

**Abundance and size composition of blue cod in the
Marlborough Sounds and Tasman Bay,
September–October 2004.**

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**Final Research Report for
Ministry of Fisheries Research Project BCO2003-01
Objectives 1–3**

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- Report Title:** Abundance and size composition of blue cod in the Marlborough Sounds and Tasman Bay, September–October 2004.
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 3. **Project Title:** To assess the status of blue cod (*Parapercis colias*) stocks in the Marlborough Sounds and Tasman Bay (BCO 7).
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 7. **Executive summary**

This report describes the results of the third in a series of pot and line fishing surveys for blue cod *Parapercis colias* in the inshore waters of the Marlborough Sounds, Cook Strait, and inshore Tasman Bay (D'Urville Island-west, and Separation Point) during September and October 2004. Two new areas in Tasman Bay, D'Urville Island west and Separation Point, were first surveyed in 2004. The report fulfils the requirements of project BCO 2003/03.

Objective 1 – To assess the status of blue cod (*Parapercis colias*) stocks in the Marlborough Sounds and Tasman Bay (BCO 7).

The survey used a two phase design optimised for blue cod, based on previous pot survey data. Relative biomass estimates for recruited blue cod (greater than or equal to 30 cm total length) remain consistently lower in 2004 than for the initial surveys in 1995 (Queen Charlotte Sound) and 1996 (Pelorus Sound/D'Urville Island), but the sharp rate of decline initially apparent for all strata in the second survey (completed for both Sounds in 2001) has eased and become more variable among strata. No change in relative biomass subsequently

occurred among the Queen Charlotte Sound strata. Mean catch rates remain generally low, particularly in inner Queen Charlotte Sound.

No consistent trend in recruited blue cod was apparent among the Pelorus Sound and D'Urville Island strata between 2001 and 2004. Relative abundance increased in Outer Pelorus, but declined in D'Urville Island east, while little change occurred among the remaining strata. Mean catch rates were also low, particularly in inner Pelorus Sound. The mean catch rates in 2004 were highest for D'Urville Island east, and lowest for Separation Point. The mean catch rates for the new D'Urville Island west stratum were generally similar to the adjacent D'Urville east stratum. The estimated sampling c.v. for recruited blue cod of under 7% (5% overall) is consistent with previous surveys, and within the target level of 20%. The relative biomass of pre-recruit (under 30 cm) blue cod generally followed similar trends to recruited blue cod between 1995 and 2004. The relative biomass of juveniles (17–27 cm) followed a similar, but more variable pattern.

The total of 3645 blue cod represented 91% of the total survey catch of 1497 kg. The bycatch mainly comprised *Octopus cordiformis* (5%), and conger eel *Conger verreauxi* (2%), consistent with previous surveys.

Scaled population length frequencies were generally unimodal, but the lack of a sharp cutoff at 28 cm suggested fishers have been returning smaller fish (28–30 cm in length) before the change in regulations. Recruitment was variable among strata and survey years. The male-skewed sex ratios present in all strata in 2004 were consistent with previous Marlborough Sounds surveys, and similar to patterns from other blue cod fisheries under high levels of fishing pressure. Size at 50% sexual maturity, as determined by frequency ogive, was 17 cm for males and 15 cm for females.

In the pilot tagging programme completed under Objective 3 of this project, 960 blue cod were tagged and released during September and October 2004, mainly in outer Pelorus Sound and off the east and west coasts of D'Urville Island. The 114 tags returned (to May 2006) represent a recovery rate of 11.9%, consistent with high fishing pressure. Preliminary data indicate a low rate of movement consistent with previous research. Most (95%) of fish were recovered adjacent to the point of tagging, but 5% had moved 15 nautical miles or more, and two fish were recovered from the northern west coast South Island (Kahurangi).

These data indicate that relative abundance of recruited blue cod in the Marlborough Sounds remains lower in all strata in 2004 than in 1995–96, consistent with local depletion of recruited blue cod, particularly in the inner areas of both Sounds. Recent trends in relative biomass (between 2001 and 2004) have varied among strata, increasing in Outer Pelorus, and decreasing off D'Urville Island west. Preliminary tagging data are consistent with a generally low level of movement, and high fishing pressure throughout the Marlborough Sounds. Recruitment appears variable, but generally low in the inner areas of both Sounds, suggesting that recovery, particularly of these areas, may be slow.

8. Objectives:

The objective for project BCO2003/01 was:

1. To assess the status of blue cod (*Parapercis colias*) stocks in the Marlborough Sounds and Tasman Bay.

Specific objectives for 2003/04 were:

1. To estimate relative abundance of blue cod in the Marlborough Sounds including D'Urville Island, and off Separation Point in Tasman Bay/Golden Bay.
2. To collect otoliths and biological information from a subset of blue cod.
3. To carry out an opportunistic blue cod tagging programme.

9. Introduction

Blue cod, *Parapercis colias* (Pinguipedidae), is the third most frequently landed finfish (after snapper and kahawai) taken by recreational fishers in New Zealand, and the preferred target species for South Island fishers (Kilner & Bell 1992, Blackwell 1997a, Hartill et al. 1998). The blue cod fishery that occurs in the Marlborough Sounds and Tasman Bay is considered to be overfished, mainly by recreational target fishing effort (Warren 1994). The recreational catch in BCO 7 (which includes the Marlborough Sounds and Tasman Bay) increased from an estimated 20 to 40 t (c.v. 21%) in 1991–92 (Teirney et al. 1997), to 239 t (c.v. 9%) in 1996 (Bradford 1998), and increased again to 288 t (c.v. 9%) during 1999–2000 (R. Boyd & J. Reilly, KPMG, unpublished results). In addition, an estimated 76 t (c.v. 13%) of blue cod were taken in BCO 7 by recreational fishers on charter vessels during 1997 (James & Unwin 2000). The total allowable commercial catch (TACC) for BCO 7 of 70 t has been considerably under-caught, with annual landings varying between 28 and 30 t between 1985–86 and 2003–04 (Sullivan et al. 2005).

This report describes a pot and line fishing survey of recruited blue cod (greater or equal to 30 cm in total length) carried out in the Marlborough Sounds and Tasman Bay during September–October 2004. This survey provided the third point in a time series of relative biomass estimates initiated by pot and line surveys completed in Queen Charlotte Sound during September 1995 (Blackwell 1997b), and in Pelorus Sound/D'Urville Island during September 1996 (Blackwell 1998). The second survey in the time series (Blackwell 2002) indicated a declining trend that appeared to be inversely proportional to the level of access to recreational fishers within the Marlborough Sounds (Blackwell 2002). In response, fishery managers increased the minimum legal size for recreational fishers (from 28 to 30 cm), and reduced the maximum recreational bag limit (from six to three blue cod) in the Marlborough Sounds and Tasman Bay subarea of the Challenger Fishery Management Area (Sullivan et al. 2005).

Other relevant research includes blue cod age validation, mortality, tagging and movement studies (Rapson 1956, Mace & Johnston 1983, Mutch 1983, Carbines 1998a, 1998b, 1999, 2000, 2002, 2004a, 2004b, Cole et al. 2000, Carbines & McKenzie 2001, 2004, Beentjes &

Carbines 2003, 2005, Carbines & Bentjes 2003), analysis of selective capture of blue cod by potting (Cole et al. 2001), and the examination of the effect of closed areas on blue cod size and relative abundance (Davidson 2001). Other surveys of relative biomass have been completed for blue cod in Dusky Sound (Carbines & Beentjes 2003) and Banks Peninsula (Beentjes & Carbines (2003), and a general review of the fishery was provided by Warren (1994).

Changes in the Marlborough Sounds recreational blue cod fishery were reviewed by Bell (2001), Bell et al. (1993), Bradford (1998), Kilner & Bell (1992), and Blackwell (2002), and for the Kaikoura and north Canterbury recreational fishery by Hart & Walker (2004). The effect of changes in bag limits and minimum legal size on yield per recruit were examined by Blackwell (1998) and Gilbert & Bradford (1999).

This report describes the results of a third point in the time series of relative biomass indices for the Marlborough Sounds blue cod fishery, which began in 1995, and summarises the results of previous surveys. The 2004 survey included two new strata: western D'Urville Island and Separation Point (Figure 1). Little is known about the blue cod stocks in these areas, although anecdotal information suggested that catch rates would be lower than for eastern D'Urville Island. The report also describes the results of a pilot tagging and release programme to review movement and growth patterns in the Marlborough Sounds.

The 2004 Marlborough Sounds survey was timed to coincide with the September spawning season, as determined from previous surveys. This is earlier than the spawning seasons along the eastern and southern parts of the South Island.

10. Project and voyage personnel.

The blue cod pot and line fishing survey (lhr0401) was carried out from 1 September to 27 October 2004, to coincide with the peak of spawning (Blackwell 1997b, 1998, 2002). The project leader was Ron Blackwell, and Craig Aston was the skipper of the fishing vessel *Lady H.R. (Helen Rose)*, chartered for the survey.

11. Methods

11.1 Survey area

The inshore waters of the top of the South Island can be divided into two regions: Marlborough Sounds, and Tasman/Golden Bays (Figure 1), areas which include diverse habitat, from sheltered reefs to exposed rocky coasts and offshore islands. Tasman Bay is a broad relatively shallow ocean bay protected by Farewell Spit in the northwest and by the North Island of New Zealand to the northeast. Blue cod habitat is essentially limited to the rocky headlands adjacent to Separation Point in the west, and to the bluffs stretching northeast from Nelson to western D'Urville Island (Figure 1).

The Marlborough Sounds (Figure 2) were formed from two drowned river valleys, Queen Charlotte Sound and Pelorus Sound. Queen Charlotte Sound is influenced by oceanic waters from the north and east through Tory Channel; Pelorus Sound is influenced by the major freshwater input of the Pelorus River (Heath 1974, 1982).

Blue cod habitat within the survey area was assumed to include all possible sites over rocky reefs and rubble banks that commonly occur off headlands and drop-offs within a band 10–100 m offshore, and about 10–60 m in depth. The nature and extent of this habitat was reviewed by side scan sonar (Cole 1999). The estimated area of blue cod habitat for each sampling stratum was used to determine the mean weighted catch per unit effort (CPUE) reported as kg/pot hour, and estimate the associated sampling c.v. (see Table 8). These data were also used as input to the NIWA Trawl Survey Biomass Estimation Programme (Vignaux 1994).

11.2 Sampling methodology and survey design

Previous surveys (Blackwell 1997b, 1998) assessed the relative abundance of all sampled blue cod. Cole et al. (2001) showed pots under-sampled small (under 20 cm) blue cod in comparison with diver count methods. The 2001 potting survey (Blackwell 2002) provided biomass estimates for blue cod that had recruited into the fishery (i.e., over 28 cm total length), based on the then minimum legal size of 28 cm. As the minimum legal size was increased to 30 cm in 2003 (Sullivan et al. 2005), the definition of “size-at-recruitment” was changed to 30 cm for the 2004 survey.

11.3 Stratification

The 2004 survey area was divided into two regions: Marlborough Sounds, and Tasman Bay. The Marlborough Sounds region comprised two sub-regions: Queen Charlotte Sound, and Pelorus Sound, which included the east coast of D’Urville Island (Figure 2). For these sub-regions, previously defined strata were used. The Queen Charlotte Sound sub-region was divided into three strata: Inner Queen Charlotte Sound (IQCH); Outer Queen Charlotte Sound (OQCH); and Extreme Outer Queen Charlotte (EQCH), as defined by Blackwell (1997b). The waters of Inner Queen Charlotte Sound inside the line adjacent to Allports Island (Figure 2) were not considered to be blue cod habitat (Blackwell 1997b), and were excluded from the 2004 survey.

The Pelorus Sound sub-region was divided into five strata: Inner Pelorus Sound (IPEL); Mid Pelorus Sound (MPEL); Outer Pelorus Sound (OPEL); and Extreme Outer Pelorus Sound (EOPE). The D’Urville Island east (DURE) stratum analysed in the 2004 survey is the same as the DURV stratum as defined by Blackwell (1998). The waters of inner Pelorus Sound inside a line adjacent to Dillon Bell Point (Figure 2) were not considered to be blue cod habitat (Blackwell 1998) and were excluded from the 2004 survey.

The Tasman Bay region included the two new strata. These were established off Separation Point (SEPR) in the east, and off the west coast of D’Urville Island (DURW) (see Figure 1).

11.4 Analysis of previous survey data

The previous Marlborough Sounds potting surveys identified 8–13 potential sampling areas of suitable rocky/rubble reef habitat within each stratum, each involving about 500 m of coastline. The 1995 and 1996 surveys randomly selected four sampling areas within each

stratum using an equal allocation sampling strategy, to estimate relative abundance of all blue cod with a sampling c.v. of 5%.

Blackwell (2002) used variance component analysis to optimise the 2001 survey design for blue cod over 28 cm using previous survey data. Sampling variability was highest among sampling strata, while the variance associated with areas and stations was relatively low. As the survey vessel can carry a maximum of nine pots, sampling variance was minimised by increasing the number of areas sampled within each stratum. The 2001 survey achieved a sampling c.v. of 7%, with additional areas sampled in the OQCH, EQCH, MPEL, OPEL, and DURV strata.

The previous survey data were used to optimise the 2004 survey. The number of sampled sites within each stratum was chosen in such a way that the abundance index had minimum variance for a given number of sites. Estimates of the means and standard deviations of numbers of fish per pot by stratum were determined from previous surveys. Catches were pooled by stratum to give estimates of mean and standard deviation per site (i.e., per nine pots). The abundance index obtained was the sum of the mean stratum catches per pot weighted by the stratum coastline lengths. As the coastline length corresponds approximately to the area of blue cod habitat, we can therefore minimise the expected variance of the abundance index.

Let M_{ij} be the catch per pot in stratum i at site j . Assuming that the sites within a stratum are homogeneous, let the expected value of M_{ij} be equivalent to m_i , the mean pot catch per stratum. Let s_i be the standard deviation of the mean of 9 pot catches from a site in stratum i and let w_i be the stratum weighting (coastline length). Then the abundance index

$$A = \sum_i w_i \left(\frac{1}{n_i^*} \sum_j M_{ij} \right)$$

where n_i^* is the number of sampled sites, the M_{ij} are summed over these sites and the outer summation is over all strata. The variance of A is

$$\text{var}(A) = \sum_i w_i^2 \left(\frac{1}{n_i^{*2}} \sum_j s_i^2 \right) = \sum_i \frac{w_i^2 s_i^2}{n_i^*}$$

We therefore seek to minimise $\text{var}(A)$ by choosing values for n_i^* , under the constraint that $\sum_i n_i^* = N$, where N is the total number of sites sampled. Lagrange multipliers can be used to obtain the solution,

$$n_i^* = N \frac{w_i s_i}{\sum_k w_k s_k}$$

Estimates of n_i^* were obtained by using our sample estimates of s_i . Since n_i^* must be integers and since there is only a finite number of potential sites in each stratum, this formula gives only an approximate solution. We imposed a further constraint that $n_i^* \geq 3$ for all strata to ensure that we could obtain adequate estimates of precision for each stratum. By rounding and applying these constraints, we obtained optimal designs for two cases with different total numbers of sites (see Table 1). The more sites fished the lower the expected c.v. of the abundance index, but both models gave very acceptable values. Sites should be chosen at random, so a random sequence of sites was provided. The survey programme followed the design indicated by Case 2, with the extra sites required per stratum given in square brackets, with the addition of one extra site in the IQCH stratum.

Since no relative abundance data were available for the two new strata in Tasman Bay (Separation Point and D'Urville Island west), an equal allocation model was used. From the Marlborough Sounds data, 10 sampling areas were randomly selected from available blue cod habitat within each of these two strata to provide estimates of sampling variance. (D. Gilbert, NIWA, pers. comm. 2004). Stations close to Separation Point were positioned within the area of bryozoan habitat identified by Grange et al. (2003).

11.5 Vessel and gear specifications

The same vessel and gear were used to ensure consistency with previous surveys. The commercial fishing vessel *Lady H.R.* is 9.6 m in length, with a 3.2 m beam and a displacement of 10 t. She is powered by a Ford diesel generating 60 kW and is fitted with power-hauling gear for cod pot fishing, a Koden colour depth sounder, and GPS. Additional survey equipment included 5 kg motion-compensating Seaway electronic scales, Trimble portable GPS system, a remote underwater video system, and the standard NIWA electronic data capture systems.

The cod pots were rectangular (1.87 x 1.40 x 0.93 m) and constructed from a 40 mm diameter steel rod framework covered with 60 mm nylon mesh. A 15 mm galvanised wire mesh inner liner was added to the bottom and sides of each pot to prevent the escapement of small fish. Each pot had four entrances leading into a short steel wire tube. The internal entrance of this tube was provided with inward-facing wire spines, as detailed by Blackwell (1997b). The pot was attached by a polypropylene rope to a large buoy with the vessel name and number. The length of rope was adjusted for differences in tide and current as appropriate.

Bait used for pot and line fishing stations in the 2004 survey was frozen guts of paua (*Haliotis iris*), as used in the 2001 survey (Blackwell 2002), and routinely used in the commercial blue cod fishery. These were stored frozen and thawed as required. When used to bait a pot, they were part-thawed, and enclosed in a perforated plastic bait box, which was attached to the inside bottom surface of the pot. The tough membranes of the paua guts were attached directly to the hooks used in the line fishing stations.

The line fishing stations were used as a control for the pot fishing method (Blackwell 2002), and to obtain fish for tagging and release under Objective 3 of this project, without compromising sampling for biological parameters where blue cod density was low. The line fishing gear consisted of two braided nylon handlines, which were fished for 15 minutes at each line fishing station, as used in the previous surveys. Each line was baited with frozen

paua guts and set with two 6/0 Kale hooks on a 0.5 m trace, fixed at 0.5 m and 1.0 m from the weight, which was set on the end of the line.

11.6 Sampling procedure

All stations were occupied in daylight, and morning sampling generally began at 0700 hours (NZST). Sampling followed the procedures of Blackwell (1997b, 1998, 2002), where the time of sampling (morning or afternoon) was randomly allocated among the four areas sampled each day to avoid bias due to time and/or tide. Two areas were generally completed in the morning, and two areas in the afternoon, with extra steaming time required for sampling in remote locations.

The nine replicate pot fishing stations (a–i) were randomly chosen from the available blue cod habitat within each previously defined sampling area. The pots were sequentially deployed at about 2 minute intervals. Each pot was deemed to be fishing once the float was detached from the vessel. The pots were fished for 1 hour, during which time the two line fishing stations were sampled.

The two line fishing stations (j & k) were established adjacent to (but more than 50 m from) the first (station a) and last (station i) pot stations, after the pots had been set. When these had been completed, the bottom type was sequentially assessed for the last and the first pot fishing station, using depth sounder data, observations of the substrate attached to the pot upon recovery, and from an underwater video camera. This unit comprised a low light video camera encased in a waterproof housing (splash-cam), and a video monitor.

