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EXECUTIVE SUMMARY

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Sustainable yields were estimated for the Snake Bank cockle fishery and the adjacent unfished McDonald Bank. Stratified random biomass surveys were undertaken in April 2000, and historical data from previous surveys were used to divide the two banks into appropriate density strata. For Snake Bank, a recruited biomass estimate of 570 t (based on cockles less than 30 mm shell length) was derived, with a coefficient of variation (c.v.) of 25%. Using $F_{0.1}$ and F_{max} values determined previously for this fishery (0.41 and 0.62 respectively), and with M = 0.30, estimates of constant annual yield (CAY) were 167 t ($F_{0.1}$) and 231 t (F_{max}). Estimates of maximum constant yield (MCY) were 196 t ($F_{0.1}$) and 296 t (F_{max}), and remain unchanged from the 1996 assessment. For McDonald Bank, a recruited biomass of 1137 t (c.v., 30%) was estimated.

1. INTRODUCTION

1.1 Overview

There has been a commercial fishery for cockles on Snake Bank since at least the early 1970s, but reported landings before 1982 were small. Reported landings increased from about 150 t to 450 t between 1982 and 1991, and have remained around this level since. Recruited (greater than 30 mm shell length) biomass fell by about two-thirds between 1982 and 1991 to about one-third of probable virgin level. The proportion of very large (over 35 mm) cockles decreased to less than 10% of the likely virgin level.

Both growth rate and recruitment of cockles appear to have increased during this time, although recruitment has been variable (σ_R= 0.31 (average log of estimated 0+ recruitment)) since the fishery has been considered to be fully developed (Cryer 1997). Estimates of $F_{0.1}$ and F_{max} were made in 1996 (Cryer 1997), 1998 (Morrison & Cryer 1999), and 1999 (Morrison 2000) using a yield per recruit (YPR) model with quarterly time steps and based on critical sizes rather than assumed rates of vulnerability by age. Using these reference fishing mortalities and estimates of abundance from surveys, current yield estimates were MCY = 200–300 t and CAY = 388–535 t, which in general are less than recent average landings (500 t).

The Ministry of Fisheries is considering new controls to ensure sustainable harvesting. Given the recruitment variability and rapid growth of cockles in this fishery, a management strategy based on CAY is likely to be favoured. Such an approach requires frequent (preferably annual) estimates of biomass. This document reports the most recent biomass survey for Snake Bank (April 2000). The specific objectives for this project were as follows.

1. To estimate the absolute biomass of cockles on Snake Bank and McDonald Bank during the 1999/2000 fishing year. The target coefficient of variation (c.v.) of the estimate of absolute recruited biomass is 20 %.

2. To estimate the Current Annual Yield (CAY) for cockles on Snake Bank for the 2000/01 fishing year.

3. To develop a length based stock assessment model for cockles.

Objective 3 was reported by Breen (in press).

1.2 Literature review

Cryer (1997) summarised information on cockles in New Zealand, and no new information has become available since.

2. REVIEW OF THE FISHERY

2.1 Catch limits and landings

Commercial picking on Snake Bank in Whangarei Harbour began in the early 1980s and is undertaken year round, with no particular seasonality. Effort and catch information for this fishery has not been adequately reported in the past, and there are problems interpreting the information that is available. Catch statistics are unreliable before 1986, although 165 t of Snake Bank cockles were exported to the United States in 1982 (Martin 1984). Landed weights reported on Catch Effort and Landing Returns (CELRs) summed to only 50–90% of weights reported on LFRRs during 1989–90 to 1992–93, although more recent data match more closely. In addition, reported landing weights are based on an assumed sack weight of 28 kg, whereas actual measured weights are closer to 30 kg. Landings are therefore estimated using LFRRs where these are available.

There are eight permit holders, each allowed to harvest a maximum of200 kg (greenweight) per day by hand-gathering. If all permit holders took their quota every day, a maximum of 584 t could be taken per year. Landings increased rapidly from less than 200 t before the 1988–89 fishing year to exceed 90% of the theoretical maximum in all years since 1991–92, other than 1992–93 when the fishery was closed during the summer because of high levels ofbiotoxins.

Reported landings for Snake Bank from Licensed Fish Receiver Returns (LFRRs) are shown in Table 1. Reported landings before 1986–87 were less than 50 t (J. Holdsworth, pers. comm., ex-technical offer, MAF), but the fishery (anecdotally) supported up to six full-time pickers in some years, suggesting that there was probably some under-reporting of landings.

