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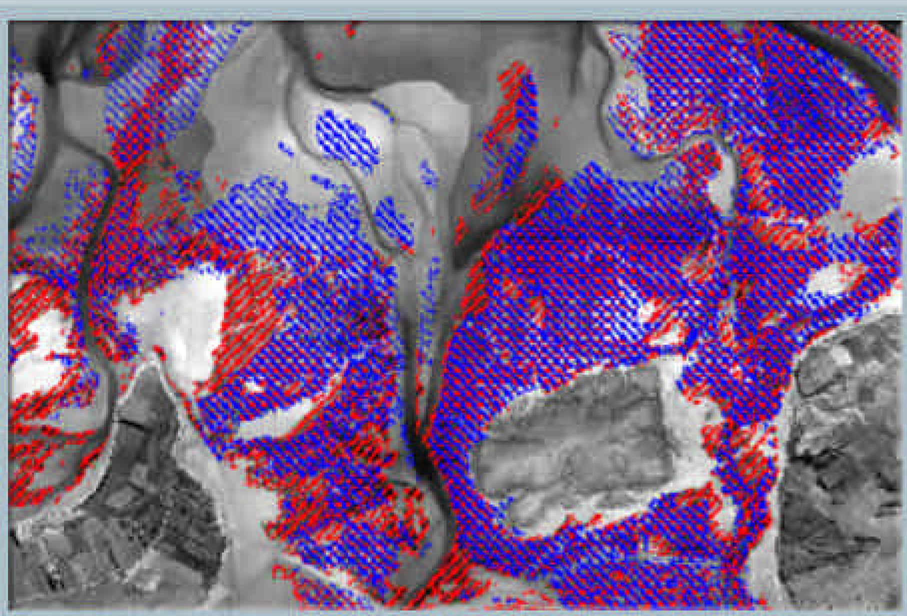
Changes in Abundance of Seagrass (*Zostera spp.*) in Tauranga Harbour from 1959-96



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Cover Photo: Seagrass distribution in central Tauranga Harbour in 1959 (red) and 1996 (blue).

Executive Summary

This report presents the results of mapping and assessing changes in abundance of seagrass throughout the whole of Tauranga Harbour between 1959 and 1996. Seagrass beds have high ecological values and contribute to the harbour ecosystem in terms of:

- stabilising the sea bed and preventing erosion,
- provide food and shelter for a range of small animals,
- increase productivity
- increased habitat complexity and hence species diversity.

Seagrass beds are particularly sensitive to human induced impacts that result in a decrease in the levels of light reaching the seabed. Overseas the main impacts are usually caused by increased suspended sediment and nutrients from land runoff and stormwater.

Overall the loss of seagrass beds between 1959 and 1996 has been assessed at 34% for the whole of Tauranga Harbour. Seagrass beds in the shallow subtidal and sub-estuary areas with larger catchments have suffered the most. Losses for the estuaries along the western fringe of the harbour average 69%. Subtidal areas have suffered the highest loss at 90% for the whole harbour. The areas near the harbour entrance with little land runoff or influence from other catchments have shown the smallest decline in seagrass abundance.

Rates of seagrass loss in the sub-estuaries analysed correlate well with the suspended sediment loading into these areas on the basis of relative area. There is also a reasonably strong but not statistically significant correlation with mud content of sediments and nutrient loads coming from the catchments. Evidence strongly points to sediment and nutrient runoff as the main factor involved in seagrass loss from the harbour. The southern harbour has relatively 3 times the catchment of the northern harbour and has experienced a far higher rate of seagrass loss confirming this impact at a larger scale.

The magnitude of loss represents a serious impact on harbour ecology and may be even worse if substantial losses have occurred before 1959. With more recent improvements to reducing land runoff of sediments and nutrients it is possible that the decline may be slowing or stopped altogether. Tuapiro Estuary is one example from the harbour's western margin that showed an increase in seagrass abundance. The assessments of abundance will provide a baseline against which future changes can be checked along with the effectiveness of land and coastal plan policies.

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Chapter 1: Introduction

1.1 Scope

This report presents the results of digitally mapping seagrass beds in northern Tauranga Harbour based on aerial photography from 1959 and 1996. The main aim of this exercise was to allow an assessment of any change in abundance over time and provide a suitable base line for any future assessments. A previous report (Park 1999) assessed and presented the changes that had occurred in the southern harbour. Completing an assessment for the entire harbour will allow a better perspective of the factors causing change over time.

It also addresses Environment B·O·P's responsibilities under the Resource Management Act (1991) in relation to the sustainable management principals set out in Part II (section 5) and directives to monitor the state of the environment as set out in Part IV (section 35; 1 and 2a, section 30; 1a). MfE have also proposed that the extent and condition of seagrass beds is monitored as one of the national environmental performance indicators for the marine environment. Changes in seagrass abundance will also provide data that can be used to monitor the effectiveness of the coastal plan and land plans, particularly in the long-term, and provide a more holistic understanding of terrestrial and other influences when reviewing these plans.

