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EXECUTIVE SUMMARY

Akroyd, J.; Walshe, K.; Manly, B.; Te Tuhi, J.; Searle, B.; Searle, R. (2008). Distribution and abundance of toheroa (*Paphies ventricosa*) on Dargaville and Muriwai Beaches, 2006– 2007.

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The distribution of toheroa (*Paphies ventricosa*) beds, and the abundance and size structure of toheroa at Dargaville and Muriwai Beaches, Northland, were determined by a two phase stratified sample survey. The Dargaville survey was undertaken between December 2006 and January 2007 and the Muriwai survey in March 2007.

For Dargaville beach an initial survey identified 50 toheroa beds of greatly varying size and population density. The beds were stratified into four strata based on the observed density of siphon holes. A fifth stratum represented the areas outside the main beds. A total of 59 transects were sampled in phase 1 with a further 34 in phase 2. Transects were run perpendicular to the shoreline from high to low water with 0.5 m^2 quadrats dug at 5 m intervals for the bed strata and at 10 m for the outside bed stratum. The population estimate for toheroa greater than 75 mm (previous legal size) was 173 898 (c.v. 20%), and for toheroa greater than 40 mm (1+ and older cohorts) was 2.83 million (c.v. 17.2%). The total number of toheroa was estimated to be 58.26 million (c.v. 59%). However, in one of the transects in stratum 5 a quadrat contained over 1 200 very small juvenile toheroa. There is some speculation that this may have been caused by severe climatic phenomenon resulting in aggregation of small toheroa in a particular location. If this transect is considered an outlier and removed from the analysis the total population estimate becomes 24.06 million (c.v. 26.8%) with very little change in the estimate for those greater than 40 mm (2.81 million, c.v.17.7%) In either case there has been a significant reduction in toheroa since the previous survey in 1999, when the total estimate was 113.5 million (SE 33 million).

Toheroa on Dargaville beach were found in all strata, but most juveniles occurred at the northern end of the beach. The population is dominated by a strong mode of juvenile toheroa with other less pronounced modes occurring at 50, 75, and 80 mm.

A preliminary survey of Muriwai beach suggested that it was not feasible to use siphon holes to determine the location of toheroa beds, so the sampling used five geographic strata. A two phase sampling design was proposed, but as the required c.v. was reached in phase 1 a second phase was not necessary.

The overall population size of toheroa was 705 416 (c.v. 14.6%), This is a significant increase on the population estimated in 2000 at 474 191 with a c.v. of 16.5%.

Toheroa on Muriwai Beach were found in all strata but the 80% were found in the northern 20 km of the beach. Most of the population was composed of animals between 40 and 74 mm in length with only seven animals over 75 mm and none over 100 mm.

1. INTRODUCTION

1.1 Overview

Toheroa (*Paphies ventricosa*) are large infaunal surf clams found in New Zealand predominantly on the west coast beaches of the North Island, Northland (Ninety Mile, Dargaville, and Muriwai beaches) and Wellington (Foxton, Waitarere, Hokio, and Otaki beaches) and on Oreti and Bluecliff beaches in Southland (Redfearn 1974). Historically, these beaches supported large toheroa populations, but numbers have declined on all beaches to levels where commercial and recreational harvests are no longer permitted. The reasons for these declines are poorly understood, but are likely to include a combination of over-harvesting, and environmental and climatic factors.

Monitoring of toheroa on the main northern North Island west coast beaches, Ninety Mile, Dargaville, and Muriwai beaches (Figure 1) have been undertaken periodically for more than 70 years. Before 1962 there were only occasional surveys, followed by annual or biennial surveys from then until 1986 (Greenway 1963, 1969, 1972, 1974, 1975, Ministry of Fisheries 1986). The main purpose of the surveys from 1962 to 1969 was to assess the effect of an 'open season' when the beach was open for limited periods to recreational fishers. Historical population estimates for the three west coast North Island beaches were compiled from various reports by Morrison & Parkinson (2001). These show that there was considerable fluctuation in the population of toheroa on these beaches, but with a general tendency towards a population decline over time. Information from these surveys also indicated that recruitment was highly variable, and often in years following high recruitment the populations suffered large-scale natural mortalities of juveniles.

With the exception of the most recent surveys of Dargaville in 1999 and Muriwai in 2000, it is difficult to directly compare population estimates and size structure as many of the previous surveys did not cover the full length of the beach and in many cases the samples were not sieved, probably underestimating the juvenile population (Redfearn 1974).

This report summarises the results of toheroa surveys on Dargaville and Muriwai beaches, undertaken between December 2006 and March 2007.

This project was funded through MFish contract TOH2006/01. The overall objective was to determine the distribution of toheroa (*Paphies ventricosum*) beds, and the abundance and size structure of toheroa on northern beaches.

The specific objective was to determine the distribution of toheroa beds and the abundance and size structure of toheroa for specific areas of Dargaville and Muriwai beaches on the west coast of the North Island. The target coefficient of variation for the estimates of absolute abundance was 20%.

2. REVIEW OF THE FISHERY

2.1 Commercial harvesting

Commercial harvesting began in Northland in the late 1800s when toheroa was considered a national delicacy (Stace 1991). Commercial canneries operated on the northern west coast beaches from 1904 until the last one on Dargaville beach closed in 1969 when substantial declines in abundance led to the termination of commercial harvesting (Redfearn 1974). Currently commercial harvesting of toheroa is prohibited on any beach in New Zealand

2.2 Recreational catch

In the early 1900s recreational harvesting on west coast North Island beaches was very intense (Redfearn 1974). In 1932, regulations were introduced to limit the recreational catch. Further restrictions including open seasons, quantity restrictions, and size limits were imposed in the 1950s. Subsequent regular estimates of the public harvest showed that despite the restrictions large quantities of toheroa were removed from the beaches.

Currently there is no allowable recreational harvest on any of the New Zealand beaches

2.3 Customary catch

Toheroa was an important food source to Maori in the pre-European era, as evidenced by archaeological research into Maori middens (Davidson 1967). The toheroa beds on the west coast beaches are said to have been a valuable source of food supply in the olden times, and it is thought that it was probably the attempts to secure the possession of these beds that gave rise to many of the old wars among Maori. (Stace 1991).

As the population of toheroa declined many Maori blamed pakeha. The situation in the 1970s was described by Stace (1991).

> *'During the 1970's Maori watched as the seemingly endless resource gradually diminished. At times the declining years of the toheroa were ones of great bitterness between Maori and pakeha and commercial interests. Many Maori were angered at the wanton plundering of their traditional kai moana.'*

Currently there is a controlled customary take on Dargaville beach with several kaitiaki issuing permits for important occasions such as hui and tangi. At present there are only a few permits issued for Muriwai as kaitiaki are concerned about the small population size.

2.4 Illegal harvesting

Estimates of illegal take are not available although large scale poaching is known to occur, in particular on Dargaville beach (Searle & Te Tuhi, pers. obs.). During the survey large areas, sometimes whole beds, were observed to have been dug up by poachers. Toheroa are valuable on the black market.

