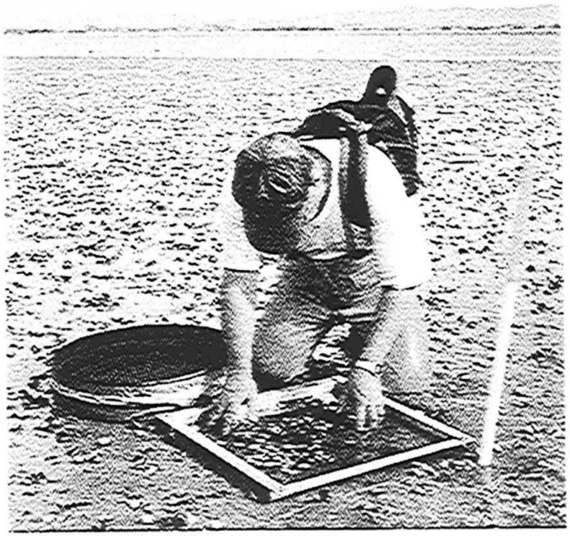
Shellfish harvesting in the Auckland metropolitan area

Bruce Hartill
Martin Cryer



NIWA Technical Report 96
ISSN 1174-2631
2000

Shellfish harvesting in the Auckland metropolitan area

Bruce Hartill
Martin Cryer

NIWA Technical Report 96
2000

Published by NIWA
Wellington
2000

Edited and produced by
Science Communication, NIWA,
PO Box 14-901, Wellington, New Zealand

ISSN 1174-2631
ISBN 0-478-23225-X

Citation:
Hartill, B. & Cryer, M. 2000: Shellfish harvesting in the Auckland metropolitan area.
NIWA Technical Report 96. 51 p.

Cover photograph by Derrick Parkinson

The National Institute of Water and Atmospheric Research
is New Zealand's leading provider
of atmospheric, marine,
and freshwater science

Visit NIWA's website at http://www.niwa.cri.nz

Contents

Page

Introduction 5
Objective 5
Methods
Estimation of annual harvest 5
Effort 6
Catch per unit effort 7
Harvest 8
Selectivity 9
Results
Effort 10
Harvest 11
Selectivity 12
Discussion 12
Acknowledgments 13
References 13

Introduction

There is a perception that intertidal shellfish communities in the Auckland metropolitan area are coming under increasing pressure from harvesting by amateur pickers. To date, however, there has been no attempt to quantify levels of shellfish harvesting in the Auckland region and to assess whether these levels of harvesting are sustainable. Drey & Hartill (1993) showed that most shellfish pickers take soft-shore bivalves such as pipi, cockles, and scallops, although a variety of other species such as Pacific oysters and crabs are taken. Intertidal shellfish population surveys conducted in the Auckland region since 1992 have found that cockle and pipi population abundances are variable but not necessarily declining (Morrison & Browne 1999). One notable exception is Cheltenham Beach, where the cockle population has steadily declined despite a harvest closure implemented in 1992. The reasons for this continued low abundance of cockles at this site are unclear.

Recreational shellfish harvests are currently managed through harvest closures for some beaches, and bag and size limits which are species-specific. The number of shellfish taken often exceeds amateur bag limits. Recreational harvests are estimated for three Auckland beaches (Figure 1) and the sustainability of cockle harvests from these beaches are assessed using population abundance and productivity estimates derived from another research programme (Morrison *et al.* 1999).

This project (REC9707) was carried out under contract to the Ministry of Fisheries.

Objective

To estimate the annual harvest of pipi, cockle, and tuatua, and characterise the overall pattern of harvest from 1 December 1997 to 30 November 1998 at the following four beaches within the Auckland metropolitan area: Cornwallis Beach, Mill Bay, Howick Beach, and Wenderholm.

Methods

Estimation of annual harvest

Sampling started at Cornwallis Beach and Mill Bay in December 1997. Sampling was not conducted at the two other beaches specified by the Ministry of Fisheries, Howick Beach and Wenderholm, because the previous year's intertidal shellfish abundance surveys indicated that shellfish densities were very low at these beaches, suggesting that these populations may already have been heavily exploited. After detailed consultation with the Ministry of Fisheries, surveying began at Beachlands in December 1997 and Okoromai Bay in January 1998. Initial results from Beachlands indicated that negligible shellfish harvesting was taking place and sampling ceased at the end of summer. Judging by patterns at other sites, it is unlikely that picking pressure increased during the winter.

A stratified random approach was used to estimate the annual harvest of key bivalve species and picking patterns of harvesters. The year was divided into four 3-month seasonal strata which were further divided into two day-type strata, weekday and weekend, the latter including public holidays. Within each of these eight season/day-type strata, eight sample days were randomly allocated, with each day being a sampling unit. Weekdays were sampled at a lower intensity, 32 sample days out of 248 in a year (13%), than weekend/public holidays, 32 out of 117 in a year (27%), with an overall sampling intensity of 17.5% given the 64 days sampled. Beaches were also divided into three to six spatial strata, depending on the area of accessible shoreline. The beaches and their spatial strata are shown in Figures 2 to 4.

The harvest, C, within each season/day-type/spatial stratum i was estimated by combining estimates of effort E, defined as the number of hours of shellfish picking, and catch per unit effort R, defined as the weight or number of shellfish picked per hour.

$$C_i = E_i \times R_i$$

Effort

Because intertidal shellfish harvesting usually takes place during low tide, interviewers sampled only 2 hours on either side of low tide, although sampling was conducted over a longer period for exceptionally low tides when shellfish harvesting was still possible. All of the interviewers lived within sight of the beaches surveyed and were therefore able to determine when picking was possible. Interviewers also remained on the beach later than 2 hours after low tide when picking was still taking place. It is still possible, however, that a small amount of picking may have occurred outside survey hours. When low tides occurred at both dawn and dusk, sampling was conducted during all daylight hours after 7 a.m. within 2 hours of either side of both tides. All daylight hours at least 2 hours on either side of low tide were therefore sampled on randomly predetermined days within each season/day-type strata (Table 1).

A method similar to that of an aerial-access survey (*sensu* Pollock *et al.* 1994) was used to estimate recreational fishing effort. Instantaneous counts of recreational fishers picking shellfish were made hourly by strategically placed ground-based observers. Counts of people actually involved in picking shellfish were taken at a pre-determined random time within each 1 hour block on either side of predicted low tide at each site.

Because days were selected at random with respect to season and day type, the influence of daily tide range was not considered in the original design. As most shellfish harvested are readily available at low tide on days when the tidal range is comparatively small, the influence of tidal range is thought to have little impact on the harvest of most species, except scallops. Spring low tides are often targeted by scallop pickers to increase the chances of detecting what is usually a subtidal species. The relatively low proportion of spring tides sampled during the year, coupled with the length of the scallop season, may have resulted in poor estimates of scallop picking effort and hence harvest. Caution should therefore be used when using these estimates of scallop harvest.

Hourly counts were made for each spatial stratum and mean daily picking effort was estimated for each season/day-type/spatial stratum as follows:

$$\hat{e}_i = \bar{I}_i \times T_i$$

where $\hat{e}_i$ is the mean daily picking effort, $\bar{I}_i$ is the average of the instantaneous count of harvesters for each day, and T_i is the number of hours in stratum i.

Because hourly counts of picking effort were made from strategic points along the shoreline, it was not possible to determine accurately the species associated with that effort. The mean daily picking effort was therefore apportioned by species using interview data. As part of the interviews discussed in the next section, pickers were asked what species were picked and how much picking effort was associated with each species picked. Within each season/day-type/spatial stratum the total hours spent picking a species was divided by the total hours spent picking all species:

$$P_{ij} = \frac{L_{ij}}{\sum_j L_{ij}}$$

where P_{ij} is the proportion of time spent picking species j, and L_{ij} is the total effort in season/day-type/spatial stratum i spent picking species j derived from all interviews. This proportion, which was calculated across all days sampled within the stratum, was applied to the random hourly counts of the number of pickers.

The picking effort from a given group of temporal strata, including for the whole period of interest for a given species j, was estimated using:

$$\hat{E}_{ij} = \sum_i \frac{\hat{e}_i P_{ij}}{\pi_i}$$

where $\hat{E}_{ij}$ is the estimated total fishing effort for a given species j, and π_i is the probability of the sample days occurring during a season/day-type stratum i.

Catch per unit effort

Between making counts of pickers, staff interviewed pickers to estimate catch rates for completed trips. Pickers leaving the beach were randomly selected and, with their permission, interviewed to determine the start and finish times of their picking, and to gather information on the harvest. Usually it was possible to interview all pickers. Random subsamples of about 20 of each species harvested were measured to the nearest millimetre with vernier calipers, and the aggregate of all of that species was weighed by the interviewer on a spring balance. While it is possible that the presence of the interviewers may have influenced pickers' behaviour, it is not possible to determine the extent of this influence. Interviewers approached pickers only as they left the beach and did not wear a uniform.

Some pickers refused to be interviewed. When the picker's harvest was not made available for measurement, the interviewer had no option but to estimate that harvest. The estimate was based on the interviewer's observation of that picker's harvesting activity and the apparent volume of shellfish that was carried off the beach. It was recognised that the harvesting habits of pickers who refused to be interviewed may not be the same as those of pickers who agreed to be interviewed. Before interviews were conducted, therefore, an estimate of the weight of each species harvested was made by the interviewer. For completed interviews, both estimated and actual weights were recorded, though for refused interviews, only the estimated harvest was available. For each interviewer, a relationship was calculated between estimated and actual weights, and these relationships were used to correct bias associated with estimated weights where the actual weight was not measured. It was necessary to use estimated weights for 9% of the interviews. Any bias due to poor estimation of harvest weights is therefore thought to have had little influence on shellfish harvest estimates.

During the study it was noted that the weight of a bag limit of scallops was usually about twice that expected using the length-weight relationship given in Table 2. Spring balances and their interpretation by interviewers were checked and found to give reliable estimates of weight. It was therefore concluded that high estimates of harvest weight were due to retention of water by scallops which were usually weighed soon after harvest. A sample of fifty harvests of scallops were counted, measured, and the weight of each harvest measured. The length frequencies of these samples were converted to weights and a relationship was calculated for converting the measured weight of a harvest to that predicted from the length frequency relationship (Figure 5).

predicted weight = 0.8144* measured weight - 0.1375

Water retention by cockles was also investigated, but there was no apparent change in sample weights 2 hours after picking.

Mean CPUE (for a given stratum and species *j*) was estimated using on-site interviews from completed trips using the same stratification as for effort. The ratio of mean harvest, in terms of weight and numbers, divided by mean effort, was used as an estimator of the average catch rate of completed trips:

$$\hat{R}_j = \frac{\sum_{t=1}^{n} c_{jt} / n}{\sum_{t=1}^{n} L_{jt} / n}$$

where L_t is the length and c_t the harvest from fishing trip *t*., *n* trips having been investigated.

Harvest

Harvest was estimated as the product of effort and catch per unit effort (CPUE: in this case mean harvest per hour)

$$\hat{C} = \hat{E} \times \hat{R}$$

where *C* is the total harvest (catch), *E* is the total fishing effort, and *R* is the average CPUE. Variances were estimated using a non-parametric bootstrapping technique. The original daily picking effort and individual picker catch and effort data were "resampled" (with replacement) and an estimate of harvest was calculated. These bootstraps were calculated 1000 times and their distribution was assumed to be representative of the error structure of the harvest estimate.

Harvest estimates and associated bootstrap variance estimates were calculated for each species for all season/day-type/spatial strata. When calculating variance estimates for combinations of season, day-type and or spatial strata, the individual bootstrap harvest estimates of each stratum were combined and variance was estimated from the distribution of their 1000 combined bootstrap harvest estimates.

In some instances, no CPUE data were available for a season/day-type/spatial stratum. When this occurred, the CPUE data from the alternative day-type were used from the relevant season/area stratum. When CPUE data were not available from the alternative day-type, data from neighbouring spatial strata were used from the relevant season/day-type strata. Any bias arising from the use of CPUE data from a corresponding stratum is unlikely to have much effect on final annual harvest estimates because the harvest estimates of the affected stratum are low due to low levels of picking effort.

Harvests were estimated in terms of the weight and numbers of shellfish taken. The numbers of shellfish harvested were estimated using the lengths of 20 shellfish randomly subsampled from each picker's harvest. These subsample lengths were converted to weights using length-weight relationships taken from other studies, or when no appropriate relationship was available, one was determined for this study (*see* Table 2, Figures 6 & 7). The ratio of the total harvest weight to that of the measured subsample was then used to scale up the length frequency distribution of the subsample. When it was not possible to measure a random subsample as part of an interview, the average weight of all other shellfish of that species measured at that beach was used to convert the picker's harvest weight to numbers caught.

Harvest estimates were calculated only for key species. At Cornwallis Beach and Mill Bay, cockle and pipi harvests were estimated because these two species were part of the study's original objective. Harvests of Pacific oysters and scallops were also estimated because these species made up a large proportion of the total shellfish harvest from these beaches. At Okoromai Bay, only cockle harvests were observed (Table 3).

Length frequency distributions were also calculated for the key species for each season at each beach. Length frequencies of the catch of individual groups of pickers interviewed were weighted according to the estimated number of shellfish taken by each group. These weighted length frequencies were then weighted again to reflect the relative predominance of the day type on which each group's harvesting took place. These length data were then combined and expressed as proportional length frequencies.

Selectivity

Picker selectivity was calculated for cockles at all three beaches using population length frequencies taken from Morrison *et al.* (1999) which were collected during the summer of 1997–98 and summer harvest length frequencies from this study. Length frequency data from Cornwallis Beach were taken only from spatial areas 4, 5, and 6 because these areas corresponded to the definition of Cornwallis beach used by Morrison *et al.* (1999).

The selectivity pattern of amateur pickers at each of the sites during summer was estimated by fitting a Richards selection curve to the proportions of cockles harvested from the population for each millimetre length class. The proportion of cockles harvested of each length class was calculated by dividing the estimated number of cockles harvested by the estimated number of cockles in the population of that length. As only a fraction of the total population was harvested for any given length class, it was necessary to scale up the estimated numbers harvested so that an average selectivity value of approximately 1.0 would be achieved for those length classes which were fully recruited. Inspection of the harvest and population length frequency distributions, and the error associated with each length class, suggested that length classes 35 to 40 mm were fully recruited (as they were of comparable relative strength and were reasonably estimated). Length based selectivity ratios were therefore calculated as follows:

$$r(i) = \frac{H_i \times \frac{\sum_{i=35}^{40} P_i}{\sum_{i=35}^{40} H_i}}{P_i}$$

where P_i is the estimated number of cockles in the population in length class i, H_i is the estimated number of cockles harvested in length class I, and $r(i)$ is the proportion of the population harvested at length class i. When cockles of a given length class were present in the harvest length frequency and absent in the population length frequency, a nominal selectivity of 1.0 was assigned to that length class.

A Richards selection curve was fitted to the length based selectivity ratios. The Richards selection curve is a generalisation of the logistic curve specified by two parameters a and b, with an asymmetry parameter, δ.

$$r(i) = \left(\frac{\exp(a + bi)}{1 + \exp(a + bi)} \right)^{1/\delta}$$

As Microsoft Excel© was unable to calculate the large negative exponents which can occur in the smaller length classes, it was necessary to constrain a to values greater than or equal to –700. There was very little difference between constrained and unconstrained Richards selection curves for those length classes for which Microsoft Excel© was able to calculate values.

Approximate confidence intervals were estimated using a non-parametric bootstrap technique. Both the population and harvest length frequency data were sampled with replacement and a Richards selection curve was fitted to the resulting length based selectivity ratios. The scaler used to adjust the estimated number of cockles harvested was calculated from the length frequencies of each bootstrap. Bootstrap estimates were calculated 1000 times and the 95% percentiles of each length class's bootstrap distribution were taken as the 95% confidence intervals for that length class.

Results

Effort

While many species were harvested at Cornwallis Beach and Mill Bay, only cockles were observed in Okoromai Bay harvests (*see* Table 3). Cockles, scallops, and Pacific oysters were the most commonly harvested species at Cornwallis Beach and Mill Bay. With the exception of pickers harvesting kina at Cornwallis Beach and horse mussels at Mill Bay, pickers generally spent an average of 1 hour gathering their harvest.

Picking effort varied at the beaches studied and appeared to take place throughout the low tide (Figure 8). Levels of picking effort did not appear to be influenced by the height at low tide (Figure 9).

Harvest

Cockles were the main species harvested from the three beaches by weight (Table 4) and numbers taken (Table 5) with sizeable harvests of Pacific oysters and scallops also taken from Cornwallis Beach and Mill Bay. The means of the bootstrap harvest estimates were usually within 5% of the analytical estimates of harvest, and bootstrap *c.v.*s were generally less than 0.20 for the main species harvested. The frequency distributions of 1000 bootstrap estimates of annual harvest for key species appear to be mostly normally distributed (Figures 10 and 11). When the level of picking effort, and hence harvest, was low, bootstrap estimates deviated mildly from normality with the left hand limb of the distribution truncated at 0 (*see* Mill Bay pipi, Figure 10).

Estimates of annual harvests of cockles at Cornwallis Beach and Okoromai Bay were similar to estimates of CAY given by Morrison *et al.* 1999 (Table 7). This is reflected in a comparison of reference fishing mortalities (Table 8). The annual harvest estimate of cockles at Cornwallis Beach given in Table 7 differs from that in Table 4 as the definition of Cornwallis Beach used in the intertidal resources survey (research programme AKI9701) corresponds to spatial areas 4, 5, and 6 in this study (*see* Figure 2).

Harvest estimates were also calculated by season and day type for each species (Appendices 1, 2, and 3). Lower levels of stratification sometimes resulted in mildly non-normal bootstrap frequency distributions. The confidence intervals given in the appendices are the bootstrap estimates associated with the 95% percentiles of proportional bootstrap frequencies. As mentioned previously, estimates of scallop harvest may not be reliable as the influence of tidal height was not considered in the experimental design.