1.2 Background

1.2.1 Seagrass

Seagrasses are not true grasses but unlike most marine plants they are true flowering plants with stems, leaves, roots, and flowers. The species of seagrass in New Zealand are *Zostera spp.* and commonly referred to as eelgrass. These species commonly occur world-wide in temperate zones. Seagrass beds are found mostly in estuaries and shallow coastal waters with sandy or muddy bottoms. Seagrass plants produce pollen to fertilise flowers and produce seeds in the same manner as terrestrial plants. Plants have extensive horizontal underground stems (rhizomes) and strong roots that anchor the plants to the soft bottom. The roots absorb nutrients but do not take up water.

Erect branches and leaves grow off the buried stem. The leaves have a thin skin that allows efficient nutrient and gas uptake from the water. The continual outward growth of seagrass beds is often not due to new individual plants but horizontal stems continually growing.

Ecological Importance

Seagrass is a highly important component of intertidal and shallow subtidal (generally 1-2 m depth) zones within most New Zealand estuaries. Seagrass forms a very productive habitat which enhances overall biological productivity and diversity. The beds stabilise the sand and mud in which they grow, and provide food, shelter, breeding grounds and nursery areas for many marine organisms including commercial fish stocks.

Erosion control – seagrass stabilises the seabed with their roots, horizontal stems and leaves. This prevents the movement of sediments making a more permanent and productive habitat that other organisms can use.

Food– some fish and other organisms can feed directly on seagrass. Decaying seagrass leaves also provide a bountiful food supply for small animals, such as bacteria, worms and crabs, which in turn are eaten by fish. Seagrass produces small amounts of nutrient required by other coastal plants and animals.

Shelter – small animals and plants shelter in the seagrass leaves, receiving protection from predators, and from too much sunlight, or temporary changes in salinity and temperature. Fast water movement is also reduced in seagrass beds, creating a well-protected environment for small organisms. The beds also increase the habitat complexity providing a range of additional microhabitats. The leaves provide a stable substrate upon which epiphytic algae can grow and increase overall productivity of these ecosystems.

Nursery – as a nursery for juvenile fish and crabs, seagrass beds enhance the survival and recruitment rates into commercial fisheries which are worth hundreds of millions of dollars.

Impacts on seagrass

Natural processes, such as storms can damage seagrass beds. However, because seagrass beds are usually found in shallow coastal waters close to human habitation, they are particularly vulnerable to the impact of human activities. Often the mechanisms by which seagrass beds are damaged are complex and may involve a number of factors.

Eutrophication – increased nutrient levels from sewage outfalls and land runoff encourage the excessive growth of microscopic algae suspended in the water above the plants, or the overgrowth of epiphytic algae on the seagrass leaves. If enough algae grows, the sunlight needed for photosynthesis cannot penetrate to the seagrass, eventually causing the plants to die. Sea lettuce when abundant acts in a similar manner by accumulating on the beds and smothering them.

Clarity reduction – decreased water clarity from suspended sediments sourced from land runoff and storm water have a similar impact to that of eutrophication. Reduced light transmittance in muddier waters will reduce seagrass growth rates and the water depth to which they can grow. Sediments settling directly on to leaves of seagrass plants will also reduce growth, or cause death of the plants if settlement occurs over longer periods.

Reclamation – several areas of seagrass in Tauranga Harbour have been lost through the reclamation of the seabed.

Dredging – dredging of shipping channels, ports and canal estates can kill seagrass. Dredging not only physically removes seagrass plants, but creates muddied water that reduces the amount of sunlight penetrating to the seagrass. Therefore photosynthesis cannot take place and the plants cannot grow. Increased water depth in dredged channels may also prevent re-colonisation because of decreased light penetration and increased sedimentation.

Oil – oil spills can directly poison seagrass plants by coating the leaves.

Physical disturbance – seagrass beds are slow growing and sensitive to any physical disturbance. Motor vehicles crossing seagrass beds, boat anchors and small towed dredges are all capable of physically damaging and killing seagrass. In the northern area of Bluegum Bay, Tauranga Harbour, the area disturbed when a pipeline was put in over 20 years ago is still evident.

Introduced organisms – introduced species such as the black swan are present in large numbers on Tauranga Harbour. Swans graze the seagrass by totally removing the plants and open up patches that may be a meter across.

Chapter 2: Methods

2.1 Introduction

To assess cover of seagrass beds in Tauranga Harbour a manual onscreen digital mapping approach was used based on aerial photography. Although complete aerial photography of Tauranga Harbour is available as early as 1943 the quality is low with extensive cloud cover. The 1959 aerial photography was deemed to be the most suitable complete aerial survey that would enable mapping of the entire harbour. A manual mapping approach was used as the 1959 photography is in black and white making the use of automated classification techniques difficult to apply with out extensive editing and checking of output. This simple approach also meant that scanned aerial photography from 1996 could be saved as a grey scale format reducing overall file storage requirements. It also resulted in a more consistent result for the 1959 and 1996 maps.

