Aspects of Mangrove Distribution and Abundance in Tauranga Harbour

Prepared by Stephen Park, Senior Environmental Scientist

Environment Bay of Plenty
Environmental Publication 2004/16
November 2004

5 Quay Street
P O Box 364
Whakatane
NEW ZEALAND

ISSN 1175 - 9372

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Acknowledgements

The assistance of the GIS section, particularly Tim Barnes has been invaluable.

Cover Photo: Mangroves in Wainui Estuary, Tauranga Harbour

Executive Summary

This report presents results of mapping and examination of trends and factors relating to the increasing spread of mangroves around Tauranga Harbour.

A number of sites were selected around Tauranga Harbour for mapping of mangrove extent from 1943 up to 2001. All sites show a pattern of exponential increase. The rate of increase appears to reflect the overall abundance of mangroves in a particular area. Blue Gum Bay for instance has one of the lowest proportions of mangrove cover relative to estuary size and also has the lowest rate of increase.

A number of variables were looked at with respect to mangrove extent. Results showed that there is a good correlation between the average mud content of an estuary and the proportion of mangrove cover, although it would not be the only environmental factor to influence extent. Those estuaries around Tauranga Harbour with higher mud content also tend to be on the western margin with larger catchments. Areas that have cleaner sands near the entrances or in open exposed areas generally have fewer mangroves. It is clear that higher rates of sediment input to sheltered estuarine environments will enhance the rate of mangrove spread.

Comparison of automated remote sensing classification of mangrove cover with manual mapping was made despite the difference in scale of the two techniques. The results showed that the automated remote sensing approach tended to slightly under-estimate mangrove cover (12% less). This appears to be mainly due to the expected scale dependant differences. The technique would be useful for mapping of large areas such as the whole of Tauranga Harbour or national extent as it has objective and repeatable criteria for the classification.

In the southern region of Tauranga Harbour, accurate intertidal bathymetry is available and was used to confirm that the maximum seaward extent of mangroves is around mean sea level. The bathymetry data can also be used to show the maximum expected extent of mangrove colonisation. In many areas factors such as currents and waves appear to commonly limit the seaward extent at around 20-30 cm above mean sea level.

Possible intrusion of Saltmarsh around Tauranga Harbour was looked at. In general there is usually only marginal intrusion into rush communities at the seaward fringe, (5-10 m). Areas that experienced a greater degree of intrusion appeared to be sparse areas of rush vegetation that were lower in the tidal zone. Where the rush communities are very healthy and there are no open pathways into the Saltmarsh areas intrusion was usually minimal. Even at the 1:5,000 minimum mapping scale that was used for assessment, it is obvious that more detailed study with a ground survey component would be required to clearly identify processes and overall changes.

The results from this study support the need to ensure that sediment runoff from the harbour catchment is carefully controlled to maintain the natural harbour environment.

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Chapter 1: Introduction

1.1 Scope

This report presents the results of mapping mangrove distribution at a number of selected sites throughout Tauranga Harbour. The mapping was undertaken to provide:

- Accurate estimates of the rate of change over time at each site.
- An indication of harbour wide patterns in relation to sediments and other environmental factors.
- A comparison between manual mapping and remote sensing using ECOSAT data processed by Landcare Research.
- An assessment of the potential tidal height range in which mangroves grow in Tauranga Harbour.
- An indication of whether mangroves are colonising Saltmarsh habitat.

In addition, an earlier component of the work assisted in looking at the role of nutrients in contributing to mangrove expansion. This study investigated mangrove distribution and expansion in relation to sediments type, nutrient content and the nutrient status of the mangroves themselves. It covered a number of the same areas as reported in this study and areas outside of the Bay of Plenty. The executive summary of this report by Schwarz (2002) has been attached as Appendix 1.

1.2 Background

The work presented in this report was part of a wider project brief to look at the impacts of urbanisation and other development on the ecology of Tauranga Harbour. There are a number of issues and basic data gaps relating to the harbour. The issue of mangrove growth and expansion around the harbour and the associated changes to the nature and character of the environment has been a very contentious topic. In the well developed harbour margins of the Tauranga urban areas, people's desires to maintain open shoreline space has caused considerable conflict with the changes that are taking place.

Many people have viewed the rapid expansion of mangroves as an un-natural and adverse biological phenomena. In part this is correct, although the mangroves are reacting in a totally natural way to changes that have taken place in the harbour environment. It is these changes that the mangroves are reacting to that have been unnatural. It is commonly accepted that one of the main causes driving the rapid expansion of mangrove throughout its northern New Zealand habitat range, is increased sedimentation from land clearance and development. Other factors such as nutrient inputs and global warming may also play a part.

In this study, the selection of areas for mapping was based partly on gaining a cross section of various harbour zones, aerial photograph availability and areas where it was already known that mangrove were expanding rapidly and causing conflicts.

1.3 Mangrove Biology

Mangroves or mangals as they are sometimes called, are literally trees in the tide. In New Zealand there is only one species of mangrove tree with the scientific name of *Avicennia marina var. australasica*. The mangrove is limited to northern areas of New Zealand as it is intolerant of hard frost. It grows best in the more northern zones where it commonly reaches a height of 7-9 m and forms mangrove forests. In its more southern range such as Ohiwa and Tauranga Harbours, it tends to form shrub lands with plants rarely exceeding 2 m in height. Ohiwa Harbour on the east coast and Kawhia Harbour on the west coast generally represent the southern limit of mangroves.

Its habitat is within the upper half of the intertidal zone with most plants establishing nearer the high tide mark in calm waters of harbours and estuaries. The trees grow from seed propagules, which generally establish on substrates with high silt and clay content, (i.e. muds) although they will grow in sandy areas. Muddy substrates have the high nutrient levels needed for prolific growth but are soft and devoid of oxygen (anoxic), so mangroves have adapted their root systems to deal with these problems. Root systems are very extensive forming a raft upon which trees can support themselves. Mangroves also have breathing roots called pneumatophores that allow air to be carried directly into the living root system.

Mangroves can tolerate being completely submerged in seawater, but need to be uncovered for at least half of each tidal cycle. Immersion in seawater requires a number of adaptations with some of the more important ones focusing on stopping water loss. Leaves have a thick waxy cuticle that makes them waterproof and the breathing pores (stomata) are confined to the lower leaf surface and are highly specialised. Mangroves also secrete any salt taken up by the roots through special glands on the upper surfaces of leaves.