Harvests of key species were seasonal, with the greatest harvests generally occurring in spring and summer and the lowest in autumn and winter (Figure 12). Scallops were picked steadily throughout the season and a small amount was harvested at Cornwallis Beach during the closed season. Annual weekend and weekday harvests of key shellfish species were similar at Cornwallis Beach and Mill Bay, although weekend harvesting is more concentrated because of the fewer days available (Figure 13). Cockle harvesting at Okoromai Bay appears to occur predominantly during the weekend. There were clear spatial patterns of harvesting at each beach (Figure 14). Differences between the spatial distribution of species harvests on each beach reflect the distributions of each population. Pacific oysters were mainly harvested from mudstone rocks found at the southern end of Cornwallis Beach at Puponga point and at the eastern end of Mill

Bay. The main scallop harvest was in areas 2, 3, and 4 on Cornwallis Beach where the greatest densities of scallops are exposed at low tides.

At Cornwallis Beach and Mill Bay there appear to be marked seasonal differences in the length frequencies of all species (Figures 15 to 22), probably partially because of the low numbers of shellfish measured. These differences are less marked when length frequencies with large sample sizes are compared. Only small pipi were observed in pickers' catches, with a mean shell length of 39.6 mm at Cornwallis Beach and 37.8 mm at Mill Bay. At Okoromai Bay, where only cockles are picked, sample sizes are larger and the seasonal length frequency distributions and their means are similar (Figure 23).

Selectivity

Richards selection curves were calculated for the Cornwallis Beach, Mill Bay, and Okoromai Bay cockle populations (Figures 25, 27 and 29, Table 6). These selectivity curves were then incorporated into a yield per recruit analysis as described by Morrison *et al.* (1999) to provide estimates of $F_{0.1}$ which were used to calculate estimates of yield ($CAY_{(F0.1)}$) using the Baranov catch equation (*see* Table 7). To demonstrate the sensitivity of estimates of yield calculated using the Baranov catch equation to different interpretations of recruited biomass, a variety of estimates was calculated (*see* Table 8). The interpretations of size at recruitment used were: size at 10% selectivity as defined by the Richards selectivity curve, size at 50% selectivity as defined by the Richards selectivity curve, selectivity as defined by the Richards selectivity curve applied to all length classes in the population, and size at maturity. Knife-edge selectivity was used for the calculation of $F_{0.1}$, recruited biomass, and CAY for the L_{10}, L_{50}, and size at maturity interpretations of recruited biomass.

Discussion

Any assessment of the sustainability of shellfish harvests estimated in this report is reliant on sound information on the yields that the populations can support. Cockle was the only species for which estimates of growth, natural mortality, and abundance were available. The criteria used to assess the recruited population being fished is, however, arbitrary. The cockle harvest at Cornwallis Beach was generally similar to the estimates of yield calculated. At Mill Bay, the estimate of annual cockle harvest appears to exceed all estimates of yield. Estimates of yield at Okoromai Bay are highly sensitive to the interpretation of recruited biomass used. These estimates of yield are based on a value of natural mortality which is thought to be poorly understood for cockles. All estimates of yield and any inferences on sustainability should, therefore, be treated with extreme caution.

Since this survey was completed, the daily bag limit for cockles in the Auckland metropolitan area has been reduced from 150 per person to 50. This could potentially have a dramatic impact on levels of harvesting in the Auckland area, although recognition of, and compliance with, this change in the bag limit by the public is likely to take some time.

Levels of pipi harvesting appear low, probably because the small size of shellfish available. Despite its specification in the objective, no tuatua were observed in pickers' harvests, nor have any been found in previous intertidal resource surveys at the beaches studied (Morrison *et al.* 1999). Tuatua are usually found subtidally on more exposed beaches.

The annual scallop harvest estimates presented in this report may not be reliable because the influence of spring, normal, and neap tides was not taken into account in the original experimental design. Because scallops are accessible only at extreme low tides, and the populations at Cornwallis Beach and Mill Bay are mostly subtidal, observed harvest levels are probably sustainable. It is not possible to assess the sustainability of Pacific oyster harvesting at Cornwallis and Mill Bay because there are no current estimates of biomass for these populations.

Acknowledgments

The authors wish to thank the interviewers, Sylvia Davies, Pam Goddard, Racheal Goddard, and Kelvin Marks, whose diligence ensured that the survey was carried out according to its design. Thanks are also due to David Fisher and the key punch operators for their prompt and efficient handling of the data. We are also grateful to William Eckard for his assistance with the Visual Basic programming of the non-parametric bootstrapping routines. The editorial review of this report by Mike Beardsell was, as always, much appreciated. Useful and constructive reviews of this and a previous report by Paul Breen were also very much appreciated. This study was funded through Ministry of Fisheries contract REC9707.

References

Cryer, M. 1997: Assessment of cockles on Snake Bank, Whangarei Harbour, for 1996. N.Z. Fisheries Assessment Research Document 97/2. 29 p. (Draft report held in NIWA library, Wellington.)

Cryer, M. & Parkinson, D.M. 1999: Dredge surveys and sampling of commercial landings in the Northland and Coromandel scallop fisheries, 1998. *NIWA Technical Report 69.* 63 p.

Drey, R. & Hartill, B. 1993: A qualitative survey of intertidal harvesting by amateur fishers in the Auckland metropolitan area. Northern Fisheries Region Internal Report No. 11. 22 p. (Draft report held at NIWA, Auckland.)

Hooker, S.H. 1995: Life history and demography of the pipi, *Paphies australis*, in northeastern New Zealand. Unpublished PhD thesis, University of Auckland, 230 p.

Morrison, M.A. & Browne, G. 1999: Intertidal shellfish population surveys in the Auckland region, 1998–99, and associated yield estimates. N.Z. Fisheries Assessment Research Document 99/43. 21 p. (Draft report held in NIWA library, Wellington.)

Morrison, M.A., Pawley, M., & Browne, G. 1999: Intertidal surveys of intertidal shellfish populations in the Auckland region, 1997–98. N.Z. Fisheries Assessment Research Document 99/25. 25 p. (Draft report held in NIWA library, Wellington.)

Pollock, K.H., Jones, C.M., & Brown, T.L. 1994: Angler survey methods and their application in fisheries management. *American Fisheries Society Special Publication No. 25.* 654 p.

Table 1: **Number of hours surveyed and number of pickers interviewed at Cornwallis Beach, Mill Bay, and Okoromai Bay by season and day type. In each season and day-type stratum, 8 days were surveyed**

Season	Day type	Number of hours surveyed	Number of pickers interviewed
Cornwallis beach			
Summer	Weekday	34	74
	Weekend	33	217
Autumn	Weekday	30	12
	Weekend	34	85
Winter	Weekday	29	40
	Weekend	31	84
Spring	Weekday	31	72
	Weekend	30	143
Mill Bay			
Summer	Weekday	36	57
	Weekend	35	204
Autumn	Weekday	30	20
	Weekend	38	86
Winter	Weekday	28	13
	Weekend	30	51
Spring	Weekday	32	28
	Weekend	32	141
Okoromai Bay			
Summer	Weekday	31	58
	Weekend	32	364
Autumn	Weekday	32	1
	Weekend	30	66
Winter	Weekday	31	11
	Weekend	32	148
Spring	Weekday	32	23
	Weekend	32	244

***Table 2*: Parameters used to derive weight from length measurements**

Weight = a (length)^b (weight in g, length in cm)

Species	a	b	Source
Cockle	0.00037	3.026	This report
Pacific oyster	0.04477	1.525	This report
Pipi	0.00003	3.315	Hooker (1995)
Scallop	0.00042	2.662	Cryer & Parkinson (1999)

***Table 3*: Number of pickers interviewed, average hours picked and average harvest of species picked at Cornwallis Beach, Mill Bay and Okoromai Bay**

Species	No. of pickers interviewed	Average hours of picking effort	Average harvest per picker (kg)
Cornwallis Beach			
Cockle (*Austrovenus stutchburyi*)	263	1.13	2.17
Scallop (*Pecten novaezelandiae*)	285	0.84	1.95
Pacific oyster (*Crassostrea gigas*)	125	1.27	2.29
Green lipped mussel (*Perna canaliculus*)	22	1.28	5.20
Cats eye (*Turbo smaragdus*)	28	1.20	2.53
Horse mussel (*Atrina zelandica*)	38	1.21	1.32
Mixed species	18	1.13	2.33
Kina (*Evechinus chloroticus*)	3	1.75	8.27
Whelk species (*Cominella* spp.)	25	0.96	0.86
Crab species	7	0.98	0.28
Pipi (*Paphies australis*)	6	1.11	0.25
Mill Bay			
Cockle (*Austrovenus stutchburyi*)	371	1.25	3.09
Pacific oyster (*Crassostrea gigas*)	182	1.32	3.14
Scallop (*Pecten novaezelandiae*)	62	1.27	1.46
Horse mussel (*Atrina zelandica*)	12	2.30	0.91
Whelk species *Cominella* spp.)	13	1.00	0.65
Pipi (*Paphies australis*)	4	0.88	0.88
Mixed species	3	0.94	0.50
Okoromai Bay			
Cockle (*Austrovenus stutchburyi*)	915	1.03	3.37

Table 4: **Estimated weight of key species harvested annually at Cornwallis Beach, Mill Bay, and Okoromai Bay**

Species	Estimated harvest (kg)	Bootstrap mean	Bootstrap c.v.
Cornwallis Beach			
Cockles	3 269	3 280	0.13
Pacific oysters	1 820	1 820	0.16
Pipi	6	6	0.27
Scallops	3 518	3 528	0.13
Mill Bay			
Cockles	4 983	4 970	0.14
Pacific oysters	2 851	2 853	0.15
Pipi	22	23	0.54
Scallops	385	399	0.17
Okoromai Bay			
Cockles	17 192	17 056	0.14

Table 5: **Estimated number of key species harvested annually at Cornwallis Beach, Mill Bay, and Okoromai Bay**

Species	Estimated harvest (N)	Bootstrap mean	Bootstrap c.v.
Cornwallis Beach			
Cockles	283 721	282 095	0.14
Pacific oysters	60 022	59 978	0.16
Pipi	980	977	0.26
Scallops	30 359	30 468	0.12
Mill Bay			
Cockles	497 401	497 984	0.14
Pacific oysters	102 422	101 179	0.15
Pipi	3 916	3 899	0.57
Scallops	3 345	3 448	0.16
Okoromai Bay			
Cockles	1 069 625	1 074 226	0.13

***Table 6*: Parameters of Richards selectivity curves fitted to cockle harvest and population length frequencies from Cornwallis Beach (spatial areas 4, 5, & 6 only), Mill Bay, and Okoromai Bay**

Beach	a	b	δ
Cornwallis Beach	-699.9	23.9	55.8
Mill Bay	-700.0	20.0	108.0
Okoromai Bay	-297.3	8.2	25.1

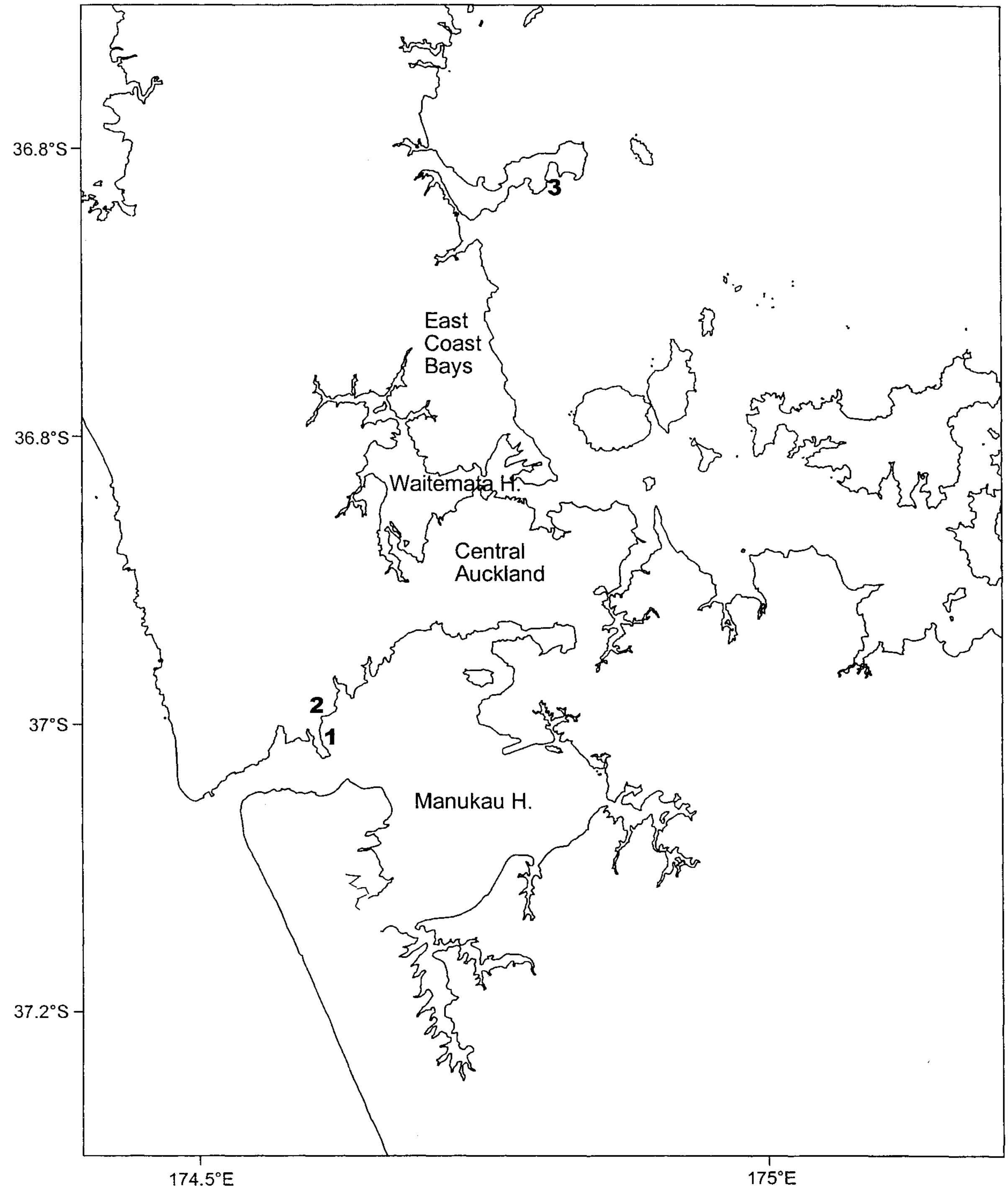
***Table 7*: A comparison of reference fishing mortality estimates for cockles for a given level of natural mortality at Cornwallis Beach (spatial areas 4, 5 & 6 only), Mill Bay and Okoromai Bay. Estimates of recruited biomass are taken from Morrison *et al.* (1999), Estimates of $F_{0.1}$ and F_{max} are calculated by applying Richard's selectivity curves to a yield per recruit analysis based on the method given in Morrison *et al.* (1999), M is taken from Cryer (1997) and F_{est} is calculated using the Baranov catch equation given the estimated harvest**

Beach	Biomass (t)	M	$F_{0.1}$	F_{max}	$CAY_{(F0.1)}$ (t)	Estimated harvest (t) ± 95% C.I.	F_{est}
Cornwallis Beach	9.7	0.30	0.31	0.50	2.2	2.88 ± 0.80	0.41
Mill Bay	13.2	0.30	0.29	0.47	2.9	5.0 ± 1.39	0.56
Okoromai Bay	91.3	0.30	0.35	0.62	23.3	17.2 ± 4.70	0.24

Table 8: **Comparison of estimates of $CAY_{(F0.1)}$ calculated using the Baranov catch equation given different interpretations of recruited biomass for cockles at Cornwallis Beach (spatial areas 4, 5, & 6 only), Mill Bay, and Okoromai Bay. Estimates of Biomass and $F_{0.1}$ are calculated using either knife-edge or Richard's selectivity curves based on the method given by Morrison *et al.* (1999); M is taken from Cryer (1997)**

Interpretation of recruitment*	Recruitment length range	Biomass (t)	$F_{0.1}$	$CAY_{(F0.1)}$ (t)
Cornwallis Beach				
L_{10}	24–42	14.4	0.28	3.2
L_{50}	28–42	11.4	0.33	2.8
Selectivity	4–42	11.5	0.31	2.6
Size at maturity	18–42	15.0	0.24	2.8
Estimated harvest	20–42			2.9
Mill Bay				
L_{10}	23–45	16.1	0.25	3.1
L_{50}	32–45	2.2	0.31	0.5
Selectivity	4–45	5.3	0.30	1.2
Size at maturity	18–45	19.3	0.21	3.4
Estimated harvest	18–45			5.0
Okoromai Bay				
L_{10}	30–50	127.6	0.32	30.8
L_{50}	35–50	21.6	0.40	6.1
Selectivity	4–50	47.8	0.35	12.2
Size at maturity	18–50	243.8	0.22	42.5
Estimated harvest	24-50			17.2

*L_{10} = knife-edge recruitment at the size relating to 10% selectivity as determined from the Richards selectivity curve; L_{50} = knife edge recruitment at the size relating to 50% selectivity as determined from the Richards selectivity curve; Selectivity = Richards selectivity curve applied to all length classes in the population; Size at maturity = knife edge recruitment at the size at which cockles first become sexually mature (18 mm).



