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# A comparison of abundance, population size structure, and sex ratio of blue cod *Parapercis colias* sampled by pot and diver count methods in the Marlborough Sounds

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**Final Research Report for Ministry of Fisheries Research Project BCO9701**

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# Final Research Report

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| **Report Title** | A comparison of abundance, population size structure, and sex ratio of blue cod *Parapercis colias* sampled by pot and diver count methods in the Marlborough Sounds |
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## 7. Executive Summary

Comparisons of abundance, size structure, and sex ratio were made for blue cod *Parapercis colias* (Pinguipedidae) sampled by pots and diver counts. Pilot studies were used to determine diver transect length and width, and to investigate the effects of time and tide. Sampling for the main comparison was randomised across the effects of time and tide, and used twelve 30 x 4 m transects prior to 1 hr sets of three commercial pots at each of 24 sites (3 sites, at each of 4 localities, within 2 areas). A separate comparison was also made of sex ratios of fish speared by divers and captured by pots. The relationship between pot catch and diver count was positive, but weak. This was the case for the entire dataset, and for the 2 areas analysed separately. Pots consistently caught larger fish than those recorded by divers. The sex ratios of blue cod captured by pots were similar to those speared in the same areas, though the sizes of blue cod in pots were greater than those speared. Attempts to estimate the area fished by pots produced estimates which we interpret as being unreliable.

## 8. Objective

1. To calibrate the cod potting technique used for estimating the relative abundance, size structure, and sex ratio of blue cod at two locations in the Marlborough Sounds.

The objective was achieved.

## 9. Methods

*Study area*

The study area was Outer Pelorus Sound (Figure 1). One diver (RGC), who was experienced at estimating sizes of fish underwater, and had previously been involved in assessments of blue cod density, carried out all transect counts.

*Pilot study 1*

The initial pilot study was done at Maud Island (Figure 1), and involved comparing 6 combinations of transect length (20, 30, 40 m) and width (2, 4 m). Timed counts were not used as the study area is subject to currents, and an important objective was to obtain estimates of density. The densities and sizes of blue cod were estimated during the counts (see Main Study below for details), and the time required to carry out each count (from tape placement to end of reeling in the tape) was recorded. Eight replicates of each transect size were sampled on 4-5 December 1997.

The precision (P, standard error / mean) for each transect size was recorded, the number of quadrats required to sample an area of 1600 $m^2$ (the greatest transect size, multiplied by the greatest anticipated replication for that size), and the time to sample that number of quadrats were calculated (Table 1). Then the time required to attain a level of precision of 0.1 was calculated following the methodology of McCormick and Choat (1987). This was done by rearranging the formula for precision:

$P = (SD / \sqrt{n}) / \text{mean}$, (SD = standard deviation, n = sample size) setting the desired P to 0.1, and solving for n, so that $n = SD^2 / (0.01 \cdot \text{mean}^2)$.

A 10-m uncounted lead-in was used on all transects, as blue cod are known to be attracted to divers, and the area close to the start of the transect could contain inflated densities of blue cod (see Cole et al. 1990, Cole 1994). As underwater visibility never exceeded 10 m during counts, depletion of the population sampled in the transect proper by attraction into the lead-in area was thought unlikely.

*Pilot study 2*

Pilot study 2 compared the abundance and size structure of blue cod at different stages of the time and tide, using the sampling protocol chosen in Pilot study 1. Two states of each of time (a.m. and p.m.) and tide (slack, running) were used, in an orthogonal experimental design. Four sites were nested in each combination of time and tide, and 12 replicate 30 x 4 m transects were counted and 3 pots were set per site. Sites were randomly chosen in the Outer Pelorus area (Figure 1), and the survey was done between 6 and 15 December 1997.

The data were analysed by mixed-model ANOVA (Proc GLM, SAS Institute Inc. 1989a), with the random factor Site being nested in the interaction of factors Time and Tide. Statistical significance and effect size are reported (see data analysis section of main Methods below).

Main Study

Three sites in each of four localities, in two areas, were sampled. The two areas chosen were Outer Pelorus Sound (Area 1), and Admiralty Bay – Guards Bay (Area 2) (Figure 1, Table 3). For the Outer Pelorus area, pilchards were used for bait, whereas in the more western area paua guts were used. This was due to the absence of pilchard bait at the time of sampling the second area. The fisher indicated that since the by-catch (particularly of conger eels *Conger verreauxi*) was greatly reduced by using paua guts, he would be continuing to use that bait in fishing operations. Hence, a decision was made to compare the performances of pots and diver transects using the newly-preferred bait, to provide a more valid basis for inference regarding future fishing.

Dive transects

At each site, divers sampled before the pots were set, to avoid pots aggregating the cod or depleting the area of cod. The divers entered the water, descended to the lower edge of the reef (usually about 15-18 m), and commenced counting. At all sites sampled, the reef plunged steeply, and comprised cobbles and boulders, with occasional bedrock outcrops near headlands. The transects were allocated so as to cover all rocky substrata at the site. (A study in Outer Queen Charlotte Sound suggested that peak abundances occurred around 10-12 m depth (Cole, Davidson and Villouta, unpubl. data)). In order to cover the entire reef, 12 replicate transects were usually allocated so that 3 replicate transects were done consecutively at each of the depths ~18, 15, 12 and 9 m. Thus a set of 3 transects usually extended slightly more than 120 m alongshore. There were occasional variations due to shallower lower limits of reefs, when the replicates were redistributed among the depth strata (e.g. 4 at 15 m, 4 at 11 m, and 4 at 8 m). This approach resulted in a zig-zag pattern up the reef from the greatest depth reached (which was desirable from a diving safety viewpoint). Shallow areas usually contained stands of macroalgae (mainly *Carpophyllum flexuosum*) which are seldom occupied by blue cod (Choat and Ayling 1987, Cole, pers. obs.), so rubble bank habitats without macroalgae were sampled preferentially.

The transects were sampled in a 1-way count, with a buddy diver holding the tape, and the counting diver count swimming 1-2 m off the substratum. Care was taken not to disturb the substratum. During the dive, all blue cod in the transects were counted, and their total lengths were estimated visually. Data were recorded on plastic slates, and subsequently transcribed. Generally the distribution of blue cod was even within transects, and there were only 1 or 2 occasions when dense patches of cod may have led to recording saturation. Occasionally currents were encountered while sampling, but they were generally not strong, and did not affect the way in which counts were done.

Potting

During transect sampling, the vessel monitored the alongshore movements of the divers by following their exhaust bubbles. After the divers surfaced, the three pots were deployed, approximately evenly-spaced through the area that the divers had counted. A pilot study (Blackwell unpubl. data) found that the pots baited with pilchards could attract cod from distances of about 30 m, suggesting that there should have been little competition between pots for fish (this was also a consideration in determining the number of replicate pots used in the potting part of the study). The pots were set for 1 hr, and then hauled sequentially. The numbers of fish, their total lengths, and the sex of all blue cod were recorded.

Sex ratios were also compared between pots and speared samples at four sites (Figure 1). The pots were set in an area at the same time as divers with a spear entered the water, and proceeded to spear cod in the vicinity (within ~50 m radius) of the pots until 20 had been captured. An initial attempt to seal the pots and prevent further escapes proved impractical, as when the divers approached the pots, the cod panicked and most escaped. Instead, the divers speared blue cod in the general near the pots while they fished. At most sites it was necessary to attract cod by disturbing the bottom in order to attract them within spearing range. The sizes and sex ratios for the two capture techniques were then compared.

A further experiment was undertaken to estimate the distance from which blue cod were attracted to pots. Blackwell (unpubl. data) found that there appeared to be a radius of depletion of blue cod of about 30 m around pots. The technique in that study was to count fish in 10-m intervals along transects arranged radially around the pot. In the present study, the attraction range was further investigated at two sites, where cod were counted in 10-m wide strips demarcated by tapes running directly offshore, the area was fished to decrease numbers, and then recensused. The count was done 4 times before fishing with pots, and then repeated 4 times after as many cod as possible had been removed from the central area by repeated pot sets. The objective was to determine at what distance from the potting site the difference between pre- and post-potting counts became zero. That distance would indicate the fishing range. For our study we used a 70 m range either side of the potting site, which on the basis of Blackwell's study, we expected would more than cover the area of depletion. One of the sites chosen was close to the original site used in Blackwell's study, which further increased the opportunity for comparisons between methodologies. The sites chosen were of necessity shallow and the reef relatively narrow, so that the divers could repeatedly census the entire area without bottom time difficulties.

Data analysis

Initially, mean abundance of blue cod from transects, and the mean catch from all pots, were calculated for each site. Subsequently, data from pots which contained conger eels were discarded, as an earlier pilot study (Blackwell unpubl.) suggested that blue cod in pots with congers either attempted to escape or were consumed by the eels. Spearman rank correlations were used to assess the relationship between pot catches and cod densities. Variance component analyses of variance (Proc Varcomp, SAS Institute Inc. 1989a) on densities and catch rates were done separately, to ascertain how the variability was distributed between the 2 random factors (sites and replicate transects or pots). These analyses are appropriate for hierarchical designs, where it may be possible to estimate proportions of variation accounted for by each level of the analysis (e.g. Snedecor & Cochran 1980). The factors Time and Tide were fixed in the analysis (Proc Varcomp, SAS Institute Inc. 1989a).

Effect sizes were also calculated for the hierarchical designs. Comparisons of P-values derived from differing sample sizes are not valid (e.g. Gibbons & Pratt 1975); the appropriate currency for such comparisons is effect size (e.g. Cohen 1988, Gurevitch et al. 1992, Gurevitch & Hedges 1993). There are a number of measures of effect size, but I have used that of Lohr & O'Brien (1984): SSH / MSE where SSH= the relevant sum of squares for the hypothesis in question, and MSE is the relevant mean square error. I used this measure of effect size because it can be calculated from a conventional analysis of variance table, but note that it is not directly comparable with the more widely-known effect size proposed by Cohen (1988), or those used in recent reviews (Gurevitch et al. 1992, Gurevitch & Hedges 1993).

Size compositions from the samples using the two different techniques were plotted for each site. Due to the widely varying sample sizes, including very low sample sizes for some sites, it was necessary to pool sites within each area for a formal comparison of sample size structure. The comparison was made by pooling the size data into 3 classes (0-15 cm, 15 – 25 cm, and > 25 cm), and using a log-linear model to analyse the frequency distributions (Proc Catmod, SAS Institute Inc. 1989b).

The area sampled by the pots was estimated by the method of Miller (1975): the mean density from the pots (units = numbers per pot) was divided by mean transect density (units = numbers per transect) to give the fished area (units = transects per pot).

## 10. Results

*Pilot Study 1*

The 20 m x 2 m transect size took the lowest time to reach a precision of 0.1, but would have required a long time to sample a given area due to the high travel time between transects (one-third of the time for the sampling time per transect was in the 10-m lead in) (Table 1). We also had concerns regarding edge effects, given the high perimeter-area ratio. A transect size of 30 m x 4 m was chosen, with a replication of 12 transects per site (Table 1, Figure 2). The chosen transect size was a practical, efficient compromise, and the replication level was a comfortable maximum for a single SCUBA tank dive.
There was no apparent effect of transect size on fish size (Figure 3a). However, when transects were pooled by widths there was a trend for more smaller fish to be counted in the wider transect (Figure 3b). The difference was not large, and given the relatively small sample size for the narrower transect width, the difference was not regarded as important.

