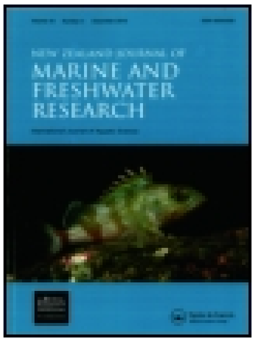

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POPULATION SURVEYS OF TOHEROA (MOLLUSCA: EULAMELLIBRANCHIATA) ON NORTHLAND BEACHES, 1962–67

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SUMMARY

Surveys made each year between 1962 and 1967 to estimate populations of toheroa (*Amphidesma ventricosum* Gray) on the three main west coast beaches of Northland, New Zealand, are described. The surveys were carried out as close as possible to the beginning and ending of each gathering season. There were striking changes in the surveyed areas, probably mainly due to natural causes and not as a direct result of gathering. One beach, Muriwai 1963, even showed an improvement in population after the gathering season, but numbers of toheroas on this beach have usually been erratic and small during the surveyed period. The other beaches showed marked declines, which were mostly sudden and unsynchronised between beaches; these declines were too big to be accounted for solely by gathering. A private commercial survey, carried out annually during the gathering season on a leased portion of Dargaville Beach, shows very similar results to the equivalent departmental surveys.

INTRODUCTION

The toheroa (*Amphidesma ventricosum* Gray) is found most abundantly on the sandy, surf-washed beaches of the west coast of North Island, though smaller numbers are found elsewhere (Rapson 1954; Cassie 1955). It is a traditional and highly-prized food of the Maori, now equally esteemed by Europeans. Evidence from shell middens and published literature (Rapson 1952; Cassie 1955; Mestayer 1921) shows that populations fluctuate widely from year to year and season to season. The Northland toheroa beaches are being visited by more and more people each year. There has been increasingly heavy exploitation of the beds, in spite of regulations which lay down a minimum takeable size of 3 in. (7.6 cm) long. The greatest number any person may take in any one day is now 10 (but a party may take 30 per vehicle) and the gathering season is usually restricted to August-September. Limit takes and gathering time are often varied from season to season, depending mainly on the abundance shown by the pre-season surveys. The beds vary in density and extent; most beds are easy to see because, when the animals below the surface withdraw their siphons, the otherwise smooth sand is left heavily "pock marked" (Fig. 1). There are, however, occasions when these signs are not so readily seen, as after heavy rain causing excessive seepage on the beaches. At other times, especially when north-easterly gales approach, the beach may be dotted with

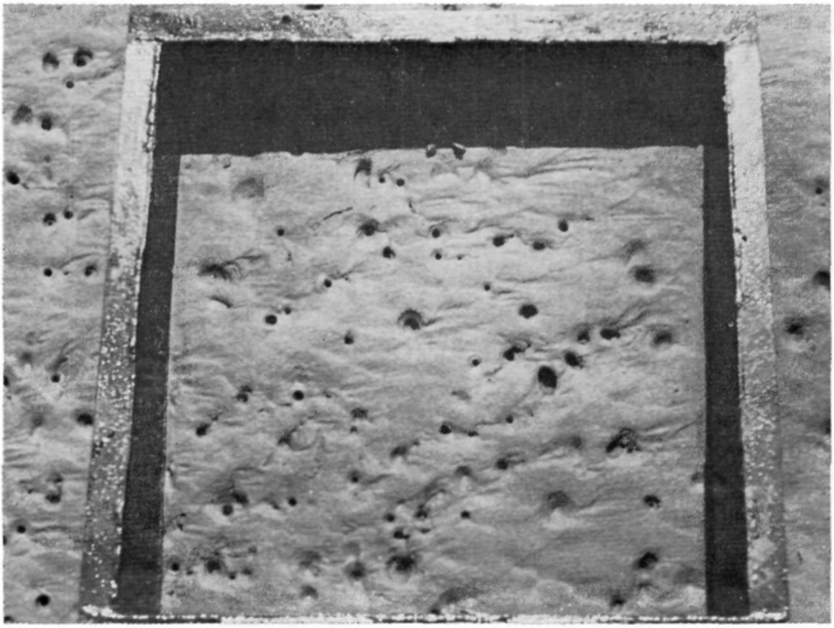

FIG. 1—An 18 in. quadrat showing the sand surface at Muriwai Beach heavily "pock marked" over a typical toheroa bed.

mounds of sand, almost "cow patted" in appearance, with the underlying toheroa nearer to the surface than usual. This phenomenon is locally held to presage the departure of the toheroa from the beach.

Surveys have been made since 1962 to try to follow the changes in populations on the beaches. Wherever possible, surveys were made both before and after the open season; the results are the basis of this paper. A comparison has also been made between the private commercial surveys carried out by the Meredith Brothers cannery concession and the departmental survey in order to test agreement.

AREAS SURVEYED

The most prolific beds are on Muriwai, Dargaville, and Ninety Mile Beaches, which are adjacent along the west coast of the Northland peninsula, North Island (Fig. 2). The beaches are all of hard sand backed by dunes or cliffs and fully exposed to the prevailing westerly winds. All three beaches have been surveyed at least once, and more usually twice, each year since 1962.

Muriwai Beach (Fig. 3) extends northward from rocky cliffs at Muriwai Settlement to the southern side of Kaipara Harbour entrance. It is backed by low dunes with pine plantings behind. The only running