Beaches

1 Cornwallis Beach
2 Mill Bay
3 Okoromai Bay

Figure 1: **Beach locations in the greater Auckland metropolitan area.**

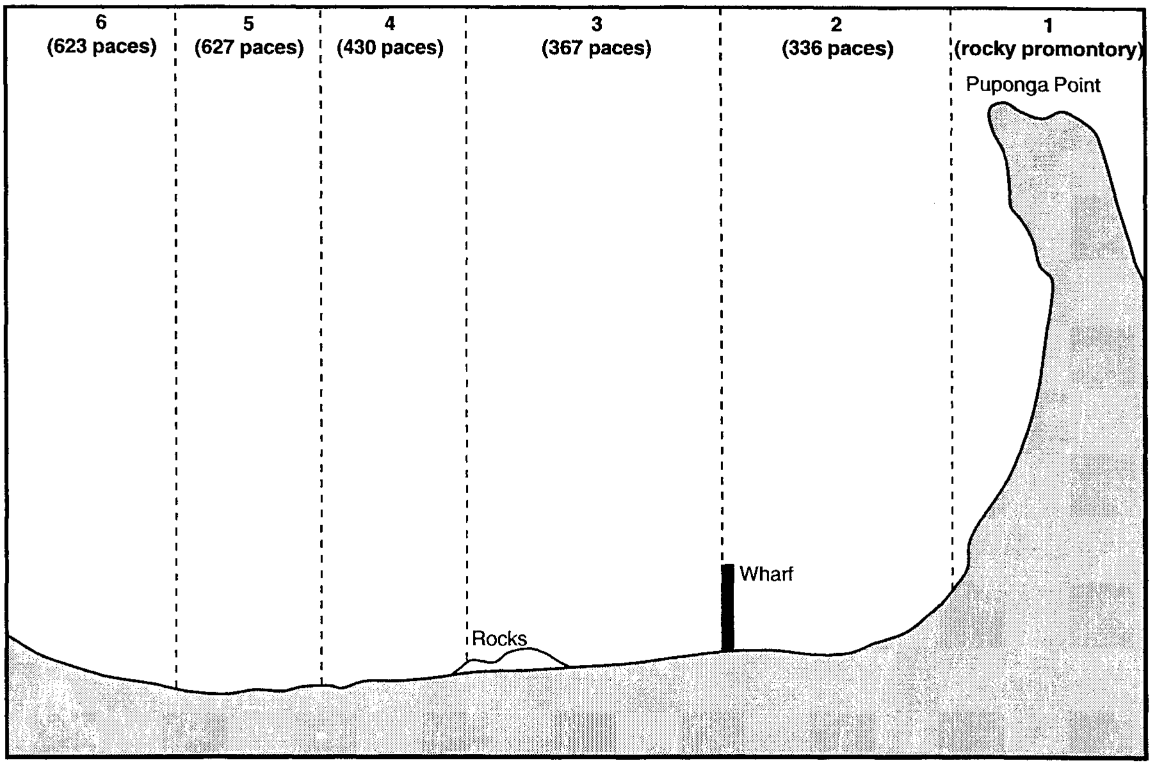


Figure 2: **Cornwallis Beach: dashed lines denote boundaries between spatial strata.**

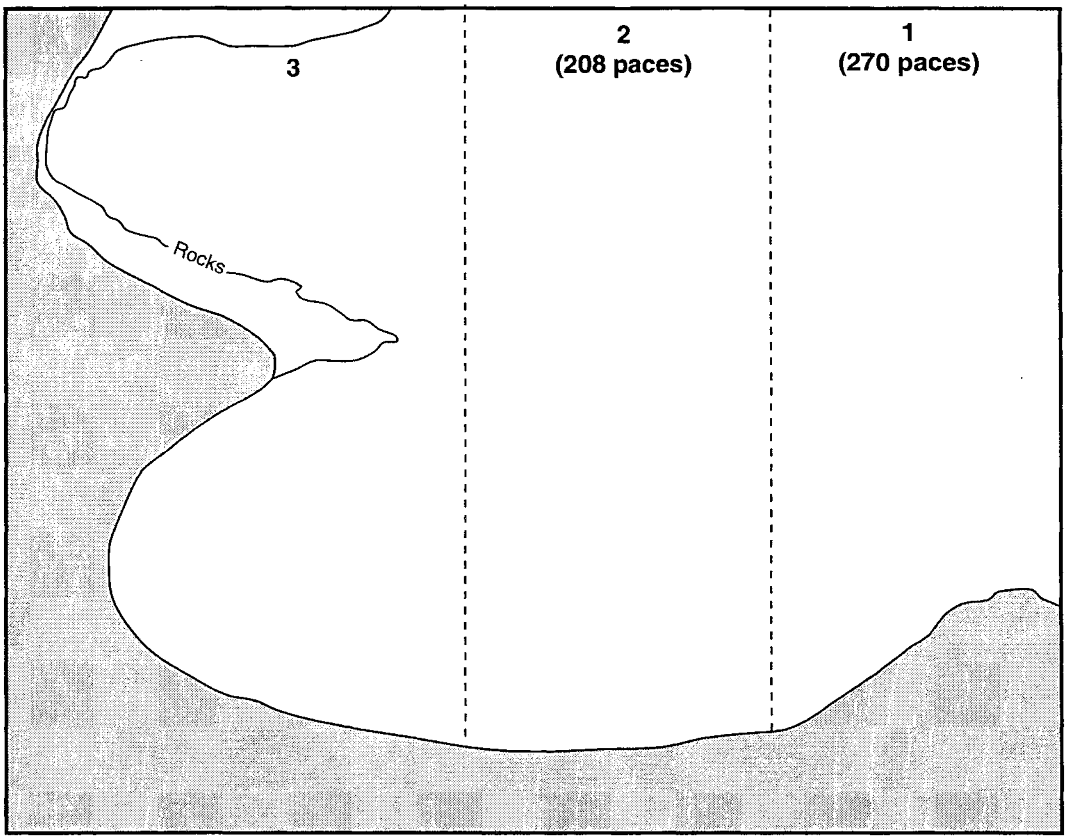


Figure 3: **Mill Bay: dashed lines denote boundaries between spatial strata.**

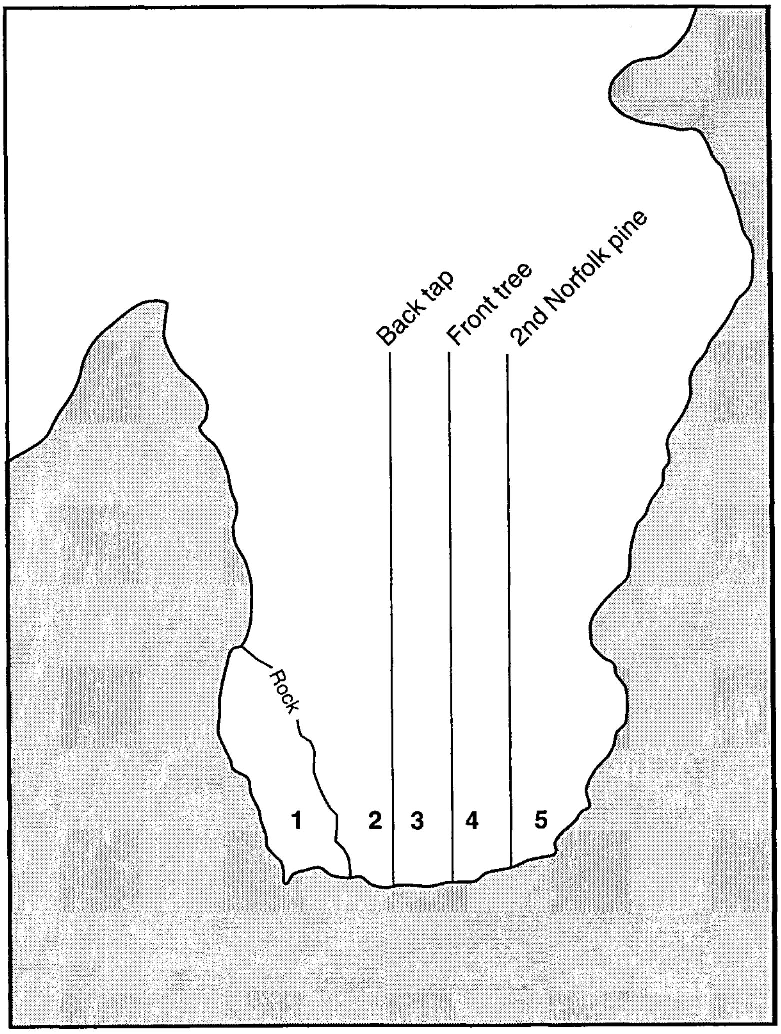


***Figure 4*: Okoromai Bay: dashed lines denote boundaries between spatial strata.**

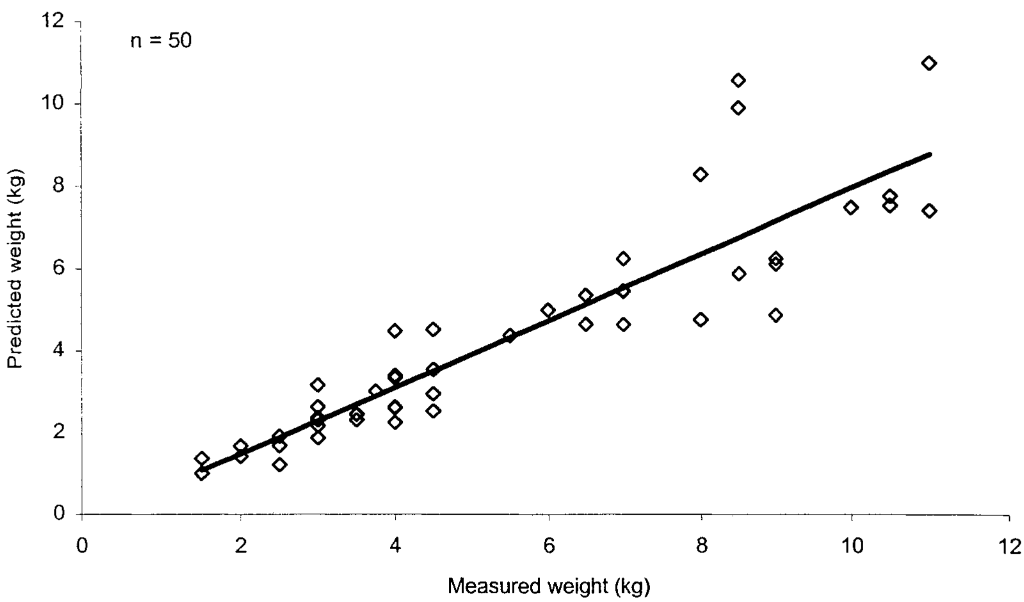


Figure 5 : **Relationship between measured weights of scallop catches and those predicted from the length frequency composition of the catch using a length weight relationship.**

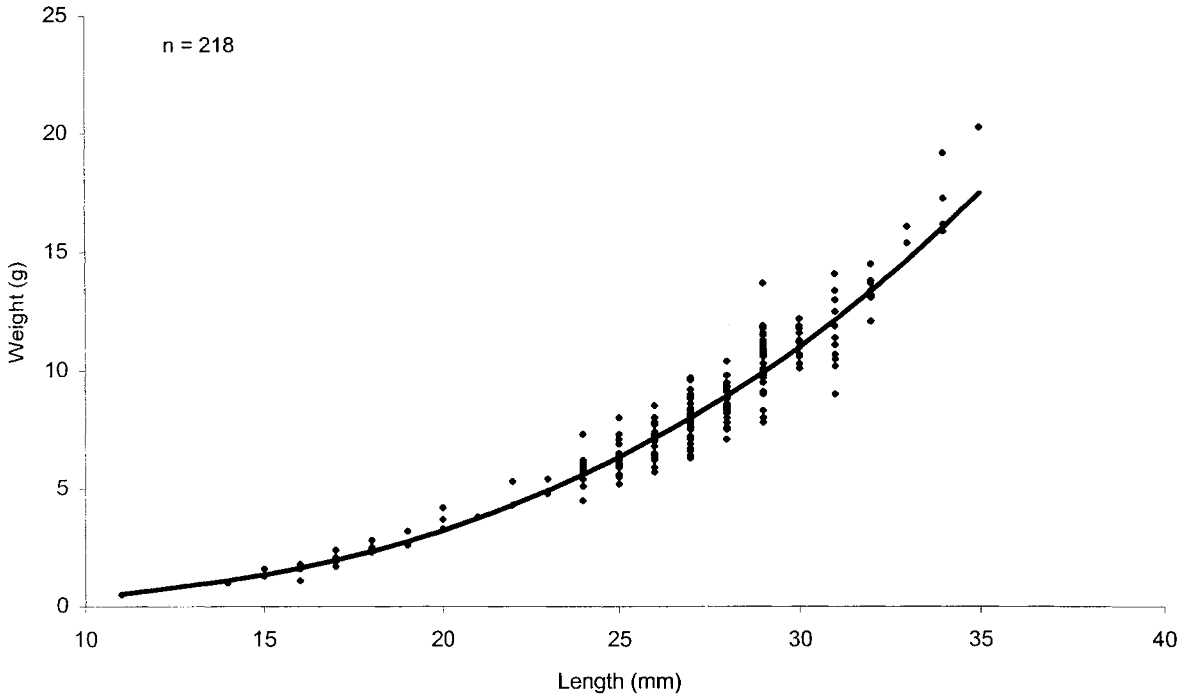


Figure 6: **Length weight relationship of cockles picked from Cornwallis Beach and Mill Bay.**

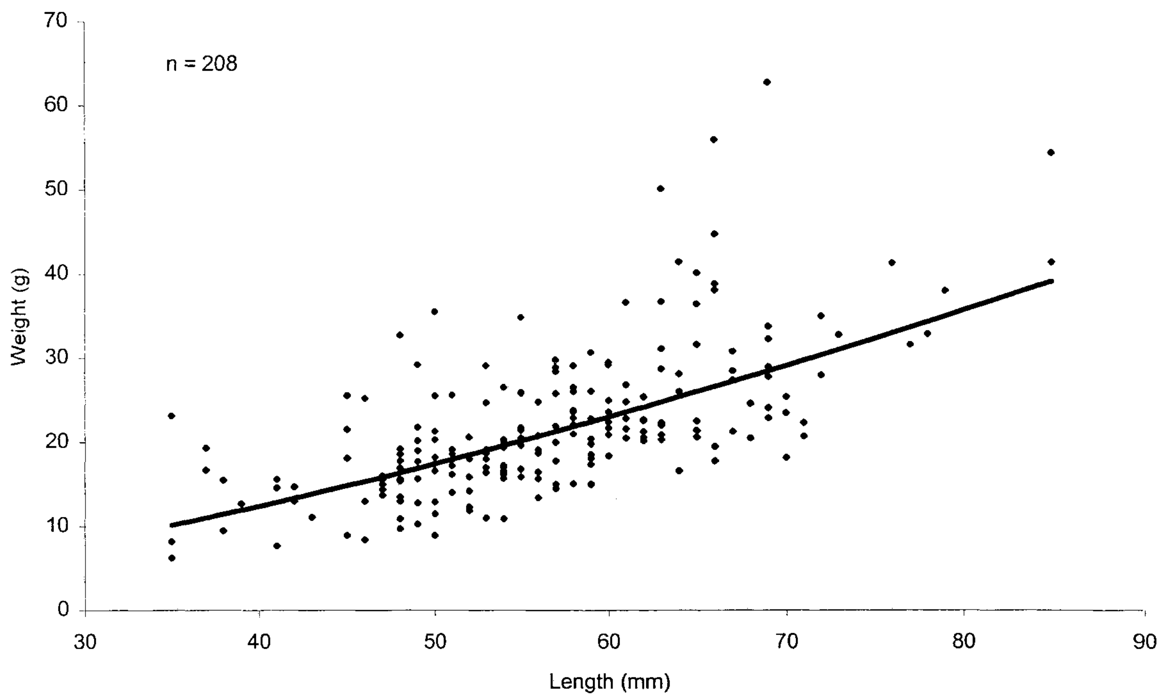


Figure 7: **Length weight relationship of Pacific oysters picked from Mill Bay.**

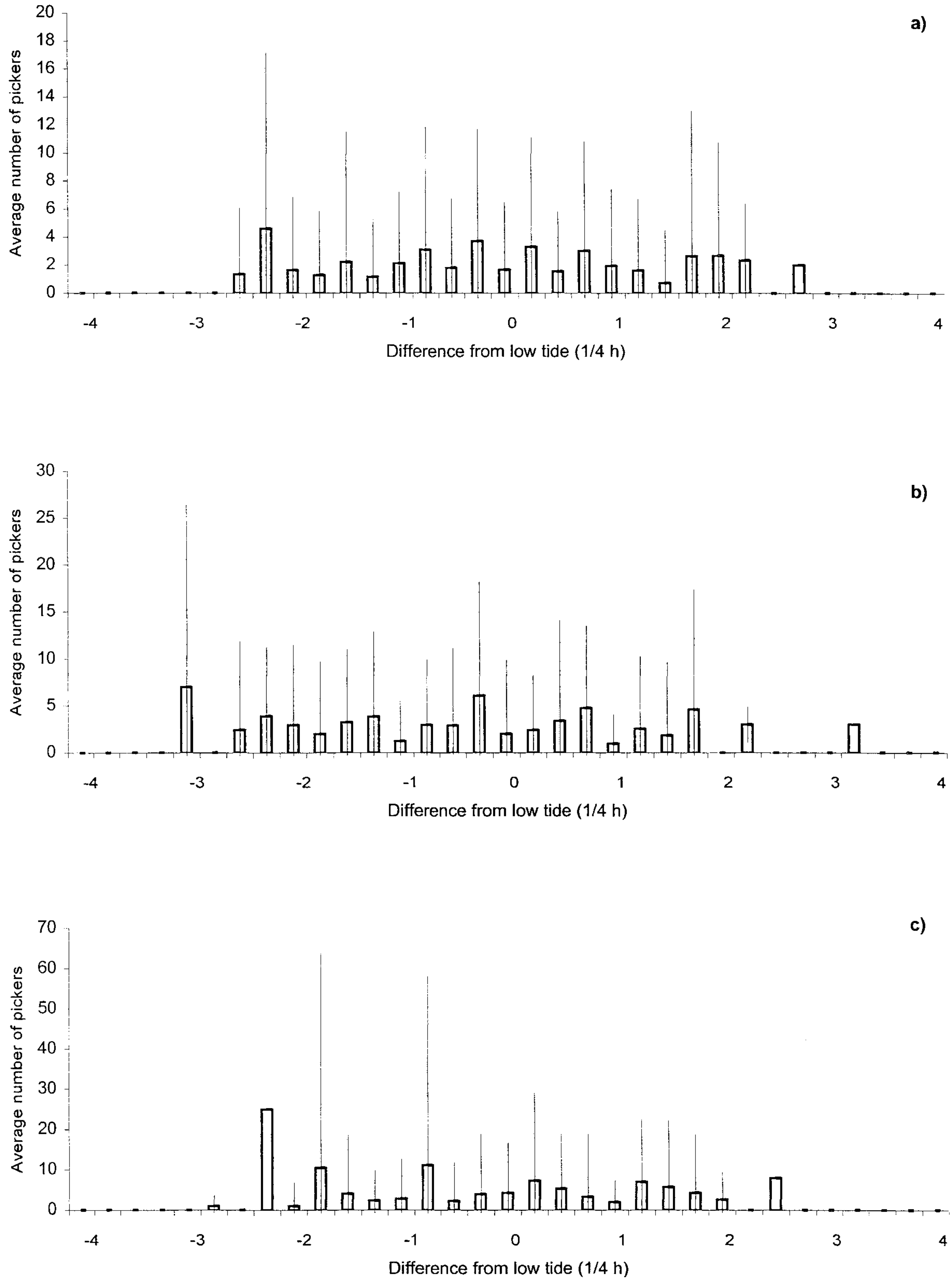


***Figure 8*: Average number of pickers observed at instantaneous hourly counts taken randomly relative to low tide at a) Cornwallis Beach, b) Mill Bay, and c) Okoromai Bay. Error bars denote 95% confidence intervals.**