3. DARGAVILLE BEACH SURVEY 2006-2007

3.1 Estimates of population and size structure

3.1.1 Phase 1 sampling plan

To estimate total population size and associated size frequency distributions of toheroa on Dargaville Beach (Figure 2), a survey of two-phase stratified random design (Francis 1984) was undertaken between December 2006 and January 2007. An initial survey of the beach used four wheel drive vehicles, with observers with experience and extensive knowledge of the beach, travelling the length of the beach, several times in different conditions looking for toheroa beds. This method for identifying toheroa beds has been used successfully in previous surveys (Morrison& Parkinson 2001, Akroyd et al. 2002). The beds are identified by shading colour change in the sand and the double siphon holes which are obvious at low tide. When the tide begins to cover the bed, the siphon holes are active (taking in and expelling water). For each of the beds the siphon holes in a specified area were counted to give an estimate of the size of toheroa bed. In addition, a series of excavations were made at 1 km intervals down the full length of the beach looking for toheroa. The position of the beds was recorded using a GPS plotter.

After the initial survey, four strata were defined based on toheroa density along the beach (holes per metre of beach). These strata were defined as Stratum 1 'low', less than 500 holes/m; Stratum 2 'medium', between 500 and 1000 holes/m; Stratum 3 'high', between 1000 and 2500 holes/m. All the beds in a stratum represent a length of beach, and were sampled along this length with transects that were systematically placed, with a random starting point.

Transects set perpendicular to the shore covered the whole width of the beach from high water (edge of dunes) to low water, with a 0.5 m^2 (1x 0.5 m) quadrat dug to a depth of 30 cm every 5 m down the transect.

The remainder of the beach, with no known beds, defined as 'other' stratum, was sampled with transects systematically placed with a random starting point at the north end of the beach. For these transects the 0.5 m^2 quadrats were dug every 10 m of transect instead of every 5 m. All toheroa found in each quadrat were measured to the nearest millimetre using electronic vernier callipers, downloaded onto an Allegro water proof computer, before being returned to the sand in the position as originally found.

The sample sizes in the four strata with beds were made approximately proportional to the total area of the strata and the estimated mean number of holes/m of beach. This was intended to be approximately an optimal allocation based on a standard result for stratified sampling.

A minimum sample size of five transects for a stratum was used to estimate the within-sample SD reasonably well for the later use of the Francis (1984) two-phase optimal stratified sampling procedure. The phase 1 sampling plan allocated 43 transects to parts of the beach where toheroa beds were known to be present and 15 transects to the remainder of the beach as shown in Table 1.

3.1.2 Phase 1 analysis

For transects in strata 1 to 4, quadrats were taken every 5 m and it was assumed that all toheroa are within the length of the transect from the first to the last quadrat, so that the total length of transect covering all toheroa is

$$\text{Length (m)} = 5^* (\#\text{quadrats}) - 4.$$

For the transects in stratum 5 (no observed toheroa holes) quadrats were taken every 10 m. In this case the total length of transect covering all toheroa is

$$\text{Length (m)} = 10^*(\#\ \text{quadrats}) - 9.$$

The total number of toheroa within the transect was estimated by the density of toheroa (number per m^2 sampled) multiplied by the length of the transect.

3.1.3 Statistical analysis

Population estimation was based on the usual equations for stratified random sampling (Cochran 1977). Although this results in a bias in the estimates of population size, the simulations described by Manly et al. (2002) and Manly (2004) show that this bias should be quite small with a c.v of 20% or less. Also, if necessary, about half of the bias can be removed by a bootstrap procedure.

Let A_{ij} = the area of stratum j at location i; n_{ij} = the number of units randomly sampled from stratum j, at location i; $\bar{x}_{ijk}$ = the mean density per unit area for size class k, in stratum j, at location i; and s_{ijk} = the sample standard deviation of density estimates for size class k, in stratum j, at location i. Then the estimated total population size for species k at location i is

$$\hat{T}_{ik} = 3\ A_{ij}\ \bar{x}_{ijk},$$

where the summation is over the strata at location i. The variance of this estimator is

$$Var(\hat{T}_{ik}) = 3\ A_{ij}^2\ s_{ijk}^2\ /\ n_{ij}.$$

As the sampling fraction is small in all strata at all locations no finite population correction is required. The estimated coefficient of variation (c.v.) in percentage terms is then

$$CV_{ik} = 100[\%\{Var(\hat{T}_{ik})\}\ /\ \hat{T}_{ik}].$$

The proposed sampling design and analysis has the following steps.

(a) A first phase sample with a total size of n_{T1} is allocated to the locations and strata, with the same number of units are allocated to each location. As far as possible the optimal allocation was used as described by Cochran (1977, p. 98) to allocate units to strata within locations.

(b) Means ($\bar{x}_{ijk}$) and standard deviations (s_{ijk}) are estimated using the first phase sample data, for use in the equations given above.

(c) An optimisation criterion is defined as Z = the mean of all c.vs over 20%.

(d) A second phase sample unit is allocated to the location and stratum where it gives the largest possible reduction in Z. This is determined by recalculating the c.v.s with the sample size increased by one, for each location and stratum, and finding the resulting change in Z. The location and stratum giving the maximum reduction is then chosen for use.

(e) The sample size (n_{ij}) for the chosen location and stratum is incremented by +1, while the sample mean ($\bar{x}_{ijk}$) and standard deviation (s_{ijk}) are left unchanged.

(f) Steps (d) and (e) are repeated until a total of n_{T2} second phase units have been allocated. The second phase data are then collected, and the data from both phases are combined for estimation using the equations given above.

3.1.4 Phase 2 sampling plan

Using the statistical analysis described above, in order to get a c.v. of about 20% for the total estimated number of toheroa of all sizes, it would have been necessary to sample at least another 200 transects from stratum 5 (areas in the beach with no holes). However, to get a c.v. of about 20% for the estimated number of toheroa over 40 mm in length (~1+ older cohorts, according to Redfearn (1974) it would require 22 additional transects to be sampled from stratum 5 and 4 from stratum 1. It was decided that phase 2 would sample an extra 30 transects from stratum 5 and 4 from stratum 1 (Table 1).

3.1.5 Results

Fifty toheroa beds of greatly varying sizes and population densities were identified in the initial survey. Ninety three transects were sampled along 72.4 km of Dargaville Beach. The number of toheroa greater than 40 mm was estimated to be 2.83 million (c.v. 17.2%). The population estimate for toheroa over 75 mm (previous legal size) was estimated to be 849 831 (c.v. 20.5%) with the 0+ cohort of less than 41 mm estimated as 55.44 million (c.v. 62.7%). The total number of toheroa was estimated to be 58.26 million (c.v. 59.7%) (Table 2).

However, in one of the transects in stratum 5, 'other', a quadrat contained over 1200 juvenile toheroa (under 26 mm). If this transect is considered an outlier and removed from the analysis, the total population estimate becomes 24.06 million (c.v. 26.8%) with very little change in the estimate for those greater than 40 mm (2.81 million, c.v.17.7%) (Table 3).

The length frequency distribution for the total population is given in Figure 3. The bulk of the population was composed of animals of less than 41 mm which were probably a 0+ cohort (Redfearn 1974). The modes in the length frequency histogram occur at around 14 mm, 50 mm, 75 mm, and 80 mm. These correspond well with the typical lengths of 0+, 1+, 2+, and 3+ year old toheroa (Redfearn 1974).

