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Introduction

Oreti Beach, about 5 km southwest of Invercargill, stretches from the New River entrance west to Riverton. Toheroa surveys usually cover 15–17.2 km of the beach, from the reserve 1.8 km south of the beach entrance north to Waimatuku Stream. Oreti Beach is an exposed, low gradient beach with fine sand backed by low dunes.

At Oreti Beach and nearby Bluecliffs Beach (Te Waewae Bay) toheroa have been surveyed regularly since 1966, often before recreational one day toheroa seasons. These seasons are a significant event in Southland, with up to 20 000 people fishing on Oreti Beach for their bag limit of five fish (over 100 mm). Apart from occasional day seasons at Oreti Beach, the toheroa fishery is totally closed throughout New Zealand. For a full review of the fishery see McKinnon & Olsen (1994).

Since 1971, population estimates of takable and undersized toheroa have been made for both Oreti Beach and Bluecliffs Beach. These have shown a relatively stable population of 1–2 million takable fish on Oreti Beach (Table 1). In March 1990, juveniles were also targeted.

Methods

Historically, the beach has been sampled with transects at 300–333 m intervals, the distance between transects being measured by a vehicle's odometer. Quadrat samples (1 x 0.5 m) were dug with garden forks to a depth of about 30 cm every fifth metre along the transects from the low to the mean high water level.

In the current survey, June 1996, the beach was sampled with transects at intervals of 350 m along the beach. The distance between transects was again measured using an odometer, but it was felt that 333 m could not be consistently read accurately, so the more obvious reading of 350 m was used. Quadrat samples were dug as described above.

As in previous surveys, sand was scattered across the beach and all visible toheroa collected by hand. Although this technique is coarse, it is fast and adequately samples toheroa over 50 mm. However, many small juveniles are likely to be missed and their abundance underestimated. This technique is consistent with all but the March 1990 survey, so direct comparisons between years can be made.

Over the 8 days of the survey low tides were 0.4 m above chart datum and the mean tidal range over the entire beach was 86 m, resulting in a mean of 17.2 quadrats per transect. The survey covered 17.8 km from New River to the Waimatuku Stream, 52 transects in all. At each quadrat the number of toheroa found was recorded and the individual lengths were measured to the nearest 1 mm.

The reserve area near New River (closed to recreational harvesting) was included in the 1996 survey and, as in most previous surveys, these toheroa were included in the final population estimate for the beach. However, there is some debate as to whether it is appropriate to include the reserve data in the final population estimate, and a separate calculation for just the harvestable area of Oreti Beach is also included.

Calculation of population estimate

Two equations have been used to estimate the number of adult toheroa.

Population estimate = (T/A) x B Equation 1

where: $A = L \times Q \times S$ or $A = \Sigma Q \times S$
$B = Da \times Du$

Da= length of beach surveyed (m)
Du= mean distance from low to high water level (m)
T = number of toheroa sampled
A = area sampled (m^2)
L = number of transects
Q = number of quadrats per transect
S = quadrat area (m^2)
B = total area of beach surveyed (m^2)

Along the distance surveyed transects were located every 350 m. Quadrat samples were 1 x 0.5 m and located every 5 m. From these variables the population has more recently been estimated from a sampling fraction. It is this method that will be used to estimate the takable population of toheroa on Oreti Beach.

$S/(DT \times DQ) = 1/3500$ Equation 2

S= quadrat area ($0.5m^2$)
DT= distance between transects (350m)
DQ= distance between quadrats (5m)

The estimated number of takable toheroa at Oreti Beach is given by multiplying the number of takable toheroa by the inverse of the sampling fraction, i.e., 3500.

The difference between these equations is that Equation 1 assumes the first and last transects are on the edges of the sampled area, whereas Equation 2 assumes that the sampled area contains half of the inter-transect distance beyond the first and last transects.

Calculation of sample variance

Until recently, the reliability of the estimated number of toheroa has been calculated using a simple random sample variance:

$$\text{Var}(Y_{++}) = \frac{IJ \sum_{i=1}^{I} \sum_{j=1}^{J} (Y_{i,j} - Y_{++}/IJ)}{IJ - 1} \quad \text{Equation 3}$$

where $Y_{i,j}$, (i = 1,..., I, j = 1,...J) are the counts of large toheroa (over 100 mm shell length) and Y_{++} is their sum.