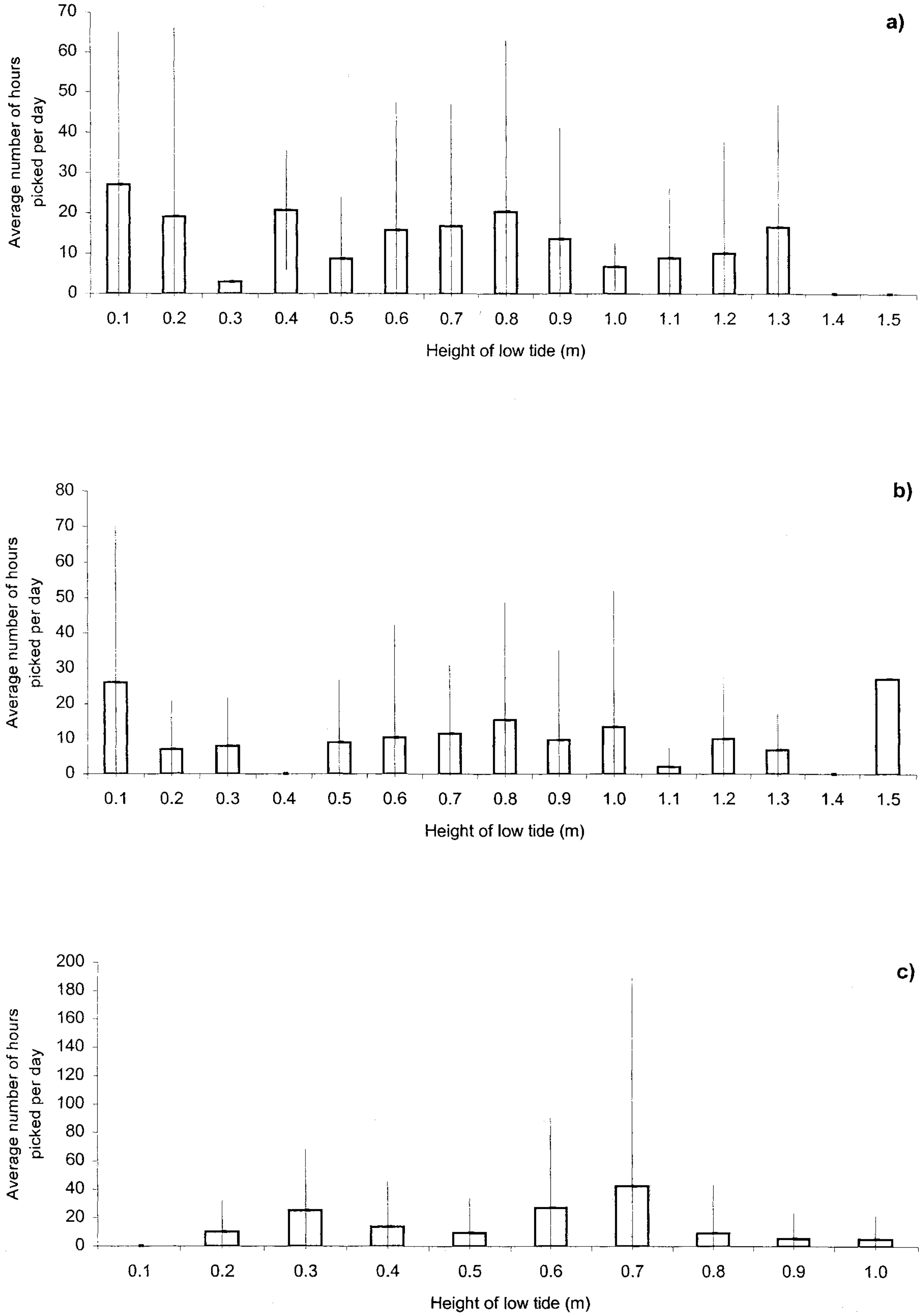


***Figure 9*: Average daily number of hours picked relative to daily low tide height at a) Cornwallis Beach, b) Mill Bay, and c) Okoromai Bay. Error bars denote 95% confidence intervals.**

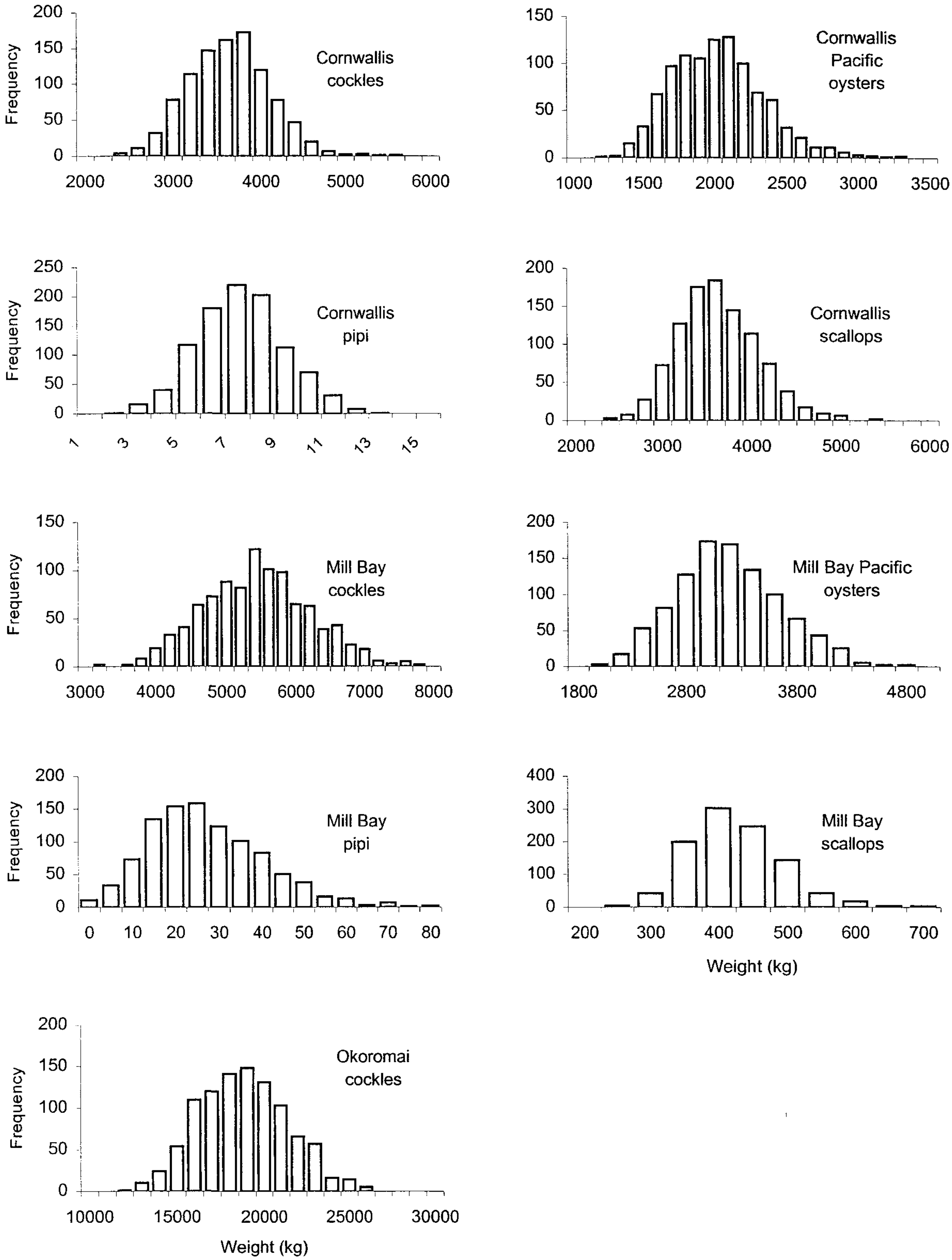


***Figure 10*: Frequency distributions of the 1000 bootstraps used to determine the variance of estimates of the harvest (kg) of the key species picked at Cornwallis Beach, Mill Bay, and Okoromai Bay.**

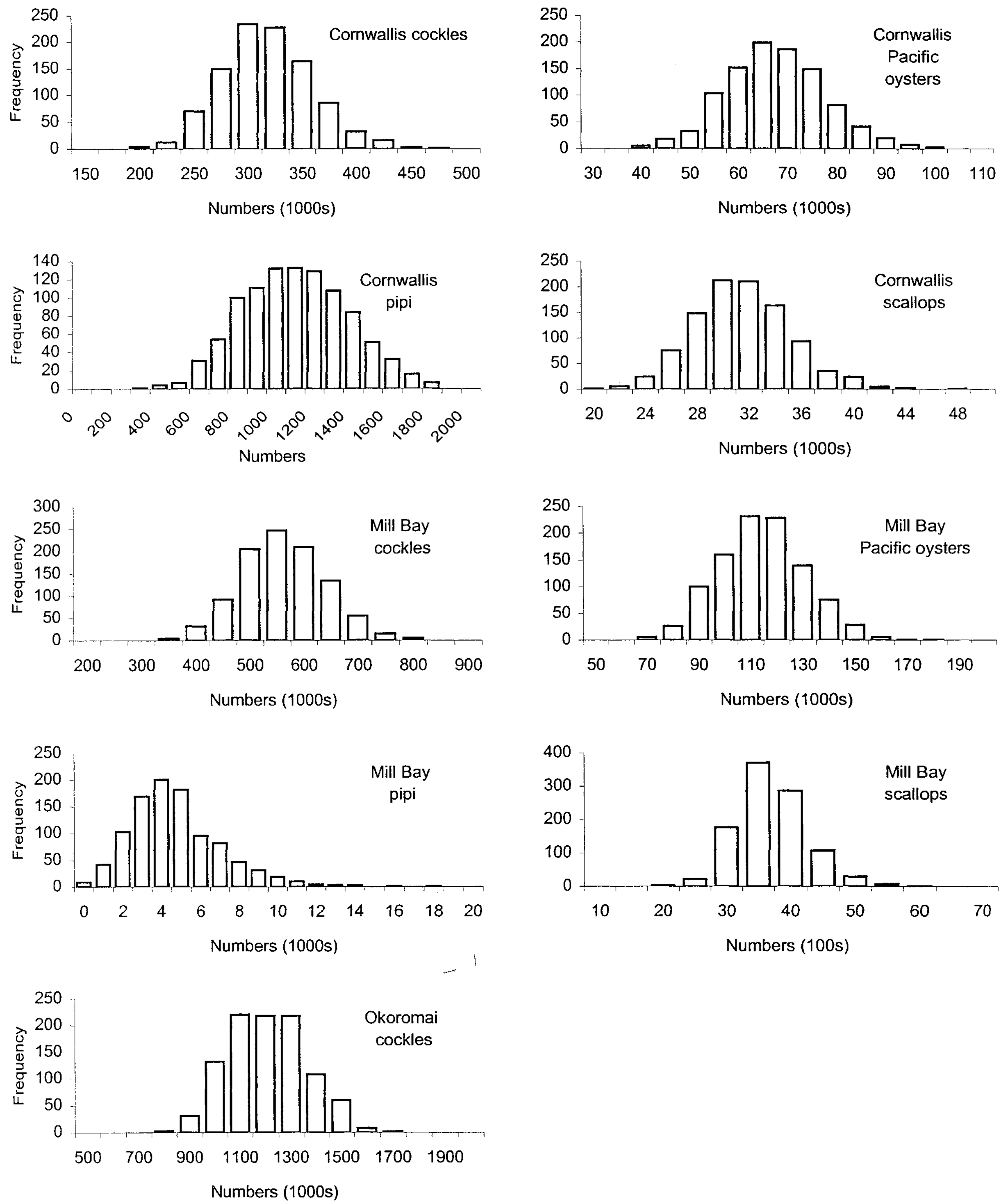


Figure 11 **: Frequency distributions of the 1000 bootstraps used to determine the variance of estimates of the harvest (numbers) of the key species picked at Cornwallis Beach, Mill Bay, and Okoromai Bay.**

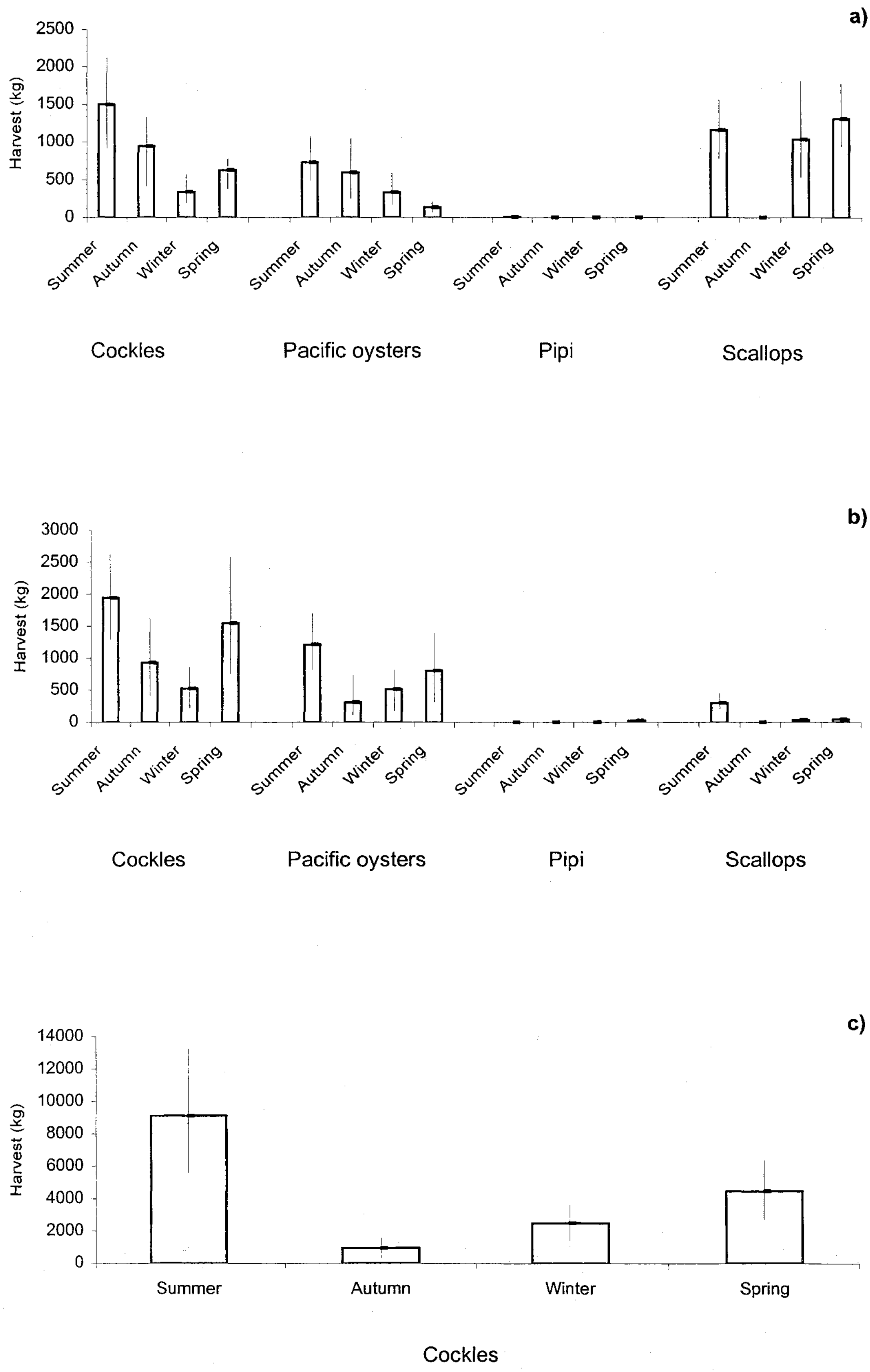


***Figure 12*: Seasonal harvests of key species picked at a) Cornwallis Beach, b) Mill Bay, and c) Okoromai Bay. Error bars denote 95% confidence intervals.**