Productivity of mangroves can be very high with between 6-8 tonnes of organic matter produced per year. Annual litter drop alone is commonly between 5 and 6 tonnes per hectare. However, these rates vary markedly depending on tree size and latitude (Saenger & Snedaker, 1993).

1.4 Increased Mangrove Distribution

Increases in mangrove distribution have been previously noted and documented by Environment Bay of Plenty. Within Tauranga Harbour, areas that have shown pronounced changes are generally confined to sheltered sub-estuaries and bays of the harbour. These estuaries and bays are located mainly on the western side of the harbour and tend to have significant catchments and land runoff.

There are two main mechanisms that likely account for the spread of mangroves and both of these are directly driven by increased sedimentation rates. Sedimentation directly raises the level of the intertidal seabed and with low slope ratios for many of the shores in the order of 1 : 300 – 500, even small vertical changes result in a large horizontal shift. A sedimentation rate of 2 mm per year on a wide shore profile could result in mangroves being able to colonise an additional 1 m per year. For a fifty-year period, this would mean an advance of 50 m.

Increased sedimentation also may change substrate characteristics from predominantly clean sands to muddy substrate. Nutrients levels are generally higher in muddy sediments and hence more available for plant growth. This type of change improves the habitat for mangrove settlement and colonisation of these areas can be very rapid. In the past, it has appeared that mangroves growing in sandy areas of Tauranga show a much lower rate of increase and spread over time.

There have also been suggestions that other factors such as global warming may be increasing mangroves growth rates and hence their distribution. Increases in growth and productivity would likely result in higher propagule production and capacity to colonise new habitat.

Increased sedimentation rates around the harbour are the direct result of historic clearance of native catchment vegetation including wetland around the harbour margin and the ongoing development of catchments.

1.5 Perspectives and Values of Mangroves

Mangroves are called manawa by Maori and in the north of New Zealand have long been regarded as a taonga (prized possession). This is in stark contrast to the attitude of many others in the past that have seen them as relatively valueless and even at local body level used for rubbish tips and places to put roads. These attitudes are however changing, as people are becoming more aware of the ecological and economic benefits of mangroves. In some instances the ecological values of mangroves may have been over stated.

In northern New Zealand, mangroves can provide the following in either economic or cultural terms:

- Additional shellfish resources.
- Firewood.

- Lichens for dyeing flax and wool.
- Honey.
- Increased fisheries productivity in adjacent ecosystems.
- Erosion protection.
- Water quality improvement.

In ecological terms they are valuable as they:

- Enhance species diversity.
- Increase ecological productivity.
- Increase habitat complexity.
- Extend and provide habitat for a number of rare bird species.
- Water quality enhancements may improve adjacent ecosystem health.
- Important colonising species in a sequence leading to wetlands.

Many of the ecological interactions of mangroves with the estuarine ecosystems, particularly in terms of productivity and biodiversity remain uncertain with more study needed. It must also be noted that the smaller mangroves of Tauranga and Ohiwa will tend to interact with the ecosystem in slightly different ways to studies on the larger trees of the north.

Mangroves do create problems but often this is dependent on perspective and conflicting desired use of an area. In most instances, issues revolve about the loss of open area in relation to boating and swimming access. The change in vista from open shore to mangroves is also viewed negatively by many people. Impacts on these types of values are usually greatest for those people with water front properties that have direct access on to the shore.

Chapter 2: Location and Methods

2.1 Location

2.1.1 General Background

Tauranga Harbour is located on New Zealand's northeast coast in the northern Bay of Plenty. It is a large estuarine inlet with two entrances and covers a total area of 201 km^2. The harbour catchment covers an area of approximately 1,300 km^2 and is well developed with extensive horticultural and agricultural use. At the southern end of the harbour, the city of Tauranga and surrounding area supports a large residential population (around 100,000). Near the southern entrance, the Mount Maunganui – Sulphur Point region of the harbour has been progressively developed for port facilities.

In geological terms, the harbour is a moderately tidal estuarine lagoon impounded by a barrier island (Matakana Island) and two barrier tombolos, Mount Maunganui at the southern entrance and Bowentown to the north (Healy and Kirk 1981). The harbour is predominantly shallow with 66% of its total area being intertidal.

There are three main harbour basins with the largest north and south basins separated by intertidal flats in the central region. The other basin is much smaller but still includes several sub-estuaries and large bays. There are many small sub-estuaries around the harbour. At mean high water, the northern basin has a volume of approximately 177,702,000 m^3 and the southern basin a volume of 277,518,000 m^3.

The northern harbour catchment is the smallest with a total area of 270 km^2 and a mean freshwater inflow of 4.1 cms^{-1}. The southern catchment has a total area of 1,030 km^2 and a mean freshwater inflow of 30.5 m^3s^{-1}. The Wairoa River catchment at 460 km^2 and mean freshwater inflow of 17.6 m^3s^{-1} is the largest feeding into Tauranga Harbour. In the northern harbour the freshwater inflow represents only 0.1% of the harbour volume per tidal cycle while the southern input represents 0.48%.

2.1.2 Sub-Estuaries

To provide more detail of the smaller sub-estuaries around Tauranga Harbour, a GIS based assessment was made of the approximate catchment area for each and the relative proportion of that catchment in scrub/forest or agriculture. The results of this assessment are shown in Table 1 below.

Figure 1 *Tauranga Harbour and the sites at which mangrove mapping was conducted as part of this study. Visible red areas are the 2003 mangrove distribution.*

Table 1 Approximate estuary size, estuary catchment area and major land use of the sub-estuaries and large embayments of Tauranga Harbour.