After 1 hour, the pots were sequentially recovered, and the catch was removed and processed. The vessel then steamed to the next sampling area. Afternoon fishing continued until 1600 hours.

11.7 Catch and biological sampling

Data were entered directly on the standard NIWA trawl survey database and later loaded on to the Ministry of Fisheries *trawl* database (as *LHR0401*), with pot fishing stations starting sequentially from number 1, and line fishing stations from number 901. For each station, date, latitude and longitude, depth, and times of set and haul were recorded. The bottom type was recorded using the standard NIWA categories: 1, mud; 2, sand/mud; 3, sand/gravel; 7, rock/rubble, and a more complete description of the observation of substrate type was recorded in the station comments section of the recording form.

The catch from each pot or line fishing station was sorted by species on deck. The number and total weight (to the nearest 0.1 kg) by species were recorded. For major commercial finfish species, the length (to the nearest whole centimetre below actual length) and sex were recorded by the method appropriate for the species. As most finfish were recovered alive, the bycatch was, where possible, returned alive to the sea.

The length, weight, and sex were recorded for each blue cod. Sex determination was generally possible by external visual examination during the September spawning season (Blackwell 2002). Within each stratum, the first 200 blue cod sampled from the pot fishing

stations were dissected to determine the sex and gonad maturity stage. These were: 1, immature or resting; 2, developing (oocytes visible in females); 3, mature (hyaline oocytes in females, milt expressible in males); 4, running ripe (eggs and milt freely flowing); 5, spent.

Subsequent biological samples were collected from a 50% subsample of blue cod from each station within the stratum. The remaining fish, including fish tagged and released under Objective 3 of this programme, were sexed by external visual examination. Fish were recorded as “unsexed” where the sex could not be determined.

To determine the minimum length at sexual maturity for each stratum, the proportion of fish at each maturity stage was tabulated for each 1 cm size class, and the size at 50% maturity was estimated by fitting an ogive to the proportions of fish in each 1 cm size class where stage 2 or higher, gonads were present.

Otoliths were collected from up to 20 blue cod from each 1 cm size class, per sex and sampling stratum. These were archived and data were stored on the Ministry of Fisheries *age* database.

11.8 Tagging of blue cod

Fish selected for tagging were held in a deep tank which was connected to the deck hose to ensure an adequate supply of constantly flushing seawater. Each fish was removed using a dip net, and the length, weight, and sex (external visual examination) were recorded. A yellow T-bar dart tag was inserted into the ventral musculature of the pelvic fin using a tagging gun following the procedure of Carbines (2004a). Tagged fish were released into the water next to the side of the vessel to avoid predation by seabirds.

11.9 Data analysis

Length frequency distributions were determined by fishing method (pot and line) for all areas combined, and for each sample stratum (pot and line data combined). The sex ratio (percentage of males, excluding unsexed fish) was determined from each sampling area.

Mean catch rates (kg per hour) were determined by stratum for the pot fishing station data only, and previous survey data were re-analysed using the revised definition of recruited blue cod (over 30 cm). Mean catch rates were determined for all blue cod, recruited blue cod, and pre-recruit (under 30 cm) blue cod. Data were also reviewed for juvenile (17–27 cm) blue cod, where 17 cm was considered the minimum effective size to be fished by pots, and the upper range represented the maximum size unaffected by the recent changes in legal size (Sullivan et al. 2005).

Following a review of the data diagnostics, the data were subjected to a log ($x+1$) transformation, and a standard amount (0.001 kg or 0.001 fish) were added as appropriate to avoid taking the log of zero (Green 1979). The mean catch rates were compared among strata and fishing years (1995, 1996, 2001, and 2004) using analysis of variance (PROC GLM; SAS 1989). Where the first order interaction between stratum and fishing year was significant, the differences between the means of the levels of the main effects could not be interpreted. Where the stratum*year interaction was not significant, the differences between the means

were analysed for each main effect (stratum, year) using the Ryan-Einot-Gabriel-Welsch multiple range test (REGWQ) of PROC GLM (SAS 1989). Given the high number of stations with zero catch of recruited blue cod, the main effects were also analysed using the non-parametric Wilcoxon Rank Sums test (Snedecor & Cochran 1980) using PROC NPAR1WAY (SAS 1989). The results are presented where these differ from the ANOVA data.

To estimate the sampling c.v.s, mean catch rates (kg per set) were weighted by the survey area for each stratum following the method of Blackwell (2002). The area of blue cod rocky bottom/cobble habitat was estimated from underwater video observations (NIWA, unpublished data) and side-scan sonar survey data (Cole 1999) to extend about 10–60 m offshore. The area of deeper water was excluded from analysis as the bottom generally consisted of silty sand or mud, which was not considered to be blue cod habitat. The sampling area was conservatively estimated by measuring the length of coastline in each stratum, assuming that the available habitat consisted of a band of equal width extending out from the coast (D. Gilbert, NIWA, pers. comm., 2004). The curvature of all strata was assumed similar, and therefore the length of the coastline was proportional to the amount of blue cod habitat. Each stratum mean catch rate and biomass was weighted by the stratum coastline length, then divided by the sum of all stratum coastline lengths, to give an overall estimated weighted mean kg per pot per hour.

Coefficients of variation for each stratum were then determined from:

$$cv_i = se_i / mean_i$$

where for the i th stratum se_i is the standard error and $mean_i$ is the mean catch rate (kg per pot per hour). The overall mean catch rate for all strata was determined by weighting each stratum mean by the stratum coastline length ($area_i$) divided by the sum of all coastline lengths ($area_{total}$) to give an overall weighted mean.

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

The overall mean standard error of the means was determined by squaring each standard error times its weighting, summing them, and then taking the square root to give an overall weighted standard error.

$$se_{overall} = \sqrt{\sum (se_i^2 * area_i / area_{total})}$$

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

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

Relative biomass indices and scaled length frequency distributions were also calculated for pot fishing stations for the 2004 survey, and previous surveys, using a modification of the NIWA Trawl Survey Analysis Programme of Vignaux (1994) (S. Hanchet & D. Gilbert, NIWA, pers. com., 2004). In trawl surveys, the sampling area is usually estimated by the area swept method (Francis 1989). For static fishing gear, such as a blue cod pot, the effective fishing area was assumed to approximate the area swept of a trawl survey. The effective fishing area was assumed to be a circle around each pot (Eggers et al. 1980, Fogarty & Addison 1997). The radius was estimated at 35 m by a series of repeated diver observations

on baited pots off D'Urville Island (Blackwell 2002). This represented an area of 0.0096 sq km, which equated to a doorspread of 0.76 m. As doorspread can be specified to only 1 decimal place (0.8 m), the resulting 5% increase in sample area was considered to provide a conservative estimate of blue cod biomass. Vertical availability, fish vulnerability, and areal availability were all assumed to be 1, i.e., all fish in the area were attracted to the pot. While Cole et al. (2001) showed that juvenile blue cod (under 18 cm) were poorly selected by pots, any size selectivity bias was assumed constant over the survey series, to allow relative biomass estimates to be determined.

The c.v. is a measure of the precision of relative biomass and is calculated from

$$CV(B)_i = \frac{SQRT(Var(B)) \times 100}{B}$$

B is the relative biomass estimate and Var (B) is the variance of the estimate.

Relative biomass estimates and scaled length frequencies were calculated for the 2004 and previous surveys by sampling stratum for the size classes: 0–17 cm, 18–27 cm, 28–29 cm, and 30–55 cm, using a modification of the NIWA Trawl Survey Analysis Programme (S. Hanchet, NIWA, pers. comm. 2004). Vulnerability, accessibility, and areal availability were assumed to be 1, and doorspread was set at 0.8 m. The length weight relationship

$$Wt = 0.012240 + (L ** 3.074600)$$

was used, where weight (Wt) was reported in grams and length (L) was reported in cm (Sullivan et al. 2005).

12. Results

Sampling was carried out between 1 September and 16 September 2004, with two days lost to bad weather and mechanical breakdown. A total of 605 stations (495 pot stations and 110 line fishing stations) were completed. Continuing bad weather and prior vessel commitments forced the postponement of sampling of the Separation Point stratum until 26–27 October 2004, when a further 90 pot stations and 20 line fishing stations were completed (Table 2).

12.1 Catch composition

Blue cod occurred at 472 (66%) of the 715 stations sampled, and represented 91% of the total survey catch of 1497 kg (Tables 2 and 3). Bycatch was low, comprising by weight, octopus (*Octopus cordiformis*) (5%), and conger eel (*Conger verreauxi*) (2%) respectively; the catch of the remaining nine species was insignificant. The size range and numbers taken of the major species are given in Table 4.

12.2 Total blue cod catch

A total of 3645 blue cod were taken: 457 fish (129 male, 93 female, 235 unsexed) from the line fishing stations, in a size range 19–49 cm, and 3188 fish (1595 male, 1324 female, 269

unsexed) from the pot fishing stations (size range 13–50 cm). The 504 unsexed blue cod represented immature fish that could not be sexed, as well as fish that were tagged and released under Objective 3 of this project, where sex could not be determined. The overall numbers and mean length of blue cod, by sex, stratum and method, are given in Table 5.

The unscaled length frequency distributions by method (Figure 3) indicate that larger length classes tended to be male-dominated in both pot and line fishing methods, while the smaller length classes (pre-recruits) tended to have a more even sex ratio. The length frequency distributions were very similar between the fishing methods (median length 29.0 cm for line fishing, 28.5 cm for pot fishing). Insufficient numbers of fish were taken by line fishing to analyse the among-stratum trends in the line catch data, and the CPUE analysis (catch per unit of effort) of mean catch rate (kg/hour) was confined to the pot fishing data only.

12.3 CPUE analysis of mean catch rate (kg/hour)

12.3.1 All blue cod

Mean catch rate (kg/hour) for 2004 varied widely among strata, with the highest rate in DURE and the lowest in SEPR (Figure 4a, Table 6a). The largest decline (20%) in mean catch rate also occurred in DURE, as noted in the 2001 survey (Blackwell 2002). For the remaining strata, the changes between 2001 and 2004 were more variable than between 1995 and 2001 (Queen Charlotte), or 1996 and 2001 (Pelorus), with increases in mean catch rate occurring in EQCH, OPEL, and EOPE. Little or no change occurred in IQCH, OQCH, IPEL, and MPEL, where catch rates were generally low. As in the previous surveys, the number of zero catches was high in the inner strata of both Sounds. Mean catch rates for the new DURW stratum were similar to the adjacent DURE stratum, while catch rates for the new SEPR stratum were very low.

12.3.2 Recruited blue cod (over 30 cm in length)

The highest mean catch rate occurred in DURE, and the lowest in SEPR, while mean catch rates were generally low in the inner areas of both Sounds. These trends were examined by ANOVA. For the Queen Charlotte sub-region, the area*year interaction term was not significant, and the main effects were able to be interpreted (Green 1979). The decline in mean catch rate from the outer to the inner strata (EQCH → OQCH → IQCH) was statistically significant, and a significant decline also occurred between survey years (Table 7a). The more sensitive Multiple Range Test (Table 7b) indicated that the decline among strata was significant for all survey years. The decline between the 1995 and 2001 survey years was significant, but not between the 2001 and 2004 survey years.

For the Pelorus Sound strata, the significant year*stratum interaction term (Table 8) precluded further analysis of the main effects. Some strata such as EOPE increased between 2001 and 2004, others showed little change, while mean catch rate decreased in the DURE stratum.

For the Tasman Bay region, the mean catch rates from the DURW stratum were similar to those from the DURE stratum, while catch rates for SEPR were very low. No historical data were available to analyse trends in these data.

12.3.3 Pre-recruit blue cod (under 30 cm in length)

Trends for all pre-recruit blue cod were generally consistent with the recruited blue cod catch rate data (Figure 4c), but catch rates for EQCH were higher in 2004 than in 1995. For the Queen Charlotte strata, the ANOVA data indicated the decline from the outer to the inner strata (EQCH → OQCH → IQCH) was statistically significant (Table 9a) but no difference was apparent among survey years. The Multiple Range Test indicated that the mean catch rate in IQCH was significantly lower than for the grouped OQCH and EQCH strata. Mean catch rates in 1995 were significantly lower than for the grouped 2001 and 2004 surveys (Table 9b).

For the Pelorus strata, the decline in mean catch rate was significant among survey years and between strata, but the significant year*stratum interaction term again precluded further analysis (Table 10). The mean catch rates decreased for DURE, increased for OPEL and EOPE, but showed little change for IPEL and MPEL (Figure 4c). The 2004 data were similar to the 1995 survey for EOPE, and similar to the 1996 survey for DURE.

12.3.4 Juvenile blue cod (17–27 cm in length)

The trends in mean catch rate of juvenile blue cod generally follow the trends for all pre-recruits, but were more variable among survey years (Figure 4d). For the Queen Charlotte strata, ANOVA data (Table 11a) indicated a decline among strata (EQCH → OQCH → IQCH), and the rate for IQCH was lower than for the OQCH and EQCH grouped strata from the Multiple Range test (Table 11b). A significant difference occurred between survey years, with low catch rates occurring in 1995, and higher catch rates occurring in the 2001 and the 2004 surveys (see Table 9b).

For the Pelorus strata, the year*stratum interaction was again significant (Table 12), indicating the rate of change between survey years varied among strata. Increases occurred for IPEL since 2001, and for EOPE since 1996, while a decrease in mean catch rate occurred for MPEL and for DURE since 2001.

12.4 2004 survey mean weighted catch rates and estimation of sampling c.v.

The relative abundance indices (kg/pot), weighted by the estimated area of coastline in each sampling stratum, for all blue cod varied from 0.01 kg/hour in SEPR, to 0.56 kg/hour in DURE (see Table 6a). The overall mean weighted catch rate of 1.70 kg/hour had an estimated sampling c.v. of 5%, which is within the survey target sampling c.v. of 20%.

Estimated mean weighted catch rates for recruited blue cod ranged from 0.01 kg/hour in SEPR, to 0.33 kg/hour in DURE (see Table 6b). The overall mean weighted catch rate for recruited blue cod of 0.91 kg/hour had an estimated sampling c.v. of 7%, which is within the target sampling c.v. of 20%.

12.5 Estimation of relative biomass by stratum

Relative biomass estimates from the Trawl Survey Analysis programme, by stratum and year, for all blue cod, recruited fish (30 cm or over in length), pre-recruits (under 30 cm in length) and juvenile blue cod (17–28 cm in length) (see Appendix 2), were generally consistent with the overall decline in relative abundance from the mean catch rate data. The calculated c.v.s were also similar to the estimated sampling c.v.s (see Table 6), with high c.v.s calculated for the IQCH, IPEL, and MPEL strata. The 2004 relative biomass estimate for all blue cod (670 t, c.v. 5%) was lower than for the 2001 survey (731 t, c.v. 7%), and both were lower than the estimate of 960 t (c.v. 5%) determined for the 1996 survey. The estimate for 1995 (532 t, c.v. 7%) may be low because the DURE stratum was not included in that survey.

12.6 Length frequency distributions

Length frequency distributions scaled by the survey area (see Table 6), by sex, stratum, and survey year were generally unimodal (Figure 5). Changes in mean length and frequency distribution suggestive of recruitment occurred in EQCH and OQCH during 2001 and 2004, EOPE during 1995 and 2001, and OPEL in 1995, 2001, and 2004. Sex ratios were generally biased towards males in all survey years. The unsexed fish in 2004 represent fish tagged and released under Objective 3 of this project, where sex could not be determined by external visual examination. Data are sparse for IQCH, IPEL, and MPEL, particularly in 2001 and 2004.

12.7 Sex ratio

The total sex ratios (excluding unsexed fish) from the 2004 survey varied among strata, from 43% male in OQCH, to 68% male in OPEL and EOPE. Males were strongly dominant in the EQCH, MPEL, OPEL, and EOPE strata (Table 13, Figure 5).

12.8 Length at sexual maturity

Of the 1491 males examined overall (see Appendix 2), 466 were maturing (31%) and 669 were running ripe (45%). Of the 1224 females examined, 276 were developing (22%), 737 were maturing (60%), and 132 were running ripe (11%), suggesting that the spawning season may have been late in 2004. The size at 50% maturity appeared to be between 18 and 20 cm for both males and females, but insufficient data were available for these smaller size classes to provide accurate estimates (Figure 6). No consistent relationship could be determined between fish length and gonad maturity stage among sampling strata (Figure 7). Spawning females were sampled in most strata, except IQCH, IPEL, and SEPR. For males, the minimum size of sexual maturity varied from 16 cm in OQCH, to 27 cm in MPEL. Actively spawning males were found in most strata, except IQCH and SEPR.

12.9 Length and weight

Overall length-weight regressions were derived for males in the size range from 15 to 55 cm, and for females from 12 to 45 cm, excluding fish tagged and released under Objective 3 of

this project (Figure 8). These data were consistent with the calculated length-weight data for previous blue cod surveys (Blackwell 1997b, 1998, 2002) and for previously published data for blue cod from trawl surveys completed in Tasman and Golden Bays (reviewed by Blackwell (1998)).

12.10 Tagging data

A total of 962 blue cod were tagged and released, 537 from pot stations and 425 from line fishing stations (Table 14). Most (406) were tagged in DURW, with 254 tagged in DURE and 131 in EOPE. Few fish were available for tagging in the remaining strata.

As of 20 May 2006, a total of 113 tags has been reported to NIWA, indicating an overall recovery rate of 11.7%. These were recovered from all strata, and recovery rates ranged from 8.9% in DURW, to 26.3% in MPEL. Recovery data were consistent with a generally low rate of movement. Most (94%) of tags were recovered immediately adjacent to the area of release, with three fish (3.3%) moving 10–15 n. miles, while two fish (2.2%) tagged in DURE and EOPE were apparently recovered from Kahurangi Shoal (west coast South Island). The recovery of three sets of tags with consecutive numbers is further evidence of a generally low rate of movement of blue cod.

13. Discussion

The Marlborough Sounds and Tasman Bay blue cod fishstock supports a locally important recreational fishery, but appears to be over-fished, with local depletion and a declining trend in relative abundance from 1995 to 2001. This trend has been attributed to recreational fishing activity (Warren 1994, Davidson 2001, Blackwell 2002). The 2004 survey represents the third in the survey series implemented to monitor changes in relative biomass, length frequency, and sex ratio. It updates previous surveys completed in 1995 and 2001 in Queen Charlotte Sound (Blackwell 1997b, 2002), and in 1995, 1996, and 2001 for Pelorus Sound and the east coast of D'Urville Island strata (Blackwell 1997b, 1998, 2002), and includes two new strata in Tasman Bay (SEPR and DURE).

Mean catch rates (kg/pot hour) appear to approximate the relative biomass of recruited blue cod (Blackwell 2002, Carbines 2004a), defined here as fish greater than, or equal to, 30 cm in total length, consistent with the current minimum recreational blue cod limit of 30 cm (Sullivan et al. 2005). Whilst the 2004 survey was completed in two parts, these estimates are unlikely to be affected by this delay, as blue cod are caught in BCO 7 all year round (C. Aston, French Pass, pers. comm., 2004), and tagging studies indicated blue cod populations are temporally stable (Mace & Johnston 1983, Carbines & McKenzie 2001, Blackwell 2002, Beentjes & Carbines 2005).

