coastalmanagement

Waimatuku Estuary 2012

Fine Scale Monitoring and Macrophyte Mapping

Prepared for **Environment Southland**
August 2012

Cover Photo: Waimatuku Estuary, near Transect E. Inside cover: Eroding marram grass dune near the estuary mouth.

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By

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WAIMATUKU ESTUARY - EXECUTIVE SUMMARY

This report summarises the results of the third year of fine scale monitoring of Waimatuku Estuary, a 2km long, shallow, tidal river mouth estuary (20ha) that periodically experiences restricted flushing to the sea. The following table summarises fine scale monitoring results, condition ratings, overall estuary condition, and monitoring and management recommendations.

FINE SCALE MONITORING RESULTS

- Sediment Oxygen: Redox Potential Discontinuity (RPD) was moderate throughout the estuary.
- The indicator of organic enrichment in sediments (Total Organic Carbon) was at low concentrations and sediment nutrient enrichment indicators for total phosphorus were at moderate-high concentrations, and total nitrogen at moderate concentrations.
- Sediments had moderate mud concentrations (~5% mud) and 30-50% gravel in the upper/middle estuary reaches, and were dominated by sand (80%) in the downstream estuary.
- Nuisance macroalgal cover was moderate and at nuisance levels in the upper and middle estuary, while there was extensive benthic microalgae growing on lower estuary sands.
- High value seagrass (*Ruppia*) and other macrophytes were present in the upper estuary.

CONDITION RATINGS

	2010			2011			2012		
	Site D	Site E	Site G	Site D	Site E	Site G	Site D	Site E	Site G
Sediment oxygenation (RPD)	Good-V. Good	Good-V. Good	Good-V. Good	Poor	Poor-Fair	Good-V. Good	Fair	Fair	Fair
Total organic Carbon (TOC)	Good	Very Good	Very Good	Very Good	Good	Very Good	Very Good	Very Good	Very Good
Total Nitrogen (TN)	Fair	Good	Very Good	Good	Fair	Very Good	Good	Good	Good
Total Phosphorus (TP)	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair
Algae	Nuisance growths present			Nuisance growths present			Nuisance growths present		

ESTUARY CONDITION AND ISSUES

The third year of baseline monitoring (undertaken at low tide), showed sediment conditions in the middle/upper estuary were in moderate condition. In areas where salinity stratification was present, sediments had a moderate RPD, moderate mud concentrations, and excessive phosphorus. Nuisance macroalgal cover was similar to the moderate cover recorded in 2011, while intertidal and subtidal flats in the lower estuary reaches supported a thick benthic microalgal growth not evident in 2010.

These conditions reflect a period of low flows, and possibly restricted flushing following natural constriction of the estuary mouth as it has been driven east by longshore drift. The monitoring results indicate how high catchment inputs of nutrients concentrate under such conditions fuelling undesirable growths in the estuary. Effects are compounded by the absence of an extensive vegetated margin to help assimilate and filter excess nutrients and sediment.

To prevent a shift to increased nuisance macroalgal blooms and reduced sediment oxygenation, and to prevent the loss of the native seagrass community in the upper estuary, it is critical to ensure nutrient loads to the estuary do not exceed the assimilative capacity of the estuary when it is most vulnerable. It is also important to ensure the maintenance of adequate high value habitat (i.e. saltmarsh, seagrass and a natural vegetated terrestrial margin).

RECOMMENDED MONITORING AND MANAGEMENT

Continue fine scale monitoring every 5 years (next scheduled for summer 2017). Also undertake annual monitoring of several low cost eutrophication indicators (RPD, DO, algal cover, substrate type) at transects B, C, D and E.
The 2010-12 fine scale monitoring results reinforced the need to manage nutrient and fine sediment sources entering the estuary. This involves three key steps;

1. Develop appropriate catchment nutrient and sediment load guidelines,
2. Estimate existing catchment loads, and
3. Introduce management actions to ensure loads do not exceed guidelines.

In order to improve estuary function, it is also recommended that steps be taken to increase the extent of high value estuary habitat (saltmarsh and natural vegetated margin) wherever possible.

1. INTRODUCTION

OVERVIEW

Maintaining an understanding of the condition and risks to coastal and estuarine habitats is critical to Environment Southland (ES) in their resource management role for Southland. Recently, ES undertook a vulnerability assessment of its region's coastline to establish priorities for a long-term monitoring programme for the region (Robertson and Stevens 2008). The assessment identified Waimatuku Estuary as being a priority for monitoring which ES began in February 2009; the work being undertaken by Wriggle Coastal Management using the National Estuary Monitoring Protocol (EMP) (Robertson et al. 2002) plus recent extensions.

The Waimatuku Estuary monitoring consists of three components:

1. **Ecological Vulnerability Assessment** of the estuary to major issues (Table 1) and appropriate monitoring design. This component has been completed for Waimatuku Estuary and is reported on in Robertson and Stevens (2008).
2. **Broad Scale Habitat Mapping** (EMP approach). This component (Table 2), which documents the key habitats within each estuary and changes to these habitats over time, is reported on in Robertson and Stevens (2008).
3. **Fine Scale Monitoring** (Synoptic survey and EMP approach). Monitoring of selected physical and chemical characteristics (water clarity, salinity, depth, sediment oxygenation, muddiness, presence of macrophytes and nuisance macroalgae - see Table 2). This component, which provides detailed information on the condition of the Waimatuku Estuary, began with a synoptic survey in February 2009 (Robertson and Stevens 2009) with monitoring scheduled annually for three years to establish a baseline, then every five years or as determined by condition ratings.

(Photo: Environment Southland 2008)

Figure 1. Waimatuku Estuary.

The first year of baseline monitoring of the key fine scale indicators of sediment nutrients - total nitrogen (TN) and phosphorus (TP); Total Organic Carbon (TOC); and grain size, as well as physical and chemical characteristics described in (3) above was reported on in Stevens and Robertson (2010). The current report describes the third annual survey of baseline conditions undertaken in January 2012.

Disease risk indicators on the Southland coast are assessed separately in ES's recreational water quality monitoring programme, while heavy metal toxicity was considered to be at such a low risk it was not considered necessary to monitor.

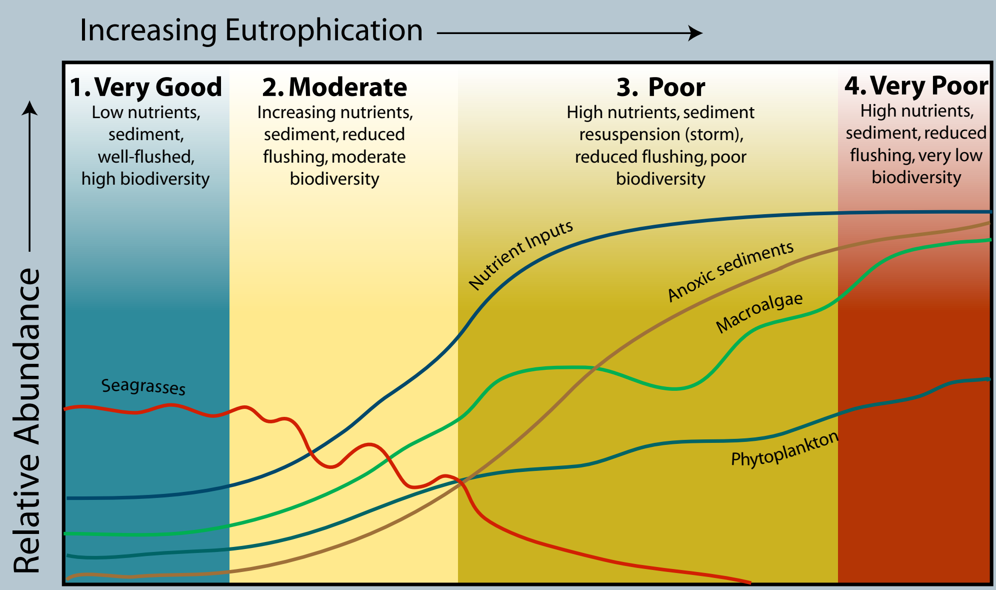
Waimatuku Estuary is a small (20ha at high tide), shallow, "tidal river mouth" estuary that drains to the sea through a sand dominated barrier beach and modified marram grass duneland (Figures 1 and 4). It has relatively small intertidal flats (typical for tidal river estuaries it is dominated by a central channel), while the estuary mouth periodically constricts, naturally reducing flushing.