Location	Area (km^2)	Catchment (km^2)	Scrub/forest %	Agriculture %
Apata Estuary	1.1	21	5	94
Wainui Estuary	3.8	36	58	41
Rereatukahia Estuary	3.8	29	54	45
Te Puna Estuary	1.6	27	16	83
Katikati Estuary	2.5	48	58	41
Aongatete Estuary	4.2	78	62	38
Matahui Estuary	5.0	26	49	50
Welcome Bay	1.5	20	1	84
Mangawhai Estuary	1.4	7	1	99
Waimapu Estuary	2.5	113	35	62
Waikaraka Estuary	0.7	10	13	86
Waikareao Estuary	2.0	79	40	54
Tuapiro Estuary	1.9	60	65	34
Hunters Creek	4.6	8	51	49
Waiau Estuary	1.0	29	49	51
Wairoa Estuary	5.4	460	68	31
Waipu Bay	1.8	4.7	1	50
Rangataua Bay	6.3	50	40	59
Bluegum Bay	2.5	11	45	55

Table 1 lists all the estuaries in Tauranga Harbour. Aongatete, Matahui, Waikareao, Waiau Estuary and Rangataua Bay were not covered by the mapping or used in any of the assessments presented in this report. The size, catchment area and land cover of the estuaries varies greatly. Wairoa and Waimapu Estuaries have large catchments relative to estuary size. Mangawhai Estuary and Waipu Bay are some of the smaller systems that also have small catchment areas with little scrub or forest remaining. The sites included in this study are shown on Figure 1.

2.2 Methods

2.2.1 Manual Digitising of Mangroves

To conduct the mapping of mangroves around Tauranga Harbour a number of sites were selected as examples for both the time series and current spatial extent. The time series sites were chosen primarily on the basis of available aerial photography and also to provide a range of geographic coverage over the harbour in terms of habitat type. The more extensive list of sites covered in the 2003 year was also aimed at providing a range of habitat variation which could be linked back to known environmental factors.

Selected aerial photos were scanned with the intent of producing images with a pixel resolution of about 0.5 m. Some photography was either flown at a higher

scale or the quality was not sufficient to produce workable images at that resolution. In these cases the pixel resolution is higher as shown in Table 2 below.

Table 2 Original scale of aerial photography and scanned pixel resolution of images used for mapping mangroves in Tauranga Harbour.

Year	Photo Scale	Pixel Resolution (m)
2003	1:15,000	0.4
1999	1:15,000	0.5
1996	1:15,000	1.0
1993	1:25,000	1.2
1986	1:25,000	0.6
1975	1:10,000	0.6
1969	1:20,000	0.6
1964	1:20,000	1.0
1959	1:17,000	0.6
1943	1:17,000	0.6

Scanned photographs used for mapping were registered in MapInfo using a combination of property boundaries and by referencing to the existing regional digital aerial mosaic. The positional accuracy of the mapping is $\pm$5 m for 95% of the work. Most of the digital onscreen mapping was done at around a scale of 1:1,000 and overall can be treated as a 1:5,000 scale product.

2.2.2 Ecosat Remote Sensing Mangrove Mapping

Landcare Research as part of the ECOSAT project have automatically mapped marine, estuarine and lacustrine wetlands in the Bay of Plenty from Landsat ETM+ satellite imagery using sets of spectral rules. The images were acquired on 29 September 1999 and have six spectral bands with 30 m pixel resolution, one thermal band with 60 m pixel resolution, and one panchromatic band with 15 m pixels. The six spectral bands were combined with the panchromatic layer to produce 15 m multi-spectral pixels (Ausseil 2003). This process (pan-sharpening) enabled the data to be used at 1:50,000 scale. Classification of mangroves was automatic, based on a hierarchical set of binary spilt rules using variation of reflectance properties.

As part of the comparison process, areas of mangrove classified from the ETM+ processed data were trimmed using the shoreline. This corrected an identifiable error of having mangroves present above mean high water spring.

2.2.3 Estimation of Mangrove Seaward Range

The seaward extent to which mangroves are able to establish within estuaries of Tauranga Harbour were derived from a detailed digital elevation survey. The survey covered the harbour south of Omokoroa Peninsula. The elevation data was obtained using a photogrammetric technique. The resultant points grid had

spacings of 3.0 m with a vertical accuracy within ±0.15 m for a minimum of 95% of the data points.

Using this elevation grid it was possible to measure the tidal height of the most seaward established mangroves throughout the estuaries of southern Tauranga Harbour.

2.2.4 Invasion of Saltmarsh by Mangroves

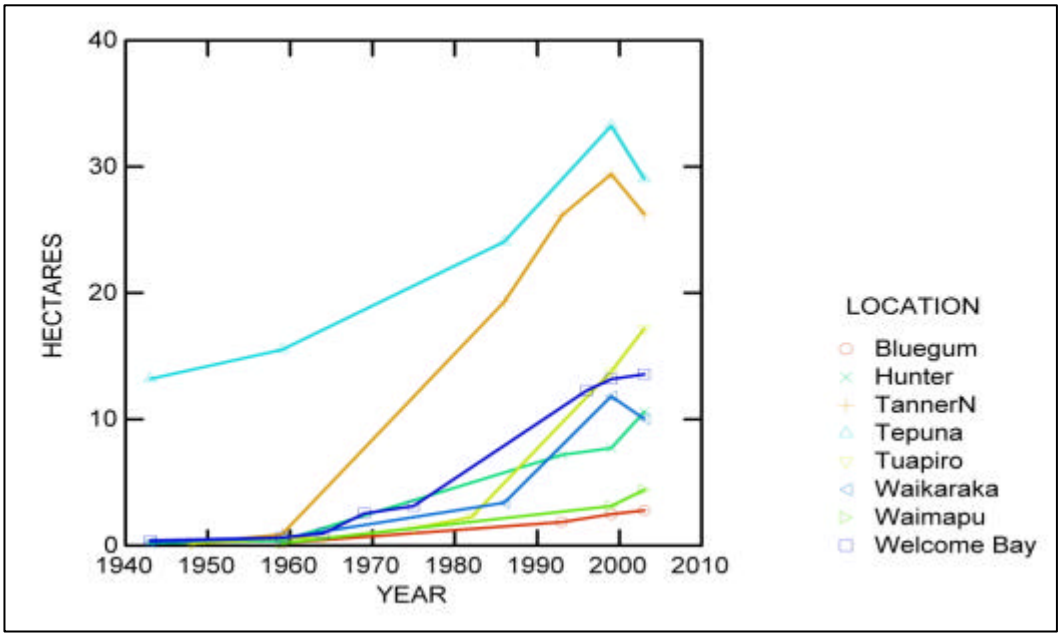
To provide an indication of whether the Saltmarsh plant communities of Tauranga Harbour are being invaded and replaced by mangroves the distribution of historic Saltmarsh vegetation was compared to the current extent of mangroves. Any overlap and features relating to the incursion were noted. In a few examples, the margin of Saltmarsh in 1959 was mapped so that the extent of overlap/incursion of mangroves in 2003 could be shown graphically in this report.