The mean catch rates of recruited blue cod (0.01 to 4.68 kg/hour, c.v. 7%) were consistent with previous Marlborough Sounds surveys (Blackwell 1997b, 1998, 2002), and with other recent surveys of recruited blue cod (30 cm or over) off Banks Peninsula (0.00 to 4.21 kg/hour, c.v. 13.2% from Beentjes & Carbines (2003)), and Dusky Sound (0.81 to 5.46 kg/hour, c.v. 7.6% from Carbines & Beentjes (2003)). These estimates assume constant catchability and selectivity over the time series. As in previous surveys, the pots were generally set 70 m apart to limit pot competition for blue cod, based on the estimated limit of pot attraction to blue cod of 35 m (Blackwell 2002). A minimum distance of 50 m between

pots was required for a few stations where suitable blue cod habitat was limited. This slight difference affected very few stations, and was ignored in density calculations, where the effective fishing area of a pot was assumed to be a circle of 35 m radius, with no competition among pots. The 70 m pot separation is less than the 100 m distance used in the Dusky Sound and Banks Peninsula surveys (Beentjes & Carbines 2005). The scaled length frequencies were using the NIWA Trawlsurvey analysis programme (Vignaux 1994). These assumptions may be affected by other factors, including freshness of bait, pot interference, and environmental factors including tidal cycle, and bottom topography (Whitelaw et al. 1991, Furevik 1994, Fogarty & Addison 1997, Blackwell 2002, Cole et al. 2000, 2001, 2003, Beentjes & Carbines 2005). Blue cod catch rates are not affected by time of day (Blackwell 1997), but may be affected by tidal cycle in strong tidal flows (Warren et al. 1997) present in areas such as southern D'Urville Island and French Pass (Cole et al. 2001). Blue cod appear territorial, and a dominant male may influence the behaviour of smaller females within its territory (Beentjes & Carbines 2005). While blue cod may enter and leave a pot several times during a 30 minute soak time, most fish are retained in the short term (30–60 minutes) by a pot until the available food is exhausted (Blackwell 2002, Cole et al. 2003). Pots are known to poorly sample juvenile blue cod (Cole et al. 2001).

Pot and line fishing methods appear relatively species specific (91% blue cod by weight). The low level of bycatch was consistent with previous Marlborough Sounds surveys (Blackwell 1997b, 1988, 2002), and with the 71% blue cod by weight derived from the 2003 Banks Peninsula survey (Beentjes & Carbines 2003) and the 87% blue cod by weight obtained from the 2003 Dusky Sound survey (Carbines & Beentjes 2003). The similarity of length frequency distributions indicated little apparent sampling bias between pot and line fishing methods in the Marlborough Sounds surveys.

Relative biomass of recruited blue cod declined substantially in the Marlborough Sounds between 1995–96 and 2001 (Blackwell 2002), and remained lower in 2004 than in 1995–96 for all strata. The rate of this decline has eased in most strata, except DURE and EOPE. An increase in relative biomass was indicated for EOPE, but a strongly declining trend continued in DURE, which had the highest catch rates in both 2001 and 2004. The low rate of change apparent for the remaining strata appears related to the relatively low levels of biomass indicated in the 2001 and 2004 surveys, with many zero catches of blue cod, particularly in the inner Sounds. The pattern of increasing biomass from the head to the mouth of both Queen Charlotte and Pelorus Sounds is consistent with previous surveys, and with the increasing trend between the inner and outer strata of Dusky Sound (Carbines & Beentjes 2003), and with the inshore and offshore strata off Banks Peninsula (Beentjes & Carbines 2003).

Mean length of blue cod increased from the inner to the outer strata of Pelorus Sound in 2004, but little trend was apparent for the Queen Charlotte strata, possibly due to the low catch rate in IQCH. These data were consistent with previous Marlborough Sounds surveys (Blackwell 2002), and with data from Dusky Sound, where smaller fish and relatively low catch rates occurred in the inner sounds strata (Carbines & Beentjes 2003), and with Banks Peninsula, where larger fish and higher catch rates occurred in the offshore strata (Beentjes & Carbines 2003). A decline in mean size was attributed to high fishing pressure in the more accessible inner and inshore areas of the Marlborough Sounds (Blackwell 2002, Beentjes & Carbines 2005). These trends were consistent with the increase in mean size and relative abundance in unfished (no-take reserve areas), as compared to fished (control) areas in outer Queen Charlotte Sound (Cole et al. 2000, Davidson 2001).

Population length frequency distributions from the Marlborough Sounds surveys between 1995 and 2004 were generally unimodal. The lack of any signal in the length frequency distributions at the previous minimum legal size of 28 cm suggested that fishers may have been returning blue cod take over 28–30 cm in length to the sea alive, before the regulation change in 2003 which increased the minimum legal size from 28 to 30 cm in the Marlborough Sounds (Sullivan 2005). This may be due to the small fillet attainable from smaller blue cod. These data were suggestive of juvenile recruitment into the mid and outer strata of both Sounds, particularly in 2001 and 2004, consistent with the strong recruitment reported between 1996 and 2001 in the Long Island Kokomohua Marine Reserve in outer Queen Charlotte Sound (Cole et al. 2000). Recruitment of juveniles in the inner sounds areas appeared generally low, but the pot fishing method may provide a biased estimate of the relative biomass of smaller blue cod (Cole et al. 2001). The recruitment patterns in the Marlborough Sounds were generally consistent with recruitment patterns for blue cod in Dusky Sound and Banks Peninsula (Beentjes & Carbines 2003, Carbines & Beentjes 2003).

The sex ratios were strongly male biased, as in previous surveys in the Marlborough Sounds (Blackwell 1997b, 1998, 2002), Banks Peninsula (Beentjes & Carbines 2003), and inner Dusky Sound (Carbines & Beentjes (2003)). Protogynous fish populations (females may change to males) such as blue cod may respond to high levels of fishing pressure where the larger, generally male fish are selectively removed, by increasing the rate of sex change. This may change the mean size, sex ratios, and size frequency distributions in complex ways (Huntsman & Schaaf 1994, Beentjes & Carbines 2005). The male-skewed sex ratios present in the Marlborough Sounds (Blackwell 1997b, 1998, 2002), and Banks Peninsula (Beentjes & Carbines 2003) may result from this process, while the neutral, or female-dominant sex ratios present in areas such as outer Dusky Sound are consistent with lower fishing pressure (Beentjes & Carbines (2005)).

These declining trends in relative abundance and mean length may be influenced by habitat degradation, particularly in the inner Sounds (Cole et al. 2001), but are most likely to be due to increases in recreational fishing effort. The Marlborough Sounds blue cod fishery is considered to still be influenced by the historically high levels of fishing pressure that operated during the 1970s, when fewer controls were in place on recreational fishing (Warren 1995, Davidson 2001, Blackwell 2002, Beentjes & Carbines 2005). Recreational catch rates in BCO 7 (which includes the Marlborough Sounds) have increased, from 20–40 t (c.v. 21%) in 1991–92, to 239 t (c.v. 9%) in 1996–97, and to 288 t (c.v. 20%) in 1999–2000. Early data (before 1999–2000) underestimate actual catch (Sullivan et al. 2005), and these data do not include catch from recreational fishers on charter boats, estimated at 76 t (c.v. 13%) in 1997–98 (Teirney et al. 1997, Bradford 1998, James & Unwin 2000, Sullivan et al. 2005).

Blackwell (2002) re-analysed the 1997–98 Marlborough Sounds recreational fishing survey data (Bell 2001), and found most (63%) blue cod target fishing occurred in the outer Queen Charlotte Sounds and D’Urville Island areas (OQCH 25%, DURE 22%, and EQCH 16%), where recreational fishing catch rates varied between 3.2 and 5.2 kg/trip among strata. Less fishing occurred in the Outer Pelorus Sound strata (OPEL 8.8%, EPOE 9.3%), although catch rates in these strata varied between 4.7 and 4.8 kg/trip. in contrast, few trips targeted the inner sounds (IQCH 4.5%, IPEL 2.5%), where catch rates were more variable (1.82 to 3.76 kg/trip). While no more recent data on recreational catch are available, the recovery rate (9.6%) from the pilot tagging programme suggests a moderate exploitation rate in this

fishery. The tagging data are difficult to interpret further without information on tag mortality and tag loss not available from the pilot tagging programme.

Recovery from local depletion may occur through settlement, growth, and migration. Little is known about the movement of pre-recruit blue cod. Diver surveys indicate small blue cod (under 17 cm total length) to be widely distributed in the shallow waters of the inner and mid areas of both sounds (Cole et al. 2001), but scaled length frequency distributions from pot catches of mid-sized fish (17–27 cm in length) were highly variable among strata and survey years.

Blue cod appear generally sedentary, although longer-term migration has been proposed by Rapson (1956) and Robertson (1973). The low rate of movement indicated by the 2004 pilot tagging programme is consistent with previous Marlborough Sounds tagging programmes (Rapson 1956, Mace & Johnston 1983, Cole et al. 2000), and from recent tagging programmes in Southland (Carbines & McKenzie 2004). Patterns of movement in blue cod are complex. Carbines & McKenzie (2004) found replenishment of the inner areas of Dusky Sound occurred from the adjacent open coast, with some areas acting as sources for migrating fish, while others acted as sinks, with net loss of fish to other areas. Cole et al. (2000) found limited movement of tagged fish in Queen Charlotte Sound outward from reserve areas, but little is known about the movement of pre-recruit and recruited blue cod in the Marlborough Sounds, and how the processes identified in Fiordland may operate under the relatively high exploitation rate acting on blue cod in this region.

The 2004 survey provides a third point in a declining time series of relative abundance estimates for blue cod in the Marlborough Sounds. The rate of this decline has become more variable since 2004, with some improvement indicated in outer Pelorus Sound, but the decline in DURE appears consistent with increased fishing effort in this area as suggested by Blackwell (2002). Little is known about the rate of recovery of the inner sounds areas where catch rates remain low. Further work is required to examine the dynamics of blue cod movement within the Marlborough Sounds. As movement appears likely to be from the open coast to the inner sounds (Carbines & McKenzie 2004), the high fishing pressure operating on these outer sounds areas suggests that recovery of the Marlborough Sounds blue cod fishery is likely to be a slow process.

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15. Publications:

None

16. Data Storage:

Data from this survey are stored in the Ministry of Fisheries *trawl* database. Otoliths have been archived and tagging data has been stored in the Ministry of Fisheries *tag* database.

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Appendix 1: Relative biomass estimates (t) and coefficient of variation (c.v.) of blue cod from the Marlborough Sounds and Tasman Bay blue cod pot surveys, by stratum and survey year. The Inner Pelorus Sound strata (IPEL, MPEL), and D'Urville East (DURE) were not surveyed in 1995, and the Queen Charlotte Sound strata (IQCH, OQCH, EQCH) were not surveyed in 1996. The D'Urville East (DURE) and Separation Point (SEPR) strata were surveyed only surveyed in 2004.

Stratum		1995	1996	2001	2004	1995	1996	2001	2004	1995	1996	2001	2004
		<30	<30	<30	<30	≥30	≥30	≥30	≥30	All	All	All	All
IQCH	Estimate (t)	4		57	3	10		69	4	14		126	7
	c.v %	22		25	31	20		28	34	19		23	26
OQCH	Estimate (t)	75		58	32	96		42	24	171		100	71
	c.v %	16		17	23	12		20	26	11		16	20
EQCH	Estimate (t)	15		24	17	57		27	32	72		50	60
	c.v %	16		16	20	16		23	25	14		15	18
IPEL	Estimate (t)		23	7	8		41	4	3		56	12	12
	c.v %		20	47	29		28	43	64		22	36	40
MPEL	Estimate (t)		84	23	7		130	12	11		170	35	23
	c.v %		17	29	27		14	33	46		12	27	32
OPEL	Estimate (t)	69	58	17	21	72	124	19	21	141	153	36	52
	c.v %	16	15	20	13	18	14	28	24	15	13	20	15
EOPE	Estimate (t)	50	30	22	22	84	88	35	66	135	118	57	109
	c.v %	16	20	15	18	14	13	18	12	12	12	14	10
DURE	Estimate (t)		95	139	46		430	177	146		462	316	243
	c.v %		18	14	12		11	11	10		11	10	9
DURW	Estimate (t)				14				64				93
	c.v %				12				10				8
SEPR	Estimate (t)				0				0				1
	c.v %				50				57				67
All	Estimate (t)	212	240	347	169	320	669	385	372	532	960	731	670
	c.v %	10	9	7	7	7	7	8	6	7	6	7	5

Appendix 2: Numbers of blue cod sampled for sexual maturity stage by sex and length class from the 2004 Marlborough sounds and Tasman Bay pot fishing survey.

Males							Females						
	Stage						Stage						
Length	1	2	3	4	5	Total	1	2	3	4	5	Total	
13	0	0	0	0	0	0	2	0	0	0	0	2	
14	1	0	0	0	0	1	6	0	1	0	0	7	
15	1	0	0	0	0	1	9	1	0	0	0	10	
16	1	0	0	1	0	2	6	3	0	0	0	9	
17	5	3	0	0	0	8	10	5	0	0	0	15	
18	7	5	0	0	0	12	10	9	1	0	0	20	
19	8	0	0	1	0	9	12	13	2	0	0	27	
20	3	7	2	8	0	20	4	18	4	1	0	27	
21	10	5	2	3	0	20	2	16	11	4	0	33	
22	11	10	5	11	0	37	2	31	14	3	0	50	
23	18	15	6	16	0	55	2	26	21	5	0	54	
24	14	21	14	20	0	69	4	19	37	4	0	64	
25	7	13	10	18	0	48	0	31	49	7	0	87	
26	5	17	13	30	0	65	4	30	73	11	0	118	
27	3	20	34	43	0	100	2	16	108	12	0	138	
28	8	28	43	61	0	140	1	24	121	19	1	166	
29	5	18	43	67	0	133	0	11	98	11	1	121	
30	3	26	59	76	0	164	0	10	76	19	0	105	
31	1	21	55	72	1	150	1	7	58	17	0	83	
32	2	12	35	62	0	111	0	4	31	10	0	45	
33	3	5	30	54	0	92	0	0	16	5	0	21	
34	1	6	22	33	0	62	0	1	7	4	0	12	
35	0	1	30	25	0	56	0	1	5	0	0	6	
36	0	1	12	26	0	39	0	0	1	0	0	1	
37	0	2	16	12	0	30	0	0	1	0	0	1	
38	0	0	7	5	0	12	0	0	1	0	0	1	
39	0	1	3	7	0	11	0	0	1	0	0	1	
40	0	1	8	2	0	11	0	0	0	0	0	0	
41	0	0	5	7	0	12	0	0	0	0	0	0	
42	0	0	2	2	0	4	0	0	0	0	0	0	
43	0	0	1	0	0	1	0	0	0	0	0	0	
44	0	0	3	1	0	4	0	0	0	0	0	0	
45	0	0	3	2	0	5	0	0	0	0	0	0	
46	0	0	1	1	0	2	0	0	0	0	0	0	
47	0	0	2	2	0	4	0	0	0	0	0	0	
48	0	0	0	0	0	0	0	0	0	0	0	0	
49	0	0	0	0	0	0	0	0	0	0	0	0	
50	0	0	0	1	0	1	0	0	0	0	0	0	
Total	117	238	466	669	1	1491	77	276	737	132	2	1224	
Percent	7.8	16.0	31.3	44.9	0.1		6.3	22.5	60.2	10.8	0.2		

Table 1: Summary of survey design analysis based on 1995-2001 survey data.

Stratum	Coastline length (n.miles)	No. of pot sets	Mean pot catch, m_i	Data		Optimal no. of sites		Random sites
				SD of site mean, s_i	No. of potential sites	Case 1 n_i	Case 2 n_i	
IQCH	20	72	0.79	0.58	8	3	3	E,C,G
OQCH	75.2	99	1.32	0.62	10	3	4	D,H,G,[A]
EQCH	30	81	2.65	1.4	8	3	4	G,H,C,[E]
IPEL	59.8	73	0.58	0.45	8	3	3	H,B,F
MPEL	62.8	81	1.44	0.78	8	3	5	D,B,A,[F,E]
OPEL	55.4	126	2.24	1.27	9	4	7	H,E,F,I,[D,C,A]
EOPE	40.8	119	2.92	1.13	8	3	4	H,G,A,[B]
DURE	52.4	90	9.22	2.57	13	8	12	H,E,M,I,A,L,J,C, [D,K,G,B]
Total						30	42	
Expected CV						7.70%	6.40%	

Table 2: Summary of sample design, showing final sampling strata, numbers of areas sampled per stratum, and the number, and type of stations sampled in each stratum in the 2004 Marlborough Sounds and Tasman Bay survey. Also shown are the number of blue cod sampled, the number biological samples collected, and the number of otolith samples collected per stratum.

Stratum	Description	No. areas sampled per stratum	No. stations sampled per stratum			All fish	Biological samples	Otolith samples
			All	Pots	Lines			
IQCH	Inner Queen Charlotte	4	44	36	8	39	24	23
OQCH	Outer Queen Charlotte	4	44	36	8	137	128	126
EQCH	Extreme Outer Queen Charlotte	4	44	36	8	242	207	154
IPEL	Inner Pelorus Sound	3	33	27	6	48	34	34
MPEL	Mid Pelorus Sound	5	55	45	10	97	77	76
OPEL	Outer Pelorus Sound	8	88	72	16	333	459	183
EOPE	Extreme Outer Pelorus	5	55	45	10	443	320	256
DURE	D'Urville Island east	12	132	108	24	1323	1236	275
DURW	D'Urville Island west	10	110	90	20	973	646	197
SEPR	Separation Point	10	110	90	20	10	9	9
	Survey total	65	715	585	130	3645	3140	1333

Table 3: Species caught, and total and percentage occurrence by weight at all stations from the 2004 Marlborough Sounds and Tasman Bay blue cod survey.

Common name	Code	Scientific name	Catch (kg)	Percent by weight	Numbers caught	Occurrence by station
Blue cod	BCO	<i>Parapercis colias</i>	1357	90	3645	472
Octopus	OCT	<i>Octopus cordiformis</i>	67	5	18	17
Conger eel	CON	<i>Conger verreauxi</i>	24	2	4	4
Leatherjacket	LEA	<i>Parika scaber</i>	10	1	49	40
Sea perch	SPE	<i>Helicolenus percoides</i>	9	1	26	22
Banded wrasse	BPF	<i>Notolabrus fucicola</i>	6	0	18	19
Red cod	RCO	<i>Pseudophycis bachus</i>	6	0	5	4
Tarakihi	TAR	<i>Nemadactylus macropterus</i>	5	0	22	16
Spiny dogfish	SPD	<i>Squalus acanthias</i>	5	0	1	1
Red mullet	RMU	<i>Upeneichthys lineatus</i>	2	0	4	4
Carpet shark	CAR	<i>Cephaloscyllium isabella</i>	2	0	3	3
Spotty	STY	<i>Notolabrus celidotus</i>	1	0	12	10
Hagfish	HAG	<i>Eptatretus cirrhatus</i>	1	0	5	4
Scarlet wrasse	SPF	<i>Pseudolabrus miles</i>	1	0	7	2
Triplefin	TRP	<i>Grahamaria</i> sp.	1	0	7	5
Total landings			1 497		3 826	

Table 4: Minimum and maximum length (cm) of the main fish species caught at all stations of the 2004 Marlborough Sounds and Tasman Bay blue cod survey. Length is fork length, except for red cod, where length is total length.

