*New Zealand Fisheries Assessment Research Document 99/7*

# Stock assessment of cockles on Snake and McDonald Banks, Whangarei Harbour, 1998

**M. Morrison & M. Cryer**

**NIWA**
**PO Box 109 695**
**Newmarket**
**Auckland**

**February 1999**

**Ministry of Fisheries, Wellington**

# Stock assessment of cockles on Snake and McDonald Banks, Whangarei Harbour, 1998

**M. Morrison & M. Cryer**

**New Zealand Fisheries Assessment Research Document 99/7. 12 p.**

## 1. EXECUTIVE SUMMARY

To assess potential current available yield (CAY) from the Snake Bank cockle fishery, a stratified random biomass survey was undertaken in March 1998. Historical data from previous grid-based surveys were used to divide Snake Bank into appropriate density strata. A recruited biomass estimate of 880 t was derived, with a *c.v.* of 17% (based on cockles less than 30 millimetres). 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 258 t ($F_{0.1}$) and 357 t ($F_{max}$). Estimates of maximum constant yield (MCY) were 180 t ($F_{0.1}$) and 273 t ($F_{max}$), and remain unchanged from the 1996 assessment

McDonalds Bank was also surveyed, giving a biomass estimate of 1678 t, with a *c.v.* of 31% (based on cockles less than 30 millimetres). Using the reference fishing mortalities derived for Snake Bank, the estimates of CAY were 493 t ($F_{0.1}$) and 680 t ($F_{max}$).

Some problems were encountered with changes having occurred in the two banks' areal extent since this area was last charted. It is recommended that in future surveys the banks' areas be re-surveyed before undertaking the biomass survey proper.

## 2. INTRODUCTION

### 2.1 Overview

There has been a commercial fishery for cockles on Snake Bank since at least the early 1970s, though reported landings before 1982 were small. Reported landings increased from around 150 t to 450 t between 1982 and 1991, and have remained around this level since. Recruited (greater than 30 mm) biomass fell by about two–thirds between 1982 and 1991, to about one–third of probable virgin level. The proportion of very large (greater than 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 ($\sigma_R$ = 0.31) since the fishery has been considered to be fully developed (Cryer 1997). Estimates of $F_{0.1}$ and $F_{max}$ were made in 1996 using a quarterly yield per recruit (YPR) model based on critical sizes rather than assumed rates of vulnerability by age (Cryer 1997). Using these reference fishing mortalities and estimates of abundance from surveys, current yield estimates were MCY = 200–300 t and CAY = 235–325 t (1997 survey data), both considerably less than recent average landings (500 t).

The Ministry of Fisheries is considering new controls to ensure the sustainable use of this fishery. 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 (March 1998), and a survey done at the same time on nearby McDonalds Bank.

### 2.2 Description of the Fishery

Commercial picking on Snake Bank in Whangarei Harbour began in the early 1980s and is undertaken year round, with no particular seasonality. Catch statistics are unreliable before 1986, although 165 t of Snake Bank cockles were exported to the United States in 1982 (Martin 1984). There was probably some under-reporting of landings before 1986, and this may have continued since. There are eight permit holders, each allowed a maximum of 200 kg (greenweight) per day by hand-gathering. If all permit holders took their quota every day a maximum of 584 t could be taken in a 365 day 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 of biotoxins.

### 2.3 Literature Review

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

## 3. REVIEW OF THE FISHERY

### 3.1 Catch limits and landings

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.), but the fishery (anecdotally) supported up to six full-time pickers in some years, suggesting that there was probably some under-reporting of landings. 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. Landed weights reported on Catch Effort and Landing Returns (CELR) 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.

**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 | 584 |
| 1996–97 | 457 | 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.

### 3.2 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 amateurs. Non-commercial harvesters of cockles prefer relatively large individuals, a length of about 30 mm or greater being acceptable. Accurate estimates of cockle harvest for amateur fishers are not available for areas as small as Snake Bank, but about 50–60 t were taken by amateurs 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).

## 4. RESEARCH

### 4.1 Recruited biomass for 1998

#### 4.1.1 Survey methods

Grid surveys have been used in previous surveys for reasons 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 was clearly erroneous, although several authors have pointed out that such an assumption is usually reasonable (e.g., 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 1997, 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 for the present 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 1997–98 was as follows for Snake Bank (*see* also Table 2).

