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Relative abundance, population structure, and stock status of blue cod in Paterson Inlet in 2014. Concurrent fixed and random site potting surveys.

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This report describes the results of the 2014 Paterson Inlet blue cod (*Parapercis colias*) potting surveys. This is the third fixed and second concurrent random site allocation potting survey to be undertaken in the time series for Paterson Inlet. Between 19 November and 12 December 2014, sixty-three sites were surveyed (6 pots per site, 378 pot lifts) from five strata throughout Paterson Inlet. The catch of each pot was weighed, and the length and sex of blue cod was recorded. Otoliths were read from 215 blue cod collected from both random and fixed sites representatively selected throughout Paterson Inlet (except the marine reserve). 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 25 phase 1 sites, with no additional sites allocated in phase 2. Total blue cod catch was 746 kg, consisting of 1284 fish. For all size blue cod catch rates by stratum ranged from 1.1 to 7.7 kg.pot^{-1}, with an overall mean catch rate of 5.2 kg.pot^{-1} and coefficient of variation (CV) of 10.8%. Catch rates of legal size blue cod (at least 33 cm) ranged from 0.8 to 5.9 kg.pot^{-1}, with an overall mean catch rate of 3.3 kg.pot^{-1} and CV of 10.7%. Catch rates of legal size fish were highest in the Ulva Island/Te Wharawhara Marine Reserve stratum, and lowest in the Big Glory Bay stratum. At fixed sites outside of the marine reserve 39% of blue cod caught were of legal size, compared to 62% inside the reserve.

Total lengths recorded at fixed sites ranged from 16 to 48 cm. The length frequency distributions were mainly unimodal, with few fish below 20 cm or over 40 cm. Males were larger than females in all strata and overall mean length was 33 cm for males and 27 cm for females. Overall sex ratios for all and for legal sized fish were 1:0.3 (M:F) and 1:less than 0.1 respectively. Age ranged from 2 to 15 years, with most blue cod between 3 and 8 years for males and 2 and 10 years for females. The total mortality estimate (Z) was 0.49, assuming age-at-recruitment to the fishery at 9 years. The spawning biomass per recruit ($F_{\%SPR}$) estimate indicates that the expected contribution to the spawning biomass over the lifetime of an average recruit has been reduced to 30% of the contribution in the absence of fishing, and this level of exploitation (F) is of some concern as it is below the Ministry of Primary Industries target reference point of $F_{45\%}$.

Temporal comparisons between fixed site surveys
The overall catch rates from the 2014 fixed site survey were remarkably similar to those recorded in both the 2006 and 2010 fixed site surveys. From 2006 to 2010, blue cod catch rates declined by 12% in the fishable part of Paterson Inlet, but increased by 38% within the marine reserve. The overall CVs from the 2014 survey catch rates (11–13%) are also similar to both the 2006 (11–12%) and 2010 (9–11%) surveys, as were gonad observations.

Random site survey
The random site survey used 35 phase 1 sites, with another three sites allocated in phase 2. Total blue cod catch was 491 kg, consisting of 1265 fish. For legal size blue cod, catch rates by stratum ranged from 0.4 to 3.4 kg.pot^{-1} with an overall mean catch rate of 2.1 kg.pot^{-1} and CV of 16%. Catch rates of legal size blue cod by stratum ranged from 0.3 to 1.5 kg.pot^{-1} with an overall mean catch rate of 1.1 kg.pot^{-1} and CV of 17%. Catch rates were highest in the marine reserve stratum, and lowest in the Big Glory Bay stratum. At random sites outside of the marine reserve 28% of blue cod caught were of legal size, compared to only 12% inside the reserve.

Total lengths recorded at random sites ranged from 12 to 45 cm. The length frequency distributions were mainly multimodal, 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 26 cm for females. Overall sex ratios for all

and for legal sized blue cod were 1:0.5 (M:F) and 1:0.2 respectively. Age ranged from 1 to 21 years, with most fish between 3 and 8 years for males and 2 and 10 years for females. The *Z* estimate was 0.35, assuming an age-at-recruitment of 9 years. The $F_{\%SPR}$ estimate indicates that the spawning biomass has been reduced to 39%, which should be of concern as this level of exploitation (*F*) is beyond the Ministry for Primary Industries target reference point of $F_{45\%}$.

Temporal comparisons between random site surveys
The overall catch rates from the 2014 random site survey were very different to those recorded in the 2010 random site survey. Blue cod catch rates had increased by 104% in the fishable part of Paterson Inlet, and also increased by 36% within the marine reserve. The overall CVs from the 2014 survey catch rates (16–20%) were somewhat lower than the 2010 survey (20–24%). Gonad observations were consistent between random site surveys.

Comparison between survey designs
The rank order of catch rates among strata was consistent between the 2010 fixed and random site surveys. However, this was not the case for 2014, which produced very different rank orders of strata catch rates from fixed and random site surveys. The catch rates at random sites were also generally less than a fifth of the catch rates at fixed sites in 2010, and less than a half of the catch rates at fixed sites in 2014. The overall CVs of the catch rates from the random site surveys were over twice the size of the CVs from the fixed site survey in 2010, but it appears that a 6% increase in the random site survey effort helped somewhat to constrain the variance of the 2014 random site survey catch estimates.

In Paterson Inlet the proportion of fish less than 28 cm has been consistently lower in fixed site surveys than in random site surveys, with the mean lengths of both male and female blue cod consequently higher at fixed sites. It is therefore inappropriate to compare mortality estimates between random and fixed site surveys as they are likely to have different size based selectivity. The random site survey is nevertheless most likely to provide a more accurate estimate of the age structure and mortality rate for the blue cod population in Paterson Inlet.

1 INTRODUCTION

Blue cod (*Parapercis colias*) is a particularly desirable finfish caught easily by line or pot from small vessels fishing over reef edges, and is 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. Most blue cod have a restricted home range (Rapson 1956, Mace & Johnston 1983, Mutch 1983, Carbines & McKenzie 2001, 2004, Carbines 2004a), and stocks of this species largely consist of many independent sub-stocks within each Fisheries Management Area (FMA) (Carbines 2004a). Due to this philopatric behaviour, blue cod may be especially susceptible to localised depletion within subareas of FMAs, and in response to local fishing pressure, managed bag limit strategies have been varied within all South Island FMAs (Ministry for Primary Industries 2017).

Paterson Inlet is a subarea of the Southland FMA (BCO 5) in which managed bag limit strategies for blue cod have been varied. An aerial survey of Stewart Island observed the most recreational fishing trips in Paterson Inlet (Figure 1), and concurrent trip reports showed that most trips targeted blue cod (James et al. 2004). Paterson Inlet has long been prized for its fisheries, and blue cod has always been the main finfish species harvested (Elvy et al. 1997) with most recreational fishing trips in Paterson Inlet targeting blue cod (Carbines 1998). The Inlet supported a commercial handline fishery from dinghies from the 1920s to the 1950s (Warren et al. 1997), but since 1992 commercial fishing has been prohibited (Elvy et al. 1997). Because of the popularity of recreational fishing for blue cod in Paterson Inlet, the daily bag limit for blue cod was reduced from 30 to 15 fish per person per day in 1994 (Elvy et al. 1997). In 2004 most of Paterson Inlet was declared Te Whaka ā Te Wera Mātaitai Reserve (strata 1, 2 and 4 in Figure 1) and Tangata Tiaki/Kaitiaki further reduced the daily bag limit for blue cod from 15 to 10 fish per person per day in 2006 (Te Rūnanga o Ngāi Tahu 2007). The no-take Ulva Island/Te Wharawhara Marine Reserve was also established in Paterson Inlet around Ulva Island in 2004 (stratum 3 in Figure 1).

Ministry of 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. These include the Marlborough Sounds, north Canterbury, Banks Peninsula, north and south Otago, Dusky Sound 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 ratio 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. Subsequent estimates of total mortality (Z) for each survey are based on catch curve analysis (Ricker 1975) of the age distributions derived specifically for each survey; thus it is possible to determine stock status using an MSY-related proxy. For blue cod populations supporting modest recreational fisheries there is insufficient information to estimate B_{MSY}, 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 and the most widely used proxy for F_{MSY} currently is from spawner per recruit analyses ($F_{\%SPR}$). Hence, we are interested in where fishing mortality, derived from the catch curve analysis (Z) and assumptions about M, lies in relation to the recommended $F_{45\%SPR}$ reference point for blue cod.

Paterson Inlet time series

With the cooperation of the Te Whaka ā Te Wera Mātaitai Reserve Tangata Tiaki, an initial standardised fixed site allocation potting survey of Paterson Inlet was done in 2006 (Carbines 2007). It was also possible (with the cooperation of the Department of Conservation) to include the Ulva Island/Te Wharawhara Marine Reserve as an unfished "control" area to monitor blue cod within the reserve and over time compare the impact of fishing in the remainder of Paterson Inlet (Carbines 2007). The Department of Conservation has also conducted regular line fishing surveys throughout Paterson Inlet since 1994 (Chadderton & Davidson 2003, Carbines 2008), however, as a survey method within Paterson Inlet, line fishing surveys suffer from a much higher variance than potting surveys (Carbines 2008).

Because the fixed site design surveyed known fishing spots (Carbines 2007) it has a number of potential biases, and the catch indices cannot be extrapolated to the whole survey area as the samples are not representative. In a review of blue cod potting surveys, Stephenson et al. (2009) suggested using a more statistically robust random site survey, but acknowledged the need for some continuity with previous fixed site survey data. Consequently, the 2010 Paterson Inlet survey began a new random survey design done concurrently with a second fixed site survey for an initial comparison of these methods (Carbines & Haist 2014).

Fixed site survey time series

The initial 2006 potting survey identified 52 possible fixed sites from previous recreational diary (Carbines 1998) and flyover (James et al. 2004) surveys of Paterson Inlet. From this pool of possible fixed sites, five sites per stratum were randomly allocated for phase 1, and a further nine sites allocated to phase 2 (Carbines 2007). From 6–15 November 2006, thirty four potting sites were surveyed (6 pots per site = 204 pot lifts) from five strata throughout Paterson Inlet, catching 950 kg of blue cod (n=1638). For all sized blue cod, strata catch rates ranged from 1.5 to 8.4 kg.pot^{-1} (kg per pot set for one hour) with an overall mean catch rate of 5.0 kg per pot and coefficient of variation (CV) of 10.7%. Strata catch rates of legal size blue cod (33 cm and over) ranged from 1.3 to 4.7 kg.pot^{-1}, with an overall mean catch rate of 3.2 kg.pot^{-1} and a CV of 11.1% (re-calculated in Carbines & Haist 2014). For all blue cod the catch rates were highest in the outermost stratum 4, and lowest in Big Glory Bay (stratum 5, Figure 1). However, for legal size blue cod, catch rates were highest in the marine reserve and lowest in Big Glory Bay. At fixed sites outside of the marine reserve 40% of blue cod caught were of legal size, compared to 59% inside the reserve.

In the 2006 survey, total lengths ranged from 15 to 47 cm, with few fish below 20 cm or over 45 cm. The overall mean length was 34 cm for males and 29 cm for females and sex ratio was 1:0.4 (M:F). Age ranged from 3 to 13 years, with most blue cod between 5 and 10 years. The total mortality estimate (*Z*) was 0.63, assuming age-at-recruitment to the fishery at 8 years (re-calculated in Carbines & Haist 2014). The spawning biomass per recruit (*F%SPR*) estimate indicated that the expected contribution to the spawning biomass over the lifetime of an average recruit had been reduced to 22% of the contribution in the absence of fishing, and is well below the Ministry of Primary Industries target reference point of 45% (Ministry for Primary Industries 2017).

Between 23 November and 11 December the 2010 fixed site survey used 25 phase 1 sites, and three additional sites were allocated in phase 2. Total blue cod catch was 828 kg (n=1506). For all blue cod, catch rates by stratum ranged from 1.5 to 8.4 kg.pot^{-1}, with an overall mean catch rate of 4.8 kg.pot^{-1} and CV of 9.3%. Catch rates of legal size blue cod ranged from 1.4 to 6.2 kg.pot^{-1}, with an overall mean catch rate of 3.1 kg.pot^{-1} and CV of 10.4%. Catch rates were highest in the marine reserve, and lowest in Big Glory Bay. At fixed sites outside of the marine reserve 38% of blue cod caught were of legal size, compared to 56% inside the reserve.

Total lengths recorded in the 2010 fixed site potting survey ranged from 15 to 51 cm, with few fish below 20 cm or over 45 cm. The overall mean length was 32 cm for males and 28 cm for females and the sex ratio was 1:0.3 (M:F). Age ranged from 2 to 25 years, with most blue cod between 4 and 12 years. The total mortality estimate (*Z*) was 0.37, assuming age-at-recruitment to the fishery at 8 years. The spawning biomass per recruit estimate indicated that the expected contribution to the spawning biomass over the lifetime of an average recruit had been reduced to 40% of the contribution in the absence of fishing (just below the Ministry for Primary Industries target reference point of 45%).

The overall catch rates from the 2010 fixed site survey were remarkably similar to those recorded in the 2006 fixed site survey. While there had been a 38% increase in the catch rates of blue cod within the marine reserve, this had been offset by a 21% decline in the larger stratum 4 where most recreational fishing occurs (Carbines 1998, James et al. 2004). When the marine reserve was not included in the overall catch rates, there had been a 12% decline in the fishable part of Paterson Inlet.

Random site survey time series

The initial random site survey in 2010 used 33 phase 1 sites, with another three sites allocated in phase 2. Total blue cod catch was 224 kg (n=639). For legal sized blue cod, catch rates by stratum ranged from 0.2 to 2.5 kg.pot^{-1} with an overall mean catch rate of 1.1 kg.pot^{-1} and CV of 21%. Catch rates of legal size blue cod by stratum ranged from 0.2 to 1.2 kg.pot^{-1} with an overall mean catch rate of 0.5 kg.pot^{-1} and CV of 21%. Catch rates were highest in the marine reserve, and lowest in Big Glory Bay. Outside of the marine reserve 26% of blue cod caught at random sites were of legal size, compared to only 22% inside the reserve.

Total lengths recorded at random sites in 2010 ranged from 11 to 45 cm, with few fish below 17 cm or over 40 cm. Mean length was 29 cm for males and 26 cm for females and the sex ratio was 1:0.4 (M:F). Age ranged from 1 to 20 years, with most fish between 3 and 12 years. The *Z* estimate was 0.43, assuming age-at-recruitment to the fishery at 8 years (re-calculated in Carbines & Haist 2014). The *F%SPR* estimate indicated that the spawning biomass had been reduced to 37% and was beyond the Ministry of Primary Industries target reference point of F40%.

Comparison between survey designs
The rank order of catch rates among strata was consistent between the 2010 fixed site and random site surveys. However, the catch rates at random sites were generally less than a fifth of those at fixed sites. The overall CVs of the catch rates from the random-stratified survey (over 23%) were more than twice the size of the CVs from the fixed site survey (11%). The random site survey may not have had sufficient effort to constrain the variance of the catch rates in 2010. The comparison between survey designs continues in 2014 with a second round of concurrent fixed and random site surveys.

Overall objective

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

Specific objectives

1. To undertake a potting survey in Paterson Inlet (BCO 5) to estimate relative abundance, size- and age at-maturity, and sex ratio. Collect otoliths from pre-recruited and recruited blue cod.

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

3. Determine stock status of blue cod populations in this area, and compare this with other survey areas.

4. To determine F_{msy} proxies for Paterson Inlet 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 (see Appendix 1).

2.1 Timing

The previous surveys for Paterson Inlet were done in November/December (Carbines 2007, Carbines & Haist 2014). To continue both the fixed and random site survey time series for Paterson Inlet with minimal temporal (i.e., seasonal) variability between quadrennial surveys, the 2014 Paterson Inlet potting survey began on 19 November and was completed on 12 December (Objective 1).

2.2 Survey area

Paterson Inlet is a shallow enclosed body of water on the northern end of Stewart Island at the southern tip of New Zealand (Figure 1). The seafloor is principally alluvial gravel overlaid with sand and shallow patches of rocky ground. Areas of potential blue cod habitat range throughout the Inlet at depths of only a few metres in the inner parts of the Inlet (strata 1 and 5) to over thirty metres in the outer stratum 4 (Figure 1, Carbines 2007). There were no detailed habitat maps available for Paterson Inlet.

The survey area used in the 2006 survey was defined after discussions with the Ministry of Fisheries (now Ministry for Primary Industries) Southern Recreational Fishing Forum, local fishers, and the Mātaitai Tangata Tiaki. 52 possible fixed sites were identified and the survey area boundary was defined as inside a line from Ackers Point to Bullers Point and the Inlet was divided arbitrarily into five strata (See Figure 1), including Big Glory Bay and the marine reserve around Ulva Island (Carbines 2007).

The area of the five strata was chosen to contain a roughly equal distribution of possible potting sites, and the area of each stratum was taken as a proxy measure of available habitat for blue cod (Carbines 2007, Carbines & Haist 2014). The same survey area and strata were used for the 2014 random site survey of Paterson Inlet, but with stratum 5 no longer subdivided on the basis of depth as in the 2010 survey (Carbines & Haist 2014).

2.3 Survey design

All Paterson Inlet random and fixed site potting surveys used six pots per site and ensured that sites were at least 300 m apart. In 2014 the fixed site survey consisted of 25 sites (150 pot lifts) allocated to strata 1–5, and the random site survey consisted of 38 sites (228 pot lifts) allocated to strata 1–5 (Figure 1). For the fixed site survey, five sites per stratum (n=25 sites, 150 pot lifts) were allocated in a phase 1 and no sites were allocated to a second phase (Table 1).

The random site survey surveys used a two-phase stratified design, with seven sites per stratum (n=35 sites, 210 pot lifts) allocated to phase 1 and three sites (7.9%) allocated to phase 2 (Table 2). 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 (See Figure 2).

2.4 Vessels and gear

The 2014 Paterson Inlet potting surveys were conducted from F.V. *Francis*, a Stewart Island-based commercial vessel equipped to set and lift rock lobster and blue cod pots. The vessel was chartered by Saltwater Science Ltd and skippered by the owner Mr Brett Hamilton. The vessel specifications are: 10.5 m length, 3.6 m breadth, 6.5 t, fibreglass monohull, powered by a 430 hp diesel engine with propeller propulsion. The trip code for the survey was FRA1402.

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

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

2.5 Sampling methods

In Paterson Inlet, fixed sites were adjacent to the coastline or submerged rocks (See Figure 1). The ADCP was initially deployed central to each fixed site, and the six pots were set in clusters, separated by at least 100 m. Once on site, the position of each of the six pots was determined by the skipper using local knowledge and the vessel sounder to locate an area of foul ground (Figure 2).

At each random site an 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 fixed grid pattern determined from an initial starting point approximately 200 m north of the random site location occupied by the ADCP (Figure 2).

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 the centre of 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 inlet (excluding the marine reserve, stratum 3).

No blue cod could be harmed in the marine reserve (stratum 3) and Te Whaka ā Te Wera Mātaitai Reserve Kaitiaki continue to restrict the number of biological samples (i.e., killing fish) in the Mātaitai (strata 1, 2, and 4). As in the 2010 surveys (Carbines & Haist 2014), blue cod were spawning during the 2014 potting survey and it was again possible to determine sex and maturity of almost all blue cod by "milking" (nonlethal) rather than by lethal dissection and direct examination of the gonads (Carbines 2004a, Carbines & Haist 2014). During the 2010 Paterson Inlet potting surveys, 303 biological samples that could be sexed and staged by "milking" were then dissected, which validated "milking" as a 100% reliable sexing method in this (Carbines & Haist 2012). However, during the 2014 potting surveys any blue cod that could not be sexed by "milking' were sexed through dissection (except in the marine reserve). For both "milking" 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 a plastic pipette within a paper envelope. These were later embedded in a polymer resin, baked (50°C for at least three hours), and sectioned transversely with a diamond-tipped cut-off wheel. The thin section was then glued with resin onto a slide and sanded with 600-grit sandpaper to about 0.25 mm thickness before viewing. Sections were observed at ×40 and ×100 magnification under reflected light with a compound microscope (Walsh 2017).

Otoliths from the 2010 Paterson Inlet potting survey were read under transmitted light counting all opaque zones according to Carbines (2004b). However, a new MPI ageing protocol (Walsh 2017) recommends reading blue cod otolith under reflected light (See Appendix 2) and otoliths from the 2014 survey were processed using this new protocol. Otolith sections exhibit alternating opaque and translucent zones and age estimates were made by counting the number of annuli (opaque zones) from outside of the juvenile zone (Carbines 2016) to the distal edge of the section (See Appendix 2, Figure 2.A). The readability of each otolith was also graded from 1 (excellent) to 5 (unreadable). Otoliths were read independently by two readers (G. Carbines and P. VanKampen), and where counts differed the readers consulted to resolve the final age estimate. Otoliths given a grade 5 (unreadable) or damaged were removed from the analysis.

2.7 Data analysis

The data analyses follow the methods and equations described in the blue cod potting survey standards and specification document (Beentjes & Francis 2011), with any exceptions noted here. Modifications of the standard analytical methods were required because fish sampled in the Paterson Inlet surveys were not all sexed. The equations for calculating catch rates of fish greater than the minimum legal size (MLS) and for calculating scaled length frequencies (LFs) need to be modified to account for the unsexed fish.

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, k=2 for females, and k=3 for unsexed) caught in pot p of set s of stratum t, m is the number of pot lifts in set s, and a_k and b_k are sex-specific length-weight parameters (described below). Note that the above equation assumes that all fish have been measured for length, which is generally the case for blue cod surveys.