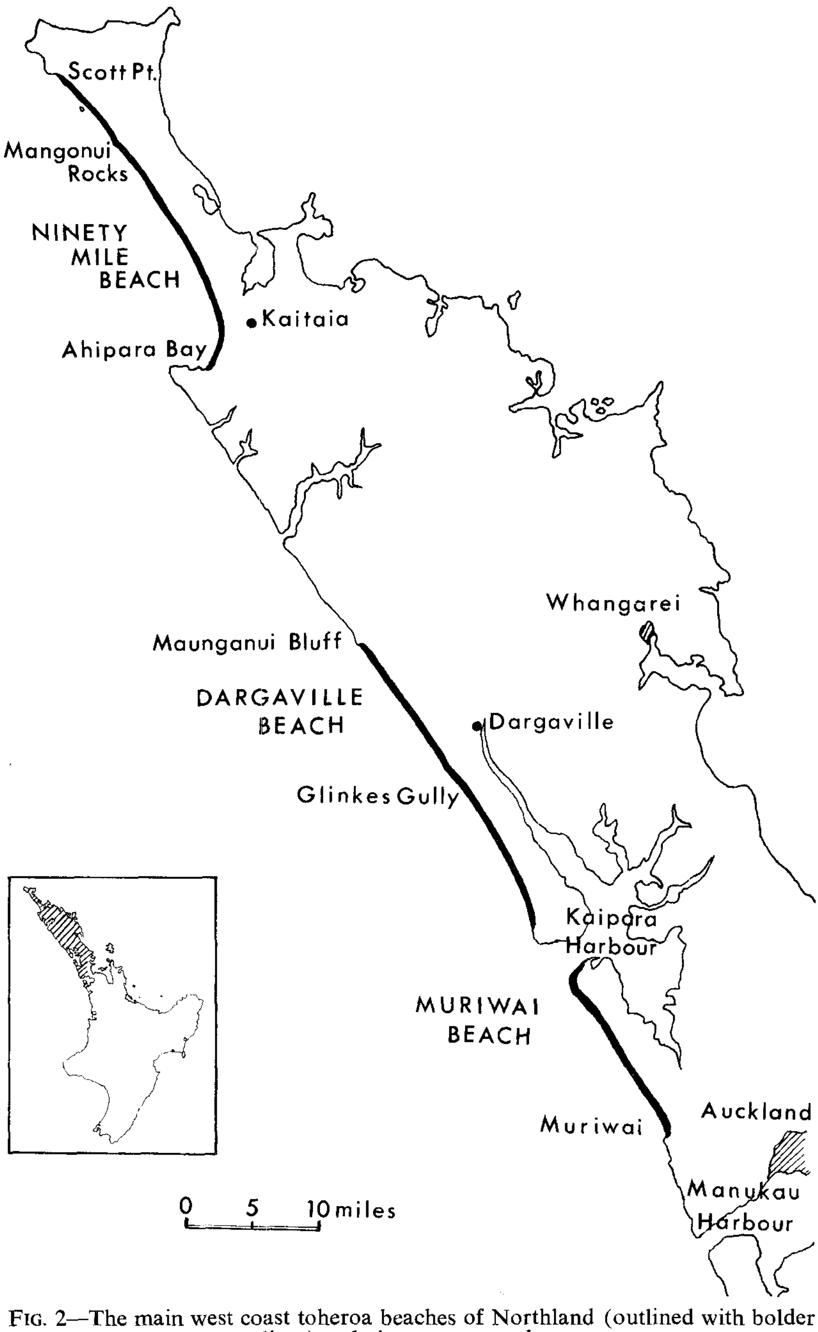

FIG. 2—The main west coast toheroa beaches of Northland (outlined with bolder lines), relative to one another.

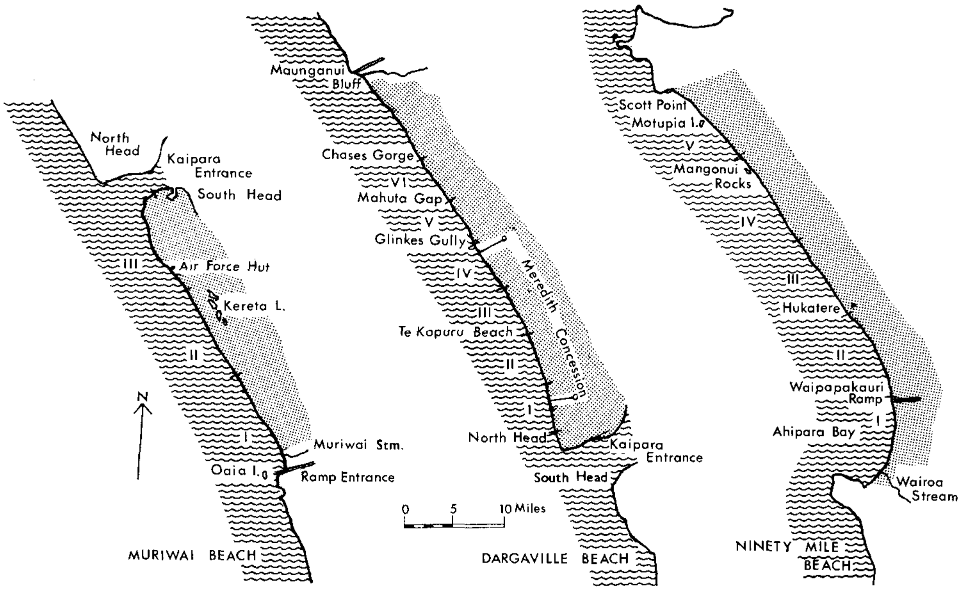

FIG. 3—Survey sections and prominent landmarks of the three main west coast toheroa beaches of Northland.

water crossing it is the Muriwai Stream, 1½ miles north of the settlement, but seepage occurs near the middle stretch of beach associated with small freshwater lakes lying where the sand and land meet.

Dargaville Beach extends 45 miles northward from Kaipara North Head to Maunganui Bluff (Fig. 3). Beyond this the shore is boulder-strewn and backed by high cliffs, but to the south, access to the beach follows small streams in steep eroded sandhills. All the beach south of Glinkes Gully is flat and backed by low sand dunes.

Ninety Mile Beach extends from Ahipara Bay in the south to Scott Point in the north (Fig. 3). The beach is wide, fairly flat and backed by low dunes with numerous small streams crossing it. There is a prominent knoll in the dunes at Hukatere, and a rocky outcrop (locally known as "The Bluff") at Mangonui Rocks, is joined to the shore by a sandspit covered at high water. This lies about two-thirds of the way along the beach from the south.

METHODS

Randomised transects were used, giving coverage of ½ yd per ½ mile of beach. This intensity of sampling was about the highest attainable within the time available; it also gave a convenient factor 1,760 × no. of transects, for calculation of the beach population. Before 1965, the position of the transect (from a table of five-figure random numbers

0–91520) was determined by odometer of the survey vehicle but later a fifth wheel attached to the survey vehicle measured the transect position to the nearest yard. Standard base points were erected on each beach. Usually the toheroa were not uniformly scattered, but aggregated about mid-tide level in dense beds, seldom more than 20 yards wide, which had sharply defined upper and lower limits (Cassie 1955). They sometimes formed continuous beds of fairly high density for thousands of yards at a stretch (e.g., Dargaville, section II, 1962) or formed discrete populations from 50–100 yards long and separated from the next bed by 1 mile or more of beach (e.g., Muriwai, most surveys). Random digging between beds occasionally reveals isolated animals.

Transects extended at least 30 yards across the beach to straddle the mid-tide level, where the animals would be if present. Before October 1963, transects were marked out on the sand and dug for their full lengths with potato forks. In thick beds, very great numbers were obtained, over 2,000 from some transects, but large errors occurred by the collapse of the transect edges where the sand was wet. To overcome this, standard 30 yd transects (long enough to cover the toheroa beds) were laid off, and ten 18 in. squares dug from each. The total from these was multiplied by six to give an estimate for the whole transect. The 18 in. square was made of steel plate 6 in. deep and supported on outwardly-facing 1 in. angle iron. To find its place in the transect the square was placed alongside a measure and trodden into the sand. The enclosed area was then carefully dug out with a potato fork and the toheroas counted and measured to the nearest ½ cm below actual length (Fig. 4).

MEREDITH CONCESSION

On the 16-mile stretch of Te Kopuru Beach (sections I–IV, Fig. 3) where Meredith Bros. and Co. Ltd. have a concession to dig toheroas, as elsewhere the public may not use any implements, but the commercial diggers are allowed to use flat-tined potato forks. Both may gather toheroas only during the open season, August–September, but the company diggers are restricted to digging over only 50% of the area of any one bed and a quota limits the total number of animals which may be taken for canning; this is set by the Marine Department, based on the number of available toheroa of 3 in. and above shown by survey. The company usually selects toheroas of a size greater than the legal minimum, because the yield of meat nearly doubles in a 4-in. animal as compared with the 3 in. minimum size, and thus the cannery has always taken less than the maximum number permitted.

