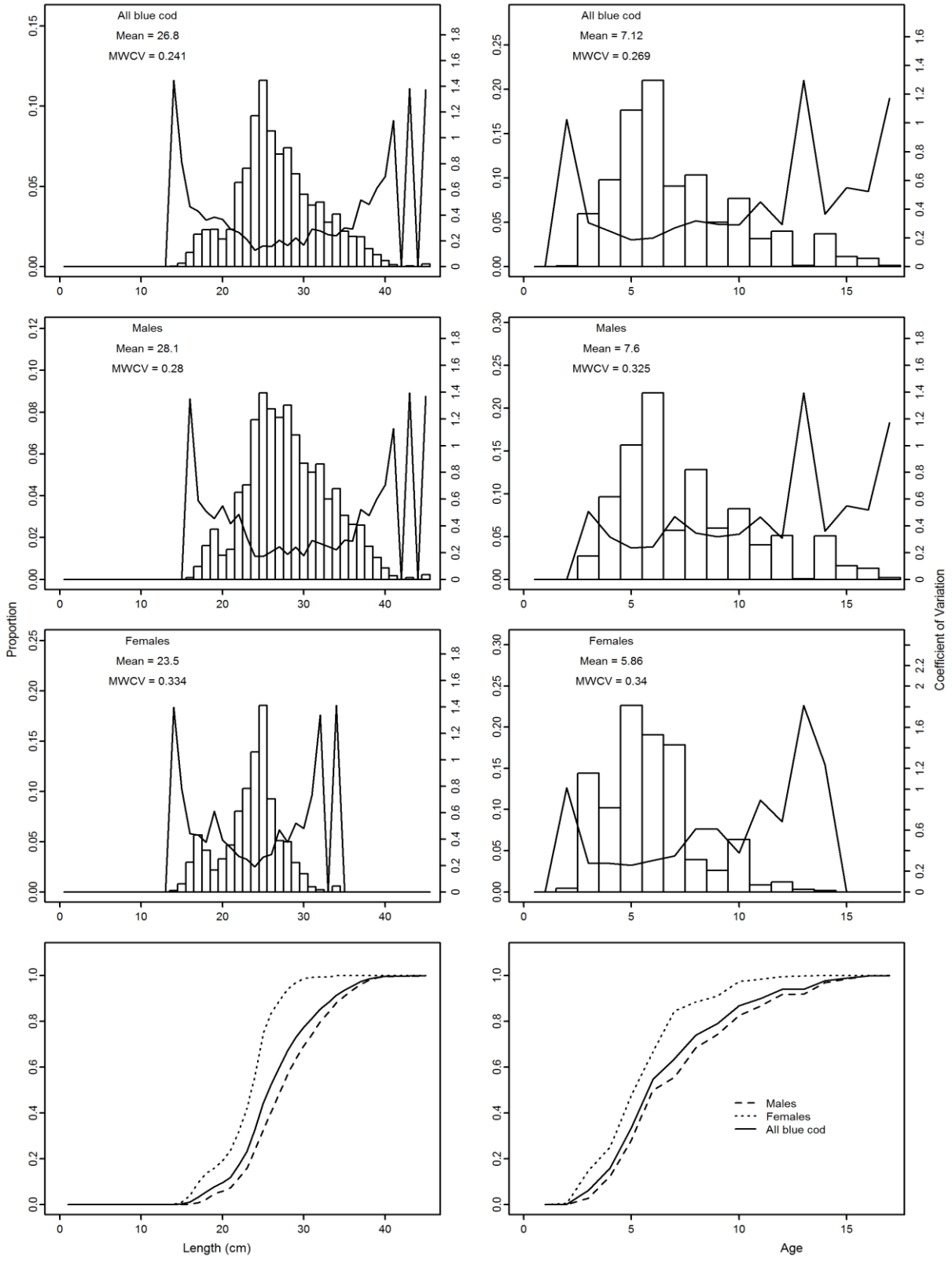


Figure 18: Scaled length frequency, age frequency, and cumulative distributions for total, male, and female blue cod for the 2012 Motunau random site survey. N, sample size; MWCV, mean weighted coefficient of variation.

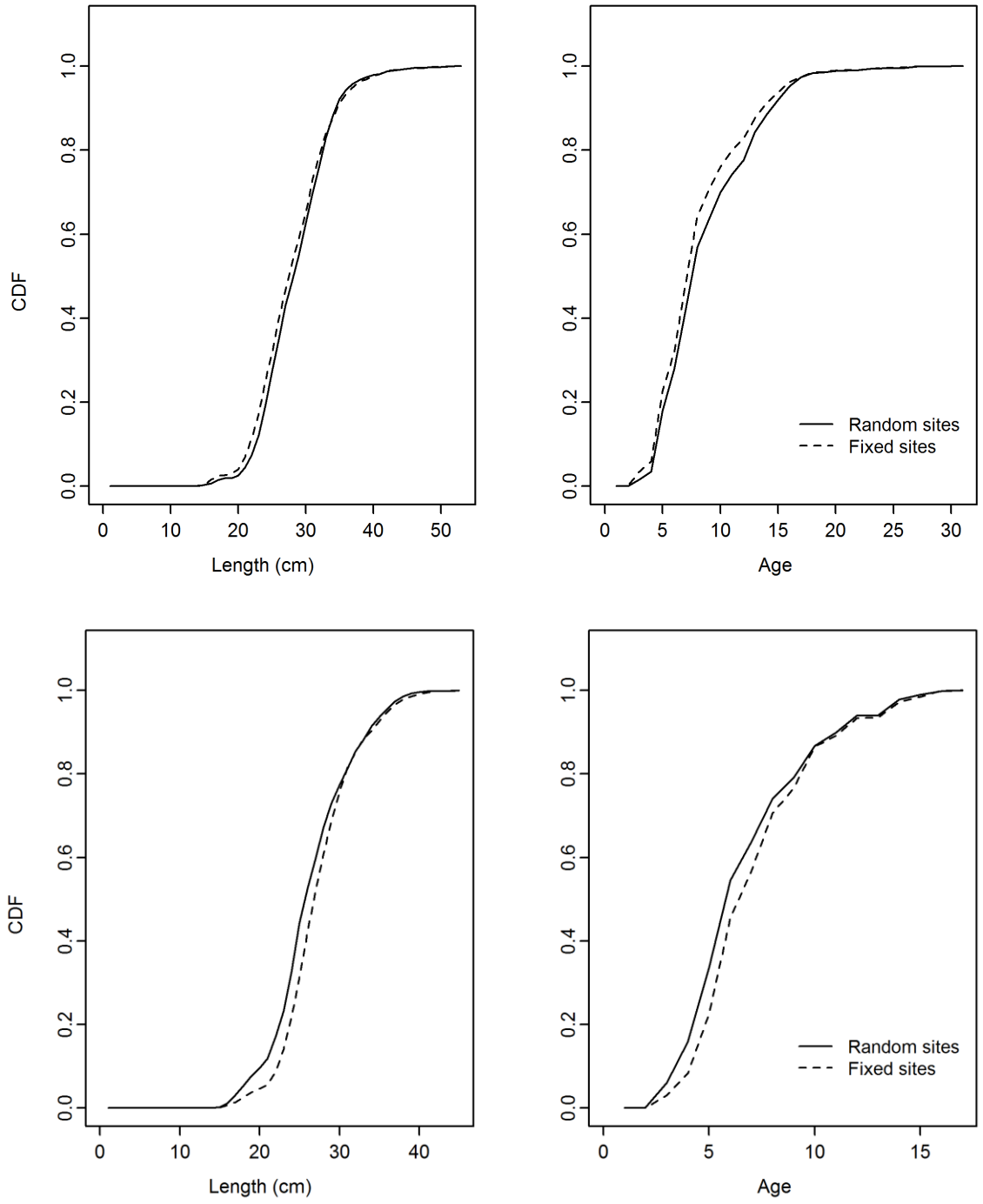


Figure 19: The 2011 Kaikoura survey (upper panel) and 2012 Motunau survey (lower panel) comparison of scaled cumulative length (left) and age (right) frequency distributions.

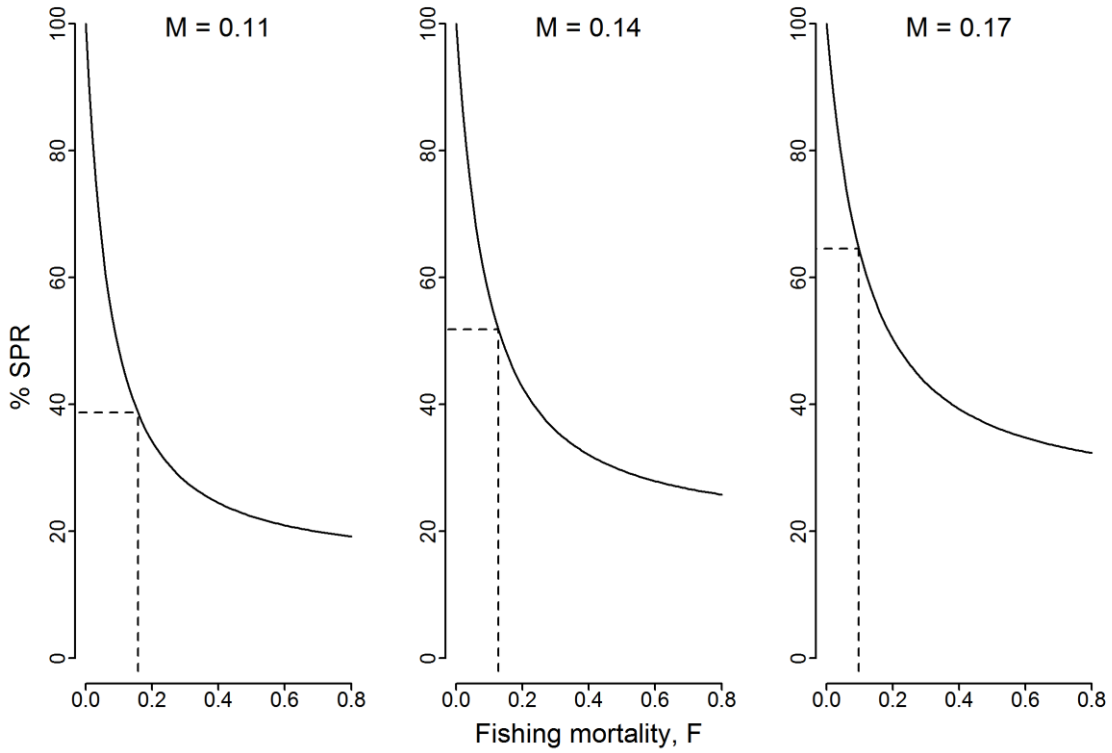


Figure 20: Plot of spawner per recruit (SPR) relative to unfished SPR as a function of fishing mortality for the 2011 Kaikoura fixed-site design survey at three values of M (0.11, 0.14, 0.17). The dashed line shows the survey estimate of F and resulting % SPR, assuming an age of recruitment of 11.

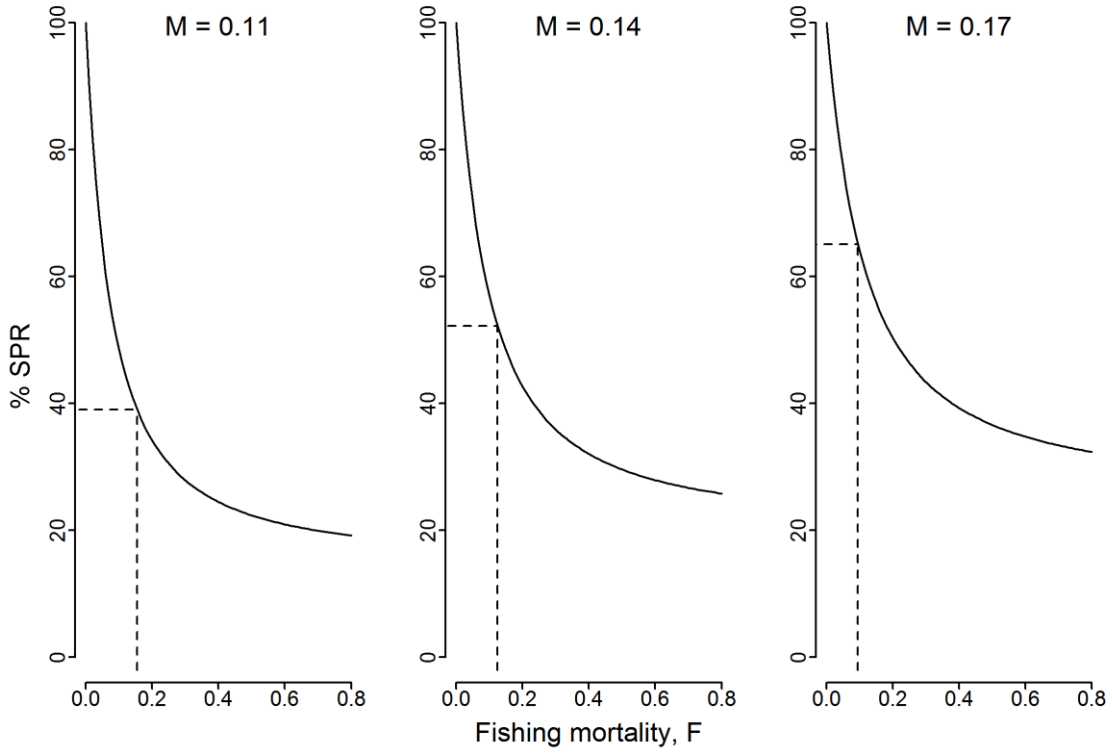


Figure 21: Plot of spawner per recruit (SPR) relative to unfished SPR as a function of fishing mortality for the 2011 Kaikoura random-site design survey at three values of M (0.11, 0.14, 0.17). The dashed line shows the survey estimate of F and resulting % SPR, assuming an age of recruitment of 11.

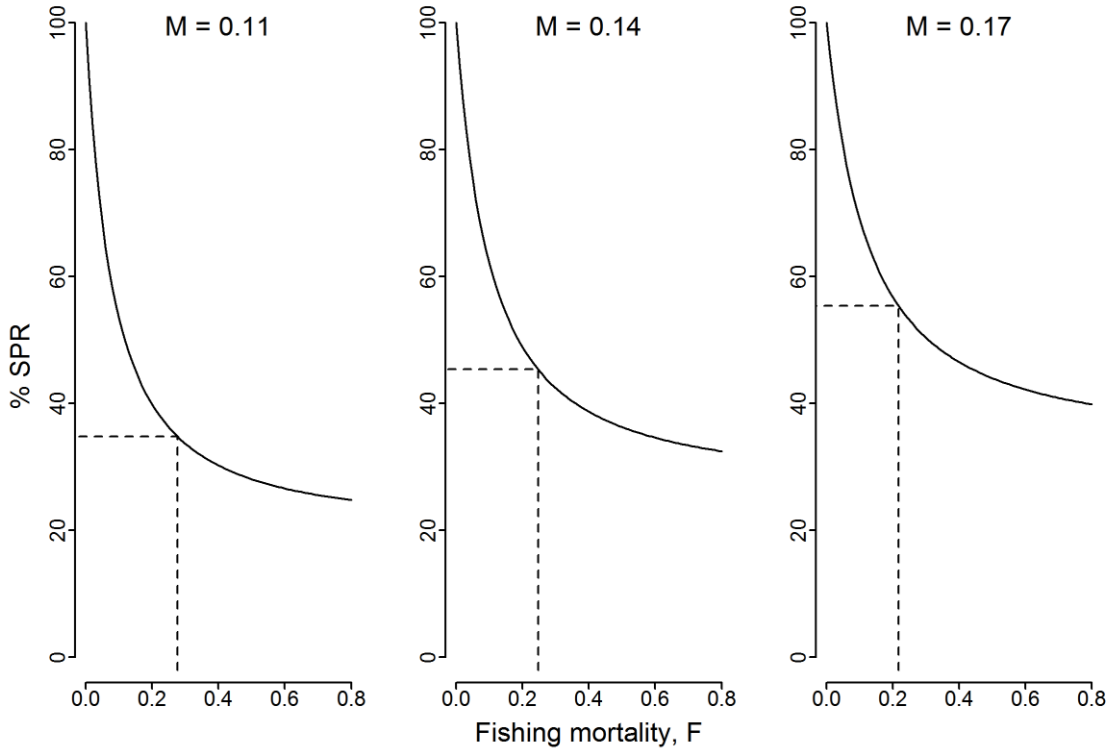


Figure 22: Plot of spawner per recruit (SPR) relative to unfished SPR as a function of fishing mortality for the 2012 Motunau fixed-site design survey at three values of M (0.11, 0.14, 0.17). The dashed line shows the survey estimate of F and resulting % SPR, assuming an age of recruitment of 11.