The surrounding 150km^2 catchment (dominated by sheep, beef and dairy farming) contributes the highest nutrient loadings per unit area of the estuaries currently monitored in Southland (TN 2877mg.m^{-2}.day^{-1}, TP 96mg.m^{-2}.day^{-1} based on NIWA's CLUES catchment surface water model outputs). A significant groundwater nitrogen input is also reported for the catchment (Greg Larkin, ES Coastal Scientist, pers. comm. 2012). These very elevated nutrient inputs make the estuary highly susceptible to eutrophication as the assimilative capacity of the estuary is very quickly exceeded when the mouth is constricted. Currently, despite most catchment inputs flowing directly to the sea, nuisance macroalgal growths (e.g. *Ulva intestinalis*) are common, particularly in summer in the middle estuary, while algal blooms also occur at the mouth and along Oreti Beach.

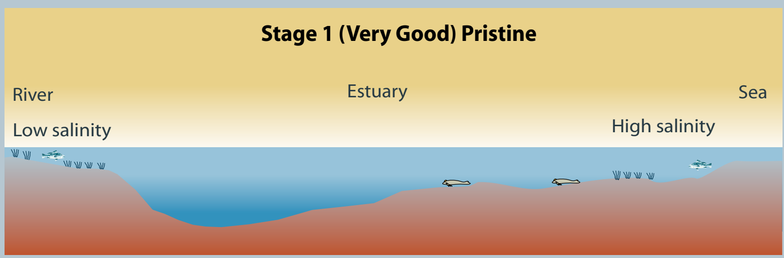
Susceptibility to eutrophication is increased by margin modification that has significantly reduced filtering and assimilation of nutrients and sediments. Only small patches of saltmarsh (<1ha - predominantly herbfield) remain in the lower estuary where it runs parallel to Oreti Beach, and most of the back dune area has been levelled, grassed, and is used for grazing. A narrow strip of tall fescue and flax separates the upper estuary from fenced pasture.

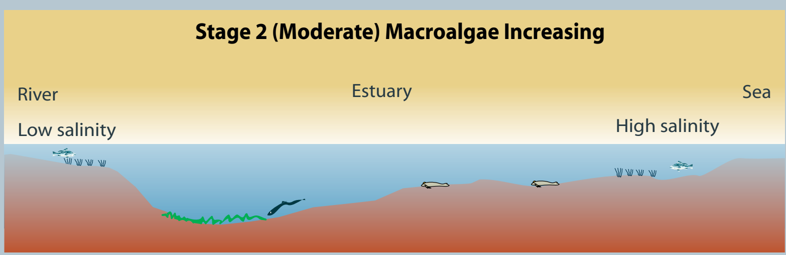
Consequently, the major threat to the estuary is increased eutrophication due to elevated nutrient inputs, exacerbated by periodic mouth constriction to the sea and consequent restricted flushing. The likely pattern of increasing eutrophication in response to increased nutrients (particularly nitrogen) is presented in Figure 2.

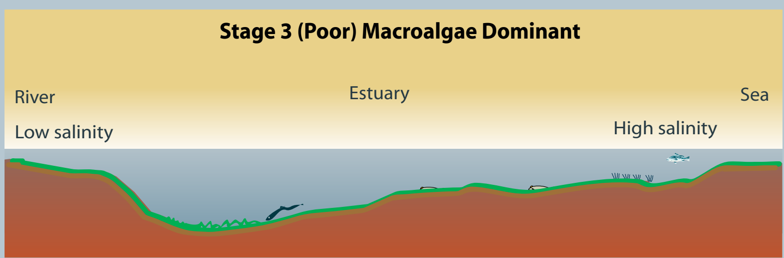
Figure 2. Small tidal river mouth estuary - Response to increasing eutrophication.

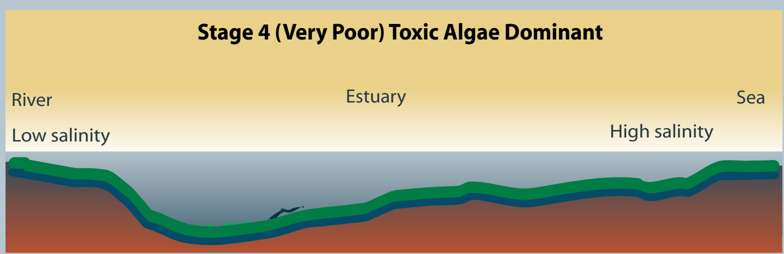


Conceptual representation of estuary response to increased nurients in tidal river mouth estuaries.









Stage 1. In their pristine state, these small, narrow estuaries are adequately flushed with river and marine tidal waters. Nutrient and sediment inputs are low and their clear, shallow, waters are dominated by submerged macrophytes where sediments are stable (e.g. seagrass and *Ruppia*) and contain adequate nutrients. Nuisance macroalgae and phyto-plankton growth is low. Sediment quality and biodiversity is high.

Stage 2. As nutrient and sediment levels increase, nuisance macroalgae (e.g. *Ulva*), and phytoplank-ton growth increases. Native macrophyte growth (e.g. seagrass and *Ruppia*), sediment oxygenation, and water clarity declines. Introduced, aggressive macrophytes can become dominant in the brack-ish upper estuary. The bed becomes muddier and a surface sulphide layer is common. If flushing is reduced due to freshwater abstraction or mouth constriction, the susceptibility to eutrophication is enhanced and biodiversity declines.

Stage 3. As nutrient inputs become elevated, native macrophytes are replaced with nuisance short-lived macroalgae and phytoplankton. Introduced macrophytes can also become dominant in upper estuary brackish areas. Water clarity is often low, muddy sediments are anoxic close to the surface and sulphide rich, and sediment macrofauna is dominated by high numbers of a few tolerant species only.

Stage 4. Nutrients in sediments and water con-tinue at high concentrations, but a lowering of the N:P ratio results in nuisance cyanobacteria and toxic bloom events. Sediment macrofauna are often absent, but nuisance macroalgae and phytoplankton are still present. Water clarity is low and sediment quality poor with anoxic and sulphide-rich muds.

1. Introduction (Continued)

Table 1. Summary of the major issues affecting most NZ estuaries.

Major Estuary Issues	
Sedimentation	Because estuaries are a sink for sediments, their natural cycle is to slowly infill with fine muds and clays. Prior to European settlement they were dominated by sandy sediments and had low sedimentation rates (<1 mm/year). In the last 150 years, with catchment clearance, wetland drainage, and land development for agriculture and settlements, New Zealand's estuaries have begun to infill rapidly. Today, average sedimentation rates in our estuaries are typically 10 times or more higher than before humans arrived.
Eutrophication (Nutrients)	Increased nutrient richness (e.g. nitrogen and phosphorus) of estuarine ecosystems stimulates the production and abundance of fast-growing algae, such as phytoplankton, and short-lived macroalgae (e.g. sea lettuce). Fortunately, because most New Zealand estuaries are well flushed, phytoplankton blooms are generally not a major problem. Of greater concern is the mass blooms of green and red macroalgae, mainly of the genera *Enteromorpha, Cladophora, Ulva,* and *Gracilaria* which are now widespread on intertidal flats and shallow subtidal areas of nutrient-enriched New Zealand estuaries. They present a significant nuisance problem, especially when loose mats accumulate on shorelines and decompose. Blooms also have major ecological impacts on water and sediment quality (e.g. reduced clarity, physical smothering, lack of oxygen), affecting or displacing the animals that live there.
Disease Risk	Runoff from farmland and human wastewater often carries a variety of disease-causing organisms or pathogens (including viruses, bacteria and protozoans) that, once discharged into the estuarine environment, can survive for some time. Every time humans come into contact with seawater that has been contaminated with human and animal faeces, we expose ourselves to these organisms and risk getting sick. Aside from serious health risks posed to humans through recreational contact and shellfish consumption, pathogen contamination can also cause economic losses due to closed commercial shellfish beds. Diseases linked to pathogens include gastroenteritis, salmonellosis, hepatitis A, and noroviruses.
Toxic Contamination	In the last 60 years, New Zealand has seen a huge range of synthetic chemicals introduced to estuaries through urban and agricultural stormwater runoff, industrial discharges and air pollution. Many of them are toxic in minute concentrations. Of particular concern are polycyclic aromatic hydrocarbons (PAHs), heavy metals, polychlorinated biphenyls (PCBs), and pesticides. These chemicals collect in sediments and bio-accumulate in fish and shellfish, causing health risks to people and marine life.
Habitat Loss	Estuaries have many different types of habitats including shellfish beds, seagrass meadows, saltmarshes (rushlands, herbfields, reedlands etc.), forested wetlands, beaches, river deltas, and rocky shores. The continued health and biodiversity of estuarine systems depends on the maintenance of high-quality habitat. Loss of habitat negatively affects fisheries, animal populations, filtering of water pollutants, and the ability of shorelines to resist storm-related erosion. Within New Zealand, habitat degradation or loss is common-place with the major causes cited as sea level rise, population pressures on margins, dredging, drainage, reclamation, pest and weed invasion, reduced flows (damming and irrigation), over-fishing, polluted runoff and wastewater discharges.