In 1962, marker posts set out by the company at ½-mile intervals along the concession were used as reference points for their surveys. In the week before the start of the season, the lengths of the beds revealed by siphon holes in the sand were measured. At the beginning of the season, samples were dug out from 2 ft^2 quadrats spaced between 80 and 120 ft apart where beds were known to exist and between 140 and 250 ft apart where no beds had been seen. All toheroas gathered were

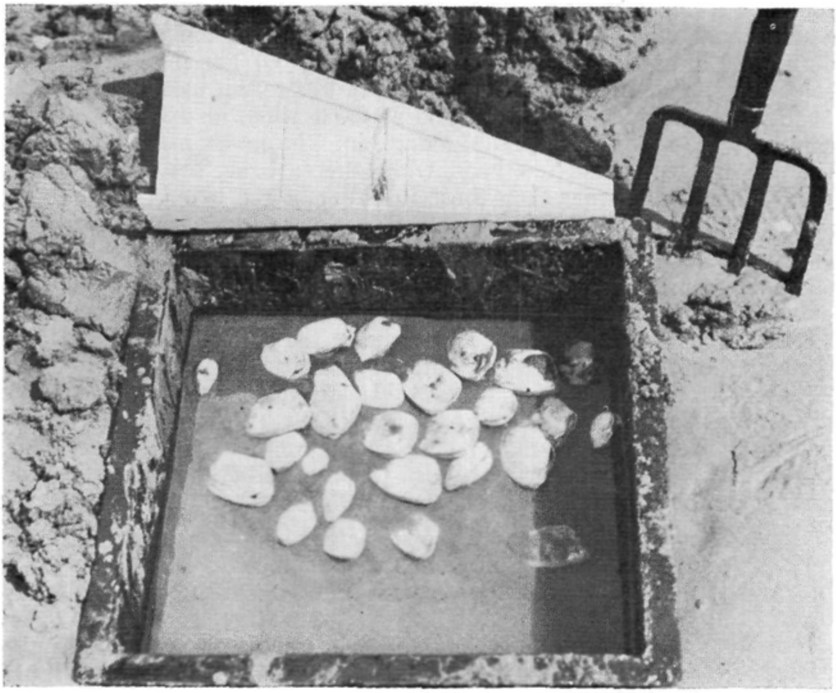

FIG. 4—An 18 in. quadrat wtih toheroa dug out ready for measuring.

measured and the sizes grouped at 0–2 in. (0–5 cm), 2.1–3.0 in. (5.1–7.6 cm), 3.1–3.75 in. (7.7–9.5 cm), and >3.75 in. (9.5 cm); the last group were the most suitable for canning. The object was to find the most suitable beds for canning, but the data from other groups also gave some indication of possible yields in future. All surveys were along the mid-lines of the beds, where shellfish populations were usually most dense.

Digging returns from the cannery were later used to calculate the total population of toheroas on the assumption that digging probably straddled the beds. The number of 4-gallon drums of animals collected from the beds was known, and the number of these drums needed to process into one drum of "tongues" was also known; the mean number of tongues (= toheroas) per drum was found by sample counts. Thus, the approximate number of large toheroa gathered was calculated.

RESULTS

MURIWAI BEACH

The survey ended 30 miles north of the car ramp (base point), on the curve of the Kaipara South Head; insignificant numbers of toheroa are found beyond this point. The beach was divided into three sections of

10 miles each; the southernmost (section I) contained only scattered toheroa; although some small beds were found in the northern half during the after-season survey in September 1963. The middle 10 miles (section II) yielded the greatest number of toheroa; it usually contained small beds from 50–150 ft long and 10–60 ft wide, in which the mean length of the shells was a little under 3 in. The northernmost 10 miles (section III) contained few beds, with toheroa being scattered along a narrow band but larger than those in either of the other two sections.

The population in each section (Table 1) was calculated by multiplying the number of toheroa in each transect within each section by 1,760 (because transects cover 1 yd per mile). Corrections were applied for sections where there were too many or too few transects because of the method of randomly selecting transects for the whole beach. The total population of the beach was calculated by simply multiplying the number of toheroa found in all the transects by 1,760. Both methods gave similar results (Table 1). In February 1964 two surveys were made simultaneously with different sets of randomised transects. In survey B the transects coincided better with beds of toheroa, and the results show how great a sampling error (a factor of almost 2), can occur in the surveys.

Figure 5 shows histograms of the frequency of lengths as percentages for the whole beach. They are remarkably similar to those shown for previous years by Cassie (1955); there is an apparent scarcity of recruits throughout. To show changes in relative abundance, as well as in the distribution of length-frequencies, all histograms were reduced to the same scale, with the highest population (Ninety Mile Beach, September 1963) taken as 100%.

DARGAVILLE BEACH

In 1962 and 1963 (Fig. 3), surveys covered only 25 miles of beach, but they were later extended to 30 miles to include the area Mahuta Gap – Chases Gorge. The 10-mile stretch from Chases Gorge to Maunganui Bluff has never been consistently surveyed, although known to contain some large toheroas. The base point for all surveys was 20 miles south of Glinkes Gully Stream. In contrast with Muriwai, toheroa beds on Dargaville Beach were sometimes long, almost continuous (e.g., September 1962). Results were subdivided into 5-mile sections of more or less consistently different characteristics. Meredith Bros. and Co. Ltd. have permission to dig toheroa for canning on this beach (sections I–IV); they dig on an area extending from 1 mile south to 16 miles south of Glinkes Gully.

Section I contained only a small population and was mostly outside the concession. Beds in sections II–IV were usually well balanced, but there was a preponderance of small, younger toheroa at the southern end of section II. Sections V and VI, lying between Glinkes Gully and Chases Gorge, are the major public gathering area. They usually contained large older toheroa. Table 2 shows the population densities in much the same way as those of Muriwai. Figure 6 shows the length frequency by percentages for the area of beach surveyed.

TABLE 1—Estimates of populations and densities of toheroas, Muriwai Beach

Date	Section I (10 miles)			Section II (10 miles)			Section III (10 miles)			Total pop'n by sections × 10³	Total pop'n whole beach × 10³
	No/yd²		Est'd pop'n	No/yd²		Est'd pop'n	No/yd²		Est'd pop'n		
	Range	Mean	× 10³	Range	Mean	× 10³	Range	Mean	× 10³		
Sep '62	0– 3.9	0.3	161	0– 46.3	7.6	3,219	0.3–15.8	3.9	1,731	5,111	5,181
Jul '63	0– 3.7	0.9	405	0–117.2	9.3	4,088	0 –14.8	2.1	910	5,403	4,717
Sep '63	0–47.3	5.2	2,277	0– 90.7	9.3	4,090	0.4–23.0	3.5	1,443	7,810	8,339
Feb '64 A	0– 5.2	0.3	128	0–124.6	9.8	4,196	1.0–59.0	6.3	2,775	7,099	7,353†
Feb '64 B	0–88.9	8.6	3,791	0–129.1	15.2	5,739	1.2–24.9	3.2	1,438	10,968	12,408†
Mar '65	..	..	..	0– 48.0	1.2	656	0 –19.4	1.9	1,006	..	..*
Oct '65	0– 4.0	0.5	90	0– 12.0	1.9	1,024	0 –19.4	4.0	2,084	3,198	3,633
Apr '66	0– 0.8	0.1	48	0–141.2	8.5	4,414	0 –12.8	2.1	1,091	5,553	5,449
Oct '66	0– 0.8	0.1	63	0– 14.8	1.6	893	0 –39.6	4.2	2,229	3,185	3,052
Apr '67	0– 0.8	0.5	211	0– 18.4	1.2	634	0 –12.4	2.8	1,456	2,301	2,313
Oct '67	0– 6.3	3.3	1,771	0– 4.0	1.1	568	0 –65.6	2.7	1,419	3,758	3,823

*Section I not surveyed. †Simultaneous random surveys.