Toheroa were distributed the entire length of the 72.4 km of beach as is demonstrated in the three dimensional distribution plot (Figure 5). The plot of the cumulative numbers of each size group by distance along the beach shows that about 50% of toheroa were found in the northern 20 km of beach (Figure 4).

3.1.6 Discussion

In the previous surveys of Dargaville and Ninety Mile beaches, siphon holes were found to be reasonable indicators of toheroa beds and densities on which to base a phase 1 sampling plan (Morrison & Parkinson 2001, Akroyd et al. 2002). However, stratification using this approach will always have issues as surface siphon holes appear to vary depending on environmental conditions. In this survey it was found that many of the beds' locations and densities had changed considerably between the initial and the phase 1 surveys. Some of this could be attributed to large scale poaching that was observed to have occurred on the beach. There was evidence of whole beds having been dug out and the toheroa removed from the beach. Another factor was the severe and prolonged southwesterly gales that occurred in the intervening time. There is speculation that these winds carry the small toheroa living just under the sand surface along the beach and deposit them where geographical conditions determine. The quadrat with the exceeding high numbers of juvenile toheroa was in the northeast corner of a low lying small bay, a location where it appears that toheroa had aggregated. The removal of this sample greatly reduces the estimate of the 0+ cohort and of the total population. Caution is advised in quoting the total estimated population size for Dargaville Beach. The historical time series for toheroa estimates and size structure shows that large recruitments occur at irregular intervals, but these fail to generate higher abundances of larger animals (Morrison & Parkinson 2001). Studies have shown that many will not survive due to a combination of weather, environmental conditions and heavy bird predation (Redfearn 1974). In the previous surveys of both Ninety Mile Beach (Morrison & Parkinson, 2001), and Dargaville Beach (Akroyd et al. 2002), the populations were heavily dominated by small toheroa under 40 mm in length (0+/1+ cohort). It is likely that these surveys may have been more efficient at sampling smaller toheroa than previous surveys. Most of the historical toheroa population estimates for Dargaville and Ninety Mile beaches were based on samples that were not sieved and therefore were probably gross underestimates of those under 40mm (Redfearn 1974). This makes comparisons with previous surveys difficult. There may be some merit in using only the population estimates of toheroa over 40 mm to determine trends and changes in population size.

The population estimates for all toheroa in this survey, 58 million (SE 34.8 million), shows a decrease in numbers from the survey in 1999 where the estimate was 113 million (SE 33 million). For toheroa greater than 75 mm there was also a decline from 3.3 million with a SE 480 000 (Akroyd et al. 2002) to 849 831 (SE 173 898) in the current survey. Because of the number of years between surveys it is difficult to speculate why the population has declined. In 1999 there was a large juvenile cohort that may not have survived. Large scale poaching is known to occur regularly; these factors combined with environmental and climatic conditions may have all contributed.

Although, as with the previous survey, toheroa were found the length of the beach, the population is not evenly distributed. In 1999 most of the toheroa occurred midway along the beach; in the current survey about 50% of the toheroa occur in the northern 20 km of the beach (Figures 4 and 5). The reason for the change is not known but largely considered to be changes in weather patterns with the occurrence of more southeasterly winds and heavy poaching (Searle & Te Tuhi, pers.obs.) especially at good beach access points that occur in the middle of the beach, Glink's Gully and Baylys Beach (Figure 2). In both surveys beds were observed to occur in and around the freshwater streams. Rapson (1952) suggested a possible correlation between freshwater seepage and the presence of toheroa.

4. MURIWAI BEACH SURVEY 2007

4.1 Estimates of population and size structure

4.1.1 Sampling plan

A preliminary survey of the beach was undertaken to establish the location of the toheroa beds to assist in stratification of the beach.

Field workers travelled the length of the beach several times in different conditions looking for toheroa beds. This was done using quad vehicles driven at low speed with experienced observers looking for signs of toheroa. However, as was the case in the previous Muriwai Beach survey, siphon holes were not obvious and could not be used to determine the location of beds (Akroyd et al. 2001). For this reason it was appropriate to repeat the sampling methodology used in the 2000 survey.

Retaining the five geographic strata defined by Akroyd et al. (2001) (Figure 6), a two phase sampling design was planned with the phase 1 sample consisting of 10 transects systematically placed every 1 km down the beach. After the collection of phase 1 data the plan was to use the Francis (1984) method to determine the optimum allocation of transects for the second phase.

4.1.2 Survey methods

The first phase sample consisted of 10 transects allocated to each of five strata covering the length of the beach (48 km). Within each stratum transects were systematically placed 1 km apart, with a random starting point.

Due to changes in the beach since 2000 the distribution of strata for the 2007 survey was changed to 11 transects in Stratum 1, 10 transects each in Strata 2, 3, and 4 and 7 in Stratum 5. The first transect in each stratum had a random starting point along the beach and transects were placed 1 km apart within the stratum. Each transect had a random starting point down the beach between 1 and 5 m, and covered the area from high water to low water. Quadrats (0.5 m^2) were positioned at 5 m intervals down the transect and excavated to 30 cm. The sample content was sieved and any toheroa in the sample were measured to the nearest millimetre. The number of quadrats sampled on each transect line depended on the width of the beach.

4.1.3 Phase 1 analysis of data

Each quadrat was regarded as representing 1 m of the total distance from high water (edge of dune) to low water. On this basis, if a transect had 'n' quadrats in it, it was assumed that the total number of quadrats that could be sampled in the transect was 5n - 4. For example, with n = 3 sampled quadrats the situation would be as shown below, where each quadrat represents 1 m of the distance from the dunes to the water line, and X shows the three sampled quadrats.

1	2	3	4	5	6	7	8	9	10	11
X					X					X

4.1.4 Statistical analysis

Refer to Section 3.1.3 above

4.1.5 Results

Toheroa were not common on the beach with a total of 79 toheroa sampled from 48 transects. Table 4 summarises the sample results.

Table 5 details population estimates with standard errors of the density of toheroa in each of the five strata, together with estimated total numbers of toheroa in each of these strata. The estimated total number of toheroa is 705 416, with a standard error of 80 513, and hence a c.v. of 14.6%. As a c.v. of less than 20% was achieved, no phase 2 sampling was carried out. Although the population is small, it has increased significantly since the previous Muriwai Beach survey in 2000 when the estimated population was 474 191 with a c.v. of 16.5% (Akroyd et al. 2001).

Although toheroa were found in all strata the cumulative distribution plot shows that for all sizes most toheroa (80%) occurred in the northern half of the beach (Figure 7). Also of note is that all toheroa occurred in a band between 10 and 35 m down the beach as can be seen in Figure 8, which shows the number of toheroa by length class vs distance down the beach.

The size structure (Figure 9) suggests that there has been no recent recruitment with only two toheroa under 15 mm being found. There are no obvious size modes.

4.1.6 Discussion

From this survey it is obvious that Muriwai Beach has a low population of toheroa with no indication of good recruitment. However, the population has increased significantly since the previous (2000) survey. Since then there has been some enhancement of the beach toheroa population by relocating toheroa from Dargaville Beach; this may have assisted in increasing the population but there are no data to verify this.