*Pilot study 2*

There was no tide or time effect (measured using both P and effect size) in the potting experiment (Table 2), though diver transects counted fewer fish in the morning than in the afternoon (Figure 4, Table 2). The greatest contribution to variation (measured by effect size) was from among-site variability (Table 2). A variance component analysis of the catch data for pots, with time and tide as fixed factors, gave a variance component for sites of 0.4 (s.e.= 2.3), and for replicates of 18.9 (s.e. =3.9). For the diver counts, the variance components were 1.7 (s.e. = 1.0), and 9.5 (s.e. = 1.0) for site and replicate components respectively. This indicates that most of the variation lay among replicate pots or transects, within a site. Given the small size of the difference between morning and afternoon for transects, and the fact that limiting sampling to morning would have doubled the field time and increased costs greatly, sampling was randomised across times, so as to avoid the possibility of confounding area with time. Small blue cod were sampled less often by pots than dive transects (Figure 5). This was consistent across tides and times.

*Main study*

Where pots caught many blue cod, divers generally also counted many, but diver count was not a good predictor of pot catch. The relationship between pot catch and diver count was positive, but extremely variable (Figure 6). With pots that contained congers included in the analysis, the Spearman's ρ values for area 1 were slightly lower than those for Area 2. When pot catches containing congers were excluded, the relationship for Area 1 (where all the congers occurred) became stronger (Figure 6).

The frequency distributions for the pot and diver counts both displayed a negative decay curve from zero, with the diver counts being more right-skewed (having more high values) than the pots (Figure 7). The diver counts also had a greater proportion of 0 counts than did the pots. Note that the replication level for diver counts was 4 times as high as pot counts.

The size frequency comparison suggested that pots generally undersampled the smaller cod in the population (Figure 8). This was evident in the time-tide pilot study (see Figure 4), the dive transect – pot comparison (Figure 8), and in the spearing – pot comparison (see Figure 10 below). The pots caught very few blue cod less than 20 cm total length, whereas that size class comprised a moderate proportion of the population sampled by the divers. The pattern was often apparent on a site-by-site basis, as well as for comparisons pooled across sites, although there were some exceptions (e.g. Site 9) (Figure 9).

Bycatch levels were low, but were higher in Area 1 than in Area 2, with only a few leatherjackets (*Parika scaber*) being caught in Area 2, where pots were baited with paua guts (Tables 3 and 4). The other species caught were spotties (*Notolabrus celidotus*), carpet shark (*Cephaloscyllium isabellum*), conger eels (*Conger verreauxi*), and octopus (*Octopus* sp.).

Sex ratios

The sex ratios obtained by potting and spearing were similar, with about 40% males and 60% females (Table 5). A chi-squared contingency table analysis revealed no differences in sex ratios between pots and spearing ($\chi^2$ =0.168, P=0.682). This was despite more smaller fish being caught by spearing than by potting (Figure 10).

Area fished by pots

The area fished by pots, as calculated from the diver counts and the pot catches, was highly variable (Table 6). There were no patterns in the data to suggest that the technique was useful.

The removal method for assessing the area fished by pots gave similarly unsatisfactory results. At the D'Urville Island site, more blue cod were counted after removal of 27 blue cod than before, when pooled across all 4 censuses (Table 7a). At that site there was a concentration of negative changes across cells 7 and 8, and the pooled cells 9 and 10 to the south, although no currents were noticed at the site which might have caused this asymmetry. This gives a range of attraction for the pots of about 20 m, and a radius of attraction of 10 m.

At the Clay Point site, there was a concentration of negative counts from 20 m south to 10 m north, suggesting a radius of 5-10 m (Table 7b). At the site there was a moderate northward-flowing current at the start of the exercise, although this dropped after the fishing had been done. Cell 9, with an increase of 11 fish between before and after totals, was the only cell out to a distance of 50 m (i.e. 1 of 5) in a northerly direction, that demonstrated an increase between censuses.

## 11. Conclusions

Suitability of pots for broadscale comparisons

The main advantage of pots as a stock assessment technique is that they can sample more sites and greater depths than divers. They can fish areas beyond 30 m depth and sites with high current, which divers cannot sample safely. They are also probably more efficient (especially with a sampling duration shorter than 1 hr), cheaper, and have fewer potential safety issues. Diving is unable to compete with potting in these practical considerations.

With the exception of conger eels, there appeared to be few inter-specific interactions in the pots (cf. Richards et al. 1982, Castro & DeAlteris 1990, Addison 1995, Miller & Addison 1995, Zhou & Shirley 1997a). By-catch was low, and mainly comprised congers, spotties and leatherjackets. We observed no evidence of intraspecific interactions modifying pot entry behaviour of blue cod. When divers approached pots containing fish however, the blue cod panicked, and most cod in the pot escaped in the flurry.

Limitations of pots

Pots appeared to under-sample small fish relative to divers. Pots successfully catch larger individuals, but would not be useful for obtaining a recruitment index. The potting technique may provide an index of relative abundance and size structure, but the high variability between pots suggests that high replications (numbers of pots per site) are required. This could cause competition among pots if the site size as used here (~120 m alongshore) was adopted (Williams & Hill 1982). Further information regarding the area fished would assist (see below). Very little is known about small blue cod, and Mace & Johnston's (1983) tagging study suggested that dispersal occurred at sizes near 20 cm TL (i.e. the greatest distances travelled were for individuals near that size). Diver counts or an alternative method will be necessary to quantify that part of the population.

Although diver counts offer a reliable assessment of blue cod populations on shallow reefs in most situations, they do have limitations. As noted, there were a few occasions on which temporary "recording saturation" may have occurred. In spring, blue cod at Long Island were observed in the water column, an atypical behaviour perhaps related to spawning. Diver counts focused on reef populations of blue cod could be negatively biased if those individuals were a substantial part of the population. Large individuals sometimes occurred in shallow water, where they fled rapidly from divers. On steep boulder bank habitats, blue cod usually responded to the diver by fleeing ahead of him, then crossing the transect path to get to deeper water. This behaviour would induce a bias in that fish encountered inshore would be more likely to occur in transects, rather than having a 50:50 chance of departing inshore or offshore. The magnitude of these biases is probably small, and no different from any other transect count, but they are noted here for completeness. The behaviour of blue cod toward divers in shallow water may have affected the use of the removal technique for assessing population size (see below).

To fully understand the dynamics of pot entry and escapement by blue cod, continuous records of fish entry and departure from pots will be required under a wide variety of conditions. Further, experiments in which pots are experimentally stocked with the target species (e.g. Richards et al. 1982, Addison 1995) are required to investigate effects on entrants and escapees (Fogarty & Addison 1997). Interference among pots may be responsible for some of the variability in the present study (e.g. Williams & Hill 1982); this will require the effective range of pots to be investigated more thoroughly (see below). While several studies have found that fish approached pots or baits from down-current (e.g. Lokkeborg et al. 1989), we observed no evidence of such behaviour, and given the highly visual nature of blue cod behaviour, it is possible that visual cues contribute to the entry of cod into pots. On the basis of our observations, and comments regarding maximum catches by the fisher (up to 80 blue cod captured in a single pot, C. Aston pers. comm.) we do not believe that a limiting catch per pot might occur.

Estimates of area fished from diver-count scaling

Estimates of area fished using this method were highly variable. Preliminary data (Blackwell, unpubl.) suggested that blue cod might be attracted from a radius of about 30 m round the pot. The laboratory study of Lokkeborg et al. (1995) suggested that the radius of attraction to baits for sablefish *Anoplopoma fimbria* might vary between 10 m and several kilometres. The diver-count scaling technique assumes a constant response, for example to an olfactory cue. In contrast, attraction to a pot probably reflects behaviour, visual cues (and thus perhaps underwater visibility), dispersion of fish at the site, and the size composition of the fish at the site. A much more focused study will be required to segregate the effects of these variables; sites with good underwater visibility (e.g. northern areas of D'Urville Island) could be used for this. An approach combining information concerning currents (which can be obtained quite cheaply – Craig & Kennelly 1991, Miller et al. 1996) and continuous records of fish entry and departure from pots (e.g. Sainte-Marie & Hargrave 1987, Zhou & Shirley 1997b) would clarify these matters.

Assessment of area fished via removal method

I believe that the removal method did not adequately estimate the number of fish in the demarcated area, into which more fish probably moved. The removal method suggested radii of attraction of 5-10 m, and found asymmetrical differences alongshore. Counts were highly variable among replicate sets of transects. Previous attempts at abundance estimates by use of this technique were done at Long Island-Kokomohua Marine Reserve, where the fish appeared to respond less to divers (Cole & Grange, unpubl.). The Clay Point site was quite shallow (maximum depth ~9 m), and the fish were noted to swim ahead of the divers for some time before circling back through the line. This would lead to a blurring of counts between the counting cells, which pooling cells into pairs did not rectify. At the Clay Point site the numbers removed were probably of the order necessary to estimate abundance, unlike the D'Urville Island site.

Similar approaches to estimating area fished have been used in other fisheries, with similar difficulties (e.g. Recksiek et al. 1991). That study could estimate the effective area fished for only three of 24 species sampled. It also incorporated a tagging study to estimate population density (using a change in ratio approach). A difficulty for such an approach is that the area fished by pots is likely highly variable (e.g. with variation in current or visibility), and asymmetric, necessitating numerous repetitions at different sites. It is also expensive – in the present study, it took four people two days to estimate area fished at two sites.

The removal of 27 fish at the D'Urville Island site was followed by an increase of 11 fish in the total seen, which suggests that more fish must have entered the area. Change in ratio methods cannot be used to estimate the total abundance in the area. At Clay Point, the removal of 73 fish led to a decline in total of 51, which suggests that there was a total of 537 fish (pooled across 4 replicate censuses), or an average of 134 fish per census.

Bait change, by-catch, and change of fishing duration

There was much lower by-catch in Area 2 than Area 1, but the difference between the Areas is confounded with differences in bait. Pilchards were used as bait in Area 1, while paua guts were used in Area 2. This was imposed on the project by the cod fisher being unable to catch pilchards to use in the second area, but offered the opportunity to collect data relevant to the recently-adopted preferred bait (the fisher intends continuing to use paua guts – C. Aston, pers. comm.). The use of paua guts coincided with no further catch of conger eels, and this is the reason for the fisher changing bait.

A video on the pots (Blackwell, unpubl.) suggested that most blue cod entered the pot soon after it was deployed. The fisher now uses shorter sets of ~ 20 mins in his commercial operation because of this (C. Aston, pers. comm.). Much more efficient surveys could be done with shorter pot sets, but there may well be difficulties scaling abundances (if not sizes) up to 1 hr sets for comparison with earlier studies (but see Smith & Jamieson 1989). Miller & Hunte (1987) found that catch at short soak times could be related to visual density estimates for reef fishes, and it is possible that shorter deployment times might provide a stronger correlation with diver counts. The review of Arreguin-Sanchez (1996) details the influence of catchability on other fisheries models, and it is apparent from our study that much greater effort, and the use of other techniques such as current meters and video to estimate entry and escapement rates (Munro 1974, Fogarty & Addison 1997), will be needed to adequately link catch rates to abundances.