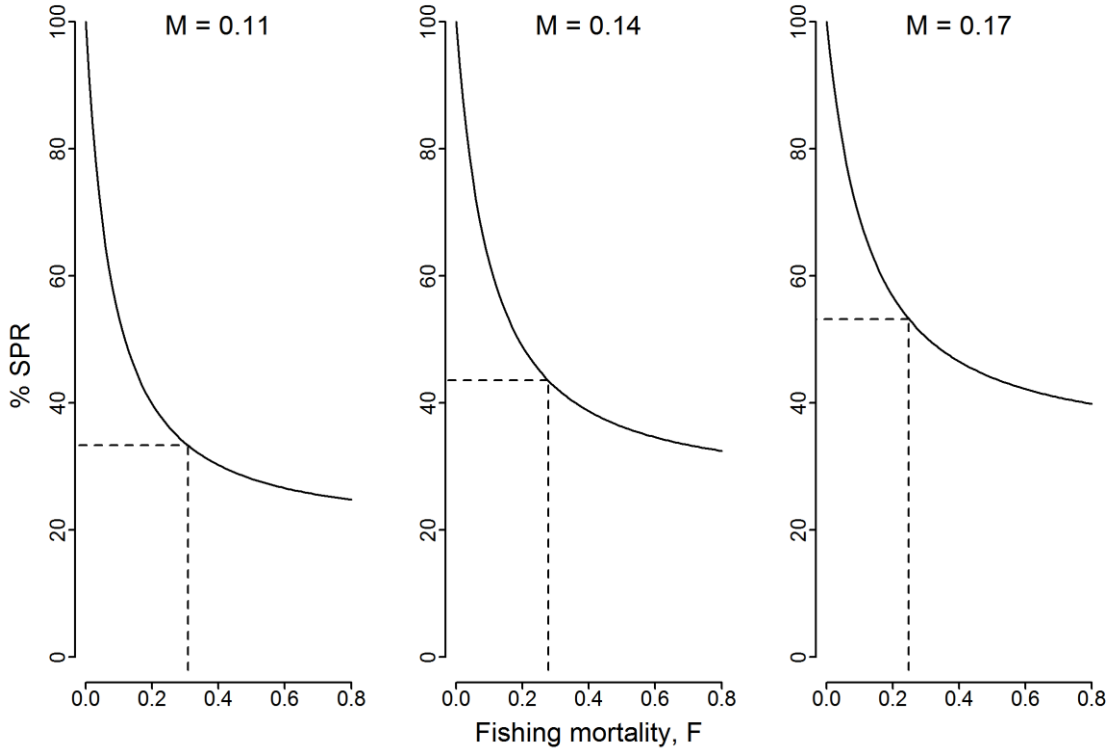


Figure 23: Plot of spawner per recruit (SPR) relative to unfished SPR as a function of fishing mortality for the 2012 Motunau random-site design survey at three values of M (0.11, 0.14, 0.17). The dashed line shows the survey estimate of F and resulting % SPR, assuming an age of recruitment of 11.

Figure 24: Six sites with DUV transects (above, n=41 transects ---) surveyed prior to pots (below, n=36 pots ○) in the 2012 Motunau survey.

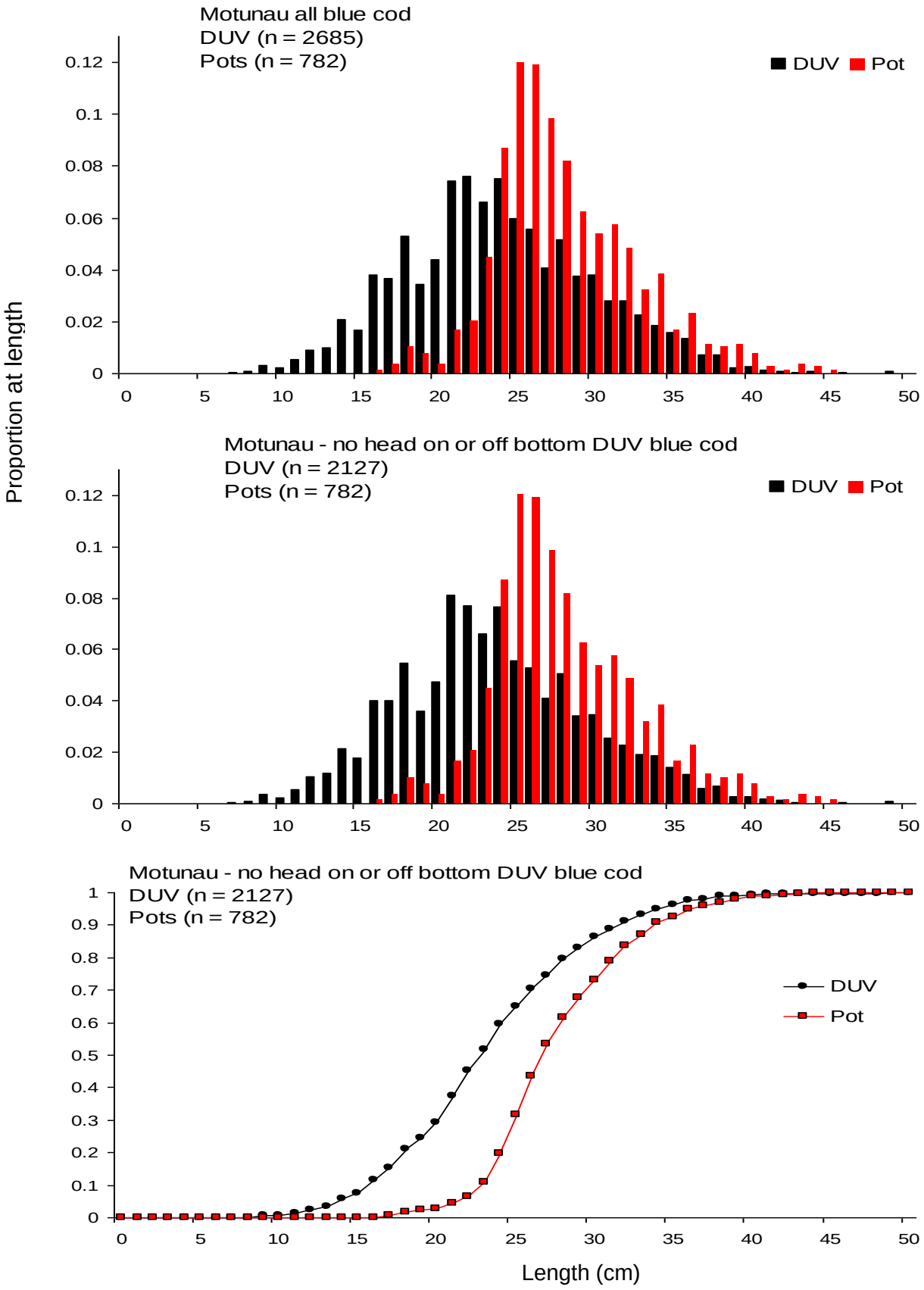


Figure 25: All measured video observations of blue cod sizes plotted against sizes from concurrent pot catch (Top). Blue cod sizes from video observations without head-on body orientation to camera or off bottom observations plotted against sizes from pot catch (Mid). Cumulative frequency distribution without video head-on body orientation or off bottom observations (Bottom).

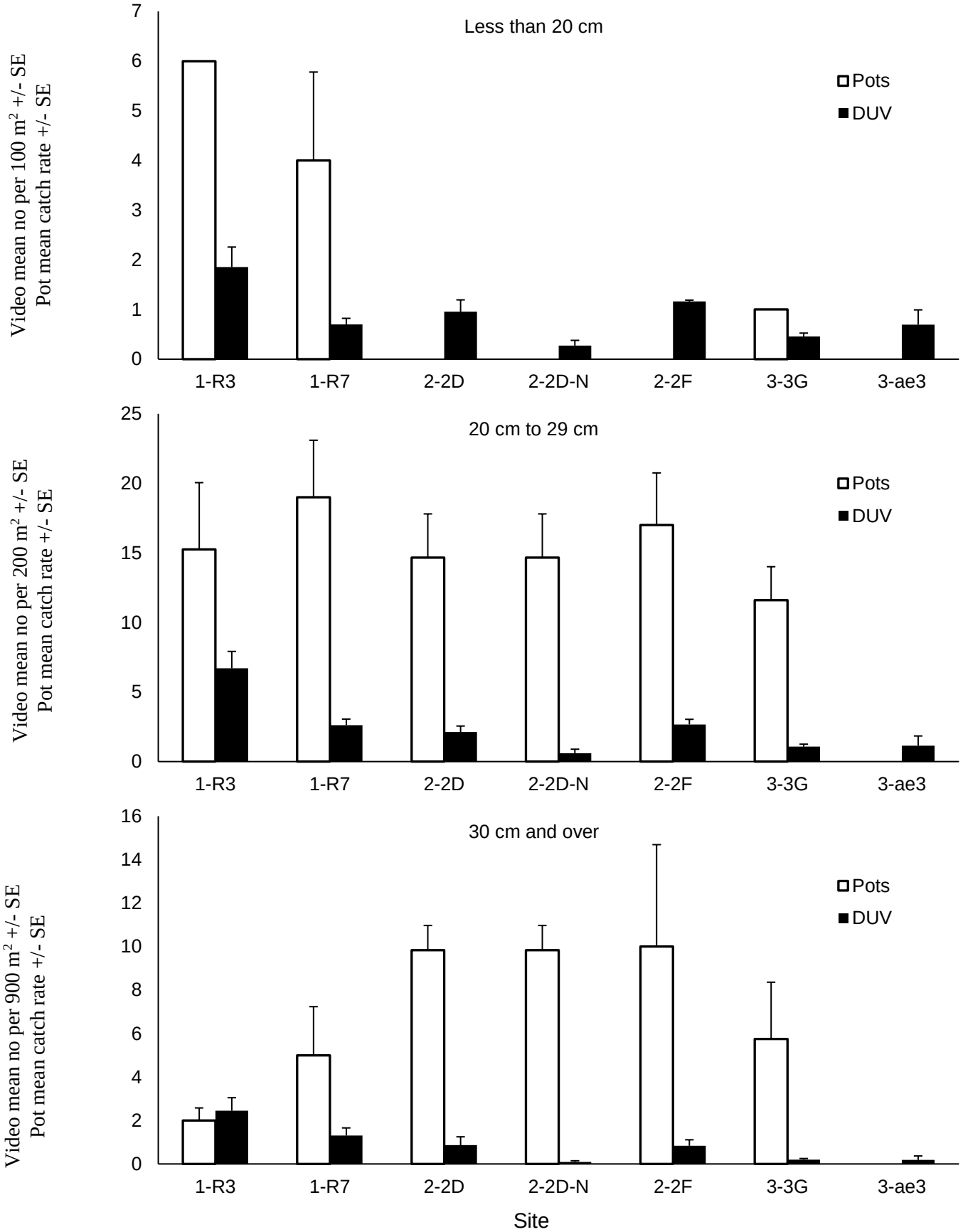


Figure 26: Mean site relative abundance (Number.pot^{-1}) from pots versus the equivalent mean site density estimates from the area swept video method for three size classes of blue cod, less than 20 cm (top), 20–29 cm (centre), 30 cm and over (bottom). Error bars are ± one standard error. Note 2-2D-N is the night survey of site 2-2D.

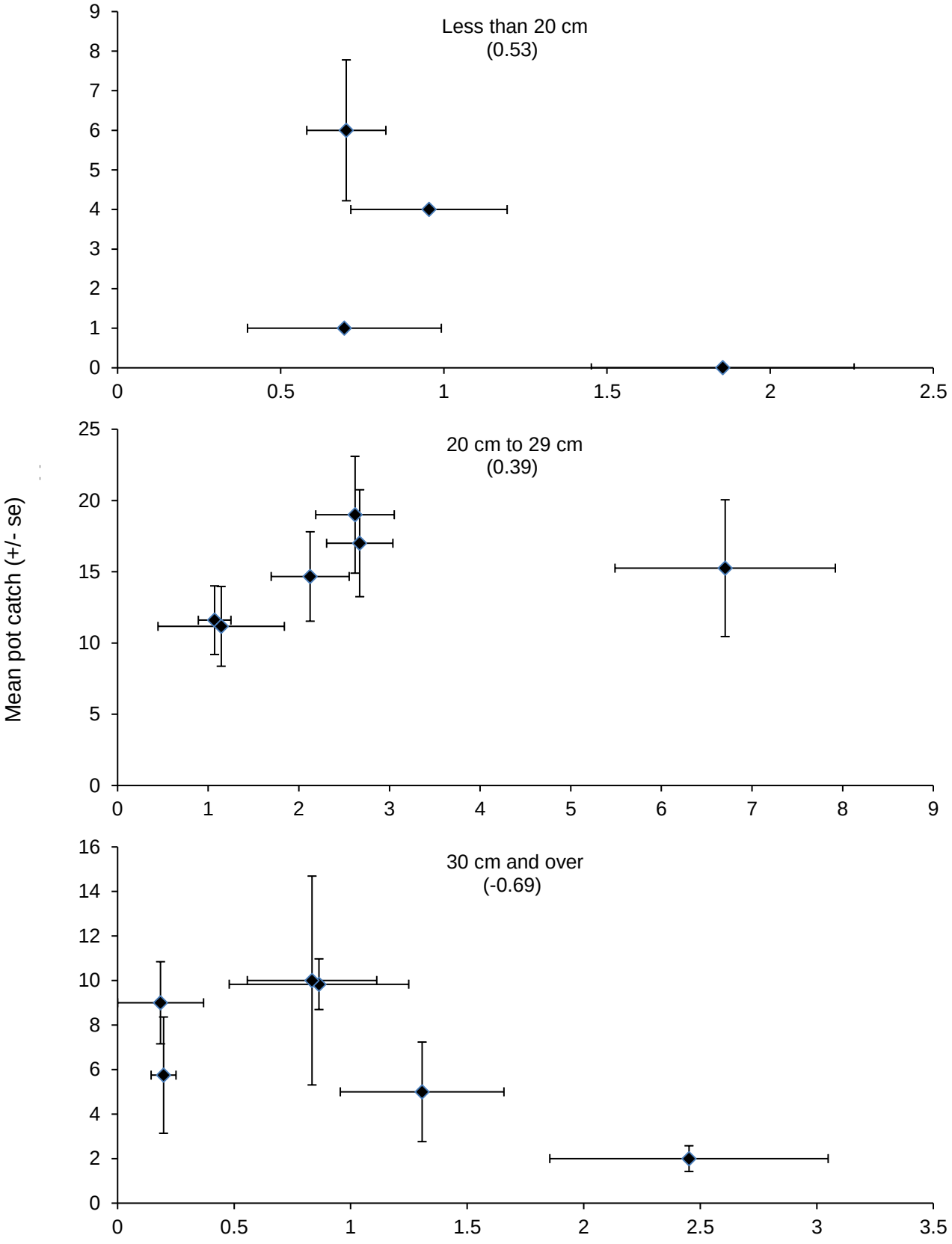


Figure 27: Mean density versus catch rate (kg.pot^{-1}) for three size classes of blue cod dual surveyed with DUV and pots, error bars are ± one standard error. The correlation coefficient is shown in brackets below the size class title.