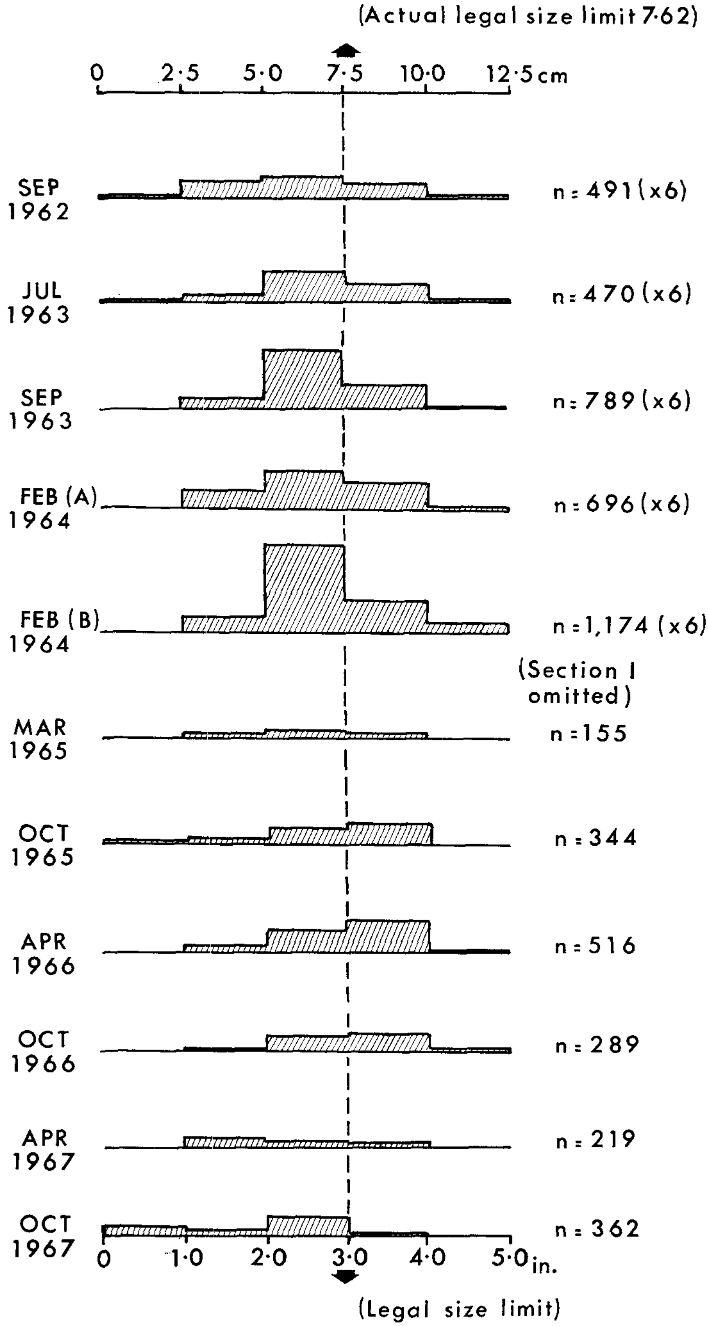

FIG. 5—Percentage length frequency, Muriwai Beach, all sections combined. (Scaled to Ninety Mile Beach, September 1963, as 100%.)

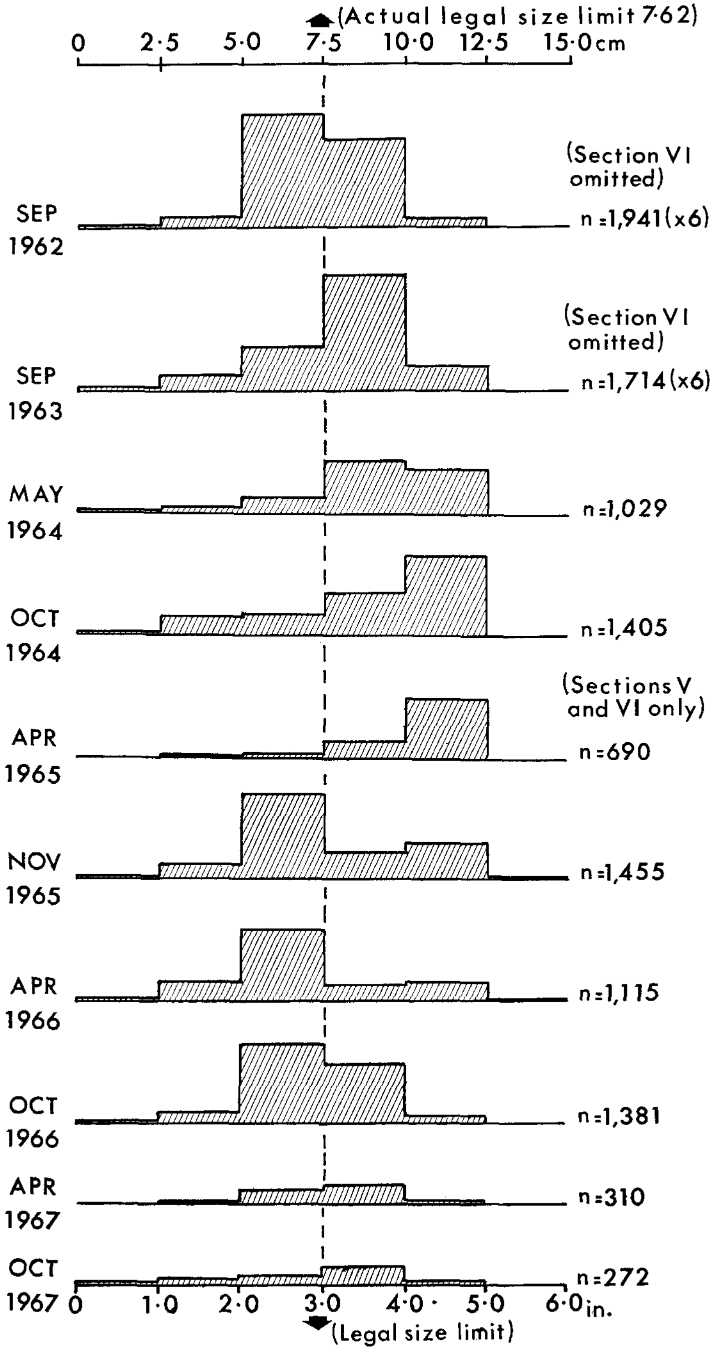

FIG. 6—Percentage length frequency, Dargaville Beach, all sections combined. (Scaled to Ninety Mile Beach, September 1963, as 100%.)