Table 1: Reported landings (t, greenweight) from Licensed Fish Receiver Returns for the Snake Bank cockle fishery. The Snake Bank fishery has, since its inception, been limited by a daily limit of 200 kg per permit which equates to an annual aggregate catch of 584 t in a 365 day year (586 t in a leap year). *, landings in 1992–93 constrained by an extended closure due to biotoxin contamination; **, the estimated landings of 566 t in 1993–94 may be unreliable.

Fishing Year	Landings (t)	Sum of daily limits (t)
1986–87	114	584
1987–88	128	586
1988–89	255	584
1989–90	426	584
1990–91	396	584
1991–92	537	586
1992–93	*316	584
1993–94	**566	584
1994–95	501	584
1995–96	495	586
1996–97	457	584
1997–98	439	584
1998–99	473	584

For several years, landings in the Snake Bank fishery were not apparently limited by the daily catch limit of 200 kg per permit. However, since the 1991–92 fishing year, reported landings have been close to the theoretical maximum imposed by the daily limit. The aggregate limit of 584–586 t was not based on research information or yield estimates.

2.2 Non-commercial fisheries

Cockles, in common with many other intertidal shellfish, are important to Maori as a traditional food source. They are also taken by recreational harvesters. Non-commercial harvesters prefer relatively large cockles, a length of about 30 mm or greater being acceptable. Accurate estimates of cockle harvest for recreational fishers are not available for areas as small as Snake Bank, but about 50–60 t were taken throughout the Auckland Fishery Management Area during the 1994 regional telephone and diary survey (T. Sylvester, MFish, pers. comm.). The proportion of these cockles taken from Whangarei Harbour (probably Snake Bank) was only about 2% of the whole, indicating that amateur harvest was insignificant (about 1 t) compared with commercial landings (about 500 t).

3. RESEARCH

3.1 Recruited biomass for 2000

3.1.1 Survey methods

Grid surveys have been used in previous surveys because of ease of location of sampling sites, good coverage of the entire bank, and to allow iterative increase in the sampled area during sampling until the periphery of the cockle "stock" had been reached. Such surveys, using a grid spacing of 50 * 50 m and about 190 sites, achieved a c.v. of 7–10% (Cryer 1997) assuming that sampling points were randomly distributed (this assumption is usually reasonable, Milne 1959, Ripley 1981). Circumstances where the assumption is not reasonable include those where there is spatial correlation of density (where the variance tends to be biased (Wolter 1984)) or patchiness on a scale "in phase" with the sampling grid (where the biomass estimate itself can be biased). In some conditions, the level of these biases can be very high (Payandeh 1970, Dunn & Harrison 1993). Several alternative variance estimators have been developed specifically for systematic surveys (e.g., Dunn & Harrison 1993, Millar & Olsen 1995), although there is no consensus as to the most appropriate; all are approximate and pragmatic solutions to a difficult problem.

Because of these difficulties with systematic sampling, a stratified random approach to the estimation of recruited biomass was adopted in 1998, 1999, and for the latest (April 2000) Snake Bank survey. Simple random sampling would have been possible for earlier surveys, but good stratification would have been very difficult due to a lack of information on spatial distribution and its consistency among surveys. Analysis of historical records revealed a consistent pattern of two major centres of high cockle density separated by a sinuous bank of slightly higher elevation and lower cockle density (the "snake") and surrounded by areas of lower density at or about the low tide mark. This basic pattern was consistent among surveys, but the location of the "snake" and the edges of the bank change slightly among years.

The stratification for 2000 was as follows for Snake Bank (see also Figure 1, Table 2).

- The two high density areas were sampled separately (SH1 and SH2).
- The medium density areas surrounding the high density areas, and throughout the "snake", were assigned to a single medium density stratum (SM1).
- The peripheral (low tide) area formed a single large low density stratum (SL1).

Stations were allocated to strata using simulation, using the 1998–99 survey data. A minimum of five stations was allocated per stratum. Additional stations were added iteratively to each of the strata, and the density and variance information used to predict the likely improvement in the c.v. for each possible stratum allocation. The station was then assigned to the stratum giving the greatest improvement in the c.v., and the process repeated until all stations available were allocated.

Table 2: Sampling design for Snake and McDonald Banks cockles to estimate absolute recruited (≥ 30 mm shell length) cockle biomass. Station density describes the relative intensity of sampling per unit area.