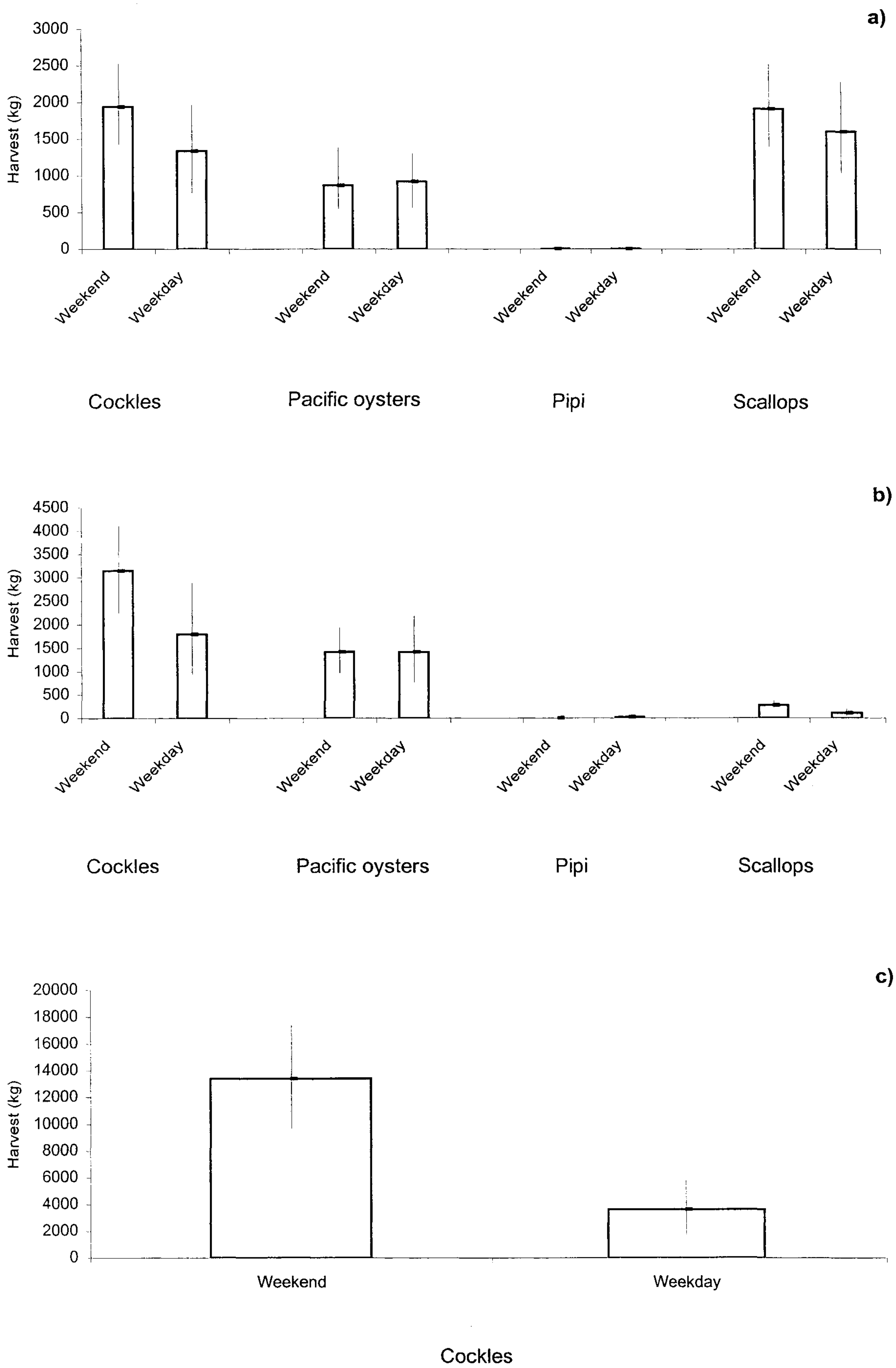


Figure 13 **: Estimated annual harvests of key species picked on weekend days and week days at a) Cornwallis Beach, b) Mill Bay, and c) Okoromai Bay. Error bars denote 95% confidence intervals.**

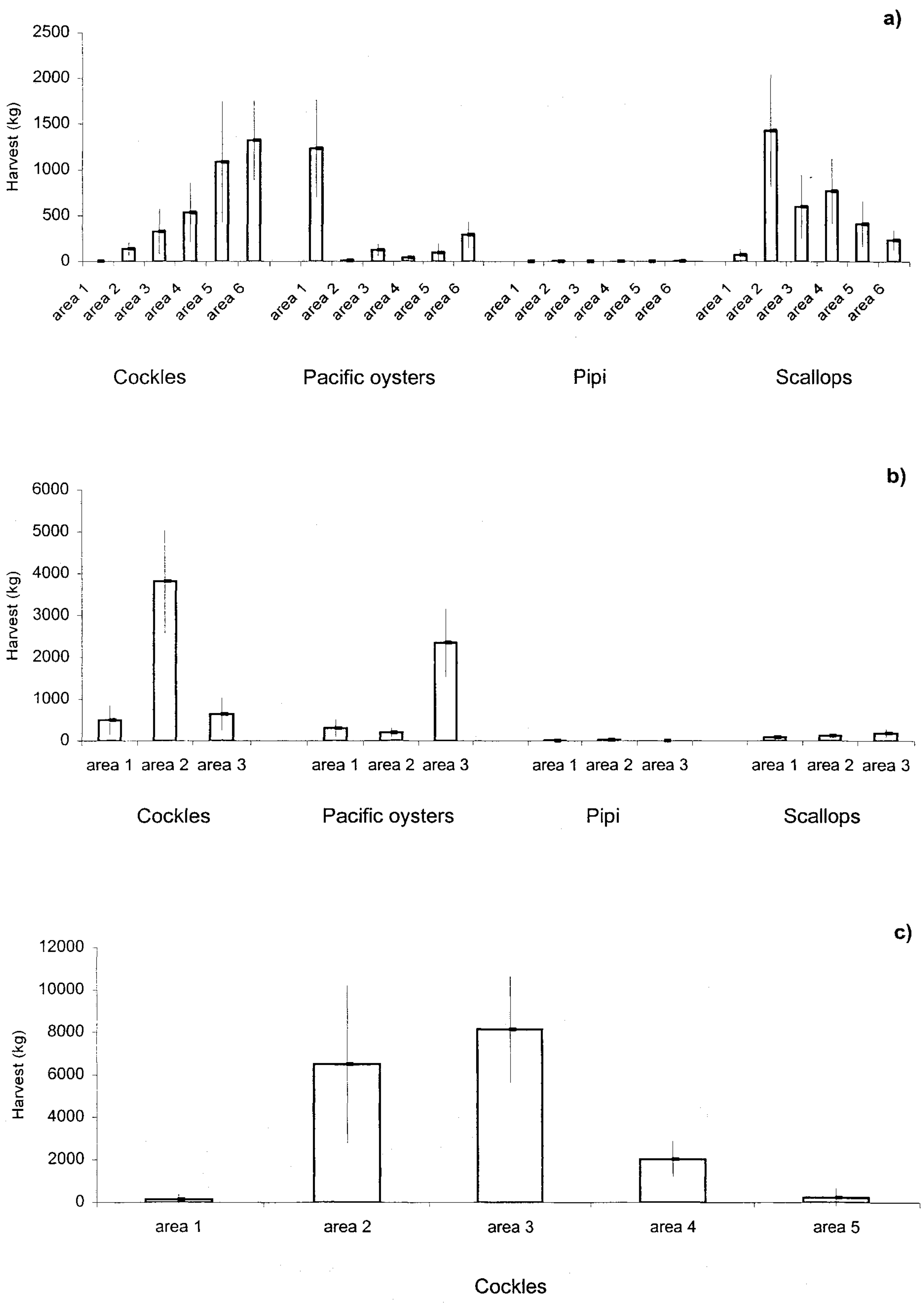


***Figure 14*: Estimated annual harvests of key species picked from each area strata at a) Cornwallis Beach, b) Mill Bay, and c) Okoromai Bay. Error bars denote 95% confidence intervals.**

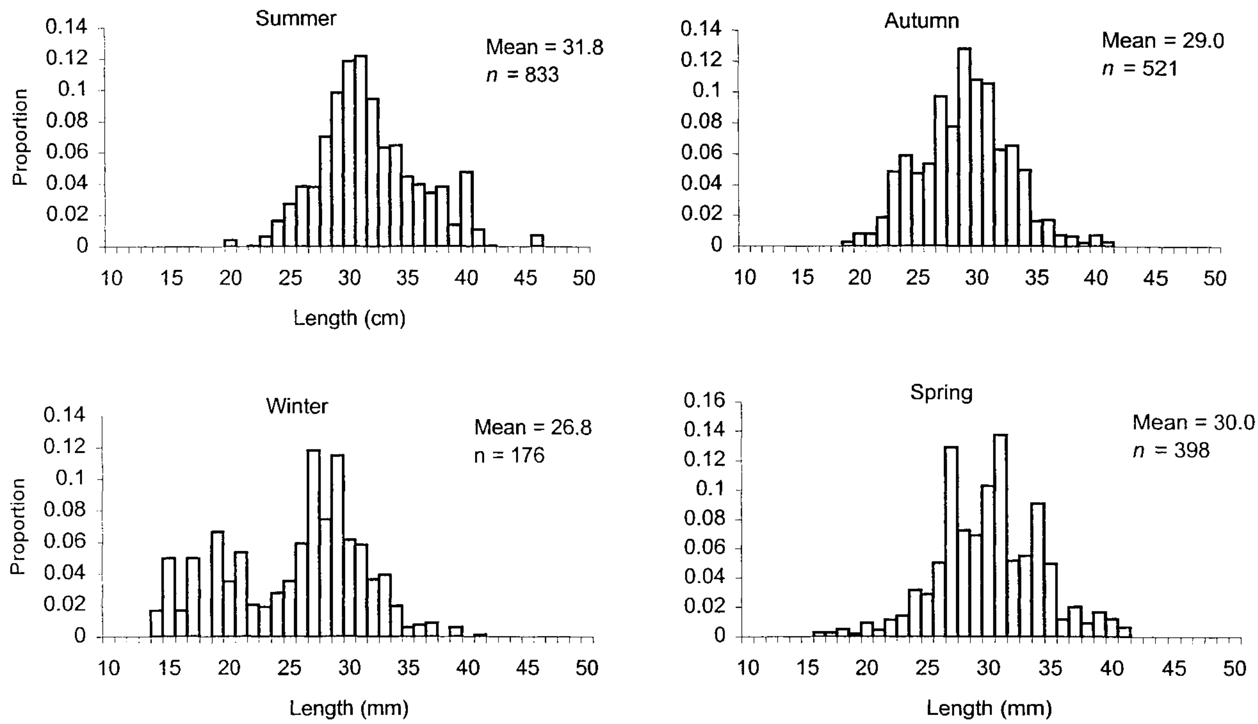


Figure 15: **Length frequencies of cockles harvested by interviewed pickers at Cornwallis Beach. Individual harvests have been weighted by the estimated number of cockles picked by that group.**

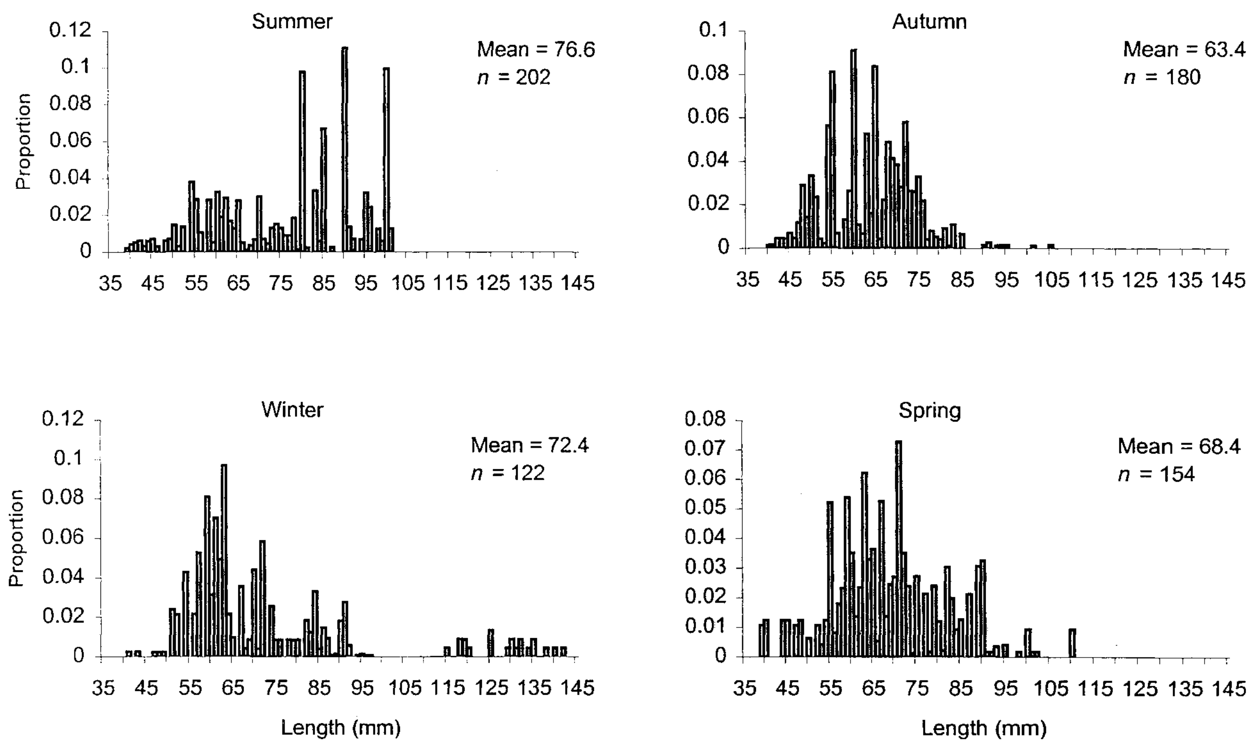


Figure 16: **Length frequencies of Pacific oysters harvested by interviewed pickers at Cornwallis Beach. Individual harvests have been weighted by the estimated number of Pacific oysters picked by that group.**

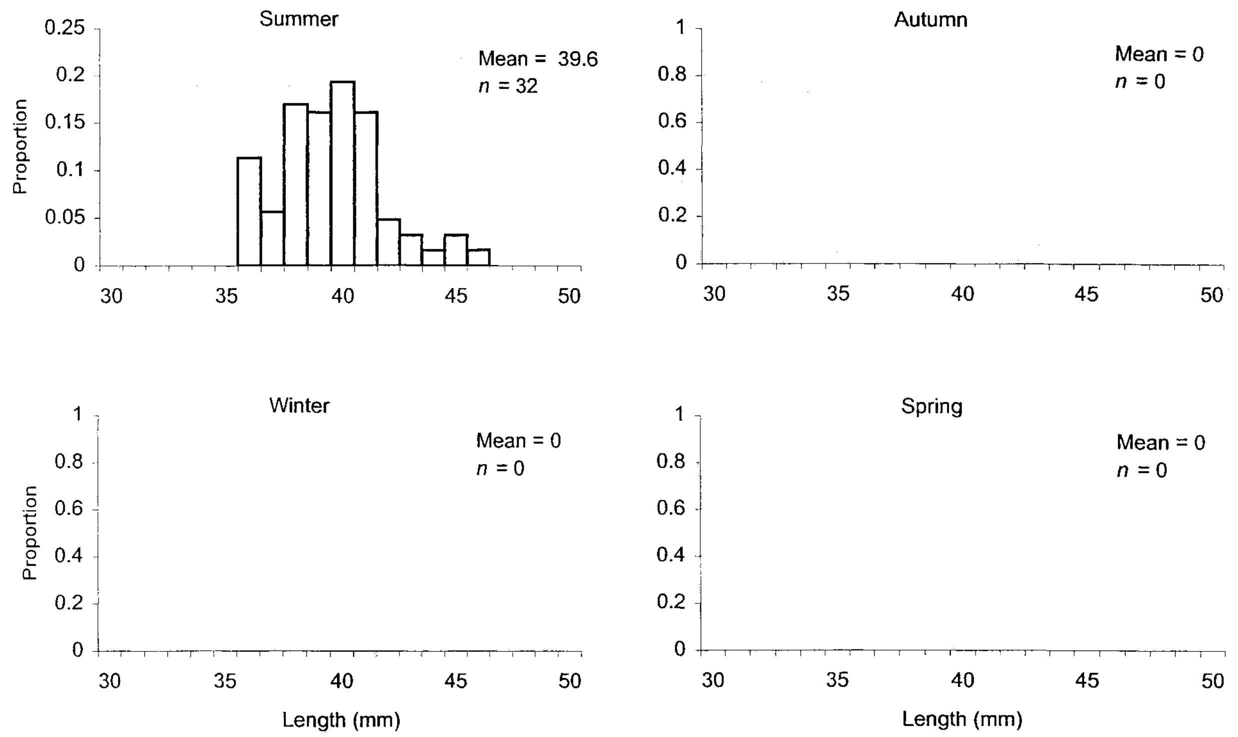


Figure 17: **Length frequencies of pipi harvested by interviewed pickers at Cornwallis Beach. Individual harvests have been weighted by the estimated number of pipi picked by that group.**

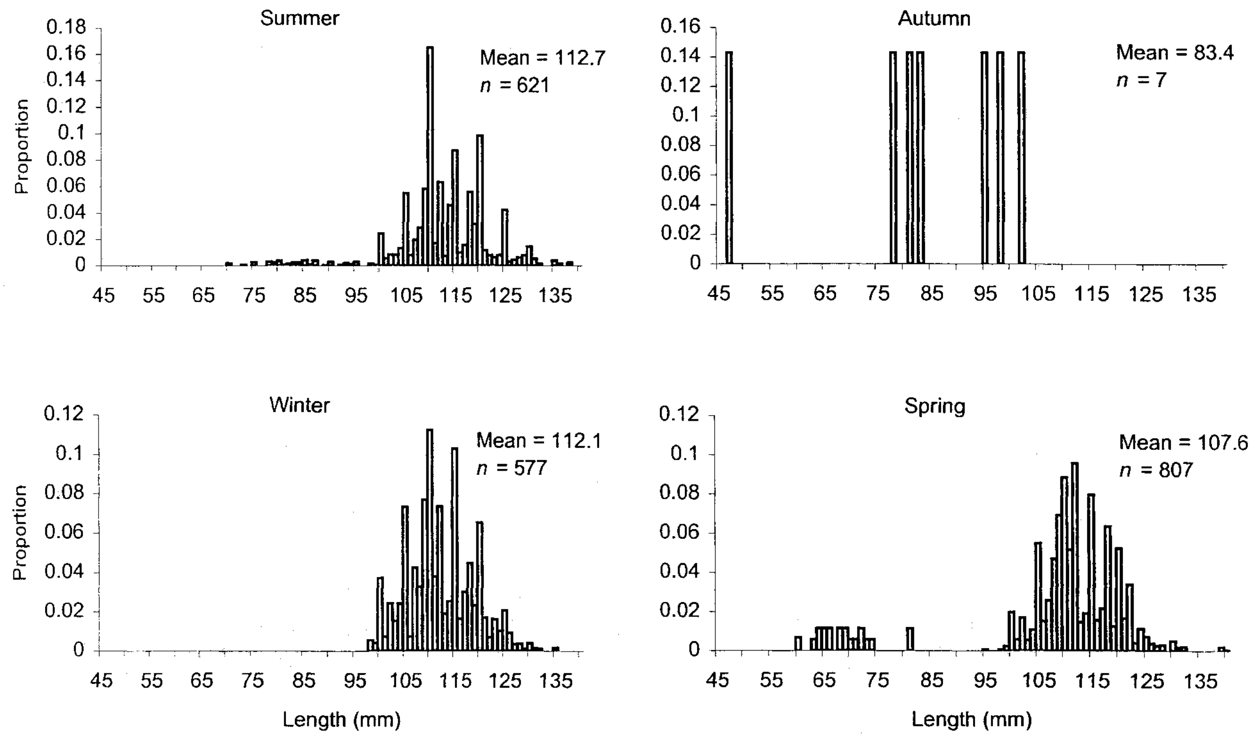


Figure 18: **Length frequencies of scallops harvested by interviewed pickers at Cornwallis Beach. Individual harvests have been weighted by the estimated number of scallops picked by that group.**