Chapter 3: Results

3.1 Changes in Mangrove Extent Over Time

The results setting out the mapped extent of mangroves within each density class and year are presented in full in Appendix II. A graphic summary of the data is provided in Figure 2 below.

Figure 2 *Mangrove canopy cover (ha) over time within a number of estuaries in Tauranga Harbour.*



All the areas mapped tend to generally display an exponential increase from 1943 up to 2003. One of the most rapidly changing areas was just north of Tanners Point along the open harbour margin. In 1943 there were only 0.2 ha of mangrove canopy cover which then increased to 26 ha in 2003. Nearby Tuapiro Estuary also shows a very high rate of increase between 1980 and 2003.

Blue Gum Bay shows one of the lowest rates of mangrove increase amongst all the sites studied. In 1959 there were only 0.2 ha of mangrove canopy cover and this had only increased to 2.8 ha in 2003. Waimapu Estuary shows the next lowest rate of increase although indications are that this rate may be starting to pick up.

A number of the sites showed a slight reduction over the last period mapped. In Welcome Bay and Waikaraka Estuary it is the result of mangrove control work by locals to try and stop the on-going spread. At the site north of Tanners point there appears to have been a small amount of natural cut-back of the mangrove stands. At all the sites, particularly Te Puna some of the apparent reduction in canopy cover may be an artefact of slight differences in the accuracy of the mapping itself. However the overall trends shown are very robust.

3.2 Remote Sensing/Manual Digital Mapping Comparison

The results of comparing manually digitised mangrove distribution and that obtained from remote sensing as part of the ECOSAT project conducted by Landcare Research are shown in Table 3.

Table 3 Area of mangroves (ha) manually mapped from 2003 aerial photography and figures derived by Landcare Research from the Landsat ETM+ remote sensing imagery from 1999 for Tauranga Harbour within defined estuaries or bays.

Location	Manually Mapped		Landsat Remote Sensing	
	Total	Canopy	Corrected	Total
Welcome Bay	18.1	13.6	14.6	16.9
Tuapiro	30.6	17.2	10.4	12.8
Te Puna	39.1	29.0	23.7	31.2
Waikaraka	13.4	10.0	10.2	15.7
Tanners Pt Nth	35.6	26.2	26.6	30.9
Hunters Creek	17.3	10.6	0.0	0.0
Blue gum Bay	6.8	2.8	0.0	0.0
Waimapu	7.3	4.4	0.0	0.0
Mangawhai	3.8	2.9	0.0	0.0
Rereatukahia	11.4	8.2	5.3	8.4
Katikati	50.1	36.9	44.3	47.4
Wainui	129.4	85.0	83.5	93.9
Apata	55.9	42.0	45.9	53.4
Wairoa	12.4	8.9	0.0	0.0
Waipu	3.2	2.4	0.0	0.0

The average percentage difference in the area of mangroves derived from manual digital mapping and remote sensing data over all sites is -12% for the shoreline corrected data. Comparing only areas where mangroves were extensive, the difference ranged from -35% to 20%. For the uncorrected data the average percentage difference over all sites is 3% but this however includes incorrect classification of terrestrial vegetation with similar spectral signals.

In comparing a number of different areas it is apparent that mangrove stands with a cover of less than 50-70% are very likely to have been missed in the classification of the Landsat data. There are some extensive areas of Tauranga Harbour that have a low percentage canopy cover. These areas have not been captured by this method. Also because of the large differences in resolution (1:50,000/1:5,000 scale and 15m pixels versus 0.4), there are numerous smaller areas of mangroves that were not picked up by the ECOSAT data classification as might be expected.

The area of mangroves for the whole of Tauranga Harbour for the uncorrected ECOSAT data was 562 ha. Applying the average difference with manual mapping suggests that a figure of around 545 canopy hectare of mangroves were present in the harbour in 1999. The 1991 survey results (Park, 2000) produced a figure of around 520 canopy ha.

3.3 Factors Influencing Mangrove Distribution

In Table 4 below are all the areas that were manually digitised from aerial photographs to derive the canopy cover present in 2003. The canopy cover has been expressed as a percentage of the total estuary area. The % mud content is the average across the whole of each estuary based on estimates obtained from extensive sediment surveys previously reported in Park (2003).

Table 4 *The area of selected estuaries from Tauranga Harbour, the average mud content of sediments in those estuaries and the canopy cover of mangroves as a percentage of the estuary area.*