2.2 Scale and resolution

1959 aerial photography was available as black and white 1:17,000 scale prints. Prints were scanned to provide a minimum resolution of 2-metre pixel size when the electronic files were viewed on screen. 1996 aerial colour photography was available as 1:15,000 scale prints. The resolution of the scanned prints was the same as the 1959 images.

2.3 Image Registration

I/RAS C software was used to register rectify and mosaic the scanned photography. This method will not achieve ortho-rectification (systematic removal of camera lens distortion in the photos). The areas being mapped were obviously flat so distortion due to varying terrain elevation was not a problem. Positional accuracy from rectification of photos depends on the degree of overlap between photos and the number of quality registration points.

Generally each photo was registered with between 12-15 known points. Most points were derived from DCDB data with some from image to image and known geographical points. It was often necessary to use the margin area of individual photos to reduce glare from the water surface. This increases distortion in the image from the camera lens. Overall however, the final product has a positional accuracy of ± 10m for 90% of the imagery.

2.4 Mapping

Areas of seagrass were digitally mapped onscreen using Mapinfo version 4.5 and stored as individual data layers for each of the 1959, 1996 surveys. Individual seagrass beds were mapped as polygons with an accuracy of around $\pm$ 5m for defining the margins of these areas. Most small isolated seagrass beds down to a size of around 5m diameter were captured.

Because many areas of seagrass are very patchy a ranked system of coverage was used. This allowed faster mapping by enclosing these areas as single polygons and assigning them to one of the density rankings. Three density rankings were used as follows;

100%: polygons with this ranking had 90-100% coverage,

75%: polygons with 60-90% coverage,

50%: polygons with 40-60% coverage.

2.5 Statistical Analysis

Data used for statistical analysis were first tested for normality using Lilliefors test. The abundance of seagrass failed this test and could not be corrected by simple transformations. Hence Spearman rank correlation tests were used to investigate relationships between the abundance of seagrass and water quality/sediment parameters.

2.6 Seagrass Taxonomy

This investigation has not resolved the taxonomy of seagrass species present in Tauranga Harbour. Various ecological reports in the past have listed *Zostera marina*, *Z. nana*, *Z. muelleri*, *Z. tasmanica*, *Z. capricorni* and *Z. novazelandica* as species present. Most are earlier names or references for the same two species, *Z. capricorni* and *Z. novazelandica*. Material collected from various areas of the harbour in the past has shown the presence of two distinct forms that match reference specimens of *Z. capricorni* and *Z. novazelandica* held by Environment B·O·P. The larger leafed Z. capricorni appears to predominate in regions of the harbour with higher catchment inflows.

Chapter 3: Results

3.1 Changes in Seagrass Abundance

Results for the change in abundance of seagrass in southern Tauranga Harbour between 1959 and 1996 is summarised in Table 3.1 below. For the whole of the southern harbour, the area of seagrass beds has reduced from 2,391 hectares in 1959 down to 1,083 hectares in 1996. This is a reduction of 54.7% from the 1959 baseline and represents a very significant and serious loss. However, losses in the northern basin of Tauranga Harbour are much lower with an overall loss of 10%.

Table 1 Catchment area, harbour area, and the cover, change and relative abundance of seagrass in Tauranga Harbour.

	Catchment (km^2)	Har Area (km^2)	Seagrass		% Reduction	Abundance	
			1959	1996		1959	1996
Southern	1019	116	2,392	1,084	-54.7	20.6	9.3
Northern	256	85	2,046	1,849	-9.6	24.1	21.8
Western	365	19	114	35	-69.0	6.0	1.8
Total	1275	201	4,437	2,933	-33.9	22.1	14.6

One of the highest declines in seagrass is in the enclosed upper reaches of sub-estuaries along the western margin of Tauranga Harbour. For those estuaries assessed in this region the average loss was 69%. One exception to this trend is Tuapiro Estuary (see Table 3.3). Selected areas of the northern harbour have been shown in more detail in Figures 3.2 to 3.5. The density of red and blue shading used in the figures to represent areas of seagrass also corresponds to the three density rankings used (most dense shading = 100% cover). Detailed maps of seagrass distribution in the southern harbour are shown in the previous report covering this area (Park 1999).

Figure 3.1 shows the distribution of seagrass for the whole of the northern harbour in both 1959 and 1996.