Scientific name	Length	Length
	min	max
<i>Parapercis colias</i>	13	50
<i>Parika scaber</i>	17	30
<i>Helicolenus percoides</i>	11	34
<i>Notolabrus fucicola</i>	13	37
<i>Pseudophycis bacchus</i>	41	53
<i>Nemadactylus macropterus</i>	20	31
<i>Notolabrus celidotus</i>	11	26

Table 5: Numbers and mean length of blue cod caught by stratum and area, and the numbers and mean length by method and stratum from the 2004 Marlborough Sounds and Tasman Bay blue cod survey (where C.I. = 2 x s.e).

Stratum	Area	Description	Number of blue cod				Mean length of blue cod					
			Males	Females	Unsexed	Total	Males	C.I	Females	CI *	Unsexed	C.I
IQCH		Inner Queen Charlotte										
	C	Luke Rock	7	8	0	15	30.00	3.46	27.50	3.04	0.00	0.00
	D	Bay of Many Coves	0	0	15	15	0.00	0.00	0.00	0.00	26.80	1.82
	E	Perano Shoal	0	1	0	1	0.00	0.00	19.00	0.00	0.00	0.00
	G	Ruakaka Bay	4	4	0	8	27.75	4.56	27.75	3.30	0.00	0.00
		Pots overall	11	13	15	39	29.18	2.70	26.92	2.24	26.80	1.82
		Lines overall	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
		Total	11	13	15	39	29.18	2.70	26.92	2.24	26.80	1.82
OQCH		Outer Queen Charlotte										
	A	Inner Tory Channel	10	4	0	14	26.50	3.22	20.50	4.78	0.00	0.00
	D	Pickersgill Island	18	44	7	69	26.27	2.22	24.88	1.12	24.46	3.00
	G	Outer Tory Channel	13	7	0	20	29.76	1.86	22.42	2.26	0.00	0.00
	H	Scott Point	13	18	3	34	24.53	2.54	23.77	1.80	28.66	6.56
		Pots overall	54	73	0	127	26.74	1.28	24.12	0.90	0.00	0.00
		Lines overall	0	0	10	10	0.00	0.00	0.00	0.00	26.00	2.90
		Total	54	73	10	137	26.74	1.28	24.14	0.90	26.00	2.90
EQCH		Extreme Outer Queen Charlotte										
	C	Cape Jackson	36	20	2	58	30.66	1.53	25.30	1.38	28.50	7.00
	D	Alligator Head	29	22	9	60	26.27	1.26	22.36	1.56	29.88	2.42
	E	Cape Lambert	52	25	9	86	30.82	1.58	25.04	1.28	30.33	3.66
	G	Taratara Bay	14	9	15	38	26.00	2.88	23.55	2.62	28.80	1.88
		Pots overall	131	76	0	207	29.25	0.94	24.15	0.81	0.00	0.00
		Lines overall	0	0	35	35	0.00	0.00	0.00	0.00	29.45	1.38
		Total	131	76	35	242	29.25	0.93	24.15	0.81	29.45	1.38
IPEL		Inner Pelorus Sound										
	B	Mary's Bay	9	7	9	25	26.66	3.64	20.14	3.78	31.33	3.34
	F	Stafford Point	9	7	5	21	26.77	3.10	22.42	2.94	28.40	1.84
	H	Grant Bay	0	2	0	2	0.00	0.00	27.50	5.00	0.00	0.00
		Pots overall	18	16	0	34	26.72	1.96	22.06	2.38	0.00	0.00
		Lines overall	0	0	14	14	0.00	0.00	0.00	0.00	30.28	2.32
		Total	18	16	14	48	26.72	1.96	22.06	2.38	30.28	2.32
MPEL		Mid Pelorus Sound										
	A	Kauauroa Bay	0	0	4	4	0.00	0.00	0.00	0.00	23.00	0.00
	B	Ram's Head	24	12	13	49	28.33	2.18	21.25	2.30	26.23	1.50
	D	Tapaapa Point	14	6	0	20	25.71	3.70	18.33	3.56	33.00	0.00
	E	Maud Island-West	6	9	2	17	25.66	4.82	18.77	2.48	26.00	12.00
	F	Cregoe Point	6	1	0	7	28.33	1.82	29.00	0.00	28.00	4.00
		Pots overall	50	28	0	78	27.28	1.60	20.10	1.64	0.00	0.00
		Lines overall	0	0	19	19	0.00	0.00	0.00	0.00	26.57	1.64
OPEL		Outer Pelorus Sound										
	A	The Reef	23	23	2	48	24.86	1.86	20.82	2.10	27.50	7.00
	C	Katira Point	39	12	0	51	27.51	1.12	23.50	2.14	0.00	0.00
	D	Duffers Reef	22	15	14	51	26.68	1.36	24.40	1.44	26.14	2.70
	E	Bulwer	2	3	3	8	26.50	7.00	24.66	3.70	15.33	1.76
	F	Camp Bay	25	17	9	51	24.8	1.74	21.64	2.34	26.66	2.08
	G	Te Akaroa	28	8	1	37	30.25	1.50	20.62	2.42	13.00	0.00
	H	Ketu Bay	23	10	1	34	29.61	2.32	23.20	3.02	33.00	0.00
	I	Trebletree Point	34	6	13	53	27.20	1.14	21.00	4.00	29.69	1.54
		Pots overall	187	92	5	284	27.22	0.64	22.25	0.92	20.00	10.58
		Lines overall	9	2	38	49	29.55	2.94	22.50	3.00	27.10	1.18
		Total	196	94	43	333	27.33	0.62	22.25	0.92	26.27	1.68

Table 5: – continued.

Stratum	Area	Description	Number of blue cod				Mean length of blue cod					
			Males	Females	Unsexed	Total	Males	C.I	Females	CI *	Unsexed	C.I
EOPE		Extreme Outer Pelorus										
	A	Forsyth Island	43	18	18	79	29.18	0.12	25.15	2.30	27.05	1.62
	B	Chetwode Island	27	15	60	102	27.03	1.60	23.46	2.44	28.26	0.88
	C	Clay Point	41	21	1	63	28.34	1.22	27.04	2.50	15.00	0.00
	G	Te Kakaho	40	34	35	109	29.60	1.50	26.64	1.50	28.37	0.58
	H	Sentinel Rock	66	20	9	95	30.75	1.02	26.30	1.26	28.44	2.58
		Pots overall	209	103	53	365	29.34	0.61	26.01	0.88	28.07	1.07
		Lines overall	8	0	70	78	28.50	1.15	0.00	0.00	27.98	1.12
		Total	217	103	123	443	29.31	0.58	26.01	0.88	28.02	0.78
DURE		D'Urville Island east										
	A	Rangitoto Island	75	81	0	156	32.81	0.92	28.92	0.28	0.00	0.00
	B	West Trios Islands	102	106	0	208	31.54	0.72	27.70	0.40	0.00	0.00
	C	East Trios Islands	92	91	0	183	32.54	0.92	27.47	0.32	0.00	0.00
	D	Penguin Bay	39	45	1	85	28.13	1.02	26.33	0.80	20.00	0.00
	E	Whangapoto Point	30	15	0	45	26.33	1.62	27.33	2.18	0.00	0.00
	G	Clayface Point	43	26	0	69	30.30	1.04	26.27	1.72	0.00	0.00
	H	French Pass	30	30	0	60	31.43	1.00	27.96	1.84	0.00	0.00
	I	Anatakapu Island	29	14	0	43	29.10	1.54	27.28	1.60	0.00	0.00
	J	Rangitoto Roadstead	54	49	0	103	32.70	1.26	28.81	0.90	0.00	0.00
	K	Rangitoto North	94	43	1	138	30.87	1.06	28.51	0.70	28.00	0.00
	L	Bonne Point	86	71	0	157	28.47	0.88	25.64	0.62	0.00	0.00
	M	Catherine Cove	41	33	1	75	30.00	1.54	28.72	1.14	28.00	0.00
		Pots overall	643	559	1	1203	30.86	3.62	27.68	0.22	28.00	0.00
		Lines overall	81	37	2	120	29.98	0.84	26.75	0.82	24.00	8.00
		Total	724	596	3	1323	30.76	0.34	27.62	0.22	25.33	5.32
DURW		D'Urville Island west										
	A	Victory Island	72	79	12	163	31.70	1.02	29.40	0.56	29.25	1.62
	B	Nile Head	13	13	49	75	28.84	2.04	27.07	1.20	32.55	1.20
	C	Bottle Point	18	25	48	91	29.11	1.85	26.64	1.26	29.16	1.34
	D	Ragged Point	28	15	80	123	29.32	1.20	28.40	1.48	31.12	0.78
	E	Sandy Bay	16	41	53	110	32.81	2.02	29.87	1.26	30.43	0.60
	F	Okarewa Point	48	84	0	132	30.95	1.46	30.00	0.68	0.00	0.00
	G	Paddock Rocks	21	33	0	54	30.00	1.40	26.18	1.16	0.00	0.00
	H	Beef Barrels	36	42	0	78	30.75	1.94	26.85	1.44	0.00	0.00
	I	Sauvage Point	46	43	0	89	30.23	0.92	25.88	1.08	0.00	0.00
	J	Cemetery Island	18	19	0	37	29.00	1.44	27.63	1.71	0.00	0.00
		Pots overall	292	354	195	841	30.56	0.54	28.19	0.38	30.94	0.52
		Lines overall	31	54	47	132	30.77	1.62	29.07	1.00	30.12	1.22
		Total	323	408	242	973	30.58	0.51	28.30	0.36	30.78	0.48
SEPR		Separation Point										
	A	Totaranui	0	1	0	1	0.00	0.00	33.00	0.00	0.00	0.00
	B	Gibbs Hill	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
	C	Mutton Point	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
	D	Mutton Cove	2	0	0	2	26.50	0.00	0.00	0.00	0.00	0.00
	E	Separation Point A	1	1	0	2	28.00	0.00	25.00	0.00	0.00	0.00
	F	Separation Point B	4	0	0	4	30.50	7.00	0.00	0.00	0.00	0.00
	G	Whariwharangi Bay	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
	H	Taupo Point	1	0	0	1	19.00	0.00	0.00	0.00	0.00	0.00
	I	Abel Tasman point	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
	J	Tata Islands	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
		Pots overall	8	2	0	10	27.75	5.34	29.00	8.00	0.00	0.00
		Lines overall	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
		Total	8	2	0	10	27.75	5.34	29.00	8.00	0.00	0.00

Table 6: Survey mean catch rate (kg/hour) and standard error (SE), mean weighted CPUE (kg/hour), and coefficient of variation (% CV), overall, and by stratum, for the pot fishing stations of the 2004 Marlborough Sounds and Tasman Bay blue cod surveys. Results are given for (a) all blue cod, and (b) those recruited to the fishery (≥ 30 cm).

Stratum	Coastline (km)	Weighting	Survey mean		Weighted mean (kg/hour)	% C.V.	
			(kg/hour)	SE		Stratum	Overall
(a) All blue cod							
IQCH	20	0.05	0.37	0.09	0.02	24.32	
OQCH	75.2	0.17	0.94	0.18	0.16	19.15	
EQCH	30	0.07	2.04	0.34	0.14	16.67	
IPEL	59.8	0.14	0.32	0.10	0.04	31.25	
MPEL	62.8	0.14	0.48	0.14	0.07	29.17	
OPEL	55.4	0.13	1.12	0.17	0.14	15.18	
EOPE	40.8	0.09	3.03	0.30	0.28	9.90	
DURE	52.4	0.12	4.68	0.42	0.56	8.97	
DURW	24.9	0.06	4.03	0.34	0.23	8.44	
SEPR	16.6	0.04	0.03	0.10	0.01	333.33	
Overall	437.9	1.00	1.70	0.22	1.64	4.81	5%
(b) Recruited blue cod (≥ 30 cm)							
IQCH	20	0.05	0.21	0.06	0.01	28.44	
OQCH	75.2	0.17	0.33	0.08	0.06	24.46	
EQCH	30	0.07	1.10	0.25	0.08	22.79	
		0.29					
IPEL	59.8	0.14	0.09	0.05	0.01	56.18	
MPEL	62.8	0.14	0.22	0.09	0.03	40.72	
OPEL	55.4	0.13	0.47	0.11	0.06	23.26	
EOPE	40.8	0.09	1.84	0.21	0.17	11.41	
DURE	52.4	0.12	2.83	0.28	0.33	9.88	
DURW	24.9	0.06	2.80	0.29	0.16	10.36	
SEPR	16.6	0.04	0.01	0.01	0.01	76.92	
Overall	437.9	1.00	0.99	0.14	0.91	5.65	7%

Table 7: Analysis of trends in recruited (≥ 30 cm) blue cod CPUE (log(kg+0.001)/hour) for pot fishing stations from the Queen Charlotte Sound strata of the 1995, 1996, 2001, and 2004 Marlborough Sounds and Tasman Bay blue cod surveys, where (a) describes results from Analysis of Variance (ANOVA), and (b) describes results from the Multiple Range (Ryan-Einot-Gabriel-Welsch (REGWQ)) test. Stratum definitions are provided in the text.

(a) ANOVA

Class	Levels	Values
Year	3	1995 2001 2004
Stratum	3	IQCH OQCH EQCH
N		360

Source	D.F.	SS	MS	F	Pr>F
Model	8	2230.27	278.77	6.35	<0.0001
Error	351	15399.31	43.87		
Total	359	17629.68			

Year	2	401.80	200.90	4.58	0.0109
Stratum	2	1554.08	777.04	17.71	<0.0001
Year*Stratum	4	274.39	68.59	1.56	0.1835

(b) REGWQ

Years, or strata grouped with the same letter are not significantly different

Variable	Level	Grouping	Relative level	N
Year	1995	A	1.55	108
	2001	B	-0.59	144
	2004	B	-0.93	108

Variable	Level	Grouping	Relative level	N
Stratum	EQCH	A	2.18	117
	OQCH	B	0.33	135
	IQCH	C	-2.95	108

Table 8: Analysis of trends in recruited (≥ 30 cm) blue cod CPUE (kg/hour) for pot fishing stations from the Pelorus Sound and D'Urville east strata of the 1995, 1996, 2001, and 2004 Marlborough Sounds and Tasman Bay blue cod surveys. Results are given from Analysis of Variance (ANOVA) only, as the significant year*stratum interaction term precluded further analysis. Stratum definitions are provided in the text.

ANOVA

Class	Levels	Values
Year	3	1996 2001 2004
Stratum	5	IPEL MPEL OPEL EOPE DURE
N		720

Source	D.F.	SS	MS	F	Pr>F
Model	14	12868.92	919.21	26.76	<0.0001
Error	705	24218.62	34.35		
Total	719	37087.55			

Year	2	2369.68	1184.84	34.49	<0.0001
Stratum	4	8827.84	2206.96	64.24	<0.0001
Year*Stratum	8	1034.72	129.34	3.77	<0.0002

Table 9: Analysis of trends in pre-recruit (< 30 cm) blue cod CPUE (log(kg+0.001)/hour) for pot fishing stations from the Queen Charlotte Sound strata of the 1995, 1996, 2001, and 2004 Marlborough Sounds and Tasman Bay blue cod surveys, where (a) describes results from Analysis of Variance (ANOVA), and (b) describes results from the Multiple Range (Ryan-Einot-Gabriel-Welsch (REGWQ)) test. Stratum definitions are provided in the text.

(a) ANOVA

Class	Levels	Values			
Year	3	1995	2001	2004	
Stratum	3	1	2	3	
N		360			

Source	D.F.	SS	MS	F	Pr> F
Model	8	2244.05	280.50	7.48	<0.0001
Error	351	13155.16	37.49		
Total	359	15399.21			

Year	2	50.33	25.16	0.67	0.511
Stratum	2	2109.34	1054.67	28.14	<0.0001
Year*Stratum	4	84.38	21.09	0.56	0.68

(b) REGWQ

Years, or strata grouped with the same letter are not significantly different

Variable	Level	Grouping	Relative level	N
Year	2001	A	1.69	144
	2004	A	1.22	108
	1995	B	0.79	108

Stratum	Level	Grouping	Relative level	N
EQCH	EQCH	A	3.62	117
	OQCH	A	2.13	135
	IQCH	B	-2.31	108

Table 10: Analysis of trends in pre-recruit (< 30 cm) blue cod CPUE (log(kg+0.001)/hour) for pot fishing stations from the Pelorus Sound and D'Urville east strata of the 1995, 1996, 2001, and 2004 Marlborough Sounds and Tasman Bay blue cod surveys. Results are given from Analysis of Variance (ANOVA) only, as the significant year*stratum interaction term precluded further analysis. Stratum definitions are provided in the text.

ANOVA

Class	Levels	Values			
Year	3	1996	2001	2004	
Stratum	5	IPEL	MPEL	OPEL	EOPE DURE
N		720			

Source	D.F.	SS	MS	F	Pr> F
Model	16	6784.03	424.00	13.46	<0.0001
Error	775	24411.58	31.99		
Total	791	31195.60			

Year	8	902.65	300.88	9.55	<0.0001
Stratum	4	4031.18	1007.79	31.99	<0.0001
Year*Stratum	9	1850.20	205.57	6.53	<0.0001

Table 11: Analysis of trends in sub-recruit (17–27 cm) blue cod CPUE (log(kg+0.001)/hour) for pot fishing stations from the Queen Charlotte Sound strata of the 1995, 1996, 2001, and 2004 Marlborough Sounds and Tasman Bay blue cod surveys, where (a) describes results from Analysis of Variance (ANOVA), and (b) describes results from the Multiple Range (Ryan-Einot-Gabriel-Welsch (REGWQ)) test. Stratum definitions are provided in the text.