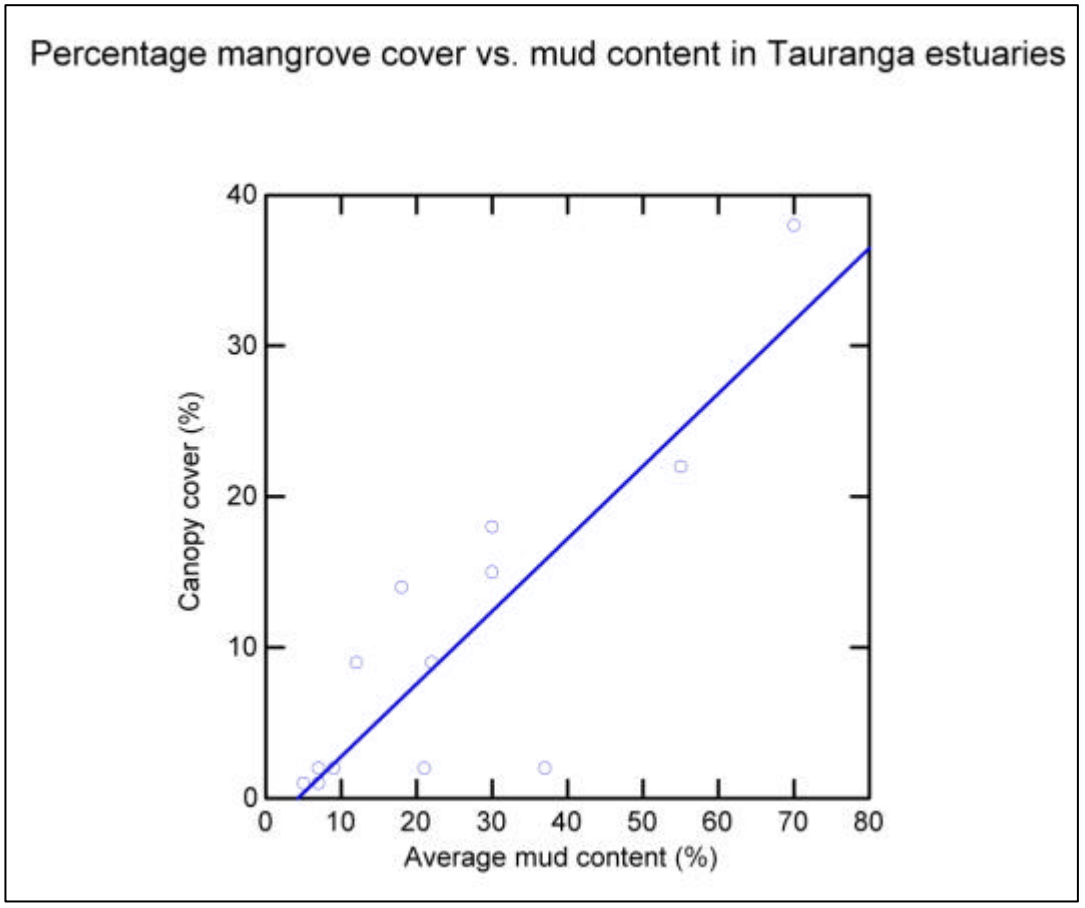
Location	Area (km^2)	% Mud Content	Canopy Cover%
Apata Estuary	1.1	70	38
Wainui Estuary	3.8	55	22
Rereatukahia Estuary	3.8	37	2
Te Puna Estuary	1.6	30	18
Katikati Estuary	2.5	30	15
Welcome Bay	1.5	22	9
Mangawhai Estuary	1.4	21	2
Waimapu Estuary	2.5	21	2
Waikaraka Estuary	0.7	18	14
Tuapiro Estuary	1.9	12	9
Hunters Creek	4.6	9	2
Wairoa Estuary	5.4	7	2
Waipu Bay	1.8	7	1
Blue Gum Bay	2.5	5	1

The absolute and percentage canopy cover within each of the mapped estuaries was correlated against the average percent mud content, estuary area, catchment area, percentage of forest/scrub cover and agriculture as land cover in the

catchment. The results of correlating these factors showed a strong relationship between percentage canopy cover and the average percentage mud content of an estuary. There was also a weak but significant correlation between the absolute area of mangrove cover and average mud content.

The r^2 value of the correlation between % canopy cover and mud content was 0.716 and the probability value is 0.0001. The relationship between % mangrove canopy cover in an estuary and the average mud content is shown in Figure 3.

Figure 3 *The percentage of mangrove canopy cover in an estuary versus the average mud content of the sediment within each estuary for locations in Tauranga Harbour.*



3.4 Potential Habitat Extent (Tidal Height)

Results from determining the most seaward extent of established mangrove plants in the intertidal zone suggested that most of the undisturbed distributions tended to average a sea level value around 0.3 m while the most extreme ranges recorded were 0.0 m. These values are in terms of Moturiki datum with 0.07 m being equal to mean sea level chart datum (1.1 m). Sea level values for the port of Tauranga are MHWS 1.9m, MHWN 1.7m, MSL 1.1m, MLWN 0.5m and MLWS 0.3m.

Two examples of these contour lines as a tool to define the habitat limit of mangroves are provided in Figures 4 and 5. The blue contour lines around the estuaries are the estimates of 0.0 m tidal height Moturiki while the yellow is 0.3 m.

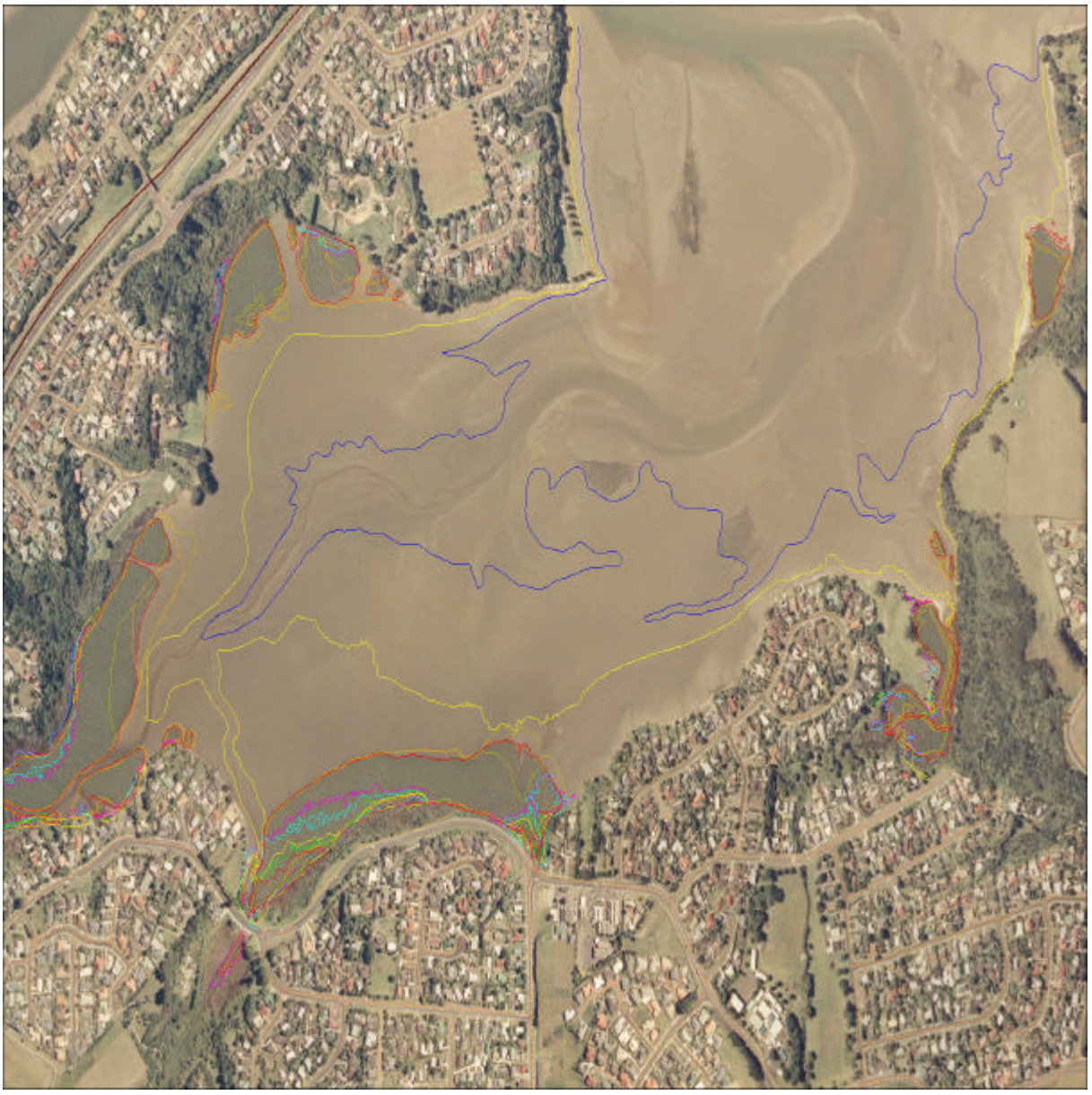
In Figure 4 of Waikaraka Estuary at Te Puna, the mangroves distribution in 2003 is highlighted with the red line work to define the boundaries. In the upper estuary the seaward extent of mangroves is close to the 0.3 m contour while in the more exposed lower estuary the mangroves are still back from this.