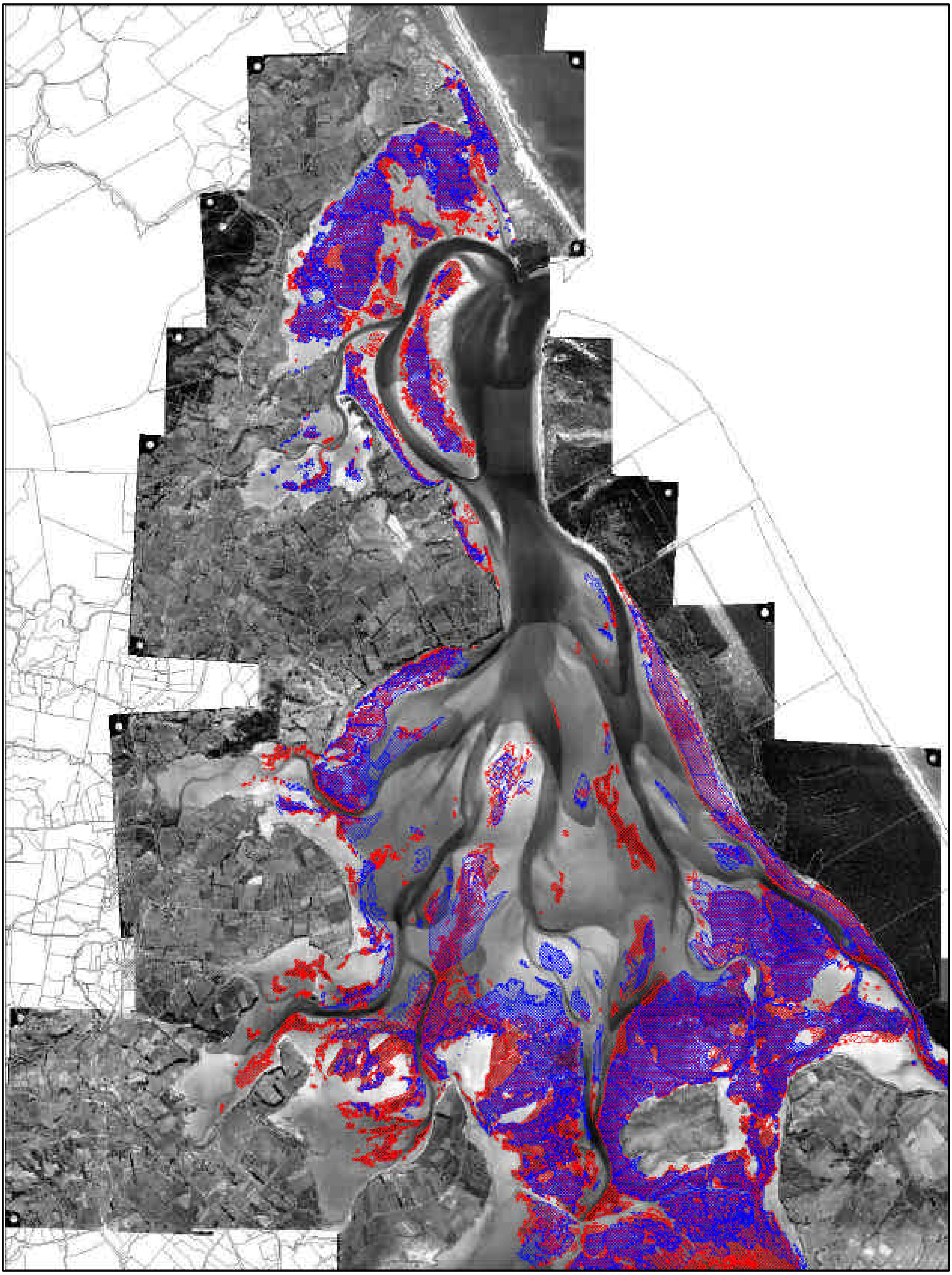

Figure 3.1 Northern Tauranga Harbour showing the presence of seagrass in 1959 (red) and 1996 (blue).

The 1959 assessment shows that seagrass used to be just as abundant in both harbour basins (Table 3.1). However, catchment area of the southern harbour is three times as great and with increasing pressures on water quality this has lead to a decline in the relative abundance of seagrass. In the northern harbour basin there is only a small decline so that the relative abundance of seagrass in 1996 is now much higher.

3.2 Factors Associated with Patterns of Seagrass Change

The sub-estuaries listed in Table 3.3 are areas of Tauranga Harbour that are relatively enclosed and sheltered. Each estuary would be highly influenced in respect of water quality parameters by the catchment area feeding into each of these areas. Table 3.3 provides catchment and water quality details along with a simple index of seagrass abundance. All water quality and catchment details were sourced from Environment B·O·P's Tauranga Harbour investigation undertaken in 1991/92 (Environment B·O·P 1994).

In addition to the water quality parameters shown in Table 3.3, the loading of each water quality parameter in terms of kg/yr per unit area of each estuary were derived. These were then used for correlation analysis to investigate the water quality relationships with seagrass abundance.

Investigation of relationships between water quality parameters and seagrass abundance in 1996 for each of the estuaries revealed only one statistically significant link. This was the negative correlation with the amount of suspended sediment load to the estuary each year relative to the unit area of the receiving environment (r = -0.869, prob. 0.005).