(a) ANOVA

Class	Levels	Values			
Year	3	1995	2001	2004	
Stratum	3	1	2	3	
N		360			

Source	D.F.	SS	MS	F	Pr> F
Model	8	514.23	64.28	7.45	<0.0001
Error	351	3026.63	8.62		
Total	359	3540.87			
Year	2	80.65	40.32	4.68	0.0099
Stratum	2	414.93	207.46	24.06	<0.0001
Year*Stratum	4	18.65	4.66	0.54	0.7058

(b) REGWQ

Years, or strata grouped with the same letter are not significantly different

Variable	Level	Grouping	Relative level	N
Year	2001	A	-3.36	144
	2004	A	-3.45	108
	1995	B	-4.43	108

Stratum	Level	Grouping	Relative level	N
EQCH	EQCH	A	-2.81	117
	OQCH	A	-3.16	135
	IQCH	B	-5.36	108

Table 12: Analysis of trends in sub-recruit (17–27 cm) blue cod CPUE (log(kg+0.001)/hour) for pot fishing stations from the Pelorus Sound and D'Urville east strata of the 1995, 1996, 2001, and 2004 Marlborough Sounds and Tasman Bay blue cod surveys. Results are given from Analysis of Variance (ANOVA) only, as the significant year*stratum interaction term precluded further analysis. Stratum definitions are provided in the text.

ANOVA

Class	Levels	Values			
Year	3	1996	2001	2004	
Stratum	5	IPEL	MPEL	OPEL	EOPE DURE
N		720			

Source	D.F.	SS	MS	F	Pr> F
Model	14	1288.01	87.71	10.22	<0.0001
Error	705	6051.21	8.58		
Total	719	7279.22			
Year	2	59.46	29.73	3.46	0.0318
Stratum	4	716.48	179.12	20.87	<0.0001
Year*Stratum	8	452.06	56.50	6.58	<0.0001

Table 13: Sex ratios of blue cod and percentage of males (excluding unsexed fish), by stratum and length class, for the 2004 Marlborough Sounds and Tasman Bay blue cod potting survey. Also shown are data for the 30 cm and 35 cm length classes as used in the 1995 and 1996 potting surveys.

* Length classes based on 30 cm and 35 cm length classes, as used in the 1995–96 surveys

* Percentage males excludes unsexed fish

Stratum	Length (cm)	Sexed fish			%	Unsexed fish	All fish
		Males	Females	Total	male		
IQCH	< 18 cm	0	0	0	0	0	0
	19–30 cm	11	10	21	52	12	33
	31–35 cm	0	3	3	0	3	6
	>35 cm	0	0	0	0	0	0
	Total	11	13	24	46	15	39
OQCH	< 18 cm	4	4	8	50	0	8
	19–30 cm	36	64	100	36	8	108
	31–35 cm	13	5	18	72	2	20
	>35 cm	1	0	1	100	0	1
	Total	54	73	127	43	10	137
EQCH	< 18 cm	2	7	9	22	0	9
	19–30 cm	83	69	152	55	21	173
	31–35 cm	33	0	33	100	12	45
	>35 cm	13	0	13	100	2	15
	Total	131	76	207	63	35	242
IPEL	< 18 cm	2	5	7	29	0	7
	19–30 cm	13	11	24	54	8	32
	31–35 cm	3	0	3	100	4	7
	>35 cm	0	0	0	0	2	2
	Total	18	16	34	53	14	48
MPEL	< 18 cm	4	12	16	25	0	16
	19–30 cm	33	16	49	67	16	65
	31–35 cm	12	0	12	100	3	15
	>35 cm	1	0	1	100	0	1
	Total	50	28	78	64	19	97

Table 13: – *continued*

Stratum	Length (cm)	Sexed fish			%	Unsexed fish	All fish
		Males	Females	Total	male		
OPEL	< 18 cm	4	21	25	16	4	29
	19–30 cm	142	71	213	67	30	243
	31–35 cm	44	2	46	96	8	54
	>35 cm	6	0	6	100	1	7
	Total	196	94	290	68	43	333
EOPE	< 18 cm	3	6	9	33	1	10
	19–30 cm	137	79	216	63	94	310
	31–35 cm	61	17	78	78	23	101
	>35 cm	16	1	17	94	5	22
	Total	217	103	320	68	123	443
DURE	< 18 cm	2	2	4	50	0	4
	19–30 cm	359	514	873	41	3	876
	31–35 cm	265	78	343	77	0	343
	>35 cm	98	2	100	98	0	100
	Total	724	596	1320	55	3	1323
DURW	< 18 cm	3	6	9	33	0	9
	19–30 cm	153	286	439	35	121	560
	31–35 cm	134	112	246	54	98	344
	>35 cm	33	4	37	89	23	60
	Total	323	408	731	44	242	973
SEPR	< 18 cm	0	0	0	0	0	0
	19–30 cm	5	1	6	83	0	6
	31–35 cm	3	1	4	75	0	4
	>35 cm	0	0	0	0	0	0
	Total	8	2	10	80	0	10

Table 14: Numbers of blue cod taken, numbers tagged, numbers recovered, and percentage recovery, by stratum and survey method, from the 2004 Marlborough sounds and Tasman Bay pot fishing survey.

Method	Pots				Lines				Overall			
	No. fish caught	No. fish tagged	Fish recaptured		No. fish caught	No. fish tagged	Fish recaptured		No. fish caught	No. fish tagged	Fish recaptured	
			No.	%			No.	%			No.	%
Stratum												
IQCH	39	15	2	13.3	0	0	0		39	15	2	13.3
OQCH	127	0	0		10	10	2	20.0	137	10	2	20.0
EQCH	207	1	0		35	35	6	17.1	242	36	6	16.7
IPEL	34	0	0		14	14	3	21.4	48	14	3	21.4
MPEL	78	0	0		19	19	5	26.3	97	19	5	26.3
OPEL	284	28	2	7.1	49	49	9	18.4	333	77	11	14.3
EOPE	365	53	5	9.4	78	78	8	10.3	443	131	13	9.9
DURE	1203	165	23	13.9	120	89	12	13.5	1323	254	35	13.8
DURW	841	275	30	10.9	132	131	6	4.6	973	406	36	8.9
SEPR	10	0	0		0	0	0	0.0	10	0	0	0.0
Total	3188	537	62	11.5	457	425	51	12.0	3645	962	113	11.7

Table 15: Distance (nautical miles) between release and recapture positions for blue cod released during the September - October 2004 Marlborough Sounds and Tasman Bay blue cod pot survey, recovered to 20 May 2006.

Distance	Number	Percentage
< 1.0	84	74
1.0-9.9	25	22
10.0-14.9	3	3
15.0-19.9	0	0
20.0-24.9	0	0
25.0 +	2	2
	114	100

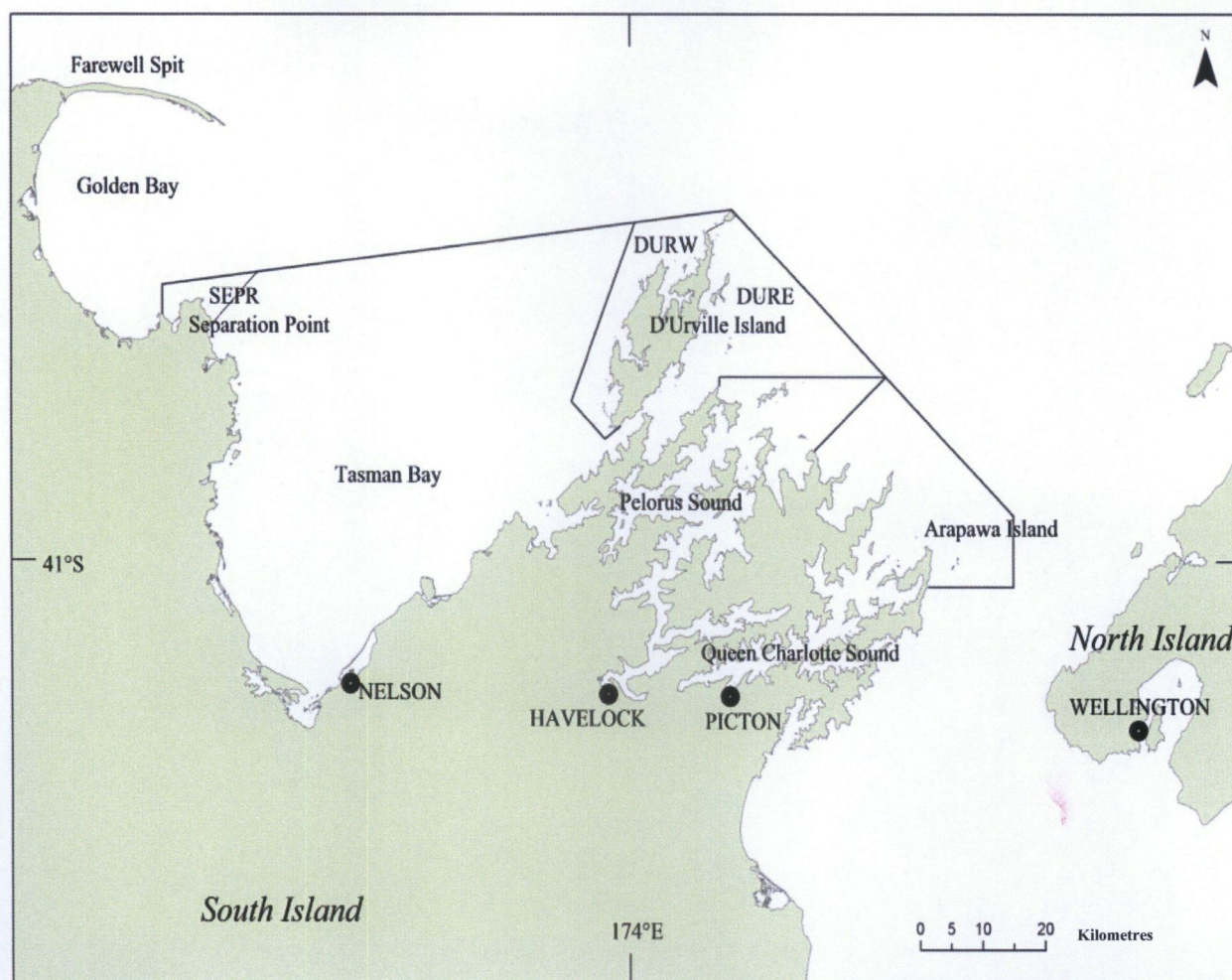


Figure 1: Survey area of the 2004 Marlborough Sounds and Tasman Bay blue cod potting survey by region: Marlborough Sounds, Tasman Bay. Also shown are the two strata sampled in the Tasman Bay region: DURW (D'Urville Island west), and SEPR (Separation Point). Sub-regions and strata within the Marlborough Sounds region are given in Figure 2. The stratum DURE within the Marlborough Sounds region is the same as the DURV stratum previously defined for the 2001 survey (Blackwell 2002).

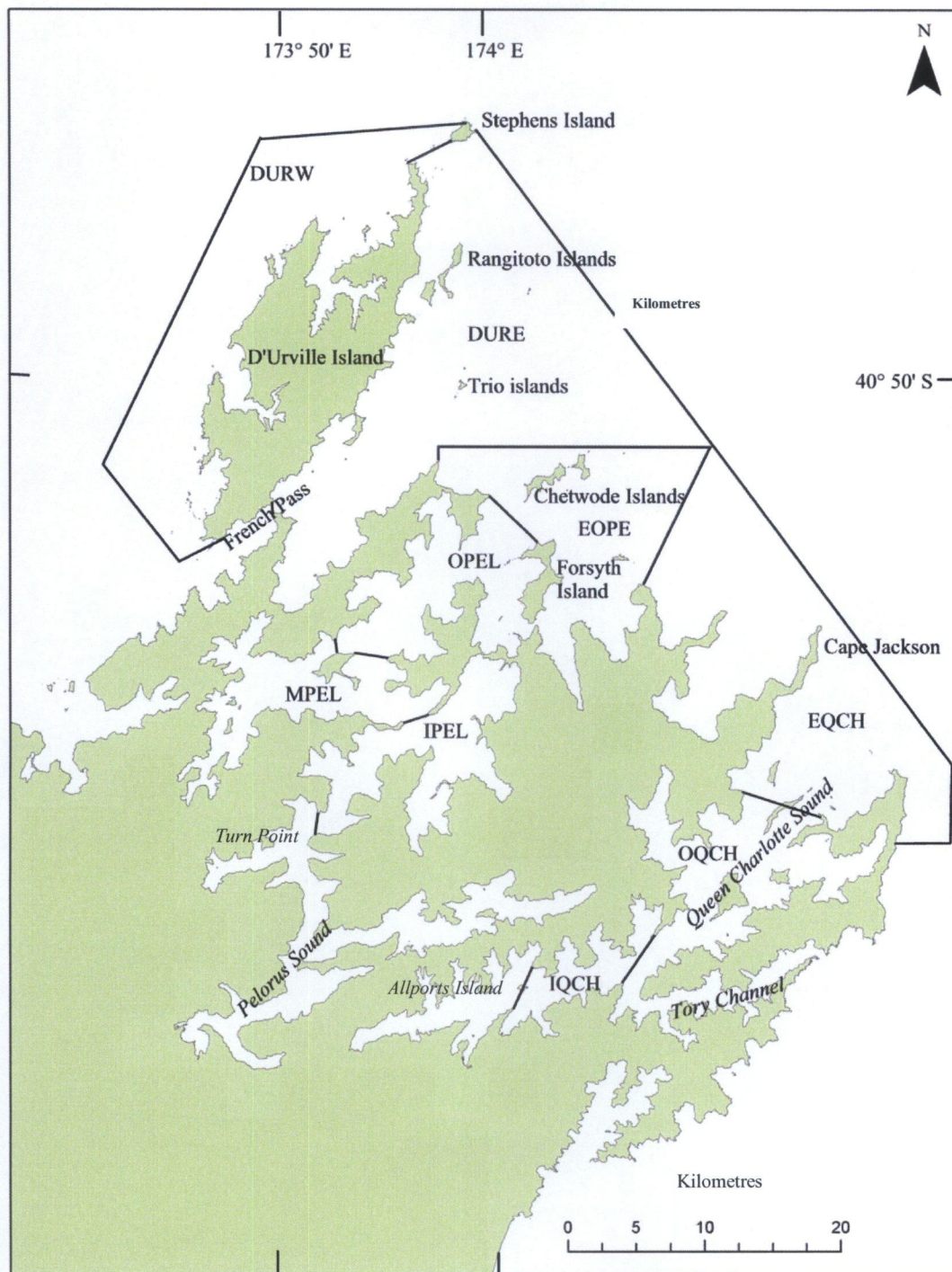


Figure 2: Strata surveyed in the Marlborough Sounds region of the 2004 Marlborough Sounds and Tasman Bay blue cod potting survey, by sub-region: Queen Charlotte Sound, Pelorus Sound, D'Urville Island east. Within the Queen Charlotte Sound sub region, strata comprised IQCH (Inner Queen Charlotte), OQCH (Outer Queen Charlotte), EQCH (Extreme Outer Queen Charlotte). Within the Pelorus Sound sub region, strata comprised IPEL (Inner Pelorus), MPEL (Mid Pelorus), OPEL (Outer Pelorus), EOPE (Extreme Outer Pelorus), and DURE (D'Urville Island east). The strata of the Tasman Bay region of the 2004 survey are shown in Figure 1.

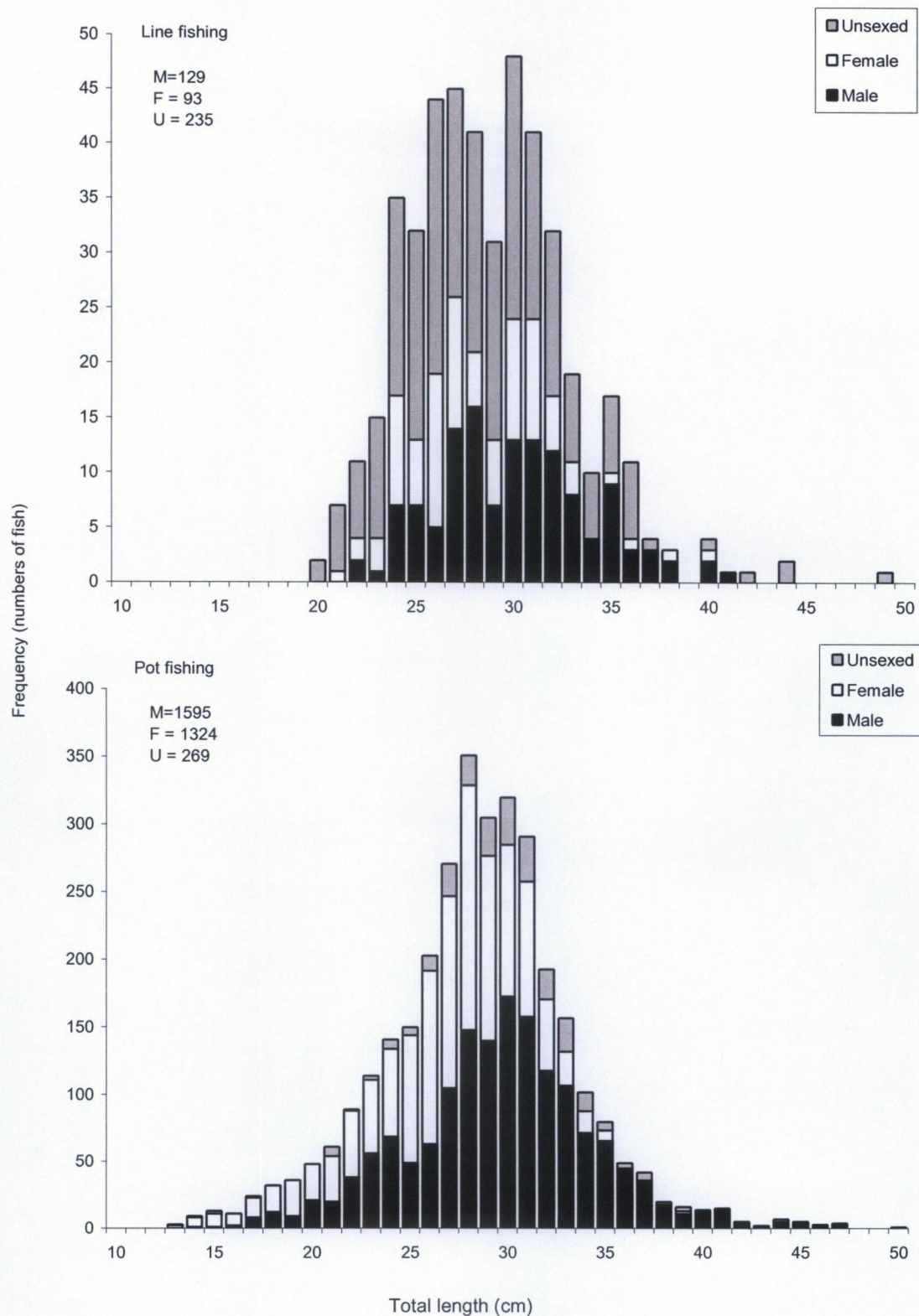


Figure 3: Length frequency distribution of blue cod from the 2004 Marlborough Sounds and Tasman Bay survey, by fishing method. The frequency of male and female blue cod are actual numbers measured. Unsexed fish represent fish tagged and released where sex was not able to be determined by external visual examination.