- The two high density areas were sampled separately, and the larger of the two split into two strata to ensure a good coverage of stations. Thus there were three high density strata
- The medium density areas surrounding the high density areas, and throughout the "snake", were assigned to a single density stratum.
- The peripheral (low tide) area formed a single large low density stratum

Stations were allocated to strata using simulation. All available historical data were pooled, and a bootstrapping procedure was used to estimate the minimum number of stations needed to achieve a target *c.v.* of 20%. A minimum of five stations was allocated per stratum.

The stratification for McDonalds Bank involved the splitting of the bank into two strata (north and south) of similar areal extent (Table 3). Stations were assigned based on the relative area of each stratum. No suitable historical data were available to allow more detailed stratification.

**Table 2: Sampling design for Snake Bank cockles to estimate absolute recruited (≥ 30 mm shell length) cockle biomass .**

| Stratum | Area ($m^2$) | Number of stations |
|---|---|---|
| High 1 | 129 196 | 11 |
| High 2 | 187 988 | 13 |
| High 3 | 118 378 | 14 |
| Medium | 302 567 | 12 |
| Low 1 | 825 500 | 5 |
| Total | 1 563 629 | 55 |

**Table 3: Sampling design for McDonald Bank cockles to estimate absolute recruited (≥ 30 mm shell length) cockle biomass**

| Stratum | Area ($m^2$) | Number of stations |
|---|---|---|
| North | 725 464 | 15 |
| South | 837 952 | 18 |
| Total | 1 563 416 | 33 |

Sites were located from bearings on excellent 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 overall average recruited biomass of cockles on Snake Bank was estimated using the weighted average of the five stratum estimates of mean recruited biomass, weights being proportional to the relative size of each stratum. For McDonalds Bank, the weighted average of the two stratum estimates of mean recruited biomass was used, again with weights being proportional to the relative size of each stratum.

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

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

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

Where $s^2$ is the variance of the estimated mean recruited biomass, $s_i^2$ is the sampling 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 (greatly less than 1% of the total available area).

A sample of up to 100 cockles from each quadrat was measured to the next whole millimetre down 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 100 animals from each of Snake Bank and McDonald Bank was also measured and animals were weighed individually to determine length-weight relationships.

### 4.1.2. Survey results and discussion

The estimated recruited biomass of cockles on Snake Bank as determined by weighing and scaling of subsamples was 880 t with a *c.v.* of 17 % (Table 4). This is slightly higher than the 1996 estimate of 796 t (*c.v.* of 8%), and 1991 and 1992 estimates of 760 and 780 t (*c.v.*s of 10 and 8%). However, 1995 had about double the estimated recruited biomass (1480 t, *c.v.* 7%) due to the full recruitment to the fished stock of a juvenile pulse first detected in 1992.

The scaled length frequency distribution for Snake Bank showed a bimodal length frequency distribution (Figure 1), which is consistent with the scaled length frequency observed since the 1992 survey. The first mode was at about 15–20 mm, and is assumed to be a recruiting year class, and the second (corresponding to the accumulated biomass of older cockles) at slightly under 30 mm.

The proportion of biomass in the "fishable" portion of the stock (shell length less than 30 mm) was about 36%, which is effectively the same as in the 1996 survey (35%). This contrasts with about 90% in the first two surveys. The proportion of cockles of shell length of 35 mm or greater is now about 5%, compared to about 70% in the initial surveys. Figure 2 shows historical trends in estimated biomass

The estimated recruited biomass of cockles on McDonalds Bank was estimated at 1750 t with a *c.v.* of 31.4% (Table 4). No reliable historical estimates are available for comparison. The scaled length frequency showed a bimodal distribution (Figure 3), with the first mode at about 11–15 mm, and the second, dominant mode around 20–30 mm. No animals larger than 35 mm were sampled.

**Table 4: 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) |
| McDonald Bank | | | | | | | | | |
| 1998 | 33 | 6 939 | (± 19) | 5 261 | (± 18) | 1 678 | (± 31) | 128 | (± 41) |

### 4.1.3 Revised length – weight relationships

Two new length–weight relationships were estimated (Table 6).

**Table 5: Length weight regressions ($W = aL^b$) for cockles on Snake Bank.(weight in grams, length in mm). Locations relate to the area on Snake Bank from which the cockles were collected**

| Year | Location | a | b | n | Reference |
|---|---|---|---|---|---|
| 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 | This FARD |
| 1998 | McDonalds | 0.00067 | 2.830 | 119 | This FARD |

## 4.2 Yield Estimates

### 4.2.1 Estimation of Maximum Constant Yield

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) being 954 t 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.