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 length-weight parameters for unsexed fish (k=3) are calculated based on all male and female samples with weights. 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 fish under age 3 are all immature, proportions mature of 0.1, 0.4, 0.7 for ages 4, 5, and 6, respectively, and 100% maturity for fish aged 7 and older; and fishery selectivity is assumed to be knife-edge at the age at MLS. The estimate of current fishing mortality (F) is equal to Z-M, and the SINS working group determined that the age of recruitment for the Z calculations would be the age where both male and female blue cod were at or above the MLS. Z and *SPR* results are also provided for ages at recruitment from 5 through to 9.

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).

3 RESULTS

3.1 Sites surveyed

Twenty-five fixed sites (6 pots per site, 150 pot lifts) and thirty-eight random sites (6 pots per site, 228 pot lifts) were surveyed over fourteen fishable days from 19 November to 12 December 2014 (Tables 1 and 2, Figure 1, Appendix 3). All of the 25 fixed sites were carried out in phase 1 (5 per stratum) with no phase 2 allocation (Table 1). Of the 38 random sites, 35 were carried out in phase 1 (7 per stratum), with 1 site allocated to stratum 1 and 2 sites to stratum 2 in phase 2 (Table 2). Depth ranged from 3 to 36 m for fixed sites and 2 to 32 m for random sites. Environmental data recorded throughout the 2014 Paterson Inlet potting surveys are presented in Appendix 4 and are stored on the Ministry for Primary Industries database *trawl*. The ADCP data is archived in a spreadsheet with the Research Data Manager, NIWA, Greta Point, Wellington.

3.2 Catch

A total of 1900 kg of catch was taken on the 2014 Paterson Inlet fixed and random site potting surveys, of which 1237 kg (65%) was blue cod, consisting of 2549 fish. The fixed site survey caught 60% of the total blue cod. Blue cod accounted for 70% of the catch in the fixed site survey (Table 3) and 59% of the catch form the random site survey (Table 4).

In the fixed site survey, bycatch included seven fish and one octopus species (Table 3). In the random site survey, bycatch included seven fish species (Table 4). For the fixed site survey, the five most common bycatch species by weight were spotty (*Notolabrus celidotus*), trumpeter (*Latris lineata*), blue moki (*Latridopsis ciliaris*) and scarlet wrasse (*Pseudolabrus miles*) (Table 3). For the random site survey the five most common bycatch species by weight were spotty (*Notolabrus celidotus*), leatherjackets (*Parika scaber*), tarakihi (*Nemadactylus macropterus*), and pigfish (*Congiopodus leucopaecilus*) (Table 4).

In the fixed site survey the mean catch rates of blue cod (all sizes) ranged from 1.05 kg.pot^{-1} for the Big Glory Bay stratum to 7.7 kg.pot^{-1} for the outermost coastal stratum 4 (Table 5, Figure 3). Overall mean catch rate and CV were 5.21 kg.pot^{-1} and 10.9%. For blue cod 33 cm and over (local minimum legal size) the lowest catch rates were also from Big Glory Bay (0.82 kg.pot^{-1}), but were highest in the marine reserve (5.93 kg.pot^{-1}). Overall mean catch rate and CV for fish of at least 33 cm from the fixed site survey were 3.30 kg.pot^{-1} and 10.7% (Table 6, Figure 3). Catch rates from the Paterson Inlet fixed site potting survey time series (2006, 2010, 2014) are shown in Figure 4.

In the random site survey catch rates were lower, and the mean catch rates of blue cod (all sizes) ranged from 0.44 kg.pot^{-1} for the Big Glory Bay stratum to 3.43 kg.pot^{-1} for the marine reserve (Table 7, Figure 3). Overall mean catch rate and CV were 2.14 kg.pot^{-1} and 16.1%. For blue cod 33 cm and over the lowest catch rates were also from Big Glory Bay (0.26 kg.pot^{-1}), but the highest catch rates were from the innermost stratum 1 (1.48 kg.pot^{-1}). Overall mean catch rate and CV for blue cod 33 cm and over from the random site survey were 1.05 kg.pot^{-1} and 17.1% (Table 8, Figure 3). Catch rates from the Paterson Inlet random site potting survey time series (2010 and 2014) are shown in Figure 5.

3.3 Biological and length frequency data

Of the 2549 blue cod caught on the 2014 Paterson Inlet fixed and random site surveys, all were measured for length and 95% were sexed, otoliths were taken throughout the inlet (except from stratum 3, the marine reserve) and read from 215 fish across the available size range (Appendix 5).

All blue cod were able to be sexed at all sites outside of the marine reserve. For the fixed site survey, (excluding the marine reserve where 3% of fish could not be sexed) the sex ratios of all blue cod ranged from 1:0.4 (M:F) in stratum 2 to 1:0.2 (M:F) in stratum 5, and overall were 76% male at 1:0.3 (M:F) (Table 9). The sex ratios for blue cod 33 cm and over (local minimum legal size) ranged from 1:less than 0.1 (M:F) in stratum 1 to 1:0.1 (M:F) in stratum 2, and was heavily skewed towards males (1:less than 0.1) (Table 9). The size of blue cod at fixed sites ranged from 17 to 45 cm for females and 16 to 48 cm for males, although size varied among strata (Figure 6).

For the random site survey (excluding the marine reserve where 23% of fish could not be sexed), the sex ratios of all blue cod ranged from 1:0.3 (M:F) in stratum 4 to 1:1.2 (M:F) in stratum 5, and overall were 60% male at 1:0.5 (M:F) (Table 10). The sex ratios for blue cod 33 cm and over all ranged from 1:0.0 (M:F) in stratum 4 to 1:0.9 (M:F) in stratum 5, but overall were skewed towards males (1:0.2) (Table 10). The size of blue cod at random sites ranged from 16 to 45 cm for females and 13 to 45 cm for males, but also varied among strata.

The length frequency distributions were unimodal for most strata in the fixed site potting survey (Figure 6), but multimodal for most strata in the random site potting survey (Figure 7). Fish taken in the random

site potting survey were noticeably smaller than those from the fixed site survey in all strata with the exception of stratum 4 (Tables 9 and 10, Figures 6 and 7).

For the fixed site survey, small blue cod (less than 20 cm) were uncommon, caught mainly in strata 1 and 2 close to the head of Paterson Inlet (Figure 6). In contrast, the largest blue cod taken in the fixed site survey came more evenly from all strata. Mean lengths of males were 5–7 cm more than females in all strata, and overall the mean male length was 33.3 cm and mean female length was 27.3 cm (Table 9). The proportion of legal sized blue cod caught on the 2014 fixed site survey was 39% outside the marine reserve and 62% inside the marine reserve.

The random site potting survey caught more small blue cod (less than 20 cm) and fewer large blue cod (over 40 cm) than the fixed site survey (Table 10, Figure 7). Mean lengths of males were 1–7 cm more than females in all strata and overall mean male length was 29.5 cm and mean female length 26.4 cm (Table 10), 3.8 cm and 0.9 cm smaller than male and females respectively in the fixed site survey (Table 9). The proportion of legal sized blue cod caught on the 2014 Paterson Inlet random site potting survey was 28% outside the marine reserve, but only 12% within the marine reserve.

Of 1276 blue cod able to be examined by either "milking" or dissection in the fixed site survey, most had gonads in the late maturing phase. Thirty-six-percent of males and 2% of females were in the running ripe stage, and only 1% of males had spent gonads (Table 11). Of the 1156 blue cod able to be examined in the random site potting survey 74% of females and 41% of males were in the late maturing phase (Table 12). Half of all males and 9% of females were in the running ripe stage, and no spent gonads were observed (Table 12).

Regardless of survey design, the smallest fish observed in the running ripe stage were 13 cm for males and 20 cm for females, with running ripe fish becoming common among males over 20 cm and females over 22 cm. Using the derived model $W = aL^b$, the length-weight parameters for Paterson Inlet in 2014 were: males – a = 0.01167, b = 3.07733, females – a = 0.00784, b = 3.20158.

3.4 Ageing (between reader analyses)

From 244 otoliths collected during the 2014 Paterson Inlet survey, 29 were rejected as unreadable or damaged, leaving 215 otoliths (126 males 14–48 cm, 89 females 16–45 cm) (Table 13). These otoliths were collected across all strata except the marine reserve (Appendix 5).

Initial independently derived reader estimates of otolith age class are compared in Figure 8 and show 43% initial agreement between the two readers, with reader 2 generally estimating slightly lower age classes than reader 1 (tabulated in Appendix 6). When the differences between age class estimates were resolved by agreement between the readers, reader 1 was 58% consistent with the agreed age class and reader 2 was 60% consistent with the agreed age classes (Figure 8, Appendix 7).

3.5 Growth

The age/length data and fitted von Bertalanffy growth models for the 2014 Paterson Inlet surveys are shown in Figure 9, and the growth parameters (K, t_0 *and* L_{inf}) are shown below. Male and female size-at-age is similar until about age 5, after which males grow a little faster and achieve a slightly larger L_{inf} than females. The growth models for both the 2010 and 2014 Paterson Inlet surveys are shown in Figure 10.

Parameter	Males	Females
K	0.1702	0.1747
T_0	-0.2087	-1.7354
L_{inf}	52.6	40.0

3.6 Length and age composition

The scaled length and age frequency distributions for all strata combined (with the exception of the marine reserve) are shown for males, females, and both sexes combined for the 2014 Paterson Inlet fixed site (Figure 11) and random site (Figure 12) potting surveys. The scaled length frequency distributions tend to be unimodal for blue cod from fixed sites, but more multimodal for blue cod from random sites (Figure 11 and Figure 12). Males are generally larger than females in both survey designs, however, the frequency of smaller fish (less than 28 cm) was greater in the random site survey than in the fixed site survey

Age of blue cod ranged from 1 to 21 years (Table 13), but there were very few fish older than 15 years. For males, the dominant age-classes were 3, 4, 5 and 6, while for females the dominant age-classes were from 3 to 5 (Figure 11 and Figure 12). The mean age was similar in the fixed site and random site survey for both males (5.8 compared to 5.2) and females (5.0 compared to 5.4). The mean weighted coefficients of variation (MWCVs) around the age distributions are moderate for males (about 25%) indicating a fair representation of the overall male population. However the MWCVs around the female age distributions were over 36% and a less convincing representation of the overall female population.

The cumulative length and age frequency distributions of blue cod from the fixed and random site surveys are shown in Figure 13. The age-length-keys (ALKs) are shown in Appendix 8 for males and Appendix 9 for females, and mean-age-at-length is shown in Appendix 10. For both males and females, all lengths measured on the survey had at least one valid age reading in the age-length-keys.

3.7 Total mortality (*Z*) estimates

Total mortality estimates (*Z*) and 95% confidence intervals for the 2014 Paterson Inlet fixed site and random site potting surveys (excluding the marine reserve) are given in Tables 14 and 15 respectively. *Z* estimates are slightly higher from the fixed site survey than from the random site survey. For the fixed site survey, *Z* estimates range from 0.49 to 0.65, and for the random site survey *Z* estimates range from 0.35 to 0.53.

3.8 Spawner per recruit analyses

The age- and sex-specific values for fish size, maturity, and selectivity used in the SPR analysis are given in Appendix 11.

Spawning biomass per recruit analyses is plotted against fishing mortality rate for the 2014 fixed site survey in Figure 14, and for the 2014 random site survey in Figure 15. Mortality parameters used in the analyses, and resulting $F_{\%SPR}$ values are shown in Tables 16 and 17. Based on the default value of *M* of 0.14 and age at recruitment of 9 years, the fishing mortality estimated for the 2014 Paterson Inlet fixed survey of 0.49 corresponds to an *%SPR* of 30%, while the fishing mortality estimated for the random site survey of 0.35 corresponds to an *%SPR* of 39%. For the fixed site survey the *%SPR* estimates for *M* values of 0.11 and 0.17 were 23% and 37% respectively (Table 16), while for the random site survey the %SPR estimates for *M* values of 0.11 and 0.17 were 30% and 49% respectively (Table 17).

4 DISCUSSION

The 2014 Paterson Inlet blue cod potting survey was the second comparison of concurrent fixed and random site stratified survey designs. This was the second random site survey and the third fixed site survey done in Paterson Inlet (Carbines 2007, Carbines & Haist 2014).

4.1 Fixed site survey design time series

For the fixed site survey, the overall catch rates of all blue cod (Table 5) and legal sized blue cod (at least 33 cm, Table 6) were similar to those recorded in both the 2006 and the 2010 surveys (Figure 4). Since the 2010 survey catch rates have improved for all blue cod within all of the strata of the Te Whaka ā Te Wera Mātaitai Reserve (i.e., strata 1 (28%), 2 (16%), and 4 (15%)). In contrast there was a decline in the catch rates of all blue cod within the marine reserve (stratum 3 down 9%) and Big Glory Bay (stratum 5 down 32%). For legal size blue cod (33 cm and over) within the Mātaitai Reserve there has been little change in the catch rates of strata 1 and 2 (suggesting possible hyper-stability), however in the outermost stratum 4 there has been a 34% increase since the 2010 survey (Figure 4). In contrast, the catch rates of legal size blue cod within the marine reserve and Big Glory Bay declined by 6% and 43%, respectively, since the 2010 fixed site survey (Figure 4). Overall there has been a 9% increase in the catch rate of all blue cod (15% excluding the marine reserve), and a 3% increase in the catch rate of legal size blue cod (7% excluding the marine reserve) in Paterson Inlet since the 2010 survey (Figure 4).

The historical increase in catch rates of blue cod within the marine reserve and corresponding decline in catch rates in the most fished stratum 4 observed between the 2006 and 2010 (Carbines & Haist 2012) has been reversed between the 2010 and 2014 surveys (Figure 4). Since 2006, the rank order of catch rates among strata (i.e., 4, 3, 2, 1, 5) changed, with the marine reserve having the highest catch rates in 2010 and 2014 (i.e., 3, 4, 2, 1, 5), however stratum 4 and the marine reserve have very similar catch rates of all blue cod in 2014 (Figure 4).

The overall CVs for the 2014 fixed site survey catch rates was 10.9% for all blue cod and 10.7% for legal sized blue cod (Tables 5 and 6); which were very similar to the overall CVs from the 2006 and 2010 fixed site surveys (Carbines 2007, Carbines & Haist 2012), despite the absence of a phase 2 in the 2014 survey (Table 1). These results suggest that future fixed site surveys of Paterson Inlet may be maintained at 25 sites.

4.2 Random site survey design time series

For the 2014 random site potting survey, the overall catch rates of all blue cod (Table 7) and legal size blue cod (Table 8) had doubled since the initial survey in 2010 (Figure 5). Excluding the marine reserve, the overall catch rates in the random site potting survey had increased by 137% for all blue cod and 160% for legal sized blue cod (Figure 5).

Subsequent to the 2010 survey there were improved catch rates of all blue cod at random sites of all strata, however the increase was much more dramatic towards the head of Paterson Inlet in stratum 1 (348%) and stratum 2 (342%) than it was in the marine reserve (36%) or outermost stratum 4 (40%). Unfortunately temporal comparisons within Big Glory Bay cannot be made due to stratum changes between the 2010 and 2014 random site potting surveys (Figure 5). There was also a large increase in the catch rates of legal size blue cod from random sites within the Mātaitai Reserve (i.e., strata 1 (300%), 2 (171%), and 4 (132%)), but a 14% decline in catch rates within the marine reserve (Figure 5).

With the most dramatic increases in random site catch rates occurring in the two innermost Paterson Inlet strata, the rank order of catch rates among strata has changed since 2010 (i.e., 3, 4, 2, 1). Although the marine reserve still had the highest catch rates in 2014, the outermost stratum 4 had declined in the

2014 strata rankings (i.e., 3, 1, 2, 4, see Figure 5). For legal size blue cod the rank order of catch rates among strata had changed even more dramatically since 2010 (i.e., 3, 4, 1, 2), with the marine reserve and the innermost stratum 1 exchanging ranks in 2014 (i.e., 1, 4, 3, 2, see Figure 5).

The overall CV for the 2014 random site survey catch rates was 16.1% for all blue cod and 17.1% for legal sized blue cod (Tables 7 and 8) which is an improvement on the overall CV from the previous 2010 random site survey (21.4% for all blue cod and 20.4% for legal sized blue cod, Carbines & Haist 2012).

4.3 Comparisons of catch rates between survey designs

Overall catch rates of all and legal sized blue cod from the 2014 random site potting survey (Tables 7 and 8) were only 41% and 33% respectively of the catch rates from the concurrent fixed site survey (Tables 5 and 6). This level of reduced catch in the random site survey was reasonably consistent among strata for both all and legal sized blue cod, with the possible exception of stratum 1 where catch rates were more similar between random and fixed sites (Figure 3). In the 2010 survey, the catch rates at random sites were only 19% and 15% of fixed site catch rates for all and legal size blue cod respectively (Carbines & Haist 2012).

The temporal variability in the two random site survey catch rates is in contrast to the stability of catch rates from the three fixed site surveys (Figure 4 verses Figure 5). Overall the fixed site survey catch rates increased by only 9% of all blue cod and 3% for legal size blue cod between 2010 and 2014, while increases of 104% for all blue cod and 106% for legal sized blue cod occurred between the equivalent random site surveys.

In the 2010 Paterson Inlet potting survey the rank order of random site catch rates of all blue cod among strata was consistent with fixed sites (i.e., strata 3, 4, 2, 1, 5, See Figure 4 and Figure 5), however, in the 2014 survey the rank order for random sites (i.e., strata 3, 1, 2, 4) was very different to that of fixed sites (i.e., strata 4, 3, 2, 1, See Figure 3). For legal size blue cod, the rank order of random site catch rates among strata was also consistent with fixed sites in the 2010 survey (i.e., strata 3, 4, 2, 1, 5, See Figure 4 and Figure 5), but also very different between random sites (i.e., strata 1, 4, 3, 2) and fixed sites (i.e., strata 3, 4, 2, 1) in the 2014 survey (See Figure 3).

In 2014 the overall CVs of the catch rates from the random site (n=38) survey (over 16% - Tables 7 and 8) were over 50% larger than the size of the CVs from the concurrent fixed site (n=25) survey (over 10% - Tables 5 and 6). In 2010, the overall CVs of the catch rates from the random site (n=36) survey (over 23%, Carbines & Haist 2012) were more than twice the size of the CVs from the concurrent fixed site (n=28) survey (11%, Carbines & Haist 2012). This suggests that the 2010 random site survey effort may not have been sufficient to constrain the variance of catch rates in Paterson Inlet, but that a 6% increase in effort for the 2014 survey has helped constrain the variance.

4.4 Reproductive condition

Observations of gonad stages in 2014 were similar between fixed and random sites with most individuals in the mature stage, and a large proportion of mainly males running ripe (Tables 11 and 12). This indicates that the timing of the survey (late spring) was during the early part of the spawning season and is consistent with the previous surveys in 2006 (Carbines 2007) and 2010 (Carbines & Haist 2012). However, the proportion of running ripe individuals was higher at random sites than at fixed sites in both the 2010 and 2014 potting surveys, and continues to suggest some fine scale variability in the onset of spawning as fixed sites tended to be along the coast compared to the more offshore locations of random sites (see Figure 2).

To accurately determine the size/age-at-sexual maturity histological samples taken throughout the year are required (see Carbines 2004a). However, with running ripe fish being relatively common among males over 20 cm and females over 22 cm in all Paterson Inlet potting surveys to date, it appears that sexual maturity in Paterson Inlet can be attained at 3 to 4 years old. However, while blue cod in Paterson Inlet may be spawning at this small size, their fecundity is likely to be low and larger fish may contribute disproportionately to the total egg production (Beer et al. 2013).

4.5 Size and sex ratio

In fixed site surveys, the relative number of males has gradually increased from 72% in 2006 (Carbines 2007) to 76% in 2014, with sex ratios remaining reasonably consistent across strata (1:0.2 – 1:0.4, M:F) throughout the time series (Carbines & Haist 2012). Ninety five percent of legal sized blue cod from fixed sites were male in 2014, and all strata were heavily biased towards males (over 91%) (Table 9). However, in both the 2010 and 2014 random site surveys, only 60% of all blue cod were male, and only 81% of legal sized blue cod from random sites were male (Table 10). The most pronounced male bias for both all and legal sized blue cod at random sites remains the coastal stratum 4 (Table 10) where fishing pressure is likely to be greatest (Carbines 1998, James et al. 2004).

4.6 Population length and age structure

Length frequency distributions were generally unimodal at fixed sites and multimodal at random sites, with blue cod taken from random sites smaller (on average 4 cm for males and 1 cm for females) than those taken from fixed sites (Tables 9 and 10). The proportion of legal sized blue cod caught on the three fixed site Paterson Inlet potting surveys has remained stable between 38% and 40% outside the marine reserve, and is higher than the 2009 fixed site potting survey in the adjacent Foveaux Strait (17%, Carbines 2009). The proportion of legal sized blue cod caught in the Paterson Inlet random site surveys (outside the marine reserve) has also remained stable (26% and 28%), but at a much lower level than at fixed sites. However, comparing proportions of legal sized blue cod across years or areas is difficult because they are affected by both recruitment and fishing mortality.

The scaled length frequency distributions show more clearly that at random sites proportionately more small fish and fewer larger fish are caught than at fixed sites (Figures 11 and 12). However, there are relatively few fish over 40 cm at either fixed or random sites, and the resulting population age structures both show an abrupt decline on the right hand limb after six years old and another after ten years old, with a low proportion of fish older than 11 years.