Table 2. Summary of the broad and fine scale EMP indicators (shaded cells used in the current report).

Issue	Indicator	Method
Sedimentation	Soft Mud Area	Broad scale mapping - estimates the area and change in soft mud habitat over time.
Sedimentation	Sedimentation Rate	Fine scale measurement of sediment deposition.
Sedimentation	Sedimentation Grain Size	Fine scale measurement of sediment grain size, including changes over time.
Eutrophication	Nuisance Macroalgal Cover	Broad scale mapping - estimates the change in the area of nuisance macroalgal growth (e.g. sea lettuce (*Ulva*), *Gracilaria* and *Enteromorpha*) over time.
Eutrophication	Organic and Nutrient Enrichment	Chemical analysis of total nitrogen, total phosphorus, and total organic carbon in replicate samples from the upper 2cm of sediment.
Eutrophication	Redox Profile	Measurement of depth of redox potential discontinuity profile (RPD) in sediment estimates likely presence of deoxygenated, reducing conditions.
Toxins	Contamination in Bottom Sediments	Chemical analysis of indicator metals (total recoverable cadmium, chromium, copper, nickel, lead and zinc) in replicate samples from the upper 2cm of sediment.
Toxins, Eutrophication, Sedimentation	Biodiversity of Bottom Dwelling Animals	Type and number of animals living in the upper 15cm of sediments (infauna in 0.0133m^2 replicate cores), and on the sediment surface (epifauna in 0.25m^2 replicate quadrats).
Habitat Loss	Saltmarsh Area	Broad scale mapping - estimates the area and change in saltmarsh habitat over time.
Habitat Loss	Seagrass Area	Broad scale mapping - estimates the area and change in seagrass habitat over time.
Habitat Loss	Vegetated Terrestrial Buffer	Broad scale mapping - estimates the area and change in buffer habitat over time.

2. METHODS

Percent Cover 0-5%

Percent Cover 5-10%

Percent Cover 10-20%

Percent Cover 20-50%

Percent Cover 50-80%

Percent Cover 80-100%

Figure 3. Percent cover categories for aquatic vegetation.

Ten previously established transect sampling sites, plus two new sites K and L, in Waimatuku Estuary (Figure 4 , Robertson and Stevens 2009), representing the range of different conditions present throughout the estuary, were visited by two scientists on 22 January 2012 when the lagoon was open to the sea. At each site, sampling was undertaken for key indicators of estuary condition as described below. The purpose was to collect information which, through repeat sampling, can be used as a rapid and robust method to indicate change within the estuary.

At each site, a 5-6cm deep layer of the surface sediments was collected with a garden hoe (area 15 x 15cm) and carefully brought to the surface (a canoe was used for sampling at the deeper sites). At the surface, the sample was photographed and records taken of;

- The taxa, height, percentage cover, and life stage of aquatic vegetation (Figure 3 gives examples of percentage cover estimates for macrophytes).
- The sediment type and depth to the blackened sulphide rich layer (Redox Potential Discontinuity layer - RPD).

Composite samples of the top 20mm of sediment (each approx. 250gms) were collected from 5 places across transects D, E and G. These transects, located near the middle estuary, capture the transition from the deeper more riverine upper estuary to the shallow intertidal lower estuary. Chilled sediment samples were sent to R.J. Hill Laboratories for analysis of:

* Grain size/Particle size distribution (% mud, sand, gravel).
* Nutrients - total nitrogen (TN), total phosphorus (TP), and
* Total Organic Carbon (TOC).

Analytical details are provided in Appendix 1.

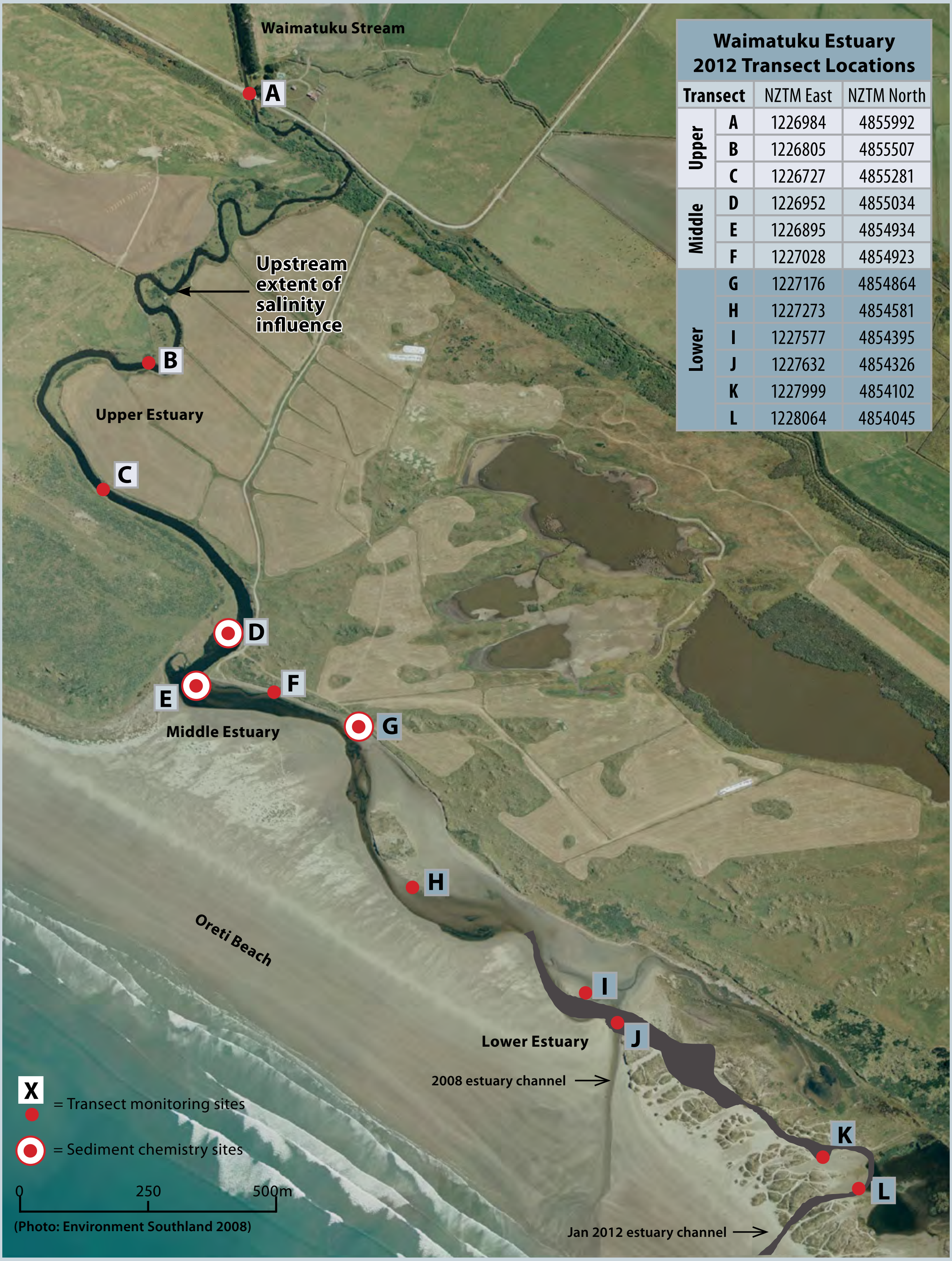
In addition, the water column at each site was sampled for:

- Secchi disc clarity
- Depth
- Dissolved oxygen
- Temperature
- Salinity (at surface and bottom)

A visual examination of the whole estuary was also undertaken to assess the extent of aquatic vegetation occurring outside of the chosen transects. Appendix 2 presents the 2012 field measurements. Results of the 2010 and 2011 monitoring are reported in Stevens and Robertson (2010, 2011).

CONDITION RATINGS

A series of interim fine scale estuary "condition ratings" (presented on page 6) have been proposed for Waimatuku Estuary (based on the ratings developed for Southland's estuaries - e.g. Robertson & Stevens 2006). The ratings are based on a review of estuary monitoring data, guideline criteria, and expert opinion. They are designed to be used in combination with each other (usually involving expert input) when evaluating overall estuary condition and deciding on appropriate management.



Waimatuku Estuary 2012 Transect Locations

	Transect	NZTM East	NZTM North
Upper	A	1226984	4855992
	B	1226805	4855507
	C	1226727	4855281
Middle	D	1226952	4855034
	E	1226895	4854934
	F	1227028	4854923
Lower	G	1227176	4854864
	H	1227273	4854581
	I	1227577	4854395
	J	1227632	4854326
	K	1227999	4854102
	L	1228064	4854045

Figure 4. Sampling sites in the Waimatuku Estuary.

2. Methods (Continued)

CONDITION RATINGS

The condition ratings presented below include an “early warning trigger” to highlight rapid or unexpected change, and each rating has a recommended monitoring and management response. In most cases initial management is to further assess an issue and consider what response actions may be appropriate (e.g. develop an Evaluation and Response Plan - ERP).

Total Nitrogen

In shallow estuaries like the Waimatuku, the sediment compartment is often the largest nutrient pool in the system, and nitrogen exchange between the water column and sediments can play a large role in determining trophic status and the growth of algae.

TOTAL NITROGEN CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<500mg/kg	Monitor at 5 year intervals after baseline established
Good	500-2000mg/kg	Monitor at 5 year intervals after baseline established
Fair	2000-4000mg/kg	Monitor at 2 year intervals and manage source
Poor	>4000mg/kg	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

Total Phosphorus

In shallow estuaries like the Waimatuku, the sediment compartment is often the largest nutrient pool in the system, and phosphorus exchange between the water column and sediments can play a large role in determining trophic status and the growth of algae.

TOTAL PHOSPHORUS CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<200mg/kg	Monitor at 5 year intervals after baseline established
Good	200-500mg/kg	Monitor at 5 year intervals after baseline established
Fair	500-1000mg/kg	Monitor at 2 year intervals and manage source
Poor	>1000mg/kg	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

Total Organic Carbon

Estuaries with high sediment organic content can result in anoxic sediments and bottom water, release of excessive nutrients, and adverse impacts to biota - all symptoms of eutrophication.

TOTAL ORGANIC CARBON CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<1%	Monitor at 5 year intervals after baseline established
Good	1-2%	Monitor at 5 year intervals after baseline established
Fair	2-5%	Monitor at 2 year intervals and manage source
Poor	>5%	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

Redox Potential Discontinuity

The RPD is the grey layer between oxygenated yellow-brown sediments near the surface and deeper anoxic black sediments. The RPD marks the transition between oxygenated and reduced conditions and is an effective ecological barrier for most, but not all, sediment-dwelling species. A rising RPD will force most macrofauna towards the sediment surface to where oxygen is available. In addition, nutrient availability in estuaries is generally much greater where sediments are anoxic, and the tendency for sediments to become anoxic is much greater if the sediments are muddy, with consequent exacerbation of the eutrophication process.

RPD CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	>10cm depth below surface	Monitor at 5 year intervals after baseline established
Good	3-10cm depth below sediment surface	Monitor at 5 year intervals after baseline established
Fair	1-3cm depth below sediment surface	Monitor at 5 year intervals. Initiate ERP
Poor	<1cm depth below sediment surface	Monitor at 2 year intervals. Initiate ERP
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

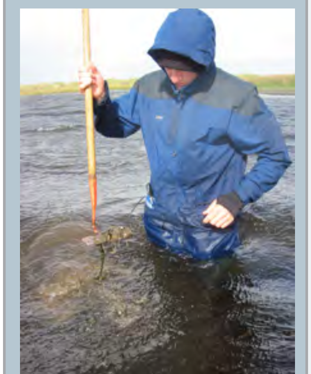
3. RESULTS AND DISCUSSION

Lower Waimatuku Estuary

A summary of the results of the 22 February 2012 fine scale monitoring of Waimatuku Estuary is presented below, with detailed results contained in Appendix 2. A summary of the sediment chemistry results and condition ratings are presented in Figures 8-11, alongside results from surveys undertaken in 2010 and 2011. Background depth, salinity, temperature and dissolved oxygen data are presented first, followed by two subsections based on the key estuary problems that the fine scale monitoring is addressing: eutrophication and sedimentation. Broad scale indicators e.g. soft mud area are reported on in Robertson and Stevens (2008).

Table 3. Sediment chemistry results (composite sample), Waimatuku Estuary, Feb. 2010, 2011 and Jan. 2012.

	Site	RPD (cm)	Salinity (ppt)		TOC (%)	Mud (%)	Sand (%)	Gravel (%)	TN (mg/kg)	TP (mg/kg)
			surface	bottom						
2010	Transect D	>5	0.0	0.0	1.80	25.3	55.8	18.9	2400	820
	Transect E	>5	1.1	1.1	0.76	9.8	90.2	<0.1	1400	850
	Transect G	>5	2.8	18.6	0.24	2.6	97.2	0.2	<500	770
2011	Transect D	0-1	1.0	20.0	0.90	15.9	50.8	33.2	1300	660
	Transect E	0-3	2.7	24.0	1.82	12.8	32.8	54.4	2200	660
	Transect G	>10	2.7	25.0	0.28	3.7	96.0	0.4	<500	560
2012	Transect D	3-5	1.9	6.8	0.65	5.3	51.6	43.1	1200	490
	Transect E	3-5	6.2	15.7	0.56	4.9	66.9	28.1	900	650
	Transect G	3-5	3.6	3.9	0.27	3.1	81.5	15.4	600	640



Measuring water quality, Site E, Waimatuku Estuary.

Water Depth and Level

Since 2011, longshore drift had pushed the estuary mouth approximately 500-600m to the east, constricting flushing and eroding large marram dunes. The estuary had similar low tide water depths (predominantly <1.5m, and the deepest area (~2m) at Transect B), compared to the previous surveys in 2009-2011, but noticeable differences in cross sectional depths at each site. In addition, the estuary was again, as in 2011, noticeably slower to drain due to increased sand deposition near the estuary mouth.

Salinity, Temperature and Dissolved Oxygen

Salinity measurements showed that in 2012, upper estuary transects A and B were freshwater-dominated (0ppt) and unstratified during low flow and low tide conditions, (Appendix 2). In the middle and lower estuary (transects C-H), surface salinity ranged from 0-4.6ppt, with bottom salinity 3.9-16ppt. Sites C-E reflected seawater trapped below 0.8m, while sites F-H were freshly draining tidal inputs stratified at ~0.4m. The relatively shallow downstream sites (I to L) were well mixed with salinity 4.4-6.1ppt.