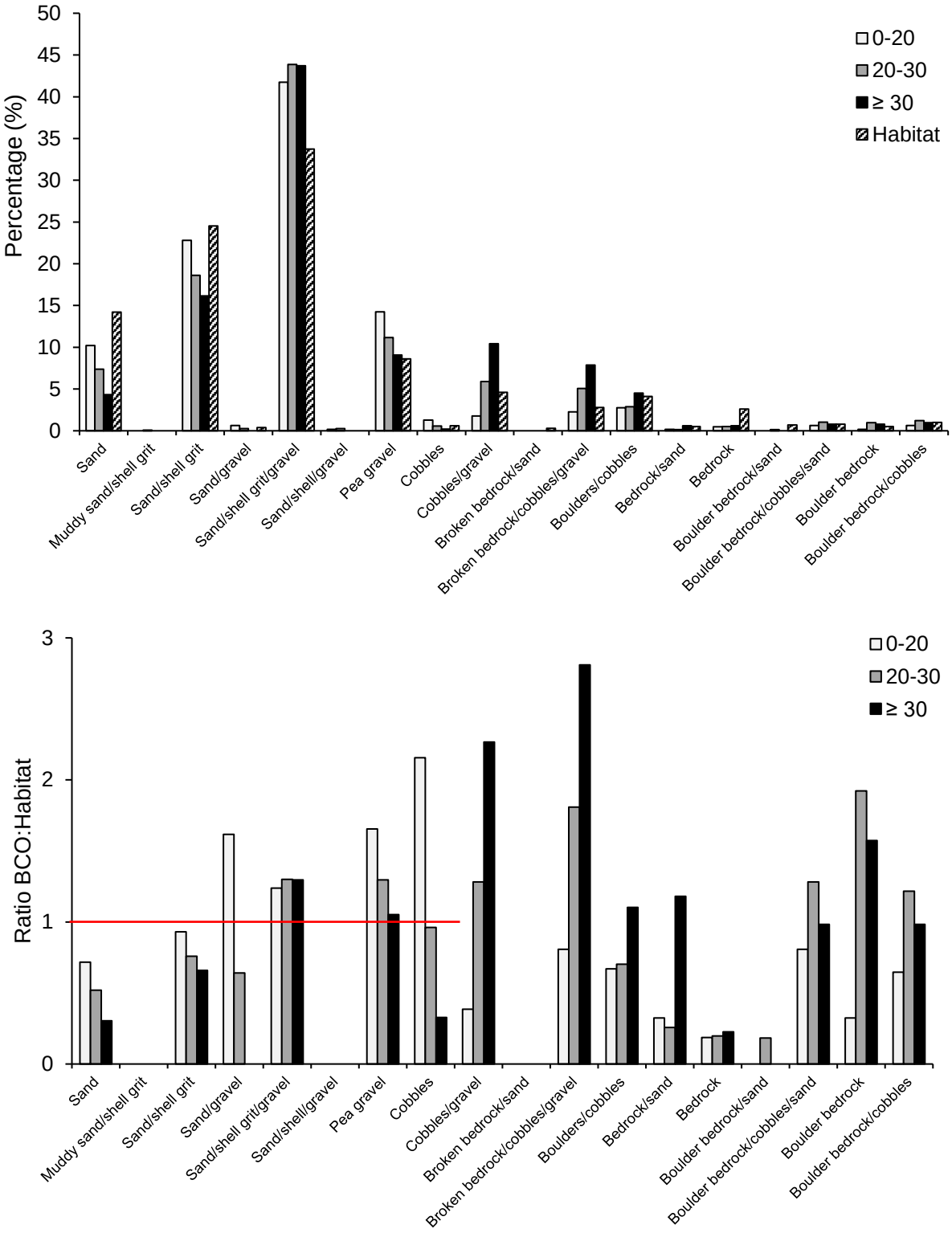


Figure 28: Proportion of blue cod (three size classes) and fish-independent DUV observations of primary substrate from all sites (top). The ratio of the proportion of blue cod-associated primary substrate and the fish-independent substrate recorded by the video at sites is shown in the bottom figure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

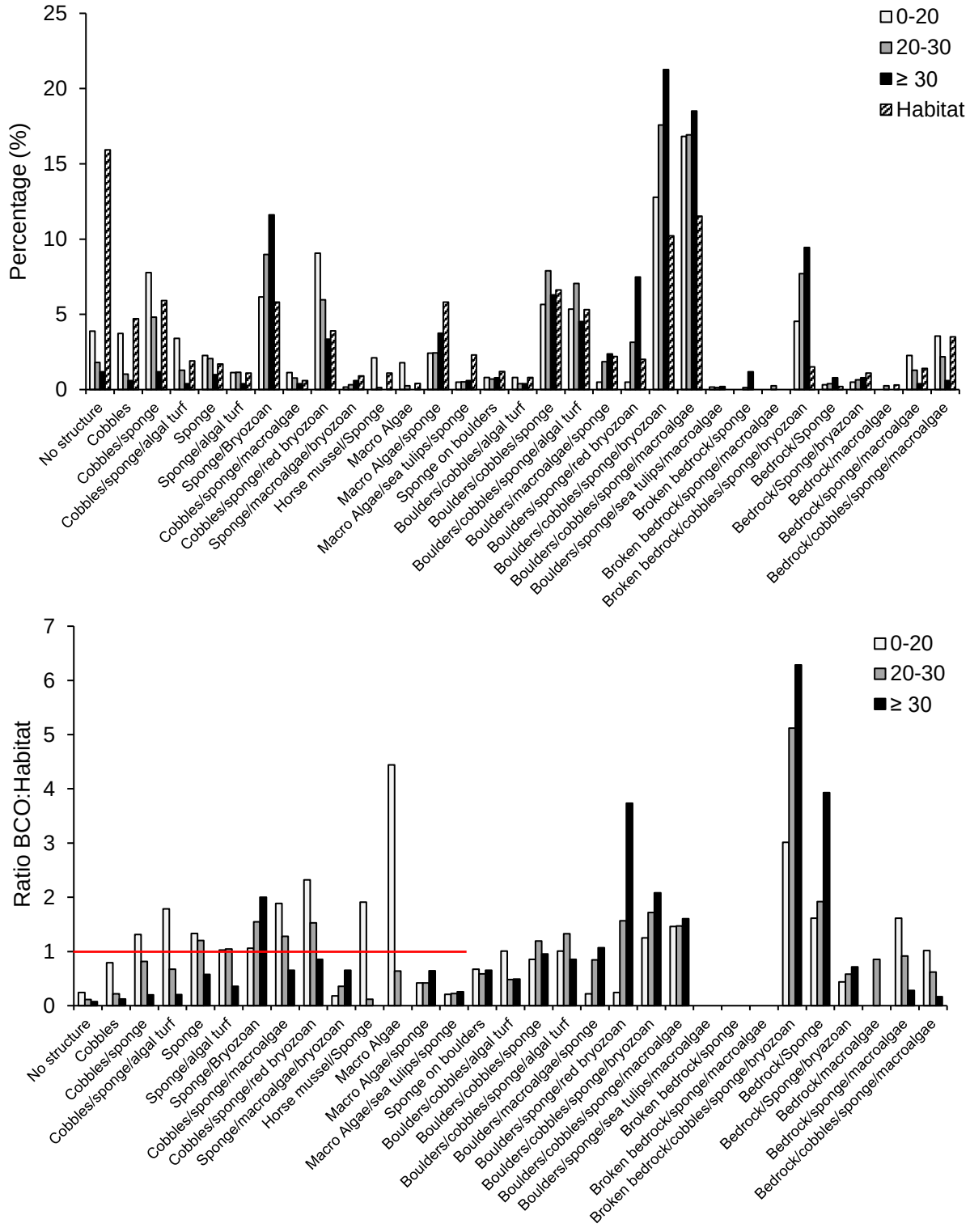
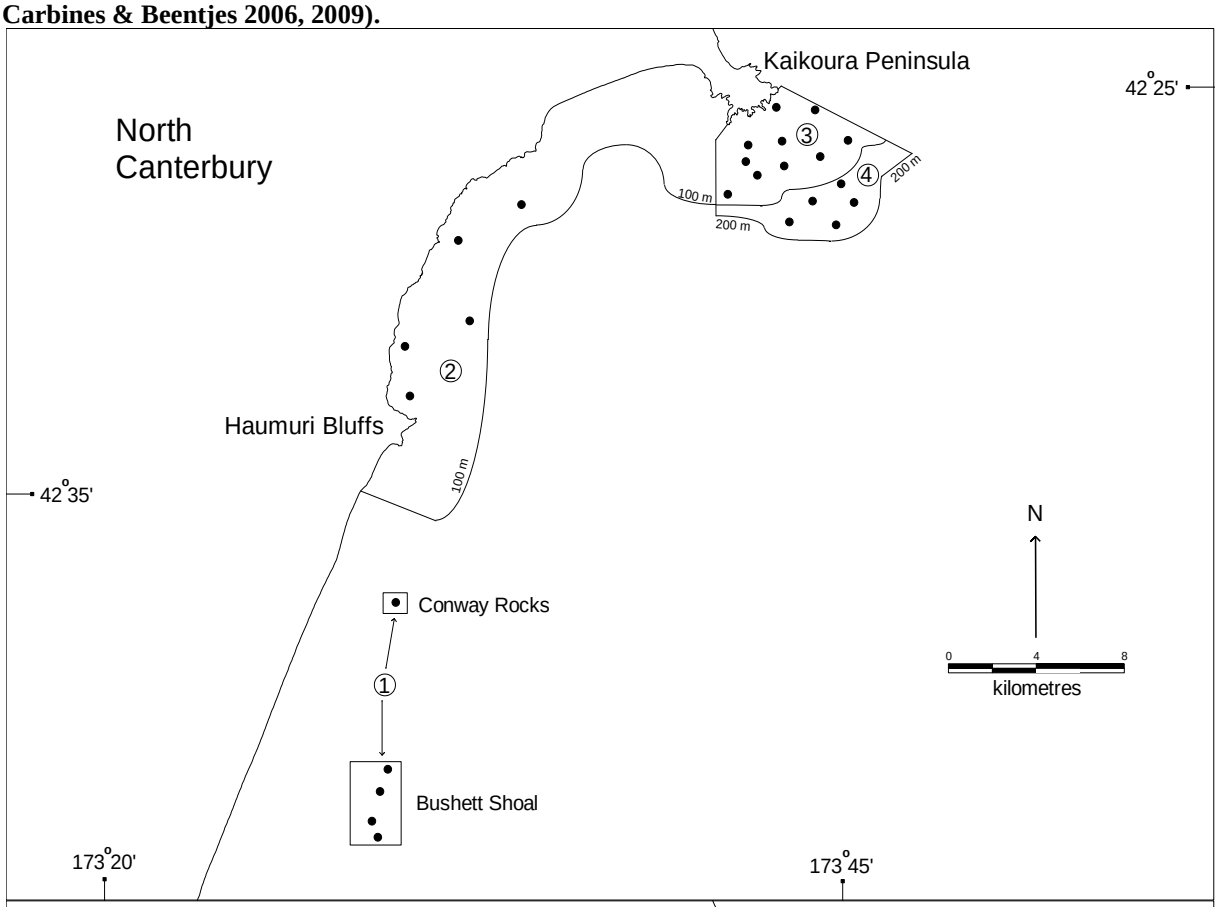
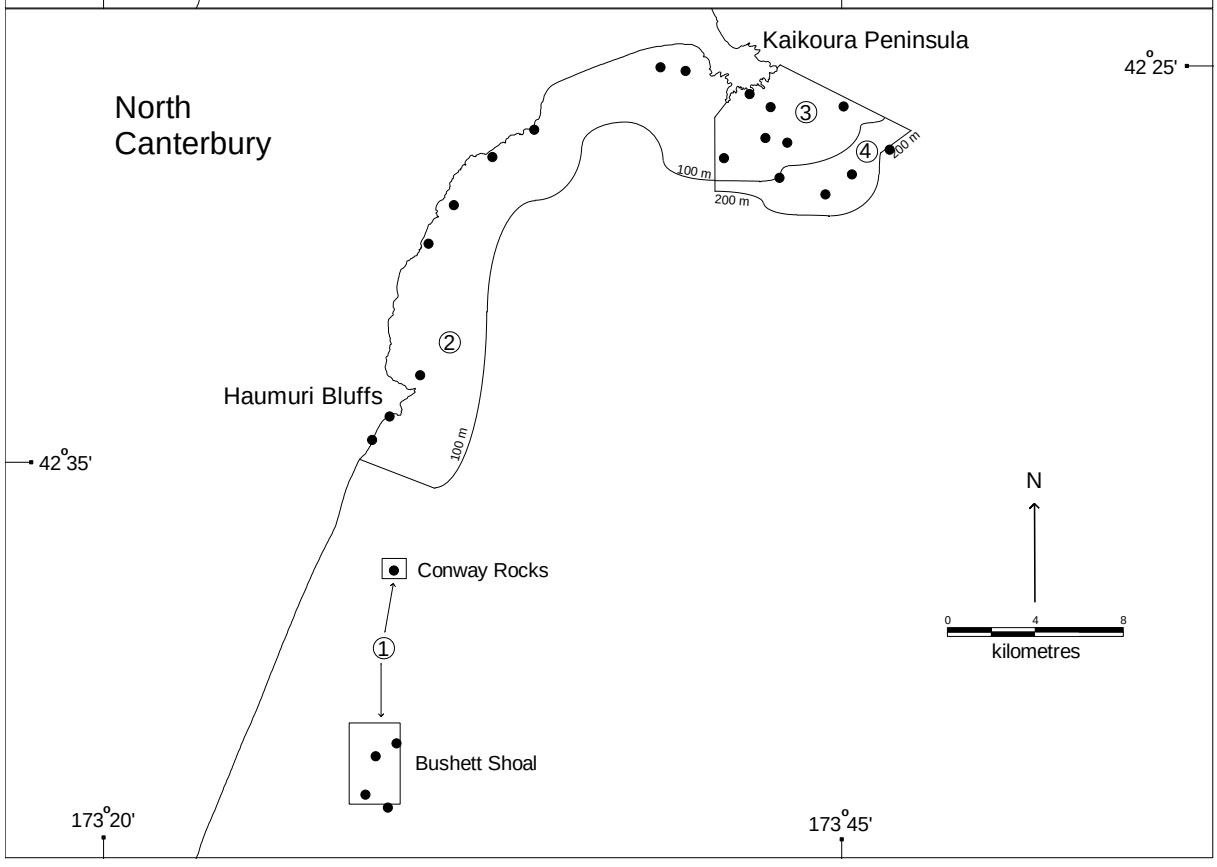


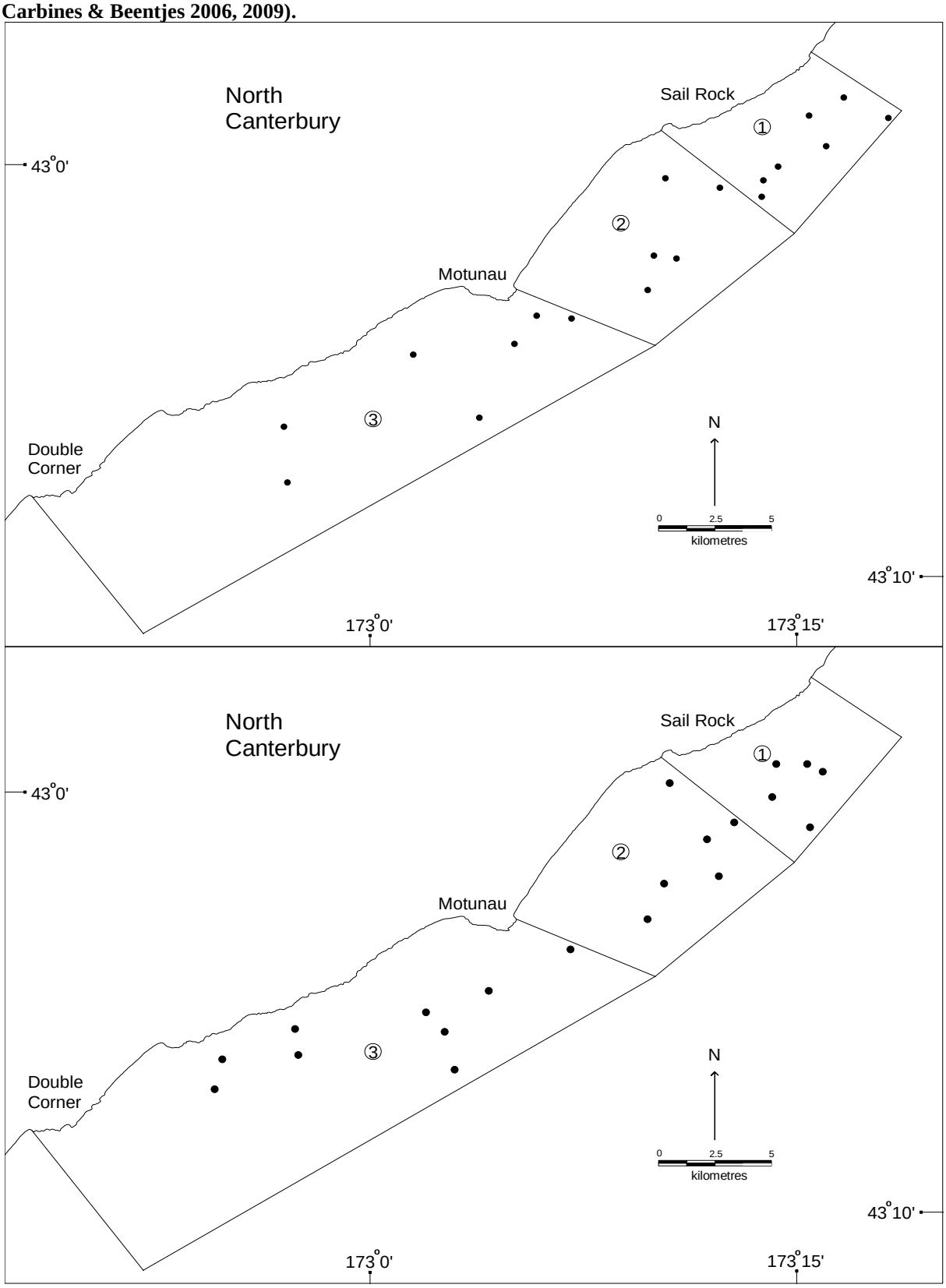
Figure 29: Proportion of blue cod (three size classes) and fish-independent DUV observations of secondary structure from all sites (top). The ratio of the proportion of blue cod-associated primary substrate and the fish-independent substrate recorded by the video at sites is shown in the bottom figure with a line drawn at a 1:1 ratio.