1. The last population estimate on Muriwai Beach when the population exceeded 1 million, was in 1977 (Morrison & Parkinson 2001). Since then there have been major changes to the beach and surrounding environment which may have impacted on the population numbers and recruitment in particular. The dune faces are severely eroded and there are is little marram or pingao grass where juveniles may be trapped before settling down the beach. Forestry activities in the surrounding environs may also have had an impact on the water levels. Unfortunately, water levels were not measured before forestation, but local knowledge refers to lakes behind the dunes which have now vanished. Redfearn (1974) reported that aggregations of toheroa generally occur in areas where the water table lies close to the sand surface at low tide.

5. MANAGEMENT IMPLICATIONS

Neither Dargaville nor Muriwai Beaches currently support the large populations of toheroa that were once present. However, in both cases the populations are showing an improvement from the estimates determined in the late 1970s and early 1980s.

The infrequency of surveys, the last being 6 and 7 years ago for Muriwai and Dargaville respectively, makes it very difficult to determine what is happening to the population and what particular events have affected the population numbers and size structure. However, given the current small population size, the customary take needs to be carefully managed, and the illegal harvest controlled, to assist populations to recover. More frequent population surveys and research on both natural as well as other sources of mortality would be beneficial in assisting kaitaki to manage this resource.

Community based management using an ecosystem approach is ideal for these two beaches. However, the local community need to be given encouragement and support and be provided with the necessary training and resources for this to be successful. Locals should be encouraged to participate in activities such as planting of marram and pingao and supporting initiatives to protect the beds.

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Table 1: Stratum description, areas, transect allocations for Phases 1 and 2, Dargaville Beach, 2006–07.

					No. of transects
Stratum	Description*	Beach length (m)	Phase 1	Phase 2	Total
1	Low	437	24	4	28
2	Medium	287	8		8
3	High	575	7		7
4	Very high	499	5		5
5	Other	70 602	15	30	45
		Total	59	34	93

* These descriptions were given after the initial beach survey.

Table 2: Results from Phase 1 and Phase 2 sampling, all transects, Dargaville Beach, 2006–07.

Toheroa > 75 mm

Stratum	Beach length (m)	Transects	Transect mean	SD	SE	Stratum total	SE
1	499	9	151.1	326.5	107.8	75 413	53 817
2	575	7	225.5	181.1	68.0	129 667	39 126
3	287	8	353.2	440.7	153.6	101 355	44 087
4	437	24	113.6	122.1	24.2	49 652	10 588
5	70 602	45	7.0	14.6	2.2	493 743	154 135
					Total	849 831	173 898
						% c.v.	20.5

Toheroa > 40 mm

Stratum	Beach length (m)	Transects	Transect mean	SD	SE	Stratum total	SE
1	499	9	457.1	781.7	258.2	228 074	128 837
2	575	7	465.5	339.3	127.5	267 669	73 289
3	287	8	1 248.2	1 113.1	388.0	358 226	111 362
4	437	24	531.4	878.8	174.4	232 220	76 207
5	70 602	45	24.6	42.2	6.3	1 739 544	443 968
					Total	2 825 733	487 121
						% c.v.	17.2

Table 2: cont.

Toheroa < 41mm

Stratum	Beach length (m)	Transects	Transect mean	SD	SE	Stratum total	SE
1	499	9	610.7	676.7	223.5	304 717	111 546
2	575	7	801.0	1 034.9	388.8	460 585	223 532
3	287	8	2 215.0	2 766.0	964.2	635 713	276 723
4	437	24	594.3	986.4	195.7	259 723	85 542
5	70 602	45	761.7	3 302.5	492.1	53 775 694	34 746 646
					Total	55 436 432	34 748 752
						% c.v.	62.7

Toheroa > 14 mm

Stratum	Beach length (m)	Transects	Transect mean	SD	SE	Stratum total	SE
1	499	9	879.5	1 028.6	339.8	438 848	169 543
2	575	7	800.3	634.7	238.4	460 175	137 088
3	287	8	2 744.0	2 486.6	866.8	787 535	248 772
4	437	24	950.5	1 588.2	315.2	415 351	137 726
5	70 602	45	316.4	1 132.4	168.7	22 340 434	11 913 992
					Total	24 442 343	11 919 379
						% c.v.	48.8

All toheroa

Stratum	Beach length (m)	Transects	Transect mean	SD	SE	Stratum total	SE
1	499	9	1 067.7	1 084.8	358.3	532 790	178 807
2	575	7	1 266.5	1 131.8	425.2	728 254	244 466
3	287	8	3 463.2	3 271.4	1140.4	993 939	327 293
4	437	24	1 125.7	1 751.6	347.6	491 943	151 893
5	70 602	45	786.3	3 304.3	492.4	55 515 238	34 766 170
					Total	58 262 165	34 769 361
						% c.v	59.7

Table 3: Results from Phase 1 and Phase 2 sampling, random transect 1 removed, Dargaville beach, 2006–07.

Toheroa > 75 mm

Stratum	Beach length (m)	Transects	Transect mean	SD	SE	Stratum total	SE
1	499	9	151.1	326.5	107.8	75 413	53 817
2	575	7	225.5	181.1	68.0	129 667	39 126
3	287	8	353.2	440.7	153.6	101 355	44 087
4	437	24	113.6	122.1	24.2	49 652	10 588
5	70 602	44	6.3	14.1	2.1	447 199	150 324
					Total	803 287	170 529
						% c.v.	21.2

Toheroa > 40 mm

Stratum	Beach length (m)	Transects	Transect mean	SD	SE	Stratum total	SE
1	499	9	457.1	781.7	258.2	228 074	128 837
2	575	7	465.5	339.3	127.5	267 669	73 289
3	287	8	1 248.2	1 113.1	388.0	358 226	111 362
4	437	24	531.4	878.8	174.4	232 220	76 207
5	70 602	44	24.4	42.6	6.4	1 721 313	453 796
					Total	2 807 503	496 095
						% c.v.	17.7

Toheroa < 41 mm

Stratum	Transects	Transect mean	SD	SE	Stratum total	SE	
Stratum	Beach length (m)	Transects	Transect mean	SD	SE	Stratum total	SE
1	499	9	610.7	676.7	223.5	304 717	111 546
2	575	7	801.0	1 034.9	388.8	460 585	223 532
3	287	8	2 215.0	2 766.0	964.2	635 713	276 723
4	437	24	594.3	986.4	195.7	259 723	85 542
5	70 602	44	277.4	602.4	90.8	19 587 757	6 409 833
					Total	21 248 495	6 421 235
						% c.v.	30.2

Table 3: cont.
Toheroa > 14mm

Stratum	Beach length (m)	Transects	Transect mean	SD	SE	Stratum total	Stratum SE
1	499	9	879.5	1 028.6	339.8	438 848	169 543
2	575	7	800.3	634.7	238.4	460 175	137 088
3	287	8	2 744.0	2 486.6	866.8	787 535	248 772
4	437	24	950.5	1 588.2	315.2	415 351	137 726
5	70 602	44	157.1	378.7	57.1	11 092 938	4 029 845
					Total	13 194 847	4 045 744
						% c.v.	30.7

All Toheroa

Stratum	Beach length (m)	Transects	Transect mean	SD	SE	Stratum total	SE
1	499	9	1067.7	1084.8	358.3	532 790	178 807
2	575	7	1266.5	1131.8	425.2	728 254	244 466
3	287	8	3463.2	3271.4	1140.4	993 939	327 293
4	437	24	1125.7	1751.6	347.6	491 943	151 893
5	70 602	44	301.8	603.3	90.9	21 309 070	6 418 894
					Total	24 055 998	6 436 158
						% CV	26.8

Table 4: Summary of the sample results Muriwai beach, 2007.