Water temperature was similar throughout the estuary, but relatively low at 11-13 degrees C, and there was little difference between surface and bottom temperatures. Similarly, dissolved oxygen concentrations were similar throughout the estuary (94-104% saturation). However, bottom water dissolved oxygen was depleted at site B (70% saturation compared to 97% at the surface).

Water Clarity (Secchi Disc)

As in the 2011 survey, the estuary was moderately clear with the bottom visible at all sites in the estuary except at the deepest sites (B) and (F) where Secchi disk clarity was 1.4m and 1.0m respectively.

3. Results and Discussion (Continued)

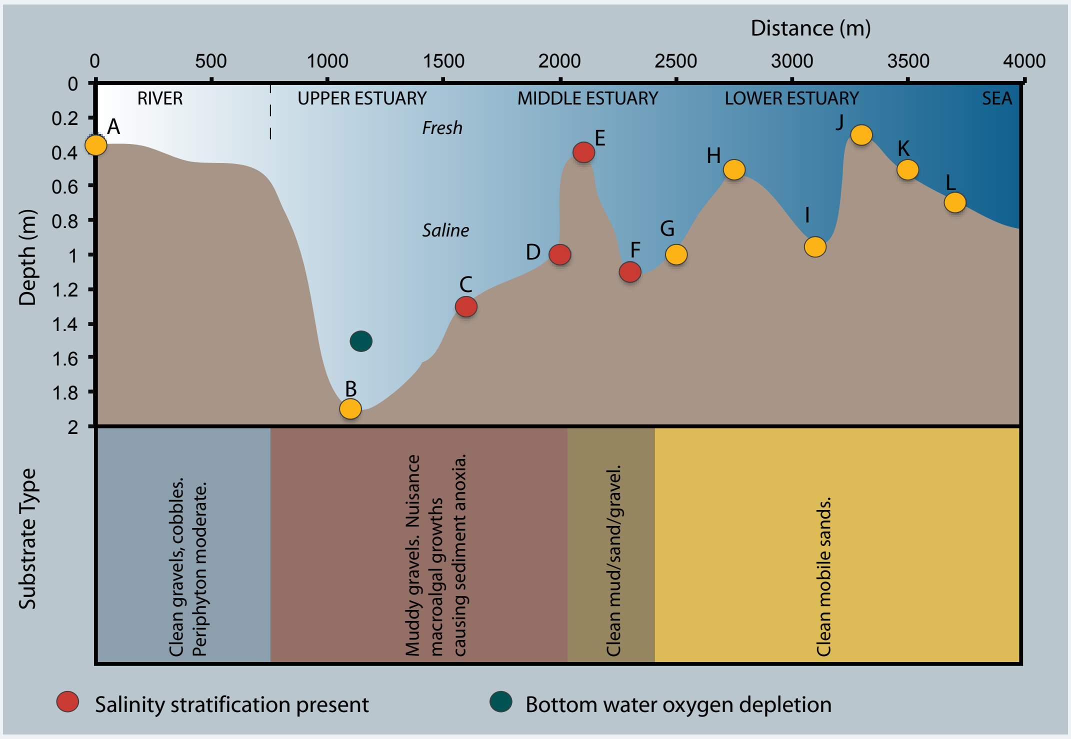


Figure 5. Longitudinal profile (river to sea) of maximum water depth (at low water) and substrate type, 22 February 2012.

Sedimentation

Accelerated soil erosion from developed catchments is a major issue for tidal lagoon estuaries in New Zealand as they form a sink for fine suspended sediments. In tidal river estuaries like Waimatuku, sedimentation is often less of an issue, because of their well-flushed nature. In such estuaries, muddiness is generally restricted to deep pools in the upper estuary. In order to assess sedimentation (particularly muddiness) in the Waimatuku, grain size, and substrate type were the main indicators.

Sediment Type: the substrate showed little change compared to the 2009-2011 period. It comprised predominantly clean gravels and cobbles in the lower Waimatuku Stream, clean muddy gravels in the upper estuary, muddy sands and gravels in the middle estuary, and clean mobile sands in the lower estuary (Figure 5).

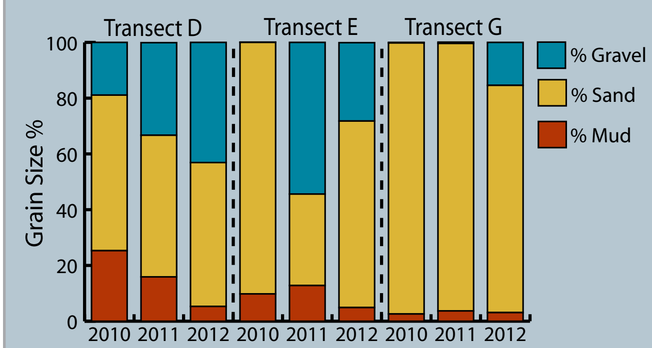


Figure 6. Grain size, at 3 subtidal sites (composite across transect), Feb. 2010, 2011 and Jan. 2012.

Grain Size: Results from the three transects sampled, D, E and G (Figure 6) show muds from the catchment accumulate predominantly in the deeper reaches of the upper estuary (Transect D), indicating it is more at risk of sedimentation effects than the more well- flushed middle and lower estuary which are much sandier. However, the results also indicate a substantial decline in mud content each year between 2010 and 2012. The reason for this decline is currently unknown, but may be related to catchment management actions to reduce fine sediment loads to streams and/or an increase in catchment gravel input loads.

Overall, the findings indicate excessive deposition of muds in Waimatuku Estuary is not a significant problem.

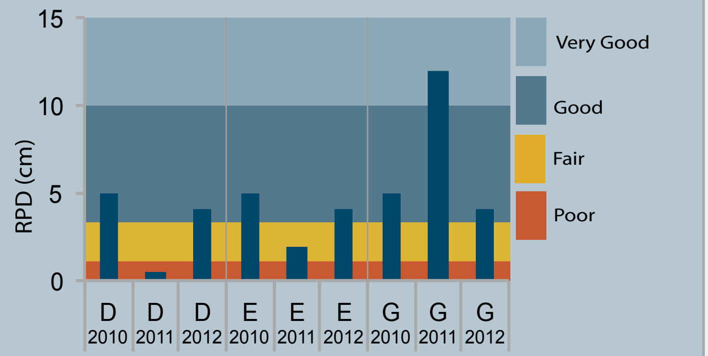


Figure 7. RPD, at 3 subtidal sites (composite across transect), Feb. 2010, 2011 and Jan. 2012.

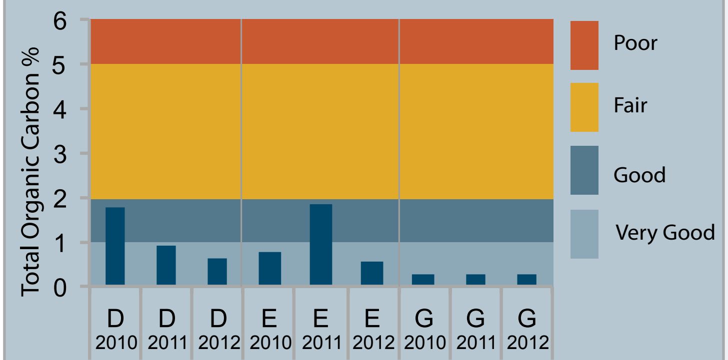


Figure 8. Total organic carbon at 3 subtidal sites (composite across transect), Feb. 2010, 2011 and Jan. 2012.

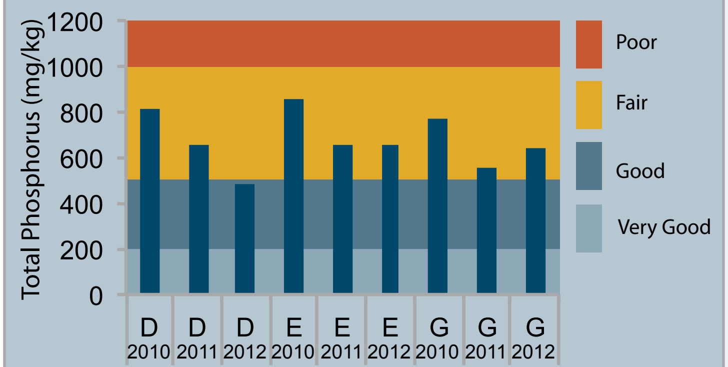


Figure 9. Total phosphorus at 3 subtidal sites (composite across transect), Feb. 2010, 2011 and Jan. 2012.