4.7 Total mortality (*Z*)

Fixed sites yielded proportionately fewer younger fish (3–4 years) than random sites in the 2014 Paterson Inlet potting surveys, but the two survey designs had similar age distributions for fish over five years old (Figures 11 and 12). However, the presence of a few female fish around 20 years old in the random site survey (Figure 12) resulted in mortality estimates (*Z*) from the fixed site survey (Table 14) that were lower than those derived from the random site survey (Table 15). Because of the difference in population structures observed between survey designs in both the 2010 (Carbines & Haist 2014) and 2014 Paterson Inlet potting surveys, we suggest it is inappropriate to compare mortality estimates between random and fixed site surveys. Carbines & Haist (2017) also demonstrated that it is inappropriate to compare mortality estimates between surveys using different pot types.

Mortality estimates from the 2014 Paterson Inlet fixed site survey were considerably higher than equivalent estimates from 2010, while *Z* estimates from the 2014 random site survey were considerably lower than equivalent estimates from 2010 (Carbines & Haist 2012). However, as the current survey

used a different ageing protocol (Carbines 2016, Walsh 2017) to the 2010 survey it will have resulted in biased comparisons of Z and $F_{\%SPR}$ estimates.

4.8 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 $\%B_0$).

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

Based on the recommendation from the Southern Inshore Working Group, blue cod is categorised as a medium productivity species which results in a fishing mortality reference point for $F_{\%SPR}$ of 40%. In the most recent Paterson Inlet surveys the SPR estimates for the default *M* value of 0.14 were 30% for the fixed site survey and 39% for the random site survey (Tables 16 and 17), indicating that the expected contribution to the spawning biomass over the lifetime of an average recruit has been reduced to 30 or 39% of the contribution in the absence of fishing. Both of these results suggest that recent levels of exploitation (*F*) for the Paterson Inlet blue cod stock are beyond 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 16 and 17, Figures 14 and 15). A higher natural mortality (0.17) increased the spawning biomass at current *F* relative to the unfished level by 7–10%. Conversely, a lower natural mortality (0.11) decreased the spawning biomass at current *F* relative to the unfished level by a similar proportion.

Given the sedentary nature of blue cod and the fact that fixed sites were determined according to popular fishing spots, the size and age composition and associated mortality estimates of the Random survey catch is likely to more accurately represent that of the Paterson Inlet blue cod population than the catch from the fixed site survey. For this reason the SINSWG concluded that all future Paterson Inlet surveys should be based on a random site design.

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Table 1: Paterson Inlet 2014 fixed site survey stratum area, number of phase 1 and 2 sites, pot lifts, and depth of sites.

	Size of strata	Number of Selected sites		Number of pot lifts	Depth (m)	
Stratum	Area (km^2)	Phase 1	Phase 2	Total	Mean	Range
1	15.6	5		30	5.2	4–8
2	20.7	5		30	8.5	3–19
3	10.7	5		30	7	3–12
4	20.7	5		30	10	4–36
5	11.1	5		30	5.7	3–10
Total	78.8	25	0	150	7.2	3–36

Table 2: Paterson Inlet 2014 random site survey stratum area, number of phase 1 and 2 sites, pot lifts, and depth of sites.

	Size of strata	Number of Selected sites		Number of pot lifts	Depth (m)	
Stratum	Area (km^2)	Phase 1	Phase 2	Total	Mean	Range
1	15.6	7	1	48	15.5	2–22
2	20.7	7	2	54	17.6	5–25
3	10.7	7		42	20.4	8–26
4	20.7	7		42	14.9	5–32
5	11.1	7		42	19.4	4–26
Total	78.8	35	3	228	17.5	2–32

Table 3: Catch weights, numbers of blue cod, bycatch species, and percentage of total weight from the 2014 Paterson Inlet fixed site survey (n=25 sites).

Common name	Scientific name	Catch (kg)	Number	Percent of total catch
Blue cod	*Parapercis colias*	746.0	1284	70.17
Spotty	*Notolabrus celidotus*	231.1	1069	21.74
Trumpeter	*Latris lineata*	23.1	15	2.17
Blue moki	*Latridopsis ciliaris*	17.2	10	1.62
Scarlet wrasse	*Pseudolabrus miles*	16.2	7	1.52
Girdled wrasse	*Notolabrus cinctus*	13.4	6	1.26
Banded wrasse	*Notolabrus fucicola*	10.8	6	1.02
Red cod	*Pseudophycis bachus*	3.3	1	0.31
Octopus	*Octopus cordiformis*	2.1	1	0.20
Total		1063.2	2399	100

Table 4: Catch weights, numbers of blue cod, bycatch species, and percentage of total weight from the 2014 Paterson Inlet random site survey (n=38 sites).

Common name	Scientific name	Catch (kg)	Number	Percent of total catch
Blue cod	*Parapercis colias*	490.6	1265	58.64
Spotty	*Notolabrus celidotus*	313.0	1919	37.41
Leatherjacket	*Parika scaber*	9.7	4	1.15
Tarakihi	*Nemadactylus macropterus*	9.4	8	1.12
Pigfish	*Congiopodus leucopaecilus*	4.6	2	0.55
Red cod	*Pseudophycis bachus*	4.5	2	0.54
Carpet shark	*Cephaloscyllium isabellum*	4.2	1	0.50
Banded wrasse	*Notolabrus fucicola*	0.7	1	0.08
Total		836.6	3202	100

Table 5: Mean catch rates for all blue cod caught in the 2014 Paterson Inlet fixed site potting survey (See Figure 1). 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. Totals are provided both including and excluding (excl 3) the marine reserve (stratum 3).

Stratum	Sites	Pot lifts (N)	Mean (kg/pot)	s.e.	CV (%)
1	5	30	3.47	0.64	18.58
2	5	30	5.06	1.16	22.93
3	5	30	7.63	1.26	16.46
4	5	30	7.66	1.60	20.89
5	5	30	1.05	0.48	45.28
Total	25	150	5.21	0.57	10.85
Total (excl 3)	20	120	4.83	0.62	12.90

Table 6: Mean catch rates for blue cod 33 cm and over (MLS in BCO 5) in the 2014 Paterson Inlet fixed site potting survey (See Figure 1). 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. Totals are provided both including and excluding (excl 3) the marine reserve (stratum 3).

Stratum	Sites	Pot lifts (N)	Mean (kg/pot)	s.e.	CV (%)
1	5	30	2.15	0.46	21.32
2	5	30	3.02	0.81	26.73
3	5	30	5.93	0.83	13.92
4	5	30	4.42	0.89	20.14
5	5	30	0.82	0.39	47.75
Total	25	150	3.30	0.35	10.65
Total (excl 3)	20	120	2.89	0.39	13.35

Table 7: Mean catch rates for all blue cod caught in the 2014 Paterson Inlet random site potting survey (See Figure 1). 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. Totals are provided both including and excluding (excl 3) the marine reserve (stratum 3).

Stratum	Sites	Pot lifts (N)	Mean (kg/pot)	s.e.	CV (%)
1	8	48	2.73	0.98	36.11
2	9	54	2.12	0.87	41.24
3	7	42	3.43	0.65	18.86
4	7	42	1.97	0.54	27.22
5	7	42	0.44	0.14	33.03
Total	38	228	2.14	0.34	16.09
Total (excl 3)	31	186	1.94	0.39	19.87

Table 8: Mean catch rates for blue cod 33 cm and over (MLS in BCO 5) in the 2014 Paterson Inlet random site potting survey (See Figure 1). 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. Totals are provided both including and excluding (excl 3) the marine reserve (stratum 3).

Stratum	Sites	Pot lifts (N)	Mean (kg/pot)	s.e.	CV (%)
1	8	48	1.48	0.53	35.93
2	9	54	0.95	0.38	39.73
3	7	42	1.09	0.22	19.87
4	7	42	1.23	0.38	31.40
5	7	42	0.26	0.11	43.30
Total	38	228	1.05	0.18	17.12
Total (excl 3)	31	186	1.04	0.20	19.67

Table 9: Mean lengths of blue cod in the 2014 Paterson Inlet fixed site potting survey, by strata and sex: m, males; f, female; u, unsexed. 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 (33 cm).

			Length (cm)			Sex ratio M:F (% male)	
Strata	Sex	N	Mean	Minimum	Maximum	All blue cod	≥ 33 cm
1	M	145	32.8	18	48	1:0.3(75.9)	1:<0.1(98.7)
	F	46	26.0	18	36		
2	M	207	32.2	16	47	1:0.4(72.9)	1:0.1(91.7)
	F	77	27.4	17	40		
3	M	250	36.1	23	48	1:0.2(81.4)	1:0.1(94.9)
	F	57	28.8	21	45		
	U	8	21.9	17	26		
4	M	338	32.0	18	47	1:0.3(75.8)	1:<0.1(96.3)
	F	108	26.9	19	37		
5	M	41	34.3	24	48	1:0.2(85.4)	1:<0.1(96.4)
	F	7	27.0	20	33		
Overall (un-weighted)	M	981	33.3	16	48	1:0.3(76.4)	1:<0.1(95.3)
	F	295	27.3	17	45		
	U	8	21.9	17	26		

Table 10: Mean lengths of blue cod in the 2014 Paterson Inlet random site potting survey, by stratum and sex: m, males; f, female; u, unsexed. 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 (33 cm).

			Length (cm)			Sex ratio M:F (% male)	
Strata	Sex	N	Mean	Minimum	Maximum	All blue cod	≥ 33 cm
1	M	188	30.2	18	43	1:0.5(66.9)	1:0.4(70.9)
	F	93	28.4	17	39		
2	M	196	27.8	13	42	1:0.6(64.1)	1:0.4(69.2)
	F	110	26.4	16	40		
3	M	229	28.7	17	45	1:0.6(63.8)	1:0.1(94.5)
	F	130	24.9	18	35		
	U	109	19.9	12	26		
4	M	131	32.1	17	45	1:0.3(76.2)	1:0.0(100.0)
	F	41	25.2	16	32		
5	M	17	30.1	21	40	1:1.2(44.7)	1:0.9(53.8)
	F	21	29.2	19	45		
Overall (un-weighted)	M	761	29.5	13	45	1:0.5(60.2)	1:0.2(80.7)
	F	395	26.4	16	45		
	U	109	19.9	12	26		

Table 11: Gonad stages of Paterson Inlet blue cod in 2014 fixed sites (n=8 unsexed). 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	0.5	15.7	46.5	36.2	1.1	981
Females	0	36.9	60.7	2.4	0	295

Table 12: Gonad stages of Paterson Inlet blue cod in 2014 random sites (n=109 unsexed). 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	0.8	8.9	40.7	49.5	0	761
Females	0.5	16.5	74.2	8.9	0	395

Table 13: Otolith raw data used in the catch at age, *Z* estimates, and SPR analyses for both the 2014 Paterson Inlet fixed and random surveys.

	No.	Length of aged fish (cm)			Age (years)		
Survey	otoliths	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Total	215	30.8	16	48	6.2	1	21
Male	126	32.6	18	45	6.0	2	15
Female	89	28.2	16	45	6.4	1	21

Table 14: 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 9 for the 2014 Paterson Inlet fixed site survey.

				Chapman-Robson Z	
		Confidence intervals		CV of	
AgeR	*Z*	Lower	Upper	Z est	%SPR
5	0.49	0.34	0.71	0.20	30.02
6	0.59	0.40	0.88	0.20	26.20
7	0.48	0.31	0.73	0.22	30.41
8	0.65	0.40	1.05	0.25	24.62
9	0.49	0.30	0.81	0.26	29.89
10	0.61	0.37	1.00	0.27	25.71

Table 15: Blue cod total mortality estimates (*Z*) with 95% confidence intervals and corresponding spawning biomass per recruit ratios (assuming M=0.14) for ages of recruitment (AgeR) from 5 to 9 for the 2014 Paterson Inlet random site survey.

				Chapman-Robson Z	
		Confidence intervals		CV of	
AgeR	*Z*	Lower	Upper	Z est	%SPR
5	0.46	0.32	0.70	0.21	31.17
6	0.53	0.36	0.79	0.21	28.14
7	0.41	0.28	0.61	0.20	34.27
8	0.45	0.29	0.69	0.23	31.82
9	0.35	0.22	0.55	0.24	39.44
10	0.37	0.24	0.61	0.25	37.13

Table 16: Mortality rates and spawning biomass per recruit ratios, assuming an age of recruitment of 9, at three values of M (natural mortality) for the 2014 Paterson Inlet fixed site potting survey. Z=total mortality.

M	Z	%SPR
0.11	0.49	23%
0.14	0.49	30%
0.17	0.49	37%

Table 17: Mortality rates and spawning biomass per recruit ratios, assuming an age of recruitment of 9, at three values of M (natural mortality) for the 2014 Paterson Inlet random site potting survey. Z=total mortality.

M	Z	%SPR
0.11	0.35	30%
0.14	0.35	39%
0.17	0.35	49%

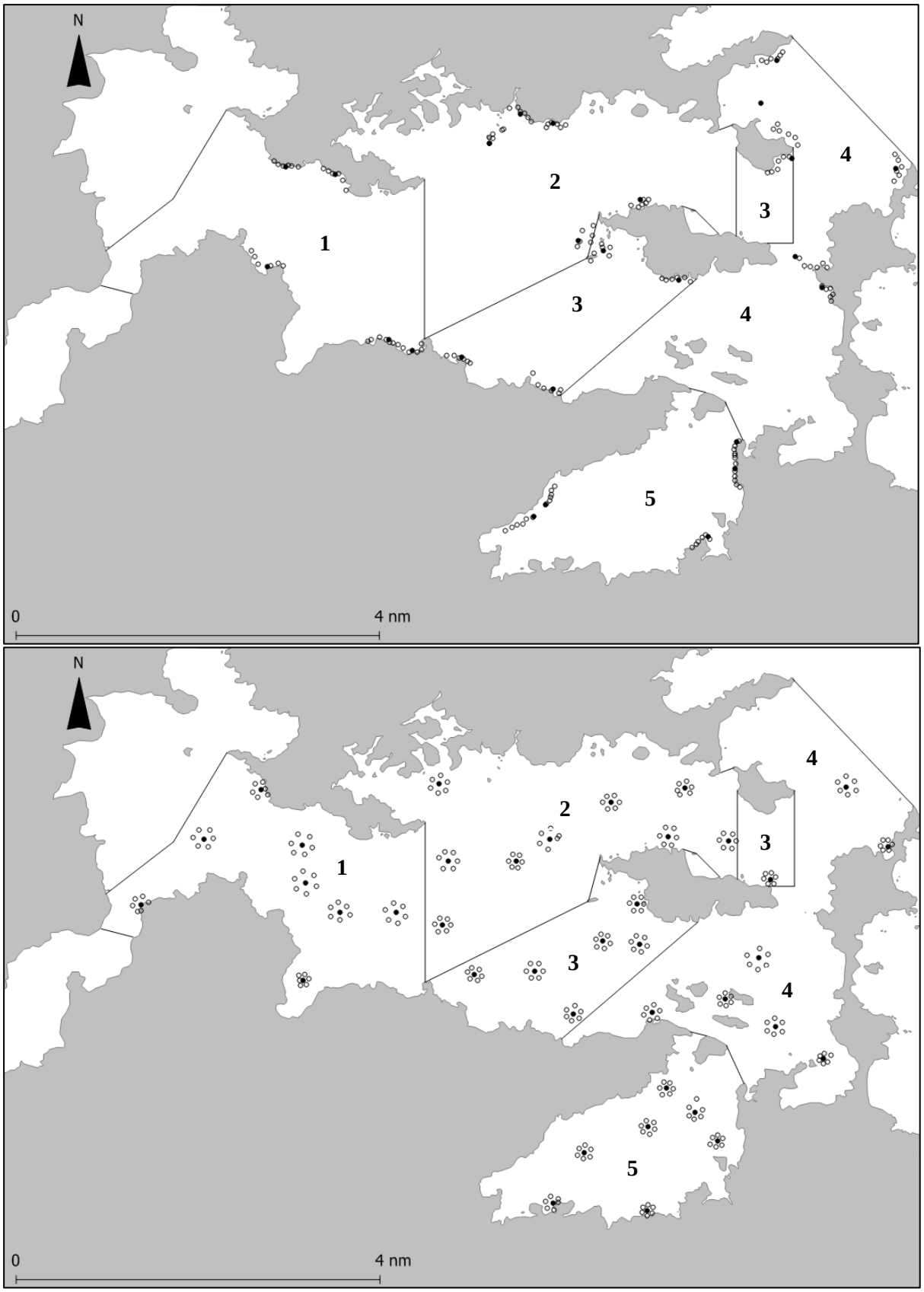


Figure 1: Strata, sites (●) and pots (○) surveyed in the 2014 Paterson Inlet selected fixed site survey (above) and random stratified site survey (below).

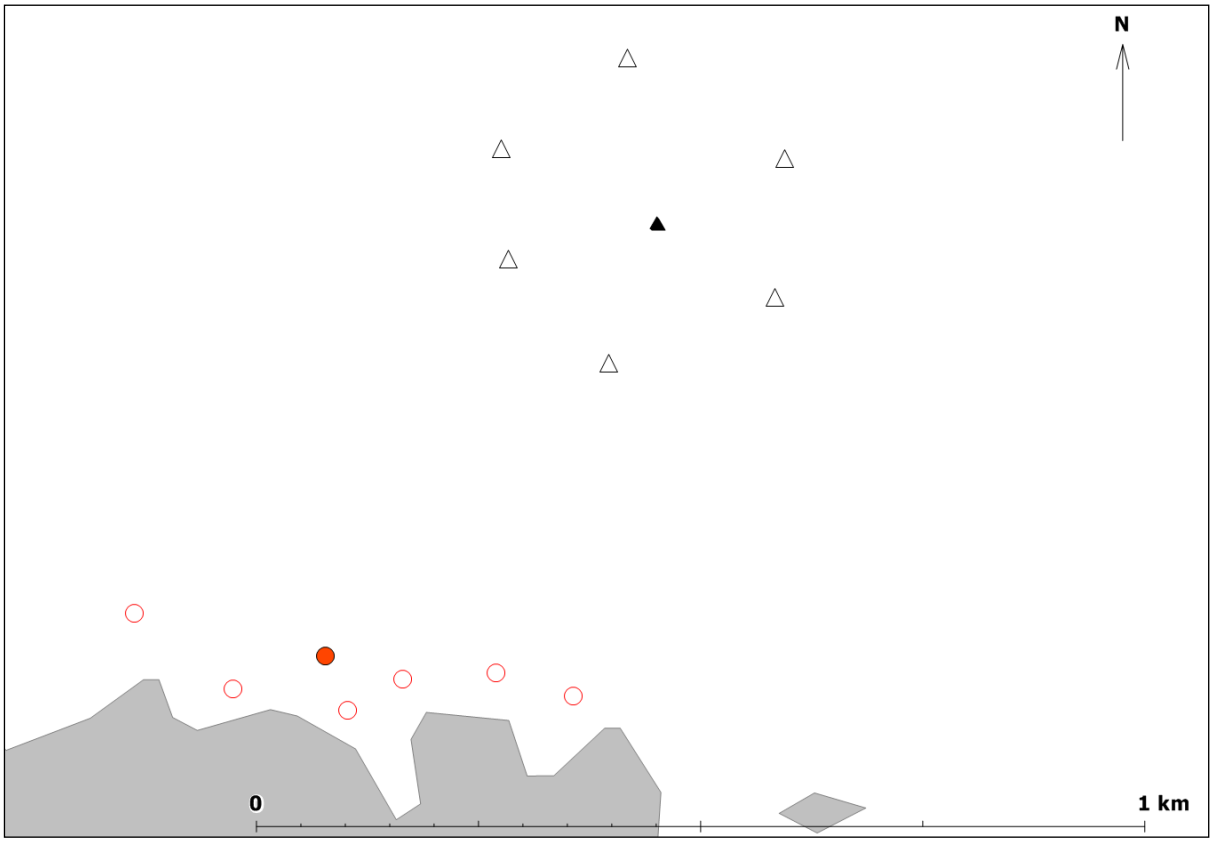


Figure 2: Placement of pots at a typical fixed (O) and random site (Δ) from the 2014 Paterson Inlet potting survey. Solid symbols are ADCP locations.