TABLE 2—Estimates of populations and

Date	Section I (5 miles)			Section II (5 miles)			Section III (5 miles)		
	No/yd²		Est'd pop'n × 10³	No/yd²		Est'd pop'n × 10³	No/yd²		Est'd pop'n × 10³
	Range	Mean		Range	Mean		Range	Mean	
Sep '62	0 –13.6	1.5	333	21.0–96.1	30.8	6,768	0.5–131.7	30.2	6,635
Sep '63	0 –10.8	2.2	486	0.4–28.4	11.1	2,918	0 –135.6	16.5	4,345
May '64	0 –14.4	1.4	361	0 –27.4	6.3	1,735	0.4– 44.4	15.1	3,685
Oct '64	0 –10.8	2.3	495	12.0–57.6	20.4	5,402	0.8–101.6	11.8	3,111
Apr '65	..	..	..†	..	..	..†	..	..	..†
Nov '65	0.4– 7.6	2.7	713	14.0–58.4	27.3	7,214	1.2– 60.0	15.1	3,974
Apr '66	0 – 6.8	1.4	364	0.8–95.2	30.1	7,941	0 – 35.2	6.8	1,531
Oct '66	0 –10.0	2.4	643	0 –84.8	29.5	7,767	0 – 45.6	12.8	3,389
Apr '67	0 – 2.0	0.5	32	0 –31.6	5.0	1,325	0.4– 14.4	4.1	1,091
Oct '67	0 – 0.4	0.1	13	0 –82.4	10.6	2,803	0 – 2.8	0.8	201

†Not surveyed

During the study period, the toheroas on this beach were large; the percentage of older individuals apparently increased, especially in the northern sections; this was well shown in the numbers for April 1965 from sections V and VI (unfortunately, the remaining sections were not surveyed then because of bad weather). In late 1965 and early 1966 favourable recruitment to the stocks in the southern sections occurred and the proportion of younger to older groups became better balanced. However, by the pre-season survey in April 1967 many of these recruits could not be found.

NINETY MILE BEACH

From a base point at the southern end of the beach near the north bank of the Wairoa Stream at Ahipara, 52 miles of beach were surveyed northward, right up to the cliff face at Scott Point. Results are shown in Table 3, in which the beach is subdivided into four 10-mile sections and a fifth of 12 miles at the northern end. Figure 7 shows the percentages of length frequencies for this beach. Throughout the period the population was dominated by the 5.0–7.5 cm size class, again with little evidence of recruitment. There was no really consistent pattern of distribution; the sections with the densest population varied from season to season.

TESTS OF SIGNIFICANCE

Because, up to 1965, each transect was found by vehicle odometer, measuring only $1/10$ mile, proper randomisation was impossible. With a "fifth wheel" attachment measuring to the nearest yard, satisfactory densities of toheroas, Dargaville Beach

Section IV (5 miles) No/yd² Range	Mean	Est'd pop'n × 10³	Section V (5 miles) No/yd² Range	Mean	Est'd pop'n × 10³	Section VI (5 miles) No/yd² Range	Mean	Est'd pop'n × 10³	Total pop'n by sections × 10³	Total pop'n whole beach × 10³
0 –28.0	7.0	1,544	0.5–62.8	28.9	6,364	..	..	..*	21,649	20,529
0 –28.4	12.3	3,261	0.4–73.6	29.7	7,841	..	..	..*	18,851	18,142
0.8–25.2	5.3	1,399	0 –26.0	7.2	1,689	0–50.0	11.9	3,147	12,016	10,866
0.8–12.4	3.8	1,016	0.4–41.6	9.9	2,760	0–76.4	16.6	3,466	16,250	14,837
..	..	..†	0 –46.4	8.2	2,175	0–71.6	10.9	3,095	..	..
0 –16.0	4.7	1,243	0 –21.4	7.9	2,102	0– 4.0	1.0	259	15,505	15,365
0.4–14.0	4.1	1,071	0 –13.2	3.0	781	0– 0.7	0.4	114	10,543	11,774
0.4–14.8	2.6	700	0 – 2.0	0.6	152	0– 1.6	0.5	141	12,792	14,583
0 – 5.6	0.9	258	0 – 1.4	0.6	154	0– 6.8	1.2	306	3,166	3,274
0 – 1.2	0.6	164	0 – 3.2	0.8	220	0–68.8	6.1	1,618	5,019	5,090

*Not surveyed; Section VI added in 1964 †Not surveyed

randomisation of transects was obtained later. Figure 8 shows the 95% confidence limits for the means of samples taken on the three beaches when the "fifth wheel" was used. Errors caused by mixing systems of systematic and random sampling (by using regularly placed quadrats within the random transects) were ignored. Most limits cover a wide range because of the clumped distribution of the toheroa into beds.

On Muriwai Beach there are no indications of any significant difference between the surveys (Fig. 8). However, on the Dargaville and Ninety Mile Beaches the pre-season surveys in 1967 show mean numbers of toheroas below the mean of the post-season surveys of 1966. For Ninety Mile Beach, the mean numbers of toheroas was larger in March 1965 than in June, but the numbers had risen again by October of that year. Results of *t* tests between these various means are set out in Table 4.

A significant fall in toheroa numbers on Dargaville Beach between October 1966 and April 1967 occurred during the closed season, and was not associated with digging. Though there was an apparent increase in population in October 1967, the numbers were not significantly different from April 1967, but both were significantly lower than those for October 1966 ($P < 0.001$). Thus, there had been a real decline in numbers despite the complete closure to digging in 1967.

Differences on Ninety Mile Beach were not so pronounced—the population was already greatly depleted—but the fall in numbers between March 1965 and June 1965 is significant at $P < 0.01$. A rise in numbers before October 1965 was not significant, and later a gradual decline was followed by a barely significant fall before May 1967; a slight recovery about November 1967 was not significant.