## 12. Acknowledgements

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## 13. Publication

Manuscript titled "A comparison of diver and pot sampling for blue cod (Parapercis colias: Pinguipedidae)", R.G. Cole, R.G. Blackwell, D.S. Tindale, is being prepared for submission to Fisheries Research.

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Table 1: Statistics for pilot study of transect size, (n=8 replicates of each transect size). Within each transect, blue cod numbers and sizes, and the time required to sample the transect, were recorded. The number of transects required for a fixed total area of 1600 $m^2$ was calculated, the standard deviation calculated, the precision (se / mean, n=8), the mean time required to sample a transect (Col 5), the time to sample 1600$m^2$ (Col 6), the sample size required to obtain precision=0.1 (see text for description of method) and the time required to sample for that precision (Col 5 x Col 7))

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| | N (for 1600$m^2$) | **Mean number of blue cod** | **SD of blue cod numbers** | **Precision** | **Mean time (seconds)** | **Sample time for 1600$m^2$ (seconds)** | **N for precision = 0.1** | **Time for precision= 0.1 (seconds)** |
| **20 x 2 m** | 40 | 2.5 | 1.69 | 0.276 | 143 | 5720 | 46 | 6578 |
| **20 x 4 m** | 20 | 3.75 | 4.30 | 0.468 | 148 | 2960 | 132 | 19536 |
| **30 x 2 m** | 26.67 | 1.75 | 3.24 | 0.756 | 193 | 5147 | 343 | 66199 |
| **30 x 4 m** | **13.33** | **3.25** | **2.38** | **0.298** | **191** | **2546** | **53** | **10123** |
| **40 x 2 m** | 20 | 2.125 | 1.96 | 0.376 | 235 | 4700 | 85 | 19975 |
| **40 x 4 m** | 10 | 5.125 | 3.68 | 0.293 | 241 | 2410 | 52 | 12532 |

Table 2: Analysis of Pilot Study 2 – Comparison of catchability at different times and tides. Table entries are mean (s.e.) catch (numbers of blue cod per pot, n=3), and count (numbers of blue cod per 30 m x 4 m transect, n=12). Four sites were sampled for each of the 4 conditions of time (a.m., p.m.) and tide (running, slack). Lower panels give analysis of variance tables for each technique, and effect sizes, calculated as SSH / MSE (O'Brien and Lohr 1984), with SSH being the sum of squares for the hypothesis, and MSE being the relevant error mean square

| **Table 2a** | **Pots** | | | | **Divers** | | | |
|---|---|---|---|---|---|---|---|---|
| | **Running** | | **Slack** | | **Running** | | **Slack** | |
| **Rep** | **a.m.** | **p.m.** | **a.m.** | **p.m.** | **a.m.** | **p.m.** | **a.m.** | **p.m.** |
| 1 | 8.0 (5.7) | 5.5 (2.3) | 9.8 (1.3) | 2.5 (1.6) | 1.7 (0.3) | 3.5 (0.7) | 4.3 (1.1) | 3.8 (0.9) |
| 2 | 8.8 (1.1) | 5.8 (1.5) | 4.5 (1.3) | 4.0 (2.3) | 3.3 (0.6) | 8.2 (2.4) | 1.6 (0.4) | 3.8 (0.5) |
| 3 | 7.0 (2.5) | 3.0 (1.7) | 5.8 (1.0) | 4.8 (1.1) | 2.7 (0.6) | 3.4 (0.9) | 2.3 (0.7) | 1.0 (0.2) |
| 4 | 5.3 (2.5) | 4.5 (1.5) | 0.5 (0.3) | 6.0 (1.5) | 0.8 (0.4) | 4.8 (1.1) | 1.1 (0.2) | 3.3 (0.8) |

**Table 2b Pots ANOVA**

| **Source** | **df** | **SS** | **MS** | **F** | **Pr > F** | **Effect size** |
|---|---|---|---|---|---|---|
| **Time** | 1,12 | 45.56 | 45.56 | 2.22 | 0.16 | 2.22 |
| **Tide** | 1,12 | 25 | 25 | 1.22 | 0.29 | 1.22 |
| **Time*Tide** | 1,12 | 12.25 | 12.25 | 0.60 | 0.45 | 0.60 |
| **Site (Time*Tide)** | 12,48 | 246.1 | 20.5 | 1.08 | 0.39 | 13.0 |
| **Error** | 48 | 907.5 | 18.9 | | | |

**Table 2c Transects ANOVA**

| | **df** | **SS** | **MS** | **F** | **Pr > F** | **Effect size** |
|---|---|---|---|---|---|---|
| **Time** | 1,12 | 152.3 | 152.3 | 5.16 | 0.04 | 5.16 |
| **Tide** | 1,12 | 39.4 | 39.4 | 1.34 | 0.27 | 1.34 |
| **Time*Tide** | 1,12 | 57.4 | 57.4 | 1.95 | 0.18 | 1.95 |
| **Site (Time*Tide)** | 12, 176 | 353.9 | 29.5 | 3.10 | 0.0005 | 37.20 |
| **Error** | 176 | 1674.4 | 9.51 | | | |

Table 3: Site and catch details for potting survey. Area 1 = Outer Pelorus Sound sites 1-12, Area 2 = Admiralty Bay – Clay Point sites 13-24. Latitude and longitude in degrees and decimal minutes. Other columns give numbers of fish caught: BCO blue cod; conger *Conger verreauxi*; octopus *Octopus* sp.; leatherjacket *Parika scaber*; spotty *Notolabrus celidotus*; carpet shark *Cephaloscyllium isabellum*

| Date | Site | Latitude (S) | Longitude (E) | BCO Total | BCO male | BCO female | Conger | Octopus | Leatherjacket | Spotty | Carpet shark |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 21/4/98 | 1 | 41° 00.12' | 174° 00.88' | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 |
| 21/4/98 | 1 | 41° 00.12' | 174° 00.88' | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21/4/98 | 1 | 41° 00.12' | 174° 00.88' | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 22/4/98 | 2 | 41° 00.50' | 174° 00.78' | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22/4/98 | 2 | 41° 00.50' | 174° 00.78' | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22/4/98 | 2 | 41° 00.50' | 174° 00.78' | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22/4/98 | 3 | 41° 00.89' | 174° 00.89' | 6 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 22/4/98 | 3 | 41° 00.89' | 174° 00.89' | 3 | 1 | 2 | 0 | 0 | 0 | 0 | 0 |
| 22/4/98 | 3 | 41° 00.89' | 174° 00.89' | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22/4/98 | 4 | 41° 00.00' | 174° 03.69' | 2 | 0 | 2 | 0 | 1 | 0 | 3 | 0 |
| 22/4/98 | 4 | 41° 00.00' | 174° 03.69' | 6 | 4 | 2 | 0 | 0 | 0 | 0 | 0 |
| 22/4/98 | 4 | 41° 00.00' | 174° 03.69' | 14 | 8 | 6 | 0 | 0 | 0 | 0 | 0 |
| 23/4/98 | 5 | 40° 59.68' | 174° 03.43' | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 23/4/98 | 5 | 40° 59.68' | 174° 03.43' | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| 23/4/98 | 5 | 40° 59.68' | 174° 03.43' | 5 | 5 | 0 | 1 | 0 | 0 | 0 | 0 |
| 23/4/98 | 6 | 41° 00.16' | 174° 03.00' | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23/4/98 | 6 | 41° 00.16' | 174° 03.00' | 8 | 4 | 4 | 0 | 0 | 0 | 0 | 0 |
| 23/4/98 | 6 | 41° 00.16' | 174° 03.00' | 7 | 6 | 1 | 0 | 0 | 0 | 0 | 0 |
| 23/4/98 | 7 | 40° 57.57' | 174° 04.14' | 11 | 8 | 3 | 0 | 0 | 0 | 0 | 1 |
| 23/4/98 | 7 | 40° 57.57' | 174° 04.14' | 8 | 8 | 0 | 0 | 0 | 0 | 0 | 0 |

| Date | Site | Latitude (S) | Longitude (E) | BCO Total | BCO male | BCO female | Conger | Octopus | Leatherjacket | Spotty | Carpet shark |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 23/4/98 | 7 | 40° 57.57' | 174° 04.14' | 9 | 4 | 5 | 0 | 0 | 0 | 0 | 0 |
| 24/4/98 | 8 | 40° 57.36' | 174° 04.09' | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24/4/98 | 8 | 40° 57.36' | 174° 04.09' | 13 | 5 | 8 | 0 | 0 | 0 | 0 | 0 |
| 24/4/98 | 8 | 40° 57.36' | 174° 04.09' | 12 | 7 | 5 | 0 | 0 | 0 | 0 | 1 |
| 24/4/98 | 9 | 40° 57.23' | 174° 03.42' | 12 | 4 | 8 | 0 | 0 | 0 | 0 | 2 |
| 24/4/98 | 9 | 40° 57.23' | 174° 03.42' | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 24/4/98 | 9 | 40° 57.23' | 174° 03.42' | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 26/5/98 | 10 | 40° 58.03' | 174° 01.01' | 3 | 0 | 3 | 0 | 0 | 0 | 0 | 0 |
| 26/5/98 | 10 | 40° 58.03' | 174° 01.01' | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 26/5/98 | 10 | 40° 58.03' | 174° 01.01' | 18 | 15 | 3 | 0 | 0 | 0 | 0 | 0 |
| 27/5/98 | 11 | 40° 58.64' | 173° 59.40' | 9 | 6 | 3 | 0 | 0 | 0 | 0 | 0 |
| 27/5/98 | 11 | 40° 58.64' | 173° 59.40' | 4 | 1 | 3 | 0 | 0 | 0 | 0 | 0 |
| 27/5/98 | 11 | 40° 58.64' | 173° 59.40' | 7 | 5 | 2 | 0 | 0 | 1 | 1 | 0 |
| 27/5/98 | 12 | 40° 59.19' | 173° 59.32' | 5 | 2 | 3 | 0 | 0 | 0 | 0 | 0 |
| 27/5/98 | 12 | 40° 59.19' | 173° 59.32' | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27/5/98 | 12 | 40° 59.19' | 173° 59.32' | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 5/8/98 | 13 | 40° 53.89' | 173° 57.47' | 20 | 14 | 6 | 0 | 0 | 0 | 0 | 0 |
| 5/8/98 | 13 | 40° 53.89' | 173° 57.47' | 9 | 4 | 5 | 0 | 0 | 0 | 0 | 0 |
| 5/8/98 | 13 | 40° 53.89' | 173° 57.47' | 7 | 6 | 1 | 0 | 0 | 0 | 0 | 0 |
| 5/8/98 | 14 | 40° 54.29' | 173° 57.13' | 10 | 3 | 7 | 0 | 0 | 0 | 0 | 0 |
| 5/8/98 | 14 | 40° 54.29' | 173° 57.13' | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| 5/8/98 | 14 | 40° 54.29' | 173° 57.13' | 7 | 0 | 7 | 0 | 0 | 0 | 0 | 0 |
| 5/8/98 | 15 | 40° 54.68' | 173° 56.75' | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5/8/98 | 15 | 40° 54.68' | 173° 56.75' | 12 | 5 | 7 | 0 | 0 | 0 | 0 | 0 |
| 5/8/98 | 15 | 40° 54.68' | 173° 56.75' | 4 | 3 | 1 | 0 | 0 | 0 | 0 | 0 |