Appendix 1: Sites and strata from the 2004 (above) and 2007 (below) Kaikoura fixed site surveys (from Carbines & Beentjes 2006, 2009).





Appendix 2: Sites and strata from the 2005 (above) and 2008 (below) Motunau fixed site surveys (from Carbines & Beentjes 2006, 2009).



Appendix 3: 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 4: Summary of survey pot lift station data, Kaikoura 2011. For sites R=random.

								Catch of blue cod	
Set	Date	Phase	Stratum	Site	Depth (m)	(NZST) Time set	Pot	(kg)	Number
1	30-Nov-11	1	1	C	48	6:02	1	1.3	3
1	30-Nov-11	1	1	C	40	6:11	2	0	0
1	30-Nov-11	1	1	C	37	6:18	3	0	0
1	30-Nov-11	1	1	C	42	6:26	4	2.9	7
1	30-Nov-11	1	1	C	47	6:32	5	2.2	7
1	30-Nov-11	1	1	C	51	6:40	6	1.5	2
2	30-Nov-11	1	1	F	36	8:08	6	1.2	2
2	30-Nov-11	1	1	F	37	8:14	5	5.8	16
2	30-Nov-11	1	1	F	32	8:20	4	6.1	19
2	30-Nov-11	1	1	F	27	8:26	3	46.5	113
2	30-Nov-11	1	1	F	33	8:32	2	9.5	23
2	30-Nov-11	1	1	F	34	8:38	1	23	72
3	30-Nov-11	1	1	R1	34	10:04	1	6.1	18
3	30-Nov-11	1	1	R1	21	10:10	2	10.8	25
3	30-Nov-11	1	1	R1	25	10:16	3	19.5	52
3	30-Nov-11	1	1	R1	34	10:22	4	2.6	8
3	30-Nov-11	1	1	R1	38	10:28	5	1	2
3	30-Nov-11	1	1	R1	37	10:33	6	1.8	6
4	30-Nov-11	1	1	R2	27	12:39	6	0	0
4	30-Nov-11	1	1	R2	26	12:44	5	0	0
4	30-Nov-11	1	1	R2	29	12:50	4	0	0
4	30-Nov-11	1	1	R2	29	12:56	3	1.7	7
4	30-Nov-11	1	1	R2	25	13:02	2	0.7	2
4	30-Nov-11	1	1	R2	29	13:09	1	0	0
5	1-Dec-11	1	1	R5	29	5:30	1	2.1	4
5	1-Dec-11	1	1	R5	41	5:35	2	8.5	27
5	1-Dec-11	1	1	R5	36	5:40	3	9.6	25
5	1-Dec-11	1	1	R5	21	5:45	4	3.5	12
5	1-Dec-11	1	1	R5	23	5:50	5	7.5	18
5	1-Dec-11	1	1	R5	25	5:56	6	5.5	18
6	1-Dec-11	1	1	I	37	7:15	6	9.5	23
6	1-Dec-11	1	1	I	41	7:20	5	11.2	31
6	1-Dec-11	1	1	I	48	7:25	4	7.9	21
6	1-Dec-11	1	1	I	46	7:30	3	5.2	10
6	1-Dec-11	1	1	I	37	7:35	2	1.9	5
6	1-Dec-11	1	1	I	39	7:40	1	4.1	11
7	1-Dec-11	1	1	E	34	8:58	1	4.9	9
7	1-Dec-11	1	1	E	33	9:03	2	7.7	16
7	1-Dec-11	1	1	E	31	9:08	3	2.8	7
7	1-Dec-11	1	1	E	34	9:13	4	10.8	16
7	1-Dec-11	1	1	E	34	9:18	5	5.2	14
7	1-Dec-11	1	1	E	31	9:23	6	20.4	39
8	1-Dec-11	1	1	R3	43	10:48	6	3.4	11
8	1-Dec-11	1	1	R3	42	10:54	5	8.5	22
8	1-Dec-11	1	1	R3	35	10:59	4	0.9	2

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot	Catch of blue cod (kg)	Catch of blue cod Number
8	1-Dec-11	1	1	R3	40	11:04	3	2.2	9
8	1-Dec-11	1	1	R3	43	11:09	2	3.5	12
8	1-Dec-11	1	1	R3	44	11:14	1	2.1	8
9	1-Dec-11	1	1	R4	28	12:40	1	0	0
9	1-Dec-11	1	1	R4	31	12:45	2	0	0
9	1-Dec-11	1	1	R4	33	12:50	3	0.6	1
9	1-Dec-11	1	1	R4	33	12:55	4	5.1	9
9	1-Dec-11	1	1	R4	32	13:00	5	4.1	5
9	1-Dec-11	1	1	R4	29	13:05	6	0	0
10	1-Dec-11	1	1	K	31	14:28	6	0	0
10	1-Dec-11	1	1	K	32	14:33	5	0	0
10	1-Dec-11	1	1	K	33	14:38	4	0	0
10	1-Dec-11	1	1	K	34	14:43	3	2.3	11
10	1-Dec-11	1	1	K	36	14:48	2	2.2	5
10	1-Dec-11	1	1	K	33	14:53	1	1.4	3
11	2-Dec-11	1	2	R4	20	6:15	1	0	0
11	2-Dec-11	1	2	R4	19	6:20	2	0	0
11	2-Dec-11	1	2	R4	18	6:25	3	0	0
11	2-Dec-11	1	2	R4	18	6:30	4	0.3	1
11	2-Dec-11	1	2	R4	20	6:35	5	3.3	17
11	2-Dec-11	1	2	R4	19	6:40	6	2.6	7
12	2-Dec-11	1	2	F	15	8:04	6	6.7	13
12	2-Dec-11	1	2	F	14	8:09	5	0	0
12	2-Dec-11	1	2	F	16	8:14	4	0	0
12	2-Dec-11	1	2	F	21	8:19	3	0.5	2
12	2-Dec-11	1	2	F	26	8:24	2	3.7	14
12	2-Dec-11	1	2	F	29	8:29	1	0.8	3
13	2-Dec-11	1	2	G	22	9:44	1	3.9	7
13	2-Dec-11	1	2	G	29	9:48	2	1.8	7
13	2-Dec-11	1	2	G	27	9:54	3	0	0
13	2-Dec-11	1	2	G	30	10:00	4	5.9	18
13	2-Dec-11	1	2	G	25	10:05	5	0	0
13	2-Dec-11	1	2	G	22	10:10	6	0	0
14	2-Dec-11	1	2	R3	18	11:25	6	0	0
14	2-Dec-11	1	2	R3	21	11:30	5	0	0
14	2-Dec-11	1	2	R3	22	11:35	4	0	0
14	2-Dec-11	1	2	R3	24	11:40	3	0	0
14	2-Dec-11	1	2	R3	21	11:45	2	0	0
14	2-Dec-11	1	2	R3	18	11:50	1	0	0
15	2-Dec-11	1	2	R2	9	13:00	1	0	0
15	2-Dec-11	1	2	R2	10	13:03	2	0	0
15	2-Dec-11	1	2	R2	11	13:06	3	0	0
15	2-Dec-11	1	2	R2	11	13:09	4	0	0
15	2-Dec-11	1	2	R2	10	13:13	5	0	0
15	2-Dec-11	1	2	R2	9	13:18	6	0	0
16	4-Dec-11	1	4	4G	152	5:46	6	13.6	21
16	4-Dec-11	1	4	4G	143	5:55	5	20.8	22
16	4-Dec-11	1	4	4G	139	6:04	4	25.5	39

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot	Catch of blue cod (kg)	Catch of blue cod Number
16	4-Dec-11	1	4	4G	128	6:13	3	14.5	22
16	4-Dec-11	1	4	4G	112	6:20	2	3.9	6
16	4-Dec-11	1	4	4G	117	6:30	1	11.3	21
17	4-Dec-11	1	4	4R2	121	7:50	1	2.6	6
17	4-Dec-11	1	4	4R2	123	8:00	2	3.1	6
17	4-Dec-11	1	4	4R2	123	8:09	3	17.2	29
17	4-Dec-11	1	4	4R2	123	8:18	4	14.1	30
17	4-Dec-11	1	4	4R2	121	8:28	5	10.9	21
17	4-Dec-11	1	4	4R2	121	8:38	6	7.1	12
18	4-Dec-11	1	4	R3	121	11:20	6	11.9	23
18	4-Dec-11	1	4	R3	123	11:28	5	9.1	16
18	4-Dec-11	1	4	R3	124	11:38	4	17.3	27
18	4-Dec-11	1	4	R3	130	11:48	3	19.6	33
18	4-Dec-11	1	4	R3	123	11:57	2	15.3	27
18	4-Dec-11	1	4	R3	123	12:06	1	5.7	12
19	5-Dec-11	1	4	R5	110	7:00	1	5.6	8
19	5-Dec-11	1	4	R5	108	7:09	2	3.4	9
19	5-Dec-11	1	4	R5	113	7:16	3	12.6	21
19	5-Dec-11	1	4	R5	110	7:26	4	9.6	17
19	5-Dec-11	1	4	R5	112	7:34	5	15.6	27
19	5-Dec-11	1	4	R5	108	7:41	6	12.6	20
20	5-Dec-11	1	3	R3	71	9:18	6	20.8	48
20	5-Dec-11	1	3	R3	71	9:26	5	6.6	12
20	5-Dec-11	1	3	R3	77	9:35	4	13.3	37
20	5-Dec-11	1	3	R3	77	9:42	3	8	30
20	5-Dec-11	1	3	R3	77	9:49	2	20.3	45
20	5-Dec-11	1	3	R3	77	9:56	1	13.4	34
21	5-Dec-11	1	3	B	46	11:23	1	0	0
21	5-Dec-11	1	3	B	51	11:30	2	2.3	6
21	5-Dec-11	1	3	B	48	11:38	3	0.1	1
21	5-Dec-11	1	3	B	49	11:44	4	3.3	9
21	5-Dec-11	1	3	B	46	11:51	5	4.5	11
21	5-Dec-11	1	3	B	44	11:58	6	5.8	12
22	6-Dec-11	1	2	R5	18	7:06	6	0	0
22	6-Dec-11	1	2	R5	18	7:10	5	0	0
22	6-Dec-11	1	2	R5	16	7:14	4	0	0
22	6-Dec-11	1	2	R5	10	7:17	3	0.12	1
22	6-Dec-11	1	2	R5	17	7:21	2	0	0
22	6-Dec-11	1	2	R5	18	7:25	1	0	0
23	6-Dec-11	1	2	C	15	8:42	1	0	0
23	6-Dec-11	1	2	C	13	8:47	2	0	0
23	6-Dec-11	1	2	C	13	8:55	3	0	0
23	6-Dec-11	1	2	C	10	8:59	4	0	0
23	6-Dec-11	1	2	C	9	9:06	5	3.6	8
23	6-Dec-11	1	2	C	13	9:09	6	0	0
24	6-Dec-11	1	2	R10	23	10:45	6	8.3	23
24	6-Dec-11	1	2	R10	25	10:49	5	0	0
24	6-Dec-11	1	2	R10	26	10:53	4	0	0

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot	Catch of blue cod (kg)	Catch of blue cod Number
24	6-Dec-11	1	2	R10	20	10:57	3	9.07	25
24	6-Dec-11	1	2	R10	15	11:01	2	0	0
24	6-Dec-11	1	2	R10	12	11:03	1	3.1	6
25	6-Dec-11	1	2	R1	18	12:25	1	0	0
25	6-Dec-11	1	2	R1	19	12:28	2	0	0
25	6-Dec-11	1	2	R1	20	12:32	3	0	0
25	6-Dec-11	1	2	R1	18	12:36	4	0	0
25	6-Dec-11	1	2	R1	16	12:40	5	0	0
25	6-Dec-11	1	2	R1	16	12:45	6	0	0
26	9-Dec-11	1	3	R10	22	5:42	6	0.37	1
26	9-Dec-11	1	3	R10	31	5:48	5	0.36	1
26	9-Dec-11	1	3	R10	31	5:52	4	0.81	1
26	9-Dec-11	1	3	R10	25	5:57	3	0.38	4
26	9-Dec-11	1	3	R10	18	6:01	2	2.6	8
26	9-Dec-11	1	3	R10	15	6:06	1	3	8
27	9-Dec-11	1	2	K	26	7:28	1	5.9	16
27	9-Dec-11	1	2	K	30	7:34	2	7.9	29
27	9-Dec-11	1	2	K	32	7:39	3	3.68	10
27	9-Dec-11	1	2	K	35	7:45	4	15.2	57
27	9-Dec-11	1	2	K	27	7:49	5	0	0
27	9-Dec-11	1	2	K	26	7:54	6	0.23	1
28	9-Dec-11	1	3	D	46	9:21	6	0.94	4
28	9-Dec-11	1	3	D	48	9:25	5	0.58	2
28	9-Dec-11	1	3	D	47	9:29	4	6.72	11
28	9-Dec-11	1	3	D	45	9:34	3	7.32	20
28	9-Dec-11	1	3	D	48	9:38	2	2.4	10
28	9-Dec-11	1	3	D	51	9:43	1	2.43	7
29	9-Dec-11	1	3	E	42	10:57	1	1.1	3
29	9-Dec-11	1	3	E	43	11:00	2	2.84	15
29	9-Dec-11	1	3	E	43	11:03	3	6.83	22
29	9-Dec-11	1	3	E	47	11:07	4	0.84	4
29	9-Dec-11	1	3	E	51	11:11	5	0.4	1
29	9-Dec-11	1	3	E	52	11:15	6	7.8	22
30	10-Dec-11	1	4	R10	115	5:07	6	3.32	5
30	10-Dec-11	1	4	R10	116	5:15	5	3.2	6
30	10-Dec-11	1	4	R10	115	5:24	4	2.5	3
30	10-Dec-11	1	4	R10	113	5:33	3	10.8	18
30	10-Dec-11	1	4	R10	112	5:42	2	7.33	12
30	10-Dec-11	1	4	R10	112	5:51	1	10.98	13
31	10-Dec-11	1	4	F	113	7:20	1	14.8	26
31	10-Dec-11	1	4	F	111	7:25	2	14.6	26
31	10-Dec-11	1	4	F	109	7:30	3	12.34	20
31	10-Dec-11	1	4	F	106	7:37	4	19.21	33
31	10-Dec-11	1	4	F	108	7:43	5	14.34	30
31	10-Dec-11	1	4	F	113	7:48	6	8.16	13
32	10-Dec-11	1	4	I	119	9:13	6	9.1	10
32	10-Dec-11	1	4	I	118	9:19	5	25.21	32
32	10-Dec-11	1	4	I	116	9:26	4	8.27	17