TABLE 3—Estimates of populations and densities of toheroas, Ninety Mile Beach

Date	Section I (10 miles)			Section II (10 miles)			Section III (10 miles)			Section IV (10 miles)			Section V (12 miles)			Total pop'n by sections × 10³	Total pop'n whole beach × 10³
	No/yd²		Est'd pop'n	No/yd²		Est'd pop'n	No/yd²		Est'd pop'n	No/yd²		Est'd pop'n	No/yd²		Est'd pop'n		
	Range	Mean	× 10³	Range	Mean	× 10³	Range	Mean	× 10³	Range	Mean	× 10³	Range	Mean	× 10³		
Oct '62	0 –53.0	6.4	1,791	0.1–13.7	5.7	2,695	0 –64.7	30.7	13,080	0– 47.9	2.3	1,296	0.2–144.3	12.8	7,541	26,411	24,992
Sep '63	0.2– 3.9	0.7	240	0 – 3.1	0.9	418	0.8–79.7	42.2	20,973	0– 79.1	15.1	7,706	0 – 33.6	9.1	5,006	34,343	37,048
May '64	0 – 7.2	1.2	534	0 – 0.8	0.4	75	0 –17.6	1.7	911	0–103.2	14.8	7,434	0 –155.6	15.0	9,411	18,365	22,081
Oct '64	0 –54.4	7.6	4,039	0 –19.4	1.9	1,027	0 –12.0	6.0	1,276	0– 88.4	15.6	3,305	0 – 52.8	7.4	4,714	14,361	15,319
Mar '65	0 – 0.8	0.2	117	0 –23.2	1.7	936	0 – 3.2	0.6	132	0– 21.2	2.3	1,229	0 – 46.0	12.9	3,254	5,668	5,586
Jun '65	0 –10.0	0.1	625	0 – 0.8	0.1	69	0 – 0	0	0	0– 8.4	1.2	596	0 – 0.4	0.1	32	1,322	1,457
Oct '65	0 –28.8	4.0	2,141	0 –18.8	1.7	928	0 – 0	0	0	0– 0.8	0.1	78	0 – 0	0	0	3,147	3,907
May '66	0 – 9.6	3.1	1,669	0 – 1.2	0.3	161	0 – 0	0	0	0– 0.8	0.08	42	0 – 11.6	1.3	325	2,197	2,314
Nov '66	0 –10.0	1.9	1,014	0 – 5.2	1.8	380	0 – 0.4	0.05	10	0– 5.2	1.8	380	0 – 2.4	0.1	158	1,942	1,901
May '67	0 – 1.2	0.2	116	0 – 6.8	0.6	293	0 – 0.4	0.04	23	0– 1.2	0.2	95	0 – 0	0	0	527	538
Nov '67	0 – 4.0	0.5	275	0 – 2.4	0.3	197	0 – 0.4	0.05	10	0– 1.6	0.2	141	0 – 4.4	0.3	199	822	834

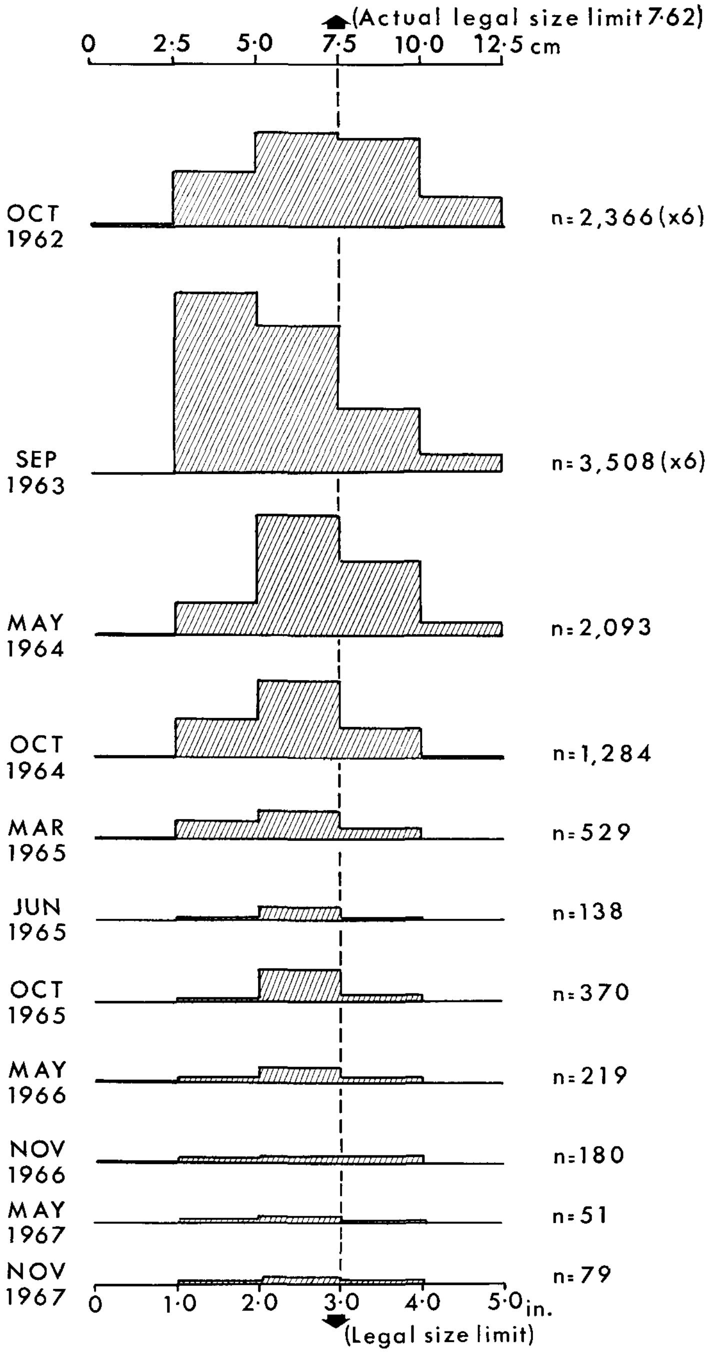

FIG. 7—Percentage length frequency, Ninety Mile Beach, all sections combined. (Scaled to September 1963, as 100%.)

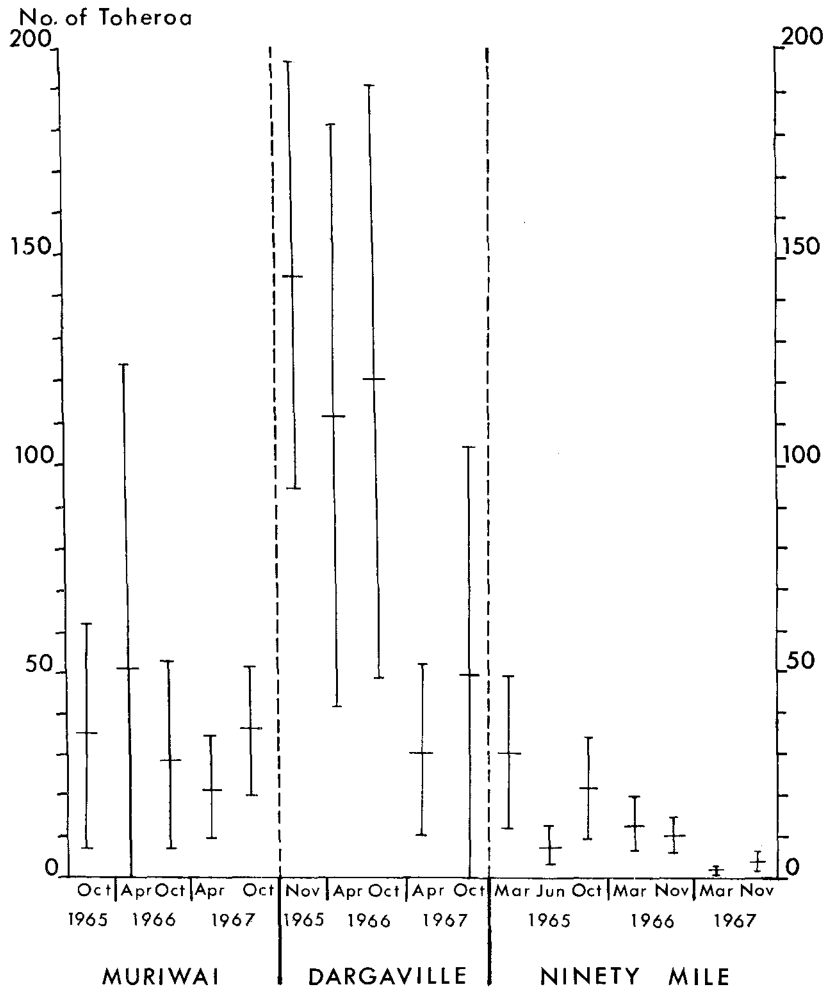

FIG. 8—Ninety-five percent confidence limits for mean number of toheroa in transects, whole beaches.