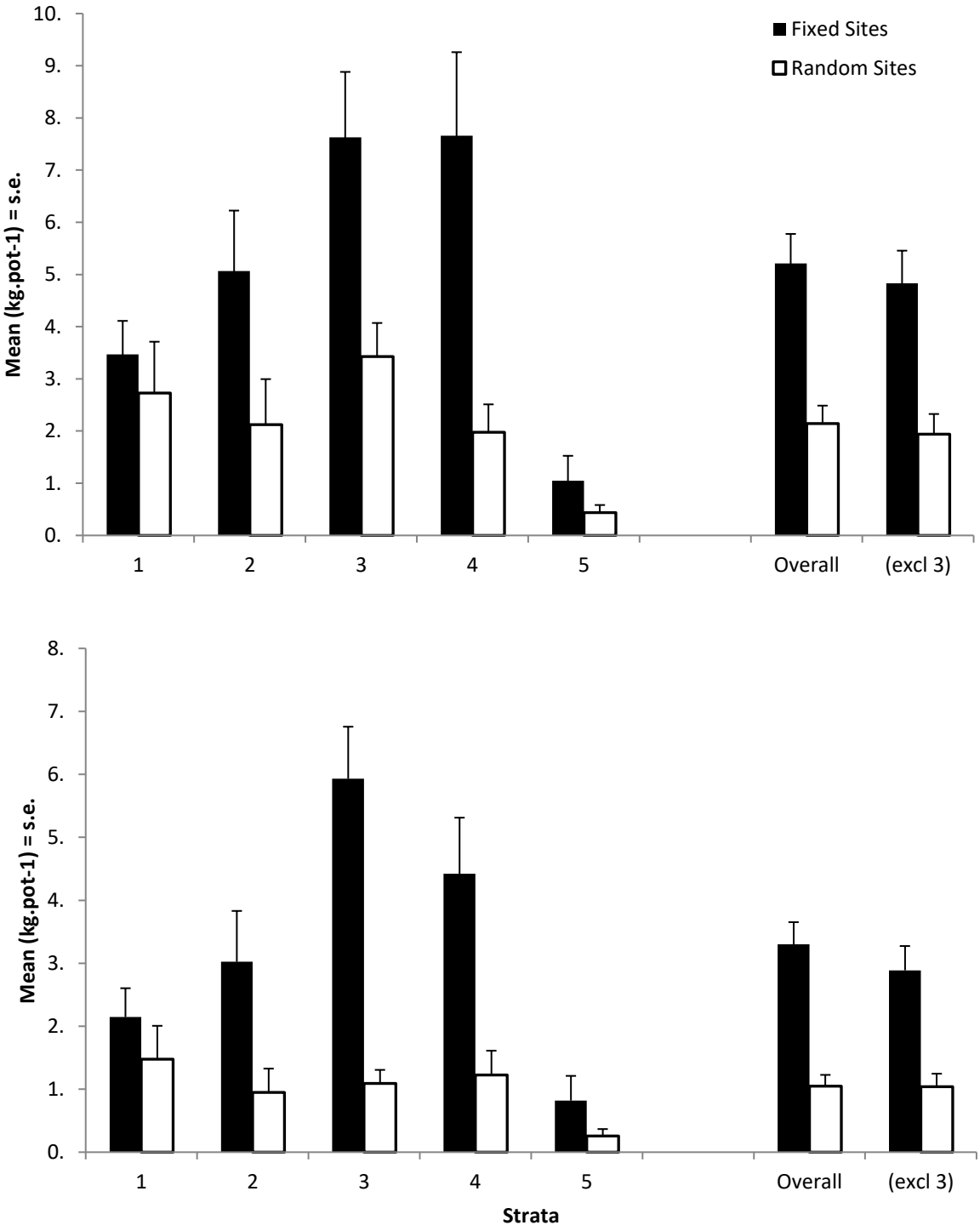


Figure 3: Catch rates (kg.pot^{-1}) and 95% confidence intervals for all blue cod (above) and those 33 cm and over (below) from the 2014 Paterson Inlet fixed and random site potting surveys. Strata and sites are shown in Figure 1.

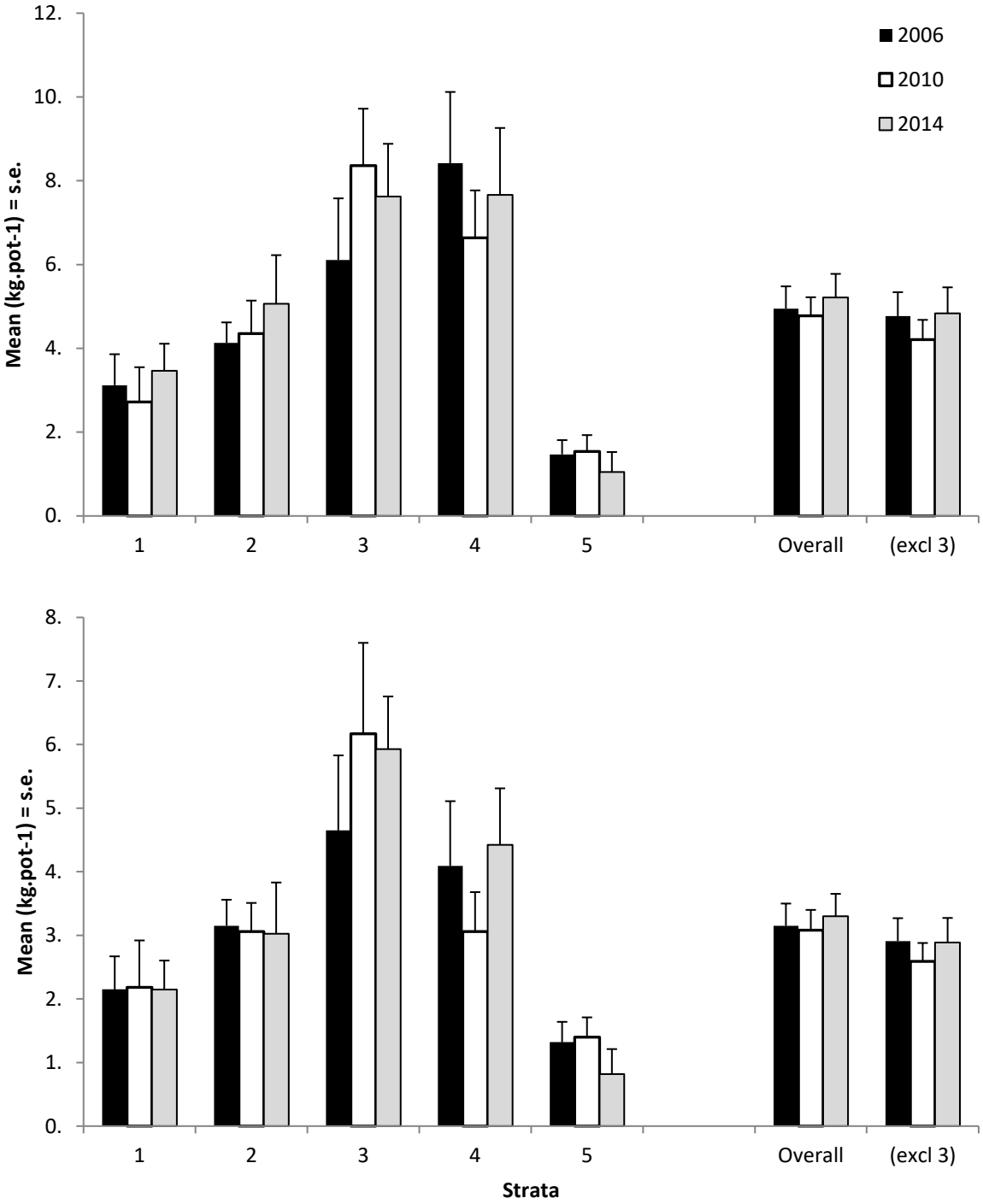


Figure 4: Catch rates (kg.pot^{-1}) and 95% confidence intervals for all blue cod (above) and those 33 cm and over (below) from the Paterson Inlet fixed site potting surveys time series. Strata and sites are shown in Figure 1.

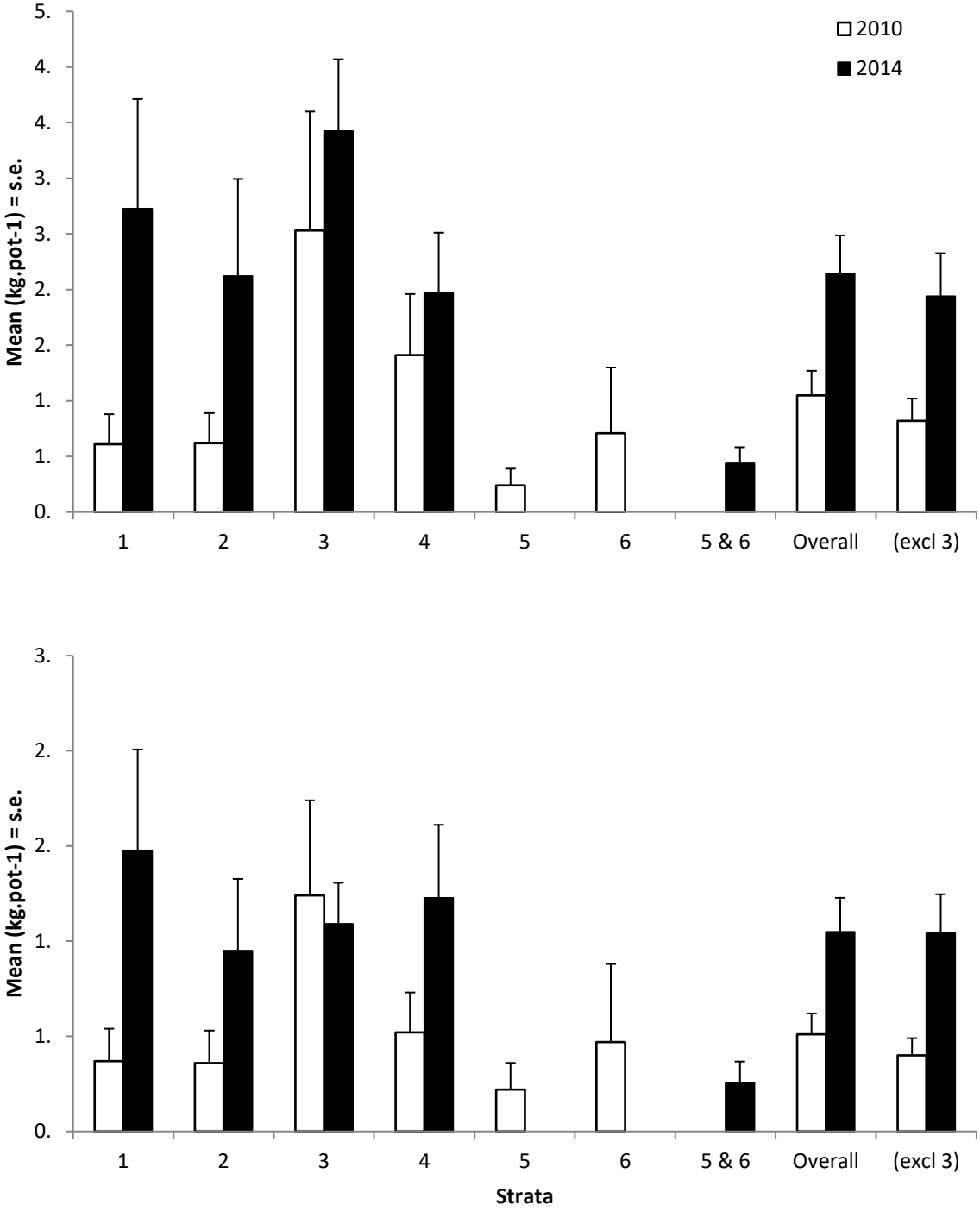


Figure 5: Catch rates (kg.pot^{-1}) and 95% confidence intervals for all blue cod (above) and those 33 cm and over (below) from the Paterson Inlet random site potting surveys time series. Strata and sites are shown in Figure 1.

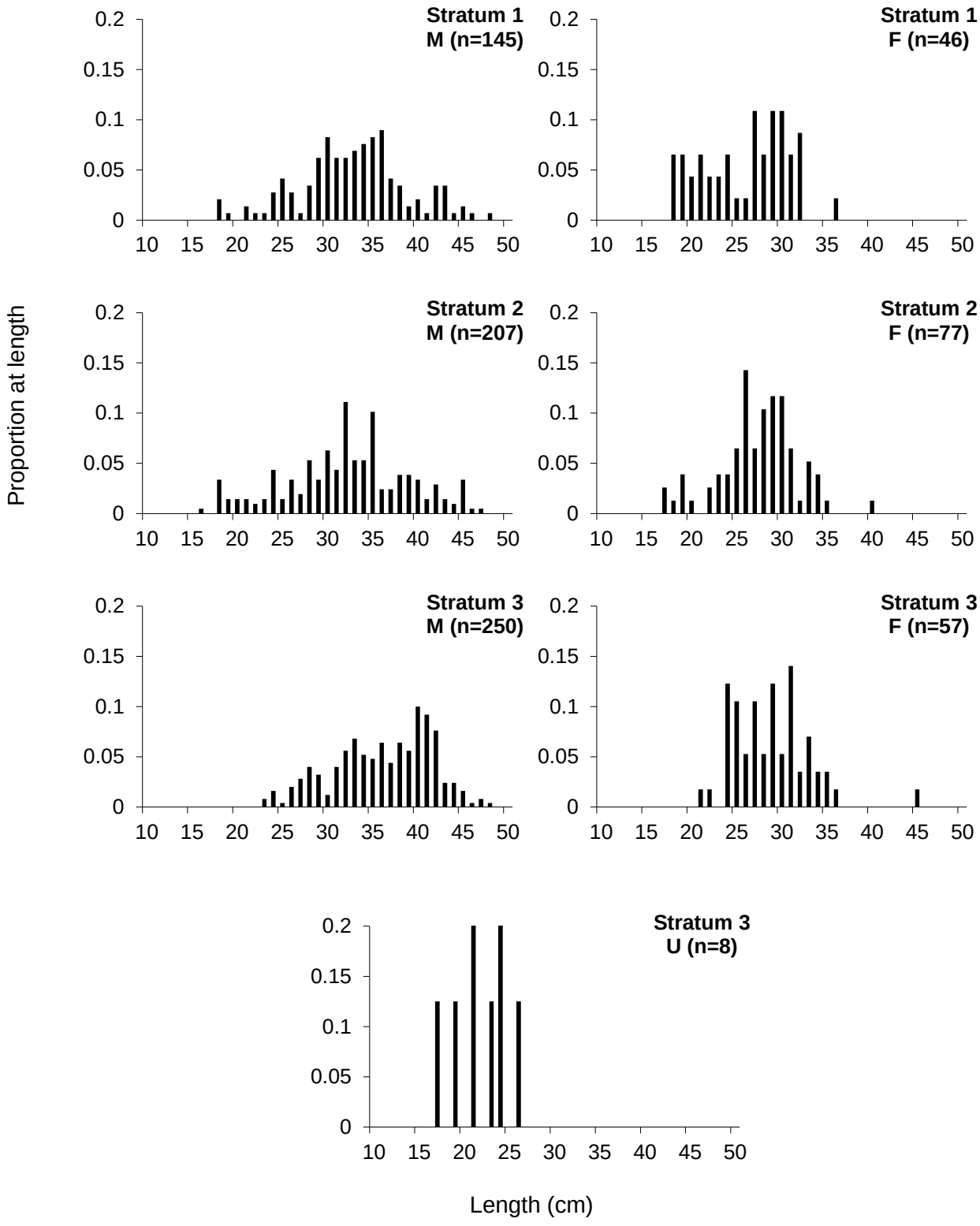


Figure 6: Unscaled proportion length frequency distributions by sex within stratum length frequency distributions by sex (M=male, F=female. U=unsexed) for the 2014 Paterson fixed site potting survey. Strata are shown in Figure 1.

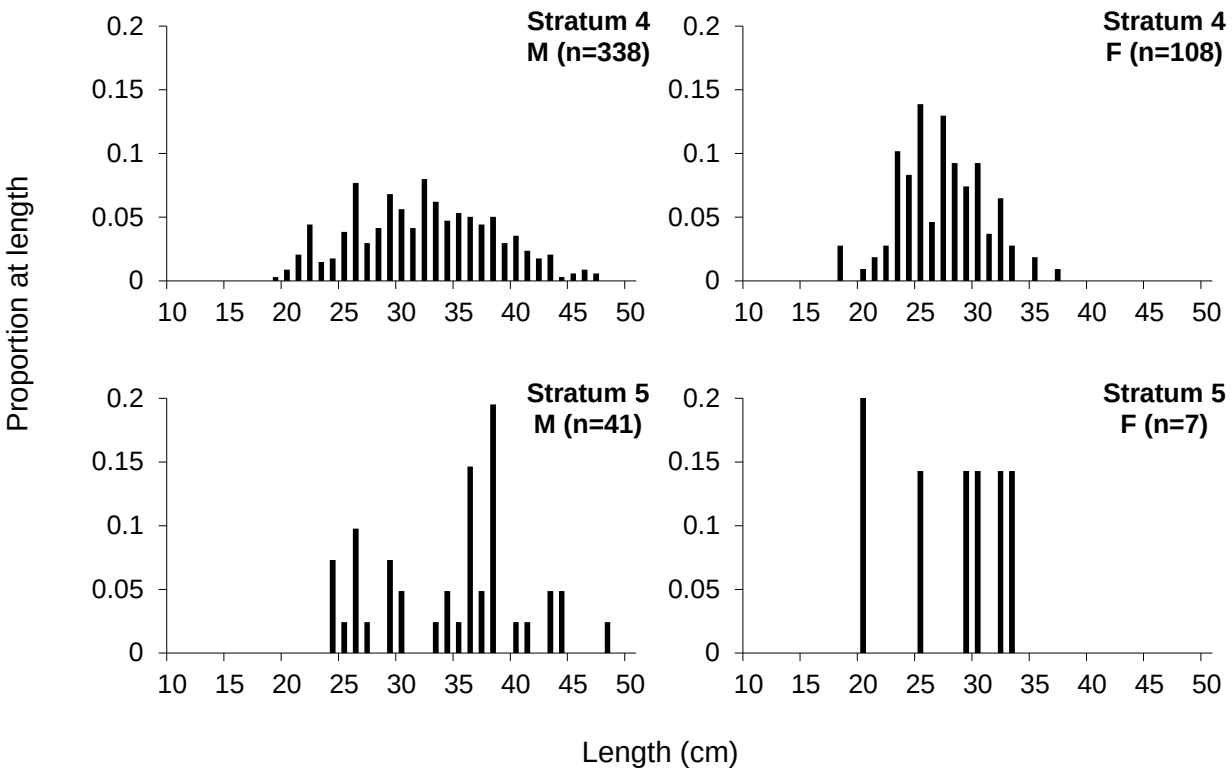


Figure 6 continued.

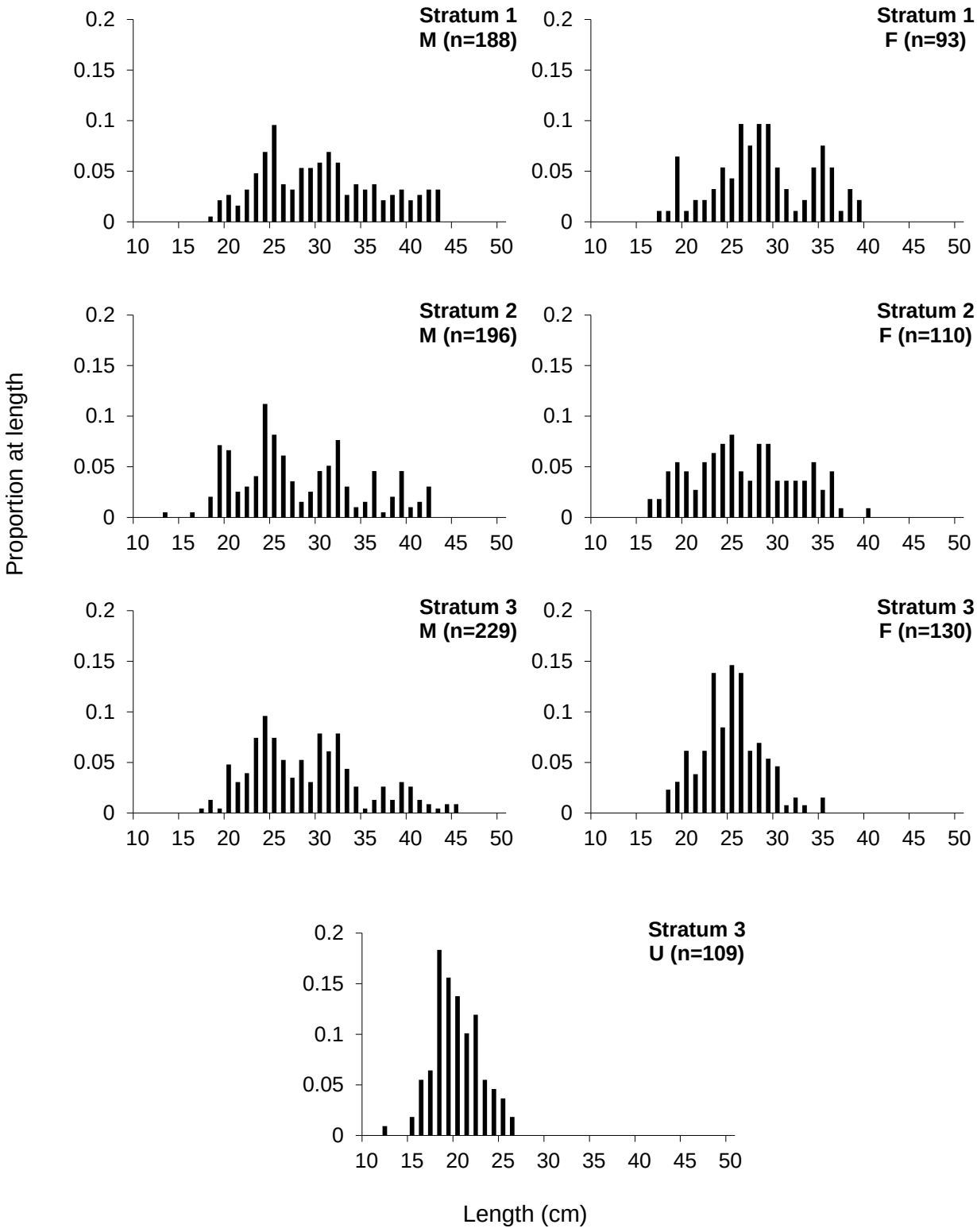


Figure 7: Unscaled proportion length frequency distributions by sex within stratum length frequency distributions by sex (M=male, F=female. U=unsexed) for the 2014 Paterson random site potting survey. Strata are shown in Figure 1.