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot	Catch of blue cod (kg)	Catch of blue cod Number
32	10-Dec-11	1	4	I	117	9:32	3	12.08	20
32	10-Dec-11	1	4	I	116	9:39	2	10.23	17
32	10-Dec-11	1	4	I	117	9:45	1	13.79	25
33	10-Dec-11	1	4	R4	110	11:27	1	4.15	6
33	10-Dec-11	1	4	R4	97	11:32	2	8.24	14
33	10-Dec-11	1	4	R4	93	11:36	3	0.33	1
33	10-Dec-11	1	4	R4	93	11:41	4	6.2	11
33	10-Dec-11	1	4	R4	101	11:46	5	4.2	3
33	10-Dec-11	1	4	R4	119	11:51	6	2.03	3
34	13-Dec-11	1	4	D	107	5:27	6	15.45	31
34	13-Dec-11	1	4	D	108	5:34	5	10.5	19
34	13-Dec-11	1	4	D	108	5:42	4	12.63	18
34	13-Dec-11	1	4	D	112	5:51	3	11.12	13
34	13-Dec-11	1	4	D	114	5:59	2	0.47	1
34	13-Dec-11	1	4	D	113	6:07	1	12.65	19
35	13-Dec-11	1	4	R1	111	7:29	1	5.12	8
35	13-Dec-11	1	4	R1	114	7:37	2	6.93	10
35	13-Dec-11	1	4	R1	114	7:45	3	9.28	14
35	13-Dec-11	1	4	R1	112	7:54	4	8.36	14
35	13-Dec-11	1	4	R1	108	8:02	5	4.78	12
35	13-Dec-11	1	4	R1	110	8:10	6	4.91	10
36	13-Dec-11	1	4	B	110	9:29	6	1.56	4
36	13-Dec-11	1	4	B	108	9:35	5	6.98	9
36	13-Dec-11	1	4	B	108	9:42	4	1.96	4
36	13-Dec-11	1	4	B	103	9:49	3	6.26	10
36	13-Dec-11	1	4	B	104	9:55	2	4.68	10
36	13-Dec-11	1	4	B	105	10:02	1	7.26	11
37	19-Dec-11	1	3	R2	86	5:07	1	2.8	5
37	19-Dec-11	1	3	R2	86	5:17	2	0.8	1
37	19-Dec-11	1	3	R2	86	5:26	3	1.05	3
37	19-Dec-11	1	3	R2	84	5:36	4	1.12	2
37	19-Dec-11	1	3	R2	82	5:46	5	2.5	5
37	19-Dec-11	1	3	R2	82	5:55	6	2.2	4
38	19-Dec-11	1	3	G	90	7:20	6	5.1	8
38	19-Dec-11	1	3	G	90	7:27	5	3.9	9
38	19-Dec-11	1	3	G	88	7:35	4	5.8	12
38	19-Dec-11	1	3	G	82	7:43	3	7.7	13
38	19-Dec-11	1	3	G	82	7:50	2	8.9	18
38	19-Dec-11	1	3	G	80	7:58	1	4.3	9
39	19-Dec-11	1	3	R5	79	9:35	1	3.4	9
39	19-Dec-11	1	3	R5	84	9:42	2	8.1	18
39	19-Dec-11	1	3	R5	86	9:50	3	6.6	11
39	19-Dec-11	1	3	R5	88	9:58	4	7.2	13
39	19-Dec-11	1	3	R5	86	10:06	5	1.8	5
39	19-Dec-11	1	3	R5	82	10:14	6	5.6	14
40	19-Dec-11	1	2	J	19	11:50	6	4.4	18
40	19-Dec-11	1	2	J	21	11:57	5	0.6	5
40	19-Dec-11	1	2	J	20	12:01	4	0	0

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot	Catch of blue cod (kg)	Catch of blue cod Number
40	19-Dec-11	1	2	J	19	12:08	3	0	0
40	19-Dec-11	1	2	J	20	12:13	2	12.1	34
40	19-Dec-11	1	2	J	19	12:18	1	1.3	4
41	20-Dec-11	1	3	R1	102	5:36	1	5.9	10
41	20-Dec-11	1	3	R1	106	5:44	2	7.8	15
41	20-Dec-11	1	3	R1	104	5:53	3	17.3	29
41	20-Dec-11	1	3	R1	108	6:03	4	4.6	8
41	20-Dec-11	1	3	R1	101	6:11	5	9.5	16
41	20-Dec-11	1	3	R1	101	6:21	6	10.6	19
42	20-Dec-11	1	3	I	91	7:44	6	3	7
42	20-Dec-11	1	3	I	88	7:53	5	4.1	7
42	20-Dec-11	1	3	I	86	8:01	4	2.7	9
42	20-Dec-11	1	3	I	80	8:09	3	0.3	1
42	20-Dec-11	1	3	I	80	8:18	2	1.2	4
42	20-Dec-11	1	3	I	82	8:29	1	2.4	9
43	20-Dec-11	1	3	R4	80	9:48	1	3	5
43	20-Dec-11	1	3	R4	82	9:55	2	7.5	9
43	20-Dec-11	1	3	R4	86	10:06	3	3.2	8
43	20-Dec-11	1	3	R4	88	10:16	4	3	4
43	20-Dec-11	1	3	R4	80	10:23	5	2.4	4
43	20-Dec-11	1	3	R4	79	10:33	6	1.9	5
44	21-Dec-11	2	2	R8	48	4:47	6	0.5	2
44	21-Dec-11	2	2	R8	48	4:52	5	0.8	5
44	21-Dec-11	2	2	R8	48	4:57	4	0.1	1
44	21-Dec-11	2	2	R8	48	5:02	3	0	0
44	21-Dec-11	2	2	R8	48	5:07	2	0	0
44	21-Dec-11	2	2	R8	48	5:12	1	1.4	3
45	21-Dec-11	2	2	A	5	6:32	1	0	0
45	21-Dec-11	2	2	A	5	6:35	2	0	0
45	21-Dec-11	2	2	A	4	6:39	3	0	0
45	21-Dec-11	2	2	A	7	6:43	4	0	0
45	21-Dec-11	2	2	A	9	6:46	5	0	0
45	21-Dec-11	2	2	A	9	6:50	6	0	0
46	21-Dec-11	2	2	D	11	8:11	6	0	0
46	21-Dec-11	2	2	D	15	8:16	5	0.4	6
46	21-Dec-11	2	2	D	13	8:22	4	5.1	16
46	21-Dec-11	2	2	D	11	8:27	3	2.5	4
46	21-Dec-11	2	2	D	15	8:31	2	8.8	19
46	21-Dec-11	2	2	D	16	8:35	1	0	0
47	21-Dec-11	2	2	R7	38	10:00	1	1.7	10
47	21-Dec-11	2	2	R7	42	10:05	2	0.5	2
47	21-Dec-11	2	2	R7	33	10:10	3	0.1	1
47	21-Dec-11	2	2	R7	22	10:15	4	0	0
47	21-Dec-11	2	2	R7	18	10:20	5	0.8	5
47	21-Dec-11	2	2	R7	18	10:25	6	0.3	2
48	21-Dec-11	2	2	R6	16	11:46	6	0	0
48	21-Dec-11	2	2	R6	18	11:48	5	0	0
48	21-Dec-11	2	2	R6	18	11:50	4	0	0

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot	Catch of blue cod (kg)	Catch of blue cod Number
48	21-Dec-11	2	2	R6	18	11:53	3	0	0
48	21-Dec-11	2	2	R6	18	11:56	2	0	0
48	21-Dec-11	2	2	R6	16	11:58	1	0	0
49	21-Dec-11	2	2	I	13	13:14	1	5.4	11
49	21-Dec-11	2	2	I	15	13:17	2	1.8	6
49	21-Dec-11	2	2	I	16	13:22	3	0.4	1
49	21-Dec-11	2	2	I	15	13:26	4	0	0
49	21-Dec-11	2	2	I	15	13:31	5	0.1	1
49	21-Dec-11	2	2	I	15	13:36	6	0	0

Appendix 5: Summary of the Kaikoura 2011 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	ADCP 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	46	000	3	12.8	1044	0	3	3	1.0	050	7	3	13.8	12.5	3.4	3.0
2	46	000	3	14.4	1044	0	3	3	1.0	050	7	3	13.8	12.4	5.9	3.0
3	46	020	4	14.0	1043	1	4	3	1.5	180	7	3	14.1	12.5	6.1	2.7
4	46	359	4	14.3	1043	0	4	3	2.0	180	7	4	14.3	12.5	8.6	2.8
5	46	260	1	9.2	1037	0	4	4	2.0	180	7	5	13.5	12.5	0.9	6.4
6	46	000	0	13.9	1036	0	3	3	2.0	180	7	3	13.5	12.5	0.8	6.5
7	35	030	0	13.8	1036	0	3	3	2.0	180	7	3	14.2	12.5	0.6	7.3
8	35	000	3	11.6	1035	0	3	3	2.0	180	7	2	14.6	13.1	4.0	4.5
9	35	000	2	10.6	1034	0	3	3	1.5	180	7	2	13.1	14.1	2.8	3.5
10	35	999	0	11.7	1033	0	3	3	2.5	180	7	3	14.2	13.1	0.0	4.4
11	35	999	0	11.4	1033	0	3	3	1.5	045	2	2	12.1	12.0	0.0	6.4
12	35	999	0	14.1	1034	0	2	3	1.0	045	7	3	12.2	12.1	0.0	6.4
13	32	999	0	15.9	1034	0	2	3	1.0	045	7	4	14.1	13.0	0.0	8.9
14	32	999	0	10.2	1033	0	2	5	0.3	045	4	1	14.1	13.1	0.0	9.1
15	32	090	2	12.1	1032	0	1	5	0.3	045	3	1	14.3	13.5	2.8	4.5
16	32	240	2	8.8	1017	8	4	6	2.5	070	10	1	14.1	13.1	2.4	7.1
17	32	330	1	10.3	1019	8	4	6	2.0	070	10	1	14.3	13.2	1.1	7.1
18	32	999	0	11.2	1020	0	4	6	1.5	070	10	1	14.2	13.1	0.0	7.1
19	27	150	1	14.2	1021	8	4	4	1.0	090	12	2	14.0	13.1	1.7	5.3
20	27	150	2	16.4	1021	8	3	4	1.0	060	11	1	14.0	13.1	2.6	5.3
21	27	240	2	17.9	1021	7	3	4	1.0	130	12	2	14.0	13.1	3.4	5.3
22	27	160	2	15.0	1021	8	3	7	0.5	150	7	2	15.2	14.9	3.1	2.6
23	27	160	2	15.2	1020	8	3	7	0.5	150	7	2	15.2	14.9	2.8	2.6
24	27	180	2	14.4	1020	8	3	7	0.5	180	7	3	15.2	14.9	2.3	2.6
25	24	180	3	13.1	1019	8	3	5	1.0	170	3	2	15.2	14.9	4.8	3.0
26	24	000	2	12.1	1035	0	2	6	0.5	270	7	3	13.3	13.1	1.7	3.1
27	24	060	2	16.0	1037	1	3	8	1.0	270	7	3	14.0	13.2	3.4	2.4
28	24	060	3	17.5	1037	3	3	6	1.0	240	7	2	14.7	13.3	3.6	4.2
29	24	000	4	17.1	1037	3	3	6	1.0	240	7	2	14.7	13.3	5.7	4.2

Appendix 5– *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	24	000	2	12.9	1040	8	4	5	1.5	060	4	2	14.5	14.0	2.9	4.3
31	43	000	3	15.9	1041	8	4	5	1.5	030	2	2	14.5	14.0	4.4	4.3
32	43	000	2	16.7	1040	7	3	5	1.0	030	4	2	14.7	14.0	3.4	4.5
33	43	000	3	16.0	1040	7	4	5	1.5	030	4	2	14.7	14.0	3.9	4.5
34	43	999	0	13.7	1024	2	4	6	2.0	040	12	1	13.5	12.7	0.0	5.7
35	43	999	0	17.5	1025	2	3	6	1.0	040	12	1	13.5	12.7	0.0	5.7
36	43	060	2	22.6	1025	2	3	6	1.0	040	11	2	13.5	13.5	1.4	6.0
37	35	210	2	10.3	1029	8	3	8	1.0	160	11	2	13.8	12.5	3.1	7.0
38	35	180	3	10.5	1031	8	4	6	1.0	160	12	2	13.8	12.7	4.7	7.0
39	35	190	3	12.2	1030	8	3	6	1.0	160	12	2	13.6	12.7	3.8	7.0
40	35	180	3	15.7	1030	8	3	7	1.0	160	2	2	13.6	13.5	5.6	3.9
41	35	090	1	11.0	1033	0	3	1	1.5	120	12	2	12.2	12.7	1.1	5.2
42	35	120	3	14.4	1035	2	2	7	1.0	120	12	2	12.6	12.7	2.2	5.3
43	42	090	1	16.6	1035	1	2	7	1.0	120	12	2	13.1	13.2	0.6	5.5
44	42	090	2	13.0	1041	8	3	7	0.5	090	2	4	15.1	12.4	2.2	2.8
45	42	040	1	12.9	1042	8	2	8	0.5	090	7	3	14.8	12.5	1.4	1.5
46	42	090	2	13.8	1042	8	2	8	0.5	120	7	2	14.3	12.7	3.1	2.3
47	42	090	1	15.5	1042	8	2	8	0.5	120	2	1	15.3	12.7	1.9	4.0
48	42	120	3	14.0	1042	8	2	8	0.5	090	2	1	15.1	12.6	3.9	1.6
49	31	090	3	18.2	1042	8	1	8	0.5	090	7	1	16.4	12.5	3.9	1.6

Appendix 6: Summary of survey pot lift station data, Motunau 2012. For sites R=random.

								Catch of blue cod	
Set	Date	Phase	Stratum	Site	Depth (m)	(NZST) Time set	Pot	(kg)	Number
1	23-Jan-12	1	1	B	29	8:20	1	11.8	27
1	23-Jan-12	1	1	B	32	8:26	2	6.5	15
1	23-Jan-12	1	1	B	33	8:32	3	7.6	26
1	23-Jan-12	1	1	B	33	8:37	4	5.1	25
1	23-Jan-12	1	1	B	33	8:43	5	0.3	3
1	23-Jan-12	1	1	B	34	8:50	6	0.6	2
2	23-Jan-12	1	1	D	32	10:06	6	1.5	12
2	23-Jan-12	1	1	D	31	10:11	5	4.4	20
2	23-Jan-12	1	1	D	33	10:17	4	10.7	36
2	23-Jan-12	1	1	D	26	10:22	3	27.5	78
2	23-Jan-12	1	1	D	27	10:27	2	15.3	41
2	23-Jan-12	1	1	D	25	10:33	1	9.3	30
3	23-Jan-12	1	1	G	26	11:41	1	6.2	28
3	23-Jan-12	1	1	G	18	11:46	2	11.5	30
3	23-Jan-12	1	1	G	18	11:51	3	2.1	7
3	23-Jan-12	1	1	G	21	11:55	4	5.9	17
3	23-Jan-12	1	1	G	18	12:00	5	14.8	44
3	23-Jan-12	1	1	G	20	12:05	6	8.3	22
4	23-Jan-12	1	1	J	27	13:17	6	13.1	42
4	23-Jan-12	1	1	J	26	13:21	5	5.7	21
4	23-Jan-12	1	1	J	20	13:26	4	6.6	17
4	23-Jan-12	1	1	J	26	13:31	3	9.5	30
4	23-Jan-12	1	1	J	20	13:36	2	3.1	9
4	23-Jan-12	1	1	J	30	13:41	1	2.9	8
5	23-Jan-12	1	1	K	22	14:50	1	13.8	42
5	23-Jan-12	1	1	K	15	14:55	2	0	0
5	23-Jan-12	1	1	K	19	14:58	3	16.5	40
5	23-Jan-12	1	1	K	18	15:02	4	16.1	30
5	23-Jan-12	1	1	K	19	15:07	5	18.1	39
5	23-Jan-12	1	1	K	19	15:11	6	6.3	16
6	24-Jan-12	1	1	R1	25	7:50	6	2.7	10
6	24-Jan-12	1	1	R1	25	7:54	5	3.4	15
6	24-Jan-12	1	1	R1	25	7:56	4	6.3	21
6	24-Jan-12	1	1	R1	24	7:58	3	6	23
6	24-Jan-12	1	1	R1	25	8:00	2	5	19
6	24-Jan-12	1	1	R1	24	8:03	1	6	21
7	24-Jan-12	1	1	R4	30	9:15	1	0	0
7	24-Jan-12	1	1	R4	29	9:17	2	8.6	24
7	24-Jan-12	1	1	R4	24	9:19	3	16.2	38
7	24-Jan-12	1	1	R4	23	9:21	4	28.8	59
7	24-Jan-12	1	1	R4	29	9:23	5	11.1	27
7	24-Jan-12	1	1	R4	29	9:25	6	17.2	40
8	24-Jan-12	1	1	R5	16	10:46	6	0.6	2
8	24-Jan-12	1	1	R5	17	10:48	5	10	21
8	24-Jan-12	1	1	R5	15	10:50	4	0.1	1