TABLE 4—Results of *t* tests between mean number of toheroa found on successive surveys on Dargaville Beach (October 1966 – October 1967) and on Ninety Mile Beach (March 1965 – November 1967).

Dargaville Beach				
October / April	1966 / 1967	$t = 5.7492$	$P < 0.001$	Very highly significant
April / October	1967 / 1967	$t = 1.4370$	$P > 0.1$	Not significant
October / October	1966 / 1967	$t = 5.1194$	$P < 0.001$	Very highly significant
Ninety Mile Beach				
March / June	1965 / 1965	$t = 2.8218$	$P < 0.01$	Highly significant
June / October	1965 / 1965	$t = 2.3459$	$P < 0.05$	Significant
March / October	1965 / 1965	$t = 1.6296$	$P < 0.1$	Not significant
November / May	1966 / 1967	$t = 2.2154$	$P < 0.05$	Significant
May / November	1967 / 1967	$t = 0.0782$	$P > 0.9$	Not-significant; nearly identical
November / November	1966 / 1967	$t = 2.2274$	$P < 0.05$	Significant

MEREDITH CONCESSION

From quadrat surveys and digging returns, Meredith Bros. and Co. Ltd. compiled an annual estimate of the population of toheroas in their concession. After allowances for the area dug, the area of the beds, and the proportional relationship of the cannable toheroas to the other size groups, it was then possible to calculate the approximate total population in the beach from the cannery returns, for example, in 1962—

12.5% of population	>3.75 in.	(>9.5 cm)	$= 2.0 \times 10^6$
28.4% of population	3.1–3.75 in.	(7.7–9.5 cm)	$= 4.5 \times 10^6$
37.5% of population	2.1–3.0 in.	(5.1–7.6 cm)	$= 6.0 \times 10^6$
21.6% of population	0 –2.0 in.	(0–5 cm)	$= 3.4 \times 10^6$
Total			15.9×10^6

Figure 9 shows the total populations found by the company's pre-season surveys, with percentages of length frequencies, compared with those from Marine Department surveys usually made after digging ceased. In 1964, only very dense beds were measured by the company surveyor; because very few toheroas are found between beds, the

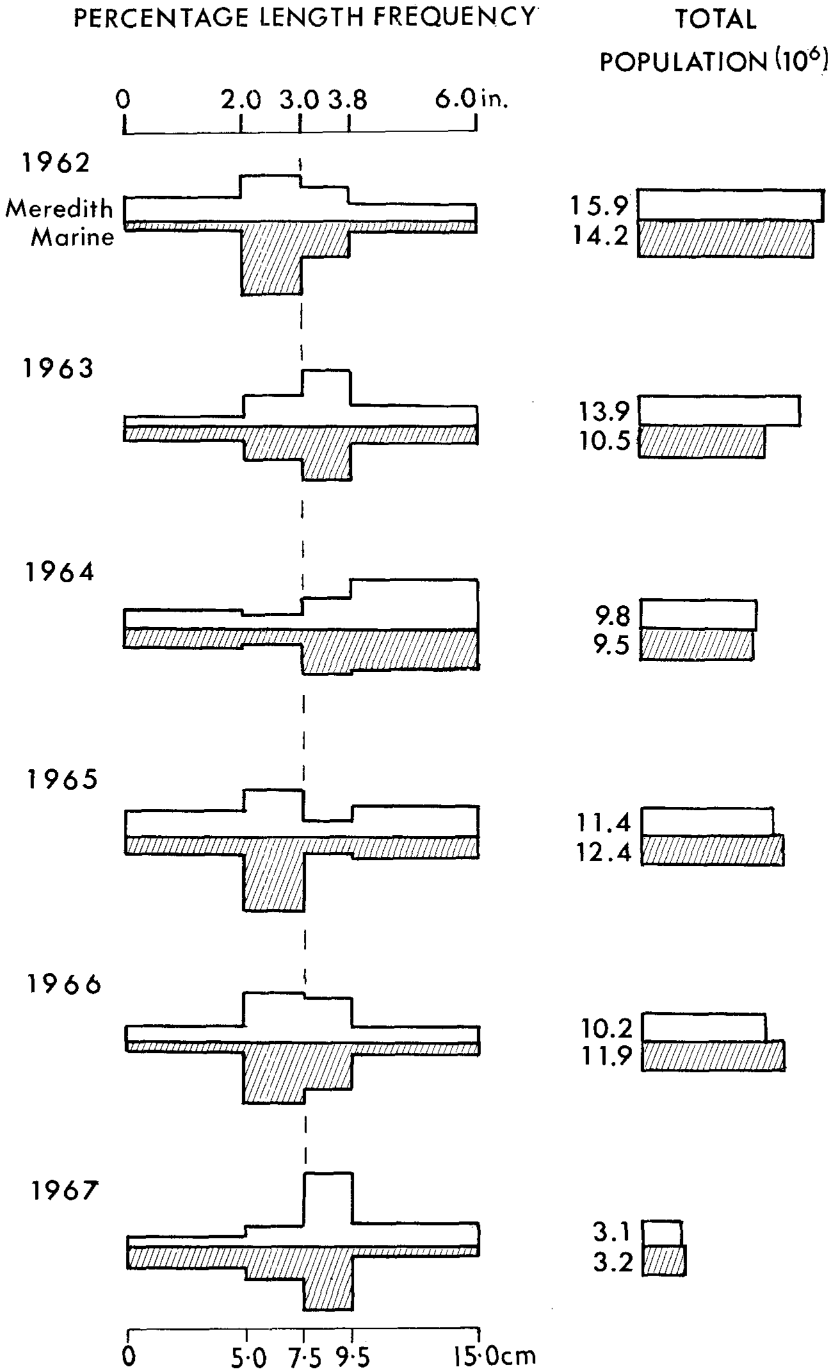

FIG. 9—Comparison of surveys on Te Kopuru Beach by Meredith Bros. and Co. Ltd. and the Marine Department (sections II, III, and IV) showing percentage length frequency and total population.

lengths of beds found previously were used to "fill in" lengths probably missed by the surveyor. Table 5 shows a comparison of toheroa densities found by Meredith Bros. and those found by the Marine Department. In 1967 the company surveyor used more quadrats, spaced across the beds, so obtaining different densities at different tide levels; previously, quadrats were restricted to a single mid-line through beds.