Stratum	Description	Area (km²)	No of stations	Station density (per km²)
Snake Bank				
SH1	High density	0.239	20	84:1
SH2	High density	0.035	5	143:1
SM1	Medium density	0.144	5	35:1
SL1	Low density	1.145	20	17:1
Total		1.563	50	
McDonald Bank				
MH1	High density	0.193	15	78:1
MM1	Medium density	0.112	5	45:1
ML1	Low density	1.283	10	8:1
Total		1.588	30	

For McDonald Bank, the bank was stratified using the results from the 1997–98 survey. Three strata were assigned to the bank, representing different densities of cockles. Stations were assigned to each of these strata in the same way as for Snake Bank (Table 2).

Sites were located from bearings on navigational landmarks to determine position using a compass and laser rangefinder. At each site, a square quadrat of 0.5 * 0.5 m (0.25 m^2) was thrown haphazardly onto the bank. All sediment beneath the quadrat was excavated by hand, including those animals directly under the south- and west-facing sides (this accounted for any possible "edge effects"). Cockles were extracted from the sediment using a metal sieve of 5 mm square aperture, agitated in water. The aggregate weight of all cockles in each of three size classes (less than 30 mm, 30–34 mm, and greater than or equal to 35 mm) was measured directly for each site.

The recruited biomass of cockles on Snake Bank was estimated using the weighted average of the five stratum estimates of recruited biomass, weights being proportional to the relative size of each stratum.

$$\bar{x} = \sum_{i=1}^{5} W_i \bar{x}_i$$

where $\bar{x}$ is the estimated biomass, W_i is the area, and $\bar{x}_i$ the estimated recruited biomass in stratum i. The variance for this mean was calculated as:

$$s^2 = \sum_{i=1}^{5} W_i^2 s_i^2 / n_i$$

where s^2 is the variance of the estimated recruited biomass, s_i^2 is the variance, and n_i the number of samples taken within stratum i (Snedecor & Cochran 1989). No finite correction term was applied because the sampling fraction was negligible (much less than 1% of the total available area).

A sample of up to 100 cockles from each quadrat was measured to the next lower whole millimetre using vernier callipers, and all unmeasured cockles were counted. Where subsampling was undertaken, an estimate of the sample length frequency was made by scaling each count within a stratum by the inverse of its sampling fraction. Estimated stratum length frequency distributions were derived by weighted averaging of all (estimated) length frequency samples taken within each stratum, weights being proportional to the estimated total density of cockles at each site. Stratum length frequency distributions were scaled to the estimated total abundance of cockles within each stratum using the overall fraction sampled. A fully scaled length frequency distribution for the whole of the survey area was then derived by addition of stratum length frequency distributions. The total number of cockles present within the surveyed areas was derived by summing the scaled length frequency distributions.

A sample of about 300 animals from McDonald Bank wase also measured and animals weighed individually to determine length-weight relationships.

3.1.2. Survey results and discussion

The estimated recruited biomass of cockles on Snake Bank was 570 t with a c.v. of 25% (Table 3). This is the lowest estimate ever recorded for Snake Bank. The estimated c.v. was greater than the target c.v. of 20%; this may have been partly attributable to a decline in abundance across the medium and high density strata, with associated changes in relative abundance throughout these areas. Evidence of fishers operating in areas of the bank not usually fished also lends some support to change in the distribution of cockles on the bank.

The scaled length frequency distribution for Snake Bank showed a broad, uni-modal length frequency distribution (Figure 2), almost certainly composed of multiple age classes. There was some evidence of modest recruitment to the overall population since 1999, with the occurrence of animals in the 6–20 mm size range.

The proportion of biomass in the "fishable" portion of the stock (shell length over 29 mm) was about 30%, which is less than in the 1999 survey (38%). This contrasts with about 90% in the first two surveys. The proportion of cockles 35 mm or larger is now about 5%, compared to about 70% in the initial surveys. Figure 3 shows historical trends in estimated biomass.

Currently 21% of the population is under 21 mm. Historical values have ranged from 14 to 38% back to 1991; before this, the range was only 5–10% (for the first two surveys, where most of the population consisted of relatively large individuals). This average proportion of small cockles does indicate that some recruitment to the fished stock should occur over the next 2–3 years.

For McDonald Bank, biomass estimates were similar to those derived from the 1998 survey given the moderate c.v.s (Table 3). The current biomass of cockles 30 mm or over in size is approximately double that of Snake Bank (1137 t, c.f. 570 t), and there is potential for this biomass to be fished, possibly to relieve pressure on the Snake Bank resource. The scaled length frequency for 2000 was very similar to that of the 1998 survey (Figure 4).