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot	Catch of blue cod (kg)	Catch of blue cod Number
8	24-Jan-12	1	1	R5	14	10:52	3	0	0
8	24-Jan-12	1	1	R5	14	10:54	2	0	0
8	24-Jan-12	1	1	R5	15	10:56	1	0	0
9	24-Jan-12	1	1	R3	33	15:46	1	5.9	26
9	24-Jan-12	1	1	R3	32	15:48	2	5.5	23
9	24-Jan-12	1	1	R3	31	15:50	3	3.3	12
9	24-Jan-12	1	1	R3	31	15:52	4	9.5	35
9	24-Jan-12	1	1	R3	33	15:54	5	2.1	16
9	24-Jan-12	1	1	R3	33	15:56	6	5.8	30
10	25-Jan-12	1	1	R6	29	7:43	6	4.1	10
10	25-Jan-12	1	1	R6	29	7:45	5	5.8	21
10	25-Jan-12	1	1	R6	26	7:47	4	32.5	85
10	25-Jan-12	1	1	R6	25	7:49	3	10.6	24
10	25-Jan-12	1	1	R6	29	7:51	2	2	7
10	25-Jan-12	1	1	R6	30	7:53	1	3.7	10
11	25-Jan-12	1	1	R7	31	12:58	1	1.7	15
11	25-Jan-12	1	1	R7	29	13:00	2	6.8	31
11	25-Jan-12	1	1	R7	29	13:02	3	5.3	16
11	25-Jan-12	1	1	R7	27	13:04	4	14.5	45
11	25-Jan-12	1	1	R7	30	13:06	5	4.3	20
11	25-Jan-12	1	1	R7	31	13:08	6	4.8	19
12	25-Jan-12	1	2	R2	18	14:45	6	7.2	22
12	25-Jan-12	1	2	R2	22	14:47	5	34	85
12	25-Jan-12	1	2	R2	22	14:49	4	15.5	34
12	25-Jan-12	1	2	R2	21	14:52	3	11.5	42
12	25-Jan-12	1	2	R2	23	14:54	2	14	36
12	25-Jan-12	1	2	R2	17	14:56	1	2.4	11
13	25-Jan-12	1	2	R4	28	16:08	1	2.6	10
13	25-Jan-12	1	2	R4	27	16:10	2	0.9	4
13	25-Jan-12	1	2	R4	28	16:12	3	5	18
13	25-Jan-12	1	2	R4	28	16:14	4	1.3	6
13	25-Jan-12	1	2	R4	27	16:16	5	1.7	21
13	25-Jan-12	1	2	R4	28	16:18	6	5	13
14	26-Jan-12	1	2	B	29	7:38	6	0.6	2
14	26-Jan-12	1	2	B	29	7:40	5	5	14
14	26-Jan-12	1	2	B	29	7:42	4	1.4	5
14	26-Jan-12	1	2	B	27	7:44	3	5.8	12
14	26-Jan-12	1	2	B	29	7:46	2	7.3	18
14	26-Jan-12	1	2	B	29	7:48	1	0.7	6
15	26-Jan-12	1	2	F	27	12:56	1	28.5	59
15	26-Jan-12	1	2	F	26	12:59	2	5.5	14
15	26-Jan-12	1	2	F	26	13:02	3	6	23
15	26-Jan-12	1	2	F	26	13:04	4	9	28
15	26-Jan-12	1	2	F	26	13:06	5	2.6	11
15	26-Jan-12	1	2	F	26	13:08	6	1.6	7
16	26-Jan-12	1	2	J	22	14:31	6	1.9	20
16	26-Jan-12	1	2	J	22	14:34	5	1.4	8
16	26-Jan-12	1	2	J	21	14:36	4	6.3	25

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot	Catch of blue cod (kg)	Catch of blue cod Number
16	26-Jan-12	1	2	J	18	14:38	3	7.9	27
16	26-Jan-12	1	2	J	20	14:40	2	3.8	18
16	26-Jan-12	1	2	J	21	14:43	1	1.2	14
17	26-Jan-12	1	2	R5	20	15:56	1	0	0
17	26-Jan-12	1	2	R5	20	15:58	2	2.5	12
17	26-Jan-12	1	2	R5	20	16:00	3	3.6	15
17	26-Jan-12	1	2	R5	17	16:02	4	11	33
17	26-Jan-12	1	2	R5	18	16:04	5	0	0
17	26-Jan-12	1	2	R5	19	16:06	6	0	0
18	28-Jan-12	1	2	R7	26	7:00	6	0.1	1
18	28-Jan-12	1	2	R7	25	7:03	5	0	0
18	28-Jan-12	1	2	R7	24	7:05	4	1.6	11
18	28-Jan-12	1	2	R7	25	7:07	3	0.3	3
18	28-Jan-12	1	2	R7	26	7:09	2	0	0
18	28-Jan-12	1	2	R7	26	7:11	1	0.1	2
19	28-Jan-12	1	2	R6	34	8:19	1	0.5	4
19	28-Jan-12	1	2	R6	33	8:21	2	0.1	1
19	28-Jan-12	1	2	R6	33	8:23	3	0.1	1
19	28-Jan-12	1	2	R6	33	8:25	4	0.1	1
19	28-Jan-12	1	2	R6	33	8:27	5	0	0
19	28-Jan-12	1	2	R6	34	8:29	6	0.5	5
20	28-Jan-12	1	2	M	22	9:50	6	4.6	14
20	28-Jan-12	1	2	M	21	9:52	5	2.7	10
20	28-Jan-12	1	2	M	22	9:54	4	7.9	26
20	28-Jan-12	1	2	M	19	9:56	3	16	41
20	28-Jan-12	1	2	M	20	9:58	2	15.5	40
20	28-Jan-12	1	2	M	19	10:00	1	0	0
21	29-Jan-12	1	3	R1	12	7:34	1	7.3	12
21	29-Jan-12	1	3	R1	15	7:36	2	6.7	16
21	29-Jan-12	1	3	R1	9	7:38	3	3.6	8
21	29-Jan-12	1	3	R1	15	7:40	4	0.1	1
21	29-Jan-12	1	3	R1	15	7:42	5	1.6	3
21	29-Jan-12	1	3	R1	11	7:44	6	4	11
22	29-Jan-12	1	3	R2	23	9:03	6	2.9	8
22	29-Jan-12	1	3	R2	23	9:05	5	5.5	19
22	29-Jan-12	1	3	R2	25	9:07	4	4.6	23
22	29-Jan-12	1	3	R2	24	9:09	3	0.3	2
22	29-Jan-12	1	3	R2	24	9:11	2	4.3	17
22	29-Jan-12	1	3	R2	22	9:13	1	6.6	19
23	29-Jan-12	1	3	R4	22	10:34	1	1.5	13
23	29-Jan-12	1	3	R4	22	10:36	2	0.3	1
23	29-Jan-12	1	3	R4	23	10:38	3	0.9	2
23	29-Jan-12	1	3	R4	22	10:40	4	3.8	8
23	29-Jan-12	1	3	R4	23	10:42	5	2.8	11
23	29-Jan-12	1	3	R4	23	10:44	6	0.5	1
24	30-Jan-12	1	3	R6	17	8:30	6	0	0
24	30-Jan-12	1	3	R6	16	8:32	5	0	0
24	30-Jan-12	1	3	R6	15	8:34	4	0	0

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot	Catch of blue cod (kg)	Catch of blue cod Number
24	30-Jan-12	1	3	R6	14	8:36	3	0	0
24	30-Jan-12	1	3	R6	15	8:38	2	3.9	7
24	30-Jan-12	1	3	R6	17	8:40	1	1.2	2
25	30-Jan-12	1	3	R7	23	9:52	1	0	0
25	30-Jan-12	1	3	R7	23	9:54	2	0	0
25	30-Jan-12	1	3	R7	23	9:56	3	0	0
25	30-Jan-12	1	3	R7	23	9:58	4	0	0
25	30-Jan-12	1	3	R7	22	10:00	5	0	0
25	30-Jan-12	1	3	R7	22	10:02	6	0	0
26	30-Jan-12	1	3	Z	21	11:20	6	5.1	11
26	30-Jan-12	1	3	Z	20	11:22	5	6.3	15
26	30-Jan-12	1	3	Z	19	11:24	4	2.5	10
26	30-Jan-12	1	3	Z	18	11:26	3	1.7	5
26	30-Jan-12	1	3	Z	20	11:28	2	10.5	25
26	30-Jan-12	1	3	Z	21	11:30	1	12.5	26
27	30-Jan-12	1	3	E	18	13:00	1	0	0
27	30-Jan-12	1	3	E	18	13:02	2	0	0
27	30-Jan-12	1	3	E	18	13:04	3	3	6
27	30-Jan-12	1	3	E	18	13:06	4	0	0
27	30-Jan-12	1	3	E	13	13:08	5	14	29
27	30-Jan-12	1	3	E	18	13:10	6	3.2	9
28	31-Jan-12	1	3	ae	22	12:06	6	9.6	22
28	31-Jan-12	1	3	ae	23	12:08	5	2.9	8
28	31-Jan-12	1	3	ae	22	12:10	4	7.6	15
28	31-Jan-12	1	3	ae	21	12:12	3	13.5	29
28	31-Jan-12	1	3	ae	22	12:14	2	11.6	18
28	31-Jan-12	1	3	ae	23	12:16	1	9	31
29	31-Jan-12	1	3	R3	7	13:34	1	2.4	4
29	31-Jan-12	1	3	R3	7	13:36	2	0	0
29	31-Jan-12	1	3	R3	9	13:38	3	0	0
29	31-Jan-12	1	3	R3	10	13:40	4	0	0
29	31-Jan-12	1	3	R3	10	13:42	5	0	0
29	31-Jan-12	1	3	R3	9	13:44	6	0	0
30	2-Feb-12	1	2	2D	23	11:55	6	7.5	16
30	2-Feb-12	1	2	2D	23	11:57	5	9.2	27
30	2-Feb-12	1	2	2D	21	11:59	4	11.5	34
30	2-Feb-12	1	2	2D	20	12:01	3	9.5	27
30	2-Feb-12	1	2	2D	20	12:03	2	10.1	23
30	2-Feb-12	1	2	2D	19	12:05	1	6.3	20
31	2-Feb-12	1	2	2R3	17	13:18	1	0.6	4
31	2-Feb-12	1	2	2R3	17	13:20	2	22.5	40
31	2-Feb-12	1	2	2R3	17	13:22	3	1.8	8
31	2-Feb-12	1	2	2R3	17	13:24	4	1.6	7
31	2-Feb-12	1	2	2R3	17	13:26	5	2.9	14
31	2-Feb-12	1	2	2R3	17	13:28	6	0.3	3
32	3-Feb-12	1	3	3G	21	12:08	6	4.5	13
32	3-Feb-12	1	3	3G	22	12:10	5	4.4	14
32	3-Feb-12	1	3	3G	22	12:12	4	15.7	33

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot	Catch of blue cod (kg)	Catch of blue cod Number
32	3-Feb-12	1	3	3G	22	12:14	3	6.6	20
32	3-Feb-12	1	3	3G	22	12:16	2	0.5	2
32	3-Feb-12	1	3	3G	22	12:18	1	0	0
33	3-Feb-12	1	3	3A	19	13:38	1	6.8	17
33	3-Feb-12	1	3	3A	16	13:40	2	6	9
33	3-Feb-12	1	3	3A	12	13:42	3	3.5	5
33	3-Feb-12	1	3	3A	16	13:44	4	2.3	5
33	3-Feb-12	1	3	3A	19	13:46	5	2	6
33	3-Feb-12	1	3	3A	18	13:48	6	0.6	2
34	4-Feb-12	2	2	R8	18	7:40	6	0	0
34	4-Feb-12	2	2	R8	19	7:42	5	0.7	2
34	4-Feb-12	2	2	R8	16	7:44	4	1.6	5
34	4-Feb-12	2	2	R8	18	7:46	3	0	0
34	4-Feb-12	2	2	R8	19	7:48	2	0	0
34	4-Feb-12	2	2	R8	18	7:50	1	0	0
35	4-Feb-12	2	2	R9	17	9:00	1	6.2	18
35	4-Feb-12	2	2	R9	20	9:02	2	4.8	16
35	4-Feb-12	2	2	R9	19	9:04	3	8.5	21
35	4-Feb-12	2	2	R9	20	9:06	4	0.3	1
35	4-Feb-12	2	2	R9	20	9:08	5	5.2	17
35	4-Feb-12	2	2	R9	21	9:10	6	2.4	10
36	4-Feb-12	2	3	R8	23	10:45	6	1.9	5
36	4-Feb-12	2	3	R8	23	10:47	5	0.5	4
36	4-Feb-12	2	3	R8	23	10:49	4	2.8	7
36	4-Feb-12	2	3	R8	20	10:51	3	1.1	2
36	4-Feb-12	2	3	R8	22	10:53	2	4.6	5
36	4-Feb-12	2	3	R8	24	10:55	1	0.2	3
37	5-Feb-12	2	3	I	26	7:27	1	3.4	15
37	5-Feb-12	2	3	I	27	7:29	2	2.1	11
37	5-Feb-12	2	3	I	24	7:31	3	6.7	20
37	5-Feb-12	2	3	I	24	7:33	4	7.8	20
37	5-Feb-12	2	3	I	25	7:35	5	4.8	19
37	5-Feb-12	2	3	I	23	7:37	6	3.9	8
38	5-Feb-12	2	3	P	15	8:55	6	0	0
38	5-Feb-12	2	3	P	16	8:57	5	1.8	5
38	5-Feb-12	2	3	P	13	8:59	4	0.6	1
38	5-Feb-12	2	3	P	17	9:01	3	3.6	11
38	5-Feb-12	2	3	P	17	9:03	2	0	0
38	5-Feb-12	2	3	P	16	9:05	1	0	0
39	5-Feb-12	2	3	Q	15	10:13	1	0	0
39	5-Feb-12	2	3	Q	14	10:15	2	3.9	7
39	5-Feb-12	2	3	Q	18	10:17	3	2.3	6
39	5-Feb-12	2	3	Q	18	10:19	4	4.8	16
39	5-Feb-12	2	3	Q	18	10:21	5	0.7	1
39	5-Feb-12	2	3	Q	18	10:23	6	0	0

Appendix 7: Summary of the Motunau 2012 survey oceanographic environmental station data recorded in the format of the trawl data base.