| Date | Site | Latitude (S) | Longitude (E) | BCO Total | BCO male | BCO female | Conger | Octopus | Leatherjacket | Spotty | Carpet shark |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/8/98 | 16 | 40° 58.59’ | 173° 50.47’ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6/8/98 | 16 | 40° 58.59’ | 173° 50.47’ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6/8/98 | 16 | 40° 58.59’ | 173° 50.47’ | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 6/8/98 | 17 | 40° 57.68’ | 173° 50.42’ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6/8/98 | 17 | 40° 57.68’ | 173° 50.42’ | 6 | 3 | 3 | 0 | 0 | 0 | 0 | 0 |
| 6/8/98 | 17 | 40° 57.68’ | 173° 50.42’ | 6 | 0 | 6 | 0 | 0 | 0 | 0 | 0 |
| 6/8/98 | 18 | 40° 57.16’ | 173° 50.72’ | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6/8/98 | 18 | 40° 57.16’ | 173° 50.72’ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6/8/98 | 18 | 40° 57.16’ | 173° 50.72’ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7/8/98 | 19 | 40° 53.29’ | 173° 58.62’ | 4 | 2 | 2 | 0 | 0 | 1 | 0 | 0 |
| 7/8/98 | 19 | 40° 53.29’ | 173° 58.62’ | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7/8/98 | 19 | 40° 53.29’ | 173° 58.62’ | 16 | 11 | 5 | 0 | 0 | 0 | 0 | 0 |
| 7/8/98 | 20 | 40° 54.26’ | 173° 58.60’ | 12 | 10 | 2 | 0 | 0 | 0 | 0 | 0 |
| 7/8/98 | 20 | 40° 54.26’ | 173° 58.60’ | 4 | 2 | 2 | 0 | 0 | 0 | 0 | 0 |
| 7/8/98 | 20 | 40° 54.26’ | 173° 58.60’ | 4 | 3 | 1 | 0 | 0 | 0 | 0 | 0 |
| 7/8/98 | 21 | 40° 54.49’ | 173° 59.26’ | 15 | 2 | 13 | 0 | 0 | 0 | 0 | 0 |
| 7/8/98 | 21 | 40° 54.49’ | 173° 59.26’ | 10 | 4 | 6 | 0 | 0 | 0 | 0 | 0 |
| 7/8/98 | 21 | 40° 54.49’ | 173° 59.26’ | 6 | 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13/8/98 | 22 | 40° 57.78’ | 173° 52.59 | 15 | 6 | 9 | 0 | 0 | 3 | 0 | 0 |
| 13/8/98 | 22 | 40° 57.78’ | 173° 52.59 | 17 | 3 | 14 | 0 | 0 | 0 | 0 | 0 |
| 13/8/98 | 22 | 40° 57.78’ | 173° 52.59 | 11 | 2 | 9 | 0 | 0 | 0 | 0 | 0 |
| 13/8/98 | 23 | 40° 57.26’ | 173° 53.10 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 13/8/98 | 23 | 40° 57.26’ | 173° 53.10 | 8 | 5 | 3 | 0 | 0 | 0 | 0 | 0 |
| 13/8/98 | 23 | 40° 57.26’ | 173° 53.10 | 5 | 0 | 5 | 0 | 0 | 0 | 0 | 0 |
| 13/8/98 | 24 | 40° 57.10’ | 173° 54.07’ | 16 | 10 | 6 | 0 | 0 | 1 | 0 | 0 |
| 13/8/98 | 24 | 40° 57.10’ | 173° 54.07’ | 10 | 5 | 5 | 0 | 0 | 0 | 0 | 0 |
| 13/8/98 | 24 | 40° 57.10’ | 173° 54.07’ | 16 | 7 | 9 | 0 | 0 | 0 | 0 | 0 |

Table 4: Mean (s.e.) numbers of fish caught in pots during the main part of the survey. See Figure 1 for location of sample sites, and Tables 1 and 3 for other details

| Area | Locality | Site | Blue cod | Octopus | Carpet shark | Conger eel | Spotty | Leather-jacket |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1.3 (0.9) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| 1 | 1 | 2 | 2.0 (1.5) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| 1 | 1 | 3 | 3.3 (1.5) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| 1 | 2 | 4 | 7.3 (3.5) | 0.3 (0.3) | 0 (0) | 0 (0) | 1.0 (1.0) | 0 (0) |
| 1 | 2 | 5 | 2.3 (1.5) | 0 (0) | 0 (0) | 1.0 (0) | 0 (0) | 0.3 (0.3) |
| 1 | 2 | 6 | 5.0 (2.5) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| 1 | 3 | 7 | 9.3 (0.9) | 0 (0) | 0.3 (0.3) | 0 (0) | 0 (0) | 0 (0) |
| 1 | 3 | 8 | 9.3 (3.2) | 0 (0) | 0.3 (0.3) | 0 (0) | 0 (0) | 0 (0) |
| 1 | 3 | 9 | 4.0 (4.0) | 0 (0) | 0.7 (0.7) | 0.7 (0.3) | 0 (0) | 0 (0) |
| 1 | 4 | 10 | 7.3 (5.4) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| 1 | 4 | 11 | 6.0 (1.0) | 0 (0) | 0 (0) | 0 (0) | 0.3 (0.3) | 0.3 (0.3) |
| 1 | 4 | 12 | 2.3 (1.5) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| 2 | 1 | 13 | 12.0 (4.0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| 2 | 1 | 14 | 6.3 (2.3) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| 2 | 1 | 15 | 5.3 (3.5) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| 2 | 2 | 16 | 0.7 (0.7) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| 2 | 2 | 17 | 4.0 (2.0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| 2 | 2 | 18 | 0.3 (0.3) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| 2 | 3 | 19 | 7.0 (4.6) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0.3 (0.3) |
| 2 | 3 | 20 | 6.7 (2.7) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| 2 | 3 | 21 | 10.3 (2.6) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| 2 | 4 | 22 | 14.3 (1.8) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 1.0 (1.0) |
| 2 | 4 | 23 | 4.7 (2.0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| 2 | 4 | 24 | 14.0 (2.0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0.3 (0.3) |

Table 5: Comparison of sex ratios obtained by potting and spearing, pooled across all 4 sites

| | Female | Male | Total |
|---|---|---|---|
| Potting | 70 | 45 | 115 |
| Spearing | 54 | 39 | 93 |
| Total | 124 | 84 | 208 |

Table 6: Area fished calculations for the 24 sites from the main study. Area fished is calculated as pot mean / transect mean (Miller 1975), and has nominal units of 120 $m^2$ (i.e. transects). Adjusted pot means have pots containing congers excluded; all pots at site5 contained congers, and hence an adjusted area fished cannot be calculated

| Area | Locality | Site | Transect mean (no. per 120 $m^2$) | Pot mean (unadjusted for congers) (no. per pot) | Area fished (number of 120 $m^2$ units) (unadjusted) | Pot mean (adjusted for congers) | Area fished (adjusted) |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 0.00 | 1.33 | . | 1.33 | . |
| 1 | 1 | 2 | 0.33 | 2.00 | 6.00 | 2.00 | 6.00 |
| 1 | 1 | 3 | 0.58 | 3.33 | 5.71 | 3.33 | 5.71 |
| 1 | 2 | 4 | 5.33 | 7.33 | 1.38 | 7.33 | 1.37 |
| 1 | 2 | 5 | 6.17 | 2.33 | 0.38 | . | . |
| 1 | 2 | 6 | 18.00 | 5.00 | 0.28 | 5.00 | 0.28 |
| 1 | 3 | 7 | 6.00 | 9.33 | 1.56 | 9.33 | 1.56 |
| 1 | 3 | 8 | 6.83 | 9.33 | 1.37 | 9.33 | 1.37 |
| 1 | 3 | 9 | 5.50 | 4.00 | 0.73 | 12.00 | 2.18 |
| 1 | 4 | 10 | 0.17 | 7.33 | 44.00 | 7.33 | 43.98 |
| 1 | 4 | 11 | 1.42 | 6.67 | 4.71 | 6.00 | 4.24 |
| 1 | 4 | 12 | 1.50 | 2.33 | 1.56 | 2.33 | 1.55 |
| 2 | 1 | 13 | 3.58 | 12.00 | 3.35 | 12.00 | 3.35 |
| 2 | 1 | 14 | 8.08 | 6.33 | 0.78 | 6.33 | 0.78 |
| 2 | 1 | 15 | 9.42 | 5.33 | 0.57 | 5.33 | 0.57 |
| 2 | 2 | 16 | 0.25 | 0.67 | 2.67 | 0.67 | 2.68 |
| 2 | 2 | 17 | 0.67 | 4.00 | 6.00 | 4.00 | 6.00 |
| 2 | 2 | 18 | 1.08 | 0.33 | 0.31 | 0.33 | 0.30 |
| 2 | 3 | 19 | 1.67 | 7.00 | 4.20 | 7.00 | 4.20 |
| 2 | 3 | 20 | 10.17 | 6.67 | 0.66 | 6.67 | 0.66 |
| 2 | 3 | 21 | 8.58 | 10.33 | 1.20 | 10.33 | 1.20 |
| 2 | 4 | 22 | 7.83 | 14.33 | 1.83 | 14.33 | 1.83 |
| 2 | 4 | 23 | 3.25 | 4.67 | 1.44 | 5.00 | 1.54 |
| 2 | 4 | 24 | 4.75 | 14.00 | 2.95 | 14.00 | 2.95 |

Table 7: Removal method of assessing area fished by pots. Table entries are the number of blue cod counted in each of the 14 10 m cells (strips of reef running across shore, and indicated by columns), on occasions before (Pre-*n*) and after (Post-*n*) blue cod were removed by pot fishing. Pots were placed between cells 7 and 8. Data are summed across replicate censuses in rows Pre-total and Post-total to provide maximal numbers for estimation. Total area fished was examined by comparing before and after fishing counts, for each cell, and for pairs of cells. These are given as Change 1 (for individual 10-m cells), and as Change 2 (with the outer 6 10-m cells on each side pooled in pairs to give 20-m cells)