Table 3: Biomass estimates (t) by shell length size classes for cockles on Snake and McDonald Banks. Approximate coefficients of variation (percentage) are given in parentheses for recent biomass estimates. N, the number of samples in each survey. Estimates for 1985 and 1991 corrected assuming measured density and sampling area as in 1982.

Year	N	Total	c.v. (%)	< 30 mm	c.v. (%)	≥ 30 mm	c.v. (%)	≥ 35 mm	c.v. (%)
Snake Bank									
1982	199	2 556		216		2 340		1 825	
1983	187	2 509		321		2 188		1 700	
1985	136	2 009	(8)	347		1 662	(8)	1 174	
1991	158	1 447	(9)	686	(10)	761	(10)	197	(12)
1992	191	1 642	(8)	862	(10)	780	(8)	172	(11)
1995	181	2 480	(7)	1 002	(9)	1 478	(7)	317	(12)
1996	193	1 755	(7)	959	(9)	796	(8)	157	(11)
1998	55	2 401	(18)	1 520	(20)	880	(17)	114	(20)
1999	47	3 486	(12)	2 165	(12)	1 321	(14)	194	(32)
2000	50	1 906	(23)	1 336	(24)	570	(25)	89	(32)
McDonald Bank									
1998	33	6 939	(19)	5 261	(18)	1 678	(31)	128	(41)
2000	30	6 037	(28)	4 899	(29)	1 137	(30)	34	(37)

3.1.3 Revised length–weight relationships

One new length-weight relationship was estimated (Table 4).

Table 4: Length-weight regressions ($W = aL^b$) for cockles on Snake Bank and McDonald Bank (weight in grams, length in mm). Locations relate to the area from which the cockles were collected.

Year	Location	a	B	n	Reference
Snake Bank					
1992	Random	0.00110	2.721	607	Cryer & Holdsworth (1993)
1995	Random	0.00015	3.285	226	Annala & Sullivan (1996)
1996	Mid-tide	0.00018	3.253	240	Cryer (1997)
1996	Lagoon	0.00037	3.060	204	Cryer (1997)
1998	Mid-tide	0.00018	3.275	103	Morrison & Cryer (1999)
1999	Lagoon	0.00009	3.450	114	Morrison (2000)
1999	Mid-tide	0.00010	3.445	122	Morrison (2000)
McDonald Bank					
1998	General	0.0007	2.830	119	Morrison & Cryer (1999)
2000	General	0.0004	3.046	371	This FAR

3.2 Yield estimates

3.2.1 Estimation of Maximum Constant Yield (MCY)

MCY was calculated using the equation

$$MCY = 0.50 * F_{ref} * B_{av}$$

where F_{ref} is a reference fishing mortality and B_{av} is the average recruited biomass during a time when the fishery is thought to have been fully exploited (Method 2, Annala & Sullivan 1996). Average recruited biomass was estimated as the mean of all survey estimates from 1991 to 1996 (during which time the fishery is thought to have been fully exploited) and was 954t with a standard error of 175 t (*c.v.* = 18%). $F_{0.1} = 0.41$ and $F_{max} = 0.62$ were selected as alternative reference fishing mortality rates (Cryer 1997).

For $F_{0.1}$, $MCY = 0.50 * 0.41 * 954 = 196$ t (rounded to 200 t), or

For F_{max}, $MCY = 0.50 * 0.62 * 954 = 296$ t (rounded to 300 t)

The level of risk to the stock by harvesting the population at either of the estimated MCY values cannot be determined, but would be greater for the F_{max} option. Both estimates of MCY would have an associated c.v. of at least 18% (that associated with the estimate of average biomass). Additional error sources would include components from the estimation of M, growth, and the length-weight relationship.

3.2.2 Estimation of Current Annual Yield

CAY can be estimated using the Baranov catch equation because fishing is carried out year round and natural and fishing mortality act simultaneously (Annala & Sullivan 1996).

$$CAY = \frac{F_{ref}}{F_{ref} + M}\left(1 - e^{-(F_{ref}+M)}\right)B_{beg}$$

where F_{ref} is a reference fishing mortality, M is natural mortality, and B_{beg} is the start of season recruited biomass. Using the estimates of $F_{0.1} = 0.41$ and $F_{max} = 0.62$ (Cryer 1997) for F_{ref}, the estimate of $M = 0.30$ from Cryer & Holdsworth (1993) and the latest estimate of recruited (30 mm or greater) biomass, therefore:

For $F_{0.1}$, CAY = 0.5775 * 0.5084 * 570 t = 167 t

For F_{max}, CAY = 0.6739 * 0.6015 * 570 t = 231 t

The level of risk to the stock by harvesting the population at either of the estimated CAY values cannot be determined. Both estimates of CAY would have an associated c.v. of 25% (that associated with the estimate of current absolute biomass). Additional error sources would include components from the estimation of M, growth, and the length-weight relationship

4. DISCUSSION

Catch continues to exceed estimates of MCY and CAY but, despite this, recruited biomass has remained remarkably consistent at 700–900 t since 1991 (with the exception of 1995 and 1999), until this 2000 survey. Recruited biomass has now fallen to 570 t, which is the lowest on record. This is of some concern, and indicates that stock abundance may be declining. Some modest recruitment to the overall population has occurred since the 1999 survey, but appears insufficient to generate substantive increases in recruited biomass in future years.

Examination of nearby McDonald Bank in 1998 and 2000 indicates a sizeable recruited cockle biomass, exceeding that of the Snake Bank fishery, and this additional area could perhaps be opened for commercial harvesting in the future to reduce harvesting pressure on Snake Bank. However, this apparently unexploited population contains a much higher proportion of smaller cockles than has been found on any of the Snake Bank surveys. Reasons for this difference are unknown, but there may be some difference in population dynamics between the two areas.

The length-based model recently developed by Breen (in press) utilises the data time series documented in this report. There are some disagreements between the raw data and the fitted model, with the model not tracking the decline seen in recruited biomass over recent years. Changes in the dynamics of the stock may at least partially explain this discepancy; these may include changes in growth rate with changes in density (circumstantial evidence given by Morrison 2000), or some similar effect on recruitment levels (e.g. low recruitment at high adult biomasses). Work is scheduled on the effects of density and tidal height on growth rates in the coming year, which will go some way towards addressing these concerns.

5. ACKNOWLEDGMENTS

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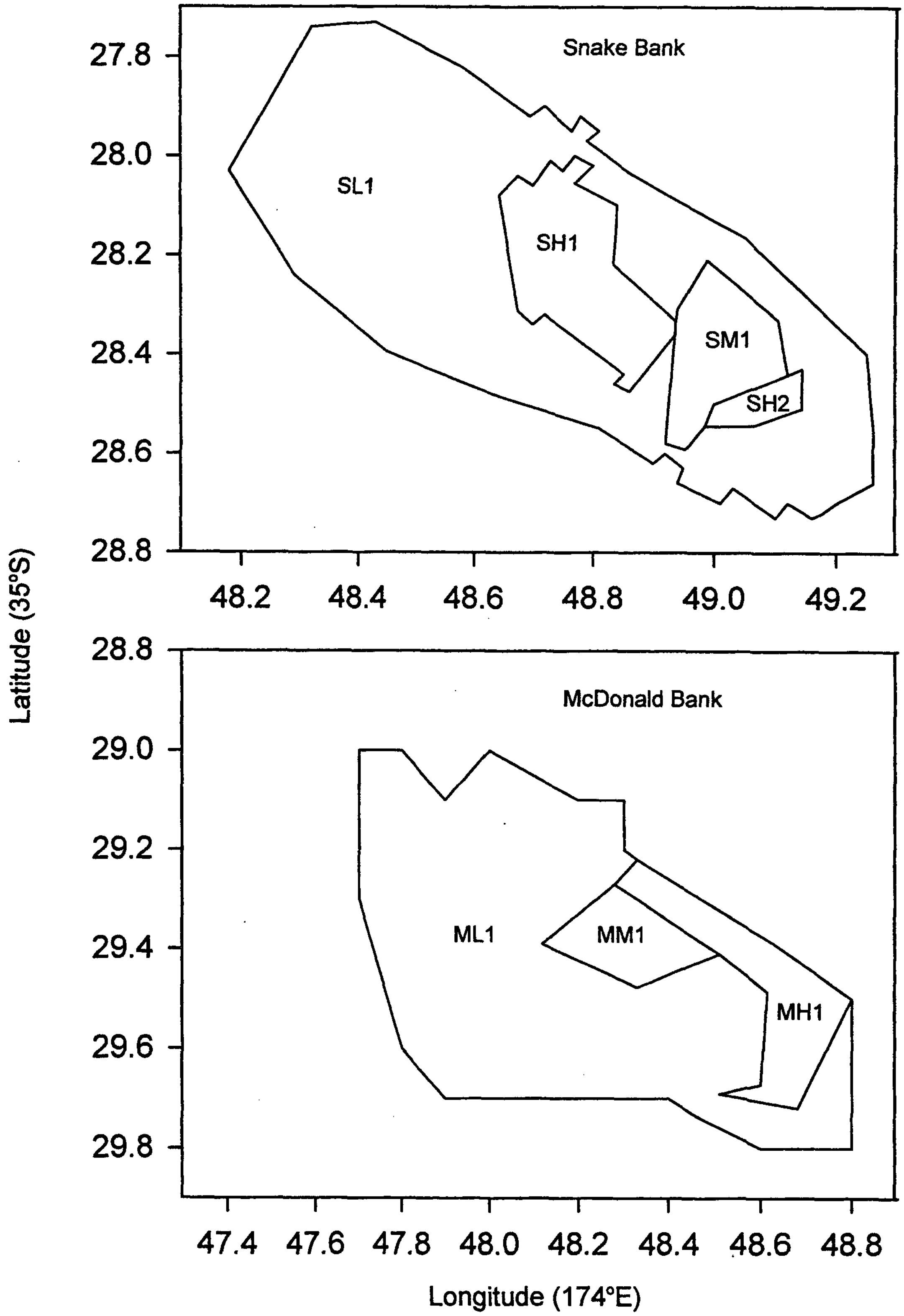