However, the theory of simple random sampling does not apply in this survey as sampling locations are totally determined from the position of the first quadrat. Millar & Olsen (1995) have shown that using this variance estimate can seriously over-estimate the sampling error and that a systematic sample variance estimator should be used. The estimator they recommended is an overlapping stratified variance estimator which calculates the variance within overlapping 2 by 2 strata, i.e., s^2_{ij} is the sample variance of four quadrat observations ($Y_{i,j}$, $Y_{i+1,j}$, $Y_{i,j+1}$, $Y_{i+1,j+1}$). Consequently, the measure of reliability for the estimated number of toheroa has been calculated using the formula of Millar & Olsen (1995):

$$\text{Var}(Y_{++}) = \frac{IJ \sum_{i=1}^{I-1} \sum_{j=1}^{J-1} s^2_{ij}}{(I-1)(J-1)} \qquad \text{Equation 4}$$

Results

Only 182 toheroa were found in the 52 transects, of which 91 were above the legal size (over 100 mm): 876 quadrats were dug.

From Equation 1, the number of takable toheroa at Oreti Beach was calculated to be 311 988. From Equation 2, the number was 318 500.

The sample variance from Equation 4 was 142 084 so that the systematic sample standard deviation was 41 720. The 95 % confidence interval, calculated from $t_u * \sqrt{\sigma}_{n-1}$, where t_u is Student's t for u degrees of freedom and $\sqrt{\sigma}_{n-1}$ is the systematic sample standard deviation, was 81 771.

However, the estimate includes the non-harvestable reserve area. The population estimate for the harvestable beach only was 262 500 ± 75 468.

The size frequency of the 182 toheroa found in the June 1996 survey is shown in Figure 1, with for comparison, the size frequencies of toheroa from previous surveys.

Discussion

Until 1995, the population of takable toheroa needed to support a 1 day season at Oreti Beach was considered to be 1 million, assuming 100 000 fish would be taken. In 1995, the Ministry of Fisheries Shellfish Working Group adopted a Current Annual Yield and calculated that a population of at least 613 497 adult toheroa would be required for a 1 day season, and a 100 000 take.

The current estimate of 318 500 ± 81 771 adult toheroa should be of serious concern to managers of the Oreti Beach toheroa fishery. Not only is the estimated population below the 613 497 fish required for a season, it is the lowest since surveys began in 1971 (Table 1). It would be inappropriate to proceed with a season at this time.

In past surveys, recruitment was evident only in March 1990 (Figure 1) when a different method was used to target juveniles (McKinnon & Olsen 1994). In comparison with all other surveys, there are relatively high numbers of small toheroa in the 1996 survey (*see* Figure 1). Although the methods used for estimating undersized

toheroa do not result in a comprehensive assessment, Figure 1 suggests that there may be stable recruitment into the present population.

The 1996 survey, however, showed comparatively weak size classes over the legal size of 100 mm: this is of particular concern as there has been a relatively consistent size mode at 110–130 mm throughout the 1970s and 1980s (*see* Figure 1).

The current toheroa population size structure suggests that significant mortality has occurred among takable individuals (over 100 mm), but as no more than 56 500 toheroa have been removed since the October 1990 survey (i.e., during the 1993 season (McKinnon & Olsen 1994)), the subsequent decline of 641 500 takable toheroa appears to be due to natural causes, such as the extremely cold temperatures recorded in Southland over the last two winters, the coldest in over 20 years. A combination of strong winds and low air temperatures may have been responsible for past mass strandings of molluscs in Southland (Eggleston & Hickman 1972). Toheroa burrowing speed at cold temperatures is reduced (G. Bremner & A. Frazer, Ministry of Fisheries, pers. comm.; pers. obs.) leaving larger individuals vulnerable if stranded by sand movement. Large scale toheroa strandings observed after recent cold snaps support this hypothesis.

In January 1996, at least 40 000 toheroa died as a result of a bloom of toxic *Gymnodinium mikimotoi.* An estimated 1.5 million surf clams were also killed when algal numbers built up off Oreti Beach (G. Bremner & A. Frazer, pers. comm.).

Whilst many toheroa have undoubtedly died as a result of these events, it is also possible that toheroa may have been shifted to areas outside their normal range on Oreti Beach. A number of researchers have proposed that toheroa can form subtidal beds within the surf zone below the low tide mark to explain either toheroa shells drilled by gastropods absent from the littoral zone (Waugh & Greenway 1967) or unexpected increases in adult toheroa numbers which have occasionally been observed, and which cannot be accounted for by juvenile growth and recruitment (Cassie 1951, 1955, Coe 1953). However, extensive hydraulic dredge sampling of the Wellington west coast surf beaches (on which toheroa are found intertidally), and less extensive sampling offshore from Te Waewae Bay and Oreti Beach (on which large beds of toheroa occur more commonly), has never produced a single toheroa (Cranfield *et al.* 1994). Perhaps more investigation is required to determine if there are subtidal populations of toheroa.

Given that the decline in toheroa numbers appears to be due to a combination of natural events, the presence of good numbers of undersized toheroa at Oreti Beach, together with favorable conditions, may provide the basis for a recovery in the population over the next few years. Further monitoring is recommended.