The sediment mud content and nutrient loadings of phosphorous and nitrogen also had reasonably strong links (r = -0.773, -0.755, -0.740 respectively) but were marginal in terms of statistical significance.

3.3 Subtidal Seagrass Abundance

Large declines in the abundance of seagrass beds in the shallow subtidal show these areas to have also been very sensitive to changes in water quality or other factors within the harbour over time.

Table 2 Cover and Change in Abundance of Subtidal Seagrass Beds.

	Seagrass (ha)		% Reduction
	1959	1996	
Southern	405	22	-94.6
Northern	74	24	-67.6
Total	479	46	-90.4

Table 3.2 shows that in 1959 the southern harbour supported substantial subtidal seagrass beds compared to the north. Following massive losses from the southern harbour of around 95% the abundance is now very similar. The high losses for the southern harbour for the period 1959-96 exceed those experienced in the western sub-estuaries grouping.

Table 3.3 Sub-estuaries in Tauranga Harbour with data on catchment, water quality, sediment silt content and the amount of seagrass present in 1959 and 1996 and the change over this period.

Estuary	Area km^2	Catchment km^2	Developed %	Mean flow l/s	Seagrass 1959 ha	Seagrass 1996 ha	Change %	Seagrass ha/km^2 1996	Silt %	SS kg/ha/yr	DRP kg/ha/yr	NOx kg/ha/yr
Tuapiro	2.32	54.09	32.4	1251	8.2	16.1	96	6.95	7	7.61	0.047	0.41
Uretara	1.95	23.75	31.4	549	11.1	6.0	-46	3.08	9	11.08	0.050	0.70
Rereatukahia	1.66	28.97	46.6	738	14.3	0.0	-100	0.00	9	11.06	0.057	0.81
Waitekohe	3.01	17.68	30.0	421	36.7	3.0	-92	1.00	-	9.48	0.026	0.63
Wainui	2.69	29.63	22.3	1318	6.5	0.0	-100	0.00	22	209.78	0.115	2.24
Mangawhai	0.70	3.06	100.0	61	11.8	4.9	-58	6.97	10	8.29	0.040	4.39
Te Puna	1.64	21.3	94.5	792	12.1	3.5	-71	2.13	10	101.68	0.105	5.33
Waikareao	2.75	74.0	59.4	2450	7.4	.74	-90	0.27	13	267.37	0.225	7.28
Waimapu	1.64	100.93	67.6	3366	0.7	0.0	-100	0.00	21	130.37	0.150	6.56
Welcome Bay	1.07	11.34	100.0	179	5.6	1.0	-82	0.93	20	23.32	0.040	1.15
Bluegum Bay*	2.31	8.3	75.0	10	23.2	23.0	-1	9.96	0	1.00	0.010	0.20
Hunters Crk.*	5.17	5.17	66.0	10	101.5	82.5	-19	15.96	2	4.00	0.010	0.20

Developed refers to % no longer in forest
* SS, DRP and NOx coefficients estimated for these estuaries