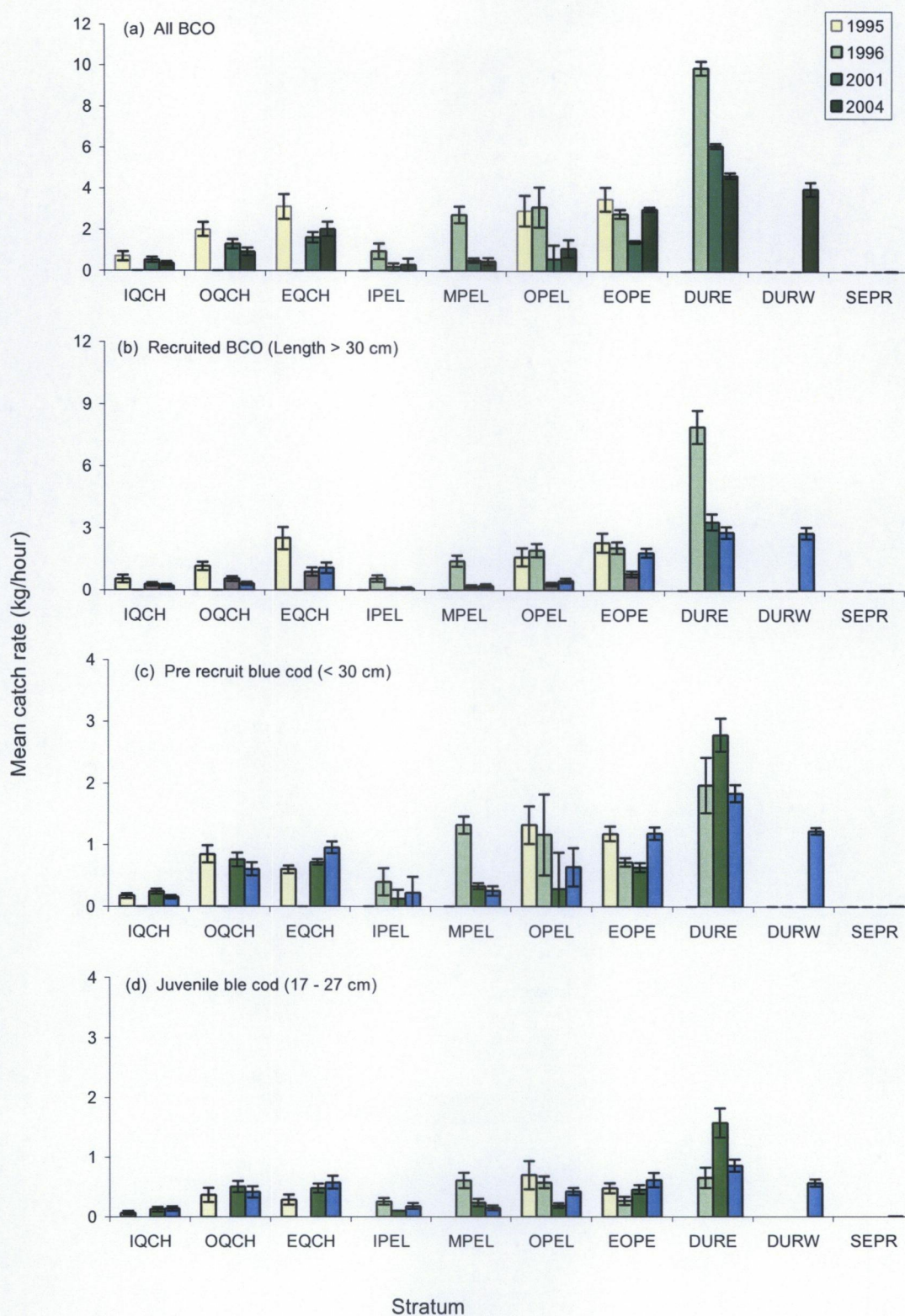


Figure 4: Mean catch rate (kg/hour) for (a) all blue cod, (b) recruited blue cod (length ≥ 30 cm), (c) pre-recruit blue cod (length < 30 cm), and (d) juvenile blue cod (length 17-27 cm), from the pot fishing stations of the 2004, 2001, 1996, and 1995 Marlborough Sounds and Tasman Bay blue cod pot surveys. Stratum codes are defined in the text. Strata IPEL, MPEL, and DURE were not surveyed in 1995, IQCH, OQCH, and EQCH were not surveyed in 1996, and DURE and SEPR were surveyed only in 2004. Error bars represent 1 x s.e.

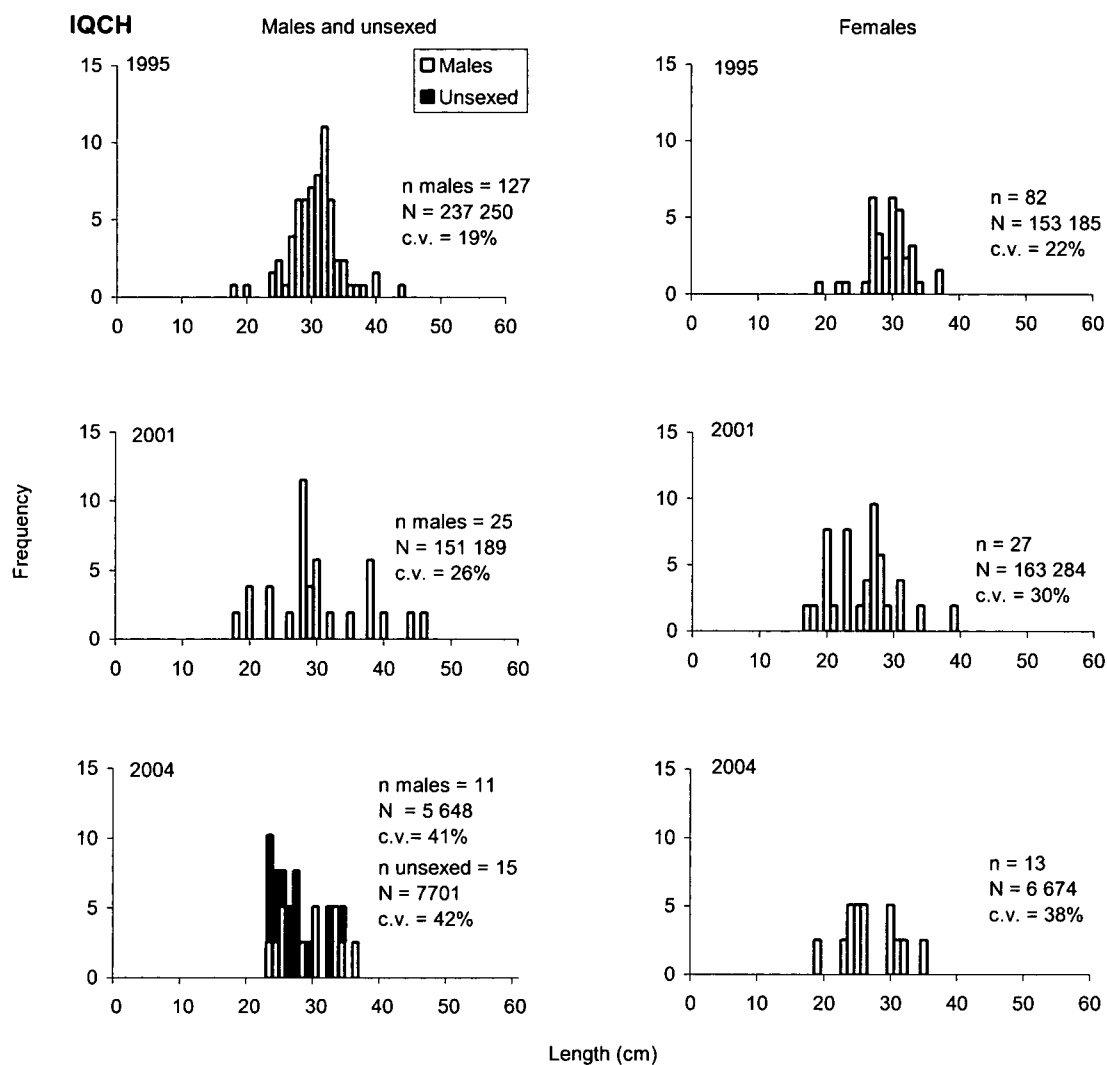


Figure 5: Scaled length frequency distributions of male, female, and unsexed blue cod from the IQCH stratum of the 1995, 2001, and 2004 Marlborough Sounds and Tasman Bay pot fishing surveys. n, numbers of fish measured, N, estimated numbers of fish scaled by stratum area, c.v., coefficient of variation of the survey estimate. Unsexed fish are shown as black bars. Mean lengths are given in Table 5.

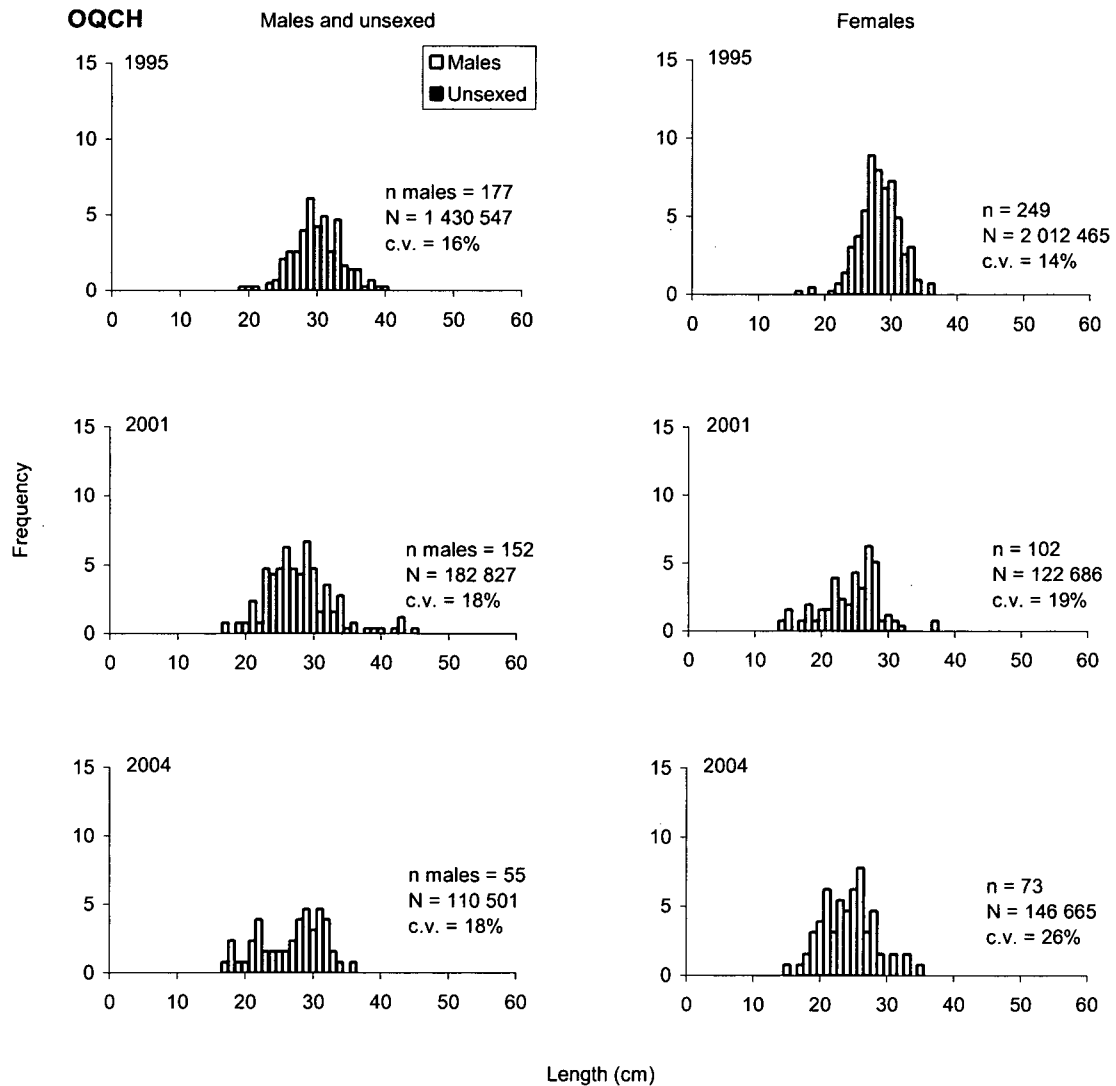


Figure 5: – *continued*. Scaled length frequency distributions of male, female, and unsexed blue cod from the OQCH stratum of the 1995, 2001, and 2004 Marlborough Sounds and Tasman Bay pot fishing surveys. n, numbers of fish measured, N, estimated numbers of fish scaled by stratum area, c.v., coefficient of variation of the survey estimate. Unsexed fish are shown as black bars. Mean lengths are given in Table 5.

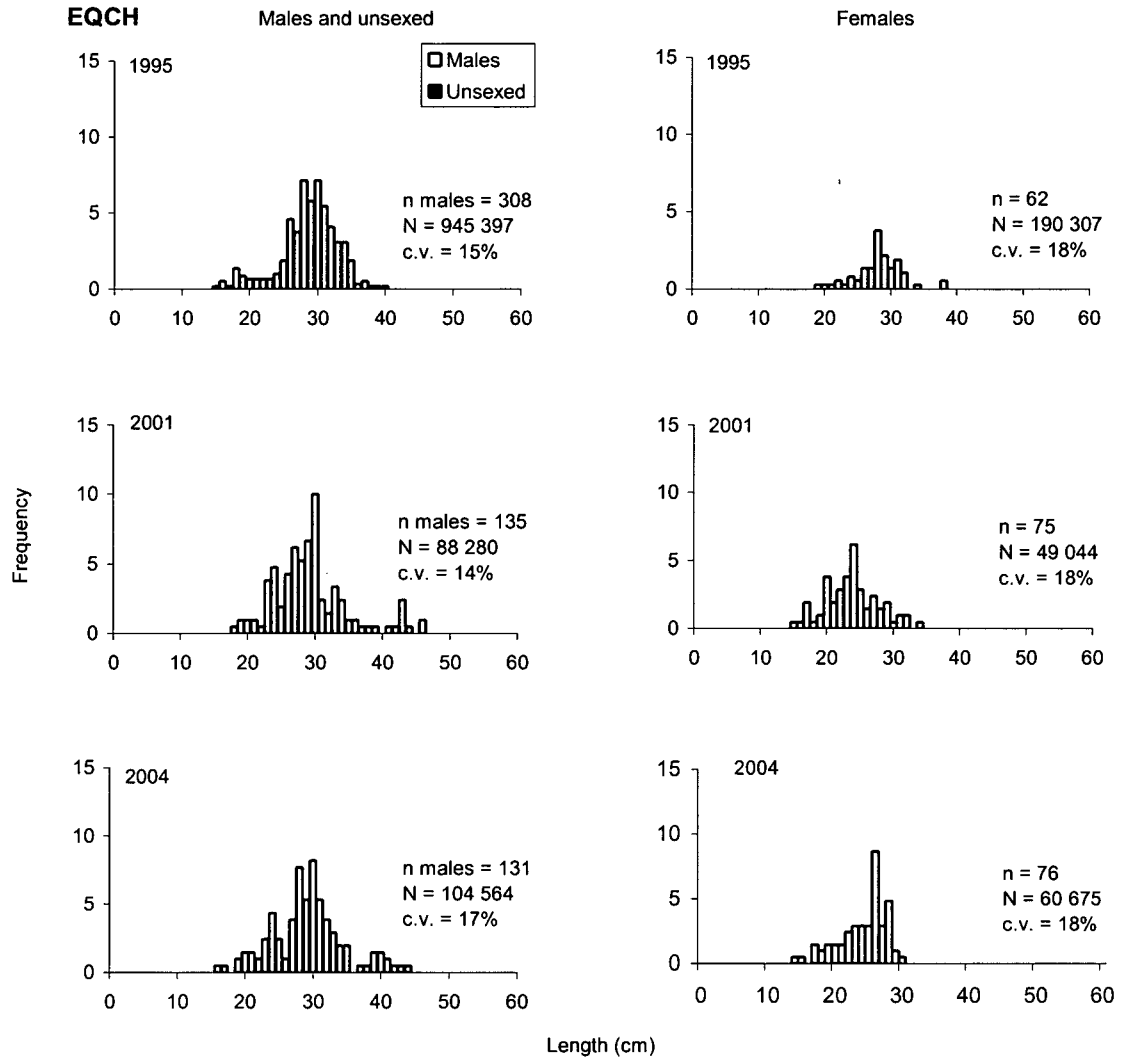


Figure 5: – continued. Scaled length frequency distributions of male, female, and unsexed blue cod from the EQCH stratum of the 1995, 2001, and 2004 Marlborough Sounds and Tasman Bay pot fishing surveys. n, numbers of fish measured, N, estimated numbers of fish scaled by stratum area, c.v., coefficient of variation of the survey estimate. Unsexed fish are shown as black bars. Mean lengths are given in Table 5.