		Quadrat												Toheroa	Sample	Total	Count/m^2	Total
Stratum	Transect	1	2	3	4	5	6	7	8	9	10	11	12	count	quadrats	quadrats	Density	toheroa
1	1	0	0	0	0	0	0	0						0	7	31	0.00	0.00
1	2	0	0	0	1	0	0	0						1	7	31	0.29	8.86
1	3	0	0	0	0	0	0	0						0	7	31	0.00	0.00
1	4	0	0	0	0	0	0	0						0	7	31	0.00	0.00
1	5	0	0	0	0	1	0	0						1	7	31	0.29	8.86
1	6	0	0	0	0	0	0							0	6	26	0.00	0.00
1	7	0	0	0	0	0	0	0						0	7	31	0.00	0.00
2	8	0	0	0	0	1	0	0						1	7	31	0.29	8.86
2	9	0	1	0	0	0	0							1	6	26	0.33	8.67
2	10	0	0	0	0	0	0	0						0	7	31	0.00	0.00
2	11	0	1	0	0	0	0							1	6	26	0.33	8.67
2	12	0	1	0	0	0	0							1	6	26	0.33	8.67
2	13	0	0	0	0	0	0	0						0	7	31	0.00	0.00
2	14	0	0	1	0	0	0	0						1	7	31	0.29	8.86
2	15	0	2	1	0	0	0	0						3	7	31	0.86	26.57
2	16	0	0	0	0	0	0	1	0	0				1	9	41	0.22	9.11
2	17	0	1	0	0	0	0							1	6	26	0.33	8.67
3	18	0	0	0	0	0	0							0	6	26	0.00	0.00
3	19	0	1	0	0	0	0							1	6	26	0.33	8.67
3	20	0	0	0	0	0	0							0	6	26	0.00	0.00
3	21	0	0	0	0	0	0	0						0	7	31	0.00	0.00
3	22	0	0	1	0	0	0	0						1	7	31	0.29	8.86
3	23	0	0	0	0	0	0	0						0	7	31	0.00	0.00
3	24	0	0	0	0	0	0	0						0	7	31	0.00	0.00
3	25	0	1	1	0	1	0	0						3	7	31	0.86	26.57
3	26	0	0	0	0	0	0	0						0	7	31	0.00	0.00
3	27	0	2	0	0	0	0							2	6	26	0.67	17.33
4	28	0	2	0	0	0	0	0						2	7	31	0.57	17.71
4	29	0	0	2	1	0	0							3	6	26	1.00	26.00
4	30	0	1	1	1	1	0	0						4	7	31	1.14	35.43
4	31	0	1	0	0	0	0							1	6	26	0.33	8.67
4	32	0	1	1	1	1	0	0						4	7	31	1.14	35.43
4	33	0	0	0	1	2	0	0						3	7	31	0.86	26.57
4	34	0	1	0	1	0	0							2	6	26	0.67	17.33
4	35	0	0	0	2	0	0							2	6	26	0.67	17.33
4	36	0	0	4	1	2	0	0						7	7	31	2.00	62.00
4	37	0	1	0	0	0	0							1	6	26	0.33	8.67
5	38	0	0	0	0	0	2	1	0					3	8	36	0.75	27.00
5	39	0	0	0	0	0	0							0	6	26	0.00	0.00
5	40	0	0	0	0	0	0							0	6	26	0.00	0.00
5	41	0	0	1	0	0	1	3	0					5	8	36	1.25	45.00
5	42	0	0	1	0	1	0	1	0	0	0			3	10	46	0.60	27.60
5	43	0	0	0	0	0	2	1	0	0	0			3	10	46	0.60	27.60
5	44	0	1	0	0	0	0	0	0	0	0			1	10	46	0.20	9.20
5	45	0	1	5	2	0	0	0	0	0	0	0	0	8	12	56	1.33	74.67
5	46	0	3	2	0	0	1	0	0					6	8	36	1.50	54.00
5	47	0	0	0	0	0	0	0	0	0				0	9	41	0.00	0.00
5	48	0	1	1	0	0	0	0	0					2	8	36	0.50	18.00

Table 5: Mean estimated toheroa numbers per transect, and the estimated total numbers of toheroa on Muriwai Beach, 2006.

All Toheroa

Stratum	Beach length (m)	Transects	Transect mean	SD	SE	Stratum total	SE
1	7 000	7	2.53	4.32	1.63	17 714	11 435
2	10 000	10	8.81	7.23	2.29	88 063	22 874
3	10 000	10	6.14	9.33	2.95	614 29	29 490
4	10 000	10	25.51	15.96	5.05	255 143	50 459
5	11 000	11	25.73	24.28	7.32	283 067	80 513
					Total	705 416	80 513
						% CV	14.6

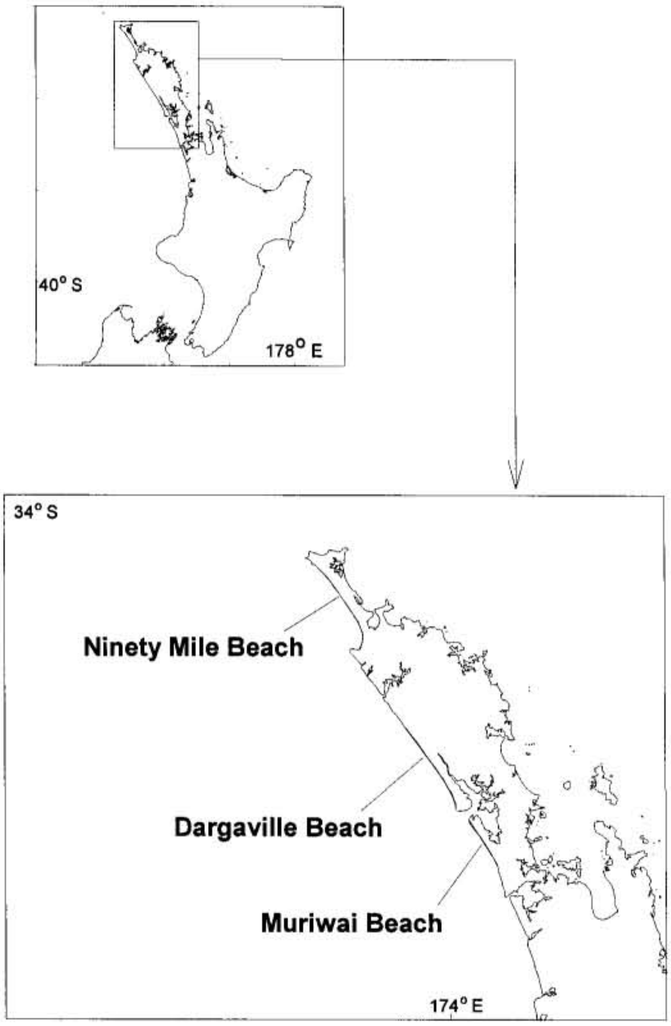


Figure 1: Location of three main northern beaches that contain important toheroa populations Morrison & Parkinson (2001).