**a. Site 1: D'Urville Island**

| | North | | | | | Census cells | | | | | | | South | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Census number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Total |
| Pre 1 | 4 | 5 | 0 | 1 | 0 | 1 | 2 | 3 | 1 | 2 | 0 | 0 | 3 | 4 | 26 |
| Pre 2 | 3 | 4 | 2 | 3 | 1 | 0 | 7 | 4 | 4 | 2 | 0 | 0 | 3 | 4 | 37 |
| Pre 3 | 3 | 3 | 1 | 1 | 2 | 5 | 10 | 8 | 1 | 0 | 1 | 7 | 10 | 3 | 55 |
| Pre 4 | 5 | 6 | 1 | 0 | 2 | 0 | 5 | 9 | 2 | 3 | 1 | 5 | 1 | 10 | 50 |
| Pre Total | 15 | 18 | 4 | 5 | 5 | 6 | 24 | 24 | 8 | 7 | 2 | 12 | 17 | 21 | 168 |
| 27 removed | | | | | | | | | | | | | | | |
| Post 1 | 2 | 7 | 2 | 2 | 0 | 1 | 3 | 9 | 1 | 0 | 4 | 0 | 3 | 4 | 38 |
| Post 2 | 7 | 4 | 1 | 0 | 1 | 5 | 4 | 2 | 3 | 1 | 1 | 6 | 6 | 4 | 45 |
| Post 3 | 3 | 9 | 4 | 0 | 5 | 4 | 2 | 10 | 4 | 1 | 4 | 5 | 7 | 4 | 62 |
| Post 4 | 1 | 4 | 1 | 1 | 0 | 2 | 3 | 2 | 2 | 1 | 0 | 4 | 6 | 7 | 34 |
| Post Total | 13 | 24 | 8 | 3 | 6 | 12 | 12 | 23 | 10 | 3 | 9 | 15 | 22 | 19 | 179 |
| | | | | | | | | | | | | | | | |
| Change 1 | -2 | +6 | +4 | -2 | +1 | +6 | -12 | -1 | +2 | -4 | +7 | +3 | +5 | -2 | |
| Change 2 | +4 | | +2 | | +7 | | -12 | -1 | -2 | | +10 | | +3 | | |

**b. Site 2: Clay Point**

| | South | | | | | Census cells | | | | | | | North | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Census number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Total |
| Pre 1 | 5 | 2 | 2 | 12 | 13 | 7 | 9 | 8 | 2 | 10 | 24 | 12 | 1 | 2 | 109 |
| Pre 2 | 4 | 4 | 2 | 13 | 6 | 8 | 18 | 12 | 2 | 4 | 11 | 2 | 3 | 0 | 89 |
| Pre 3 | 3 | 5 | 8 | 4 | 11 | 4 | 7 | 3 | 8 | 19 | 19 | 7 | 3 | 7 | 108 |
| Pre 4 | 4 | 3 | 3 | 4 | 7 | 4 | 4 | 8 | 3 | 5 | 9 | 8 | 3 | 4 | 71 |
| Pre Total | 16 | 14 | 15 | 33 | 37 | 23 | 38 | 31 | 15 | 38 | 63 | 29 | 10 | 13 | 375 |
| 73 removed | | | | | | | | | | | | | | | |
| Post 1 | 9 | 5 | 3 | 7 | 12 | 3 | 7 | 9 | 7 | 6 | 7 | 2 | 4 | 1 | 82 |
| Post 2 | 13 | 4 | 5 | 8 | 20 | 5 | 7 | 3 | 3 | 5 | 15 | 5 | 1 | 2 | 96 |
| Post 3 | 3 | 2 | 4 | 6 | 4 | 5 | 3 | 1 | 7 | 6 | 1 | 4 | 2 | 3 | 51 |
| Post 4 | 5 | 2 | 6 | 18 | 8 | 3 | 3 | 5 | 9 | 12 | 7 | 8 | 5 | 4 | 95 |
| Post Total | 30 | 13 | 18 | 39 | 44 | 16 | 20 | 18 | 26 | 29 | 30 | 19 | 12 | 10 | 324 |
| Change 1 | +14 | -1 | +3 | +6 | +7 | -7 | -18 | -13 | +11 | -9 | -33 | -10 | +2 | -3 | |
| Change 2 | +13 | | +9 | | 0 | | -18 | -13 | +2 | | -43 | | -1 | | |

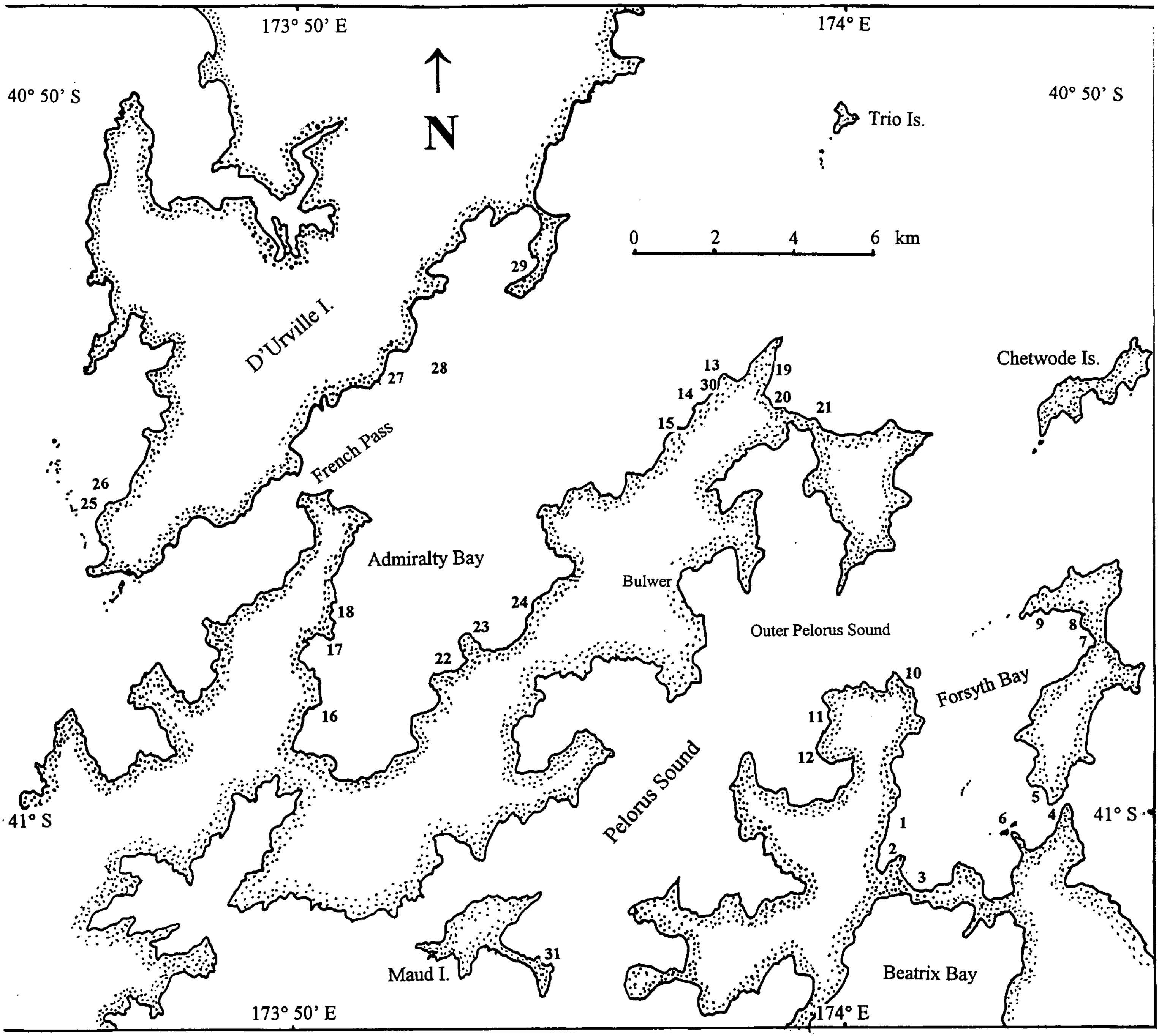



**Figure 1. Sites used in the study. Sites 1-12 = transect and pot sites for main study, Area 1; sites 13-24 = transect and pot sites for main study, Area 2; sites 25-28 = spearing vs potting comparison for sex ratios; sites 29, 30 = removal method for assessing range fished by pots; site 31 = location of pilot study to determine transect length and width.**

Figure 2. Mean numbers of blue cod per transect and times to sample 6 different transect sizes, in diver transect pilot study at Maud Island, December 1997. N=8 replicate transects per size.

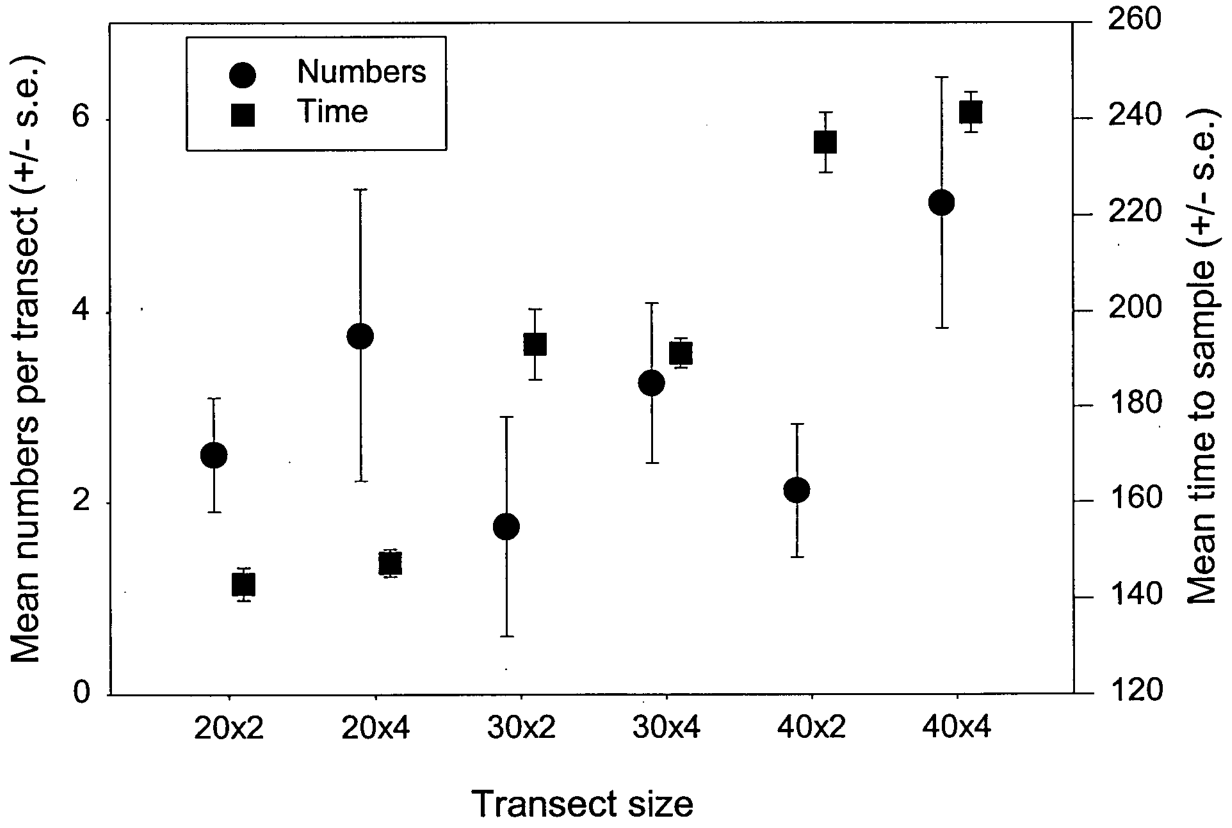


Figure 3. a. Sizes of blue cod counted in transects of 6 different sizes during pilot study at Maud Island, December 1997. N = 8 transects per size, n = number of fish counted. b. Sizes of blue cod counted in transects of 2 different widths during pilot study at Maud Island, December 1997. N= 24 replicate transects per width, n = number of fish counted.