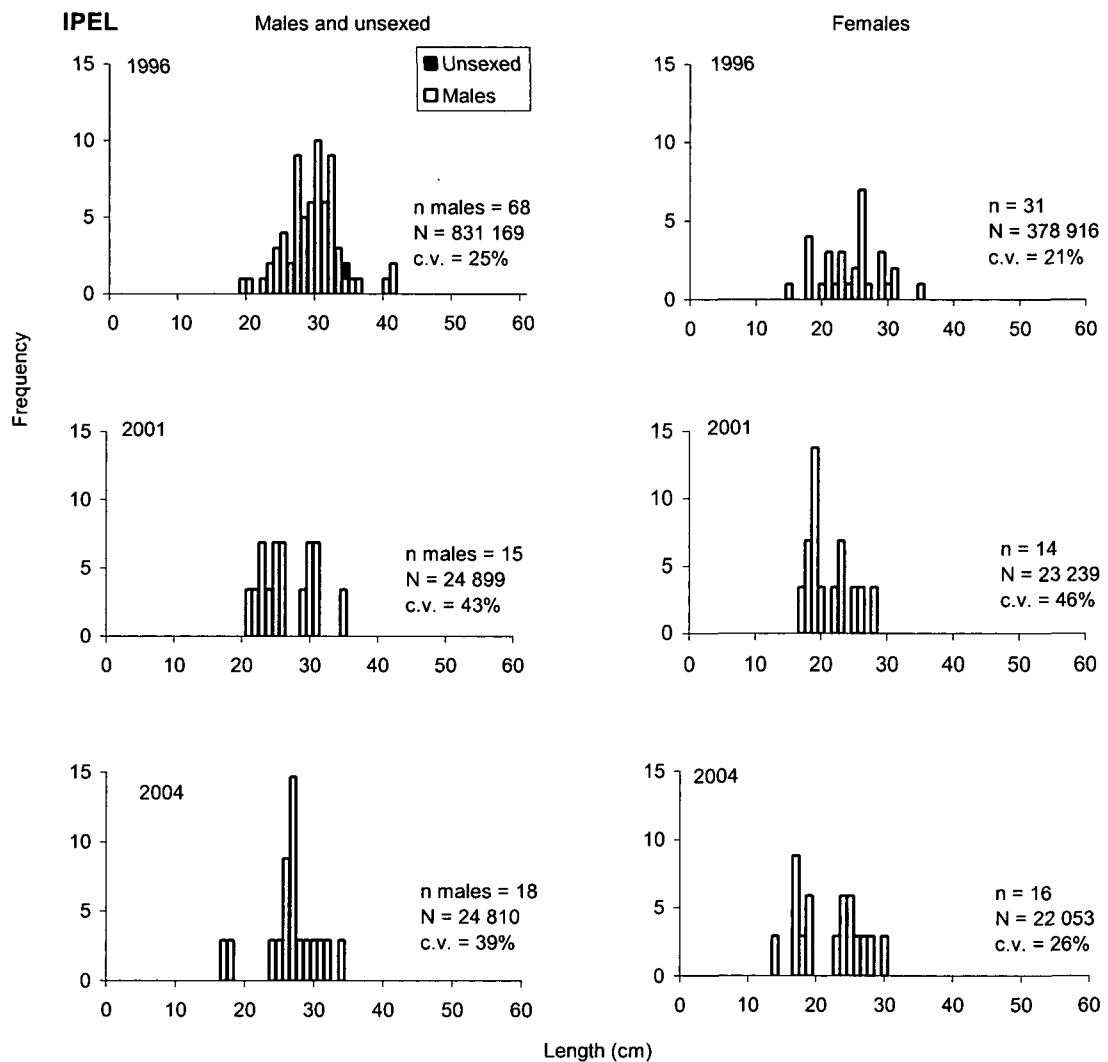


Figure 5: – continued. Scaled length frequency distributions of male, female, and unsexed blue cod from the IPEL stratum of the 1996, 2001, and 2004 Marlborough Sounds and Tasman Bay pot fishing surveys. n, numbers of fish measured, N, estimated numbers of fish scaled by stratum area, c.v., coefficient of variation of the survey estimate. Unsexed fish are shown as black bars. Mean lengths are given in Table 5.

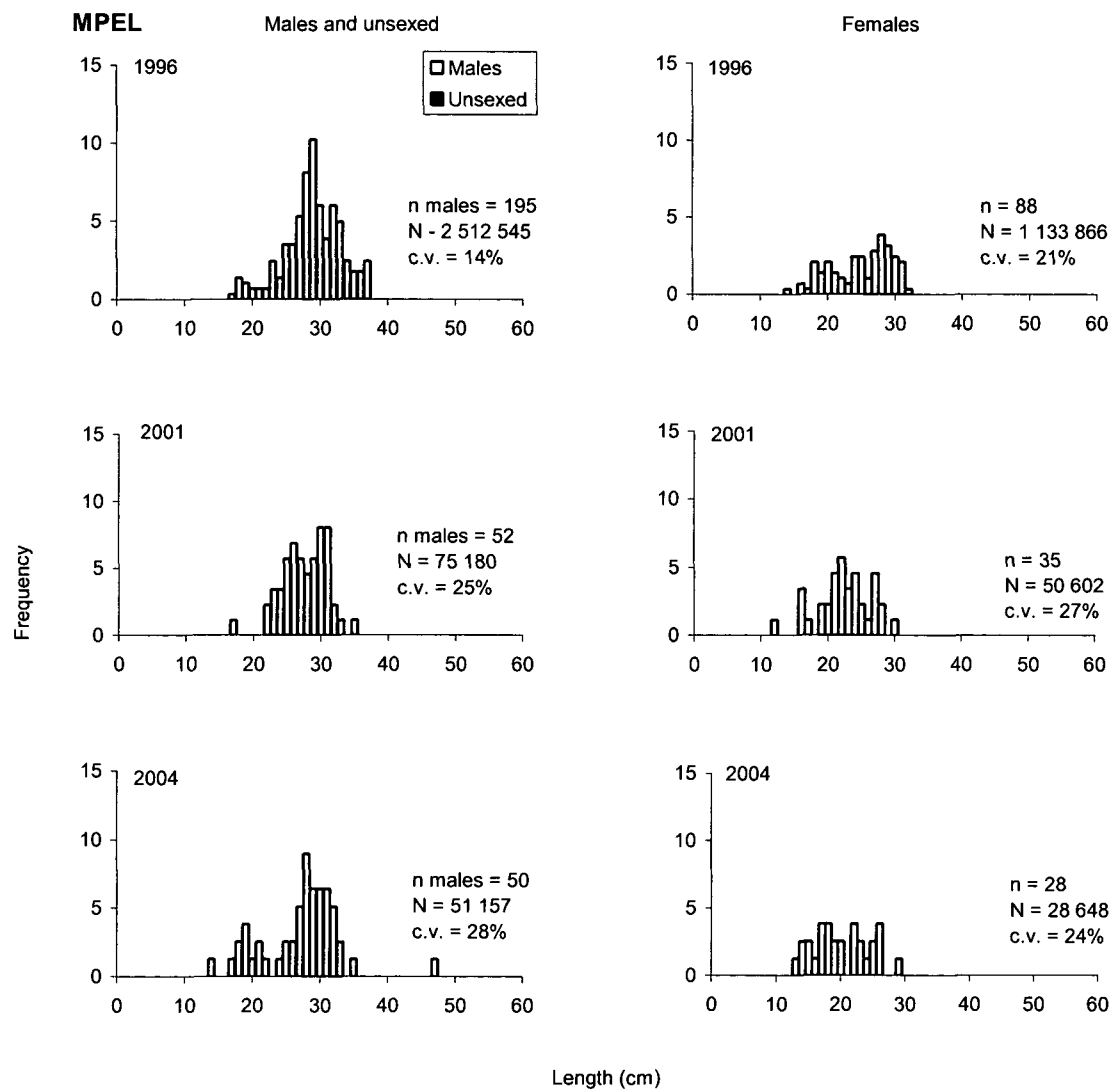


Figure 5: – continued. Scaled length frequency distributions of male, female, and unsexed blue cod from the MPEL stratum of the 1996, 2001, and 2004 Marlborough Sounds and Tasman Bay pot fishing surveys. n, numbers of fish measured, N, estimated numbers of fish scaled by stratum area, c.v., coefficient of variation of the survey estimate. Unsexed fish are shown as black bars. Mean lengths are given in Table 5.

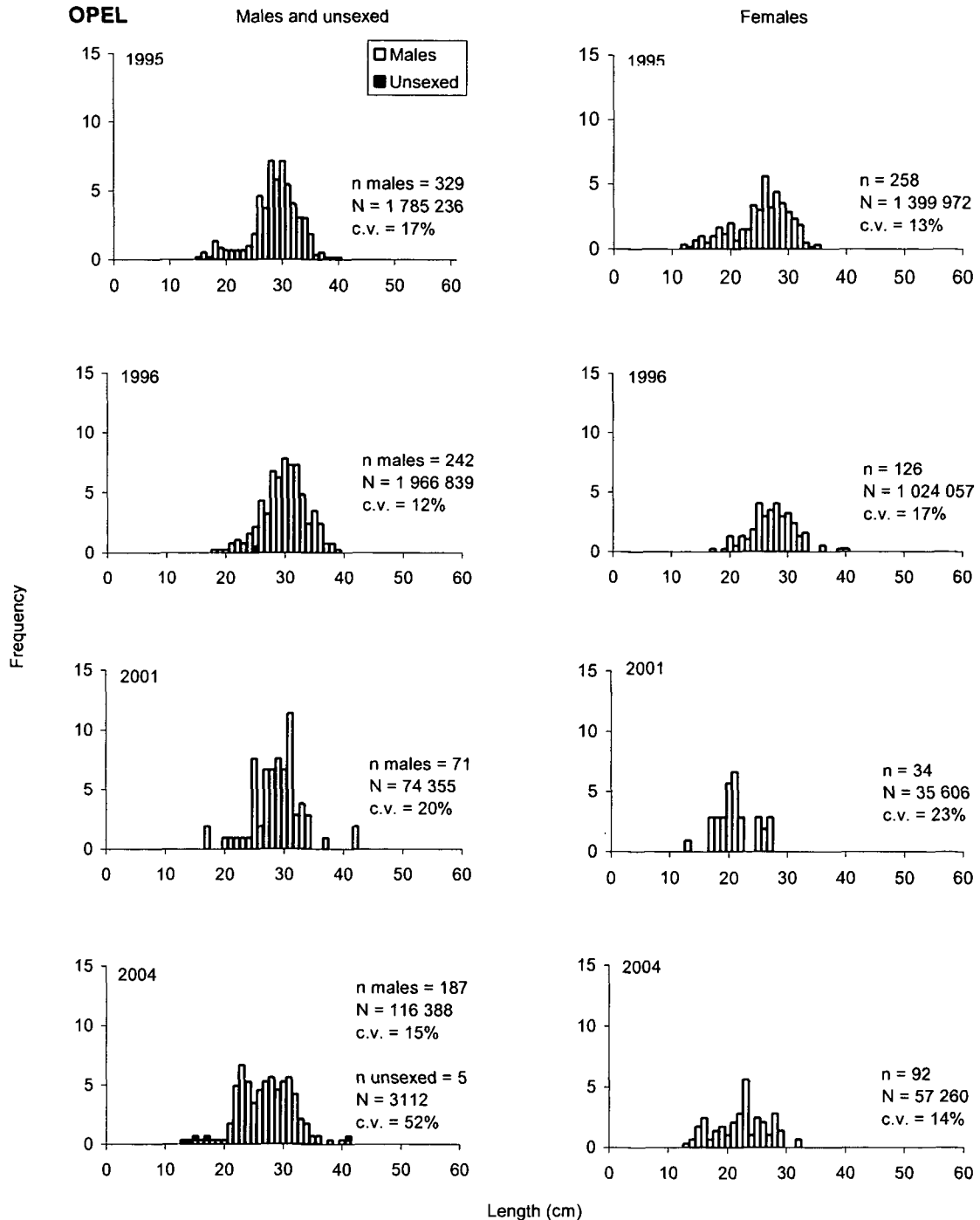


Figure 5: – continued. Scaled length frequency distributions of male, female, and unsexed blue cod from the OPEL stratum of the 1995, 1996, 2001, and 2004 Marlborough Sounds and Tasman Bay pot fishing surveys. n, numbers of fish measured, N, estimated numbers of fish scaled by stratum area, c.v., coefficient of variation of the survey estimate. Unsexed fish are shown as black bars. Mean lengths are given in Table 5.

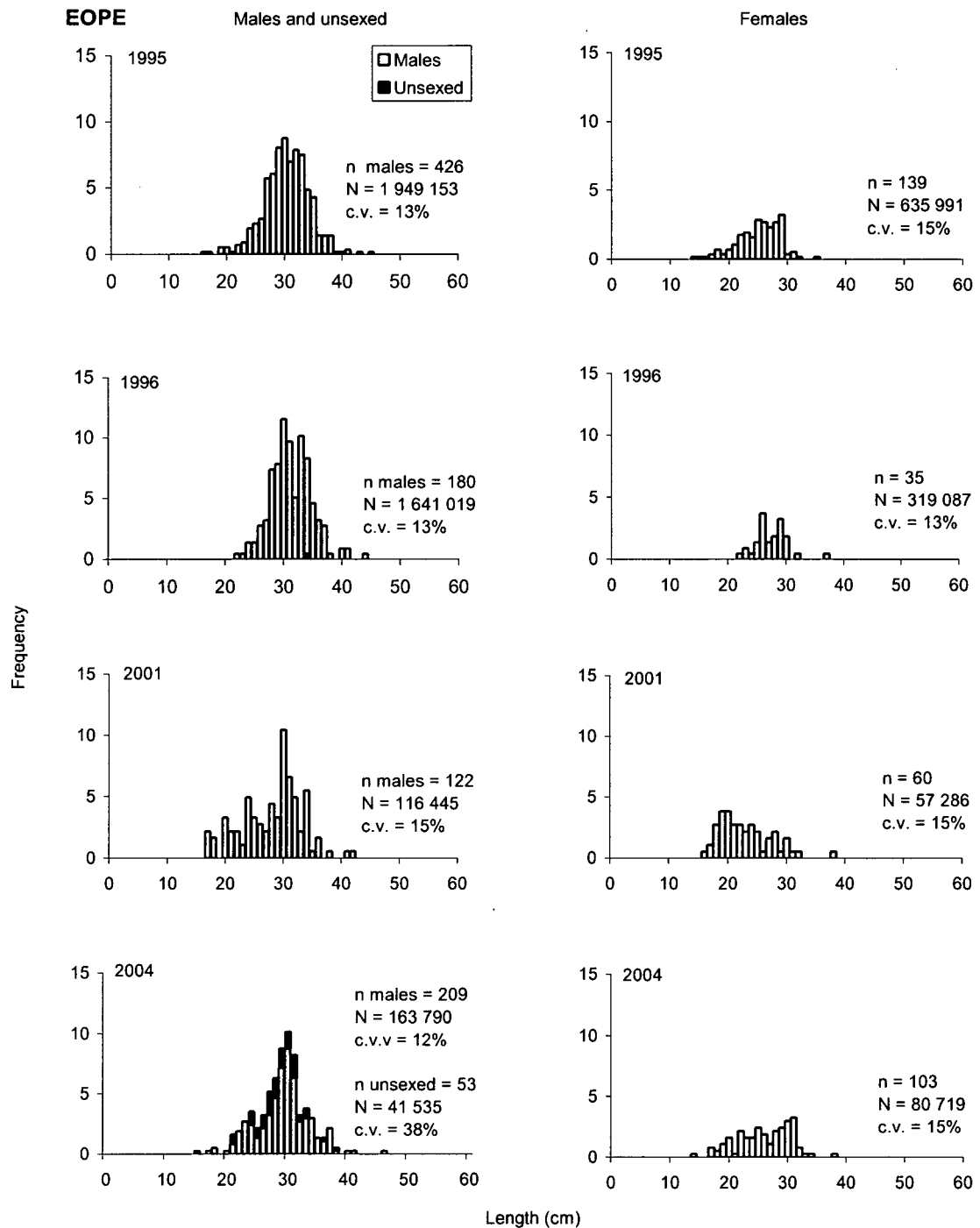


Figure 5: – continued. Scaled length frequency distributions of male, female, and unsexed blue cod from the EOPE stratum of the 1995, 1996, 2001, and 2004 Marlborough Sounds and Tasman Bay pot fishing surveys. n, numbers of fish measured, N, estimated numbers of fish scaled by stratum area, c.v., coefficient of variation of the survey estimate. Unsexed fish are shown as black bars. Mean lengths are given in Table 5.

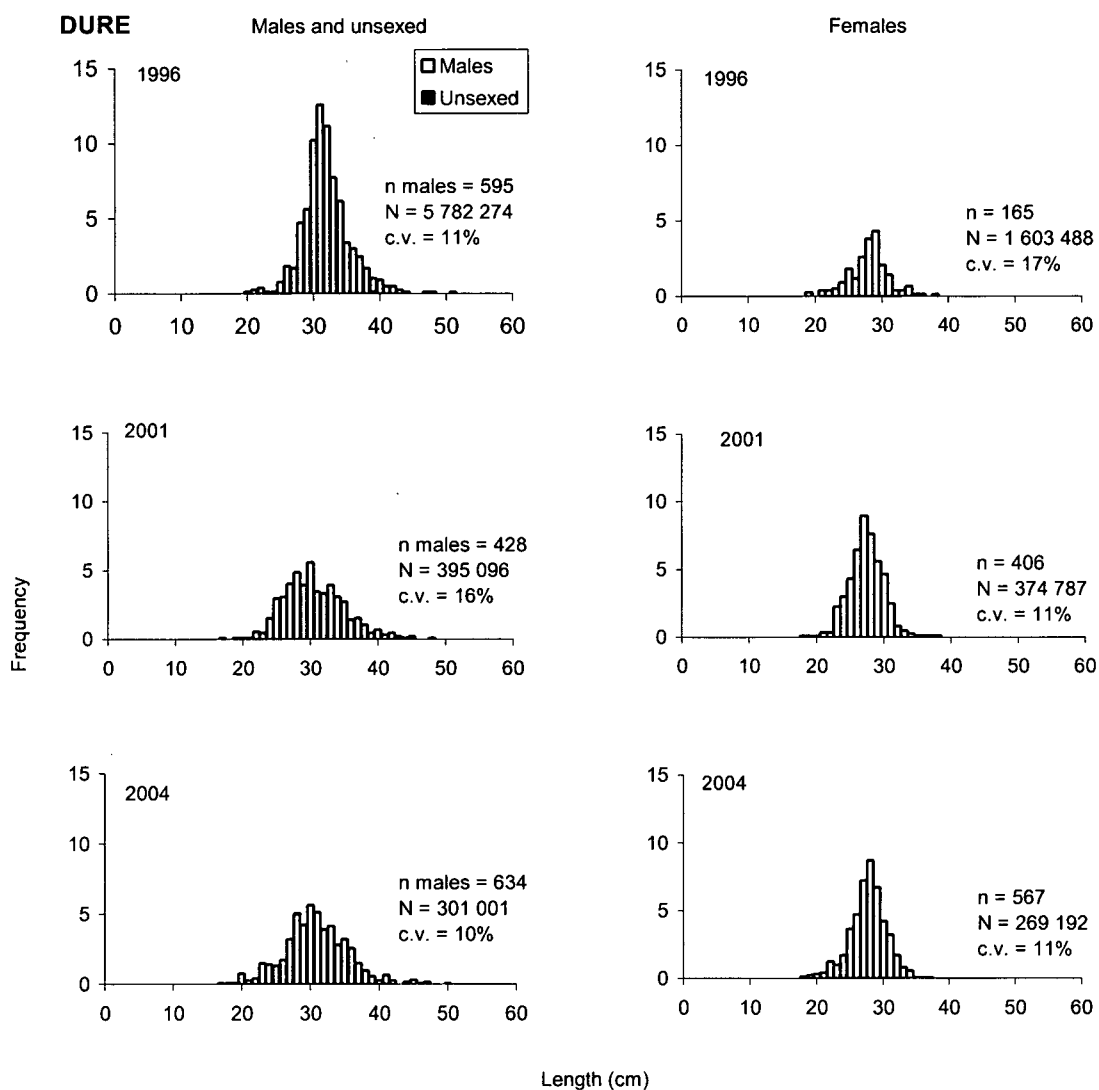


Figure 5: – continued. Scaled length frequency distributions of male, female, and unsexed blue cod from the DURE stratum of the 1996, 2001, and 2004 Marlborough Sounds and Tasman Bay pot fishing surveys. n, numbers of fish measured, N, estimated numbers of fish scaled by stratum area, c.v., coefficient of variation of the survey estimate. Unsexed fish are shown as black bars. Mean lengths are given in Table 5.