Acknowledgments

I thank Allen Frazer and Graham Bremner for their historic information on previous surveys of Oreti Beach. Thanks also to members of the Murihiku Marae who assisted in the survey. This project (SOT001)was carried out as part of the contract for fisheries research services between NIWA and the Ministry of Fisheries.

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Table 1: Takable toheroa population estimates for Oreti Beach

	Takable (000's)	±95% CI (000's)	95% CI (% of estimate)	Size limit (mm)
1971	890[2]	125	28	75
1973	1 350[1]	215	32	75
1974	2 480[1]	260	21	75
1975	1 050[2]	170	23	75
1976	2 580	310	24	75
1977	2 370	275	23	75
1978	2 380[1]	280	24	75
1979	1 600	220	28	100
1980	2 010[1]	235	23	100
1981	1 660[1]	200	24	100
1982	1 350	190	28	100
1983	1 400	175	25	100
1984	1 700	210	25	100
1985	2 160	250	23	100
1987	1 190	205	34	100
1988	1 330[2]	240	36	100
1990[M]	1 230[1,2,3]	190	31	100
1990[O]	960[2,4]	150	31	100
1996	319	82	51	100

1, Years that open seasons were held
2, Survey did not cover all of beach
3, New survey method for recruits
4, Post-season estimate (recruits not surveyed)
M, March survey
O, October survey