### 4.5.2 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).

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

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) as alternatives 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 * 880 t = 258 t

For $F_{max}$, CAY = 0.6739 * 0.6015 * 880 t = 357 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 17 % (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

## 5. DISCUSSION

Catch continues to exceed estimates of MCY and CAY, but despite this the recruited biomass has remained remarkably consistent at 700–900 t since 1991 (with the exception of 1995). Some recruitment appears to have occurred since 1996.

Examination of nearby McDonalds Bank indicates a sizeable recruited cockle biomass to be present, exceeding that estimated for 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.

Some problems were encountered during the survey with the extent of the two banks having shifted slightly compared to past surveys, making estimation of total stratum areas more difficult. In future surveys it would be beneficial to conduct a brief survey before sample allocation and sampling are carried out.

**Acknowledgments**

Thanks are due to Derrick Parkinson for organising the survey, and to G. MacKay and R. Tasker for assisting in carrying out the survey. P. Breen provided review on a draft of this report, and M. Beardsell and J. Annala provided editorial comment. This research was funded by MFish contract COC9702.

## References

Annala, J.H. & Sullivan, K.J. (Comps.) 1996: Report from the Fishery Assessment Plenary, April–May 1996: stock assessments and yield estimates. 308 p. (Unpublished report held in NIWA library, Wellington)

Cryer, M. & Holdsworth, J. 1993: Productivity estimates for Snake Bank cockles, August 1992 to August 1993. MAF Fisheries Northern Fisheries Region Internal Report, Auckland. (Draft report held at NIWA, Auckland)

Cryer, M. 1997: Assessment of cockles on Snake Bank, Whangarei Harbour, for 1996. *N.Z. Fisheries Assessment Research Document 97/2.* 29 p.

Dunn, R. & Harrison, A.R. 1993: Two dimensional systematic sampling of land use. *Applied Statistics 42:* 585–601

Holdsworth, J. & Cryer, M. 1991: Assessment of the cockle, *Chione stutchburyi*, resource and its associated fishery in Whangarei Harbour. (Unpublished report held at NIWA, Auckland)

Martin, N.D. 1984: *Chione stutchburyi* population responses to exploitation. Unpublished MSc thesis, University of Auckland, N.Z.

Millar, R.B. & Olsen, D. 1995: Abundance of large toheroa (*Paphies ventricosa* Gray) at Oreti Beach, 1971–90, estimated from two dimensional systematic samples. *N.Z. Journal of Marine and Freshwater Research 29:* 93–99

Milne, A. 1959: The centric systematic area-sample treated as a random sample. *Biometrics* 15: 270–297

Payandeh, B. 1970: Relative efficiency of two dimensional systematic sampling. *Forrest Science* 16: 271–276

Ripley, B.D. 1981: *Spatial statistics.* Wiley, New York, USA. 252 p.

Snedecor, G.W. & Cochran, W.C. 1989: *Statistical Methods.* 8th ed. Iowa State University Press, Ames, Iowa, USA.

Wolter, K.M. 1984: An investigation of some estimators of variance for systematic sampling. *Journal of the American Statistical Association* **79**: 781–790