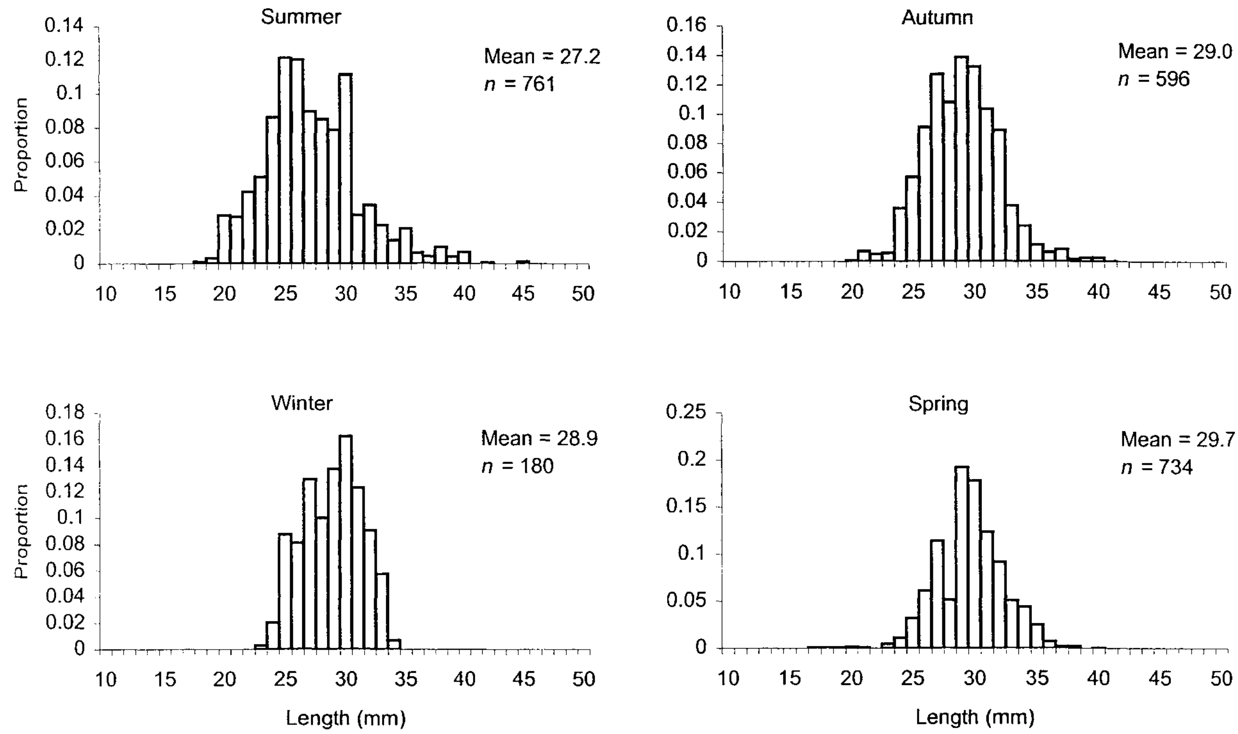


Figure 19: **Length frequencies of cockles harvested by interviewed pickers at Mill Bay. Individual harvests have been weighted by the estimated number of cockles picked by that group.**

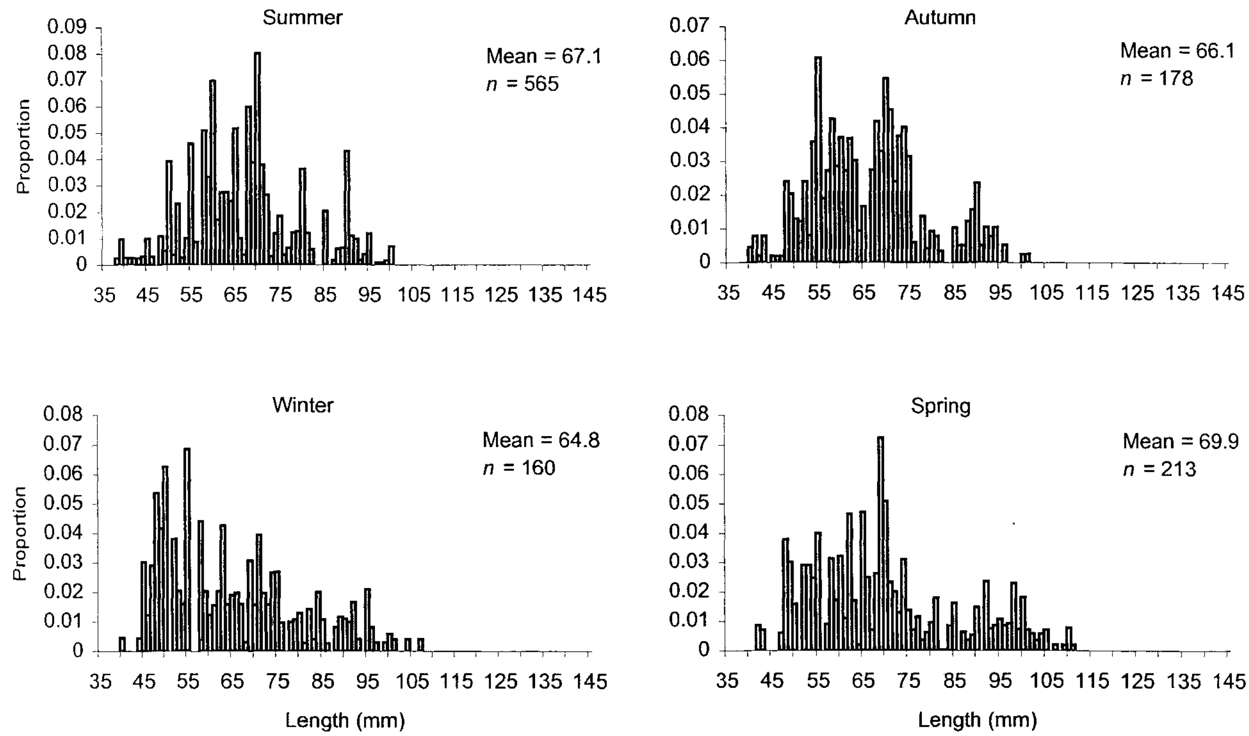


Figure 20: **Length frequencies of Pacific oysters harvested by interviewed pickers at Mill Bay. Individual harvests have been weighted by the estimated number of Pacific oysters picked by that group.**

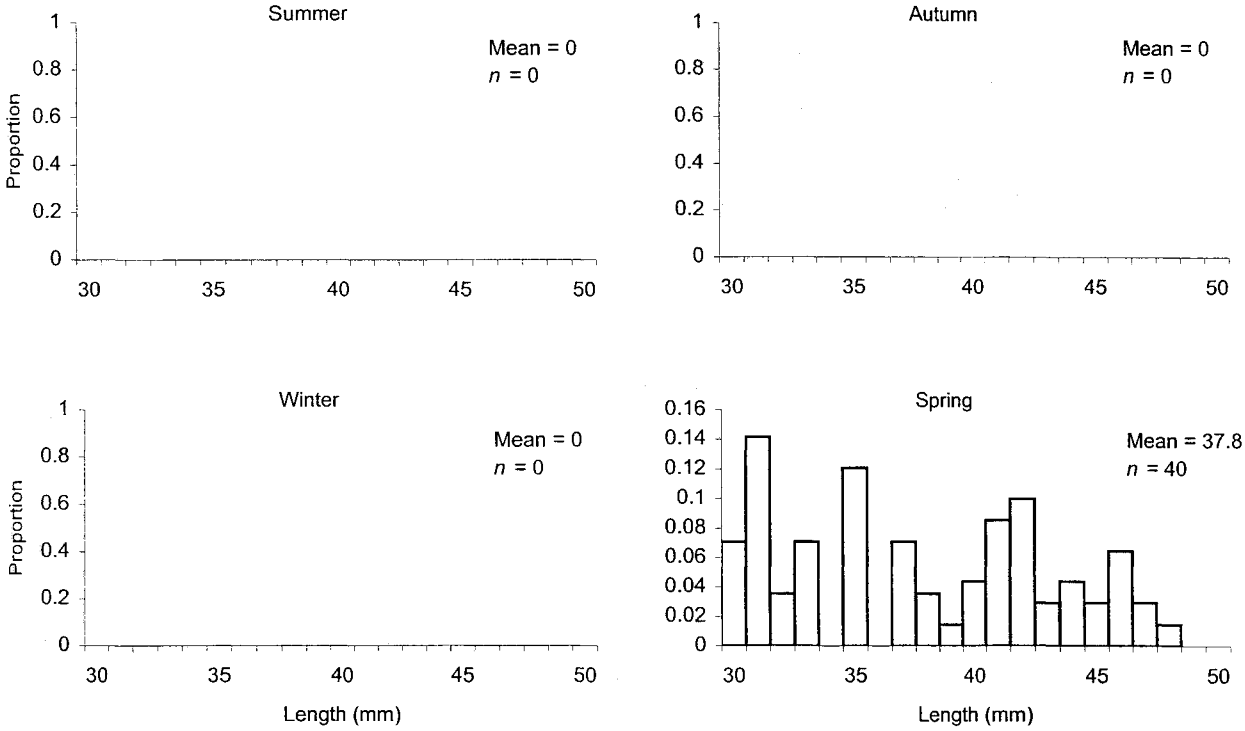


Figure 21: **Length frequencies of pipi harvested by interviewed pickers at Mill Bay. Individual harvests have been weighted by the estimated number of pipi picked by that group.**

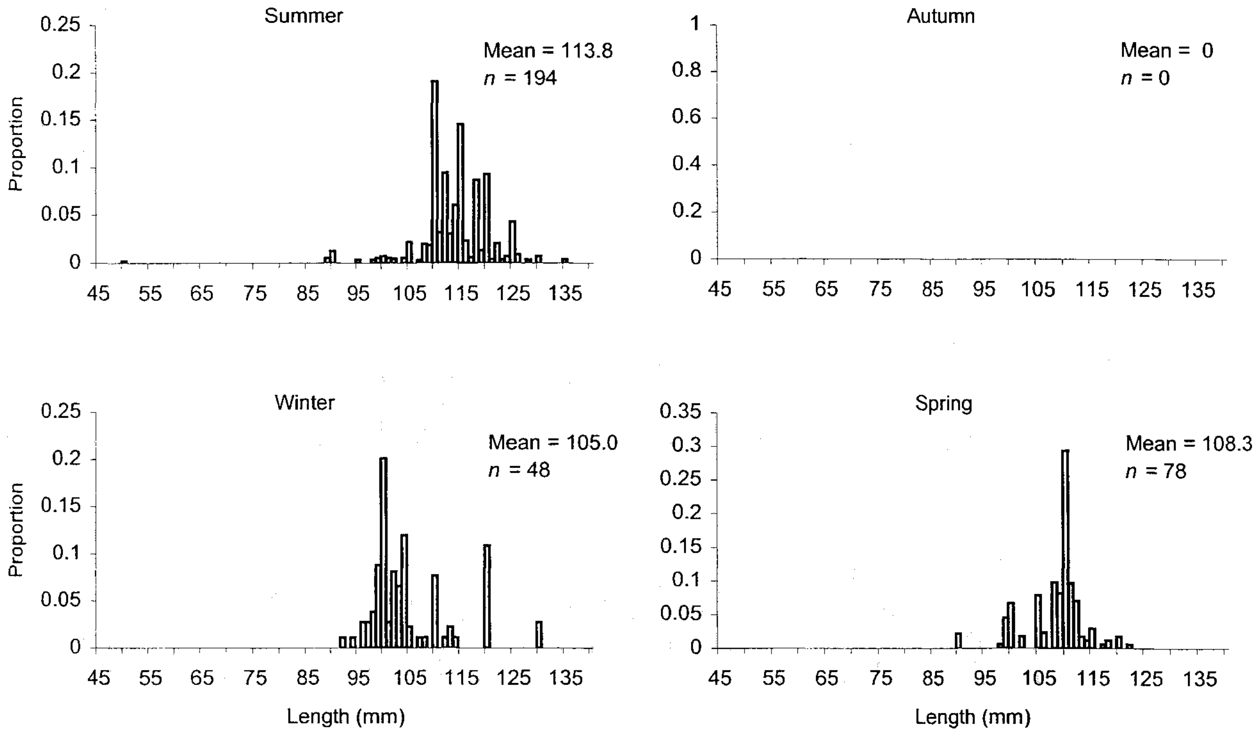


Figure 22: **Length frequencies of scallops harvested by interviewed pickers at Mill Bay. Individual harvests have been weighted by the estimated number of scallops picked by that group.**

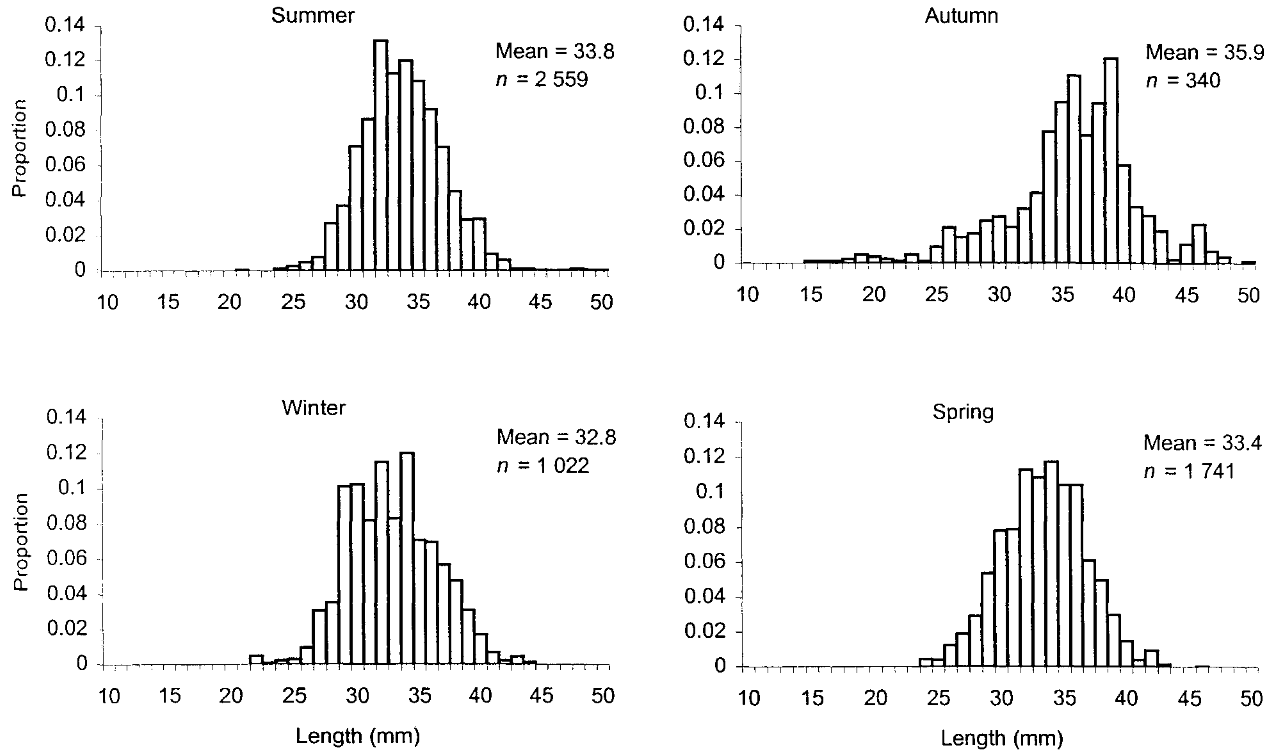


Figure 23: **Length frequencies of cockles harvested by interviewed pickers at Okoromai Bay. Individual harvests have been weighted by the estimated number of cockles picked by that group.**