Figure 1: Stratification maps for Snake and McDonald Bank 1999/2000 survey See Table 2 for definition of stratum codes.

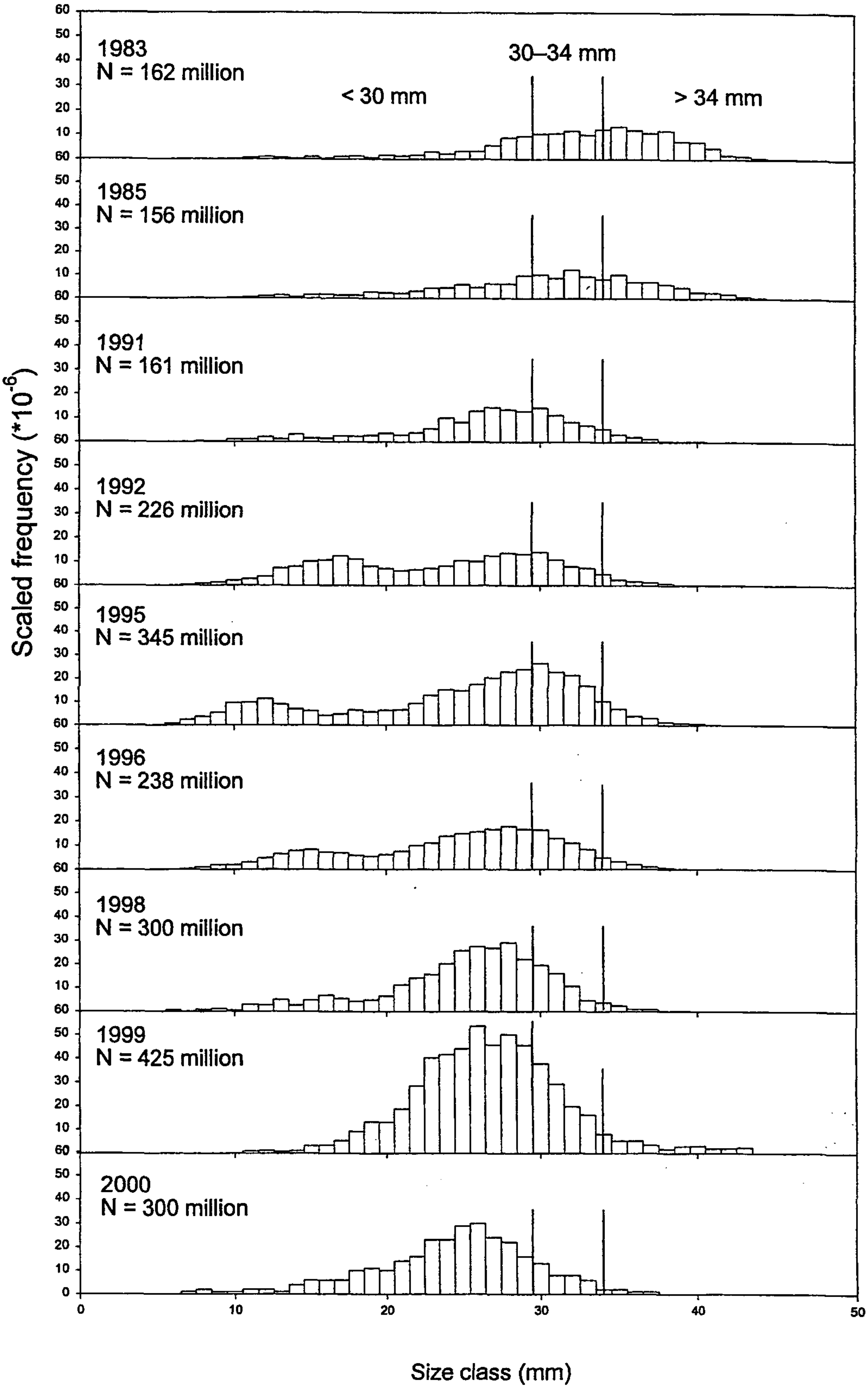

Figure 2: Length frequency distributions, scaled to total population size, for cockles on Snake Bank, Whangarei Harbour, during full