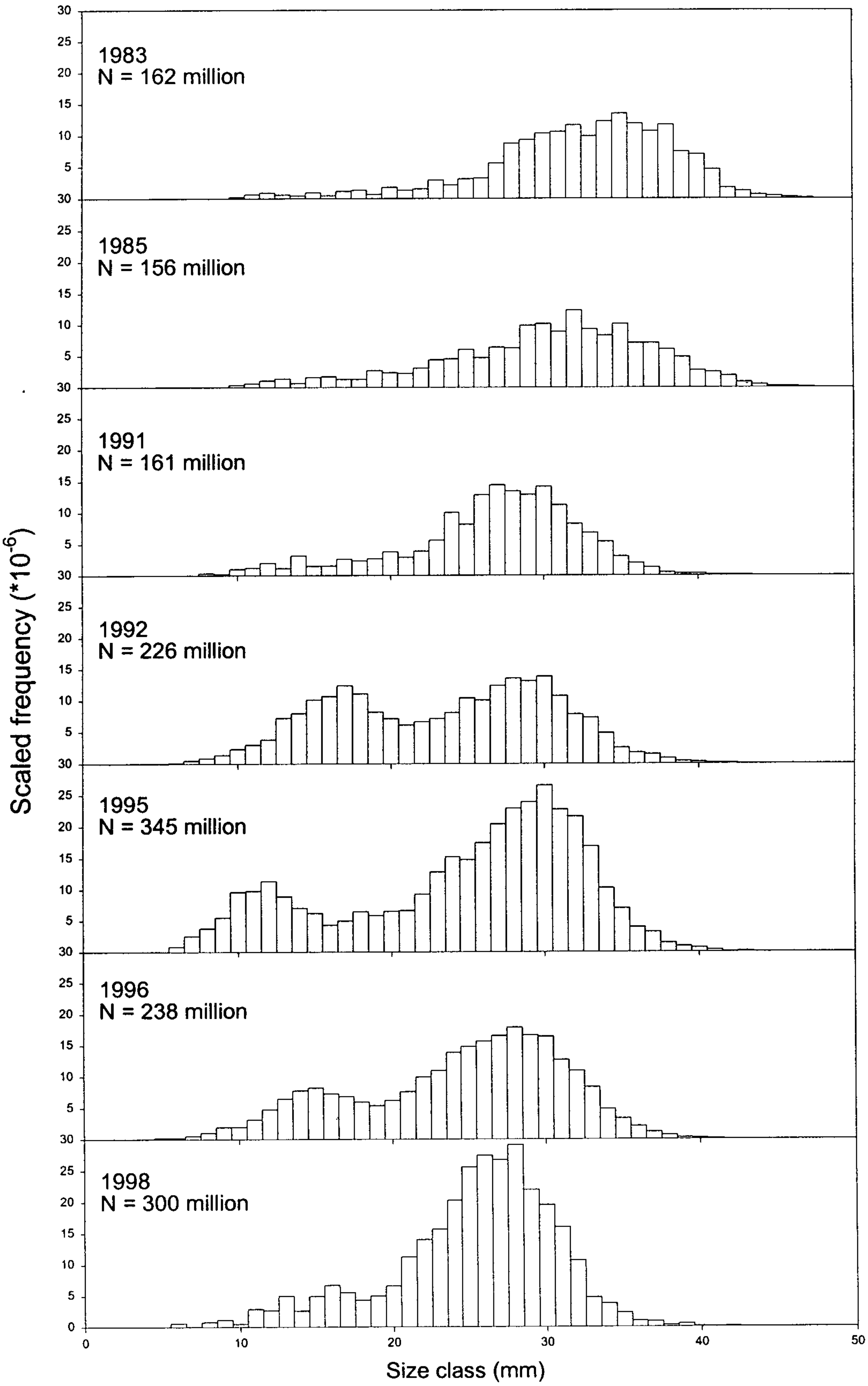


Figure 1: Length frequency distributions, scaled to total population size, for cockles on Snake Bank, Whangarei Harbour, during full biomass surveys, 1983–98. N, total estimated cockles present within the surveyed area.