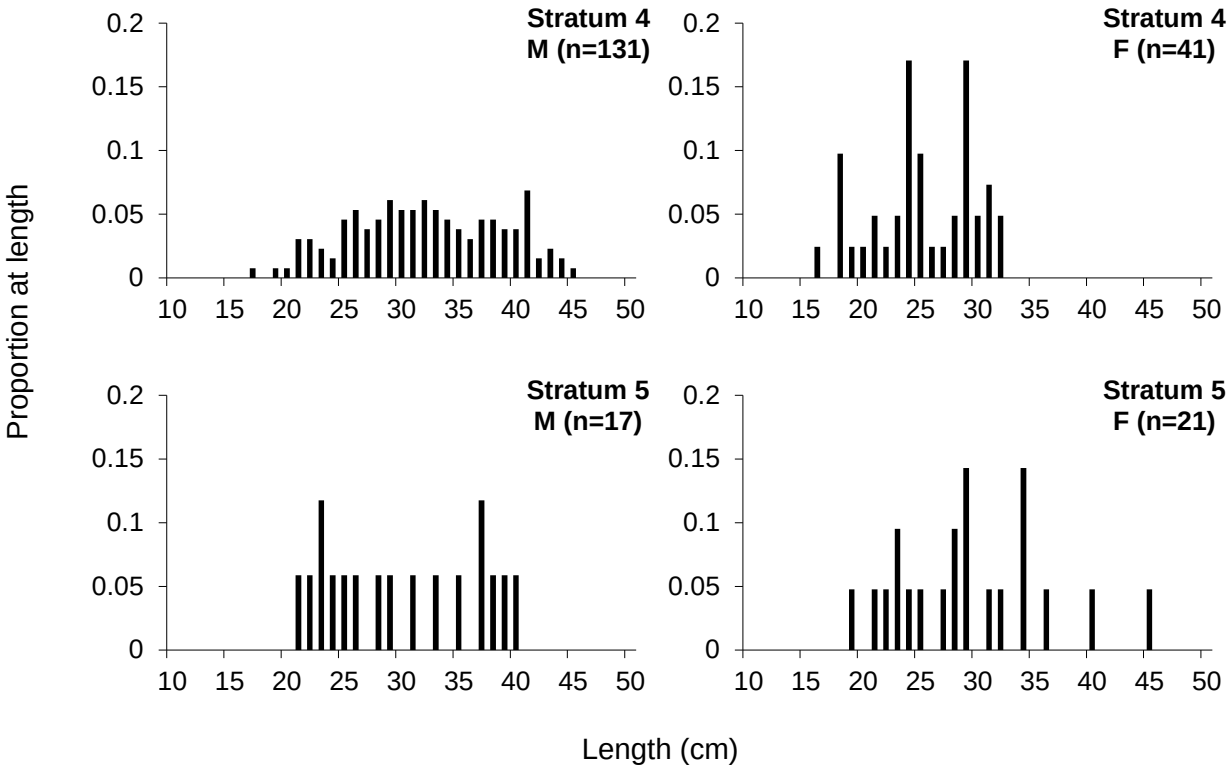


Figure 7 continued.

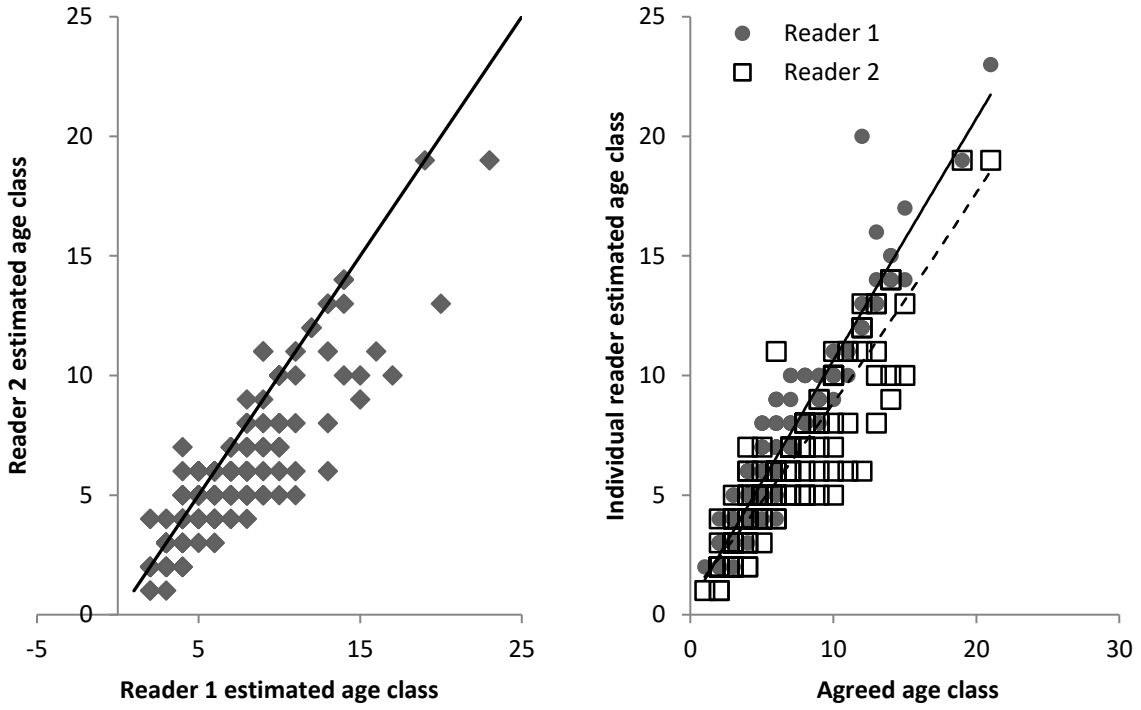


Figure 8: Paterson Inlet 2014 survey comparison of individual reader age class estimates from otoliths (n=215), on the left plotted against each other and on the left with the 1:1 line plotted. In the right panel the agreed age class estimates is plotted against the individual readers age class estimates with a polynomial trend line fitted for each reader.

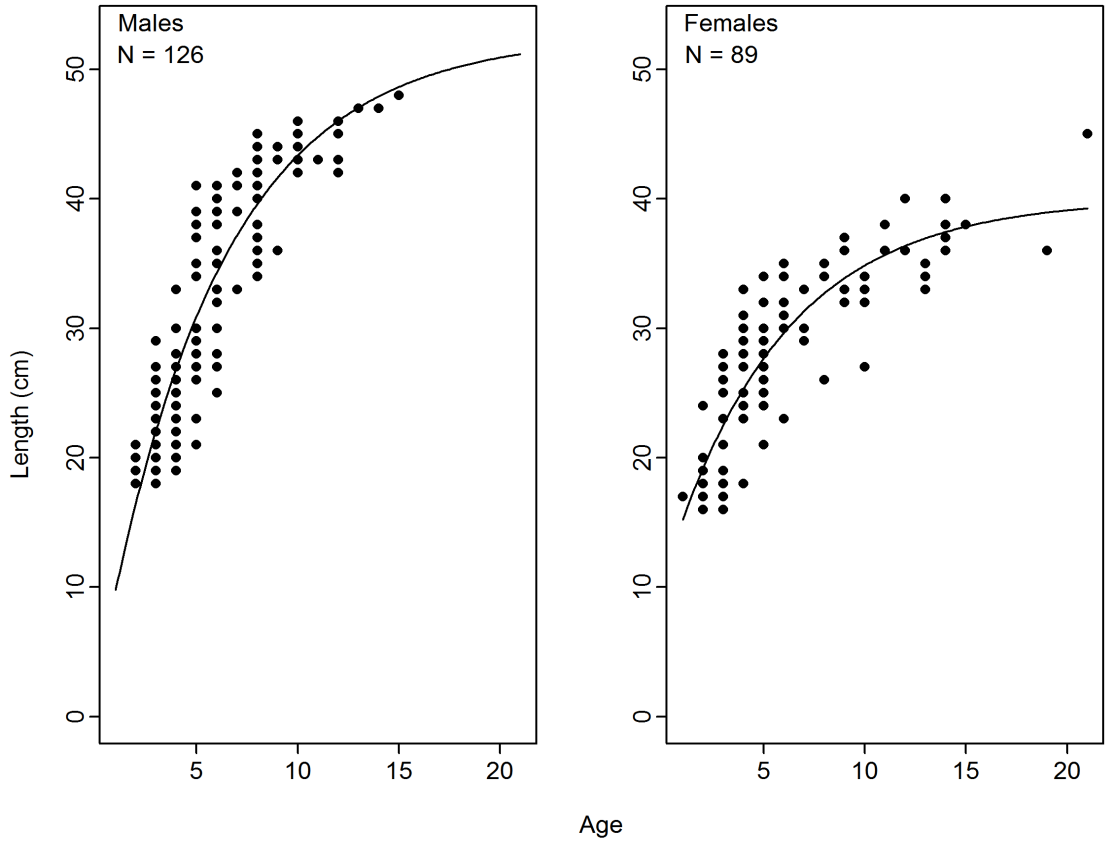


Figure 9: Observed length-at-age data and fitted von Bertalanffy growth models by sex for the 2014 Paterson Inlet survey. See Table 13 for description of biological samples.

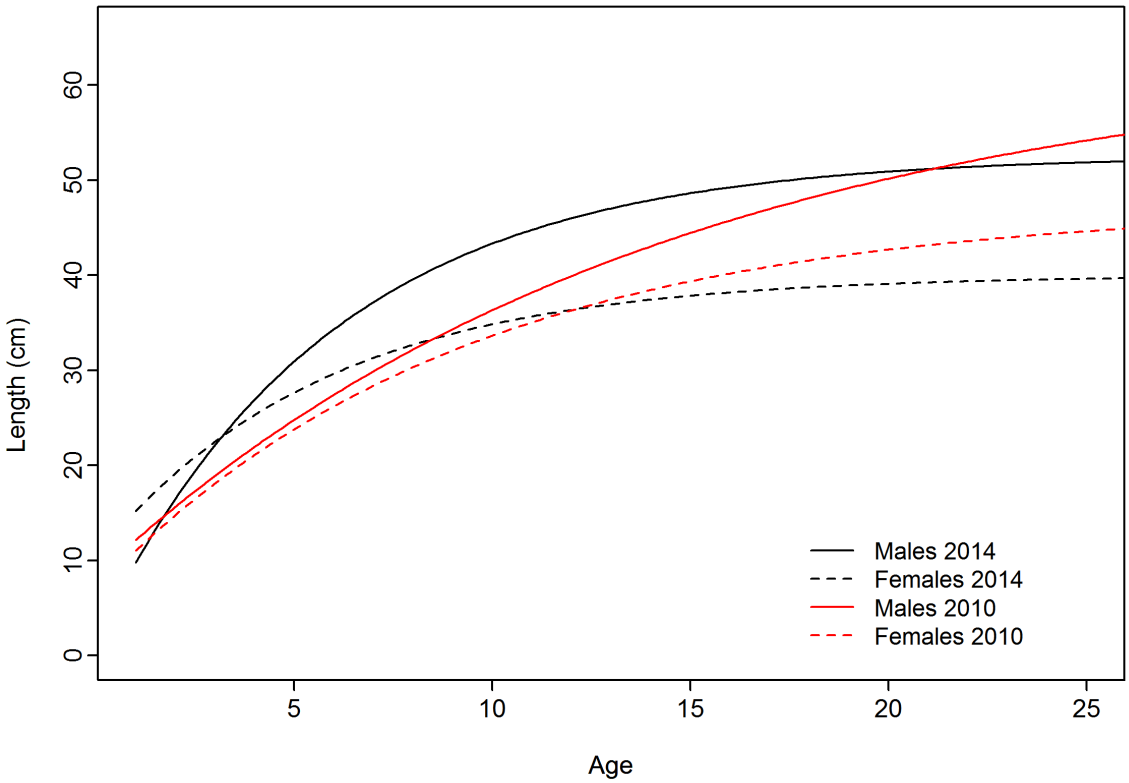


Figure 10: Fitted von Bertalanffy growth models by sex for the 2010 and 2014 Paterson Inlet surveys.

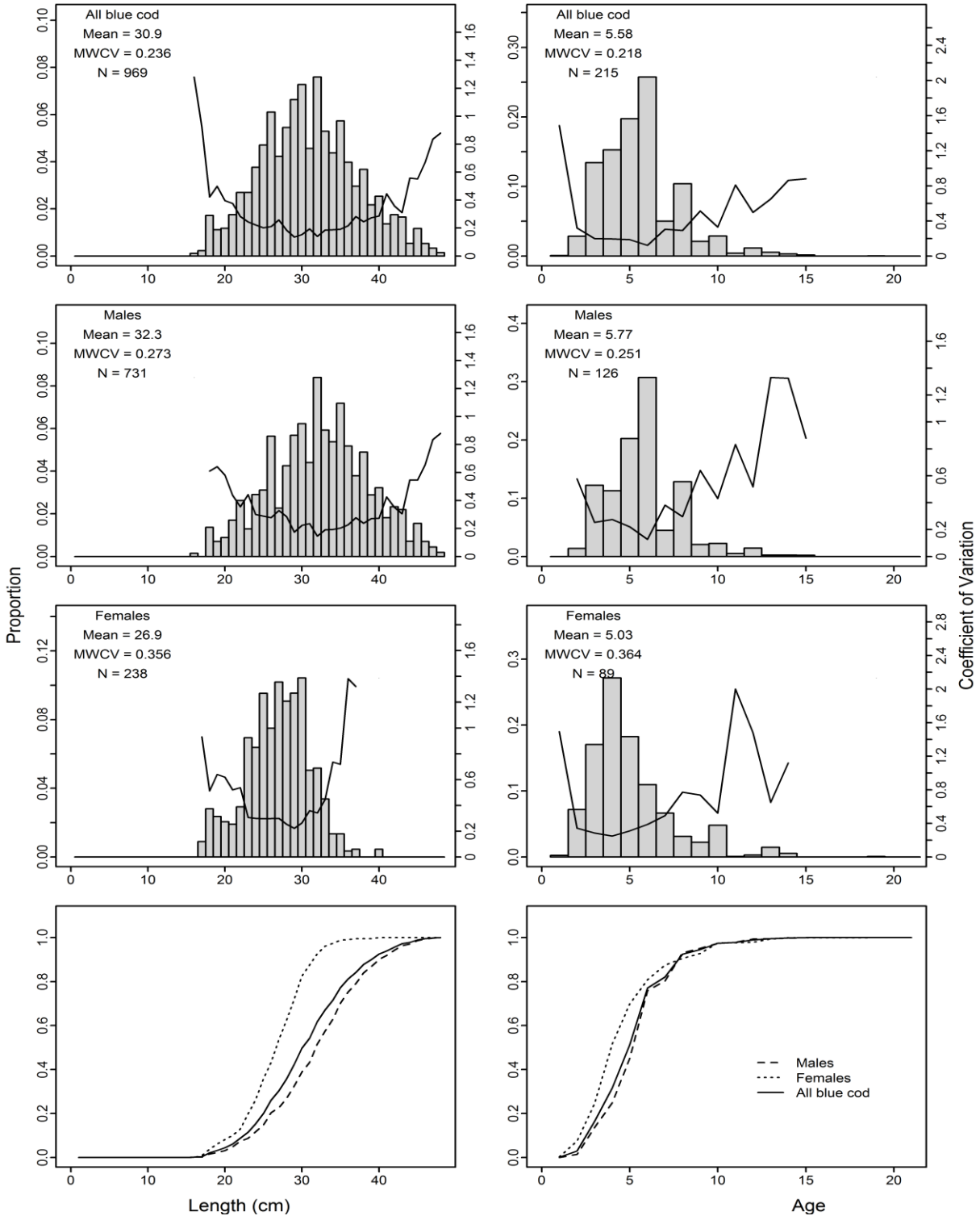


Figure 11: Scaled length frequency, age frequency, and cumulative distributions for total, male, and female blue cod for the 2014 Paterson Inlet fixed site potting survey. N, sample size; MWCV, mean weighted coefficient of variation.

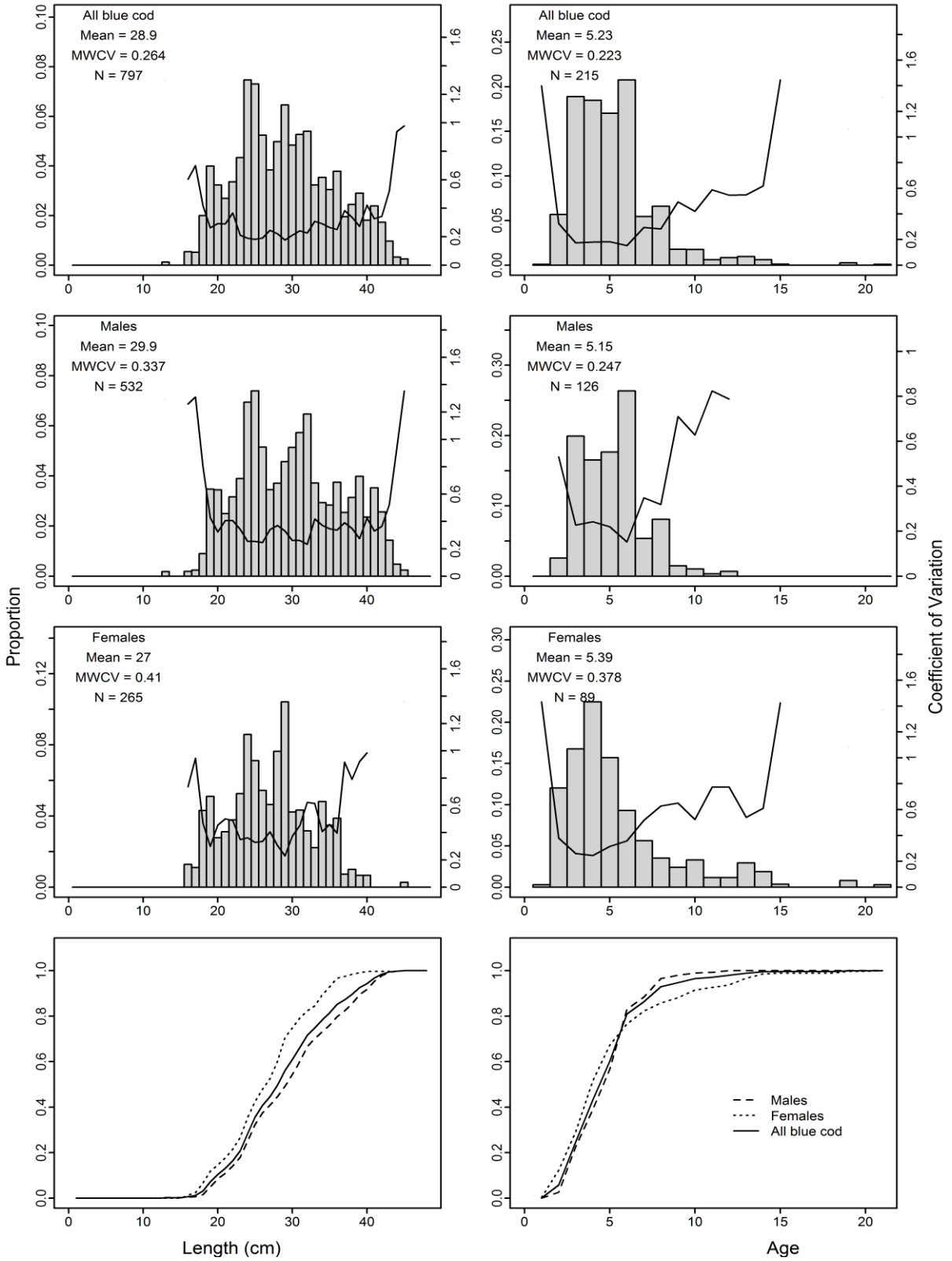


Figure 12: Scaled length frequency, age frequency, and cumulative distributions for total, male, and female blue cod for the 2014 Paterson Inlet random site potting survey (excluding the marine reserve). N, sample size; MWCV, mean weighted coefficient of variation.

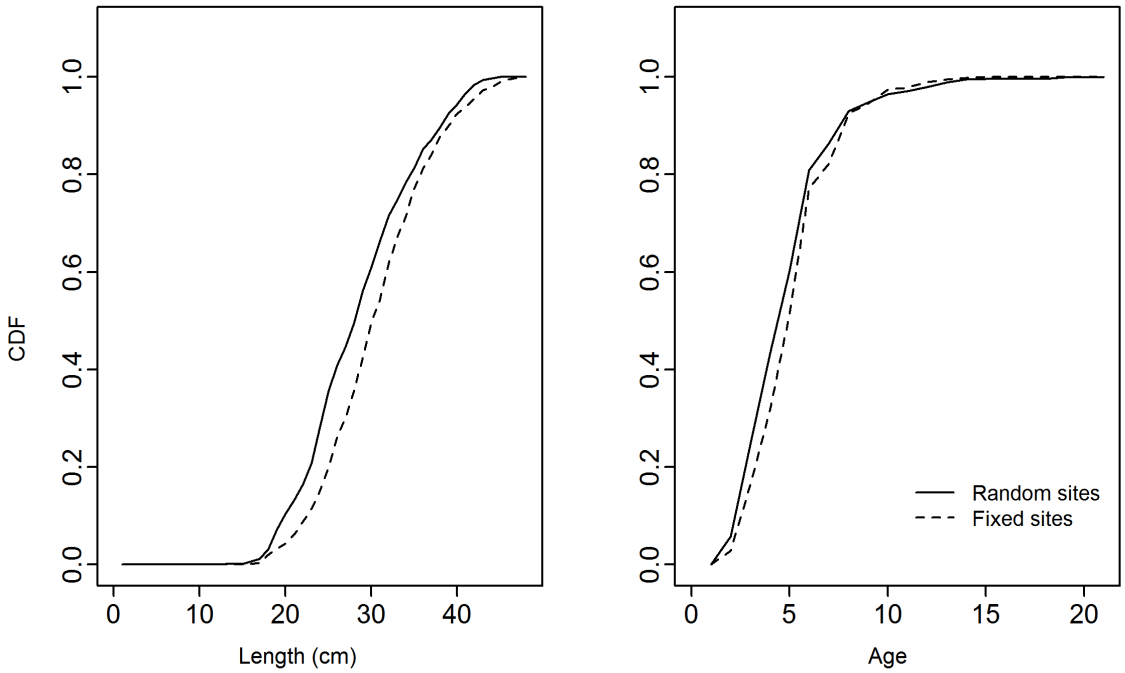


Figure 13: Cumulative length and age frequency distribution of all blue cod for the 2014 Paterson Inlet fixed and random site potting surveys (excluding the marine reserve).