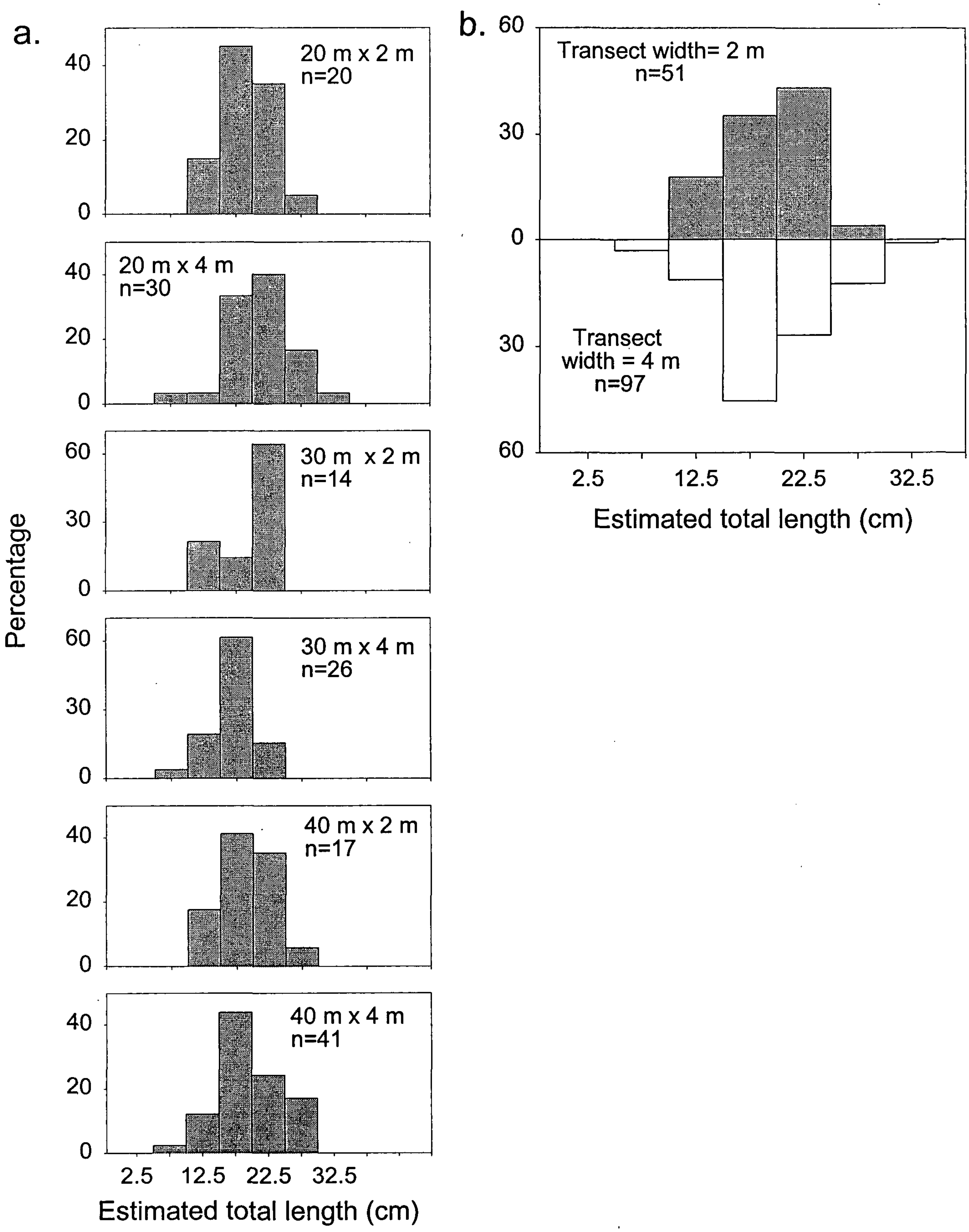


Figure 4. Density of blue cod in diver transects (numbers per 120 $m^2$, N=12 transects per site) and mean pot catch (numbers per pot, N=3 pots per site) for 4 sites in each combination of time (morning, afternoon) and tide (slack, running). The 16 sites were in the Outer Pelorus area.

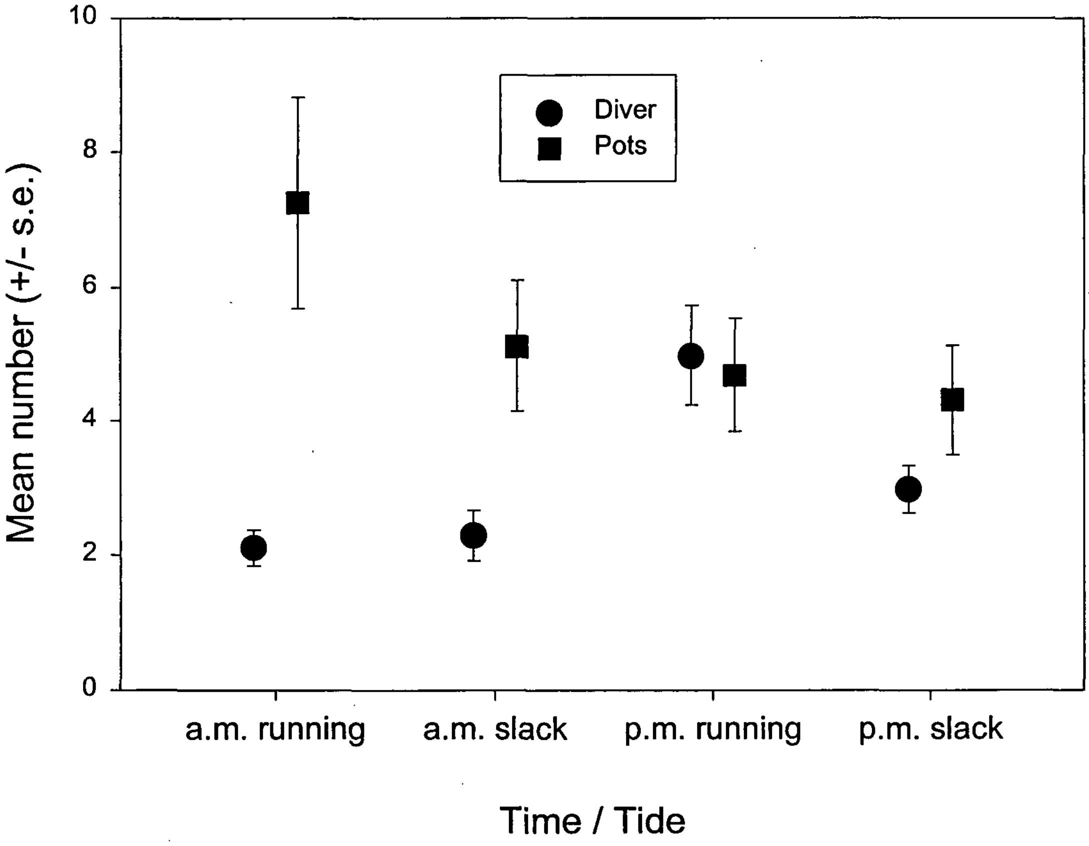


Figure 5. Blue cod size composition for 4 combinations of time (morning, afternoon) and tide (slack, running). There were 4 sites within each combination of time and tide, N = 12 transects per site, and 3 pots per site. Shaded bars are the sizes estimated by a diver, clear bars are sizes measured from pot captures. n = number of blue cod sampled.

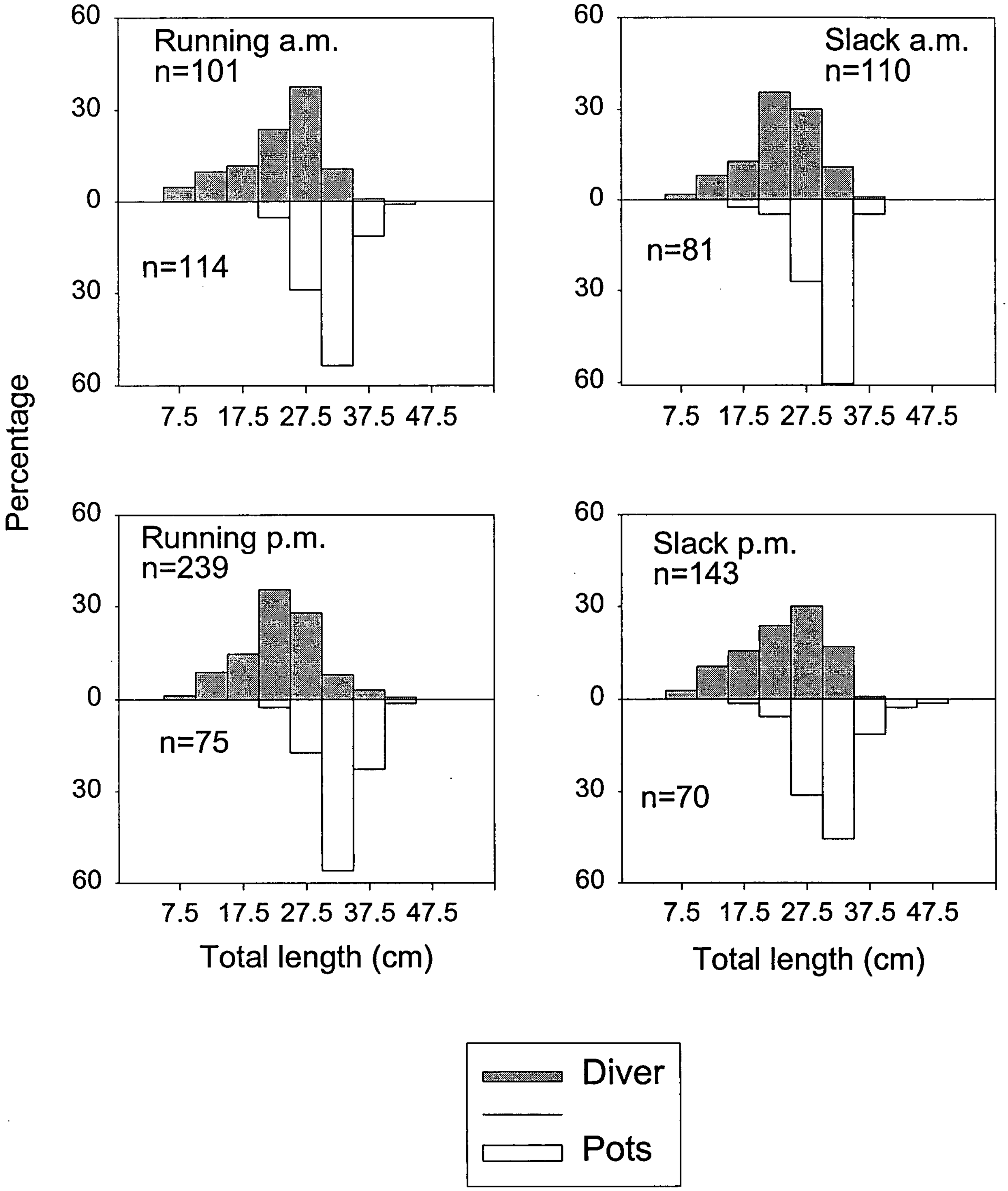


Figure 6. Mean catch from pots (+/- s.e., N=3) vs densities from diver transects (+/- s.e., N=12). Each symbol indicates a single site, numerical symbols are the areas in in which samples were taken. Data are presented (a) with and (b) without pots which contained congers included. Spearmans ρ is the rank correlation coefficient between mean pot catch and mean diver count.