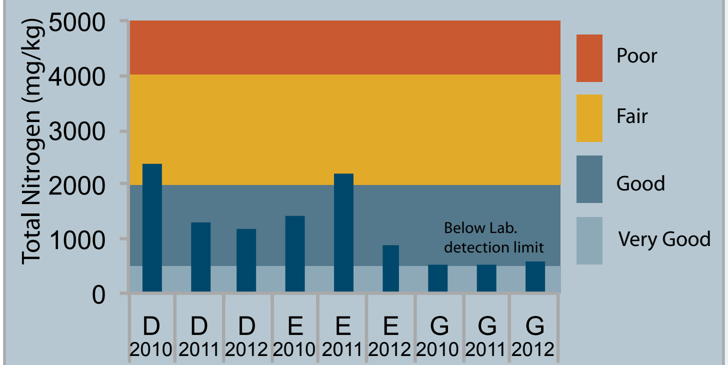


Figure 10. Total nitrogen at 3 subtidal sites (composite across transect), Feb. 2010, 2011 and Jan. 2012.

EUTROPHICATION

Excessive organic input, either from external sources or growing within the estuary in response to high nutrient loads, is a principal cause of physical and chemical degradation and faunal change in estuarine environments. In tidal river estuaries, the sediments become deoxygenated, nuisance algal growth becomes abundant and the number of suspension-feeders (e.g. bivalves and certain polychaetes) declines and deposit-feeders (e.g. opportunistic polychaetes) increase as organic input to the sediment increases (Pearson and Rosenberg 1978). The primary indicators of eutrophication in this survey were grain size, RPD boundary, sediment organic matter, nitrogen and phosphorus concentrations, and aquatic plant and algal growth.

Redox Potential Discontinuity (RPD). The depth of the RPD zone provides an indication of the level of sediment oxygenation. The results (Figure 7), showed that the 2012 RPD depth at the Waimatuku sites was ~3-5cm at all sites, and therefore the sediments were likely to be moderately oxygenated. The RPD ratings at sites D and E were slightly deeper than those measured in previous years, and at site G the RPD was shallower. Such variable RPD values indicate the changeable conditions often experienced in tidal river estuaries where river flow is a major influence on estuary condition. As a result, the benthic community was likely to be transitional and dominated by organisms and plants tolerant of moderate organic enrichment.

Total Organic Carbon and Nutrients. The concentrations of organic matter (total organic carbon - TOC) and sediment nutrients (total nitrogen- TN and phosphorus - TP) also provide valuable trophic state information. In particular, if concentrations are elevated, and eutrophication symptoms are present (i.e. shallow RPD, excessive algal growth), then TN, TP and TOC concentrations provide a good indication of loadings exceeding the assimilative capacity of the estuary. However, a low TOC, TN or TP concentration does not necessarily indicate an absence of eutrophication symptoms. It maybe that the estuary, or part of an estuary, has reached a eutrophic condition and exhausted the nutrient supply. Obviously, the latter case is likely to better respond to input load reduction than the former.

In relation to the Waimatuku Estuary (Sites D, E and G), the results (Figures 8-10) indicate that concentrations of TOC and TN were highest in the middle and upper estuary, but TP was elevated throughout. Such data indicates a likely oversupply of TP in relation to TN in the estuary.

Aquatic Macrophyte and Macroalgal Cover

As in 2009, 2010 and 2011 the lower Waimatuku Stream and the upper Waimatuku Estuary supported growths of rooted aquatic macrophytes (Figure 11). *Ranunculus trichophyllus* (water buttercup Figure 12) was relatively abundant in the clear, 0-0.5m deep, flowing freshwater of the lower Waimatuku Stream Site A, growing in 1-2m long strands in the clean gravel bed, while *Mimulus guttatus* (monkey musk) was common along the margins.

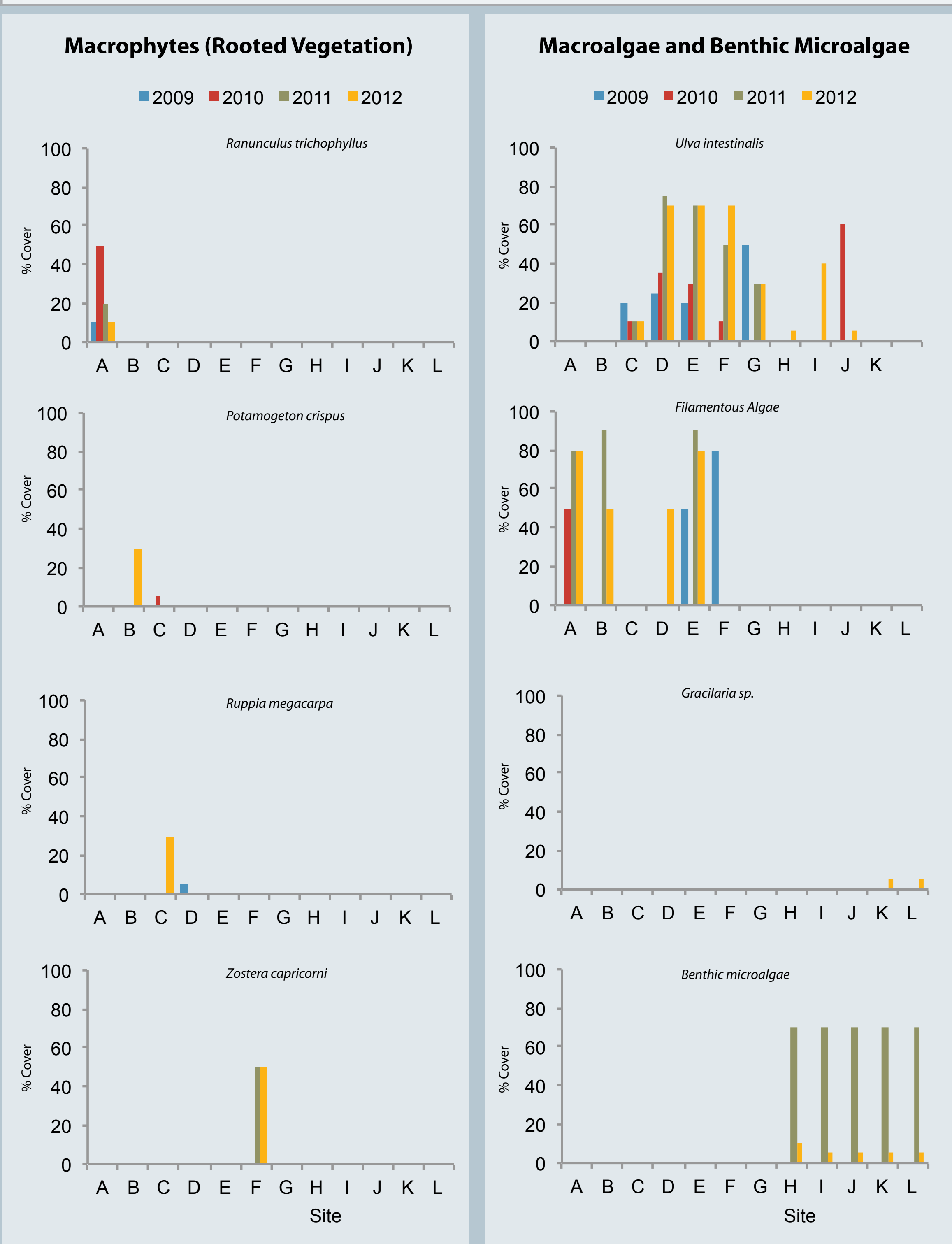


Figure 11. Percent cover of aquatic vegetation at 12 Waimatuku estuary transects 2009-2012.