Figure 4 *Sea level contour lines (0.3m – yellow and 0.0m - blue Moturiki datum) in Waikaraka Estuary, Tauranga Harbour.*

In Figure 5 the same tidal height contour lines of 0.3 and 0.0 m are shown for Welcome Bay. The extent of mangroves in 2003 is once again shown by the red line work which in some areas is reduced from earlier extent. Most areas come close to but do not extend beyond the 0.3 m contour although without the extensive mangrove removal that has occurred in the bay it may be different. One of the few areas were mangroves are present beyond the 0.3 m contour line is near the

entrance to Tye (Park) Estuary on the east side of the bay. Here it is sheltered and the sediments are quite muddy.

Figure 5 *Sea level contour lines (0.3m – yellow and 0.0m - blue Moturiki datum) in Welcome Bay, Tauranga Harbour.*

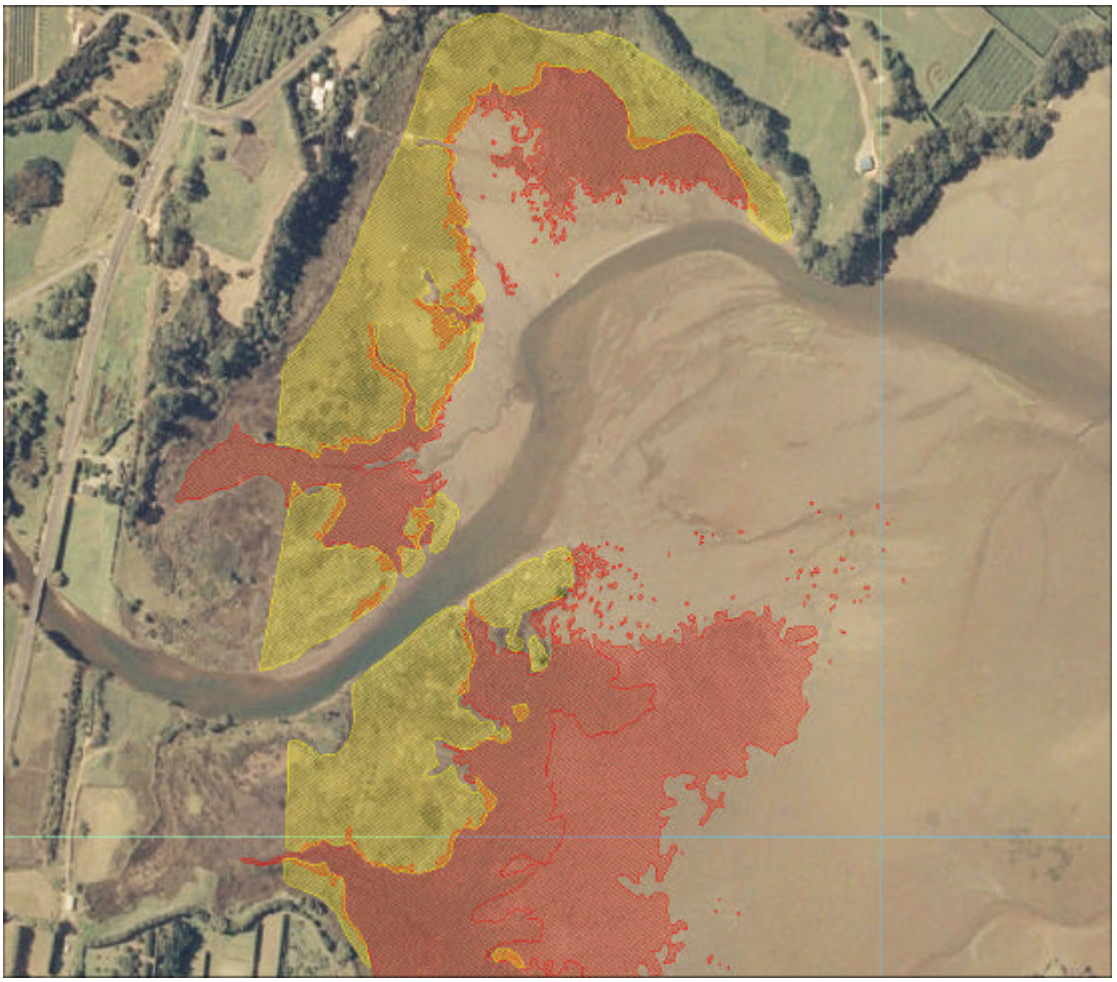


3.5 Mangrove Colonisation of Saltmarsh

A number of areas around Tauranga Harbour were looked at to see if extensive colonisation of Saltmarsh vegetation by mangroves was apparent. The scales of the mapping completed in this report (minimum 1:5,000) meant that it is only possible to make an assessment where the plants are either reasonably large or produce large patches at least several metres square.