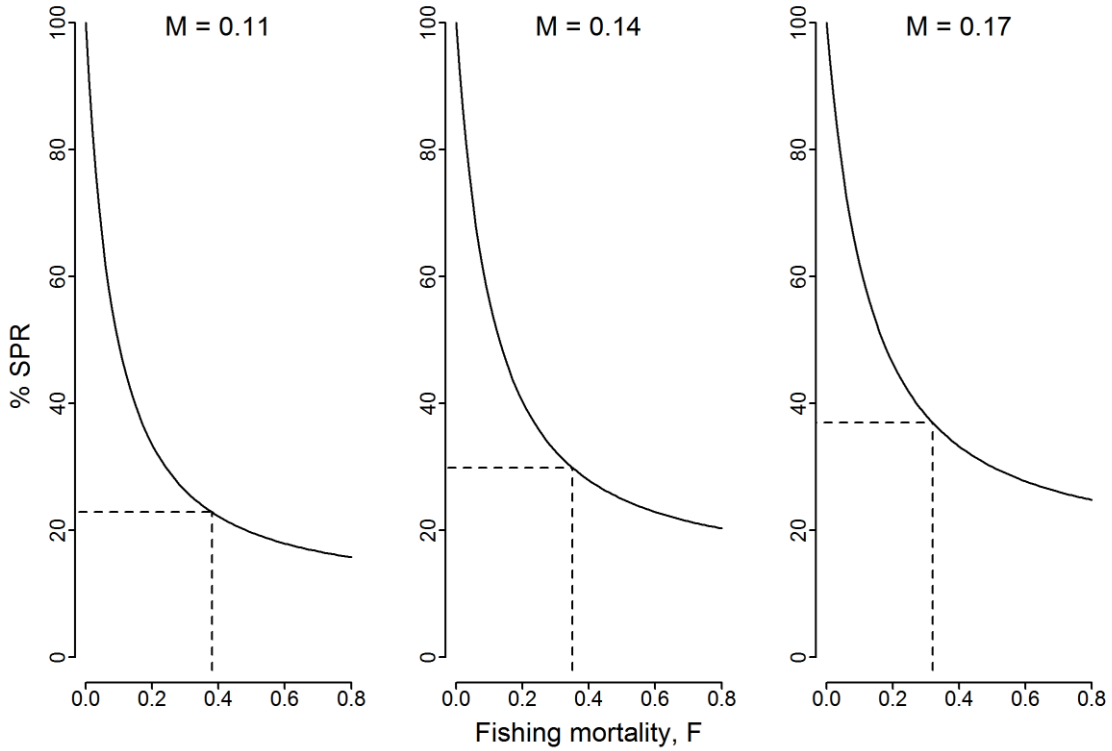


Figure 14: Plot of spawning biomass per recruit (SPR) as a function of fishing mortality for the 2014 Paterson Inlet fixed site potting surveys (excluding the marine reserve) at three values of M (0.11, 0.14, 0.17), assuming age at recruitment of 9.

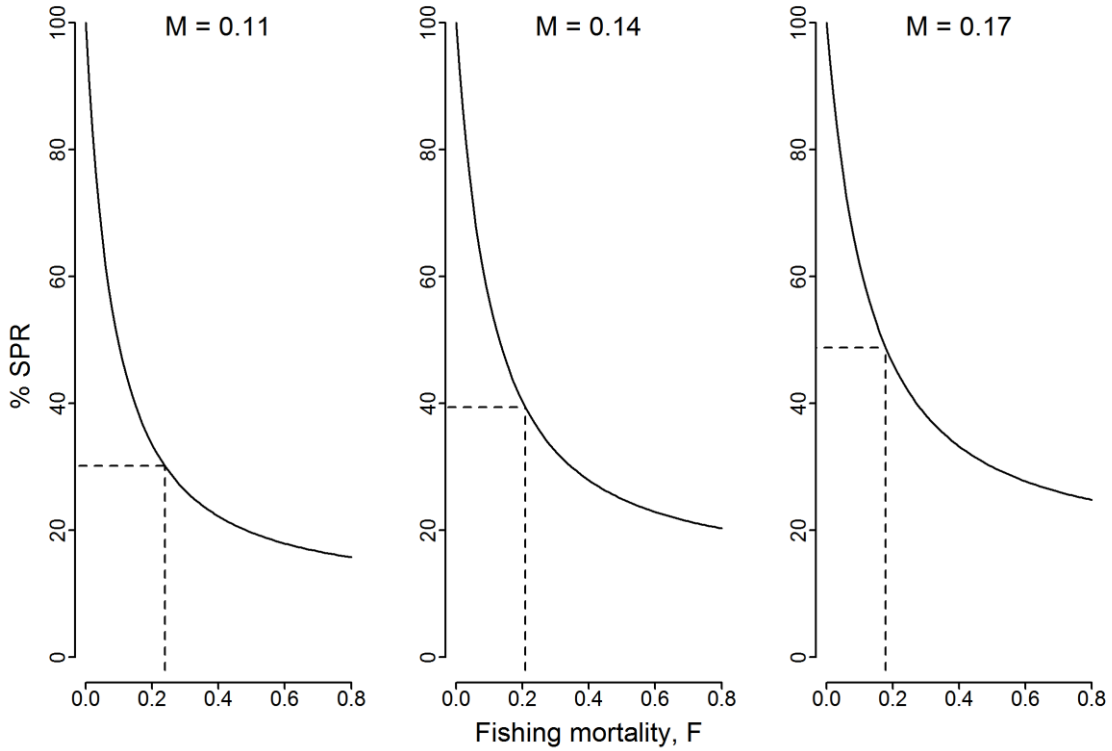


Figure 15: Plot of spawning biomass per recruit (SPR) as a function of fishing mortality for the 2014 Paterson Inlet random site potting surveys (excluding the marine reserve) at three values of M (0.11, 0.14, 0.17), assuming age at recruitment of 9.

Appendix 1: Terminology used in potting surveys.

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

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

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

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

Site label An alphanumeric label of no more than 4 characters unique within a survey time series. A site label identifies each site and also specifies which stratum it lies in. Fixed site labels are constructed by concatenating the stratum code with an alpha label (A–Z) that is unique within that stratum. Thus, sites within stratum 2 could be labelled 2A, 2B, and sites in stratum 3 could be labelled 3A, 3B etc. Note that fixed site label remain constantly fixed to that location for all surveys. In contrast, random sites are regenerated for each survey and use a numeric label based on the order in which they were randomly generated, followed by the letter R and then concatenated with the stratum code. Thus, sites within stratum 2 could be labelled 2R1, 2R3, and sites in stratum 3 could be labelled 3R1, 3R2 etc.

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

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

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

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

Station number A number which uniquely identifies each station within a survey. The station number is formed by concatenating the set number with the pot number. Thus, pot 4 in set 23 would be station number 234. This convention is important in enabling users of the *trawl* database to determine whether two pots are from the same set.

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

Appendix 2: Change of ageing method between the 2010 and 2014 surveys

Otoliths from the 2010 Paterson Inlet random site potting survey (Carbines & Haist 2012) were read under transmitted light counting all opaque (dark) zones according to Carbines (2004b). However, a new validation study shows that the first opaque zone previously counted as the first annuli, is in fact a juvenile check (Carbines 2016). Furthermore, a new ageing protocol recommends reading blue cod otolith under reflected light (where opaque zones appear light and translucent zones appear dark), and counting only translucent (dark) zones beyond the juvenile portion of the otolith (Figure A). Otoliths from the 2014 Paterson Inlet random site potting survey were read under the reflected light according to the new ageing protocol as it better distinguished the banding patterns and allows for the previously unknown juvenile check.

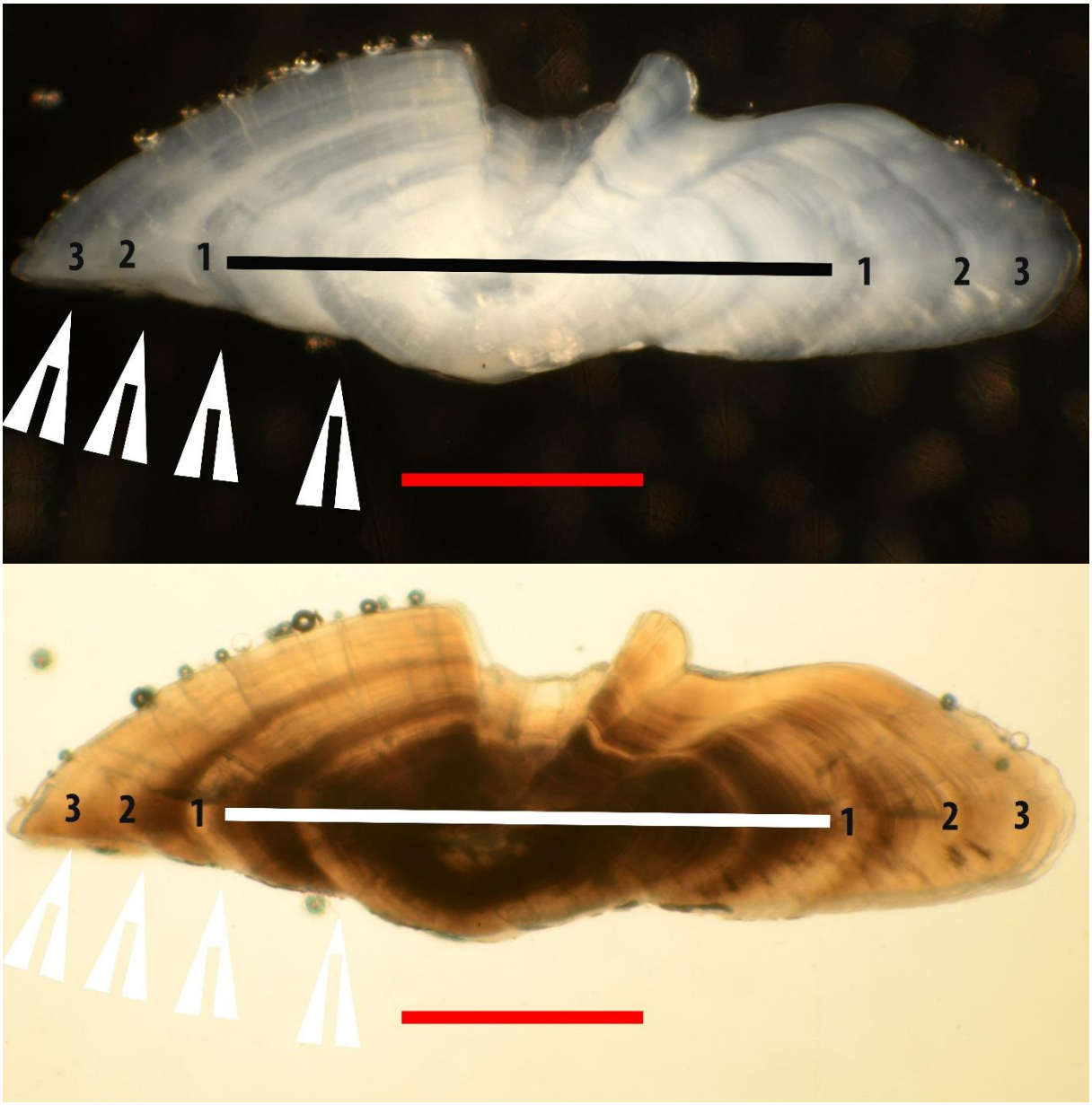


Figure A: Sectioned otolith from a three plus blue cod shown in (A) reflected light (B) transmitted light. The area of the zero plus portion of the otolith is shown by the black/white bar and the annuli are marked. The red scale bar is 0.5 mm, and arrows show the notches on the dorsal distal edge marking the juvenile check and annuli (numbered). Figure from Carbines (2016).

Appendix 3: Summary of survey pot lift station data, Paterson Inlet 2014.

								Catch of blue cod	
Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot	(kg)	Number
1	19-Nov-14	1	4	R2	20.7	10:03	1	1.2	1
1	19-Nov-14	1	4	R2	18.3	10:13	2	1.4	1
1	19-Nov-14	1	4	R2	18.8	10:23	3	4.5	1
1	19-Nov-14	1	4	R2	29.3	10:33	4	4.9	1
1	19-Nov-14	1	4	R2	32.4	10:43	5	1.9	1
1	19-Nov-14	1	4	R2	26.5	10:53	6	1.1	1
2	19-Nov-14	1	4	R5	16.8	12:45	6	0	2
2	19-Nov-14	1	4	R5	16.6	12:53	5	0	2
2	19-Nov-14	1	4	R5	17.2	13:01	4	0	2
2	19-Nov-14	1	4	R5	17.6	13:09	3	0	2
2	19-Nov-14	1	4	R5	21.0	13:17	2	0	2
2	19-Nov-14	1	4	R5	17.6	13:25	1	0	2
3	19-Nov-14	1	4	4C	10.1	14:43	1	6.2	3
3	19-Nov-14	1	4	4C	12.4	14:53	2	2.9	3
3	19-Nov-14	1	4	4C	11.7	15:03	3	4.9	3
3	19-Nov-14	1	4	4C	8.8	15:13	4	4.1	3
3	19-Nov-14	1	4	4C	9.5	15:23	5	6.2	3
3	19-Nov-14	1	4	4C	7.9	15:33	6	2.3	3
4	21-Nov-14	1	4	4E	6.2	10:28	6	2.8	4
4	21-Nov-14	1	4	4E	6.8	10:38	5	3	4
4	21-Nov-14	1	4	4E	6.6	10:48	4	11.5	4
4	21-Nov-14	1	4	4E	4.6	10:58	3	2.1	4
4	21-Nov-14	1	4	4E	6.9	11:08	2	4	4
4	21-Nov-14	1	4	4E	12.8	11:18	1	16.7	4
5	21-Nov-14	1	4	R3	6.2	12:45	1	9.4	5
5	21-Nov-14	1	4	R3	5.5	12:55	2	5.7	5
5	21-Nov-14	1	4	R3	6.4	13:05	3	3.6	5
5	21-Nov-14	1	4	R3	8.8	13:15	4	2.2	5
5	21-Nov-14	1	4	R3	12.1	13:25	5	2.8	5
5	21-Nov-14	1	4	R3	9.0	13:35	6	1.4	5
6	22-Nov-14	1	2	2I	6.9	6:05	6	1.9	6
6	22-Nov-14	1	2	2I	5.5	6:15	5	3.2	6
6	22-Nov-14	1	2	2I	3.8	6:25	4	2	6
6	22-Nov-14	1	2	2I	5.5	6:35	3	1.6	6
6	22-Nov-14	1	2	2I	10.8	6:45	2	5.1	6
6	22-Nov-14	1	2	2I	9.7	6:55	1	5.4	6
7	22-Nov-14	1	2	R5	22.9	8:26	1	2.6	7
7	22-Nov-14	1	2	R5	22.9	8:32	2	4.4	7
7	22-Nov-14	1	2	R5	22.9	8:38	3	5.9	7
7	22-Nov-14	1	2	R5	23.8	8:44	4	4.8	7
7	22-Nov-14	1	2	R5	23.4	8:50	5	2.9	7
7	22-Nov-14	1	2	R5	23.2	8:56	6	7.5	7
8	22-Nov-14	1	1	R2	21.0	10:07	6	3.9	8
8	22-Nov-14	1	1	R2	21.0	10:27	5	6.7	8
8	22-Nov-14	1	1	R2	21.4	10:37	4	7.5	8

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot	Catch of blue cod (kg)	Catch of blue cod Number
8	22-Nov-14	1	1	R2	21.6	10:47	3	5.1	13
8	22-Nov-14	1	1	R2	21.4	10:57	2	3.5	6
8	22-Nov-14	1	1	R2	21.8	11:07	1	21	43
9	22-Nov-14	1	1	R5	6.9	12:33	1	0	0
9	22-Nov-14	1	1	R5	6.6	12:41	2	0	0
9	22-Nov-14	1	1	R5	6.4	12:49	3	0	0
9	22-Nov-14	1	1	R5	7.3	12:57	4	0	0
9	22-Nov-14	1	1	R5	8.0	13:05	5	0	0
9	22-Nov-14	1	1	R5	8.0	13:13	6	0	0
10	22-Nov-14	1	2	R3	24.5	14:39	6	5.9	16
10	22-Nov-14	1	2	R3	24.7	14:47	5	0	0
10	22-Nov-14	1	2	R3	24.7	14:55	4	0	0
10	22-Nov-14	1	2	R3	24.7	15:04	3	0.6	3
10	22-Nov-14	1	2	R3	25.1	15:12	2	1.5	3
10	22-Nov-14	1	2	R3	24.9	15:21	1	3	4
11	23-Nov-14	1	1	R7	19.2	5:33	1	4.2	22
11	23-Nov-14	1	1	R7	19.4	5:42	2	5.3	15
11	23-Nov-14	1	1	R7	19.0	5:50	3	3.2	9
11	23-Nov-14	1	1	R7	18.1	5:58	4	10.6	20
11	23-Nov-14	1	1	R7	10.6	6:06	5	0.2	1
11	23-Nov-14	1	1	R7	12.3	6:13	6	0	0
12	23-Nov-14	1	1	R3	18.5	7:30	6	4.9	14
12	23-Nov-14	1	1	R3	18.7	7:40	5	5.3	10
12	23-Nov-14	1	1	R3	18.1	7:50	4	2.5	6
12	23-Nov-14	1	1	R3	16.6	8:00	3	5.4	10
12	23-Nov-14	1	1	R3	15.5	8:10	2	3.8	10
12	23-Nov-14	1	1	R3	17.6	8:20	1	0	0
13	23-Nov-14	1	1	R1	19.6	9:35	1	2.1	4
13	23-Nov-14	1	1	R1	19.6	9:45	2	0.2	1
13	23-Nov-14	1	1	R1	19.2	9:55	3	0	0
13	23-Nov-14	1	1	R1	18.8	10:05	4	4.7	10
13	23-Nov-14	1	1	R1	18.8	10:15	5	8.7	12
13	23-Nov-14	1	1	R1	18.8	10:25	6	10.5	20
14	23-Nov-14	1	1	R6	11.9	11:43	6	0.5	1
14	23-Nov-14	1	1	R6	5.5	11:53	5	9.6	12
14	23-Nov-14	1	1	R6	8.0	12:03	4	0	0
14	23-Nov-14	1	1	R6	7.3	12:14	3	0	0
14	23-Nov-14	1	1	R6	18.1	12:24	2	0	0
14	23-Nov-14	1	1	R6	18.5	12:34	1	0	0
15	23-Nov-14	1	1	R4	18.3	13:48	1	0	0
15	23-Nov-14	1	1	R4	18.5	13:56	2	0.8	1
15	23-Nov-14	1	1	R4	18.5	14:04	3	0	0
15	23-Nov-14	1	1	R4	18.5	14:12	4	0	0
15	23-Nov-14	1	1	R4	19.4	14:20	5	0	0
15	23-Nov-14	1	1	R4	19.6	14:28	6	0	0
16	24-Nov-14	1	2	R2	23.2	5:35	6	1.9	7
16	24-Nov-14	1	2	R2	22.7	5:45	5	4.8	9
16	24-Nov-14	1	2	R2	21.9	5:55	4	4.1	13