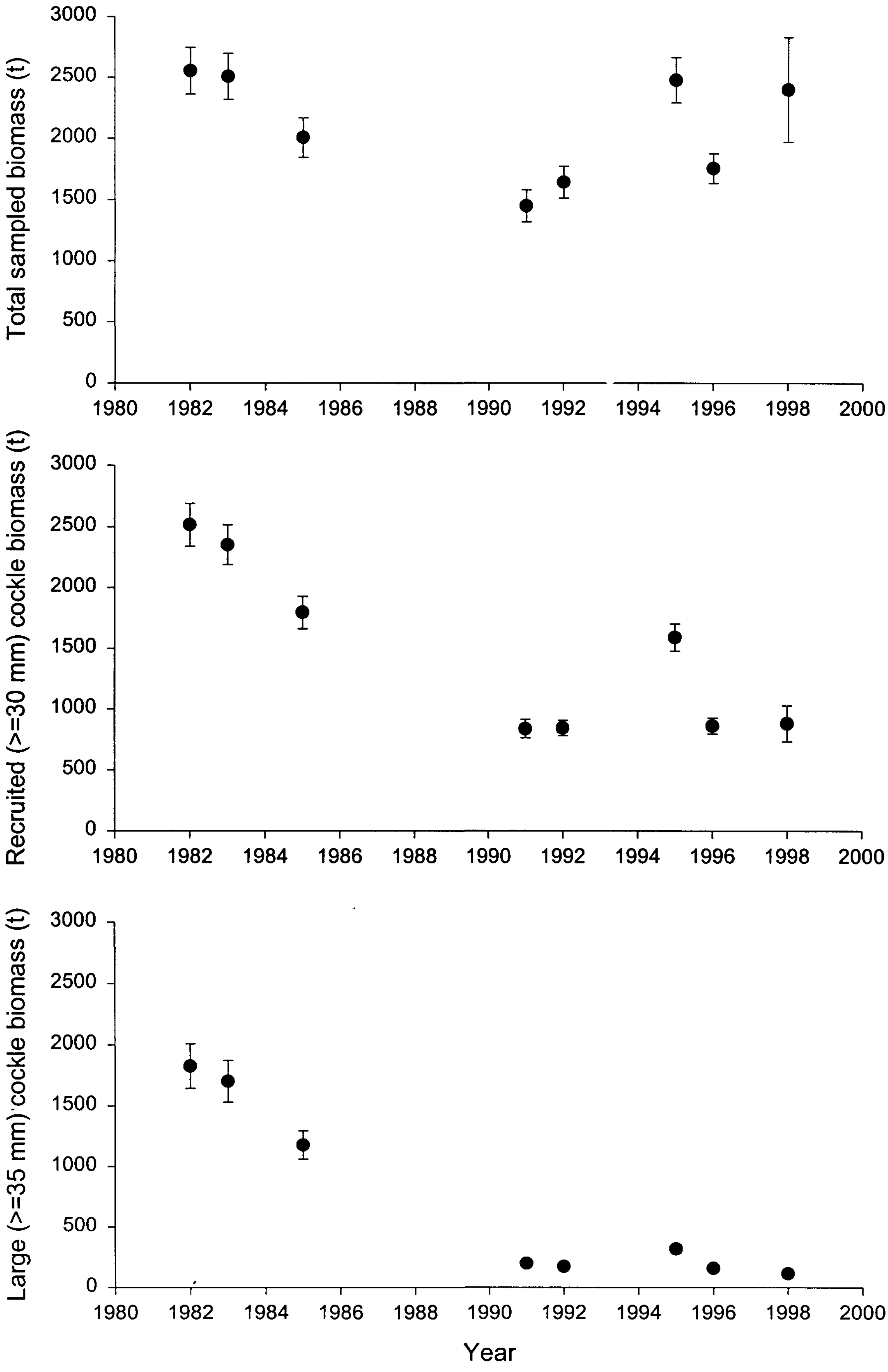


Figure 2: Trajectories (+/- one standard error) of total, recruited (>30 mm) and large (>35 mm) cockle biomass on Snake Bank since the inception of the fishery in 1992.

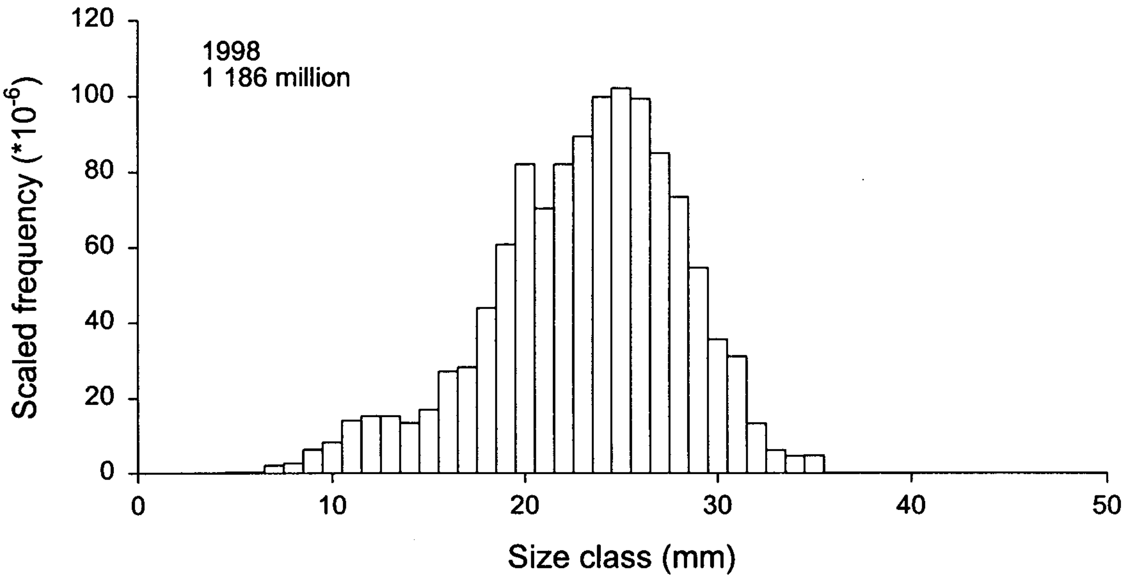


Figure 3: Length frequency distribution, scaled to total population size, for cockles on McDonalds Bank, March 1998. N. total estimated number of animals within the surveyed area.