Figure 6 shows (top) the south–eastern and (bottom) western Saltmarsh areas of Tuapiro Estuary.

Figure 6 *Saltmarsh distribution in 1959 (yellow) and mangroves 2003 (red) in Tuapiro Estuary.*



The areas where the mangroves have overlapped the 1959 saltmarsh vegetation appear orange in colour. These two examples from Tuapiro Estuary and Rereatukahia Estuary in Figure 7 below are fairly typical for most of Tauranga Harbour.

Figure 7 *Saltmarsh distribution in 1959 (yellow) and mangrove distribution in 2003 (red) in Rereatukahia Estuary.*

Overall the amount of overlap or colonisation of Saltmarsh vegetation (generally rushes) by mangroves is usually slight and often only 5-10 m at the most. There are many areas where intrusion is minimal and even some areas where Saltmarsh has extended further out since 1959 as in the south-eastern area of Tuapiro Estuary.

It is also obvious from the photos and mapping that mangroves tend to colonise the Saltmarsh where there is open access. This may be either man-made drainage, or natural channels feeding into the Saltmarsh. In a similar manner the areas of

Saltmarsh that are patchy also allow significant incursion of mangroves to occur. On the over hand, many of the Saltmarsh areas to show very little incursion have very dense stands of rushes.

Chapter 4: Discussion

Mangrove Spread

Overall the results of this study lends further support to the hypothesis that sedimentation of estuaries is one of the processes accelerating mangrove spread (Nicholls & Ellis 2002). Tauranga Harbour due to it large size with a variety of habitat and degree of sedimentation provides an excellent opportunity to conduct such a comparative investigation. The results however do not mean that a range of other factors may not also be important in determining rates of colonisation and overall abundance.

For example two of the areas with the highest rates of increase, Tuapiro Estuary and north of Tanner's Point are geographically very close. Factors such as the supply of propagules for colonisation may be higher in this area due to interactions with tides winds, local climate etc. Blue Gum Bay had the lowest rate of mangrove increase and % canopy cover which may be partly due to the low mud content of the sediments, but the next lowest rate and % canopy cover was recorded in Waimapu Estuary which has considerably muddier sediments. Two other estuaries that stood out from the observed trends were Mangawhai and Rereatukahia Estuaries which also had reasonably muddy sediments but relatively low % canopy cover of mangroves.

Tidal Height Limitations

One of the factors which potentially limits the seaward spread of mangroves is availability of habitat. This is commonly defined as mean sea level based on Australian studies (Bird 1971) but has not been measured in New Zealand. The mean sea level boundary is defined by physiological limitations related to immersion time. In many areas current and wave damage impose further restrictions. The observations from southern Tauranga Harbour where tidal height data is available suggests that the same applies to New Zealand mangroves. In the sheltered Mangawhai Estuary for example, the data suggests that there is potential for large increases of mangroves into available habitat.

Mangrove Invasion of Saltmarsh

Mangrove colonisation of Saltmarsh has been noted in Australia (Saintilan & Williams 1999) but it does not always occur and factors responsible where it has have not been clearly identified. There is a great deal of interest in whether it is occurring in New Zealand. Observations from this study indicate that edge colonisation of Saltmarsh areas occurs often. That is mangroves tend to most commonly overlap only a short distance (5-10 m max) into the Saltmarsh areas. Where incursion of Saltmarsh areas appeared to be greater it seems to be related to the Saltmarsh being either sparse or having

depressions/channels through which the mangrove propagules could be carried by tides and establish. Drainage channels tended to open up access for mangroves to establish along these pathways, but only where substrate is low enough relative to tidal height.

There is a certain amount of tidal height separation of Saltmarsh and mangrove distribution with an overlap zone. The areas of Saltmarsh, particularly the healthy rush communities seem to be reasonably resistant to colonisation. Also as mangroves attempt to establish higher up the shore at their upper habitat limit they tend to become very stunted in growth form even in the far north. This reduces the ability of mangroves to displace rush species at higher tidal levels.

Although the mapping scale (1:5,000 min) of this desk top study provides a number of useful observations there were limitations. There is a real need for these incursion processes to be looked at in more detail on the ground as well as utilising very low scale aerial photography. In the future raising tidal levels are likely to exacerbate Saltmarsh intrusion by mangroves.

Remote Sensing Comparison

The comparison between the manual mapping and the ECOSAT is useful. The exercise showed a lot of differences that might be expected due to scale. Error due to inclusion of terrestrial vegetation could effectively be eliminated in any such future automatic classification of mangroves and the average difference of 12 % is quite good. The difference between ECOSAT and manual mapping tended to be largest in the locations with smaller patches of mangroves which is attributable to the scale differences. It does mean that in locations with large areas of dense mangrove the difference between ECOSAT and manual mapping will tend to be less than the 12 % obtained in this comparison.

The advantage of the ECOSAT classification would be particularly evident in providing a consistent national inventory of extent with identical repeatability to track future changes. Even in large harbours such as Tauranga the ease of automatic repeat assessments based on non-changing criteria would provide useful long-term trends. However when considering local changes the lower mapping scale of the manual mapping is far more informative with greater practical use as might be expected.

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Appendices

Appendix I	NIWA Report "The role of Nutrients in Contributing to Mangrove Expansion" - Executive Summary
Appendix ii	Mangrove Cover Over Time
Appendix iii	Mangrove Bibliography

Appendix I – NIWA report – "The Role of Nutrients in Contributing to Mangrove Expansion"

Executive Summary

In New Zealand, an increase in the extent and distribution of mangroves is commonly attributed to increased sedimentation following changes in land use. This study was jointly commissioned by Environment Waikato (EW) and Department of Conservation (DOC) with the aim of establishing the role of nutrients in contributing to mangrove expansion. The dataset was considerably enhanced by contributions from Environment Bay of Plenty (EBOP).