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot	Catch of blue cod (kg)	Catch of blue cod Number
16	24-Nov-14	1	2	R2	21.0	6:05	3	5.6	11
16	24-Nov-14	1	2	R2	21.9	6:15	2	10.3	26
16	24-Nov-14	1	2	R2	22.5	6:25	1	12.7	27
17	24-Nov-14	1	2	R7	21.2	7:52	1	4.6	12
17	24-Nov-14	1	2	R7	21.8	8:02	2	6.6	13
17	24-Nov-14	1	2	R7	22.5	8:12	3	2.6	9
17	24-Nov-14	1	2	R7	22.3	8:22	4	7.2	18
17	24-Nov-14	1	2	R7	22.3	8:32	5	6.4	16
17	24-Nov-14	1	2	R7	21.4	8:33	6	3.7	12
18	24-Nov-14	1	2	R1	13.2	11:11	6	0	0
18	24-Nov-14	1	2	R1	13.5	10:20	5	1.6	11
18	24-Nov-14	1	2	R1	13.2	10:30	4	0	0
18	24-Nov-14	1	2	R1	13.4	10:40	3	0	0
18	24-Nov-14	1	2	R1	13.2	10:50	2	0	0
18	24-Nov-14	1	2	R1	13.2	11:00	1	0	0
19	24-Nov-14	1	2	R8	9.9	12:35	1	0	0
19	24-Nov-14	1	2	R8	7.3	12:40	2	0	0
19	24-Nov-14	1	2	R8	7.9	12:45	3	0	0
19	24-Nov-14	1	2	R8	8.6	12:50	4	0	0
19	24-Nov-14	1	2	R8	9.7	12:55	5	0	0
19	24-Nov-14	1	2	R8	12.8	13:00	6	0	0
20	24-Nov-14	1	2	2G	13.0	14:13	6	4	10
20	24-Nov-14	1	2	2G	9.1	14:21	5	6.2	13
20	24-Nov-14	1	2	2G	8.8	14:26	4	2.8	7
20	24-Nov-14	1	2	2G	18.7	14:32	3	3.3	10
20	24-Nov-14	1	2	2G	5.5	14:39	2	7.2	14
20	24-Nov-14	1	2	2G	9.3	14:46	1	2.7	11
21	25-Nov-14	1	2	2E	8.4	5:23	1	0.7	1
21	25-Nov-14	1	2	2E	12.3	5:33	2	2.6	8
21	25-Nov-14	1	2	2E	11.9	5:44	3	10.8	15
21	25-Nov-14	1	2	2E	13.2	5:54	4	4.3	8
21	25-Nov-14	1	2	2E	11.2	6:03	5	5.9	14
21	25-Nov-14	1	2	2E	11.7	6:13	6	24.6	44
22	25-Nov-14	1	4	R6	6.4	7:46	6	0	0
22	25-Nov-14	1	4	R6	6.0	7:55	5	7.5	16
22	25-Nov-14	1	4	R6	10.6	8:05	4	0	0
22	25-Nov-14	1	4	R6	9.0	8:15	3	0	0
22	25-Nov-14	1	4	R6	5.3	8:25	2	0	0
22	25-Nov-14	1	4	R6	5.5	8:35	1	0	0
23	25-Nov-14	1	4	R4	22.3	9:45	1	0	0
23	25-Nov-14	1	4	R4	22.3	9:55	2	1.4	3
23	25-Nov-14	1	4	R4	24.3	10:05	3	1.1	8
23	25-Nov-14	1	4	R4	17.6	10:15	4	1.9	10
23	25-Nov-14	1	4	R4	21.6	10:25	5	0.6	3
23	25-Nov-14	1	4	R4	28.9	10:35	6	3.9	24
24	25-Nov-14	1	4	4H	8.4	12:15	6	7.5	20
24	25-Nov-14	1	4	4H	9.5	12:25	5	19.5	35
24	25-Nov-14	1	4	4H	5.3	12:35	4	11.8	24

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot	Catch of blue cod (kg)	Catch of blue cod Number
24	25-Nov-14	1	4	4H	4.0	12:45	3	7	8
24	25-Nov-14	1	4	4H	6.2	12:55	2	6.6	11
24	25-Nov-14	1	4	4H	6.9	13:05	1	13.4	22
25	25-Nov-14	1	4	4B	24.3	14:25	1	0	0
25	25-Nov-14	1	4	4B	35.7	14:35	2	22.6	45
25	25-Nov-14	1	4	4B	11.7	14:45	3	22.7	65
25	25-Nov-14	1	4	4B	6.9	14:55	4	4.1	12
25	25-Nov-14	1	4	4B	9.0	15:05	5	17.1	26
25	25-Nov-14	1	4	4B	4.2	15:15	6	4.8	6
26	4-Dec-14	1	4	R7	12.8	5:58	1	0	0
26	4-Dec-14	1	4	R7	11.7	6:08	2	0.2	1
26	4-Dec-14	1	4	R7	8.4	6:18	3	1.9	6
26	4-Dec-14	1	4	R7	6.6	6:28	4	1.7	4
26	4-Dec-14	1	4	R7	12.3	6:38	5	1.6	3
26	4-Dec-14	1	4	R7	19.4	6:48	6	1.5	2
27	4-Dec-14	1	5	5I	6.2	8:04	6	6	12
27	4-Dec-14	1	5	5I	6.2	8:14	5	0.1	1
27	4-Dec-14	1	5	5I	4.0	8:24	4	0.4	2
27	4-Dec-14	1	5	5I	4.0	8:34	3	0	0
27	4-Dec-14	1	5	5I	3.8	8:44	2	1.2	1
27	4-Dec-14	1	5	5I	3.8	8:54	1	0.4	2
28	4-Dec-14	1	5	5J	6.9	10:08	1	6.6	7
28	4-Dec-14	1	5	5J	7.7	13:18	2	0	0
28	4-Dec-14	1	5	5J	9.5	10:28	3	0.6	1
28	4-Dec-14	1	5	5J	9.0	10:38	4	0.4	1
28	4-Dec-14	1	5	5J	8.6	10:48	5	0.8	1
28	4-Dec-14	1	5	5J	6.4	10:58	6	0	0
29	4-Dec-14	1	5	5R	25.2	12:12	6	0	0
29	4-Dec-14	1	5	5R	24.9	12:22	5	0	0
29	4-Dec-14	1	5	5R	24.3	12:32	4	0	0
29	4-Dec-14	1	5	5R	24.5	12:42	3	1.7	2
29	4-Dec-14	1	5	5R	24.3	12:52	2	0	0
29	4-Dec-14	1	5	5R	23.6	13:02	1	4.1	9
30	4-Dec-14	1	5	R6	25.6	14:18	1	0.1	1
30	4-Dec-14	1	5	R6	25.6	14:26	2	0.1	1
30	4-Dec-14	1	5	R6	21.9	14:34	3	2	4
30	4-Dec-14	1	5	R6	23.8	14:42	4	1.8	5
30	4-Dec-14	1	5	R6	26.2	14:50	5	0	0
30	4-Dec-14	1	5	R6	26.3	14:58	6	0	0
31	5-Dec-14	1	5	R4	10.2	5:57	6	0	0
31	5-Dec-14	1	5	R4	22.1	6:07	5	2.1	7
31	5-Dec-14	1	5	R4	23.6	6:17	4	0	0
31	5-Dec-14	1	5	R4	20.8	6:27	3	0.2	1
31	5-Dec-14	1	5	R4	8.4	6:37	2	0	0
31	5-Dec-14	1	5	R4	8.2	6:47	1	0	0
32	5-Dec-14	1	5	R7	23.4	7:58	1	3.2	3
32	5-Dec-14	1	5	R7	24.5	8:08	2	0	0
32	5-Dec-14	1	5	R7	24.5	8:18	3	1	1

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot	Catch of blue cod (kg)	Catch of blue cod Number
32	5-Dec-14	1	5	R7	24.7	8:28	4	0	0
32	5-Dec-14	1	5	R7	24.3	8:38	5	0.7	1
32	5-Dec-14	1	5	R7	24.0	8:48	6	0	0
33	5-Dec-14	1	5	5D	5.1	10:07	6	0	0
33	5-Dec-14	1	5	5D	6.2	10:15	5	0	0
33	5-Dec-14	1	5	5D	6.4	10:23	4	0	0
33	5-Dec-14	1	5	5D	7.1	10:31	3	0	0
33	5-Dec-14	1	5	5D	5.7	10:39	2	0	0
33	5-Dec-14	1	5	5D	7.1	10:47	1	0	0
34	5-Dec-14	1	5	R3	24.7	12:00	1	0	0
34	5-Dec-14	1	5	R3	23.0	12:10	2	0	0
34	5-Dec-14	1	5	R3	18.5	12:20	3	0	0
34	5-Dec-14	1	5	R3	22.9	12:30	4	0.2	1
34	5-Dec-14	1	5	R3	24.5	12:40	5	0	0
34	5-Dec-14	1	5	R3	24.7	12:50	6	0	0
35	5-Dec-14	1	5	R5	7.9	14:01	6	0	0
35	5-Dec-14	1	5	R5	7.7	14:07	5	0	0
35	5-Dec-14	1	5	R5	3.7	14:13	4	0	0
35	5-Dec-14	1	5	R5	7.7	14:19	3	0	0
35	5-Dec-14	1	5	R5	7.5	14:25	2	0	0
35	5-Dec-14	1	5	R5	5.9	14:31	1	1	1
36	6-Dec-14	1	5	5B	3.7	8:18	1	0	0
36	6-Dec-14	1	5	5B	9.9	8:24	2	5.6	8
36	6-Dec-14	1	5	5B	8.0	8:30	3	7.5	11
36	6-Dec-14	1	5	5B	3.8	8:36	4	0	0
36	6-Dec-14	1	5	5B	3.8	8:42	5	1.9	1
36	6-Dec-14	1	5	5B	3.7	8:48	6	0	0
37	6-Dec-14	1	5	R2	5.7	10:00	6	0	0
37	6-Dec-14	1	5	R2	6.0	10:06	5	0	0
37	6-Dec-14	1	5	R2	23.6	10:12	4	0.2	1
37	6-Dec-14	1	5	R2	23.4	10:18	3	0	0
37	6-Dec-14	1	5	R2	24.5	10:24	2	0	0
37	6-Dec-14	1	5	R2	19.6	10:30	1	0	0
38	6-Dec-14	1	4	R1	7.3	12:05	1	4.5	6
38	6-Dec-14	1	4	R1	6.8	12:11	2	12.4	18
38	6-Dec-14	1	4	R1	10.6	12:17	3	0.4	1
38	6-Dec-14	1	4	R1	14.3	12:23	4	1.1	2
38	6-Dec-14	1	4	R1	17.7	12:29	5	0	0
38	6-Dec-14	1	4	R1	16.6	12:35	6	1.1	5
39	7-Dec-14	1	3	3C	5.5	5:40	6	6.7	7
39	7-Dec-14	1	3	3C	4.4	5:50	5	1.4	1
39	7-Dec-14	1	3	3C	4.4	6:00	4	10.8	13
39	7-Dec-14	1	3	3C	6.0	6:10	3	18.5	20
39	7-Dec-14	1	3	3C	6.6	6:20	2	0.3	1
39	7-Dec-14	1	3	3C	7.1	6:30	1	12.5	24
40	7-Dec-14	1	3	R3	13.0	8:00	1	0	0
40	7-Dec-14	1	3	R3	12.3	8:10	2	0	0
40	7-Dec-14	1	3	R3	12.3	8:20	3	0	0

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot	Catch of blue cod (kg)	Catch of blue cod Number
40	7-Dec-14	1	3	R3	10.4	8:30	4	3.8	10
40	7-Dec-14	1	3	R3	14.1	8:40	5	0	0
40	7-Dec-14	1	3	R3	14.3	8:50	6	0	0
41	7-Dec-14	1	3	3H	6.2	10:25	6	2.2	4
41	7-Dec-14	1	3	3H	6.0	10:35	5	5	5
41	7-Dec-14	1	3	3H	5.9	10:45	4	6.5	8
41	7-Dec-14	1	3	3H	7.3	10:55	3	5.3	7
41	7-Dec-14	1	3	3H	5.3	11:05	2	3.5	4
41	7-Dec-14	1	3	3H	6.8	11:15	1	4.6	6
42	7-Dec-14	1	1	1J	4.6	12:30	1	3.8	6
42	7-Dec-14	1	1	1J	7.7	12:40	2	6.9	14
42	7-Dec-14	1	1	1J	6.9	21:20	3	0.7	4
42	7-Dec-14	1	1	1J	4.6	13:00	4	1	3
42	7-Dec-14	1	1	1J	5.1	13:10	5	3.3	5
42	7-Dec-14	1	1	1J	6.6	13:20	6	1.5	4
43	7-Dec-14	1	1	1I	7.3	14:32	6	0.7	3
43	7-Dec-14	1	1	1I	6.9	14:37	5	2.4	4
43	7-Dec-14	1	1	1I	5.7	14:42	4	0	0
43	7-Dec-14	1	1	1I	4.2	14:47	3	2.3	6
43	7-Dec-14	1	1	1I	4.4	14:52	2	1.6	3
43	7-Dec-14	1	1	1I	6.8	14:57	1	0.7	1
44	8-Dec-14	1	2	2H	5.1	5:27	1	1.4	1
44	8-Dec-14	1	2	2H	3.7	5:32	2	1.6	4
44	8-Dec-14	1	2	2H	3.1	5:37	3	0.7	1
44	8-Dec-14	1	2	2H	3.7	5:42	4	6.5	7
44	8-Dec-14	1	2	2H	3.7	5:47	5	0.3	1
44	8-Dec-14	1	2	2H	4.8	5:52	6	2.8	3
45	8-Dec-14	1	1	1C	5.9	7:17	6	5.8	7
45	8-Dec-14	1	1	1C	5.9	7:22	5	3.9	5
45	8-Dec-14	1	1	1C	5.3	7:27	4	5	9
45	8-Dec-14	1	1	1C	3.7	7:32	3	4.3	11
45	8-Dec-14	1	1	1C	4.8	7:37	2	4.2	9
45	8-Dec-14	1	1	1C	6.2	7:42	1	3.2	9
46	8-Dec-14	1	1	1B	4.9	9:00	1	4.2	9
46	8-Dec-14	1	1	1B	4.2	9:05	2	10.4	18
46	8-Dec-14	1	1	1B	4.0	9:10	3	6.8	10
46	8-Dec-14	1	1	1B	3.7	9:15	4	3.2	7
46	8-Dec-14	1	1	1B	4.0	9:20	5	1	3
46	8-Dec-14	1	1	1B	4.0	9:25	6	4	5
47	8-Dec-14	1	1	1G	3.7	10:43	6	2.7	3
47	8-Dec-14	1	1	1G	6.2	10:48	5	11	18
47	8-Dec-14	1	1	1G	4.8	10:53	4	4.5	9
47	8-Dec-14	1	1	1G	3.7	10:58	3	0	0
47	8-Dec-14	1	1	1G	5.5	11:03	2	4.9	6
47	8-Dec-14	1	1	1G	6.0	11:08	1	0	0
48	8-Dec-14	1	3	R6	22.9	12:35	1	5	17
48	8-Dec-14	1	3	R6	21.2	12:45	2	2.8	14
48	8-Dec-14	1	3	R6	22.1	12:55	3	3.5	9

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot	Catch of blue cod (kg)	Catch of blue cod Number
48	8-Dec-14	1	3	R6	22.5	13:05	4	2.4	7
48	8-Dec-14	1	3	R6	24.3	13:15	5	3.9	22
48	8-Dec-14	1	3	R6	24.5	13:25	6	2.8	5
49	9-Dec-14	1	2	2C	6.6	5:21	6	14.9	18
49	9-Dec-14	1	2	2C	5.9	5:31	5	1.2	3
49	9-Dec-14	1	2	2C	6.6	5:41	4	10.9	14
49	9-Dec-14	1	2	2C	7.3	5:51	3	5.7	8
49	9-Dec-14	1	2	2C	6.0	6:01	2	2.3	6
49	9-Dec-14	1	2	2C	10.2	6:11	1	9.3	15
50	9-Dec-14	1	2	R4	16.5	7:25	1	0	0
50	9-Dec-14	1	2	R4	16.5	7:30	2	0	0
50	9-Dec-14	1	2	R4	16.6	7:35	3	0	0
50	9-Dec-14	1	2	R4	11.2	7:40	4	0	0
50	9-Dec-14	1	2	R4	5.5	7:45	5	0	0
50	9-Dec-14	1	2	R4	7.3	7:50	6	0	0
51	9-Dec-14	1	3	3G	11.5	9:06	6	0	0
51	9-Dec-14	1	3	3G	9.9	9:16	5	9.2	17
51	9-Dec-14	1	3	3G	10.4	9:26	4	6	8
51	9-Dec-14	1	3	3G	11.2	9:36	3	6.7	6
51	9-Dec-14	1	3	3G	9.1	9:46	2	14.5	19
51	9-Dec-14	1	3	3G	9.0	9:56	1	14.1	22
52	9-Dec-14	1	3	R5	19.6	11:12	1	0.5	3
52	9-Dec-14	1	3	R5	21.0	11:22	2	0	0
52	9-Dec-14	1	3	R5	21.6	11:32	3	0	0
52	9-Dec-14	1	3	R5	8.4	11:42	4	13.5	17
52	9-Dec-14	1	3	R5	8.6	11:52	5	0	0
52	9-Dec-14	1	3	R5	13.0	12:02	6	0.8	1
53	9-Dec-14	1	3	R1	25.8	13:25	6	3.1	7
53	9-Dec-14	1	3	R1	24.7	13:32	5	5.2	28
53	9-Dec-14	1	3	R1	24.7	13:39	4	1.7	16
53	9-Dec-14	1	3	R1	26.2	13:46	3	0	0
53	9-Dec-14	1	3	R1	26.3	13:53	2	2.8	3
53	9-Dec-14	1	3	R1	26.3	14:00	1	8.1	27
54	11-Dec-14	1	5	5E	3.8	6:02	1	0	0
54	11-Dec-14	1	5	5E	3.7	6:07	2	0	0
54	11-Dec-14	1	5	5E	7.3	6:12	3	0	0
54	11-Dec-14	1	5	5E	3.8	6:17	4	0	0
54	11-Dec-14	1	5	5E	2.9	6:22	5	0	0
54	11-Dec-14	1	5	5E	3.3	6:27	6	0	0
55	11-Dec-14	1	3	3F	6.2	8:04	6	14.8	22
55	11-Dec-14	1	3	3F	4.2	8:14	5	12	16
55	11-Dec-14	1	3	3F	3.3	8:24	4	5.6	9
55	11-Dec-14	1	3	3F	6.6	8:34	3	12	21
55	11-Dec-14	1	3	3F	8.6	8:44	2	8.2	11
55	11-Dec-14	1	3	3F	10.8	8:54	1	16.6	28
56	11-Dec-14	1	3	3I	5.9	10:23	1	4.5	4
56	11-Dec-14	1	3	3I	7.1	10:31	2	12.1	14
56	11-Dec-14	1	3	3I	6.8	10:39	3	1.2	1

Set	Date	Phase	Stratum	Site	Depth (m)	Time set	Pot	Catch of blue cod (kg)	Catch of blue cod Number
56	11-Dec-14	1	3	3I	4.4	10:47	4	11.2	12
56	11-Dec-14	1	3	3I	3.3	10:55	5	0	0
56	11-Dec-14	1	3	3I	10.6	11:03	6	2.8	5
57	11-Dec-14	1	3	R7	19.4	12:17	6	1.9	13
57	11-Dec-14	1	3	R7	21.4	12:23	5	1.6	5
57	11-Dec-14	1	3	R7	20.5	12:29	4	5.1	16
57	11-Dec-14	1	3	R7	19.2	12:35	3	8.2	14
57	11-Dec-14	1	3	R7	15.9	12:41	2	2.2	6
57	11-Dec-14	1	3	R7	17.0	12:47	1	0	0
58	11-Dec-14	1	3	R4	24.9	14:00	1	10.3	35
58	11-Dec-14	1	3	R4	24.7	14:06	2	4.4	18
58	11-Dec-14	1	3	R4	24.9	14:12	3	3.2	12
58	11-Dec-14	1	3	R4	24.9	14:18	4	8	22
58	11-Dec-14	1	3	R4	24.5	14:24	5	2.2	13
58	11-Dec-14	1	3	R4	24.7	14:30	6	0.5	2
59	11-Dec-14	1	3	R2	25.6	15:40	6	1	7
59	11-Dec-14	1	3	R2	24.0	15:46	5	7.9	29
59	11-Dec-14	1	3	R2	19.4	15:52	4	15.9	39
59	11-Dec-14	1	3	R2	19.9	15:58	3	9.6	38
59	11-Dec-14	1	3	R2	23.6	16:04	2	0.05	1
59	11-Dec-14	1	3	R2	24.0	16:10	1	1.9	12
60	12-Dec-14	2	1	R8	17.6	5:45	1	0	0
60	12-Dec-14	2	1	R8	17.6	5:50	2	0.2	1
60	12-Dec-14	2	1	R8	3.3	5:55	3	0	0
60	12-Dec-14	2	1	R8	2.4	6:00	4	0	0
60	12-Dec-14	2	1	R8	13.4	6:05	5	0.4	1
60	12-Dec-14	2	1	R8	16.3	6:10	6	0.1	1
61	12-Dec-14	2	2	R9	15.4	7:54	6	0	0
61	12-Dec-14	2	2	R9	17.7	7:59	5	1.8	2
61	12-Dec-14	2	2	R9	18.7	8:04	4	0	0
61	12-Dec-14	2	2	R9	19.6	8:09	3	0	0
61	12-Dec-14	2	2	R9	16.8	8:14	2	0	0
61	12-Dec-14	2	2	R9	14.4	8:19	1	0	0
62	12-Dec-14	2	2	R10	12.6	9:35	1	0	0
62	12-Dec-14	2	2	R10	11.0	9:40	2	0	0
62	12-Dec-14	2	2	R10	12.6	9:45	3	0	0
62	12-Dec-14	2	2	R10	15.7	9:50	4	1.5	2
62	12-Dec-14	2	2	R10	18.8	9:55	5	0	0
62	12-Dec-14	2	2	R10	16.3	10:00	6	0	0
63	12-Dec-14	1	4	4D	13.5	11:21	6	8.5	22
63	12-Dec-14	1	4	4D	12.6	11:28	5	7	16
63	12-Dec-14	1	4	4D	9.5	11:35	4	3.6	7
63	12-Dec-14	1	4	4D	11.3	11:42	3	4.1	11
63	12-Dec-14	1	4	4D	9.1	11:49	2	1.3	7
63	12-Dec-14	1	4	4D	7.3	11:56	1	1.5	1