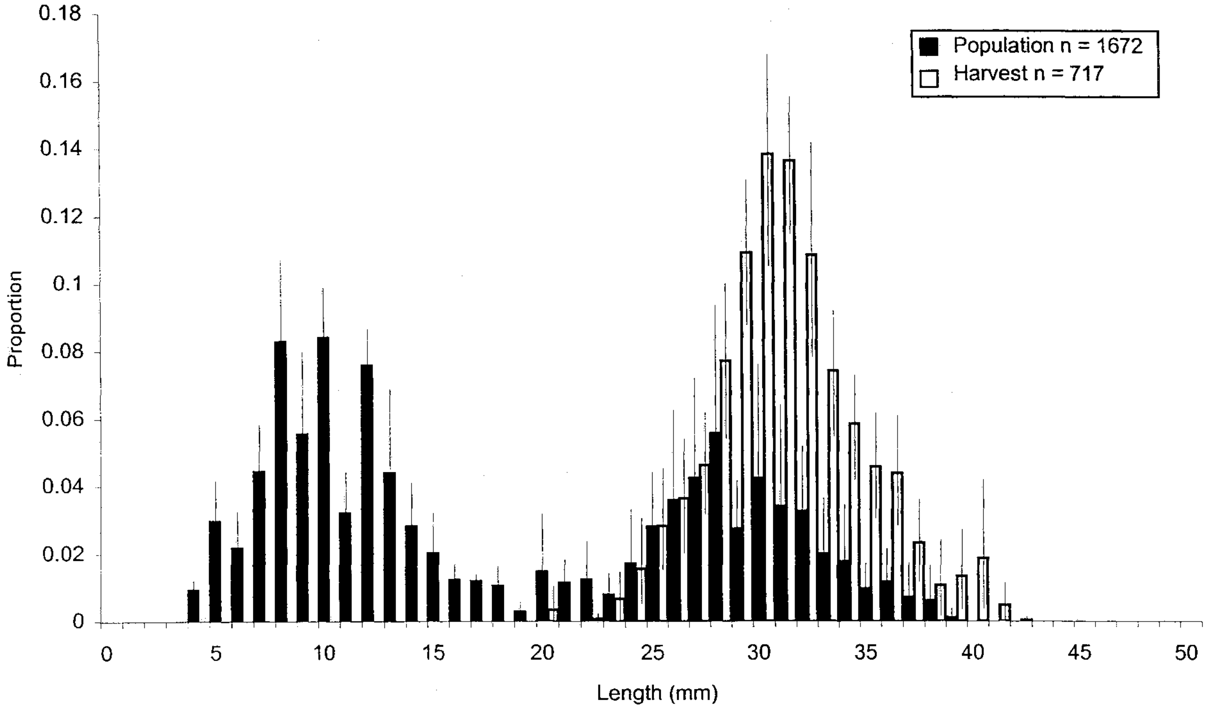


Figure 24: **Proportional length frequency distributions of the Cornwallis Beach cockle population and cockles harvested from that population by recreational pickers. Error bars denote approximate 95% confidence intervals calculated using bootstrap techniques.**

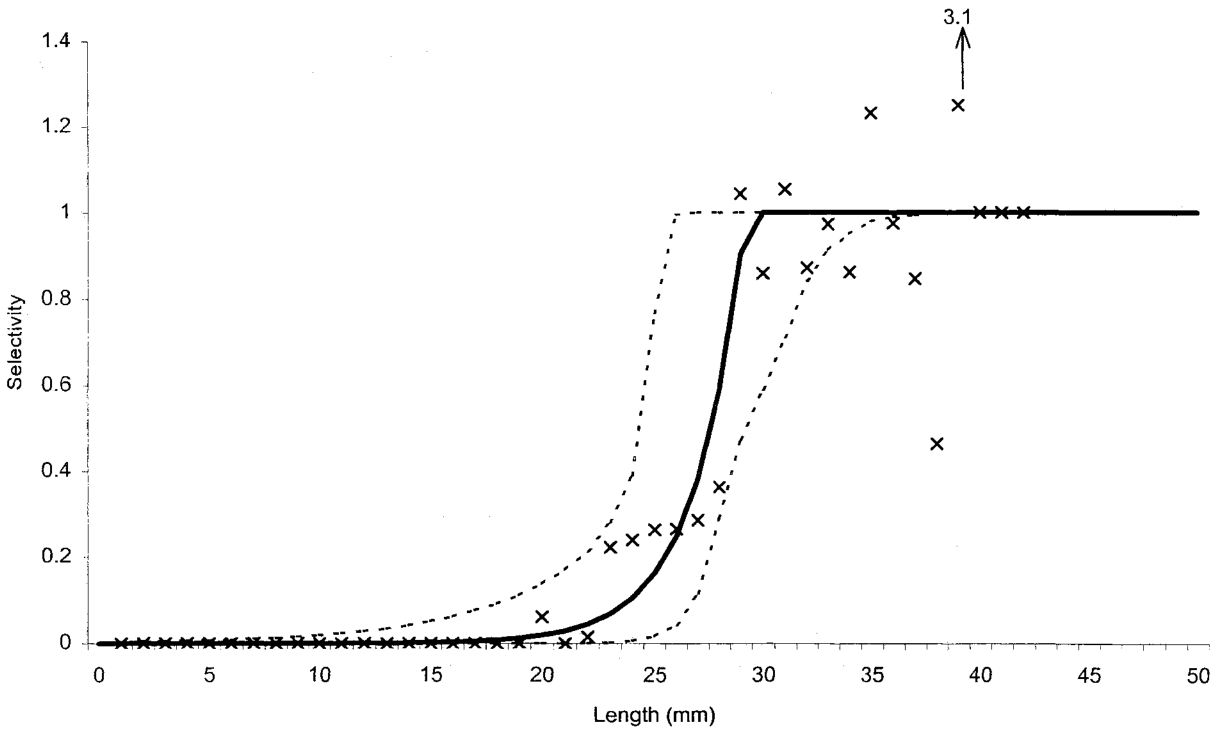


Figure 25: **Selectivity of recreational cockle pickers at Cornwallis Beach. Actual values of scaled estimates of the number of cockles harvested divided by estimates of the number of cockles in the population for each length class are denoted by crosses. The solid line denotes the estimated selectivity and the dashed lines denote approximate 95% confidence intervals calculated using a bootstrap technique.**

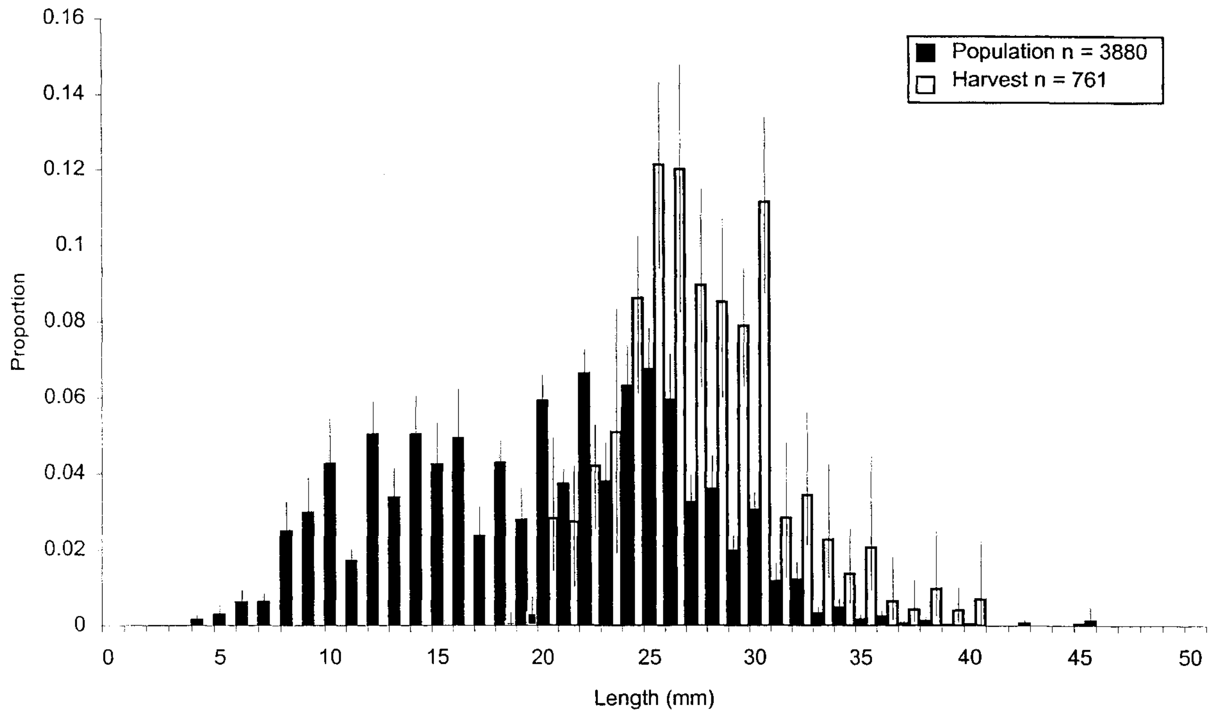


Figure 26: **Proportional length frequency distributions of the Mill Bay cockle population and cockles harvested from that population by recreational pickers. Error bars denote approximate 95% confidence intervals calculated using bootstrap techniques.**

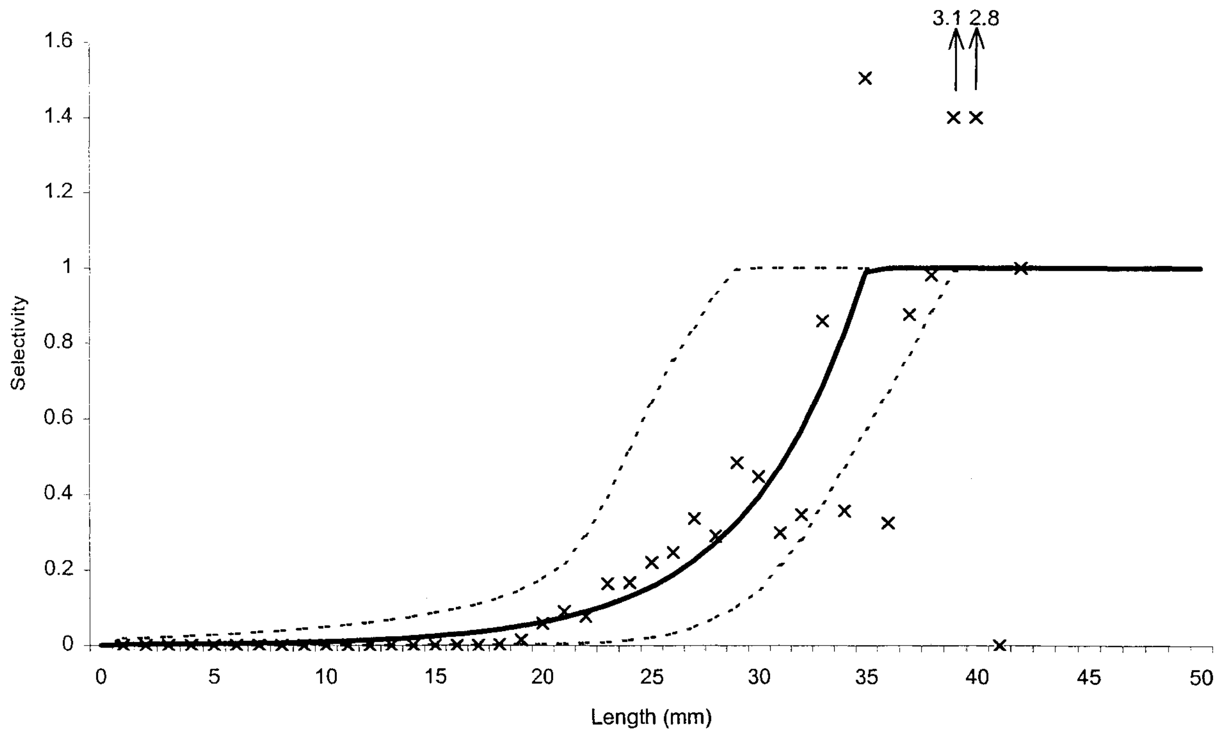


Figure 27: **Selectivity of recreational cockle pickers at Mill Bay. Actual values of scaled estimates of the number of cockles harvested divided by estimates of the number of cockles in the population for each length class are denoted by crosses. The solid line denotes the estimated selectivity and the dashed lines denote approximate 95% confidence intervals calculated using a bootstrap technique.**

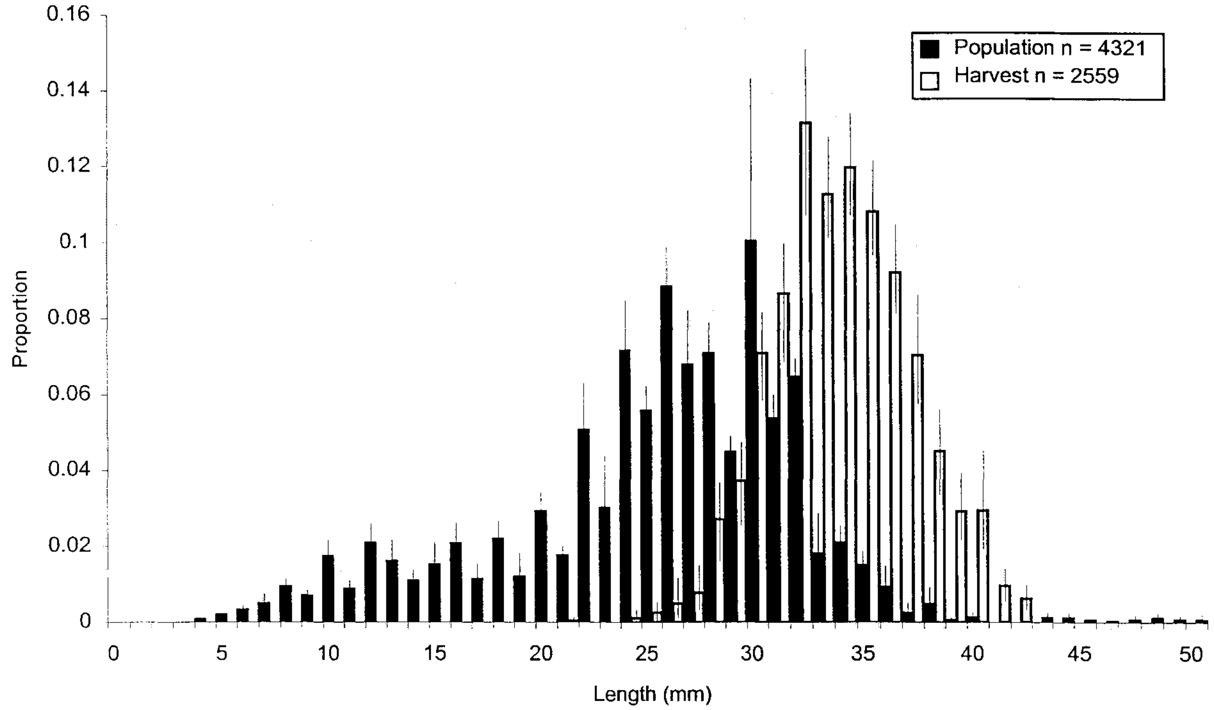


Figure 28: **Proportional length frequency distributions of the Okoromai Bay cockle population and cockles harvested from that population by recreational pickers. Error bars denote approximate 95% confidence intervals calculated using bootstrap techniques.**

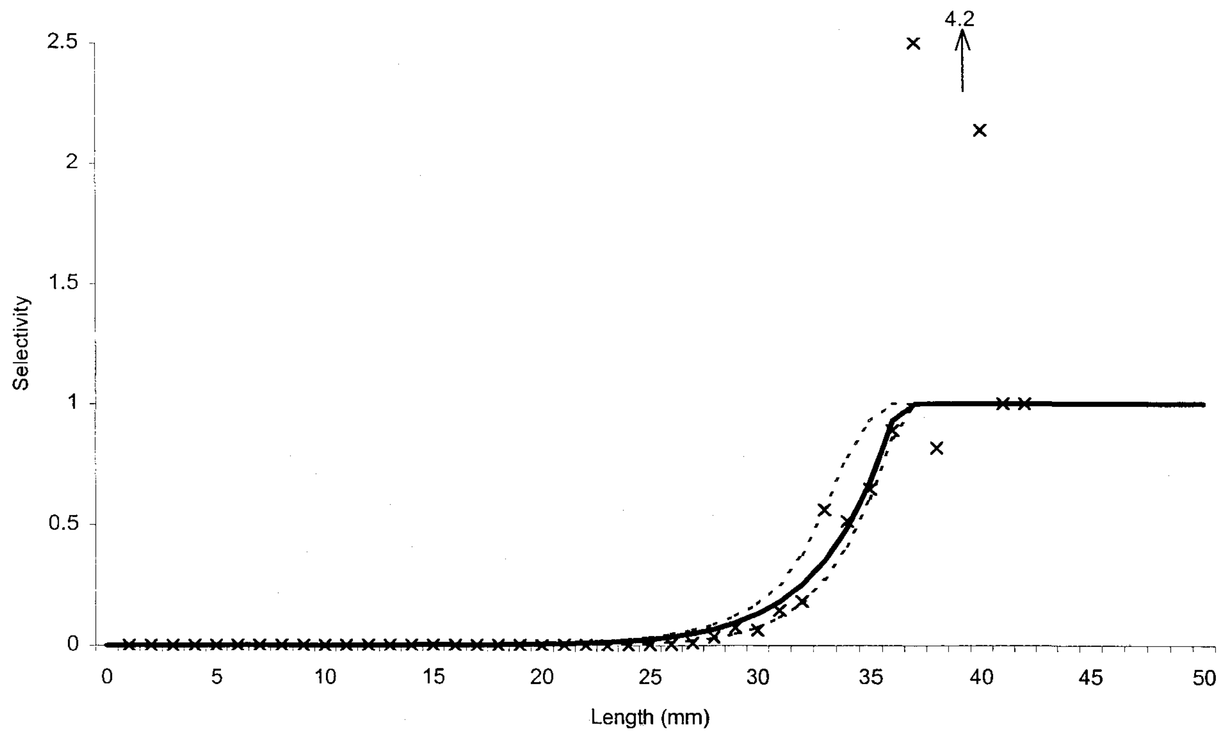


Figure 29: **Selectivity of recreational cockle pickers at Okoromai Bay. Actual values of scaled estimates of the number of cockles harvested divided by estimates of the number of cockles in the population, for each length class are denoted by crosses. The solid line denotes the estimated selectivity and the dashed lines denote approximate 95% confidence intervals calculated using a bootstrap technique.**

Appendix 1: Estimated weight (kg) of key species harvested at Cornwallis Beach, Mill Bay and Okoromai Bay by season and day type

Species	Season	Day type	Estimated harvest (kg)	Bootstrap mean	Lower C.I.	Upper C.I.
Cornwallis Beach						
Cockles	Summer	Weekend	727	730	471	1 062
		Weekday	764	771	282	1 348
		Total	1 491	1 500	928	2 155
	Autumn	Weekend	708	705	338	1 170
		Weekday	106	105	0	276
		Total	814	810	413	1 339
	Winter	Weekend	223	227	90	411
		Weekday	127	127	26	248
		Total	350	353	180	572
	Spring	Weekend	279	285	172	435
		Weekday	335	331	145	574
		Total	614	616	378	884
	Annual	Weekend	1 936	1 946	1 431	2 550
		Weekday	1 332	1 334	769	1 978
		Total	3 269	3 280	2 513	4 145
Cornwallis Beach						
Pacific oysters	Summer	Weekend	432	423	217	721
		Weekday	318	327	162	534
		Total	751	750	493	1 091
	Autumn	Weekend	231	228	48	633
		Weekday	373	367	93	658
		Total	605	595	246	1 053
	Winter	Weekend	131	132	51	239
		Weekday	209	213	50	447
		Total	339	344	162	589
	Spring	Weekend	110	110	53	175
		Weekday	15	21	0	92
		Total	126	131	63	222
	Annual	Weekend	905	892	549	1 398
		Weekday	915	928	564	1 306
		Total	1 820	1 820	1 313	2 488