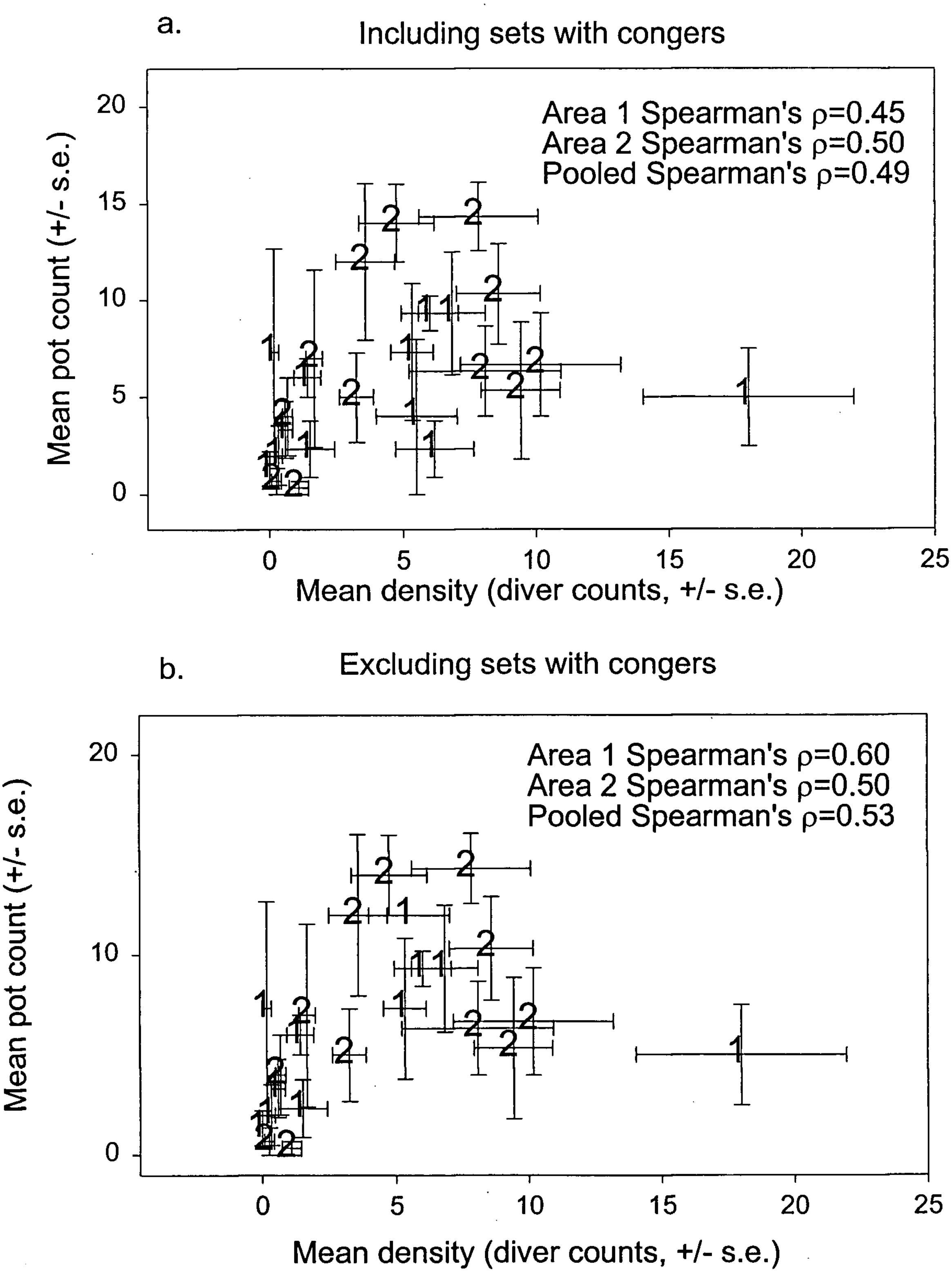


Figure 7. Percent frequency distributions for abundances of blue cod in diver counts (numbers per 120 m$^2$) (above x-axis) and pots (numbers per pot) (below x-axis).
N = number of transects or pot sets.

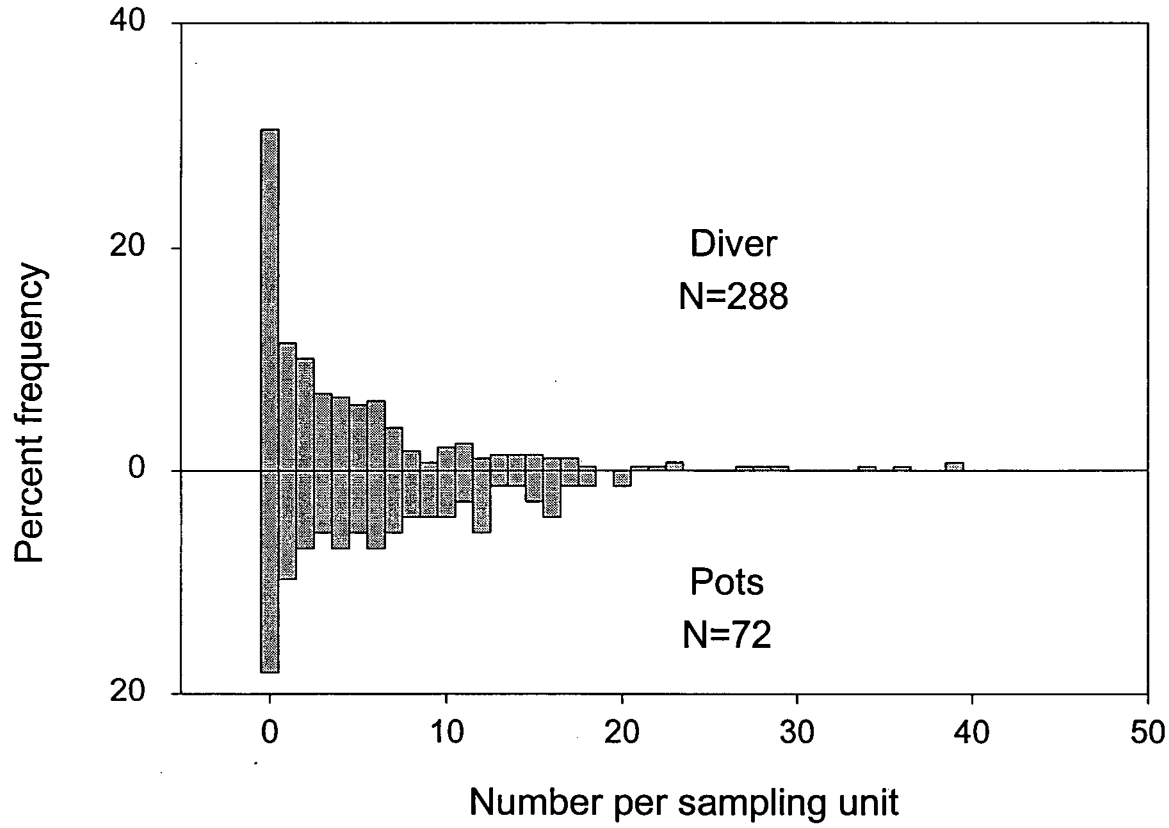
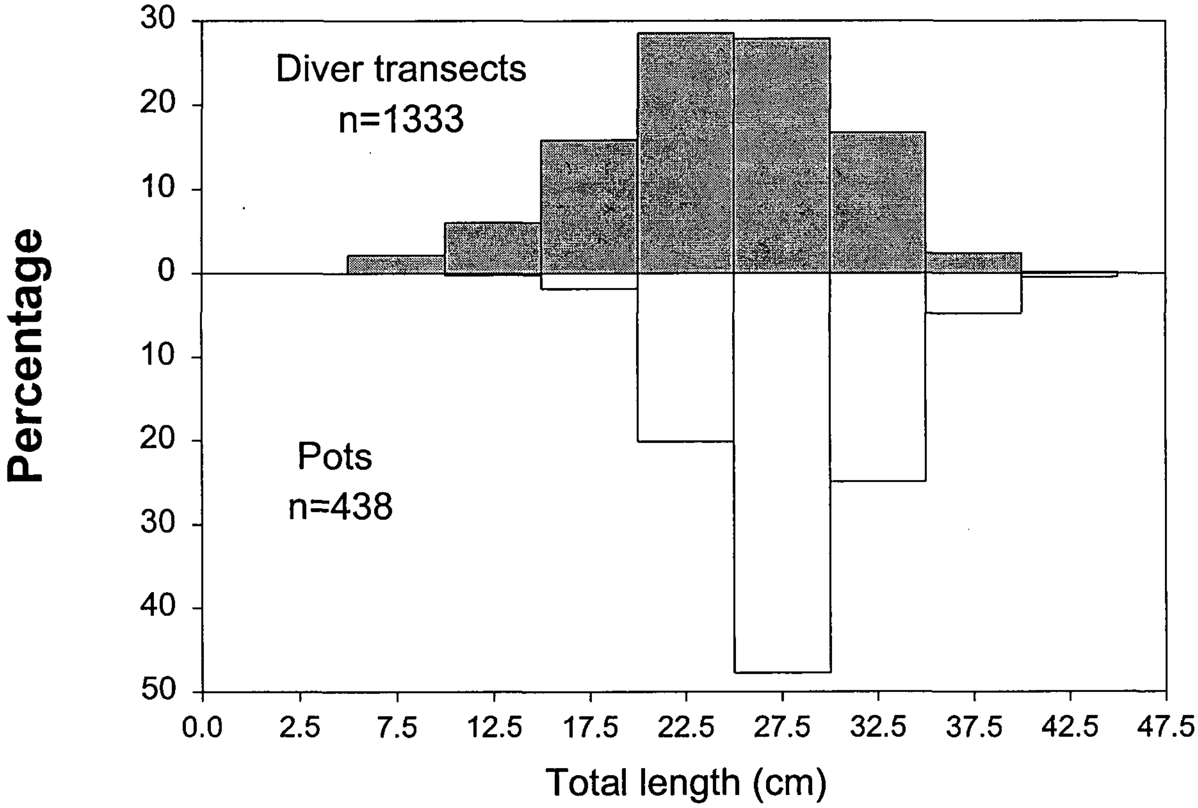


Figure 8. Size frequency distributions from diver transects (shaded bars), and pot catches (open bars). Data are pooled across all 24 sites used in the main study.
n=number of blue cod sampled.