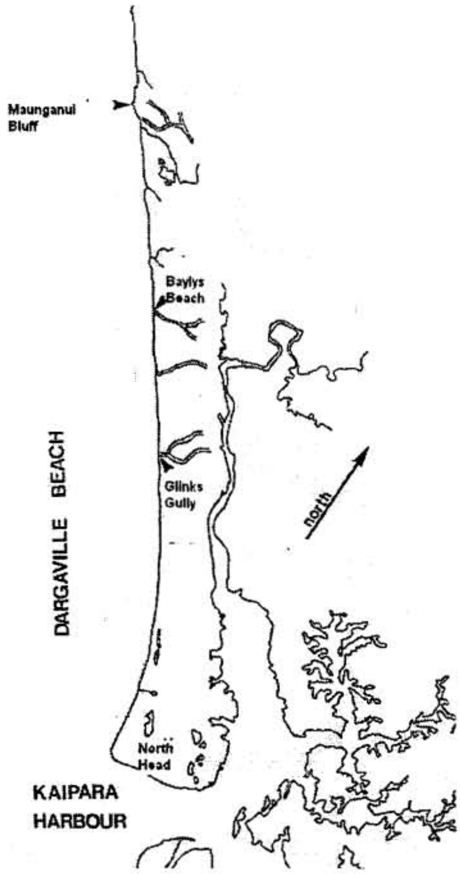


Figure 2: Dargaville Beach.

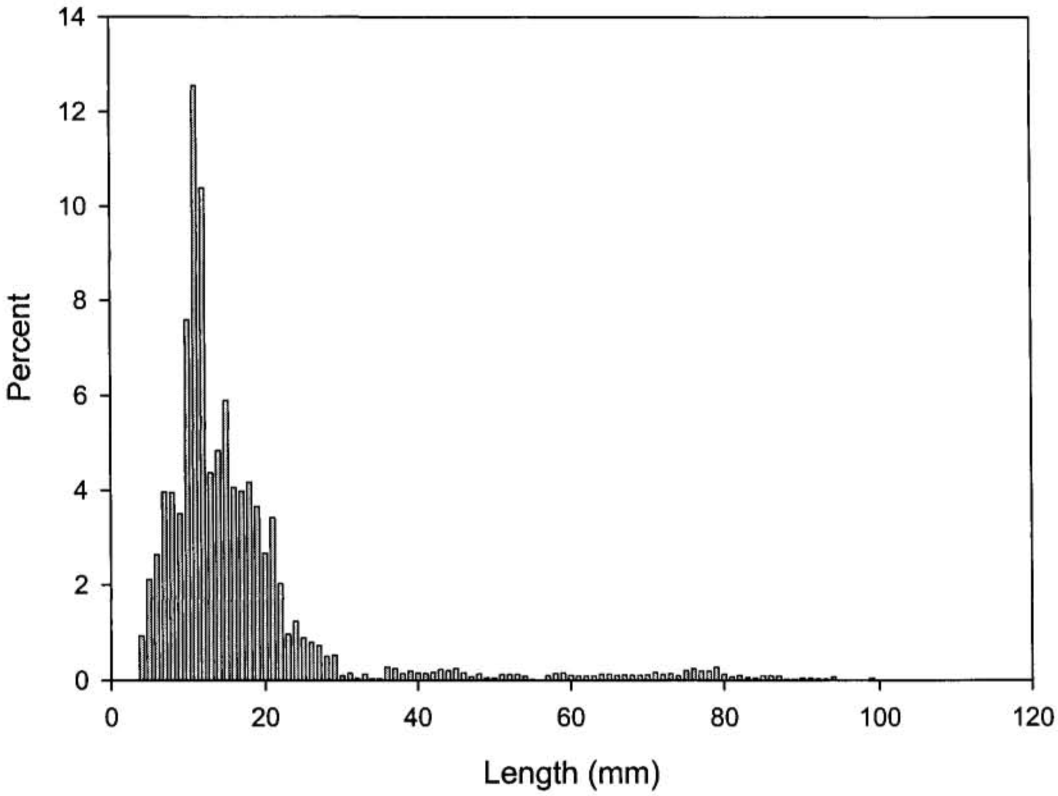


Figure 3: Dargaville toheroa – percent length frequency, 2007.
N = 9 692 toheroa
N = 92 transects

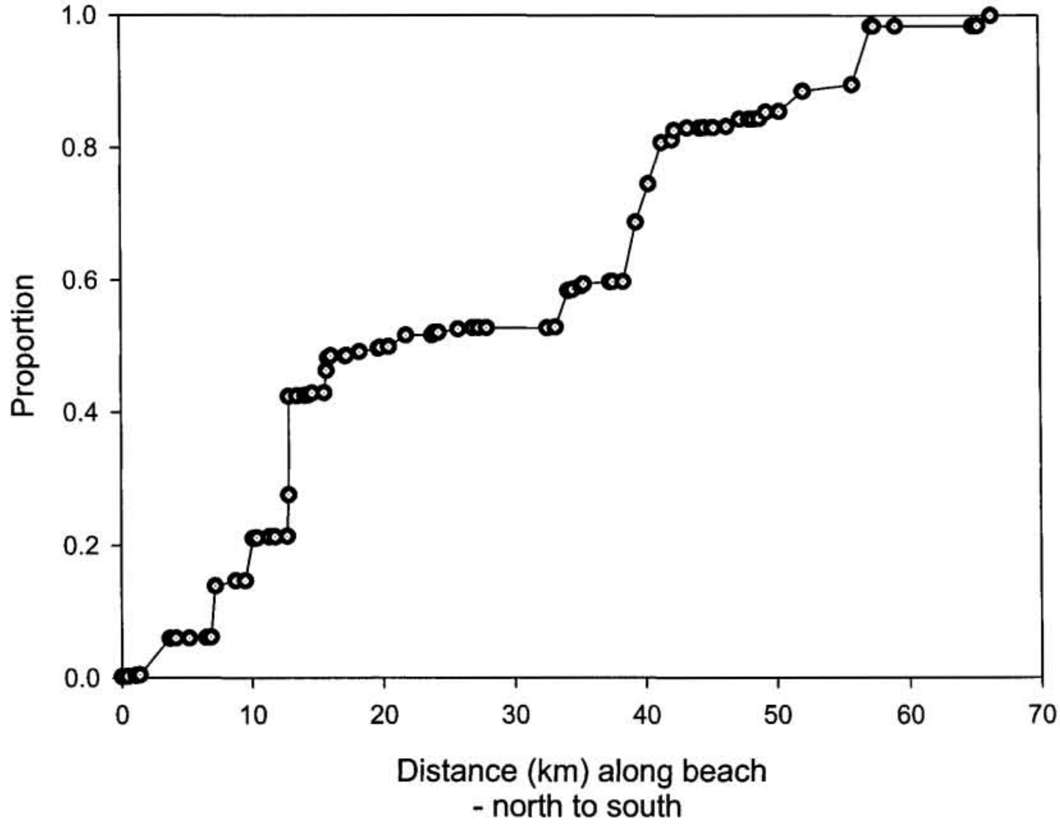


Figure 4: Cumulative distribution of toheroa along Dargaville Beach – all size classes, transect 51 removed.