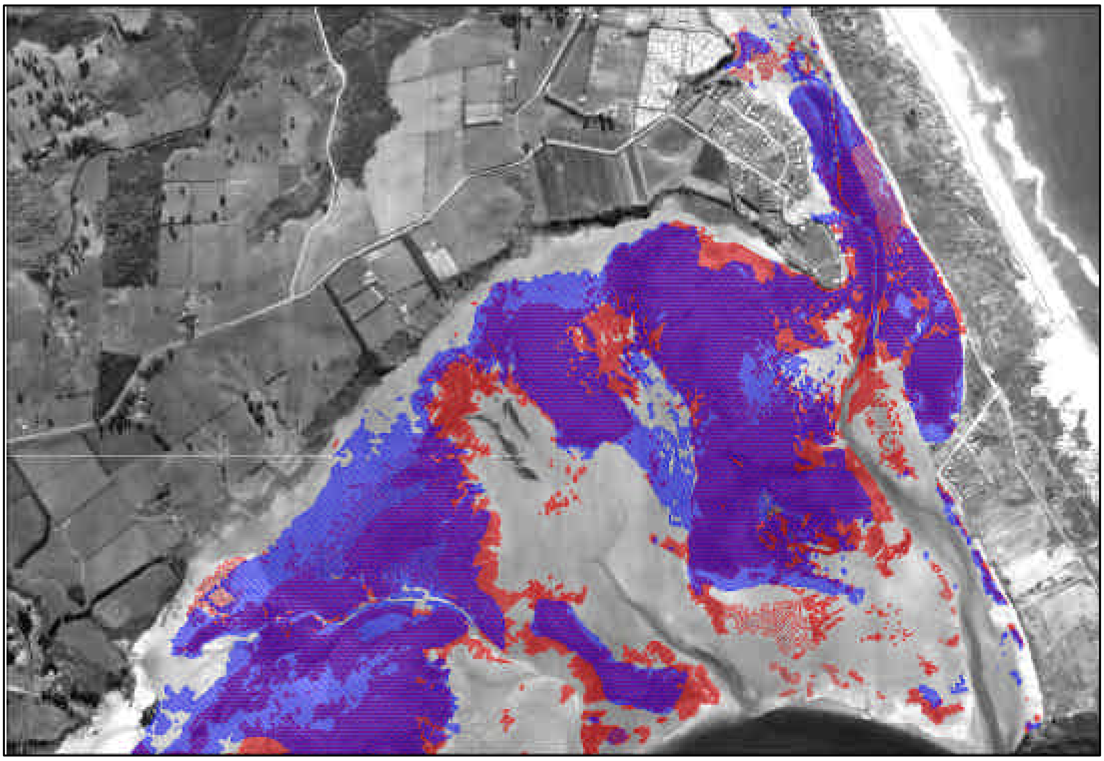

Figure 3.2 Athenree area showing the presence of seagrass in 1959 (red) and 1996 (blue).

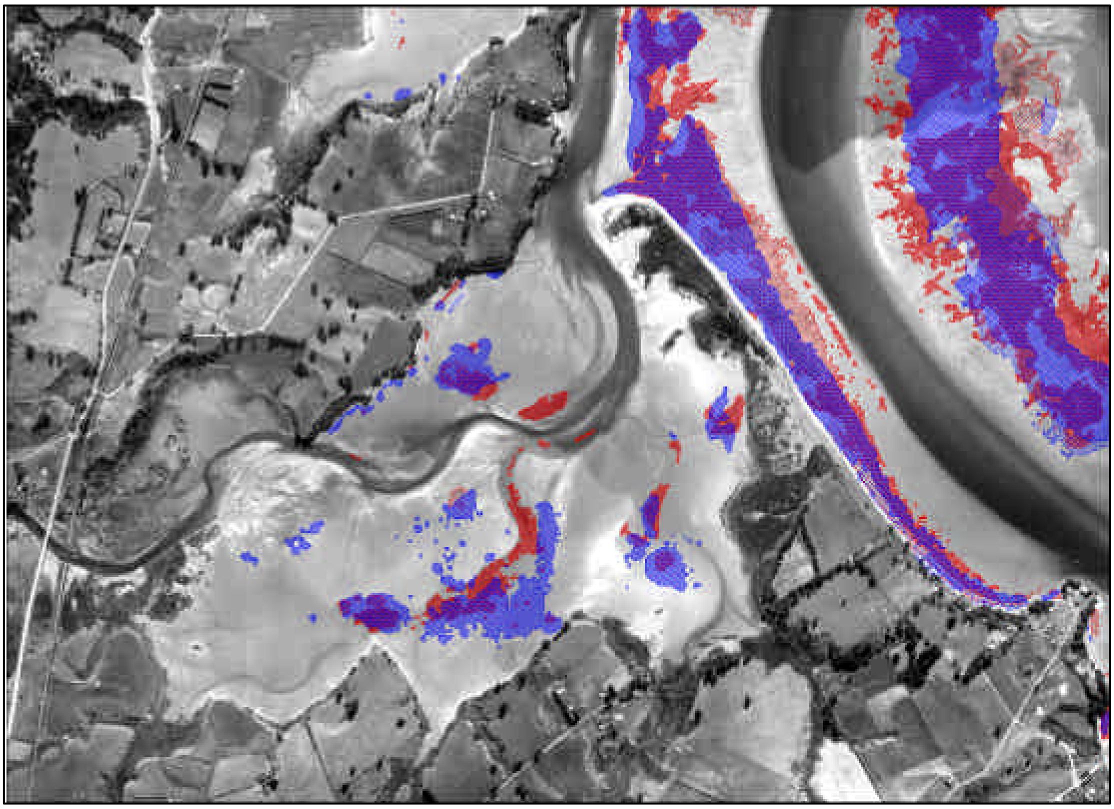

Figure 3.3 Tuapiro Estuary showing the presence of seagrass in 1959 (red) and 1996 (blue).