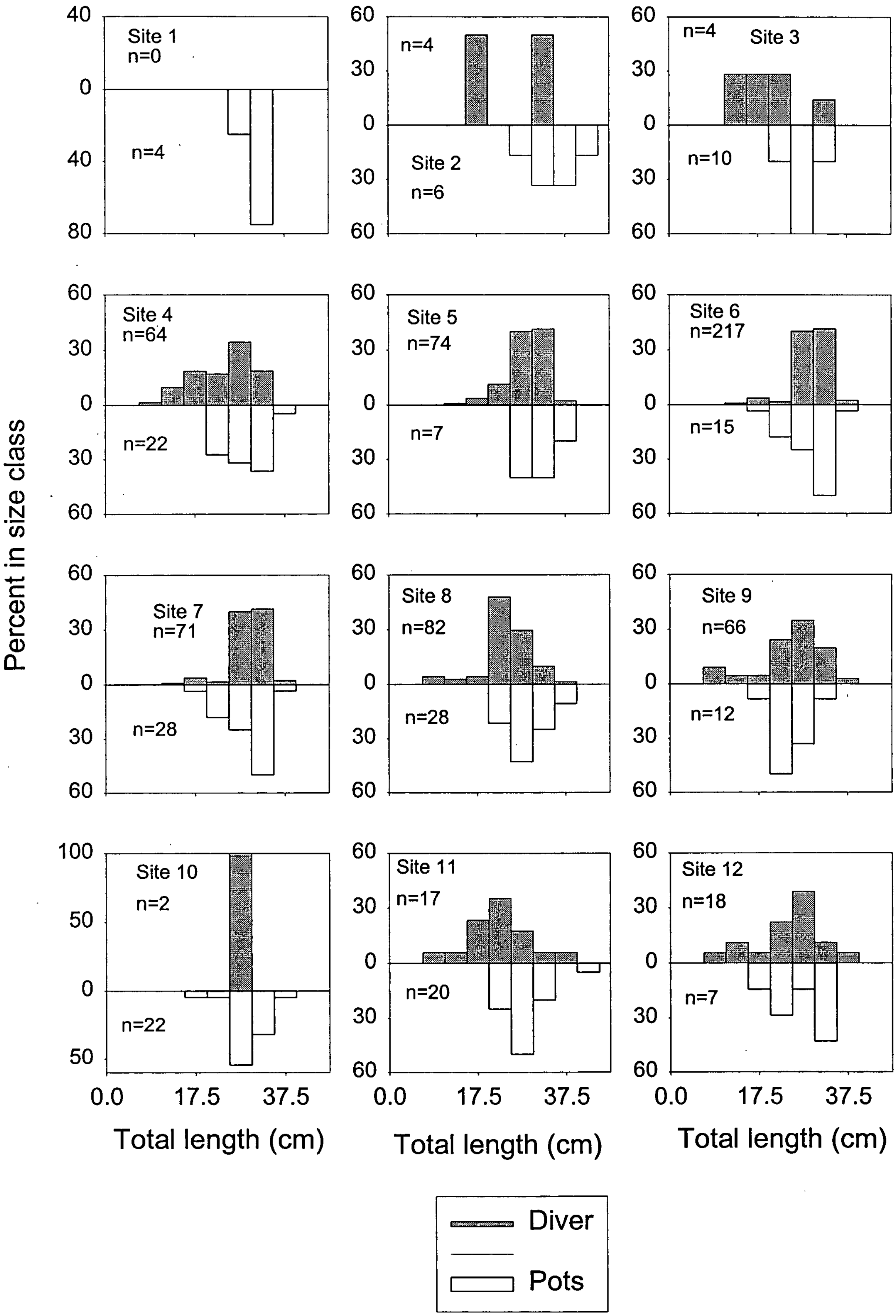



Figure 9. Size frequency distributions for blue cod from diver transects (shaded bars), and pot catches (open bars). Data are given for each of the 24 sites used in the main study. See Figure 1 for location of sampling sites. n = number of blue cod sampled.

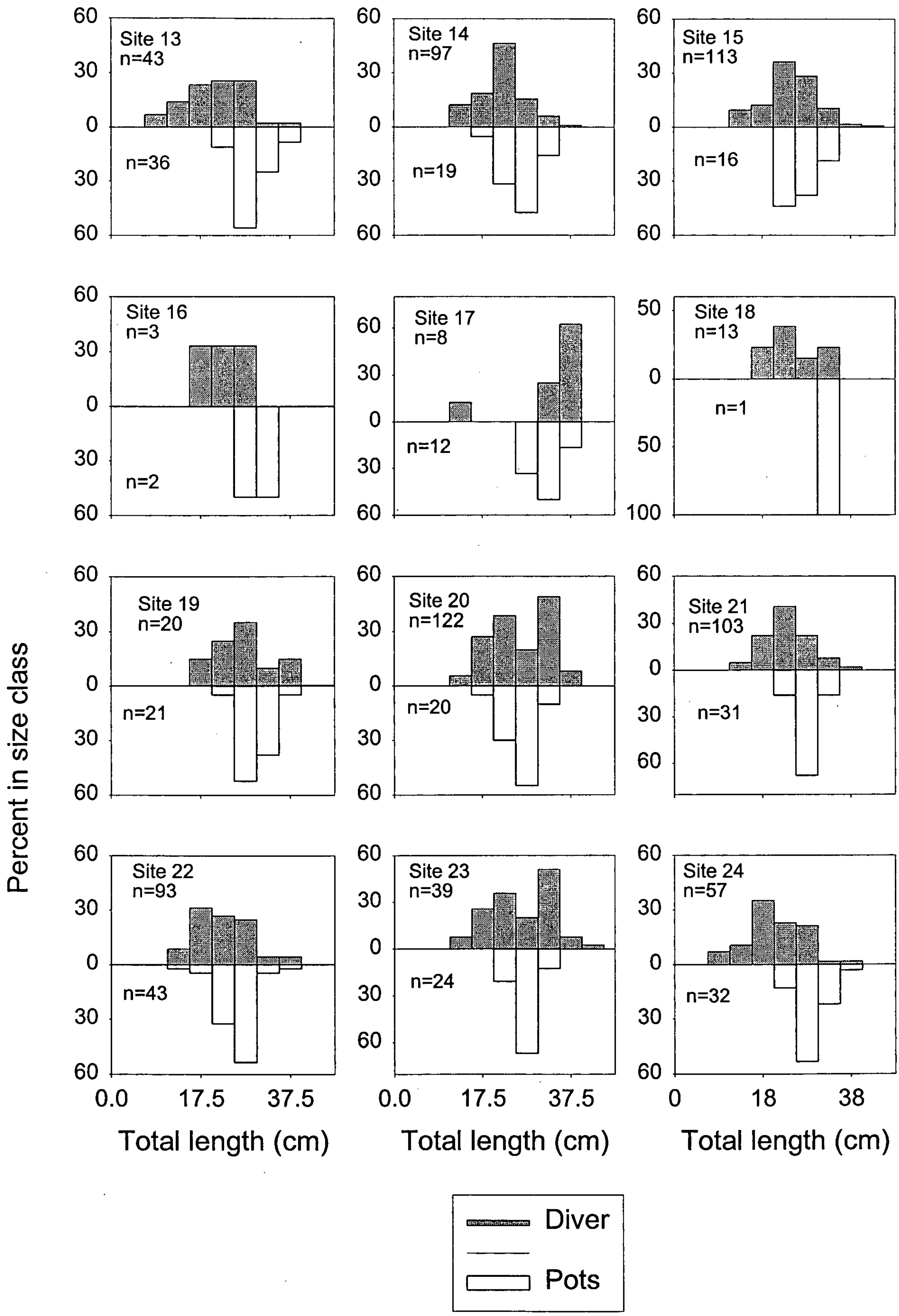



Figure 9 (continued). Size frequency distributions for blue cod from diver transects (shaded bars), and pot catches (open bars). Data are given for each of the 24 sites used in the main study. See Figure 1 for location of sampling sites. n = number of blue cod sampled.

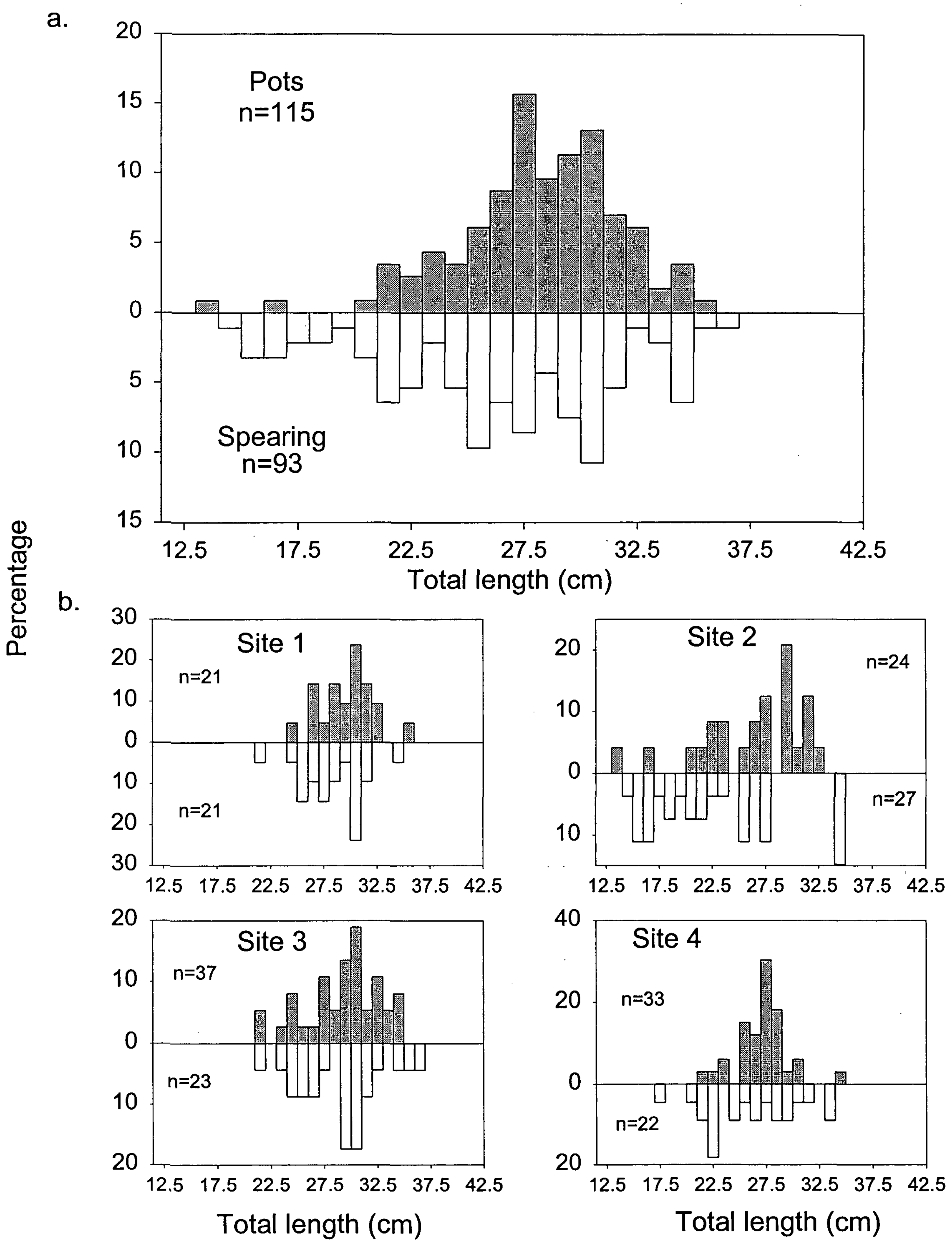



Figure 10. Sizes of blue cod sampled by spearing (open bars) and from pots (shaded bars). a. Pooled data. b. Data by site. n = number of blue cod sampled.