TABLE 5—Mean density of toheroas of Meredith Concession

Year	Length of visible beds (ft)	No. of 2 ft² quadrats	Total no. toheroa from quadrats	No./ft² Meredith survey	No./ft² Marine survey
1962	31,979	318	19,925	15.66	7.55
1963	29,042	358	15,397	10.76	4.43
1964	14,460	625	7,140	2.85	4.0
1965	22,525	544	13,487	6.19	5.23
1966	12,280	425	10,427	6.13	4.98
1967	11,185	821	11,139	3.39	1.33

DISCUSSION

MURIWAI BEACH

The total population on Muriwai Beach showed some changes, but these were not significant; large sampling errors were probably caused by the clumped distribution of the toheroas (Cassie 1955) and by the short length of the beds. The wide range of densities and the low means show how few and small are the beds on this beach.

There was no significant difference between the estimates of population made before and after the gathering season. In 1963 and 1964 there was an apparent improvement in post-season stocks which would not be expected if the numbers removed were particularly great. The portion of the population longer than 7.5 cm—the class most likely to show the effects of exploitation (Fig. 5)—remained steady and even increased in 1965–66. In 1967 there was a slight increase in the proportion of younger stocks, but, despite the prohibition on all gathering in that year, the population appeared to decline.

DARGAVILLE BEACH

Until 1967 this beach had been fairly well stocked and its surveyed population showed no very pronounced changes in total numbers. However, before 1967, some separate sections did show changes. Until 1965, sections IV, V, and VI were fairly well stocked with large older toheroa, but these stocks declined later. From November 1965 until October 1967, section II, followed by section III, had consistently higher populations than any others and section I had a consistently low population. Gathering does not appear to have affected the populations; within the experimental error of the method used, there is no indication of a decrease in population after the end of the digging season, even on sections III, IV, and V, which are nearest to the main access at Glinkes Gully. Stocks of younger toheroa in November 1965 became the modal class of the distribution of length-frequencies (Fig. 6) but, between October 1966 and April 1967, their stocks fell substantially; the reason for this is obscure because these small toheroas disappeared during the closed season. In mid-July 1967, the beach was considerably scoured at its southern end and there were an unusual number of dead toheroa shells with fresh muscle tissue attached washed up. Live specimens taken from the area appeared healthy, with no obvious internal parasites. Possibly heavy seas and longshore currents may have been partly responsible for the sudden disappearance.

There is remarkably close agreement between the results of surveys by Meredith Bros. and the Marine Department. The trends, both for total numbers and percentages of length-frequencies, are very similar. Both showed a mode in the 5.0–7.5 cm range in 1962; the mode changed to the >7.5 cm group by 1964, followed in 1965 by a fresh mode rising in the 5.0–7.5 cm range, thus following the same cycle again, although later in a much reduced population. Agreement is not as good between densities in the two surveys (Table 5), possibly because Meredith's survey was biased towards the best areas of beds near the transects.

NINETY MILE BEACH

On this beach there were great fluctuations in total populations and the populations of individual sections, with a virtual disappearance of toheroa from sections III and V. This took place after exceptionally heavy spat-falls of tuatua (*Amphidesma subtriangulatum*), a smaller congener of the toheroa in October 1962. In sections II and III a continuous band of spat yielded tuatua up to 25/in.^{2} but only 2/in.^{2} for toheroa. Identification of these two species as spat can be difficult but is well illustrated by Cassie (1955); a useful field method of distinguishing them is to press the shell between thumb and forefinger, the thicker and harder shells needing more pressure to fracture are tuatua. Samples taken may be identified more positively in the laboratory. In March 1965 there were more heavy concentrations of small tuatua ($<\frac{1}{2}$ in.) in section V; the adult toheroas nearby appeared to be in very poor condition. No obvious parasites were found, though the "tongues" were often limp, grey, and watery in appearance. Toheroas seem to be remarkably free of parasites, but a detailed study would be needed to confirm this. The reason is obscure why the young stock, obvious in September 1963, apparently failed to develop normally.

GENERAL

Despite the variations inherent in the sampling method (which could not be refined further with the labour available), the toheroa populations on all three beaches have declined during the period of the surveys. Changes have occurred, but neither at the same time nor in the same way. The most pronounced and sudden changes were on Ninety Mile Beach associated with very heavy spatfalls of tuatua, a species not found in quantity on the other two beaches. Maori middens in the dunes behind Ninety Mile Beach contain many tuatua shells but only a few toheroa shells; tuatuas were probably the dominant animal on this beach for a long time in the past. Though tuatua are found below low water near Auckland, on this beach at least they may invade the littoral zone in large numbers.

Although Cassie (1955) and Waugh and Greenway (1968) predict that part of the toheroa population may be sublittoral, there is still no direct evidence for this. Migratory movements from a sublittoral population might explain either the fluctuations or the maintenance of littoral populations. Any sudden reappearance of toheroa in quantity on Ninety Mile Beach could provide further useful evidence on what sort of population is involved: resurgent, associated with spatfall from offshore currents (Coe 1953), or migratory, arriving from the sublittoral. Results from a few marking experiments show little tendency for toheroa to move along the three beaches (Marine Department unpublished data); most recoveries were close to release points, though individuals have been returned from several miles to the north and south. At Muriwai during the 1966 gathering season, 6% of 3,000 toheroa marked 2 months previously were returned.

Changes shown by surveys mostly occurred during closed seasons and thus could not be associated with gathering. Muriwai Beach, situated within easy reach of the largest city in New Zealand, appears to have maintained a comparatively steady toheroa population but on remote Ninety Mile Beach, toheroa numbers have fallen substantially. Though more widespread use of cars has increased the amount of traffic on the beaches, there is no evidence to support the widely-held belief that traffic shatters living toheroas beneath the surface; certainly larger-sized animals are unharmed. Surface-dwelling juveniles might be affected, but this has not been observed.

Because of the difficulty in checking the numbers of people gathering toheroa, and their average individual take, it is very difficult to make reliable estimates of the quantities removed. Predators also take an unknown number: at Muriwai, before 1966 black-backed gulls (*Larus dominicanus*) took only toheroas that had been left by diggers. By 1966 the whole population of gulls had learned to dig small toheroas from undisturbed beds (E. K. Saul pers. comm.). Complete closure of beaches to gathering in 1967 caused no unequivocally significant changes in populations in that year.

CONCLUSIONS

Several years of surveys on three major beaches revealed no consistent pattern of changes. The surveys themselves were insufficient in detail and in time to show the cause of the sudden declines observed. Seasonal gathering does not account for these declines but the effects of digging would probably not be detectable in random surveys of such low intensity. The surveys were, however, sufficiently sensitive to draw attention to impending trouble such as the need to vary limit takes, and to close the beds in 1967. They emphasise the need for more fundamental knowledge of possible migration, parasitism, and the ecology of successful colonisation by toheroa. There was good agreement in size-frequency and population trends between a commercially-biased survey and the more random departmental survey; the decline in population observed on all three beaches very probably represents reality. At all levels on the beach, many searches never revealed spat or juveniles in quantity: only continued surveys and other work will show whether beach populations recover by spatfall or by the sudden appearance of older animals from below the littoral zone.

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