Appendix 1– continued: Estimated weight (kg) of key species harvested at Cornwallis Beach, Mill Bay and Okoromai Bay by season and day type

Species	Season	Day type	Estimated harvest (kg)	Bootstrap mean	Lower C.I.	Upper C.I.
Cornwallis Beach						
Pipi	Summer	Weekend	4	4	2	7
		Weekday	3	2	0	4
		Total	6	6	3	10
	Autumn	Weekend	0	0	–	–
		Weekday	0	0	–	–
		Total	0	0	–	–
	Winter	Weekend	0	0	–	–
		Weekday	0	0	–	–
		Total	0	0	–	–
	Spring	Weekend	0	0	–	–
		Weekday	0	0	–	–
		Total	0	0	–	–
	Annual	Weekend	4	4	2	7
		Weekday	3	2	0	4
		Total	6	6	3	10
Cornwallis Beach						
Scallops	Summer	Weekend	536	533	564	455
		Weekday	628	621	453	492
		Total	1 164	1 155	1 017	947
	Autumn	Weekend	1	1	1	1
		Weekday	0	0	–	–
		Total	1	1	1	1
	Winter	Weekend	524	530	536	802
		Weekday	513	515	532	454
		Total	1 037	1 046	1 068	1 256
	Spring	Weekend	853	861	921	913
		Weekday	463	466	515	488
		Total	1 316	1 327	1 435	1 401
	Annual	Weekend	1 914	1 925	2 021	2 170
		Weekday	1 604	1 603	1 500	1 434
		Total	3 518	3 528	3 521	3 604

Appendix 1– continued: Estimated weight (kg) of key species harvested at Cornwallis Beach, Mill Bay and Okoromai Bay by season and day type

Species	Season	Day type	Estimated harvest (kg)	Bootstrap mean	Lower C.I.	Upper C.I.
Mill Bay						
Cockles	Summer	Weekend	1 270	1 274	789	1 853
		Weekday	703	692	307	1 146
		Total	1 973	1 966	1 314	2 676
	Autumn	Weekend	694	702	232	1 352
		Weekday	235	232	15	521
		Total	929	934	409	1 622
	Winter	Weekend	411	401	135	713
		Weekday	109	108	0	268
		Total	520	509	211	859
	Spring	Weekend	799	798	409	1 225
		Weekday	761	763	90	1 707
		Total	1 560	1 561	763	2 605
	Annual	Weekend	3 174	3 174	2 266	4 143
		Weekday	1 809	1 796	946	2 913
		Total	4 983	4 970	3 674	6 368
Mill Bay						
Pacific oysters	Summer	Weekend	864	883	685	849
		Weekday	367	340	197	310
		Total	1 230	1 223	983	1 189
	Autumn	Weekend	111	112	66	104
		Weekday	195	219	78	175
		Total	306	331	184	285
	Winter	Weekend	295	270	134	247
		Weekday	210	203	101	202
		Total	505	473	303	448
	Spring	Weekend	159	162	63	143
		Weekday	651	664	386	614
		Total	810	826	523	776
	Annual	Weekend	1 429	1 427	1 166	1 390
		Weekday	1 422	1 426	761	2 205
		Total	2 852	2 853	2 398	2 784

Appendix 1– continued: Estimated weight (kg) of key species harvested at Cornwallis Beach, Mill Bay and Okoromai Bay by season and day type

Species	Season	Day type	Estimated harvest (kg)	Bootstrap mean	Lower C.I.	Upper C.I.
Mill Bay						
Pipi	Summer	Weekend	0	0	–	–
		Weekday	0	0	–	–
		Total	0	0	–	–
	Autumn	Weekend	0	0	–	–
		Weekday	0	0	–	–
		Total	0	0	–	–
	Winter	Weekend	0	0	–	–
		Weekday	0	0	–	–
		Total	0	0	–	–
	Spring	Weekend	0	0	–	–
		Weekday	22	23	2	51
		Total	22	23	2	51
	Annual	Weekend	0	0	–	–
		Weekday	22	23	2	51
		Total	22	23	2	51
Mill Bay						
Scallops	Summer	Weekend	200	210	240	202
		Weekday	102	103	88	115
		Total	302	314	328	317
	Autumn	Weekend	0	0	–	–
		Weekday	0	0	–	–
		Total	0	0	–	–
	Winter	Weekend	35	34	26	2
		Weekday	2	2	2	2
		Total	37	36	27	4
	Spring	Weekend	39	41	29	38
		Weekday	7	8	7	3
		Total	46	49	36	41
	Annual	Weekend	274	285	295	243
		Weekday	111	114	96	120
		Total	385	399	391	362

Appendix 1– continued: Estimated weight (kg) of key species harvested at Cornwallis Beach, Mill Bay and Okoromai Bay by season and day type

Species	Season	Day type	Estimated harvest (kg)	Bootstrap mean	Lower C.I.	Upper C.I.
Okoromai Bay						
Cockles	Summer	Weekend	7 287	7 250	4 219	11 193
		Weekday	1 978	1 957	539	4 029
		Total	9 265	9 207	5 682	13 527
	Autumn	Weekend	907	893	278	1 591
		Weekday	42	42	0	125
		Total	948	935	308	1 633
	Winter	Weekend	1 854	1 853	995	2 831
		Weekday	604	597	105	1 254
		Total	2 458	2 450	1 399	3 598
	Spring	Weekend	3 485	3 478	2 188	4 938
		Weekday	1 035	985	190	2 292
		Total	4 520	4 464	2 728	6 457
	Annual	Weekend	13 532	13 475	9 791	17 615
		Weekday	3 659	3 581	1 761	5 875
		Total	17 192	17 056	12 707	21 655

Appendix 2: Estimated number of key species harvested at Cornwallis Beach, Mill Bay and Okoromai Bay by season and day type

Species	Season	Day type	Estimated no. harvested	Bootstrap mean	Lower C.I.	Upper C.I.
Cornwallis Beach						
Cockles	Summer	Weekend	55 954	56 517	37 116	80 379
		Weekday	58 136	57 811	16 598	107 472
		Total	114 090	114 328	69 464	170 013
	Autumn	Weekend	66 481	66 146	29 042	110 833
		Weekday	8 074	6 567	0	16 153
		Total	74 555	72 714	34 345	119 575
	Winter	Weekend	21 606	21 733	9 220	37 994
		Weekday	22 518	22 406	3 832	48 681
		Total	44 124	44 139	20 073	71 911
	Spring	Weekend	19 270	19 507	11 775	29 303
		Weekday	31 682	31 407	12 420	52 844
		Total	50 952	50 914	29 945	74 699
	Annual	Weekend	163 311	163 904	118 868	216 807
		Weekday	120 410	118 191	66 904	175 696
		Total	283 721	282 095	213 896	360 754
Cornwallis Beach						
Pacific oysters	Summer	Weekend	13 701	13 651	7 765	21 469
		Weekday	9 529	9 722	4 560	16 972
		Total	23 231	23 374	15 087	33 231
	Autumn	Weekend	9 354	9 457	2 129	23 452
		Weekday	12 379	12 002	3 250	22 747
		Total	21 732	21 459	9 179	37 182
	Winter	Weekend	4 329	4 328	1 709	7 700
		Weekday	6 223	6 418	1 354	13 355
		Total	10 552	10 746	4 858	18 421
	Spring	Weekend	3 828	3 804	1 629	6 461
		Weekday	679	595	0	2 555
		Total	4 507	4 399	2 024	7 347
	Annual	Weekend	31 212	31 241	19 672	46 395
		Weekday	28 810	28 737	16 968	43 504
		Total	60 022	59 978	42 683	79 263

Appendix 2 – continued: Estimated number of key species harvested at Cornwallis Beach, Mill Bay and Okoromai Bay by season and day type

Species	Season	Day type	Estimated no. harvested	Bootstrap mean	Lower C.I.	Upper C.I.
Cornwallis Beach						
Pipi	Summer	Weekend	594	591	269	954
		Weekday	386	387	0	739
		Total	980	977	519	1 478
	Autumn	Weekend	0	0	–	–
		Weekday	0	0	–	–
		Total	0	0	–	–
	Winter	Weekend	0	0	–	–
		Weekday	0	0	–	–
		Total	0	0	–	–
	Spring	Weekend	0	0	–	–
		Weekday	0	0	–	–
		Total	0	0	–	–
	Annual	Weekend	594	591	269	954
		Weekday	386	387	0	739
		Total	980	977	519	1 478
Cornwallis Beach						
Scallops	Summer	Weekend	4 158	4 132	4 379	3 201
		Weekday	5 363	5 334	6 573	6 381
		Total	9 521	9 466	10 952	9 582
	Autumn	Weekend	27	23	32	5
		Weekday	0	0	–	–
		Total	27	23	32	5
	Winter	Weekend	4 326	4 354	4 400	3 462
		Weekday	4 319	4 333	2 894	4 620
		Total	8 645	8 688	7 294	8 082
	Spring	Weekend	6 938	6 994	5 789	5 277
		Weekday	5 228	5 298	4 383	5 689
		Total	12 166	12 292	10 171	10 966
	Annual	Weekend	15 449	15 503	14 600	11 945
		Weekday	14 910	14 965	13 849	16 690
		Total	30 359	30 468	28 449	28 634

Appendix 2 – continued: Estimated number of key species harvested at Cornwallis Beach, Mill Bay and Okoromai Bay by season and day type

Species	Season	Day type	Estimated no. harvested	Bootstrap mean	Lower C.I.	Upper C.I.
Mill Bay						
Cockles	Summer	Weekend	141 946	142 251	79 150	216 782
		Weekday	71 540	71 113	30 570	128 266
		Total	213 486	213 365	137 093	301 097
	Autumn	Weekend	65 973	65 326	21 019	127 780
		Weekday	25 338	25 874	1 388	56 741
		Total	91 311	91 199	37 200	160 960
	Winter	Weekend	41 458	40 066	14 629	73 215
		Weekday	10 435	10 758	0	25 478
		Total	51 893	50 824	22 587	85 575
	Spring	Weekend	67 964	67 675	35 491	104 069
		Weekday	72 747	74 920	13 403	157 008
		Total	140 711	142 596	66 447	230 498
	Annual	Weekend	317 341	315 318	222 599	418 600
		Weekday	180 059	182 666	93 087	290 413
		Total	497 401	497 984	362 880	637 784
Mill Bay						
Pacific oysters	Summer	Weekend	29 749	30 292	19 708	42 853
		Weekday	13 778	12 663	4 296	24 292
		Total	43 527	42 955	28 748	59 680
	Autumn	Weekend	3 570	3 512	1 022	6 756
		Weekday	7 616	8 127	480	22 749
		Total	11 185	11 639	3 425	27 173
	Winter	Weekend	11 112	10 341	1 974	22 098
		Weekday	8 266	7 858	0	15 872
		Total	19 378	18 199	7 169	32 572
	Spring	Weekend	4 314	4 372	1 097	9 946
		Weekday	24 017	24 014	5 919	44 625
		Total	28 331	28 386	10 187	48 731
	Annual	Weekend	48 744	48 517	32 546	66 159
		Weekday	53 677	52 662	29 011	77 368
		Total	102 422	101 179	72 815	131 811

Appendix 2 – continued: Estimated number of key species harvested at Cornwallis Beach, Mill Bay and Okoromai Bay by season and day type

Species	Season	Day type	Estimated no. harvested	Bootstrap mean	Lower C.I.	Upper C.I.
Mill Bay						
Pipi	Summer	Weekend	0	0	–	–
		Weekday	0	0	–	–
		Total	0	0	–	–
	Autumn	Weekend	0	0	–	–
		Weekday	0	0	–	–
		Total	0	0	–	–
	Winter	Weekend	0	0	–	–
		Weekday	0	0	–	–
		Total	0	0	–	–
	Spring	Weekend	0	0	–	–
		Weekday	3 916	3 899	477	9 057
		Total	3 916	3 899	477	9 057
	Annual	Weekend	0	0	–	–
		Weekday	3 916	3 899	477	9 057
		Total	3 916	3 899	477	9 057
Mill Bay						
Scallops	Summer	Weekend	1 593	1 647	1 616	1 620
		Weekday	890	907	740	572
		Total	2 483	2 554	2 355	2 192
	Autumn	Weekend	0	0	–	–
		Weekday	0	0	–	–
		Total	0	0	–	–
	Winter	Weekend	393	398	231	57
		Weekday	37	37	28	48
		Total	431	436	259	104
	Spring	Weekend	358	376	373	282
		Weekday	74	83	108	97
		Total	432	459	482	379
	Annual	Weekend	2 344	2 421	2 220	1 959
		Weekday	1 001	1 027	876	717
		Total	3 345	3 448	3 096	2 676

Appendix 2 – continued: Estimated number of key species harvested at Cornwallis Beach, Mill Bay and Okoromai Bay by season and day type

Species	Season	Day type	Estimated no. harvested	Bootstrap mean	Lower C.I.	Upper C.I.
Okoromai Bay						
Cockles	Summer	Weekend	444 368	445 732	266 897	686 374
		Weekday	126 483	128 625	40 360	265 216
		Total	570 851	574 357	350 445	825 913
	Autumn	Weekend	45 808	46 181	16 165	83 465
		Weekday	1 912	1 862	0	5 736
		Total	47 720	48 044	17 594	86 496
	Winter	Weekend	118 170	117 409	63 691	174 352
		Weekday	49 487	49 424	9 950	99 812
		Total	167 657	166 833	96 303	242 037
	Spring	Weekend	218 954	220 372	139 332	306 493
		Weekday	64 443	64 621	13 155	148 920
		Total	283 397	284 992	184 804	406 107
	Annual	Weekend	827 300	829 694	608 146	1 099 336
		Weekday	242 325	244 532	114 760	417 753
		Total	1 069 625	1 074 226	811 788	1 360 850

Appendix 3: Estimated weight (kg) and number of cockles harvested at Cornwallis Beach as defined in the intertidal survey (Morrison *et al.* 1999) by season and day

Season	Day type	Estimated harvest (kg)	Bootstrap mean	Lower C.I.	Upper C.I.
Summer	Weekend	645	694	420	1 032
	Weekday	535	592	127	1 195
	Total	1181	1285	727	1 962
Autumn	Weekend	692	749	342	1 264
	Weekday	106	115	0	301
	Total	798	864	425	1 407
Winter	Weekend	215	239	86	438
	Weekday	82	87	6	187
	Total	297	326	148	542
Spring	Weekend	228	251	129	408
	Weekday	335	357	148	619
	Total	564	608	352	901
Annual	Weekend	1780	1933	1 374	2 580
	Weekday	1059	1151	598	1 814
	Total	2839	3084	2 262	3 973

Season	**Day type**	**Estimated no. harvested**	**Bootstrap mean**	**Lower C.I.**	**Upper C.I.**
Summer	Weekend	50 267	54 387	33 432	80 818
	Weekday	47 734	51 209	9 611	103 855
	Total	98 001	105 596	59 201	165 797
Autumn	Weekend	65 216	70 422	30 270	118 915
	Weekday	8 074	7 159	0	17 607
	Total	73 290	77 580	35 885	129 085
Winter	Weekend	20 385	22 530	8 798	39 909
	Weekday	8 466	9 047	601	19 087
	Total	28 852	31 577	14 793	51 568
Spring	Weekend	15 451	16 865	8 924	27 420
	Weekday	31 682	33 887	13 380	57 017
	Total	47 133	50 752	27 563	76 384
Annual	Weekend	151 319	164 204	115 680	222 182
	Weekday	95 956	101 302	51 924	163 899
	Total	247 275	265 505	197 683	345 071

Appendix 4: Forms used in the survey

SHELLFISH HARVEST SURVEY FORM
SESSION INFORMATION

Page ....of........

Interview location: ______________________ Interviewer name: ______________________

Interview location code	interview time of day code	Date (d d / m m / y y)	Session time start (24 hour)	Session time finish (24 hour)	Day type	Interviewer Initials

Day type: 1=Weekend or Public holiday; 2=Weekday

Time of low tide (24 hour): ____

Environmental data:

Sea conditions	Rain	Overhead conditions	Wind speed	Wind direction
1=Smooth (0.1 - 0.5m)	1=Nil	1=Sunny continuous	1=Nil	1=Nil (no wind)
2=Slight (0.5 - 1.0 m)	2=Light continous	2=Mainly sunny	2=Light (1-10 kts)	2=Variable
3=Moderate (1.0 - 2.5m)	3=Light scattered	3=Mainly cloudy	3=Medium (11-20 kts)	3=North
4=Rough (2.5 - 4.0m)	4=Medium scattered	4=Continuous cloudy	4=Strong (21 + kts)	4=South
				5=NorthEast
				6=SouthWest
				7=East
				8=West
				9=SouthEast
				10=NorthWest

Fisher count data:

Hour	Strata No.	Count	Hour	Strata No.	Count	Hour	Strata No.	Count

Hour	Strata No.	Count	Hour	Strata No.	Count	Hour	Strata No.	Count

Appendix 4 continued: Forms used in the survey

SHELLFISH HARVEST SURVEY FORM

INTERVIEW INFORMATION

Page ....of........

Interview location code	Time of day code	Date
		d d / m m / y y

Group No.	No. of Fishers	Strata No.	Time of intercept	Intercept outcome	Target species	Time start (24 hour)	Time finish (24 hour)	Species	Estimated Weight	Agreed Weight

Group No.	Species	Max Length (cm)	Group No.	Species	Max Length (cm)	Group No.	Species	Max Length (cm)

NIWA

Taihoro Nukurangi

National Institute of
Water and Atmospheric
Research Limited