3. Results and Discussion (Continued)

In the brackish upper estuary (Sites B-D, the native seagrass *Ruppia megacarpa* (horse's mane weed - Figure 12) and introduced *Potamogeton crispus* (pondweed) were the dominant plants (Figure 13). *Ruppia* was present throughout the upper estuary as occasional dense patches in the 0-1m depth range. *P. crispus* was present at similar depths, but restricted to patches in the upper estuary reaches.

The nuisance macroalgae *Ulva (Enteromorpha) intestinalis,* was common throughout the estuary, and filamentous algal growths were present as dense mats among *Ruppia* beds in the brackish upper estuary, and on sediments in the upper-middle estuary. These algal growths were almost certainly restricting *Ruppia* growth through smothering, and reducing water and sediment quality wherever the current was not too strong, contributing to black, anoxic, sulphide-rich surface sediments.

The lower estuary was relatively clean of macroalgae (apart from occasional patches of *Gracilaria* and *U. intestinalis* present in the low tide channel near the estuary mouth), but supported a thick film of microalgae on the intertidal sediment surface in 2011 and to a lesser extent in 2012 (Figure 11).

Figure 12. Dominant macrophytes and macroalgae, Waimatuku Estuary.

***Ruppia megacarpa* (Horse's mane weed)** is a native surface-flowering submerged aquatic annual or perennial; stems 20-30 cm long and are often zigzag in form. Grows in fresh to hypersaline coastal lakes, lagoons and estuaries and is relatively common in the 0-1.5m depth range (depending on water clarity).

***Potamogeton crispus* (Curly pondweed)** is an introduced species that is tolerant of slightly brackish as well as freshwater. It can survive in low light and low temperatures, and prefers high nutrient water. It spreads mostly by means of vegetative buds (turions) that germinate in autumn, grow vigorously in spring, and die off in the summer. The decaying plant matter can make the water extremely enriched, encourage nuisance algal mats near the sediment surface, inhibit the growth of native aquatics, and can interfere with boating and other water recreation. These plants germinate in autumn, grow vigorously in spring, and die off in the summer.

***Ranunculus trichophyllus* (Water buttercup)** is an introduced species common in freshwater and slightly saline waterbodies. Stems are up to 2m long, leaves are narrow and bright green. Flowers are white with a yellow centre.

Ulva (Enteromorpha) intestinalis, a nuisance green macroalgae, is found worldwide, and can grow to nuisance proportions in nutrient enriched estuaries, coastal lagoons and embayments. It can cause sediment deterioration, oxygen depletion, bad odours and have adverse impacts to biota.

Gracilaria spp., a relatively small (10-25cm) red macroalgae that grows in dense tufts both subtidally and intertidally in harbours, estuaries and moderately exposed open coasts, on rock, pebbles and shells in sandy/muddy areas. Generally bright crimson to dark maroon, but gets bleached by the sun.

SUMMARY

The combined influence of high catchment nutrient inputs, periodic mouth closures, and limited assimilative capacity (exacerbated by the highly modified and scarce vegetated terrestrial margin and saltmarsh), makes Waimatuku Estuary highly susceptible to adverse impacts from eutrophication. However, this is ameliorated to some extent by the narrow channel which, at times of high river flows, causes flushing of contaminants and nuisance growths out to sea.

In summary, the combined 2009-2012 results showed the following:

Sedimentation. Mud content was found to be declining over the survey period which may be related to catchment management actions to reduce fine sediment loads to streams and/or an increase in catchment gravel input loads. Overall, the findings indicate excessive deposition of muds in Waimatuku Estuary is not a significant problem.

Eutrophication. The results confirm the presence of excessive blooms of nuisance macroalgae concentrated in the middle and lower estuary, while the middle/upper estuary had variable, and at times relatively poor sediment conditions (shallow RPD, high nutrients, nuisance macroalgae, elevated mud concentrations), particularly in areas where salinity stratification was present.

Figure 13. Examples of thick *Potamogeton crispus* **beds in upper estuary (top),** ***Ruppia megacarpa*** **from the upper estuary (left), and benthic microalgae on sands (right) in the lower Waimatuku Estuary, 22 February 2012.**

3. Results and Discussion (Continued)

Figure 14. Coastal algal bloom at the mouth of Waimatuku Estuary, March 2012. Photo ES.

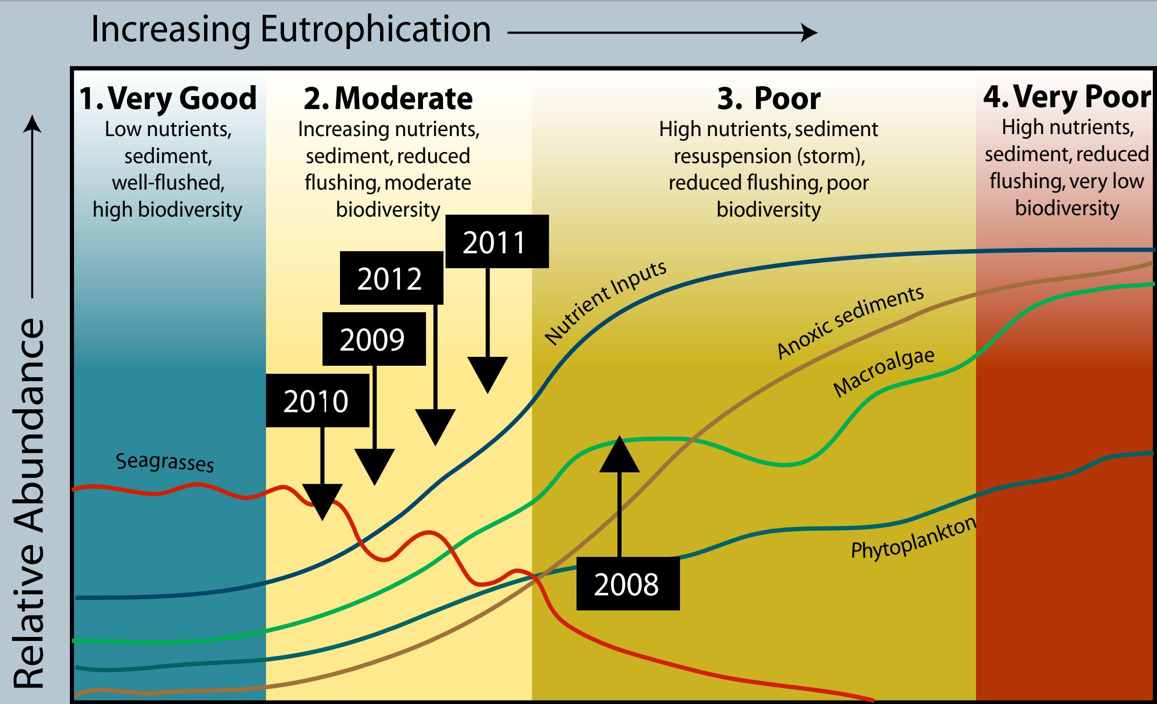
Intertidal and subtidal flats in the lower estuary supported a thick benthic microalgal growth not evident in 2010. The water also had a noticeable green stain in 2011 and 2012. These conditions place the estuary in a Stage 2 "moderate" state (Figure 15). Consequently, the native seagrass community in the upper estuary is at risk of being degraded and lost. Macroinvertebrates, fish, birdlife, and human use of the estuary is all likely to be adversely impacted.

At present, eutrophication symptoms are minimised by the short residence time of water within the estuary. This is maintained by the mouth remaining open to the sea which minimises the build up of nutrients. Despite this however, eutrophication symptoms have been evident every year since the estuary was monitored in 2008, with the 2011 results showing eutrophication symptoms increase very quickly and persist following even short duration estuary mouth constriction. If mouth migration continues to constricts flows, the estuary quality is likely to deteriorate quickly. Notwithstanding, discharges of elevated nutrient loads to the coast from the Waimatuku, plus Jacobs River and New River estuaries, may also be contributing to the presence of coastal algal blooms nearby at Oreti Beach, as evident in Figure 14.