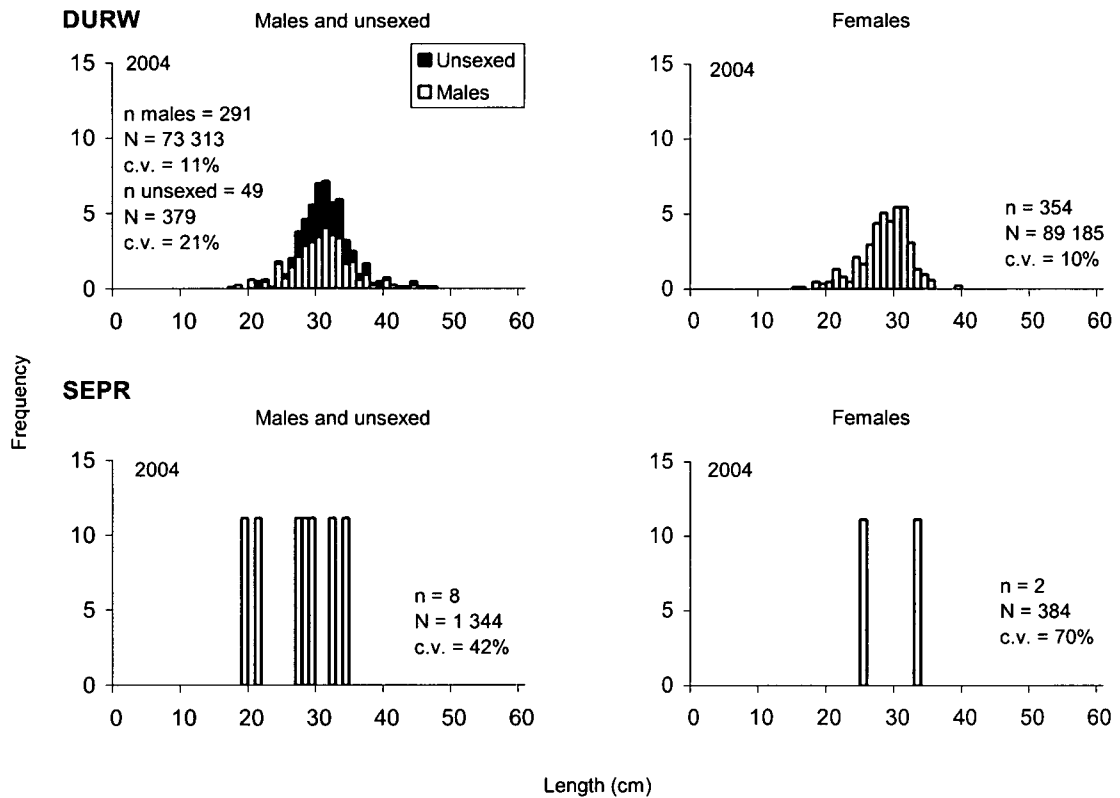


Figure 5: – *continued*. Scaled length frequency distributions of male, female, and unsexed blue cod from the DURW and SEPR strata of the 2004 Marlborough Sounds and Tasman Bay pot fishing survey. n, numbers of fish measured, N, estimated numbers of fish scaled by stratum area, c.v., coefficient of variation of the survey estimate. Unsexed fish are shown as black bars. Mean lengths are given in Table 5.

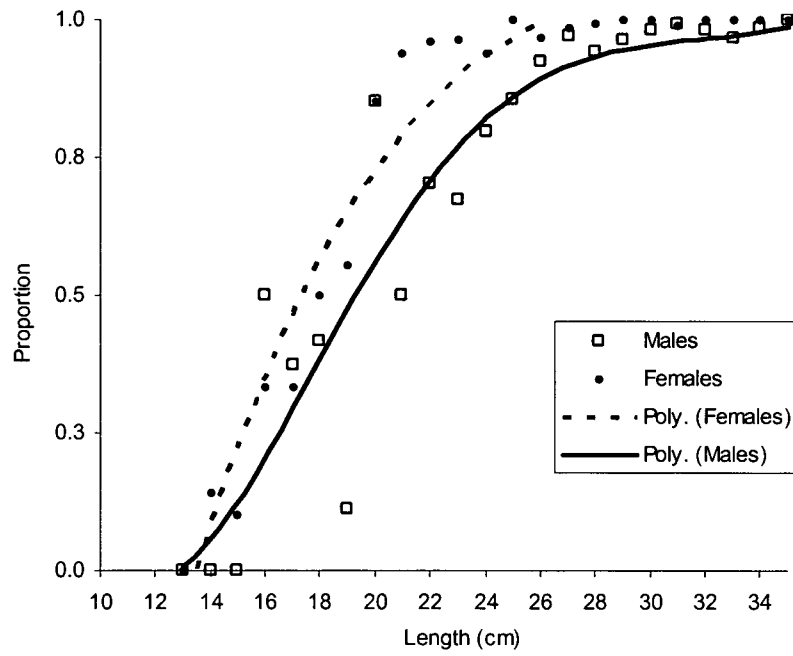


Figure 6: Proportion of mature blue cod (gonad stages 2–5) from the 2004 Tasman Bay and Marlborough Sounds, by sex and length class. Fitted curves are cubic polynomials. Numbers of fish sampled in each size class are given in Appendix 2.

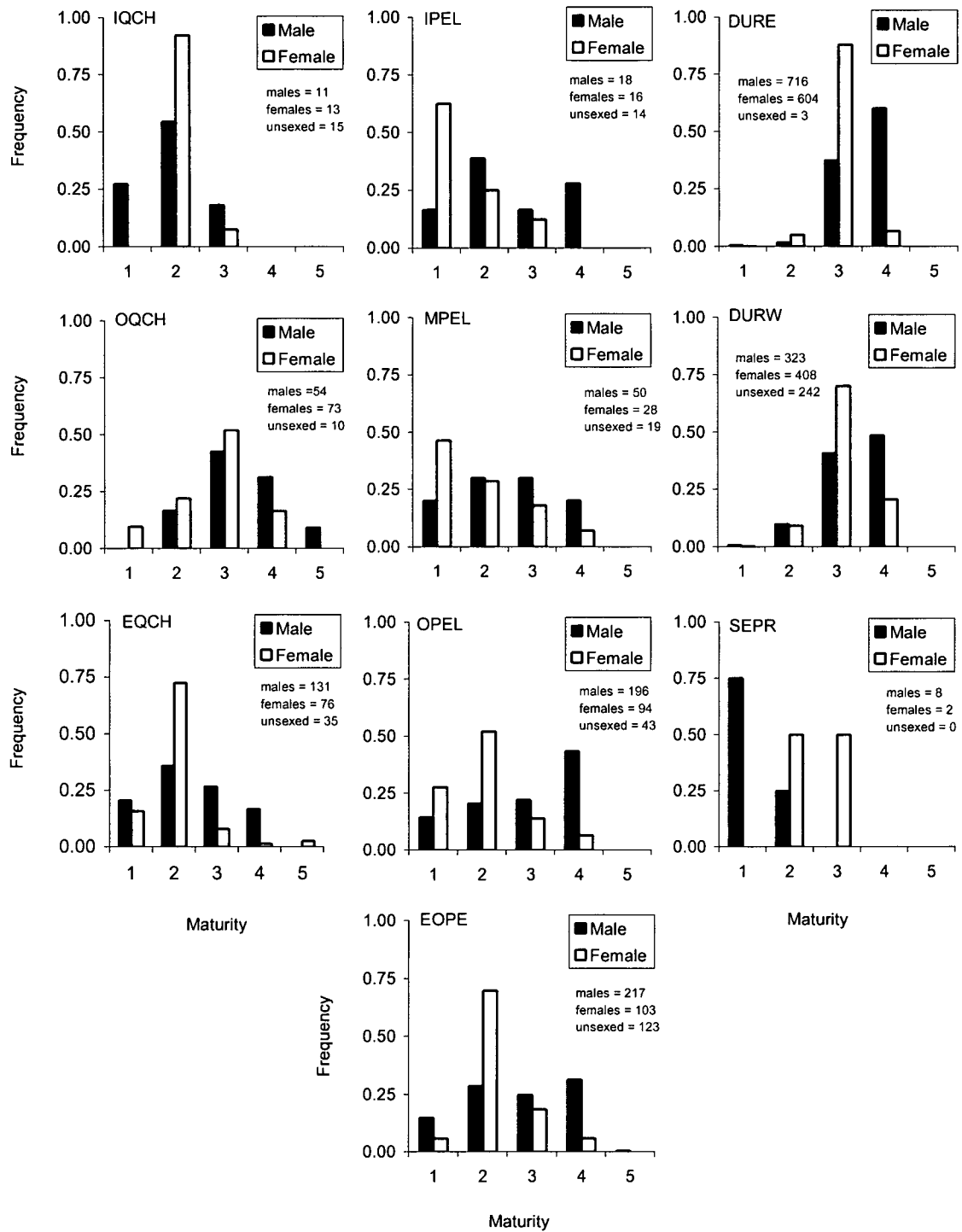


Figure 7: Relative sexual maturity stages as a proportion of sexed blue cod from the 2004 Tasman Bay and Marlborough Sounds pot survey, by sex and stratum. Maturity stages 1, immature or resting; 2, developing (oocytes visible in females); 3, mature (hyaline oocytes visible in females, milt expressible in males), 4, running ripe (eggs and milt freely flowing); 5, spent.

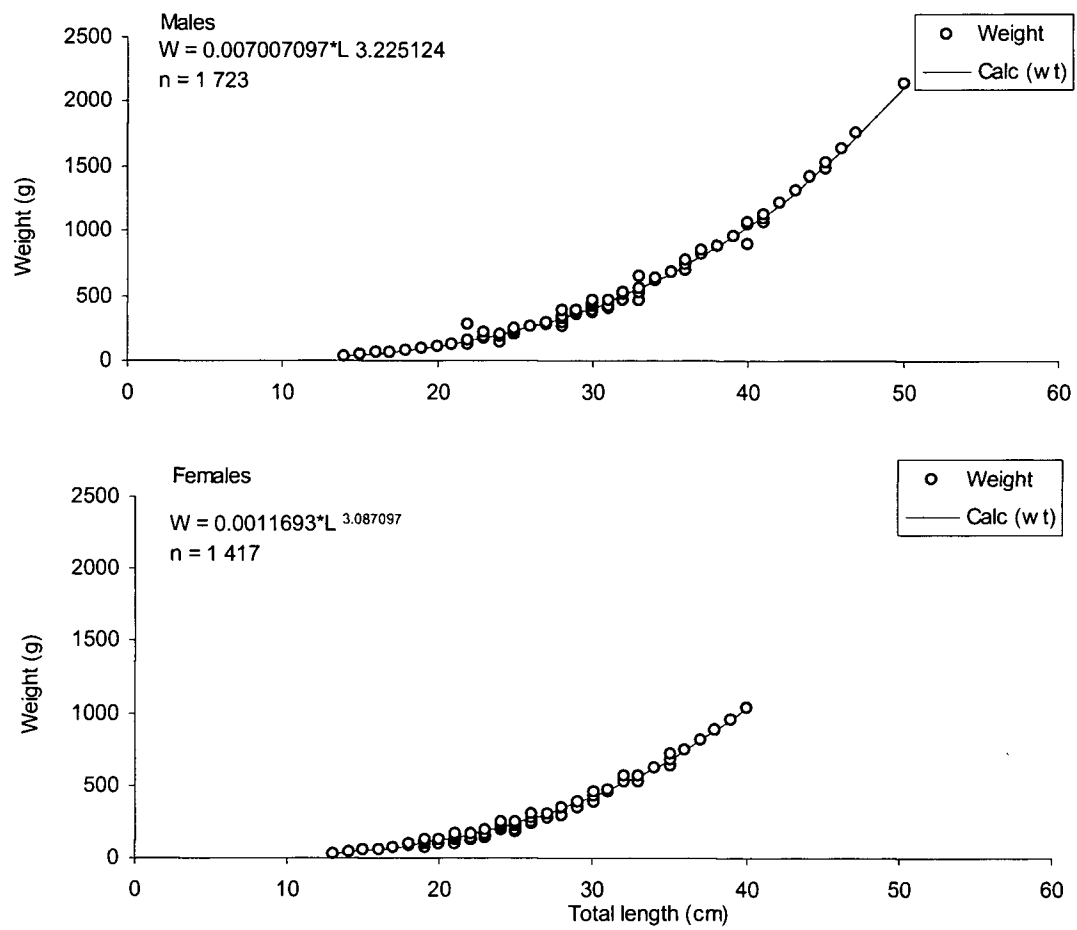


Figure 8: Length-weight relationships for blue cod biologically sampled on the 2004 Tasman Bay and Marlborough Sounds pot fishing survey.

NIWA

Taihoro Nukurangi

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BCO2003-01
FILE COPY

22 May 2006

Corporate Monitoring Unit
Ministry of Fisheries
P O Box 1020
WELLINGTON

Dear Sirs

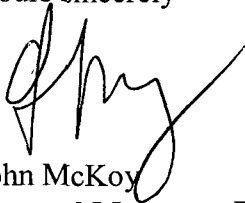
**PROJECT BCO2003-01 : ABUNDANCE OF BLUE COD IN THE MARLBOROUGH
SOUNDS**

On the 26th of October 2005 we submitted the Final Research Report for Project BCO2003-01.

That report was in the format of a NZ Fisheries Assessment Report. Following discussions with the Ministry's science team, it has been agreed that it would be appropriate for this piece of work to be reformatted into the format of a Final Research Report. This is to allow subsequent publications of some of the elements of this report in the International Scientific literature.

A revised version of the report in the form of a Final Research Format is attached.

Yours sincerely



John McKoy
General Manager, Fisheries

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MFISH MANUSCRIPT REVIEW FORMBCO2003-01
FILE COPY**MFish Project Scientist:** Marc Griffiths**Date received:** 9 November 2005**Project Code:** BCO2003/01**Date reviewed:** 22 November 2005**Document Type:** FAR**Objective(s):** 1 & 2**Title:** Abundance and size composition of recruited blue cod in the Marlborough Sounds and Tasman Bay, September-October 2004.**Author(s):** R.G. Blackwell**Recommendations:**☒ *Report meets reporting requirement for objectives 1 & 2 (minor, if any, editorial suggestions only)*☐ *Accept as FRR*☒ *Suitable as FAR; or*☐ *Minor revisions required, but need to resubmit to MFish for re-evaluation; or*☐ *Major revisions required; need to substantially revise and resubmit to MFish*☒ **Recommendations endorsed by Science Manager**

Date

28/11/05

General Comments:

The revised manuscript should be passed directly on to Mike Beardsell, the FAR editor.

Send marked-up manuscript back to authors? ☒ Yes ☐ No**SPECIFIC COMMENTS**

See editorial comments on attached manuscript.

Title: The report provides information on the relative abundance of juvenile blue cod, as well as blue cod above and below the minimum size limit. "Recruited" should therefore be removed from the title.

Introduction: The introduction should mention that the survey was timed to coincide with the spawning season and that the spawning season is earlier than along the east coast of the south island and in Southland.

Section 2.2: Recruitment is the process wherein additional fish are added to either the fishable or another component of the population. Recruitment is cannot therefore be defined as a number. "recruitment" should possibly read "size-at-recruitment".

Section 2.7: Owing to the presence of precocious fish in many populations the minimum size developing gonads can provide a very biased understanding of the size at sexual maturity. It would be more informative to calculate that size at 50% maturity by fitting an ogive to the proportions of fish in each 1cm size class that have gonads above a predetermined stage of development.

Discussion, 3rd para: If the pots were 50m apart and one assumed that each pot had a fishing radius of 35m there would firstly be competition between pots but also an overlap in fishing

area ($35 + 35 = 70$). This would need to be taken into account when calculating fish density and relative biomass by removing the area of overlap from the area fished by each set (as determined by the sum of the area of 9 circles with 35m radii). It is not clear whether this was the case and should be addressed in the discussion.

Page 15, Last sentence: It is not clear why an increase in the abundance of blue cod in EOPE is consistent with a high level of fishing pressure. An overall tag recovery rate of 9.6% is also not necessarily indicative of heavy fishing pressure. One would expect populations of fish with longevities similar to blue cod to sustain annual catches of 10-15% of recruited biomass.

Title Does the title adequately convey the main subject or message of the paper succinctly? (Consider the needs of information retrieval.)	No, see above comments
Abstract/Executive Summary Is the abstract a clear and adequate indication of the paper's content; does it state the purpose of the paper and the investigation on which it is based, state the methods used, and summarise the results and conclusions?	Yes
Introduction Are the objectives clearly stated?	Yes
Presentation and Style Is the information presented logically? Is the length of the paper adequate (rather than being either too brief for clarity, or so long that it's cumbersome)?	Yes Yes
Does the paper contain irrelevant material?	No
Is the arrangement of sections suitable, or would rearrangement improve the paper?	OK
Do the abbreviations, formulas, units, and nomenclature used conform with applicable international standards and rules?	Yes
Is the quality of the English language	Yes

satisfactory?	
Calculations and Statistical Treatment Is the statistical treatment of the data adequate?	Yes
Illustrations and Tables Could the information in parts of the text be more clearly and concisely presented by the use of more illustrations and/or tables?	OK
Are other tables or figures required?	No
Should any illustration or table be rearranged to present data more clearly?	No
Interpretation Are the conclusions justified? Is the interpretation adequate and warranted by the data, and not compromised by important omissions or loose generalisation?	Yes
References Are they all justified? Has the author omitted reference to any significant work?	Author's responsibility
Acknowledgements Do the acknowledgements adequately recognise the role of the Ministry of Fisheries and any other assistance received by the author?	Yes

Chambers
* 562 7540



MINISTRY OF FISHERIES
Te Tautiaki i nga tini a Tangaroa

Memorandum

BCO2003-01
FILE COPY

To:	Marc Griffiths			
CC:	Kevin Sullivan			
From:	Kim Hughes			
Date:	9 November 2005	File Ref:	BCO2003-01	
Subject:	Review FRR			
Remarks	☐ Urgent	☐ Reply ASAP	☒ For your Review	☐ Please Comment

Final Research Report for project BCO2003-01 Objectives 1 and 2

Marc,

Please provide Kevin with a review of this Final Research Report by 7 December 2005 that addresses the following two issues:

1. An assessment as to whether this report satisfactorily meets the Reporting Requirement for a Final Research Report or Draft FAR for Objectives 1 and 2 of project BCO2003-01
2. An assessment of the suitability of this draft as a FAR

Thanks

Kim

O:/BCO2003-01/Corr/CMU/26Oct

26 October 2005

Corporate Monitoring Unit
Ministry of Fisheries
P O Box 1020
WELLINGTON

Dear Sir

Project BCO2003-01 : Estimation of relative biomass of blue cod in the Marlborough Sounds

Attached please find a Final Research Report which we submit to meet the requirements of Objective 1, Milestone 4, and Objective 2, Milestone 9 of Project BCO2003-01.

This work has been prepared by Dr Ron Blackwell, and has been reviewed internally by Dr Glen Carbines.

Yours sincerely



John McKoy
General Manager, Fisheries