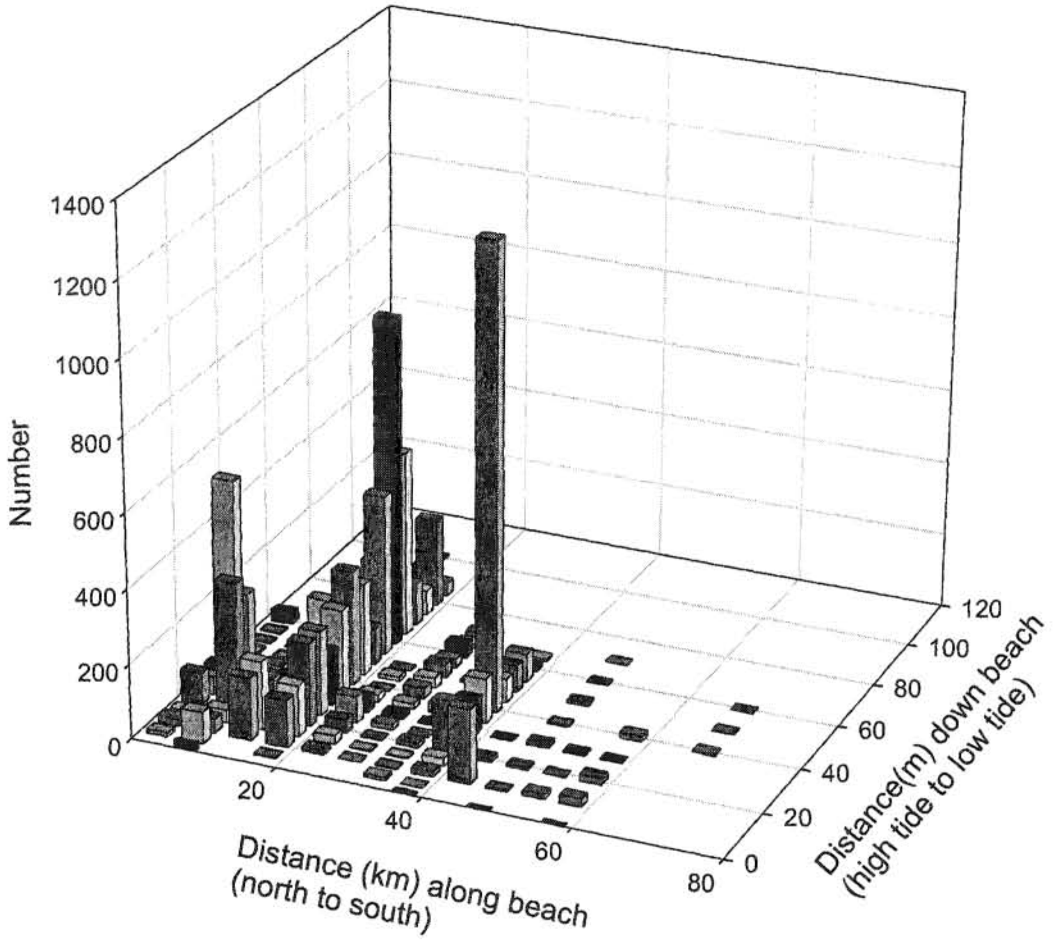


Figure 5: Distribution of toheroa by distance (m) down the beach, and by distance (km) along Dargaville Beach (Transect 51 included).