This study aimed to establish the role of nutrients in contributing to mangrove expansion in different estuaries as well as in specific areas within each of those estuaries. The approach was to determine if there were within and/or between estuary differences in sediment composition and nutrient content that could be related to structural characteristics of mangrove forests and to rates of spread in different parts of the estuaries. To help interpret cause and effect in any observed relationships, the nutrient content of leaves was used as an integrator of the nutrient status of the plant.

Case study estuaries were Whangamata (EW), Whangapoua (DOC) and Tauranga (EBOP) with the inclusion of additional information from a previous study by NIWA for the Auckland Regional Council (ARC) in the Whitford embayment.

The three main questions addressed were:

- Do environmental variables that either reflect or influence nutrient availability show statistical relationships with characteristics of mangrove growth (e.g. tree density and height) in tidal fringe mangroves?
- Are there relationships between the rate of expansion of mangroves in the study estuaries and environmental variables, specifically sediment and plant nutrient contents?
- Do nitrogen to phosphorus ratios of leaves and sediments provide evidence that the mangroves in the study estuaries are nutrient limited?

Salinity, organic matter and nutrient content of sediments, for the data set that included all sites, suggested that along with other environmental variables, nutrients may be sufficiently important as to be influencing rates of growth and therefore potentially spread. There was however, no conclusive evidence, on the basis of sediment and leaf nutrient content that nutrients were the main driving factor for increased spread of mangroves in the study

estuaries in general. This does not however, rule out nutrients having local effects, i.e. within part of a bay.

There is a growing body of evidence (including the results from this study) that the growth of some New Zealand mangroves may be nitrogen limited. Overall leaf N:P ratios are relatively low compared to plants that have been shown to be phosphorus limited elsewhere in the world and the lower N:P ratios are more indicative of nitrogen limitation. Continuing NIWA research funded by the Foundation for Research Science and Technology (FRST) is addressing some of the longer-term nutrient cycling processes occurring in the sediments of mangrove stands and the effects of adding nutrients to sediments, on mangrove growth. We expect that the results of these ongoing experiments will increase our understanding of the nutrient supply and demand of New Zealand mangroves. This in turn will provide insight into the possible effects of future increases in catchment nutrient inputs on mangrove growth and rates of spread.

The analyses to date support the understanding that there are likely to be a number of estuary-specific factors that contribute to different rates of mangrove spread in New Zealand estuaries. While nutrients may enhance those rates in some locations there is as yet no evidence that they are the main causal factor for the spread itself. However if mangroves are indeed nitrogen limited then it is worth giving consideration in catchment management to the likelihood of elevated catchment nutrient loadings enhancing growth and rates of mangrove spread in the future.

Appendix II – Mangrove Cover Over Time

Location	Year	0-5%	5-20%	20-50%	50-100	Total Area mapped	Canopy Cover (ha)
Welcome Bay	1943	0.00	0.00	0.18	0.45	0.63	0.4
Welcome Bay	1959	0.00	0.51	0.19	0.67	1.38	0.6
Welcome Bay	1964	0.00	0.82	0.23	1.03	2.08	1.0
Welcome Bay	1969	0.00	0.30	0.35	3.18	3.84	2.5
Welcome Bay	1975	0.00	0.63	0.50	3.84	4.97	3.1
Welcome Bay	1996	0.00	0.67	2.69	14.99	18.35	12.3
Welcome Bay	1999	0.00	0.00	1.87	16.71	18.57	13.2
Welcome Bay	2003	0.00	0.00	0.00	18.09	18.09	13.6
Tuapiro	1948	0.00	0.05	0.43	0.01	0.49	0.2
Tuapiro	1960	1.76	0.33	0.83	0.31	3.23	0.6
Tuapiro	1964	1.76	0.35	0.83	0.27	3.21	0.6
Tuapiro	1975	4.05	1.55	0.28	1.35	7.23	1.4
Tuapiro	1982	1.91	0.51	1.90	1.96	6.28	2.3
Tuapiro	1999	9.92	9.49	0.06	16.55	36.02	13.8
Tuapiro	2003	0.00	7.77	2.31	20.50	30.58	17.2
Tepuna	1943	0.00	1.54	1.61	16.60	19.75	13.2
Tepuna	1959	0.00	3.54	0.69	19.77	24.00	15.5
Tepuna	1986	0.00	0.72	2.34	27.85	30.91	24.1
Tepuna	1999	0.00	0.82	0.00	41.17	41.99	33.2
Tepuna	2003	0.00	0.00	0.72	38.39	39.11	29.0
Waikaraka	1943	0.00	0.00	0.76	0.00	0.76	0.3
Waikaraka	1959	0.00	0.00	1.58	0.07	1.65	0.6
Waikaraka	1986	0.00	0.00	0.20	4.43	4.63	3.4
Waikaraka	1999	0.00	0.00	0.00	15.76	15.76	11.8
Waikaraka	2003	0.00	0.00	0.05	13.37	13.42	10.0
TannerN	1943	0.00	0.00	0.03	0.25	0.28	0.2
TannerN	1959	0.00	0.00	0.09	1.16	1.25	0.9
TannerN	1986	0.00	0.00	4.80	23.48	28.28	19.3
TannerN	1993	0.00	0.86	0.50	33.47	34.83	26.1
TannerN	1999	0.00	0.00	1.76	38.38	40.14	29.4
TannerN	2003	0.00	0.00	1.25	34.39	35.64	26.2
Hunter	1943	0.00	0.00	0.00	0.26	0.26	0.2
Hunter	1959	0.00	0.00	0.00	0.52	0.52	0.4
Hunter	1993	0.00	0.00	0.81	9.20	10.01	7.2
Hunter	1999	0.00	0.00	3.21	10.12	13.33	7.7
Hunter	2003	0.00	0.15	5.76	11.41	17.32	10.6
Bluegum	1959	0.00	0.00	0.00	0.19	0.19	0.2
Bluegum	1993	0.00	0.00	0.00	1.87	1.87	1.9
Bluegum	1999	0.00	0.00	0.23	2.25	2.48	2.5
Bluegum	2003	0.00	0.00	5.69	1.07	6.76	2.8
Waimapu	1959	0.00	0.00	0.00	0.22	0.22	0.2
Waimapu	1999	0.00	0.00	0.00	4.16	4.16	3.1

Waimapu	2003	0.00	1.40	0.22	5.68	7.30	4.4

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