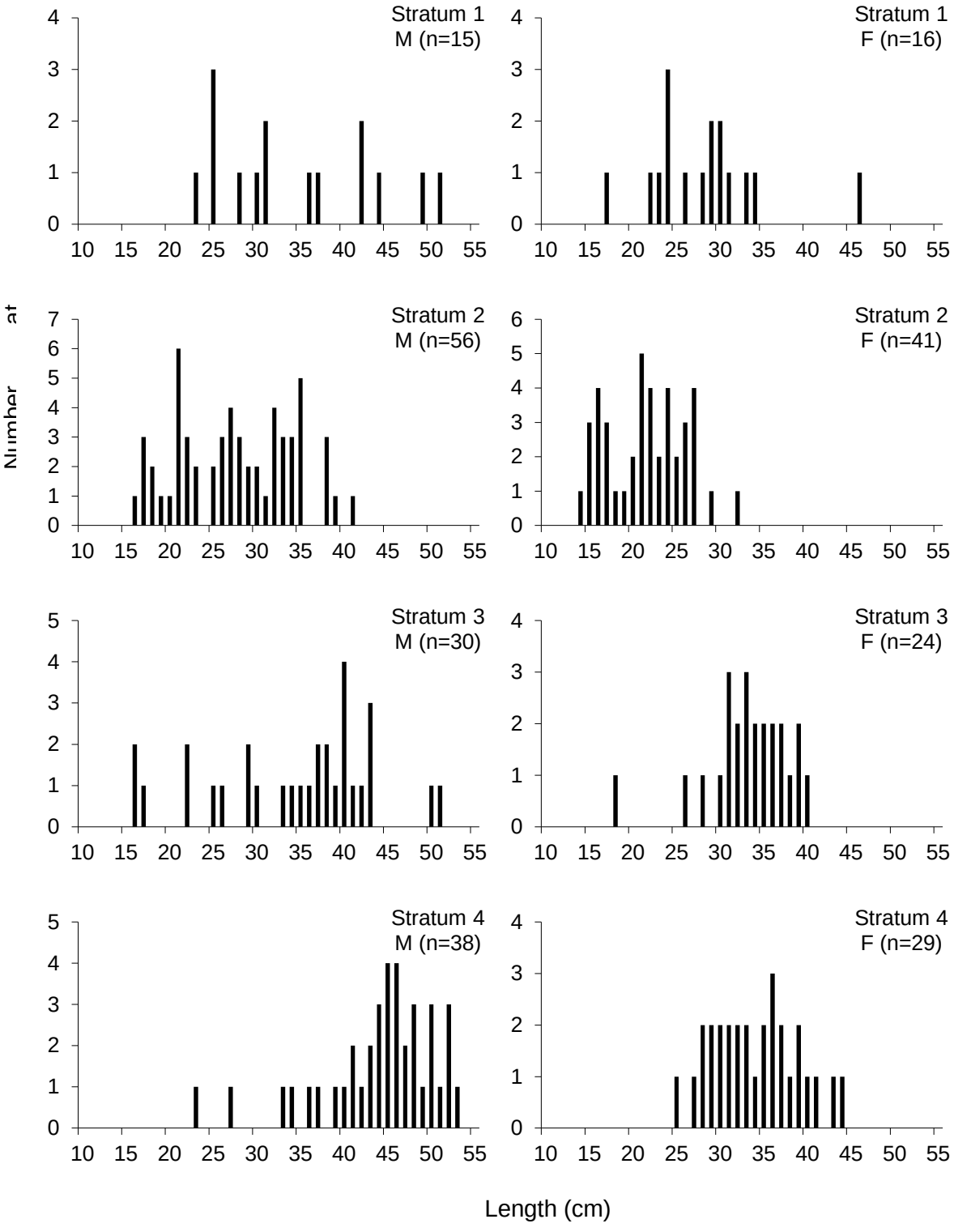
Depths are measured in metres, directions in compass degrees (999 = nil), wind force in the Beaufort scale, temperatures in degrees Celcius (* not available), air pressure in millibars, cloud cover in oktas, sea condition in the Douglas scale, sea colour in a categorical scale from 1 (deep blue) to 8 (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	ADCP 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	29	240	4	13	1032	4	5	5	2.5	130	7	2	*	*	7.2	2.5
2	25	200	4	15	1029	4	4	4	2.0	130	7	3	*	*	6.9	2.5
3	26	180	4	17	1029	7	5	4	2.0	150	7	4	*	*	6.4	2.8
4	30	180	4	19	1029	7	4	4	2.0	150	7	4	*	*	6.1	2.9
5	22	180	3	18	1028	7	4	4	1.8	150	7	5	*	*	4.7	3.5
6	24	270	2	14	1028	5	3	4	1.0	120	7	2	*	*	2.4	4.0
7	29	210	4	16	1029	6	3	4	1.0	120	7	4	*	*	5.8	4.2
8	15	220	3	17	1029	7	3	4	1.0	120	7	2	*	*	4.2	4.1
9	32	120	2	17	1029	1	3	3	1.0	120	7	3	*	*	3.4	6.0
10	32	060	2	16	1029	7	2	4	1.0	110	7	3	*	*	2.6	5.3
11	30	060	3	18	1022	8	2	4	1.0	110	7	3	*	*	3.6	5.9
12	22	070	3	16	1022	8	2	4	1.0	110	7	3	*	*	3.7	4.8
13	27	060	4	16	1017	8	2	4	1.0	110	7	2	*	*	5.6	5.6
14	28	330	4	15	1017	0	2	4	1.0	130	7	3	*	*	3.9	5.7
15	28	300	4	23	1013	0	5	4	1.0	030	7	3	*	*	7.2	6.1
16	22	100	3	24	1015	5	4	4	1.0	090	7	3	*	*	5.3	5.3
17	19	270	4	26	1015	6	4	7	1.0	090	4	2	*	*	8.6	5.8
18	25	030	2	11	1016	0	3	7	0.5	050	4	1	*	*	2.0	5.8
19	34	310	4	16	1017	0	7	3	0.5	050	4	1	*	*	8.1	5.5
20	19	320	3	22	1017	0	7	3	0.5	050	7	4	*	*	6.9	5.8
21	14	060	3	11	1013	7	3	7	0.5	090	7	3	*	*	3.9	5.0
22	24	130	4	12	1015	8	3	7	0.5	090	7	3	*	*	6.7	5.0
23	24	130	4	12	1015	8	4	7	0.5	090	7	2	*	*	7.8	5.3
24	15	055	3	13	1031	5	3	7	0.5	030	7	2	*	*	4.2	3.1
25	23	040	3	18	1031	7	3	7	0.5	030	4	1	*	*	4.2	7.5
26	20	090	4	19	1030	5	4	7	1.0	070	7	3	*	*	6.1	4.1
27	19	090	4	19	1030	5	4	7	1.0	070	7	3	*	*	6.4	4.2
28	21	330	5	21	1018	0	5	6	0.5	090	7	3	*	*	9.2	6.0
29	9	270	4	23	1018	7	2	8	0.0	999	7	1	*	*	6.4	3.7

Appendix 7– ***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	22	090	2	16	1031	8	3	7	0.8	090	7	4	*	*	2.1	5.2
31	17	030	1	20	1031	7	3	7	0.5	090	3	1	*	*	1.9	5.4
32	22	050	3	16	1032	8	3	7	0.5	040	7	3	*	*	4.2	6.1
33	20	030	3	15	1032	8	4	7	0.8	070	7	4	*	*	4.8	5.4
34	17	090	1	16	1029	7	4	7	2.5	045	7	3	*	*	1.7	4.3
35	20	030	1	22	1029	3	4	7	2.5	045	7	3	*	*	1.1	4.6
36	23	060	3	20	1029	3	4	7	2.0	045	7	2	*	*	5.6	3.8
37	26	030	4	15	1028	8	4	8	3.0	330	7	3	*	*	6.1	2.4
38	15	050	3	16	1028	8	4	8	2.5	330	7	4	*	*	3.6	3.4
39	15	030	4	15	1029	8	3	8	2.5	330	7	3	*	*	6.7	3.3

Appendix 8: Unscaled length frequency distributions of blue cod for each stratum from which otoliths were used in the Kaikoura 2011 age length keys.



Appendix 9: Between-reader comparisons (using first independent readings only) for otolith data collected in Kaikoura 2011.

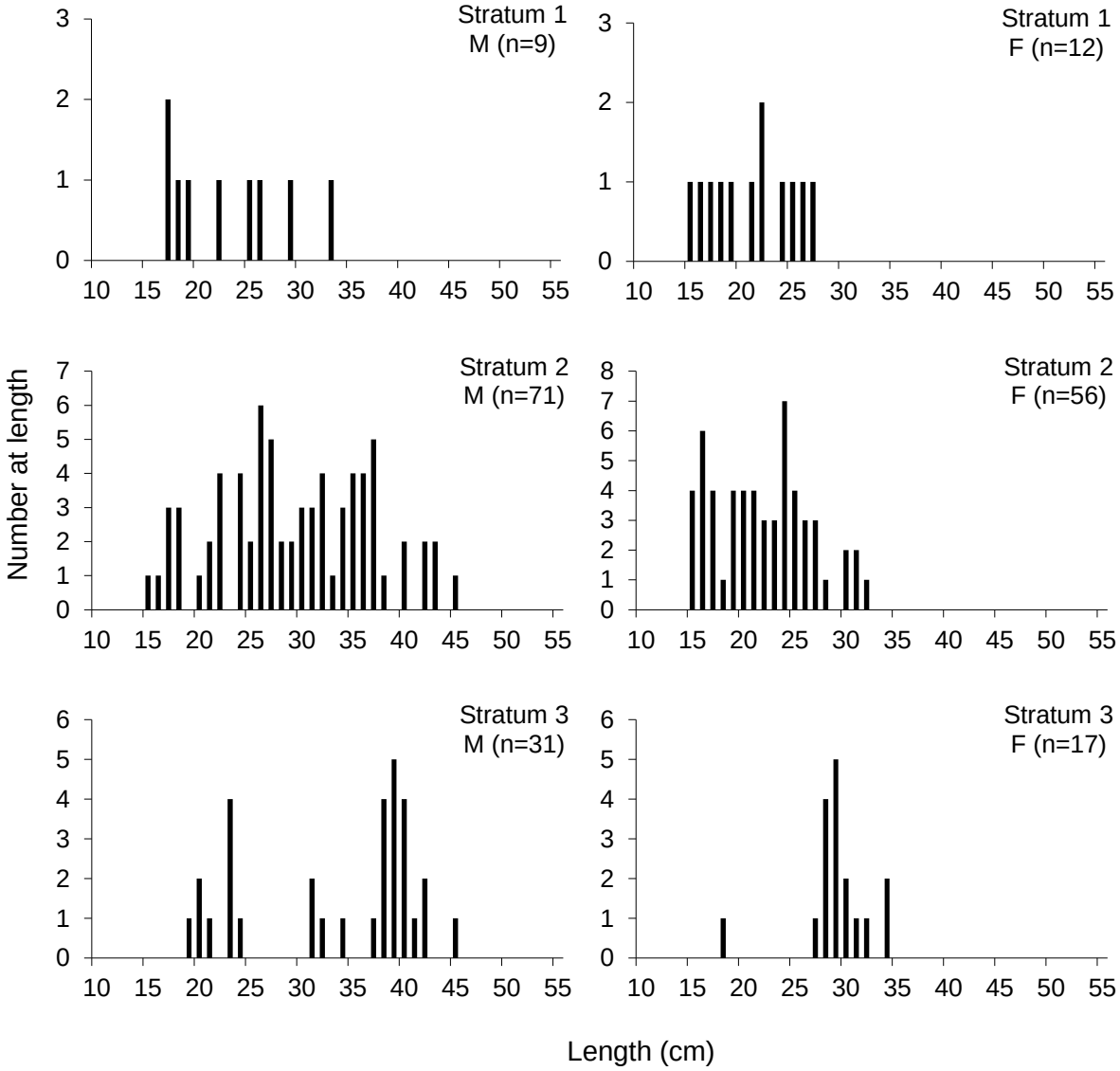
Reader two	Age class (reader one)																	
difference	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	>18	Total
-9																	2	
-8																	3	
-7																	6	
-6														1	2	1	6	10
-5												1		2	1		3	7
-4								1	1	1	2	2				2	11	20
-3					1	5	1	1	6	4		2	1	2	1	2	7	33
-2			2			3	4	3	1	2	1	2		4	2	1	6	31
-1	1	10	6	5	5	3	7	1			2	6		2	1		4	53
0	14	5	13	7	6	2	3	2	2	1	2		1	1		1	3	63
1		2	1				2	1	1						1		4	12
2								2			1	1	1			1	0	6
3							1				1						1	3
Total	15	17	22	12	12	13	18	11	11	8	9	14	3	12	8	8	56	238
% agreement	93	29	59	58	50	15	17	18	18	13	22	0	33	8	0	13	5	26

Appendix 10: Independent reader comparisons with agreed age from otolith data collected in Kaikoura 2011.

Reader two	Agreed age class																	
difference	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	>17	Total
-5																	1	1
-4												1	1		1		1	4
-3												1					6	7
-2				1		1	2		1	1		1	2		4	2	10	25
-1			4	5	3	5	3	2			1	2	4	3	3	2	7	44
0	1	21	7	21	10	12	16	9	7	8	7	7	3	5	5	1	18	158
1				1			1		1	1				1	1	1	1	8
2																	1	1
3												1						1
Total	1	21	11	28	13	18	22	11	9	10	8	13	10	9	14	6	33	249
% agreement	100	100	64	75	77	67	73	82	78	80	88	54	30	56	36	17	55	63

Reader one	Agreed age class																	
difference	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	>17	Total
-3											1	1						2
-2														1			1	2
-1				2					2	1	1		1	1	1		4	13
0		14	8	19	8	8	5	3	3	2	1	4	4	1	4	3	12	99
1	1	7	3	4	3	4	8	1		1	1	4		2	2	1	4	46
2				1	2	4	4	2	3	1	2		2		4		12	37
3				2		1	5	3		1	1	3		1		1	4	22
4						1		1	1					1	1		4	9
5								1		1	1		1		1		1	6
6										2			1	1	1	1	2	8
7														1			1	2
8										1								1
9												1	1					2
Total	1	21	11	28	13	18	22	11	9	10	8	13	10	9	14	6	45	249
% agreement	0	67	73	68	62	44	23	27	33	20	13	31	40	11	29	50	27	40

Appendix 11: Unscaled length frequency distributions of blue cod for each stratum from which otoliths were used in the Motunau 2012 age length keys.



Appendix 12: Between-reader comparisons (using first independent readings only) for otolith data collected in Motunau 2012.

Reader two	Age class (reader one)																	
difference	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	>17	Total
-4													1					1
-3																		0
-2				1														1
-1			6	3	2	2	3	2										18
0	1	31	19	17	19	9	6	4	16	7	9	1	4	6	5	2		156
1				1				1	1		2	2	5		4			16
2															2			2
3											1			1				2
Total	1	31	25	22	21	11	9	7	17	7	12	3	10	7	11	2		196
% agreement	100	100	76	77	90	82	67	57	94	100	75	33	40	86	45	100		80

Appendix 13: Independent reader comparisons with agreed age from otolith data collected in Motunau 2012.

Reader one	Agreed age class																	
difference	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	>17	Total
-3											1							1
-2				1			1								1			3
-1				2	2	1	1		2	1	3	1	5	1	3	1		23
0	1	29	25	18	18	6	7	7	15	5	6	2	5	5	6	1		156
1		2		1	1	4				1	2			1	1			13
Total	1	31	25	22	21	11	9	7	17	7	12	3	10	7	11	2		196
% agreement	100	94	100	82	86	55	78	100	88	71	50	67	50	71	55	50		80

Reader two	Agreed age class																	
difference	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	>17	Total
-4													1					1
-3																		0
-2				1														1
-1			6	3	2	2	3	2										18
0	1	31	19	17	19	9	6	4	16	7	9	1	4	6	5	2		156
1				1				1	1		2	2	5		4			16
2															2			2
3											1			1				2
Total	1	31	25	22	21	11	9	7	17	7	12	3	10	7	11	2		196
% agreement	100	100	76	77	90	82	67	57	94	100	75	33	40	86	45	100		80

Appendix 14: The proportion of fish at age and length and the total number at length and at age for male blue cod sampled from the 2011 Kaikoura survey (age -length-key, ALK).

	Age (years)																										
Length	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	26	27	28	30	31	Total
16	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	0	0	3
17	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	0	0	4
18	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	0	0	2
19	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	0	0	1
20	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	0	1
21	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	0	0	0	0	6
22	0	0.2	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
23	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
25	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	0	6
26	0	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	4
27	0	0	0.2	0.2	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
28	0	0	0	0.25	0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
29	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	0	4
30	0	0	0	0	0.25	0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
31	0	0	0	0	0.33	0.33	0	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
32	0	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
33	0	0	0	0	0	0.4	0.4	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
34	0	0	0	0	0	0.4	0.2	0	0	0	0.2	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
35	0	0	0	0	0	0	0.5	0.33	0	0	0	0	0	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	6
36	0	0	0	0	0	0	0	0	0.67	0	0	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
37	0	0	0	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	4
38	0	0	0	0	0	0	0	0	0.4	0.2	0	0.2	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
39	0	0	0	0	0	0	0	0	0.33	0	0	0	0	0.33	0	0.33	0	0	0	0	0	0	0	0	0	0	0	3
40	0	0	0	0	0	0	0	0	0	0.2	0.2	0.4	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
41	0	0	0	0	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
42	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	0	4
43	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0.2	0.2	0.4	0	0	0	0	0	0	0	0	0	0	0	5
44	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0.5	0	0	0	0.25	0	0	0	0	0	0	0	0	0	4
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0.25	0.25	0	0	0.25	0	0	0	0	0	0	4
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0	0.25	0	0	0.25	0.25	0	0	4
47	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	2
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0	0	0	0	0.67	0	0	0	3
49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0	0.25	0.25	0	0	0.25	4
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0.67	0	0	0	3
52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.67	0	0	0.33	0	3
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	1	0	1
Total	11	5	14	7	11	14	7	3	7	4	6	7	4	8	2	4	1	3	2	0	3	2	4	6	1	2	1	139

Appendix 15: The proportion of fish at age and length and the total number at length and at age for female blue cod sampled from the 2011 Kaikoura survey (age -length-key, ALK).