biomass surveys, 1983–2000. N, total estimated cockles present within the surveyed area.

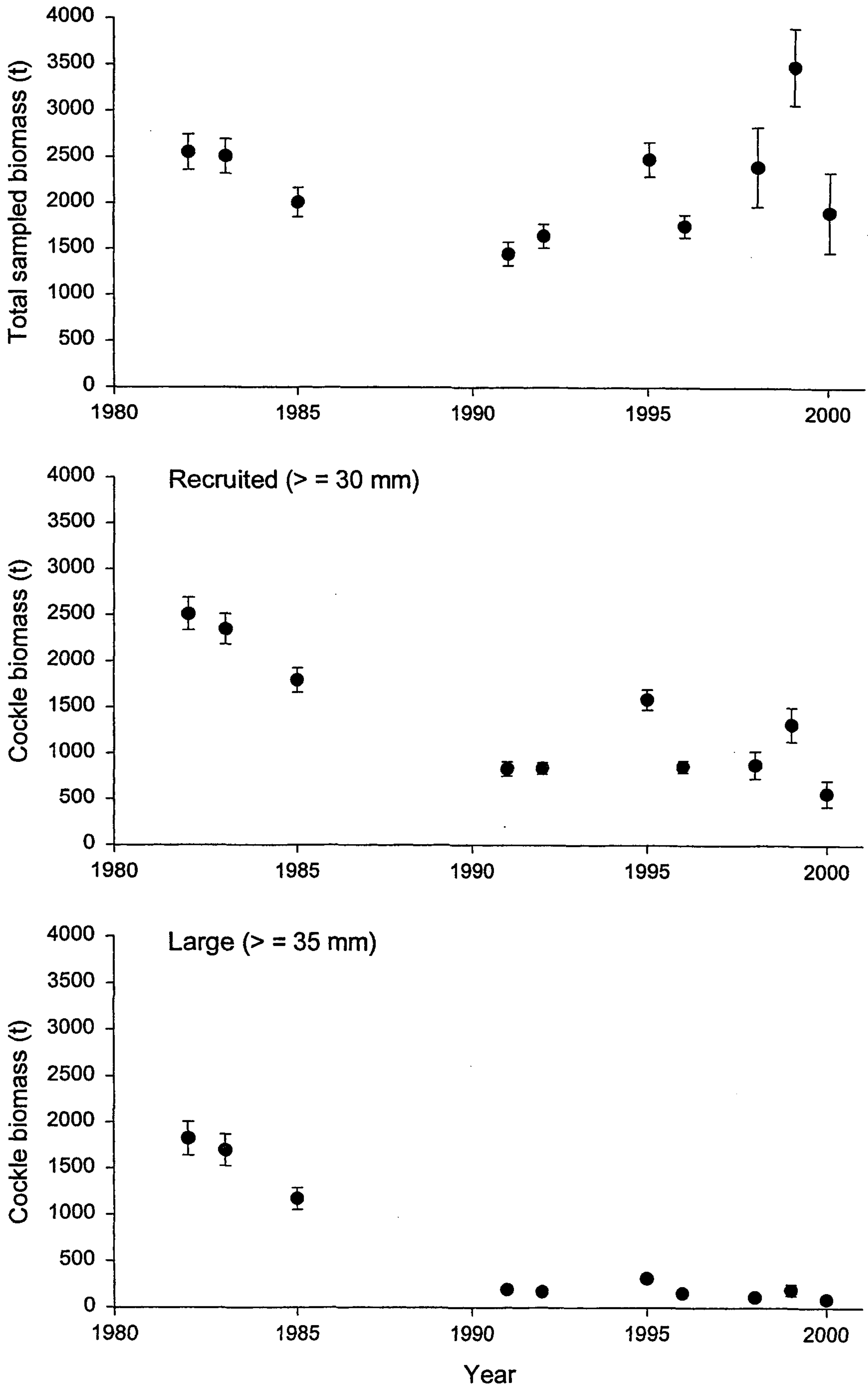

Figure 3: Trajectories (+/- one standard error) of total, recruited (> 30 mm) and large (> 35 mm) cockle biomass on Snake Bank since the inception of the fishery in 1982.