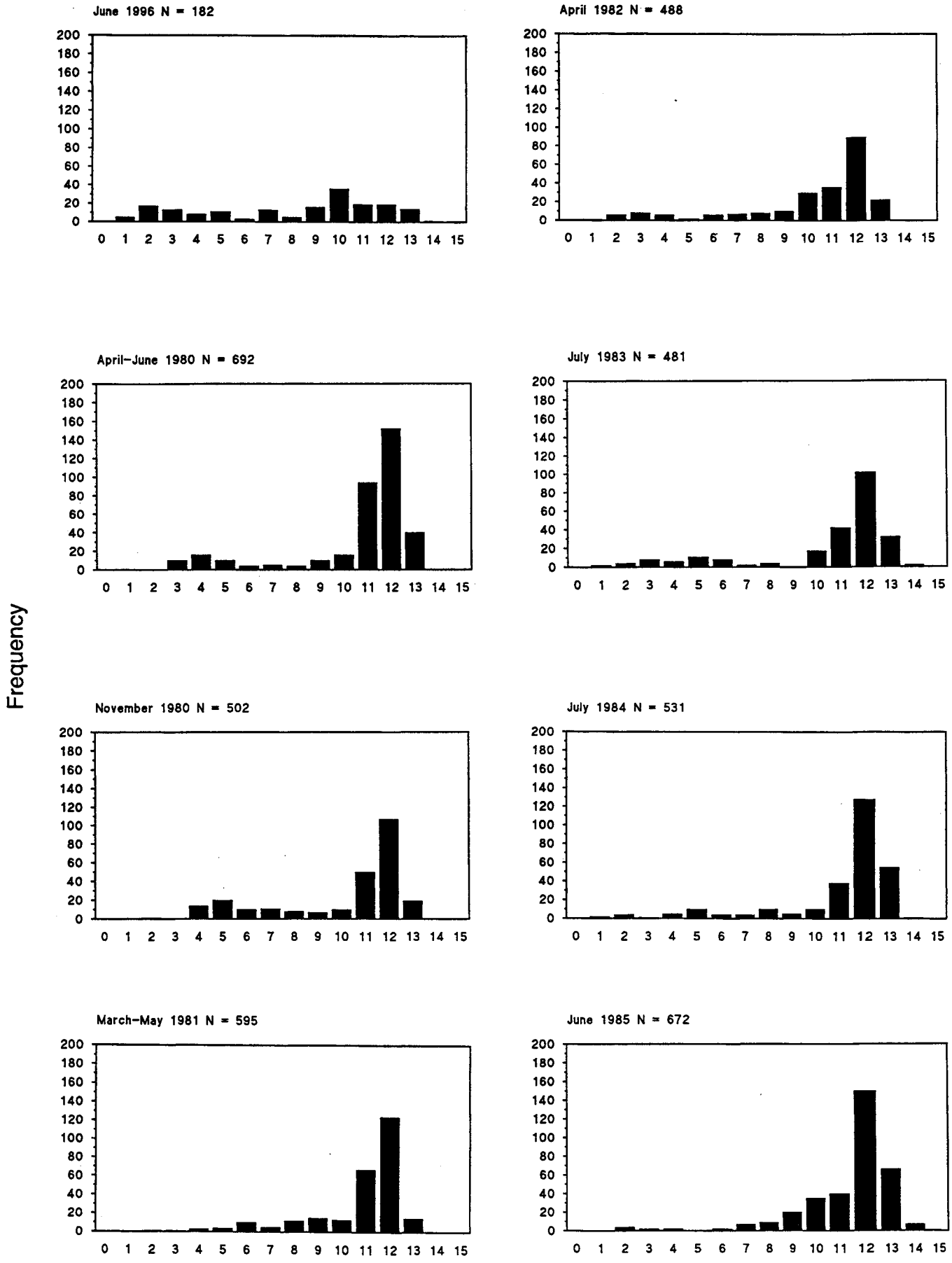
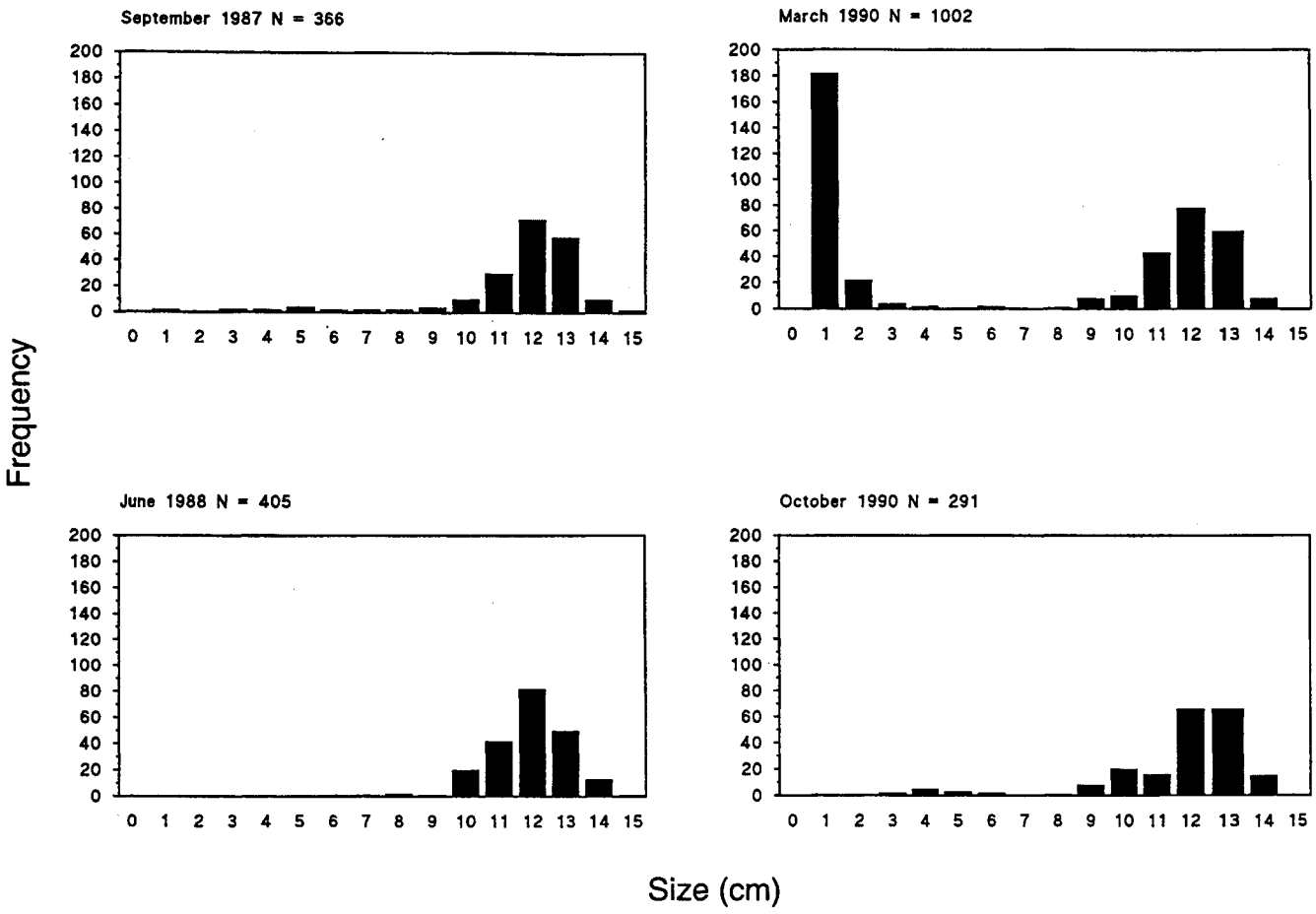


Figure 1: Length frequencies of the toheroa population on Oreti Beach from June 1996 survey and from surveys from 1980 to 1990.


September 1987 N = 366
March 1990 N = 1002
June 1988 N = 405
October 1990 N = 291
Frequency
Size (cm)
0 20 40 60 80 100 120 140 160 180 200
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15