	Age (years)																									
Length	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	Total
14	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	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	3
16	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	4
17	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	4
18	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
19	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
20	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	2
21	0	0	0.2	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
22	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	0	5
23	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	3
24	0	0	0	0	0.43	0.43	0.14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
25	0	0	0	0.67	0	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
26	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
27	0	0	0	0	0.2	0.2	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
28	0	0	0	0	0	0	0	0.5	0	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
29	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	0	5
30	0	0	0	0	0	0	0	0.2	0.4	0.2	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	5
31	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	0	0	6
32	0	0	0	0	0	0	0	0	0.4	0	0	0.4	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	5
33	0	0	0	0	0	0	0	0	0	0	0.17	0.33	0.17	0.17	0.17	0	0	0	0	0	0	0	0	0	0	0	6
34	0	0	0	0	0	0	0	0.25	0	0	0	0.25	0	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	4
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0.25	0.5	0	0	0	0	0	0	0	0	0	0	4
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0.2	0	0.4	0	0	0	0	0.2	0	0	0	0	5
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0	0.5	0.25	0	0	0	0	0	0	0	4
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0.5	0	0	0	0	0	2
39	0	0	0	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	4
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0.5	0	0	0	2
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
43	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	0	1
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
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	0	1	1
Total	1	10	6	14	6	7	8	4	6	3	4	7	3	5	6	4	5	2	1	0	2	1	2	1	1	1	110

Appendix 16: Mean age-at-length for the 2011 Kaikoura survey.

	Males		Females		All fish	
Length (cm)	N	Mean age	N	Mean age	N	Mean age
14	0	0.0	1	2.0	1	2.0
15	0	0.0	3	3.0	3	3.0
16	3	3.0	4	3.0	7	3.0
17	4	3.0	4	3.5	8	3.3
18	2	3.5	2	4.5	4	4.0
19	1	3.0	1	3.0	2	3.0
20	1	4.0	2	4.0	3	4.0
21	6	4.0	5	4.8	11	4.4
22	5	4.8	5	5.2	10	5.0
23	4	5.0	3	5.0	7	5.0
24	0	0.0	7	6.7	7	6.7
25	6	5.5	3	5.7	9	5.6
26	4	6.5	5	7.2	9	6.9
27	5	6.4	5	7.4	10	6.9
28	4	6.8	4	10.3	8	8.5
29	4	8.0	5	9.4	9	8.8
30	4	7.8	5	11.0	9	9.6
31	3	8.3	6	13.0	9	11.4
32	4	8.0	5	12.6	9	10.6
33	5	9.6	6	13.8	11	11.9
34	5	10.4	4	13.3	9	11.7
35	6	10.5	4	16.3	10	12.8
36	3	12.0	5	18.0	8	15.8
37	4	12.0	4	18.8	8	15.4
38	5	12.6	2	20.0	7	14.7
39	3	15.0	4	18.5	7	17.0
40	5	13.6	2	20.0	7	15.4
41	4	12.5	1	24.0	5	14.8
42	4	16.5	0	0.0	4	16.5
43	5	16.8	1	26.0	6	18.3
44	4	16.8	1	25.0	5	18.4
45	4	20.0	0	0.0	4	20.0
46	4	24.8	1	27.0	5	25.2
47	2	16.5	0	0.0	2	16.5
48	3	25.0	0	0.0	3	25.0
49	2	24.0	0	0.0	2	24.0
50	4	26.8	0	0.0	4	26.8
51	3	26.7	0	0.0	3	26.7
52	3	27.3	0	0.0	3	27.3
53	1	30.0	0	0.0	1	30.0
Total	139	12.0	110	10.6	249	11.4

Appendix 17: 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 Motunau survey (age -length-key, ALK).

	Age (years)																	
Length	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
15	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
16	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
17	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
18	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	4
19	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	2
20	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3
21	0	0	0	0.67	0.33	0	0	0	0	0	0	0	0	0	0	0	0	3
22	0	0	0	0.6	0.4	0	0	0	0	0	0	0	0	0	0	0	0	5
23	0	0	0	0	0.75	0.25	0	0	0	0	0	0	0	0	0	0	0	4
24	0	0	0	0.4	0.4	0.2	0	0	0	0	0	0	0	0	0	0	0	5
25	0	0	0	0	0.67	0.33	0	0	0	0	0	0	0	0	0	0	0	3
26	0	0	0	0	0.14	0.43	0.29	0.14	0	0	0	0	0	0	0	0	0	7
27	0	0	0	0	0	0.8	0.2	0	0	0	0	0	0	0	0	0	0	5
28	0	0	0	0	0	0.5	0	0.5	0	0	0	0	0	0	0	0	0	2
29	0	0	0	0	0	0.33	0	0.67	0	0	0	0	0	0	0	0	0	3
30	0	0	0	0	0	0	0.33	0.33	0	0.33	0	0	0	0	0	0	0	3
31	0	0	0	0	0	0	0	0.2	0.2	0.6	0	0	0	0	0	0	0	5
32	0	0	0	0	0	0	0	0	0.2	0.6	0.2	0	0	0	0	0	0	5
33	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2
34	0	0	0	0	0	0	0	0	0	0	0.5	0.25	0	0.25	0	0	0	4
35	0	0	0	0	0	0	0	0	0	0	0.25	0	0	0.75	0	0	0	4
36	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	4
37	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0.33	0.17	0	0	6
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0.4	0.2	0	5
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0.4	0.4	0	5
40	0	0	0	0	0	0	0	0	0	0	0	0.17	0	0	0.17	0.5	0.17	6
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0.75	0	4
43	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5	2
Total	0	0	10	13	11	12	4	6	4	7	4	9	2	9	7	11	2	111

Appendix 18: 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 Motunau survey (age -length-key, ALK).

	Age (years)																	
Length	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
15	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
16	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
17	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
18	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	4
19	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	2
20	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3
21	0	0	0	0.67	0.33	0	0	0	0	0	0	0	0	0	0	0	0	3
22	0	0	0	0.6	0.4	0	0	0	0	0	0	0	0	0	0	0	0	5
23	0	0	0	0	0.75	0.25	0	0	0	0	0	0	0	0	0	0	0	4
24	0	0	0	0.4	0.4	0.2	0	0	0	0	0	0	0	0	0	0	0	5
25	0	0	0	0	0.67	0.33	0	0	0	0	0	0	0	0	0	0	0	3
26	0	0	0	0	0.14	0.43	0.29	0.14	0	0	0	0	0	0	0	0	0	7
27	0	0	0	0	0	0.8	0.2	0	0	0	0	0	0	0	0	0	0	5
28	0	0	0	0	0	0.5	0	0.5	0	0	0	0	0	0	0	0	0	2
29	0	0	0	0	0	0.33	0	0.67	0	0	0	0	0	0	0	0	0	3
30	0	0	0	0	0	0	0.33	0.33	0	0.33	0	0	0	0	0	0	0	3
31	0	0	0	0	0	0	0	0.2	0.2	0.6	0	0	0	0	0	0	0	5
32	0	0	0	0	0	0	0	0	0.2	0.6	0.2	0	0	0	0	0	0	5
33	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2
34	0	0	0	0	0	0	0	0	0	0	0.5	0.25	0	0.25	0	0	0	4
35	0	0	0	0	0	0	0	0	0	0	0.25	0	0	0.75	0	0	0	4
36	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	4
37	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0.33	0.17	0	0	6
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0.4	0.2	0	5
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0.4	0.4	0	5
40	0	0	0	0	0	0	0	0	0	0	0	0.17	0	0	0.17	0.5	0.17	6
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0.75	0	4
43	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5	2
Total	0	0	10	13	11	12	4	6	4	7	4	9	2	9	7	11	2	111

Appendix 19: Mean age-at-length for the 2012 Motunau survey.

	Males		Females		All fish	
Length (cm)	N	Mean age	N	Mean age	N	Mean age
15	1	3.0	5	3.0	6	3.0
16	1	3.0	7	3.0	8	3.0
17	5	3.0	5	3.0	10	3.0
18	4	3.5	3	3.0	7	3.3
19	2	3.5	5	3.6	7	3.6
20	3	4.0	4	3.8	7	3.9
21	3	4.3	5	4.4	8	4.4
22	5	4.4	5	4.8	10	4.6
23	4	5.3	3	5.3	7	5.3
24	5	4.8	8	5.5	13	5.2
25	3	5.3	5	6.4	8	6.0
26	7	6.4	4	7.0	11	6.6
27	5	6.2	5	7.4	10	6.8
28	2	7.0	5	9.8	7	9.0
29	3	7.3	5	9.8	8	8.9
30	3	8.3	4	10.8	7	9.7
31	5	9.4	3	12.0	8	10.4
32	5	10.0	2	10.5	7	10.1
33	2	9.0	0	0.0	2	9.0
34	4	12.0	2	12.0	6	12.0
35	4	13.3	0	0.0	4	13.3
36	4	12.0	0	0.0	4	12.0
37	6	13.2	0	0.0	6	13.2
38	5	14.8	0	0.0	5	14.8
39	5	15.2	0	0.0	5	15.2
40	6	15.3	0	0.0	6	15.3
41	1	16.0	0	0.0	1	16.0
42	4	15.8	0	0.0	4	15.8
43	2	13.0	0	0.0	2	13.0
45	2	16.5	0	0.0	2	16.5
Total	111	9.1	85	6.1	196	7.8

Appendix 20: Parameter values used in the 2011 Kaikoura SPR analyses.

	Males				Females			
Age	Length	Weight	Selectivity	Maturity	Length	Weight	Selectivity	Maturity
1	10.6	0.018	0	0	12.2	0.023	0	0
2	14.3	0.044	0	0	14.8	0.044	0	0
3	17.7	0.085	0	0	17.2	0.071	0	0
4	20.7	0.139	0	0.1	19.4	0.104	0	0.1
5	23.5	0.206	0	0.4	21.4	0.144	0	0.4
6	26.1	0.284	0	0.7	23.3	0.189	0	0.7
7	28.4	0.370	0	1	25.0	0.238	0	1
8	30.6	0.463	1	1	26.6	0.290	0	1
9	32.6	0.561	1	1	28.0	0.345	0	1
10	34.3	0.663	1	1	29.4	0.401	0	1
11	36.0	0.765	1	1	30.6	0.459	1	1
12	37.5	0.868	1	1	31.8	0.517	1	1
13	38.9	0.970	1	1	32.8	0.574	1	1
14	40.1	1.070	1	1	33.8	0.631	1	1
15	41.3	1.168	1	1	34.7	0.687	1	1
16	42.3	1.262	1	1	35.5	0.741	1	1
17	43.3	1.352	1	1	36.3	0.793	1	1
18	44.1	1.439	1	1	37.0	0.844	1	1
19	44.9	1.521	1	1	37.6	0.893	1	1
20	45.7	1.599	1	1	38.2	0.939	1	1
21	46.3	1.673	1	1	38.7	0.983	1	1
22	46.9	1.742	1	1	39.2	1.025	1	1
23	47.5	1.807	1	1	39.7	1.065	1	1
24	48.0	1.868	1	1	40.1	1.103	1	1
25	48.5	1.925	1	1	40.5	1.138	1	1
26	48.9	1.978	1	1	40.9	1.172	1	1
27	49.3	2.027	1	1	41.2	1.203	1	1
28	49.7	2.073	1	1	41.5	1.233	1	1
29	50.0	2.116	1	1	41.8	1.260	1	1
30	50.3	2.155	1	1	42.1	1.286	1	1
31	50.6	2.191	1	1	42.3	1.310	1	1
32	50.8	2.225	1	1	42.6	1.333	1	1
33	51.0	2.256	1	1	42.8	1.354	1	1
34	51.3	2.285	1	1	42.9	1.373	1	1
35	51.4	2.311	1	1	43.1	1.391	1	1
36	51.6	2.336	1	1	43.3	1.408	1	1
37	51.8	2.358	1	1	43.4	1.424	1	1
38	51.9	2.379	1	1	43.6	1.438	1	1
39	52.1	2.398	1	1	43.7	1.452	1	1
40	52.2	2.415	1	1	43.8	1.464	1	1
41	52.3	2.431	1	1	43.9	1.476	1	1
42	52.4	2.446	1	1	44.0	1.486	1	1
43	52.5	2.460	1	1	44.1	1.496	1	1
44	52.6	2.472	1	1	44.2	1.506	1	1
45	52.7	2.483	1	1	44.3	1.514	1	1
46	52.7	2.494	1	1	44.3	1.522	1	1
47	52.8	2.503	1	1	44.4	1.529	1	1
48	52.8	2.512	1	1	44.5	1.536	1	1
49	52.9	2.520	1	1	44.5	1.542	1	1
50	53.0	2.527	1	1	44.6	1.548	1	1

Appendix 21: Parameter values used in the 2012 Motunau SPR analyses.

	Males				Females			
Age	Length (cm)	Weight (kg)	Selectivity	Maturity	Length (cm)	Weight (kg)	Selectivity	Maturity
1	11.5	0.025	0	0	11.6	0.025	0	0
2	14.8	0.053	0	0	14.6	0.051	0	0
3	17.8	0.094	0	0	17.4	0.086	0	0
4	20.6	0.146	0	0.1	19.8	0.128	0	0.1
5	23.1	0.208	0	0.4	22.0	0.177	0	0.4
6	25.5	0.278	0	0.7	23.9	0.229	0	0.7
7	27.6	0.355	0	1	25.6	0.283	0	1
8	29.5	0.437	0	1	27.2	0.339	0	1
9	31.3	0.523	1	1	28.6	0.394	0	1
10	33.0	0.610	1	1	29.8	0.448	0	1
11	34.5	0.698	1	1	30.9	0.501	1	1
12	35.8	0.786	1	1	31.9	0.551	1	1
13	37.1	0.873	1	1	32.7	0.599	1	1
14	38.3	0.958	1	1	33.5	0.643	1	1
15	39.3	1.040	1	1	34.2	0.685	1	1
16	40.3	1.119	1	1	34.8	0.724	1	1
17	41.2	1.196	1	1	35.4	0.760	1	1
18	42.0	1.269	1	1	35.9	0.793	1	1
19	42.7	1.338	1	1	36.3	0.823	1	1
20	43.4	1.403	1	1	36.7	0.851	1	1
21	44.0	1.465	1	1	37.1	0.876	1	1
22	44.6	1.523	1	1	37.4	0.899	1	1
23	45.1	1.578	1	1	37.7	0.920	1	1
24	45.6	1.629	1	1	37.9	0.938	1	1
25	46.0	1.677	1	1	38.1	0.955	1	1
26	46.4	1.722	1	1	38.3	0.971	1	1
27	46.8	1.763	1	1	38.5	0.985	1	1
28	47.1	1.802	1	1	38.7	0.997	1	1
29	47.4	1.837	1	1	38.8	1.008	1	1
30	47.7	1.871	1	1	39.0	1.018	1	1
31	47.9	1.901	1	1	39.1	1.027	1	1
32	48.2	1.930	1	1	39.2	1.036	1	1
33	48.4	1.956	1	1	39.3	1.043	1	1
34	48.6	1.981	1	1	39.3	1.049	1	1
35	48.8	2.003	1	1	39.4	1.055	1	1
36	48.9	2.024	1	1	39.5	1.060	1	1
37	49.1	2.043	1	1	39.5	1.065	1	1
38	49.2	2.060	1	1	39.6	1.069	1	1
39	49.3	2.076	1	1	39.6	1.073	1	1
40	49.5	2.091	1	1	39.7	1.076	1	1
41	49.6	2.105	1	1	39.7	1.079	1	1
42	49.7	2.118	1	1	39.7	1.082	1	1
43	49.8	2.129	1	1	39.8	1.085	1	1
44	49.8	2.140	1	1	39.8	1.087	1	1
45	49.9	2.150	1	1	39.8	1.089	1	1
46	50.0	2.158	1	1	39.8	1.090	1	1
47	50.0	2.167	1	1	39.8	1.092	1	1
48	50.1	2.174	1	1	39.9	1.093	1	1
49	50.2	2.181	1	1	39.9	1.094	1	1
50	50.2	2.188	1	1	39.9	1.096	1	1