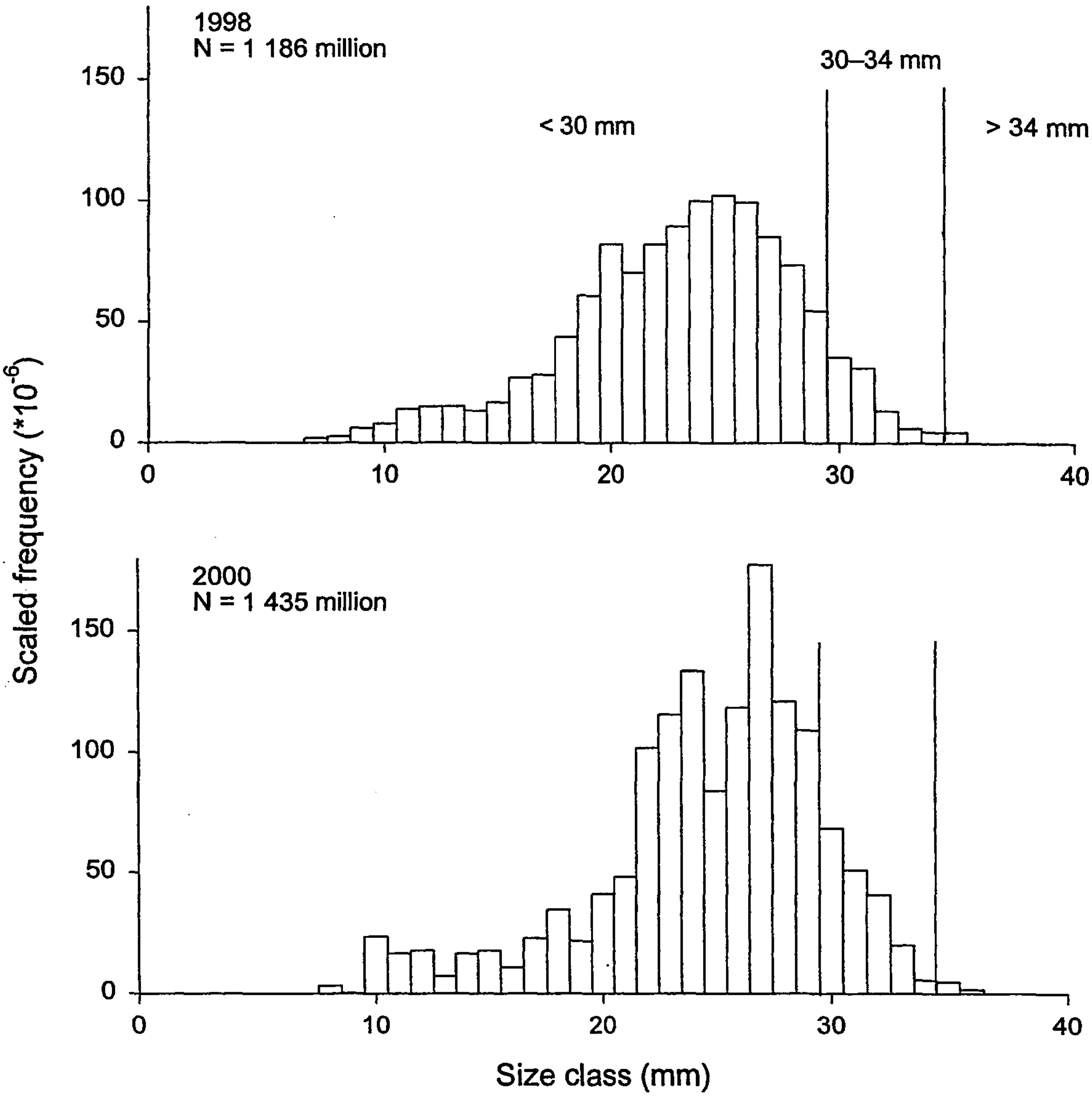

Figure 4: Length frequency distribution, scaled to total population size, for cockles on McDonald Bank, 1998–2000. N, total estimated number of animals within the surveyed area.