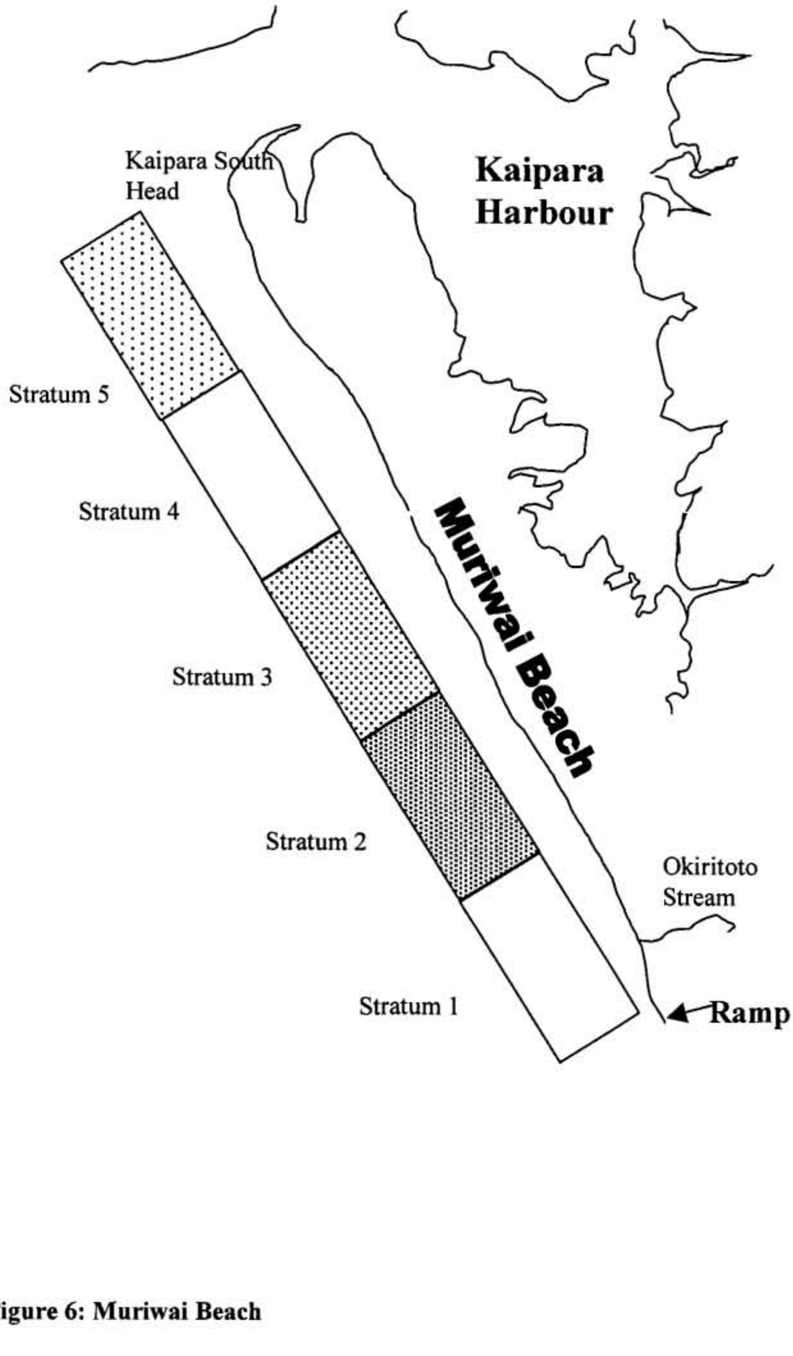


Figure 6: Muriwai Beach

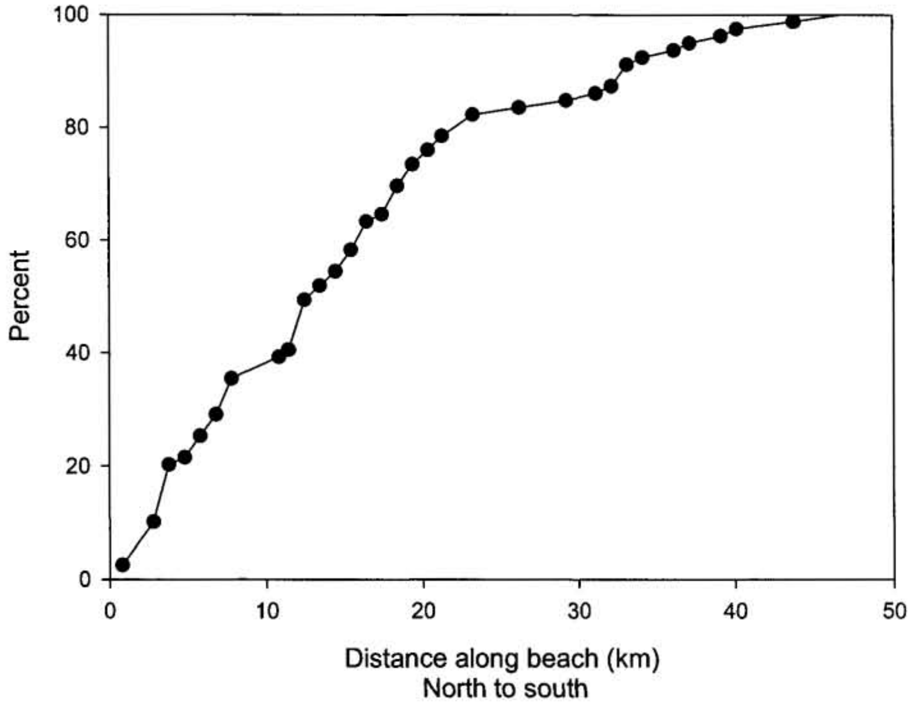


Figure 7: Cumulative frequency graph toheroa Muriwai Beach.

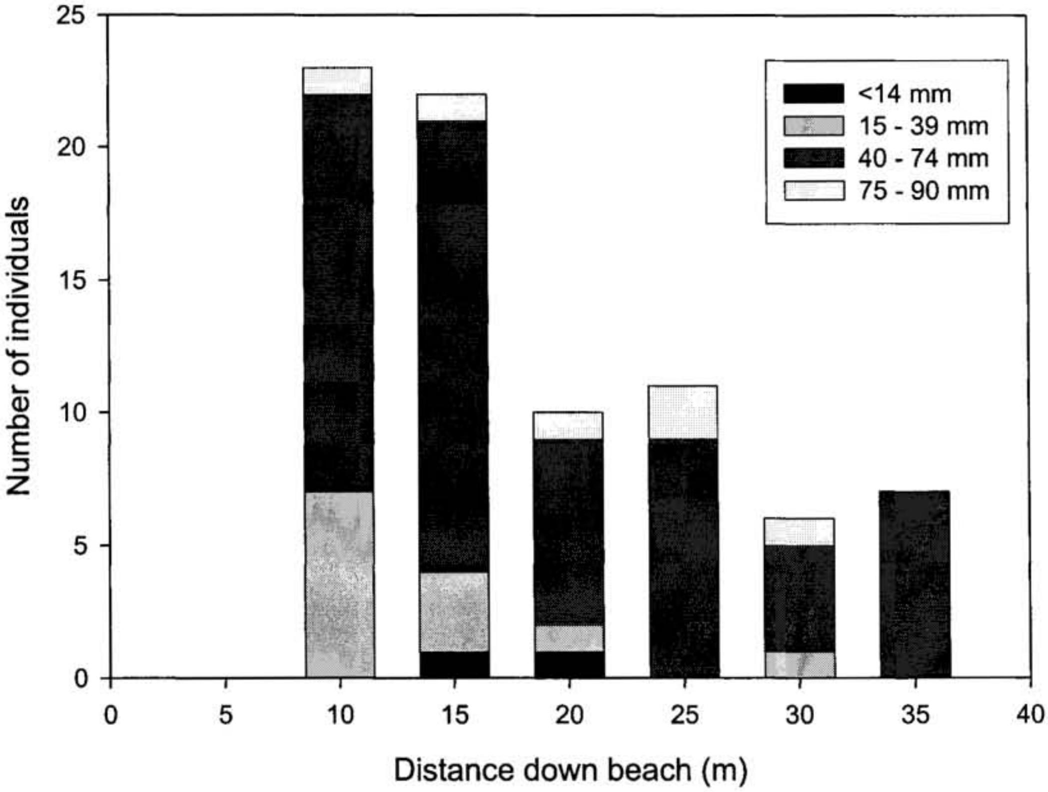
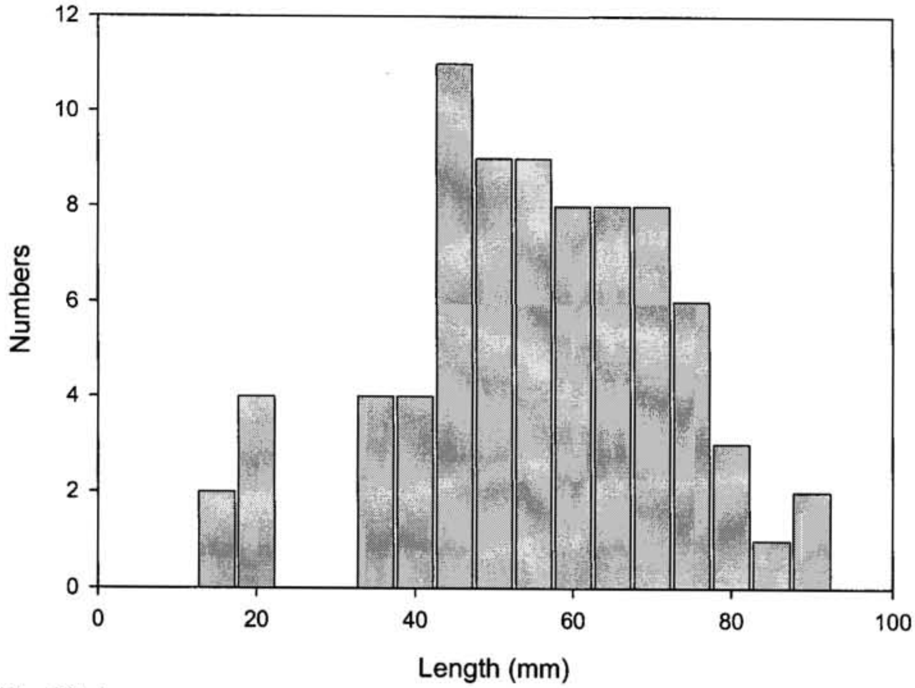


Figure 8. Number of toheroa by length class vs distance down Muriwai Beach.



N = 79 toheroa
N= 48 transects

Figure 9: Length frequency of toheroa, Muriwai Beach.