These results highlight the priority need to manage nutrient inputs from the catchment. Saltmarsh and terrestrial margin habitat is also modified and scarce, so maintaining these in good condition will help provide important filtering and uptake of sediment and nutrients, and help other important parts of the ecosystem to thrive.

Pathogens, the other key issue facing the estuary, are currently being addressed as part of Environment Southland's state of the environment monitoring programme.

Figure 15. Waimatuku Estuary - condition rating and trophic state, 2008, 2009, 2010, 2011 and 2012.



Conceptual representation of estuary response to increased nurients in tidal river mouth estuaries.

4. MONITORING

Waimatuku Estuary has been identified by ES as a priority for monitoring, and is a key part of ES's coastal monitoring programme. Based on the current monitoring results and those reported previously (Robertson and Stevens 2008, 2009; Stevens and Robertson 2010, 2011), it is recommended that monitoring continues as outlined below:

Fine Scale Macrophyte and Sediment Condition. Continue fine scale monitoring once every 5 years (next scheduled for Feb. 2017). That is;

- Seagrass and nuisance macroalgae presence, location, % cover and life stage (including salinity, depth and clarity at established transect sites).
- Sediment quality at 3 sites - broad scale (depth to RPD layer, sediment type) and fine scale (grain size, total nitrogen, total phosphorus and total organic carbon).

In order to address the issue of eutrophication, it is recommended that cost effective indicator monitoring be undertaken annually as follows: RPD, water column DO, salinity, substrate type and vegetative % cover at Transect E, combined with a coarse assessment of vegetative cover elsewhere in the estuary.

Undertake broad scale habitat mapping every 5 years (next due in summer 2013).

Water Quality. Monitor nutrients and turbidity in the lower Waimatuku Stream in order to assess the nutrient inflows to Waimatuku Estuary. In addition, characterise pathogen inputs to the estuary.

Catchment Landuse, Freshwater Abstractions, Mouth Openings/Constrictions.
Monitor key stressors including reduced flushing, catchment landuse, freshwater abstraction, mouth constriction, and changes to water level. Any significant changes to stressors should trigger an evaluation of the likely impact on estuary susceptibility.

5. MANAGEMENT

Eutrophication and, to a lesser extent, sedimentation have been identified as major issues in Waimatuku Estuary, as has been the case for several other Southland estuaries (e.g. New River, Jacobs River, and Waituna Lagoon). To address these issues, it is recommended that appropriate catchment nutrient and sediment guideline criteria be developed for each estuary type in Southland, and that these guideline criteria are then used to assess the extent to which catchment loads meet these guidelines. Estuaries where guidelines are exceeded are prioritised for more extensive investigations, monitoring and management. The key steps in such an approach are as follows:

- Assign catchment nutrient and sediment load guideline criteria to each Southland estuary (using criteria appropriate to each type of estuary). Guideline criteria should be based on available catchment load/estuary response information from other relevant estuaries.
- Estimate catchment nutrient and suspended sediment loads to each estuary using available catchment models and stream monitoring data.
- Determine the extent to which each estuary meets guideline catchment load criteria.
- Rank estuaries according to exceedance of recommended guideline criteria.
- Assess the potential for requiring more detailed assessments of priority estuaries (e.g. estuary response modelling, stream and tributary monitoring, catchment load modelling).
- Develop plans for the effective management and restoration of priority estuaries.

Overall, if the approach is followed and the estuary and its surroundings are managed to ensure that the assimilative capacity is not breached, then the estuary will flourish and provide sustainable human use and ecological values in the long term.

6. ACKNOWLEDGEMENTS

This survey and report has been undertaken with the help and support of Greg Larkin (Coastal Scientist, Environment Southland).

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APPENDIX 1. DETAILS ON ANALYTICAL METHODS

Indicator	Laboratory	Method	Detection Limit
Grain Size	R.J. Hill	Air dry (35 degC, sieved to pass 2mm and 63um sieves, gravimetric - (% sand, gravel, silt)	N/A
Total Organic Carbon	R.J. Hill	Catalytic combustion, separation, thermal conductivity detector (Elementary Analyser).	0.05g/100g dry wgt
Total Recoverable Phosphorus	R.J. Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	40 mg/kg dry wgt
Total Nitrogen	R.J. Hill	Catalytic combustion, separation, thermal conductivity detector (Elementary Analyser).	500 mg/kg dry wgt

APPENDIX 2. 2012 SURVEY RESULTS

Aquatic Vegetation and Site Details - Waimatuku Estuary - Low Tide (07.15h) 22 January 2012. Water quality measures collected from the surface and mid-channel bottom water.

	Transect	Shape of cross section	Channel width	Channel depth	Secchi Disk Clarity	RPD Depth	Sediments	Sample Location	Temperature	Salinity	DO	Vegetative Cover	Height	Stage	Percent Cover
		west east	(m)	(m)	(m)	cm			°C	ppt	%		cm		%
Upper Estuary	A		6	0.35	Bottom	>5	Gravel	Surface	12.7	0.0	101.1	*Ranunculus trichophyllus*	50	v	10
								Bottom	12.7	0.0	103.5	Periphyton & filamentous algae	10	v	80
	B		15	1.9	1.4	3	Clean muddy Gravels	Surface	12.5	0.0	97.5	*Ranunculus trichophyllus*	10	v	5
								Bottom	12.5	0.0	70.5	Filamentous algae	10	v	50
												Potamogeton crispus	80	v	30
	C		15	1.3	Bottom	3-5	Clean muddy Gravels	Surface	12.7	0.0	93.1	*Ulva (Enteromorpha) intestinalis*	10	v	10
								Bottom	13.3	16.1	89.5	*Ruppia megacarpa*	80	v	30
			Ruppia beds above and below transect C concentrated in <1m deep water along channel edges.												
Middle Estuary	D		18	1.0	Bottom	3-5	Muddy Sand/ Gravel	Surface	12.7	1.9	103.4	*U. intestinalis*	20	v	70
								Bottom	13.4	6.8	101.3	Filamentous algae	10	v	50
	E		35	0.4	Bottom	3-5	Muddy Gravel/Sand	Surface	12.8	6.2	95.2	*U. intestinalis*	50	v	70
								Bottom	12.8	15.7	96.2	Filamentous algae	10	v	80
			Anoxic sediments and decaying macroalgae present in shallow water across the transect.												
	F		20	1.1	1.0	3-5	Clean mobile Sand/Gravel	Surface	12.6	3.5	94.3	*U. intestinalis*	40	v	70
								Bottom	13.1	5.1	94.1	*Zostera capricorni*	10	v	50
Lower Estuary	G		19	1.0	Bottom	3-5	Clean mobile Sand	Surface	11.9	3.6	99.0	*U. intestinalis*	30	v	30
								Bottom	12.2	3.9	98.1				
	H		20	0.5	Bottom	>10	Clean mobile Sand	Surface	12.0	4.6	94.5	*U. intestinalis*	30	v	5
								Bottom	12.0	4.4	93.7	Benthic microalgae	<0.1	v	10
	I		11	0.95	Bottom	>10	Clean mobile Sand	Surface	11.7	4.4	99.9	*U. intestinalis*	10	v	40
								Bottom	11.7	4.4	98.3	Benthic microalgae	<0.1	v	5
	J		30	0.3	Bottom	>10	Clean mobile Sand	Surface	11.5	4.5	100.4	*U. intestinalis*	20	v	5
								Bottom	11.5	4.5	100.6	Benthic microalgae	<0.1	v	5
	K		9	0.5	Bottom	>10	Clean mobile Sand	Surface	11.1	6.0	101.3	*Gracilaria*	10	v	5
								Bottom	11.1	5.5	100.4	Benthic microalgae	<0.1	v	5
	L		10	0.7	Bottom	>10	Clean mobile Sand	Surface	12.0	6.1	104.2	*Gracilaria*	10	v	5
								Bottom	12.0	5.9	101.4	Benthic microalgae	<0.1	v	5

V=vegetative stage
F=flowering
Fr=fruiting