Appendix 4: Summary of the Foveaux Strait 2014 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	28.7	275	4	12.6	0995	6	3	7	0.7	260	3	1	12.1		5.7	6.5
2	19.2	200	6	12.0	0987	6	2	7	0.5	210	3	1	12.4		13.7	6.5
3	11.0	210	4	12.2	984	7	2	7	0	999	7	2	12.3		6.4	6.0
4	6.2	225	5	13.3	937	8	2	3	0.5	290	7	3	12.0		8.1	5.8
5	6.6	225	4	13.8	935	8	1	5	0.3	290	7	3	12.0		6.9	6.1
6	5.5	060	3	9.8	996	8	0	8	0	999	7	3	11.0		4.8	5.5
7	23.4	060	4	10.5	996	8	0	3	0	999	3	1	10.4		5.8	6.4
8	21.0	999	0	12.6	996	8	0	3	0	999	3	1	10.2		0	6.5
9	7.3	999	0	12.3	998	8	0	8	0	999	3	1	10.5		0	4.5
10	24.7	150	4	13.4	1000	7	1	4	0	999	3	1	11.0		6.1	5.8
11	18.8	225	4	10.7	1015	6	2	8	0	999	3	1	10.2		7.3	6.1
12	17.6	270	5	11.6	1015	6	2	8	0	999	3	1	10.2		8.3	6.0
13	19.6	280	4	13.1	1016	6	1	8	0	999	3	1	10.5		6.5	5.9
14	14.6	250	5	16.0	1017	6	1	8	0	999	7	2	10.8		10.3	3.6
15	19.0	250	4	17.5	1018	5	2	8	0	999	3	1	11.0		7.4	6.3
16	22.7	270	4	14.2	1010	8	8	8	0	999	3	1	11.0		7.1	5.5
17	22.1	230	5	14.5	1010	5	2	5	0	999	3	1	15.2		9.6	5.5
18	12.8	260	4	15.5	1010	8	1	8	0	999	3	2	11.2		5.8	7.1
19	8.6	230	3	17.3	1010	7	1	8	0	999	3	2	11.2		4.9	3.7
20	16.5	240	5	15.5	1010	7	1	7	0	999	7	4	11.2		9.0	4.5
21	15.0	999	0	12.6	1010	8	0	7	0	999	7	3	11.1		0	6.5
22	6.8	120	1	13.7	1010	8	0	7	0	999	4	1	11.2		1.0	6.5
23	26.3	070	3	13.3	1010	8	1	7	0	999	3	2	11.1		4.7	6.2
24	11.5	075	3	14.4	1010	8	1	4	0	999	7	3	11.2		3.8	7.5
25	30.5	005	3	14.6	1010	6	1	4	0	999	7	4	11.1		4.1	9.1
26	11.0	230	3	14.8	1008	8	0	7	0	999	7	2	11.5		4.4	6.1
27	8.0	190	4	14.2	1010	7	1	7	0	999	7	2	1.0		6.8	6.1
28	8.0	180	4	15..7	1010	6	0	5	0	999	7	2	11.4		5.9	6.4
29	24.7	190	3	14.2	1010	6	1	5	0	999	11	1	11.5		4.9	6.5

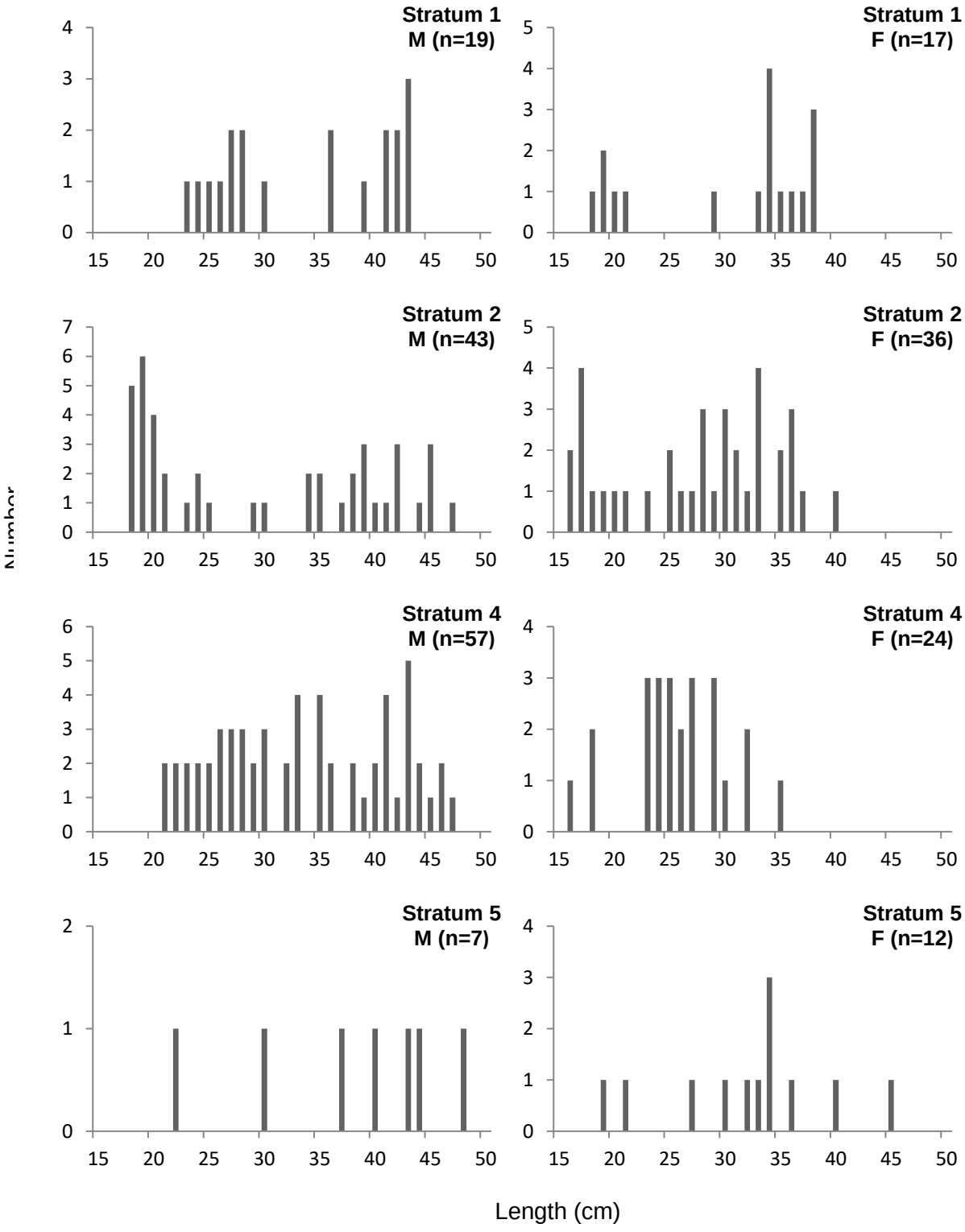
Appendix 4– *continued*

Set	Average Depth	Wind Direction	Wind Force	Air Temp	Air Pressure	Cloud Cover	Sea Condition	Sea Colour	Swell Height	Swell Direction	Bottom Type	Bottom Contour	Surface Temp	Bottom Temp	Wind Speed	Secchi Depth
30	25.2	180	4	13.5	1010	6	1	5	0	999	11	1	11.4		7.8	6.4
31	20.1	999	0	7.3	1021	7	0	8	0	999	11	2	10.5		0	6.6
32	24.0	100	3	12.2	1020	6	1	8	0	999	11	2	10.5		4.9	6.5
33	6.0	055	3	11.6	1021	2	0	4	0	999	7	2	10.6		4.4	6.3
34	24.1	030	3	11.2	1022	0	0	4	0	999	11	1	10.6		5.2	6.5
35	9.1	030	3	11.9	1022	0	0	4	0	999	2	1	10.8		5.5	6.1
36	6.8	999	0	14.8	1018	8	0	8	0	999	7	2	11.0		0	6.6
37	21.0	999	0	15.8	1017	8	0	8	0	999	11	2	11.0		0	6.4
38	13.7	240	1	15.5	1017	8	0	7	0	999	4	2	11.1		0.9	6.5
39	6.2	180	3	11.5	1005	8	1	7	0	999	7	3	11.0		3.6	7.5
40	13.2	999	0	12.9	1004	8	0	7	0	999	3	2	11.0		0	7.1
41	9.7	340	1	11.9	1004	8	0	7	0	999	7	3	11.0		0.9	6.5
42	7.1	340	2	13.6	1004	8	0	7	0	999	7	2	10.8		1.9	6.4
43	8.0	999	0	13.9	1004	8	0	7	0	999	7	2	11.0		0	6.6
44	5.9	090	2	12.1	1023	6	0	7	0	999	7	2	11.0		2.3	6.2
45	8.0	999	0	12.2	1021	6	0	7	0	999	7	2	11.0		0	6.1
46	5.7	090	3	16.1	1020	5	1	7	0	999	7	2	11.1		5.1	6.5
47	5.1	100	3	13.7	1019	4	1	7	0	999	7	2	11.1		5.3	6.4
48	21.9	090	3	14.5	1018	5	1	7	0	999	2	1	11.0		5.1	6.2
49	11.3	280	1	13.9	1005	8	0	7	0	999	7	3	11.0		1.0	6.5
50	11.9	290	2	15.5	1004	7	0	7	0	999	3	1	11.0		2.0	6.8
51	9.3	340	4	18.2	1005	8	1	7	0	999	7	3	11.0		6.4	6.3
52	19.5	305	4	20.0	1007	8	2	7	0	999	3	2	11.0		7.4	6.8
53	24.7	290	3	20.3	1006	7	1	7	0	999	3	1	11.1		4.6	6.4
54	3.8	090	3	12.5	1110	8	1	7	0	999	7	1	10.6		5.4	4.6
55	10.2	090	4	10.4	1010	8	2	7	0	999	7	2	10.9		6.9	6.0
56	9.5	090	2	10.6	1008	8	2	7	0	999	7	2	10.9		3.3	6.3
57	19.0	090	5	11.4	1006	8	2	7	0	999	3	1	11.0		9.3	6.1
58	24.7	090	4	11.1	1004	8	2	7	0	999	3	1	11.0		7.0	6.6
59	22.7	080	3	11.3	1003	8	2	7	0	999	3	1	11.0		5.1	6.6
60	13.2	210	3	11.5	1006	6	0	8	0	999	2	1	10.4		3.5	4.1
61	16.3	230	3	11.6	1005	6	1	5	0	999	3	1	10.8		5.5	6.5

Appendix 4– *continued*

Set	Average Depth	Wind Direction	Wind Force	Air Temp	Air Pressure	Cloud Cover	Sea Condition	Sea Colour	Swell Height	Swell Direction	Bottom Type	Bottom Contour	Surface Temp	Bottom Temp	Wind Speed	Secchi Depth
62	13.7	210	5	12.0	1005	4	2	7	0	999	3	1	11.0		9.8	6.8
63	13.0	260	4	13.3	1005	6	1	5	0.5	060	7	3	11.1		5.8	6.8

Appendix 5: Unscaled length frequency distributions of blue cod for each stratum from which otoliths were used in the Paterson Inlet 2014 age length keys.



Appendix 6: Between-reader comparisons (using first independent readings only) for otolith data collected in Foveaux Strait 2014.

Reader two	Age class (reader one)															
difference	2	3	4	5	6	7	8	9	10	11	12	13	14	15	≥16	Total
-7												1			2	3
-6										1				1		2
-5									1	1		1		1	1	5
-4							1	3	1				1		1	7
-3					2	2	7	1	4	1						17
-2		1	4	1	5	5	8	2	5			1				32
-1	2	7	5	6	5	7	4	1		1			1			39
0	8	21	11	15	9	5	6	1	6	2	3	2	3		1	93
1		2	3	5			1									11
2	2		1					2								5
3			1													1
Total	12	31	25	27	21	19	27	10	17	6	3	5	5	2	5	215
% agreement	67	68	44	56	43	26	22	10	35	33	100	40	60	0	20	43

Appendix 7: Independent reader comparisons with agreed age from otolith data collected in Paterson Inlet 2014.

Reader one	Agreed age class															
difference	1	2	3	4	5	6	7	8	9	10	11	12	13	14	≥15	Total
-2						1										1
-1			1	1	1	2			2	1	1				1	10
0		10	26	16	17	12	5	13	4	8	3	3	3	3	1	124
1	1	4	6	6	3	10	5		2	3		2	1	2		45
2		1	2	6	4	4	1	4							2	24
3					3	4	2						1			10
8												1				1
Total	1	15	35	29	28	33	13	17	8	12	4	6	5	5	4	215
% agreement	0	67	74	55	61	36	38	76	50	67	75	50	60	60	25	58

Reader two	Agreed age class															
difference	1	2	3	4	5	6	7	8	9	10	11	12	13	14	≥15	Total
-6												1				1
-5										1	1		1	1	1	5
-4									1	1				1		3
-3								3	1	1	1		1			7
-2				2	1	2	2	1	1	1			1		2	13
-1		2	6	3	5	9	4	5	3			1				38
0	1	11	24	17	19	21	7	8	2	7	2	3	2	3	1	128
1		1	4	4	2					1		1				13
2		1	1	2	1											5
3				1												1
5						1										1
Total	1	15	35	29	28	33	13	17	8	12	4	6	5	5	4	215
% agreement	100	73	69	59	68	64	54	47	25	58	50	50	40	60	25	60

Appendix 8: The proportion of fish at age and length and the total number at length and at age for male blue cod sampled from the 2014 Paterson Inlet (age -length-key, ALK).

	Age																					
Length	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Total
18	0	0.4	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
19	0	0.17	0.67	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
20	0	0.25	0.5	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
21	0	0.25	0.25	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
22	0	0	0.67	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
23	0	0	0.5	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
24	0	0	0.4	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
25	0	0	0.25	0.25	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
26	0	0	0.5	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
27	0	0	0.2	0.2	0.4	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
28	0	0	0	0.2	0.6	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
29	0	0	0.33	0	0.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
30	0	0	0	0.33	0.33	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
32	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
33	0	0	0	0.25	0	0.5	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
34	0	0	0	0	0.5	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	2
35	0	0	0	0	0.17	0.5	0	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	6
36	0	0	0	0	0	0.5	0	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	0	4
37	0	0	0	0	0.5	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	2
38	0	0	0	0	0.25	0.5	0	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	4
39	0	0	0	0	0.2	0.6	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
40	0	0	0	0	0	0.75	0	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	4
41	0	0	0	0	0.14	0.14	0.57	0.14	0	0	0	0	0	0	0	0	0	0	0	0	0	7
42	0	0	0	0	0	0	0.5	0.17	0	0.17	0	0.17	0	0	0	0	0	0	0	0	0	6
43	0	0	0	0	0	0	0	0.33	0.22	0.11	0.22	0.11	0	0	0	0	0	0	0	0	0	9
44	0	0	0	0	0	0	0	0.25	0.25	0.5	0	0	0	0	0	0	0	0	0	0	0	4
45	0	0	0	0	0	0	0	0.25	0	0.5	0	0.25	0	0	0	0	0	0	0	0	0	4
46	0	0	0	0	0	0	0	0	0	0.5	0	0.5	0	0	0	0	0	0	0	0	0	2
47	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	2
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Total	0	5	21	15	18	24	9	14	4	7	2	4	1	1	1	0	0	0	0	0	0	126

Appendix 9: The proportion of fish at age and length and the total number at length and at age for female blue cod sampled from the 2014 Paterson Inlet survey (age-length key, ALK).

	Age																					
Length	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Total
16	0	0.67	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
17	0.25	0.25	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
18	0	0.5	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
19	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
20	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
21	0	0	0.67	0	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
23	0	0	0.5	0.25	0	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
24	0	0.33	0	0.33	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
25	0	0	0.2	0.6	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
26	0	0	0.33	0	0.33	0	0	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	3
27	0	0	0.2	0.4	0.2	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0	5
28	0	0	0.33	0.33	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
29	0	0	0	0.4	0.2	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
30	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
31	0	0	0	0.5	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
32	0	0	0	0	0.25	0.25	0	0	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	4
33	0	0	0	0.17	0	0	0.17	0	0.17	0.33	0	0	0.17	0	0	0	0	0	0	0	0	6
34	0	0	0	0	0.14	0.43	0	0.14	0	0.14	0	0	0.14	0	0	0	0	0	0	0	0	7
35	0	0	0	0	0	0.25	0	0.25	0	0	0	0	0.5	0	0	0	0	0	0	0	0	4
36	0	0	0	0	0	0	0	0	0.2	0	0.2	0.2	0	0.2	0	0	0	0	0.2	0	0	5
37	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0.5	0	0	0	0	0	0	0	2
38	0	0	0	0	0	0	0	0	0	0	0.33	0	0	0.33	0.33	0	0	0	0	0	0	3
40	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0.5	0	0	0	0	0	0	0	2
45	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	14	14	10	9	4	3	4	5	2	2	4	4	1	0	0	0	1	0	1	89

Appendix 10: Mean age-at-length for the 2014 Paterson Inlet survey.

	Males		Females		All fish	
Length (cm)	N	Mean age	N	Mean age	N	Mean age
16	0	0.00	3	2.33	3	2.33
17	0	0.00	4	2.25	4	2.25
18	5	2.60	4	2.75	9	2.67
19	6	3.00	4	2.50	10	2.80
20	4	3.00	2	2.00	6	2.67
21	4	3.50	3	3.67	7	3.57
22	3	3.33	0	0.00	3	3.33
23	4	3.75	4	4.00	8	3.88
24	5	3.60	3	3.67	8	3.62
25	4	4.75	5	4.00	9	4.33
26	4	3.75	3	5.33	7	4.43
27	5	4.60	5	5.20	10	4.90
28	5	5.00	3	4.00	8	4.62
29	3	4.33	5	5.40	8	5.00
30	6	5.00	5	5.60	11	5.27
31	0	0.00	2	5.00	2	5.00
32	2	6.00	4	7.50	6	7.00
33	4	5.75	6	8.83	10	7.60
34	2	6.50	7	7.71	9	7.44
35	6	6.50	4	10.00	10	7.90
36	4	7.25	5	13.00	9	10.40
37	2	6.50	2	11.50	4	9.00
38	4	6.25	3	13.30	7	9.29
39	5	6.00	0	0.00	5	6.00
40	4	6.50	2	13.00	6	8.67
41	7	6.71	0	0.00	7	6.71
42	6	8.50	0	0.00	6	8.50
43	9	9.56	0	0.00	9	9.56
44	4	9.25	0	0.00	4	9.25
45	4	10.00	1	21.00	5	12.20
46	2	11.00	0	0.00	2	11.00
47	2	13.50	0	0.00	2	13.50
48	1	15.00	0	0.00	1	15.00
Total	126	6.03	89	6.40	215	6.19

Appendix 11: Parameter values used in the 2014 Paterson Inlet SPR analyses.

	Males				Females			
Age	Length (cm)	Weight (kg)	Selectivity	Maturity	Length (cm)	Weight (kg)	Selectivity	Maturity
1	9.8	0.013	0	0	15.2	0.048	0	0
2	16.5	0.065	0	0	19.2	0.100	0	0
3	22.1	0.161	0	0	22.5	0.168	0	0
4	26.9	0.293	0	0.1	25.3	0.244	0	0.1
5	30.9	0.450	0	0.4	27.7	0.325	0	0.4
6	34.3	0.620	1	0.7	29.6	0.405	0	0.7
7	37.2	0.793	1	1	31.3	0.482	0	1
8	39.6	0.962	1	1	32.7	0.554	0	1
9	41.6	1.123	1	1	33.9	0.620	1	1
10	43.3	1.272	1	1	34.9	0.679	1	1
11	44.8	1.407	1	1	35.7	0.732	1	1
12	46.0	1.529	1	1	36.4	0.779	1	1
13	47.0	1.636	1	1	37.0	0.819	1	1
14	47.9	1.731	1	1	37.4	0.855	1	1
15	48.6	1.814	1	1	37.9	0.885	1	1
16	49.3	1.886	1	1	38.2	0.911	1	1
17	49.8	1.948	1	1	38.5	0.933	1	1
18	50.2	2.001	1	1	38.7	0.952	1	1
19	50.6	2.047	1	1	38.9	0.968	1	1
20	50.9	2.086	1	1	39.1	0.982	1	1
21	51.2	2.120	1	1	39.2	0.994	1	1
22	51.4	2.148	1	1	39.4	1.004	1	1
23	51.6	2.172	1	1	39.5	1.012	1	1
24	51.7	2.193	1	1	39.6	1.019	1	1
25	51.9	2.211	1	1	39.6	1.025	1	1
26	52.0	2.225	1	1	39.7	1.030	1	1
27	52.1	2.238	1	1	39.7	1.034	1	1
28	52.2	2.248	1	1	39.8	1.037	1	1
29	52.2	2.257	1	1	39.8	1.040	1	1
30	52.3	2.265	1	1	39.8	1.043	1	1
31	52.3	2.271	1	1	39.9	1.045	1	1
32	52.4	2.277	1	1	39.9	1.047	1	1
33	52.4	2.281	1	1	39.9	1.048	1	1
34	52.4	2.285	1	1	39.9	1.050	1	1
35	52.5	2.289	1	1	39.9	1.051	1	1
36	52.5	2.291	1	1	39.9	1.051	1	1
37	52.5	2.294	1	1	40.0	1.052	1	1
38	52.5	2.296	1	1	40.0	1.053	1	1
39	52.5	2.297	1	1	40.0	1.053	1	1
40	52.5	2.299	1	1	40.0	1.054	1	1
41	52.5	2.300	1	1	40.0	1.054	1	1
42	52.6	2.301	1	1	40.0	1.054	1	1
43	52.6	2.302	1	1	40.0	1.055	1	1
44	52.6	2.302	1	1	40.0	1.055	1	1
45	52.6	2.303	1	1	40.0	1.055	1	1
46	52.6	2.304	1	1	40.0	1.055	1	1
47	52.6	2.304	1	1	40.0	1.055	1	1
48	52.6	2.304	1	1	40.0	1.056	1	1
49	52.6	2.305	1	1	40.0	1.056	1	1
50	52.6	2.305	1	1	40.0	1.056	1	1