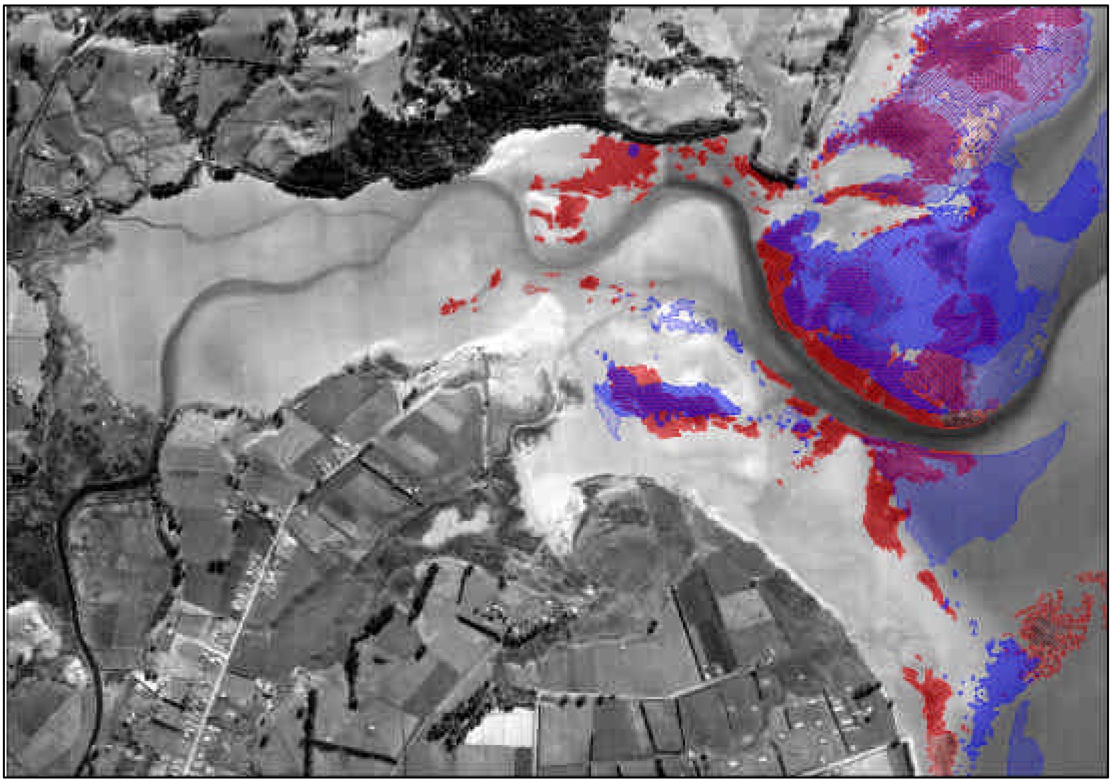

Figure 3.4 Uretara Estuary showing the presence of seagrass in 1959 (red) and 1996 (blue).

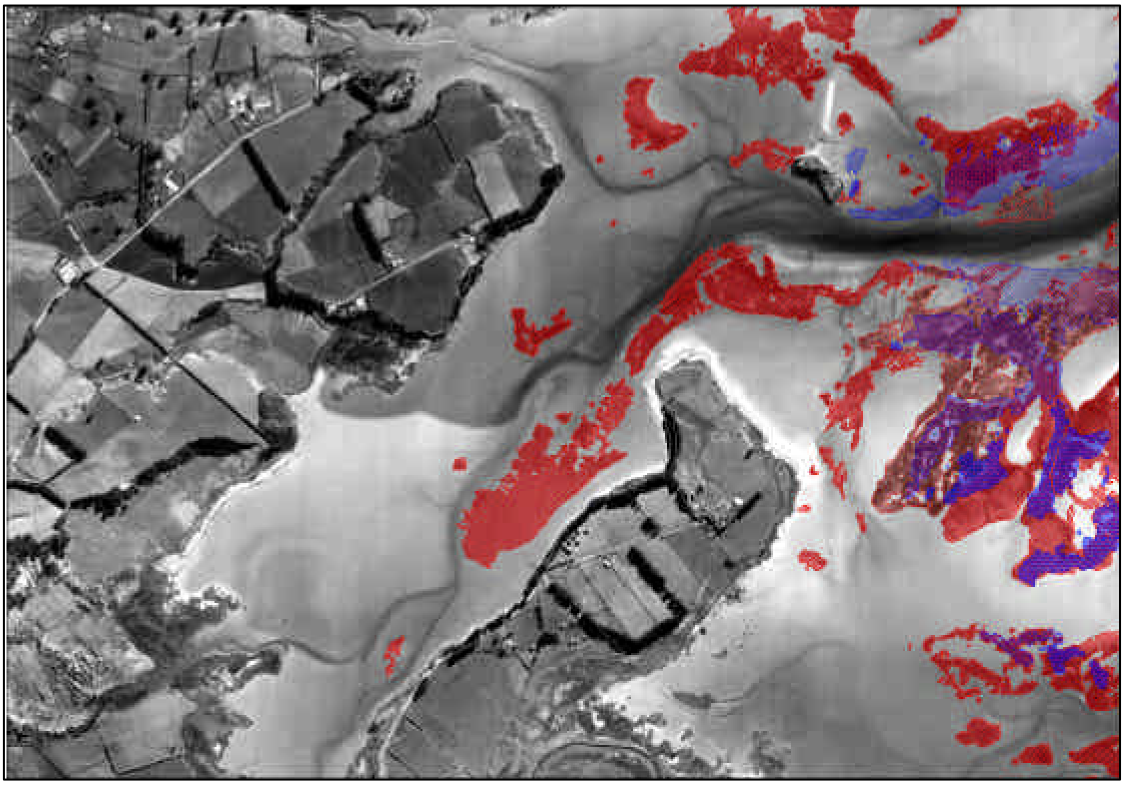

Figure 3.5 Rereatukahia Estuary showing the presence of seagrass in 1959 (red) and 1996 (blue).

Chapter 4: Discussion

Patterns and causes of change

The degree of loss assessed in this mapping exercise represents a very serious impact on the ecological values of Tauranga Harbour. This decline does however, mirror the same scenario experienced by many countries overseas including our nearest neighbour Australia. Numerous bays and estuaries on both the western and eastern side of Australia have suffered losses in the order of 50% or more (Walker & McComb 1992). Within New Zealand extensive loss of seagrass has been noted in the Auckland area and the Avon-Heathcote Estuary. In the Avon-Heathcote Estuary, seagrass declined from 1920 until it had almost disappeared in 1952 (Knox & Kilner 1973).

The primary cause of seagrass decline worldwide is related to human-induced impacts. Principally decreased light reaching seagrass for photosynthesis and growth is the major impact. The decrease may result from increased turbidity from particulates in the water, or from the deposition of silt or the growth of epiphytes on leaf surfaces or stems. Eutrophication of coastal waters can lead to reduced light penetration through the water from enhanced plankton growth as well as the direct stimulation of epiphytic algal growth.

Statistical investigation of relationships between seagrass and water quality parameters show reasonably strong links for the Tauranga Harbour data by itself. There are however, several likely reasons why the relationships do not appear as strong as they could be in this investigation. Firstly the gradients of impact from water quality within an estuary are not consistent throughout. This means that the areas defined as each estuary are somewhat arbitrary and will not be consistent between the areas in terms of defining water quality impacts. Next, the water quality data of 1990/91 may not be the same as some earlier point in the 1959-96 period that may have caused the seagrass decline. Also there will be some influence in terms of water quality between adjacent/nearby estuaries and overall the sample size is not large.

Despite the shortcomings of this desktop study, the data does point to sediment and possibly nutrient load playing a major part in changes of seagrass abundance. Analysis shows that the upper reaches of sub-estuaries along the western margin of the harbour have a huge loss at 69%. Mud content of these areas also tends to be higher and they have been shown to form a discrete geographical unit in terms of poorer sediment quality (Environment B·O·P 1994). A previous analysis of seagrass distribution in Tauranga Harbour also showed that seagrass is generally absent once the mud content of surficial sediments reaches 13% (Park 1994). Tuapiro was the only estuary along the western harbour margin that did not show a seagrass decline and if omitted from this group the loss would be calculated as 82%. Water quality data show this estuary to have one of the lowest sediment and nutrient loads.

The relationship between water quality and land runoff is also apparent at other scales and habitat groupings. Apart from the estuaries grouped along the western fringe of the harbour the relationship implicit between catchment area, water quality and percentage loss shows up strongly when comparing the southern harbour to the north. The southern harbour has proportionately three times the catchment area of the north and hence is far more sensitive to catchment and water quality changes.

In addition a number of extreme one-off siltation events such as Ruahihi Canal collapse may also have contributed to losses within the southern harbour. In the past there have also been more point nutrient sources that may have had a localised but significant influence. Tauranga sewage was discharged to the harbour until 1994. Overall the likely impact of all these factors is evident in that the least affected areas in the harbour appear to be the seagrass beds near the harbour entrance and in catchments with very negligible land runoff.

Seagrass losses between 1959-96 in the subtidal habitat were the highest of all subgroups investigated. Reduced light transmittances as one goes deeper in the water column limits the ability of plants to photosynthesise and grow. Hence plants in this habitat will be the most sensitive to any reduction in water clarity and the first to die off. The high loss appears to reflect impacts from reduced light transmittance. One confounding factor in the assessment is that reduced water clarity will also make it more difficult to identify and map subtidal seagrass beds if they are present.

Losses over time

The loss of seagrass assessed in this study is only for the period 1959 –1996. There is likely to be have been considerable loss before this time, particularly in the sub-estuaries on the western side of the harbour. It is also possible that the decline in seagrass beds may be slowing as environmental practices improve. Tuapiro Estuary could be an example where impacts from before 1959 have now been reversed. The removal of point nutrient sources to the harbour and improvement in reducing land runoff and its associated nutrients and suspended sediments has progressed markedly in recent years. The work presented in this report provides a baseline against which future changes in seagrass abundance can be assessed in Tauranga Harbour.

Overall the evidence points strongly to sedimentation and eutrophication as having a major influence on the patterns of distribution and past/present losses of seagrass in Tauranga Harbour. Monitoring changes over longer time periods such as the 1959-96 comparison has provided valuable information for resource management of this ecosystem. As a monitoring tool, particularly in terms of a national environmental performance indicator, an analysis of changes over shorter time periods would be valuable. As the dynamics of seagrass growth in New Zealand is still poorly known it is currently difficult to say what the most useful length of monitoring period would be. Areas of stressed and declining seagrass beds would obviously require more frequent monitoring than those in a healthy stable environment.

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